Human Ecological Implications of Climate Change in the Himalaya: Investigating Opportunities for Adaptation in the Kaligandaki Basin, Nepal

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Abstract

Climate change and associated impacts are pressing issues for the twenty-first century. The climatic impacts and associated adaptation responses are altering complex interrelationships between people and the environment. Although the problems generated by such change are global, the intensity of impacts varies spatially. This research examines the implications of climate change on the local social-ecological systems of the Kaligandaki Basin, Nepal; it maps the adaptation efforts of communities; and assesses food and livelihood (in)security and vulnerability of the social-ecosystems to inform adaptation policy and practice.

The study applies a geographical approach to explain human-environmental interrelationships by drawing from both social and natural scientific methodologies inherent to the discipline. The concepts of human ecology and social-ecology, climatic and environmental change, vulnerability and adaptation, are explored and applied in the research. The Sustainable Livelihood Approach (SLA) is integrated with the Drivers-Pressure-State of Change-Impacts-Response (DPSIR) analysis framework to explain the complex local human-environmental interactions with climate change. Case studies are drawn from three different ecological zones: the Tarai, the Middle-Mountains and the Trans-Himalaya to inform a comparative analysis in the Kaligandaki Basin. Climate change in the Kaligandaki Basin is assessed by analysing both meteorological data for the past 40 years and social perceptions of change in the last decade. Primary data on impacts and adaptation responses were collected through face-to-face interviews with household heads from 360 households, 24 focus group discussions, 7 historical timeline calendars, 75 key informant interviews, and 9 crop calendar sketches.

The findings suggest that the social-ecological systems of the Himalaya are highly sensitive to both climatic and non-climatic stressors. Climate sensitive livelihood capitals are increasingly exposed to climate change, as both scientific and social analyses indicate increased temperatures and more extreme weather events. The changes and variability in the climate system have negatively impacted all social-ecological systems, particularly in the Middle-Mountains. Consequently, many local communities are trapped in a situation of multiple livelihood constraints associated with ecological, economic, social and political environments. To respond to those constraints and reduce the negative implications of change, people are trying to adopt adaptation strategies, mostly at the individual household or community levels.

The studied communities demonstrate significant adaptation knowledge; however, such knowledge is not sufficiently translated into adaptation actions. Many households are losing hope of agricultural adaptation due to climate change impacts and unfavourable political-economic environments. Cash income is now the preferred option for many, and young adults are leaving communities and the country in search of paid employment. The poor quality of livelihood capitals; increasing climate change impacts; and poor adoption of adaptation strategies together have significant negative implications for local food and livelihood security.

The research has important implications for policy that aims to integrate disaster management, agricultural development, livelihood diversification, and community empowerment in relation to climate change adaptation in Nepal. The research supports theoretical discussions on the value of undertaking complex social-ecological analyses to generate knowledge that is both holistic and directly applicable for local adaptation planning and practice. By applying similar approaches in other contexts, especially in the developing world, the issues inhibiting broader development processes could be integrated with an understanding of climate change impacts for targeted, comprehensive adaptation policy outcomes.

Declaration

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission in my name for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint award of this degree.

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Rishikesh Pandey

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Dedication

I dedicate this work to my deceased parents.

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Acronyms

ACAP	Annapurna Conservation Area Project
ACI	Adaptive Capacity Index
AR	Assessment Report
CBO	Community Based Organization
CBS	Central Bureau of Statistics, Nepal
CDMC	Community Based Disaster Management Committees
CNP	Chitawan National Park
CI	Cropping Intensity
CPI	Crop Potential Index
COP	Conference of the Parties
DDC	District Development Community
DHM	Department of Hydrology and Meteorology, Nepal
DPSIR	Drivers-Pressures-State of Changes-Impacts-Responses
EI	Exposure Index
ENSO	El Niño Southern Oscillation
FANTA	Food and Nutrition Technical Assistance Project
FGD	Focus Group Discussions
GHG	Green House Gas
Gg	Giga gram
GLOF	Glacial Lack Outburst Flooding
GM	Genetically Modified
GoN	Government of Nepal
HDI	Human Development Index
HDR	Human Development Report
HED	Himalayan Environmental Degradation
HFIAS	Household Food (In)Security Access Scale
HTC	Historical Timeline Calendars
HYV	High Yielding Varieties
ICIMOD	International Centre for Integrated Mountain Development
I/NGOs	International/Non-governmental Organizations
IPCC	Intergovernmental Panel on Climate Change
KII	Key Informants Interviews
KSL	Kailash Sacred Landscape
LARC	Lumle Agriculture Research Centre
LPG	Liquefied Petroleum Gas
MDG	Millennium Development Goals
NAPA	National Adaptation Plan of Actions
LAPA	Local Adaptation Plan of Actions
PRA	Participatory Rural Appraisal
SI	Sensitivity Index
SLA	Sustainable Livelihood Approach
SVI	Social-Ecological Vulnerability Index
TAR	Third Assessment Report
UNFCCC	United Nations Framework Convention on Climate Change
UoA	the University of Adelaide
VDC	Village Development Community
WCED	World Commission on Environment and Development
WMO	World Meteorological Organization

CHAPTER I

INTRODUCTION AND STATEMENT OF THE PROBLEMS

1.1 Introduction

Climate change is one of the most important environmental threats to human populations, ecologies and ecosystems. Climate scientists have provided evidence of a changing climate. They have also predicted that the change will continue at least throughout the 21st century even if the Greenhouse Gas (GHG) emissions are stabilised. Some parts of the world, including the Himalaya [1], have experienced climate change at an alarming rate, which have already affected human populations and local ecologies; although the effects vary spatially.

This study investigates the dimensions of human-environmental interactions in the Nepali Himalaya in relation to climate change. The research examines the changes in climate and their implications on human-environmental systems. To achieve that aim the study analyses the livelihood systems; maps adaptation strategies adopted by the communities; assesses livelihood outcomes in relation to climate change; and critically evaluates vulnerability of the social-ecological systems of the Himalaya. The Kaligandaki Basin in the Central Himalaya, Nepal, is the study site. The findings of this study provide important information for a climate change adaptation framework for South Asia in general and for Nepal in particular. The study contributes to the holistic approach of understanding human-environmental relationships, suggests an innovative methodology to study complex social-ecological systems; and generates insights for scholarly discourse in the discipline of human geography.

This chapter introduces the research problems, aims and rationale. The problem statements provide a brief introduction to human ecology and introduce important research gaps through a review of previous works on climate change and human ecology. The identified research gaps help frame the research goals and structure the research questions and objectives. The rationale of the research includes an explanation of the importance of the research theme, as well as

[1]The Himalaya is the mountain systems of the Central Asia, originated at Pamir-Knot in the north-west and extended over 1500 miles towards the east (boarder of Asham). This system generally includes major four different physiographic features namely Outer Himalaya (the Southern *Churiya* range), Lesser Himalaya (the Middle hills or *MahabharatLekh*), the Greater Himalaya (Northern snowcapped mountains), and Trans-Himalaya (Northern Himalayan valleys and foot hills) along with river valleys, *Duns*, and *Tars* in between the mountains (Burathokey 1968).

specific research questions to promote climate change adaptation in Nepal. The last section of the chapter details the overall structure of this thesis.

1.2 Problem Statements

1.2.1 Human Ecology in the context of Climate Change

Human ecology is a geographical tradition of studying human–environmental relationships. It is a discipline in contemporary human geography that explores the geographies of socio-natures and techno-natures (Haraway 1997; Swyngedouw 1999). The interrelationships between humans and the environment are dynamic, such that changes in society and the environment affect each other and the existing interrelationships between them. Therefore, shedding light on societal interactions with nature forms the background for a detailed discussion on the human ecological implications of climate change.

1.2.1.1 The Society-Nature Interactions

In a study of interactions between society and nature, an understanding of the complexity of the system is important. A poor level of understanding of systems and models of human adaptation to environmental changes can cover-up the existing complexities in human-environmental interrelationships (Berkes and Folke 1998). In fact, the nature-culture divide is often presented as a dualism that leads to conflicting connections. Others argue that 'nature' is not nearly as natural as it seems – it is profoundly a human construction (Cronon 1996). The concept of 'cultural landscapes' - the outcome of the human transformation of 'nature' (Sauer 1925), and the 'social constructions of nature' (Jasanoff 2010; Fitzsimmons 1989; Greider and Garkovich 1994), also illustrate complexities in understanding society-nature interrelationships. The increasing tradition of using methodologies of the natural sciences in the social sciences, although is highly contested, are making it more difficult to draw a clear boundary between the natural and the social (Adger 2006).

In the context of climate change, understanding human-environmental interactions can be even more difficult. The variable exposure, sensitivity and adaptive capacity of the social-ecological systems to climate change across different places and times, have resulted in an incredible complexity of adaptation responses. A social-ecological system is a system of interaction between nature and people. It is an ecosystem approach of viewing human society and social spheres and the bio-physical environment as an integral part of the system, although there is no single universally accepted way of formulating the linkages between human and natural systems (Berkes and Folke 1998). Considering the difficulties in drawing boundaries between society and nature, this study simply presents 'natural' factors of climate change as exogenous stressors, and the endogenous stressors as being linked to socio-economic and political change to investigate the human-environmental interactions.

1.2.1.2 Climate Change in the Global Context

The increasing vulnerability of global social-ecosystems has been recognised since the 1960s. In particular, pollutant levels that exceed the capacities of natural sinks have gradually led many environmental systems towards disequilibrium. The World Commission on Environment and Development (WCED) in 1987 brought the particular issue of global climate change into focus for global society. The Intergovernmental Panel on Climate Change (IPCC) was formed by the UN General Assembly in December 1987 with the mandate of collecting, reviewing, verifying, compiling and disseminating research findings on climate change impacts, adaptation and mitigation. Contemporary science has confirmed that the climate of the globe is changing and will continue to change (Aldhous 2004; Christensen et al. 2007; Christensen et al. 2013; Hartmann et al. 2013; Folland et al. 2001; Lemke et al. 2007; Mann et al. 1999; Meehl et al. 2007; Salinger 2005; Trenberth et al. 2007; Trenberth and Hoar 1997; Wigley et al. 2006).

The problems created by climate change differ from any other problems that humanity has faced, and if not checked in time, the consequences are likely to be catastrophic for human life on Earth (Giddens 2008). The potential effects on humans, animals and plants are broad and complex. In many places, the environmental resources on which societies rely are at risk since no land, water, forest or any other resources will remain unaffected (Adger et al. 2004; Field et al. 2014).Thus, climate change impacts pose risks to ecological, social, cultural and economic systems (Cruz et al. 2007; Parry et al. 2007; Schneider et al. 2007; Scheraga and Grambsch 1998). To deal with such implications, effective adaptation actions are required, but while some efforts have already been made in different parts of the globe further climate change is inevitable (Adger et al. 2007; Allison et al. 2009; Leary et al. 2007; Mortimore 2010; Schneider 2009; Wheaton and Maciver 1999) and investigating opportunities for adaptation is required.

The rates of change in climate and the intensity of impacts vary spatially. There is uncertainty in the implications of change for different systems because of the non-linearity or inter and annual variability in weather patterns, and difficulties in mapping and modelling the primary, secondary and tertiary implications of those changes. Serious effects, however, are already visible in climate-sensitive social-ecological systems like the dry areas, the coastal plains, and importantly for this thesis, the high mountains including the Himalaya.

1.2.1.3 Climate Change and Human Ecology in the Himalayan Context

The Himalaya is the main watershed divider of two densely populated areas of the world: South Asia and East/South-East Asia. The Himalaya is the largest accumulation of the ice outside of the poles (Dyhrenfurth 1955; UNESCO 2011). Climatic warming is higher in the mountains and in the Himalaya in particular, than the global average (Lemke et al. 2007; Nepal 2012; NRC 2012; Shrestha et al. 2012; Shrestha et al. 1999). As a consequence the Himalayan glaciers are melting rapidly and the risk of Glacial Lack Outburst Flooding [2] (GLOF), is increasing (Prasad et al. 2009; Sveinbjörnsson and Björnsson 2011; WWF 2005; Xu et al. 2007), and negatively impacting on water storage, hydrology, and dependent ecosystems in the Himalaya (Moiwo et al. 2011). An increase of 3 ^{O}C to 4 ^{O}C temperature in the Himalaya would eliminate an estimated 58 percent to 70 percent of the snow and ice in the Himalaya (GoN 2004). In addition, the behaviour of the monsoon is also changing and has become variable, uncertain and violent (Christensen et al. 2007; Nepal 2012; Shah and Lele 2011; Shrestha et al. 2000; Turner and Annamalai 2012). The warming and variable monsoonal rainfall in the Himalaya alters the surface characteristics and drainage systems of the region (Nepal and Shrestha 2015), which in turn is having increasing implications for the social-ecological systems within and down-stream of the Himalaya.

Changing climate has affected the poor people of the Himalaya socially, emotionally and economically. The changing climate in the region has impacted the lives and livelihoods of the people of South Asia including Nepal, caused social and ecosystem disruptions, and increased the risk of socio-ecological vulnerability (Bhatta et al. 2015; Chhetri et al. 2013; Macchi et al. 2014; Moiwo et al. 2011). Estimations indicate that crop yields could decrease up to 30 percent in South Asia by the end of the century, even if the direct positive physiological effects of CO_2 are taken into account (Cruz et al. 2007).Studies have already suggested water scarcity is a growing problem in terms of supply, storage and access in South Asia (Kehrwald et al. 2008; Rees and Collins 2006; Sullivan 2011; Winiger et al. 2005). In this context, abrupt climate change and associated consequences within and in the vicinity of the Himalaya, have become important concerns for the global community because of the population that is affected. The failure of this region to maintain livelihoods of billions of people would result in a global catastrophe; including the potential challenge of human mobility (Bardsley and Hugo 2010; Massey 2010; Piguet et al. 2011; Poncelet et al. 2010), since no other region in the world is capable of accommodating the region's populations.

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[2] Glacier lakes are those features, which forms when the thickened glacier ice blocks a valley causing river and meltwater to accumulate against an ice barrier. Increase in temperature leads to rapid melting and increase the size of the lakes on the one hand and weakens the ice barriers on the other, causing suddenly releases of accumulatedwater, the event called GLOF.

Nepal is a relatively small Asian country in terms of area, but covers a number of climatic and ecological zones and is rich in social and biodiversity (Gurung 1968; Gurung 2003; Naya Va 1975; Shrestha 1999).The changes in climate and associated impacts on agro-livestock livelihood systems have already been noticed by the people of Nepal and they have made some efforts to reduce the negative implications (Ghimire et al. 2010; Manandhar et al. 2011; Mukherji et al. 2015; Onta and Resurreccion 2011; Macchi et al. 2014). Previous studies have reported some corresponding elimination of agro-biodiversity; tropical and warm-temperate crops have become more feasible at higher altitudes (Dahal et al. 2009; Malla 2008); and, temperature and vector borne diseases related health problems are increased in higher altitudes (Aggarwal and Shivakumar 2011; Ebi et al. 2007; Lal 2002; Macchi 2011). Some scholars have also suggested increased crop-livestock diseases and pathogens as well as farm weeds and invasive species and associated production loss (Bhatta et al. 2015; Paudel, B et al. 2014), farmland abandonment (Chapagain and Gentle 2015; Paudel, K et al. 2014), and the potential for more climate change induced migration (Bardsley and Hugo 2010). Considering just a few of the reported implications, many aspects of the social-ecological systems of the Himalaya are yet to be studied in relation to climate change. The following section highlights some of the prominent research gaps this study intends to bridge.

1.2.2 Research Gaps and Research Aims

Exploring research gaps involves a process of examining what we know, do not know and need to know (Ford and Pearce 2010). The process helps frame important research questions. Research gaps, which this study intends to narrow, are identified through the review of literature on climate change and its human ecological implications.

There has been a boom in scholarly writings on climate change impacts and adaptation responses in the global context. Until the release of the IPCC Third Assessment Report (TAR) in 2001, the focus of climate research was on the impacts on the physical and biological world and possible mitigation options. The research focused on social and economic determinants of vulnerability and adaptation options are relatively recent phenomena in climate change research. Ford et al. (2012) after a review of 117 peer reviewed articles related to human dimensions of climate change concluded that research in adaptation aspects has only just begun. Specifically, studies on the effects of climate change on human-environmental interactions, and the implications for livelihoods and social-ecological sustainability are just emerging in a global context (Adger 2000a; Beg et al. 2002; Bardsley 2007; Bardsley and Wiseman 2012; Brouwer et al. 2007; Duerden 2004; Kelly and Adger 2000; Lal, M 2011; Wreford et al. 2010).

There is a notable lack of geographic balance in data and literature on the study of climate change, vulnerability and adaptation responses (IPCC 2007a; IPCC 2014). The dearth of scholarly publications in the Nepalese context is clearly evident; although as will be indicated in the following chapter, research work is increasing. A few of the studies: Duncan et al. (2013) analysed precipitation trends between 1951 to 2007 and its impacts on water resource management; Shrestha et al. (2012)analysed annual mean temperature and precipitation data between 1982 and 2006; Chaulagain (2006)also analysed meteorological data of few stations from 1971 and 2000; Shrestha et al. (2000) on the other hand analysed only precipitation data between 1971 and 1994, while Shrestha et al. (1999) analysed only annual average of maximum temperature between 1971 and 1994. All of these studies reported a higher rate of warming in the Himalaya than the global average. However, considerable time has passed after these studies, and much of the research did not focus on many of the other meteorological elements while conducting research on climate change.

Some other studies analysed social perceptions of climate change, associated impacts and adaptation efforts of the communities in different parts of Nepal (Bhatta et al. 2015; Chaudhary et al. 2011; Devkota et al. 2011; Gentle and Maraseni 2012; Manandhar et al. 2011; Onta and Resurreccion 2011; Paudel, B et al. 2014). These studies also reported rapid climate change that caused many negative implications in the social and ecological systems, and documented adaptation efforts of the communities. However, many of the adaption actions are not very effective because of the adaptation barriers the societies are facing (Jones and Boyd 2011). In addition, few of the other studies focussed on impacts and vulnerability of climate change. For example: estimation of agricultural impacts of climate change (Palazzoli et al. 2015); climate impacts and livelihoods vulnerability (Aryal, S et al. 2014; Gentle et al. 2014); climate sensitivity of agricultural intensity (Chhetri 2011); interaction on climate change and agricultural technology (Chhetri and Esterling 2010); droughts induced livelihoods vulnerability (Ghimire et al. 2010); impacts of climate change in nature-based tourism (Nyaupane and Chhetri 2009); impact of climate change on forests and livelihoods (Alamgir et al. 2014; Dahal et al. 2009); and climate change-related health impacts (Ebi et al. 2007).

Despite a number of studies conducted in the Nepali Himalaya, there still is a lack of research literature on climate change and associated implications on the social-ecological systems. After a review of literature a number of research gaps are identified. Previous studies ignored many of the social-ecological implications of climate change and poorly mapped adaptation strategies. The interrelations between recent environmental changes and livelihood systems have not been fully established by the studies at the catchment level. Nor have they made the effort to comprehensively explore ethno-cognitive knowledge on climate change, although social understanding of climate change is more effective than the scientific modelling to promote adaptation at the local level. Moreover, previous work overlooked adaptation outcomes in relation to food and livelihood security issues, and did not assess vulnerability of the social-ecosystems. The theoretical and methodological limitations of the work of existing researchers are that most of them adopted single theoretical approaches, and one-dimensional analyses. Consequently, they could not capture the existing complexities of the human-environmental systems sufficiently, and did not fully associate both the ecological and socio-cultural components at the same time. Therefore there is a serious lack of integrated research that provides comprehensive knowledge on human-environmental interactions in relation to climate change.

The Himalaya has the most diverse and difficult topography. It is also one of the more isolated regions of the world. In many respects, modelling methodologies of climate change are less meaningful for regional climate change study, particularly for the Himalayan region (Gillies et al. 2013; Karmacharya et al. 2015), and more so in the Himalaya because of topographical and climatic diversity. The region also lacks sufficient observational data or the sharing of the data that is available, so the region is considered as a 'white spot' for climate research (Christensen et al. 2007; Messerli 2009; Schild 2009). Available studies are not sufficient to develop effective adaptation policy for the Nepali Himalaya. Therefore, there is a great need for location specific studies within the country. To fulfil the gaps in knowledge, this research adopts an interdisciplinary research strategy to analyse the complex social-ecosystems. This study integrates scientific and social dimensions to assess climate change, maps autonomous, planned, private and public adaptation responses and discusses potential limits; and finally, assesses implications for the food and livelihood security and social-ecological vulnerability issues by considering both climatic and non-climatic stressors in the Nepali Himalaya more broadly. To achieve these goals, this study answers specific research questions.

1.2.2.1 Research Questions

- How has the climate of the Himalaya changed over time?
- How are local people perceiving, observing the trends and experiencing the impacts of environmental changes on their livelihoods?
- Is there consistency or contradiction between scientific and social understanding of climate change?

- What contributes to the livelihoods of the Nepali Himalayan communities? Are the livelihoods sensitive to climate change and its impacts?
- What sorts of coping and adaptation strategies have been developed at the local level and what is the outcome of such strategies for food and livelihoods security?
- What is the level of exposure, sensitivity and adaptive capacity of the social-ecological system and the implications for the sustainability of the system?

1.2.2.2 Research Objectives

This study explores the changes in climate of the Kaligandaki basin, Nepali Himalaya and associated implications on human-environmental interrelationships. The research also sheds light on changing human perceptions and behaviours towards the ecosystem services. The specific objectives of the study are as follows:

- To assess climate change trends and impacts in the livelihoods of the communities
- To understand the livelihood systems of the people of the Kaligandaki Basin and measure their sensitivity to changing climate
- To explore adaptation strategies adopted in response to climate change impacts and the challenges faced in the adaptation process
- To evaluate the food and livelihood security and assess vulnerability of the social-ecological system
- To make conceptual and theoretical contributions to the discipline of human geography and provide policy feedback for climate change adaptation and social-ecological sustainability in the Himalaya, Nepal
- To interrogate and contribute to the conceptual assumptions of climate change adaptation, livelihood systems, and social-ecological vulnerability

1.3 Rationale of the Study

The changes in climate and associated impacts interact dynamically with underlying social-ecological problems (Head 2010) and will force increasing change across these systems (Schneider et al. 2007). Due to the lack of effective adaptation, negative implications of climate change will increasingly lead communities towards vulnerability. Therefore, adaptation to climate change has been considered a major concern for development policies globally. More recently, many countries, including Nepal, have developed and implemented a National Adaptation Plan of

Action (NAPA) under the guidelines of the UN Framework Conference on Climate Change (UNFCCC).

As has been mentioned above in the research gap section Nepal has experienced a number of social-ecological problems, which are directly or indirectly linked to climate change; and the country requires effective adaptation policy. Local people hold rich knowledge of indigenous adaptation strategies; however, they may not be sufficient in reference to expected future climate change in the Himalaya (Macchi et al. 2014). To achieve an effective policy, appropriate up-to-date knowledge on various aspects of climate change and its relationship with society and ecosystems is required. The information collected to answer the research questions listed above aim to help craft appropriate adaptation policy for Nepal.

Adaptation is a fundamental necessity to reduce many of the adverse impacts of climate change on physical and anthropogenic environments, limit vulnerability of social-ecological systems and enhance the benefits of change (Debels et al. 2009; IPCC 2007a; IPCC 2014; Leary et al. 2007). The importance of adaptation is high also because the further warming throughout the 21st century is certain, due to the inertia of already released emissions (Collins et al. 2013; Ford and Smith 2003; Meehl et al. 2007; Nath and Behera 2011). Adaptation, especially for poor and subsistence farming communities, is urgent because they suffer the most by climate impacts despite their small contribution to GHG emissions (Baumert et al. 2005; Eriksson et al. 2008; Morton 2007; Ngaira 2007; Tanner and Mitchell 2008). Adaptation to climate change is a complex process so adaptation policies require consideration of a number of elements such as the pace of climate change and interconnected impacts, local adaptation knowledge and associated challenges in translating them into action, risk of maladaptation and to be critical, metric measurement of policy success may not actually happen in the field (Adger and Barnett 2009).

Local knowledge is credible for policies therefore the findings of this research have sound policy importance. Knowledge on climate change is seen as a pre-condition to initiate adaptation actions. However, local communities often poorly translate the knowledge produced by sophisticated modelling and the mastery of science (O'Neill and Hulme 2009). Capra (2007, p.13) stated that 'transformative' community-based learning rather than 'transmissive' expert-based knowledge can contribute to the sustainability of the social-ecological system. In addition, specific adaptation actions taken at community or individual levels could be of great importance to replicate, as well as to develop new mechanisms (Bardsley 2007). In this context, community perceptions on climate change impacts and adaptation actions give feedback for effective adaptation policies. Nepal lacks research that combines scientific and local knowledge for a viable policy in addressing the issues of climate change. This study narrows the gap by reconciling the expert-based knowledge with non-expert communities' by generating knowledge at the household level and provides knowledge to design policies for climate adaptation and sustainable development in Nepal.

Climate change is likely to impinge on sustainable development (IPCC 2007a). The UN Millennium Development Goals (MDG) to halve poverty and food insecurity by 2015 has been challenged by accelerated climatic change. South Asia, one of the places in the globe with the highest concentrations of malnourished people, will suffer from the significant impact of global warming on food production (Cruz et al. 2007; Lal, M 2011). Frequent floods triggered by heavy monsoons, massively damage lives, property, crops and infrastructure in South Asia, further challenging food security (Mirza 2011). Additionally, climate change and associated implications are seen as a source of potential conflict (Adger 2010; Ansorg and Donnelly 2008; Barnett 2006; Barnett and Adger 2007; Verhoeven 2011). Nepal is still in a political transformation stage from a decade long armed conflict (1996-2006). Lack of or poor adaptation outcomes or exacerbation of existing socio-economic and political inequalities by climate change, put the country at risk of returning to severe conflict. Therefore, the explicit inclusion of climate change adaptation into Nepali development policies and plans is essential. The findings of this study provide knowledge required to craft integrated development policy aiming to promote adaptation and sustainability of the social-ecological system in Nepal.

Moreover, the findings of this study conducted in the Kaligandaki Basin, have policy rationale for the Ganges Basin in general, and in Nepal specifically. The Kaligandaki Basin is one of the major basins in the Ganges System. The head of Kaligandaki River lies in Tibet, China and crosses the Trans-Himalaya, Greater Himalaya, Middle-Mountains, and meets with the Ganges River at Patna (India). While intersecting the highly erosive Himalayan landscape and passing through the highest rainfall area of Nepal (Lumle), the Kaligandaki River becomes the source of both water supply for domestic and farm use as well as for severe floods in the Gangetic plain in India and Nepal. In this context, the Himalaya is strategically important for the management of climate change impacts in the Ganges Basin because the roots of the severe floods in the basin lie upstream in the Himalaya. The study of climate change and associated implications, adaptation responses and the vulnerability of the social-ecosystem of the Kaligandaki Basin can be one of the representative studies for the Ganges Basin. This study selects three clusters from different ecological zones in Kaligandaki Basin: Meghauli from the Tarai [3], Lumle from the Middle-

[3] 'Tarai' of Nepal in general is not a part of the Himalayabut Meghauli VDC lies in-between Churiy Range and Middle-Mountains, therefore, is the part of the Himalaya. However, the valley is classified as Tarai in broader physiographic

Mountains and Upper-Mustang from Trans-Himalaya (see Chapter Three 3.3.3: Study Area for details), and undertook a face-to-face interview with the heads of 360 households to generate required knowledge.This study integrates the disciplines of climatology and human geography and covers wide thematic and methodological areas. Therefore, apart from policy rationale, this research also supports a scholarly discourse on the importance and validity of a holistic research approach and integrated methodology on understanding human-environmental interactions in the age of climate change

1.4 Journey of the Researcher

The researcher is a Nepali citizen and has one and a half decades of work experience in the fields of social research, teaching at tertiary level, and managing community development programmes. The researcher is a geography graduate, specialising in human ecology and development geography. Human ecology is a holistic approach of seeing human-environmental interactions. The researcher received foundation knowledge on human ecology while doing research on human ecology of mountain environment as a Master's Degree Thesis in 1998 (Pandey 1998; Subedi and Pandey 2002). The researcher has extensive experience of research work particularly in the field of human-environmental interactions and livelihood outcomes (Pandey 2008; Subedi et al. 2007a; Subedi et al. 2007b). The researcher also supervised several Masters' Degree theses and has examined few Master's Degree theses. In this context, the researcher is well trained in research processes and research ethics, which are duly followed in this project as well. Therefore the results presented are made as unbiased as much as possible. Furthermore, the researcher is well aware of socio-cultural diversity in Nepal, including on the issues of social exclusion and marginalization, and their manifestation in the sections of communities in the country, Nepal. The researcher has also worked as human rights activist and conflict mitigation facilitator, as well as has conducted a number of researches on social exclusion and peoples' suffering in Nepal (Pandey 2007; Pandey and Adhikari 2013; Pun et al. 2010). Hence, the researcher is concious on various issues in Nepal in general and in development planning and management, social justice, and social research in particular.

The idea of conducting research on human ecological implications of climate change originated in 2008 and since then the review of accessible literature and the framing the research project began. Feedback on the proposed research project has been received from a number of perspective supervisors from different universities, although the project is finally accepted at the

division and inner-Tarai in specific classification in Nepal. Furthermore, the climate of the VDC is sub-tropical, similar to the Tarai.

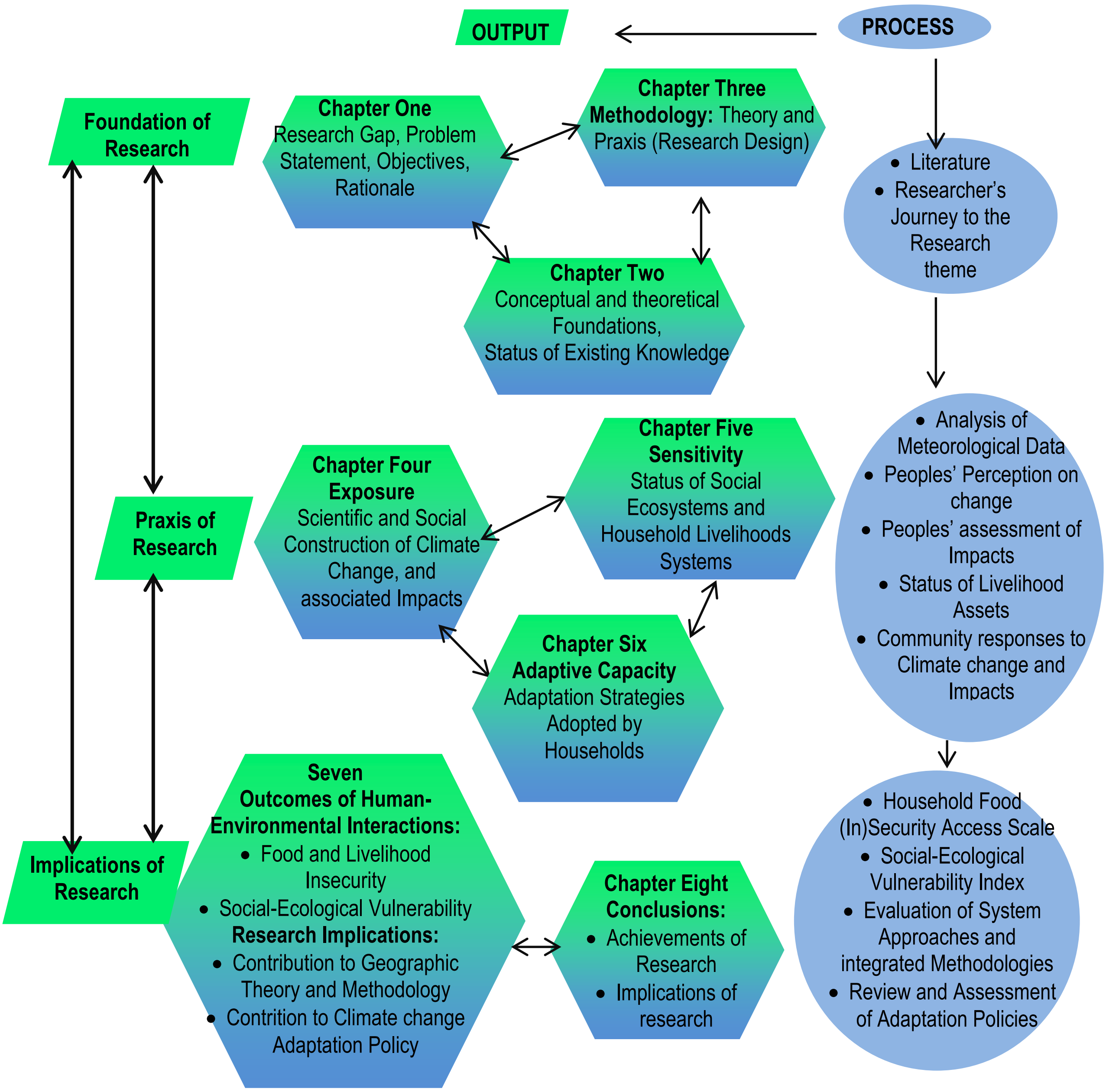
University of Adelaide. The project is of deep interest of the researcher, so he developed a clear conceptual framework after a rigorous review of literature. That in turn assisted this research to run smoothly. The result is that the comprehensive analysis has been completed on time. Yet, some of the components as mentioned in the limitation section (see 3.6) could not been covered by the project, particularly because of the limitations of time and budget, as well as the specified length of the report. Moreover, during the PhD journey, it become relevant to limit some of the tasks of an optimistic project. The intended works, which could not been included in this thesis, are proposed as future research agenda in chapter eight (see 8.2.3.4).

1.5 Research Processand Structure of Thesis

This thesis is divided into three sections and eight chapters (Figure 1.1). The first section is the foundation, second is praxis and the third is implications. There are three chapters in the first section: 1) Introduction, 2) Literature Review and 3) Methodology. Chapter One introduces the research theme, states the research problems, identifies research gaps and presents research aims. The chapter also provides the research rationale and information about the researcher's journey to this research project. The chapter also summarises the overall process the research work has followed, and the structure of the research report. Chapter Two reviews the literature ranging from key concepts and theories to empirical findings, and constructs a theoretical framework for the study. In the chapter, geographical concepts such as human ecology, social ecology, climate and environmental change, vulnerability, adaptation, sustainable livelihoods and institutions are defined in relation to their application in this research. Furthermore, the theories associated with mentioned concepts are critically evaluated. Empirical findings, both local and foreign studies have been reviewed to be familiar with the existing knowledge in climate change and associated implications, adaptation responses of the communities, and adaptation limits and barriers they have experienced. Based on the knowledge gained from literature review, conceptual framework to guide this research is skatched (see Figure 2.1).

Chapter Three clarifies the adopted research methodology and constructs detail research design. The aim of this chapter is to develop various guidelines to collect data, and analyse and interpret the results in the second sections.

Figure 1.1: Research Process and Structure of Thesis



The second section also has three chapters: 4) Climate Change and Impacts, which provides information on exposure of social ecosystem to climate change using both physical science (analysis to meteorological observations) and community perceptions, and searches for the implications for the social-ecological system; 5) The state of Social-Ecological System of the Study Area, which explains the level of sensitivity of livelihood assets of the households to climate change, and 6) Adaptation Responses that explains adaptive capacity of the communities and households to climate change together with . the adaptation challenges faced by the communities. Hence, the chapters of the second section are linked to each other to explain the exposure, sensitivity and adaptive capacity of the system to climate change on the one hand, and on the other, are linked to section one to demonstrate the relationships with the concepts, theories, and existing knowledge to fulfil the stated objectives of the research.

The third section elaborates upon the research outcomes, their implications and conclusions. This section has two chapters: 7) Livelihood Outcomes and Research Implications, and 8) Conclusions. Chapter Seven presents food (in)security as an indicator of livelihood outcomes and the social-ecological vulnerability as an overall outcome of human-environmental interactions. The chapter also describes research implications especially for the discipline of geography in relation to adaptation policies for Nepal. Chapter Eight concludes the research, and identifies an agenda for further research.

CHAPTER II

CONCEPTUAL AND THEORETICAL FOUNDATIONS AND EMPIRICAL WORK RELEVANT TO CLIMATE CHANGE ADAPTATION IN NEPAL

2.1 Introduction

The aim of this chapter is to develop the conceptual and theoretical understanding of the research theme and construct a research framework. This chapter is based on the review of both peer-reviewed academic and grey literature. A review of literature is an essential stage of research that fills the philosophical vacuum and assists to validate the research findings (Kitchin and Tate 2000). The chapter initially introduces the geographic concept of human-environmental interrelationships in relation to Nepal. It goes on to introduce and define human ecology, social ecology, climate change, vulnerability, adaptation, food and livelihood security, social ecological sustainability and institutions, which are the major conceptual and theoretical components relevant to the thesis. The chapter also reviews existing knowledge on climate and environmental change, climate change induced impacts and adaptation efforts made by communities with a focus on the Nepali Himalaya. Both local and foreign literature was reviewed so the findings of this research could be compared as required. At the end of the chapter a conceptual framework, a theoretical assumption of human-environmental interactions in the Nepali Himalaya, is developed to investigate human ecological implications of, and adaptation to, climate change in the Kaligandaki Basin, Nepal.

2.2 The Geographic Concept of Human-Environmental Interactions

Geography, especially human geography, is the study of the interrelationships between people and environment. Geographic research focuses on how human and non-human environments interact and affect each other (Cronon 1996). The environment in general is a ‘non-human’ component of nature that includes land and sea, ecosystems, species and geological components (Judkins et al. 2008). This study aims to answer the questions ‘what is?’ and ‘what ought to be?’ the relationship between people and the environment in the Nepalese context (Kates 1987). The answers to the question ‘what is the relationship?’ involves descriptions of prevailing interactions, whereas the answers to the question ‘what ought to be the relationship?’ are explained by the requirements of social-ecological systems to achieve their goals of sustainability.

Geographers have adopted and abandoned in turn, environmental determinism, possibilism and neo-environmental determinism approaches in the past to explain the interactions between people and the environment (Sluyter 2002). The deterministic geographers see environment as a powerful agent that frames human actions within environmental limits. The deterministic concept interprets the environment as hostile to human freedom (Urry 2011). That concept has been challenged by progress in the fields of culture, science and technology that have demonstrated that the controlling elements of the environment can be overcome through human transformation of nature. Traditional human-environmental interrelations are transformed by the modern, with humanity perceiving itself as a conqueror of the environment. The dominant human economic system sees the environment as having no limits, only possibilities. This approach of explaining human-environmental interrelations is known as possiblism or cultural determinism (Leighly 1987). However, the modernization process has made human-environmental interactions more critical and complex.

Societies' eagerness to exploit nature has created a traditional (natural control) and modern (human control) dichotomy in human-environmental interactions (Urry 2011). Thus, increased disharmony between humans and the environment has caused many environmental problems, including anthropogenic climate change. As will be integrated further, climate scientists have come to a consensus that anthropogenic climate change is having dangerous impacts on the human-environmental system (Field et al. 2014; IPCC 2007a). Extremely powerful weather events and degrading climatic trends in recent decades have seen a decline in the relevancy of the cultural determinism approach of interpreting human-environmental interactions. Consequently, a neo-environmental determinism approach is being adopted by many theorists and practitioners to better explain human-environmental interrelationships.

Neo-environmental determinism theory is probably the most comprehensive approach to explain human-environmental relationships. Neo-environmental determinism recognizes invariable dynamics between society and the environment and attributes causal determinacy for one over another through complex interactions (Judkins et al. 2008; Radcliffe et al. 2010). In this case, societies are conceptualised as interlocking human ecosystems, which operate on the basis of individual initiatives and acts that are embodied in aggregate community behaviour and institutional structures (Butzer 1990). Neo-environmental determinism combines analysis of human and natural ecosystems and explains cybernetic interactions. While neo-determinism is evolving as a vital theoretical framework, poor recognition or adoption of the approach in human-environmental research suggests an on-going disregard of the new complexities influencing the conditions on planet Earth.

Adoption of quantitative methodology in the social sciences in some degree is responsible for framing a detachment of humanity from the environment. The intellectual structure of the geographic discipline has particularly emphasised a false detachment of humanity from nature since the discipline was divided into physical and human geography, and these sub-disciplines adopted different research methodologies (Adger 2006; Bunge 1962; Fitzsimmons 1989; Johnston 1983; Sluyter et al. 2006; Stoddart 1987; Thrift 2002). Given the need for understanding complex human-environmental relationships simultaneously there is a need to narrow the differences between physical and human geography. Framing interactions of humanity and nature from neo-environmental perspectives is a way of bridging the gap and human ecology, a sub-discipline of geography, has evolved to combine both physical and human geography, therefore, the neo-environmental outlook is appropriate in this thesis.

2.3 Conceptual and Theoretical Underpinnings

In social science research, the meaning of concepts often differs with the context of their use. Therefore, the concepts used in this research are defined to inform the readers about their application in the context of this study. This section illustrates perceptions and the laws and logic of interconnections and interactions of the components of the social-ecological system in the climate change context that help validate the research findings. The perceptions, hence, are applied as social theory or the system of belief and assumption (Jaggar and Rothenberg 1993), while the laws and logic are considered as an abstract and mathematical logic system as adopted by natural science (Bunge 1962).

2.3.1 Human Ecology

Human ecology is an approach to geographical enquiry of human-environmental interactions. It is the science of ecology that explains the complex and dynamic interrelations between societal and bio-physical systems (Barrows 1923; Lawrence 2003; Prudham 2009). It is also used to explain highly specific relationships between natural processes and human actions (Bohle et al. 1994; White et al. 2001). Societies develop a complex but systematic interaction with the environment; and climate has always been an important negotiating component. Therefore, studies of human ecology in the context of climate change become an important research theme. The concept of 'human ecology' covers a wide range of physical and social phenomena and the complex web of interactions that produce and reproduce particular forms of life systems in different places and at different times across the planet. Human ecology accommodates a number of concepts within its broader definition: Cultural ecology (Steward 1977), political ecology - applied initially by

Cockburn, Wolf and Beakhurst in the 1970s (Watts 2009); environmental psychology (Kitchin and Blades 2001) and social ecology (Berkes and Folke 1998; Bookchin 1995). All of these concepts are closely related to human ecology and are overlapping fields.

Some scholars criticise human ecology for being overly managerialist or technocratic - too concerned with adjustment or adaptation and not with social processes (Pelling 2001; Mazlish 1999; Mustafa 2005). The concept provides limited attention to historical and political dimensions of human-environmental interactions. Zimmerer (1994) and Zimmerer and Bassett (2003) blame the approach for conceptualizing the environment as an influential actor in human–environment relations and ignoring the role of political economy in interactions (. To accommodate socio-political and economic institutions into classical human ecology, Berkes and Folke (1998) highlight human agencies like population, technology, organization and culture in ecosystems to generate the concept of 'social ecology'.

2.3.2 Social Ecology

Social ecology is the study of a complex web of interactions among the components of social-ecological systems. It tries to explain the complex and interactive interrelationships of social phenomena within both bio-physical environments and the political-economic, cultural, institutional and technological trajectories of social development (Adger 2000a; Berkes and Folke 1998; Capra 2007; Prudham 2009). The approach criticises the mainstream focus on social, political and anti-ecological economic development. Therefore, social ecology is an approach, a paradigm or worldview and a praxis of the communities that emphasizes the ethical responsibilities of humanity for environmental sustainability, and advocates a reconstructive, ecological, communitarian and ethical society (Bookchin 1995; Hills n.d.). The concept stresses the transformation of social and environmental issues and links humanity with the environment both systematically and holistically.

The difference between human ecology and social ecology is only the perspective from which the environment is seen. Human ecology is concerned with 'what is the interrelationship' (existing system of interaction), whereas social-ecology is associated with 'what ought to be the interrelationship' (expected system of interaction) for the resilience and sustainability of human and environmental systems. Both of these concepts are highly relevant in this study; and due to their similarity the term social-ecology is used. Many elements, both natural and social, affect human-environmental interactions that lead to a change; and climatic change is the primary element relevant to this research.

2.3.3 The Concepts of Climate and Environmental Change

The average condition of weather at a place over a period of years as exhibited by atmosphere, hydrosphere, cryosphere, lithosphere and biosphere as a whole is understood as a climate (IPCC 2007b). Climatologists define climatic types through average statistics of measurable weather elements, generally over a period of 30 years as defined by World Meteorological Organization (WMO) as the average period, however, it may range from months to million years (Hulme et al. 2009; Le Treut et al. 2007). The climate is a constructed idea because it is a complex interactive system that consists of physical (meteorological statistics, water course, vegetation, soil moisture and earth surface, snow and ice), non-human living things, and cultural elements such as sensory experiences, mental assimilation, social learning and cultural interpretations (Hayman et al. 2011; Hulme 2008a; Rayner 2003). In this study, climate is considered as an average condition of both physical and non-physical elements over a period of roughly four decades.

Climate scientists have found that observed patterns of weather over the centuries change due to both natural and anthropogenic drivers. Since the 1980s, anthropogenic climate change has become an important scientific, environmental, social, economic and political issue (Urry 2011). The change in climate refers to any alteration in climate systems over time, whether due to natural or anthropogenic forcing (IPCC 2007c). There are different theoretical postulations about the driving forces of climate and environmental changes (Berkes and Folke 1998), and those relevant to the present study are briefly noted below.

2.3.3.1 Neo-Malthusian Models of Environmental Change

The neo-Malthusian paradigm of environmental change sees population growth as a factor of environmental change and natural forces such as environmental disasters as the natural way of balancing population. This theory explains human-environmental interactions under the IPAT [4] model (Ehrlich and Holdren 1971) and STIRPAT [5] model (Dietz et al. 2007). Many studies on environmental changes are still dominated by the IPAT model, even though it overlooks the role of social, economic and cultural forces and technological development in human-environment interactions and change (Douglas et al. 1998; Fischer-Kowalski and Amann 2001; Forsyth 2003). Some reforms have been made in the neo-Malthusian model by incorporating socio-political and

[4] The changes in environmental system, the impacts (I) are seen as a function of three variables i.e. the population (P), level of affluence (A) and the level of technological advancement (T)

[5] Stochastic impacts by regression on population, affluence and technology so the model accommodates many components of population, ecological footprint and the technologies

techno-economic dimensions in the model (MEA 2005; Stern et al. 1992); however, these reforms have not been put into practice in climate change adaptation and environmental policies of Nepal.

2.3.3.2 Ecological Modernization Approach to Environmental Change

According to the ecological modernization paradigm, the technological development, economic expansion and the growth of environmental governance are both the cause of, and solution to, environmental degradation. Economic development and shifts in technology generate environmental problems initially, while further advancement in development and technology mitigate problems later. Modernization and advanced technologies shift highly polluting technology into less polluting ones (Murphy 2000), which is referred to as the process of 'ecological restructuration' (Mol 2001).

The limitation of the ecological modernization model is its emphasis on carefree consumption of environmental resources until reaching affluence (Inglehart 1990; Inglehart 1997; Inglehart and Welzel 2005; Murphy 2000). This approach fails to recognize the inequalities and marginalization, and environmental injustices, which force the majority to bear the cost of environmental degradation caused by a few affluent communities. The assumption of the theory - the growth of institutions against environmental pollution would create effective political pressure to heal the environmental wounds and begin ecological restructuring is just an irrational statement because having such advocates does not necessarily influence the capitalist mode of production. For example, Brulle (2010) stated that if it was so the US would have signed the Kyoto Protocol 1997 very early since the country had the highest number of environmental institutions and affiliated members advocating for it. Despite many disappointing results like global warming and climate change, the ecological modernization approach is well practiced throughout the world.

2.3.3.3 Theory of Political Economy of Environmental Change

The theory of political economy views environmental change through a neo-Marxist lens, and especially the World System Approach of Wallerstein. In the world-system, all the nations of the world are connected into a single global economy so every state makes an effort to benefit from global capitalism (Wallerstein 1974a; Wallerstein 1974b). Among the countries: core, semi-periphery and periphery, are categorised based on their ability to benefit from the world system, the core becomes affluent by causing socio-economic and environmental marginality of the periphery. In this context, the theory of political economy is highly critical of the ecological modernization approach.

The theory of political economy of environmental change claims that ecological crises are the product of the lure of increased capital accumulation of core nations by reducing production costs. Capitalism seeks technological replacement by advancing technologies in the core and transferring polluting industries to the periphery (Bergstø and Endresen 1992; Hesselberg 1995; the Economist 1992). This process leads to environmental injustice in the periphery. However, it is increasingly recognised that major environmental issues do not respect political boundaries so the problems of anthropogenic climate change are common issues also to the core nations. While at the same time, the impacts of climate change are disproportionately concentrated into the periphery because of the inadequate adaptive capacity of poor communities and countries.

The changing climate poses new risks as well as increases the likelihood and intensity of environmental hazards and changes further lead to socio-ecological vulnerability. The theory of social-ecology considers the opinions of the theory of political economy that advocates a transformation of the economic and governance systems controlled by elites; emphasizes changes in consumption patterns, and pressurises to restructure societies to create environmental justice and sustainable social-ecological systems (Beck 1992; Bookchin 2007; Urry 2011). The political economy of a country also influences climate change impacts, vulnerability and adaptation directly or indirectly. Therefore, the theory of political economy of environmental change is adopted in this research to explain the changing human-environmental system in the Himalaya, Nepal.

2.3.4 Vulnerability

The concept of vulnerability is interconnected with risk and hazards. Risks directly or indirectly lead people towards hazards and vulnerability (Alexander 2000; Brooks 2003; Brooks et al. 2005; Dao and Peduzzi 2003; Sarewitz et al. 2003). Therefore, these terms cannot be isolated from each other. Vulnerability in relation to climate change is a function of the sensitivity of the system to climate change, the adaptive capacity of the system, and exposure of the system to climatic variability and change (McCarthy et al. 2001). However, the concept is complex and multi-faceted.

There are many definitions of vulnerability and as a result there is no consensus on the meaning (Maxim and Spangenberg 2006; Thywissen 2006), while Newell et al. (2005) considered vulnerability as a ‘conceptual cluster’. Some scholars took vulnerability as a ‘context’ or ‘pre-existing condition’ of a system having potential loss or transformation due to exposure of the system to environmental hazards (Adger 2006; Allen 2003; Burton et al. 1993; Cutter et al. 2000; Cutter et al. 2003; Gallopin 2006). Some other scholars considered it as an ‘event’ or ‘stimuli’ that harms a system (O'Brien et al. 2004; Sining 2011), while some of the others viewed it as an 'outcome', or the inability of a system to cope with and recover from the pressure of hazards (ADRC 2005). However, in many respects, it is difficult to separate vulnerability in terms of the context-events-outcome cycle.

The concept of vulnerability is applied in various fields of studies: in natural hazards after the work of Hewitt (1983), in food security after the works of Sen (1981) and Dreze and Sen (1990); and in environmental change after the work of Liverman (1990), Kasperson et al. (1995) and Cutter (1996). The roots of the concept, however, are embedded in the social sciences (Luers et al. 2003). It is increasingly been applied in climate change adaptation and mitigation context, particularly since the evolution of the IPCC. In climate change, vulnerability refers to the state of susceptibility to harm from exposure to stresses or hazards associated with environmental and social changes and the absence of the capacity to adapt (Adger 2006; Brooks 2003; Cutter et al. 2003; IPCC 2007a; McCarthy et al. 2001). In this study, vulnerability is taken as the probability of occurrence of environmental (climatic) hazards and their likely impacts on the social-ecological system. In other words, it is the exposure of individual households or the communities to livelihood stresses caused by climate and environmental change and households' inadequate capacity to cope with, and recover from, the implications, and maintain household and community well-being (Adger 1999; Kelly and Adger 2000; Robert and Barry 2006). The range of definition of the concept indicates that the causes of vulnerability and its assessment are complex.

The causes of vulnerability are wide, and go beyond the local environmental settings, creating a myriad of connections of local people with the national and international political economy (Allen 2003; van Aalst et al. 2008). The poor, marginalized and powerless people are more likely to live in risk and hazard prone areas and suffer from vulnerabilities, while more privileged people get opportunities of escaping the hazards and vulnerability (Chakraborty et al. 2005; Fitzpartrick and LaGory 2000; Hewitt 1983; Pasteur 2010; Sen 1981). Some scholars categorise vulnerability based on the causes: physical-environmental, socio-economic and external assistance (Moss et al. 2001); physical, economic, social and environmental or social, bio-physical, technological and institutional (Sining 2011). However, others believe that physical vulnerability does not exist in isolation to socio-cultural, politico-institutional, techno-economic factors; therefore vulnerability is an integrated phenomenon (Adger 2006; Blaikie et al. 1994; Brooks 2003; Cutter 1996; Haanpaa and Peltonen 2007; Hewitt 1997; Martens et al. 2009; Satterfield et al. 2004).

Vulnerability is a function of multiple factors such as the nature of the physical hazard, the frequency of occurrence of the hazards, the extent of human exposure to the hazard, and the system's sensitivity to the impacts of the hazard (Brooks 2003). Individual behaviour in responding to environmental crisis (Robert and Barry 2006), and public policies and institutional mechanisms (Adger 2000b; Bakker and Downing 1999; Bohle et al. 1994; Robbins 1998) are also implicated in vulnerability. In the climate change context, the magnitude, frequency, spatial distribution and duration of hazards are the stimuli of vulnerability (IPCC 2007a). Therefore, it is an interactive function of exposure [6] of climate sensitive [7] systems to the change and the capacity of the system to absorb the impacts without suffering for the long-term (Adger 2006; McCarthy et al. 2001).

Vulnerability of a social-ecological system increases when the system cannot mutually reinforce the structures and process to preserve the system and increase its resilience, but suffers from hazards associated with the disturbances and stresses (Adger 2006; Carpenter et al. 2001; Folke et al. 2002; Holling 1995). Here, resilience refers to the capacity of a system to absorb stresses during perturbations without experiencing fundamental structural changes in the original state of system, or achieve a speedy recovery from disturbances, or maintain basic functions of the system at critical thresholds (Adger et al. 2011; Carpenter et al. 2001, Folke 2006; Folke et al. 2010; Füssel 2007; Holling et al. 1995; Klein et al. 2003; Walker et al. 2006).The degrees of vulnerability vary with available adaptation options, societal history, infrastructure and technologies (Wheaton and Maciver 1999).It is argued that the poor adaptation caused by adaptation barriers also increases vulnerability (Deressa et al. 2009; Jones and Boyd 2011; Moser and Ekstrom 2010; Nielsen and Reenberg 2010).

Principally, vulnerability can be reduced by changing socio-political institutions and addressing the physical, socio-economic, politico-institutional and technological stressors. Vulnerability assessment provides the point for policy intervention. There are several methods of assessing vulnerability (Adger 2006; Brooks 2003; Pratt et al. 2004; Luers et al. 2003).The Drivers→Pressures→ State of Changes→ Impacts→ Responses (DPSIR) framework is used by scholars as an effective tool of system analysis for environmental problems (Atkins et al. 2011; Jesinghaus 1999; Maxim and Spangenberg 2006; Smeets and Weterings 1999).Many elements both environmental and non-environmental can be attached to the DPSIR chain. Therefore, this research evaluates vulnerability using a holistic approach that incorporates the resource entitlements, climate and environmental changes, associated impacts, adaptive strategies and adaptation barriers into the DPSIR framework (Figure 2.1). Adaptive capacity and effective adaptation are very important to reduce vulnerability.

[6] Exposure is the nature and degree to which a system experiences environmental or socio-political stress (Adger 2006)

[7] Sensitivity is the degree to which a system is modified or affected by perturbations (McCarthy et al. 2001)

2.3.5 Adaptation

Adaptation is a process of altering or modifying the context of an individual, community and ecosystem to limit harm and prepare for change (Watts 2009). Adaptation is one of the most diverse concepts, having a variety of meanings and applications (Head 2010; Moser and Ekstrom 2010). Sayer (1979) has perceived adaptation as an influential metaphor of relations between human and non-human environments. In a climate change context, adaptation is the fitness of the human being and the prosperity and sustainability of both the natural and human systems. The adaptation process strengthens the fitness of a system to its environment (Adger et al. 2003; Adger et al. 2007; Manuel-Navarrete et al. 2009; van Aalst et al. 2008).From a political ecology perspective, it should also enable the poor and vulnerable societies to reduce the negative implications of stressors on a systems' functioning. In this research, adaptation is taken as the 'process of adapting' and the 'state of being adapted' in face of climate change (Wheaton and Maciver 1999).

There is no single theory of adaptation (Adger 2000b). The process goes through the interplay of a range of factors of socio-cultural, politico-institutional, techno-economic and psycho-behavioural spheres and their relationships to the production and reproduction processes. The factors include, but are not limited to, technological development and infrastructure, economic resources, human and social capital, political institutions and governance systems; identification of adaptation barriers, provision of information communication and dissemination; acquiring social support, promoting creative resource management, and changing the values and beliefs of social institutions for an equitable society and environment (Adger et al. 2009; Klein 2004; Sining 2011; Thornton et al. 2006;Wildemeersch 2007). The goal of adaptation is to strengthen the adaptive capacity of a system.

The adaptation process empowers individuals, communities and countries to cope with the consequences of climate change, reduces the negative impacts and vulnerability through behavioural adjustments, and makes the system resilient to climatic and non-climatic stressors (Leary 1999; Lim et al. 2005; Smit and Wandel 2006). In other words, adaptation is the ability of a system to modify or change its characteristics or behaviours to cope with actual or expected climatic stimuli or their effects by adjusting systems' (ecological, social and economic) behaviour and characteristics, reducing harm, exploiting opportunities and maintaining resilience (Burton et al. 2002; IPCC 2001; Martens et al. 2009; Parry et al. 2007; Smit et al. 2000; Tompkins and Adger 2003).

The adaptation process varies across place, people and time. Many of the communities and countries have significant capacity to adapt through latent local knowledge and experience (Berkes and Jolly 2001; Mortimore and Adams 2001). The adaptation effectiveness or level of vulnerability varies with people's levels of understanding of impacts (Füssel and Klein 2006). Spatially varying adaptation limits, barriers and obstacles, and distant or fuzzy signals of changing climate and uncertain implications influence communities' adaptation abilities (Adger et al. 2009; Bardsley 2015; Deressa et al. 2009; Jones and Boyd 2011; Moser and Ekstrom 2010; Nielsen and Reenberg 2010; Tol et al. 1998).The goal of adaptation, especially for farming communities could be seen to be achieving food and livelihood security and the maintenance of social-ecological sustainability. For that reason, adaptation in this study is defined as the action of embracing strategies to moderate harm and exploit beneficial opportunities of climate change and assist meeting food and livelihood security, and to promote the sustainability of the social-ecological system (Adger 2000a; Adger et al. 2007; Holling et al. 1995; Nelson and Stathers 2009).

2.3.6 Food and Livelihood Security

Food security is a major component of livelihood security. Food security of a household and a community depends on the social-ecological conditions where the household and community gain their income and other resources. Vulnerability of a social-ecological system may increase food insecurity and in association, livelihood insecurity. Also, food and livelihood insecurity tend to increase vulnerability of a social-ecological system since food and livelihood insecurity can put extraordinary pressure on environmental resources.

Climate is an important driver of food systems. Changes in climate affect production, storage, supply and the consumption of food. Food security is the primary goal of agrarian communities. However, many factors, both climatic and non-climatic (food production, income, culture or religion, equity, crop disease, food pests and pathogens, food sanitation and hygiene, and political and market elements) determine the food security of a place, community and household (Adger et al. 2007). Although security and insecurity themselves are not easily measured, better adaptation to climate change is expected to promote food and livelihood security.

Livelihood is the means of gaining a living that includes the bundle of assets, abilities and activities a person or household commands that enable life. It is closely linked to natural resource use or obtaining ecosystem services, particularly in the rural context. Here, ecosystem services refer to the range of environmental benefits like water, air, food, natural resources within the region and away, provided to human by nature and managed ecosystem (Millennium Ecosystem Assessment

2005). Livelihood security is about satisfying or meeting the basic needs (Sneddon 2000) and achieving personal or household well-being (Ellis 2000). Livelihood security comprises the capabilities (ability to cope with stress and shocks and ability to find or make livelihood opportunities), assets (resources, stores, claims, and access), activities (livelihood strategy) and social institutions and gender relations (Chambers and Conway 1991). A changing climate can damage or destroy the quantity and quality of livelihood assets and can lead to livelihood vulnerability (Adger 1999; Eakin 2000; Eakin et al. 2006). Therefore, a livelihood perspective gets special attention in this research of climate change implications for Nepali social-ecological systems.

Livelihoods can be made secure and sustainable or vulnerable, depending upon the management of livelihood capital (Folke et al. 2002; Osbahr et al. 2008). Livelihood capital collectively ensure the resilience and sustainability of a livelihood system since natural capital delivers ecosystem goods and services; social capital builds relations of trust, norms, obligations and institutions fundamental to collective actions; human capital produces the technologies for well-being and physical and financial capital provides infrastructure and financial resources (Pandey and Jha 2012; Pretty 2011; Pretty 2003). The sustainability of a livelihood system can also be strengthened through social learning to build livelihood assets and integrate them into constructive and positive feedback loops (Selby 2007; Tidball and Krasny 2007; Wals and van der Leij 2007). To promote the sustainability of the livelihood system, there is a need to include: strategies of poverty reduction, income diversification, respecting common property management rights and promoting collective security of those communities who are most exposed to social and environmental hazards through collective application of livelihood capital (Adger 2000b; Auty 1997; Kelly and Adger 2000; Machlis et al. 1990). The Sustainable Livelihood Approach (SLA) is one of the perspectives of livelihood security practiced widely, including in Nepal.

The SLA emphasizes capability and entitlement (Sen 1984). People's differential access to resources is seen as the principle determinant of sustainability or vulnerability of their livelihoods (Blaikie et al. 1994). The interplay of livelihood capital, institutional context, shocks and vulnerability, policy issues and adaptation strategies collectively regulate households' livelihoods (Berkes and Folke 1994; Chambers 1988; Carney et al. 1999; Frankenberger 1996; Ostrom 1990). Therefore, the capability of a community to deal with risk and hazards in reference to the types of resources they can access and exploit, are important components of livelihood sustainability (Adger 2000b; Osbahr et al. 2008; Watts and Bohle 1993).

Climate change impacts on existing interactions among the livelihood components with negative implications generating poverty and slowing processes of rural livelihood renewal (Osbahr et al. 2008). The SLA helps systematic analysis of poverty, provides wider and better information for development opportunities and places people at the centre of the analysis (Chambers 1988; DFID 1999). However, in a climate change context the outcomes of the interplay of the components of the SLA may not be straight-forward and positive. The interplay can also produce unexpected results because of the environmental uncertainties and variability. This research integrates SLA into the DPSIR chain and designs a conceptual framework (Figure 2.1) to accommodate both endogenous and exogenous stressors of the interactive system. Therefore, the framework is an evolution of earlier SLA that helps households and communities achieve livelihood security and the sustainability of the social-ecological system through adapting to climatic and non-climatic stressors.

2.3.7 Social-Ecological Sustainability

The discourse on sustainability has already occurred for more than four decades, although the formal use of the term in development policy only began after the WCED in 1987. WCED defined sustainable development as the development that "meets the needs of present without compromising the ability of future generations to meet their own needs" (WCED 1987, p.8). Sustainability is a point of view on transformation of mainstream development and consumption practices for a sensible, desirable and feasible economy, ecology and society, and the maintenance of nature's ability of sustaining life through its self-regulating and self-organizing web of life (Bardsley 2015; Capra 2007). The concept has been criticised as overly vague, holding an ambitious approach for growth-oriented development (Escobar 1995); and trying to accommodate conflicting values such as existential needs, responsibility, power, position, autonomy, inequalities and beliefs (Loeber et al. 2007; Wals and van der Leij 2007). Nevertheless, sustainability has become a framework concept of development policy globally, including Nepal.

Climatic processes and events on the one hand and non-climatic factors such as social, economic, political and cultural institutions on the other, affect sustainability of a social-ecological system. According to Robert McLeman, University of Ottawa, climate processes are slow-onset changes such as sea-level rise, salinisation of agricultural land, desertification, growing water scarcity and food insecurity, while climate events are sudden and dramatic hazards such as monsoon floods, glacial lake outburst floods, storms, hurricanes and typhoons which damage social ecosystem quickly and dramatically (as cited in Brown 2007). Social-ecological sustainability is associated with the maintenance of a harmonic relationship between societies and the environment, addressing underlying causes of vulnerability by enhancing adaptive capacity, and increasing the resilience of the system (Berkes and Folke 1998; Kelly and Adger 2000). Achieving social-ecological sustainability is very important in the climate change context because the success or failure of adaptation affects sustainability outcomes on the one hand, and levels of sustainability determine the pace of future climate change and adaptation process on the other. For that reason, there is a recognised need for greater cohesion between climate change adaptation and social-ecological sustainability (Adger 2000a; Martens et al. 2009).

The dominant modern system is in crisis because of its emphasis on the 'parts', rather than on the 'whole' social-ecosystem. The difference between ecological and non-ecological thinking is all about the emphasis, whether on the 'parts' or on the 'whole' system of interactions; giving importance to 'parts' is reductionist, mechanistic, atomistic and non-ecological; whereas the emphasis on the 'whole system' is holistic, organismic or ecological (Capra 1996). In this context, sustainability of a social ecosystem in relation to climate change requires an emphasis on the whole system, because both the causes and consequences of change are linked to how the system functions. As climate extremes drive a social ecosystem towards vulnerability; the capacity of the system to respond to such extremes fabricates the progress on sustainability. Therefore increasing the capacity of the social-ecosystems to accommodate environmental variability, enhancing transformative learning of communities to maintain the sustainability threshold of the system and upholding the ability of the system to accommodate further variability help achieve sustainability.

As stated above, the sustainability of a social-ecological system is a viewpoint, and institutions, from micro to macro levels, play a great role in constructing that viewpoint for the environment, society and development. Both formal and informal institutions are interlinked with knowledge and power in the society (Mehta et al. 2001), and provide collective security and allocate environmental resources (Adger 2000b). Therefore, the institution is a central component of social-ecological systems (Adger 2000a). In this context, insight into the concept 'institution' is relevant here.

2.3.8 Institutions

Institutions are socially mediated formal (rules, laws and constitutions) and informal (norms, behaviour and self-imposed code of conducts) constraints, that structure human actions and socio-ecological interactions (Agrawal 2001; Bakker and Downing 1999; Leach et al. 1999; Ostrom 1992). Institutions are the intentional concepts of social interactions embedded in socially specified values, legitimated by both social practices and struggles over meanings (Adger 2000b; Johnston et al. 2000). In the context of human-environmental interactions, institutions are the systems of knowledge and ethics for interpreting nature from a human perspective (Berkes and Folke 1998). Institutions regulate the entitlements to and endowments of environmental resources and provide the opportunity for livelihoods for a person, a household and a community. In this sense, institutions transform 'physical nature' into a 'socially constructed nature' through institutional practices (Pandey 1998; Pun 2004). The institutions mediate the relationship between self and the society (March and Olsen 1984), and the collaborative factors influence an actor's preferred solutions to collective problems (Ostrom 1986). The institutions in this research are the nodes of the values that regulate human-environmental interactions in Nepal. A comprehensive institutional approach helps examine social-ecological vulnerability (Adger 2000a).

The review of conceptual and theoretical aspects above has provided a strong foundation to interpret human-environmental interactions in reference to climate and environmental change. In the next section studies on climate change, its impacts and adaptation responses, conducted in various parts of the globe are reviewed in the context of vulnerability and adaptation in Nepal.

2.4 Review of Empirical Studies on Climate Change, Vulnerability and Adaptation

A review of empirical work is undertaken here to outline the existing knowledge of social-ecological dimensions of climate change. Previous research on climate change, its implications in human and ecological systems, and the adaptation responses are summarised below with a focus on the Himalaya and Nepal. The summary of existing knowledge is presented under two sub-sections namely, climate change and its impacts, and adaptation responses.

2.4.1 Climate Change and its Impacts

2.4.1.1 Global Overview of Climate Change

The history of climate change research began in the 19th century when Svante Arrhenius (1896) identified the greenhouse effect. However, global warming has emerged as a global issue only since the 1960s. There has been rapid progress in climate change research since the establishment of the IPCC in 1988 with the aim of developing collaborative research, review research findings and store and disseminate information (IPCC 1988). That research has emphasized that climate variability is a natural phenomenon. There have been periods of both natural heating and cooling of the Earth's surface in the history of the planet. It is estimated that average global temperatures were 5 to 6^{o} C less during the last glacial maximum (approximately 20,000 years ago) than those at the beginning of the 21st century (IPCC 2001). The change in the recent past (after AD 1000) over the Northern Hemisphere also shows both heating and cooling trends (Folland et al. 2001). However, the change observed in the 20th and 21st centuries is anomalous to the trends of the past millennium (Hartmann et al. 2013; Salinger 2005; Trenberth et al. 2007).

In the last 420,000 years, temperature varied by 6^{O} C between glacial and inter-glacial periods and the most rapid pace of change was 1^{O} C per century (Salinger 2005). However, the recent increase i.e. 0.065^{O} C per decade and 0.85^{O} C in between 1880-2012 (IPCC 2013) is approaching the maximum pace of change the globe has experienced in its history. The worrisome issue is that the IPCC AR 5 estimates a warming of surface temperature (land) by 0.3^{O} C to 6.2^{O} C for 2080-2100, varying with the scenarios (Collins et al. 2013), generally comparable to earlier estimations of 1.8 to 6.4^{O} C (IPCC 2007c) or 3 to 10^{O} C (Stern 2006). Together with warming, extreme weather events have also increased and have changed their characteristics (McEvoy et al. 2010; Mitchell et al. 2006; Trenberth et al. 2007). Scholars are predicting more intense and frequent extreme events in the future (Collins et al. 2013; Meehl et al. 2007; Schewe et al. 2011; Trenberth and Hoar 1997).

The rates of the change vary across place and time, as well as in terms of particular weather events. For example, the rise in minimum temperature in many locations has been nearly twice the rise in maximums since the 1950s (Hartmann et al 2013; IPCC 2001). South Asia generally follows this global trend (Christensen et al. 2007), whereas in the Indo-Pacific region more broadly, maximum temperature extremes have increased, while minimum temperature extremes have not increased as much (Caesar et al. 2011). Additionally, while global land precipitation has increased on average, changes are highly variable spatially (IPCC 2007c). The precipitation across the Asian monsoon region is heterogeneous and spatially complex (Conroy and Overpeck 2011; Kripalani et al. 2007; Lal, R 2011; Meehl et al. 2008; Shrestha et al. 2000; Turner and Annamalai 2012). Scholars also outlined that extreme rainfall events and associated implications such as severe floods, landslides and mud flows have are increased in many parts of the globe (Cruz et al. 2007; Kattelmann 2003; Meenawat and Sovacool 2011; Mirza 2011; Nyaupane and Chhetri 2009; Poncelet et al. 2010). Furthermore, heat waves and droughts have become more frequent and severe across the globe: in Europe (Ciais et al. 2005); in Africa (Alcamo 2008; Arthur et al. 2009; Mortimore 2010; Sissoko et al. 2011); in Australia (Alston 2012); in China (Su et al. 2012); in South Asia (Lal, M 2011; Poncelet et al. 2010); and importantly for this research, in Nepal (Chhetri and Easterling 2010; Ghimire et al. 2010).

Climatic warming, changing to precipitation and changes to other elements of climate regimes are not only detected by climate science but also increasingly perceived by people. The study of community perceptions of climate change is one important way to understand the social constructions of change and associated risks. Many scholars have investigated people's perceptions of climate and environmental changes to understand its social construction in Nepal (Bhatta et al. 2015; Bhatta and Aggarwal 2015; Chaudhary et al. 2011; Devkota et al. 2011; Manandhar et al. 2011; Paudel, B et al. 2014) and abroad (Deressa et al. 2009; Lazo et al. 2000; Mertz et al. 2009a; O'Connor et al. 1999; Rao et al. 2011; Wu et al. 2014). However, scholars claim that the perceptions of change and associated risks vary across social-demographic, economic and cultural backgrounds (Lazo et al. 2000; Rowe and Wright 2001; Sundblad et al. 2007). Perceptions also vary with: personal epistemology and worldviews; climate politics, media and understanding of public debates on climate change (Bråten et al. 2009; Leiserowitz 2005; Stedman 2004); country of citizenship (stage of development);available amenities to respond the climatic extremes; and the source of climate information (Hulme et al. 2009; Spellman et al. 2003). Considering the Himalayan diversities, further studies are required.

The observed as well as perceived changes in climate are already affecting social-ecological systems globally. The projected rates of warming, intensity of rainfall and its variability and increases in extreme weather events for the 21st century are extremely challenging for adaptation planning, so many of climate-sensitive social-ecological systems are highly vulnerable.

2.4.1.2 Global Overview of Climate Change Implications

The implications of climate change on social-ecological systems are potentially severe and unlimited. It has already impacted physical and biological systems significantly, both globally and regionally (Field et al. 2014; Rosenzweig et al. 2008; Schneider et al. 2007). There is a real concern that the implications cannot be judged accurately because of non-linear patterns of change; uncertainties in impacts; and spatial variability in changes; impacts and responses (Beck 2009; Pittock and Jones 2000). The impacts range from changing the position of resources (Atkins et al. 2011) to growing human security challenges (Adger 2010; Ansorg and Donnelly 2008; Barnett and Adger 2007).The social-ecological systems already at sustainability thresholds, having adopted inadequate adaptation responses, are becoming vulnerable due to climate change impacts (Dovers 2009).

Climate change induced vulnerability is not a new problem to the globe. Archaeological studies of historic civilizations such as Mayan, Indus, Mesopotamian, Viking and of the Central US have generated both successful and failed stories of adaptation, depending on the integration of society and the physical world (deMenocal 2001; Lal, R 2011; Orlove 2005; Sluyter 1997). It is believed that most social-ecological systems are adaptable to a modest rate of change, warming or cooling in the rate ~1^{O} C per century (Salinger 2005). However, the recent experience of changes is beyond the ‘modest rate’, which are causing serious impacts to social-ecological systems. For example, the European heat wave in July 2003 caused the temperature rise of 6^{O} C above long-term means for the month and precipitation deficits of up to 300 mm, 50 percent below the average caused an average reduction of primary agricultural productivity by 30 percent (Ciais et al. 2005). This type of weather event generated serious public health problems in the region (Haines et al. 2006; Wolf et al. 2010). Challinor et al. (2014) expected losses in aggregate production for wheat, rice and maize in both temperate and tropical regions by 2° C of local warming, with greater in magnitude for the second half of the century even in moderate warming if adaptation measures are not adopted. Several studies in Africa have also demonstrated that the African continent is regularly devastated by the impacts of extreme floods and droughts on agriculture (Barbier et al. 2009; Maddison 2007; Mubaya et al. 2012; Ngaira 2007; Ngigi 2009).

Whether these types of events are driven by climate change is in dispute, nevertheless they are just the type of impacts that are projected for the future.

Many scholars analyse the complicated implications of both environmental and societal stressors on social-ecological systems. Implications on agriculture and ecosystems such as the changes in agroecological zones, changes in soil moisture and alterations in timing and length of growing seasons, variable water availability and expansion in fallow land (Grasso and Feola 2012; Howden et al. 2007; Mizina et al. 1999; Parry et al. 2005; Reilly 1995; Rosenzweig and Parry 1994);and rangeland degradation (Aryal, S et al. 2014; Wu et al. 2015; Wu et al. 2014; Yeh et al. 2014); and conflict over local resource and overall implications on human security and well-being (Barnett and Adger 2007), are frequently reported. All of the mentioned impacts cumulatively have implicated in food and livelihood security and social-ecological sustainability. Furthermore, both direct and indirect adverse health impacts (Chou et al. 2010; Ebi et al. 2007; Hossain et al. 2011; Kjellstrom and Weaver 2009; McMichael and Lindgren 2011); increased events of forced migration or displacement due to push or pull factors (Bardsley and Hugo 2010; Djoudi and Brockhaus 2011; Piguet et al. 2011; Poncelet et al. 2010), are also some of the reported complex social-ecological implications. Amongst these, the implications on agricultural ecological systems are potentially the most serious because of the climate sensitive nature of the agricultural system and the immediate reliance of the majority of the poor globally on agriculture for their livelihoods.

Global climate change and the inter-annual variability in the climate system due to El Niño Southern Oscillation (ENSO) are reported as the major climatic causes of the devastating consequences in agriculture. The ENSO climatic fluctuations are expected to increase throughout the 21st century (Brondizio and Moran 2008; Salinger 2005). Heavy and frequent precipitation events damage crops, increase soil erosion and cause water logging in cultivated land; while drought can lead to land degradation, lower yields, crop damage and crop failure; whereas increased temperature and drought lead to livestock deaths and increased risk of wildfire (Barbier et al. 2009; Grasso and Feola 2012; IPCC 2007a; McLeman and Smit 2006). Similarly, increased temperatures and CO_2 concentrations can lead to a decline in grain quality (Hocking and Meyer 1991; Oh-e et al. 2007; Ziska et al. 1997), and alter crop–pest interactions and pest' distribution, leading to crop losses (Bhatta et al. 2015; Macchi 2011; Lal, M 2011; Pruneau et al. 2012; Paudel, B et al. 2014; Ramirez-Villegas et al. 2012). Scholars have also summarised the impacts of climate change on food security at local, regional and global scales (Bryant et al. 2000; Parry et al. 2005; Rosenzweig and Parry 1994; Schmidhuber and Tubiello 2007; Seo et al. 2005); and the implications are even wider in natural ecosystem services.

In the 20th century numerous shifts in the distribution and abundance of species have occurred (Lenoir et al. 2008; Parmesan and Yohe 2003; Pettorelli 2012; Root et al. 2003), which have been implicated in species extinctions (Hare et al. 2011; Pounds et al 1999; Thuiller et al. 2005). The unprecedented combination of climate change associated disturbances and the other drivers such as land use change, pollution and over exploitation of resources, are threating the resilience capacities of many ecosystems and many are likely to be exceeded within the 21st century (Butchart et al. 2010; IPCC 2007a; Pettorelli 2012). Thomas et al. (2004) has predicted an extinction of 15–37 percent of species by 2050 within the mid-range warming; whereas the IPCC (2007b) has predicted extinction of 20-30 percent of plant and animal species if global average temperatures exceed 1.5-2.5^{o} C. The adaptive capacity of natural ecosystems is different from that of human systems. Natural adaptation takes place over generations so most natural ecosystems in places undergoing rapid climate change are vulnerable. The Himalayan ecosystem is at high risk because of rapid pace of climate change.

2.4.1.3 The Himalayan Scenario of Climate Change

Regional and local atmospheric and environmental elements like landforms, elevation, slope aspects, drainage and hydrology, wind systems, vegetation cover, landuse patterns and many more, affect the climate system of a place. Therefore, the changes to global average temperature do not necessarily represent the local situation. Research reveals that in some parts of the globe, especially in the Himalaya, the warming is more rapid than global average trends. Some scholars report the warming of 0.06^{o} C yr^{-1}on average in Nepal (Shrestha et al. 2012 [8]; Shrestha et al. 1999 [9]), while others report even higher rates of warming in particular locations: 0.07^{o} C yr^{-1} in the Middle-Mountains at Daman and 0.27^{o} C yr^{-1} in the high Himalaya at Lamgtang (Chaulagain 2006 [10]). A report by the National Research Council, USA also stated that warming in the Himalaya was at least three times higher than that of the global average in-between 1960 and 2010 (NRC 2012). Other location specific studies have also measured the changing climate in Nepal. For example, Manandhar et al.(2011) found increases in temperature, as well as cold waves and variability in rainfall events in the Tarai (Bhairahawa), and increases of both temperature and rainfall in the Trans-Himalaya (Lower-Mustang); Paudel, B et al. (2014) found increases in both the minimum and maximum temperatures without a specific trend of change in rainfall but decreased winter rainfall; and Duncan et al. (2013) report trend-less precipitation change. Most of the research conducted in Nepal suggests an important spatial variation in the warming trend and the level of

[8] Between 1982-2006
[9] Between 1971-1994
[10] Between 1971-2000

rainfall variability. The consequences of rapid warming in the Himalaya is already visible through a faster rate of glacial retreat (Armstrong 2010; Prasad et al. 2009; Sveinbjörnsson and Björnsson 2011; Wiltshire 2014; WWF 2005; Xu et al. 2007). Gargi and Sejuti (2010) observed a reduction of the glaciated area of the Himalaya from 2077 km^2 to 1,628 km^2 between 1962 and 2007. Warming and melting glaciers are causing increased incidents of GLOF in the Nepali Himalaya. For example, Eriksson et al.(2008) reported 25 GLOF events in the region in the last 70 years.

The projected changes in the climate system of the Himalaya are also notably higher than that of global average. The IPCC AR4 has estimated a median increase of temperature by 3.3° C in South Asia by the end of the 21st century (Christensen et al. 2007). The IPCC AR5 has also projected the continuation of warming, mostly in winter, and frequent heat waves and rainfall extremes in the region (Christensen et al. 2013). For Nepal, MAGICC/SCENGEN analysis [11]has projected 1.2° C and 3° C rises in mean temperatures under the B2 scenario [12]by 2050 and 2100, respectively (Agrawala et al. 2003), while NCVST (2009) estimates an increase of 4.7° C (mean of different models) ranging from 3.0° C to 6.3° C by 2090. Because of further warming, more extreme rainfall events and rapid melting of the Himalayan glaciers during the 21st century are both anticipated, which increases the likelihood of severe floods during the summer monsoon and longer drought and water scarcities in the dry period (Kripalani et al. 2007; Prasad et al. 2009; Schewe et al. 2011; Sun and Ding 2010).

The change in climate of the Himalaya is also explained by the studies of people's perceptions. The bulk of the research on community perceptions of Himalayan climate change suggests that people in different parts of the region perceive increased frequencies and magnitudes of extreme events; warming in the winter and pre-monsoon periods; reduced winter rainfall; shifts in the monsoon season; increased variability in rainfall and extreme rainfall events (Chaudhary et al. 2011; Devkota 2014; Devkota et al. 2011; Gentle and Maraseni 2012; Manandhar et al. 2011;Oxfam 2009; Paudel, B et al. 2014). Research conducted in the Trans-Himalaya also showed increased avalanches, flash floods, erratic rainfall and long and severe droughts (Dahal 2005; Fort 2015; Vetås 2007).

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[11]MAGICC/SCENGEN is a coupled gas-cycle/climate model (MAGICC) that drives a spatial climate-change scenario generator (SCENGEN). MAGICC is a Simple Climate Model that computes the mean global surface air temperature and sea-level rise for particular emissions scenarios for greenhouse gases and sulphur dioxide (Raper et al. 1996 as cited by Agrawala et al 2003)

[12]The B2 scenario assumes a world of moderate population growth and intermediate level of economic development and technological change. SCENGEN estimates a mean global temperature increase of 0.8 °C by 2030, 1.2 °C by 2050, and 2 °C by 2100 for the B2 scenario.

The studies reviewed above demonstrate remarkable changes in the Himalayan climate, but at variable rates across locations. Based on the review, it is possible to conclude that both observed and perceived changes are impacting the social-ecological system and associated livelihoods of the people in the Himalaya. In the context of variability in the rates of climate changes and diversity in the social-ecological environment of the Himalaya, this study generates location specific knowledge of climate change produced through an integrated approach between climate science and social science. The social-ecological system of the Himalaya is unique so it requires specific adaptation policy to adapt effectively to generate sustainability. Below, the literature on implications of climate change on the social-ecological system and associated livelihoods of the Himalayan communities, are reviewed to understand the adaptation necessity in the region.

2.4.1.4 Himalayan Scenario of Climate Change Impacts

Several studies have discussed the implications of socio-economic and environmental changes on livelihoods of rural people in the Nepali Himalaya (Bishop 1990; Chapagain 2008; Haffner 2003; Koirala 2006; Olsen and Larsen 2003; Pokhrel 2010-2011; Pun et al. 2010; Subedi et al. 2007a; Subedi and Pandey 2002). Most of these studies have found that Himalayan livelihoods are diverse and complex; are at the margins of sustainability, or already experience significant vulnerability, such that they cannot withstand further internal or external stress. Considering the pace of changes in the Himalayan climates it can be speculated that climate change has affected the social-ecological systems and associated livelihoods of the region directly or indirectly. However, the studies on the implications of climate change in these sectors in the Himalaya, Nepal, are just emerging (Bhatta et al. 2015; Bhatta and Aggarwal 2015; Chhetri et al. 2013; Devkota et al. 2011; Macchi et al. 2014; Paudel, B et al. 2014). Agriculture is the primary source of livelihoods in the region; therefore, the implications of climate change specifically on agriculture are of particular importance to discuss here.

Numerous studies document the challenges that agro-livestock livelihoods of the poor people of the region face due to climate change.Among the negative implications, reductions in crop yield, increased crop pests and diseases, and farm weeds due to increased drought and reduced water availability, as well as increases in extreme rainfall events are at the forefront of the livelihood vulnerability of poor farmers (Chhetri and Easterling 2010; Gentle et al. 2014; Ghimire et al. 2010; Palazzoli et al. 2015; Rijal 2006). Reduction in farmland and its productivity due to increased temperature and diminished snowfall on the one hand, and relocation of villages due to increased landslides and erosions on the other, have become common in the Trans-Himalaya (Aryal, A et al. 2014; Fort 2015). Forest and grassland in the Trans-Himalaya are also diminished with changing climate (Paudel and Andersen 2012), that have increased the livelihood vulnerability of transhumant communities (Aryal, S et al. 2014).

The Trans-Himalayan communities of Manang, Nepal have found their traditional knowledge of farm and livestock management have becoming poorly relevant in modern day due to climate change and associated implications, while their socio-economic activities and social systems are constantly facing the pressure for change brought about by global environmental change and globalization (Chaudhary et al. 2007). Problems of resource degradation, food scarcity, lack of basic services are exacerbated by climate change which challenge rural livelihoods in various parts of Nepal (Gentle and Maraseni 2012; Gentle et al. 2014). Ecosystem based livelihoods such as the combination of agro-livestock-forestry-pasture, which the farmers have been practicing since generations in the Nepali Himalaya have been challenged because of changing tree and vegetation compositions; the emergence of new invasive species; increased crop diseases and changed plant phenology; and losses of livestock due to floods, landslides, lightning strikes, as well as due to increased livestock diseases and pathogens (Chaudhary et al. 2011; Chapagain and Gentle 2015; Dahal et al. 2009; Macchi 2011; Persha et al. 2010). In addition, a major shift of ecological regions including: an upward shift in mean elevation of bioclimatic zones and ecoregions, decreases in area of the highest elevation zones and ecoregions, a large expansion of the lower tropical and sub-tropical zones and ecoregions, and the disappearance of several ecological strata within the Kailash Sacred Landscape (KSL) of China, India and Nepal are also projected (Zomer et al. 2014).

The snow and glaciers of the Himalaya are the principal water sources for the major rivers in South and Central Asia. The Himalayan glacier melt supplies more than 20 percent of the annual flow of these rivers ranging between 1.3 percent for the Yellow River to 44.8 percent for the Indus River (various sources as cited in Xu et al. 2007). The higher rate of glacier retreat in the Himalaya is expected to cause a sharp decline in water availability (Barnett et al. 2005; Ebi et al. 2007;Kehrwald et al. 2008;Rees and Collins 2006) since overall negative trend of about 21mk^3/year in water storage in the Himalaya between 2003-2008 was reported (Moiwo et al. 2011). Research shows that people are expressing anxiety about increasing water stress caused by reduced rainfall, decreased stream flow and early drying of natural springs, while the frequency and intensity of droughts are increasing (McDowell et al. 2012; Oxfam 2009). On the other hand, increased or variable rainfall intensities at other times, especially during the summer monsoon, have caused water management problems on one hand and landslides and flooding on the other in the Himalayan region (Christensen et al. 2007; Duncan et al. 2013; Mirza 2011; UNDP and DFID 2007; WWF 2005).

The agricultural implications of changing climate in agrarian societies cause profound effects on employment in the agricultural sector, household food security and the sustainability of the livelihood systems (FAO 2008; ILO 2007). However, integrated research focusing on this issue is still lacking in Nepal. In addition, limited livelihood options lower the adaptive capacities of Himalayan households, because they are already constrained by non-climatic stressors, such as socio-economic and physical factors, poor access to services and inequitable access to productive assets. The Nepali Himalaya is characterised by high population densities, agrarian livelihoods dependent on marginal land, and human settlements on the banks of rivers and dynamic mountain slopes (Bardsley and Hugo 2010; Patwary 2009), is further facing sustainability challenges due to climate change impacts.

Apart from the implications of climate change on the agricultural ecology and natural resources, wider social-ecological effects of climate change are also reported. Increased incidents of malnutrition and the consequent implications for child growth and development; increased disease burden, injuries and deaths due to heat waves, floods, storms, fires and droughts; and the altered spatial distribution and extended habitats of infectious disease vectors and pathogens have been reported in South Asia and Nepal (Dahal et al. 2009; Ebi et al. 2007; Oxfam 2009).Studies from different parts of the globe report increased mortality and morbidity associated with diarrhoeal diseases, cholera, hepatitis and malaria, and the sources of infections are associated with bacterial proliferations and increased disease vectors due to flooding and droughts in poverty stricken communities (Bouma and van der Kaay 1996; Checkley et al. 2000; Glantz 2001; Lobitz et al. 2000; Rodo et al. 2002). Although, Nepal lacks specific studies focusing on these sectors in relation to climate change, such health problems are common in the country and may be increasing with climate change. Extreme events such as disastrous floods in the Koshi River in August 2008 and in Karnali and Mahakali in September 2008 [13]; a snow avalanche in the Seti River in May 2012 [14]; and a landslide in Bhotekoshi River in August, 2014 [15] have killed hundreds of people, displaced hundreds of thousands and caused many public health problems. The

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[13]More than 50,000 people in Nepal and many more in the north Indian states of Bihar and Utter Pradesh have been displaced by Koshi flood of 18 August, 2008; more than 180,000 people have been affected by the floods in the Karnali and Mahakali Rivers in 19-21 September. Viewed 16 April 2015 <http://www.nepalmonitor.com/2008/08/koshi_floods_2008.html>

[14] Relatively small mountain rock avalanche induced flooding on 5th May 2012 in Seti basin (Kaski, Nepal) killed more than 70 people.

[15] Landslide in Sindhupalchowk, Nepal kills 156, Viewed 16 April 2015 <http://www.disaster-report.com/2014/08/massive-landslide-near-barabise-blocks-bhotekoshi-river.html>

damage to productive assets and sources of livelihoods in different parts of Nepal and in South Asia due to floods and landslides has become common in recent decades (Gargi and Sejuti 2010; Macchi 2011; UNDP and DFID 2007).

The implications of the impacts described above are having far-reaching socio-economic and ecological consequences and challenging the sustainability of Himalayan ecosystem services. There are very few reports of the positive effects of climate change, especially in Trans-Himalayan agriculture due to changes in growing seasons (Dahal et al. 2009; Gentle and Maraseni 2012; Manandhar et al. 2011). Nevertheless, available as well as extended growing seasons have not been utilized effectively in Nepal, especially because of insufficient growing season flexibility in the Trans-Himalaya (Chapagain 2008; Subedi 2007; Vetås 2007) and the declining priority for agricultural activities due to local effects of global changes, such as modernization and globalization and inadequate policy attention in the Middle-Mountains and in the Tarai (Chapagain and Gentle 2015; Paudel, K et al. 2014; Tamang et al. 2014).

This review of literature on both the science of climate and people's perceptions and associated implications, confirm that the climate of the Himalaya is changing and is having wide and complex implications for social and natural ecosystems. The change is rapid and the impacts are severe in the social-ecological system of the Nepali Himalaya. However, many of the effects and their spatial variability are yet to be investigated in detail. Furthermore, the knowledge on climate change produced by climate science is often poorly interpreted into social contexts, especially in reference to the needs of the general population and their communities (Challinor 2008; O'Neill and Hulme 2009; Patt and Gwata 2002). In this context, research that integrates scientific and social knowledge of climate change is very important for effective policy formation. The perceptions, beliefs and knowledge on changing climate increases people's willingness to initiate adaptation steps at the micro level (Heath and Gifford 2006; O'Connor et al. 1999), while scientific knowledge provides trends and projections that help formulate long-term adaptation planning and mitigation strategies at macro levels. This study aims to generate integrated knowledge of climate change and its implications on the social-ecological system of the Himalaya, with a focus on the Kaligandaki Basin, Nepal. The knowledge expanded by this research is expected to help in designing effective adaptation policy in Nepal and reduce the negative implications of climate change. The research aims in part to recommend adaptation strategies, so those already practised provide important background knowledge for this study. Scholarly works on adaptation efforts of people in different parts of the globe in general, and within the Nepali Himalaya in particular, are reviewed in the next section.

2.5 Climate Change Adaptation Strategies

The discussion above has demonstrated that there is common acknowledgment that the climate of the globe is changing and the changes are impacting upon social-ecological systems. Therefore, adaptation is recognised as a necessary action to reduce the negative impacts and increase the resilience of social-ecological systems (Adger and Barnett 2009; Allison et al. 2009; Debels et al. 2009; IPCC 2014; Leary et al. 2007; Mortimore 2010; Schneider et al. 2007).Adaptation and mitigation are very important aspects of climate change management and can facilitate each other (Klein et al. 2007). Some scholars identify adaptation as the local issue of climate change policy while mitigation is considered as a global development issue (Füssel and Klein 2006; Tol 2005; Venema and Rehman 2007; Wilbank 2005). A shift in the global energy regime from dominant fossil fuel use to alternative energy sources is required for effective mitigation. However, no remarkable progress has been made in this field, so it has been increasingly acknowledged since the beginning of the 21st century that the importance of adaptation to reduce local socio-economic vulnerabilities of climate change has increased (Adger et al. 2005; Dovers 2009; Mertz et al. 2009b; Moser and Ekstrom 2010; Smithers and Smit 1997; Tol et al. 1998; Wheaton and Maciver 1999).

Many scholars document the strategies adopted by communities of different countries and regions showing an extensive wealth of adaptation knowledge is developing communities. The adopted strategies vary with available technology, across various scales, local socio-ecological circumstances and partnerships among the stakeholders. The strategies are variable across places and livelihood systems, as well as climatic stimuli. For that reason, the adaptation strategies identified by previous works are summarised below by categorizing them into three groups: adaptation through bio-physical resource management; adaptation through social and institutional efforts and external support; and adaptation through livelihood diversification and migration.

2.5.1 Adaptation through Management of Ecosystem Services

Changes in the resource management system enhance adaptation processes and the adaptive capacity of natural resource dependent communities (Cruz et al. 2007). Among the various strategies, bio-physical resource management is arguably the most important and effective option for the agro-livestock based livelihood system of the Kaligandaki Basin. Bio-physical resource management includes, but is not limited to: watershed management; forestry, crop and pasture management; and soil and water conservation. Many of the communities in Nepal are adopting numbers of strategies associated with bio-physical resource management: changing cropping patterns and adoption of climate change resilient crop varieties (Bhatta and Aggarwal 2015), and utilization of ecosystem services (Macchi et al. 2014). However, the types and degree of adoption of a particular strategy is likely to depend on the types of resources on which a household or community is dependent for a living. Agro-livestock adaptation is one of the most important concerns of the present study because it is the primary occupation of the majority of households. Many scholars have proposed an array of agricultural adaptation options. Some of the strategies suggested as well as practiced, include but are not limited to: adoption of *in situ* agrobiodiversity conservation (Bardsley and Thomas 2005); change in crop calendar, crop diversification, specialized crop practice, increased irrigation and soil conservation together with non-farm activities (Bradshaw et al. 2004; Choudri et al. 2013); and reliable weather forecast and provision of agrometeorological information (Salinger et al. 2000); appropriate management, sustainable harvest of forest resources and practice of agro-forestry (Schoene and Bernier 2012; Seck et al. 2005), as well as both individual and collective actions of bio-physical resource management (Su et al. 2012). In addition, supporting farmers during the transition to a free market, regional centres for preserving genetic diversity of seeds, and forecasting pest outbreaks, and developing and reducing soil erosion through the use of changed farming practices, are also expected to promote agricultural adaptation (Mizina et al. 1999).

Agricultural adaptation to climate change is interlinked to many elements of socio-cultural, political and economic institutions (Blaikie and Brookfield 1987; Chiotti and Johnston 1995; Mizina et al. 1999). The elements of the institutions can range from very small entities like a plant, plot, field and farm to the region, sector, nation and international organizations (Smit and Skinner 2002) that implicate in adaptation action at different institutional scales (Bastakoti et al. 2014; Esham and Garforth 2013;Xu and Grumbine 2014). Scholars often suggest agricultural adaptation measures, such as modifying farming practice, improving livestock and crops through breeding, new technologies and infrastructure, including improvements to the irrigation system (Droogers 2004; Parry 2002; Vlek et al. 2004). Similarly, agro-meteorological information and early warning systems for farm decision-making and risk management are also recommended for successful agricultural adaptation (Bradshaw et al. 2004; Glazebrook 2011; Howden et al. 2007; Salinger et al. 2000; Sivakumar 2011; Stigter 2007; Su et al. 2012). Chhetri et al. (2013) suggests for niche-based adaptation, while other incorporate different strategies under wider ecosystem based adaptation (GoN et al. 2012; Persha et al. 2010; Salerno et al. 2010). The adaptation options, such as the adoption of innovations, risk management, and increased agro-input and irrigation, can often lessen the negative implications of climate change. In the context of the agricultural implications of climate change in the Himalaya, Nepal (discussed in the previous section), existing knowledge on agricultural adaptation in the region is reviewed.

The climate system of a place generally exhibits many uncertainties, such that the impacts of change are not very clear. In addition, it is not always easy for farmers to adopt new strategies because of the uncertainty about the risks and benefits of and new strategy. Nevertheless, a small negative consequence for farm production caused either by climate change, or by a new strategy, could mean a lot to the poor farmer. Relatively aware farmers will also need to see profitability, complexity and compatibility in strategies before adopting them (Guerin and Guerin 1994). Therefore, agricultural innovation, insights into the decision-making, adoption of the innovation and diffusion among the farming communities are important components of agricultural adaptation (Bryant et al. 2000; Mertz et al. 2009a; Nelson and Stathers 2009; Smit and Skinner 2002). The attitudes, values, motivations and risk perceptions of farmers also influence the adaptation process. Therefore, studies on agricultural adaptation require a focus on the characteristics and procedures of adaptation strategies that influence adaptation decision making (Baker 2007; Bradshaw et al. 2004; Eakin 2000; Glazebrook 2011; Vogel et al. 2007). This study maps specific strategies adopted by the Nepali farming communities to promote agricultural adaptation through bio-physical resource management.

As the communities of the study area are mostly natural resource-based, they hold unique traditional knowledge and methods of resource management developed over generations. Traditional agricultural management practices such as intercropping, mulching and agro-forestry, shelterbelts and crop diversification (Persha et al. 2010; Seck et al. 2005); changes in agronomic practices such as earlier planting or cultivar switching, shorter rotations and larger spacing in dry areas, changes in crop type and provision of adaptive crop varieties together with provision of agro-climatological information (Bhatta and Aggarwal 2015; Oxfam 2009; Paudel, B et al. 2014); improved water management and regulated and rational irrigation; pest, disease and weed management; use of organic fertilizer; and change in livestock type, herds size and barter of fodder for manure, are beneficial strategies for agricultural adaptation (Aggarwal and Sivakumar 2011; IPCC 2007a; Mertz et al. 2009a; Ramirez-Villegas et al. 2012).These strategies are mostly ‘no-regret’ strategies that would be effective whatever the trend of climate change would be in the future. This study examines the adoption of these strategies and their effectiveness in the study area.

Together with agricultural adaptation through bio-physical resource management, some scholars recommend the retention of complexity to enhance the resilience, stability and ecosystem functioning (Mooney and Ehrlich 1997; Tilman 1997). Such forest management (Schoene and Bernier 2012), and water resource management (Dovers 2009; Sullivan 2011), are important strategies for simultaneously aiding biodiversity conservation and agriculture. This study verifies the relevance of some of these strategies in the study area.

2.5.2 Adaptation through Social and Institutional Efforts and External Supports

Together with appropriate management of bio-physical resources, the strength of human agency such socio-political institutions and techno-economic environment, are critical to reduce farm level risks and assist climate adaptation (Bryant et al. 2000; Esham and Garforth 2013; Xu and Grumbine 2014). Strong social institutions, and the provision for climate change and adaptation information as well as innovations and micro-credit facilities (Bastakoti et al. 2014; Osbahr et al. 2008); reducing the social-institutional adaptation barriers (Biesbroek et al. 2013; Howden et al. 2007; Jones and Boyd 2011); and technological developments, government programs on accessibility, farm production marketing, and farm insurance and financial management (Kaul and Thornton 2014; Smit and Skinner 2002), can be valuable adaptation strategies also to the farming communities of the Nepali Himalaya.

Social and institutional capital can play notable roles in providing the capacity for climate change adaptation. Scholars have suggested numerous institutional adaptation options such as irrigation, flexible use of indigenous adaptation knowledge and their inclusion in adaptation policies, participatory policy planning and responses, and government provision of social security as a safety net (Bastakoti et al. 2014; Mortimore 2010; Næss et al. 2005; Nkomwa et al. 2014). Furthermore, local level weather forecasting and early warning systems, risks and hazards management and an assessment of vulnerability, to design the adaptation policies would provide a sound opportunity for institutional adaptation (McBean 2004; Mizina et al. 1999; Ramirez-Villegas et al. 2012). The collective actions of local institutions can often substitute for state provisions (Adger 2000b). The Nepali communities have traditionally coped with numerous environmental hazards through social and institutional efforts. Until recently, they are utilizing social and institutional capital to adapt to climatic changes and associated hazards (Chaudhary et al. 2011; Ghimire et al. 2010; Gentle and Maraseni 2012; McDowell et al. 2012; Onta and Resurreccion 2011).

Strong institutionalism promotes collective efforts for awareness on climate information, removing adaptation barriers, making financial and other resources available, translating the known adaptation options into operational practices, changing behaviour, and installing and operating new technologies also support the adaptation process (Jones and Boyd 2011; Klein 2004; Moser and Ekstrom 2010; Salinger 2005). Studies are revealing positive results from collaborative work in various parts of the world. A few of the examples are: reduction of the implications of coastal floods through coastal dike construction and management in Vietnam (Adger 2000b); coastal defence infrastructure in the Maldives and in the Netherlands, the Confederation Bridge in Canada, prevention of GLOF and associated loss in Nepal (IPCC 2007a); and flood and water management in Australia (Adger and Barnett 2009). Furthermore, state-led strategies to respond to water scarcity in California are also producing positive results (Hanak and Lund 2012).The government initiation of climate change adaptation in Bangladesh is also expected to produce positive results [16]. Routine monitoring of floods, flood forecasting, data exchange, institutional reform, bridging organizations, contingency planning for disasters, insurance and legal incentives to reduce flood related vulnerability are practiced and found to be effective in Australia (Wilby and Keenan 2012). Many of these adaptation efforts, however, are difficult to implement in the context of poor countries like Nepal, where there are limited public or other institutional funds to support adaptation.

The changes in traditional unequal relationships or patron–client relationships of labour reciprocal relations can strengthen social cohesion and promote resilience and adaptation in some contexts (Adger 2000b; Pelling 1998). Changes in social norms and values, such as both gender and caste boundaries, are helping adaptation in India (Ray-Bennett 2009), as well as in Nepal (Folmar 2007; Onta and Resurreccion 2011). Seeking and obtaining external support is also a strategy that a household or a community can adopt. Yet, the existing social and economic hierarchies and the strength and structure of social institutions determine the likelihood of effective responses. In the context of climate change adaptation, social and informal institutional capital may not be strong enough because the extent and effectiveness of adaptation could be affected by the stress of hazards and capacity of the institutions to respond; additionally, extreme events can affect the structure and functioning of the social and institutional capital so a timely response to hazards may not be possible. In such situations, external support, especially from the government and international communities is necessary to compensate for the adaptation limits faced by community institutions.

Despite the limitations of social and institutional capital mentioned above, social capital in the form of linkages and exchange with kinfolk, mostly with those who are living external to a place where

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[16] Bangladesh currently spends $1 billion a year, 6 to 7 percent of its annual budget, on climate change adaptation, and will need $5.7 billion for adaptation by 2050, viewed 16 April 2015 <http://www.unep.org/newscentre/default.aspx?DocumentID=2788&ArticleID=10864&l=en#sthash.PmjEvt9v.dpuf>

the likelihood of being affected by the same stressor at the same time is less, is important. For those reasons, this study maps the social and institutional capital of Nepali communities, as well as the state provision of physical capital and analyses their contribution to adaptation.

2.5.3 Adaptation through Livelihood Diversification and Migration

Livelihood diversification is one of the most important strategies of adaptation because of the changing environmental system, because climate change affects different livelihood options differently. Livelihoods derived from climate sensitive activities such as agriculture, livestock, fisheries and forest products, may not provide sufficient options for adaptation. Reducing the share of livelihood activities dependent upon them through diversification can help build a livelihood safety net. Livelihood diversification distributes risks and hazards, buffers losses and compensates for the loss of one economic option by another activity. Diversification can also be practiced within the agro-livestock system through crop diversification, off-season agriculture, crop-livestock combination, integration of poultry, bee-keeping, fishery and agro-based enterprises, as well as selecting different crop varieties and livestock types adaptive to changing climate. Apart from agro-based multi-functionalities, economic activities such as employment, small enterprises, occasional paid labour and labour migration to distant cities or abroad, are important strategies of livelihood diversification. Many scholars have either observed or recommended these strategies to adapt to climate change(Bardsley and Hugo 2010; Black et al. 2011; McLeman and Smit 2006; Piguet et al. 2011; Poncelet et al. 2010; Tacoli 2009; Wrathall 2012).

Studies reported positive results of livelihood diversification in reducing vulnerability in Kenya and Tanzania (Eriksen et al. 2005), in the Sahel (Mertz et al. 2009a; Nielsen and Reenberg 2010), in Mozambique (Osbahr et al. 2008) and in Mali (de Haan et al. 2002). The farmers of Nepal are also struggling to diversify their livelihoods despite owning limited livelihood capital (Biggs and Watmough 2012; Dahal et al. 2009). Many of the diversification strategies adopted in Nepal are associated with livelihood security, although some of them directly or indirectly support climate change adaptation.

Among the diversified livelihood options, migration is seen as a critical option. This is because of its implications on population-resource distributions and relationships. Many scholars expressed concern that climate change would lead to large scale migration, especially from the places with negative implications of climate change to the place with positive impacts (Barnett and Adger 2003; Brown 2007; Mendelsohn et al. 2007; Locke 2009; Paxson and Rouse 2008; Yonetani

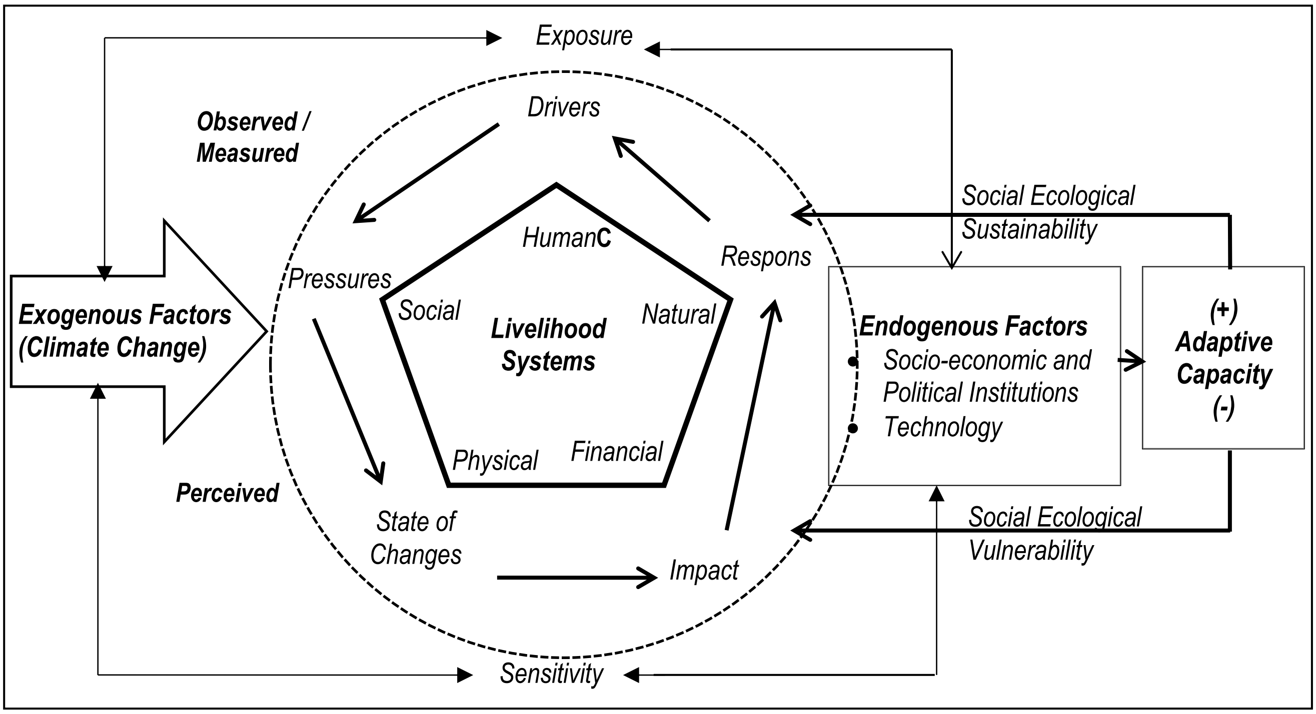
2011). Migration helps support people secure their livelihood through reducing the consumption requirements at the source of origin and provides more resources (remittance) to those left behind (Crook 1997). In addition, circular and seasonal migrations maintain social stability, contribute to livelihood diversification and reduce resource dependency (Adger 2000b). Therefore, migration is a widely adopted strategy in any social, political, economic situation globally. Migration in relation to climate change can be recognised as the phenomenon that is both a failure of *in situ* adaptation methods and a rational component of creative adaptation(Bardsley and Hugo 2010). Studies have found migration to be a part of an effective adaptation strategy to climate change in Nepal (Bhatta and Aggarwal 2015; Chapagain and Gentle 2015; Gentle and Maraseni 2012; Onta and Resurreccion 2011). Yet, out-migration often leads to demographic fragmentation, downgrades livelihood chains, reinforces a class divide and has a cascading effect of ecological and social regime shift (Pandey and Adhikari 2013; Wrathall 2012). It also increases vulnerability of women due to the extra burden of work (Djoudi and Brockhaus 2011). Therefore, the strategy requires to be adopted carefully so that negative effects can be controlled.

2.6 Conceptual Framework

Climate change affects human-ecological systems in two ways: by putting stress on to parts of systems and by straining the whole system at once. Adaptation responses can reduce harmful impacts, minimise the risk of vulnerability and increase the resilience capacity of the system. The two-way communication of pressure-response is a complex and dynamicprocess (Rial et al. 2004), which is presented in a schematic flow (Figure 2.1), and will be used as the conceptual framework of social-ecological sustainability for this research.

A conceptual framework is neither a model nor a theory but a conceptual map or a set of assumptions that reveals the patterns of interactions and may lead to develop a model and a theory (Ostrom 1999; Rapoport 1985). The conceptual framework of this research (Figure 2.1) demonstrates a broader system of interactions between humans and the environment with a range of important components. The sketched framework applies an appropriate system approach. Figure 2.1 shows the framework as an integrated system in which several sub-systems are attached to form a holistic social-ecological system in which a livelihood system can flourish.

Figure 2.1: Theoretical Framework on Adaption to Climate Change and Social Ecological Sustainability
(Source: Modified from Allen Consulting Group 2005; Atkins et al. 2011; Berkes and Folke 1998; Chambers and Conway 1991; Maxim and Spangenberg 2006; Sining 2011; Smeets and Weterings 1999; Subedi 1995)



Climate change induced environmental dynamism and human responses to such dynamism are the core elements of this study. A household gains its livelihood from different livelihood capital (the capitals at the pentagon in the framework). Livelihood contributions of different capital vary across households, depending on the household's command over different capital. Livelihood capital is subject to risks and hazards from both endogenous [17] and exogenous [18] forces many of which are climate related. The drivers of endogenous factors put pressure on livelihood capital, as well as facilitate adaptation strategies, depending upon interactions between livelihood capital and endogenous factors. Such interactions in turn bring about changes in the livelihood system. When such changes are not beneficial for livelihood security, further adaptation responses are required to reduce the negative effects of change. The endogenous factors affect both adoption of, and outcomes from adaptation strategies and the overall livelihood system. The Driver→Pressure→Stage of Change→Impacts→Response (DPSIR) cycle of the framework maintains a dynamic functioning of a system in general. However, when the system is exposed to the unmanageable consequences of exogenous forces, such as rapid climate change, the system may lose its resilient capacity and experience vulnerability.

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[17] The endogenous factors are those which are 'in the place' or are 'within the system' (Füssel 2007) such as quality, quantity, behaviour and characteristics of population; economy, resource, technology, information, skills, infrastructures, institutions and equity (Subedi 1995)

[18] Exogenous factors are those which are beyond the place or are 'outside of the system' (Füssel 2007)

The responses to exogenous factors are often learning based and mostly dependent on the structure and process and the health of socio-political institutions, as well as the capacity of available technology. Local people use culturally transmitted knowledge to manage their environmental resources. The learning from reflection or from indigenous knowledge (Agrawal 1995), local knowledge (Berkes and Folke 1998) or social learning (Wals and van der Leij 2007); organizing power of the system and ability of community to diversify knowledge; embracing the inevitable conflicts in collaboration; and ensuring the participation of diverse community, are the essential strands of learning based adaptation and sustainability (Dyball et al. 2007). However, when the cybernetic interactions of livelihood capitals under the DPSIR chain encounters exogenous stressors such as climate change, for which the system is not prepared to respond, all the elements of the system are affected by the change.

In this context, the framework (Figure 2.1) explains the interactions among the exposure, sensitivity and adaptive capacity of the system to climate change. The degree of exposure of systems to change; the level of sensitivity of livelihood capital and the social-ecological systems, and the system's ability to absorb, withstand or react to the climate change determine the sustainability or vulnerability of a social-ecological system. Vulnerability is inherent to each system (Sining 2011). Therefore, the feedback mechanism of interaction (exposure →sensitivity→ adaptive capacity) and the feedback of such interactions in relation to outcomes provide a systematic approach to social-ecological sustainability.

2.7 Conclusion

There are number of theories and approaches to explain human-environmental interactions. Global climate change has put remarkable pressure on social-ecological systems, and many systems are struggling to adapt. Available adaptation options emphasize the modification of existing modes of interactions between humans and the environment. However, non-linearity of climate change, uncertainty in impacts, and structural inequalities associated with socio-economic and political stressors collectively, challenge the adaptation process and reduce the resilience capacity of the system. Reduced resilient capacity leads the systems towards vulnerability, the social-ecological systems of the developing countries and those societies that primarily depend on agro-livestock and forestry related livelihoods, suffer the most. Literature has reported that Himalayan social-ecological systems are exposed to rapid climate change and are sensitive to such changes. Existing research work also demonstrated the limited adaptive capacity of Himalayan social ecosystems. In this context, this study investigates human ecological implications of climate change in the Himalaya, particularly in the Kaligandaki Basin, Nepal.

This study explores human-environmental interactions in relation to climate change using an integrated approach. The conceptual framework provided above is a model applied in this study. The framework explains the functioning of the social-ecological system of the Nepali Himalaya. As the conceptual framework is complex, its adoption in the research is not simple and linear. The next chapter, Research Methodology, explains the systematic ways of applying this framework in this study.

CHAPTER III

RESEARCH METHODOLOGY

3.1 Introduction

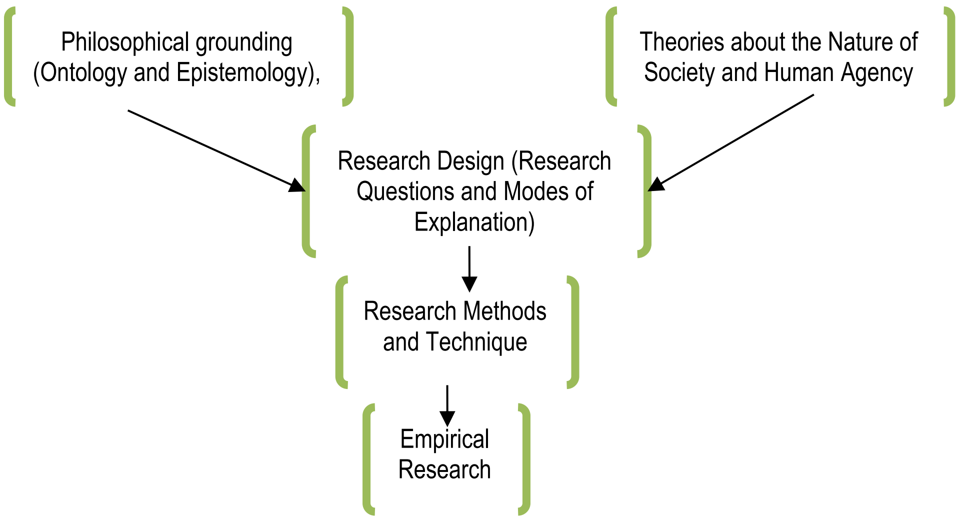
A research methodology prescribes methods of conducting the research based on the philosophical traditions adopted in an academic discipline. This study adopts the geographic methodology of understanding human-environmental interactions to describe the implications of climate change in Nepal. The chapter introduces the research methodology with a focus on the triangulated social learning approach. The chapter also elaborates upon the adopted research design and explains in detail the quantitative and qualitative research methods used in the research. The study area is introduced, along with the tools and techniques of sampling, data collection and analysis. The chapter also concludes by explaining the validity and reliability of the research approach and research ethics adopted; and research limitations experienced while conducting this study.

3.2 Research Methodology

A methodology is a coherent set of rules and procedures for investigating a phenomenon or situation that makes research findings scientific (Graham 1999; Kitchin and Tate 2000; Neuman 2003). A methodology helps researchers to structure a study and develops interactions between researchers and a research theme (as shown in Figure 3.1), so data can be generated logically to warrant reasonable conclusions (Harvey 1969; Mills 2014). In this context, the methodology is a scientific movement between the theory of knowledge (epistemology) and the reality of knowledge (ontology): epistemology→ theory→ research→ reality knowledge→ ontological claim (Bradshaw et al. 2001; Sterling 2007).

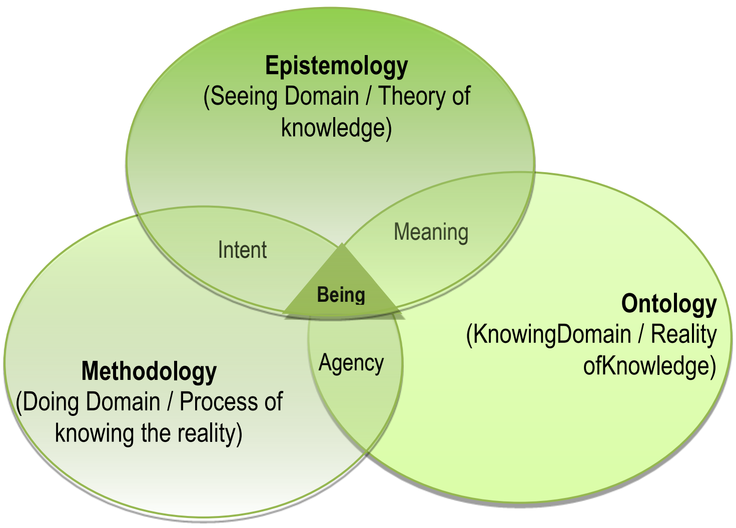
Epistemology is the theory of truth or perception, ontology is the philosophical reality or actual knowledge and the methodology is the actions required to acquire knowledge (Bryman 2012; Sterling 2007). Epistemology is concerned with the perception or observational domain, whereas ontology is concerned with the conception or knowledge domain. In this research, the value of learning about a set of beliefs or ideas that will determine social actions over the environment in the context of climate change is the epistemological basis of the study. The actions of individuals and communities in response to environmental change are the ontological reality. Therefore, the methodology aims to mediate the interaction between epistemology and ontology to accumulate knowledge (the meanings of the collected data) through the valid process (theory) of the geographic discipline (Johnston 1984).

Figure 3.1: Research Methodology
(Source: Graham 1999, p. 87)



The methodology creates 'agency' by interacting with the ontology; creates 'intent' (expected theory of knowledge) by interacting with the epistemology; and finally generates an epistemology-ontology-methodology interaction that aims to define the 'being' of the social reality(Figure 3.2). In many respects, a methodology can be perceived as a process of marrying epistemology and ontology (Shurmer–Smith2002) or the exchange between the percept and the concept (Bunge 1962).

Figure 3.2: Research Process
(Source: Sterling 2007, p. 69)



In the history of geographic research, the discipline has applied a range of approaches and methods used by both natural and social sciences. Therefore, geographical research approaches and expertise are diverse (Kitchin and Tate 2000), and geographers are continually re-creating their fields of discipline (Sluyter et al. 2006). Part of that ongoing criticism has seen a reduction in the domination of empiricism in human geography, while application of the interactive or triangulated methodologies is increasing.

3.2.1 Use of Triangulated Research Methodology

By applying a systematic or holistic approach of an integrated methodology the capacity to triangulate various methods of empiricism and interpretive sciences is generated. Such holism generates insights into connective, analytical and representational dimensions across scales and types of phenomena (Sluyter et al. 2006; Thrift 2002). Triangulation is a process of using several methods, data, theories and investigators to target effective knowledge creation on a particular issue (Bryman 2012; Grix 2004). The method can reduce the risk of systematic biases or limitations of specific methods, and help to increase the validity of findings (Patton 1990; Maxwell 2005; Neuman 2003; Robson 1993). A triangulated methodology is a cross-fertilized, integrated or hybrid methodology. Its adoption to conduct research on human-environmental systems in relation to climate change can be particularly appropriate, because it can bridge the fractional divergence between physical and human geography and narrow the gaps between knowledge generated for the physical and social sciences. This study recognized the advantage of such an approach by integrating the positivist and phenomenological approaches; quantitative and qualitative methods; secondary and primary data collected through a social learning approach using a complex, integrated triangulated methodology.

Research methods vary with the epistemological and ontological basis of research objectives, research questions, theoretical and conceptual models and adopted methodology (Bailey 1987; Hanssen 1998; Graham 1999; Maxwell 2005; Stewart 2014). Triangulated methodology answers different research questions using different epistemological foundations. The methods used to answer various research questions of this study are summarised in Table 3.1. Positivism is based on empirical epistemology, in which knowledge is generated through objectively verifiable data (Johnston et al. 2000; Kitchin and Tate 2000). Empiricism and positivism are often regarded as core to the 'scientific method' (Bunge 1962; Johnston 1984; Neuman 2003), though their uses in social sciences also have a long history. Positivism is harder to integrate with the other approaches in general because of the necessary objectivity. However, here it was logically integrated with humanistic approaches to answer specific research questions at different stages of the research.

Knowledge in humanistic disciplines such as human geography is often created by the interpretation of subjective phenomena. Subjectivity is the meaning given to the real world by individuals (Kitchin and Tate 2000). The ontology of the interpretive approach is that the conceived wisdom (knowing) is the outcome of the lenses by which the real world is perceived (seen). In other words, what exists is that which people perceive to exist. The interpretive approach, also known as 'Historical-Hermeneutics', is the interpretation of history in relation to actual social context; and as a result, it focuses on 'being' rather than simply 'knowledge' (Johnston et al. 2000;Pile 1991). An interpretive approach investigates a person's worlds and emphasizes the individuality and subjectivity of knowledge and actions, with the goal of understanding phenomena (Johnston 1984; Neuman 2003).

Table 3.1: Methods adopted to answer different Research Questions

Research Questions	Methodology	Methods of data collection	Data Analysis	Supplementary data
How has the climate of the Himalaya changed over time?	Positivist	Secondary (archive of meteorological observations)	Quantitative (inferential statistics)	Secondary data
How are local people perceiving, observing and experiencing the trends and impacts of environmental changes on their livelihoods?	Interpretive	Primary (face-to-face household survey interviews, Focus Group Discussions, Key Informant Interviews, Historical Timeline Calendars)	Scalogram	Case studies, Secondary data
Is there consistency or contradiction between scientific and social understanding of climate change?	Interpretive	Further explanation of the results of above research questions	Search for consistencies and contradictions between observed and perceived changes in reference to meaning	Secondary data
What sorts of coping and adaptation strategies have been developed at the local level and what is the outcome of such strategies in the food and livelihoods security?	Interpretive	Face-to-face household survey interviews	Qualitative (scalogram)	Focus Group Discussions, Key Informant Interviews, Historical Timeline Calendars and Crop Calendar, Secondary data
What makes the livelihoods of the Nepali Himalayan communities? Are the livelihoods sensitive to climate change and its impacts?	Positivist	Face-to-face household survey interviews	Quantitative (descriptive statistics)	Case studies, secondary data
What is the level of exposure, sensitivity and adaptive capacity of the social-ecological system and what are the implications for the sustainability of the system?	Positivist and Interpretive	Face-to-face household survey interviews	Quantitative	Focus Group Discussions, Key Informant Interviews, Historical Timeline Calendarsand Crop calendar, Secondary data

This study analyses the changes in climate, assesses the strength of livelihood capitals, and evaluates livelihood outcomes (food security) and social-ecological vulnerabilities in Nepal using positivism. By applying the phenomenological approach, this research interprets the specific meanings and values the studied communities have consigned to the changing climate, and the adaptation responses they have made through their conscious judgement of implications of the changes on their social-ecological systems.

Human ecology is a contemporary field of scholarly enquiry on the interactions between human and bio-physical resources using a holistic approach (Bassett 1988; Gaile and Willmott 2003; Prudham 2009). This study adopted an integrated methodology to analyse the environmental, social-environmental and societal dynamics of human-environmental interactions in the Kaligandaki Basin. Such a holistic approach in human ecological research reduces the risks of developing a false understanding of human-environmental interactions (Judkins et al. 2008). The holistic approach is concerned with the integration of places, interdependence between places and interdependence across scales (Neuman 2003). Because of the importance of an integrated methodology, many scholars have contributed to its theoretical development and practical use to conduct research on social-ecological systems (Adger 2006; Adger et al. 2011; Berkes and Folke 1998; Berkes et al. 2003; Berkes and Jolly 2001; Folke 2006; Folke et al. 2010; Lereboullet et al. 2013; Osbahr et al. 2008; Tschakert 2007; Wrathall 2012). This study therefore applied an integrated, triangulated methodology adopting a social learning approach and provides an example of how the complex phenomena of climate change and human-environmental interactions can be studied systematically.

3.2.2 Adoption of Social Learning Approach

The term social learning has context specific definitions. It allows for the epistemological and ontological inclusion of the life-world of people and the encounters they have within their environments (Reed et al. 2010; Wals and van der Leij 2007). Social learning can be perceived as the web of social life that produces interactive relations among the components of the system as a whole. Therefore, it is an interactive, participatory, negotiated approach to, and process for, guiding collective problem-solving (to improve the management of human and environmental interrelationships) and decision making (Glasser 2007; Keen et al. 2005). In many ways, the social learning research approach has generated the cultural shift needed for better understanding of the sustainability of social-ecological systems (Sterling 2007).

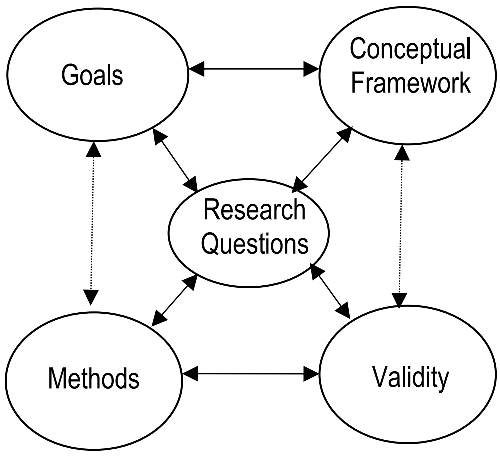
Communities have their own intelligence and learning capacities. A 'living community' is a 'learning community' that learns from past mistakes through the process of social learning (Capra 2007). Power mechanisms within societies, however, influence learning processes and determine the success or failure of the learning (Wildemeersch 2007).Social learning develops in a complex terrain of the interface between science and practice, the process goes on within a multi-level system where a range of actors engage in reflecting upon, understanding and managing human-environmental interactions (Cash and Moser 2000; Cash et al. 2006). In such a manner, the approach aims to provide communities with socially robust and context specific knowledge to inform flexible options to deal with challenges and disturbances (Capra 2007; Vogel et al. 2007). This research explores the consistencies and contradictions between 'non-expert' knowledge on climate change developed through social learning in Nepali villages and the findings of scientific observations, following other researchers who examined climate change and its implications on complex social-ecological systems (Chaudhary et al. 2011; Crate and Fedorov 2013; Devkota 2014; Gioli et al. 2014; Lereboullet et al. 2013; Kaul and Thornton 2014; Xu and Grumbine 2014).

3.3 Research Design

Research design is a plan of action to carry out research, which outlines the underlying structures and interconnections of the components of a research project. Positivist research generally applies explicit research designs that involve a one directional sequence of steps from problem formulation to the drawing of conclusions (Maxwell 2005; Yin 1994). However, research design is not linear in triangulated methodologies. Therefore, the research design for this study is not a set of rigid rules but rather is an ongoing process of tracking the complex interactions back and forth between and among the separate components (Figure 3.3).

As presented in Figure 3.3, the research questions are the central focus of this study. The interconnections and interactions between the Goals, Conceptual Framework and Research Questions are the epistemological aspect. On the other hand, the interactions between the Research Questions, Methods and Validity describe the praxis or ontological elements. The theoretical perspectives adopted to answer particular research questions are not necessarily appropriate to answer other research questions. The interactions between the methods and goals demonstrate a requirement for selecting appropriate research theoretical elements to inform a unique design so that the goals are achieved. Additionally, the interactions between Validity and Conceptual Framework validate the conclusions both theoretically and conceptually. In this context, this study adopted the research design presented in Figure 3.3 through an integration of both qualitative and quantitative research designs.

Figure 3.3: Interactive Research Design
(Source: Maxwell 2005, p. 5)



3.3.1 Quantitative and Qualitative Research Designs

Quantitative research designs are based on empiricism and positivist philosophies, which use deductive, particularistic and *etic* approaches. They are characterized by experimental settings, identification of behaviour, adoption of the principles of natural science, pursuance of scientific laws and the realistic perspective. Quantitative methods collect data through counting, census or survey and questionnaire and the data are analysed using descriptive and inferential statistics and mathematical modelling (Graham 1999). This research used quantitative design to explore and examine climate change trends in Nepal, to explore the statuses of livelihood capitals, to assess livelihood outcomes and the social-ecological vulnerability.

Qualitative research designs, on the other hand are based on interpretive or Hermeneutics philosophy and use inductive, *emic* and holistic approaches. Qualitative methods identify unanticipated phenomena and influences, and generate new grounded theories (Neuman 2003). Qualitative methods explore the feelings, understanding and knowledge of others by identifying the context specific meanings of the words of respondents, participants or archived documents (Maxwell 1996; Limb and Dwyer 2001). The data obtained are analysed and interpreted by description and textual interpretation (Graham 1999; Kitchin and Tate 2000; Neuman 2003; Winchester 2000; Yin 1994). Qualitative researchers detect patterns and regularities of the responses, formulate explorative hypotheses and develop general theories as conclusions. In this study, a qualitative research design was adopted to develop the understanding of the social reality of changing climate in Nepal, the implications of the change on the social-ecological system and people's response to the change and its effects.

Quantitative and qualitative methods are conflicting in their philosophical and epistemological positions (Bryman 2007; O'Cathain et al. 2007; Robson 1993), but not necessarily in the methodologies employed (Bryman 2012). These methods can be integrated and applied in social science research as triangulated methods (Denzin 1989; Greene et al. 2004), or as mixed methods (Grix 2004). The application of both quantitative and qualitative approaches can reduce the methodological bias (Creswell 2009; Ritchie and Lewis 2003), and for that reason, scholars have suggested to combine their use in social research (Bryman 2004; Neuman 2003). Considering the importance of mixed methods, this research adopted both quantitative and qualitative elements in a triangulated approach to mutually reinforce the findings, develop understanding and help to validate the conclusions (Hay 2000).

3.3.2 Adoption of Pilot Study Approach

A pilot study is a small study, intended to examine applicability of the methods planned to be adopted during the detailed study. In some cases, it is similar to the feasibility study or mini-version of the full study that tests the efficacy of proposed concepts and allows for modification prior to full-scale study (Borg and Gall 1989; Thabane et al. 2010). Pilot studies are common in large scale quantitative surveys (Lanphear 2001). They are an important approach also in field-based social science research. Pilot studies help to save time and costs of research, as well as increasing the quality of the research by providing feedback on the adopted methodology (Morgan 1998; van Teijlingen and Hundley 2001). This study conducted a pilot study to know more about the socio-ecological setting of the study area and to evaluate the appropriateness of the research questions and proposed field methods in the Nepali context. A pilot study was conducted in September 2012. Two study sites (Lumle in the Middle-Mountains and Meghauli in the Tarai) were visited. The settlements are the locations of where the offices of the Village Development Community (VDC), the local council, were purposively selected for the pilot study. Three Focus Group Discussions (FGDs), two Historical Timeline Calendars (HTCs), three Key Informants Interviews (KIIs) and five household survey interviews were undertaken in each of the sites (Plate 3.1).

FGD is a process for exploring specific issues through a discussion with 6-10 matured community members; the HTC is a similar discussion, however with a small group of 3-5 senior citizens. KII on the other hand is a form of in-depth enquiry with information rich individuals on required information for the research. The pilot study helped to identify the deficiencies in the initial field instruments and offered the opportunity to refine them.

Plate 3.1: Discussions in Nepali villages that formed the Pilot Study
(Source: Pilot Study 2012)

a. Meghauli   b. Lumle

3.3.3 Introduction to Study Area

Nepal is located between the geographic grid of 26°12’ and 30°27’ North latitudes and 80°4’ and 88°12’ East longitudes (Figure 3.4). The country is bounded by India on three sides (East, South and West) and by China to the North. The country’s total area is 147,181 km^2. The topography is complex - composed of the high Himalaya (15 percent), the Middle-Mountains (68 percent) and the Tarai (17 percent). The elevation ranges between 60 masl to 8848 masl, with permanent human settlements located up to 3900 masl. The place is also a transitional zone between Tropical, Temperate and Cold desert climate types. The topography and climatic transitions have resulted in highly compressed climatic zones in a short distance, so a number of micro-climatic zones prevail in the country. Based on the thermal efficiency index and altitude, the climates of Nepal are classified into six types [19].Topographic and climatic diversity has played a role in the social and ecological richness of the country.

In addition, the compound topography and relief pattern have produced the complex drainage pattern so the small country accommodates over 6000 drainage basins. Major river systems are the Koshi, the Gandaki, the Karnali and the Mahakali; all of them are tributaries of the Ganges. This study is conducted in the Gandaki Basin (also known as the Kaligandaki in the Middle-Mountains and the Narayani in the Tarai). The head of Kaligandaki River lies in Tibet, China and is older geologically than the Himalayan range. Through active erosion, the river has made the world’s deepest gorge (5571 m deep) near Ghansa village (2520 masl) between the mountain

[19]Tropical - below 400 masl, Mesothermal (warm-temperate) in between 400-2600 masl, Microthermal (cool-temperate) in between 2600-3600 masl, Taiga (subalpine) in between 3600-4300 masl, Tundra (alpine) in between 4300-4800 masl (Naya Va 1975), and polar (Frigid Zone) above 5000 masl.

peaks – Dhaulagiri (8167 m) and Annapurna First (8091 m).Annual precipitation in Nepal ranges from as little as 270 mm in Jomsom (Trans-Himalaya) to above 6000mm at Lumle (Middle-Mountains) and both of these places are located within the Kaligandaki Basin. The tropical Asian monsoon generates most of the rainfall in summer months [20].

Physical geographic factors play a significant role in determining the social-ecological system and climate change implications in general. Therefore, the selection of the study area occupies important meaning. Brookfield (1964) advocates micro-geography as an important approach for developing in-depth knowledge on human-environmental interactions. Following such an approach, this study was conducted in three small spatial units within each of the ecological zones. Three spatial clusters with particular focus on a VDC (introduced below) in the Kaligandaki Basin [21] were selected with the idea of focusing on: the lowest rainfall region of the Trans-Himalaya [22](Upper-Mustang [23]), the highest rainfall region of the Middle-Mountains (Lumle), and the region vulnerable to flood in the Tarai (Meghauli). Hence, the study area is full of natural and social diversity.

3.3.3.1 The Tarai and Meghauli VDC

The Tarai is a narrow strip of flat land situated in the Southern part of Nepal. It covers 17 percent of Nepal's land surface and houses over 50 percent of the country's population. The elevation ranges between 60 to 300 masl. The Tarai has a sub-tropical [24] climate and before extensive clearing, contained subtropical hardwood forest. For the present study, Meghauli VDC was sampled to represent the Tarai considering its location in the lowest altitude in the Basin and is one of the flood prone areas in the country.

[20]Over 80% of annual rain falls during June-September

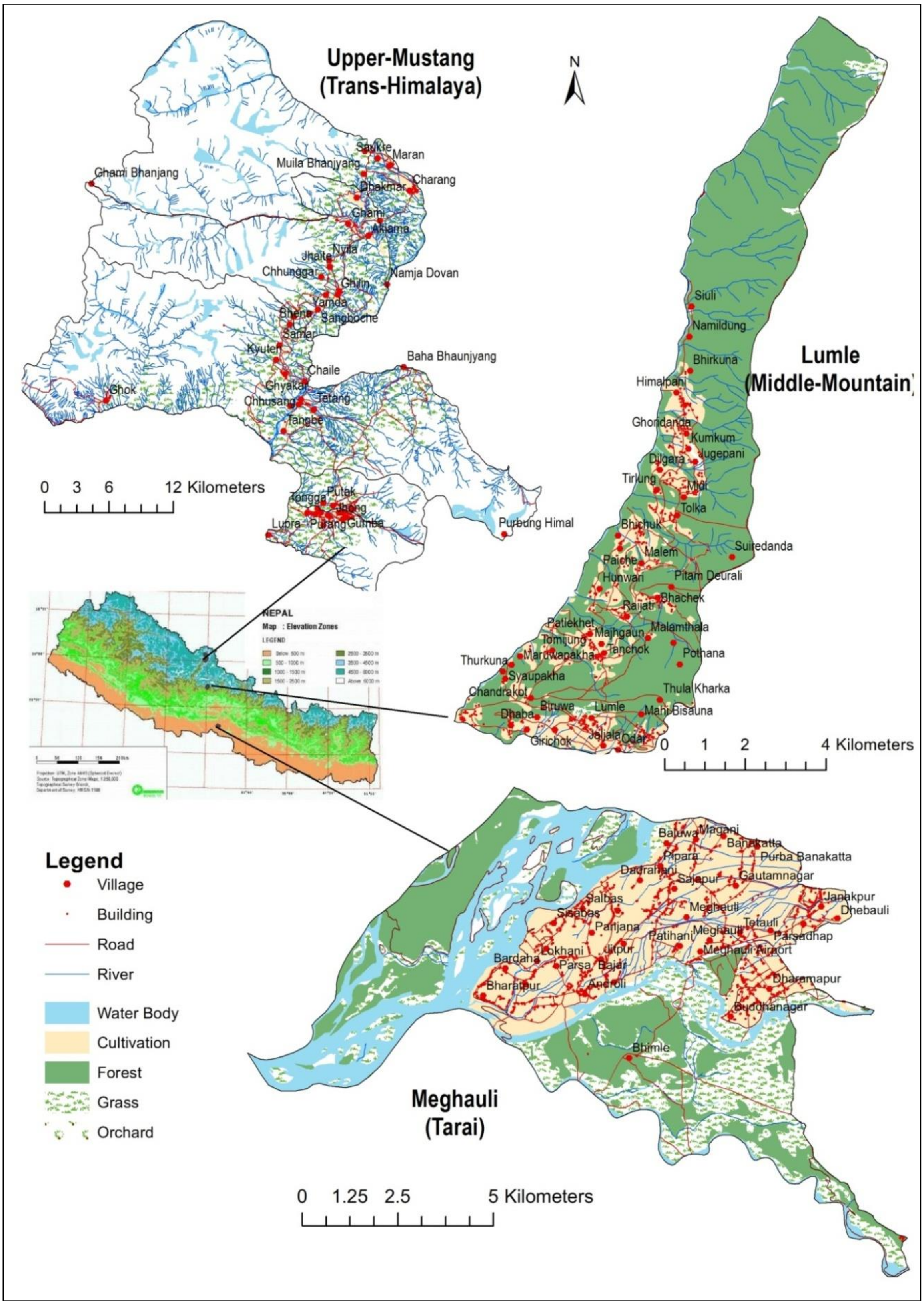
[21] Hot/wet below 300 masl, Tarai; cool/wet temperate in between 1200–1800 masl - Middle-Mountains; and cold/dry 3000-4000 masl Trans-Himalaya

[22] The Trans-Himalaya is sparsely populated so to make representative sample size, 5 VDCs (Muktinath, Zhong, Tsusang, Ghami, Tsaran) of Upper-Mustang (above 3000 masl) were selected

[23] Upper Mustang (in terms of elevation, above 3000 masl, and located within the Upper Kaligandaki catchment was selected purposively; though the term 'Upper Mustang' also regarded as 'Forbidden Kingdom' is different than the term used here. For instance, Muktinath and Zhong VDCs are not the part of 'Forbidden Kingdom'.

[24]Tropical in Macro level classification as of Naya Va (1975)

Figure 3.4: Map Showing Study Sites in Different Ecological Zones in the Kaligandaki Basin, Nepal
(Source: Digitised from Topographical Map Department of Survey, GoN 1996, Original map scale 1: 25000 for Lumle and Meghauli, and 1: 50000 for Upper Mustang)



Meghauli [25]VDC is located in the Gandaki Basin in the Central-South of the country, and is bordered by the Narayani River in the South-West and by the Rapti River in the South-East (Figure 3.4). These rivers are the major drivers of floods in the VDC. The Gandak barrage constructed a few kilometres downstream from the VDC also leads to drowning problems in the area. The VDC shares a border (25 km) with the Chitawan National Park (CNP) and experiences the risks and hazards of wildlife encroachment. Table 3.2 shows that the population of the VDC is 14149 (7808 females) in 3086 households, with household size of 4.6 persons. Among the population, the domination of females is evident. In terms of climatic conditions, the long-term means (1971-2010) of maximum and minimum temperatures and precipitation recorded at the nearest meteorological station (Rampur) indicates maximum temperatures of around 35^{o} Celsius, minimum temperature of around 15^{o} Celsius and annual precipitation of over 2050mm (Figure 3.5).

Table 3.2: Household and Population by Sex and Study Sites in the Kaligandaki Basin, Nepal
(Source: CBS 2012a: Population Census 2011)

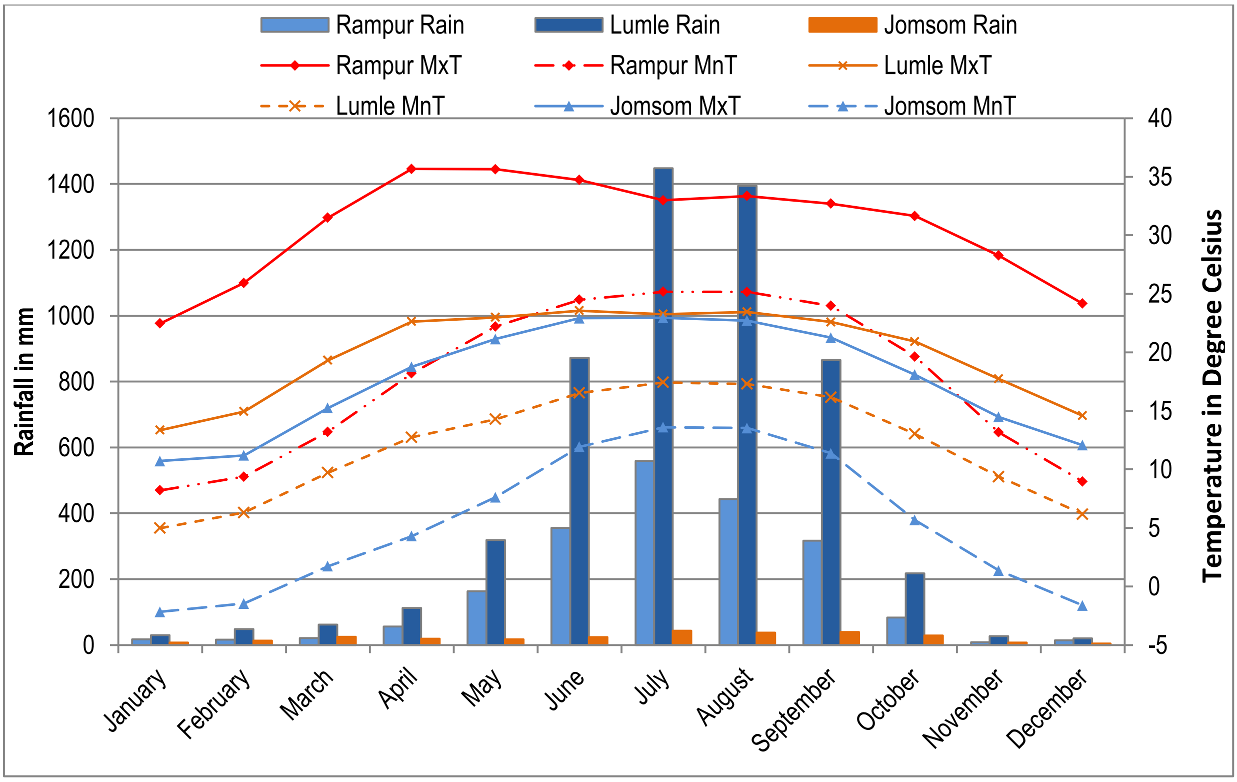
Study Clusters (VDCs)		HH	Total Population	Male	Female	Sex Ratio (male/100 female)	Household Size
Lumle		**1,056**	**4,258**	**1,910**	**2,348**	**81.4**	**4.0**
Meghauli		**3,086**	**14,149**	**6,341**	**7,808**	**81.2**	**4.6**
Upper-Mustang	Charang	132	452	217	235	92.3	3.4
	Ghami	169	611	285	326	87.4	3.6
	Jhong	85	253	112	141	79.4	3.0
	Tsusang	168	512	247	265	93.2	3.1
	Muktinath	198	628	301	327	92.0	3.2
Upper-Mustang Total		**752**	**2456**	**1162**	**1294**	**89.8**	**3.3**

Different caste and ethnic communities live in Meghauli. The *Tharus* are the indigenous people who make up over 25 percent of the VDC's population. Over 60 percent of the present inhabitants are in-migrants, who mostly moved from the Middle-Mountains in the last 60 years, mostly after the Malaria Eradication Program and country's policy to re-settle the flood and landslide affected people of the Middle-Mountains in Chitwan, under the Rapti Valley Development Programme launched in 1954 (Müller-Böker 1999; Ojha 1983). The literacy rate in the VDC is 59.4 percent. Of the total, only about 15 percent of households have some surplus food production, whereas more than 60 percent produce sufficient food for the household. Most of the land (over 60 percent) of the VDC is used for farming. The community forest or buffer zone forest covers 7.4 percent of the

[25] Data used in this section are from the VDC Profile of Meghauli 2068BS (2011) wherever the particular source is not given

area; bushland covers 6 percent; grass land and meadows 7.6 percent; and water bodies and sand 6.2 percent of the total area.

Figure 3.5: Long-term mean of Temperatures and Precipitation Records at different Meteorological Stations in the Kaligandaki Basin, Nepal (1971-2010)
(Source: computed from raw data (1971-2010) obtained from DHM, GoN)



Note: Long-term means (1971-2010) of monthly maximum and minimum temperatures and long-term mean of annual total precipitation. MxT = Maximum Temperature, MnT= Minimum Temperature

Major economic activities and sources of income of the VDC are agro-livestock based, together with tourism (home stay hospitality), poultry, fisheries, and remittances from labour migration abroad. Over 85 percent of the farmland of Meghauli has irrigation facilities. The source of household energy for cooking is Liquefied Petroleum Gas (LPG) and for light is electricity. Almost all households of the VDC have toilets, although the majority of the toilets are non-flush. The VDC is linked with all-season unpaved roads; the nearest city (Narayanghat) is about 35 km away from the VDC.

3.3.3.2 The Middle-Mountains and Lumle VDC

The Middle-Mountains of Nepal occupies over two-thirds of the country's land surface. The region has complex mountains, slopes and narrow valleys. Except in the major cities, accessibility and many other facilities are poor, but the Middle-Mountains are very rich in cultural and natural heritage. Major environmental problems of the region are soil erosion, landslides, and flooding in narrow flood plains. Precipitation varies with the altitude and slope aspect of the mountain ranges, although, the tropical monsoon is the source of precipitation. Lumle VDC represents the Middle-Mountains in this study (Figure 3.4), and was chosen because the VDC is located in the highest rainfall region of Nepal.

Lumle [26] is located in the Gandaki Basin in the central part of Nepal, bordered by the Modi Khola (River) in the West, and Lwanggale, Reevan, Ghachok, Dhital, Dhampus, Dhikur Pokhari and Salyan VDCs clock-wise from the North to the South. Lumle VDC is the part of the Annapurna Conservation Area Project (ACAP), which is a major project of Nepal that aims at harmonizing physical nature and human communities. The population of the VDC is 4258 (2348 females) in 1056 households with an average household size of 4 persons (Table 3.2). Long-term weather records (1971-2010) at the Lumle meteorological station suggests average mean values of around 20^{O} Celsius for maximum temperatures, 15^{O} Celsius minimum temperatures and over 5400 mm annual precipitation (Figure 3.5).

Lumle VDC is located between 988 masl to 3667 masl. The VDC is inhabited by different castes [27] and ethnic communities such as *Brahmin/Kshetries*, *Magars*, *Gurungs*, *Newars*, and *Dalits*. Most of the land is covered by forest (over 68 percent). Agricultural lands make up only about 17 percent and bushland and meadows cover about 5 percent of the total area. Major economic activities and sources of income are agro-livestock based, together with tourism (hospitality), small enterprises, service, and remittances from retirement (mostly from the British and the Indian Army) and labour migration abroad. Farming practices are mostly rain fed. The source of household energy for cooking is firewood and for light is electricity. Some of the settlements are electrified through local micro-hydropower projects. Almost all households have toilets, but the majority of them are, however, the traditional pit-latrine. The VDC is connected by a regional highway, but many settlements within the VDC lack access to the road network. The nearest city (Pokhara) is about 25 km away from the VDC.

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[26] Data used here are from VDC Profile of Lumle 2067BS (2010) if particular source is not given.

[27] Castes are endogamous divisions of society in which membership is hereditary and permanent (Berreman 1972). Caste has been an element in the social structure of Hinduism categorised based on the occupation, believed to be practiced since the *Licchavi* period (AD300 - ca. 879).

3.3.3.3 The Trans-Himalaya and Upper-Mustang

The Trans-Himalaya is the northern foothills of the Greater Himalaya and the southern frontier of the Tibetan plateau. Climatically, it is the rain-shadow of the Greater Himalaya. Consequently, the annual average precipitation is only to 267 mm at Jomsom, even though it is only about 30 km north of Lumle that gets over 5400 mm of annual rainfall (Figure 3.5). The East-West strip of the Trans-Himalaya in Nepal is interrupted by the Greater Himalaya and Manang-Mustang of which is the biggest block lies inside Nepal. Due to relatively low population densities, five VDCs [28] from Upper-Mustang represent the Trans-Himalayan in this study(Figure 3.4).Because of the lack of meteorological stations within the study site, meteorological data from the nearest station (Jomsom)was analysed to illustrate the climatic situation of the Trans-Himalaya. The long-term average (1971-2010) maximum temperatures at Jomsom are about 15^{O} Celsius and minimum temperatures are about 8^{O} Celsius (Figure 3.5). The region has the cool-temperature arid climate, however, frequently experiences at a mid-latitude high pressure belts and associated extreme blizzards.

The Upper-Mustang is located in the upper Kaligandaki Basin, and studied cluster is located between 3000 to 3900 masl. The area is mostly barren and rugged so cultivated farmland is limited; however, small fields are managed almost as fertile oases. Therefore, the place is called 'Mustang' that means 'fertile plain' in *Mustangi* dialects. The region is sparsely populated so has 2456 (1294 females) people in 752 households with an average of 3.3 persons per household (Table 3.2). Inhabitants are mostly known as *Mustangies* and include several social strata including *Brahmin*/*Kshetries*, *Gurungs*, *Ghales*, *Thakalies*, and *Bhotes*. The region comprises subalpine scanty vegetation, alpine pastures and some planted orchards. The major economic activities are agro-livestock based, together with tourism (hospitality and trekking) and seasonal business (hawking) in other areas. The region has only one growing season, April to September. The source of household energy (for cooking) is firewood, although the hotels use LPG for cooking. Some settlements have electricity but most do not. Almost all households have toilet facilities; modern flush toilets are available only in hotels.

The studied VDCs of the Trans-Himalaya are connected by recently constructed seasonal unpaved roads, although some of the sections of the road are yet to be connected with the main network. Public transport (jeep)is available occasionally if the weather is favourable. Jomsom is the nearest town, which is connected by air-route to Pokhara (city) and by seasonal road to Beni Bazaar (town). The region was isolated not only from the outer world but also from the mainstream

[28] Muktinath, Zhong, Tsusang, Ghami, Charang

societies and governance systems of Nepal for many years. Many traditions of the Trans-Himalaya are common to Tibetan culture. Because of the area's remoteness and low population density, the place lacks effective basic services in areas such as health and education.

3.3.4 Sampling Process and Sample Size

Sampling is required in research to select an amount of work feasible under specific circumstances. No one can study everyone, everywhere and everything; so choices need to be made (Miles and Huberman 1994), but, such choices should be unbiased. To make an unbiased choice, several sampling methods have been developed and practiced. These sampling methods are generally categorised into two broad groups, namely: representative and non-representative (Kumar 1999; Kitchin and Tate 2000). For quantitative research, representative and probability sampling are considered to be more appropriate. Both representative and non-representative, or probability and non-probability sampling, however, can be adopted in qualitative research.

3.3.4.1 Sampling of Households and Informants

This research has adopted both representative and non-representative sampling techniques. A representative sample size was obtained to collect quantitative data from the households. A total sample size of 356 was calculated from the total households (N = 4849) of 3 study sites [29] using n=N*384/N+384, where 384 is the estimated sample size for large scale population at e = 0.05 (5 percent error), significance = 0.05 (95 percent confidence level), and estimated probability of success (p) = 50 percent values (Dixon and Leach 1978, as cited by Kitchin and Tate 2000). The calculated sample size was further divided into 3 ecological zones using proportional representative sampling [30] at first then controlled further considering the socio-economic and spatial diversities within the study sites. The actual sample size was 153 households in the Tarai (Meghauli), 141 households in the Middle-Mountains (Lumle) and 66 households in the Trans-Himalaya (Table 3.3).

The households for face-to-face interviews were randomly selected from the lists of households prepared in consultation with the VDC secretaries and key informants of respective VDCs. A total of 35 (10 percent) households were selected as the 'reserve' sample to replace the sampled

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[29] N = 4894 (Meghauli 3086, Lumle 1056, Mustang 752) (Ghami 169+Zhong 85+ Muktinath 198 + Tsusan 168+ Tsarang 132)in 2011 population census.

[30] This 'n' is further divided proportionally to 3 places that come to be 224 for Meghauli, 77 for Lumle, and 55 for Upper-Mustang then considering internal homogeneity in Meghauli and higher diversity in Lumle and Upper-Mustang, the sample of Meghauli was reduced to 70% and remaining 30% were added to Lumle (70%) and Upper-Mustang (30%).

households when the respondent refused to participate in the study. The respondents from the sampled households were mostly the heads of households. In the absence of the household head, an adult member of the household was the respondent. The dominant age group of respondents was 45-59 in the Tarai and the Middle-Mountain, while it was 30-44 years in the Trans-Himalaya. Almost 30 percent of respondents were female from each cluster (Table 3.4).

Table 3.3: Number of Sampled Households by Place and Sex of Household Head
(Source: Field Survey, 2013)

Places	Female		Male		Total	
	Number	Percent	Number	Percent	Number	Percent
Tarai	47	30.7	106	69.3	153	42.5
Middle-Mountains	40	28.4	101	71.6	141	39.2
Trans-Himalaya	19	28.8	47	71.2	66	18.3
Total	**106**	**29.4**	**254**	**70.6**	**360**	**100**

Table 3.4: Age and Sex of Respondents by Place (Percentage)
(Source: Field Survey, 2013)

Age Categories	Tarai (n=153)			Middle-Mountains (n=141)			Trans-Himalaya (n=66)			Total (n=360)		
	Female	Male	Total	Female	Male	Total	Female	Male	Total	Female	Male	Total
18 - 29 Years	2.0	0.7	**2.6**	5.7	2.8	**8.5**	1.5	4.5	**6.1**	3.3	2.2	5.6
30 - 44 Years	15.0	14.4	**29.4**	7.8	18.4	**26.2**	9.1	28.8	**37.9**	11.1	18.6	29.7
45 - 59 Years	7.8	30.7	**38.6**	8.5	22.0	**30.5**	7.6	19.7	**27.3**	8.1	25.3	33.3
60 - 74 Years	5.2	19.6	**24.8**	6.4	24.8	**31.2**	10.6	15.2	**25.8**	6.7	20.8	27.5
>=75 Years	0.7	3.9	**4.6**	0.0	3.5	**3.5**	0.0	3.0	**3.0**	0.3	3.6	3.9
Total	**30.7**	**69.3**	**100.0**	**28.4**	**71.6**	**100.0**	**28.8**	**71.2**	**100.0**	**29.4**	**70.6**	**100.0**

3.3.4.2 Sampling of Study Period and Stations for Climate Data

Meteorological data (temperatures and precipitation) observed at the nearest meteorological stations from the study sites [31]for the last forty years (1970 to 2010) were obtained for analysis [32]. For primary data, the informants (household heads) were asked to share their perceptions on climate change, their experiences of the implications, and their social learning of adaptation responses in the preceding decade (mostly in the 2000s). Conversely, information on historical

[31] Meteorological data observations at Jomsom station (2744 masl, 28°47' NL, 83°43' EL, established in 1972) in the Trans-Himalaya, Lumle (1740 masl, 28°18' NL, 83°48' EL, established in 1969) in the Middle-Mountains, and Rampur (256 masl, 27°37' NL, 84°25' EL established in 1967) in the Taraiwas acquired.

[32]However, because of data lacking, temperature data of 40 years form Lumle, of 36 years from Rampur, and of 30 years from Jomsom; and precipitation data of 40 years form Lumle and Rampur, and of 38 years from Jomsom were obtained.

climatic events and their consequences were explored for forty years and compared with the weather extremes observed in the meteorological records.

3.3.4.3 Sampling for Qualitative Data

It is believed that scientific sampling may not always be appropriate to collect qualitative dataand there are no set of rules on the sample size for qualitative research (Miles and Huberman 1994; Travers 2010). Often purposive sampling that selects information rich respondents is more relevant in qualitative research (Patton 1990).This study collected qualitative data from a total of 24 Focus Group Discussions (FGD), 7 Historical Timeline Calendars (HTC),75 Key Informant Interviews (KII), and 9 Crop Calendars (Table 3.5).

Table 3.5: Number of events of Focus Group Discussions, Key Informant Interviews, Historical Timeline Calendars and Crop Calendars Applied to Collect Qualitative Data
(Source: Field Survey, 2013)

Place	Focus Group Discussions			Key Informant Interviews			Historical Timeline Calendars	Crop Calendar
	Female	Mixed	Total	Female	Male	Total		
Tarai	2	7	9	7	26	33	2	4
Middle-Mountains	3	6	9	7	13	20	3	2
Trans-Himalaya	2	4	6	7	15	22	2	3
Total	**7**	**17**	**24**	**21**	**54**	**75**	**7**	**9**

The participants of the FGDs, KIIs and Crop Calendar discussions were the adult members of the communities, mostly 30 years of age or above. As key informants, they were either prominent farmers of the communities; executive members of the resource management committees or user groups (forest, irrigation, water supply); Community Based Disaster Management Committees (CDMC); or people engaged in the field of nature conservation, agroecological management, environmental awareness campaigns, or promotion of food and livelihood security within the VDCs. The participants of the HTCs were senior members of the communities who were capable of remembering major climatic events and their major consequences in the last 40 years.

3.3.5 Methods of Data Collection

3.3.5.1 Secondary Data Sources

Primary field work was conducted from April through to September 2013.Firstly, secondary data was collected through a review of the relevant literature. The problem statement and research gaps identified in chapter one indicated the required secondary data for this research. The relevant literature was collected from the library of the University of Adelaide databases using:

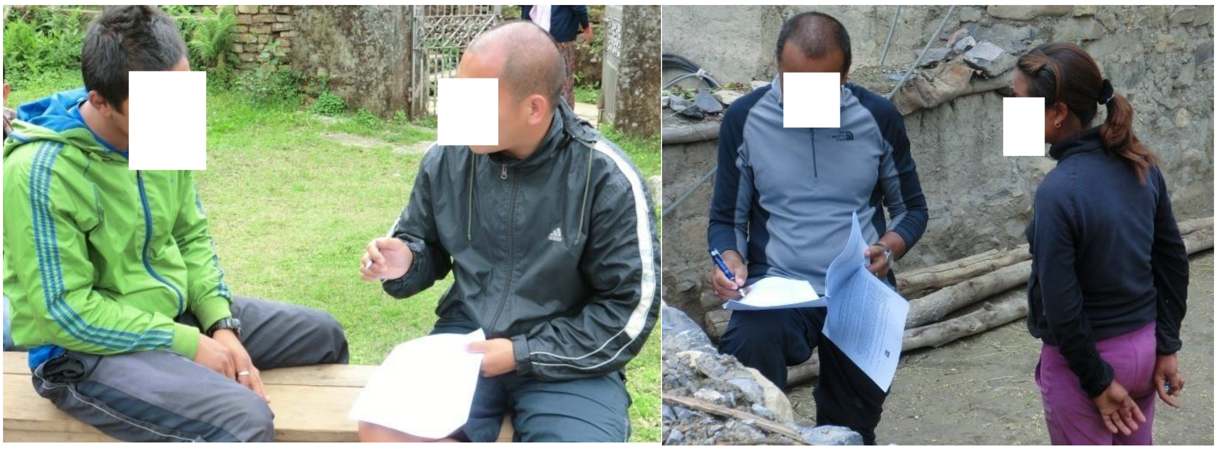
Scopus, Google Scholar, PubMed, Web of Science, Academic OneFile, as well as from Primo-library. The selective, comprehensive, critical and current literature, as assessed by the researcher and suggested by supervisors, was critically reviewed.

For the analysis of climate change trends and variability, the researcher purchased meteorological records from sampled stations stored in the database of the Department of Hydrology and Meteorology, Nepal (DHM, Nepal). Further, unpublished VDC profiles and the publications of the Central Bureau of Statistics (CBS), Nepal and publications of the International Centre for Integrated Mountain Development (ICIMOD) were also reviewed.

3.3.5.2 Face-to-Face Interviews with Household Head

To obtain primary data, a questionnaire survey is a common method in social science research (Nardi 2006; Walter 2010). This part of the research involved face-to-face interviews with respondents to obtain the data within their private domain (Plate 3.2). A case study method was also adopted whenever the particular case was identified during the face-to-face interviews. The case study approach helps acquire the information on sub-questions like 'how' and 'why' and facilitate an in-depth interaction with the respondents (Neuman 2003; Stewart 2014; Yin 2009).The questionnaire schedule had both open and closed questions on the socio-economic status and livelihood systems of the households, their perceptions of climate change, associated impacts and adaptation responses (Appendix 1). The face-to-face interviews at the household level were conducted by the researcher and four field-assistants. All the field-assistants were social science graduates and were closely supervised and monitored by the researcher during the field work.

Plate 3.2: Face-to-Face Interviews with Household Head
(Source: Field Survey, 2013)



a. *at Landruk, Lumle* b. *at Jhong, Mustang*

The term ‘climate change’ and associated processes are highly technical terms for the rural and uneducated respondents. Therefore the term was simplified by providing several simple questions related to weather patterns. There were 14 questions related to climate change, 16 questions linked to implications, 35 questions associated with adaptation strategies and 11 questions allied to adaptation challenges. As far as possible, the questions were structured in such a way so that confusion, jargon, false premise and overlapping issues could be avoided (Lewin 2005; Neuman 2003). The household for this study is considered as a minimum management unit of the environmental resources (Judkins et al. 2008); therefore each questionnaire schedule provides the status of the social-ecological system of the smallest unit of production i.e. household. Data on the private domain is further supported by public domain data collected using various tools of Participatory Rural Appraisal (PRA).

3.3.5.3 Participatory Rural Appraisal

The tools of PRA are very important to understand the institutional context of environmental change and participatory risk and hazard assessment (van Aalst et al. 2008;Wals and van der Leij 2007). The participatory approach can make precise assumption and prediction in the case of lacking recorded quantitative data (Chaudhary et al. 2012). In addition, they are useful in well-being and vulnerability assessments and development planning, and can form important elements of a broader social learning approach (Chambers 1983; Chambers 1994; Mosse 1994; Chambers and Guijt 1995).Among the various tools of PRA, this research adopted FGDs, KIIs, HTCs and Crop Calendar to collect data on public domain. All of these activities were moderated by the researcher, while field-assistants helped in note-taking.

Focus Group Discussions: FGD was conducted in selected communities (Plate 3.3). The cluster of households (settlement) known by the single name is considered as the community, although the term ‘community’ holds a specialised definition [33]. The researcher working in small teams of 2 or 3 individuals moderated such discussions as per the issues listed in the checklist (Appendix 2),and ensured that the discussions focused on the defined issues. Follow-up queries were also generated during the discussions as required. Notes were taken in the field as well as audio recordings with later transcription.

[33] Community is a cultural group, informal unifying institutions, administrative units of government, or the division based on political economy like class or caste (Judkins et al. 2008)

Plate 3.3: Focus Group Discussions in different Villages in Nepal
(Source: Field Survey, 2013)

a. At Shisabas, Meghauli 2 | b. At Landruk, Lumle 9

Photos by Dharma Raj Parajuli

Historical Timeline Calendars: The HTC is the 'folk memory' of the community that encourages people to recall hazard events, their trends and associated impacts and adopted strategies to reduce the negative implications of change (van Aalst et al. 2008). In the HTC, 3 to 5 senior citizens were invited into a discussion and the stories they shared were recorded (Plate 3.4). The HTC guideline was framed using the Driver →Pressure →Stage of Change →Impact →Response (DPSIR)framework (Appendix 3). The audio records of the discussions were transcribed and the information was applied to support the claims made by the informants at the household level.

Crop Calendars: Crop calendars record the annual cycle of crops and their connections with weather events and hazards. A crop calendar is a part of the seasonal calendar that demonstrates the activities related to the agro-ecosystem: the amount and distribution of rainfall, seasonal changes in soil moisture, crop sequences, pests and disease, agricultural and non-agricultural labour, diet, food consumption, sickness, and migration (Chambers and Guijt 1995). This study used crop calendars to identify the changes in activities over time. To sketch crop calendars, six to ten farmers within settlements were invited to a discussion, where they explained monthly activities related to agriculture. Two sets of calendars – for the year 2012 and for a decade earlier (around 2002) were sketched based on their memories (Appendix 4). The changes observed in the crop calendars over time were interpreted as the impacts of climate change and community responses to that change.

Key Informant Interviews: Key informant interviews use descriptive questions (Newman 2003) and allow the researcher to discover the complexities of participants' perceptions and experiences and promote greater accuracy in responses through cross-questioning (Bryman 2012; Mack et al. 2005; Patton 1990). They can produce a rich and varied data set for in-depth analysis (Kitchin and Tate 2000). Wolcott (1995; 2005) argued that interviews are self-reporting of experiences, opinions and feelings. The interviews here were framed by the same set of questions (Appendix 2); nevertheless, context specific sub-questions varied across the informants. All the interviews were undertaken by the researcher, while field-assistants assisted for note-taking (Plate 3.5). The data obtained through interviews was used to supplement the household survey data.

Plate 3.4: Historical Timeline Calendars at Tsusang, Upper-Mustang, Nepal
(Source: Field Survey, 2013)

Photo by Dharma Raj Parajuli

Plate 3.5: Key Informant Interview at Lumle, Nepal
(Source: Field Survey, 2013)

Observations and Photographs with Field Notes: Observations, photographs and notes are often attached to one-another in field methods and are effective tools for collecting qualitative data (Bickman and Rog 2009; Fetterman 2009). The major advantage of observation is its 'directness' (Frankfort-Nichanias and Nachmias 1996), which helps the researchers understand the participants' perspectives, norms and events in their environment (Denzin 2009; Mack et al. 2005). Observation helps the researcher produce accurate images of studied phenomenon (Yin 2009). Photographs can jog the memory of field experiences and allow the researcher to recall detailed information during data analysis and writing-up of findings. The quality of data from observations and photographs relies on the observer's ability to observe and interpret. The technological advancement in the contemporary world poses the risk of manipulated photography and generating false interpretations. To avoid such risk, this research interpreted only the photographs taken either by the researcher himself or by the accompanying field-assistants. This research used observation and photographs to collect data on visible impacts of climate change and the adaptation strategies the communities have adopted. Brief field notes about the observed objects were written at the time of observation and photography.

3.3.6 Analysis and Interpretation

Data collected in the field requires categorization (Graham 1999), analysis, organization and interpretation to explore meanings (Marshal and Rossman 2006). The purposes of analysis are: to categorize collected data meaningfully; and make sense of data; formalize the concepts in reference to data and methodology; develop relationships between data, methods and theory; and to make the findings communicable for scientists so that it contributes to the cumulative growth of knowledge. The methods and techniques of analysis adopted by this research are presented below.

3.3.6.1 Analysis of Meteorological Data

Meteorological data (temperature and rainfall) was analysed using the Statistical Package for Social Sciences (IBM SPSS Statistics 19) and MS Excel 2010 computerised software. The rate of change in temperature and rainfall is estimated using the LINEST function of MS Excel. The LINEST function uses formula given below to detect the change:

$$Rate\ of\ Change = \frac{(Temperature2 - Temperature1)}{(Time2 - Time1)}$$

The level of significance of the detected annual change was tested through Linear Regression Analysis as well as the Mann-Kendall Test in SPSS. The Mann-Kendall Test (Gilbert 1987; Kendall 1975; Mann 1945) is a non-parametric test that is appropriate to test a monotonic upward or downward trend, but the trend may or may not be linear. Temperatures and rainfall anomalies are also examined to identify the variability. There are several methods of detecting anomalies. This research used the central tendency technique that describes the distance of observed temperatures and rainfall within a particular month from the long-term mean. To make the findings visible, both observed data and detected anomalies were presented in the graphs showing trend lines, Coefficient of Determination Variance (R^2) and regression statistics.

3.3.6.2 Analysis of Household Survey Data

Classification and Categorization of Responses: Classification and categorization of collected data are important parts of research data management. While digitising data into SPSS, each household was assigned a unique code that provided the opportunity to disaggregate at the household level and re-aggregate at spatial clusters. Household data were classified based on the sex (male and female) and seven age groups (<5 years, 5 – 14 years, 15 – 29 , 30 – 44 years, 45 – 59 years, 60 – 74 years, and 75 years and above). Similarly, literacy and educational attainment was classified by sex and four educational statuses (Illiterate, Just literate or primary, Secondary, and Tertiary). The occupations of the population were classified by sex and eight types of professions (Agriculture, Service or Job, Business or Enterprises, Foreign Employment, Retirement, Wage Labour, Unemployed, Study or Household Support [34]).

In addition, *the* Guttman Scale and Scores (also called scalogram) are useful tools to measure attitudes and public opinion in unipolar measurement (Abdi 2010; Blouin n.d.; Hays and Ellickson 1990-91; encyclopaedia [35]), and were adapted to scale peoples' perceptions on climate changes, its impacts, adoption of strategies and adaptation barriers. The scale ranges from 1 (the least) to 5 (the most). The responses were considered as Guttman Scores and applied to normalize the responses. Different levels of responses (1 to 5) were transformed into a single category to get the 'Normalized Responses'. Normalized Response (percent) = (Total score of actual response / Total of the highest possible score) * 100. Here, the 'Total score of actual response' refers to the cumulative score of the particular level of response from all the respondents (number of respondent * level of response); the 'Total of highest possible score' denotes the total score of all

[34]The unemployed and students are not the types of occupations *per se*, however to separate from working persons, they were classified accordingly. Considering the partial support of students in household livelihood system, they were placed in 'support for domestic chore' category.
[35]Viewed 22 September 2014 <http://www.encyclopedia.com/topic/Guttman_Scale.aspx#sthash.y1PaZjGs.dpuf>.

the respondents if they have scaled their response to '5' in a particular question (Total respondents multiplied by the highest score 5); whereas 100 is the 'constant' applied to calculate percentile. The results are presented mostly in the form of charts, graphs and tables using descriptive statistics.

Household Food (In)Security Access Scale (HFIAS): Level of food (in)security was assessed using the HFIAS scale. The HFIAS was developed by the Food and Nutrition Technical Assistance (FANTA) Project (Coates 2004; Coates et al. 2007; Bilinsky and Swindale 2010). The HFIAS includes nine food security related questions (Appendix 5), which are categorised into three broad groups: anxiety and uncertainty in food supply; insufficient quality of food (food variety and preferred food); and impacts of food deficiency (insufficient food intake and its physical consequences). Respondents expressed the level of deficiencies on each of the questions in a 0 to 3 scale: 0 = no food deficiency, 1= rarely (once or twice a month), 2 = sometimes (three to ten times a month) and 3 = often (more than ten times a month). The total score of a household hence ranged from '0' ('no' responses in all of the questions) to '27' ('often' responses in all of the questions) is the HFIAS for the household for the month. The monthly HFIAS was further transformed into the annual HFIAS. Also, the monthly average of the HFIAS was calculated from the annual HFIAS. To understand the changing scenario of food insecurity over time, the HFIAS of 10 years ago (as of the present memory) and for the present time (2012) were calculated and compared.

Social-Ecological Vulnerability or Sustainability Index (SVI): The assessment of vulnerability in relation to climate change has numerous challenges. As introduced previously, the concept of vulnerability is multi-dimensional, context specific and caused not only by the physical systems, but is also linked to socio-cultural, techno-economic and politico-institutional elements (see Chapter Two: 2.3.4 for details). Vulnerability is not a directly observable phenomenon but can be identified through a systematic analysis of a complex system (Luers et al. 2003). Therefore the method of assessing vulnerability is itself complex. Some of the assessment challenges have led to the development of robust and credible measures of vulnerability by integrating diverse methods (Adger 2006); however, the vigorous methods, which translate complex sets of parameters of vulnerability into a quantitative metric can be criticised for hiding the conceptual complexity of vulnerability and reducing its implications (Alwang et al. 2001). Many other scholars have also contributed in development and practice of the index-based approach of vulnerability assessment in relation to climate change (Aryal, S et al. 2014; Hahn et al. 2009; Mohan and Sinha

2010; Sining 2011; Sullivan 2011; Thornton et al. 2007; Turner et al. 2003). These scholars have treated vulnerability as a function of exposure, sensitivity and adaptive capacity.

There are several methods of measuring vulnerability or sustainability quantitatively (Lindenberg 2002; Ramachandran 2002; Pratt et al. 2004), as well as qualitatively using participatory approaches (Daze et al. 2009; de Dios 2002; Marshall et al. 2009; Pasteur 2010; Regmi et al. 2010; Wiggins 2009). These methods have different strengths as well as weaknesses for investigating human-environmental interrelationships. These methods assess relative vulnerability across spatial scales (political or administrative boundary or ecological zones or the countries), so generally cannot capture the variability prevailing within the spatial unit or the micro-unit of a social-ecological system. The unit of analysis for social-ecological sustainability or vulnerability is the social-ecological system itself, that includes society (human) and ecological (bio-physical) sub-systems of an integrated system (Berkes and Folke 1998). This study assesses vulnerability of the socio-ecological system at the micro-level i.e. households by applying the method used by Hahn et al. (2009) with necessary modifications.

This study adopted the holistic approach of assessing vulnerability that explicitly considers relevant non-climatic and non-natural drivers together with bio-physical and climatic drivers. This form of assessment is also termed as the "second generation of vulnerability assessment" (Füssel and Klein 2006). This research assessed the levels of exposure, sensitivity and adaptive capacity of households by calculating respective sub-indices at first, and then the social-ecological vulnerability index.

Equations:

$$\text{Index } \mathrm{e}_{\mathrm{v1}}\mathrm{h}_1 = \frac{e_{v1}h_1 - e_{v1}h_n Min}{e_{v1}h_n Max - e_{v1}h_n Min}$$

Here, $\text{Index } \mathrm{e}_{\mathrm{v1}}\mathrm{h}_1$ refers to the indexed value of 'variable #1' belonging to the 'Exposure Component' (e.g. perceived warming) in 'household #1'; $\mathrm{e}_{\mathrm{v1}}\mathrm{h}_1$ is the actual value of the variable for that household; $e_{v1}h_n Max$ is the maximum value among the surveyed households of the region; and $e_{v1}h_n Min$ is the minimum value among the surveyed households of the same region. Using the similar method, index values for all the applicable variables for each group were calculated (Table 3.6). The index values for a total of 23 exposure related variables; 36 sensitivity related variables; and 59 adaptive capacity related variables were calculated at first and weighted mean of exposure components, sensitivity components, and adaptive capacities components were calculated as respective sub-indices. For example:

$$\text{Exposure Index (EI)} = \frac{\sum_{i=1}^{n=14+9} \text{Index}\, e_{v1} h_1}{\sum_{i=1}^{14+9} wm}$$

Here, wm refers to the weighted mean of the variables for exposure components. In the same way, the Sensitivity Index (SI) and the Adaptive Capacity Index (ACI) were also calculated. After obtaining sub-indices the Social-Ecological Vulnerability Index (SVI) was calculated using the IPCC Vulnerability Framework: Social-Ecological (Livelihoods) Vulnerability Index (SVI) = (EI-ACI)* SI (Hahn et al. 2009; Mohan and Sinha 2010). Here, 'EI' refers to Exposure Index, 'ACI' refers to 'Adaptive Capacity Index' and 'SI' refers to 'Sensitivity Index.

Table 3.6: Vulnerability Components and associated Variables applied by the Study

Components	Variables components
Exposure: A total of 23 variables (questions) from the mentioned variable components	Perception on climate change (a total of 14 questions related to weather variability and change), Experienced adaptation Barrier (9 questions those are limiting households to take adaptation strategies)
Sensitivity: A total of 36 variables (questions) from the mentioned variable components	Household Head, Dependency ratio, Climate sensitive occupations, Population having health problems, Severity of health problems, Fallow farmland, Never irrigated farmland, Current share of agriculture in livelihoods, Household debt, Perceived economic status, Monthly Household Food Insecurity Access Scale (HFIAS), Experienced impacts of climate change (7 questions)
Adaptive Capacity (Actual adaptation in practice): A total of 59 variables (questions) from the mentioned variable components	Level of skills and education, Kinship and Neighbourhood supports, Land entitlement, Land ownership, Size of farmland, Size of *Khet* land (level terrace), Cropping intensity, Irrigated land, Livestock, Annual food sufficiency (household production), Annual household budget sufficiency, Household possessions (house, vehicles, equipment, valuables / convertibles), Share of non-agro sector in household livelihoods, Level of adoption of adaptation strategies (24 questions)
Social-Ecological Vulnerability Index	(Exposure Index – Adaptive Capacity Index) * Sensitivity Index

After obtaining all these indices, households were further categorised into four groups having very high, high, medium and low levels of exposure, sensitivity, adaptive capacity and vulnerability. The SVI value ranges between '-1' (least) to '1' (most). The threshold of Human Development Index (HDI) is thought to be appropriate to classify the households in reference to adaptive capacity indices [36], while the reverse scale is used to categories households' sensitivity and exposure

[36] Very high (>=0.8), High (>=0.7 and <0.8), Medium (>=550) and (<0.7), and Low (<0.550)

considering their opposite relations to adaptive capacity [37]. Considering vulnerability as an opposite concept to development, the range of the HDI (0 to 1) is transformed into '1' to '-1' to categorise households in reference to the SVI [38].

The method used by this research generates indices of vulnerability for the social-ecological system at the household level relative to other households in the region. This index value has important policy implications, especially to the resource poor countries like Nepal because the government should assist the most vulnerable household first and then expand services gradually. Furthermore, it is vital that the index can also be aggregated or averaged as required and compared among spatial and social strata, which would help the country to design appropriate policy responses to ensure social justice.

3.3.6.3 Analysis of Qualitative Data

The purpose of qualitative data analysis is to represent details of a person's life, lived experiences, behaviour, emotions and feelings as well as institutional functions (Strauss and Corbin 1990). In this research, qualitative data were digitised into the NVivo9 computerised software and the texts were coded. From the coded texts, the node-based queries were built to explore similar responses across the interviews as well as in group discussions. Such query reports were further described in the text as required, for example, the paraphrasing in block quotes placed in this thesis, using narrative accounts to establish respondents' opinions. The description of narrative accounts was useful to shed light on how people adapted to perceived climate change and experienced impacts by negotiating adaptation barriers. The results were interpreted in relation to data obtained from household survey interviews.

3.4 Validity and Reliability

Validity and reliability are the most important aspects of research that makes the study both consistent and useful (Bryman 2012). The sound demonstration of links or blending of theory, methodology and the results generates validity. Validity is the search for truth (Hammersley 1990; Silverman 2000) that fulfills the theoretical and practical aspects of research (Kitchin and Tate 2000).On the other hand, reliability refers to the degree of consistency or trustworthiness. It is an examination of research to see whether the findings are biased. The deliberate, planned and consistent application of methodology increases the procedural precision, henceforth; upgrades reliability (Birks 2014).This study focused each step of the research to maintain validity and

[37] Very high (>=0.450), High (>=0.3 and <0.450), Medium (>=0.2) and (<0.3), and Low (<0.2)
[38] Very high (>=0.3), High (>=0 and <0.3), Medium (>=-0.3) and (<0), and Low (<-0.3)

reliability. The researcher himself was the primary data collector, editor, compiler, designer and analyser. The employed field-assistants were closely supervised and monitored by the researcher. Therefore the standard for data quality was maintained. Regular feedback from supervisors has further assisted to maintain the validity and reliability. Moreover, the adoption of multiple research strategies and multiple sources of data increased internal validity and helped answer the research questions more effectively than could have been achieved with the application of a single approach (Creswell 2009; Daldeniz and Hampton 2013). The adoption of the integrated or holistic approach and triangulation methodology increased the reliability of this research.

3.5 Consideration of Research Ethics

Intellectual honesty and professional ethics call for scientists to acknowledge the work of predecessors and colleagues (Le Treut et al. 2007). Respecting this notion, the authors of both the scientific and grey literature from where the ideas were derived are duly acknowledged.

The research process also needs to assure that the research participants are informed about the research and they are not harmed physically, legally, economically or psychologically (Bailey 1987; Neuman 2006). To ensure this, no identification of the respondents is reflected in the findings (Neuman 2003; Piper and Simmons 2005). It is not very easy to maintain anonymity in research that uses qualitative information and includes case studies because data are presented in a real life context of place, people and events (Yin 2009). However, respecting the National Statement on Ethical Conduct in Human Research and the Australian Code for the Responsible Conduct of Research, all ethical concerns, including maintaining the anonymity of respondents is respected. Every attempt was made to maintain the ethics of do-no-harm in the research process, even though the research was of the 'low risk' category. The respondents were informed about the research project (Appendices6a, 6b), and their voluntary consent was obtained (Appendices 7a, 7b) prior to administering the field instruments. No inappropriate means were applied to obtain information. The respondents were allowed to withdraw their participation at any time during the interviews and discussions. Special attention was paid in framing the field instruments and the wording of their contents so that every respondent felt that they were honoured. The primary information obtained has been kept confidential and used only for research purposes.

3.6 Research Limitations

This research experienced some limitations during the research process. Meteorological observations and monitoring systems in Nepal are relatively weak; therefore, numbers of missing cases were averaged from the nearest observed dates. The changing intensity of precipitation could not be understood meaningfully because of the lack of hourly rainfall data.

Because of the internal homogeneity, the sample size of Meghauli (Tarai) was reduced to 70 percent (157 households) and the excess of 67 households of Meghauli were further divided in 30 percent and 70 percent and added to the existing samples of Upper-Mustang (Trans-Himalaya) and Lumle (Middle-Mountains), respectively so internal diversity of these places could be represented. As a result, the ratio of sample to the total population was smaller in the Tarai than that of other places. To increase the richness in collected information, the sample size for the KIIs was increased in the Tarai. Further, because of many weather related disturbances and problems associated with accessibility during the field work, and a higher proportion of refusals (no consent given) the sample size of Trans-Himalaya was reduced to 66 households. Nevertheless, the diversity in the source of the informants was maintained.

Some methodological limitations were also experienced during the analysis of climate data. The science of climate change is very advanced and uses sophisticated techniques, which the researcher could not apply in this research. The study adopted simple methods of detecting change and anomalies. Data were available only for a short period, which can generally define the climate of the study area, however, not for long enough to analyse the change. Therefore, the findings of meteorological data analysis are only indicative of changing climate. Similarly, while assessing livelihood vulnerability, the importance of various elements were weighted differently due the emphasis given to ecosystem-based resources as suggested by the SLA in rural contexts. However, it is lately recognized that despite living in rural settings, various factors lead studied households to exploit cash-income sources, like of households in urban areas. Also the low level contribution of physical capital in household livelihoods, particularly due to their poor statuses at both private and public domains, received equal status to other capitals while calculating the overall livelihood vulnerability index (as presented in Table 5.11 and Figure 5.17). Nevertheless, there is notable variation in the importance of different capitals in household livelihoods. These sorts of limitations are required to be considered by the reviewers, or those researchers who intend to replicate the methodology used in this research.

This study also experienced some limitations in the vulnerability assessment process despite adopting a convensional method. Most of the methods of vulnerability assessment available in the literature deal with relatively larger spatial units so they use regional to national indicators, which are not applicable for household vulnerability assessment. The human ecological implications of climate change are wide and complex. In addition, the concept of human ecology overlaps with concepts of cultural ecology, political ecology and social ecology. Despite lacking distinct boundaries, each of these concepts is applied variably in different disciplines of social sciences. Being a geographic study, this research focussed particularly on human ecology and social ecosystems. Therefore, the emphasis was given to analysing bio-physical and local social-economic elements of the local social ecosystem. Although it would have been better if this research would have integrated more elements from cultural ecology as well as from political ecology and political economy considering Nepal's cultural diversity, remittance-based economy, feminization of communities, contemporary volatile politics and lack of elected local government for one and a half decades. In addition,the development aid regime together with critical geopolitics involving India and China, Nepal's participation in world trade organization and the world economic system strongly influence communities' livelihoods and the sustainability of local social-ecosystems. These global and international factors affect the endogenous and exogenous factors discussed here, but are not analysed in detail. Furthermore, incorporating various elements of multi-dimensional concepts like human ecology, political ecology and economy, cultural ecology, as well as social ecology in a PhD project that has time, financial and word length limitations, is difficult. Due to this reason, the assessment of social-ecological vulnerability was conducted mostly using the elements of private domains applicable to households.

Climate change impacts are not independent of each other or other livelihood factors. Political ecology and economy, cultural ecology, and global political and economic systems, including the globalization and associated implications into peoples' livelihoods and into local social-ecosystems, all influences climate change impacts. Inclusion of the influence of these factors into local social ecosystems is also needed to obtain a comprehensive integrated vulnerability index. Therefore, this research would have been strengthened if the project could have incorporated a wider range of variables. Yet, the primary focus of this research was to understand the climate impacts at micro social-ecosystem, which in this case was deemed to be the household level. Most of the elements of national and global political economy have similar implications for different households within a cluster, whereas biophysical and socio-ecological elements of private domains differentiate the influence of political economy and associated livelihood outcomes across the households. For that reason, elements of national and global political economics are not incorporated into this study. Importantly, many methods used previously to assess social-ecological vulnerability have provided flexible options in selecting variables applicable to the theme of a research, which this study modified to make it applicable to the households of the Kaligandaki Basin, Nepal to conduct analysis of social ecosystems at micro level. As a result, this study particularly focused onto bio-physical resources of the households. In addition, the gender dimension of human-environmental interactions, which also is an important issue in Nepal, particularly because of feminization of agriculture associated with male labour migration abroad, also could not be analysed in detail in this thesis. In this context, further research work on different sectors (as proposed under future research agenda in chapter eight); using the concepts of local, regional and national, and aid related political economies; is important.

3.7 Conclusion

This research adopted a comprehensive methodology to investigate human-environmental interactions in the Kaligandaki Basin, Nepal. This research adopted a social learning approach and field methods of both quantitative and qualitative research design and demonstrated the underlying complexities of human-environmental interaction in relation to climate change. Using a triangulated methodology, this research tries to bridge the gap between the knowledge generated through natural and social science methodologies. Study of human-environmental interactions requires answering a range of questions that a single research approach cannot effectively answer. Therefore, different methods are adopted to answer different research questions. The adoption of integrated methodology hence became an important strategy for this research. The research also adopted a pilot study that provided an opportunity to understand the social-environmental settings of the study area and refine the initial research design.

This research used both secondary and primary data. Meteorological data from three meteorological stations of the basin was obtained and analysed. Primary data was collected through face-to-face interview with household heads, while focus group discussions, historical timeline calendars, key informant interviews and sketches of crop calendar tools were adopted to generate data at the community level. The study was conducted in three spatial clusters and a total of 360 households were surveyed. Data was analysed using SPSS and MS Excel computerised software. To investigate the outcomes of human-environmental interactions, research adopted the HFIAS scale to measure food (in)security and the multi-dimensional vulnerability index to assess social-ecological vulnerability. The research was conducted giving due attention to necessary research ethics. The integrated approach adopted by this research helped to make the research findings reliable and valid. Adoption of triangulated methodology was found to be an effective strategy to investigate human-environmental interactions in the Himalaya, Nepal in relation to climate change. Chapter Four assess the exposure of the social-ecological systems to climate change and its associated impacts.

CHAPTER IV

CLIMATE CHANGE AND ASSOCIATED IMPACTS IN THE HIMALAYA

4.1 Introduction

Research work on climate change throughout the world has increased significantly over the last two decades. The studies have demonstrated that climate is changing more rapidly in the 20th and 21st centuries than the earth has experienced in the past millennium, and anthropogenic forcing is reported as the primary cause (Hartmann et al. 2013; IPCC 2001; Stern 2006; Weaver 2003). The literature, however, has concentrated on global and regional level generalizations with some local examples. Available scholarly works have also found spatial variability in the alteration of climate and its implications. Some parts of the world have experienced extraordinary variations, whereas others have a relatively stable climate. The Himalayan region is interpreted as a place having unusual rates of warming (Chaulagain 2006; Christensen et al. 2013; Christensen et al. 2007; NRC 2012; Shrestha et al. 2012; Shrestha et al. 1999) and extended, extreme rainfall events (UNDP and DFID 2007; Trenberth et al. 2007). Nevertheless, not enough research has been conducted within the complex, heterogeneous environment of the Nepali Himalaya.

The climate of a place is co-produced by the interactions between natural and human systems, and is understood through both meteorological statistics and cultural interpretations (Hulme 2008;Rayner 2003). Studies on climate change, however, have been dominated by climate science and modelling that generates a problem for climate change adaptation, because people may not recognise the scientifically measured variability due to the fact that they measure climate dynamism based on their own meanings and values they give to particular climate events. In addition, the inherent uncertainty in climate change modelling, in part because of uncertain feedback mechanisms within the climatic system (Challinor 2008); poor concerns given to civic epistemology by techno-centric climate science (Jasanoff 2010; Prowse and Scott 2008); and insufficient focus of climate science towards social interpretation of acquired knowledge, particularly in reference to the people who need climate information the most (O'Neill and Hulme 2009; Patt and Gwata 2002). There are differences between the scientific and socio-cultural assessments of climate change and it is not clear that the findings of which methods are reliable (Rowe and Wright 2001). However, it is expected that the integration of expert and lay knowledge can best facilitate adaptation (Adger et al. 2014; Roncoli 2006).

The livelihoods of the many of the studied households are on the margins of thresholds of sustainability, because of widespread poverty associated with limited access to different resources. As a consequence of this marginality, and reliance on agroecology, the social-ecological systems of the study area could be seen to be climate sensitive (elaborated in detail in Chapter 5).To understand the impacts of climate change on vulnerable systems also requires knowledge on the exposure [39] of the system to the changing climate of the Himalaya, Nepal. The Himalayan topography generates micro-climatic spots such that the climate dynamics of a local area and its impacts may not be consistent with global or even regional studies. Additionally, the effects of climate change are complex because some of the influences are direct and primary, and some of the others are indirect and secondary. In this light, this chapter assesses the changes in the climate of the Nepali Himalaya, and the Kaligandaki Basin in particular, by analysing both scientific data and societal perceptions. The chapter further discusses the implications of changing climate on the social-ecological systems of the study area. The analyses are conducted at two spatial scales: the three different ecological zones (the Tarai, the Middle-Mountains and the Trans-Himalaya), and the Kaligandaki Basin with an aggregation of all of the three study sites. The chapter provides extensive information on climate change and impacts through the tables and figures, while key points of those tables and figures are mentioned also in the text.

4.2 Climate Change Trend in the Himalaya

Warming in the Himalaya is markedly higher i.e. 0.2 ^{O} C - 2.7 ^{O} C per decade (Chulagain 2006; Shrestha et al. 2012; Shrestha et al. 1999), than that of the global average of 0.065 ^{O}C per decade on average or 0.85 ^{O}C between 1880 and 2012 (Hartmann et al. 2013). The accelerated warming in the Himalaya is leading to rapid melting of the Himalayan glaciers (Armstrong 2010; Kulkarni and Bahugana 2002; Prasad et al. 2009; Sveinbjörnsson and Björnsson 2011; Xu et al. 2007). Enhanced glacier melt will result in Glacier Lake Outburst Flooding (GLOF), and associated losses in the downstream populations and agriculture. The melting glaciers are likely to increase river discharge and water availability in Himalayan basins in the short-term, but will decrease in the long-term because of the disappearance of the major glaciers (Aggarwal and Sivakumar 2011).

Warming in the cold regions and changes to the Asian monsoon effects slope stability, erosion processes, hydrology and in association, people's livelihoods in the Himalaya(Eriksson et al. 2008; Moiwo et al. 2011).The socio-ecological implications of floods during the wet season and increased water scarcity during the dry seasons in the Himalaya, where agriculture is the primary

[39]Exposure is defined as the nature and degree to which a system is exposed to significant climatic variables (Füssel and Klein 2002)

livelihood of the majority of the population, could be grave. Therefore, knowledge on long-term climatic trends and variability can help design appropriate strategies to adapt to climate change. Therefore, observed and perceived changes in climatic variables in the study area are assessed below.

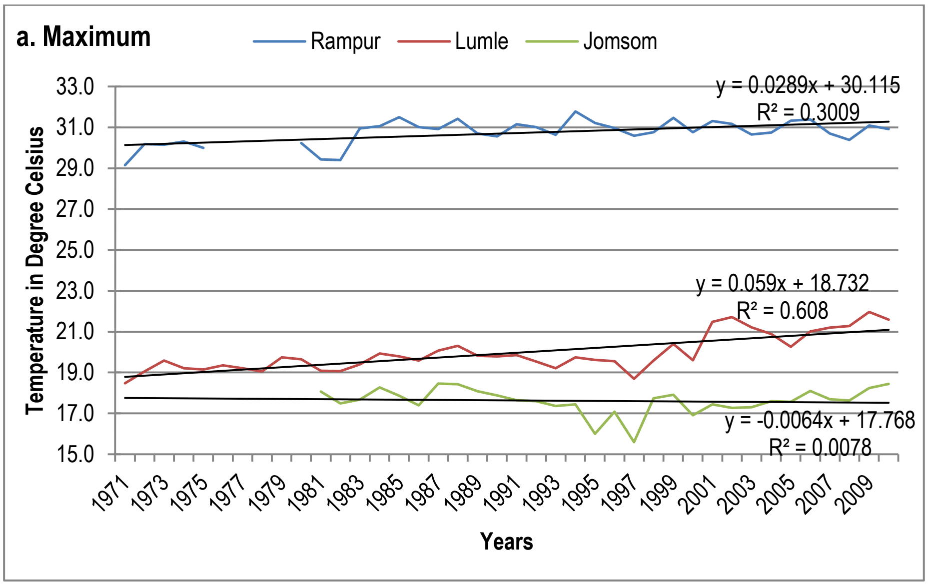
4.2.1 Changes in Temperature

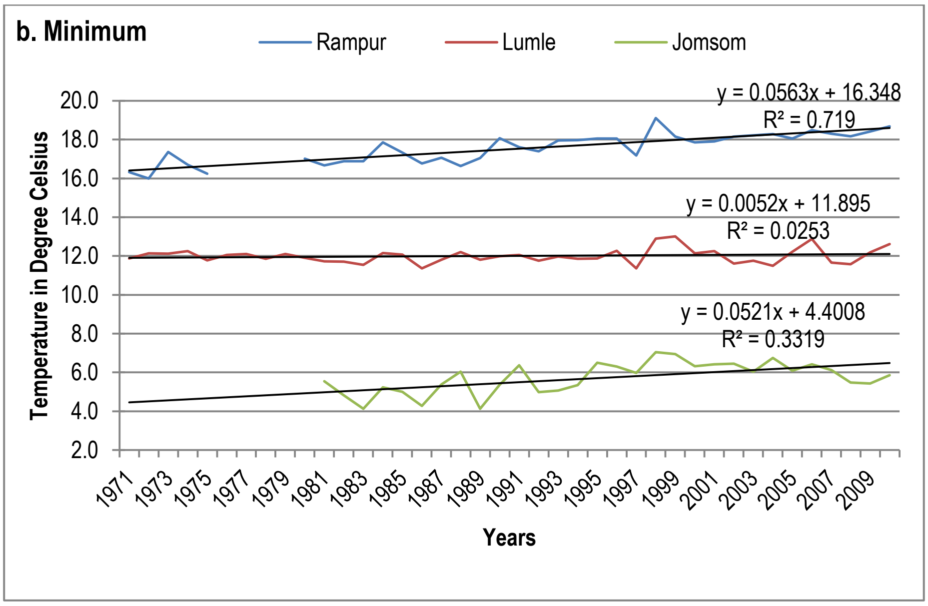
4.2.1.1 Changes in Annual Averages of Maximum and Minimum Temperatures

Both maximum and minimum temperatures of the study area are increasing, but there is variability across meteorological stations. The maximum temperatures of Lumle (Middle-Mountains) and Rampur (Tarai) stations have increased by 0.059 ^{O}C yr-^{1} and by 0.029 ^{O}C yr-^{1}, respectively from 1971-2010. These rises are statistically significant (at 95 percent) with p=0.000 at Lumle $p=0.001$ at Rampur over last 40 years. The Mann-Kendall Test that examines significance of change in non-linear data also indicates a significant rise of maximum temperatures (at 99 percent and 95 percent confidence levels at Lumle and Rampur, respectively). By contrast, the maximum temperature at Jomsom (Trans-Himalaya) has been generally stable (-0.006 ^{O}C yr-^{1}) during that period (Figure 4.1a, Table 4.1, Appendix 8).

Not many climate change studies conducted in Nepal have analysed minimum temperature. Nevertheless, Chaulagain (2006), Gentle and Maraseni (2012) and Paudel, B et al. (2014) are some exceptions. In the global context, the rises in minimum temperatures has been more rapid than that of the maximum since the 1950s (IPCC 2001), however they are following generally similar trend after 1997 (Hartmann et al. 2013). This study found significantly raised minimum temperatures at Rampur (0.06 ^{O}Cy-^{1} with p=0.000) and at Jomsom (0.05 ^{O}Cy-^{1} with p=0.001). These upsurges are significant also with the Mann-Kendall Test. Increased minimum temperatures in the Trans-Himalaya are narrowing the temperature range, which is one element of change that could contribute to better agroecology and human habitation in the harsh (cold) Trans-Himalaya. By contrast, the minimum temperatures at Lumle in the Middle-Mountains have been almost constant (Figure 4.1b, Table 4.1 and Appendix 8).

Figure 4.1: Trends in Annual Averages of Monthly Maximum and Minimum Temperatures (1971-2010) by Meteorological Stations of the Kaligandaki Basin, Nepal
(Source: Data obtained from DHM, GoN)





The changes identified in maximum and minimum temperatures by this study vary spatially, such that they are either consistent or contradictory to the existing literature. The stable average maximum monthly temperatures of Jomsom conflict with the literature, while the increases in minimum temperatures at Rampur and Lumle are generally consistent with the changes recorded in parts of Nepal (Chaulagain 2006; Ren et al. 2007; Shrestha et al. 1999),although the rates are variable and there may be unique regional and temporal characteristics in temperature trends that influence this finding. For example, the studies conducted previously had a different study-period and meteorological stations [40].

4.2.1.2 Changes in Annual Averages of Extreme Maximum and Extreme Minimum Temperatures

Climate change has increased uncertainties in global, regional and local climate systems (Hulme and Mahony 2010; Patt and Dessai 2005; Prabhakar et al. 2009; Turner and Annamalai 2012; White 2004). The large-scale warming, often accompanied by extreme atmospheric circulation has increased the frequency and intensity of extreme weather events (Berrang-Ford et al. 2011; McEvoy et al. 2010; Mitchell et al. 2006; Trenberth et al. 2007). The maximum and minimum temperature extremes have increased since 1950 globally (Donat et al. 2013), with a faster increase in minimum temperature extremes than maximum on a global scale (Hartmann et al. 2013). There is some regional variability in rates of change in extreme temperatures, however, South Asia generally follows the global trend (Christensen et al. 2007), whereas in the Indo-Pacific region, maximum temperature extremes have increased while the minimum decreased (Caesar et al. 2011). *El Niño Southern Oscillation* (ENSO) events are reported as the cause of both the extreme cases and spatial variability; although other changes to the Asian monsoon and Hadley cell circulation may also be important(Alexander et al. 2009).

A social-ecological system could be expected to adapt to gradual change; however, it would be significantly and permanently affected by high rates of change, or if important thresholds are met (IPCC 2007c; McBean 2004; Salinger 2005; Wolf et al. 2010). Therefore, to understand the implications of climate change, an analysis of extreme events is important. This study assessed changes in temperature extremes by analysing the annual average of monthly extreme maximum and monthly extreme minimum temperatures. This study found accelerated extreme maximum temperatures in all of the studied stations. The rates of change, however, are variable. The increase is highest at Jomsom (0.097 $^{O}Cy^{-1}$); which is not significant in linear regression but is significant in the Mann-Kendall's statistics (at 95 percent confidence level). The rise of 0.04197 $^{O}Cy^{-1}$ at Lumle (*p=0.000*) and of 0.027 $^{O}Cy^{-1}$ at Rampur (*p=0.001*) were statistically significant in both regression analysis and Mann-Kendall's statistics (Figure 4.2a, Table 4.1 and Appendix 8).This study found significantly raised extreme minimum temperatures (in both linear regression analysis and in the Mann-Kendall Test) at all of the referenced stations (Figure 4.2b, Table 4.1 and

[40]Chaulagain (2006) used data prior to 2000 and Jomsom station (Trans-Himalaya) was not included in his analysis; Shrestha et al. (1999) used data prior to 1994 and data aggregated from many stations; Manandhar et al. (2011) used Marpha, downstream in the Kaligandaki Basin from Jomsom.

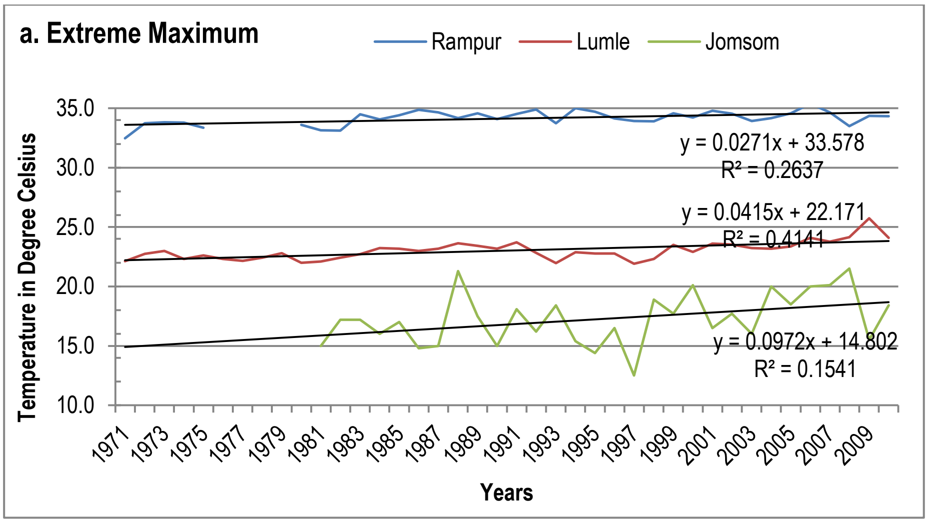
Appendix 8). The increase is the highest (0.1 $^{O}C\ yr^{-1}$) at Jomsom, followed by Rampur (0.06 $^{O}C\ yr^{-1}$) and Lumle (0.04 $^{O}C\ yr^{-1}$).

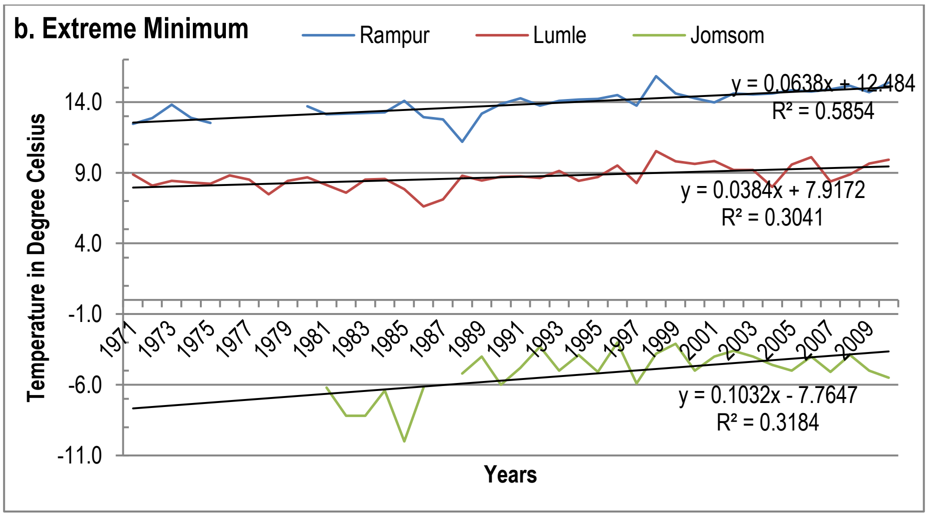
Table 4.1: Test of Significance change of meteorological data over time using Rank Correlation (Mann-Kendall Test) by Meteorological Stations (1971-2010)

Variables / Stations	Jomsom	Lumle	Rampur
Annual Average of Maximum Temperature	-0.071	.556**	.293*
Annual Average of Minimum Temperature	.362**	0.024	.702**
Annual Average of Extreme Maximum Temperature	.331*	.490**	.308**
Annual Average of Extreme Minimum Temperature	.324*	.405*	.695**
Annual Total Precipitation	0.143	0.203	0.13
Annual Total Rainy Days	0.196	-0.026	0.087

*. Correlation is significant at 95 percent (2-tailed).
**. Correlation is significant at 99 percent (2-tailed).

Figure 4.2: Trends in Annual Averages of Monthly Extreme Maximum and Extreme Minimum Temperatures (1971-2010) by Meteorological Stations of the Kaligandaki Basin, Nepal
(Source: Data obtained from DHM, GoN)





The changes in extreme temperature events found in this study are generally comparable to the global, regional and local literature, with some temporal and spatial variability (Ciais et al. 2005; Hartmann et al. 2013;Paudel, B et al. 2014; Trenberth et al. 2007). Some other studies (Caesar et al. 2011; Chambers and Griffiths 2008; Choi et al. 2009) have revealed highly variable findings: with increased extremely warm days and nights, and extremely cold days and nights, as well as intense heat waves in South-East Asia and Oceania. It is believed that the changes in mean temperature (which is well noted in the Himalaya) will lead to temperature and rainfall extremes (Mitchell et al. 2006). The extremes and variability seen in the temperatures of the studied locations can be explained in part by anomaly analysis.

4.2.1.3 Annual Temperature Anomalies

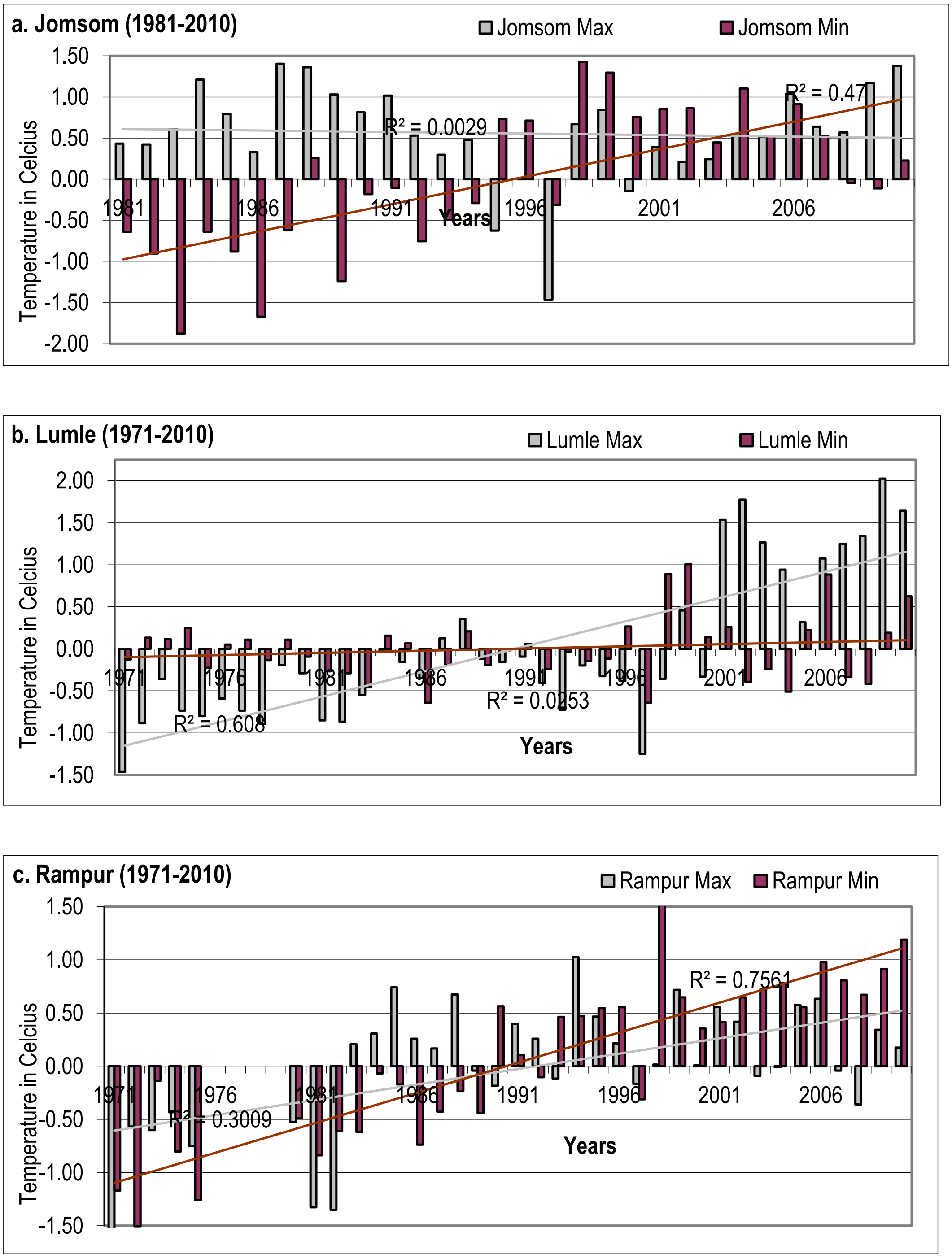
An analysis of temperature anomalies is important because it is an indicator of the variability, which leads to high impacts on public health (Izmerov et al. 2004, as cited in Cruz et al. 2007). Anomaly data are not easily interpreted due to levels of variability. In general, high levels of anomalies in temperatures indicate higher variability and a poorly justified model of the change. Anomaly analyses of recorded temperatures show inter-annual variability indicating uncertainty and poor predictability of weather patterns in the Himalaya (Figures 4.3a, b, c).

The changes in temperature anomalies show high inter-annual differences. However, conclusions of escalating maximum temperatures at Lumle and minimum temperatures at Rampur are justified by the data. The variability in minimum temperature at Lumle and both the minimum and maximum temperatures at Jomsom demonstrate particularly strong inter-annual variability (Figures 4.3a, b and c). The descriptive statistics (Appendix 9) show higher levels of deviations in minimum and maximum temperature extremes. The deviations are the highest at Jomsom in each temperature type.

The analysis of temperatures above suggests a changing climate in the Nepali Himalaya. However the heterogeneous Himalayan environment has responded to the global climate change variably. The increase in maximum and minimum temperature extremes are the highest in the Trans-Himalaya, the positive change of maximum temperatures are the highest in the Middle-Mountains and the rise of minimum temperatures are the highest in the Tarai. Reading the changes through people's personal narratives and perceptions is important to represent integrated knowledge. Perceptions are largely short-term memories so can decrease in accuracy over time (Brondizio and Moran 2008; Conway and Pleydell-Pearce 2000). They are normalised by knowledge of everyday life that is affected by changing climate and can be incorporated into complex narratives

(Folke 2006; Hulme et al. 2009; Vedwan and Rhoades 2001). However, communities have difficulty reporting changes in annual averages because seasonal climatic conditions vary significantly. Therefore, respondents' opinions have been collected in seasonal contexts and compared with changes in seasonal temperatures from meteorological records.

Figure 4.3: Anomalies of Annual Average of Monthly Temperatures (1971-2010) by Meteorological Stations of Kaligandaki Basin, Nepal
(Source: Data obtained from DHM, GoN)



Irrespective of altitude, four clearly distinguishable seasons (spring, summer, autumn and winter) prevail in Nepal [41]. Yet, hot and wet periods associated with the Asian monsoon, accompanied by a longer dry period are the dominant annual climatic seasons in the country.

4.2.1.4 Changes in Seasonal Averages of Temperatures

Analysis of climatic dynamism in reference to seasons is important to understand the social-ecological implications of change. Agriculture is a primary livelihood option of the studied households and it is largely a seasonal activity, susceptible to inter-annual variability in seasonal climate and particular weather patterns and events (McCarthy et al. 2001; Reilly 1995). Climate extremes even for a short period of time are sufficient to damage the agroecology and other ecological resources, putting at risk the primary livelihoods in many communities. Lobell et al. (2008) warned that if adaptation measures were not undertaken, climate impacts on the South Asian agriculture would lead the region towards greater food insecurity. Below the climate change of the Himalaya is assessed across the seasons [42].

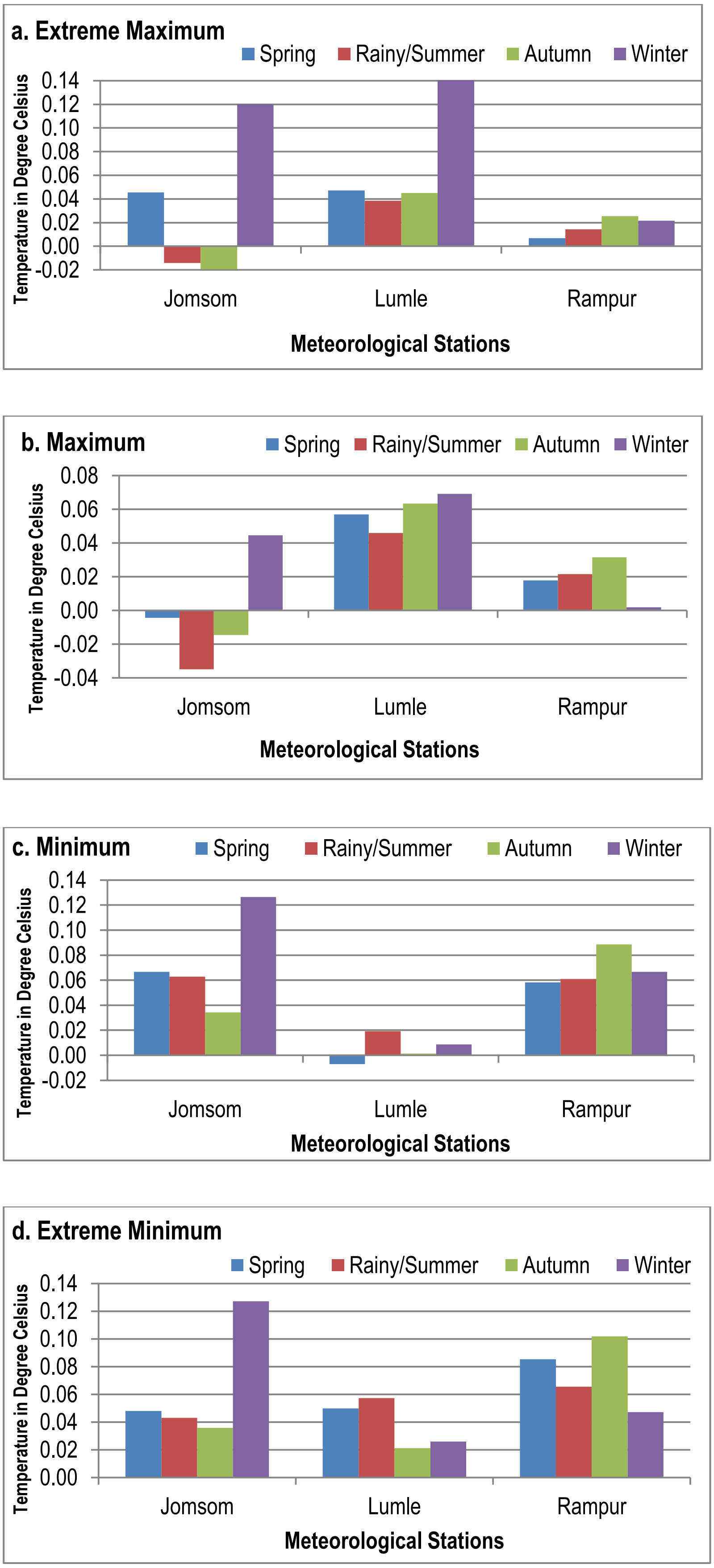
Changes in Temperatures of the Winter Season

Both the observed (Figures 4.4a, b, c, d) and perceived (Figures 4.5) temperatures of the study sites have increased in the winter. However, not all the measured increases are statistically significant. The rises in maximum temperatures at Jomsom (0.045 $^{O}Cy^{-1}$) and Lumle (0.069 $^{O}Cy^{-1}$), minimum temperature at Rampur (0.067 $^{O}Cy^{-1}$) and extreme temperature at Jomsom (0.120 $^{O}Cy^{-1}$) are statistically significant at 95 percent with p=0.000 (Appendix 10).

[41]Spring (Pre-monsoon): March-May with hot and dry climate and active thunderstorms; Summer (Monsoon): June – August with hot and wet climate; Autumn (Post-monsoon): September-November with cool and wet climate; and Winter: December –February with cold and dry climate.

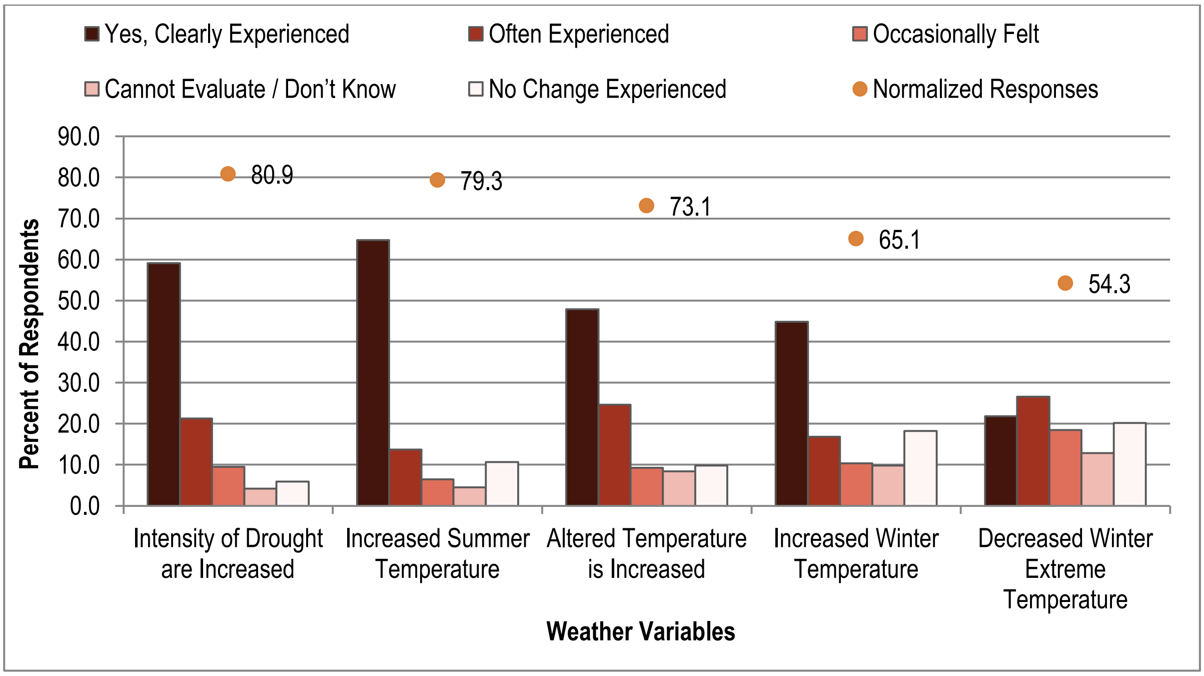
[42] The collected monthly temperatures are aggregated for seasons. The winter season falls in 2 different calendar years; therefore the winter average temperature is calculated from the temperatures of December of the previous year and the temperatures of January and February of present year. Three months' average temperatures of the same year are calculated for the other seasons.

Figure 4.4: Observed Changes in Seasonal Temperatures (1971-2010) By Meteorological Stations of the Kaligandaki Basin, Nepal (per year)
(Source: Data obtained from DHM, GoN)



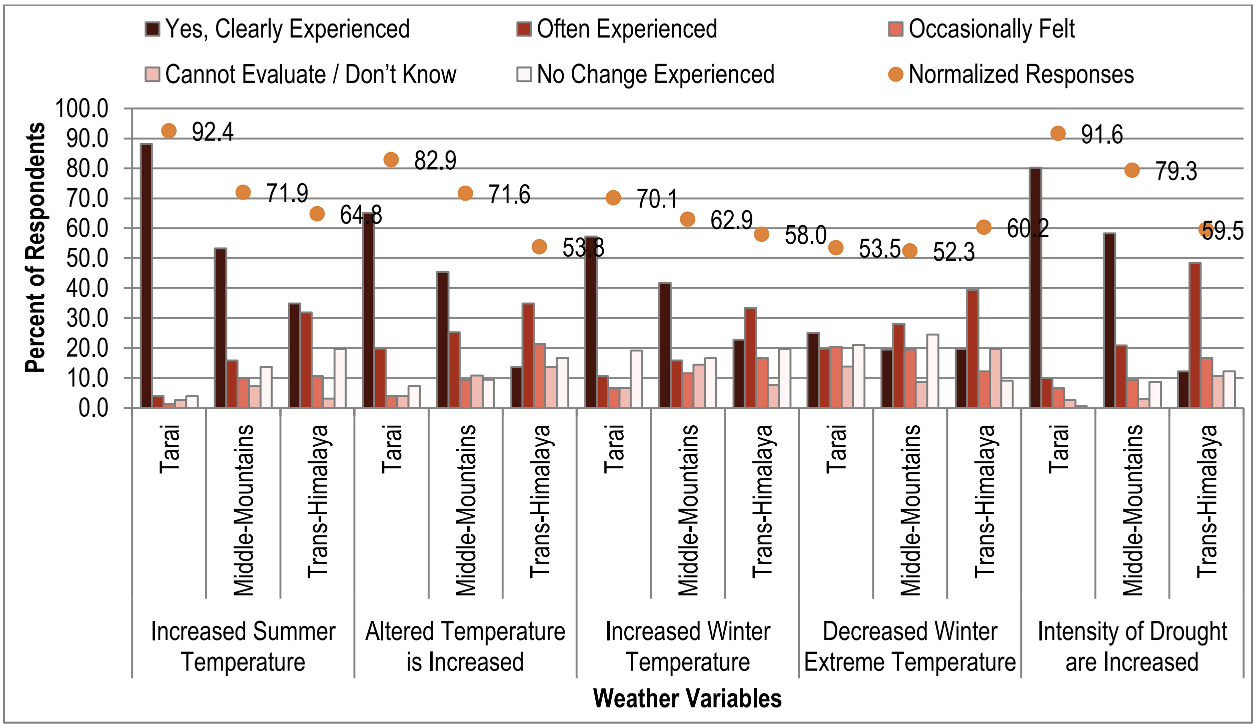
Consistent with the observed-warming, a majority of the respondents of all the ecological zones stated that they are experiencing warmer winters. The proportion of the normalized response (5 different levels of responses transformed into a single category) on warming is almost two-thirds (65.1 percent). Out of the total respondents, 44.8 percent have clearly experienced a warming trend (Figure 4.5), although the heterogeneity of the studied region leads to a range of views from the different ecological zones (Figure 4.6).

Figure 4.5: Perceived Changes in Seasonal Temperatures in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)



The normalized responses show the highest proportion of respondents (70.1 percent) in the Tarai reveal that the winters are warmer, followed by the Middle-Mountains (62.9 percent) and the Trans-Himalaya (58 percent). The proportion of respondents with the opinion of 'clearly' experienced rising in winter temperature are 57.2 percent, 41.7 percent and 22.7 percent, respectively in the Tarai, Middle-Mountains and Trans-Himalaya (Figure 4.6). The participants of the FGDs further explained warming in winters as reduced length of the winters due to the early arrival of the spring and the autumn lasting later. The informants reported increased numbers of snow-free winters in the Trans-Himalaya.

Figure 4.6: Perceived Changes in Seasonal Temperatures by Ecological Zones in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)



There are some contradictions between measured and perceived changes in winter warming. The rate of increase in observed winter temperatures is highest in the Trans-Himalaya and lowest in the Tarai. By contrast, the highest proportion of respondents in the Tarai and lowest in the Trans-Himalaya perceived warming in the winter. The variation might have been influenced by the overall perception of climatic conditions of the regions. Households were equipped with relatively better clothes, linen and heating equipment in the Tarai, which may have helped respondents not to feel severe cold even during below-average winters. By contrast, the residents of the cold Trans-Himalayan may have felt cold even during the average winters. Moreover, most of households of the Trans-Himalaya with relatively high economic status migrate to the cities in the winter, and some middle-age men go for hawking business in warmer places. In contrast, the aged, females and children in poor households living with limited resources in the Trans-Himalaya, feel intense cold in winter which could inhibit their ability to recognize small warming trends. Furthermore, over two-thirds of the respondents were male in the Trans-Himalaya and most of them do not live in the Trans-Himalaya in the winter, which might lead to a bias in the information provided or they might have reported their experiences of extreme cases, even if most of the winters were remaining similar or becoming warmer.

Changes in Temperatures of the Spring Season

The observed changes in temperatures in the spring are different than those in the winter. The spring maximum temperatures at Lumle are raised by 0.057 $^{O}Cy^{-1}$ and minimum temperatures at Jomsom and Rampur are raised by 0.067 $^{O}Cy^{-1}$ and 0.058 $^{O}Cy^{-1}$, respectively. Similarly, extreme maximum temperatures of Jomsom and Lumle are amplified by 0.048 $^{O}Cy^{-1}$ and 0.050 $^{O}Cy^{-1}$, respectively, whereas extreme minimum temperatures of Lumle and Rampur escalated by 0.047 $^{O}Cy^{-1}$ and 0.007 $^{O}Cy^{-1}$, respectively. Contrary to these shifts, the spring maximum temperature of Jomsom has decreased at a rate of -0.004 $^{O}Cy^{-1}$ (Figures 4.4a, b, c, d, Appendix 10). The community perceptions of these changes are generally consistent with the detected rise in most cases and the decrease in some. The spring season is shrinking in the Tarai because of warming with a more abrupt change from winter to summer. The participants of a discussion at Meghauli stated:

> … The winter is not even passed, within few weeks, temperature increases in such a way that it is already summer. It is hard to recognize the spring season in these days. …[43]

However, the level of change in the Tarai is not at the same level in the Middle-Mountains and in the Trans-Himalaya.

Changes in Temperatures of the Summer Season

Recorded temperatures at Lumle in the summer had risen significantly. Observed summer temperatures at Rampur also increased, however only the maximum temperature (0.022 $^{O}Cy^{-1}$) was statistically significant (Appendix 10). Contrary to Lumle and Rampur, extreme summer maximum and maximum temperatures of Jomsom reduced (-0.014 $^{O}Cy^{-1}$ and -0.035 $^{O}Cy^{-1}$, respectively), but the minimum and extreme minimum temperatures increased. Warming in winter and spring, and cooling in summer in the Trans-Himalaya are also reported by Paudel and Andersen (2012).

The respondents perceived changes in summer temperatures similar to measured changes. Nearly four-fifths of the respondents (79.3 percent) generally agreed (the normalized response) that summer temperatures have increased (Figure 4.5). The proportion of the respondents reporting a ‘clear’ experience of the advancement of summer temperature was almost two-thirds (65 percent), but the responses varied spatially (Figure 4.6).

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[43] These sorts of block quotes, which are not under quotation marks, are parapharased information collected from different group discussions.

The normalized responses show 92.4 percent of respondents in the Tarai, followed by a lower representation in the Middle-Mountains (71.9 percent) and the Trans-Himalaya (64.8 percent) perceive warming summers. The proportion of respondents clearly perceiving 'increases in summer temperatures was highest in the Tarai (88.2 percent), followed by the Middle-Mountains (53.2 percent) and the Trans-Himalaya (34.8 percent). The community perceptions support the larger warming trends in the Tarai, as found in the empirical analysis. By contrast, the community assessment in the Trans-Himalaya contrasts to the reduction in maximum and extreme maximum temperatures. Significant growth in measured minimum and extreme minimum temperatures in the Trans-Himalaya might have affected peoples' opinion.

Changes in Temperatures of the Autumn Season

The changes in temperatures in the autumn season are also variable. For example, extreme autumn maximum temperatures at Jomsom are declining significantly (-0.019 $^{O}Cy^{-1}$), whereas minimum and extreme minimum temperatures are rising by 0.034 $^{O}Cy^{-1}$ and 0.036 $^{O}Cy^{-1}$. Similarly, maximum and extreme maximum temperatures at Lumle and all types of temperatures analysed at Rampur significantly increased in the autumn (Figures 4.4a, b, c, d, Appendix 10).

Peng et al. (2004) stated that each degree Celsius of increase in minimum temperature during the rice growing season leads to a 10 percent decline in production in Philippines. At times, the warming has reached the temperature tolerance of rice, causing a decline in yield in the tropics (McCarthy et al. 2001). That situation has contributed to a reduction in overall crop yields in Asia and is projected to reduce further by 30 percent by 2050 (Cruz et al. 2007). Accordingly, the warming of 1-3 ^{O}C by 2080 could lead to a 30 percent decline in agricultural production in South Asia (Fischer et al. 2002; Parry et al. 2004). However, there are contrary findings in the Nepalese context. An agricultural research study in Nepal showed a marginal increase (up to 7 percent) in rice yield when the temperature rises up to 4 ^{O}C with a rainfall rise of 20 percent but reduced maize production (Oxfam 2009). The research participants expressed concerns that the situation is more serious than reported in the literature, with rice production already 25 percent lower in the last decade. The major problem reported by the respondents was that higher temperatures during the rice growing season (autumn) require more frequent irrigation, but additional water was not available.

The rises in the rates in the minimum and extreme minimum temperatures at Jomsom and Rampur, are higher than the rates of increase in extreme maximum and maximum temperatures in each season. This phenomenon suggests decreasing altered temperatures (maximum-minimum range) in these places. Such changes have negative implications in the agroecology and human habitation in the Tarai, while they may have improved them to some degree in the Trans-Himalaya.

Perceived Changes in Altered Temperature

In general, monthly 'altered' [44] temperatures are observed to have declined and winter-summer ranges are found to be increasing slightly in the study area (Appendix 11). Consistent with the observed winter-summer ranges, the studied communities have perceived increases in altered temperatures (Figure 4.5). The normalized response shows 73.1 percent of the respondents are feeling increased altered temperatures, with 47.9 percent of respondents clearly expressed an 'increased' temperature range. The finding is further supported by the Key Informant Interviews (KIIs) that were conducted. Extremely cold nights with a clear sky and frosty mornings in the winter, accompanied by extra hot days in the summer, are increasingly being reported. Respondents suggested that reduced winter rainfall and increased length of the dry season caused the increase in both minimum and maximum temperature extremes.

Social perceptions of changes in altered temperature varied spatially. The proportion of the normalized response reporting increased temperature range was the highest in the Tarai (82.9 percent), followed by the Middle-Mountains (71.6 percent) and the Trans-Himalaya (53.8 percent); while the highest proportion of respondents (65.1 percent) of the Tarai, followed by the Middle-Mountains (45.3 percent) and the Trans-Himalaya (13.6 percent) described a 'clear experience of increased' temperature range (Figure 4.6).

There is a lack of literature discussing climate change in a seasonal context in Nepal. Generally consistent with present findings, few have noted increased winter warming, particularly the minimum temperatures (Chaudhary et al. 2011; Paudel, B et al. 2014; Shrestha and Devkota 2010).

[44] Difference between Extreme Maximum and Extreme Minimum

4.2.2 Changes in Precipitation

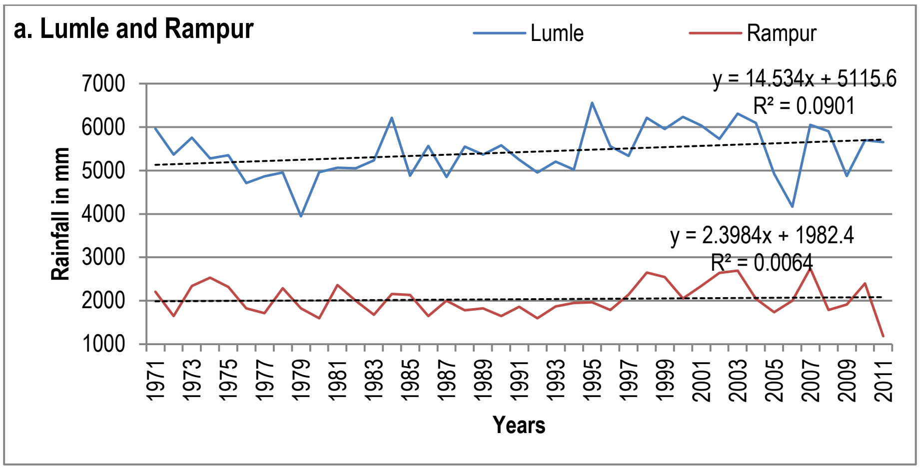
It is suggested that for each degree Celsius rise in global mean temperature, the global mean precipitation would increase on average, by 7 percent but the changes will be highly variable spatially (Wentz et al. 2007). The preceding analysis has demonstrated that temperatures are generally increasing in the study area. At the same time, various published studies have claimed that rainfall in monsoon Asia (including in Nepal), has increased and it has caused frequent and intense flooding (IPCC 2001; IPCC 2007c; Shrestha et al. 2000; UNDP and DFID 2007). In addition, future projections of rainfall suggest further intensification of the monsoon (Agrawala et al. 2003; Schewe et al. 2011). The increased rainfall, however, is not benefiting the agriculture of the region since the extreme rainwater of the wet period is lost through runoff (Agrawal 2007). The precipitation trends also variable spatially within the monsoon region (Caesar et al. 2011).

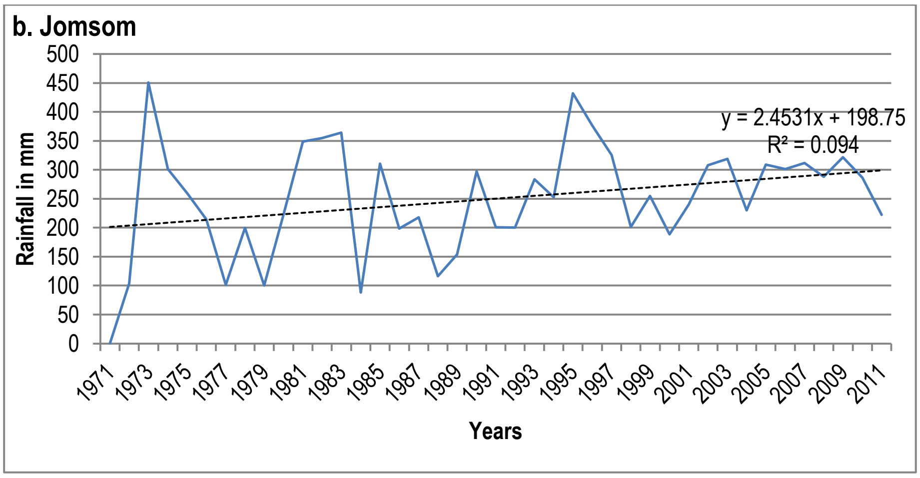
Along with other aspects of climate change, monsoon behaviour is receiving increased research recognition. Numerous scholars - Bin and Qinghua (2006), Cherchi et al. (2011), Gao and Wang (2012), Kripalani et al. (2007), Seo et al. (2005), Turner and Slingo (2009) and Zhou (2012), have directed their research to monsoon dynamics in Asia, including in the Himalaya. Monsoonal rainfall is very important in maintaining the livelihoods of the people of the Himalaya, so a study of monsoon behaviour is required in a broader analysis of development and climate change in South Asia (Lal, R 2011). Some scholars claim that monsoon precipitation affects the life of over 65 percent of the world's population, so increasing variability in the monsoon would have serious impacts for social-ecology of the region (Wang et al. 2012). In this context, the present study analyses the changing monsoon precipitation in the Kaligandaki Basin, Nepal.

4.2.2.1 Changes in Annual Precipitation

The rainfall pattern in the Kaligandaki Basin is highly variable (Figure 3.5 in Chapter 3). The analysis of recorded annual rainfall of the study area does not demonstrate a particular trend. The rainfall at Lumle has intensified by 14.5 mm yr^{-1}, at Jomsom by 2.5 mm yr^{-1} and at Rampur by 2.4 mm yr^{-1} (Figures 4.7a, b), but they are not statistically significant(Appendix 10). Annual rainfall anomalies (Figures 4.8a, b, c) also imply strong inter-annual variability of rainfall.

Figure 4.7: Trend of Annual Precipitation (1971-2010) by Meteorological Stations in Kaligandaki Basin, Nepal
(Source: Daily Rainfall Data obtained from DHM, GoN)

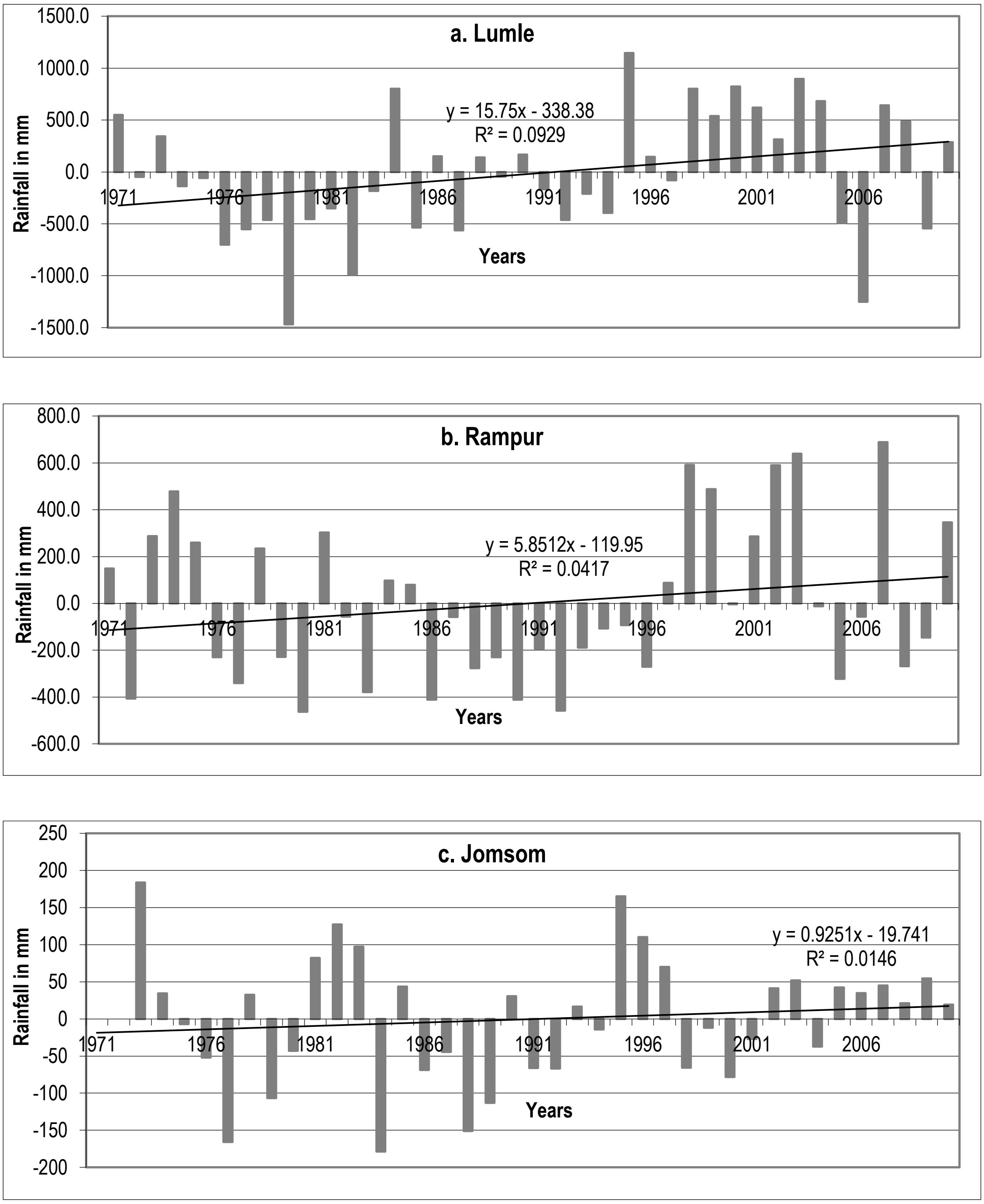




There are some exceptional rainfall events especially at Lumle and at Rampur. In 1995, annual rainfall at Lumle exceeded the long-term average by more than 100 cm, whereas in 1979, 1982 and 2006, it was more than 100 cm below the long-term average. In 40 years at Lumle there have been only ten [45] which could be thought of as typical in that their rainfall was above 50 cm of the long-term average, while of the other 30 years; nine [46] had annual rainfall 50 cm less than the long-term average. Annual rainfall anomalies are also high in Rampur. In most cases the anomaly years vary between Lumle and Rampur till 1990, but are generally similar after 1990 (Figure 4.8). The lack of any particular trend in change, but increased inter-annual variability in the precipitation observed in this study, is consistent with previous studies (Bhatta et al. 2015; Duncan et al. 2013; Pant 2003; Shrestha et al. 2000).

[45]1971, 1984, 1995, 1998, 1999, 2000, 2001, 2003, 2004 and 2007
[46]1976, 1977, 1979, 1982, 1985, 1987, 2005, 2006 and 2009

Figure 4.8: Anomalies of Annual Rainfall (1971-2010) Across the Meteorological Stations in Kaligandaki Basin, Nepal
(Source: Daily Rainfall Data obtained from DHM, GoN)



4.2.2.2 Changes in Intensity and Frequency of Drought

The livelihood implications of drought for peasant families are immense, especially for crop and livestock productivity and increased incidents of disease (Cruz et al. 2007). Studies have shown an increased frequency and intensity of drought and associated implications on the social-ecological systems.Some of the experienced impacts in different countries include: increasing male suicide in rural Australia due to drought and easy access to firearms (Alston 2012);

increased dry extremes and associated livelihood vulnerability in the Sahel (Arthur et al. 2009) and in Ethiopia in particular (Carter et al. 2007). Ciais et al. (2005) described a Europe-wide reduction of primary production due to drought and heat wave in 2003; and Su et al.(2012) and Zhang and Zhou (2011), documented climate-induced water stress and reductions in agricultural production in China, Similarly, increases in variability in rainfall and drought frequency also have implications for South Asian agriculture (Kripalani et al. 2007; Lal, M 2011; Mirza 2011).Studies from Nepal have reported that the extended length of the dry season in the last two decades has reducedagricultural production and altered other aspects of life in the country (Chhetri and Easterling 2010; Devkota et al. 2011;Gentle and Maraseni 2012; Macchi 2011; Manandhar et al. 2011).Due to drought, Nepal experienced a deficit of agricultural production by 22000 metric tones in 2005/06 and 180000 metric tones in 2006/07 (Aryal and Rajkarnikar 2011).

The studied communities also perceived increased drought frequencies. The normalized response demonstrates 80.9 percent of the respondents report the elevated intensity and frequency of drought. Some 59.1 percent of the respondents clearly noted that drought has 'increased' (Figure 4.5). However, there were large differences in the responses across the ecological zones.The normalized responses show 91.6 percent of the respondents of the Tarai, followed by the Middle-Mountains (79.3 percent) and the Trans-Himalaya (59.5 percent) perceived prolonged droughts. The 80.3 percent respondentsin the Tarai stated there has clearly been increased drought in the Tarai compared to 58.3 percent in the Middle-Mountains. The Trans-Himalaya receives limited rainfall so peoples' understanding of drought was different to other places. Perhaps as a consequence, only 12.1 percent of the respondents clearly recognised more drought in the Trans-Himalaya (Figure 4.6).

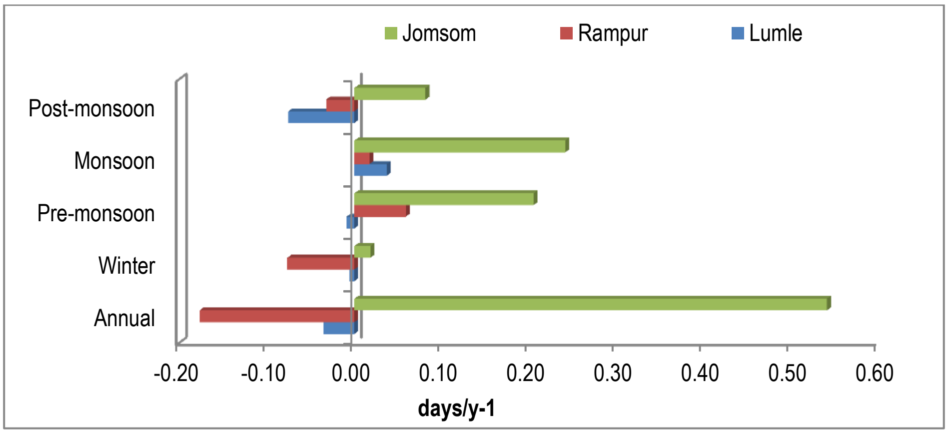
4.2.2.3 Changes in Annual Rainy Days

The change in the number of wet-days [47] is one of the indicators of rainfall variability. On average, there are 192, 129 and 48 annual wet-days at Lumle, Rampur and Jomsom, respectively (Figure 4.9). The wet-days have slightly decreased over time at Rampur and at Lumle and risen at Jomsom. None of these changes, however, are statistically significant (Appendix 10). The existing literature claims decreased annual rainy days between 1971 and 2000 in Nepal (Chaulagain 2006), and in between 1901 and 1989 in India (Kothyari and Singh 1996), which are contradictory to the findings of the present study.

---

[47]Wet-Days are defined as the day having >=0.1 mm rainfall

Figure 4.9: Observed Change in Annual and Seasonal Rainy Days (1971-2010) at Meteorological Stations of the Kaligandaki Basin, Nepal
(Source: Daily Rainfall Data obtained from DHM, GoN)



The opinions of respondents in relation to fewer annual rainy days were generally comparable to the meteorological data. The normalized response shows a little over 60 percent of them reported a decrease in annual wet-days, while over one-thirds (35.3 percent) expressed that there was a 'clear experience of' decrease (Figure 4.10). Figure 4.11 shows some spatial differences in the normalized responses: 73.6 percent of the respondents in the Middle-Mountains followed by the Tarai (54.6 percent) and the Trans-Himalaya (46 percent) reported a reduction in annual rainy days. Out of the total, the majority of the respondents (50.4 percent) in the Middle-Mountains, followed by 30.9 percent in the Tarai and 13.6 percent in the Trans-Himalaya believed there has been a 'clear experience of decrease' in the number of rainy days (Figure 4.11).

Figure 4.10: Perceived Change in Precipitation related Variables in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)

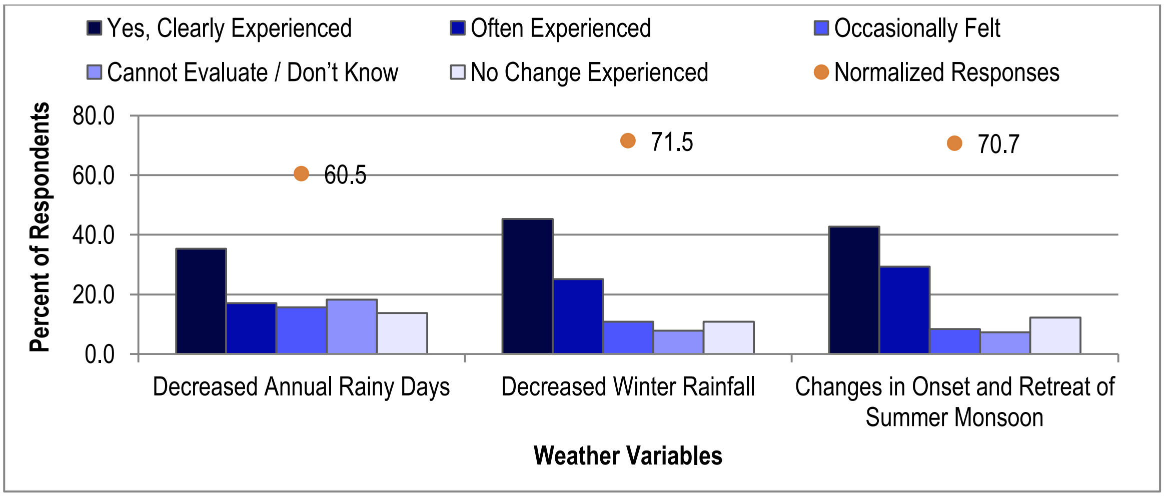
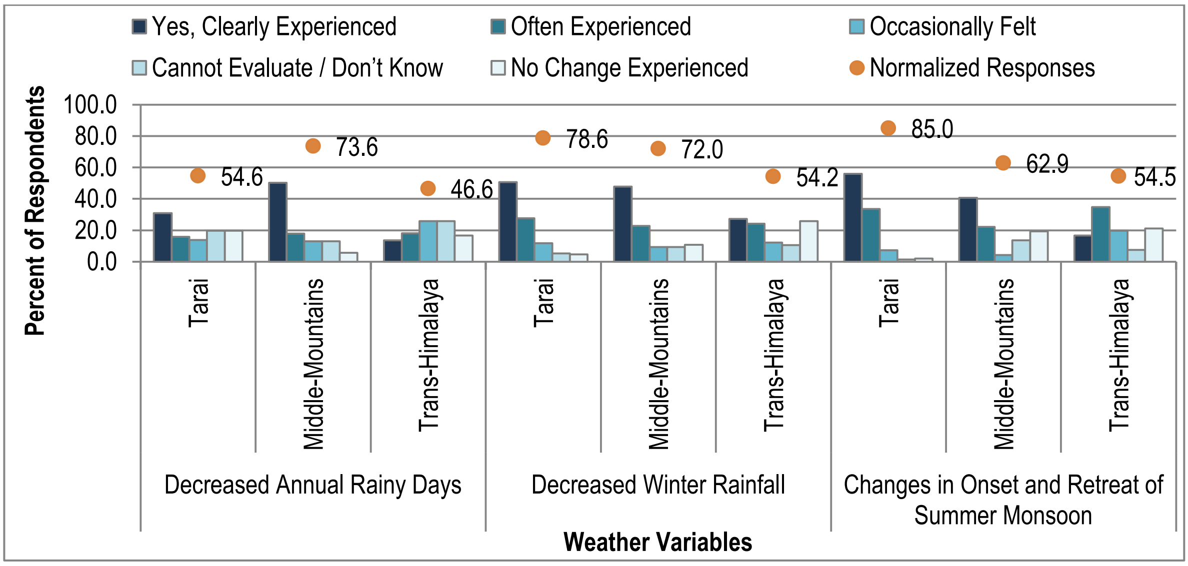


Figure 4.11: Perceived Changes in Precipitation related variables across the Ecological Zones in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)



The research participants, especially of the Tarai and the Middle-Mountains, reported a decline in rainy days in winter, spring and in the pre-monsoon seasons. However, in the Trans-Himalaya, the rainy days were reported to be increasing, especially because of the decreased winter snow but there had been increased rainfall in early spring. Macchi (2011) and Bhatta et al. (2015) also reported a similar pattern of decreased snowfall and increased rainfall in high altitudes of the Himalaya. The respondents of the Trans-Himalaya reported increased extreme rainfall events also in summer.

4.2.2.4 Frequency of Extreme Rainfall Events

The frequency and intensity of extreme weather events are projected to increase with climate change (Berrang-Ford et al. 2011; McBean 2004; McEvoy et al. 2010; Mitchell et al. 2006; Sheridan 2011; Wilby and Keenan 2012).The different types of events which are claimed to be amplified due to climate change include: tropical cyclones and associated storm surges in tropical coasts (Bengtsson 2007; Knutson et al. 2010; Power and Pearce 2006), erratic rainfall, landslides, flooding and the GLOF in the Himalayan basins [48] (Evans and Clague 1994; Kattelmann 2003; Meenawat and Sovacool 2011; Mirza 2011; Nyaupane and Chhetri 2009; Poncelet et al. 2010), heat waves and associated bushfires in Australia (Adams 2010; Bushfire CRC 2006; Hughes and Steffen 2013; Loepfe et al. 2014; Lucas et al. 2007) and Boreal forest fires (Amiro et al. 2001; Bedia et al. 2014; Flannigan et al. 2000; Gillett et al. 2004).Both extreme rainfall and extreme

[48] Floods in 2002 in Ganges Basin, in 2005 in Mumbai, in 2008 in Koshi Basin, in 2013 and in 2014 in Ganges Basin have been catastrophes for the social-ecology of respective places.

droughts have serious implications for social-ecological systems (Holmgren et al. 2006). Monsoon flooding caused by extreme rainfall was ranked the fourth largest global disaster in terms of the loss of life between 1970 and 2000 (Tompkins 2002). In this context, the extreme rainfall events of the study area are discussed here.

The term 'extreme rainfall' holds different meanings for different stakeholders. The Department of Hydrology and Meteorology (DHM), Nepal, defines extreme rainfall as rainfall that exceeds 100mm on particular day [49]. This threshold has several major problems. On the one hand, places that receive very little annual rainfall (like the Trans-Himalaya) would never experience an extreme rainfall event on the basis of this threshold. On the other hand, for Lumle 100mm events are sufficiently frequent [50] that they may not be considered 'extreme'.

Erosive rainfall events, 1.5 mm of rainfall in 30 minutes (Kemp 1984), provide another option to measure extreme rainfall. There is no hourly rainfall data available for the study so daily rainfall having more than 72 mm/day is considered as an erosive rainfall event for the Middle-Mountains. On that basis, a total of 11.13 percent of rainy days in the last 40 years at Lumle would be considered as erosive events. However, the use of daily rainfall rate to mark the erosive rainfall seems to be inappropriate because rainfall gauged in the Fewa watershed, where the Lumle meteorological station is located, showed 39 percent of the total rainfall as erosive i.e. 1.5 mm rainfall in 30 minutes (Kemp 1984). Rather than classifying events based on rainfall thresholds, communities define extreme rainfall in reference to the damage a particular event causes. The damage of rainfall events varies with slope gradient, vegetation coverage, soil structure, and drainage management practice. This makes the IPCC notion that there is a problem providing a universal definition of 'extreme precipitation' (Hartmann et al. 2013) particularly relevant to this study. Consequently, this study analyses the rainfall events of different thresholds without defining 'extreme rainfall events' (Figures 4.12a, b, c).

The analysis of daily rainfall data shows increasing extreme rainfall events, particularly at Lumle. The events of over 50 mm of daily rainfall at Lumle has increased by 0.18 days yr^{-1} and cases of daily rainfall that exceeding the 150 mm threshold (extended by 0.04 days yr^{-1}). Both of the increases are statistically significant (Figure 4.12, Appendix 10). Although some increase in

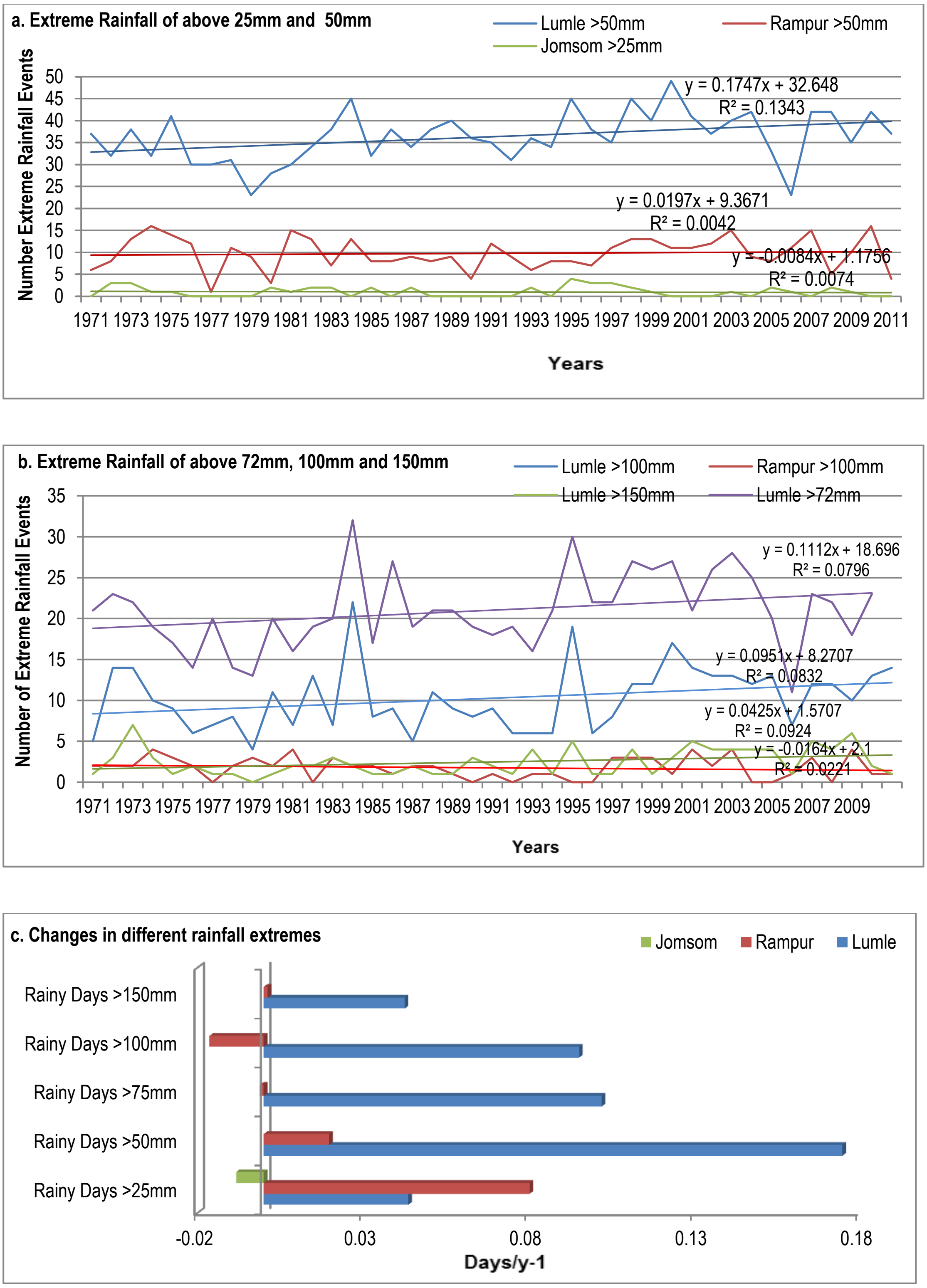
[49] A day is defined as 24 hours' time starting from 08:00 hours of previous day to 08:00 hours of today

[50]The Lumle station holds 421 rainfall events exceeded 100 mm, 20 events crossed 200 mm and 6 events surpassed 250 mm rainfall/day in last 40 years. In addition, there were and a totalof 22 events of over 100 mm rainfall in a single year (1984). The place receiveda torrential cloud burst on the 230th day of the year 1998 that dumped 295 mm rainfall in 24 hours. These evidences give room to suspect if 100 mm rainfall is the 'extreme' for Lumle.

extreme precipitation in the Tarai, and a decrease in the Trans-Himalaya is identified, however, such changes are insignificant.

Figure 4.12: Observed Extreme Rain Events of different Thresholds (1971-2010) in Kaligandaki Basin, Nepal

(Source: Daily Rainfall Data obtained from DHM, GoN)

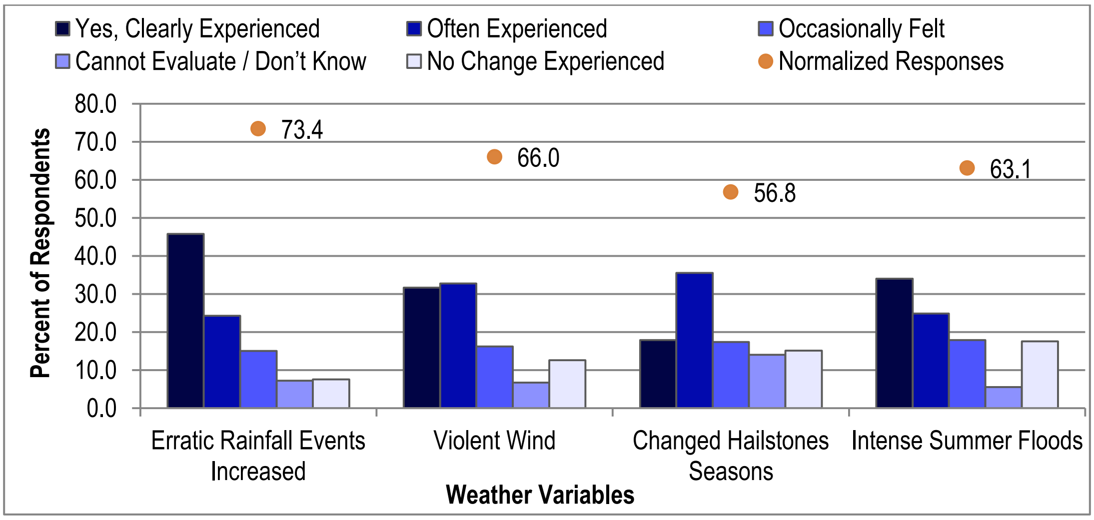


The respondents of the study area generally agreed that there were an increasing number of extreme rainfall events. A very high proportion of the normalized response (73.4 percent) suggested that extreme or erratic rainfall events have increased. Out of the total, 45.8 percent of respondents indicated they experienced a clear increase in the erratic rainfall events (Figure 4.13). This perception is consistent with the measured extreme rainfall events at the meteorological station in Lumle but contradictory to observations at the other places.

There was some spatial variation in the perception of changes in extreme rainfall events. The normalized responses show 78.8 percent of respondents in the Middle-Mountains, followed by the Tarai (77.1 percent) and the Trans-Himalaya (53.4 percent), recognised an increase in extreme rainfall events. Amongst all respondents, 51.4 percent of respondents in the Middle-Mountains, 50 percent in the Tarai and only 24.2 percent in the Trans-Himalaya recognised a clear experience of increased erratic rainfall events (Figure 4.14). In particular, the FGD participants of Lumle and Meghauli stated that:

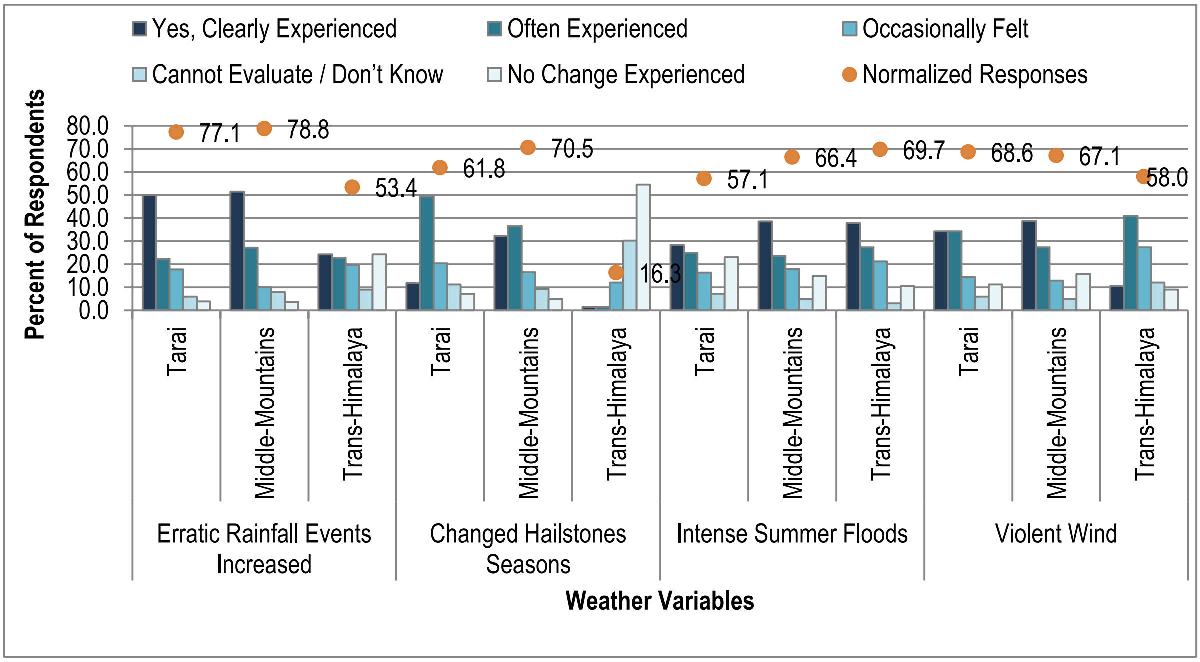
> … Continuous light rain in the monsoon used to be an episode of 15 to 20 days, however, these days; almost the same amount of rainfall is dumped in an episode of only 2-3 days, which brings devastating floods and landslides. …

Figure 4.13: Perceived Changes in Extreme Weather Events in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)



The research participants of the Trans-Himalaya also reported increasing continuous rainfall events, which is consistent with other literature (Chaulagain 2006; Shahi 2011).Frequent extreme rainfall events have caused intense monsoon floods in the study area. Nearly two-thirds (63.1 percent) of the respondents reported frequent and intense summer floods in recent years. The proportion of the respondents recognizing a clear increase in monsoon floods was a little over one-thirds of the total, although, it varies spatially.

Figure 4.14: Perceived Changes in Extreme Weather Events across the Ecological Zones in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)



Extreme rainfall events are concentrated in the monsoon season of less than two months (July-August). This unique nature of monsoon in South Asia causes frequent floods and losses of rainwater, limits infiltration and ground water recharge in wet periods and generates water scarcity in dry seasons (Agrawal 2007; Chaulagain 2006; Cruz et al. 2007). The people surveyed have seen similar impacts as those described in the literature. The proportion of respondents who have felt summer floods have intensified was greatest in the Trans-Himalaya (the proportion of normalized response of 69.7 percent). The corresponding proportions for the Middle-Mountains and the Tarai are 66.4 percent and 57.1 percent, respectively. Some 38 percent respondents who have noted a clear rise in summer flooding was uniform across the region. The communities of Landruk, Lumle reported bare black rocks in the Himalaya due to rapid melting of Himalayan snow and ice:

> … The Himalaya does not smile! The Himalaya has become bare/black rock without snow and ice …

The participants of group discussion in the Trans-Himalaya perceived the increase in flooding was due to an increase in rainy days instead of snowfall. However, meteorological records are not available to verify the reduction in snowfall events. The claims of the communities are consistent with the literature (Dahal 2005; Macchi 2011). Moreover, frequent rainfall events, rapid melting of snow/ice and the disappearance of permanent snow (as reported by survey respondents), and the fragile topography or erosive soil structure (Plate 4.1a), together with recent, haphazard construction of roads in the sensitive environment (Plate 4.1b), have contributed to an increase in flooding, soil erosion and landslides in the Trans-Himalaya. Decreased snow cover, glacier retreat, GLOF and associated downstream effects in the Himalaya are reported also in the literature (Barnett et al. 2005; Prasad et al. 2009; IPCC 2007c; Merz et al. 2002). It has been reported that unpredictable fluctuations in stream flow, reduced water availability in spring and severe floods in summer, are evident in the Trans-Himalaya. Such flooding and erosion in the Trans-Himalaya could possibly cause some settlements to be threatened (Plate 4.1c).

Plate 4.1: Erosion Sensitive Landscape, Floods and Landslides and the Settlement at verge to Collapse in the Trans-Himalaya
(Source: Field Survey, 2013)

a. Highly Erosive Trans-Himalayan Landscape

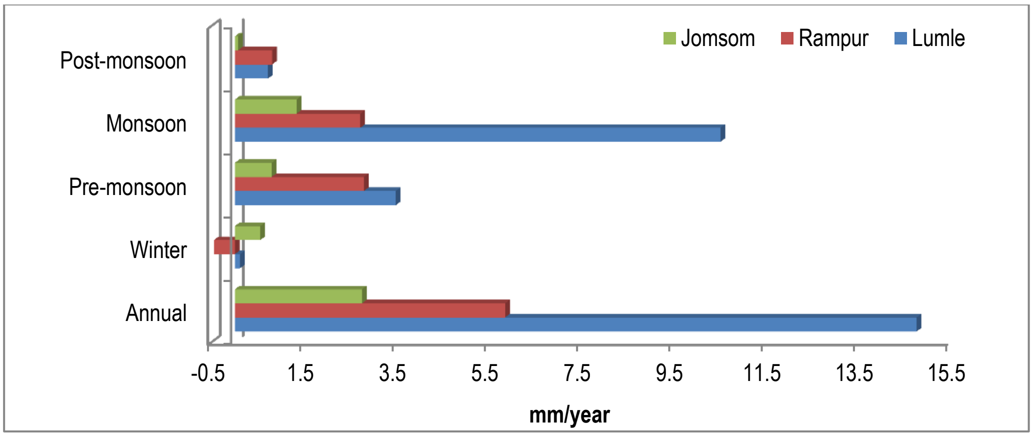
b. Haphazard Construction of Mountain Road is Causing Heavy Landslides in the Trans-Himalaya

c. The Trans-Himalayan Settlement at Verge to Collapse

4.2.2.5 Seasonality of the Changing Rainfall

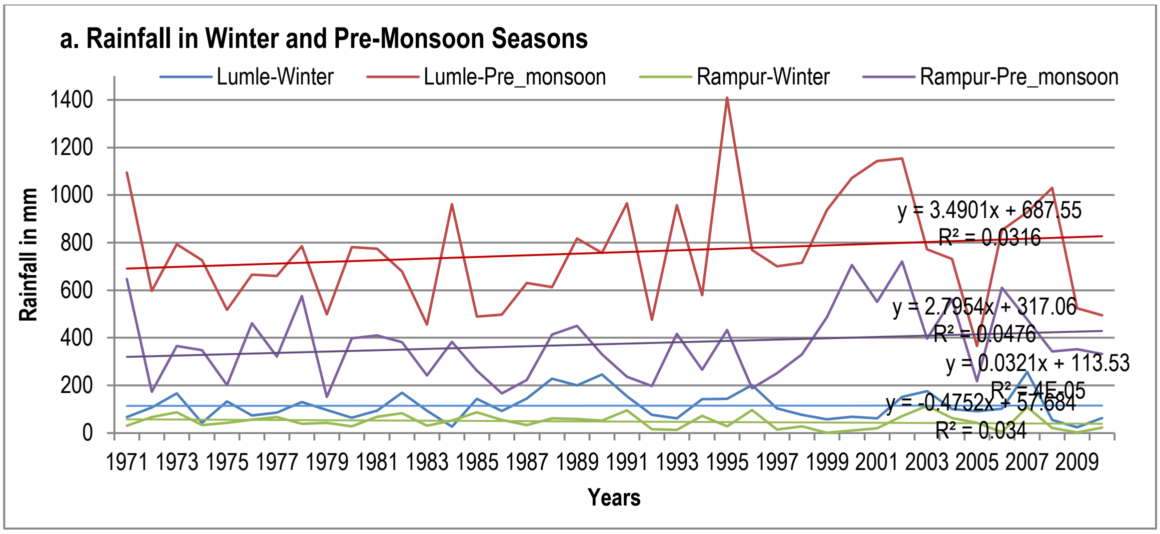
Agriculture in Nepal is predominantly rain-fed. Therefore the analysis of changes in seasonal precipitation is an important component of the research. The results of the analyses show variability across the meteorological stations. Marginal increases in rainfall in the monsoon season (summer) vary across the stations, with the highest rate (10.5 mm y^{-1}) of increase at Lumle, although none of the increases are statistically significant (Figure 4.15, Appendix 10). The Coefficient of Variances (R^2) of all of the seasonal precipitation trends are below 10 percent, indicating high inter-annual variability in meteorological stations and seasons (Figure 4.16 a, b).

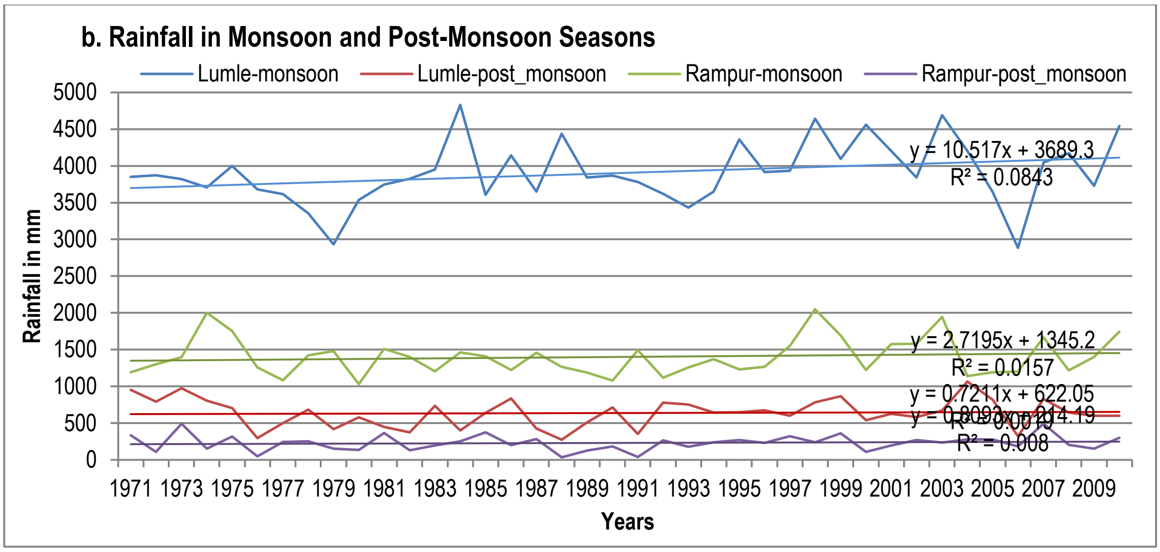
Figure 4.15: Observed Changes in Rainfall (1971-2010) by Seasons in the Kaligandaki Basin, Nepal
(Source: Calculated from Daily Rainfall Data obtained from DHM, GoN)



The social perceptions of seasonal rainfall dynamics are contrary to the measured changes. Sharp reductions in winter rainfall and winter rainy days are reported by 71.5 percent of the respondents. The proportions of respondents reporting reduction in winter rainfall and rainy days vary across the ecological zones. For example, the proportions of the normalized responses of 78.8 percent in the Tarai, 72 percent in the Middle-Mountains and 54.2 percent in the Trans-Himalaya recognized reduced winter rainfall and rainy days. Among the total respondents from the Kaligandaki Basin, 45.3 percent of respondents expressed an opinion that winter rainfall had 'clearly decrease' (Figure 4.10). The proportions of respondents who clearly recognised a decrease in winter rainfall was 50.7 percent, in the Tarai, 47.9 percent in the Middle-Mountains and 27.3 percent in the Trans-Himalaya (Figure 4.11).

Figure 4.16: Observed trends of Seasonal Rainfall (1971-2010) in the Kaligandaki Basin, Nepal
(Source: Daily Rainfall Data obtained from DHM, GoN)





As well as reductions in winter rainfall and rainy days, the communities described reductions in pre-monsoon (spring) rainfall, but this is contrary to scientific observations, especially in the Tarai and Middle-Mountains. The peoples are concerned about the increasing mismatch between experienced rainfall and the crop calendar. For an example, FGD Participants of Rampur and of Lumle stated that:

> … It does not rain when required, but it rains erratically and it harms the crops. Rainfall events at present are like allergic reactions, torrential showers but for very short periods, and mostly mismatch with cropping seasons. …

This mismatch might have been interpreted as a reduction in pre-monsoon rainfall by the communities, which meteorological observation does not show.

Many studies have demonstrated that communities in various parts of the world consider rainfall to have decreased (Ciais et al 2005; Conroy and Overpeck 2011; Kripalani et al. 2007; Meehl et al. 2008). The literature from Nepal suggests similar results, especially unusually decreased winter rainfall(Gentle and Maraseni 2012; Onta and Resurreccion 2011; Manandhar et al. 2011; Moiwo et al. 2011), and respondents' perceptions support these studies.

4.2.2.6 Change in Onset and Retreat of Summer Monsoon

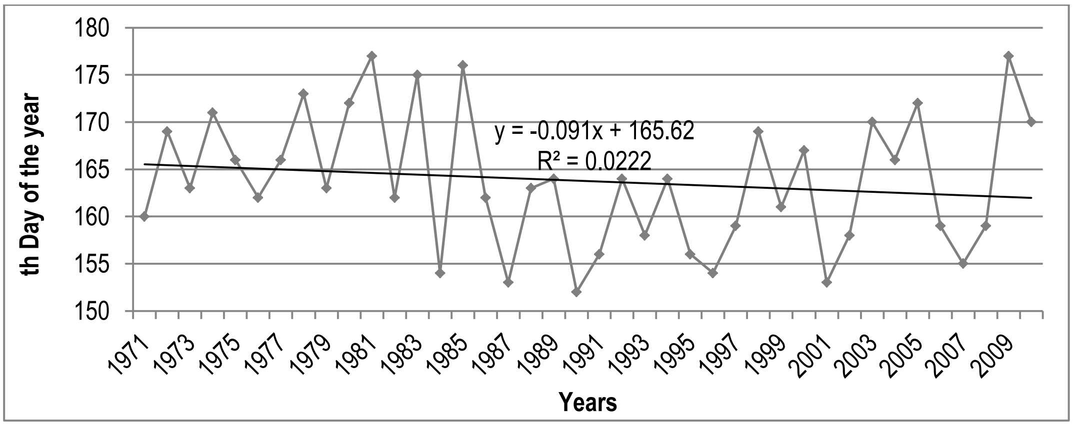
The monsoon system is an interactive mechanism between atmosphere, land and ocean systems (Webster et al. 1998). Studies of the Himalayan rainfall patterns have shown variations in timing, amount, intensity, and onset of summer monsoon rainfall (Macchi 2011; Oxfam 2009; Pant 2003). The onset and retreat of the monsoons play important roles in the livelihood security of the studied communities. The onset of the summer monsoon in Nepal is accompanied by distinct changes in large-scale circulation and rainfall distribution. The official date of its onset is June 10 and the date of retreat is September 23; the DHM Nepal, defines the onset of the monsoon based on total rainfall of 30 mm or over in three consecutive days, with a minimum of 10 mm average daily rainfall in the month of June. This study analyses the onset of the summer monsoon in the study area (at Lumle station) based on the DHM Nepal definition. The result shows a large variability (almost a month) in the timing of the monsoon arrival[51] (Figure 4.17).The communities of the Himalaya consider long-lasting, light rainfall events as 'monsoon'. A normalized response of over 70 percent of respondents reported changes in the onset and retreat of the summer monsoon. The proportion of the respondents reporting a clear experience of shift was 35.3 percent (Figure 4.10).

There is, however, spatial variation in the responses, with 85 percent of respondents in the Tarai (the normalized response) noting a change in the onset and retreat of monsoon, followed by the Middle-Mountains (62.9 percent) and the Trans-Himalaya (54.5 percent). Of the total, the proportion of the respondents reporting a 'clear experience of change' is 55.9 percent in the Tarai, 40.7 percent in the Middle-Mountains and 16.7 percent in the Trans-Himalaya (Figure 4.11). The findings are not consistent with either observed or official timings (Figure 4.17). It appears that the communities interpreted variability in the onset of monsoon as a delayed arrival. The FGD participants of the Tarai stated:

[51]Monsoon at Lumle came as early as June 03 and as late as June 27 (152th day to 177th day of the year) in last 40 years.

> … Onset of summer monsoon is delayed by about 2 weeks and its retreat occurs about 2 weeks earlier. The total duration of the monsoon season is shortened to 2 months (July-August) in recent years from 3 (June- August) in the past. …

Figure 4.17: Observed Changes in Onset of Summer Monsoon at Lumle Station, Nepal
(Source: Daily Rainfall Data obtained from DHM, GoN)



In addition, the witnessed delayed monsoonal onsets in the very recent past (2009-2012) have probably biased the community responses. The variable monsoon onset has negatively impacted agriculture, especially the growth of maize and the timing of both sowing and transplanting rice seedlings in the Tarai and in the Middle-Mountains.

4.2.2.7 Changes in Wind - Storms and Cyclones

The monsoon, equatoral trade wind, westerlies and siberian blizzard are the major regional wind systems that influence atmospheric circulation in Nepal. The complex topography of the country generates a number of local wind systems. The major local winds are the valley breeze (blowing towards mountains in the day) and mountain breeze (blowing towards the valley in the night). The Siberian blizzard (called *Sireto* in Nepal) ocasionally causes exceptionally low temperatures in the winter. Further, trade winds bring heat waves (called *Loo* in Nepal) in the summer to the Tarai.Nepal is a landlocked country so it does not experience the extreme primary effects of tropical cyclones. Nevertheless, Trenberth et al. (2007) have claimed an increase in the intensity of tropical cyclones and westerlies due to climate change will affect the Himalayan climate system.

The greater frequency and intensity of wind is attested by the communities in the Kaligandaki Basin. Thenormalized response shows 66 percent of the respondents reported the increased intensities of violent winds. Of the total respondents, 31.7 percent reported a 'clear experience of increase' in wind intervensions (Figure 4.13). The normalized responses do not show major spatial variations since 68.6 percent of the respondents of the Tarai, 67.1 percent of the Middle-Mountains and 58 percent of the Trans-Himalaya recognised increasing strong winds. However, the proportions of the respondents who consider a 'clear experience of' increase in violent winds are comparable for the Middle-Mountains and Tarai (38.8 percent and 34.2 percent, respectively), but are notably low (10.6 percent) in the Trans-Himalaya [52] (Figure 4.14). Consistent with this research, an increase in violent windshas also been reported in the Himalaya (Macchi 2011).

4.2.2.8 Changes in Occurrence of Hailstones

The impacts of hailstones on agroecology are immense. Households reported a change in the timing and intensity of hail eventswith 56.8 percent of the respondents noting the change (Figure 4.13). However, there are large spatial differences. The Trans-Himalaya rarely receives hail, while it is severe in the Middle-Mountains and the Tarai. The FGD participants of Tsusang, Trans-Himalaya reported:

> … This place does not receive hailstones in general, however, in recent years; we have noticed some small hail falling at the start of rain especially in the spring season. …

A totalof 70.5 percent of the respondents of the Middle-Mountains and in the Tarai professed changes in the timing and intensity of hailstones. A mere 3 percent of the respondents of the Trans-Himalaya considered hail to have reported a clear experience of increased compared to 69.1 percentin the Middle-Mountains and 61.2 percentin the Tarai (Figure 4.14).

The comprehensive discussion on climate change using both scientific and social analytical approaches suggests that the climate of the Himalaya is changing; the social-ecological implications of that change is presented in the next section.

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[52]Some parts of the Trans-Himalaya are severely affected by the violent valley winds and mountain breezes. Jomsom (2743 m) is located just behind of some of the tallest mountains of the world: mt. Annapurna I (8091 m), mt. Annapurna South (7219 m), mt. Nanga Parbat (8126 m) and mt. Dhawalagiri (8167 m). The virtical slope of almost 5000 metres in short arial distance makes very strong valley and mountain breezes in the place. Low air pressure developed in the valley after sunsine and cold wind of mountain peaks exchange each others regimes and become violent. The influence of such phenomenon decreases farther from Jomsom. Consequently, settlements located well above the river bank and away from Jomsom (present study sites of the Trans-Himalaya) are poorly influenced by such winds.

4.3 Climate Change Impacts on the Social-Ecological System of the Himalaya

The assessment of climate impacts is a process of identifying and evaluating positive and negative consequences of climatic change on natural and human systems (Füssel and Klein 2002). This process is also the first step for exploring adaptation strategies (Cruz et al. 2007). The climate change impacts perceived by the studied communities are collected by asking people in the community various questions about floods and landslides, the changed nature of rainfall and extended drought, and the incidents of thunder and hailstorms, which are generally the primary impacts of extreme weather events. This information was collected at the community level through group discussions and key informant interviews. On the other hand, information on fire and associated losses, alteration in vegetation composition and plant phenology, amplified crop-livestock diseases and pests, and diminished water sources, which could have indirect or secondary impacts of the change, was collected at the household level to understand whether household respondents have perceived such impacts. This direct and indirect categorization is just a prototype classification made in reference to the nature of impacts and their attribution to weather events and climate change.

4.3.1 Direct Impacts of Climatic Extreme Events

Extreme weather events cause a number of disasters, although the impacts vary between individuals and communities. Disasters cause loss of life and property, disturb production and distribution systems, decrease income and consumption, and overall human development (IBRD/WB 2010). Poor people and poor countries suffer more because they lack reserve assets to buffer the loss caused by disasters (McCarthy et al. 2001; POST 2006). Losses can rise because of inadequate and ineffective post-disaster rescue and relief work (Mallick et al. 2011). As a result, disasters are major challenges for the sustainability of social-ecological systems in Nepal, and they are increasing with climate change.

4.3.1.1 Impacts of Floods and Landslides

Floods and landslides are becoming more common with the increase in sudden and intense rainfall events in Nepal (Oxfam 2009; Shrestha et al. 2000; UNDP and DFID 2007). The respondents of the study area reported diminished frequency but claimed an amplification in the intensity of flooding. Such flooding has changed the state of natural resources, particularly farmland with the increased accumulation of debris and silt, as well as greater erosion. People for all the study sites reported that farmland and forests are regularly damaged, and homes and livestock sheds are occasionally destroyed by floods and landslides. The loss of farmland for households with small-holdings exacerbates their food insecurity and in turn, their livelihood security.

Injuries and loss of life, including livestock, are also reported. Floods and river-bank erosion have displaced hundreds of households over time. However, impacts vary across the ecological zones. The Trans-Himalaya, despite it being an arid zone has experienced severe flooding and landslides, and while they may be attributed to inappropriate road engineering, climate is playing a role. Irrigation infrastructure is frequently damaged and farmlands are silted. The management of infrastructure has become increasingly difficult and costly (Plate 4.2a, b). The spiralling effects extend to agriculture, livestock and social life of the Trans-Himalaya. Key informant at Ghami, Trans-Himalaya stated:

> "… The opening of a track for a district road is in progress, although it was started almost a decade ago. The work is not effectively considering the environmental sensitivity of the Trans-Himalaya. Not many efforts have been made to control landslides while constructing the road. As a consequence the place is seeing more landslides and floods than ever before… ".

Plate 4.2: Costly Management of Infrastructure in the Trans-Himalaya, Nepal
(Source: Field Survey, 2013)

a. Heavy gabion construction in the edge of the Mountain road track in the Trans-Himalaya, Nepal

b. Highly silted irrigation infrastructure in the Trans-Himalaya, Nepal

The studied communities of the Middle-Mountains reported that the floods and landslides have destroyed large areas of farmland as well as have killed numbers of livestock in the last decade. Damage to drinking water, irrigation infrastructure, houses and livestock sheds are common. Major floods in 2003, 2007 and in 2011 in the Modi Khola damaged over 800 Ropani [53] (nearly 40ha) of farmland, where all of the flooded farmlands have been transformed into barren land. The research participants emphasized that this involuntary landuse change has made the livelihoods of dozens of households significantly more difficult.

Floods are common in the Tarai. The respondents indicated that the region experiences a number of small floods during the monsoon each year which damage crops. Major floods are experienced roughly in a decadal cycle, according to the participants at the HTC discussion. The floods in the Tarai (Meghauli) are often caused by heavy rain in the mountains, inappropriate management of the Gandak Barrage [54] and occasional failure of the flood-control dikes constructed along the banks of Narayani and Rapti Rivers. Heavy bank cutting and change in the river courses have severely affected farmland and human settlements in the last 10-12 years, with an estimated loss of over 400 ha/700 Bigha [55] farmland, which has been transformed into either the river course or barren land. Additionally, such floods and erosion forced some 50-60 households to re-locate to safer places each year, with an estimated displacement of over 400 households in the last decade. Many households of the Tarai have also become landless due to flooding and erosion reported by the participants of the group discussion. Another implication of floods is the submerging of tube-wells for drinking water that causes a number of health problems. While it is difficult to attribute these floods to climate change, as more extreme rainfall is projected, such flood-related issues are likely to become more problematic.

4.3.1.2 Impacts of Warming, Changed Nature of Rainfall and Increased Dry Season

The farmers of the Tarai and the Middle-Mountains have confirmed substantial losses of crop-livestock production due to changes in rainfall patterns. Dry weeks within the monsoon season have affected paddy seeding and its transplantation. The pre-monsoon droughts have severely damaged maize crops. A sizable area of farmland has been transformed into barren land due to

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[53] *Ropani* is land measurement unit practice in the Middle-Mountains and in the Trans-Himalaya, 1 hector consist 20.7555 *Ropani*

[54] The Gandak Barrage is constructed in Nepal near to border with India and was built in Indian interest. Appropriate functioning of the barrage (reduce the water level before the flood from mountain arrives at the barrage) would not lead flooding in Indian as well as in Nepali settlements. However, diplomatic solution to this problem, along with many of the other problems has not been searched. Over researcher's query: why not India reduces the water level before the flood arrives? The informants have expressed the bitter truth of being victim of the Gandak barrage: "India would not even spite on your hand if it knows that the spite will treat the wound in the hand."

[55] *Bigha* is land measurement unit practice in the Tarai, 1 *Bigha* equals to 0.6414ha.

reduced rainfall in the winter, spring and pre-monsoon seasons. Natural springs in the Middle-Mountains are flowing for a shorter season, or have dried up completely, and the ground water table in the Tarai has dropped; with both regions experiencing water scarcity.

The farmers expect a timely onset of the monsoon and prepare paddy seedlings according to a crop-calendar practised over many years. However, the process is often stressed by the variable monsoon onset. The participants of group discussion in Meghauli mentioned:

> … The delayed onset of monsoon often causes maturity of paddy seedlings if not burned and dead from extreme drought. The matured seedlings ultimately reduce production even if better rain is received after rice transplantation. …

The respondents also said that ground-water irrigation, which is possible in the Tarai, can require up to four times more water during the drought, yet, because of the costs of irrigation (fuel and hiring of pumping-set), farmers compromise on the frequency and intensity of irrigation. By not having irrigation facilities, and without rainfall in the winter, more than 70 percent farmland has remained fallow in the winter in the Middle-Mountains. The informants of the Tarai also reported some 25 percent of farmland was left fallow in the winter (Plate 4.3).

Plate 4.3: Fallow Farmland in the Middle-Mountains in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)

Many agroecological impacts of the changed nature of rainfall and longer dry seasons are expressed in the Tarai and in the Middle-Mountains. For example, diminished rainfall in June affects rice transplantation; dry weeks within the monsoon increases farm-weeds and cracking in paddy-fields; heavy rainfall in September damages blossoming paddy fields; lack of rainfall in November affects the ability to sow winter crops; and heavy rain in February-March destroys ready-to-harvest winter crops. The maize of the Tarai in the spring and the wheat and maize of the Middle-Mountains (in the winter and spring), are the most affected crops. The production of wheat is also negatively impacted throughout the country (Bhatta et al. 2015). The dryness has increased problems of farm pests such as bugs (*patero*) and farm-weeds. The frequently reported farm-weeds are nilogandhe jhar (*Ageratum houstonianum*), and aalupate jhar in the Middle-Mountains and lahare banmara (*Mikania micrantha)* and marati jhar (*Spilanthes uliginosa*) in the Tarai, a few of them are shown in the Plate 4.4a, b. To reach a minimum threshold of production, most of the farmers in the Tarai have increased the use of agro-chemicals. The participants of the FGDs in Meghauli reported that this has in turn increased the costs of production, diminished soil quality and has compromised consumers' health.

Plate 4.4: Increasing Farm Weeds Invasive Species in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)

a. *Nilo Gandhe* (Farm weed of the Middle-Mountains)

b. *Marati Jhar* (Farm weed of the Tarai)

The situation of the Trans-Himalaya is different to that of the Middle-Mountains and the Tarai. The farmlands of the Trans-Himalaya have been damaged by soil erosion and landslides. Accumulation of silt and debris in farmlands and large scale sedimentation in the lower reaches of rivers are common problems. The FGD participants of the Trans-Himalaya reported:

> … We have never experienced such landslides, floods and active streams and rivers like we are seeing in recent years. …

According to the respondents, snowfall stores water for dry periods and supplies soil-moisture for a longer period. It also controls surface runoff so does not encourage soil erosion and landslides. However, intense rainfall and surface run-off has caused severe soil erosion and flooding in the rainy season, and there has been a scarcity of moisture in the dry season in recent years, according to the research participants. In addition, the snow accumulated on flat mud-roofs and was used to supply water for domestic use for longer periods in the past. However, the changed pattern of precipitation from snowing to rainfall has increased the problem of roof leakages and damage on the walls on the one hand, and now more households have to fetch more water from public taps on the other. Off-season snowfall (snowing in early spring) in recent years has damaged crops including oats, wheat and barley. It has also encouraged crop diseases and increased insect numbers. Furthermore, the farmers reported that grazing animals in the high altitude pastures lack fodder, forage, drinking water and shelter due to off-season snowfall, leading to an increased number of livestock deaths. Frequent rain-storms during the apple blooming season reduced the quality and quantity of fruits. These findings are largely consistent with the findings from other studies conducted in the Trans-Himalaya, Nepal (Dahal 2005; NTNC/ACAP 2012; Paudel and Andersen 2012; Sharma et al. 2009).

4.3.1.3 Impacts of Lightning Strikes and Hailstones

The impacts of lightning strikes and hailstones are serious in the study area. They are most common in the Middle-Mountains, followed by the Tarai. Respondents from the Middle-Mountains mentioned that lightning strikes have killed 3 people and approximately 10 livestock in the last 3 years. Deaths of one person and of approximately 5 livestock in the last 2-3 years were reported in the Tarai. However respondents stated that losses to property in the last decade are quite high, with reported damages to the household electrification system and to electronic devises particularly important [56].

Similarly, losses from hailstones are also high in the Middle-Mountains and in the Tarai. Informants estimated the losses to be more than 50 percent of the expected production of a particular crop from hail in the Middle-Mountains and in the Tarai in most of the years in the last decade. The reported proportion of loss is notably high, yet the FGD participants of Landruk, Lumle stated:

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[56]The informants told that electrification in houses lackinstallation of the earthing devices, which is expected to control extra current received from the lightning strikes. Lack of such provision have caused additional losses

… The patterns of hailstorm occurrences have become so wild; hailstones in 2008 and 2012 caused almost 90 percent losses of maize. The sizes of hailstones were so big they peel the bare trees and damaged water tanks. …

The major crops damaged by hailstones are maize, paddy, fruits and vegetables. The farmers believed that a lack of winter rainfall gave rise to risks of more thunderstorms and hailstones. The FGDs and KIIs conducted at different places reported different levels of losses and that hailstorms led localised impacts. The problems of lightning strikes and hail are not common in the Trans-Himalaya. Nevertheless, the respondents from the Trans-Himalaya reported that they had heard thunder during May through July and had seen small hail occasionally. Other studies from Nepal also reported thunder strikes and hailstorm related losses in Nepal (Paudel, B et al. 2014).

Apart from the direct impacts discussed above, the study area has also experienced a number of indirect implications of climate change. In the next section, the indirect or secondary impacts are explained.

4.3.2 Indirect Impacts from Climatic Change

Many climate change impacts are secondary or tertiary, making it particularly difficult to attribute them to a changing climate, and yet are likely to become more important with climate change. Higher temperature and longer growing seasons play a major role in increasing insect populations, their range and longevity along with an increase in various disease vectors (Cruz et al. 2007; Rosenzweig et al. 2001; van Lieshout et al. 2004; Watt and Chamberlain 2011; WHO 2005),that can adversely affect human health in different ways (McMichael et al. 2006). Floods and droughts in Asia have caused increased vector borne diseases (McCarthy et al. 2001), the spread of malaria and dengue fever vector (IPCC 2007a; Goklany 2004; McMichael and Lindgren 2011; Patz and Kovats 2002), and black fever [57] (Hossain et al. 2011). On the other hand, scarcity of water in the dry season has increased diarrhoea incidents (NTNC/ACAP 2012). The literature have also described that the environmental change and social, demographic and economic disruptions caused by climate change, which have created multiple health problems such as malaria, malnutrition, respiratory disease, stomach disorders and heat stress (Berrang-Ford et al. 2012; Haines et al. 2006). Climate change has also been identified as a contributor to invasive species diffusion, elimination of valuable species and changed vegetation composition (Barton et al. 2009; Reed 2012; Thomas et al. 2004; Thuiller et al. 2005; VijayaVenkataRaman et al. 2012). The next section elaborates some of the impacts that the surveyed communities attributed in part to climate change.

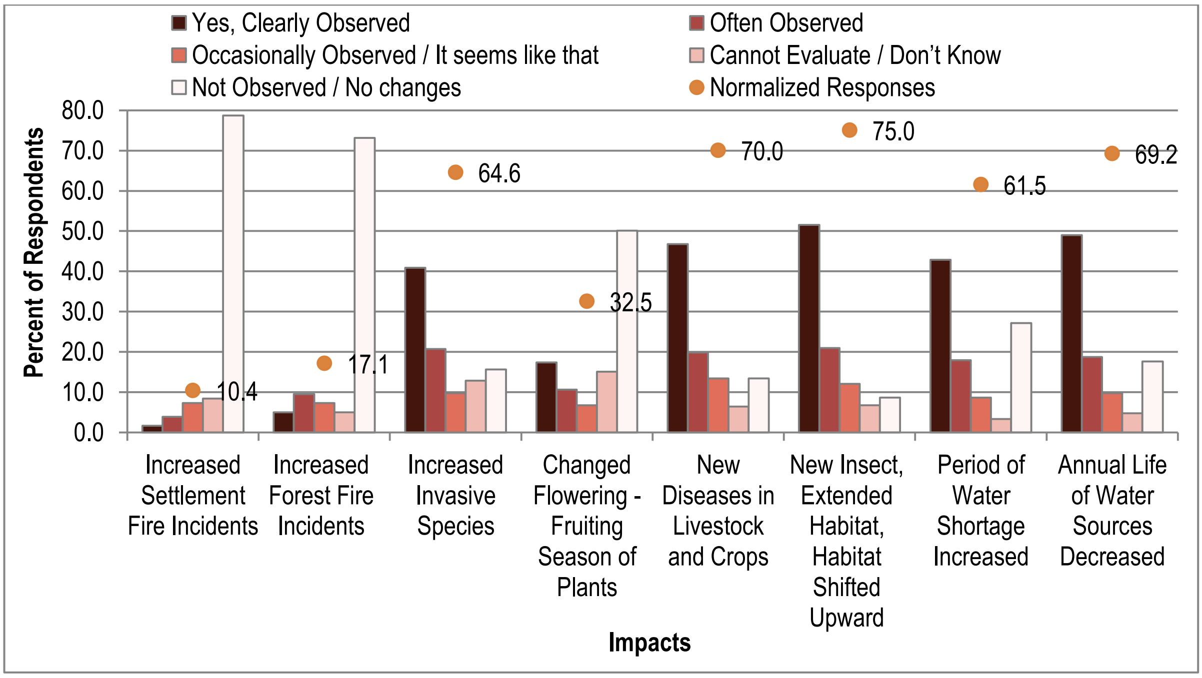
[57] Kala-Azar

4.3.2.1 Fire Incidents

Outbreaks and expansion of fire incidents have been observed and are expected to continue with the escalation of droughts, heat waves, violent winds and lack of precipitation and moisture. Fire is seen as the fourth biggest disaster in Nepal in terms of the number of deaths. There is no time-series data available; however, in general, fire incidents are on the rise. For example, NDR (2013) documents the death of 34 and injury to 32 individuals in terms of annual average increase between 1971 and 2012, from an annual average of 167 fire incidents in Nepal. Problems from fire in the study area were, however limited, was reported by only 10.4 percent of respondents (Figure 4.18).

Apparent increases in settlement fires varied spatially (Figure 4.18). The proportion of the normalized response of 18.2 percent of the Trans-Himalaya followed by the Tarai (10.5 percent) and the Middle-Mountains (6.5 percent) reported increased settlement fires. The relatively higher incident of fire reported in the Trans-Himalaya could be associated with the area's clustered settlements and use of open-fires for heating; whereas, in the Tarai, thatch-roofed small huts and careless handling of fire might have caused higher settlement fires.

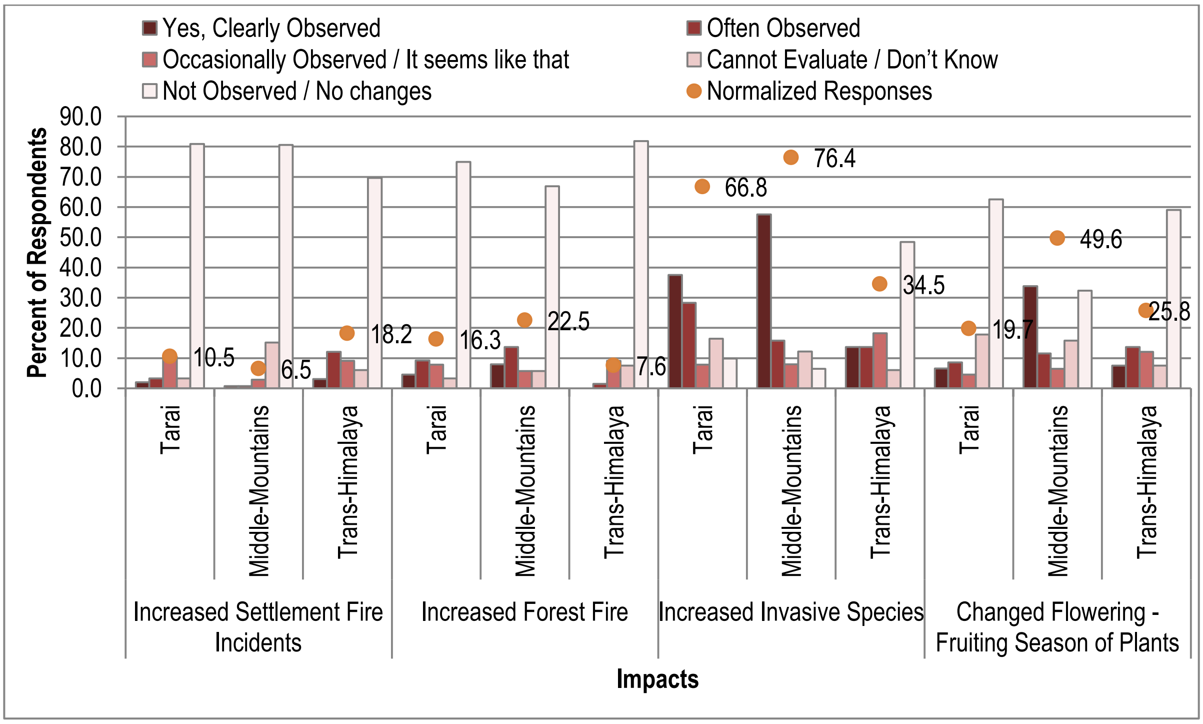
Figure 4.18: Socially Perceived Impacts of Climate Change on the Social-Ecological System of Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)



Studies have found that the increased intensity and spread of forest fires after the 1980s are mostly associated with warming, heat waves, increased number of extremely hot days and drought (Cruz et al. 2007; Gillet et al. 2004; Hughes and Steffen 2013). It is predicted that the duration of forest fires will increase by 30 percent with each Degree Celsius of temperature rise (Vorobyov 2004). This suggests a further increase in the likelihood of forest fires (Bedia et al. 2013; Flannigan et al. 2000). Yet, fire incidents in relation to climate change are complex phenomena. Not only temperature and precipitation but also forest species, decomposition rates or in other words, availability of fuel in the forest influence the fire outbreak and spread. In this context, forest fire incidents discussed here need to be understood as informative rather than in relation to climate change independently.

Communities have seen bigger forest fires in recent years. The proportion of the normalized response of 17.1 percent of the respondents stated they were aware of an increase in forest fires (Figure 4.18). The results vary spatially: the highest proportion of positive response (22.5 percent) was from the Middle-Mountains, while corresponding proportions in the Tarai and the Trans-Himalaya were 16.3 percent and 7.6 percent respectively (Figure 4.19). Some of the key informants of the Trans-Himalaya mentioned that the forest of the region lacks fuel for burning, so it does not experience severe forest fires.

Figure 4.19: Socially Perceived Impacts of Climate Change on the Components of the Social-Ecological System across the Ecological Zones of Kaligandaki Basin, Nepal (Fire, Invasive Species, Flowering or Fruiting Season)
(Source: Field Survey, 2013)



Respondents stated that they largely ignore forest fires until they threaten settlements. The lack of timely responses to forest fires increases their intensity and multiplies the losses. The informants further mentioned that they are not well equipped to deal with forest fires since traditional methods of extinguishing fires by using banana leaves and steam, green forage and mulch, and soil, are not effective in controlling forest fires. The people of the Middle-Mountains experienced four major forest fires (2011, 2009, 2008, and 2002) in the last decade causing the loss of over 150ha [58] forest. The fire incident of 2011 was severe and lasted for a week, while the incident of 2002 lasted for three days. These fires resulted in substantial losses of forest resources such as valuable medicinal and aromatic plants, mulch and forest biodiversity. The fires also caused the death of wildlife. Consistent with the literature (Alston 2012; Brondizio and Moran 2008), people in the study area said that fire incidents increased, as well as travel faster, with the advancement of the dry season. Forest fires in the Nepali Tarai are frequent; however, the studied communities of Meghauli have not experienced severe forest fires.

4.3.2.2 Increased Invasive Species and Changed Flowering and Fruiting Seasons

There are many implications of climate change on biodiversity. The reported impacts are habitat fragmentation, loss of species, change in phenology and species distribution, reduced forest regenerations (McCarthy et al. 2001;Kurukulasuriya and Rosenthal 2003; Root et al. 2003;Rosenzweig et al. 2008); and ecological regime shift as well as physical damage by weather extremes, fires, and landslides (Bardsley and Wiseman 2012; Briones et al. 2009). However, these implications can also be connected to other factors, such as over exploitation, plant migration (natural or induced) and natural cross-fertilization. The Hindu-Kush and Himalaya region houses 25 percent of global biodiversity hotspots and 40 percent of the global 200 ecological regions; however, they are threatened by climate change (Sharma and Tsering 2009). Whatever the reasons, the study area is experiencing a greater number of invasive species and the altered phenology of plants (especially flowering, fruiting and ripening seasons), consistent with the literature (Bhatta et al. 2015).

Respondents have seen progressive diffusion and increased densities of invasive species. The normalized response shows 64.6 percent of the respondents having noticed an increased range of invasive plants. Many respondents (40.9 percent) have ‘clearly noted’ such an expansion (Figure 4.19), yet, there are some differences between the spatial units. The proportions of the normalized responses of 76.4 percent, 66.8 percent and 34.5 percent of the respondents of the Middle-Mountains, Tarai and Trans-Himalaya respectively, indicated the spread of invasive species. The

[58] The 150ha forest is in Lumle VDC, although the fire extended into the forest of adjoining VDCs. There was a large forest destroyed by fire. The research participants also reported that the fire was lasted for a week. However, their meaning of one week is not the fire expansion in general, but it remained burning as no effort was made to extinguish it.

problem of hostile plants is revealed as a serious issue in the farmlands and forests of the Middle-Mountains and Tarai. Contrary to these places, the communities of the Trans-Himalaya noticed little increase in invasive species.

The participants of the FGDs further supported the responses collected from households. They reported the emergence of several kinds of weeds and herbs in the farmlands, forests, grazing lands and grasslands (*Kharbari*) in the Tarai and Middle-Mountains. One of the widely reported invasive species is *Banmara* (*Eupatorium adenophorum and Mikania micrantha* in the Tarai and *Eupatorium adenophorum* in the Middle-Mountains). Further, *Maratijhar* (*Spilanthes uliginosa*) and *nilogandhe* (*Ageratumhoustonianum*) in the Tarai and *Nilogandhe* and *aalupate jhar* in the Middle-Mountains are newly emerged farm-weeds (Plate 4.5a, b). However, no new weeds have become established in the Trans-Himalaya, although farmers report seeing new weeds occasionally.

Plate 4.5: Newly Emerged Invasive Species in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)

a. *Banmara* (Invasive species of the Tarai and Middle-Mountains)

b. *Lahare Banmara* (Invasive species of the Tarai)

People reported that the forest of the Middle-Mountains had been invaded by *banmara* in the last 15-20 years. Highly valued medicinal and aromatic plants like *Chiraito (Swertia chirayita)*, *Panchaunle (Datylorhiza hatageria)*, *Satuwa* (*Paris polyphylla*) are destroyed by *banmara*. According to the respondents, the community forestry and the nature conservation programmes (the CNP in the Tarai and the ACAP in the Middle-Mountains), are reducing human interventions in the forest that used to control invasive species at regular intervals, which is facilitating the rapid spread of invasive species like *banmara*. Respondents noted that destructive plants are adaptable to climatic vagaries (they do not die in long dry season, even during up-rooting and burning). The *banmara* is vigorous, has a fast migrating ability both through seeds and roots, and consequently out-competes the non-timber medicinal plants. Further, respondents indicated that its spread has reduced the availability of fodder and forage for herbivores of the forest, leading to wildlife encroachments in the farmlands. Although such changes are difficult to attribute to climate change, it can be argued that changes in the climatic conditions may favour invasion.

The people of the study area also witnessed changes in the flowering, fruiting and ripening seasons of fruit. The normalized response shows 32.5 percent of the respondents reporting changed plant phenology. Of the total, 17.4 percent of the respondents mentioned a 'clearly observed change' in plant phenology in the study area (Figure 4.19). The spatial differences indicated that the proportion of the normalized response on altered plant phenologies was 49.6 percent in the Middle-Mountains, 25.8 percent in the Trans-Himalaya and 19.7 percent in the Tarai (Figure 4.19). The proportion of respondents who had clearly noticed the change was the highest in the Middle-Mountains (33.8 percent), followed by the Trans-Himalaya (7.6 percent) and the Tarai (6.6 percent).

Participants in the FGDs listed some of the plants, in which the changes are clearly seen. The *Rhododendron* blooms some two weeks earlier in the Middle-Mountains and some 3 weeks earlier in the Trans-Himalaya than in 'usual' seasons. Fruit trees (mangoes, jackfruits, lychees) in the Tarai have been blooming some two weeks earlier in recent years. Changes in flowering and fruiting seasons had been seen also in peach, pear, apricot, mangoes, *kafal* (bay-berry/box myrtle: *Myrica esculenta*), *Aaiselu* (wild raspberry: *Rubus ellipticus*) in the Middle-Mountains and the Trans-Himalaya (mostly below 3500 masl), with most of the early blooming leading to unsuccessful fruiting. Similar to the literature that reports a significant decline in the quality of fruit, vegetables, tea, coffee and aromatic medicine due to climate change (Agrawal 2007), the farmers of the Tarai mentioned that early blooming and fruiting have reduced the quantity as well as the quality of fruits. Successful early fruiting often leads to earlier ripening in the Tarai. Informants stated that excessive temperature during the blooming season of mangoes caused blossoms to die and withered fruits at an early stage. In comparison to the Tarai, farmers of the Trans-Himalaya reported larger apples with a better taste in higher altitudes because of warming.

4.3.2.3 New Diseases in Crops and Livestock, New Insects and Changed Habitats

The global and regional literature on the implications of climate change for crops and livestock have shown a general consensus on new diseases, disease vectors and insects, and their fragmented and extended habitats (Howden et al. 2007; Parry et al. 1999; Ramirez-Villegas et al. 2012; Rosenzweig 2011; Sivakumar 2011). Insects and disease vectors often impact on crop-livestock productivity, such that in South Asia, crop-livestock diseases and associated losses are projected to increase (Bosello et al. 2009). In the meantime, the activities of agricultural modernization like mono-cropping, improved seeds, use of agro-chemicals are also suspected to be factors contributing to an increase in crop-livestock diseases and pests (Macchi 2011). A large proportion (70 percent of the normalized response) of the study area reported new crop-livestock diseases. Some 46.8 percent of the total respondents reported an emergence of crop-livestock diseases (Figure 4.18). There is, however, inconsistency across the ecological zones in that result as indicated in Table 4.2.

The environment of the Tarai facilitates the breeding and spread of disease vectors. A total of 75.3 percent of respondents noticed an increased distribution of crop-livestock diseases, with a similar proportion (72.3 percent) in the Middle-Mountains, although this was relatively less (53 percent) in the Trans-Himalaya (Table 4.2). Among the total respondents, 58.3 percent of the Middle-Mountains, 46.1 percent of the Tarai and 24.2 percent of the Trans-Himalaya clearly noted an increase in crop-livestock diseases and insects in the last decade.

Table 4.2: Socially Perceived Impacts of Climate Change on Crop-livestock Diseases and Extended habitat of insects by Ecological Zones in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)

Level of Impact Experienced / Reported	New Diseases in Livestock and Crops			New Insect, Extended Habitat, Habitat Shifted Upward		
	Tarai	Middle-Mountains	Trans-Himalaya	Tarai	Middle-Mountains	Trans-Himalaya
Yes, Clearly Observed	46.1	58.3	24.2	46.1	64.7	36.4
Often Observed	25.7	13.7	19.7	28.3	14.4	18.2
Occasionally Observed / It seems like that	16.4	4.3	25.8	11.8	7.2	22.7
Cannot Evaluate / Don't Know	7.2	6.5	4.5	9.2	6.5	1.5
Not Observed / No changes	4.6	17.3	25.8	4.6	7.2	21.2
Normalized Responses	**75.3**	**72.3**	**53.0**	**75.5**	**80.8**	**61.7**

Increased crop-livestock diseases and the emergence of new insects have negatively impacted on the mixed crop-livestock systems of the study area. Many participants of the FGDs and individuals interviewed during the field study, confirmed the increased prevalence of crop-livestock diseases and insects. Some of the typical problems the informants expressed include: with the lack of winter precipitation in the Tarai, potato farms suffer from fungal diseases, which cannot be cured by agro-chemicals; and the *Rate,* a common disease in the paddy, which makes the plants brown/red before they die, often leads to significant loss of paddy production in the Tarai; and the risk increases with changes in the rainy season or when the rainfall calendar does not coincide with the crop calendar. The farmers also stated that local varieties were less susceptible to many disease and insects; however local crop varieties have mostly disappeared in recent years. The compounding effects of amplified crop-livestock diseases lead to a decline in production and a rise in production costs. As a result, many farms are operating at a loss, according to the survey participants in the Tarai and of the Middle-Mountains. The situation of crop-livestock disease in the Trans-Himalaya differs with snow in the wrong season that is not harmonised with the crop calendar leading to a higher risk of crop-disease and insect problems.

The people of the study area reported a number of losses caused by more prevalent crop-livestock diseases. Approximately 10 livestock have died of '*Bhyakute'* (a communicable disease in livestock) in the last few years in the Middle-Mountains. Since the sick livestock did not get timely treatment and the authorities did not offer support to control the *Bhyakute* in time, the loss was severe. Nevertheless, the people do not know if climate change has any role in the spread of *Bhyakute*. Some of the informants have indicated that the advancement of transportation facilities (linking the Middle-Mountains with the Tarai and bordering India), and poor quarantine practices, have promoted the diffusion of crop-livestock diseases as well as human health problems and disease vectors. One of the examples an agro-vet technician at Lumle Agriculture Research Centre shared is:

> "… Bhyakute disease in livestock in Lumle originated from the illegal slaughter of infected animals in the village. It was the incident of some 15 years before, when Bhyakute killed 70 to 80 livestock within Lumle VDC. An investigation afterwards unveiled the facts that some vendors were carrying live male buffaloes from India to Baglung (a city located some 40 km west of Lumle and the road passes through Lumle). While transporting, one of the male buffalo died of Bhyakute. The vendors slaughtered the dead animal in the nearby bushland and sold the meat in local shops. Further, they left the remains of the slaughter in open bushland, which led to the spread of disease throughout the village and the farmers suffered from heavy losses. After the incident, the disease has not been fully controlled. The livestock get sick often and if not cured on time, they die. The transportation induced diffusion of disease vectors is common on human health problems, expansion of mosquitoes, the other crop insects, as well as invasive species. We did not have mosquitoes here before the opening of Pokhara-Baglung Highway. …".

Together with the perception of more prevalent crop-livestock diseases, the respondents of the study area have seen new insects and disease vectors and the extended habitats of such pests. A normalized response of 75 percent of the respondents reported increased insect numbers and extended habitats for them (Figure 4.18). Over a half (51.5 percent) of the total respondents had felt a 'clear' increase in insect populations. However, the response varied spatially (Table 4.2). Over 80 percent of the respondents of the Middle-Mountains, followed by the Tarai (75.5 percent) and the Trans-Himalaya (61.7 percent) expressed an increase. Moreover,64.7 percent of the total respondents in the Middle-Mountains, 46.1 percent of the Tarai and 36.4 percent of the Trans-Himalaya clearly perceived an increase in numbers of insects and extended habitats.

The informants named some of the insects and disease vectors which are more prevalent in the study area: various kinds of bugs (*lema praeusta*: stink bug, big horns bug) in citrus fruits, apple and paddy; *Beruwa kira* (leaf roller) in paddy; harmful ants like *Dhamiro* (wood ants: termites/microtermes species), *Gabaro* (shoot boarer: white, brown), which damage roots and stems of sugarcane, maize and root crops during drought and *raato kamila* (*dorylus orientalis*) in potato. They also reported an expansion of various kinds of moths and leeches which harm animals and humans; various kinds of caterpillars which damage leafy crops and vegetables; different types of worms (red/brown cutworms - *emmalocera depressela*) which destroy root crops like radish, carrot, yam, potato, beetroots and sweet potato; and many kinds of grass hoppers and aphids which damage leafy vegetables and crops. Furthermore, respondents also identified tremendously enlarged populations of other insects, such as several kinds of ladybugs, beetles, dragonflies, flies, centipedes, stick insects, spiders, wasps and bees, scorpion and clock insects (*Jhyaukiri* and *Ghantikira*), although their implications in the social-ecological system are unclear. An increase in phytophthora (fungal) and *Lahikira* (Aphididae/Plant-lice) in lettuce, legumes, mustard, cabbage, broccoli and cauliflower have also been noted. Gastropods like snail (*sankhekira)* and slug (*chiplekira*) flourished after the floodings of 1994 (the deadliest flood in Nepal over the last half century) in the Tarai damaging valuable vegetables. The research participants confirmed the increase in crop-livestock diseases and insect populations irrespective of place. However, the intensity is highest in the Tarai, followed by the Middle-Mountains and the Trans-Himalaya.

4.3.2.4 Decreased Availability of Water Sources and Increased Water Scarcity

The availability of water sources and extended water shortages are associated with diminished rainy days and rainfall amounts, the increasing variable nature of rainfall and extended dry seasons. Reduced water availability has grave implications for socio-ecological systems globally, as well as regionally. The IPCC has predicted a severe water shortage for over 5 billion of the global population by 2025 (McCarthy et al. 2001), and over 1.2 billion within Asia by 2050 (Cruz et al. 2007). The IPCC (2007b) also states that the availability and quality of water will be the main issue for societies and the environment under climate change. The communities of the Kaligandaki Basin are already experiencing rising water scarcity. A high proportion of respondents reported diminished water availability (70 percent with 50 percent identifying a 'clear decrease') suggesting potentially grave implications of climate change on water resources in the study area (Figure 4.18).

The perception of reduced availability of water varies across the ecological zones (Table 4.3) with 74.5 percent respondents noting the decline in the Middle-Mountains, 72.7 percent in the Tarai and 50 percent in the Trans-Himalaya. Some 56.6 percent of respondents of the Tarai and 54 percent of respondents of the Middle-Mountains have 'clearly' witnessed the diminished availability of water. The respondents' experiences include falling water tables, springs drying up early and a reduced flow of natural sources.

Table 4.3: Socially Perceived Impacts of Climate Change on Water Resources by Ecological Zones in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)

Level of Impact Experienced / Reported	Period of Water Shortage Increased			Annual Life of Water Sources Decreased		
	Tarai	Middle-Mountains	Trans-Himalaya	Tarai	Middle-Mountains	Trans-Himalaya
Yes, Clearly Observed	55.3	41.0	18.2	56.6	54.0	21.2
Often Observed	19.7	12.2	25.8	15.8	19.4	24.2
Occasionally Observed / It seems like that	8.6	4.3	18.2	5.9	10.1	18.2
Cannot Evaluate / Don't Know	2.6	4.3	3.0	5.3	3.6	6.1
Not Observed / No changes	13.8	38.1	34.8	16.4	12.9	30.3
Normalized Responses	**75.0**	**53.4**	**47.3**	**72.7**	**74.5**	**50.0**

Water shortages are reported by 61.5 percent of respondents (42.9 percent indicating the shortage was severe), but the extent of the problem varies spatially (Figure 4.18). The normalized response shows 75 percent of the respondents of the Tarai, followed by the Middle-Mountains (53.4 percent) and the Trans-Himalaya (47.3 percent) reported extended water scarcity. The Tarai had the highest proportion of respondents (55.3 percent), followed by the Middle-Mountains (41 percent) and the Trans-Himalaya (18.2 percent) who clearly noted an increased water scarcity (Table 4.3).

The participants of the FGDs in the Middle-Mountains stated that natural springs are drying-up just after the end of monsoon rain, as much as three or four months earlier than previous experiences. Respondents suspect that declining rainfall in the winter might also have contributed to diminished availability of water. The eruption of natural springs has become uncertain and irregular due to the altered nature of monsoonal rainfall and less *Saune Jhari* (continuous light rainfall for many days during the monsoon). In the Tarai, changes witnessed in the rainfall pattern have disrupted the crop calendar especially for rice, causing serious losses in production.

The shortened annual life of water sources impact both irrigation and domestic use. Accessing groundwater for irrigation and domestic use in the Tarai has become increasingly expensive because of ever-declining levels of ground water. The FGD participants of the Tarai mentioned:

> … Till 1997-98, groundwater through shallow tube-well used to be accessible within 15 feet of the depth, but it is accessible only in 27 feet or more these days. To access groundwater for irrigation, 45 feet depth of bore pipe used to be enough previously, now it needs to be installed as deep as 75 feet. Many hand-pumps installed decades earlier cannot pump water in spring and pre-monsoon seasons and that is leading to a scarcity of drinking water. …

Extensive extraction of groundwater for irrigation and domestic use throughout the Gangetic plain, together with a reduced rate of infiltration and groundwater recharge due to loss of rainwater through run-off, are likely causes of the reductions in groundwater tables. Although there are some reports of increased water shortages in the Middle-Mountains and in the Trans-Himalaya, the problem is not as large as in the Tarai.

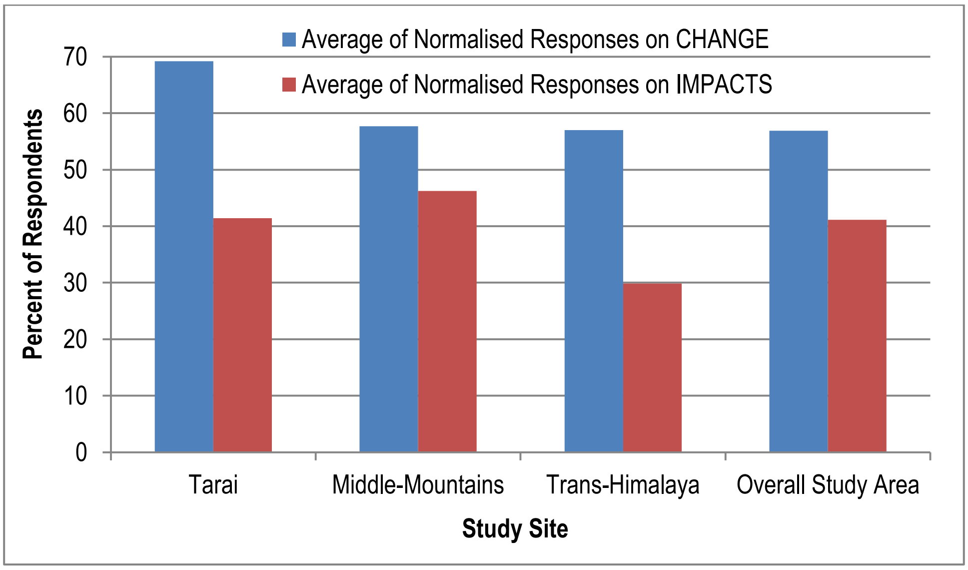
The extensive discussion above shows that the climate of the Himalaya, particularly in the Kaligandaki Basin, is changing rapidly. The changing climate is impacting the social-ecological system of the basin in a complex way, which are summarised below.

4.4 Conclusion

The changes in the climate system of the Nepali Himalaya and associated impacts on the social-ecological system of the region are discussed extensively. To understand the overall situation, the normalized responses on various questions are averaged (Figure 4.20). In total, 56.9 percent of the respondents believe that the climate of their location has changed, with the highest proportion (69.2 percent) being in the Tarai, followed by the Middle-Mountains (57 percent) and the Trans-Himalaya (57.7 percent). The summarised impacts show 43.4 percent of the respondents of the basin believe that the changing climate has increased negative impacts on the social-ecological systems, in the Middle-Mountains (47.7 percent) followed by the Tarai (43.5 percent) and the Trans-Himalaya (33.9 percent).

The comparision between perceived and observed climate change shows both consistencies and contradictions. Rising summer temperatures are similar except in the case of extreme maximum and maximum temperatures at Jomsom, where the opposing results were found in the variability of winter temperatures, with no significant decrease in empirical assessment, but the majority of the respondents perceiving a decline in winter temperature extremes. Respondents might be noticing occasional extremely cold mornings and frost and linking those experiences to decreases in average temperature. Also the nearest meteorological station available for the Trans-Himalaya is located at a considerable distance from the survey region, so detected temperature may not represent the situation of the surveyed communities in the Upper-Mustang.

Figure 4.20: Overall Scenarios of Perceived Climate Change and the Impacts of Change on the Social-Ecological Systems of the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)



The expansion of rainfall in the Trans-Himalaya is analogous to observed change, however, this is not the case in the Middle-Mountains and the Tarai. In general, community opinions regarding increased extreme rainfall events and floods agree with the scientific observations. Most of the respondents agreed that the monsoon has been coming later and withdrawing earlier in recent years, which is not supported by the meteorological data. It seems that communities are shaping their judgment by the recent past and they might have interpreted recent inter-annual variability as change. Some of the differences between empirical and social analysis of change are because society reacts to weather incidents (events) on the basis of both experienced and desired outcome. Most of the results of this survey in general are consistent with other studies in the Nepali Himalaya (Bhatta et al. 2015; Chaudhary et al. 2011; Gentle and Maraseni 2012; Macchi

2011; Manandhar et al. 2011; NTNC/ACAP 2012; Onta and Resurreccion 2011; Paudel, B, et al. 2014).

Changing climate is identified as a new environmental challenge for the social-ecological systems of the study area. Most of the reported impacts are negative, with some limited positive effects for Trans-Himalayan agriculture. Major drivers of the primary impacts identified are increased impacts of soil erosion, landslides, floods, erratic rainfall events, drought, thunderstorms and hailstones. Overall poor people have been particularly stressed by the additional burden as the limited livelihood assets available to them are being affected by changing climate. Losses in crop yields, damage to houses and other infrastructure, and increased food insecurity are contributing to the vulnerability of social-ecological systems of the studied households. The impacts identified by this study are consistent with the literature at national and regional scales (FAO 2008; Shah and Lele 2011; Sharma and Tsering 2009).

The impacts differences across the ecological zones tends to be associated with the agriculture systems practised in a particular place, the environment of that place and the level of exposure of the local social-ecological system to climate change. The Trans-Himalaya has only one cropping season and although warming is restricted to the non-cropping season, the area is experiencing increased erosion, landslides and flooding due to the changed form of precipitation. The effects of these changes are making the already marginal environment of the Trans-Himalaya more vulnerable. However, dealing with harsh environmental conditions is routine for Trans-Himalayan communities, and this could explain their lower perceptions of negative impacts compared to the communities of the other two regions, which have year-round cropping.

In summary the stressors of climate change have caused significant loss of life and property, reduced livelihood resources, pressured the community people to seek alternative ways of life, and challenged the sustainability of the social-ecological systems of the study area. Furthermore, other environmental, socio-economic and political problems of the country have been aggravated by climate impacts. Therefore, many secondary and tertiary effects, which are difficult to map but have the ability to damage the capitals of the social-ecological systems with obvious direct effects, could appear as the most costly implications of changing environmental conditions.

The discussion above has demonstrated that communities hold rich knowledge of climate change and its associated influences. Therefore, by combining their knowledge with the knowledge produced by climate science provides valuable insights for dealing with climate change issues. The reported implications are serious; and some will not be easily manageable. Many other risks and hazards could be reduced at relatively low costs. Variability in climate change and uncertainties about the social-ecological implications remain in the Himalaya, which are generating external pressures on the livelihoods of the Kaligandaki Basin. In this context, the next chapter discusses the sensitivity of the social-ecological systems to climate change with a particular focus on the livelihood resources of the communities.

CHAPTER V

THE SOCIAL-ECOLOGICAL SYSTEM OF THE STUDY AREA

5.1 Introduction

A social-ecological system of a place describes the existing interaction of physical environment and its inhabitants. The level of exposure and sensitivity of the system to climate change, and its adaptation response determine the sustainability or vulnerability of the system. Impacts of climate change and adaptation responses are not standalone issues but are attached to poverty and overall development policies of a country (Adger and Kelly 1999; AfDB et al. 2003; Füssel 2008; Loster 2008; Skoufias et al. 2011). Therefore, the study of the social-ecological system, with special focus on the livelihood system is important to understand the implications of climate change. This chapter highlights the status of the social-ecological systems of the Kaligandaki Basin, Nepal so that the implications of climate change impacts on those systems can be put in context. This chapter provides comprehensive information on livelihood systems using figures and tables. The general scenario of Kaligandaki Basin is provided at first, followed by the specific situation of different ecological zones. The key points of the figures and tables are narrated in the text.

The socio-ecological system is a concept that incorporates many sub-systems, and is varied by space, time, and society. The heterogeneous Himalaya holds a range of social-ecological sub-systems made possible, in part, by its environmental variability. The chapter describes the different livelihood systems of the studied communities. The sustainable livelihood approach focuses on the various factors and processes which either constrain or enhance people's ability to make a living in an economically, ecologically, or socially sustainable manner (Bennett 2010; Chambers and Conway 1991; Connell 2010; Frankenberger et al. 2000; Krantz 2001; Scoones 1998; Sneddon 2000). Human beings are at the centre stage in a social-ecological system so they bear the ethical responsibility for many of its elements (Adger 2000a; Angermeier 2000; Ehrlich 2002; IPCC 2007a; Lade et al. 2013). In addition, livelihood assets of people indicate the local capacity for adaptation (Prowse and Scott 2008). The human system is intimately linked to the geographic environment of a place (Kaltenborn and Bjerke 2002; El-Shafie 2010; Kasperson and Kasperson 2001) and the political, economic and structural constraints of the society (Adger et al. 2014; Barnett and Adger 2007; Rocheleau et al. 1995). Environmental changes undermine human security only after coupling with a broader range of social factors, including those social-ecological and political-economic interactions (Adger et al. 2014; AfDB et al. 2003; Barnett and Adger 2007;

O'Brien 2006). Therefore, the analysis of livelihood systems discussed here represents the current social-ecological systems of the study area.

5.2 Social-Ecological (Livelihood) Systems of the Himalaya

A livelihood is a means of gaining a living that can only be secured and sustained by multiple resources. Sen (1985), WCED (1987), Chambers (1988), Chambers (1986), Chambers and Conway (1991), UNDP (1990), and UN (1992) have made major contributions in the field of sustainable livelihoods. The theory of sustainable livelihoods has been transformed into a programmatic form by a number of development and aid agencies including DFID, the UNDP, Oxfam International and Care International (Carney et al. 1999; Sanderson 1999; Scoones 1998). Livelihood in various parts of the world has been extensively studied. More recently, such studies have focused also on climate change. Various authors (AfDB et al. 2003; Davies et al. 2008; Fraser et al. 2010) have stated that climate change affects the livelihoods of communities through a complex web of impacts. Some scholars (Eakin 2005; Hahn et al. 2009; Howden et al. 2007; Kelly and Adger 2000; Mertz et al. 2009a; Mubaya et al. 2012; Wong 2009; Wrathall 2012) have provided evidence of such impacts. The IPCC (Hijioka et al. 2014) claimed with high confidence that weather extremes will affect livelihoods in Asia by impacting on human health, security and levels of poverty in varying degrees across the regions. Researchers (Chaudhary et al. 2011; Dahal et al. 2009; Gentle and Maraseni 2012; Ghimire et al. 2010; Macchi 2011; McDowell et al. 2012; Onta and Resurreccion 2011; Shrestha 2008) also found particularly severe implications of climate change for Himalayan livelihoods.

Livelihood security comprises the capability of using livelihood assets and activities to cope with and recover from stress and shocks. The sustainability of livelihood systems depends on the interplay of assets, vulnerability, coping/adaptation strategies, and the structure and process of endogenous and exogenous factors. The changing climate has become the major, new exogenous factor to challenge the sustainability of the livelihood systems in the Himalayan region, where such systems are already at the margins of sustainability because of many non-climatic factors.

The livelihood systems of communities in the Himalaya are mostly agriculturally based, and are derived from the major livelihood capitals (human, social, natural, financial, and physical). Such agricultural livelihoods are assisted by small scale enterprises, services, the sale of labour, and remittances. As will be examined in some detail, all of these livelihood options are directly or indirectly sensitive to climate change. Together with climate change, livelihood capitals become the key determinants of social-ecological vulnerability. Therefore, the concern of this study is that vulnerable ecosystems of the Himalaya may not be able to support and sustain the livelihoods of inhabitants in the face of climate change. Despite the Himalayan livelihoods being integrated, dynamic, and complex, the marginality of the Himalayan niche for agro-based livelihoods has undermined the broader sustainability of the livelihood system (Bardsley and Thomas 2005).

To overcome the livelihood security [59] related challenge created by climate change, strong livelihood capitals are a fundamental requirement (Adger 2003; Adger and Kelly 1999; Eriksen et al. 2011). In addition, vulnerability and adaptation with responses have interactive relationships with a number of systems: livelihood, infrastructure, health, food and water supply, communication (Schneider et al. 2007). The climate change adaptation strategies that the individuals and communities of developing countries design and adopt are not very different from the strategies they incorporate in any environmental risks and hazards (Raleish et al. n.d.). The interaction among the systems and the strength of strategies depend on the status of available livelihood assets. It is in this context that the statuses of the livelihood capitals, and their sensitivity to climate change, are discussed.

5.2.1 Human Capital

Humanity has the ability to make use of environmental objects as livelihood capitals. Human capital includes the quantity (labour force), quality (education, health, skills), and behaviour of the human population. It is crucial for gaining access to and making use of other capitals, hence it is the basis of the other capitals and a building block of livelihood outcomes. Human capital is a way of overcoming poverty and underdevelopment (Sen 1985; 1989; 1993). Many scholars (Fukuda-Parr 2003; Fukuda-Parr and Kumar 2009; Nussbaum 2000; Nussbaum and Sen 1993; UNDP/HDR1990) have taken human capability as key measure of development, and ill health and lack of education (poor human capital) as the core dimensions of poverty and marginalisation. Demographic responses to climate change are adaptive responses (Ezra 2001; Hunter 2005), so a lack of such responses due to poor human and other capitals are major obstacles to climate change adaptation (Leary et al. 2007).

Nepal is a country with a low level of human development: the 157th in the world with an HDI 0.463 in 2012 (UNDP/HDR 2013). Demographic dynamics (fertility, mortality, morbidity, spatial distribution, and migration), the base of human capital, drives, and is transformed by, climate change (Bailey 2011; Black et al. 2008; Cameron 2013; IPCC 2007a; Jiang and Hardee 2009).

[59] Livelihood security includes adequate and sustainable access to livelihood resources: food, potable water, health facilities, educational opportunities, housing and time for community participation or integration (Frankenberger 1996)

The population growth rate in Nepal is quite high, though it is decreasing: 2.01 percent per annum from 1991 to2001 to 1.35 percent per annum in-between 2001-2011 (CBS 2001; CBS 2012b). However, the country lacks the required levels of investment in many fields of research and development, causing the poor quality of human capital and higher impacts of climate change.

Studies have shown that poor human capital both in terms of quantity and quality significantly affects households' adaptation capacity to climate change. For example, climate change disproportionately affects different sections of population such as the elderly, the sick and young children (AfDB et al. 2003; McCarthy et al. 2001; Kasperson and Kasperson 2001; Polack 2010). The elderly, the sick and young children generally cannot respond quickly or independently to evacuation emergencies, and are subject to health complications (McMaster 1988; O'Brien and Mileti 1992), so they are more sensitive to climatic events. In another example, poor human capital in Tibetan pastoral communities reduced households' ability to drive herds towards a safe place during snowstorms, leading to severe losses of livestock (Yeh et al. 2014). Also, poor human capital reduces the institutional capacity to promote adaptation, the chances of earning cash, the ability to manage financial and natural resources and invest in adaptation measures (Adger et al. 2003; Smit and Skinner 2002). In this context, labour, education, and the health of the studied population are discussed below to understand the status of the human capital of the study area.

5.2.1.1 Labour Force

The labour force of a household is determined by both natural changes in demography, as well as by socioeconomic and political transformations of a state. A population of young adults accompanied with sound health, skills, knowledge, and a positive outlook and appropriate motivation, can be assimilated with the natural and social environments to increase livelihood capability. Researchers have found a correlation between better adaptive capacity of households having better labour power (Eriksen et al. 2005; Yeh et al. 2014). The labour force data of the study area show 5.8 to 5.9 persons per household across the ecological zones (Table 5.1), which is higher than the national average of 4.9 persons (CBS 2012b).

Age structure is an important component of analysis to understand both the labour force to support livelihoods and potential sensitivity to extreme events in climate. The sex ratio of sampled households of the entire study area is 106 males per 100 females, but this varies across the ecological zones. The population of males outnumbers females in the Trans-Himalaya (118) and the Tarai (111), but females outnumber males in the Middle-Mountains (97). The proportion of males in sampled households is found to be higher than the national average of 94.2 (CBS 2012b). Figure 5.1 shows that 23.6 percent of the sampled population were aged below 15 years, while one-third were young adults (15-29 years), 10.4 percent were elderly, (60 years of age and over), which was higher than the national figure of 8 percent (CBS 2012b).

Table 5.1: Demographic Characteristics of the Population in the Kaligandaki Basin, Nepal
*(Source: *CBS 2012a; ** Field Survey, 2013)*

Variables	Population Census 2011*				Sample Households**			
	Meghauli	Lumle	Upper Mustang	Total	Tarai	Middle-Mountains	Trans-Himalaya	Total Sample
Number of Households	3086	1056	752	4894	153	141	66	360
Total Population	14149	4258	2456	20863	894	827	392	2113
Male	6341	1910	1162	9413	470	407	212	1089
Female	7808	2348	1294	11450	424	420	180	1024
Sex Ratio (Number of male per 100 female)	81.2	81.3	89.8	82.2	110.8	96.9	117.8	106.3
Household Size	4.6	4.0	3.3	4.9	5.8	5.9	5.9	5.9
Dependency [60] Ratio	na	na	na	na	49.0	61.2	39.5	51.6

There are some spatial variations in the age and sex structures of the population across the ecological zones (Figure 5.2). The proportion of older children (aged 5-14 years) is lower in the Trans-Himalaya sample (10 percent), than in the Tarai (over 15 percent) and the Middle-Mountains (over 16 percent). On the other hand the proportion of adults (aged 30-44 years) is higher in the Trans-Himalaya sample (24.7 percent), compared to 19.4 percent and 18.1 percent in the Tarai and in the Middle-Mountains, respectively. The ever declining population of the Trans-Himalaya [61] is reflected in the sample age structure of population, with a small proportion of young people (Figure 5.2).

[60]Dependency ratio is defined as the ratio between economically active (working age population) mostly aged 15 to 59 years) and non-working population (aged below 15, and 60 and over) adopted by Central Bureau of Statistics, Nepal (CBS 2012b). Though, it has many limitations in terms of economic/livelihoods dependency. For an example, the remittance earners (retired and over 60 years of age) in many cases (retired military of British Gorkhas) may earn more than many of working age individuals and can bear the other dependent.

[61] Manang and Mustang recorded negative population growth rate in the last 2 decades 1991-2001-2011 (CBS 2001; CBS 2012b).

Figure 5.1: Age and Sex Composition of the Population in Sampled Households in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)

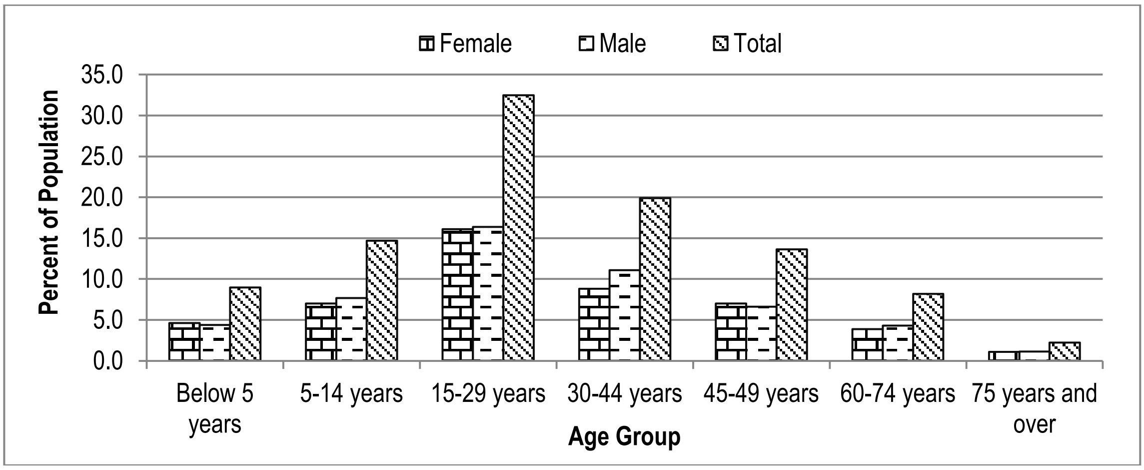
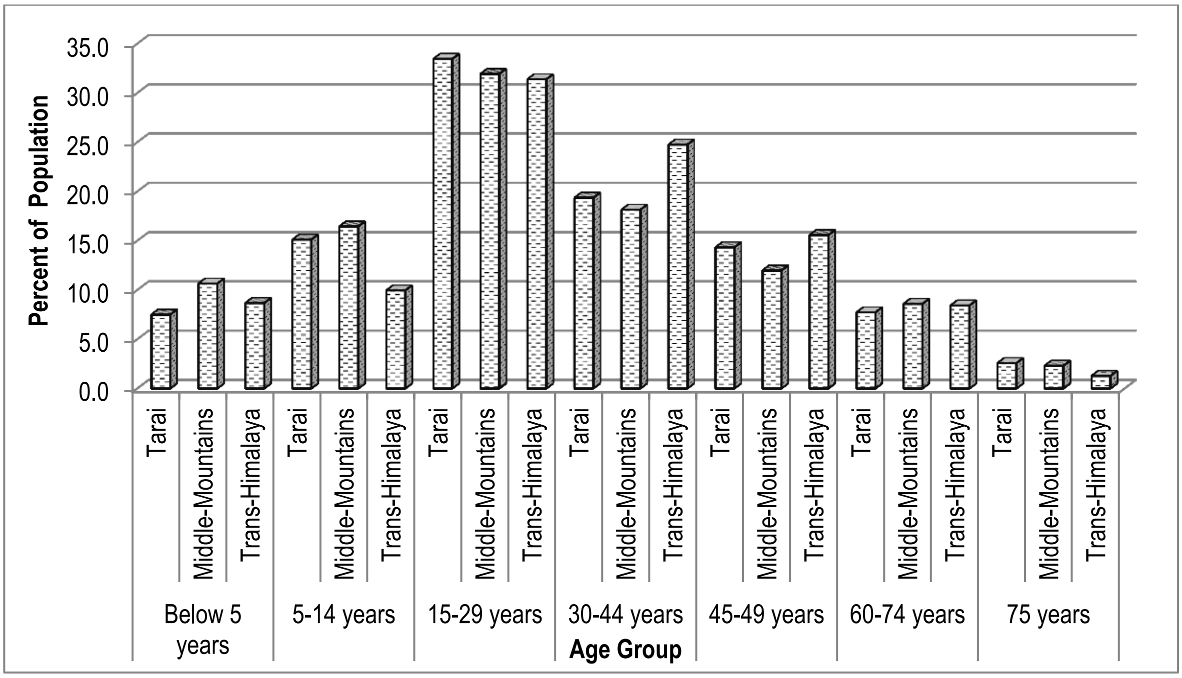


Figure 5.2: Age and Sex Composition of the Population (Sampled Households) by Ecological Zone in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)



The design, adoption and management of adaptation strategies depend on the availability of the households' labour force, especially in agro-livestock livelihood systems (Yeh et al. 2014). Further, the domination of children and elderly, who are more susceptible to climate change-induced health problems (IPCC 2007a; Kjellstrom and Weaver 2009), tend to increase the work, care, and financial (medical costs) burden on working adults (Pandey 2004). However, working age populations of the study area are bearing a higher load of dependents than the national average. On average, each member of the working-age population of the study sample had to bear the livelihood load of more than one another person. For example the total dependency ratio for the study sample was 51.6 persons per 100 persons of working age compared to the national average of 43 person (CBS 2012b), and hence greater pressures are put on the working age population. Yet, the dependency ratios vary spatially, the highest being 61.2 persons in the Middle-Mountains, while the lowest (39.5 persons) was in the Trans-Himalaya (Table 5.1). Better education and skills and the sound health of the population make higher dependency loads feasible through higher incomes.

5.2.1.2 Educational Status

Education is one of the most important determinants of the quality of life. Education and training, and easy access to climate change information are also one of the most effective measures of enhancing adaptive capacity (Cruz et al. 2007). Education is crucial in the search for employment and an educated person generally has multiple livelihood options to improve their lives (Barnett and Adger 2007). In climate change too, educated farmers are more likely to respond to climate change through strategic adaptation (Macchi 2011). However, exclusion from education or being unable to undertake educational opportunities to improve their lives, often fuels conflict and instability (Gurung 2005; Mercy Corps 2003; Pandey 2007; Upreti 2004). Such conflicts damage social capital and severely reduce the knowledge transfer and labour exchange, which is vital in farmers' livelihoods. There are conflicting notions on the contribution of education in farming communities. For example, the herders of Mongolia demanded education and training to improve rangeland and livestock conditions (Batimaa et al. 2007); while in contrast, compulsory education for all children has severely affected the livestock herding activities of pastoralists in Tibet (Yeh et al. 2014), and in Kenya and Tanzania (Eriksen et al. 2005); while the farmers of different villages of Nepal often take their children out of school to fulfil their increased labour requirements (Gentle and Maraseni 2012; Onta and Resurreccion 2011; Oxfam 2009).

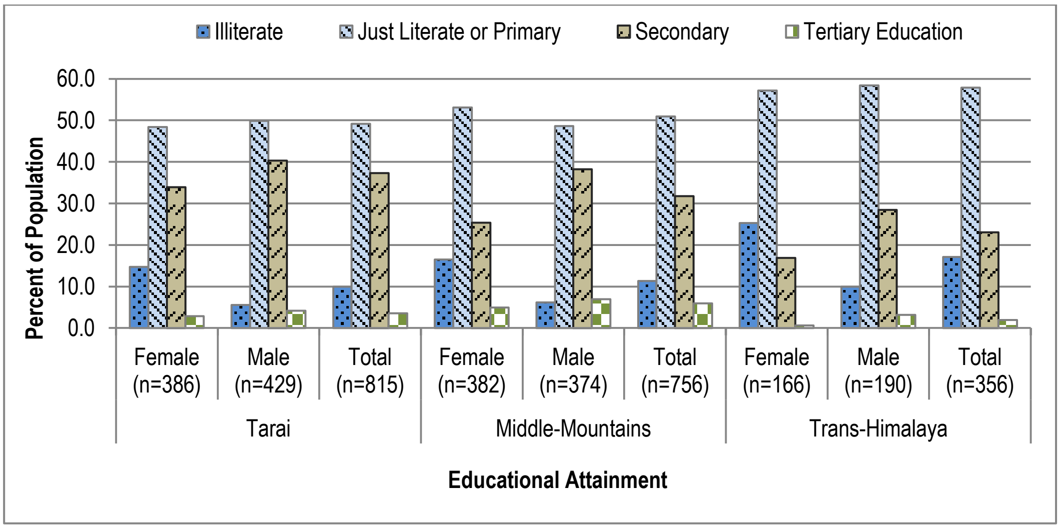
The study sample showed higher literacy status i.e. 88 percent in comparison to the national average of 65.9 percent (CBS 2012b). However, the level of formal education of the respondents was generally low, with the majority (51.5 percent) having received only primary education. The proportion of the sample having secondary and higher secondary education was 32.5 percent, and very few (4.2 percent) had obtained tertiary education. The proportion of female population is lower than that of male particularly in secondary and tertiary levels while it is higher in 'illiterate' level (Table 5.2). However, there are spatial variations across the three ecological zones in relation to levels of educational attainment (Figure 5.3).

Table 5.2: Literacy Status and Educational Attainment by Sex in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)

Educational Attainment	Female	Male	Total
Illiterate	17.3	6.6	11.8
Just Literate or Primary	51.9	51.1	51.5
Secondary	27.4	37.3	32.5
Tertiary Education	3.3	5.0	4.2
Total	**100**	**100**	**100**

The primary-educated proportion is the highest in the Trans-Himalaya (58 percent), followed by the Middle-Mountains (51 percent) and the Tarai (49 percent). In the case of tertiary education, the proportion of graduates is the highest in the Middle-Mountains (7 percent), followed by the Tarai (4.2 percent) and the Trans-Himalaya (2 percent). On average, females have a lower educational attainment than men, particularly in secondary and tertiary levels in each ecological zone (Figure 5.3).

Figure 5.3: Literacy Status and Educational Attainment of by Sex and Ecological Zones in the Kaligandaki Basin, Nepal (among six years of age and over)
(Source: Field Survey, 2013)



It is generally expected that educated and skilled persons can earn other livelihood capitals. However, the educational status of the studied populations is very low. Poor education may be compelling individuals to engage primarily in labour intensive activities (see section 5.2.4.1 and Figure 5.12). Livelihood earnings from labour intensive occupations, however, also depend on the health status of the labourer.

5.2.1.3 Health

'Health is wealth' is a popular saying among people of many different walks of life. Marx (1867) in his essay on 'working day' has interpreted health as a 'commodity' that can be transformed into economic assets. Health bears a significant role in earning livelihoods through labour intensive occupations in Nepal (Pandey 2008). The World Health Organization (WHO 1948 - Preamble to the constitution of the WHO) defines health as “a state of complete physical, mental and social well-being and not merely the absence of disease of infirmity”. Structuralism claims components of political and economic systems (poverty and inequalities, social structure, human activities, and access to healthcare) affect individuals’ health (Gatrell 2002). Better welfare produces good health and poor welfare leads to bad health (Jørgensen 1985). Nepal is well known for high levels of poverty, underdevelopment, and unstable politics for decades that have contributed to poor social welfare and outcomes for its population. In addition, people often suffer from health impacts associated with limited resource access and weather extremes.

Studies have demonstrated increased mortality and morbidity due to extreme weather events: heat stress, respiratory diseases, cardio-vascular diseases, water and food contamination, vector borne diseases, pathogens and parasites, food and water scarcity and displacement and forced migration (Bosello et al. 2009; Chou et al. 2010; Hashizume et al. 2007; Hijioka et al. 2014; Kjellstrom and Weaver 2009). The drivers of health problems can be from secondary effects from extreme weather events, including damage to public infrastructure, or damage to productive systems such as agriculture. South Asia endemically affected by diarrhoeal diseases and cholera, and the spatial expansion of habitat of such waterborne and vector-borne diseases may be driven by changing climates (Cruz et al. 2007; McMichael et al. 2004). Increased breeding and distribution of mosquitoes and spread of associated diseases such as malaria, Kala-azar, dengue fever and Japanese encephalitis, and the higher incidence of water-borne diseases in children of under 5 years of age with the course of climate change have been reported in Nepal (Eriksson et al. 2008; GoN 2004; Oxfam 2009).

Human health is a complicated mechanism. Climate change affects it directly as well as indirectly. In some cases, commonly promoted means of adaptation such as the construction of irrigation systems, hydropower, or water storage and reservoirs may lead to an increase in malaria (Garg et al. 2009). Therefore, health adaptation measures like early warnings and effective responses through reliable weather monitoring, have become part of public health responses in many parts of the world (Ligeti 2004; Sheridan and Kalkstein 2004;Smoyer-Tomic and Rainham 2001). However, in developing countries like Nepal, with inequalities, deprivations, marginalisation, and a poor social security system already limiting peoples’ livelihood options, many have experienced the health impacts of climate change largely in the absence of the preventive measures that have been practiced in the developed countries.

The study sites exhibit many health issues. Out of the total surveyed population (2115), almost a quarter (524) had suffered from poor health in the previous year (Table 5.3). The health problems reported ranged from very common flu and seasonal allergies (in 51 percent of cases) to some chronic health problems associated with the kidneys, heart, lungs, or nervous system. Another 152 individuals (29 percent) suffered from gastro-intestine (diarrhoea, dysentery, worm infestation) health problems. Out of the total population who reported that they were sick, 7.6 percent suffered from health problems related to the kidneys, heart, lungs, or nervous systems.

Gastro-intestinal problems are the major killer of people in the developing world (WHO n.d.), because of the practice of open defecation, poor sewerage management, poor sanitation practice, the communicable nature of gastro-intestinal diseases, and poor quality drinking water. Nepal is not an exception, with 38.2 percent of households in the country still practicing open defecation, and many use pit-latrines (CBS 2012b) which are not covered. Poor management of human faeces not only contaminates surface water, it also finds its way into drinking water, the food chain, and in some cases even milk. Coliform bacteria are frequently reported (OnlineKhabar 2014/03/182750) in the water supplied to many municipalities, including Kathmandu. 'Pasteurized' milk sold in the market place by many dairies in Nepal is found to be highly contaminated by coliform bacteria (Nepalnews.com 20/06/2013). In a situation of contemporary unhealthy environments, a rise in temperature or increased flooding caused by climate change could encourage the rapid multiplication and spread of disease vectors, leading to the increasing severity of gastro- intestinal disease issues.

Health problems in the study area vary spatially (Table 5.3). Despite being cool climate zones, population in the Trans-Himalaya and the Middle-Mountains experienced a higher proportion of gastro-intestinal problems last year, 40.6 percent and 30.2 percent, respectively. The corresponding proportion in the Tarai was 24.7 percent. It is not clear why there was a higher influence of gastro-intestinal problems in the cool climate regions; however, poor sanitation practices might have contributed to it. Further, the prevalence of pneumonia was reported to be higher in the Tarai (4.5 percent) than in the Middle-Mountains (3.3 percent); malaria and dengue fever were only reported in the Tarai; ailments of high blood pressure was identified in all zones with the highest proportion of sufferers in the Middle-Mountains (4.7 percent) likely due to the older age structure of the study population.

Table 5.3: Prevalence of Diseases in the Kaligandaki Basin, Nepal (n=524)
(Source: Field Survey, 2013)

Health Problems	Ecological Zones			Total (n=524)
	Tarai (n=243)	Middle-Mountains (n=212)	Trans-Himalaya (n=69)	
Flu	52.7	49.5	49.3	**51.0**
Gastro intestine	24.7	30.2	40.6	**29.0**
Pneumonia	4.5	3.3	0.0	**3.4**
Malaria and Dengue	2.1	0.0	0.0	**1.0**
High Blood Pressure	2.5	4.7	1.4	**3.2**
Blood Sugar	1.6	1.4	0.0	**1.3**
Tuberculosis	0.8	0.5	0.0	**0.6**
Physical Disability	0.4	3.8	0.0	**1.7**
Chronic Illness	9.1	5.7	8.7	**7.6**
Reproductive Health Problem	1.6	0.9	0.0	**1.1**
Total	**100.0**	**100.0**	**100.0**	**100.0**

The human capital of the study area in general was poor, due to the high dependency rates, low levels of education, and poor health. Poor education and health have challenged the people to benefit from human capital at optimum levels. During the focus group discussions, participants claimed that sick household members not only impacted on labour resource of the sick person, but also on other family members and care givers, and unavoidable medical expenses added to the financial burden. The following section investigates the social capital of the studied households to see whether it can compensate for the limitations of human capital.

5.2.2 Social Institutions and Social Capital

Social capital is the collective value and inclination of social networks that form important asset for livelihoods. Social capital includes both tangible and non-tangible elements of the society that together constitute the social safety net (Adger 2003; Pretty and Ward 2001; Subedi et al. 2007a). Social capital also includes power structures and influences, and patron-client relations, though such capital often risks social exploitation. Households rich in social capital are likely to be more adaptive to climate-extremes and environmental change (Jones and Boyd 2011; Leary et al. 2007). Social capital contributes to adaptation by generating community-based disaster management and preparedness responses (Cruz et al. 2007) so stakeholders can be engaged for proactive problem solving. Such engagements support decision making like what to do, where to go or who will be the host in the case of displacement or forced migration (Adger et al. 2007). An Honduras study found that sustained reciprocal relations, or mutual support promotes adaptation whereas displacement following extreme weather events can generate greated livelihood vulnerability (Wrathall 2012). Driving herds to alternative pasturesowned by neighbours during severe snowstorms has helped Tibetan herdsmen to adapt herding practice (Yeh et al. 2014). Similarly, the engagement of the *Dalits* [62] of North-Western Nepal in the Trans-Himalayan trade with *Lamas* helps to increase cash income and compensate for decreased agricultural production (Onta and Resurreccion 2011).

Social capital consists of both public and private elements and can be particularlyimportant to compensate for the lack of other assets and reduce livelihood vulnerability by lowering transaction costs (Adger 1999; Adger 2003; Adger et al. 2007; Wolf et al. 2010). It is the web of networks that helps transform structures and processes that generates strong social capital. However, in a climate change context, social capital and adaptation processes lack straightforward relations because climate change and weather extremes affect the entire community. The components of social capital are discussed below.

5.2.2.1 Extended Family and Kin/Clan Networks

Links and attachments to extended families and kin/clan are valuable social assets in Nepalese society and different cultures. This study found physical distance between, and economic status of, extended families kin/clan were influencing factors of reciprocal relations. Many respondents have a similar opinion that they are unable to help others because of their own deprivation. Poor households also have little prospect of receiving help, as a respondent stated:

> *"… We are poor so no one helps us. What would they get by helping the poor like us? ..."*

The latter remark reflects that the ability to exchange rather than being solely a recipient, strengthens social capital.

Figure 5.4 shows that over half of the households (53.7 percent) have their kin/clan living within the proximity (in neighbourhood adjoining VDCs), which facilitates the exchange of help and support. By contrast, 10 percent of respondents reported having satisfactory reciprocity despite the kin/clan being located about a day's travel distance by public transport. On the other hand, 7.6 percent of households located at a similar distance, and 5.3 percent of households located within the same neighbourhoods, stated they lacked satisfactory reciprocity. Furthermore, despite being located even further away i.e. in the cities or abroad; 13.3 percent respondents have good reciprocity, so the spatial relationship with mutual support is not simple or linear.

[62] '*Dalit'* is a caste group, considered as the lowest in the social hierarchy in the Nepali society.

Figure 5.4: Distance to Extended Family and Kinfolk and the Status of Help Exchange in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)

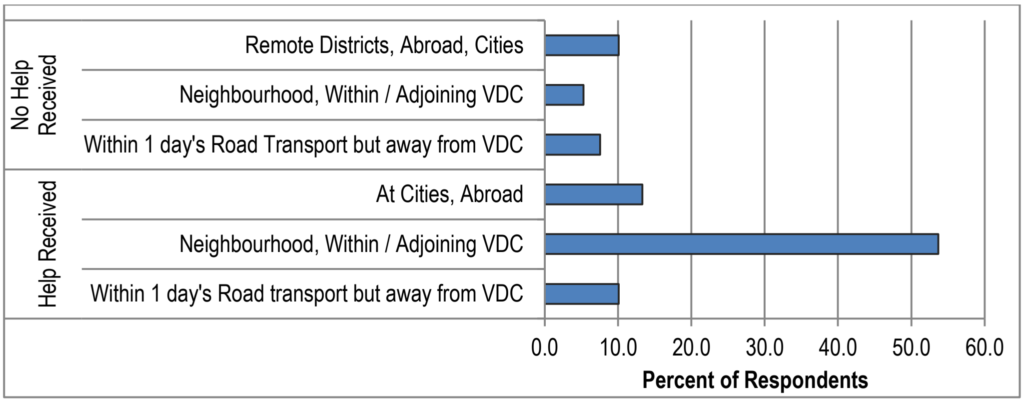
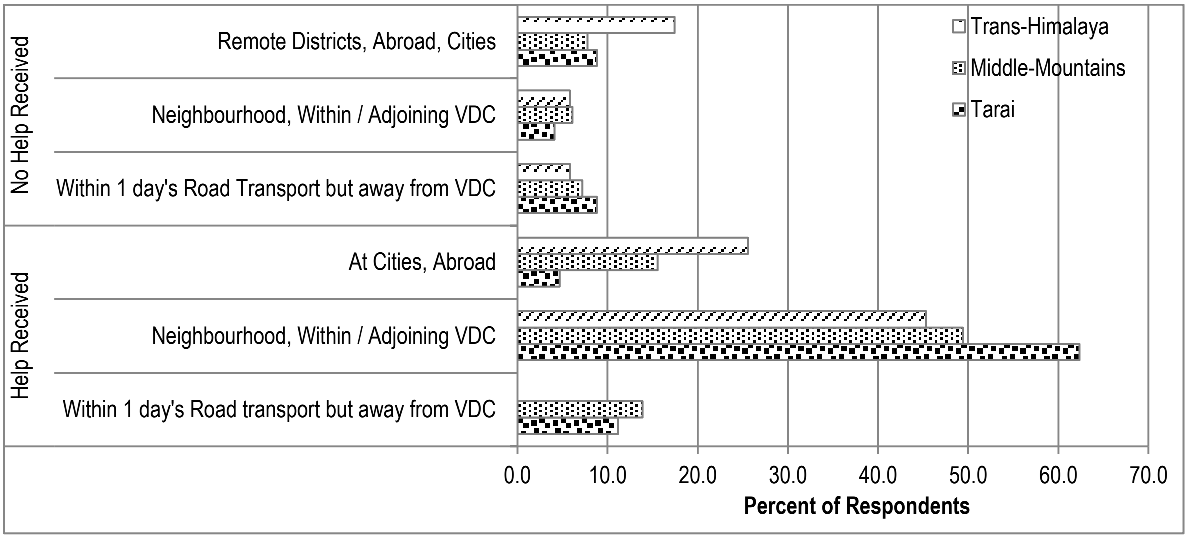


Figure 5.5 shows that both socio-economic and cultural factors influence the reciprocal relationships of clan networks in different contexts and as a result spatial variations are observed across the ecological zones. Over two-thirds of the respondents of all the study sites reported satisfactory reciprocal relations with extended family and kin networks. Among them, a total of 62.4 percent respondents of the Tarai, followed by the Middle-Mountains (49.4 percent), and the Trans-Himalaya (45.3 percent) reported satisfactory reciprocity with the extended family and kin who live in close proximity i.e. within their neighbourhood. Satisfactory exchange of help with the kin living away (in other districts, cities, and abroad) was reported by 25.6 percent respondents of the Trans-Himalaya, as opposed to 15.6 percent of the Middle-Mountains, and only 4.7 percent of the Tarai.

This study noted that the people who have migrated from the area are those kinfolk who have relatively better economic status, and those left behind expected support from them. The in-migrant respondents of the Tarai generally reported that they need to support their kinfolk at their place of origin. The Middle-Mountains and the Trans-Himalaya tended to lack in-migrants, so the respondents of these places revealed that they receive some help from kinfolk who have moved away from the villages, mostly to cities and abroad.

Figure 5.5: Distance to Extended Family and Kinfolk and Status of Help Exchange in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)



5.2.2.2 Neighbourhood Reciprocal Relations

Culture has a remarkable influence on reciprocal relations. Nepal is rich in cultural heritage where different caste and ethnic groups with distinctive cultural values and norms generally live harmoniously together, or in other words, there are not much violent conflicts in relation to social hirarchy observed, although some incidents in relation to caste-based discrimination have surfaced in recent years. However, with broader societal processes including modernization, a decade long internal armed conflict (1996-2006), and political instability thereafter, the cohesive traditional bonds that lead to valuable social capital have been weakening. Notwithstanding these issues, over 90 percent of respondents reported having good reciprocal relations with their neighbours, while 7.2 percent reported that they received support from neighbours only in case of emergencies, and very few respondents (2.5 percent) had not received any help from their neighbours - mostly because of being poor and *Dalit*. There is little spatial variation observed in the reciprocity in neighbourhoods across the ecological zones.

The findings of this study reveal that the social structure and a process of exclusion are regulating the beneficiaries of reciprocal relations. The respondents who belong to the *Dalit* caste group remarked that no one from the upper caste helps them, just because they are *Dalits*. According to them, people who belong to the upper caste think that supporting a lower caste is not an act of pride. This form of discrimination is seen as a fundamental adaptation barrier, especially to *Dalits.* This situation is true in other parts of Nepal as well. For example *Dalits* of Western Nepal are constrained within their traditional occupations and discouraged from seeking alternative livelihoods (Jones and Boyd 2011), generating livelihood vulnerability. Nonetheless, they are struggling to engage in new professions like trans-Himalayan trade (Onta and Resurreccion 2011).

5.2.2.3 Affiliation to Community Based Organizations

Memberships of Community Based Organizations (CBOs) bring a sense of belonging. Such membership increases the scope and broadens the horizon of social networking beyond kinship or cultural links, and enhances the probability of obtaining help in times of need. Many social organizations are identified in the study area; some of them are loosely organized and are ethnically based while others are relatively formal. Table 5.4 shows that members from a total of 299 households (83.1 percent) were affiliated with some sort of CBOs in the study area. The majority of the CBOs include formal Saving and Credit Groups, Mothers' Groups, Resource Management and Beneficiary Groups (forest, irrigation, water supply) and Disaster Management Groups, while there were a few informal ethno-cultural groups, mostly limited within the *Tharu*s of the Tarai, *Gurungs* of the Middle-Mountains and traditional governance system [63] in the Trans-Himalaya.

Some spatial variation was observed in the participation of households in CBOs (Table 5.4). The proportion of households affiliated to CBOs is the highest in the Tarai (92.8 percent), followed by the Middle-Mountains (75.6 percent) and the Trans-Himalaya (74.2 percent). Different members from the households were affiliated to different CBOs, making a total of 367 female and 188 male members, with an average of 1.9 CBO members per household, amongst households participating in a CBO, and 1.4 people per household if all households are considered.

Participation of household members in the CBOs is the highest in the Tarai (1.8 persons per household) and lowest in the Trans-Himalaya (0.9 persons per household). The traditional governance system of the Trans-Himalaya performs similar roles to most of the CBOs elsewhere, so participation in formal CBOs is poor. In all of the ecological zones, female membership is higher; with, for example, almost every village having a Mothers' Group, which covers almost all the households.

[63]Mustang has *GauMukhiya*, who used to collect revenue from the people and pay to the government (this role is not practice at present). At ptesent, they regulate social and justice system, resolve the dispute.*Mukhiya*is chosen by consensus of meeting of villagers. The fine collected becomes a village development fund that is equally distributed to the households as borrowing until sum of money required for specific purpose. The *Mukhiya* in consensus with the villagers specify the crop calendar. As a result, households do not have freedom of sowing or harvesting crops whenever they want.

Table 5.4: Membership in CBOs by Ecological Zone and Sex of Members in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)

Ecological Zones	Male	Female	Total	Members per Household	Membership Percent	
					Yes	No
Tarai	79	196	275	1.8	92.8	7.2
Middle-Mountains	36	131	167	1.2	76.6	23.4
Trans-Himalaya	20	40	60	0.9	74.2	25.8
Total	**135**	**367**	**502**	**1.4**	**83.1**	**16.9**

The analysis of social capital suggests generally rich social capital in terms of its quantity, but the quality aspects are not so evident. Socio-cultural boundaries caused by the poor quality of social capital will negatively impact climate change adaptation, and there has been little rigorous analysis of how that boundary influences adaptation responses (Adger et al. 2007). The available kinship and social networks in the study area may not be sufficient to compensate for the impacts and vulnerability created by exogenous factors like climate change; yet, it will be valuable to mitigate the risk. Natural capital is also a significant livelihood asset that helps generate adaptive capacity in the communities is discussed below.

5.2.3 Natural Capital

Natural capital is the set of environmental resources that supply goods and services for human and non-human life, and translation of natural capital is required for economic progress (Daily 1997; Ekins 2000). Exploitation of natural resources is the primary source of livelihood for farming communities throughout Asia (Haggblade et al. 2010; IFAD 2010), including those studied in Nepal. The livelihoods earned through farming, fishing, and gathering of forest products or use of pastures is all based on natural capital. Among them, agriculture is the key driver of the Nepali livelihood system, and it is strongly influenced by the availability and variety of natural resources and the management abilities of inhabitants. Climate change has negatively impacted natural resource based livelihoods in many parts of Asia (Hijioka et al. 2014). For example, farmland has already suffered from soil erosion, decreased water and land quality, which may cause poor reflection of increased farm input into yielding. In this context, the access to, and control over, natural capital in the study area is discussed.

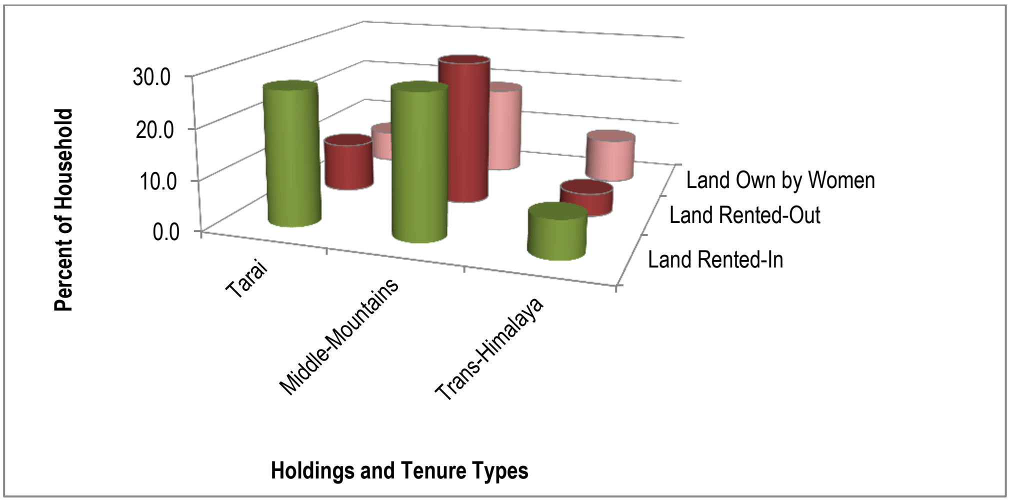
5.2.3.1 Land Capital

Land is the most important natural resource for the rural people of Nepal. Land not only signifies wealth, but also social status and political power. As a result, the clan and lineage of *Jimidar* (large landlords) are still the key political and economic leaders in Nepal (Subedi et al. 2007b).Moreover, land has mediated the attachment of people to place (Jones 1993; Pun 2008), and is linked to culture in complex interrelationship (Tao and Wall 2009). Lastly, land stimulates adaptive capacity. In particular the size and quality of the land resource are strongly influential over farming households' livelihood capacities and abilities to adjust or remain resilient in response to change.

Land Holding

Although land is a vital resource for livelihood security in Nepal, high population densities are placing increasing pressure on land resources. Inheritance practices in the country have given access to land to 70.6 percent of the country's households (CBS 2013). The proportion of households with land in the study area is even higher, with 97.8 percent, or almost all of them having access to land, with fairly comparable proportions across the ecological zones. Access to land ownership for women was limited to only 11.7 percent of households, less than the national average of 19.7 percent (CBS 2012b). Notwithstanding the predominance of owner-cultivator households in the study area, complex tenancy arrangements are also common, with 16.4 percent of households being landlords and 23.9 percent tenants. Most rental arrangements involve only part of a household's land (Figure 5.6).

Figure 5.6: Land Holdings and Land Tenure Status by Ecological Zone in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)



There is little spatial variation in the proportions of households having land under women's ownership, as well as land under different tenancy arrangements (Figure 5.6). A total of 18.4 percent of respondents' households in the Middle-Mountains have land under women's ownership, while corresponding proportions for the Trans-Himalaya and the Tarai are only 9.1 percent and 6.5

percent, respectively. In the case of tenancy arrangement, it is identified that the Trans-Himalayan communities rarely practice tenure exchange [64], while in the Middle-Mountains and Tarai, 29.1 percent and 9.8 percent respectively of households have rented land out, and 28.4 percent and 26.8 percent respectively have rented land in. The landless squatters of the Tarai cultivate land rented from medium and large land holders in the area.

Although respondents generally had access to land in the study area, plot sizes were mostly small. Mean sizes of total operational [65] and owned lands were 0.69 ha and 0.60 ha, respectively, with standard deviations of 0.60 ha (Table 5.5). The areas of land held ranged from holdings without land to 3.42 ha (total operational land), and 3.21 ha (owned land). Mean sizes of both total operational and owned lands are largest in the Trans-Himalaya, followed by the Tarai, and then the Middle-Mountains.

Table 5.5: Descriptive Statistics of Entitled and Owned Land in the Study Area by Ecological Zone in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)

Statistics	Entitled Land in Hectare				Owned Land in Hectare			
	Tarai	Middle-Mountains	Trans-Himalaya	Total (Study Area)	Tarai	Middle-Mountains	Trans-Himalaya	Total (Study Area)
Mean	0.70	0.63	0.73	0.69	0.57	0.52	0.70	0.60
Std. Deviation	0.58	0.56	0.68	0.61	0.57	0.54	0.69	0.60
Maximum	3.85	2.89	3.42	3.39	3.85	2.41	3.37	3.21
Total Land Area	**107.20**	**88.94**	**47.89**	**244.04**	**86.86**	**73.94**	**46.06**	**206.86**

The size of land available to households in the study area was generally insufficient to secure the livelihoods through agro-based activities alone. The quality of land affects farm outputs, however, with better quality of land, combined with irrigation and sufficient growing seasons; it will result in better livelihoods. Therefore, the quality of land is discussed below in terms of cropping intensity and irrigation facilities.

Cropping Intensity

Cropping intensity differs across the ecological zones. Table 5.6 shows the lowest in the Trans-Himalaya, with the major part of farmland in the region under a single crop. The mean size of land held by an individual household under a single crop per year was the largest (0.34 ha) in the

[64] *Mustangi* indigenous governance system does not support changing land-tenure right (entitlement) in general. If a particular household cannot cultivate the farmland that will remain fallow and the user right of irrigation is delisted for corresponding year/season, stated one of the key informants of Zhong VDC.
[65] 'Total operational land' includes both land under the legal ownership and rented-in with operational rights, while 'owned land' refers to the land under households' legal ownership.

Trans-Himalaya compared to 0.14 ha in the Middle-Mountains, and 0.03 ha in the Tarai. By contrast, the mean size of land under two crops per year was the largest in the Middle-Mountains (0.22 ha), while mean size of land under three crops per year was larger (0.45 ha) in the Tarai.

Because of its favourable environment, the Tarai has the highest cropping intensity where on average, three crops could, in an ideal situation, be successfully grown annually, compared to two crops on average in the Middle-Mountains, and in general, one crop in the Trans-Himalaya. In practice, however, many farmers do not fully utilise the available growing season. As a result, actual cropping intensities of the Tarai, of the Middle-Mountains, and of the Trans-Himalaya are 264.4 percent, 183.8 percent, and 138.1 percent, respectively.

Table 5.6: Descriptive Statistics of Crop Land by Ecological Zone in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)

Statistics	One Crop Land			Two Crop Land			Three Crop Land		
	Tarai	Middle-Mountains	Trans-Himalaya	Tarai	Middle-Mountains	Trans-Himalaya	Tarai	Middle-Mountains	Trans-Himalaya
Maximum	1.28	1.45	1.69	2.57	2.17	1.45	3.85	0.96	0
Mean	0.03	0.14	0.34	0.18	0.22	0.21	0.45	0.07	0
Std. Deviation	0.14	0.23	0.47	0.42	0.31	0.40	0.50	0.16	0
Annual Cropping Intensity (percent)							264.4	183.8	138.1

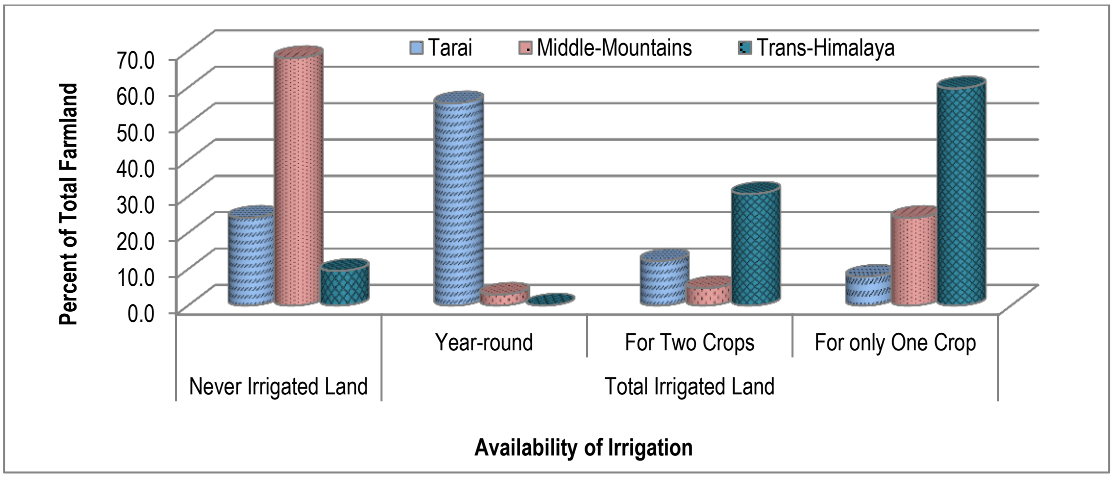
Climate change is expected to increase the growing season in the high altitudes. Some farmers of the Trans-Himalaya reported such an increase by a few days on average. However, this increase is not sufficient for another crop. Nevertheless, they are trying to produce some vegetables in lower land areas during the spare growing season. The reported causes behind not utilising the available growing season fully in the Middle-Mountains and the Tarai was lack of irrigation, wildlife encroachment in the farmland, higher wage of farm labour, and poor farm output compared to the cost of farm input.

Irrigation

The importance of irrigation increases with higher surface temperature, uncertain rainfall, and frequent and intense drought. As farmers have to support large families from relatively small farms, as found across the study zones, the value of irrigation increases sharply. Irrigation is, however, not widely used by everyone in the study area. A total of 64.8 percent of farmland has some irrigation facilities, and less than one-third (28.4 percent) of farmland was under year-round irrigation.

Figure 5.7 shows a large spatial variation across the ecological zones in relation to irrigation use. Since the Trans-Himalaya has only one growing season in general, over 90 percent of farmland is under irrigation during the cropping season. Irrigation in the Tarai is, however, better if considered year-round irrigation or in three crops in a year as 55.7 percent of farmland has year-round irrigation. The availability of private irrigation options in the Tarai resulted in better irrigation in the region. The coverage of irrigation in the Middle-Mountains is poor with only 3 percent farmland having year-round irrigation.

Figure 5.7: Status of Irrigation Facility by Ecological Zone in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)



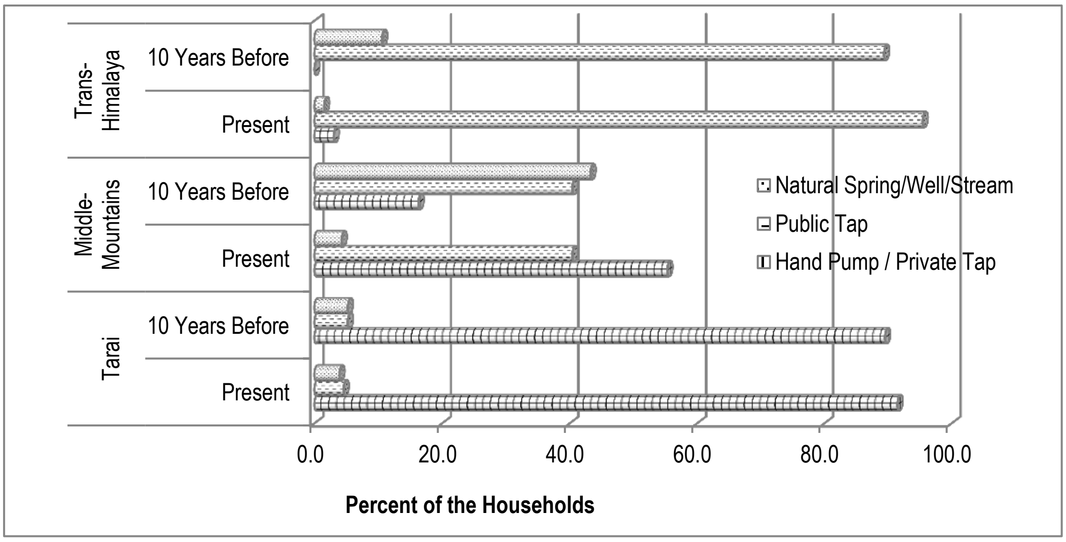
The analysis of the land resource shows its poor status, due to the marginal size of landholdings, which results also in farmers having no farmland. Below, the use of other natural resources such as water, forest, and pasture is discussed briefly to assess their contribution towards rural livelihoods.

5.2.3.2 Water Resource and Use

Water is vitally important for life systems, and its availability for use per capita in South Asia has decreased by a factor of five in the last 60 years (Shah and Lele 2011). It is used for at least three purposes in the study area: domestic use including drinking water, irrigation for agriculture and energy from small hydro-power systems. Groundwater is the main source of water for irrigation and domestic use in the Tarai, but it is likely to be affected by changing rainfall. According to respondents, light rainfall events that support groundwater recharge have almost disappeared in recent years and rainwater from large rainfall events may be lost through surface run-off, although the science of this perception is unclear.

Unlike the Tarai, the Middle-Mountains and the Trans-Himalaya only have surface runoff (streams) for irrigation, and natural springs and streams for domestic use. Out of the total, 41 percent of households in the Middle-Mountains and 94 percent in the Trans-Himalaya use water channelled from nearby streams for irrigation. Figure 5.8 shows just over 55 percent of the households in the Middle-Mountains had private taps, whereas 40 percent of households in the Middle-Mountains and 95.5 percent in the Trans-Himalaya fetch water from public taps for domestic use. In the Tarai, the source of water is mostly ground water.

Figure 5.8: Changes in the Sources of Drinking Water in Last one Decade by Ecological Zones in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)



This study found that sources of water have changed over time in the Middle-Mountains, but have remained almost constant in the Tarai and the Trans-Himalaya. In the Middle-Mountains, the use of water from private taps has increased whereas the dependence on natural springs, wells and stream has decreased in last 10 years. As well as for the irrigation and domestic use, in the Middle-Mountains, water is used to support micro-hydro plants (Lumle 9, Landruk for example).

5.2.3.3 Forest Resource and Use

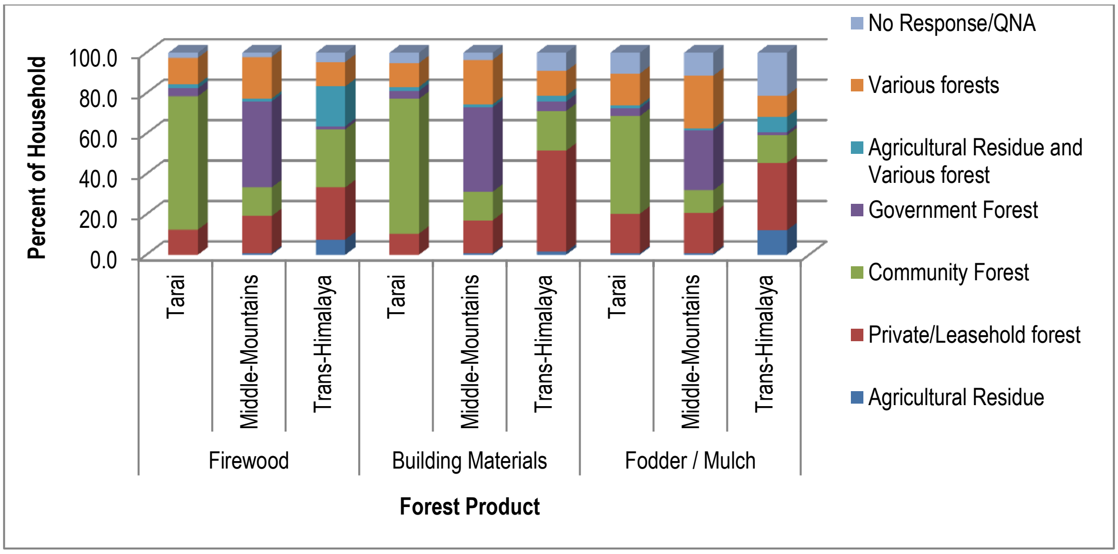
Forests directly support the livelihoods of 90 percent of the 1.2 billion people living in extreme poverty and are home to nearly 90 percent of the world's terrestrial biodiversity (IBRD/WB 2004). Many researchers have noted that ruralfarming households of the Himalaya draw a sizable portion of their livelihood from forest resources (Ephrosine 1994; Koirala 2006; Rijal 2010-2011; Subedi and Pandey 2002). The forest also supports adaptation to climate variability, through the collection and sale of forest products when weather extremes severely affect farming activities. Various forest products such as jungle greens, wild fruits, roots and shoots, firewood, fodder, forage and mulch, and building materials are collected by the studied communities. Also medicinal and aromatic herbs are collected and sold to earn cash. However, it was learned from the Key Informant Interviews (KII) of the Tarai and of the Middle-Mountains, that some forest resources of the regions are not exploited to their potential because the authorities of the Chitwan National Park (CNP) and Annapurna Conservation Area Project (ACAP), restrict access even for what respondents considered to be sustainable levels of collection.

The displacement and exclusion of people by formal conservation processes and restricted user rights, have already affected the livelihoods of forest resource dependent poor people and will continue to do so in the future in various parts of the globe (Cernea 2005). The changing climate is impacting upon the range and abundance of plant species globally, which has increased disease vectors (Rosenzweig et al. 2008), and has affected human wellbeing and natural resource productivity in association (Adger 2010). Such issues are common in Nepal, including in the study area. The participants of the Focus Group Discussion (FGD) stated that protected areas rarely give the opportunities for them to benefit from the forest resources. Yet, there is the possibility of conserving nature as well as alleviating poverty (CBD 2010; Wells and McShane 2004), through ecosystem-based adaptation to ensure the livelihood sustainability of farming households (Colls et al. 2009). However, the conservation programs and associated constraints on natural resource exploitation are imposed largely on people, who are marginalised, poor, and powerless (Agrawal and Redford 2009). The National Parks and Conservation Areas cover almost 20 percent of the total area of Nepal; the proportion doubles the global target of 10 percent needing protection (World Conservation Union 2003). Therefore, the conservation approach is seen to be causing severe erosion of the agro-livestock livelihood system of the Himalaya. However, the claims of local people to regain entitlement over their livelihood resources are suppressed (Pandey 1998; Pun 2008; Pun et al. 2010). Shrestha and McManus (2008) also reported underutilised forest resources, largely because powerful actors emphasise protection-oriented management that resulted in local poor people getting few benefits.In the context of a lack of access to forest resources, respondent households gathered firewood, fodder, forage, and building materials from private land or buy from vendors.

Figure 5.9 shows the sources of forest product that communities arrange. Community managed forests provide an alternative to public forest for two-thirds of the households of the Tarai for access to firewood. The corresponding proportion is 14.2 percent for the Middle-Mountains and 28.8 percent for the Trans-Himalaya. Despite the forest of the ACAP not having been declared a 'community forest'; some households of the Middle-Mountains (14.2 percent) consider it to be so, while 42.6 percent treat it as government forest.

The Trans-Himalaya is mostly semi-arid so there is only a small amount of natural forest (alpine needle-shrubs). As a result, a higher proportion of households rely on agricultural residues and on private forests for fodder, forage, firewood, and building materials. Households relying on private forest and agricultural residue are minimal in other places. Nevertheless, households of all studied sites relied on multiple sources for a range of forest products.

Figure 5.9: Proportion of Households Relying on Different Sources for Various Forest Products by Ecological Zone in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)

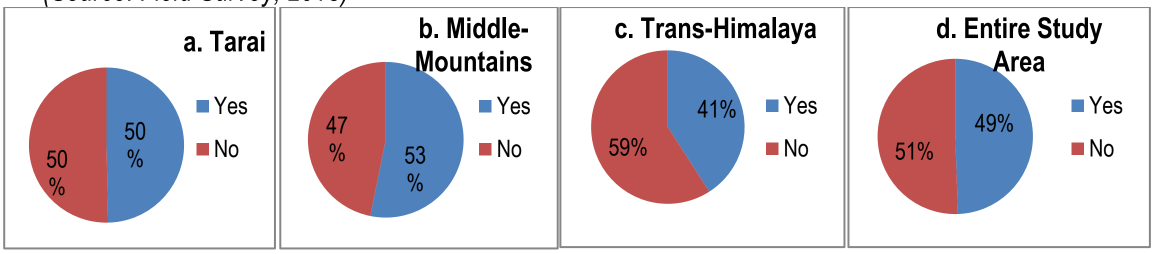


The collection of forest foods, especially green vegetables is deemed to be an important climate adaptation process, since it provides dietary supplements when households lack sufficient food supply and/or nutrition (Eriksen et al. 2005). The study area is rich in terms of the availability of forest greens, fruits, medicinal and aromatic plants. However, many factors limit their collection including: firstly restricted access to conservation areas; secondly, risk of wildlife attack in the Tarai, and thirdly, leeches in the Middle-Mountains. There is also a risk of none-edible varieties being collected and consumed. Edible and non-edible varieties are differentiated based on traditional knowledge and practice, which sometimes can be very hazardous [66].In the Trans-

[66]Wild mushrooms killed 14 in Eastern Nepal – Ilam, viewed 15 March 2015<http://www.news24.com/xArchive/Archive/Wild-mushrooms-kill-14-in-Nepal-20010606>; poisonous mushrooms killed 10 in western Nepal-Palpa, viewed 15 March 2015<http://www.island.lk/2005/07/27/world7.html>; mushroom poisoning: toll 6 in Central Nepal – Chitwan (The Himalayan Times 2 June 2010); mushrooms killed two kids in Eastern Nepal-Sankhuwasabha (The Kathmandu Post 10 June 2008); mushrooms kill three children in Western Nepal-Dailekh (Kantipur 24 July 2011).

Himalaya, the harsh climatic conditions and limited availability of edible items reduces the scope for collecting greens and fruits. The region is, however, rich in medicinal and aromatic forest products. Across all of the studied regions and in total, approximately half reported their engagement in collection of edible forest products (Figures 5.10 a, b, c and d).

Figure 5.10: Proportion of Households Engaged in Collection of Greens and Foods from the Forest in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)



The varieties of forest products collected in the study area are generalised into 5 groups: 1) greens and leafy vegetables [67], 2) vegetables [68] (fruits and shoots for curry), 3) fruits [69], 4) spices [70] and 5) Medicinal/aromatic plants [71]. Out of the total, 46.9 percent respondents have reported the collection of greens and leafy vegetables in the study area. After greens, 32percent of households collect vegetables, 8.6 percent collect fruits, 5.6 percent collect spices, and 6.9 percent collect medicinal and aromatic plants.

There is some variation across the ecological zones in the observed proportion of households collecting different types of forest foods (Figure 5.11). Spices and medicinal and aromatic plants are collected mostly in the Trans-Himalaya. A total of 23.6 percent of households collected spices and 32.7 percent collected medicinal and aromatic plants there. Despite the wide availability of vegetables in the forests of the Tarai, few households collected them because of a risk wildlife attack, as well as the risk of being suspected of being a wildlife poacher or timber/firewood collector by park security.

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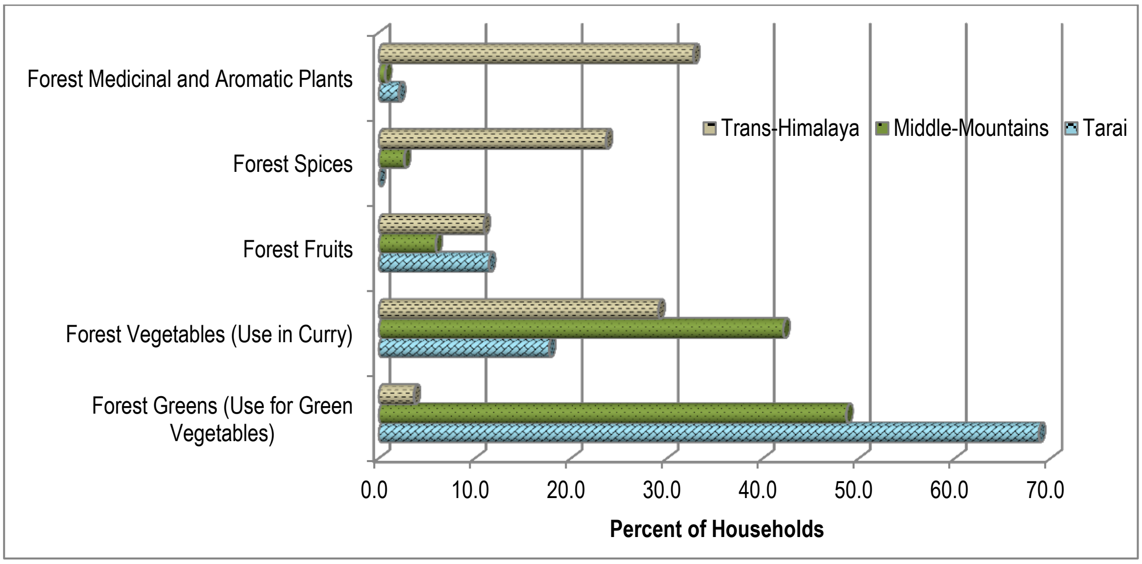
[67]Greens leafy vegetables include but not limited to: *nyuro* (fiddlehead ferns), *sisnu*(stinging nettle), *jaluka*(wild taro), *pindar*(*Xeromphis uliginosa*), *halhale*sag (wild spinach), *kholesag*(watercress), wild buckwheat leaves, and *jibre*(*ophioglossum reticulatum*)
[68]Vegetables include but not limited to:mushroom, bamboo shoot, asparagus, wild yam, *parbar*(pointed gruid/patol), *chattela*(indian gourd, kantola shoots**)**, *karela*(bitter gourd), *githa*(air potato), *bhyakur*(chush-cush yam)
[69]Fruits include but not limited to:*bayar*(bead plum/chinese date**)**, *badahar*(*Artocarpus lakoocha*), *aaiselu*(wild raspberry), *kafal*(bay berry), *chutro*(bar berry), *okhar* (wall nuts**)**, *katus*, (chestnut), apple, apricot, peach
[70]Spices include but not limited to:wild garlic, *jimboo*, *lapsi*(*Choerospondias axillaris*), *timur*(Nepal/red pepper)
[71] Medicinal, aromatic plants/fruits include but not limited to: *ritha*(soapnut), *kusum*(*Cleistocalyx operculata),* cinnamon, *yartsagunbu*(caterpillar fungus: *Ophiocordyceps sinensis*)

Figure 5.11: Proportion of Households Collecting different Forest Resources by Type and Ecological Zones in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)



The study has demonstrated that the statuses of various natural capitals available to the households are generally weak considering that most households still depend on them for their livelihoods. Yet, only portions of the livelihoods of the communities are derived from natural capital. The next section discusses financial capital to see if it can compensate for the inadequacy of natural capitals for livelihood security.

5.2.4 Economic / Financial Capital

The economic status of any household, community, or country has relationships with both climate change impacts and adaptation responses. The poor and marginalised are generally affected the most by any hazards, including climatic ones, in part because they can afford only hazardous places to live and often hold insufficient resources to absorb shocks or adapt to change (Dasgupta 1995; Fitzpartrick and LaGory 2000; McCarthy et al. 2001; Kasperson and Kasperson 2001). Hence, financial capital is a very important resource to facilitate both adaptation to climate change and to create a safety net mechanism to cope with extreme weather events (AfDB et al. 2003; Burton et al. 1993; Cannon 1994).

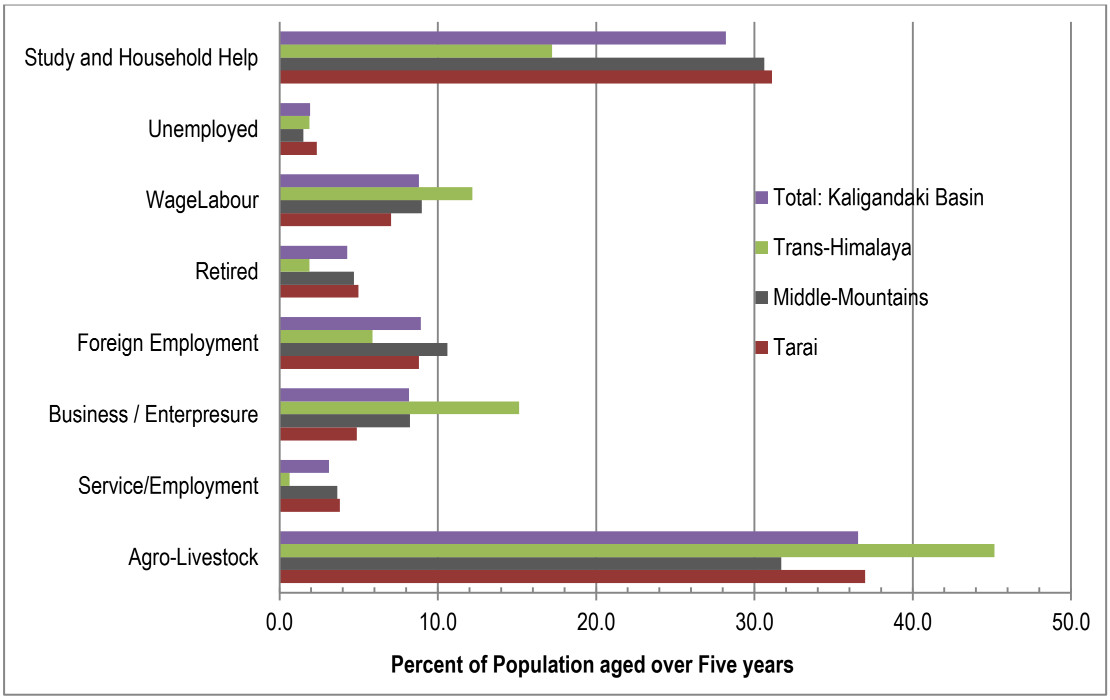
Economic poverty in rural Nepal is acute. Hence, an analysis of the financial capital of the studied households is an important aspect of livelihood research. It is also important in a climate change context because it will generally act to exacerbate poverty and inhibit economic growth, especially in marginal rural areas of developing countries (Beg et al. 2002). On the other hand, increased economic growth of emerging economies of Asia has expanded consumption and carbon emissions, creating new challenges for climate change mitigation (Jiang et al. 2000). Financial capital includes the stocks and flow of money: loan, deposits, and shares, access to financial markets, incomes and remittances. It also contains other convertibles and precious metals like gold, silver, and gemstones - diamonds, pearls, ruby, quartz and topaz. In addition, livestock and household possessions are also the store of wealth that generates income through the production and sale of dairy products, wool, and draught-power, and buffers against bad times in rural areas, including Nepal (Ellis 2000; Pun et al. 2010; Subedi et al. 2007; Subedi and Pandey 2002). However, in the context of adaptation to climate change, there is great uncertainty about the impacts upon, and roles of, financial capital (Hijioka et al. 2014). Below, various elements of financial capital possessed by households in the study region are discussed.

5.2.4.1 Occupational Status of Population

Himalayan livelihoods generally rely upon a range of on-farm and off-farm activities. Scholars have observed a complex combination of options adopted by poor households of the Himalaya to generate income (Subedi 2007; Tao and Wall 2009). Respondent households also exploited multiple sources of livelihoods; however, Nepali societies have a typical characteristic of reporting 'farming' (*Krishi*) as their principal occupation even if farming contributes a small share to their livelihoods. The overwhelming majority of households have land of a marginal size: 97 percent own less than 2 ha, and of them 52 percent own less than 0.5 ha. The national average is similar with 52 percent of the Nepali households owning less than 0.5 ha and 95 percent owning less than 2 ha (CBS 2013). However, even though it contributes little to their livelihoods, most people want to keep land as a safety net (Subedi et al. 2007b). In such contexts, households adopt multiple livelihood strategies.

The diversification of livelihood options is an important aspect of coping and adaptation. Figure 5.12 shows occupational status of the studied population. Among the options, a combination of cropping and livestock is adopted by 36.6 percent population, while those engaged in activities supplying cash income (wage labour, business/enterprises and foreign employment) was a little over 8 percent. A significant part of the population, mostly the young, are studying as well as helping with household chores. Although such help may not be accounted as an income generating activity, engagement of students and minors in household chores is typical in Nepali rural households that make it possible for working adults to allocate time for outdoor work and generate income or resources (Onta and Resurreccion 2011; Subedi et al. 2007a; Pun et al. 2010). For example, 28.2 percent of the sampled population (above 5 years of age) are full-time students; however as they help with household chores, their assistance makes a significant contribution to sustain agro-based livelihood systems in the study area.

Figure 5.12: Occupational Status of Population by type of Occupation and Ecological Zones in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)



There is some evident spatial variation across the ecological zones in the proportion of population engaged in various occupations (Figure 5.12). The highest proportion of the population of the Trans-Himalaya (45.2 percent) is engaged in agro-livestock activity, compared to 37 percent in the Tarai and 31.7 percent in the Middle-Mountains. With ongoing modernization, changes have already been taking place in the traditional landscape of the *Tharu* communities of Tarai, where strong familial ties, societal cohesion, and the high dependence on agriculture and land are all weakening (Pun 2008; Pun et al. 2010). As a result, some *Tharus* households have already started hospitality businesses (home stay tourism) and many young people have already migrated abroad for work, even though the *Tharus* people used to be known as 'the Sons of the Land' (*Bhumi Putra)*.

The proportion of the population engaged in paid labour is the highest in the Trans-Himalaya (12.2 percent) followed by the Middle-Mountains (9 percent) and Tarai (7 percent). The larger tourism industry in the Middle-Mountains and in the Trans-Himalaya has resulted in higher proportions of the population being engaged in business/entrepreneurship (8.2 percent in each). Population going abroad as migrant labour was the highest (10.6 percent) in the Middle-Mountains, followed by the Tarai (8.8 percent) and the Trans-Himalaya (5.9 percent). These rates are markedly higher than the national average of 0.07 percent [72], although the low national figure is probably the result of poor recordings, as it is known that many Nepalese do seek work abroad informally (Pandey and Adhikari 2013).

The proportion of population engaged in household chores is lowest (17.2 percent) in the Trans-Himalaya compared to over 30 percent in the other two regions. This probably reflects poor educational attainment in the remote Trans-Himalaya, resulting in prospective students participating in the labour force.

5.2.4.2 Stock and flow of Monetary Assets

Financial capital, especially cash income that can be transformed into forms of livelihood assets, is highly desirable for supporting climate change adaptation (Eriksen et al. 2005). Savings, investments and indebtedness are all financial indicators of financial capital. It was found in the Kaligandaki Basin however, that the stock and flow of monetary assets is relatively weak. Very few households (3.9 percent) have invested financial resources in productive sectors. On the other hand, one-third of households have taken a loan to support livelihoods and were indebted at the time of the study, which could be considered a risky livelihood strategy for those who hold limited productive assets.

Table 5.7 shows that descriptive statistics in debt and investment levels across the ecological zones. The large differences in standard deviation indicate intra-household variability in financial resource mobilization. The mean amount of debt is highest in the Middle-Mountains (NPR 405K), coinciding with the largest deviation of NPR 1361K. In the Tarai, the mean amount of debt is NPR 189K and in the Trans-Himalaya, it is relatively small (NPR 53K).

Table 5.7: Descriptive Statistics of Indebtedness and Investment by Ecological Zone in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)

Sector	Places	HH	Minimum	Maximum	Mean	Std. Deviation
Indebtedness	Tarai	53	2000	800000	189641.5	174164.9
	Middle-Mountains	56	1600	10000000	405796.4	1361188.3
	Trans-Himalaya	9	20000	150000	53333.3	47169.9
Investment	Tarai	3	10000	600000	303333.3	295014.1
	Middle-Mountains	11	30000	4000000	1347272.7	1686962.3
	Trans-Himalaya	0				

[72] 1 labour migrant: 1445 inhabitants (World Bank Database as cited in <http://www.ulandssekretariatet.dk/sites/default/files/uploads/public/PDF/LMP/nepal_2013_final_web.pdf>viewed on 19 October 2014.

Very few households (only 3 in the Tarai and 11 in the Middle-Mountains) have made any capital investments apart from on their own lands. Nevertheless, the standard deviation indicates huge variation in invested amount (Table 5.7).

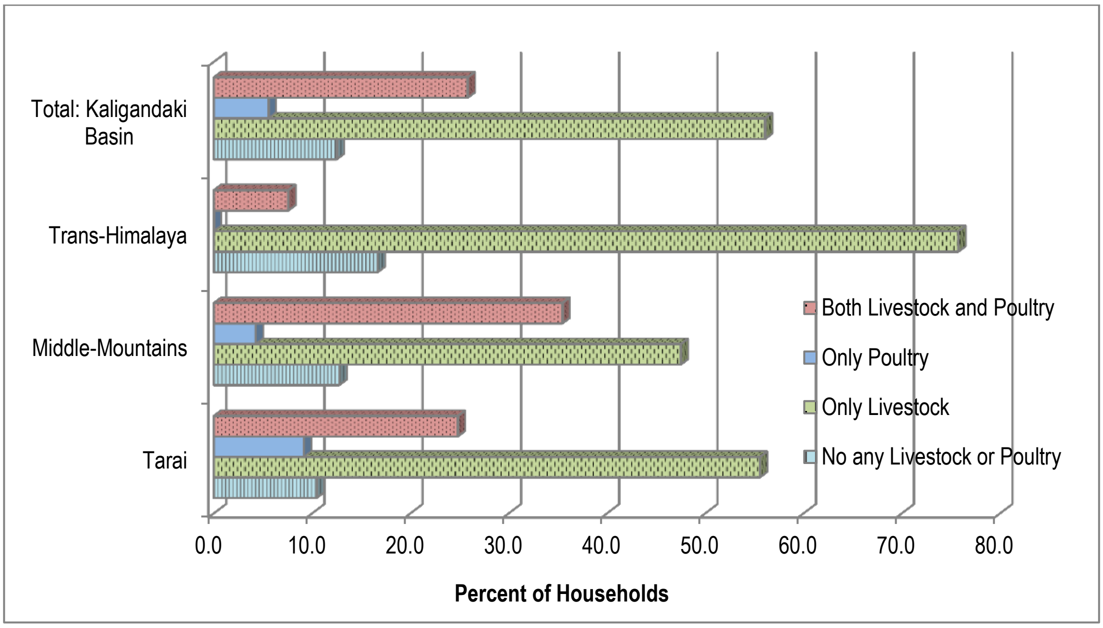
5.2.4.3 Livestock and Poultry

Livestock such as cattle, buffaloes, goats, sheep, as well as poultry, are an integral part of livelihoods in farming communities. Livestock supplies dairy and meat products for domestic consumption; supplies manure for better farm production; and earns cash through draught power. Selling livestock for cash is also a common coping strategy for rural poor households during periods of livelihood stress (Davies et al. 2008; Subedi and Pandey 2002). A lack of livestock can act to trap poor people in chronic poverty cycles (CPRC 2004; World Bank 2001).Figure 5.13 shows most households in the study area keep livestock and poultry, with others (56.1 percent) only kept livestock, and a quarter kept both livestock and poultry. The rest (12 percent) did not have any livestock and poultry. There is a spatial variation in animal husbandry across the ecological zones as shown in the Figure 5.13.

The proportion of households only keeping livestock was highest in the Trans-Himalaya (75.8 percent), followed by the Tarai (55.6 percent), and the Middle-Mountains (47.5 percent). On the other hand, the proportion of households keeping both livestock and the poultry was the highest in the Middle-Mountains (35.5 percent), followed by the Tarai (24.8 percent) and the Trans-Himalaya (7.6 percent). Figure 5.14 shows spatial variation by types of livestock. The differences are strongly influenced by the area's climate, the adaptability of the livestock types and the usability of livestock as draught power. Trans-Himalayan households mostly keep cows, mountain goats, sheep, horses and mules, and Yaks/*Jhocpos* [73]. Horses and mules are the means of transportation in the Trans-Himalaya so they earn cash to support livelihoods. The Tarai has the largest number of poultry; mostly in commercial poultry farms. Male buffaloes in the Tarai are used as draught power, while Middle-Mountains hold a larger number of buffaloes and oxen.

[73]*Jhocpo* is a cross breed of cow and yak that can adapt in high altitude as well as lower altitude 3000 to 3900 masl.

Figure 5.13: Proportion of Households with Livestock and Poultry by Ecological Zone in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)



Poultry, goats and sheep are major sources of cash income [74]. Higher numbers of goats and/or sheep substantially increase the economic status of a household [75]. However, livestock are sensitive to climatic events, and are directly affected by heat stress, the quality and quantity of available feed, availability of water, diseases and pathogens, and many more indirect impacts (Thornton et al. 2009). Yeh et al. (2014) reported snowstorm related deaths of over 80 percent of livestock in the Tibetan pastoralists; that is a common problem also in the Trans-Himalaya, according to FGD participants. Livestock is typically not insured in the study area so this form of wealth creation is not risk free.

Changes in grassland and grazing conditions, institutions and governance for pasture management, and resource entitlements, also impact on livestock health (Yeh et al. 2014). The research participants of the Tarai and the Middle-Mountains have reported a peculiar experience of livestock dynamism both in terms of numbers and types due to nature conservation programmes, and the effect of climate change in the availability of fodder and forage. There was a high level of consensus amongst respondents that the contribution of livestock to household livelihoods is continually eroding.

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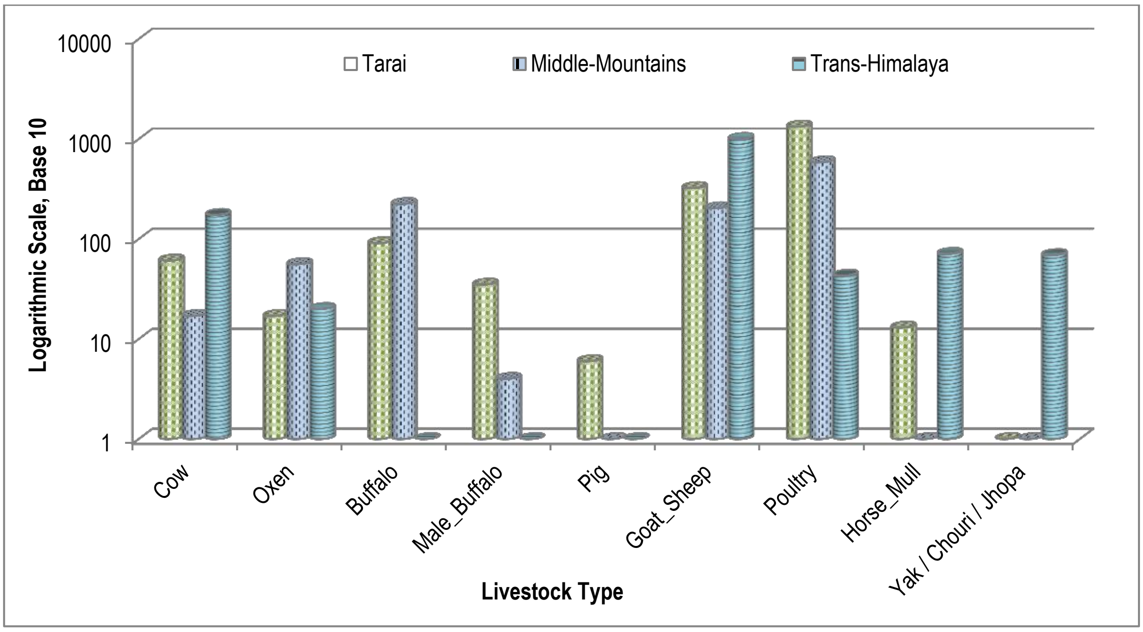
[74] The local free range chicken meat costs more than NPR500 ($6)/kg and the male goat (mutton) costs over US$7/kg, a milking buffalo costs about NPR60000 ($650), and a high breed milking cow costs about NPR80000 ($850).
[75] Some of the households in the Trans-Himalaya own over 250 mountain goats, an accumulation of about 3.75 million Nepalese Rupees (US$37500), which is quite big in the context of Nepalese rural households.

Figure 5.14: Number and Types of Livestock Kept by Households by Ecological Zone in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)



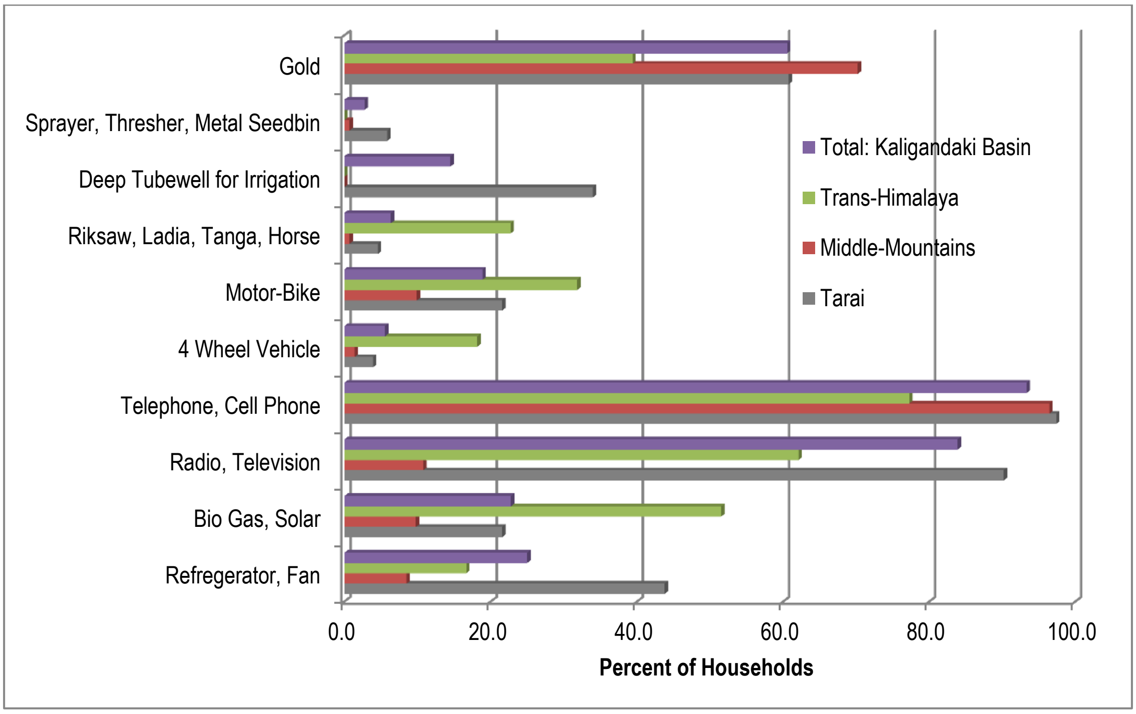
5.2.4.4 Household Possessions and Valuables

Possession of household appliances and valuables contribute significantly to household livelihood security. As well as making the domestic environment comfortable, some of the appliances support adaptation to climate change; some increase household income by hiring them out, and others increase or strengthen the social network by sharing amongst households. Figure 5.15 indicates the possessions and valuables are categorised by 9 types [76]. One quarter of households in the study area possessed refrigerators and fans as cooling devices. However, refrigerators are mostly for commercial use, primarily by grocery stores and hotels. A total of 22.8 percent of households had invested in alternative energy like solar and biogas; 83.9 percent had a radio and/or television. Despite poor network coverage in many places, 93.3 percent of households possessed a cell phone, while only very few households (5.6 percent) had income-generating vehicles such as buses, trucks, vans, tractors, and jeeps; although almost one-fifth (18.9 percent) possessed a motorcycle or scooter, for private transportation. Motorcycles have become popular on unpaved country roads, especially among young people, because they are cheaper than four-

[76]Alternative energy (Bio Gas, Solar), means of information and entertainment (Radio, Television), means of communication (Telephone, Cell Phone), means of motorised transportation (Four Wheel Vehicle), means of non-motorised transportation (Rickshaw, Ladia, Tanga, Horse), irrigation equipment (Shallow Tube well and motor/pumping set), farm-equipment (Sprayer and Thresher), and valuable metals (gold).

wheel vehicles and perform well in rough, high gradient rural-roads. Furthermore, a little over 60 percent household possessed very limited amounts [77] of gold.

Figure 5.15: Possession of Household Appliances and Equipment by Types and Ecological Zones in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)



Some spatial variations across the ecological zones in the possession of household appliances are indicated in Figure 5.15. The proportion of households having a fan or refrigerator was the highest (43.8 percent) in the Tarai where it is hotter on average, and alternative sources of energy (solar) are installed in 51.5 percent of households in the Trans-Himalaya, 21.6 percent in the Tarai and 10.6 percent in the Middle-Mountains. However, solar energy in the Trans-Himalaya is only for the purpose of water-heating using an inverse umbrella device (Plate 5.1).

In the Tarai, 90.2 percent of households have a radio or television, followed by the Middle-Mountains (87.2 percent) and the Trans-Himalaya (62.1 percent). The proportions of households having a cell phone are similar in the Tarai and the Middle-Mountains, but are relatively less important in the Trans-Himalaya where the network coverage is limited. It was interesting that the highest proportion (18.2 percent) of households with a motor vehicle was in the Trans-Himalaya, due to the recently constructed rural roads, which have increased the scope of transportation enterprises, more households in the Trans-Himalaya had invested in tractors and jeeps.

[77] Little over 32% possess only one *tola,* 28.4% hold 2 *tolas* and 39.5% have three *tolas* and more gold (*Tola* is a unit of measurement for the valuable metals in Nepal. One *Tola* is approximately weight 11.5 grams.

Plate 5.1: Use of Solar Energy for Water-heating Purpose in the Trans-Himalaya, Nepal
(Source: Field Survey, 2013)

A motorcycle is a more convenient vehicle for the Tarai due to region's flat surface. However, recently constructed unpaved rural roads and poor access to public transportation have also increased the scope for motorcycles in the Trans-Himalaya. Consequently, 31.8 percent of households in the Trans-Himalaya, as opposed to 21.6 percent of the Tarai and 9.9 percent of the Middle-Mountains possess them. Some of the respondents of the Trans-Himalaya stated that horses are being replaced by motorcycles, especially amongst the younger generation. The participants of the FGDs in all zones indicated that motorcycle, mobiles, and money have diverted the younger generation from agro-livestock activities. The key informants from the Trans-Himalaya stated that as motorcyclists cannot drive livestock herds, the size of grazing herds have decreased. A similar problem in Tibetan pastoralists' communities has been reported by Yeh et al. (2014).

Many farms lack modern farm equipment. Although a reasonable proportion of households in the Tarai have a shallow tube-well (bore) for private irrigation, it is seldom accompanied by a pumping-set or motor. In the context of rural livelihoods, both available assets and confidence to deal with circumstances, play a crucial role in providing readily available resources to support independent adaptation to climate change. Confidence, however, is difficult to measure. Self-perception of economic status, discussed below, provides some indication of the level of confidence in local peoples' own capacities.

5.2.4.5 Self-Perceptions on Economic Status

Table 5.8 illustrates perceived economic status of studied households. A predominance of middle-class, followed by poor and upper-middleclass is the perceived economic status of the households of the Basin. Few of the households reported themselves as affluent (only 2 households), or ultra-poor (6 households) out of the total 360 households. There is no marked difference in the proportions of poor and middle-class households across the ecological zones, and little difference exists in the perception of upper-middleclass status.

Table 5.8: Self-Perception of Household on Economic Status in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)

Economic Status	Tarai	Middle-Mountains	Trans-Himalaya	Total
Rich / Affluent	0.0	0.7	1.5	0.6
Rich / Upper Middle class	10.5	8.5	3.0	8.3
Middle class	69.3	71.6	75.8	71.4
Poor	19.0	17.0	18.2	18.1
Ultra Poor	1.3	2.1	1.5	1.7
Total	**100.0**	**100.0**	**100.0**	**100.0**

Multiple occupations adopted by household members across the case study zones are a positive aspect of livelihoods in some regards, as the complexity provides resilience if one income source fails. So far the discussion has focussed on the capitals wholly in the private domain: human, social, natural and financial. The following section considers physical capital, which can be both private and public, to see if it can compensate for inadequate levels of the other capitals.

5.2.5 Infrastructures and Physical Capital

Physical capital mostly denotes public utilities and infrastructure and main elements relevant to the study are: roads and transportation, schools, water supply and sanitation provisions, health facilities, and other extension services like agro-veterinary service centres and farm-product marketing mechanisms. Accessibility to and reliability of physical capital affect the local economy, social capital and livelihoods (Subedi et al. 2007a), which further influences the capacity of communities to adapt to climate change (Adger et al. 2007; Biggs and Watmough 2012; Pielke et al. 2007). Physical capital is important in the climate adaptation process; ‘climate-proofing’ physical capital is highly recommended (AfDB et al. 2003). Apart from public utilities and infrastructure, private houses and residential arrangements, and their productive use can also be included as physical capital, which status is briefly discussed below.

5.2.5.1 Housing and Residential Arrangements

Housing is more than a home-space or shelter: ownership of a house brings social prestige in Nepal. Although houses can be used as economic spaces to support livelihoods by running micro-enterprises, as such is relatively rare in the study area. Table 5.9 shows that most households (96 percent) own a private house, which is more than the national average of 85.3 percent (CBS 2012b). The dominant construction material is "non-concrete" (73.6 percent), and two-thirds of houses are two-storey.

The proportions of households with private housing are fairly similar across the ecological zones. The proportion of concrete houses was the highest (22.9 percent) in the Tarai in contrast to 6.4 percent in the Middle-Mountains and 4.5 percent in the Trans-Himalaya. Houses with two or three-storey buildings is largest in the Trans-Himalaya [78] (75.8 percent), followed by the Middle-Mountains (70.2 percent) and the Tarai (59.5 percent). Interestingly, despite the need for multi-storey houses in the Tarai so that they are safer from floods, such housing is rare because of the higher costs of construction.

Table 5.9: House Ownership, Building Types, and Storeys in the Houses in the Kaligandaki Basin, Nepal (in Percent)
(Source: Field Survey, 2013)

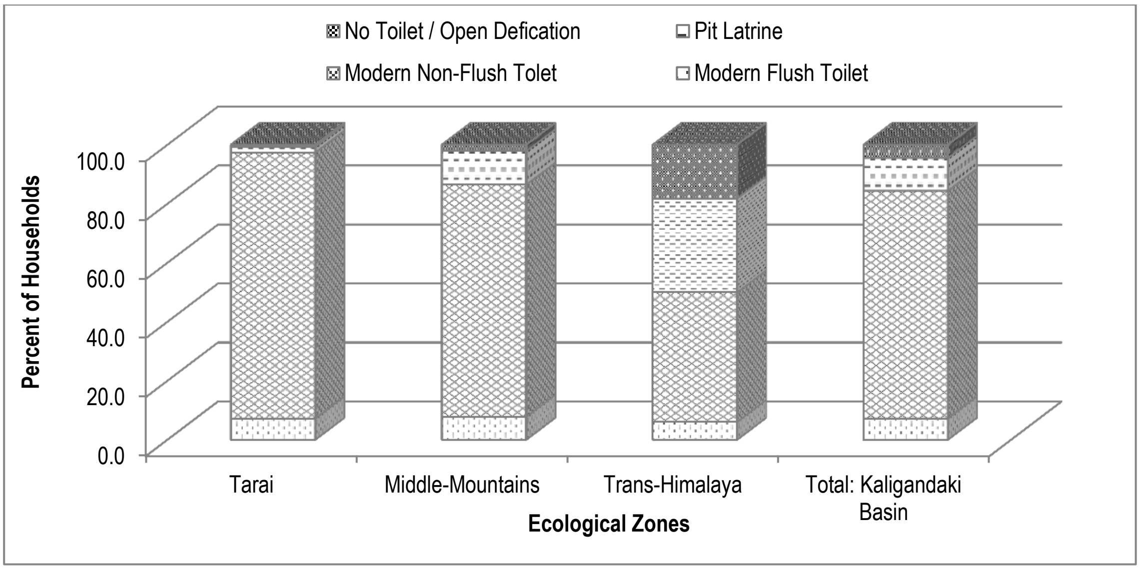
Elements	Tarai	Middle-Mountains	Trans-Himalaya	Total
House Ownership Type				
Self-Owned	96.7	95.7	95.5	96.1
Rental	2.0	2.1	4.5	2.5
Property of Trust / *Guthi*	0.0	0.7	0.0	0.3
Other	1.3	1.4	0.0	1.1
Total	100	100	100	100
Building Type				
Concrete	22.9	6.4	4.5	13.1
Non-Concrete, tin/slate/tiled roof	68.6	86.5	57.6	73.6
Mud/Stone Dry grass roof	5.9	1.4	37.9	10.0
Small hut	2.6	5.7	0.0	3.3
Total	100	100	100	100
Storeys in the Houses				
One Storey	40.5	28.4	7.6	29.7
Two Storeys	59.5	70.2	75.8	66.7
Three Storeys or more	0.0	1.4	16.7	3.6
Total	100	100	100	100

[78]Houses in the Trans-Himalaya are structured in such a way that they keep livestock in the floor and people live at first and second levels. This practice makes upper levels relatively warmer.

5.2.5.2 Availability of Toilets

The importance of toilet facilities in the context of a livelihood system is that they reduce the spread of waterborne diseases, which in turn, reduces medical expenses and increases the work efficiency of individuals to earn other capital. Figure 5.16 demonstrates the availability of toilets in the sampled households. Most of the households have (77.2 percent) a modern non-flush type toilet. However, there is a difference across the ecological zones in the types of toilets. Mostly, the proportions of households without a toilet, as well as having the pit latrine are higher in the Trans-Himalaya, compared to the other zones.

Figure 5.16: Proportion of Households with Toilet Facilities by Types of Toilet and Ecological Zones in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)



In recent decades, the practice of open defecation in Nepal has reduced notably through community awareness and campaigns to construct toilets. Nonetheless, 38.2 percent of households in the country lack toilets (CBS 2012b), and the majority of those that exist are still of poor quality so that food and water supply are often contaminated. In this context, many water-borne health problems reported by the respondents (discussed earlier) might have been associated with the poor quality of toilets, and poor hygiene and sanitation practices.

5.2.5.3 Access to Public Services and Service Centres

Access to public services reduces with the increasing distance of the household from state and regional capitals. The Trans-Himalaya is among the remotest parts of the country, while the other two regions are relatively accessible in terms of road networks; nevertheless, all three regions lack many basic public services as shown in Table 5.10.

Only primary schools are generally located within an accessible distance to all locations. The Trans-Himalaya has the poorest access to secondary schools of the three zones. Seasonal unpaved roads connect major villages in the study area, but public transport is infrequent and unreliable, especially in the Trans-Himalaya. Local markets are accessible for most of the villages, providing farmers with access to wholesale buyers for their excess production of fruits and vegetables, although the prices given by such middlemen are generally low, according to the respondents from Lumle and Meghauli. Vegetables in the Tarai and Middle-Mountains, and fruits (apple), and livestock (mountain goat) in the Trans-Himalaya are important marketable products. Monetary transactions are carried out in cash often because banks are not accessible.

Table 5.10: Accessibility to Public Service and Service Centres across the Ecological Zones in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)

Types of service/ facility available	Travel Time (Walking Distance in Hours) Travel Time * = Hours in Public Transport										
	Middle-Mountains			Tarai				Trans-Himalaya			
	Lumle-9, Landruk	Lumle: 7-8 Tolka	Lumle 1-3 Majhgaun, Patle khet, Tanchok)	Meghauli -5, Jitpur	Meghauli-7, Maghani	Meghauli-1-2-3(Shishabas)Sisabas	Meghauli-9, Buddha Nagar	Tsuang-3, Tsusang	Muktinath-4,5,6, Jharkot	Jhong	Ghami
Primary school	A	A	A	A	A	A	A	A	A	A	A
Secondary school	1.5	A	1	A	A	A	A	3	2.5	2.5	NA
All season Motorable road	6	4	1.5	1.5	1	1	0.75*	NA	NA	NA	NA
Dry season Motorable Road	2	4	1	A	A	A	A	A	A	A	A
Safe shelter for emergency	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Local market	A	A	1.5	A	0.75	A	A	A	A	A	A
Banking facility	NA	NA	1.5+1*	A	1+1.5*	NA	A	2*	3	3	NA
Milk Dairy/collection	NA	NA	NA	A	A	NA	A	NA	NA	NA	NA
Agro-product collection centre	NA	NA	NA	A	A	NA	A	NA	NA	NA	NA
Agriculture /Veterinary service	NA	NA	NA	1*	0.75	0.5+1*	A	NA	NA	NA	NA
Wizard/ traditional healer	A	NA	A	A	NA	A	NA	A	A	A	A
Health Post	1.5	A	1	0.5*	0.75	1	A	A	A	1	1*
Hospital	NA	NA	1.5+1*	1.5*	1+1.5*	1*	1*	2*	3	3	NA

Note: A= Accessible within 30 minute walk, NA= Not Available within 1 hour walking +1 hours public transport

Within a livelihood system, health may refer to access to health care facilities, medicine and hygiene (Biggs and Watmough 2012). However, facilities for addressing crop and livestock health are as limited in the study area as they are for humans. Sanitation and hygiene are also poor. Furthermore, not having an effective emergency response system and poor road transportation makes it difficult to access health services. Better health-related physical infrastructure and a well-developed health care system are critical for effective adaptation to climate change (Kjellstrom and Weaver 2009). However, the hospitals are located at considerable distance from the villages. Each of the VDCs only has a sub-health-post [79] run by assistant health workers (para-medic). The lack of an early warning system and emergency response mechanisms has increased the loss of life from weather related disasters frequently. In fact, it is possible to conclude that adaptation to health problems related to extreme weather is not possible with the current public services.

5.2.5.4 Social Security System

The state can be a critical institution for livelihood security by providing welfare support during crises (Barnett and Adger 2007). Social protection helps the poor expand their assets, and to use the assets efficiently, adopt better strategies and enhance adaptive capacity (McCarthy et al. 2001). Social protection as a form of climate change adaptation is a growing policy agenda because it has been shown to effectively reduce poverty and secure the livelihoods of people across the globe (Davies et al. 2008). Nepal, however, still lacks effective social protection mechanisms, although efforts have been made to improve policy.

The Government of Nepal provides minimum economic support to the needy through unemployment benefits, soft loans and grants to obtain skills and training, loans to encourage entrepreneurships (especially for youth), and a social security pension for elderly, single women and physically-challenged individuals (GoN 2063BS). The Social Security Allowances commenced only recently (1994), initially through the provision of a universal flat pension of NRS 100 a month to the elderly (75 years of age and over). The allowance has gradually increased to NRS 500/months, and since 2008, the age threshold has also been reduced. It is now 60 years for deprived people such as *Dalits* and citizens of the remote Karnali zone, and 70 years for the elderly of other places and communities. No age threshold is imposed for single women, endangered races (such as *Raute*, *Kusunda*, who practice a nomadic lifestyle) and the disabled. Disability benefits, however, are limited to a certain number per VDC.

The status of physical capital has been reported as poor in the areas inhabited by poverty stricken households in Nepal (Pun et al. 2010; Subedi et al. 2007). The study also demonstrated the poor status of physical capital, which is unable to compensate the inadequacy of other capital discussed above.

[79] Sub-health-post is the smallest health service structure under government health service mechanism that runs by semi-trained health professional.

5.3 Conclusion

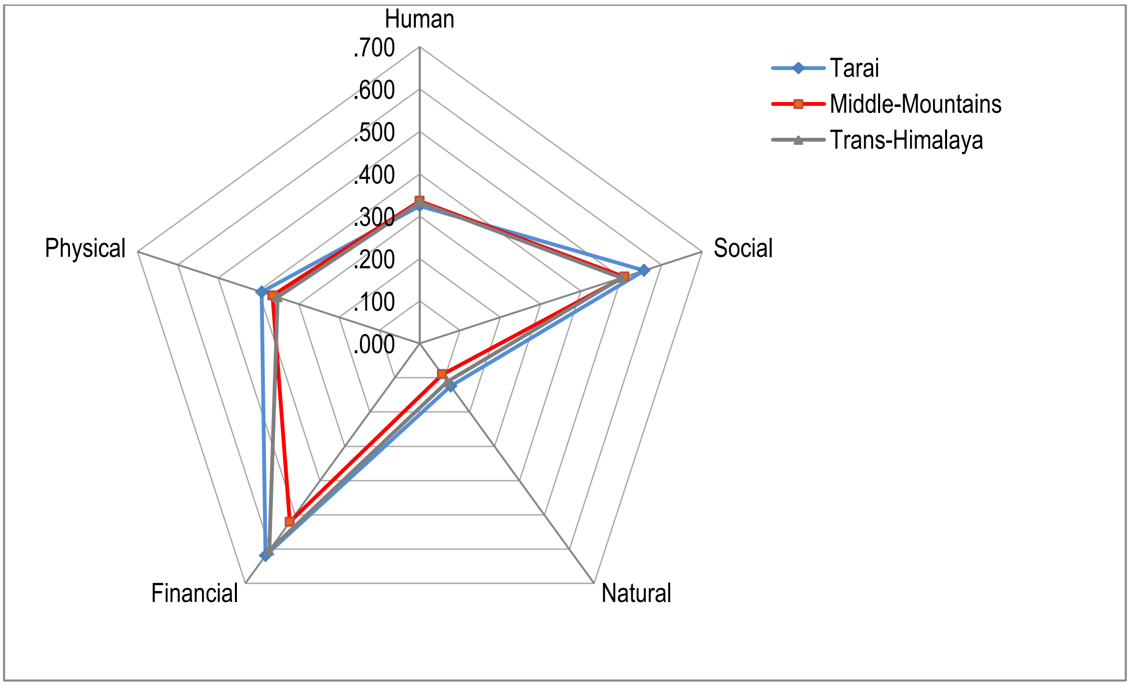
The livelihood system of a household contains most of the components of the social-ecological system of a place, especially in a rural setting. The analyses of the five major livelihood capitals suggest there is limited capacity to withstand shocks or adapt to change. The livelihood system is stressed from both endogenous and exogenous factors. The index-based assessment of livelihood assets using the formulae: (actual value of the household – minimum value in the cluster) / (maximum value in the cluster – minimum value in the cluster) showed different contributions of various assets in household livelihoods, both in terms of intra and inter ecological regions. The index-based assessment of livelihood assets that is transformed into livelihood capital index (Table 5.11 and Figure 5.17) demonstrates these variations.

Table 5.11: Descriptive Statistics of Livelihood Capital Index Values across the Ecological Zones in the Kaligandaki Basin, Nepal
(Source: Calculated from Field Survey Data, 2013)

Ecological Zones	Livelihood Capital	N	Minimum	Maximum	Mean	Std. Deviation
Tarai	Human Capital	145	.155	.555	.324	.085
	Social Capital	153	.050	1.000	.557	.153
	Natural Capital	153	.000	.750	.125	.105
	Financial Capital	153	.313	.938	.619	.104
	Physical Capital	153	.131	.571	.392	.072
Middle-Mountains	Human Capital	117	.176	.603	.336	.085
	Social Capital	141	.000	.850	.508	.150
	Natural Capital	141	.000	.465	.090	.083
	Financial Capital	141	.188	.756	.521	.103
	Physical Capital	141	.067	.588	.365	.074
Trans-Himalaya	Human Capital	45	.209	.528	.333	.072
	Social Capital	64	.050	.800	.501	.146
	Natural Capital	66	.000	.507	.111	.106
	Financial Capital	66	.368	.806	.604	.102
	Physical Capital	66	.208	.675	.352	.083

The mean indexed values of the combined livelihood capitals (relative to households of ecological zones: ‘0’ weakest to ‘1’ strongest) indicate the poor statuses of most of the capitals, and none of them are in the position of compensating for the inadequacy of the other capitals (Figure 5.17). Poor education and a lack of skills in the work force, together with health burdens have made human capital weak. Admittedly, the studied communities are relatively rich in social capital; it is however, unlikely to remain sufficiently effective in support of climate change adaptation. The status of natural capital is also markedly poor for people largely dependent on it for their livelihoods. Most households have access to marginal areas of land, without irrigation facilities, resulting in poor farm output. Access to forest and pasture resources are constantly reducing so the livestock population has sharply decreased. Simultaneously, the decreased interest of young people in agro-livestock activities has led to an increase in fallow farmland. Financial capital in terms of stock and flow of money is low, and in many cases borrowed money is utilised to manage day to day expenses. The public infrastructure that would compensate for the lack of private capital is inadequate. The social security mechanisms of the state although developing, have been compromised. All these have detrimental implications for the livelihoods of the studied communities, climate change further increasing their vulnerability, since weather-related disasters and rapid trends in related resource conditions can compel people to sell their vital assets such as land, home, tools or equipment for the sake of immediate survival.

Figure 5.17: The Mean of Livelihood Capital Indices across the Ecological Zones
(Source: Field Survey, 2013)



Because of variation in the level of entitlement over natural resources and services and social determinants of adaptation, human security across the globe is different (Barnett and Adger 2007). Such general disparities are common across the studied households; with only minor differences in the mean of indices between the livelihood capitals of the different ecological zones. The interplay of the components of livelihood systems is found to be insufficient to generate new assets and strengthen existing ones, perhaps apart from opportunities for migration and remittances. The livelihood system of the study area is climate sensitive and is exposed to the risk of higher levels of climate change (as explained earlier). Therefore, the integration of adaptation processes with stronger development and social security systems is required.

Many factors across all five capitals can foster adaptation to climate change. The optimum utilisation of the available labour force, development of sound social capital, and community engagement in nature conservation so that local people can benefit from appropriate levels of extraction of forest resources, could all strengthen livelihood security and adaptation to climate adaptation. Additionally, empowering young people in agro-livestock activities, increasing cash income from supplementary occupations, and sound investment in both physical infrastructure and social security mechanisms, would increase the capitals locally to generate adaptive capacity. These advances would then contribute to the sustainability of the social-ecological system of the Kaligandaki Basin more broadly. In the context of higher exposure of climate sensitive livelihood systems to climate change, the next chapter investigates the strategies that the studied households and communities adopted to strengthen the adaptive capacity of their social-ecological systems.

CHAPTER VI

ADAPTATION STRATEGIES AND ASSOCIATED LIMITS

6.1 Introduction

Adaptation to experienced and anticipated climate change is very important for human communities globally. Previous chapters have demonstrated that the social-ecological systems of the Kaligandaki Basin, Nepal are both exposed and sensitive to climate change. To adapt to ongoing environmental variability and change, households in the study area are adopting various strategies. Adaptation to climate change is an integrated, heterogeneous and complex process with many factors determining the success or failure of adaptation (Monirul Islam et al. 2014; Nielsen and Reenberg 2010). These elements of adaptive capacity are explained below in relation to livelihoods in the Kaligandaki Basin, Nepali Himalaya.

As has been discussed in Chapter Five the livelihood systems of the study area have been built through interactive relations among bio-physical, techno-economic, socio-cultural, psychological and politico-institutional spheres. Climate change adaptation must interact with and support those spheres. The types of effective strategies that the small farmers adopt are locally appropriate and they have context specific benefits. For example, farmers' primary concerns are generally to produce sufficient grain for their households. In such a context, this chapter maps the strategies developed and adopted by households in response to perceived climate change and associated impacts. The strategies adopted by the communities and are categorised into eight groups and discussed in detail below: 1) strategies associated with the cropping system; 2) farmland management; 3) water resource management; 4) farm skills and agro-input; 5) livestock and fodder management; 6) livelihood diversification; 7) migration; and 8) improvement in home environment. This chapter presents comprehensive information on adaptation strategies through figures and tables. In most of the cases, overall scenario of Kaligandaki Basin is provided at first, followed by spatial variation across the ecological zones.

Numerous constraints and barriers exist that hinder adaptation strategies. The obstacles associated with the government, market and civil society produce many unforeseen challenges for adaptation (Adger 2010). Examples of such adaptation barriers are also identified and expanded upon below, including the issues such as a lack of reliable weather forecasts; the lack of adaptable and extreme event tolerant crop varieties; the lack of adaptation skills and technologies; the inability of households and communities to manage contemporary environmental risks; and the unavailability of external support, such as from governmental and non-governmental organizations. Yet, it is important to note that the adaptation barriers do not stand alone, nor are they fixed in time or space, but rather are interconnected and reinforcing upon each other within specific contexts.

6.2 Adaptation Strategies Adopted in the Kaligandaki Basin

6.2.1 Strategies associated with Cropping System

Extreme weather events are expected to reduce crop production around the globe (IPCC 2012), with the potential for lower yields of rice with higher precipitation and flooding (Mohammed and Tarpley 2009). Local farmers are adjusting their cropping systems according to their capacities and are expecting support to adapt to change and weather variability (Bhatta and Aggarwal 2015). The very limited size of farmland available to households has led farmers to focus on changes in their crop varieties, adopting drought resistant crops, and changing the crop calendars to meet minimum production requirements.

6.2.1.1 Change of Crop Varieties

The selection of crop varieties able to yield well, irrespective of changing weather patterns is crucial to agricultural adaptation. To change crop varieties farmers require multiple capitals such as finance (to buy), physical (to access) and social (information from peers) to enable effective adaptation. The lack of availability of appropriate crop varieties in the study area has challenged farmers to adopt this strategy. The research participants stated that there is a lack of reliable steps taken towards development and diffusion of crop varieties that are adaptive to the changing climate. Few households in the study area reported adoption of new crops. As mentioned earlier (3.3.6.2 section) that the responses collected under 5 different levels are normalised into a single category using a Guttmann Score, to understand the general situation of the entire study area, as well as of the specific ecological zones. Figure 6.1 shows the normalized response that only about a quarter of the households had changed crop varieties, although very few farmers (3.1 percent) adopted the strategy at 'very high level' by buying new seeds for their crops every year. According to the respondents, however, new crop varieties are, not considered as 'adaptive to change' but as High Yielding Varieties (HYV), that could increase production; although, the short growing periods and higher productivity of the HYVs are supporting agricultural adaptation in some circumstances.

Agricultural modernization has caused enormous losses in genetic and cultural diversity of agriculture in association with Green Revolution technologies (Shiva 1990; Ehrenfeld 2005). Despite having a rich history in agro-biodiversity in large parts of Nepal, the country has already incorporated many modern elements into the agro-ecosystem (Bardsley and Thomas 2005). Consistent with the literature, the informants of this study also reported the disappearance of many flavoursome local varieties because of the introduction of HYVs. The form that agricultural modernization has taken largely promotes mono-culture, which could be diminishing the complexities of systems, and compromising the resilience of those systems in association.

Figure 6.1: Adoption of Strategies Associated with Cropping Systems in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)

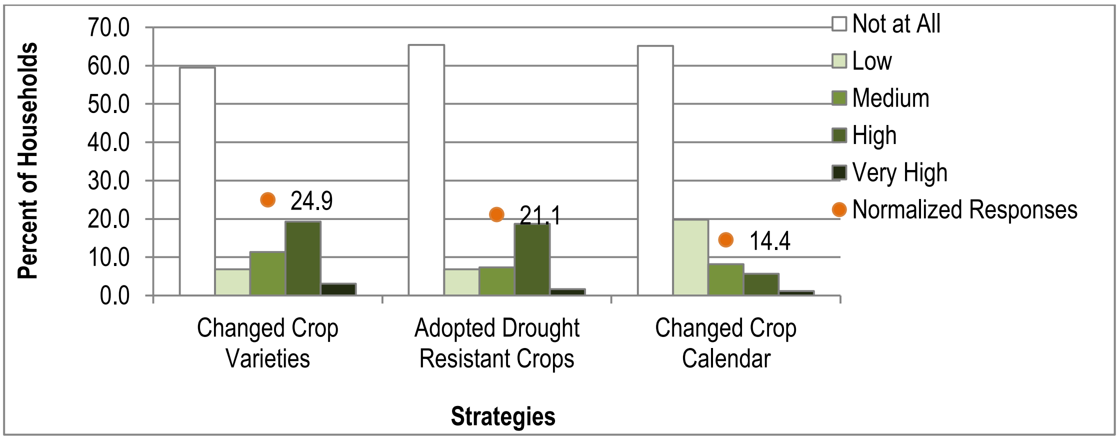


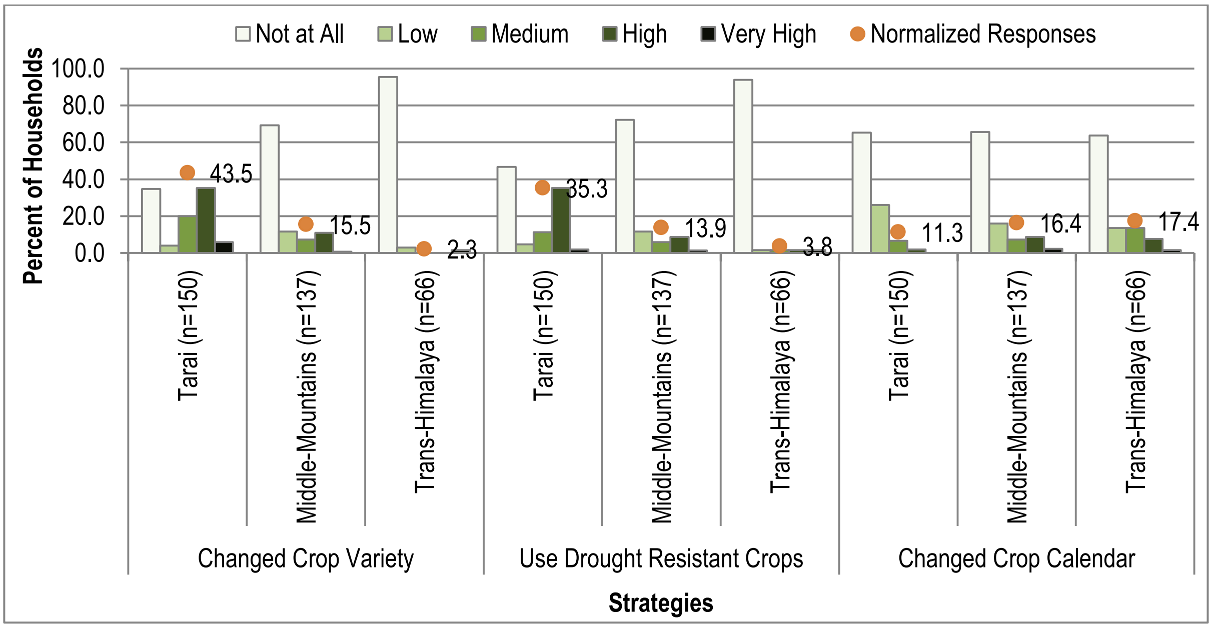
Figure 6.2 shows a notable spatial variation in the proportions of households who have adopted new crop varieties. Many households (43.6 percent) in the Tarai use HYVs; followed by the Middle-Mountains (15.5 percent) and the Trans-Himalaya (2.3 percent). The proportion of households using it at a 'very high level' was only 6 percent in the Tarai; with almost none in the Middle-Mountains and the Trans-Himalaya. Higher use of HYVs in the Tarai is probably due to the government's emphasis on the region as the 'bread basket' of the country (MoA 1998), and so National Agriculture Research Centre activity is focused in the region.

Many respondents expressed their concerns over the lack of availability of climate change adapted varieties. The recommended HYVs for the Tarai might have increased problems for some farmers, because respondents had experienced frequent and severe crop failures, especially of maize in the last few years (2009 to 2012). The respondents reported the incidents of seedless cobs of maize, and paddy seeds did not germinate. The problem of crop failures has also been reported from other parts of the Tarai: Bara and Rupandehi (The Himalayan Times 24 March 2012), and Sarlahi (Republica 19 December 2013). The victims of crop failure have blamed USAID for distributing Genetically Modified (GM) seeds from Monsanto (www.radioaustralia.net.au) 80. Local

[80]Viewed 24 April 2014<http://www.radioaustralia.net.au/international/radio/onairhighlights/nepal-seeks-explanation-for-corn-crop-failure>.

agronomists also suspect the GM seeds might have been inappropriate (www.dw.de) 81. However, some officials have also claimed that it was caused by climate change and changes in the crop calendar by farmers (The Kathmandu Post, 2 April 2013).

Figure 6.2: Adoption of Strategies Associated with Cropping System by Ecological Zone in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)



It is not clear whether GM seeds were distributed in Nepal or the HYVs being inappropriate for the region caused crop failures. The Government of Nepal has banned GM seeds in Nepal; however, the open border to India and poor quarantine mechanisms cannot block GM or any other non-recommended seeds entering the country. Farmers of the study area are also not sure if the current level of change in the climate had caused crop failures. Problems of crop failure are not reported in the Middle-Mountains and the Trans-Himalaya as local varieties are dominant in these regions. A prominent farmer of Lumle 5 said:

> *"… We are looking for climate change adaptive HYVs, however, recommended HYVs are not adapted to climate change adaptation… "*.

Bhatta and Aggarwal (2015) also noted similar demand from farmers in parts of Nepal, India and Bangladesh. There is not much literature discussing whether HYVs or local varieties will be more or less adaptive to changing climate in Nepal. The research participants of the Tarai, claimed that the available HYVs are not resilient in the face of climate variability, and that local varieties were more drought and disease resistant. Nevertheless, many farmers in the Tarai use HYVs as an

[81]Agronomists suspect GM seeds behind Nepal crop failure, Viewed 24 April 2014<http://www.dw.de/agronomists-suspect-gm-seeds-behind-nepal-crop-failure/a-6003064>.

alternative to an adaptive variety, considering the short growing periods that make is ready to harvest before the dry season starts, although farmers do not prefer HYV for household consumption because of its poor flavour.

There are many problems associated with the HYV seeds available in the market. According to the participants, there is no effective monitoring system over the quality of seeds sold there, so the seeds labelled as HYV are often not pure. Mutations, genetic exchange and other evolutionary processes reduce the quality of open-pollinated HYVs over time (Bardsley and Thomas 2005), which may not have been considered during seed production. Consequently, respondents did not find noteworthy increases in production even after adopting HYVs.

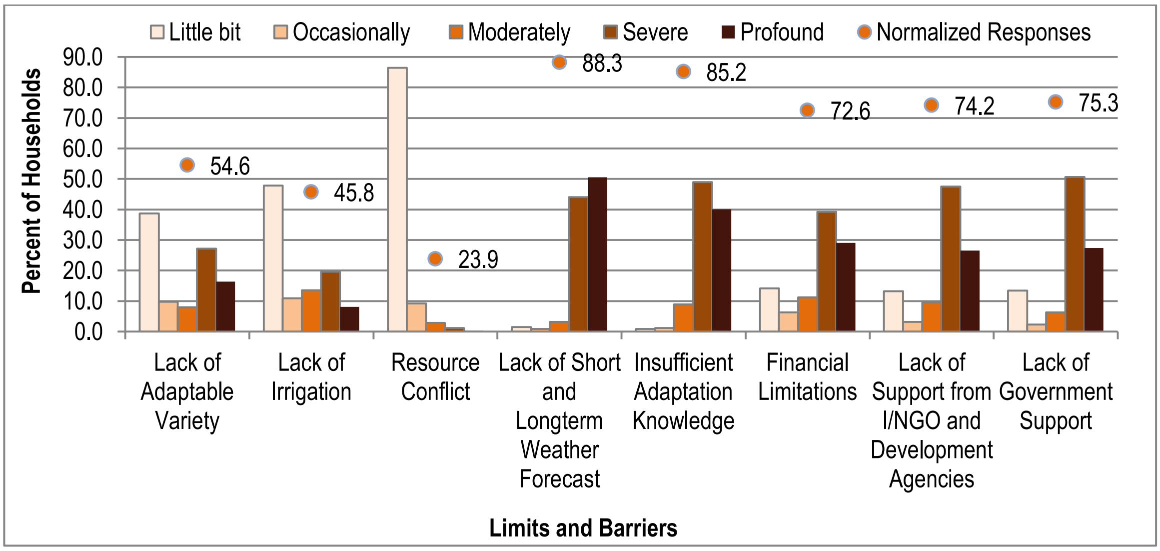
6.2.1.2 Use of Drought Resistant Crops

Crop breeding varieties that are adaptive to high temperature is a very promising adaptation option for Asia (Hijioka et al. 2014). The studied communities are also demanding such adaptive varieties. Communities in North-Western Nepal are growing more drought-resistant crops (Onta and Resurreccion 2011), although they are landraces local varieties. Respondents stated that they are using short growing season (paddy) varieties and have shifted to the crops that require less water. In the normalized response, 21.1 percent of households adopted drought resistant crops in the study area, which is shown in Figure 6.1.

Figure 6.2 shows some spatial differences in the proportions of households adopting drought resistant crops. The highest proportion of households (35.3 percent) of the Tarai, followed by the Middle-Mountains (13.9 percent) and the Trans-Himalaya (3.8 percent) adopted drought resistant varieties. The participants of the FGDs confirmed that the limited adoption of drought resistant crops was because of the lack of recommendations from the authorities. According to them, the HYV paddy that is ready to harvest before the start of dry season can be considered a drought resistant crop. The local paddy takes 4 to 4.5 months to get ready for harvest; by contrast, the HYV could be harvested a month earlier. The farmers of the Tarai reported that they cultivate rain-fed crops such as maize, millet, sesame, buckwheat and lentils instead of rice in some of the plots generally suitable for rice cultivation.

Nepal lacks investment and research to develop locally adapted varieties. Crop research to make it adaptive to particular environmental conditions takes considerable time - generally 30 years (Jones et al. 2008 as cited in Thornton et al. 2009). The non-linearity and uncertainties that existed in climate dynamics may pose problems for HYVs. For example, research is underway whether the GM crops are climate change adaptive, with some GM maize and soybean varieties apparently drought tolerant (ABCA 2012). However, GM crops risk rejection from consumers, and are also facing objections from environmental activists throughout the world [82, 83]. In such contexts, the lack of adaptive varieties has become a vital adaptation challenge in the study area. A dominant proportion of the respondents (54.6 percent) felt the lack of adaptable varieties as an adaptation barrier (Figure 6.3), and only 16 percent of them assessed the lack of adaptive varieties as a 'profound adaptation limitation'.

Figure 6.3: Types of Adaptation Limits and Barriers Faced by the Studied Households in the Kaligandaki Basin
(Source: Field Survey, 2013)



There exists spatial variation in the level of challenges faced by the households in relation to the lack of adaptive varieties (Figure 6.4). The problem is reported by most of the respondents in the Middle-Mountains (66.3 percent), followed by the Trans-Himalaya (48.9 percent) and the Tarai (46.6 percent). The proportion of respondents who saw the barrier to be profound was 21.8 percent in the Middle-Mountains, 18.5 percent in the Trans-Himalaya and little above one-tenth in the Tarai. Most of the farmers of the Tarai use HYVs, although the varieties are not recommended as being particular drought resistant. However, the HYVs, have short growing periods and help farmers to adapt to limited water availability.

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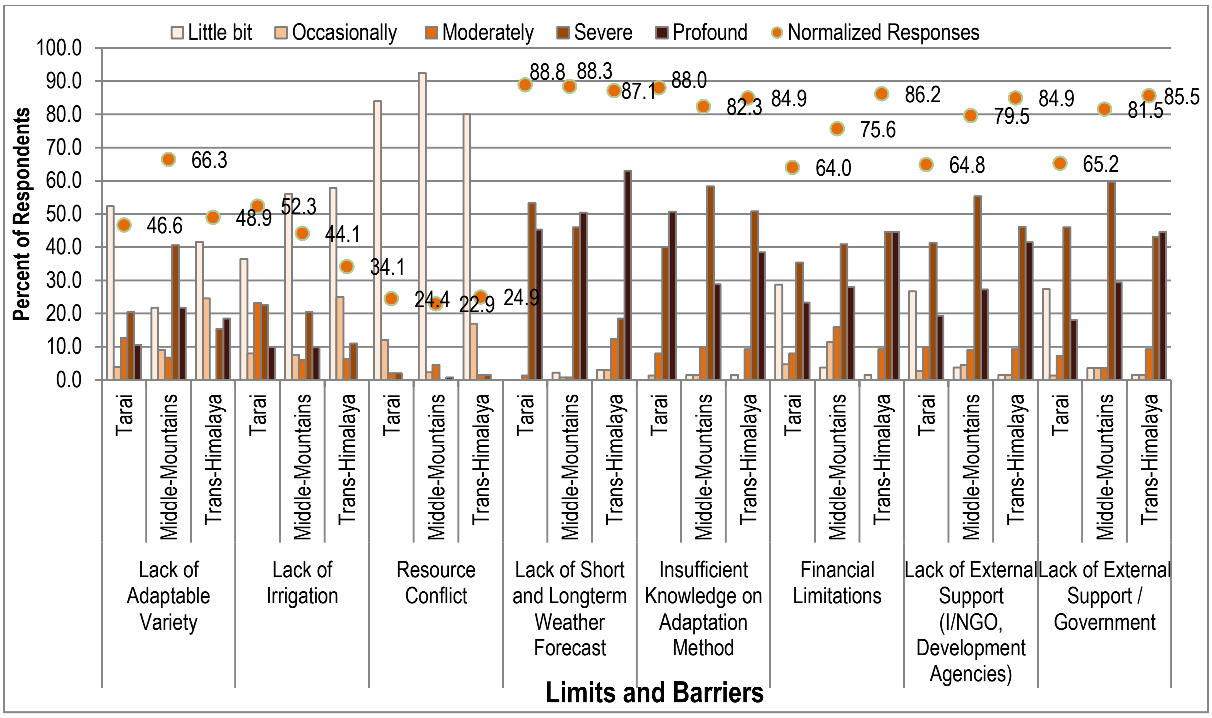
[82]We want Monsanto out of Nepal, viewed 15 September 2012 <http://gsdmagazine.org/2012/03/13/get-monsanto-out-of-nepal-an-interview-with-an-activist/>.
[83]Millions against Monsanto, viewed 15 September<https://maps.google.com/maps/ms?msid=214501227332220173973.0004d2d36a70b627ee02e&msa=0&dg=feature>.

Figure 6.4: Types of Adaptation Limits and Barriers Faced by the Studied Households across the Ecological Zones in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)



6.2.1.3 Change in Crop Calendar

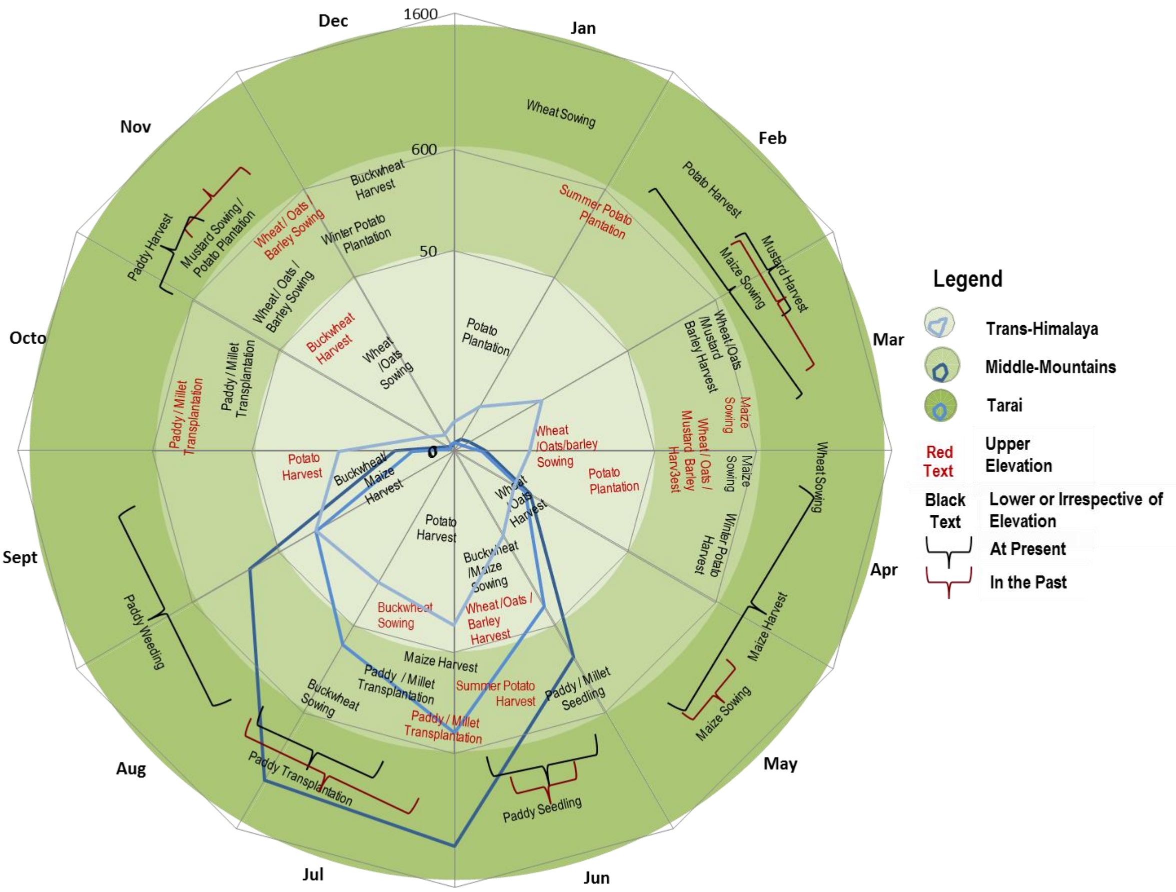
Climate change has badly affected crop production so changes in crop calendars are considered one of the most important adaptation strategies. Changing crop calendars refers to changes in crop timing, crop varieties and crop cycles to reduce farm production losses (Agrawal 2007). Effective changes in the crop calendar can support adaptation to moderate negative implications without major investment (Lobell et al. 2008). It can be a tricky strategy, which is dependent upon farmers' awareness of the recent trends in the climate system. Seasonal weather forecasts with appropriate levels of accuracy can help farmers effectively change the crop calendar.

Figure 6.1shows that 14.4 percent of the respondents reported a change in crop calendar, although there is no significant variation across the ecological zones (Figure 6.2).Crop calendars for dry crops such as maize and wheat in the Middle-Mountains, and for barley, oat, potato and buckwheat in the Trans-Himalaya, have changed the most dramatically. Irrigation is reported as a main determinant of decision making on changes to crop calendars.

The changes in crop calendars constructed by the representative farmers are presented in Figure 6.5. The participants of the FGD stated that the harmony between crop calendars and rainfall calendars has become detached; however, farmers have not been able to reconcile them successfully, as evident in the Figure indicating that many crops are grown in dry seasons.

According to the farmers of the Tarai and of the Middle-Mountains, occasional changes in the crop calendar are limited to paddy trans-plantation, which is determined by the onset of the summer monsoon. The perceived early arrival of the spring season and the late winter rainfall in the Middle-Mountains also leads farmers to sow maize approximately 15 days before the normal sowing dates.

Figure 6.5: Crop and Rainfall Calendar by Ecological Zone in the Kaligandaki Basin, Nepal (Rainfall in mm)
(Source: Field Survey, 2013)



The farmers of the Tarai reported that they irrigate cropped-farmlands if the weather is exceptionally dry. Whenever they experience the late onset of the summer monsoon, they have no choice but to delay for up to 3 weeks, since private irrigation is costly for paddy transplantation. Paddy seedlings are prepared during the pre-monsoon rain expecting the onset of monsoon within 3 to 4 weeks. In some cases, they have to re-sow paddy seeds if the seedlings that are ready to transplant die of severe drought. Many of the farmers have not changed crop calendars because they expect better weather patterns each year, although uncertain weather has caused frequent losses. The participants of the FGD at Tsusang (the Trans-Himalaya) reported a shift of approximately 10 days in crop calendar in the last 10 years. They also stated that the shift in crop calendar mostly depends on the winter snowfall in the Trans-Himalaya. Early winter snowing or the lack of it leads to an early start of the crop calendar whereas late snowing causes some delay.

Except in the Trans-Himalaya, paddy is the primary crop cultivated by the farmer in the study area. Therefore, on average the crop calendar for paddy is the most affected by changing weather patterns. The participants of the FGDs in the Tarai and the Middle-Mountains stated that if the monsoon is delayed, the seedlings mature and that leads to a reduction in paddy production by 10-15 percent even if the other conditions (post-transplantation rainfall, manure supply and use of insecticide) remain appropriate. The households also practiced early harvest and thrash it immediately to reduce loss from hailstorms. However, the moisture remaining in paddy or straw can damage the quality of both. The change in harvest and threshing activities are found to be a relatively ineffective strategy.

Reliable weather forecasts, both long-term and short-term, are important determinants of climate adaptation. They also help farmers harmonise crop calendars with weather calendars. The absence of skills for agro-climatological information inhibits farmers' abilities to perform farm related activities (Oxfam 2009). The literature has suggested the provision of agro-climatological information and adaptation knowledge for better adaptation (AfDB et al. 2003; Howden et al. 2007; Mizina et al. 1999). Studies have shown that weather forecasts and early warning systems have effectively saved lives and property in the developed world: in the US (Ebi et al. 2004); in Shanghai – China (Tan et al. 2004), and in Australia (personally observed fire and extreme weather related alerts through mass media). However, the lack of reliable weather forecasts and early warning systems in the developing world inhibits effective adaptation. For example, extreme weather related losses in coastal communities of Bangladesh (Monirul Islam et al. 2014); in farming communities of Andhra Pradesh, India (Satishkumar et al. 2013) and in North-East Ghana (Antwi-Agyei et al. 2014), were mounting due to the lack of reliable forecasts and access to information.

The respondents of the study area reported difficulties changing crop calendars due to the lack of agro-climatological information. The people were also not sure if changes in crop calendars would lead to positive effects. While farmers are not informed about future weather conditions they do perceive inter-annual variability and uncertainty in rainfall patterns. Therefore farmers reported the lack of reliable long-term weather forecasts as one of the biggest challenges to changing crop calendars, while the lack of short-term forecasts and early warning systems are barriers to a reduction in crop losses. As shown in the Figures 6.3 and 6.4, a very high proportion (88.3

percent) of respondents, which was similar across the three regions outlined the lack of reliable weather forecasts as an adaptation barrier. Of the total respondents, 50.6 percent identified the lack of weather forecasts as a 'profound adaptation barrier', while 63.1 percent did so in the Trans-Himalaya, 50.4 percent in the Middle-Mountains and 45.3 percent in the Tarai.

6.2.2 Strategies associated with Farmland Management

Protecting fertile farmland is very important for farming communities. Farmland management is a process of maintaining or upgrading the quality of farmland, including soil-moisture, nutrition and reducing soil erosion, for better farm output. Appropriate management of farmland maintains the productivity even in periods of stress or shocks (Scoones 1998). Ecological, economic, socio-cultural, political, and market related factors, as well as climate change, affect farmland management in complex ways (Cooper 2011). Therefore, farmland management is an integrated task that includes, but is not limited to: use of mulch; zero or reduced tillage; erosion control; drainage management; changes in farm size; changes in landuse type; and slope transformation. Farm management is an on-going process of agricultural dynamics within the Kaligandaki Basin, and the adoption of a particular strategy is framed by the technologies, and expected risks and benefits within particular environments.

6.2.2.1 Drainage Management and Erosion Control

Drainage management and erosion control are very important strategies for agricultural adaptation. In one study in Nigeria, 1 cm of soil loss caused a reduction in the yield of maize by 75 percent (Lal 1990). The livelihood implications of such losses are severe for farming communities so their efforts are directed to conserve erosion. The steep and tectonically active Himalayan topography is highly erosive, which is further promoted by the monsoon rainfall that dumps over 80 percent of annual rainfall in just two to three months. Considering the heavy erosion in the Himalaya, scholars have developed the theory of Himalayan Environmental Degradation (HED) in 1970s, although the theorists did not fully consider the natural process of soil erosion (Pandey 2013), rather blaming farming practices and deforestation (see for example: Eckholm 1976). The households of the Kaligandaki Basin have made some efforts to control severe erosion on their farmland.

This study found 17.1 percent of households made efforts to control erosion, yet, the proportion adopting the strategy at a 'very high' level was only 2 percent (Figure 6.6).The drainage management and erosion control strategies were adopted at a higher level in the Trans-Himalaya than in the other regions, with 31.1 percent of households in the Trans-Himalaya, followed by 14.1

percent of the Middle-Mountains and 13.7 percent of the Tarai practicing the strategy (Figure 6.7). The traditional techniques for controlling soil erosion in the Trans-Himalaya was the construction of mud-stone walls, planting trees along the edges of farmland, and the construction of flood control dikes (Plate 6.1).However, the effectiveness of these techniques has declined with the increase in run-off induced erosion, landslides and flooding in the region. In recent years, gabion boxes and concrete dikes are becoming common strategies for controlling severe erosion in the Trans-Himalaya (Plates 6.3; 6.4).

Figure 6.6: Adoption of Strategies Associated with Farmland Management in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)

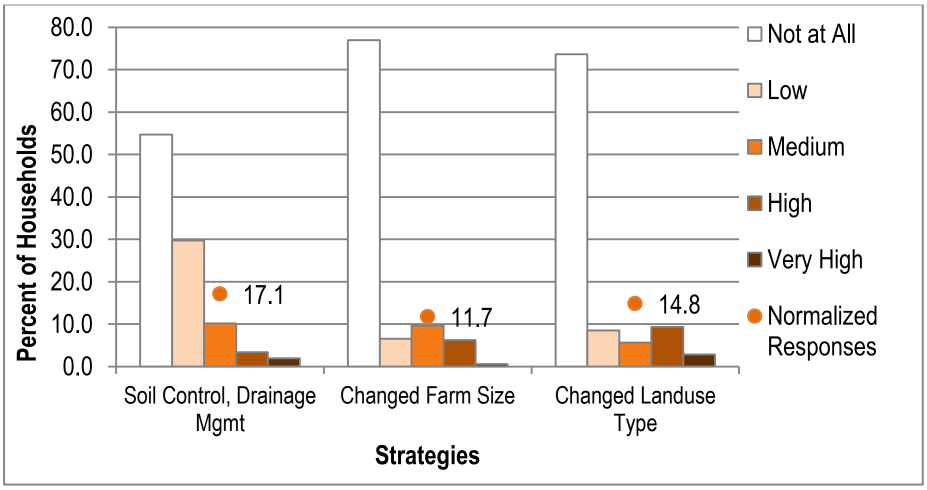


Figure 6.7: Adoption of Strategies Associated with Farmland Management by Ecological Zone in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)

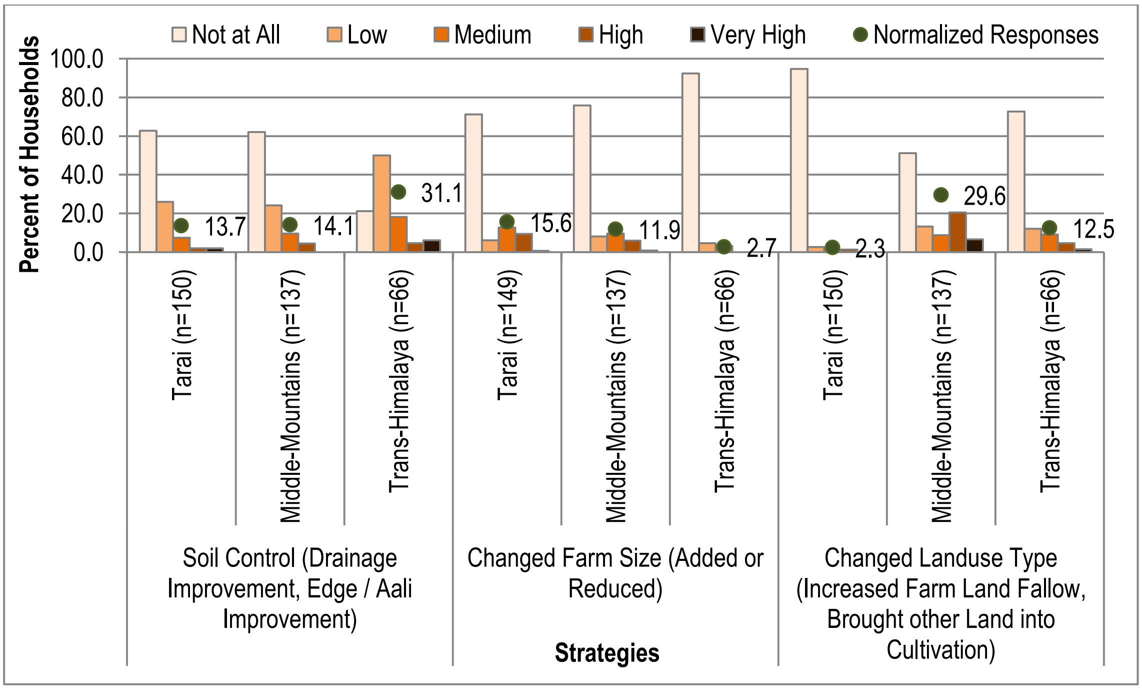


Plate 6.1: Mud-Stone Wall to Control Debris in Farmland in the Trans-Himalaya in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)

In the Tarai, flood control dikes and retaining-walls are constructed to control floods from the Narayani and the Rapti Rivers (Plate 6.2), and a similar strategy is adopted in the Trans-Himalaya (Plate 6.3). The participants of the Historical Timeline Calendar (HTC) analysis at Meghauli (Tarai) stated that more than 4 km of retaining walls of gabion boxes are constructed along the river banks [84]. The construction of such walls was initiated after the heavy flood in 1998. The flood encroachment into settlements has reduced notably, except from the areas where such dikes are yet to be constructed (approximately 2 km river bank).Because of the relatively flat topography, the problem of erosion is not as severe in the Tarai. In contrast, the problem is critical in the Trans-Himalaya and that is why soil control and drainage management strategies are adopted by a higher proportion of households in the Trans-Himalaya.

Some of the key informants in the Middle-Mountains reported that despite having high slope-gradients, soil control and drainage management strategies are not required in the region since the slopes are notably stable. Few of the households of Tolka (Lumle 8) in the region felt the need for drainage management, so they consolidated the drainage and diverted it towards a nearby stream. However, their effort failed and increased the losses because of inadequate technical knowledge they had applied in attempting such a diversion.

[84]Government provides hard materials like gabion wire, stone and wage to technical work, whereas community people provide free labour to construct such devices.

Plate 6.2: Flood Control Dikes and Retaining Wall along the Narayani River at Meghauli, Nepal
(Source: Field Survey, 2013)

Plate 6.3: Flood Control Dikes along the Kaligandaki River in the Trans-Himalaya, Nepal
(Source: Field Survey, 2013)

6.2.2.2 Changing Farm Size

Changes in farm size either by bringing new land under cultivation or leaving the farmland fallow, is one of the strategies associated with farmland management. The land positively affected by climate change may be brought into farming whereas the negative affected areas may be left barren. However, only 11.7 percent of households in the study area reported a change in farm size (Figure 6.6), with the proportion of households who have changed farm size by over 75 percent in terms of the area was only 0.6 percent. The farmers of the Tarai have made the highest level of change, with 15.6 percent of them reporting it (Figure 6.7), while the corresponding proportions for the Middle-Mountains and the Trans-Himalaya were 11.9 percent and 2.7 percent, respectively. The participants of the FGD in the Tarai mentioned that the change in farm size is mostly due to leaving farmland fallow, which is, mostly a seasonal issue. Various obstacles, such as lack of irrigation, crop losses due to wildlife encroachment, and poor farm production, limit the use the farmland throughout the available growing season. Therefore, changing farm size by leaving farmland fallow has negatively affected the livelihoods of many households in the Tarai and in the Middle-Mountains due to a reduction in total farm production. Abandonment of farmland has become common in rural Nepal in recent years and has severely affected social, economic and agroecological systems and has led to serious food insecurity in poor households (Chapagain and Gentle 2015; Paudel, K et al. 2014; Tamang et al. 2014). Because there is only a single cropping season, no farmland was left fallow during the cropping season in the Trans-Himalaya.

6.2.2.3 Changed Landuse Type

Landuse change promotes the resilience of vulnerable ecology and facilitates climate adaptation (Pyke and Andelman 2007). The changes in landuse can be both planned (owners' decision) or voluntary (natural response) in relation to climate change. Negative implications of climate change force the farmer either to leave the farmland fallow or convert it into another use. On the other hand, the positive effects would encourage bringing the other types of landuse into cultivation. Landuse change, despite being an important strategy to adapt to climate change, was not widely adopted. Only 14.8 percent of households changed the types of landuse from farming into other landuse (fallow, private forest or grass land). The proportion of households who have changed the landuse at a 'very high' level (the major portion or over 75 percent of the total farmland) was only 2.8 percent (Figure 6.6). However, the response varies spatially, with the highest proportion (29.6 percent)in the Middle-Mountains followed by the Trans-Himalaya (12.5 percent) and the Tarai (2.3 percent) having transformed agricultural land into other uses (Figure 6.7).

The higher cropping intensity, relatively low level of farmland left fallow, and availability of private irrigation in the Tarai have resulted in lower levels of landuse change. On the other hand, lack of these qualities, and agricultural land being affected by landslides and erosions, probably has led to higher levels of landuse transformations, from agricultural use to barren or forest/grassland in the Middle-Mountains and in the Trans-Himalaya.

6.2.3 Strategies associated with Water Resource Management

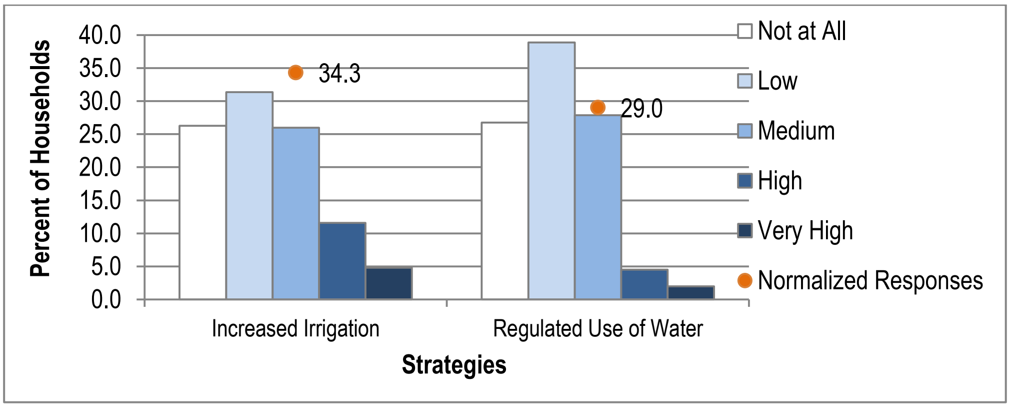
Fresh water is a highly affected resource due to climate change. Around 2000-3000 litres of fresh water/day is required to grow each persons' food, with an individuals' daily domestic water consumption also ranging between 30 litres to 300 litres (Turner et al. 2004). The scarcity of water impacts on both rain-fed and irrigated agriculture, and is having severe implications in the drier parts of the world where half of the human population live (FAO 2008). The use of water is also growing at twice the rate of population growth globally (UN Water and FAO 2007). Considering these facts, the appropriate management of fresh water can be an invaluable adaptation strategy. To overcome the problems associated with the scarcity of fresh water, various strategies are recommended, and some of them are adopted by different communities in the Kaligandaki Basin.

The cases of integrated water resource management throughout the basin are found to be an effective strategy to manage the scarcity of fresh water (Kranz et al. 2010; Sadoff and Muller 2009; Uprety and Salman 2011). Protection of the catchments and construction and operation of dams, may ensure a sustained supply of ground and surface water, and keep the natural springs 'alive' for longer periods. In Nepal, improved drainage and water management, rain water harvesting and better storage are practiced to cope with water scarcities (Oxfam 2009; Pandey 2010). In the study area accessing water from distant sources and regulating its use are the strategies primarily adopted by households to overcome the scarcity of water.

6.2.3.1 Water accessed from distant Sources for Irrigation

Irrigation helps farming communities cope with drought and helps to ensure appropriate levels of farm production. Rain-fed agriculture in South Asia uses some 60 percent of agriculture lands and those areas generally receive poor attention from agricultural modernization (Hobbs and Osmazzai 2011). The increased frequency and intensity of drought and more dry weeks within the rainy seasons have challenged a large section of agriculture in the region. This increased variability increases the importance of irrigation. In the study area, acquiring water from distant sources for irrigation (surface water in the Middle-Mountains and the Trans-Himalaya and ground water in the Tarai) is one of the strategies adopted by some households to adapt to the change. Of the total, one-third of households increased irrigation over the last decade (Figure 6.8).However, only 4.8 percent of them have extended to a 'very high' level. Despite the desire to increase irrigation, farmers have encountered many problems like lack of financial resources, lack of reliable sources of water, falling ground water tables (in the Tarai) and the lack of large irrigation schemes.

Figure 6.8: Adoption of Strategies Associated with Water Resource Management in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)



The feasibility of increasing irrigation varies spatially. Figure 6.9 shows that the Tarai has the highest proportion of households (51.3 percent), who have increased irrigation over the last decade, with 31.1 percent in the Trans-Himalaya and 17.4 percent in the Middle-Mountains. It is very hard for communities to autonomously manage irrigation in the Trans-Himalaya while government support is minimal. A senior citizen at Zhong reported that

> "… the government spends an outstanding budget to construct administrative buildings like VDC offices and party-offices; however, it does not give priority to irrigation infrastructure. Does a building produce grain to feed the people? Until the investment is made in irrigation and transportation, the development of the country cannot be expected… "

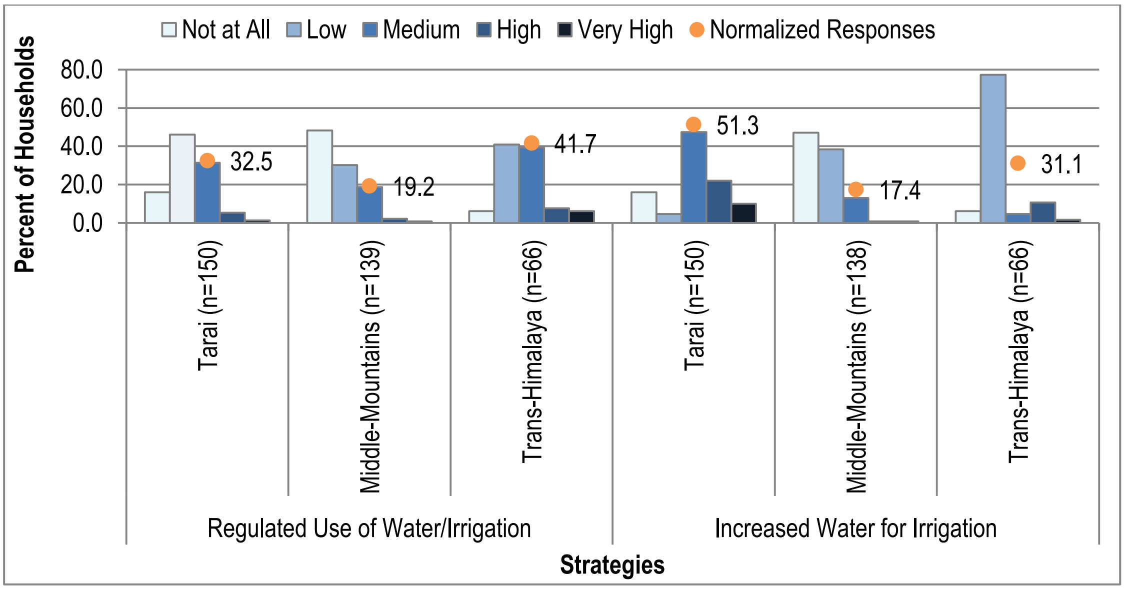
The respondent went on to claim that the "pork barrelling" by the political parties in power justifies the inappropriate use of state treasury funds.

There are some variations across the ecological zones with the normalized responses indicating 51.3 percent of households increased irrigation in the Tarai, followed by 31.1 percent in the Trans-Himalaya and 17.4 percent in the Middle-Mountains (Figure 6.9). However, the proportion of households who have adopted the strategy at a 'very high' level was low: one-tenth in the Tarai, followed by only 1.5 percent in the Trans-Himalaya and 0.7 percent in the Middle-Mountains.

Although the respondents have made a number of efforts to increase irrigation, they were not very successful. The normalized response shows 45.8 percent of households reporting the lack of irrigation facilities as an adaptation barrier (Figure 6.3), with the problem seen as 'profound' by 8 percent of all respondents. In the zonal context, 52.3 percent of respondents in the Tarai followed by 44.1 percent in the Middle-Mountains and 34.1 percent in the Trans-Himalaya considered it as an adaptation challenge (Figure 6.4). The FGD participants of Dhaba, Lumle stated:

> … Despite the place being suitable for 3 crops a year, we cultivate only one or two crops a year because of the lack of irrigation. …

Figure 6.9: Adoption of Strategies Associated with Water Resource Management by Ecological Zone in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)

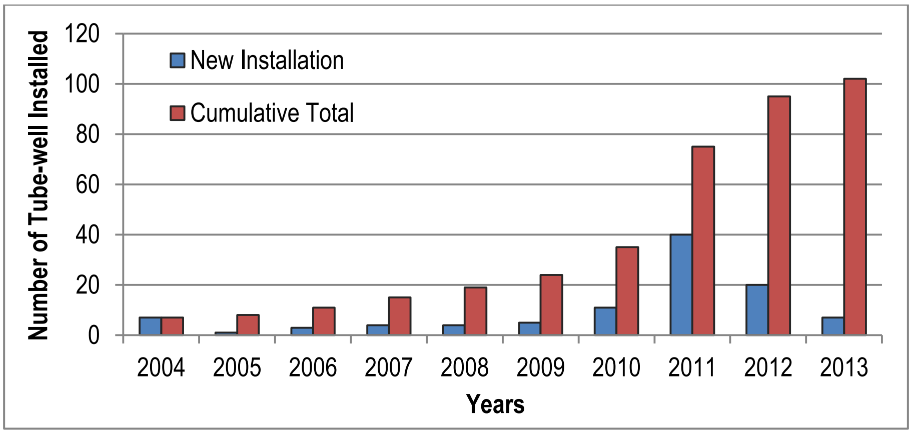


The lack of irrigation is a common problem in Nepal, with just over 52 percent area of total holdings in the country having some irrigation (CBS 2013). Consequently, potential cropping seasons are underutilised. Although this study did not assess this, the literature shows significant differences between the Crop Potential Index (CPI) and Cropping Intensity (CI) in each ecological zone in Nepal (Chhetri 2011).

Many factors such as the availability of water, topography, farmland, cropping intensity, climatic conditions, feasibility, cost of irrigation infrastructure and affordability for users, affects the irrigation potential of a place. These factors have led to spatial variation in the adoption of the strategy as well as perceptions of the lack of irrigation as an adaptation barrier. The respondents of the Tarai reported accessible ground water helped them to expand irrigation, although only the households with better economic status could afford private irrigation. The respondent reported that increases in irrigation are consistent with official figures of the cumulative numbers of bores installed shown in Figure 6.10. The respondents of the Tarai also reported that both the depth of bore-holes and the size of pipe used to pull water were increasing over time. For example, Community Boring Installation and Operation Technician of Meghauli states:

"… The size of the pipe and the installation depth of the shallow tube-wells are increased frequently to ensure a steady supply of irrigation water. The depth of tube-well is used to be 32-33 feet in between 2001-2007, which is increased to 40 feet in 2008-2009, and 45-50 feet in 2010. Similarly, the diameter of pipe used to be of 2-3 inches in between 2001-2007, which increased to 4 inches afterwards. …".

Figure 6.10: Trend of Tube-well Installation in Meghauli VDC [85], Nepal
(Source: Community Boring Operator's Work Log, Meghauli, 2013)



The farmers of the Tarai feel that the lack of irrigation is a serious adaptation challenge. The region has a year-round growing season and is relatively easily irrigated. However, the lack of irrigation has become an obstacle for optimum farm production. Private irrigation through extraction of ground water has become both very expensive, as well as unreliable, because of expensive and poor access to fuel for pumping. The farmers of the Tarai have invested a remarkable amount of resources to increase irrigation. The Middle-Mountains lack feasible sources of water to increase coverage, while in the Trans-Himalaya; the management of irrigation infrastructure is a big challenge due to the terrain, and increasing landslides and floods.

6.2.3.2 Regulated Use of Water

Regulated use of water can maximise the efficiency of water use. The regularised distribution of common property resources can insure fair distribution among the users. Ordered use, better channelling and the use of sprinkler and drip irrigation, are some of the actions taken by the studied households to regularise use. Of total households, 29 percent adopted a 'regulated use of water' strategy (Figure 6.8). However, the proportion of households adopting such strategies

[85] The cumulative number of shallow tube-well has increased by 11.2 sets per year in the last decade. The number of new instalment is halted after 2011. According to the participants of the FGDs this pause is mostly because of 3 reasons: 1. the households who want a subsidized pumping-set need to consolidate at least 4 *Bighas* of plot (2.5656ha). To make this size of plot, user group consisting many marginal holders requires, which is not feasible because of the dominance of thesmall plots and being located apart, 2. Even if the farmers got the pumping-set in subsidised rate, installation and operation costsare beyond the affordability of the poor households, 3. The well-off households have already installed the bores.

varied across the ecological zones, with 41.7 percent in the Trans-Himalaya, followed by 32.5 percent in the Tarai and 19.2 percent in the Middle-Mountains (Figure 6.9).

The practice of 'regulated use' for irrigation depends on the type of irrigation available. The general argument of respondents was that the greater possibility of private irrigation, the less households are likely to practice regulated use. However, since the poor households of the Tarai cannot afford pumping-sets for private irrigation, they hire it in an orderly manner; they compromise the frequency and intensity of irrigation due to its high cost. The farmers of the Middle-Mountains and the Trans-Himalaya adopted an ordered use in most cases and 'drip irrigation' on a small scale. Some of the respondents of these regions reported the construction of small reservoirs near natural springs to ensure the steady supply of water.

6.2.4 Strategies Associated with Farm Skills and Inputs

Sound farm skills and the increased use of appropriate agricultural inputs accelerate farm production, which can further ensure food security and help farming households adapt to climate change. A number of strategies are attached to farm skills and inputs. Improved human capital (farm labour and skills), financial capital (ability to invest for agricultural inputs), social capital (knowledge sharing), and physical capital (state provisioned agro-technicians and farm skill related information) mediate farm skills and inputs. Other strategies such as migration and remittance earnings, off-farm activities, small business and services, also help the farmers improve farm skills and increase farm inputs through cash income. The studied households have advanced their farm skills through education and training, and have invested in farm inputs such as seeds, manure, pesticide, insecticide, labour and technology.

6.2.4.1 Increased Farm Skills

Trained and educated farmers are more likely to adopt various strategies to reduce the detrimental effects of climatic events. The farmers of Nawalparasi, Nepal considered adult education, environmental awareness, agricultural knowledge and training as important components of adaptation to environmental changes (Biggs and Watmough 2012). However, there are few educated and trained individuals in agriculture in the study area. Many participants reported that the educated and young generation were not interested in agricultural activities. Therefore, very few respondents in the study area (less than one-tenth) reported an increase in farm skills either from basic agricultural training or through social learnings (Table6.1). There are some spatial variations in the proportions of households who have increased farm skills. For example, little over

12 percent of households in the Middle-Mountains and the Trans-Himalaya each have increased farm skills, whereas the corresponding proportion for the Tarai is only 4.7 percent.

Table 6.1: Adoption of Strategies Associated with Increased Farm Skills in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)

Level of Response	Tarai (n=149)	Middle-Mountains (n=137)	Trans-Himalaya (n=66)	Total (n=352)
Not at All	89.9	68.6	60.6	76.1
Low	4.0	16.1	31.8	13.9
Medium	3.4	11.7	6.1	7.1
High	2.7	3.6	1.5	2.8
Very High	0.0	0.0	0.0	0.0
Normalized Responses	**4.7**	**12.6**	**12.1**	**9.2**

Despite the location of the study area especially Meghauli VDC (Tarai), within 5 km distance of the Agriculture University of Nepal, and Lumle VDC (Middle-Mountains) which accommodates the Lumle Agriculture Research Centre (LARC), these institutions do not engage sufficiently with the communities. The respondents of these places reported that they have not benefited from the neighbouring institutions. The gaps between the communities' needs and the programs of these institutions were also reported in group discussions.

The contribution of family members as farm labourers is an integral part of the subsistence agriculture of Nepal, but government policies are not encouraging youth to work in agriculture. As a result, thousands of youth go abroad for labouring work and the agricultural economy of the country has weakened. The vulnerability of the younger generation increases because of the unsustainable nature of remittance flows and the lack of knowledge on agriculture and livestock transferred from elders (Ford et al. 2006; Yeh et al. 2014); Nepal, in general and the study area in particular, experience such vulnerability. Some prominent farmers of Lumle and Meghauli suspect there are horrifying livelihood situations for current labour migrants, as later many return back to the village with fragile health and age-related inabilities or disability, as well as the lack of traditional knowledge on farm management. The marginal size of farmland and limited growing seasons on the one hand, and the better opportunities from tourism in the Trans-Himalaya on the other, are limiting young people's interest in agriculture.

Consistent with poor levels of farm skills in the study area, respondents reported a lack of adaptation knowledge as one of the leading adaptation challenges. Of the total households, 85 percent stated that insufficient knowledge on adaptation methods was a barrier; with fairly similar proportions across the ecological zones (Figure 6.3 and 6.4). The participants of group discussions also stated that they are confused about the patterns of recent changes in weather and cannot forecast the impacts. Therefore they have not adopted some known adaptation strategies. At this stage they are in a state of uncertainty and they are expecting technical advice that would facilitate their decisions to adapt to environmental change.

6.2.4.2 Increased Agricultural Labour, Fertilizer, and Agrochemical Inputs

The increase in agricultural inputs can improve farm production and promote adaption to climate change. Respondents reported a reduction in labour inputs because of labour shortages and increased wage rates for farm labourers. On the other hand, the uses of manure and agro-chemicals have increased. Of the total households 32.4 percent confirmed that they are employing additional amounts of agricultural inputs (Table6.2). The proportion of households who extended the application of manure and agricultural chemicals varied across the ecological zones. The normalized response shows that 62.3 percent of households in the Tarai, followed by the Middle-Mountains (13.3 percent) and the Trans-Himalaya (3.8 percent) applied more manure and agro-chemicals on their farms. However, the proportion of households who adopted the strategy at 'very high' level was minimal.

Table 6.2: Adoption of Strategies Associated with Increased Agro-Input in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)

Level of Response	Tarai (n=150)	Middle-Mountains (n=137)	Trans-Himalaya (n=66)	Total (n=353)
Not at All	11.3	65.0	90.9	47.0
Low	5.3	26.3	4.5	13.3
Medium	10.0	1.5	3.0	5.4
High	69.3	5.1	1.5	31.7
Very High	4.0	2.2	0.0	2.5
Normalized Responses	**62.3**	**13.3**	**3.8**	**32.4**

Farm production for many respondents in the study area is already at the edge of a threshold because of a combination of challenges. The largest proportion of households in the Tarai used chemical fertilizers and agro-chemicals to reduce production risks, but they have not been able to increase production. Warming and the lack of irrigation reduce the efficacy of fertilizer and other chemicals on farms in the Tarai, as they do elsewhere (Agrawal 2007; Kattwinkel et al. 2011). According to respondents, the water is not sufficient to decay animal dung, farm weeds and green mulch that would enrich soil fertility. Instead, farm insects and bugs are increasing and strengthening their resistant power against agro-chemicals. Consequently, the application of chemical fertilizer and insecticides is now seen as compulsory to ensure minimum production despite their poor efficacy in production and serious health implications for farmers and consumers. FGD Participants of the Tarai mentioned:

> … In the past water used to promote production, however, in these days minimum production can only be ensured through heavy applications of chemical fertilizer ….

Prominent farmers of the Middle-Mountains and of the Trans-Himalaya stated that agricultural inputs cannot change farm outputs effectively because of the regions' environmental limitations. The farmers of the Middle-Mountains have increased their use of organic fertilizer after considering the negative effects of agro-chemicals on both soil quality and human health. The farmers of the Trans-Himalaya do not use chemical fertilizers and other agro-chemicals. The public health concerns in relation to agro-chemicals have risen in Nepal in recent years [86], and many are advocating the need for controlled use [87]. However, crop diseases and pests on the one hand, and lack of irrigation on the other, are still seen as compelling farmers to continue their use.

Poverty is noted as the largest barrier to cope with and adapt to climate change in the Kaligandaki Basin. The majority of the studied households are poor and hold marginal areas of farmland. Some 72.6 percent of respondents reported financial limitations as the primary cause of their poor level of investment in agriculture (Figure 6.3), although there are some spatial variations (Figure 6.4). Each of the regions had households reporting poverty as an adaptation barrier, with the proportions of the normalized response of 86.2 percent in the Trans-Himalaya, 75.6 percent in the Middle-Mountains and 64 percent in the Tarai. The most studied households worry about day to day problems as they live a hand to mouth existence, and do not own a stock of assets to invest in long-term adaptation strategies. They even use resources located within disaster areas, such as collecting firewood during the floods, cultivating and residing on slopes and land with marginal productivity, so they are trapped in a vicious circle of survival with limited prospects of adaptation.

6.2.5 Strategies associated with Livestock and Fodder Management

Livestock is a fundamental part of subsistence agriculture in the study area. Better availability of livestock fodder and a strengthened livestock economy directly contribute to livelihood sustainability. However, climate change impacts on the quantity and quality of fodder and forages. Warming of up to 2°C is expected to have positive effects on pasture and livestock productivity in

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[86] Pesticide use in agriculture, our health and risk on underground water in Nepal, viewed 07 August 2014<http://agriculturecornerblog.blogspot.com.au/2012/07/pesticide-use-in-agriculture-our-health.html>.

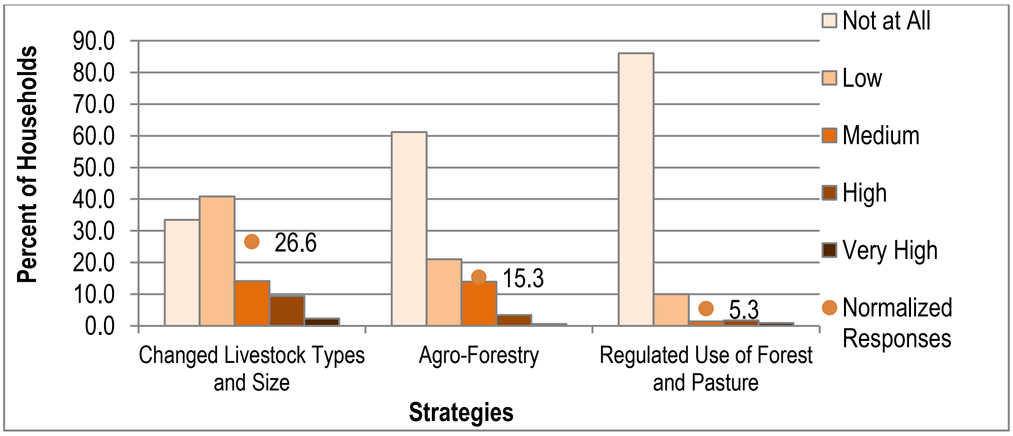
87 Use of pesticides in vegetables falls: viewed 07 August 2014<http://www.karobardaily.com/news/2014/08/use-of-pesticides-in-vegetables-falls>.

humid temperate regions; vulnerability of livestock to heat stress varies according to the species, genetics, life stage and nutritional status (Thornton et al. 2009). Some livestock are also adaptable to particular climatic conditions and some others are not, for example, heat stress adversely affects the productive and reproductive performance of dairy cattle (IPCC 2007a).Nevertheless, very limited research has been conducted on the implications of climate change on the livestock system globally and in Nepal (Aryal, S et al. 2014; Eid 2014; Mary and Majule 2009;Thornton et al. 2007). Therefore, the respondents of the study area were asked if they have adjusted livestock and fodder management as part of an adaptation strategy to climate change.

6.2.5.1 Change in Livestock Types, Herd Size, and Feeding Practices

Change in the types of livestock, herd size and feeding practices can assist climate change adaptation because different types and numbers of livestock require different amounts of feed. The proportion of the normalized response of 26.6 percent of households in the study area have changed [88]their livestock types, herd size and feeding practices in the last decade (Figure 6.13). However, those decisions cannot simply be attributed to climate change. The proportion of households adopting this strategy at a 'very high' level is very small i.e. 2.3 percent (Figures6.14), and there was little variation across the ecological zones. Out of the total, 31.8 percent of households in the Tarai, followed by the Middle-Mountains (24.2 percent) and the Trans-Himalaya (21.9 percent) have changed livestock types and herd sizes (Figure 6.12).

Figure 6.11: Adoption of Strategies Associated with Livestock and Fodder Management in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)

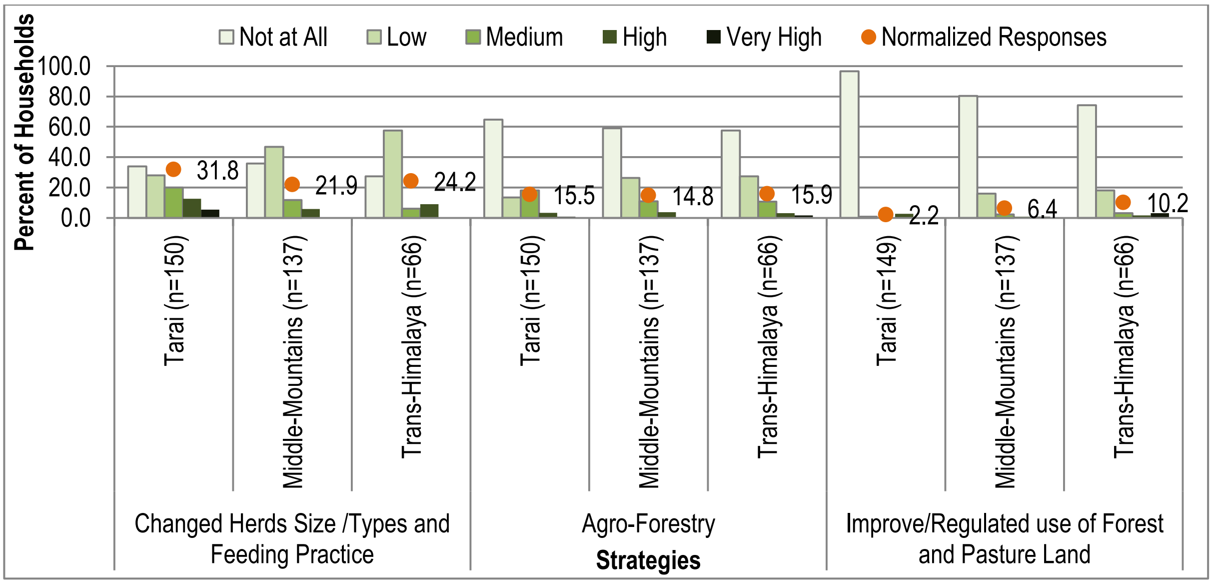


Access to fodder resources was identified as the dominant change. The households of the Tarai have experienced restrictions on forest and grazing resources on the one hand, and lack private

[88] The term 'change' refers to decreased size of herds, priorities given to small animals like goat/sheep instead of big rudiments like cow and buffaloes, and practice of stall-feed instead of grazing.

grassland (*kharbari*) on the other. Consequently, a relatively higher proportion of those households changed livestock types to smaller animals, reduced their herd sizes, and changed feeding practice moving from pasture to stall-feeding.

Figure 6.12: Adoption of Strategies Associated with Livestock and Fodder Management by Ecological Zone in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)



Although access to forest and grazing is poor in the Middle-Mountains, having private grassland, fodder trees at the edge of farmland and fallow farmland, provides a supply of fodder and forage. As a result a relatively lower proportion of households have changed livestock types, herd sizes or feeding practice. In the Trans-Himalaya, there are no formalised restrictions on grazing areas; nevertheless, the region is not very rich in fodder and grazing resources. The herd sizes have decreased in the Trans-Himalaya mostly due to increasing difficulties to manage the livestock at a household level and the high wages of hired herdsmen.

6.2.5.2 Agro-Forestry (Grass Seedling, Fodder and Timber Trees Plantation)

Agro-forestry is sometimes understood also as eco-farming (ADB 1999). Agro-forestry is used more than many of the other strategies because it maintains the stability of production by changing micro-climates; improving soil and biological environments; increasing adaptive capacity of ecosystems; and supporting agro-biodiversity conservation for food security (AfDB et al. 2003; Bosello et al. 2009; Seck et al. 2005; Verchot et al. 2007). In addition, agro-forestry stores carbon, increases organic matter in soil and may help resilience against floods, landslides and drought (Hijioka et al. 2014). Appropriate management of agro-forestry helps reduce poverty and make the rural livelihoods resilient (Chhatre and Agrawal 2009; Larson 2011; Persha et al. 2010). Contours of farm-trees have multiple benefits for adaptation since they supply fodder, firewood, timber, and help to provide shade. Figure 6.11 indicates 15.3 percent of households practiced afforestation, grass seedling and planting of fodder trees at the edge of terraced farmland and private land. In the spatial context, the proportion of households adopting the strategy is fairly similar (Figure 6.12).The households of the Tarai have the poorest level of access to fodder and forage that is compensated by convenient agricultural residues. On the contrary, limited availability of agricultural residues in the Middle-Mountains and the Trans-Himalaya are compensated by agro-forestry and private grassland.

6.2.6 Strategies associated with Livelihood Diversification

Livelihood diversification is a process of entertaining multi-functionalities or multiple livelihood options at a particular time. In diversified livelihoods, various options derived from different assets and skills are integrated (Agrawal and Perrin 2008; Nguyen 2007). The importance of livelihood diversification is high because the failure or the loss of one option can be compensated by another. Studies have demonstrated improved abilities of households to mitigate risk, uncertainty and contingencies and adapt to climate change, and extreme weather events' impacts through livelihood diversification (Byg and Herslund 2014; Motsholapheko et al. 2012; Weldegebriel and Prowse 2013), and promotes sustainability and resilience of social–ecological systems (Goulden et al. 2013). Accumulation of surplus food, keeping livestock, generating financial and other assets, small business and migration to earn cash, are important components of livelihood diversification in the study area. The bonds and commitments among the household members also help some to diversify their livelihoods successfully. Agricultural diversification is particularly important and is investigated further in relation to farming, livestock, fruits and vegetables farming, agro-based off-farm activities; small business, enterprises and tourism (home stay); farm labour work, receiving food aid and changing existing livelihood options.

6.2.6.1 Integrated Agriculture

Integrated agriculture is an important component of agricultural adaptation in Nepal and involves the integration of forest, grazing and farmland practices in a single crop-livestock system. Integrated agriculture is an ecological model that incorporates land management, drainage management, soil conservation, crop nutrition and crop protection, biodiversity conservation, waste management and application of human and social capitals. Integration of seasonal climate forecasting; community based disaster management; crop-livestock insurance; water storage (Adger et al. 2007; FAO 2008; Heltberg et al. 2010); market-based and off-farm activities; effective and integrated decision making (Merrey et al. 2005; Niino 2011; Paul et al. 2009); and community based techniques of providing community assistance at the grassroots (van Aalst et al. 2008), are also the components of the broader social-ecological model of development.

In the social-ecological model, the by-products of one activity become resources for another. For example: crop and vegetable farming provide residues (fodder and forage) for livestock that supplies manure for farmland, draught power and provides cash income from dairy and other products. Furthermore, poultry and fisheries; fruit farming, flower production and bee keeping provide additional income on the one hand and supply nutrition to the household on the other. Therefore, integrated agriculture is a bundled approach for agro-based development of the livelihood system that can alleviate extreme poverty (Acosta–Michlik and Espaldon 2008; Bardsley and Thomas 2005; Fleischer et al. 2011). Integrated agriculture is not new for the Nepalese farming households; however, in many case, the management knowledge has not been transformed and made appropriate for new generations.

The studied households demonstrated little integration of the components of their social-ecological agricultural system. Some of the KIIs stated that many households entertain fringe activities targeting cash income but most have limited confidence in positive outcomes from agricultural adaptation. Table 6.3 shows about one-fifth of households reported that they have made some effort to integrate agriculture. The practice is relatively advanced in the Tarai as 31 percent of households practiced the strategy, while for the Middle-Mountains and the Trans-Himalaya only 12.8 percent and 7.7 percent, respectively. The Tarai have a year-round growing season so it is suitable for agro-based activities. Nevertheless, the respondents reported that the integration was limited to a few activities such as crop-livestock-dairy, vegetable cultivation and poultry farming. The other regions also have combinations of similar activities, however, to a lesser degree.

Table 6.3: Adoption of Strategies Associated with Integrated Agriculture by Ecological Zone in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)

Level of Response	Tarai (n=150)	Middle-Mountains (n=137)	Trans-Himalaya (n=65)	Total (n=352)
Not at All	20.0	70.1	89.2	52.3
Low	43.3	13.1	1.5	23.9
Medium	30.0	12.4	3.1	18.2
High	6.0	4.4	1.5	4.5
Very High	0.7	0.0	4.6	1.1
Normalized Responses	**31.0**	**12.8**	**7.7**	**19.6**

6.2.6.2 Food Aid and Subsidized Food

The farmers' strategies are mainly to adapt, rather than external intervention, which are critical to manage climate change stress sustainably (Eriksen et al. 2005). However, food aid or other forms of support are very important for highly vulnerable people. The respondents of the study area reported that climate change impacts on both rich and poor similarly, however, other socio-economic characteristics of the households increase the sensitivity, and therefore the vulnerability of poor people. According to respondents, when farmland is affected by weather extremes, landlords may reduce farm activities that reduce the employability of poor people as farm labourers. Reduced farm production also increases food prices, which makes it difficult for poor people to supplement their diets. The studied communities have received limited external support. As evident in Table 6.4, only 7 percent of households had received food aid. However, this form of support was mostly limited to the Trans-Himalaya, with households in the Tarai and the Middle-Mountains receiving food aid (relief materials from the Red-Cross, Government, or the public) only in emergency situations. Because of the area's remoteness, the Trans-Himalayan communities receive regular food support from the government.

Table 6.4: Adoption of Strategies Associated with Food Aid and Subsidised food by Ecological Zone in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)

Level of Response	Tarai (n=152)	Middle-Mountains (n=138)	Trans-Himalaya (n=66)	Total (n=356)
Not at All	92.1	94.2	24.2	80.3
Low	7.9	5.1	51.5	14.9
Medium	0.0	0.7	10.6	2.2
High	0.0	0.0	7.6	1.4
Very High	0.0	0.0	6.1	1.1
Normalized Responses	**2.0**	**1.6**	**29.9**	**7.0**

The climate of the Trans-Himalaya is particularly harsh and the place is difficult to access. The short growing season and poor productivity of the region have led to it being the food deficit region. Therefore, it needs special consideration from the Nepali government. Because of the lingual, cultural and trade links to Tibet in China, the Chinese Government also provides special aid and support to the communities of Upper-Mustang (Trans-Himalaya). The participants of the FGDs in the Trans-Himalaya reported that they receive salt, oil and rice from the Chinese Government. Table 6.4 indicates almost 30 percent of households in the Trans-Himalaya acknowledged the receipt of some support. On the other hand, only 2 percent of households in the Tarai and 1.6 percent in the Middle-Mountains reported receiving external support. The majority of the respondents of the study area also reported the lack of support from I/NGOs, development agencies and government as an adaptation challenge.

External support ranges from community awareness programs at the local level through to international development assistance for wider aspects of development. More broadly, foreign development assistance has been the major reason for of Nepal's progress. However, the distribution of the assistance within the country is unequal. Some development agencies and I/NGOs are working in parts of Nepal to promote local communities adapt to climate change: UNDP, DFID, Practical Action, Care International, International Institute for Environment and Development (IIED), the Development Fund-Norway, Li-Bird. Nonetheless, none of these organizations have programmes for the study sites. The respondents of the study areas said that they lacked support from international development agencies that hindered their adaptation process.

As shown in Figure 6.3 earlier, the majority of respondents (74.2 percent) revealed a lack of external assistance as an adaptation barrier, although responses vary spatially, with the highest being84.9 percent in the Trans-Himalaya, followed by the Middle-Mountains (79.5 percent) and the Tarai (64.8 percent) indicated in Figure 6.4.It would be good if the lack of international support could be substituted by the government to promote adaptation. Governance can create both opportunities and constraints for climate change adaptation, depending on the level of accountability of the government. Poor governance is often reported as an adaptation barrier (AfDB et al. 2003). However, the Nepali government, as in other developing countries, are often blamed for not being accountable to their citizens, and even corrupt. Nepal's constantly decreasing performance is indicated by the corruption index: 126th among the 175 countries with 29/100 score and -0.6854 index score in 2014, 116th out of 177 in 2013 and 139th among the 174 countries in 2012 [89]. In this context, Figure 6.3 shows that the majority of households (75 percent) reported a lack of government support as a prominent adaptation barrier. Among the ecological zones, most respondents of the Trans-Himalaya, followed by the Middle-Mountains (81 percent) and the Tarai (65 percent) accused the government of not doing enough to promote climate change adaptation (Figure 6.4). Relatively better acknowledgment of the government support by the households of the Tarai suggests that the presence of government programmes are concentrated in accessible places like the Tarai; yet, government's actions even there are not promoting climate change adaptation.

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[89]Viewed 07 August 2014<http://www.transparency.org/country/#NPL
><http://www.thehimalayantimes.com/fullNews.php?headline=Nepal+ranked+third+most+corrupt+country+in+South+Asia&NewsID=435683>; Viewed 07 August 2014<http://www.ktm2day.com/2012/12/05/nepal-ranks-139th-in-global-corruption-index/>

6.2.6.3 Changes in Livelihood Options

The changing livelihood option when the existing one is not enough to cope with and recover from the stress and shock, is seen to be very important for vulnerable households (Scoones 1998). Studies on Himalayan livelihoods have demonstrated that many households have changed their livelihood options over time (Onta and Resurreccion 2011; Subedi and Pandey 2002; Subedi et al. 2007). However, the process of change is challenging, especially for poor households, because they lack the minimum financial resources required to shift to a new option (AfDB et al. 2003). Table 6.5 indicates 22.1 percent of the studied households reported a change in existing livelihood options in the last decade. Traditional agriculture has changed because it has been challenged by the lack of irrigation, wildlife encroachments, and the lack of access to traditional forest and grazing resources. The proportions of households who changed options are fairly similar across the ecological zones: 26.1 percent in the Middle-Mountains, 20.1 percent in the Tarai and 18.6 percent in the Trans-Himalaya. However, the availability of particular alternative livelihood options differs across the ecological zones. The ability of households to diversify livelihoods is influenced by the livelihood assets available to the household. The lack of minimum assets required to diversify household livelihoods prevents many households from adopting such a strategy.

Table 6.5: Adoption of Strategies Associated with Change in Livelihood Options by Ecological Zone in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)

Level of Response	Tarai (n=152)	Middle-Mountains (n=138)	Trans-Himalaya (n=66)	Total (n=356)
Not at All	63.2	54.3	53.0	57.9
Low	12.5	10.1	31.8	15.2
Medium	7.2	13.8	6.1	9.6
High	15.1	20.3	6.1	15.4
Very High	2.0	1.4	3.0	2.0
Normalized Responses	**20.1**	**26.1**	**18.6**	**22.1**

6.2.7 Strategies associated with Migration

Migration is a widely used strategy to maintain livelihoods in a period of socio-political and environmental change (Adger et al. 2014). The rural households of Nepal have adopted the strategy while coping and adapting to any forms of socio-political and environmental stress (Subedi 1993; Subedi and Pandey 2002). Climate change induced migration is already observed in dry land areas in developing countries (Meze-Hausken 2000). Perhaps because of the attachment to place and particularly to the land by inhabitants, migration from traditional societies is low in Nepal (Pun 2004). However, the modernization process, personal desires of young generations, deficit output of traditional agricultural (Pandey and Adhikari 2013; Pun et al. 2010);related decline in land productivity, and increased time required to collect firewood associated with climate change, have encouraged people of Nepal to move (Bardsley and Hugo 2010; Chapagain and Gentle 2015; Massey 2010).

Migration is a dynamic social process that produces different interactions between humans and the ecological systems (Wrathall 2012). Migration that is at least in part induced by climate change is well articulated by scholars (Barnett and Adger 2003; Mendelsohn et al. 2007; Locke 2009; Yonetani 2011). Migration is caused both by forced change and by appropriate adaptation to climatic impacts (Bailey 2011; Hugo 2011; Hulme 2008; Piguet et al. 2011; Poncelet et al. 2010). It is estimated that 73 million people suffering from climate change induced vulnerability across the globe have migrated to safer places between 2008 and 2010 (Yonetani 2011). When risks associated with climate change are concentrated in a place, the desire to move towards safer places emerges more strongly (Cruz et al. 2007).

The benefit of migration is that it provides opportunities to earn cash, however, welfare may be limited to the migrant individual and the household (Biggs and Watmough 2012). Nonetheless, it helps households adapt to environmental changes in two ways: the migrants send remittances to those left-behind that can be invested for adaptation options, and the migrants living away reduce the pressure on limited resources at the origin (Adger et al. 2002; Hugo 1996).The studied households also adopted migration strategies to adapt to climate and other non-climatic stressors. Migration to local market centres, migration to cities and international migration for paid work are the major strategies the studied households adopted.

6.2.7.1 Migration to Market Centres

The sale of labour in local market centres, although taking place on a seasonal basis, is a common strategy for the poor to supplement incomes that can aid adaptation to climatic variability (Gentle and Maraseni 2012; Little et al. 2001; Onta and Resurreccion 2011). The individuals who migrated to nearby market centres in the study area have generally been engaged in informal jobs; and 27.5 percent of households reported members who had done so to earn cash income (Figure 6.13).

Figure 6.13: Adoption of Strategies Associated with Migration in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)

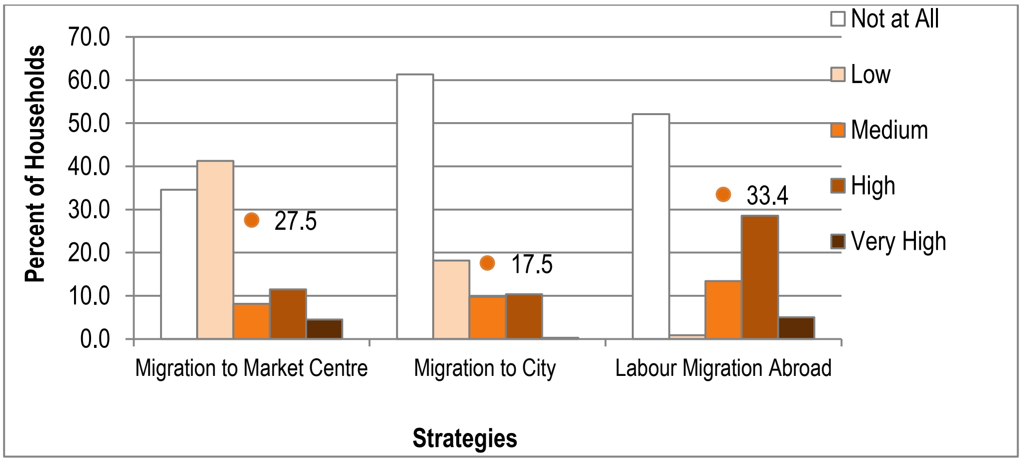


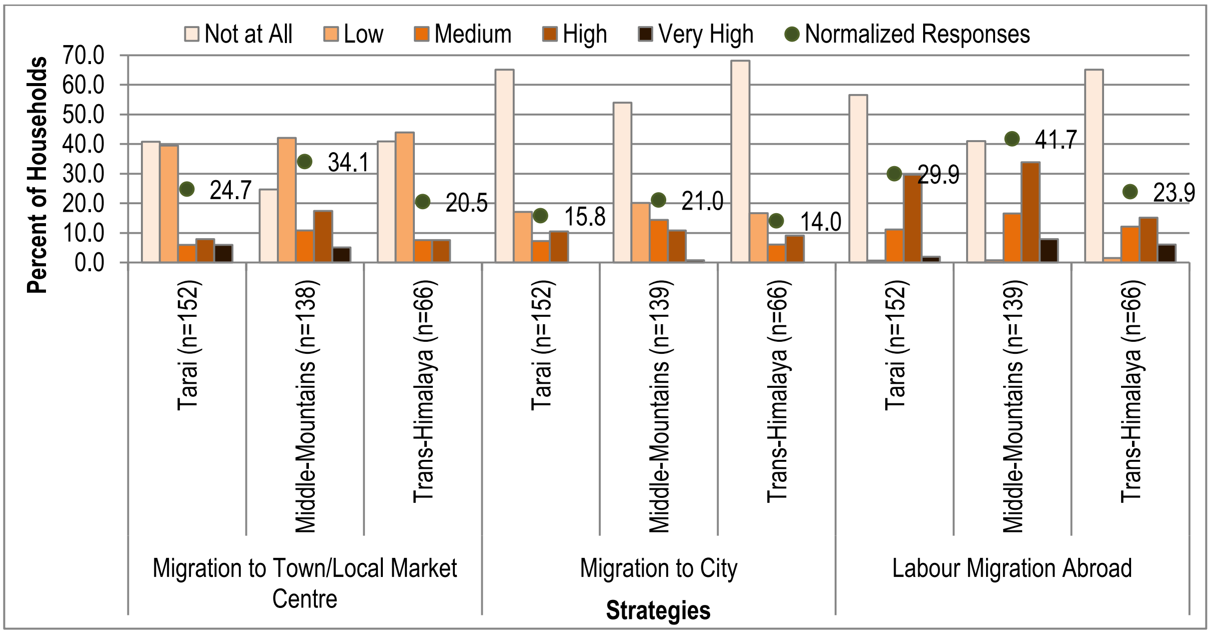
Figure 6.14 shows some spatial variations in the proportions of households having members migrating to market centres. The highest proportion of households was in the Middle-Mountains (34.1 percent), followed by the Tarai (24.7 percent) and the Trans-Himalaya (20.5 percent). Most of these migrants are seasonal job seekers, who work as wage labourers during the off-farm seasons and return back home during the crop planting and harvesting seasons. However, not all of them return back, causing a reduced labour supply for agricultural activities in their home communities.

6.2.7.2 Migration to Cities

Migration to cities is adopted by some of the studied households, with 17.5 percent households having members who employed that strategy (Figure 6.13).Many respondents stated that due to not getting fulltime jobs as labourers and the higher cost of living in the city, many preferred to work in the neighbourhood and in local market centres. Therefore, the proportion of households having household members working in the cities is comparatively less than those working at market centres.

Figure 6.14 illustrates some variation in the adoption of 'migration to cities' strategy across the ecological zones. Of the total, 21 percent of households in the Middle-Mountains followed by the Tarai (15.8 percent) and the Trans-Himalaya (14 percent), have members working or who have worked in the cities. Kathmandu, Pokhara and Narayanghat are the major cities for the labourers, with Kathmandu common for all the study sites, whereas Pokhara is in close proximity was preferred by the labourers from the Middle-Mountains and the Trans-Himalaya, while labourers of the Tarai prefer to work in Narayanghat.

Figure 6.14: Adoption of Strategies Associated with Migration by Ecological Zone in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)



6.2.7.3 Migration Abroad for Paid Work

International migration is emerging as an important adaptation strategy to climate change that is being practiced by people in different parts of the globe (Bailey 2011; Brown 2007; Hulme 2008; McLeman and Smit 2006; Piguet et al. 2011) although climate change impacts are not independent factors. Labour migration abroad is already a major livelihood strategy of rural Nepali communities, with India as the dominant destination until recently. The proportion of labour migrants to Malaysia, Middle-East and South Korea from Nepal has increased rapidly in the last two decades. Some argue, however, that international labour migrants of Nepal are highly exploited [90] (Davis and Monk 2007; Pandey and Adhikari 2013).

Figure 6.13 indicates that the 33.4 percent of the studied households have at least one family member in the international labour market. Of the total 5 percent of households had 3 or more members, and another 28.6 percent had two or more members working abroad at the time of the interviews. Figure 6.14 shows the proportion of households having family members abroad for labour work was the highest (41.7 percent) in the Middle-Mountains, followed by the Tarai (29.9 percent) and the Trans-Himalaya (23.9 percent).

90

- Nine Nepalis die each week in Malaysia: Embassy, viewed 10 January 2015, <http://www.ekantipur.com/2014/11/21/editors-pick/9-nepalis-die-each-week-in-malaysia-embassy/397977.html>;
- Death toll among Qatar's 2022 World Cup workers revealed, viewed 10 January 2015, <http://www.theguardian.com/world/2014/dec/23/qatar-nepal-workers-world-cup-2022-death-toll-doha>

Labour migration abroad is a temporary strategy of risk management for households in the study area. The studied communities revealed that the remittances from abroad have become necessary to cover the livelihood challenges caused by reduced access and entitlement to natural resources. Furthermore, the migrants are mostly young and not interested in traditional occupations such as agriculture. Although, the remittances earned are generally not invested in productive sectors, respondents stated that it was better to receive cash income from labour migration abroad rather than the youth staying idle at home. Although in most cases climate change is not the primary driver of migration, it is a contributing factor in out-migration and some of the negative impacts of change are reduced in the process.

6.2.8 Strategies Associated with Improvements in the Home Environment

Making living conditions more comfortable by installing heating or cooling instruments, mosquito nets and changing a house's structure are important to adapt to weather extremes. Warmer indoor temperature promotes growth and spread of pathogens. Therefore, mitigating indoor temperature extremes is important to reduce food contamination and associated health implications in the region.

6.2.8.1 Installation of Heating and/or Cooling Instruments and Mosquito Nets

Effective early warning systems help people to prepare for extreme events. Many societies in developed countries have successfully adapted to extreme events as they receive timely information and are equipped with effective emergency responses. However, early warning systems are mostly lacking in Nepal. Nevertheless, 36.4 percent of the studied households have installed heating or cooling devices to cope with extreme temperatures (Figure 6.15). Figure 6.16 shows two-thirds of the households in the Tarai have installed heating or cooling devices; corresponding proportions are 21.2 percent in the Middle-Mountains and only 1.9 percent in the Trans-Himalaya. To make an indoor environment comfortable, households require a large amount of money, so despite knowing about the risks from heat and/or cold, the poor households of the study area lacked resources to implement such a strategy.

Figure 6.15: Adoption of Strategies Associated with Comfortable Living in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)

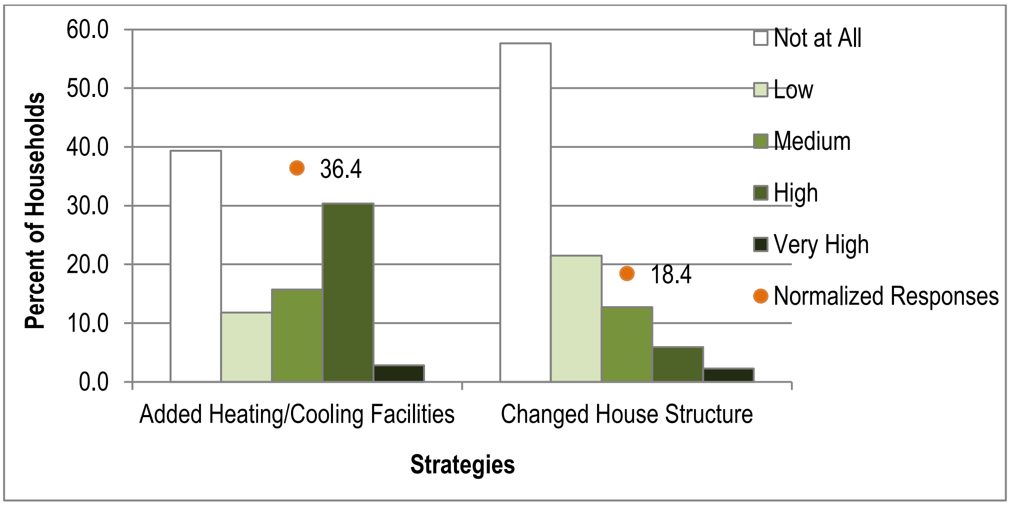
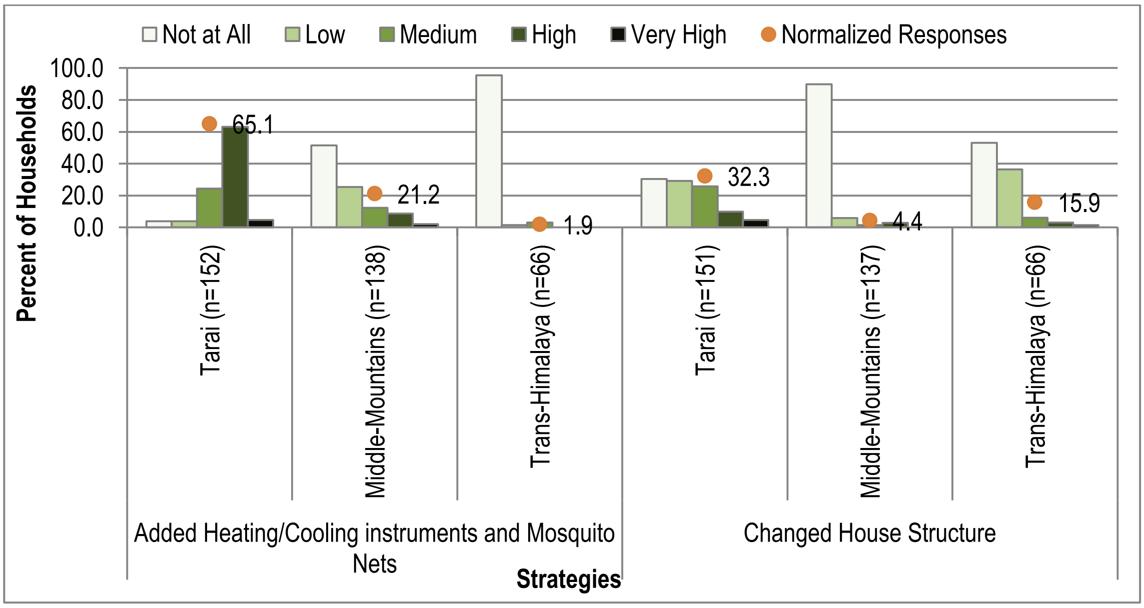


Figure 6.16: Adoption of Strategies Associated with Comfortable Living by Ecological Zone in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)



The Tarai requires both heating and cooling devices for different seasons together with mosquito nets throughout the year, which has helped to reduce the risk of malaria, kala-azar, Japanese encephalitis and dengue fever. In the Middle-Mountains, mosquito nets for summer and heating devises for winter are preferred. In the Trans-Himalaya, heating devices are desired and also installed by a few households (solar for water heating) and LP gas-run hot-water shower (especially in hotels). To make the indoor environment warm, households of the Trans-Himalaya use firewood, and also keep livestock on the ground floor while people live on the first floor, and the heat from livestock helps keep the first floor warmer. These strategies are practiced traditionally in the Trans-Himalaya and are not directly linked to recent climate change.

6.2.8.2 Changed House Structure

Changing house structures are another way to assist adaptation to a changing climate. The changes include the lifting of the foundation wall (to be safe from the floods), changes in roofing materials (to be safe from heavy rain, leakage, windstorm and fire incidents) and the construction of stronger buildings. Figure 6.15 shows that the strategy, however, is adopted by 18.4 percent of households in the study area, 32.3 percent in the Tarai, 15.9 percent in the Trans-Himalaya and 4.4 percent in the Middle-Mountains have adopted the strategy (Figure 6.16).

Many households of the Tarai and the Trans-Himalaya would like to change the structure of their houses. The participants of the FGDs in the Tarai stated that lifting the foundation wall was very important to improve safety from floods. However, respondents also reported that constructing stronger and multi-storey buildings was too expensive. In the Trans-Himalaya, changed form of precipitation from snowing to more rainfall has increased the leaking potential of traditional roofs of the buildings. Therefore, households desired to replace existing roofs with gabion sheets or concrete because clay roofs required frequent repairs due to the increased rainfall. However, this involved financial limitations, due to costs.

6.2.8.3 Infrastructure, Disaster Prevention and Preparedness

Extreme events are often experienced in the short-term, but their impacts are devastating and long-lasting. If communities could escape extreme events, coping and adapting to climate change would be more feasible. However, escaping extreme events is only possible if people have information on their likely occurrence in sufficient time ahead of the events. The disaster preparedness of communities and the provision of early warning systems, emergency shelters and post-event rescue and recovery, have significant implications in coping and adaptation to floods and other disasters. However, these services are in their infancy in the study area. Respondents reported that there is no very effective work that has been done towards the development of early warning systems or emergency shelters. The participants of the FGDs at ward 1, 2, 3 of Meghauli share their story:

… Emergency sirens are installed in few locations in Meghauli and adjoining VDC to warn inhabitants in the event of flooding. The local FM radios also broadcast warnings. However, there is no safer place (shelter) to go so the efficacy of siren is poor. During flooding, the place (Wards 1, 2, 3of Meghauli) becomes an island surrounded by the Rapti River in the East and South, and the Narayani River in the North and West. Therefore, construction of a shelter is very urgent for this place. The schools and open grounds are used as a shelter during normal floods, but there is no way to escape a severe flood. People would be alive only if rescued by air-lifting. The place has a Disaster Management Committee (DMC) that is working as best as it can, given available expertise and resources. The DMC and local people own a few small boats for rescue purpose; which are not sufficient during the severe floods. …

To reduce flooding and landslides, communities are constructing retaining walls using gabion boxes at erosion sites as it is challenging settlements, public infrastructure and utilities. Households in the Trans-Himalaya have also constructed mud-stone walls at the edge of farmlands to protect private property from debris, whereas gabions boxes and concrete walls are constructed to save common property resources, like water supply infrastructure, irrigation and roads as well as settlements (Plates 4.1c, 4.2a 6.4).

Plate 6.4: Flood Control through Concrete wall in the Trans-Himalaya, Nepal
(Source: Field Survey, 2013)

Research participants acknowledged the receipt of some external support from the government and I/NGOs to construct, repair and restore roads, dams, flood control dikes, retaining walls and gabion boxes, drinking water supply and irrigation systems. Yet, raising community awareness of extreme events and associated coping strategies was not implemented widely by these organizations.

6.2.8.4 Pray to God

Pray to god is not an adaptation strategy *per se* but it may reduce the prayer's stress caused by climate change and associated impacts. Praying to the faith he/she holds for peace of mind is the last resort for individuals. Some of the farming households stated that adapting to the impacts associated with extreme events is beyond their capacity and only god can protect them, so they pray to god that there are no further calamities. The Himalayan communities believe that god is punishing human beings because the present world has lost harmonic relation to the environment and so praying is the only hope.

Table 6.6 shows that noteworthy proportions of the respondents (32 percent) reported faith in god, so they pray regularly. Higher proportion of respondents of the Trans-Himalaya (59.1 percent) held faith in god, with corresponding proportions in the Middle-Mountains and the Tarai were 30.3 percent and 21.7 percent. The participants of the FGD at Lumle-9 believed that *Surya Baraha* (a local deity) got angry because communities forgot about him for a long time; and as a result incidents of heavy hailstones have become more frequent. The community performed an offering at a *Surya Baraha* temple to wish for no more disastrous hailstorms. These issues of faith are important because they may delay the community from preparing for change. On the other hand these activities suggest an important level of resilience and mutual support.

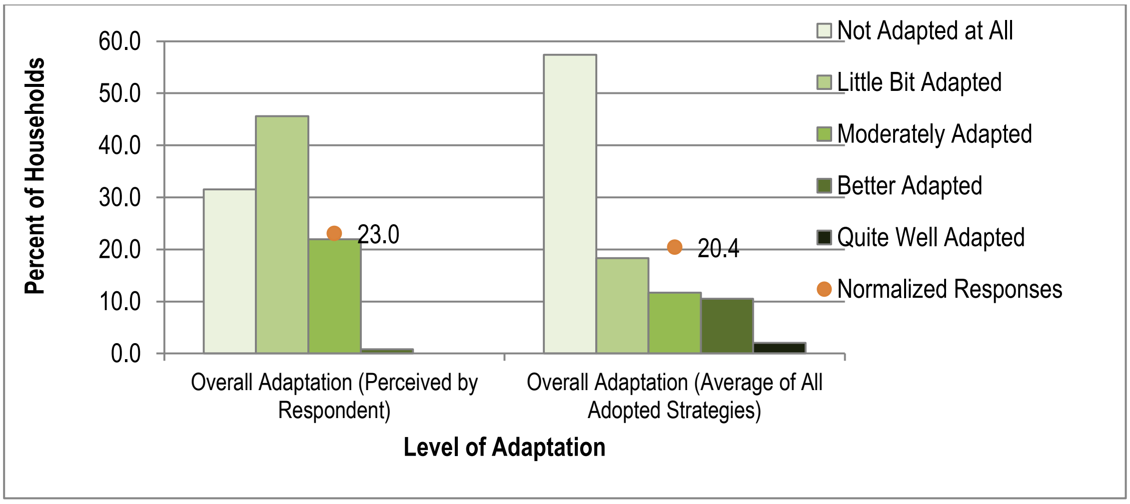
Table 6.6: Adoption of Strategies 'Pray to God' by Ecological Zone in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)

Level of Response	Tarai (n=152)	Middle-Mountains (n=137)	Trans-Himalaya (n=66)	Total (n=355)
Not at All	52.6	34.3	22.7	40.0
Low	13.2	17.5	7.6	13.8
Medium	28.9	40.9	3.0	28.7
High	5.3	7.3	43.9	13.2
Very High	0.0	0.0	22.7	4.2
Normalized Responses	**21.7**	**30.3**	**59.1**	**32.0**

6.3 Overall Adaptation Situation in the Kaligandaki Basin

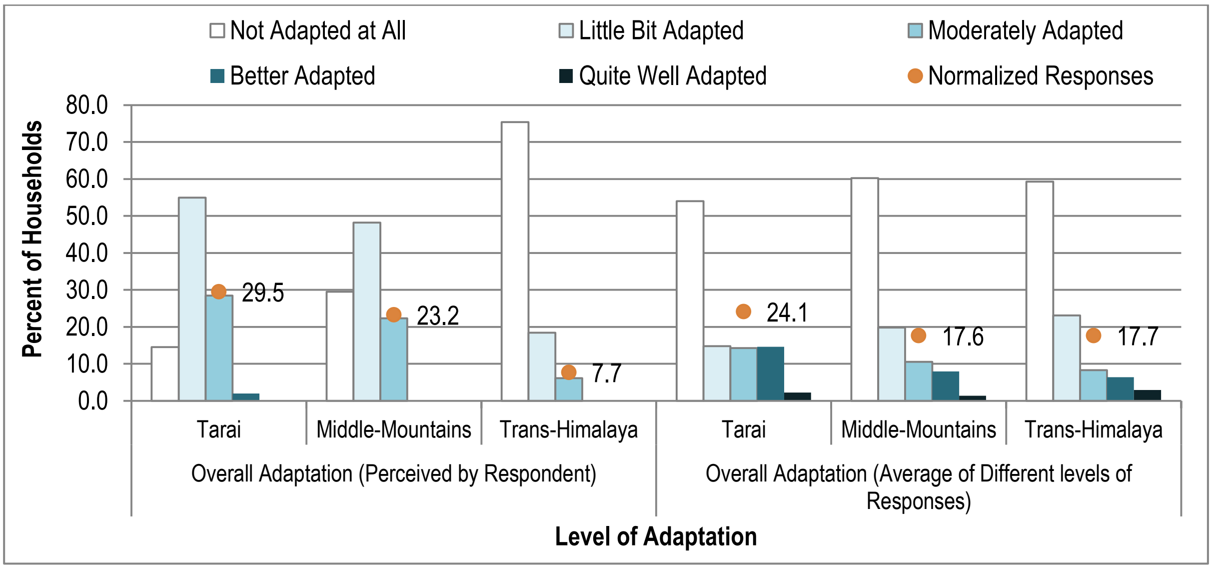
The strategies adopted by the studied communities are summarised in two ways: an overall assessment of the adoption of strategies by respondents themselves. For an example, all respondents answered a question: what level do you think your household is adapting to climate change? This is referred to as 'perceived by respondent' in the Figure 6.17. Another is the average of different levels of adaptation responses given by the respondents on different strategies discussed above, termed as 'average of all adopted strategies' in the same figure. Although both are perceptions, the former is an overall perception while the latter is the average of different strategies. The normalised response of overall perception suggests that 23 percent of all households are adapting to climate change at some level. Of the total, none of the households reported themselves as 'well adapted', while only 0.8 percent households classified themselves as 'quite well adapted' and 22 percent of households reported as 'moderately' adapted. On the other hand, the average of all the strategies demonstrates 20.4 percent of the households are adapting at some level, with 2 percent 'well adapted', 10.5 percent 'quite well adapted' and 11.7 percent 'moderately adapted' (Figure 6.18).

Figure 6.17: Levels of Overall Adaptation in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)



There are some variations in the proportions of households adapted to climate change different degrees between the zones. As shown in Figure 6.18, 29.5 percent, 23.2 percent and 7.7 percent households in the Tarai, the Middle-Mountains and the Trans-Himalaya reported some level of adaptation. On the other hand, the 'average of all adopted strategies' demonstrates a quarter of households in the Tarai, followed by little over 17 percent in the Middle-Mountains and the Trans-Himalaya are found to have adapted at some level. However, the proportions of 'well adapted' households are negligible in all the regions.

Figure 6.18: Level of Adoption of Various Strategies by Ecological Zone in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)



It is interesting to note that the Trans-Himalayan communities could be seen to be more adapted to their local environmental conditions than they think, in comparison to the communities of other places. For instance, 7.7% households of the Trans-Himalaya perceived to be adapted, while overall adoption of various strategies suggests 17.7% households are adapted to some level. This finding does not support the general hypothesis that the Trans-Himalayan communities would be more vulnerable to climate change. On the contrary, communities of the Tarai and Middle-Mountains perceived that they are less adapted than they think since the proportion of households of overall perceived adaptation is higher than the actual adoption of different adaptation strategies. The cultural influence and physical environment of different places together with variable levels of expectations of people might have generated this difference.

6.4 Conclusion

The studied communities demonstrate poor levels of adaptation despite many of them holding relatively rich knowledge of adaptation options and the associated positive implications for their livelihoods. Bio-physical adaptation strategies, the strategies associated with farmland management, water resource management, livestock and forest management, are effective and relevant strategies for most households in the study area. However, the small size of farm holdings, poor access to forest resources, and insufficient water for irrigation led to poor levels of adoption of such strategies in the study area. This research supports arguments that adaptation knowledge alone is insufficient to ensure effective adaption to climate change (Adger et al. 2007; Adger and Barnett 2009). Livelihood diversification, mostly agricultural diversification, is not considered an important adaptation option, while efforts to diversify income from paid labour outside of agro-livestock activities are emphasized. In particular, labour migration abroad, which is highly exploitative, has been utilised because it provides access to cash incomes for poor households. The non-linearity of change and the temporal and spatial variability in the magnitude of the impacts generates adaptation uncertainties in the study area. Some of the informants reported that the lack of knowledge transfer to younger generations, especially because of the lack of interest among young people in agriculture, has resulted in poor agricultural adaptation. Some respondents also stated that the lack of community consensus on adaptation had reduced the households' up-take of adaptation options. In general, households in the study area are not very serious about the implications of climate change as they mentioned that "It goes its way (*yestai ho chalchha*)". Consequently, whatever strategies they have adopted are primarily associated with short-term risk management, although the needs of households in the wake of climate change will involve both short-term and long-term change management [91].Considering the unique characteristics of the Himalayan social ecosystem, an ecosystem based or niche-based adaptation option is probably the best option, however, transformative adaptation policy is required to promote adaptation in the Himalaya.

Most of the strategies adopted by the communities cannot be justified by climate change alone. Most of the strategies adopted in the study area are reactive; adopted either to cope with economic stress and/or the immediate impacts of environmental change. Yet, proactive adaptation is required to ensure food and livelihood security within a broadly sustainable social-ecological system. Chapter seven assesses those elements within the study area, and discusses the implications of the findings for theory and practice.

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[91] Risk management is to deal with shocks and change management is to modify behaviour over medium-to-long term to avoid disruption or decline caused by climate change (FAO 2008).

CHAPTER VII

LIVELIHOOD OUTCOMES, SOCIAL-ECOLOGICAL VULNERABILITY AND IMPLICATIONS OF THE RESEARCH

7.1 Introduction

From the previous chapters it is clear that the livelihood systems of the Himalaya vary spatially and socially, and are made up of a complex combination of agro-livestock activities, that are also increasingly linked to different forms of service provision, small businesses, wage labouring and remittances. The construction of climate knowledge is also complex since it is made-up of interactions of the elements of the atmosphere, cryosphere, biosphere, and the anthroposphere with information drawn from scientific measurements and social perceptions. The interactions between livelihood strategies and changing climates have compounded human-environmental challenges. The complex systems are already characteristically non-linear, variable and uncertain, and are unpredictable (Costanza et al. 1993; Gunderson and Holling 2002), so greater exposure of the livelihood systems of the Himalaya to climate change adds more pressure on those systems. Together it is possible to conclude that the implications of climate change on the social-ecological systems of the Himalaya are non-linear, compounding and uncertain, and adaptation responses are inadequate to meet the local needs.

Households have made efforts to reduce the negative impacts of climate change on their livelihood systems. However, the responses are hindered by existing socio-economic and political problems, such that many of the adopted strategies remain ineffective and have reduced the adaptation confidence of many households. Consequently, effective policies that consider climate proofing and 'no regret' actions as important components, are necessary to improve the sustainability of local systems. In this context, this chapter presents the implications for food security, the primary indicator of livelihood security, and the vulnerability of social-ecological systems as an outcome of new human-environmental interactions in the Himalaya.

This research has considered climate change as an exogenous stressor, and socio-economic and political factors as endogenous stressors of the dynamic human-environmental interactions in the Kaligandaki Basin, Nepal. The positive implications of both exogenous and endogenous risks to the social-ecological system should be the focus of policies and resources for the adaptation and sustainability of local systems. Although the more substantial negative implications remain the cause of vulnerability and the extreme adaptation challenges. In this context, the theoretical and methodological premises this study established in understanding human-environmental interactions in relation to climate change are critically examined in relation to the findings. The chapter outlines the implications of the research for the integration of development policies to reduce the negative effects of climate change, while also promoting the sustainability of the Himalayan social-ecosystems.

7.2 Livelihood Outcomes

7.2.1 Food Security

Safeguarding food security is the ultimate goal of communities whose livelihoods are primarily derived from subsistence agro-livestock systems. Food security refers to food processes and outcomes in reference to its availability, accessibility, utilization and stability (FAO 2008). The World Food Summit of 1996 defined food security as a situation that:

> "…exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (WFS 1996, para.1).

The FAO further refined this definition in 2002 and stated that it is present when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life. It is the latter definition that will guide the discussion here.

Food availability is the physical quantity of food that is produced, stored, processed, consumed, or exchanged (FAO 2008), while its access refers to food entitlement – a set of resources that an individual requires to obtain access to food (Sen 1989). The set of resources refers to alternative commodity bundles that a person can command in a society using the totality of rights and opportunities that he or she faces (Sen 1984). The utilization of food indicates that essential nutrients have been obtained from consumed foods (FAO 2008), and stability designates that the food in the sense of availability, access and utilization is present at all times, with no interruptions. In this context, food security is a function of the food system with different processes all along the food chain. Here, the food system is defined as a dynamic interaction between and within the bio-geographical and human environment that leads to production–procession-preparation-consumption of food to underpin food security (Gregory et al. 2005). In brief, the food system is that which functions as the mechanism to achieve the goal of food security.

The impacts of climate change on food security are complex and uncertain because climate impacts upon multiple components of, and actors in, the food system (FAO 2008). Some scholars claim that climate change impacts on agriculture and food production at a global scale are manageable if the warming does not exceed 2^{O}C from 1990-2000 levels (FAO 2002; Parry et al. 1999; Reilly 1995; Schneider et al. 2007). However, availability of food itself cannot ensure food security it includes access to food, utilization and stability (sustainability of supply and access), together with availability. The changes in climate can challenge food safety and nutritional aspects of food. Food supply is often linked to socio-economic and political power relations that later impact on nutritional aspects and nutrition related health (FAO 2008). Climate change could also relate negatively to other socio-political and market dimensions of food security (Rosenzweig 2011; Selvaraju 2011). Therefore, interaction between climate change and food security are compounded. This study has adopted Sen's theory of food entitlement that refers to households' own production, income, gathering of wild food, community supports, assets, and migration to express food security (Sen 1981). To analyze local capacity to achieve food security, including physical sufficiency or availability, annual budget sufficiency (economic access to food), and the HFIAS scale (food utilization and stability), are analyzed in detail in relation to the situation of households in the Kaligandaki Basin.

7.2.1.1 Food Sufficiency

Food sufficiency is a major indicator of food security. South Asia contains the largest numbers of the world's malnourished people (FAO 2014 [92]; Lobell et al. 2008), and has over a half of the total labour force engaged in agriculture (Shah and Lele 2011). Nepal is dependent on agriculture and is poor, so the country is broadly food insecure. The IPCC AR4 has stated that it is such countries with a higher dependency on agriculture that would suffer most from food insecurity due to climate change, and the poor will feel the impacts disproportionately (Cruz et al. 2007).

The status of food sufficiency varies across the studied households, so they are categorised into five classes: no food deficiency, little, moderate, severe and profound food deficiency. Out of the total, 45.6 percent of the households reported food sufficiency. However, the remaining 54.5 percent have experienced some levels of food deficiency, and among these households, the majority (23.3 percent of the total) experience moderate deficiency, whereas 6.7 percent and 7.5 percent of households suffer from severe and profound levels of food deficiency respectively (Table 7.1).

[92] Interactive hunger map (2012-2014) viewed 7 February 2015 <http://www.fao.org/hunger/en/>.

Table 7.1: Proportion of Households by levels of Annual Food Deficiency and Annual Deficiency of Cash Requirement, and Ecological Zone in the Kaligandaki Basin, Nepal

(Source: Field Survey, 2013)

Levels of Deficiency	Food Deficiency (percent of Households)				Budget Deficiency (percent of Households)			
	Tarai	Middle-Mountains	Trans-Himalaya	Total	Tarai	Middle-Mountains	Trans-Himalaya	Total
No Deficit	75.2	16.3	39.4	45.6	81.0	75.9	56.1	74.4
Deficit of Less than 25 percent (Little)	11.8	14.2	33.3	16.7	15.0	15.6	37.9	19.4
Deficit of Up to 50 percent (Moderate)	6.5	44.7	16.7	23.3	3.9	6.4	3.0	4.7
Deficit of Up to 75 percent (Severe)	2.0	12.1	7.6	6.9	0.0	1.4	3.0	1.1
Deficit of Over 75 percent (Profound)	4.6	12.8	3.0	7.5	0.0	0.7	0.0	0.3

Notable spatial variation exists across the ecological zones in relation to food sufficiency (Table 7.1). The highest proportion of households in the Tarai (75.2 percent), followed by the Trans-Himalaya (39.4 percent) and the Middle-Mountains (16.3 percent) reported food sufficiency. The highest severity of food deficiency is found in the Middle-Mountains with 12.8 percent reporting profound and 12.1 percent reporting severe levels of deficiency. The corresponding proportions of households of the Trans-Himalaya are 3(profound) and 7.6(severe) percent and in the Tarai are 4.6 percent (profound) and 2 percent (severe). The production of sufficient food required for the household is very important indicator of livelihood security within subsistence farming households; with many households unable to produce enough food. In discussions the informants reported that because of limited production they often are unable to save seeds for the next sowing season, so they suffer from the additional financial burden of buying expensive seeds from the market during the sowing season.

7.2.1.2 The Sufficiency of Annual Household Budgets

Climate impacts on food production and on the income of poor people, decreasing their capacity to pay for food. This phenomenon is expected to increase the problem of hunger in the rural population of South Asia (Cruz et al. 2007). As discussed, many of the studied households retain multiple livelihood options (Appendix 12) and the sufficiency of the annual household budgets is discussed here to evaluate the economic access to food.

In the study area, economic access to food is relatively better than the physical availability of food. Yet, over a quarter of the households (26 percent) faced some level of household budget deficit in the last year, although, the proportion with severe to profound levels of budget deficiency was minimal (1.4 percent). The observed spatial variation shows a higher deficiency in the annual household budget in the Middle-Mountains and the Trans-Himalaya, with 2.1 percent and 3 percent of the households respectively, and those households faced the equivalent of a 50 percent deficiency in annual household budget (Table 7.1).

7.2.1.3 Household Food (In)Security Access Scale

Social safety nets and welfare are another important means of generating food security for those who lack their own immediate resources. Here, food security of the studied households is assessed using Household Food (In)security Access Scale (HFIAS), which incorporates the availability, access, utilization and stability aspects of food security.

The Nepal Living Standard Survey 2010-2011 suggested that around 8 percent households could not afford to eat one or more times within the previous month (CBS-NLSS 2012). Chaulagain (2006) reported that the poorest 20 percent of the population in Nepal consumed less than 40 percent of the daily calorie requirements and only 6.2 percent of the total national food. Estimations show some 3.4 million people in Nepal need food assistance, partly to overcome disaster related losses of production but also due to increasing food prices and regular annual food deficiencies (Oxfam 2009). In the study area, over one-third of households have experienced food insecurity to some level. Amongst them, very few households (0.8 percent) face severe levels of food insecurity, while other households are facing moderate (8.9 percent) or occasional food (26.8 percent) food insecurity.

The problem of food insecurity varies spatially, but is a typical characteristic of mountain households. Over a half of the households in the Middle-Mountains and the Trans-Himalaya experienced some levels of food insecurity with the corresponding proportion in the Tarai less than 20 percent. Furthermore, over the previous decade, the proportion of households occasionally facing food insecurity has increased in the Middle-Mountains, while the proportion of households facing other forms of food insecurity remained the same or declined. The severity of food insecurity has decreased in the Tarai (Table 7.2). The assessment suggests a general improvement in food security over time, with the weakest improvement in the Middle-Mountains.

Food insecurity in Nepal is closely related to poverty, and the incidence of poverty has seasonal characteristics. Most households are cultivators-consumers, often leading to variable food security situations between the pre-harvest and post-harvest seasons (Figures 7.1 and 7.2). As shown in the Figure 7.1, October - December are the months with fairly similar food security status across the ecological belts. Notably, however, December and January in the Trans-Himalaya and July through September in the Middle-Mountains are critical to food insecurity levels. The proportion of food insecure households is higher in the Middle-Mountains, followed by the Trans-Himalaya for most of those months. The months with better food security conditions coincides with the post-harvest months, while the shortages in food availability are most pronounced after sowing crops (Figure 7.2).

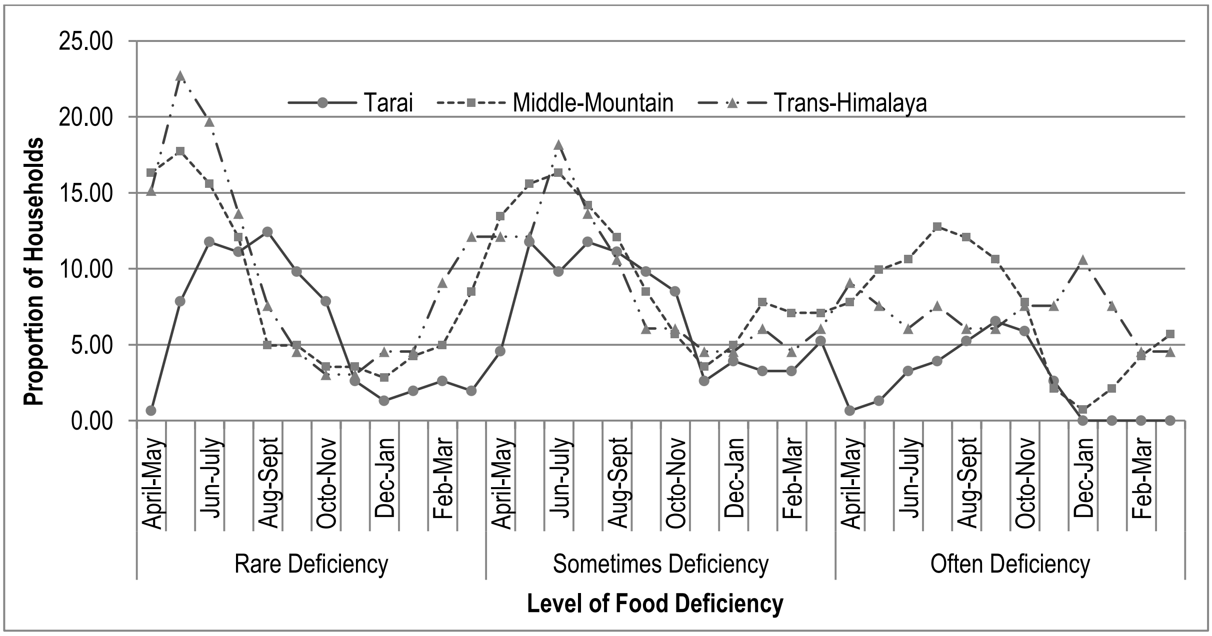
Table 7.2: Level of Food (In)Security at Present and Before 10 years Ecological Zone in the Kaligandaki Basin, Nepal (in Percent)
(Source: Field Survey, 2013)

Level of Food (In)Security	Present				10 Years Ago			
	Tarai	Middle-Mountains	Trans-Himalaya	Total	Tarai	Middle-Mountains	Trans-Himalaya	Total
No Food Deficiency	83.0	48.9	50.0	63.6	65.4	50.4	31.8	53.3
Occasional Food Deficiency	11.8	35.5	42.4	26.7	26.8	31.9	59.1	34.7
Moderate Food Deficiency	5.2	13.5	7.6	8.9	5.9	13.5	9.1	9.4
Severe Food Deficiency	0.0	2.1	0.0	0.8	2.0	4.3	0.0	2.5
Total	100	100	100	100	100	100	100	100

Inherent seasonality of agriculture makes risk and uncertainty intrinsic to agriculture (Davies et al. 2008). Negative but localised impacts of climate change on subsistence farming will lead to food insecurity, though that of a local area is also influenced by the global food market (IPCC 2007a). Developed countries are the primary producer of marketable foods so reduced production reduces the affordability of food by the poor. The seasonal agricultural implications of climate change in the study areas, such as crop damage by hail and rain during the harvesting periods are advancing the severity of food insecurity.

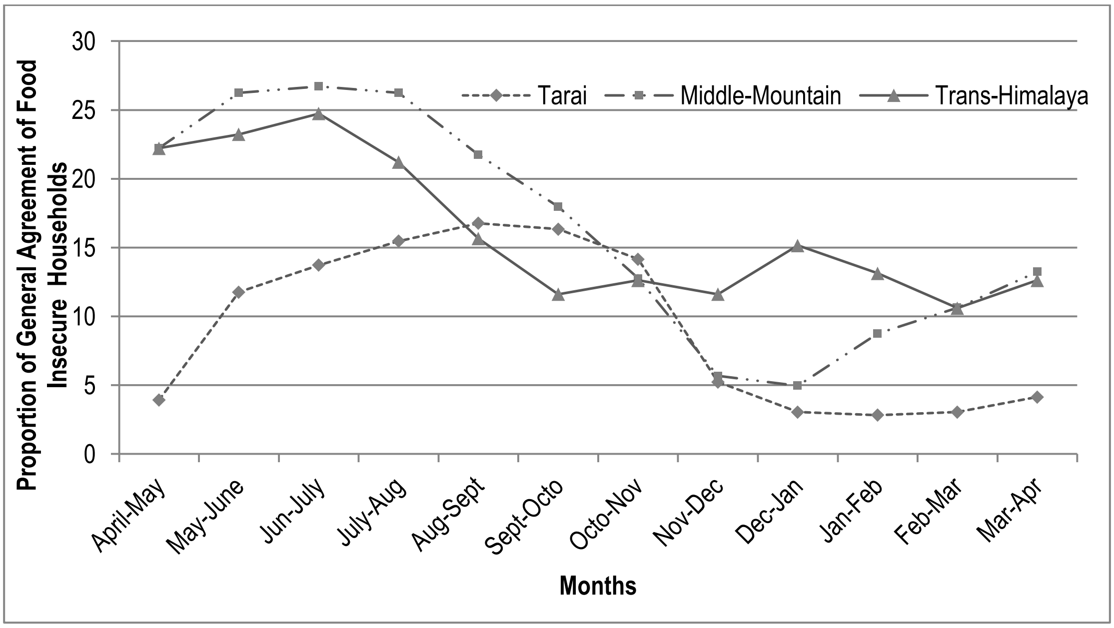
Food insecurity is common in resource poor communities in Nepal that have many health implications, especially for young children. National figures show 41 percent of children under five year old are short for their age (16 percent severely stunted), 11 percent are thin (3 percent severely thin), 29 percent are underweight (8 percent severely underweight), and 46 percent of children under 5 years, and 35 percent of women are anaemic (MoHP/NDHS 2011).All these health problems are directly or indirectly associated the availability of food and nutrition. The situation of the study area may not be very different to that of the country in general as many places have experienced food insecurity, but there was no primary evidence of this.

Figure 7.1: Monthly Scenario of Food Insecurity by Level of Insecurity and Ecological Zone in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)



Note: The responses were transformed from Nepali Calendar so months overlaps, Nepali New Year falls around the 14th or 15th of April.

Figure 7.2: Monthly Scenario of Generalized Food Insecurity by Ecological Zone in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)



Note: The responses were transformed from Nepali Calendar so months overlaps, Nepali New Year falls around the 14th of April.

Food security and the sustainability of the livelihood system is a major requirement for the sustainability of the social-ecological system. Clearly, the study area has experienced food insecurity and the livelihood system is also weak and insecure suggesting the vulnerability of their social-ecological systems. Below, the social-ecological vulnerability of the study area is assessed to see if the systems can cope with and recover from stresses and pressures posed by climate change.

7.3 Social-Ecological Vulnerability to Climate Change

Understanding climate change induced social-ecological vulnerability is one of the important aspects of this study. The vulnerability of a system is a function of exposure of the system to risk, the sensitivity of the system to the drivers of risk, and the system's ability to deal with the risk (Adger 2006; McCarthy et al. 2001; Robert and Barry 2006).

The levels of exposure of the social-ecosystem to climate change, sensitivity of livelihood resources, and adaptive capacity of households to climate change developed in earlier chapters, are utilised below in a vulnerability assessment. Indices of exposure, sensitivity, and adaptive capacity were initially calculated using the variables classified into respective groups (Table 3.5) and the method is applied to calculate and assess the Human Development Index. For example, sub-indices of each variable was obtained by applying the formula [(Actual value-Minimum value)] / [Maximum value – Minimum value)], and the weighted means of the variables relating to particular components (exposure, sensitivity, and adaptive capacity) are obtained as respective indices. Afterwards, the social-ecological vulnerability index was calculated using the IPCC Vulnerability Framework: Social-Ecological (Livelihoods) Vulnerability Index (SVI) = (Exposure Index –Adaptive Capacity Index)* Sensitivity Index (see Chapter Three for details). The calculated exposure, sensitivity, adaptive capacity and vulnerability are social constructions since they use the status of socio-economic and bio-physical variables, mostly on the basis of the particular meaning that respondents give to specific variables. This method of vulnerability assessment was adopted because it allows for the integration of the socio-economic and bio-physical attributes that structure the vulnerability of the social-ecological system. The analysis was performed at the household level so the results are presented in two sets. At first the status of individual households are presented, which is followed by the categorisation of households into four different groups of very high, high, medium and low levels of sensitivity, exposure, adaptive capacity and vulnerability. The average status of the ecological zones is also presented.

7.3.1 The Exposure of Social-Ecological System to Climate Change

Exposure of a social-ecological system to climate change is the nature and degree to which the system is exposed to significant climatic variations that compromise the adaptive capacity of the system (McCarthy et al. 2001). This study found variable levels of exposure of households within and across the ecological zones to climate change (Figures 7.3, 7.4, 7.5). Nevertheless, a high proportion of the households fall into a single group having a 'very high level' of exposure (Figure 7.4). Almost 4 out of 5 households in the Tarai and the Middle-Mountains are exposed to climate change to a very high level with 48.5 percent of households having the same level of exposure in the Trans-Himalaya. Of the total, 36.4 percent of households in the Trans-Himalaya, 15.7 percent in the Tarai and 14.9 percent in the Middle-Mountains are exposed to climate change to a 'high level'. The mean of the exposure index is the lowest in the Trans-Himalaya (0.473) followed by the Tarai (0.520), while it is 0.588 in the Middle-Mountains (Figure 7.9), indicating that the Middle-Mountains are the most exposed to climate change, followed by the Tarai and the Trans-Himalaya.

Figure 7.3: Exposure of Households to Climate Change by the Ecological Zone in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)

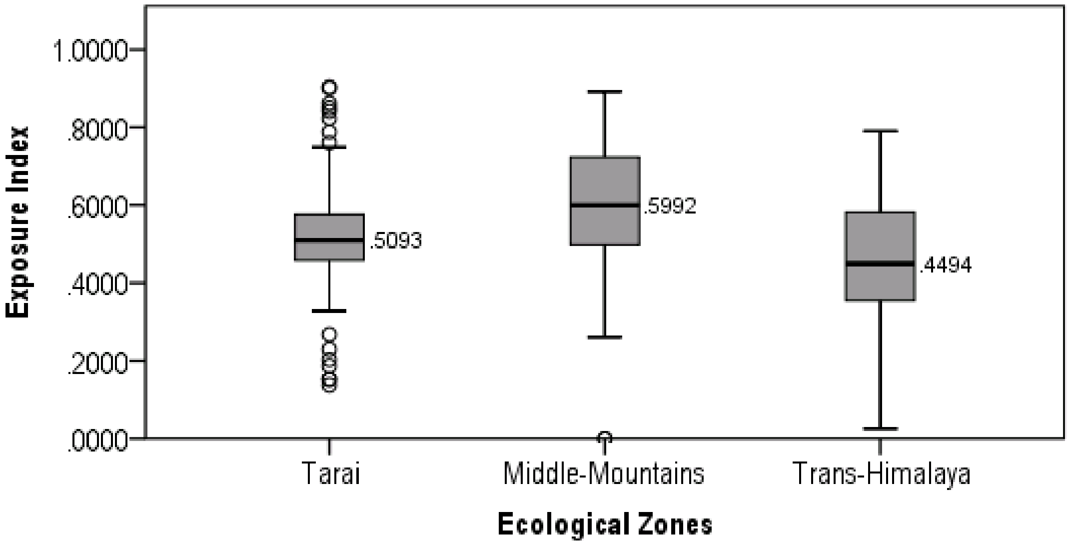
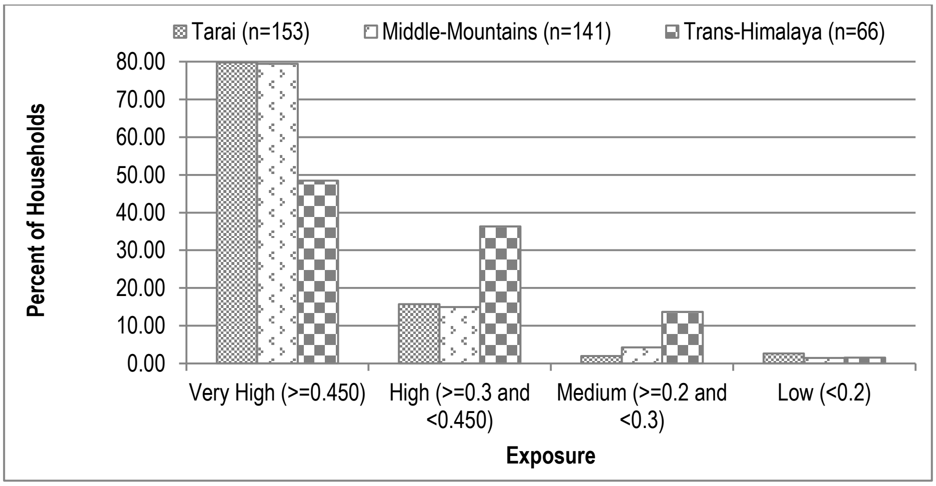


Figure 7.4: Proportions of Households by degree of Exposure to Climate Change by the Ecological Zone in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)



The analysis suggests a very high level of general exposure of the social-ecological system of the study areas to climate change. The vulnerability of a system is not merely the product of physical exposure to environmental change and hazards but also connected to the political, economic, and social context (Adger 2006; Brooks 2003; Martens et al. 2009). A higher level of sensitivity of the social-ecological system to climatic and non-climatic drivers increases the vulnerability of the system, so these were assessed for the three ecological zones.

7.3.2 Sensitivity of Social-Ecological System to Climate Change

The sensitivity of a social-ecological system is the degree to which the system is affected by stimuli in relation to the degree of exposure to the stressor such as climatic factors and the adaptive capacity of the system (Adger and Vincent 2005; Füssel 2007;McCarthy et al. 2001; Mendelsohn et al. 2001). In general, societies highly dependent on primary products for their livelihoods are more sensitive to climatic variability and change. In this context, the social-ecological systems of the studied households are mostly climate sensitive; however, the level of sensitivity varies across households (Figure 7.5) and across ecological zones (Figure 7.6). Out of the total households, one-third of the households of the Middle-Mountains have a 'very high level' of sensitivity to climate change. Corresponding proportion of the households in the Trans-Himalaya are almost a quarter and a little over one-tenth in the Tarai. Similarly, 68 percent, 51.1 percent and 36.4 percent of the households of the Tarai, the Middle-Mountains and the Trans-Himalaya respectively, have a 'high level' of sensitivity (Figure 7.6).The mean sensitivity index is the lowest in the Trans-Himalaya (0.352) followed by the Tarai (0.366). It is the highest in the Middle-Mountains i.e. 0.429 (Figure 7.9). Among the studied ecological zones, the Middle-Mountains are the most sensitive system to climate change.

The human–environmental interactions in a system determine its sensitivity (Turner et al. 2003). The degree of income diversification, levels of education, strength of social networks within a community or a household govern, are the indicators of, the sensitivity of the social-ecological system at the household level. Better agricultural productivity with a year-round growing season and adoption of irrigation strategies in the Tarai reduced the level of sensitivity. On the other hand, low population density and relatively high levels of engagement of people in alternative economic activities, such as livestock, horticulture, hospitality and businesses operated in other cities like Pokhara and Kathmandu of the Trans-Himalaya, helped reduce the sensitivity of that household livelihood system to climate change. The absence or lower degree of adoption of intensive agriculture or alternative income activities in the Middle-Mountains resulted in higher levels of sensitivity to climatic impacts. Yet, all of the ecological zones of the Kaligandaki Basin are sensitive to climate change. Better adaptive capacity will help reduce the vulnerability of a system to climate change so it is assessed for the respondent households of the Kaligandaki Basin.

Figure 7.5: Sensitivity of Households to Climate Change by Ecological Zone in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)

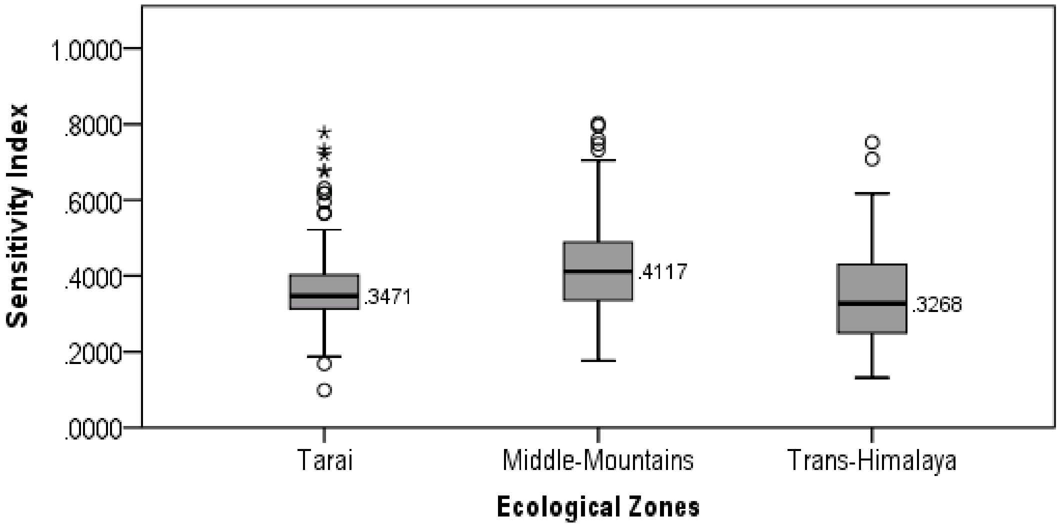
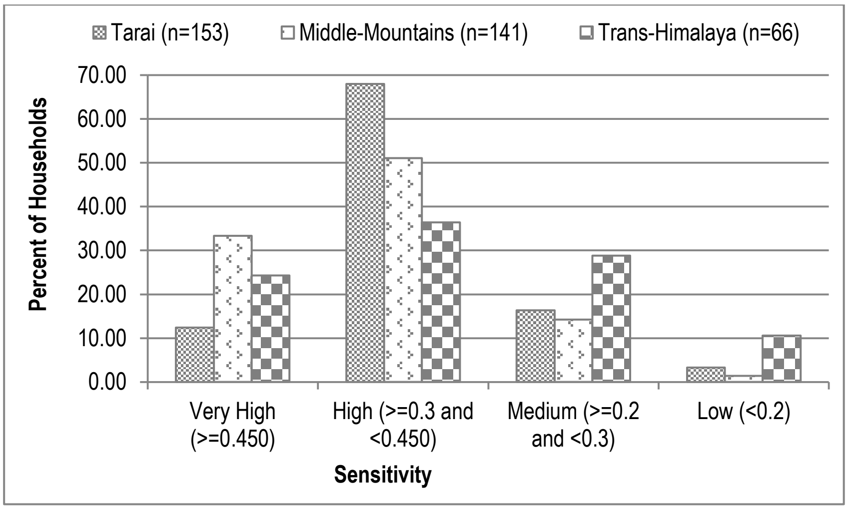


Figure 7.6: Proportions of Households by degrees of Sensitivity to Climate Change by Ecological Zone in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)



7.3.3 Adaptive Capacity of Social-Ecological System to Climate Change

Adaptive capacity is the ability or potential of a system to respond to climate variability and change, and plan for and adapt to the exposure (Adger et al. 2007; Ebi et al. 2006). Better adaptive capacity reflects a communities' ability to reduce harmful outcomes of climate change

(Brooks and Adger 2005). Because of the multiple links with exogenous and endogenous systemic factors, the adaptation process may lead to uncertain adaptation outcomes, maladaptation or 'double exposure' (Adger and Vincent 2005; Barnett and O'Neill 2010; Leichenko and O'Brien 2002; Wiseman and Bardsley 2013). This work assessed the adaptive capacity of the studied households through a systematic analysis of the variables that help adaptation processes.

Adaptive capacity of the studied households is found to be very poor, although, variable across households (Figure 7.7). Almost all households: 99.3 percent of the Middle-Mountains, 97 percent of the Trans-Himalaya, and 96.1 percent of the Tarai fall into a single group and have 'low adaptive capacity'. The remaining households of the Tarai, the Trans-Himalaya and the Middle-Mountains were calculated to have a 'medium level' of adaptive capacity (Figure 7.8). The mean adaptive capacity index is the highest in the Tarai (0.436) while it is 0.381 in both the Middle-Mountains and the Trans-Himalaya. Although there is inter-household variation in households' adaptive capacity, the means of index values across the ecological zones were generally comparable (Figure 7.9).

Figure 7.7: Adaptive Capacity of Households to Climate Change by Ecological Zone in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)

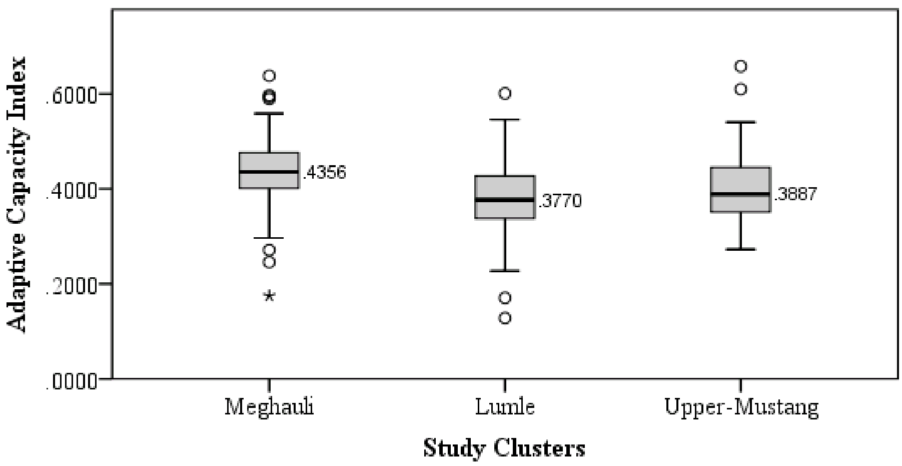


Figure 7.8: Proportions of Households by degrees of Adaptive Capacity by Ecological Zone in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)

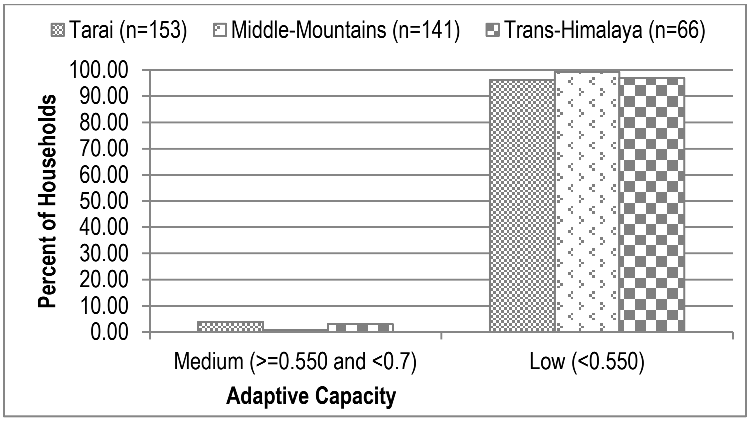
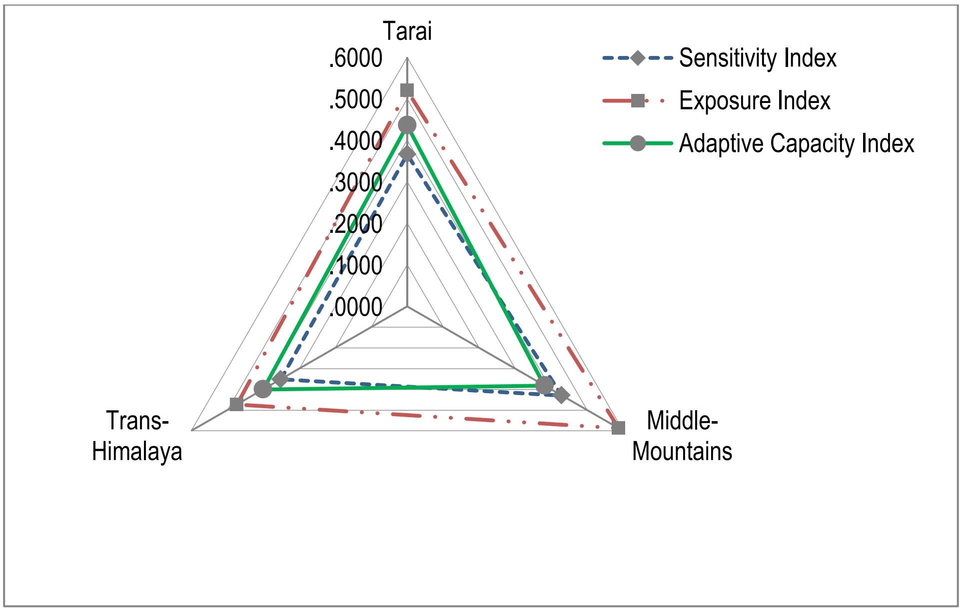


Figure 7.9: Mean Exposure, Sensitivity and Adaptive Capacity Indexes by Ecological Zone in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)



The limited adaptive capacity within the communities of Kaligandaki Basin because of adaptation limits such as poverty; unavailability of climate change adaptive crop varieties; lack of irrigation; lack of reliable weather forecasts; and limited external support, infers a poor ability to modify systemic characteristics or behaviours to adopt, which significantly enhances household vulnerability. The changes in climate reduce the life-supporting capacities of social-ecological systems by altering the quality and functioning of the system. For example, the agro-based livelihood system of the studied households are sensitive to drought as well as flooding on the one hand, and increased crop diseases, pests and weeds on the other. In addition both climatic and non-climatic stressors constrained the adaptive capacity of households. Due to poor governance and lack of accountability in the face of the political transition in Nepal, the situation of the wider social-ecological system of the country receives little policy attention. In this situation the social-ecological systems of the Kaligandaki Basin would suggest high levels of vulnerability to climate change as detailed below.

7.3.4 Social-Ecological Vulnerability to Climate Change

Vulnerability is a multidimensional concept. It is a function of exposure to climate change, associated sensitivities, and adaptive capacity of a system. The Social-ecological Vulnerability Index (SVI) is calculated from the exposure, sensitivity and adaptive capacity indices using the IPCC Vulnerability Framework: Social-Ecological (Livelihoods) Vulnerability Index (SVI) = (Exposure Index –Adaptive Capacity Index)* Sensitivity Index. The SVI lies between '1' profound vulnerable to '-1' least vulnerable (Hahn et al. 2009; Mohan and Sinha 2010).The results of vulnerability assessment show that the social-ecological systems of the studied households are vulnerable. Yet, the intensity of vulnerability is highly variable across households (Figure 7.10). The households are categorised using the Human Development Index scale to categorise countries. At first, the HDI range from '0' to '1' is transformed into the SVI range to '-1' to '1' and the categorizations range applied accordingly. As vulnerability is opposite to development, the HDI value 'High HDI' is regarded as 'profoundly vulnerable' in relation to the SVI. Applying this categorization method, the majority of households fall into the single 'highly vulnerable' group, with 84.4 percent of households in the Middle-Mountains, 75.2 percent in the Tarai and 63.6 percent in the Trans-Himalaya, since their SVI sits within a range between >=0 and <=0.3. Further, 25.8 percent of the households in the Trans-Himalaya 20.3 percent in the Tarai and 11.3 percent in the Middle-Mountains fall into a 'moderately vulnerable' household group, with the SVI in-between -0.3 and 0. Few households (10.6 percent in the Trans-Himalaya, 3.9 percent in the Tarai, and 3.5 percent in the Middle-Mountains) are 'less vulnerable', with their SVIs below 0.03 (Figure 7.11). The mean of the SVI is the highest in the Middle-Mountains (0.0971) while it is 0.0398 in both the Tarai and Trans-Himalaya (Figure 7.12), suggesting that the Middle-Mountains is the most vulnerable zone. Nevertheless, all of the studied ecological zones in the Kaligandaki Basin are highly vulnerable to climate change.

Figure 7.10: The Social-Ecological Vulnerability Index by Households and Ecological Zone in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)

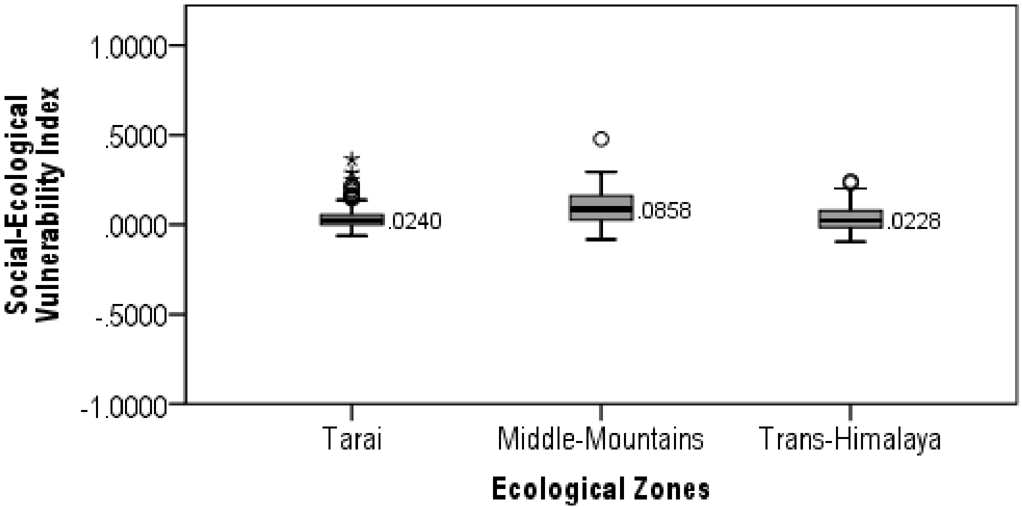
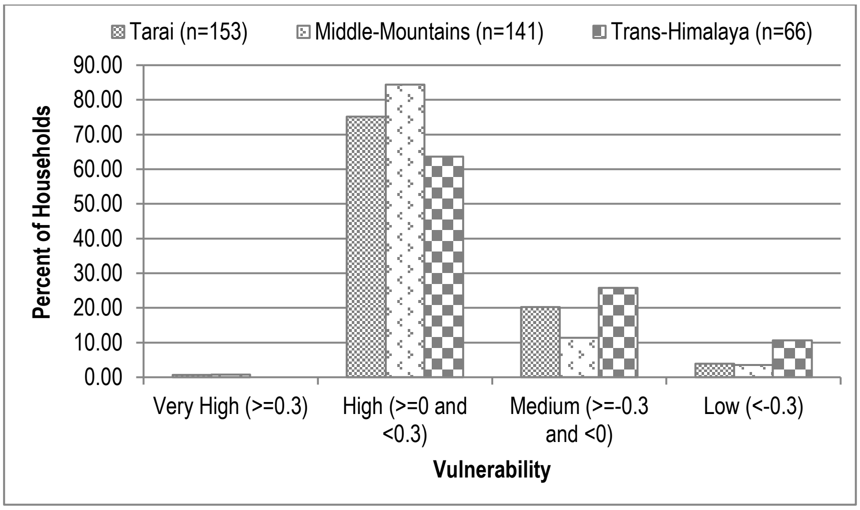
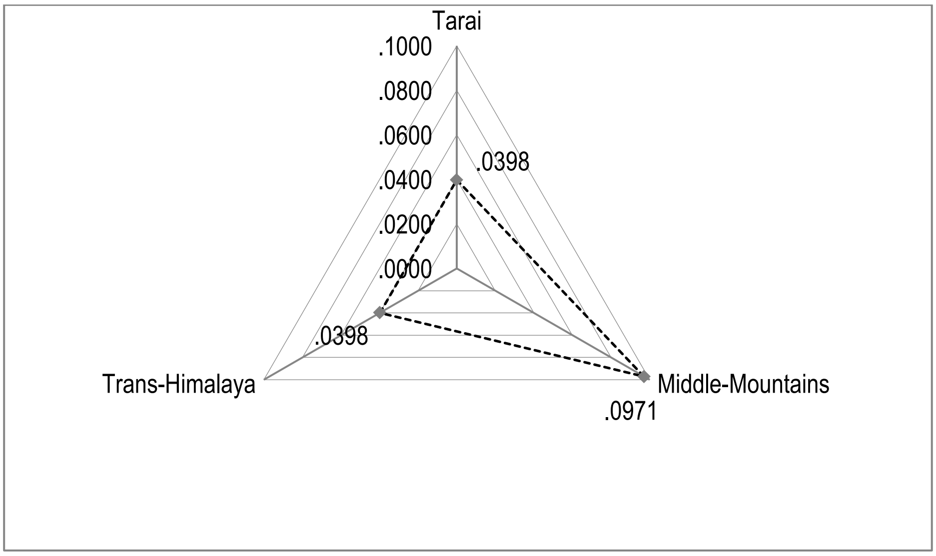


Figure 7.11: The Proportion of Households by degree of Social-Ecological Vulnerability by Ecological Zone in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)



The holistic vulnerability assessment conducted through the analysis of the major components of household social-ecological systems demonstrates a high level of vulnerability to climate change for the people of the Kaligandaki Basin. Such a vulnerability assessment at the household level is a new approach adopted by this study to provide summative information of the relative risks of environmental changes across households and ecological zones. Assessment of exposure of the livelihood resources a household command; sensitivity to climatic and non-climatic stressors; and the capacity of household to deal with such stressors is very important to understand the holistic vulnerability at the micro level.

Figure 7.12: The Distribution of the Mean of the Social-Ecological Vulnerability Index by Ecological Zone in the Kaligandaki Basin, Nepal
(Source: Field Survey, 2013)



The vulnerability assessment conducted using interdisciplinary experimentation with climate change and livelihood system analysis provides valuable insights for meeting the needs of a society with limited resources to improve outcomes from climate change adaptation investments (Maxim and Spangenberg 2006). By applying such an integrated vulnerability assessment methodology, this study has created new knowledge that has implications for the advancement of the field of understanding human-environmental interrelationships in Nepal in particular, but also for the universal response to climate change. It also helps develop the policy response to manage the negative implications of climate change by targeting the distribution of the state's capital to maintain the sustainability of the different social-ecological systems. In the next section, the implications of this research for the discipline of human geography and for public policies are presented in more detail.

7.4 Research Implications

The research has revealed the complexity and high levels of exposure of the climate sensitive livelihood systems of the Kaligandaki Basin to climate change. The inadequate adaptation responses available to communities have also been strongly highlighted. Together those situations suggest extreme vulnerability of the local social-ecological systems to the changing circumstances. In this section, the theoretical and practical contributions of this research are synthesized.

The theoretical implications discussed below frame the research findings in relation to existing scholarship. In particular, the contribution to knowledge generation in relation to exposure, sensitivity and adaptive capacity in the Himalaya, Nepal is explained further at first by summarising the research findings. Additionally, the contribution to the geographical discipline and methodologies to conduct research in human-environmental interactions and assessing sustainability or vulnerability of social ecosystems are also discussed in relation to the theoretical contributions of research. The contribution to knowledge generation section is intended to demonstrate the applied components of this research while the theoretical contribution provides evidence of how the work influences theory to better understand human-environmental interactions in the climate change context. At the end of the section, the overall implications of research findings for policy and practice are illustrated in relation to existing policy and practices recommended by the literature.

In order to make a contribution to geographic theory, this work contributes to strengthening and developing further the three theoretical approaches to socio-ecological systems analysis: the Sustainable Livelihood Approach (SLA); the System Analysis Framework (Driver →Pressure→Stage of Change→Impacts→Response or DPSIR chain); and Integrated Vulnerability Assessment or Second Generation Vulnerability Analysis in relation to climate change impacts. The integration of these theoretical frameworks together provides a complex and appropriate approach for critically analysing adaptation to climate change, particularly for Nepal and the Himalayan region at first and provides a number of policy options for better adaptation, and to achieve social-ecological sustainability. On the other hand, methodological contributions highlight the importance of applying a triangulated methodology and the integration of different approaches to studying human-environmental interactions in relation to climate change. It also demonstrates how various levels of exposure to climate change perceived by the households, the level of sensitivity of the resources the households command to maintain livelihood systems, and the levels of adoption of various adaptation strategies and associated outcomes in relation to adaptive or maladaptive natures can generate a composit index with a high level of reliability and applicability for public policies in Nepal. Finally, the policy implications are summarised to provide important information for supporting the design of an effective adaptation policy for Nepal. The policy implications section provides various alternatives to be adopted for sector-specific policies as wellas for an integrated or a holistic development policy relevant to Nepal and the Himalaya.

7.4.1 Contribution to Expansion of Knowledge on Climate Change, Impacts, and Adaptation

This study seeks to explain existing human-environmental interrelationships in the Kaligandaki Basin, Nepal, as comprehensively as possible from a neo-environmental deterministic perspective. As Berkes and Folke (1998) anticipated, this study indicates that social and bio-physical environments are an integral part of social-ecological systems, such as those described within the Kaligandaki Basin, and they interact in complex, non-linear and dynamic ways such as that: the rapid but variable pace of change in the climate system across the ecological zones has generated both primary and secondary impacts with highly uncertain tertiary impacts; while communities' adaptation efforts are limited, and there is a necessity for non-linear, long-term adaptation responses from communities. The overall situation has attributed to the dynamic and complex interactions that lead to a comprehensive vulnerability for several of the communities, especially in the Middle-Mountains (see section 7.3.4). Yet, the dynamic interactions, particularly the response of the communities and their effectiveness, are not that strong and dynamic as required for the suatainability of the social ecosystem.

Sining (2011) states that dynamic interactions mould a system's ability to withstand and react to different stresses. Dynamic interactions bring changes in the state of both social and environmental systems. It is partly identified in the Kaligandaki Basin that bio-physical, and especially climatic factors, as well as socio-economic and political changes, compel people to modify their environment. As a consequence, people are attempting to adapt to socio-economic and environmental changes both in the short-term and over time, with the aim of harmonising the relationship with ecosystems under the code of conduct defined by their social institution (Adger 2000b; Ostrom 1992). However, existing institutional capacities are already inadequate to deal with the problems created by dramatic changes in both climatic and non-climatic systems, which in turn undermine the sustainability of local social-ecological systems. A number of elements ranging from personal behaviours and attitudes of household decision makers to national political economy; the country's political instability and global political and economic systems, including the ever-expanding international labour market; and the increasing emphasis given to cash incomes by rural households are changing the pattern of human-environmental interactions. Therefore existing social and ecological interactions in the basin indicate that the orthodox concepts of 'human ecology' and 'neo-environmental determinism', could be inadequate theoretical frameworks for analysis because they do not sufficiently recognize the different social processes involved in change, and as a result, cannot comprehensively explain the adaptation complexities created by climate change. For example, people attempt to adopt multiple adaptation strategies such as increase agro-input, start-up small grocery, acquire some livestock or chicken, or send household members abroad for paid employment (see section 6.2.6). Households then evaluate the feedback from these attempts particularly in relation to economic gain to generate forward loops of learning from these activities and modify them as required.

The ecosystem services-based livelihood systems of the study area are receiving less attention than the livelihoods relaint on a cash-economy in recent years, which in turn has reduced the importance of natural resources in terms of agricultural production. Consequently, much farmland has either been sold for other uses or left fallow because of poor agricultural return. Hence, the orthodox human ecological views of explaining 'existing' interactions do not provide adequate insights into such complex interactions. It could be argued that the orthodox concept of human ecology lacks intuition for making decisions to understand the 'expected' interactions that aim to achieve social-ecological sustainability.

Orthodox theoretical perspectives could also be seen to be relatively weak in analysing human-environmental systems from an interdisciplinary perspective that encompasses bioecological, macro-economic, social, psychological, institutional, and cultural contexts (Moos 1979; Ostrom 2009; Peterson 2010; Redman 1999; Stokols 1996). It is within such a theoretical context that this study partly re-defines the concept 'human ecology' by incorporating the components such as dynamic interactions of the multidimensional structures and processes within human-environmental systems. In fact, the results suggest that unless such complexity is examined and understood, recommendations for adaptation could have a façade of adequacy but fail in relation to specific local social and/or environmental processes. Therefore, in this study human ecology is closely allied to social-ecology, which has been shown to be capable of incorporating the intricate components of both the bio-physical environment and socio-political and techno-economic structures, into an interactive human-environmental system. Social-ecology emphasizes the need for a reconstructive, ecological, communitarian and ethical society to adapt to environmental and social change simultaneously (IPCC 2007a; Lade et al. 2013; Sterling 2007). Yet, the findings suggest that the social changes brought by modernization and world economic system are transforming the ecological, ethical, and communitarian societies. Poor adoption of agroecology-based strategies or 'no regret' adaptation options (as less than 25% households are adaptive at some levels and only 1% think they are well adapted - see Figures 6.17 and 6.18 for details) by the studied households is a good example of this situation. The goal of social-ecology in the context of this thesis is to learn about, and if possible facilitate adaptation, promote systemic resilience, to guide adaptive processes that lead to sustainability.

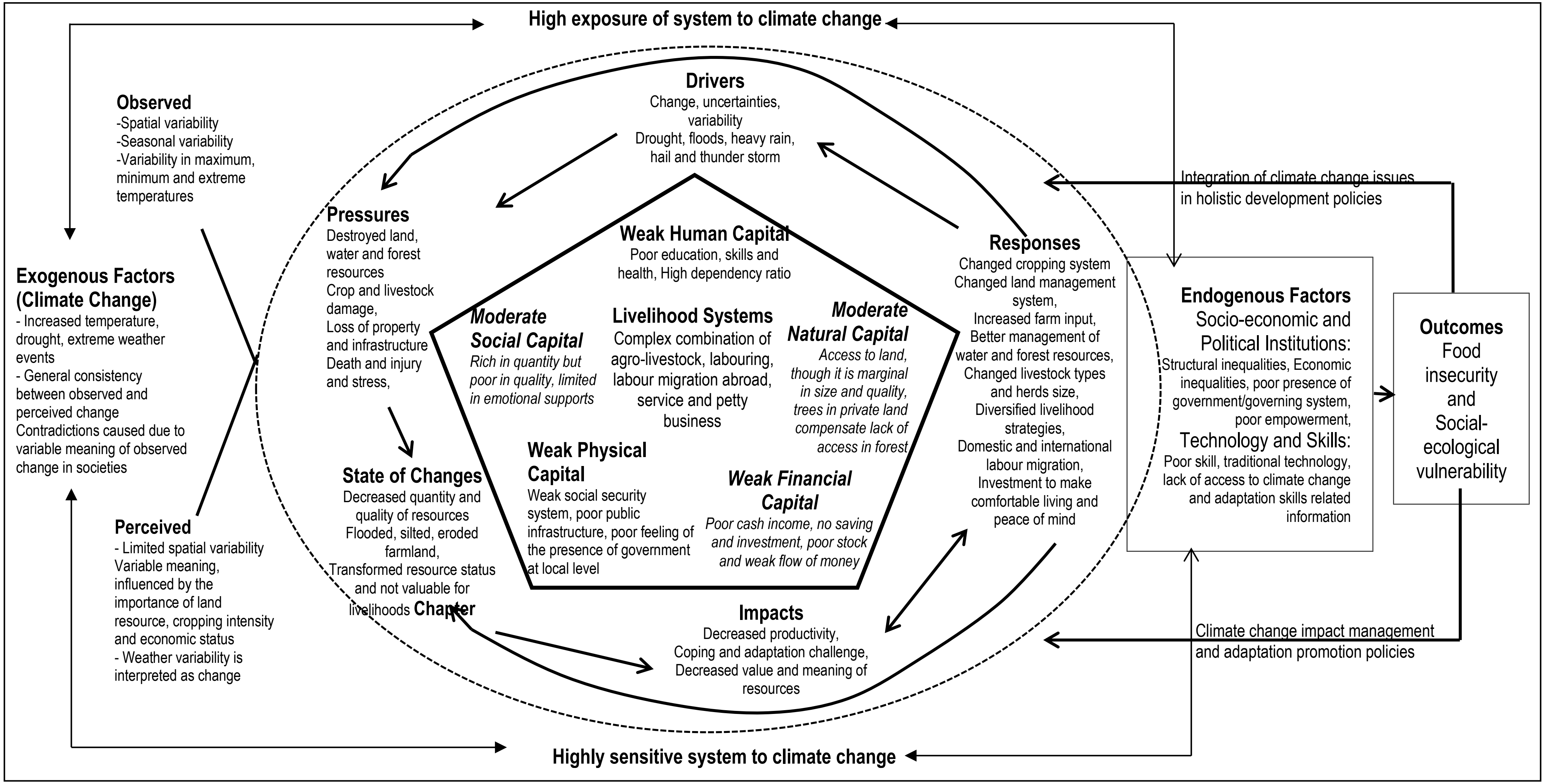
The summary of the complex, existing interrelationships between people and the environment in the Kaligandaki Basin in relation to climate change are presented in Figure 7.13. The figure outlines the linkages that define levels of exposure, sensitivity, and adaptive capacity within the regions, and helps to indicate why the outcome of existing interactions of humanity and the environment in the basin are broadly vulnerable. This enables the modelling of the dynamic human-environmental interactions (Figure 7.14) that would be necessary to achieve a sustainable state for the social-ecological systems (Figure 7.15). In the section below, the frameworks presented in the figures are discussed in detail.

7.4.1.1 Exposure of Social Ecosystem to Climate Change

The temperatures in the Kaligandaki Basin have increased, with a generally higher increase in minimum temperatures than maximum (see section 4.2.1.1). As summarised towards the left of Figure 7.13, along with increased temperatures, the increase in drought, floods, erratic rainfall, and hailstorms are observed in meteorological data and people's reports (see section 4.2.1 and 4.2.2). These results are generally consistent with other recent studies in Nepal (Bhatta and Aggarwal 2015; Chaudhary et al. 2011; Devkota et al. 2011; Macchi et al. 2014; Manandhar et al. 2011; Paudel, B et al. 2014). Nevertheless, the rate of change is variable across the ecological zones in the Kaligandaki Basin. Meteorological data analyses revealed higher spatial variability in the rates of change than expected, with the annual average of minimum temperature in the Tarai increasing at the highest rates (0.06^{O} Cy^{-1}), followed by the Trans-Himalaya, while increases in annual average maximum temperatures are highest in the Middle-Mountains (0.06^{O} Cy^{-1}), followed by the Tarai. The variability in the rates of change is also observed over seasons, with temperatures in the winters increasing faster than in the summer, with rainy days sharply decreasing in the winter. The social perceptions of climate are also variable across the three zones, mostly, higher level of changes (increased temperatures and drought) reported in the Tarai, followed by the Middle-Mountain and the Trans-Himalaya (see Figure 4.6), while higher variability in rainfall are reported in the Middle-Mountains followed by the Trans-Himalaya (see Figure 4.14). The social ecosystem of the Kaligandaki Basin is exposed to a high degree of climate change. Yet, there are variable rates of exposure across the ecological regions as well as variable perceptions across the households. Additionally, there are significant differences in: the perceptions of change and impacts across the households; the types of livelihood resources the households command; the strategies available to them; and the economic status of households in relation to adaptive capacity.It is generally observed that the poor households, who are affected by extreme events are also poorly adapted to changes and highly dependent on agriculture for livelihoods, tend to perceive higher levels of change, while the households who derive a large part of their livelihoods through the cash-based market economy feel relatively lower levels of exposure to climate change. Hence, the spatial and systemic variability suggests that climate change impacts and adaptation in the Himalaya cannot be generalised from limited studies that fail to incorporate the local complexity into their analyses.

The studied communities revealed during discussions in the field that they receive some scientific information on weather phenomenon and climate change from media and occasional interaction with local climate scientists, while they experience variability in micro-climatic conditions and retain different opinions in relation to the same climatic conditions. This indicates that the people of the Himalaya describe 'climate' using meteorological measurements, bio-physical responses and socio-cultural judgements of climatic events, which are consistent with other scholars' opinions (Bråten et al. 2009; Hulme et al. 2009; Rudiak-Gould 2014). The inconsistencies that do exist between scientific measurement and social perceptions in the Kaligandaki basin are likely to be associated with the memories of respondents and different 'meanings' that they give to weather events. The respondents emphasize recent weather events to construct their perceptions of climate change (for example annual precipitations after 2005 is observed to be more variable than for preceding years, particularly in the Middle-Mountains and the Tarai, which are interpreted as decrease in rainfall (see Figures 4.7 and 4.11), as has also been found elsewhere (Adger 2000b; Hulme et al. 2009; Nelson and Stathers 2009). The studied communities appear to be concerned over the negative impacts of climate change, so their perceptions are strongly influenced by their experiences of extreme events rather than average, long-term meteorological measurements. This suggests that the memories are not independent of experienced climatic impacts and psychological concerns (Friedman 1993; Levine and Safer 2002; Wilson and Ross 2003). The results also suggest that 'meaning' can be more important than 'measurement' in understanding local conceptions of climate change. Consequently, the social perceptions of climate change rather than simple metric measurements are important determinants of the implications of climate change in the Nepali Himalaya.

Figure 7.13: Human and the Environmental Interactions in the Kaligandaki Basin, Nepal



Considering the importance of social perceptions of climate change in adaptation, researchers highlight the need for participation of various stakeholders at different levels, and particularly disadvantaged communities, to generate clear and accurate information on climate change (Alamgir et al. 2014; McManus et al. 2014; Patt and Schröter 2008; Salerno et al. 2010; Wu et al. 2015). Without such holistic analyses the acquired knowledge could lack practical importance, or could marginalise disadvantaged people further. Consistent with the notion of O'Neill and Hulme (2009), this study suggests for collective knowledge and strategic modelling of impacts and adaptation processes using both climate science and social understanding of climate change, to increase the practical use of knowledge for equitable and justice-based adaptation policies in Nepal. In this context this study provides important lessons for further studies.

7.4.1.2 Climate Sensitive Social-Ecological Systems

The studied households generate their livelihoods through the utilization of livelihood capital (see Chapter 5), as represented inside the pentagon in the centre of Figure 7.13. The levels of contribution of the different capitals to household livelihoods are variable. Despite generally being farming households within rural areas, the index-based assessment of livelihood capital shows natural capital as the weakest and financial capital as the strongest, with fairly similar situations across the ecological zones (see Figure 5.17). Nevertheless there is variation in the contribution of different capitals contributing to households' livelihoods, withindexed values of some of the capitals is as little as '0' (the lowest) through to as high as '1' (the highest) in social capital, 0.93 in financial capital and 0.75 in natural capital (Table 5.11). The majority of the adult population (almost 37 percent in the basin) with 45 percent as the highest in the Trans-Himalaya were engaged in agro-livestock activities (see Figure 5.12), its contribution into household livelihoods is the lowest, while cash income of some 26 percent of the workforce, mostly coming from labour work away from the communities and country, and small business locally, contributes for the highest part of livelihoods.

This study indicated that the livelihood assets of the studied households are weak in general, which inhibits local capital development. Moreover, in most of the cases, one form of capital does not compensate for the inadequacy of others (Figure 5.17), although some variability across the households was visible.

Human Capital

Quality human capital is a critical resource for adaptation (Barnett and Adger 2007; Cruz et al. 2007). However, as summarised in Figure 7.13, it could be seen as mostly poorly developed in the Kaligandaki Basin, with low levels of education, lack of formal skills or training, poor health, and high dependency ratios (see section 5.2.1). In particular, the people who do work within households are supporting a large number of dependent household members, with over a half of the total population dependent, which rises to 61 percent in the Middle-Mountains.

At the same time, manual labour is highly exposed to weather extremes such as droughts, floods, heat stress and cold spells. Temperature and rainfall anomalies have brought a number of health problems and injuries, as well as loss of life. Almost a quarter of the population suffered from some sort of illness in the last year (see section 5.2.1.3). The cumulative implication of health problems is a decline in efficiency of labourers, which negatively affects households' income and livelihoods in turn. Similar issues of health problems associated with climate change and weather variability are widely reported, particularly in developing countries and societies (Berrang-Ford et al. 2012; Kjellstrom and Weaver 2009; McMichael and Lindgren 2011), including the Nepali Himalaya (Ebi et al. 2007; Eriksson et al. 2008; WHO 2005). It could be argued that the people of the Kaligandaki Basin have not been able to adapt to changing environmental conditions effectively, rather they are sensitive to changing climate and extreme weather events primarily due to their low capabilities associated with poor education, skills and health.

Additionally, family labour is an integral part of the agro-livestock livelihood system of the respondents, which has been weakened as many of the young, physically capable and relatively educated individuals are choosing paid employment overseas or in the cities (see Figures 5.12 and 6.14). Over one-third of households reported having members working in foreign countries. Farmers of the basin considered subsistence agriculture as a low-return activity, and as agro-livestock activities are given low priority, agricultural adaptation opportunities are insufficiently explored or applied. The cascading effect is that members of households are migrating abroad in search of paid employment, while farmlands have been abandoned or under-utilised due to a lack of farm labour and irrigation (Bardsley and Hugo 2010). Yet, it is not easy to evaluate whether laour migration abroad is adaptive or maladaptive. Migration is supporting cash-based livelihoods, but at the same time it is damaging ecosystem-based livelihoods in all of the study areas, such that the contribution of agro-livestock based activities in household livelihoods has largely declined (see Appendix 12).

Social Capital

Adger (2003) describes social capital as a very important asset to frame both the public and private institutions of resource management that guide climate change adaptation. The status of social capital in the Kaligandaki Basin is moderate (see section 5.2.2), while most people are rich in quantity but poor in quality of social capitals, which is also summarised in Figure 7.13. On average across all zones, more than 53 percent of households receive support from their extended family; with 62 percent in the Tarai obtaining such support (see Figures 5.4 and 5.5). Although most of that support is emotional, despite the material needs of households. The physical distance and economic status of the extended family members are identified as important determinants of social support.

Climate and environmental change, and associated implications are reducing the quality of socio-cultural and institutional capital across the zones. The reciprocal relationships, including mutual support among neighbours have been affected by flood and landslide induced displacement, and the re-location or migration of households (see section 4.3.1). Neighbourhood supports are mostly limited to emotional attachment, and generally remain strong in the households who have not been displaced. Such emotional attachments have been found to be very important in the Nepali context, especially for the livelihoods and welfare of senior citizens (Pun et al. 2010). They are, however, considered as secondary resources in climate change adaptation because the households' primary needs are material support and the exchange of labour amongst neighbours. Such reciprocal exchanges, however, are weak in the study area due to poverty and the migration of young adults. Households' affiliation to formal and informal Community Based Organizations (CBOs) also suggests strong social capital, with an average of 83 percent of households, and 92 percent of households in the Tarai, affiliated with such CBOs.

Researchers believe communication and information dissemination, including the social learning of adaptation methods within the communities, can strengthen livelihood systems (Pandey and Jha 2012; Tidball and Krasny 2007). These elements also strengthen both human and social capitals (DFID 1999), which in turn, contribute to effective adaptation. However, this study observed poorly developed or under-utilized social and institutional capital (see section 5.2.2). As a consequence, there are quite different adaptation outcomes between the households that have a relatively rich knowledge of, and experience with, agroecological adaptation, and others who are not learning from experienced farmers.

Social capital in many senses is associated with social structure and process. Inequality within the hierarchical society and ineffective civil society and local governance structures in Nepal, suggest weak social capital. The available social capital is mostly 'self-reinforced' and is not very successful in producing positive adaptation outcomes (see section 5.2.2). Adger et al. (2007) state that socio-economic and cultural boundaries associated with poor social capital negatively affect climate change adaptation processes. This notion is typically valid in Nepal, and suggests that the slow structural transformation of the Nepali social system is affecting them. Poor households who also belong to the *Dalit* community are particularly deprived of both emotional and material support from neighbours. In this context, the social capital of the studied households is not associated with a strong social safety net as required for effective adaptation (Adger 2003; Grosh et al. 2008; Mortimore 2010; Tao and Wall 2009; Wolf et al. 2010). Nevertheless, there are exceptions to this general rule in the Kaligandaki Basin. Transformative social learning is relatively well practiced by some households, with good consensus on issues of common interest such as construction and restoration of public infrastructure and services, including flood control dikes, retaining walls and roads as well as water supply and irrigation.

Natural Capital

As summarised in Figure 7.13, natural capital in the Kaligandaki Basin is of moderate quality. There is a good access to land, though it is marginal in size and quality (see section 5.2.3.1). Almost all households (98 percent) have access to land, a higher figure than the national average of 71 percent (CBS 2012b). Plot sizes average only 0.69 ha across the ecological zones, however there are marked differences in the quality of land. The Tarai has the highest cropping intensity (annual 264 percent), followed by the Middle-Mountains (184 percent) and the Trans-Himalaya (138 percent). Similarly, 56 percent of land in the Tarai has year-round irrigation, while irrigation in the Middle-Mountains and the Trans-Himalaya is available for part of the land and only for one cropping season. Other natural resources such as forest and pastures are less important in the basin, mostly due to a lack of access.

The implications of climate change and weather extremes on natural resources are immense in the Kaligandaki Basin. Already, socio-political and economic structures have severely affected households' access to, and control over, ecosystem resources, which in turn hinders local adaptive capacity. The opportunities for transforming such structures in Nepal are challenging. For example, climate change and associated implications haveled to a reduction in farm production, fodder and forage availablility, and in turn, livestock productivity. However, the decline in agro-livestock production is also due to many social factors, such as: limited ownership of farmland;

poor access to forest and grazing resources; lack of irrigation; high wage-rates of farm labourers, declining priorities for agro-livestock activities; which all, in turn, contribute to the abandonment of farmlands. These factors all increase the sensitivity of natural capital to climate change and associated weather variability and in turn reduced the importance of agro-livestock activities in household livelihood system. The contribution of agro-livestock activities to livelihoods decreased sharply for households while the share of remittances in household livelihoods has increased rapidly in the last decade (see Appendix 12). In this context, it is possible to argue that poor entitlement (Sen 1984) and limited access to resources (Blaikie 1994) are major determinants of livelihood vulnerability in the Kaligandaki Basin; and climate change is partly contributing for it.

Financial Capital

Financial capital is seen as an important resource to facilitate adaptation to climate change and to support social welfare across the globe (Ahmed and Fajber 2009; AfDB et al. 2003). Financial capital secures the daily needs of most households of the study area (see sections 5.2.4.5 and 7.2.1.2). Jones and Boyd (2011) in North-Western Nepal and Deressa et al. (2009) in Ethiopia identify financial limitations as one of the prominent adaptation barriers, although Hijioka et al. (2014) see a greater uncertainty in the role of financial capital in the future of adaptation. Weak financial resources, particularly, poor cash income, no savings, and lack of investment in productive sectors in the Kaligandaki Basin have generated poor stocks and facilitated weak flows of monetary capital as summarised in Figure 7.13 and indicated in Table 5.7. Weak financial capital cannot strongly compensate for the inadequacy of other livelihood capitals, which in turn, leads to livelihood insecurity. Weak financial capital is also identified as an obstacle to investment in new adaptation assets. Yet, despite lacking in stocks, financial capital is contributing to fulfil day-to-day needs of the households more than any other capitals in general (see Figure 5.17) and its share in household livelihoods is ever increasing (see Appendix 12).

The causes of weak financial capital are linked to the limitations of other capitals, as well as broader political-economic situations that are common to many developing countries, but have been particularly bad in Nepal in recent decades. For example, the marginal size of farmland holdings hinders surplus production, which could be sold into the market to earn cash. Almost 37 percent of the workforce is engaged in agro-livestock activities, while the other 26 percent are supporting households through cash income (see Figure 5.12). Even for that smaller group, the poor quality of human capital has led to the majority of people working in labour intensive, low-paid jobs. The cash income from paid labour work within the country is low, while in foreign countries, the prominent destinations such as Gulf countries and Malaysia are highly exploitative. Together, the poor quality of human capital and household poverty compels labourers to accept unfavourable working conditions.

Livestock and poultry is one of the sources of intermittent cash income for many households, since 56 percent of households are keeping livestock, with the highest proportion of such households (76 percent) in the Trans-Himalaya. Yet livestock ranching has also been degrading because of increased livestock morbidity and decreased productivity, particularly as livestock diseases are extended and insect populations have increased with climate change (see sections 4.3.2.2, 4.3.2.3 and 6.2.5.1). Such impacts of climate change are reported elsewhere in the literature (Thornton et al. 2009; Yeh et al. 2014). The households also lack possession of valuables such as gold and silver or household appliances. Together, this suggests that poor income on one hand, and the requirement of the majority to generate income to fulfil immediate livelihood needs on the other, prevents households from investing in productive sectors and asset building. As a result, financial capital is contributing poorly to adaptation processes although it is vital for coping with immediate impacts of changing circumstances.

Physical Capital

Within to the context of climate change adaptation, physical capital refers but is not limited to public housing and shelters, weather forecasts and early warning systems, and effective disaster responses (Wilby and Keenan 2012). Adequate physical capital is crucial for adaptation to climate change and to sustain the livelihoods of those who are poor in other capital (Adger et al. 2007; Biggs and Watmough 2012; Pielke et al. 2007). In the study area, almost all households (96 percent) have private housing; although much is of poor quality (see section 5.2.5.1). A house is not only a shelter but can also be used as production space such as using it for renting out and earning cash or creating micro-enterprises (Pandey 2004; 2008). Yet, this sort of utilization of private houses is very limited in the study area. Also whatever utilization of houses for hospitality or grocery businesses has been made, are accounted for by economic/financial capitals in this study. Hence, the contribution of physical capital in household livelihoods is not comparable to other capitals, although the systematic calculations (as shown in the Table 5.11 and Figure 5.17) do not show this limitation. State provisioned social security and welfare can support poor people during crises (Barnett and Adger 2007; McCarthy et al. 2001), but access to public services is poor throughout the area, with chronic shortages in the Trans-Himalaya, particularly due to underdeveloped public infrastructure, so many settlements lack basic services. Moreover, Nepali social security mechanisms are weak and cannot compensate for the inadequacy of private capital.

Many factors cause the scanty contribution of physical capital to household livelihoods. A low level of private infrastructure such as housing; inadequate public infrastructure such as roads, bridges, emergency shelters; insufficient basic services such as water supply, health and sanitation; poor coverage of extension services such as agro-livestock centres and product marketing; and poor social security and welfare systems, all are of notably poor quality (summarised in Figure 7.13). Because of inadequate access to physical facilities, the development of human, social, natural and financial capital is also hindered in the basin. Social-political and economic structures and processes and the high construction costs of physical capital are also affecting the availability of physical capital in poor countries like Nepal. DFID (1999) claims physical capital that is built by communities is more effective, and the communities' work observed in the Kaligandaki Basin also marches this claim. However, despite their effective management capacity, communities have inadequate knowledge and resources to build, operate and maintain autonomous services.

If, as Norris et al. (2008) state, there are four primary requirements to generate adaptive capacity, including economic development, social capital, information and communication, and community competence, it is unsurprising that the adaptive capacities of communities in the Kaligandaki Basin are poor. The organisational, social-economic and political drivers summarised above drive the sensitivity of household social-ecological systems to climate change. As a consequence, despite trying to apply a complex combination of various livelihood strategies, most households' livelihoods remain vulnerable to change and further adaptation options are required.

7.4.1.3 Household Adaptative Capacity to Climate Change

Households are already experiencing crop and livestock losses, property and infrastructure losses, as well as injury, stress, and even the death of fellow community members as a result of climatic impacts at least partly attributable to climate change. As a result, the quantity and quality of resources and ecosystem services have reduced and as the capitals diminish, the communities of the Kaligandaki Basin become more vulnerable to change (Figure 7.13). Nevertheless, people are trying to respond to the impacts in various ways including: changes in cropping systems (see section 6.2.1); changes in land management systems (see section 6.2.2); appropriate management of water and forest resources (see section 6.2.3); increased farm input (see section 6.2.4); changes in livestock types and herds size (see section 6.2.5); diversification of livelihood strategies (see section 6.2.6); domestic and international labour migration (see section 6.2.7); and investments to make living more comfortable (see section 6.2.8). Therefore, there are numerous complex strategies employed under the broader banner of adaptation. In the opinion of Smit and Skinner (2002) adaptation, particularly in agro-based communities, is made through technological development, government programmes and insurance, farm production management and farm finance management. However, it is unsurprising that the adaptive capacities of communities in the Kaligandaki Basin are poor in most of the mentioned aspects. Most of the strategies adopted in the study area are agro-based, however, they continue to rely on traditional or physical changes to systems rather than other strategies associated with agricultural modernisation.

Households of the Kaligandaki Basin are enhancing their adaptive capacity through better management of agricultural resources. The major strategies adopted are: adoption of drought resistant crop varieties, particularly HYVs which have shorter growing periods (by a quarter of households); increased application of manure and agro-chemicals (by one-third of households); regulated use of water and increased irrigation (by one-third of households); and, changed livestock types and size (by a quarter of households). In addition, migration for paid employment to support the household economically is also practiced by of one-third households. The degree of adoption of these strategies varies across the ecological zones as well as across households, which are discussed in Chapter Six. In particular, adoption of HYVs and other agro-inputs is more common in the Tarai, while migration is the dominant phenomenon of the Middle-Mountains, followed by the Tarai. Table 7.3 provides a summary of the major spatial variations in climate change impacts and adaptation responses. Based on these findings, it can be generalised that many of the studied households have good knowledge of potential adaptation methods, although feasible strategies are also not translated effectively into practice. This reveals that 'knowing' is not a sufficient condition for 'doing', and in fact adaptation may not always lead to positive outcomes in a climate change context if it is not appropriately applied (Adger and Barnett 2009). Nevertheless, it can be argued that there are uncommitted potentials for adaptation and speculation of the researcher is that when people really feel the need of adopting agro-ecological adaptation, they would reclaim the potentials or translate adaptation knowledge to practice.

Among the various strategies associated with agricultural adaptation relevant to the Kaligandaki Basin, development and adoption of agro-technologies and government programmes, including agro/farm insurance could act to buffer risks and reduce the losses (Fazey et al. 2010). However, adoption of agro-technology is not very relevant, particularly in the Middle-Mountains and Trans-Himalaya because of the terrain of the regions and small sizes of farm plots available to households. Technology adoption is also poorly practiced in the Tarai because of the domination of small holdings farmers. Farm insurance has not really been introduced in the study area and in relation to climate change impacts, farm insurance is virtually absent. Also government programmes are ineffective because of their poor implementations, associated with poor accountability and corruption, political instability, and absence of democratic mechanisms at the local level, particularly the lack of elected local governments for one and a half decades.

Most of the strategies adopted by the households of the Kaligandaki Basin can be categorised under farm production practice and farm financial management. These strategies are expected to empower the farmer by giving them opportunities to remove the drivers of negative change; keep or increase the potential number of future management options; and increase the adaptive capacity of farmers (Fazey et al. 2010; Wandel et al. 2009). Therefore, these strategies are recognised as the best strategies considering their ability to prepare farmers for behavioural changes through social learning. Nevertheless, despite having sound practical importance, agro-based adaptation such as farm production practice and farm financial management, are given poor emphasis.

Adaptation strategies similar to those mapped by this study are also reported from different parts of Nepal, although studies conducted earlier did not comprehensively investigate the available and practiced strategies as did in this study (Bhatta and Aggarwal 2015; Bhatta et al. 2015; Chapagain and Gentle 2015; Macchi et al. 2014; Mukherji et al. 2015; Paudel, B et al. 2014). Limited mapping of strategies of previous studies have resulted in the partial similarity in the combinations of strategies, the extent to which they are implemented, and adaptation outcomes. Moreover, they vary across the ecological regions and between communities. Most of the strategies adopted in the Kaligandaki Basin are ‘no’ or ‘low’ regret options in relation to climate change. Wilby and Keenan (2012) describe ‘no’ or ‘low regret’ strategies as those that yield benefits regardless of the climate scenario.

Notwithstanding this, due to both climatic and non-climatic challenges, adaptation outcomes in the Kaligandaki Basin are poor. Among other reasons, and consistent with the literature (Adger 2010; Persha et al. 2010), the cost of restricted access to forest resources is seen to have an immediate negative impact on human wellbeing and natural resource productivity in the Kaligandaki Basin (see section 5.2.3.3). In other cases, adaptation options adopted in the study area are helping households to modify the context and prepare for change as expected in adaptation theory (Watts 2009); however, they are inadequate. For example, farmers face problems in adjusting crop calendars to the higher inter-annual variability in weather patterns due to the lack of reliable weather forecasts or other government support (see section 6.2.1.3). Although most of the strategies adopted by the households have not produced noticeable levels of maladaptation yet, the poor adoption of the strategies or prevailing barriers in adaptation have compromised the efficacy of adaptation.

Table 7.3: Comparative Assessment of Climate Change, Impacts and Adaptation Responses across the Ecological Zones in the Kaligandaki Basin

Climatic Drivers	Implications			Adaptation Strategies		
	Tarai	Middle-Mountains	Trans-Himalaya	Tarai	Middle-Mountains	Trans-Himalaya
Increased Drought	Stress, Health Problems, Water Scarcity, Paddy seedling burned/died	Health Problems, Water Scarcity,	Decreased availability of water	Increased irrigation, Regulated/compromised use of water, Re-seedling	Regulated/compromised use of water	
Increased Summer Temperature	Heat stress, increased mosquitoes and insects			Added fans and mosquito nets		
Increased Erratic Rainfall Events and Intense Summer Floods	Floods and river cutting Stress, Health Problems, Injuries, and Death , Farmland flooding, settlement flooding, damage of public as well as private infrastructure, service gap, displacement, forced migration, Detached Social and Institutional Capitals,	Floods, soil erosion and landslide related damages Farmland flooding, and landslides, damage of public as well as private infrastructure, service gap Displacement, forced migration, Detached Social and Institutional Capitals		Construction of flood control dikes, retaining walls using gabion boxes Desire to uplift foundation wall of house, however, not much adopted due to poverty, Migration, Pray to God	Construction of retaining walls using gabion boxes, Pray to God	Flood control dikes, retaining walls using gabion boxes and concrete structures, Frequent repair of roof and wall of house Migration, Pray to God
Increased Altered Temperature	Health problems in both human and livestock			Added Heating/Cooling Facilities		Added Heating Facilities
Decreased Annual Rainy Days				Increased irrigation	Use of mulch, Regulated/compromised use of water	
Changes in Onset and Retreat of Summer Monsoon	Problem to start crop calendar			Changed crop calendar, late transplantation of rice		
Increased Violent Wind	Crop damage, damage of animal shed and houses			Intended to construct stronger roofs		
Increased Winter Temperature	Increased mosquitoes and insects and associated health problems		Reduced winter snowing and negatively affected crop sowing	Increased use of mosquito nets		Crop calendar changed
Changed Hailstones Seasons	Increased crop loss			Early harvest, but found ineffective		
Increased growing season			Better production in high altitude, better quality fruits			Initiated vegetable production in low altitude
New Diseases in Livestock and Crops, New insects, Extended habitats, Habitat Shifted towards high altitude				Increased Agro-Inputs, chemical fertilizer, insecticide, pesticide, livestock medicines	Increased Agro-Inputs, organic fertilizer, livestock medicines	Increased Agro-Inputs, organic fertilizer
Overall changes in climate system	Degraded Natural Resources quality and quantity, Declined Agricultural Production and Abandoned Farmland		Better production in high altitude, better quality fruits	Soil Control, Drainage Management, Changed Source of Fodder, Agro-Forestry, Increased fallow land, Changed Landuse Type, Adopted Drought Resistant Crops, Crop calendar change		
Annual life of Water Sources declined	Implications in overall social and natural ecosystems, abandoned farmland			Changed Farm Size, Changed Crop Varieties		
Increased Invasive Species, fodder and forage shortage				Changed Livestock Types, Size and feeding practice, Agro-forestry and fodder trees plantation		
Period of Water Shortage Increased				Regulated/compromised use of water		
		Increased Forest Fire Incidents			Community collectively extinguish fire using traditional methods	
Occasional Settlement Fire				Community collectively extinguish fire using traditional methods		
	Overall challenge in livelihoods			Increased Farm Skills and input, Migration to Market Centre, Cities and abroad for labour work, Started small business such as grocery stores and hospitality		

The goal of adaptation, which could be defined as the sustainability of households' social-ecological systems, remains largely unmet for many people in the Kaligandaki Basin. The same can be said for the rest of Nepal as reported by literature (Bhatta and Aggarwal 2015; Paudel, B et al. 2014; Subedi et al. 2007a). In many cases, people struggle to understand or implement adaptation options. Other strategies that are adopted by households are not effectively contributing to households' social ecosystems, as expected by adaptation theory (Adger et al. 2007; Manuel-Navarrete et al. 2009; van Aalst et al. 2008). Consequently food and livelihood systems are insecure and the social-ecological systems are vulnerable.. Effective adaptation must follow an interactive and dynamic approach that allows interplay among the components of social-ecological systems and provides both feedback and forward loops. Therefore, a heuristic device for effective adaptation to climate change is proposed below (Figures 7.14 and 7.15) as a major theoretical contribution of this research.

7.4.2 Theoretical Implications

7.4.2.1 Theoretical Contribution to the Discipline of Geography

It was mentioned earlier that the livelihood systems of the studied households are exposed to both climatic and non-climatic drivers and the SLA has not provided an adequate framework to promote livelihood security in a climate change context. The social-ecological model is an innovative and effective way to address different social-environmental problems in a sustainable way (Neudoerffer et al. 2005). The model in this study incorporates the scientific data and social perceptions of climate change and associated impacts. Both endogenous and exogenous stressors of social-ecological systems have been analysed by integrating the SLA within a system analysis framework or DPSIR framework (represented by the area inside the dashed-oval in Figure 7.13). The integrated framework is an 'issues' based, practical, but compound framework that can accommodate multiple perspectives of a system approach to solve complex social-ecological problems. According to Berkes and Folke (1998) a system approach takes a holistic view of the components of the system and the interrelationships between them. In this integrated approach, human societies and nature are recognised as integral parts of social-ecological systems. Importantly in this case, the framework allows for analysis of existing interactions between humanity and the environment in the Kaligandaki Basin. Such recognition of the local complexity provides the required information for a compound policy framework to address both climatic and non-climatic issues of the Nepali Himalaya.

The outcomes of the interplay of the components of the SLA produce strong feedback knowledge for livelihood sustainability (Chambers 1988; Chambers and Conway 1991). Specifically, Carney et al. (1999) found higher local incomes, increased well-being, reduced vulnerability, improved food security and sustainable use of natural resources after adopting complex adaptive strategies. However, this study found that not all the strategies adopted by households and communities produce the expected results, and in many cases adaptation responses remain inadequate. A notable proportion of households (almost 40 percent) experience moderate to profound levels of food insecurity due to poor access to food, with the greatest severity in the Middle-Mountains (almost 70 percent), followed by the Trans-Himalaya (see Table 7.1). While income from other sources is helping to maintain access to food for some households, the utilization and stability of food access are limiting security for a substantial number of households in the study area: over 15 percent in the Middle-Mountains; 8 percent in the Trans-Himalaya; and 5 percent in the Tarai.

Many impacts of climate change are slow, indirect, compound and invisible, and are also difficult to attribute to climate change. The key indicator of food insecurity is only partially attributable to climate change impacts, but the cumulative implications of climatic impacts on sensitive social ecosystems can be severe.

The SLA is a fairly static model. This model demonstrates relevancy of five livelihood capitals in the rural context. However, despite having many rural characteristics in the Kaligandaki Basin, livelihood contribution of cash income in the producer-consumer status of the farmers is growing rapidly. In this context, food security is dependent on access to marketed food. Government contributions to adaptation responses are nominal in the basin. In the context of climate change adaptation, the process is seen to be a continuous to cope with climate events and adapti to climate processes, and contribute to a broader approach to generate resilient communities. Therefore, in this study of the Kaligandaki Basin, the SLA is an important approach to highlighting concerns, but does not necessarily provide a strong model to respond to climate change impacts in a specific way.

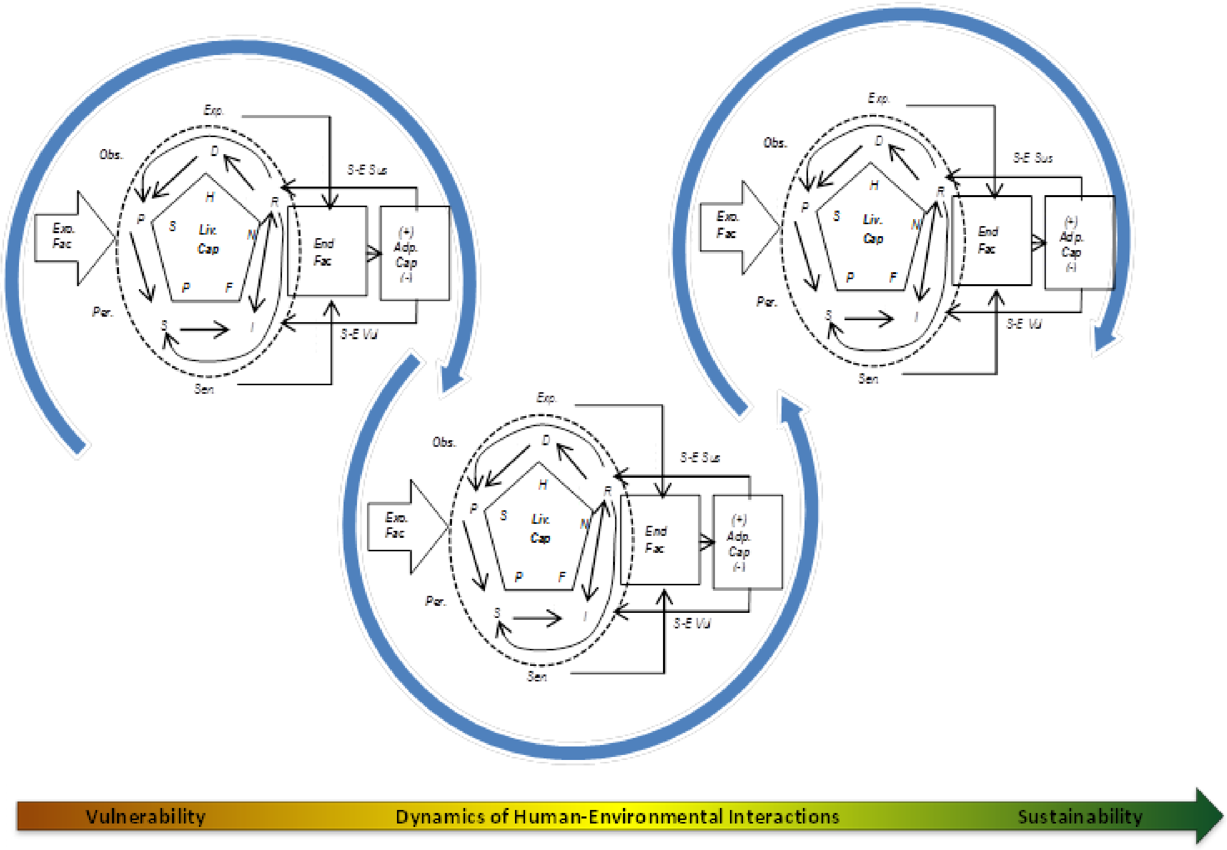
The variable pace of climate change, complex and uncertain impacts, and non-linearity of adaptation outcomes (Adger and Barnett 2009), and the compound interactions of the socio-economic and political environments with climate and environmental changes, global capitalism and globalization, all create complexities in Himalayan livelihood systems. Therefore, a careful revision of the SLA by integrating it with the DPSIR framework may be an important strategy to promote ecosystem-based adaptation in the Himalaya. Such a social ecosystem approach has been increasingly recognised as means of studying and providing knowledge to increase the resilient capacity of social-ecological systems (Berkes and Folke 1998; Neudoerffer et al. 2005; Salerno et al. 2010), and this research suggests that it is particularly relevant for Nepal.

This study identified that the adaptability and sustainability of a social-ecological system depends on how different components of the system interact, form networks and develop response strategies. As highlighted in the models and discussion above, many elements, both bio-physical and socio-economic and political, cumulatively affect adaptation process in the Kaligandaki Basin. People's differential access, entitlement and control over resources (Blaikie et al. 1994; Gupta et al. 2010; Sen 1984); perceived risk, experienced impacts and person's ability of decision making (Lorenzoni and Pidgeon 2006); human cognition and willingness (Heath and Gifford 2006; Moser 2005); and technology and institutional structures (Adger et al. 2009; Sining 2011; Thornton et al. 2006), have been identified as some of the prominent factors affecting adaptation, as those key concerns have also been broadly acknowledged in the literature on adaptation within developing countries.

Other scholars consider the DPSIR framework as an expert-driven and evidence-focussed device for explaining complex relationships between natural and anthropogenic systems, to enable stakeholders to assess and manage the impacts of both exogenous and endogenous stressors (Atkins et al. 2011; Maxim and Spangenberg 2006; Smeets and Weterings 1999). However, as adaptation to climate change is a continuous process, the DPSIR framework, which is mostly applied in a 'static' form in both research and policy fields by limiting its dynamic characteristics, which may not adequately address the issues of climate change adaptation. This study found that people do not wait for impacts to make an attempt to respond the stressors. They tackle the issues at different stages in the DPSIR chain: at the driver, pressure, change, as well as at impact stages (Figure 7.13). Climate change has increased inter-annual variability in the local climate system, which have affected local learning processes, since there is less certainty that next year will be similar to the previous years. Nevertheless, each of the responses made at different stages of DPSIR chain produce variable adaptation outcomes, therefore, the DPSIR cannot remain linear or static. Adaptation to climate change must aim to fulfil the livelihood needs of the communities together with making social-ecological systems resilient to climate change. Therefore, the integration of the SLA and the DPSIR frameworks in a dynamic model (Figure 7.14) is an important theoretical step to address concomitant problems of climate change and existing socio-economic and political concerns within developing countries such as Nepal.

Chambers (1988) sees a linear approach of problem solving as 'first thinking' or 'normal professionalism' that gives a simple but wrong solution. The same results could occur in climate change adaptation with a linear approach, as it may miss the micro-level interactions and feedback processes, and in turn provide wrong or inadequate adaptation to the rural poor. In this context, Armitage et al. (2009) sees learning as a vital starting point for adaptive co-management. However, as Amaru and Chhetri (2013) also found, such complex learning-based adaptation requires innovative institutional arrangements, which are currently under-developed in Nepal. Households are not learning to adapt to the changing climate using non-expert based knowledge, neither is formal adaptation knowledge being disseminated through public policies. In sum, adaptation to climate change has not been institutionalised yet, which hinders the household and community adaptation processes.

Figure 7.14: Schematic flow of Dynamics Human-Environmental Interactions



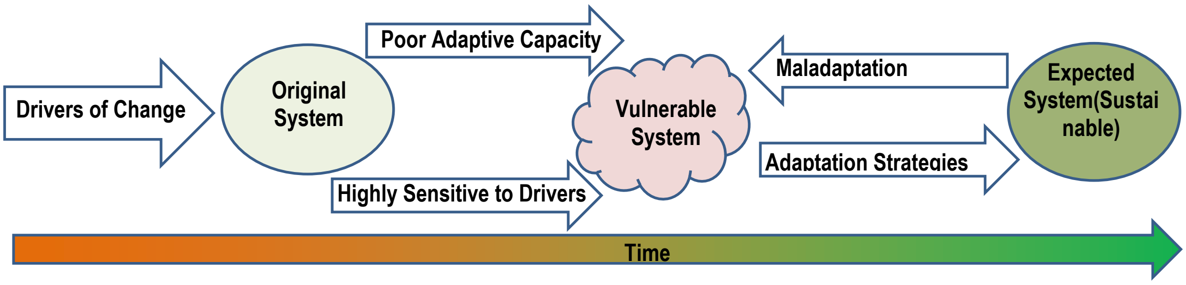
Note: Components inside the figure are the same those presented in the Figure 7.13

Wildemeersch (2007) suggests four strategies of learning (action, reflection, communication and negotiation; and their balanced adoption), which can make learning effective also in climate change adaptation. Therefore, this research suggests an integration of both the SLA and DPSIR frameworks, and dynamism in the integrated policy framework to strengthen communities' adaptive capacities over time (as demonstrated in Figure 7.14). The framework in the long-term develops both forward and feedback loops to promote adaptation and achieve social-ecological sustainability as assumed in Figure 7.15. This dynamic system is a flexible and practical strategy for approaching social-ecological resilience through adaptation in the Himalaya. The positive outcomes of adopted strategies during each of the phases increase the adaptive capacity of both social and ecological systems (Folke et al. 2002; Osbahr et al. 2008; Pretty 2011). The proposed

Meta framework could be modified with due consideration of relevant variables according to context, place, people and time, to make it applicable for climate change adaptation in other local contexts globally.

The outcomes of complex human-environmental interactions are poorly predictable. Therefore, a dynamic or learning-based adaptation process provides opportunities for refining or withdrawing irrelevant strategies and adopting new and robust ones. By addressing the issues at different stages, households and communities are able to tackle integrated and compound problems over time, to build local capacity more broadly (Lee 1993).

Figure 7.15: Schematic flow of Dynamic Social-Ecological System



As explained above, human-environmental interactions are dynamic. The case found in the Kaligandaki Basin is similar to the assumptions of the world system approach to environmental change developed by Wallerstein (1974b). Anthropogenic climate change could be considered to be the result of unsustainable or anti-ecological consumption, and the implications are disproportionately concentrated on the periphery. Because of the limited benefits that Nepal, and the communities of the Kaligandaki basin in particular, have gained from the world system; they suffer the most from climate change impacts. Within the basin, the households who have benefited relatively better from the world system through access to jobs, business or political decision-making, are relatively less vulnerable; while socially, politically and economically marginalised households are more vulnerable. For example, the integrated vulnerability assessment shows that 84 percent of households in the Middle-Mountains, 75 percent in the Tarai and 64 percent in the Trans-Himalaya are 'highly vulnerable' (see Figure 7.11). While only a few of the households, 11 percent in the Trans-Himalaya and 4 percent each in the Tarai and the Middle-Mountain are 'less vulnerable' to the change that is apparent, in all cases, those households had little role in the generation of the problem.

This study demonstrates the strength of the geographic discipline in conducting research into complex phenomena using an integrated framework. Through an integrated vulnerability assessment that acknowledges important social and environmental elements of place, this study has answered the adaptation questions such as: What to adapt with? Who should adapt? How to adapt? The answer to the first question is ‘adapt to exposure or negative implications of climate change’; the answer to the second question is ‘the climate sensitive social-ecological systems of the Kaligandaki Basin require adaptation’; and the answer to the third question is ‘adapt by utilizing adaptive strategies or by increasing the adaptive capacity of the social-ecological system’. This study also soughts answers to the broader questions of what is and what ought to be the relationship between society and the environment (Kates 1987). The answers are that the social-ecological systems of the Kaligandaki Basin are ‘vulnerable’ and the desired outcomes of new interrelationships are ‘sustainable social-ecological systems’.By providing an integrated and interactive approach to adapt to climate change, this research has helped develop a useful framework to meet the needs of a developing society, while also creating benchmark knowledge on human-environmental interactions. The research also aims to initiate a discourse on the need for integrated research approaches to assimilate the problems of the present world to explain human-environmental interactions and to search for adaptation opportunities to climate change. To validate this proposition, further studies adopting a similar conceptual model and methodology are necessary.

7.4.2.2 Methodological Contribution

This study applied an integrated or hybrid methodology that assimilated most of the components of the social-ecological systems framework to examine associated connections, and to provide a comprehensive insight into human-environmental interactions in the Kaligandaki Basin. The triangulated methodology brought together information collected using various methods, as well as integrating scientific and social perspectives on climate change. As Holling et al. (1998) suggest, such a triangulation method as an alternative to a reductionist approach can help to develop understanding of complex social, economic and ecological environments to inform policy, and it is an important decision-making tool for addressing social-ecological vulnerability to climate change.

A new interaction between different knowledge (scientific and social) has widely been recognized as producing optimal outcomes for research and policy beneficial for both nature and society (Pretty 2011). Integration of the components of the SLA and DPSIR frameworks, incorporating both endogenous and exogenous factors of vulnerability, and the index-based assessment of social-ecological vulnerability at the household level, act to evolve the theoretical concept within the practical experience of the researcher and stakeholders. The integration of the three analytical frameworks assimilates social, political, economic and environmental factors and associated challenges, and provides common ground for the development of policy and practice. This integration is important because, as described above, the independent use of the SLA or DPSIR frameworks reveals a gulf between the interpretation of climate change, responding to impacts and approaches for social-ecological sustainability.

This research followed a simple but systematic, step-by-step method to comprehend human-environmental systems in the Nepali Himalaya. The result was a holistic examination of exposure, sensitivity and adaptive capacity of the social-ecosystem. A wide range of variables were used to evaluate multiple dimensions (availability, access, utilization and stability) of food (in)security and assess social-ecological vulnerability. This integrated methodology brings multiple stakeholders and their perspectives together to generate knowledge to inform collaborative adaptation policy. Therefore, the approach is both a transformative conceptual and practical problem-solving tool (Atkins et al. 2011; Maxim and Spangenberg 2006).

Households and environment co-evolve over time and space that act to represent complex human-environmental dynamics. However, forms of multi-dimensional vulnerability analysis (Adger 2006; Luers et al. 2003; Sining 2011), including the second generation (Füssel and Klein 2006), or cross-sectoral integrated vulnerability assessment tools (Füssel 2007), have not recognised households as a unit having their own unique social-ecological system. Consequently, vulnerability analyses are mostly based on spatial or systemic units. Hahn et al. (2009), for example, monitored livelihood vulnerability of two villages in Mozambique, and suggested that the method was an important decision-making tool for resource assistance, and to evaluate potential policy effectiveness. Mohan and Sinha (2010) applied the method to assessing ecosystem vulnerability in relation to climate change in the Ganges Basin in India, and identified it as an important decision-making tool, although they also noted non-climatic factors played a major role in making the system vulnerable. Sullivan (2011) studied sector-specific vulnerability, such as supply-driven and demand-driven vulnerability to water resources in the Orange River Basin in Southern Africa. The methods these researchers followed, however, failed in each case to recognize the socio-economic inequalities across households within a small spatial unit, which has remarkable implications for the adjustment of socio-ecological systems at the micro level.

Previous studies have considered livelihood assets or capitals as a part or the components of adaptive capacity largely homogenously. The lack of consideration of the adaptive or sensitive nature of different components of livelihood capitals could lead to inappropriate index formation. Each variable of the livelihood system has characteristics of both sensitivity to climate change and adaptive capacity against the negative implications to some level. The existing literature rarely considers such complexity in relation to assessments of livelihood vulnerability. In this research, the variables were assigned different importance in the index in relation to sensitivity and adaptive capacity based on their natures. For example, very young and elderly people or people with health problems or disabilities, are assigned higher weight in sensitivity and lower weight in adaptive capacity, while adult, healthy and educated individuals are counted as people having higher level of adaptive capacity. Similarly, fallow farmland, non-irrigated farmland, and land with low cropping seasons received higher weight in sensitivity, while land having year-round irrigation and cropping season are assigned higher weight in adaptive capacity. This sort of micro-level classification of hundreds of variables using similar techniques provides realistic pictures of sensitivity and adaptive capacity to calculate various sub-indices and then reliable livelihood vulnerability index and social-ecological vulnerability index. In this manner, the research has pioneered a method of assessing social-ecological vulnerability to climate change. Hence, as Eakin and Luers (2006) also emphasize, a diversity of approaches is required to study vulnerability in order to address the local complexity of the concept, and just such an approach has been developed here.

In addition, prevailing inequalities in global and local spatial scales reduces the importance of vulnerability assessments at spatial scales, especially in developing countries where impacts vary dramatically across households, communities and regions. In the Nepali case, where the inequalities are high and households are affected differently by climate change due to their variable exposure to non-climatic stressors; varying access to and control over productive resources; and their differing abilities to benefit from global and local political-economic systems; and most importantly, the management capacity of households (Folke et al. 2002; Osbahr et al. 2008; Pretty 2011); the degree of vulnerability across the households vary. It has been shown in Figure 7.10 that indices of vulnerability range from 0.477at the highest level (in the Middle-Mountains) to -0.095at the lowest level (in the Trans-Himalaya). In this context, this research worked to assess social-ecological vulnerability at a household level and provides a mechanism to strengthen ‘second generation vulnerability assessment’ by making the household the unit of vulnerability analysis.

The adopted method can be an important tool for adaptation decision-making, especially for policy makers as it offers a way that they can prioritise assistance to the most vulnerable households, consistent with the concept of ‘poor people first’ (Chambers 1988). The method adopted here makes it clear that a hierarchy of needs or weighting of vulnerability assessment outcomes helps to identify the importance of pro-poor adaptation policy. On the other hand, the flexibility of the methods helps researchers and policy makers understand the importance of specific elements for particular households or cluster and decide whether it should be included or excluded, or assign different weight in assessment process. For example, the weight of household appliances in relation to power or water shortage might be lower while it may have higher weight in relation to toilet facilities. These sub-components have been grouped for exposure, sensitivity and adaptive capacity based on their importance for the local social-ecological systems and assigned different weightings to assess social-ecological vulnerability. The method can also include proxy variables to refine the variables and make it applicable to different scenarios.

Boyd and Charles (2006) notice the inappropriateness of the indicators commonly used in large-scale systems analysis at the community level; in the same context, these indicators and variables adopted for community and household level analyses may not be meaningful at national, regional and global levels of analysis. Up to date, and in the absence of specific information regarding the vulnerability of households, the efficacy of positive discrimination policies of the Nepali government, introduced in the 1990s, has been poor since the gaps in the economy, empowerment and human development have widened (DFID/WB 2006; Gurung 2006). The recent ineffectiveness of the post-disaster relief work after the major earthquake on 25 May 2015 has largely been acknowledged in the mass media, with the problem largely attributed to the lack of information about the overall situation of affected households accompanied by the absence of an elected local government (Arora 2015; Dalrymple 2015). The integrated vulnerability assessment method applied here offers options for aggregating the SVI within administrative boundaries, economic or social classes, and the sex of household heads. Such aggregation provides information for designing policies based on social justice, and as the method is flexible in selecting key variables, it can be re-organised for particular contexts. The approach also explains both historical (what has occurred?) and the future (how could resilience and sustainability be achieved?) perspectives of human-environmental interactions.

7.4.3 Policy Implications of the Study

For several decades, climate change has been an important policy issue for governments and development agencies, both globally and at country levels [93] (see for example: Earth Summits 1992, 2002, 2012, MDGs 2000-2015, Kyoto Protocol 1997, meetings of UNFCCC COP and related agreements). The impacts of climate are visible throughout the globe and impacts will continue long into the future (Collins et al. 2013; Nath and Behera 2011). In addition, inadequate progress over climate change mitigation has increased the necessity for effective adaptation responses (Tompkins and Adger 2005). The social ecosystems of the Himalaya are very sensitive to climate change because of the region's unique characteristics such as dynamism, complexities and marginality. Therefore, any policy that focuses upon particular, single issues may not be effective for the sustainability of the social ecosystem of the Himalaya.

Researchers and policy makers are proposing and practising numerous complex approaches to adaptation. For example, Alamgir et al. (2014), and Patt and Schröter (2008) suggest an integration of indigenous knowledge with modern technology to improve the outcomes of adopted strategies. Salerno et al. (2010) suggest an integrated and participatory model for adaptive management, while Armitage et al. (2009) propose adaptive co-management of regions. Adaptive co-management is a combination of adaptive management (Holling 1978; Walters 1986) and co-management (Pinkerton 1994; Jentoft et al. 1998) that provides opportunities to link scientific findings directly into adaptation policies. However, it also risks mismanagement if effective coordination among scientists, resource users, government managers, and other stakeholders for collaborative problem-solving are not established. Therefore, adaptive co-management is suitable to specific places and situations, supported by, and working in conjunction with, various organizations at different scales (Olsson et al. 2004). Pant et al. (2014) propose the integrated management of social-ecological systems in Nepal, and this research provides a framing mechanism to identify concerns and target integrated responses. In this model, the participation of stakeholders (community people, experts, policy decision makers) is necessary at various stages. Additionally, once local knowledge is responded to and applied, stakeholders would play key roles in both implementation and monitoring the progress of adaptive management policy.

Nepal still lacks widespread assessment of climate change impacts and adaptation opportunities; however, given the socio-cultural diversities, economic inequalities, and bio-physical niches in the country, impacts and vulnerability across communities and spatial units would be expected to vary

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[93] By November 2013, 50 Least Developed Countries (LDC) have submitted their NAPAs to the UNFCCC. Viewed 3 June, 2015 <http://unfccc.int/adaptation/workstreams/national_adaptation_programmes_of_action/items/4585.php>.

significantly. Chhetri et al. (2013) suggests that such an applied research approach could lead to appropriate niche-based adaptation in Nepal. They focused on *in situ* methods such as selecting change-adaptive varieties, changes in cropping systems and traditional seed exchange. Although *in situ* adaptation methods are very important and relevant to the Himalayan environment, many of them are under-developed or failing in the Kaligandaki Basin. As Bardsley (2015) argues, adaptation policy needs to work to develop *in situ* methods by integrating them with *ex situ* methods, in a learning-based adaptation continuum.

The serious challenge of achieving most of the Millennium Development Goals (MDGs) within the context of a weak state and climate change, indicates that Nepal has specific adaptation needs. Mertz et al. (2009b) recommend a transfer of funds and technology from global communities to improve the capacity of institutions in developing countries to deal with existing socio-economic and environmental vulnerability. In this context, the discourse has also emerged during the research as to whether addressing governance-related adaptation barriers and limits are sufficient for social-ecological sustainability in relation to climate change. Pahl-Wostl (2009) reports governance failures as the origin of many resource management problems, while Bardsley (2015) proposes comprehensive social-ecological governance to address similarly comprehensive socio-ecological challenges. Perhaps the local needs based approach structured by this research provides a mechanism for targeting rights-based adaptation and development, with particular recognition of the rights and needs of the individual and communities at the lowest socio-economic levels (Baer et al. 2007; Polack 2008).

Amaru and Chhetri (2013) suspect that the top-down planning model may not enable local resilience in the long-term, and that there is a need for widespread, but flexible, participation of local communities and integration of stakeholders. However, many vulnerable groups in Nepal lack the resources required to participate in planning processes or local governance. For example, the Local Adaptation Plan of Action (LAPA) was conceptualised in the National Adaptation Plan of Action (NAPA) of Nepal (GoN/MoE 2010). However, no initiation has been made to design the LAPA during the planned period of NAPA. In such a situation, resource poor communities should be supported to facilitate their access directly to productive livelihood resources, including technologies, markets and employment so they can take a lead in local adaptation planning and actions for sustainability. The vulnerability analysis model practised in this research is one option for information collection, management and policy practice that could help improve the accountability of local governance (Moser and Ekstrom 2010; Sining 2011).

Taking into consideration the policy and governance issues discussed above, three sector-specific policy options are proposed for Nepal. However, given the damage caused by the major earthquake of 25 April 2015 and subsequent aftershocks, these sectoral approaches require even stronger integration. Clearly, the rebuilding policy needs to incorporate a climate sensitive approach to meet the sustainable development needs of the country.

7.4.3.1 Risk and Disaster Management Policy for Human Security and Welfare

It is clear from the vulnerability assessment that policies to make social-ecological systems resilient to climate change are required for Nepal. Programmes to increase the ability of communities to recognize the impacts, analyse the risks, identify and develop adaptation mechanisms, and manage hazards are necessary to increase human security. In this context, adaptation policies should: design and implement hazard prevention and protection strategies; establish and practice early warning systems; assist communities with contingencies and emergency planning; and provide knowledge and awareness on climate change, its implications, and long-term adaptation initiatives. It is clear from the post-earthquake response (25 April 2015) that Nepal lacks both preparation for, and ability to manage large scale disasters. In some situations, inappropriate local governance has impacted the effectiveness of post-disaster responses (Grube and Storr 2014; Webster 2015). Therefore, functionalizing and strengthening local councils and Disaster Management Committees (DMC) at the local level should be recognised as a valuable contributor to policy planning and implementation.

Disaster management is strongly linked to human security and the welfare of people. The state is a critical mechanism to reduce vulnerability, ensure human security and social welfare, and strengthen peoples' livelihoods (Barnett and Adger 2007). The development and implementation of climate-resilient development and social protection (Davies et al. 2008; Macchi 2011) would help to transform existing socio-cultural, politico-institutional, and techno-economic structures towards effective, efficient and accountable institutions, and in turn, promote adaptation. Also, considering the recent history of internal armed-conflict and ever increasing demand for 'identity' based federalism in Nepal, development and adaptation policy that integrates spatially could help to prevent conflict. Currently both the resources and the political will to aim for comprehensive welfare outcomes is lacking in Nepal. In such a situation, widely collected and analysed information such as the SVI undertaken here could provide information on vulnerability 'hot spots', which would offer government the opportunity for targeting the most just responses.

7.4.3.2 Agriculture and Livelihood Diversification Policy for Food and Livelihood Security

The findings from the Kaligandaki Basin demonstrate that households experience moderate to high vulnerability to climate change, which aligns broadly with other research findings in Nepal (Chapagain and Gentle 2015; Devkota et al. 2011; Macchi et al. 2014). To respond to that situation, adaptation policy requires enhanced food and livelihood security, with a particular goal of assisting communities to escape the poverty trap. Livelihood diversification is a key to increase households' capacities to cope with change because a greater range of livelihood options reduces sensitivity to the loss of specific elements (Folke et al. 2004).Adoption of social-ecological perspectives towards adaptation planning, which allow for the internal renewal of systems while maintaining their overall structure (Folke et al. 1998), could provide multiple livelihood options in Nepal. However, the past and existing agricultural policies largely overlook the importance of agriculture on the mountain slopes and the country's conservation practices do not sufficiently account for people as an integral part of local 'ecosystems'. Lack of conservation of local agricultural biodiversity has negatively implicated local food security (Bardsley and Thomas 2005; Adhikari 2008), while restrictions imposed on sustainable exploitation of forest resources has undermined ecosystem-based adaptation. The extra-ordinary emphasis given to the consumption of white rice, which is not produced on mountain slopes; and the higher cost to transport food from other parts of the country has reduced food security in many mountain regions in Nepal and conservation programmes have failed to win local communities' admiration. The appropriate management of natural resources is now vital for adaptation of agro-livestock based communities. Niino (2011) recommends that South Asia in general needs conservation and the efficient use of agricultural land and water resources, with the provision of technical and policy support that allows for targeted local environmental considerations, land management and land-use planning. However, farmland abandonment is becoming an increasingly serious problem in the region, and Nepal in general, due to a combination of instability, reduced agricultural production, insufficient policy attention to hill and mountain agriculture, and availability of more attractive alternative opportunities (Paudel, KP et al. 2014).

1. Resource management in the Himalaya requires fundamental changes from the conventional approach to an alternative paradigm – building social-ecological resilience where societies are considered as the part of holistic system (Berkes and Folke 1998). Holly et al. (2012) noted the overwhelming focus given to hard-engineering structures to promote adaptation in many parts of the globe, which are not ecosystem based, flexible, or cost-effective, and may not be the appropriate strategies to buffer the impacts of climate change. Considering the environmental sensitivity of the Himalayan environment, ecosystem-based adaptation is appropriate and feasible in Nepal. In this context, Tamang et al. (2014) proposed the restoration of agriculture and in particular low input and less labour-intensive agriculture such as agro-forestry and livestock activities, together with livelihood diversification, which in turn help both mitigation of climate change and increase social-ecological resilience.

7.4.3.3 Climate Change Mitigation Policy for Social-ecological Sustainability

The Sustainable Development Agenda of Nepal (HMGN/NPC/MOPE 2003) was probably the first policy document that comprehensively considered a climate change agenda for development in Nepal. It was followed by NAPA 2010 (GoN/MoE 2010) and Nepal's Climate Change Policy 2011 (GoN/MoST 2011). The common goal of these policies is to improve peoples' livelihoods through mitigation of, and adaptation to, climate change. However, the NAPA also had many limitations in its planning process, no need to mention its implementations and achievements have been very poor.

The NAPA was prepared under the Ministry of Environment (MoE) by administrative staff with the assistance of a number of foreign experts hired by donor agencies. There was no representation of local academics or researchers from relevant fields, as well as no representation from the Ministry of Local Development (MoLD). Since it was not prepared under the National Planning Commission (NPC), which is the main government body responsible for overall planning in the Nepal, the NAPA was not an integrated plan of action. Rather, it was treated as a sectoral plan and problems have been addressed as if they were independent of other, broader concerns. For example, two of the important provisions placed in the NAPA were: the consideration of ecosystem services as the major source of Nepali livelihoods, and the promotion of community-based adaptation through ecosystem approaches under the LAPA (GoN/MoE 2010). However, the government did not take ownership of NAPA so the actions were not implemented and local authorities and people who were expected to be the planners and implementers of the LAPA, did not receive necessary guidelines for their design. Despite Nepal being ranked fourth globally in terms of climate related vulnerability (as cited in GoN et al. 2012), the governance of adaptation policy in Nepal remains very challenging. Research that allows for targeted responses by local governments to meet specific adaptation needs, such as was undertaken here, could help to fill this gap.

7.5 Conclusion

The social-ecological systems of the Kaligandaki Basin are exposed and sensitive to rapid climate change, and are associated with poor adaptive capacities, and therefore they are highly vulnerable. However, it is difficult to distinguish vulnerability from poverty and multidimensional deprivation in the Kaligandaki Basin. Particularly, the studied households are generally poor and marginalised already, lacking basic necessities or a voice in policy decision making, so they are vulnerable irrespective of climatic factors. The studied communities have relatively rich local adaptation knowledge but it has not been translated into adaptation practice. In some contexts, it seems that the studied households are losing confidence in their own knowledge and labour because they do not perceive that their local responses will make a significant difference, and many are not effectively practising their adaptation knowledge.

This study has provided a new approach to understanding the human-environmental interrelationships relevant to adaptation. It has explained that human-environmental interactions in relation to climate change cannot be understood comprehensively through orthodox human ecology and neo-environmental determinism approaches. The integration of societal and natural processes and their dynamism, as the concept of ‘social-ecology’ suggests, is a more complete approach to comprehending human-environmental interactions. In the same way, no single approach to system analysis, such as the SLA or the DPSIR frameworks, is sufficient to deal with the complex issues created by the interaction of climatic and non-climatic stressors. Therefore, the integration of both SLA and DPSIR frameworks to create a holistic analytical methodology becomes imperative. In addition, considering households as a key unit of vulnerability analysis instead of the spatial cluster, is more appropriate for effective policy practice within marginal contexts, because such practice informs vulnerability ‘hot spots’. Based on the theoretical contributions of this research, an integrated and dynamic adaptation framework has been proposed to make the research findings applicable to adaptation policy.

Together with climate change, communities of the Kaligandaki Basin are highly exposed to non-climatic physical hazards like verticality, slope, altitude, the dynamic process of mountain building, as well as non-physical hazards related to inaccessibility, isolation, poor infrastructure, lack of public services, high politico-cultural tensions, limited livelihood options - in short, poverty and marginality. Therefore adaptation policy in Nepal must integrate responses to the different stressors. However, weak and poor governance associated with political transition, and most recently, the severe implications of the major earthquake of 25 April 2015 continue to limit Nepal’s adaptive capacity. While this chapter has discussed the livelihood outcomes and the socio-ecological vulnerability analysis for the Kaligandaki Basin, it has also provided implications of research for both the discipline of geography, and adaptation policy, particularly for Nepal. The next chapter concludes this research work.

CHAPTER VIII

CONCLUSIONS

8. 1 Introduction

Changing climatic conditions and the implications of associated adaptation responses are altering interrelationships between humanity and the environment. In this context, this study examined human-environmental interactions and associated social-ecological dynamics in the Nepali Himalaya, with a particular focus on the Kaligandaki Basin. The study assessed the exposure and sensitivity of social ecosystems to climate change and mapped the adaptation efforts of communities. The outcomes of the impact-response dialectic were evaluated in terms of food and livelihood (in)security, as well as the broader social-ecological vulnerability. The findings of this study are expected to contribute to the evolution of adaptation theory and practice, including adaptation policy for Nepal. Since major elements of the value of the study have already been presented in Chapter Seven, this chapter briefly outlines the motivation and logic of the work that has been done and summarises the research achievements. The final section briefly concludes the major implications of the research for geographical theory and climate change adaptation policies, and suggests a future research agenda.

8.2 Context Specific Conclusions

8.2.1 Motivation and Logic

Climate scientists have confirmed that the climate of the world is changing rapidly, with variable rates of change across and within different regions. Climate change is altering existing, dynamic human-environmental interactions and generating different types of problems for societies because of their complex interference with every aspect of human and ecological systems (Adger et al. 2004; IPCC 2014; Schneider et al. 2007). Yet, the intensity of change and the implications vary spatially, with the Himalayan region experiencing high rates of change. Communities around the globe are attempting to adapt to the change and reduce the impacts. However, once again, the opportunities for, and outcomes from, adaptation actions are uneven. Considering the unique environmental situations, variable rates of climate change within the small spatial unit of the Kaligandaki valley, and the complex and unclear impacts, this study has attempted to holistically investigate the interactions between society and environmental dynamics, with the aim of seeking opportunities for adaptation.

Climate change is increasingly being recognised as a challenge for social-ecological sustainability. The problem is particularly critical for vulnerable regions like mountains and small islands, where impacts are high but opportunities for adaptation are limited. In this context, a poor understanding of the adaptation process of communities to environmental changes could undermine the complex human-environmental interactions in the Himalaya. Local adaptation knowledge is an important component of effective adaptation (Bardsley 2007); and if collated and integrated effectively, the 'transformative' community-based learning of adaptation can contribute to the sustainability of social-ecological systems (Capra 2007). Therefore, the impact-response interactions between humans and the environment in the Kaligandaki Basin were studied to understand the key issues, and to investigate the opportunities for resilient and sustainable social-ecological systems.

The Himalaya is one of the most diverse and complex regions in the world in terms of both climatic and physiographical features. The review of the literature confirmed that social-ecological implications of climate change and the associated dynamism in human-environmental interactions in the Himalaya have not been assessed sufficiently. As stated in detail within the researcher's journey (see section 1.4), exploration of human-environmental interactions from the perspective of the geographical discipline is the core interest of the researcher. The rapid climate change in the Himalaya and observed responses by communities motivated the researcher to make a systematic inquery on the theme and document and disseminate the results. Hence, as location-specific studies are required to understand the implications of climate change in the context of local social-ecological systems and identify feasible adaptation options to guide future policy in Nepal because a lack of effective adaptation is leading communities and their associated social-ecological systems towards increasing vulnerability or even failure; this research was conducted to answer a set of research questions: At what level are Nepali communities exposed to climate change? Are their livelihood options sensitive to, and affected by, climate change? And if so, what sorts of adaptation strategies have been adopted and what are the outcomes of impact-response chains in relation to livelihood sustainability?

This study adopts a geographical approach to explain human-environmental interrelationships. The dynamic and often conflicting connections are described and expected interrelationships mapped. The concepts of human ecology and social-ecology provide the foundation knowledge to interpret those dynamic interactions.

This study adopted the 'adaptation' concept as both a 'process of adapting' and the 'state of being adapted' (Wheaton and Maciver 1999), while vulnerability is applied as an integrated outcome of exposure to both endogenous and exogenous factors and climatic and non-climatic stressors

(Adger 2006; Füssel 2007). To explain the human-environmental systems in a systematic way, this study used a comprehensive framework constructed through integration of the Sustainable Livelihood Approach (SLA) and the system analysis framework (Driver→Pressure→Stage of Change→Impacts→Response or DPSIR). The compound model applied here has demonstrated the important interactions between the key components: the livelihood capitals, endogenous and exogenous stressors, and adaptation strategies. The composite index-based vulnerability assessment (Hahn et al. 2009) was applied to measure the vulnerability of the social-ecological systems at a micro, or household level. The methodology used in this research is pioneering because of its integration of scientific and social dimensions of climate change, its application of a triangulated methodology, and realistic categorization of variables at micro-level under exposure-sensitivity-adaptive capacity components and their utilization to obtain livelihood vulnerability and social-ecological vulnerability indices.

The core rationale behind conducting this research was that: the Himalayan environment is exposed to rapid climate change and the diverse social ecosystem of the region is climate sensitive, and communities' response to climate change is leading existing human-environmental interactions to a change, although the communities and the country have limited adaptive capacity to deal with the implications of climate change. In this context the knowledge generated through a comprehensive assessment of exposure, sensitivity, adaptive capacity, and evaluation of social-ecological vulnerability would provide valuable insights into the state of human-environmental interactions and expected interactions for the sustainability of the Himalayan social ecosystem, which in turn, would provide valuable information for public policies, particularly for climate change adaptation policy for Nepal. Therefore to generate applicable knowledge, the research drew from natural and social science methodologies and has created a holistic analytical approach. The integration of methodologies increased the relevance, and arguably the precision of findings, as well as making the knowledge understandable to local communities and policy makers by highlighting the key conflicts in local socio-ecological processes. The importance of community-based knowledge is high because climate change modelling is inherently uncertain due to uncertain feedback mechanisms within the climatic system (Challinor 2008). Also, expert led knowledge is poorly interpreted as required for lay people who need adaptation the most (O'Neill and Hulme 2009; Patt and Gwata 2002). Further, societal knowledge increases people's willingness to adaptation at the local level (Heath and Gifford 2006; O'Connor et al. 1999), and scientific knowledge helps formulate long-term macro adaptation policies; the integration of expert and lay knowledge can best facilitate adaptation (Adger et al. 2014; Roncoli 2006) and lead to sound research and policy outcomes (Pretty 2011). Considering multiple rationale relevant in the

Himalayan context, this research generates integrated knowledge on the field of climate change research.

8.2.2 Achievements of the Study

Both scientific data and social perceptions on climate change demonstrated that the social-ecological systems of Nepal are exposed to high levels of climate change and variability. Temperatures have increased; rainfall has become more variable and uncertain; and extreme weather events and their seasonality are also changing in the country (see sections 4.2.1 and 4.2.2). There are spatial variations in the rates of changes found in the meteorological data analysis, with increases in maximum and minimum temperature extremes highest in the Trans-Himalaya, while the maximum temperatures have increased fastest in the Middle-Mountains and the minimum temperatures fastest in the Tarai (see Figures 4.1 and 4.2). The influence of a range of meteorological factors outside the scope of this thesis would have caused such differences. Nevertheless, the complexity of climatic change is an important factor in understanding local impacts and adaptation opportunities.

In many cases, results are consistent between the meteorological observations and social perceptions. Yet, the interpretation of extreme rainfall events and reduced precipitation trends reveals a contradiction between meteorological and perception data. People recognise the changes in the duration and intensity of rainfall and use that information to report shifts in the monsoon. They report on extreme or normal weather events by noticing and articulating the specific losses or benefits to their systems, especially by examining the matches/mismatches between weather conditions and crop calendars. In addition, the availability of heating or cooling devices in peoples' homes influences their perceptions of climate change and extreme temperatures. Similarly, the nature of livelihood resources the households command (whether they are climate sensitive of not) affects on overall construction of climate change knowledge. Additionally, communities intended to evaluate climate change in relation to the impacts on their social ecosystems rather than seeing over metric measurement. Together these findings suggest that the 'meaning' given to weather patterns in relation to climate change is strongly influenced by contradictions between received wisdoms and learnt knowledge. As a result, there are also notable inter-household variations in perceptions along with differences across spatial scales.

The changes and increased variability in the climate system have impacted negatively on the livelihood capitals of the studied households. All of the components of the social ecosystems and livelihood assets are affected by the changing climate. Private and public properties, natural resource conditions, and basic services have been damaged and destroyed by climatic events or changes that are becoming more common, with the occasional loss of lives. Yet, many secondary and tertiary effects are largely unclear. For example, displacement and forced migration due to weather related disasters are commonly reported, with more cases in the Tarai, followed by the Trans-Himalaya, but the links between climate and peoples' decisions are not direct (see section 4.3.1 for details).

In addition, crop production has been severely affected by changing weather patterns, including the increased intensity of drought, mismatches between crop calendars and rainfall, increased hail events and more crop diseases, farm weeds and pests. Reduced soil moisture and a lack of irrigation have also made manure application less effective, further contributing to reduced farm productivity. Reductions in farm production capacity have led many farmers to reduce their production investments or abandon their farmlands. Livestock productivity has also been influenced by warming and drought, as well as increased livestock disease. Herd size has reduced due to decreased access to quality fodder and forage, associated also with the expansion of invasive species and increasingly restricted access to forest resources. In all, the climate sensitive livelihood resources have been impacted severely by climate change, particularly in the Middle-Mountains (see section 4.3.2). In these contexts, understanding social perceptions of climate change and associated implications are important components of climate change research to bridge the gaps between scientific knowledge generation and their translation into policy and practice by lay farmers as well as by non-technical policy makers.

The extended analysis of the livelihood capital of households indicates that livelihood systems are sensitive to both climatic and non-climatic stressors. Household access to and control over livelihood capital are generally weak, and they unable to tolerate further stresses, whether climatic, economic, ecological, social or political. The major limitations of livelihood resources are:

1) the poor level of education and skills; high levels of dependency within households; labour intensive occupations; and health problems associated with both climatic and non-climatic stressors (see section 5.2.1);

2) inadequate social capital in terms of quality; and material poverty among kin-folk and neighbours that is affecting reciprocal relationships (see section 5.2.2);

3) household ownership of only small farm plots; and the lack of entitlement to exploit forest resources even in a sustainable manner (see section 5.2.3);

4) economic poverty of households limits the accumulation of livelihood capital; households lack a stock of monetary capital and other high-value convertibles which could be helpful in stressful times; and livestock, which in some cases provide occasional cash income, are also at risk of extreme weather events and disease (see section 5.2.4); and,

5) despite owning a house, houses are not strong enough to protect people and property during extreme weather events such as flooding, fires and landslides; and state provisions for social welfare and public infrastructure are not sufficient to compensate the inadequacy of private livelihood capitals (see section 5.2.5).

The indexed values of the variables associated with different capitals, which later were used to calculate livelihood and social-ecological vulnerability indices, reflect the variable importance of different capitals for different households to generate livelihoods. This recognition of variability is evident across the households as well as across the ecological regions (see Table 5.11 and Figure 5.17). Also, the share of different capitals in household livelihood contribution is changing over time. In particular, the share of agro-livestock activities is declining while of the remittance and other activities those give cash-income to the households is increasing (see Appendix 12).

Within the context of the limited opportunities outlined above, the adoption of appropriate strategies is vital for communities to negotiate environmental change. The respondents demonstrated rich adaptation knowledge developed through a complex but systematic interaction with their ecosystems. However, their adaptation decision-making is notably poor; demonstrating that having adaptation knowledge is not the only condition sufficient for effective adaptation (Adger et al. 2007). Some of the livelihood adaptation strategies adopted by a relatively high proportion of households are: increased home heating/cooling instruments (see section 6.2.8.1); increased irrigation and regulated use of water (see section 6.2.3); labour migration to both local and international labour markets (see section 6.2.7); and increased agro-inputs (see section 6.2.4.2). For effective climate change adaptation, particularly in adaptation of farming communities, Smit and Skinner (2002) suggested four ways – technological development, government programme and insurance, farm production practice and farm financial management. In the study area adoption of the strategy related to technological development is very limited and the insurance is virtually absent. The government programmes are not very effective while farm production practice and farm financial management are applied at household level in relation to the farm return or the cost of production. The feasible strategies are not institutionalised in the study area since many farmers complained over poor return of farm activities due to multiple reasons including climate change. Therefore people are withdrawing from agricultural activities, increasingly leaving the farmland fallow. Consequently the adoption of strategies mapped in this research is limited only in few households(Section 6.3 and Figures 6.17 and 6.18). The lack of transfer of knowledge on agro-livestock management to the new generation for example, and the lack of sharing of effective adaptation knowledge between community members are also limiting adaptation processes. In addition, existing adaptation limits and barriers have challenged households' adaptation process (see Figure 6.3).However, based on the adaptation knowledge of household and communities, it can be envisaged that people may translate their adaptation knowledge into practice when they feel adaptation crises.

People are reducing the negative implications of climate and environmental changes by altering or modifying the components of their social-ecosystems (Adger et al. 2003; Head 2010; van Aalst et al. 2008; Watts 2009). However, the socio-political and economic problems that are being exacerbated due to climate change impacts, are also inhibiting effective adaptation processes and many households are losing hope; although assessing the role of political economy in determining climate change impacts was not the scope of this research. Importantly for the predominantly rural communities, adaptation through altered agro-livestock activities is seen by many as unattractive due to a reduction in interest in subsistence agriculture and a high preference for cash income. Partly as a result, many young adults are leaving their communities in search of paid work, and so the local agro-ecosystems are further marginalized. In this context the outcomes of out-migration are complex, depending upon particular cases so it is difficult to generalise whether labour migration abroad is adaptive or maladaptive since it has produced both positive and negative outcomes. For example, it is assisting adaptation (see section 6.2.5) while also damaging agro-ecological systems through increases in fallow farmland and feminization of agriculture, as well as damaging social cohesion and familial / spousal bonds.

There are some spatial variations in the adoption of different strategies. Farmers in the Tarai use HYVs, chemical fertilizers and other agro-chemicals, and irrigation at a higher rate than in the other zones (see Figure 6.2). Changes in crop calendars and the regulated use of water are common in Trans-Himalaya and the Tarai (see Figures 6.2 and 6.9); while a higher proportion of households in the Trans-Himalaya utilise drainage management and gain access to external assistance (see Figure 6.7 and Table 6.4). The construction of flood control dikes and retaining walls are practiced in both the Tarai and the Trans-Himalaya (see Plates 4.1c, 4.2a and 6.4). Migration is a common strategy to all of the ecological zones with the highest level of adoption by households in the Middle-Mountains, followed by the Tarai and the Trans-Himalaya (see Figure 6.14). Land productivity, the length of growing seasons, and levels of livelihood stress faced by households, together with the variable emphasis of the country's agricultural policy on different ecological zones, have played complex roles in creating such variations. Together it is possible to conclude that opportunities for effective adaptation policies are very limited due to the high sensitivity of local socio-ecosystems to climate change, and limited livelihood development opportunities beyond those that are highly uncertain. In the longer-term the apparent endogenous and exogenous stressors are likely to undermine the sustainability of many local communities, and again that risk is most evident in the Middle-Mountains (see section 7.3.4).

8.2.3 Implications of the Study

8.2.3.1 Implications for Food and Livelihood (In)Security and Social-Ecological Vulnerability

It is evident from this study that the outcomes of environmental impacts and human responses in the Kaligandaki Basin have resulted in less secure food and livelihood systems and vulnerable social ecosystems (see sections 7.2 and 7.3). The Household Food (In)security Access Scale (HFIAS) suggests that the quality and stability of food security is notably poor in the basin, but it varies across the ecological zones. In particular, the severity of food insecurity is highest in the Middle-Mountains followed by the Trans-Himalaya, where the situation of poor food security has not improved significantly in the last decade (see Table 7.2). In fact, household livelihood systems do not satisfy basic needs in many cases throughout the basin because of the overall poor quality of livelihood capital (see Figure 5.17).

The assessment of vulnerability using the IPCC framework also suggests that the social-ecological systems of the Kaligandaki Basin are vulnerable (see Figure 7.12), with high exposure and sensitivity to climate and environmental change and limited adaptive capacity. In the spatial context, the Middle-Mountains exhibit the highest levels of exposure and sensitivity, while the same region has the lowest level of adaptive capacity (see Figure 7.9). It was generally assumed earlier that the Trans-Himalaya, which is the most remote area with severe gaps in public services and a limited growing season, might be the most vulnerable region in Nepal. However, the results here do not support this assumption, indicating that vulnerability of social-ecological systems in the basin is a complex phenomenon. The answer to the question of why the Middle-Mountains are more vulnerable than Trans-Himalaya is generally unclear. However, relatively less intensive impacts of climate change (see Figure 4.20), better status of overall livelihood capitals (see Figure 5.17), and higher levels of adoption of location specific adaptation strategies (see Figure 6.18) in the Trans-Himalaya rather than the Middle-Mountains might have resulted in such variation. The availability of adaptation options, societal history and expectations, and perception of adaptation barriers are also likely to underlay such differences (Deressa et al. 2009; Jones and Boyd 2011; Nielsen and Reenberg 2010). Moreover, this study assessed vulnerability by applying social perception data in various elements of the social-ecological system (see Table 3.6). Lower population density; more opportunities for alternative livelihoods, particularly tourism; and generally low development expectations in the Trans-Himalaya (as people have accepted the area's harsh environmental situation and inaccessibility as a fact not a problem) influence the research results that have shown that the Trans-Himalaya as less-vulnerable than the Middle-Mountains. This finding forms an interesting question – why? It appears that despite severe weather conditions, higher rates of climate change and impacts, and limited growing seasons, including the lack of other opportunities for comfortable livelihoods in the Trans-Himalaya, the lower expectation of the communities in the context of the extreme geographic reality in the region, suggests a relatively better situation than that of the Middle-Mountains. The communities living in the transitional zone like the Middle-Mountains on the other hand have higher expectation as they are living to proximate location of major cities but their expectations are largely unmet, which might have influenced their perceptions, and in turn, perceptions of higher levels of vulnerability. The Tarai on the other hand, appeared to be relatively less vulnerable than both of the other zones, with considerably more livelihood development opportunities.

In the context of the unpacking of the vulnerabilities of households in the Kaligandaki Basin described above, and as stated in literature, it is seen that social-ecological vulnerability is an outcome of integrated problems of climate change associated with: 1) people's level of understanding of impacts of environmental changes (Füssel and Klein 2006); 2) local effects of the national and international political economy (Allen 2003; Chaudhary et al. 2007; van Aalst et al. 2008); 3) the bio-physical, socio-economic and techno-institutional problems of the country (Adger 2006; Brooks 2003; Martens et al. 2009; Sining 2011); 4) poor and inadequate public policies and institutional mechanisms (Adger 2000b); and 5) the behaviours of individual and household head as decision makers in relation to the environmental crisis (Robert and Barry 2006).

8.2.3.2 Implications for the Discipline of Geography

This research has very important implications for the discipline of human geography, particularly in relation to the evolution of geographical methodologies for guiding adaptation. The social-ecological model developed to comprehend human-environmental interactions represents an innovative method of systems analysis by integrating SLA and the DPSIR frameworks (see Figure 2.1). The findings of this research are summarised under the adopted framework (Figure 7.13). It has been understood from this study that the SLA cannot generate an appropriate mechanism for local livelihood sustainability in a climate change context, although it has been acknowledged as a suitable approach for the sustainability of rural livelihood systems in other contexts (Carney et al. 1999; Chambers and Conway 1991). It is because the pace of climate change is so variable, the impacts are unclear and often complex, and adaptation knowledge either is not translated into practice effectively or some of the strategies may have generated maladaptation. In such situation a dynamic and interactive framework having other elements of the social-ecological system included, is required to address the complex issues adequately. The DPSIR framework is also inadequate in itself to address the complex issues of social-ecological systems in relation to climate change because of the assumed linear and static nature of the framework as applied in various context although the DPSIR can be make dynamic. Together, however, the findings from the holistic analysis indicate that the impacts of climate change on social-ecological systems are complex and human responses to impacts vary over time, space, households and communities. Analyses made in this research allow for greater understanding of temporal and spatial systemic complexities that in turn assist to generate targeted recommendations.

The holistic approach provides an opportunity to understand such complex interactions and provide valuable insights for adaptation policy and practice. It is identified from this study that the people of the Himalaya do not wait for the impacts of external drivers to impact negatively upon their systems. Rather, they respond to the stressors at different stages, depending on their learning-based knowledge and the availability of resources. For example: farmers construct flood control dikes or arrange cooling/heating devices based on learning from the previous year (response to drivers); use private irrigation when drought increases (response to pressure); transform the farmland into other types of use when the quality of farmland changes (response to change); and the community can adopt coping strategies such as borrowing, wage labouring, or looking for paid employment away from the communities and the country (response to impacts). Many factors influence household adaptation decision-making. The response to stressors at different stages is largely determined by a households' economy, and especially the ability to afford technologies, and public policies. In addition, the rural households are in transition because increasing proportions of households derive their livelihoods from the cash economy. Therefore, the relevancy of the SLA is declining even in the rural context. The DPSIR framework is applied in sector-specific systems and further work is required to test its applicability to analyse complex social ecosystems in relation to climate change and to assess the sustainability or vulnerability of systems incorporating both endogenous and exogenous factors and climatic and non-climatic stressors. Therefore, for a successful assessment of the human-environmental interrelationship to contribute effectively to the adaptation process, it is necessary to integrate the SLA and DPSIR frameworks into a dynamic model of adaptation (as presented in the Figure 7.14).

The integrated and dynamic model of adaptation proposed by this study is an important theoretical contribution of this thesis, as it provides a mechanism for researchers to help communities adapt through learning-based adaptation at a local scale (Armitage et al. 2009; Wildemeersch 2007). In such a heuristic model: outcomes of adaptation strategies increase the adaptive capacity of the social-ecological systems (or not), and people verify the relevance of adopted strategies, while researchers continuously refine them as an ongoing learning process. The feedback and forward loops at different stages provide learning opportunities and can approach the system towards sustainability, as demonstrated in Figure 7.15. The learning-based adaptation framework is relevant also due to uncertainties in climate change and associated impacts as well as notable inter-annual and inter-decadal variabilities in weather patterns.

To provide a comprehensive review of existing human-environmental interactions in the Kaligandaki Basin one needs a systematic assessment of climate change and associated impacts (see chapter 4); comprehensive description of livelihood assets available to households and their sensitivity to climate change (see chapter 5); the broad mapping of adaptation responses (see chapter 6); adaptation outcomes in relation to food and livelihood security (see section 7.2); and critical analysis of overall social-ecological vulnerability (see section 7.3). In addition, this research assessed the social-ecological vulnerability at the household level using the composite vulnerability index, which enabled the articulation of vulnerability hot spots (see Figure 7.10). In particular, the findings highlights that those households who gain limited benefits from the world system suffer the most from climate change impacts, while households who have benefited through access to jobs, business or supportive policies, mostly associated with cash income or direct material support, are relatively less vulnerable. In this context, social-ecological vulnerability to climate change can be at least partially explained through the world system analytical approach (Wallerstein 1974b) although this research could not incorporate many of the elements of national and global political economic systems to analyse human-environmental interactions (see section 3.6).

By undertaking household level vulnerability assessments as shown here (see section 7.3.4), state policy mechanisms could target assistance to households by adopting equity and justice based approach to 'support the most vulnerable first'. The limited resources of the country should be spent to support the households with the highest vulnerability index (see Figure 7.10), and gradually expand the support to those less vulnerable. To enable this complex assessment, the research integrated different methodologies of knowledge formation, and brought multiple stakeholders and their perspectives into the knowledge production process. This form of knowledge generation, which details context specific issues in relation to climate change impacts and adaptation, generates information that is more directly applicable for both policy and practice, than that knowledge generated using singular research approaches. Moreover, the vulnerability assessment approach adopted in this thesis is a heuristic decision making tool, with flexibility to include or withdraw variables relevant to a community or country, to increase its applicability in different contexts, including both developed and developing countries. The applied theoretical integration and methodological triangulation are the pioneer contributions of this research that support scholarly discourse on integrated approaches to provide an understanding of the interrelationship between societies and nature in relation to climate change. The holistic approach adopted has shown how complex systems can be studied systematically for positive applied and theoretical outcomes.

8.2.3.3 Implications for Adaptation Policy

In the context of the growing need for climate change adaptation through public policy development, this research provides important information for Nepal. The adaptation challenge is complex mostly due to uncertain impacts; unclear outcomes of adaptation actions; and often not effectively coordinated autonomous adaptations. Furthermore, the outcomes of adopted strategies may not necessarily lead to effective adaptation (Moser and Ekstrom 2010); in fact, they can lead to maladaptation (Adger and Barnett 2009; Barnett and O'Neill 2010; Wiseman and Bardsley 2013). Therefore, climate change adaptation requires addressing multidimensional issues at a point in time through integrated policy. The research here suggests that human responses to environmental or non-environmental stressors vary strongly with the situations of households, and adaptation knowledge will need to reflect that complexity to support policy for positive outcomes.

As noted in section 7.4.3, there are several policy options to promote adaptation. Some appropriate models for Nepal include: integration of indigenous knowledge and technology with scientific knowledge and modern technologies (Alamgir et al. 2014; Patt and Schröter 2008); integrated and participatory adaptive management (Salerno et al. 2010); ecological niche-based approach (Chhetri et al. 2013);adaptive co-management (Armitage et al. 2009); and experimental or social learning-based adaptive management (Berkes and Folke 1998; Wildemeersch 2007). In addition, Bardsley (2015) proposes social-ecological governance to address related problems comprehensively, while others emphasize rights-based adaptation (Baer et al. 2007; Polack 2008), linked to flexible, participatory bottom-up adaptation policy (Amaru and Chhetri 2013).

However, none of these policy options are independent of the global political-economic system. As the world system approach (Wallerstein 2004; Wallerstein 1974b) notes, increased capital accumulation has led to social-ecological crises, it is becoming increasingly clear that the communities and the countries on the periphery, who benefit the least from the global political economy, are also being disproportionately affected by the negative consequences of the environmental change generated by that economy. The components of local social-ecological systems in the Kaligandaki Basin increasingly interact with the world system and environmental changes in a range of complex ways, including changing agricultural economies and migration opportunities. Therefore, local adaptation challenges are observed that are not controllable at the household, community or national level, but are instead complex and dynamic and require global political-economic solutions or safeguards to generate hope.

At the same time, adaptation policy in Nepal must recognise the need for flexible approaches that simultaneously empower and generate development opportunities within disadvantaged regional and cultural contexts. Considering the wide gap in assessing climate change impacts and adaptation opportunities in Nepal on the one hand, and existing uncertainties in the adaptation process on the other, a comprehensive and a continuous adaptation policy is urgent to overcome the potential for cascading social-ecological systemic failures. A continuous adaptation policy requires both feedback and forward loops. Many of the policy alternatives mentioned above and discussed in detail in chapter seven (see section 7.4.3) may not be able to address the complex issues effectively if they are adopted in isolated or static forms. The effectiveness of adaptation policy depends on whether the people at risk, feel that such policies are addressing their needs. In addition, current policy approaches are mostly ecosystem based, but still require the strong integration of stakeholders at various spatial scales (local, regional, national) and across the sectors (social, ecological, economic, and political).

Considering household poverty and marginality on the one hand and rapid climate change impacts on sensitive social-ecological systems on the other, Nepal require the integration of disaster management and human security (see section 7.4.3.1); food and livelihood security through agricultural promotion and livelihood diversification (see section 7.4.3.2) to approach social-ecological sustainability (see section 7.4.3.3). Such integrated policy may be able to address the socio-political and techno-economic problems of the country together with new climatic and ecological issues. To make the integrated adaptation policy effective, participation of local people and other stakeholders (based on the appropriate local, regional, national, or international scales) is critical. In this context, this research provides important information on exposure and sensitivity of social ecosystem to climate change, existing and reclaimable adaptation options, and the social-ecological vulnerability index to help designing both sectoral and integrated adaptation policies for different households and the communities. Yet, the poor performance of Nepali state mechanisms that lacks comprehensive social-ecological governance, and the catastrophic damage caused by the recent earthquake in Nepal, all suggest that the country has enormous adaptation challenges ahead.

8.2.3.4 Future Research Agenda

Similar studies to this research on climate change, its impacts and adaptation responses in Nepal are emerging. However, considering the bio-physical and socio-economic diversities of the country, more studies are required to guide specific local adaptation and to generalize findings for the Nepali Himalaya. Some of the prominent further research agendas identified by this study are:

- A requirement of numerous location specific studies using a similar framework and methodology to this research to enrich knowledge on the human-environmental systems of the Himalaya.
- To assess sector specific stressors and vulnerabilities to climate change to generate appropriate knowledge for sector-specific policies.
- To evaluate climate change impacts and adaptation responses of different groups of people with a particular focus on social and economic strata like gender, class, caste and ethnicity to develop effective, equitable and just social policies.
- To investigate health implications and livelihood burdens of the extreme weather events and to map the strategies adopted or needed to manage them.
- To assess various adaptation strategies in relation to their adaptive/maladaptive interactions and investigate the determinants of replicating ‘no’ or ‘low’ regret adaptation strategies.

8.3 Conclusion

The study comprehensively analysed human-environmental interactions in the Himalaya in relation to climate change using an integrated framework and methodology. The approach could be an important foundation to explain human ecological implications of climate change, investigate adaptation opportunities, and accommodate location specific elements of the compounding interactions between human and environmental systems. The systematic and integrated assessment of climate change and associated impacts, a broad description of livelihood capital of the communities, and careful mapping of adaptation responses provide important information on the exposure, sensitivity and adaptive capacity of the social-ecological systems of the Kaligandaki Basin, Nepal. Because of the higher level of exposure and sensitivity but poor adaptive capacity of the systems to climate change, the households' social-ecological systems are highly vulnerable in the basin, and especially in the Middle-Mountains. In this context, integrated adaptation policy to increase the broader resilience of social-ecological systems is proposed, and such a proposition will require support external to the households, communities and state of Nepal.

APPENDICES

Appendix 1: Household Interview Questionnaire Schedule

Human Ecological Implications of Climate Change in the Himalaya: Investigating Opportunities for Adaptation in Kaligandaki Basin, Nepal

Household Interview Questionnaire Schedule **Questionnaire Code: ....**

Please Circle the Appropriate Code or write the code on the space provided wherever applicable

(Note: Respondents must be 18 years and above)

A. Details of Household Head (Obtain the details of HH head even the respondent is not the Head)			Code
A.1 Name (Optional)	…………………………………..	A.2 Sex: 1. Female, 2. Male	
A.3 Age (years):	A.4 VDC: ………………………..	A.5 Settlement: ………………..	
A.6 Ward No: ……..	A.7 Ethnicity/Caste: 1= Hill-Brahmin/Chhetri/Dasnami, 2 = Tarai –Brahmin /Chhetri /Dasnami, 3 = Hill Ethnic Group, 4 = Tarai Ethnic Group (Tharus), 5 = Hill Dalits, 6 = Tarai Dalit, 7 = Madhesi Community, 8. Others (Specify) ………………………………		

B.1 Demographic detail (Labour Force) of Household

B.1.1 Please provide demographic information of your household

SN	Age by Sex	Below 5 yrs	5-14 yrs	15-29 yrs	30-44 yrs	45-59 yrs	60-74 yrs	75 and Above
1	Female							
2	Male							

B.1.2 Please provide number of your household member with level of their education (only of 5 years and above age)

SN	Educational Status by Sex	Illiterate	Just Literate	Primary Level	Secondary level	Higher Secondary	Graduate level	Post Graduate
1	Female							
2	Male							

B.2 Migration and Associated Causes:

B.2.1 Have you migrated here from somewhere else? **1= Yes** **2= No**

B.2.2 If **YES,** please give the details

Migrated from			d. Type:1=Permanent 2=Temporary	e. Cause of migration	f. How long ago (years)
a. District	b. VDC/Municipality	c. Ward			

B.2.3 Please provide the number by sex and occupational status of your household members (their current engagement)

SN	Primary Occupation by Sex (15+ yrs)	Agriculture	Service	Business	Foreign Employment	Retired	Wage Labourer skilled	Unemployed	Study/ Home Activities support
1	Female								
2	Male								

B.3 Health issues with Household Members

B.3.1 Which diseases have been experienced by your family frequently? Please list them with the level of their severity

Example of Health Problems: Flu, Malaria, Diarrhea, Dysentery, Worm infestation, Pneumonia, Encephalitis, Dengue Fever,

SN	a. Name of the diseases	b. Level of Severity of health problem (1= Little/occasional, 3= More frequent, 4= Severely)
1		
2		

B.4 Status of Social Capitals

B.4.1 Are you or any member of your family affiliated with any Community Based Organizations? **1= Yes 2= No**

B.4.2 If **YES**, please give the following details

SN	a. Types of CBOs/ Groups	b. Number of family members involved in particular CBO /Groups		c. Designation: 1= General member, 2= Executive/ board member, 3 = Executive Chair/secretary
		Female	Male	
1	Forest User Group			
2	Disaster Management Committee			
3	Saving/Credit group			
4	Traditional Ethno-based groups			
5	Mother's Group			
6	Formal Organizations			
7	Other, Specify ………..			

B.4.3 Could you please provide information on your kinship and family network (who is where? Who can assist you at the time of need?)

………………………………………………………………………… ……………………………………………

B.4.4 Who else helps you when you suffer crises?

…………………………………………………………………………

B.5 Status of Natural Capitals

B.5.1 Land Resource

B.5.1 Do you/ your family member have any land? **1. Yes** **2. No**

B.5.1.1 If **YES**, Please discribed the land ownership and tenure status of your household (**Mark** whether the Area is in *Ropani* OR *Bigha*)

SN	a. Land Type	b. Total land area	c. Land under Female Ownership	d. Area under Tenure out	e. Area under Tenure in
1	Level Terrace (Khet)				
2	Sloping Terrace (Bari)				
3	Homestead				
4	Grass Land (Kharbari)				
5	Forest (Private/leasehold)				

B.5.1.2 What areas of your farm land are crop under different intensities and phases of a crop rotation in a typical year (last year)?

SN	a. Cropping Intensity	b. Farming area (Ropani/ Bigha)	c. Annual Crop rotation in a typical year	d. Reason of limited intensity: 1= long growing season, 2= lack of irrigation, 3= not having profitable productivity, 4= Other………..(specify)
1	One time a year			
2	Two times a year			
3	Three times a year			

B.5.1.3 Is any area of your farmland remained /left uncultivated? **1. Yes** **2. No**

B.5.1.4 If **YES**, what is the total area of land that is not cultivated: Give the area **…………..** (Area in Ropani or in Kattha)

B.5.1.5 What are the causes behind not cultivating any crops in that land?

1……

2. ……

B.5.2 Water Resource

B.5.2.1 Does your farm land have irrigation facilities? **1. Yes** **2. No**

B.5.2.2 If yes, could you please provide the area that has different levels of irrigation facilities?

SN	a. Level of Irrigation	b. Irrigated area (Ropani/ Bigha)
1	Year round	
2	Only for 2 seasons (monsoon-post monsoon)	
3	Only for 1 season (monsoon)	
4	Never (always depends on rain-fed)	

B.5.2.3 Could you please share the source of drinking water that your household uses? Has a dependency on a particular source has changed over last 10 years? Why did that change occur?

a. Sources	Hand pump	Private Tap	Public Tap	Spring/ Well	Stream, River, Pond	Rain water harvest
Remarks						

B.5.3 Source of forest products

B.5.3.1 Could you please share the source of the forest products that your household uses?

SN	a. Forest Product	b. Source (note: list the multiple sources if mentioned) **Code:** 1= Agriculture Residue, 2= Private/leasehold Forest/*Pakho /Kharbari*, 3= Community Forest, 4= Government Forest, 5= Public Pasture (*Kharka)Transhumance*	c. Had the share of particular source changed since last 10 years? **Code:**1= Not at all, 2= little-bit, 3= notable, 4= significantly, 5= completely
1	Firewood		
2	Building material (wood)		
3	Grass/fodder/mulch		
4	Grazing animal		

B.5.3.2 Do you collect jungle food/ greens for household consumption or to sale in the market?

1. Yes **2. No**

B.5.3.3 if **YES** please describe the type, seasons and amount of their availability.
……………………………………………………………………………
……………………………………………………………………………

B.5.4 Could you please provide information on the livestock and poultry your household holds/keeps?

Type of Livestock	1. Cow	2. Bull/ Oxen	2. Buffalo	4. Male buffalo	5. Pig	6. Goat/ Sheep	7. Poultry	8. Horse/ Mule	9. Yak/ Chouri
Numbers									

B.6 Food Sufficiency and Household Economy

B.6.1 Out of your annual food requirement, what share of that do you need to buy?

Answer: 1= none, 2= less than 25%, 3= up to 50% 4= up to 75% 5=Over 75%

B.6.2 Out of the total annual expenditure (cash requirements) for your household for different purposes (to buy food, clothing, housing, health, education, fuel, other household materials…), what share of your annual expenditure is covered by your annual cash income from various sources (sale of farm/animal product, income from salary/remittance, business/enterprises)?

Answer: 1= All expenditure covers (no annual budget deficit but some saving), 2= covers over 75% requirements, 3= covers over 50% requirements, 4= covers over 25% requirements, 5= cannot cover even 25% requirements

B.6.3 If there is more than a 50% annual budget deficit, what are you unable to pay for or how do you manage a lack of income? (**eg.** Investing in education, investing for foreign employment, investing for critical health problems, …)

……………………………………………………………………………………….

………………………………………………………………..

B.6.4 Do you have any debt? **1. Yes 2. No**

B.6.5 if **YES** could you please tell me the amount of debt and the annual interest you pay for it?

Amount NRS. ………………….Annual Interest Rate ……………%

B.6.6 Do you have any investment? **1. Yes 2. No**

B.6.7 if **YES** could you please tell me the amount you have invested and the annual interest / return rate you are paid for?

Amount NRS. ………………….Annual Interest Rate ……………%

B.7 Status of Private possession:

B.7.1 Could you please give the details of Residential Arrangement, Ownerships and types of your house/s?

SN	Residential Arrangement: Ownerships and types of your house	Answer Code	Code
1	Ownership of house	1= Self owned, 2. Rental, 3. Property of Trusts (Guthi), 4 Other (specify) …………	
2	Types of house	1= Concrete, 2 = Non-concrete Tin/Slate/Tiled roof, 3=Mud and stony with dry grass roof, 4= Small hut	
3	Storey in house	1= One storey, 2= Two storeys, 3=Three storeys, 4= Four or more	
4	Does your house have toilet facility? If **YES**, please provide the information on the type of toilet you have	1= Modern flush, 2= Modern non-flush, 3= Simple toilet (Pit Latrine), 4= No toilet	

B.7.2 Could you please give the details of facilities that your Household possesses

SN	**Facilities Available at Household**	**Answer Code:** (1= 1 set Available, 2= 2 sets, 3= More than 2 sets available, 4= Not available	SN	**Facilities Available at Household**	**Answer Code:** (1= 1 set Available, 2= 2 sets, 3= More than 2 sets available, 4= Not available
1	Refrigerator/ Air Conditioning		7	Deep-tube well (private/irrigation)	
2	Bio-Gas plant/ Solar Energy		8	Rickshaw/ Ladiya/Tanga/ Horse/Hull (as the source of income)	
3	Radio/Television		9	Stock of monetary (convertible) capitals (valuables/ ornaments)	
4	Telephone/internet		10	Agricultural equipments (Sprayer / Thrasher /Metal Seed bin)	
5	Vehicle (4 wheeler)		11	Others: (Specify) ………	
6	Motorcycle / Scooter				

B.7.3 How do you evaluate your household's economic status?

1= Affluent 2= Rich (higher middle) 3= Middle class

4= Poor 5= Ultra poor

C. Livelihood out Come - Food (In)security Status and Livelihood Strategy:

C.1 Please share the level of food sufficiency at your family last year's by months if you experienced **any of these situations happened:** worried about food supply, reduced the quantity of food, escaped some meal, could not change meal types for several days, children did not get sufficient nourished food, did not have desired food in festivals, food bought in credit, money borrowed to buy food, cereal harvested before being ready to harvest, food borrowed from neighbour, seek/received food aid, ...)

(Scale the level of deficiency for each month using the Code: 1 = Rarely (1-2 times in a month),

2 = Sometimes (3–10 times in a month), 3 = Often (more than 10 times in each Months)

Months	Baisakh	Jestha	Ashad	Shrawan	Bhadra	Aswin	Kartik	Mangsir	Push	Magh	Falgun	Chaitra
Situation at present (Codes)												
Situation10 years ago (Codes)												

C.2 How has the contribution of the following sources of income/livelihood changed in last 10 years?

Sources of Livelihoods	a. Agro-livestock	b. Employment	c. Enterprise	d. Remmittance	e. Wage labour	f. Others (specify)
Annual share at present (%)						
Annual share before 10 years (%)						

C.3 Have you or any family member adopted any new methods to support your livelihood in the last 10 years?

1. Yes 2. No

C.4 If yes, what is it and why did you adopt this option?

…………………………………………………………………..

D. Climate change perceptions and Adaptation practice

D.1 Climate change perception/ evidences of change:

D.1.1 Could you please share your observations / experiences in regards to changes in **Precipitation, Drought and Temperature** in your village over last 10 years?

SN	**Answer Codes:** 1= Yes, Clearly Observed, 2= Often Observed, 3= occasionally observed (it seems like that), 4= Cannot evaluate/ Don't know , 5= None observed / No changes	**Answer Codes: (Circle the number)**					**Entry Codes**
	Precipitation						
1	Annual Rainy days increased	1	2	3	4	5	
2	Annual Rainy days decreased/ Longer dry periods	1	2	3	4	5	
3	Rainfall in winter /dry period decreased	1	2	3	4	5	
4	Intensity of rain in summer increased (Erratic rainfall in short periods)	1	2	3	4	5	
5	Summer Floods are more frequent and more intense / strong	1	2	3	4	5	
6	Hailstones occur beyond autumn and spring season	1	2	3	4	5	

	Drought						
7	The weather is becoming drier every year / Intensity and Frequency of droughts is increasing	1	2	3	4	5	
8	Water shortages are observed and getting longer every year	1	2	3	4	5	
9	Annual days with sufficient water availability at regular sources are decreasing (Annual life of water sources is decreasing)	1	2	3	4	5	
10	Arrival / withdrawal of the monsoon has changed	1	2	3	4	5	
	Temperature						
11	Temperature in summer is increasing (Hotter summers)	1	2	3	4	5	
12	Altered climatic range (the difference or range of minimum and maximum temperatures has increased)	1	2	3	4	5	
13	Temperature in winter is increasing (winter is not so cold as it used to be)	1	2	3	4	5	
14	Level of coldness (intensity) in winter increased	1	2	3	4	5	

D.1.2 Could you please share your observations / experiences in regards to the trends in local **Ecology/Ecosystem** in your village over the last 10 years?

S N	**Answer Codes:** 1= Yes, Clearly Observed, 2= Often Observed, 3= Somehow / occasionally observed (it seems like that), 4= Cannot evaluate/ Don't know , 5= Not observed / No any changes	**Answer Codes: (Circle the number)**					**Entry Codes**
1	Frequencies of fire in settlements are increasing	1	2	3	4	5	
2	Frequencies of fire in forest are increasing	1	2	3	4	5	
3	Wind storm / cyclone is getting stronger / More violent weather pattern	1	2	3	4	5	
4	Some plant species are migrated/ shifted upward (higher elevation)	1	2	3	4	5	
5	Flowering/fruiting season of fruits/flowers has changed	1	2	3	4	5	
6	New diseases in crops and/or livestock are observed	1	2	3	4	5	
7	New insects are identified (Extended vector habitats (malaria, dengue, typhoid) to different seasons migrated/ shifted upward (higher elevation)	1	2	3	4	5	
8	Other, specify: ________________	1	2	3	4	5	
	(Hereunder to be asked only for Trans Himalayan Community)						
9	Number of snow days are reduced/decreased	1	2	3	4	5	
10	Winter snow melts quickly (used to last longer)	1	2	3	4	5	
11	Amount / level of snowfall has reduced	1	2	3	4	5	
12	Some places that received snowfall in the past are lacking snowfall	1	2	3	4	5	
13	Other, specify: ________________	1	2	3	4	5	

D.1.2.14 Snow cover at particular location in the Mountains has disappeared

(Answer: 1=Yes, 2= No)

D.1. 2.15 Days of practicing transhumance (going to *Kharkas*) has changed (Upward, downward mobility days),

Answer: 1= early up - late down, 2=early up-early down, 3= late up-late down, 4= late up-early down)

D.1. 2.16 Altitude of places that can be visited during transhumance (the *Kharkas*) has shifted up-ward?

Answer: 1=Yes, 2= No 3= Don't No/ Don't Practice

D.2 Climate change Adaptation strategies adopted at household level (What has been done to adapt with climate change?)

D.2.1 Which, and at what level, of the following strategies have you/ your family adopted to reduce the loss / or adapt to climatic events or change within last five years?

S N	**Strategies Adopted** (Level of Adaptation: **Answer Code:** 1= Not at all, 2= Little-bit, 3= Often, 4= Very often, 5= Mostly	**Answer Codes: (Circle the number)**					**Entry Codes**
	Strategies Adopted for continuation of Agro-based livelihood systems						
1	Changed crop varieties / practising / selection of crops with short growing season/ Introduction / use of new crops varieties	1	2	3	4	5	
2	Changed the irrigated to dry farming (Selected drought resistant crop types)	1	2	3	4	5	
3	Different planting dates (crop-calendar changed)	1	2	3	4	5	
4	Changed cropping system (crop diversification, rotation, inter-cropping, crop spacing, Crop Location)	1	2	3	4	5	
5	Regulated distribution and use of water resource / Improve irrigation (channelling, lining, drip-irrigation)	1	2	3	4	5	
6	Increased water sources for irrigation (improved/brought from new sources/ Accessing from Ground Water Extract / Rain water-harvesting)	1	2	3	4	5	
7	Increased use of chemical fertilizer / insecticide	1	2	3	4	5	
8	Mulching/ Soil conservation / moisture protection, practiced zero Tillage	1	2	3	4	5	
9	Making ridges across farms, degradation and erosion control	1	2	3	4	5	
10	Specialized livestock as per cold/hot period	1	2	3	4	5	
11	Used mixed / integrated agriculture (Crop-Livestock-vegetable/fruits)	1	2	3	4	5	
12	Farming experience / received training/ formally educated family member joined in agriculture	1	2	3	4	5	
13	Farm size change (increased land to grow more food) (bought new land/ conversion of other use to farm land)	1	2	3	4	5	

14	Farm land change (conversion of farm land type: slopping terrace to level terrace)	1	2	3	4	5	
15	Farm size change (conversion of farm land to other use: grass land/forest/barren due to poor productivity)	1	2	3	4	5	
17	Changed livestock types / size/ feeding practice (from grazing to stall-feed)	1	2	3	4	5	
18	Afforestation / Grass seedling and fodder trees planting	1	2	3	4	5	
19	Increased use of Agricultural residue as fodder/firewood	1	2	3	4	5	
21	Changed House structure (foundation up-lifted, roofing material/roof structure changed)	1	2	3	4	5	
22	Installed / added heating/cooling systems, and mosquito nets	1	2	3	4	5	
23	Started rain water harvesting	1	2	3	4	5	
24	Other, specify: ________________	1	2	3	4	5	
	Other Strategies Adopted for change / Change in livelihood options						
25	Crop/livestock insurance	1	2	3	4	5	
26	*Transhumance* for longer period/even higher altitude,	1	2	3	4	5	
27	Receiving food aid/ subsidies and other external supports	1	2	3	4	5	
28	Advocacy and campaign and / or quest of external support /	1	2	3	4	5	
29	Shifted from agriculture to non agriculture occupation	1	2	3	4	5	
30	Migration of family members to nearby town/market centre for different occupation	1	2	3	4	5	
31	Migration of family members to city for different occupation	1	2	3	4	5	
32	Migration of family members to other rural area (for agro-based occupation)	1	2	3	4	5	
33	Migration of family members to other country (labour migration)	1	2	3	4	5	
34	Prayer / accept God's blessing	1	2	3	4	5	
35	Other, specify: ________________	1	2	3	4	5	
36	At what scale you think that you have adopted above strategies because of perceived climate change?	1	2	3	4	5	

D.3 Climate change Adaptation Challenges:

D.3.1 You have mentioned that you observed the changes in weather patterns and that has impacted in your daily life. Also you have mentioned that you have not adopted many of the available adaptation options. Why is that? ***(Optional question based on quick analysis of face-to face interview above: ask only if found perceived the change but not adopted strategies)***

D.3.2 What sort of adaptation barriers have you encountered?

....

....

D.3.3 What are the perceived hindrances to adaptation to climatic events and or change? (Scale your assessment in 1-5 scale)

SN	**Hindrances** (**Answer Code:** Scale of Hindrance: 1= Not at all, 2= Little-bit, 3= Often, 4= Very often, 5= Mostly)	**Answer Codes: (Circle the number)**					**Entry Codes**
1	Lack of improved seeds /New varieties adaptable to new climate	1	2	3	4	5	
2	Poorly developed new varieties (new variety not suitable for the place: like case of no seeds in maize)	1	2	3	4	5	
3	Lack of access to source for irrigation / No irrigation facilities	1	2	3	4	5	
4	Conflict in resource stewardship / entitlement (source of water/forest/grazing)	1	2	3	4	5	
5	Lack of information on weather incidence/ reliable forecast/ short and/or long-term	1	2	3	4	5	
6	Lack of sufficient and current knowledge on adaptation methods	1	2	3	4	5	
7	Lack of money to acquired modern techniques	1	2	3	4	5	
8	Lack of external support (I/NGO, Development Agencies)	1	2	3	4	5	
9	Lack of external support (Government)	1	2	3	4	5	
10	Other, specify: ________________	1	2	3	4	5	

E. Any other Extra Information

E.1 Do you want to share any other information? If so please share your issues

....

Thank You very much for your help

Name of enumerator: ……………… Date of Enumeration: ………………..

Appendix 2: Issues to be discussed at Focus Group Discussions and Key Informant Interviews

Human Ecological Implications of Climate Change in the Himalaya: Investigating Opportunities for Adaptation in Kaligandaki Basin, Nepal

Issues to be discussed at Focus Group Discussions and Key Informant Interviews

(Climate change perception, vulnerability and adaptation at Community Level over the last 10 years)

Method: Focus Group Discussions: Discussion with 8 - 12 adult farmers and resource user group members, local teachers and environmental activists. Two to Three FGDs in each study VDC, with participation of both sexes, and 1-2 FGDs in each study VDC with female-only participants will be conducted, representing different wards of the VDC. Discussion on issues associated with perception on changing weather patterns, its impacts and adaptation responses made over the last 10 years or so. It should take approximately two hours.

1 Drivers: Issues for Discussion:

1.1 Is annual variability and seasonal variation in rainfall perceived? If so lease describe with examples. (Get example of extreme /poor rain years, and abnormal seasonal rainfall)
1.2 Are the numbers of extreme rainfall events increasing or decreasing annually?
1.3 Are the variations in temperatures by year, change in winter/summer temperature trends experienced? If so, please describe with examples. (Get example of extreme deviations in summer-winter temperature by year /month, hotter summers, warmer winters).
1.4 Are there changes in drought pattern, length, frequency, intensity, seasonal change seeming? If so, please describe with examples. (Get example of extreme drought years and months)
1.5 Have you felt any changes in seasonality, frequency, and intensity of hailstone, storms, cyclones, and thunderstorm? If so, please describe with examples.

2. Level of Pressure and Stage of Change, and vulnerability: Issues for Discussions:

2.1 What consequences (type and intensity) have been observed in livelihood capitals {**human:** injuries/deaths, **social:** resource conflict/displacement, **natural:** farmland/forest/grazing loss, **financial:** farm productivity/crops/livestock/valuables damage, **physical capitals:** public/private infrastructures/ household possession damage) by Extreme rain, flood/land slide, drought/fire, cold/snow/frost, and by storms and thunder strikes *(Fill the information in Table 2.1)*
2.2 Are the impacts specific to particular social groups? Who suffers the most and why? (**Age:** children, adult, elderly; **sex:** Male, female; **economic status:** marginal/ultra-poor, poor, medium, rich)?
2.3 What changes have there been in intangible livelihood assets including air quality, biodiversity, general water quality, soil quality?
2.4 Is there any change in resources quality, quantity, or accessibility due to climatic incidents? If so how such change has occurred (detail story)? Is productivity of particular crop declined /increased in particular places?
2.5 Are new species of plants / insects appearing/ disappearing in farmland and agro-ecosystems, in forest, or pastures? If so name the new or lost species in different places.
2.6 Are some new types of crops introduced in the place because of positive weather pattern?
2.7 Who (institution/organizations) are working in which sectors (Health and sanitation, education and awareness, hazard management, agriculture, forestry, livestock and poultry, infrastructure)? Is there any gap that some aspects/ sectors have strong or poor partnership? If so, which sector has poor partnership and why?
2.8 Do new diseases observed in human, crops, animals, and poultry? Are new diseases observed in trees, fruits, forest, and grass? Are there new / seasonal shift of disease out-break? Disease vectors (flies, mosquito, leech, and other insects harmful to human, crops, fruits, and animal...) observed? Please provide detail information about the characteristics so such diseases/insects the hazards brought by such diseases and insects.
2.9 Are the cases of Kala-Azar found in this place? How often? How many individuals have been identified as affected? In which season?
2.10 Are there more and strong/larger fire incidents in forests/settlements? Why so?

2.11 Is the work burden of women (more stress and time to fetch water, forest product / women doing non-traditional roles as men migrated due to changing weather pattern resulted poor agro-productivity) increased?

2.12 Is changing weather pattern making some sort of tense/ scare/ fear/ uncertainty, anxiety and havoc? Is it dangerous? What are the dangerous aspects of changing weather pattern?

3. Adaptation Response/ Strategies Adopted: Issues for Discussions:

3.1 Please provide the Status of Public Services available in this settlement/cluster *(Fill the information in Table 3.1)*

3.2 What strategies have been practiced and since when and at what scale to reduce the impacts of climatic extreme events in human lives, property, livestock, farming, forest, grazing, water, ecosystem management, and other multi-dimensional livelihood options? List the strategies, their level of practice (approximate % of household adopting particular strategy) adopted to reduce the impacts of: drought, heavy rain, extreme heat, hailstone, cyclones, landslide, flooding.*(Fill the information in Table 3.2)*

3.3 What were the results of adopting coping and adaptation strategies over the time? Positive/negative, effective/not effective, efficient/non-efficient) *(Fill the information in Table 3.2)*

3.4 Why do have people reduced the ploughing frequencies while preparing plot for rice transplantation? What impacts have been observed due to reduced ploughing frequencies? Mention positive/negative impacts.

3.5 What encourages / limits adaptation process? What are the barriers to adoption of particular adaptation option? List social, political, economic, physical, and other barriers)

3.6 Are there castes / gender specific restriction or opportunities in particular form of labour work?

3.7 Has daily working hours in farm changed due to changes in heat / cold weather pattern? If so mention particular season, and changed daily working hours / shift. What was the working shift earlier (10 years before) and what is it at present?

3.8 Do women also migrate for seasonal work leaving the agricultural activities? If so how many, for what sort of work they have left agro-activities? And where are they mostly working? (local market centre, cities, abroad)

3.9 Are there some livelihood resources that are highly resistant to climatic hazards? Are there any useful resources created by climatic hazards?

3.10 Are there places in the community that are safe from the hazards? How are these places used to protect people and assets from hazards?

3.11 Are there any activities associated with GLOF monitoring in Mustang?

4. Suggestion and expectations for effective adaptation

4.1 How can vulnerability be reduced and how can adaptation are promoted? What can be done at community level and what sort of external support is needed (list current adaptation gaps in particular sector/ particular incident)

4.2 Please provide detail story by hazard type and beneficiaries.

4.3 Adaptation partnership: Were food/shelter/clothing/rescue/relocation support asked /obtained during the climate extreme events? Who are the major partners available for the place? Who did what for what incident/ for what resource/sector/ for whom (by individuals/ communities/ external institutions (I/NGO or Government)? Are the partners working in peoples' interest on changing weather pattern?

4.4 Have you heard about the NAPA and the LAPA? Has anyone from this community participated in the NAPA (information collection/analysis) formulation process? What sort of programmes of the concern of this place have incorporated in the NAPA?

4.5 What have been done in the community in last 2 years (after lunching the NAPA) especially in watershed management, disaster reduction, and agriculture / livestock promotion sector?

4.6 What do you want to recommend to local communities, Development Agencies and I/NGOs and State to enhance adaptation to climate change?

5 Is there anything you want to share? If so please share your issues

Thank You for your help and cooperation

Appendix 3: **Historical Time Line Calendar**

Human Ecological Implications of Climate Change in the Himalaya: Investigating Opportunities for Adaptation in Kaligandaki Ba sin, Nepal

Historical Time Line Calendar *Place of Discussion..............................,* *Date...............*

Climate events and associated impacts: History of Climate Events and associated Impacts in last ~40 years

Method: Discussion among 3-5 elderly people, 2-3 discussions in each study site, note taking, and audio recording, expected length of discussion: one and half hours (Maintain attendance and signature of the participants)

Could you please remember the tentative year if any of the following climatic incidents occurred in this place in last 40 years, which were devastating (stronger than regular pattern) and outline the losses and actions taken (response)?

Note: Major Floods in Nepal in reference to number of reported deaths were - 1970, 1978, 1981, 1983, 1984, 1986, 1993, 1996, 1998, 2000, 2002, 2008, ..., so verify if they had impacted study areas)

SN	**Driver:** Name of Events/Incidents **Checklist:** a. Downpour/Rain Shower b. Unseasonal rain c. Drought / Hot Wave/ Intense Heat d. Fire (Settlement/ Forest) e. Cyclone/ Storm/ Hail- stone f. Thunder/lightning g. Flood / Land Slide h. Extreme Cold /Cold Wave i. Heavy snow fall j. Snow Avalanche/ GLOG k. Other Specify	**Date (Years) of event occurrence** (May not be chronological, so note as per informant's recall)	**Change brought in livelihood capitals:** What happened to particular Livelihood Capital? (Immediate consequences of events, and Post events changes in quality /quantity/ and accessibility of capitals **Checklist:** **Human:** Injured / Disabled/Killed **Social:** Resource Conflict /Displaced/ forced migration **Natural:** Farm Land flooded/Silted / piled the debris, Forest / grass land destroyed **Economic:** Crop destroyed/ Livestock/Poultry killed /fishery destroyed / Valuable/ cash destroyed **Physical:** Livestock shed/ House / Household possession/ Public infrastructure (schools, roads, bridges, emergency shelter, canal, reservoir) destroyed	**Vulnerability:** What are the long-term impacts in different livelihood capitals, in comparison to their pre-event status?	**Response / adaptation action:** What has been done? Strategies to cope {Immediate response (cope), Adaptation strategies, Outcome of adopted coping and adaptation strategies

Appendix 4: Seasonal Activities and Crop Calendar

Seasonal Activities and Crop Calendar *Place of Discussion..............................,* *Date..............* *R Pandey 2013,*

Prominent farmers of the study cluster prepare the crop calendar of major crops of the place for present time and that of before 10 years so changes in Seasonal activities and crop calendar identified.

Method: Discussion among 3-4 noted farmers of the study cluster (2-3 discussions in each study site but depends on elevation range) and marking the weeks of particular activity of particular crops using different coloured markers

Crop calendar: sowing.........., weeding.........., Harvesting......... of Major crops: Rice, Maize, Wheat, Millet, buck-wheat, Barley, Potato, Mustard

Seasonal Activity Calendar: Busy in Agriculture, Firewood collection, Forest food/greens/ NTFP collection, Engage in wage labour, Seasonal migration

Weather Pattern: hot weeks, cold weeks, foggy weeks, hazy weeks, rainy weeks,

Activity/	**Months**	**1**				**2**				**3**				**4**				**5**				**6**				**7**				**8**				**9**				**10**				**11**				**12**			
Crop/ Weather	Weeks	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
	10 Years Ago																																																
	At present																																																
	10 Years Ago																																																
	At present																																																
	10 Years Ago																																																
	At present																																																

Appendix 5: Household Food Security

Questionnaire Code: ....

Human Ecological Implications of Climate Change in the Himalaya: Investigating Opportunities for Adaptation in Kaligandaki Basin, Nepal

Household Food Security

(Supplementary Questionnaire to Household Questionnaire Schedule)

Please Circle the Appropriate Code or write the code on the space provided wherever applicable

Answer codes: 0= Never, 1= Rarely (1-3 times a month), 2= Sometimes (4-10 times a month), 3= Often (More than 10 times a month)

1) Anxiety and uncertainty about the household food supply:

- Did you worry that your household would not have enough food?

0= Never 1= Rarely 2= Sometimes 3= Often

2) Insufficient Quality (includes variety and preferences of the type of food):

- Were you or any household member not able to eat the kinds of foods you preferred because of a lack of resources?

0= Never 1= Rarely 2= Sometimes 3= Often

- Did you or any household member have to eat a limited variety of foods due to a lack of resources?

0= Never 1= Rarely 2= Sometimes 3= Often

- Did you or any household member have to eat some foods that you really did not want to eat because of a lack of resources to obtain other types of food?

0= Never 1= Rarely 2= Sometimes 3= Often

3) Insufficient food intake and its physical consequences:

- Did you or any household member have to eat a smaller meal than you felt you needed because there was not enough food?

0= Never 1= Rarely 2= Sometimes 3= Often

- Did you or any household member have to eat fewer meals in a day because there was not enough food?

- Was there ever no food to eat of any kind in your household because of a lack of resources to get food?

0= Never 1= Rarely 2= Sometimes 3= Often

- Did you or any household member go to sleep at night hungry because there was not enough food?

0= Never 1= Rarely 2= Sometimes 3= Often

- Did you or any household member go a whole day and night without eating anything because there was not enough food?

0= Never 1= Rarely 2= Sometimes 3= Often

Appendix 6a: Participant Information Sheet for Households

Participant Information Sheet[94] Date: ....

From,
Rishikesh Pandey
PhD Student, University of Adelaide, Australia

Subject: Information about the research on *Human Ecological Implications of Climate Change in the Himalaya: Investigating Opportunities for Adaptation in Kaligandaki Basin, Nepal*

Dear Participants,
Namaskar!

I am Rishikesh Pandey. I am undertaking a research as part of my PhD Study. The objective of this research is to understand the people's experience of climate change and their responses (adaptation/adjustment) to this change. This study is collecting information from the people living in three different climatic zones in Kali Gandaki River basin. To obtain information, I am visiting, asking, and discussing with the people living in cold and dry climatic region (upper Kaligandaki - Mustang), people living in cool and highest rain fall area (Lumle / Chanarung), and people living in hot and wet tropical flood plain (Chitwan). Based on the information obtained, I will write a PhD thesis that would be helpful for the government and other development agencies to formulate appropriate adaptation policies and programmes. The adaptation strategies that you are practicing and have found helpful to adapt to climate change will also be communicated with a wider audience and that may help people to adapt to the changes in the environment. In this context, your help and assistance in completing the questionnaire and your active participation in discussion will be highly valuable for this study. Therefore, I kindly would like to request for your participation in this research process. The interview to get household level information would take about 45 minutes. All information collected at this survey will be treated as strictly confidential and the information will only be disseminated in anonymous of general formats. Individual's details will not be disaggregated in publications.

Please note that you can avoid any questions that you do not want to answer. Please also consider that:

- Your participation in this study is completely voluntary
- The information you provide is strictly confidential and anonymous
- No audio/visual records will be made without your permission
- Results of the study will not be analyzed and published at individual level and will not be able to identify or trace you personally
- If you agree to participate in the study, you will be asked to sign a consent form

Please do not hesitate to contact me and/or my supervisors Dr. Douglas K Bardsley and/or Dr. Dianne Rudd if you need to obtain more information about the study.

Meantime you may also discuss the any unclear issues on the implication of participating in this study with the Secretary of your Village, as well as with Local Development Officer and Chief District Officer if required.

Thank you very much!

---

[94] This Information sheet was translated in Nepali language before field study

Sincerely Yours,
Rishikesh Pandey

……………………….

Contact details

Rishikesh Pandey
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Local Independent authority with whom participants can discuss any complaints:

1. Secretaries of concerned (of study sites) Village Development Committees (Meghauli, Lumle, Kagbeni VDCs and /or other surrounding VDCs within the Kali Gandaki Catchment)
2. The Local Development Officer (District Development Committee) of Chitwan, Kaski and Mustang Districts
3. Chief District Officer (District Administrative Office of Chitwan, Kaski and Mustang Districts) in case of severe misunderstanding/ conflict

Appendix 6b: Participant Information Sheet for Individuals and Group Discussion

Participant Information Sheet[95] Date:............................

From,
Rishikesh Pandey
PhD Student, University of Adelaide, Australia

Subject: Information about the research on *Human Ecological Implications of Climate Change in the Himalaya: Investigating Opportunities for Adaptation in Kaligandaki Basin, Nepal*

Dear Participants,
Namaskar!

I am Rishikesh Pandey. I am undertaking a research as part of my PhD Study. The objective of this research is to understand the people's experience of climate change and their responses (adaptation/adjustment) to this change. This study is collecting information from the people living in three different climatic zones in Kali Gandaki River basin. To obtain information, I am visiting, asking, and discussing with the people living in cold and dry climatic region (upper Kali Gandaki - Mustang), people living in cool and highest rain fall area (Lumle / Chanarung), and people living in hot and wet tropical flood plain (Chitwan). Based on the information obtained, I will write a PhD thesis that would be helpful for the government and other development agencies to formulate appropriate adaptation policies and programmes. The adaptation strategies that you are practicing and have found helpful to adapt to climate change will also be communicated with a wider audience and that may help people to adapt to the changes in the environment. In this context, your help and assistance through active participation in discussion and providing me the information that you have gained with the course of time will be highly valuable for this study. Therefore, I kindly would like to request for your participation in this research process. The discussion will take about one and half hour in a single sitting. All information collected at this study will be treated as strictly confidential and the information will only be disseminated in anonymous of general formats. Individual's details will not be disaggregated in publications.

Please note that you can avoid any questions that you do not want to answer. Please also consider that:

- Your participation in this study is completely voluntary
- The information you provide is strictly confidential and anonymous
- No audio/visual records will be made without your permission
- Results of the study will not be analysed and published at individual level and will not be able to identify or trace you personally
- If you agree to participate in the study, you will be asked to sign a consent form (Attendance Sheet)

Please do not hesitate to contact me and/or my supervisors Dr. Douglas K Bardsley and/or Dr. Dianne Rudd if you need to obtain more information about the study.

Meantime you may also discuss the any unclear issues on the implication of participating in this study with the Secretary of your Village, as well as with Local Development Officer and Chief District Officer if required.

[95] This Information sheet was translated in Nepali language before field study

Thank you very much!

Sincerely Yours,
Rishikesh Pandey

……………………….

Contact details

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Local Independent authority with whom participants can discuss any complaints:

1. Secretaries of concerned (of study sites) Village Development Committees (Meghauli, Lumle, Kagbeni VDCs and /or other surrounding VDCs within the Kali Gandaki Catchment)
2. The Local Development Officer (District Development Committee) of Chitwan, Kaski and Mustang Districts
3. Chief District Officer (District Administrative Office of Chitwan, Kaski and Mustang Districts) in case of severe misunderstanding/ conflict

Appendix 7a: Consent Form for Individuals

Human Research Ethics Committee (HREC)

THE UNIVERSITY of ADELAIDE

CONSENT FORM[96]

I have read / listen up the attached Information Sheet and agree to take part in the following research project:

Title:	*Human Ecological Implications of Climate Change in the Himalaya: Investigating Opportunities for Adaptation in Kaligandaki Basin, Nepal*
Ethics Approval Number:	**HP-2012-046**

I have had the project, so far as it affects me, fully explained to my satisfaction by the research worker. My consent is given freely.

I have been given the opportunity to have a member of my family or a friend present while the project was explained to me.

Although I understand the purpose of the research project it has also been explained that involvement may not be of any benefit to me.

I have been informed that, while information gained during the study may be published, I will not be identified and my personal results will not be divulged.

I understand that I am free to withdraw from the project at any time.

I agree to the interview being audio/video recorded. Yes ☐ No ☐

I am aware that I should keep a copy of this Consent Form, when completed, and the attached Information Sheet.

Participant to complete:

Name: …………………..Signature: _____ …………………Date: …………………

Researcher/Witness to complete:

I have described the nature of the research to ………………………………… *(print name of participant)*

and in my opinion she/he understood the explanation.

Signature: …………………….. Position: …………………………….. Date: ……………

[96] This form was translated in Nepali Language while using at the field

Appendix 7b: Consent Form for Individuals

Human Research Ethics Committee(HREC)

CONSENT FORM[97] for Group Discussion

We have read /listen up the attached Information Sheet and agree to take part in the following research project:

Title:	*Human Ecological Implications of Climate Change in the Himalaya: Investigating Opportunities for Adaptation in Kaligandaki Basin, Nepal*
Ethics Approval Number:	**HP-2012-046**

We have had the project, so far as it affects us, fully explained to our satisfaction by the research worker. Our consent is given freely.

We have been given the opportunity to have a member of our neighbourhood or local social worker or the member of local authority present while the project was explained to us.

Although we understand the purpose of the research project it has also been explained that involvement may not be of any benefit to us.

We have been informed that, while information gained during the study may be published, we will not be identified at individual level and our personal opinion or results will not be divulged.

We understand that we are free to withdraw from the project at any time.

We agree to the discussion being audio/video recorded. Yes ☐ No ☐

We are aware that we should keep a copy of this Consent Form, when completed, and the attached Information Sheet.

Signatures: (Participants' detail is attached as Attendance Sheet) Date: --------------------

Researcher/Witness to complete:

I have described the nature of the research to ……………………………………………

……………………………………………………………………. *(print name of participant)*

and in my opinion she/he understood the explanation.

Signature: Position: Date:

[97] This form was translated in Nepali Language while using at the field

Topics of Discussion: ....

Place of Discussion: --- Date:

Participant's Attendance

SN	**Participant's Name:**	**Representing Sector/ Organization**	**Sex** 1=Female 2= Male	**Signature**

Appendix 8: Rates of Changes and the Levels of Significance of Temperatures and Precipitations

(Linear Regression Coefficients - Dependent Variable = Year)

Meteorological Stations	***Unstandardized Coefficients***		***Standardized Coefficients***	***t***	***Sig. (95% Confidence level)***	**Model Summary**				**LINEST**
	B	**Std. Error**	**Beta**			**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**	**Rates of change**
Annual Average of Maximum Temperature										
Jomsom	-1.236	2.6112	-0.0891	-0.4733	0.64	0.089	.008	-.027	8.924	-0.003
Lumle	10.2935	1.3418	0.7795	7.6713	0.000*	0.78	.608	.597	7.419	0.059
Rampur	10.3873	2.7179	0.5482	3.8219	0.001*	0.548	.301	.280	9.701	0.018
Annual Average of Minimum Temperature										
Jomsom	6.3852	1.709	0.5768	3.7362	0.001*	0.577	.333	.309	7.319	0.008
Lumle	4.8704	4.9298	0.1582	0.9879	0.329	0.158	.025	-.001	11.694	0.005
Rampur	12.7709	1.3686	0.8481	9.3317	0.000*	0.848	.719	.711	6.146	0.057
Annual Average of Extreme Maximum Temperature										
Jomsom	3.9256	2.0817	0.3357	1.8858	0.07	0.336	.113	.081	8.439	0.063
Lumle	10.043	1.9164	0.6477	5.2406	0.000*	0.648	.420	.404	9.023	0.042
Rampur	9.6842	2.7886	0.5117	3.4728	0.001*	0.512	.262	.240	9.965	0.016
Annual Average of Extreme Minimum Temperature										
Jomsom	5.1465	1.4983	0.5445	3.4349	0.002*	0.544	.296	.271	7.515	0.068
Lumle	7.9896	1.9388	0.5558	4.1209	0.000*	0.556	.309	.291	9.846	0.038
Rampur	9.2032	1.3154	0.7682	6.9965	0.000*	0.768	.590	.578	7.426	0.056
Annual Total Precipitation										
Jomsom	0.0239	0.021	0.1863	1.1376	0.263	0.186	.035	.008	11.069	2.750
Lumle	0.0059	0.0031	0.2943	1.8984	0.065	0.294	.087	.063	11.319	14.760
Rampur	0.0071	0.0055	0.2042	1.2859	0.206	0.204	.042	.016	11.594	5.849

Annual Total Rainy Days										
Jomsom	0.1707	0.1355	0.2055	1.2602	0.216	0.206	.042	.016	11.026	0.541
Lumle	-0.0438	0.135	-0.0526	-0.3248	0.747	0.053	.003	-.023	11.827	-0.036
Rampur	-0.0298	0.1401	-0.0345	-0.213	0.832	0.035	.001	-.025	11.836	-0.177
Extreme Rainfall Events >50mm										
Jomsom (>25mm)	-0.208	1.626	-0.021	-0.128	0.899	0.021	.000	-.027	11.264	-0.0084
Lumle	0.7582	0.304	0.3751	2.4943	0.017*	0.375	.141	.118	10.979	0.1747
Rampur	0.46414	0.52493	0.14198	0.8842	0.3822	0.142	.020	-.006	11.723	0.0197
Extreme Rainfall Events >100mm										
Jomsom										
Lumle	0.77	0.4631	0.2604	1.6628	0.105	0.26	.068	.043	11.435	0.095
Rampur	-1.1381	1.414	-0.1295	-0.8049	0.426	0.129	.017	-.009	11.744	-0.016
Extreme Rainfall Events >150mm										
Jomsom										
Lumle	2.4909	1.0544	0.3578	2.3623	0.023*	0.358	.128	.105	11.059	0.043
Rampur	1.1511	3.1711	0.0588	0.363	0.719	0.059	.003	-.023	11.823	0.001

*Statistically Significant Change at 95% as the value is <0.04

Appendix 9:Descriptive Statistics of Annual average of Temperatures by Stations of Kaligandaki Basin, Nepal (19701-2010)

Descriptive Statistics	Rampur				Lumle				Jomsom			
	Extreme Max	Max	Min	Extreme Min	Extreme Max	Max	Min	Extreme Min	Extreme Max	Max	Min	Extreme Min
Mean	34.17315	30.75023	17.58287	13.8838	23.02188	19.94229	12.00125	8.704375	17.28	17.60611	5.728548	-5.10345
Standard Error	0.100561	0.100474	0.126448	0.158812	0.119232	0.139967	0.060065	0.128708	0.397851	0.115836	0.145272	0.299115
Standard Deviation	0.603367	0.602842	0.758688	0.952871	0.754091	0.885227	0.379883	0.814022	2.179117	0.634463	0.79569	1.610786
Sample Variance	0.364052	0.363419	0.575608	0.907964	0.568653	0.783627	0.144311	0.662632	4.748552	0.402543	0.633122	2.594631
Kurtosis	0.681177	0.841004	-0.74354	0.543814	2.866941	-0.27742	1.036238	0.40561	-0.38986	3.331598	-0.48798	2.106492
Skewness	-0.63406	-0.94548	-0.27212	-0.49089	1.132355	0.790416	0.840483	-0.10272	0.114893	-1.47176	-0.43375	-1.33125
Range	2.925	2.625	3.116667	4.641667	3.833333	3.491667	1.65	3.916667	9	2.875	2.916667	7
Minimum	32.45833	29.15	16	11.175	21.9	18.475	11.35833	6.608333	12.5	15.59167	4.125	-10
Maximum	35.38333	31.775	19.11667	15.81667	25.73333	21.96667	13.00833	10.525	21.5	18.46667	7.041667	-3
Sum	1230.233	1107.008	632.9833	499.8167	920.875	797.6917	480.05	348.175	518.4	528.1832	171.8564	-148
Count	36	36	36	36	40	40	40	40	30	30	30	29

Appendix 10: Rates of Changes and the Levels of Significance of Temperatures and Precipitations (Linear Regression Coefficients - Dependent Variable = Year) by Seasons and Meteorological Stations

Meteorological Stations	*Unstandardized Coefficients*		*Standardized Coefficients*	*t*	*Sig. (95% Confidence level)*	Model Summary				LINEST
	B	Std. Error	Beta			R	R Square	Adjusted R Square	Std. Error of the Estimate	Rates of change
Winter Maximum Temperature										
Jomsom	1.784	.236	.775	7.560	.000*	0.775	.601	.590	7.484	0.045
Lumle	6.071	1.152	.650	5.268	.000*	0.65	.422	.407	9.004	0.069
Rampur	3.292	2.321	.236	1.418	.165	0.236	.056	.028	11.270	0.002
Winter Minimum Temperature										
Jomsom	.228	1.206	.031	.189	.851	0.031	.001	-.025	11.838	0.126
Lumle	2.581	2.763	.150	.934	.356	0.15	.022	-.003	11.710	0.009
Rampur	7.143	1.310	.683	5.454	.000*	0.683	.467	.451	8.471	0.067
Winter Extreme Maximum Temperature										
Jomsom	1.266	.147	.812	8.589	.000*	0.812	.660	.651	6.906	0.120
Lumle	4.730	1.698	.412	2.786	.008	0.412	.170	.148	10.792	0.141
Rampur	4.817	2.259	.343	2.132	.040	0.343	.118	.092	10.893	0.021
Winter Extreme Minimum Temperature										
Jomsom	-1.644	.582	-.416	-2.823	.008	0.416	.173	.152	10.768	0.127
Lumle	3.102	1.708	.283	1.816	.077	0.283	.080	.056	11.360	0.026
Rampur	4.501	1.530	.450	2.941	.006	0.45	.203	.179	10.356	0.047
Winter Total Precipitation										
Jomsom	.145	.080	.282	1.810	.078	0.282	.079	.055	11.363	0.548
Lumle	.004	.031	.021	.131	.897	0.021	.000	-.026	11.841	0.112
Rampur	-.072	.062	-.184	-1.156	.255	0.184	.034	.009	11.640	-0.454
Winter Total Rainy Days										
Jomsom	.194	.527	.060	.367	.715	0.06	.004	-.023	11.822	0.018
Lumle	-.018	.300	-.010	-.061	.952	0.01	.000	-.026	11.843	-0.005
Rampur	-.638	.457	-.221	-1.398	.170	0.221	.049	.024	11.550	-0.077

Spring Maximum Temperature										
Jomsom	1.068	.159	.737	6.725	.000*	0.737	.543	.531	8.003	-0.004*
Lumle	5.211	1.303	.544	3.999	.000*	0.544	.296	.278	9.936	0.057
Rampur	1.509	1.783	.144	.846	.403	0.144	.021	-.008	11.478	0.018
Spring Minimum Temperature										
Jomsom	3.748	.512	.765	7.326	.000*	0.765	.585	.575	7.625	0.067
Lumle	-1.577	2.433	-.105	-.648	.521	0.105	.011	-.015	11.778	-0.007
Rampur	6.332	1.397	.614	4.533	.000*	0.614	.377	.358	9.157	0.058
Spring Extreme Maximum Temperature										
Jomsom	.903	.123	.765	7.325	.000*	0.765	.585	.574	7.626	0.048
Lumle	4.676	1.425	.470	3.282	.002*	0.47	.221	.200	10.454	0.050
Rampur	.584	1.541	.065	.379	.707	0.065	.004	-.025	11.574	0.085
Spring Extreme Minimum Temperature										
Jomsom	2.483	1.283	.300	1.935	.060	0.3	.090	.066	11.300	0.046
Lumle	4.060	1.304	.451	3.115	.003*	0.451	.203	.182	10.570	0.047
Rampur	4.363	1.123	.555	3.887	.000*	0.555	.308	.287	9.651	0.007
Spring Total Precipitation										
Jomsom	.061	.044	.220	1.392	.172	0.22	.048	.023	11.553	0.796
Lumle	.009	.008	.178	1.113	.273	0.178	.032	.006	11.655	3.490
Rampur	.017	.012	.218	1.378	.176	0.218	.048	.023	11.558	2.795
Spring Total Rainy Days										
Jomsom	.874	.303	.423	2.882	.006	0.423	.179	.158	10.729	0.205
Lumle	-.016	.213	-.012	-.074	.942	0.012	.000	-.026	11.842	-0.009
Rampur	.147	.255	.093	.575	.569	0.093	.009	-.017	11.792	0.059
Summer Maximum Temperature										
Jomsom	.853	.129	.732	6.619	.000*	0.732	.535	.523	8.072	-0.035*
Lumle	10.837	1.771	.705	6.119	.000*	0.705	.496	.483	8.405	0.046
Rampur	7.935	2.162	.533	3.670	.001*	0.533	.284	.263	9.816	0.022
Summer Minimum Temperature										
Jomsom	1.618	.199	.797	8.142	.000*	0.797	.636	.626	7.149	0.063
Lumle	15.321	3.856	.542	3.973	.000*	0.542	.293	.275	9.955	0.019
Rampur	2.439	1.169	.337	2.087	.044	0.337	.114	.087	10.920	0.061

Summer Extreme Maximum Temperature										
Jomsom	.787	.115	.743	6.842	.000*	0.743	.552	.540	7.927	-0.014*
Lumle	6.190	1.779	.491	3.479	.001*	0.491	.242	.222	10.314	0.038
Rampur	6.270	2.181	.442	2.875	.007	0.442	.196	.172	10.403	0.014
Summer Extreme Minimum Temperature										
Jomsom	2.050	.267	.780	7.682	.000*	0.78	.608	.598	7.412	0.043
Lumle	3.916	1.173	.476	3.337	.002*	0.476	.227	.206	10.415	0.057
Rampur	2.807	1.086	.405	2.584	.014	0.405	.164	.140	10.604	0.066
Summer Total Precipitation										
Jomsom	.079	.037	.326	2.123	.040	0.326	.106	.083	11.198	1.337
Lumle	.008	.004	.290	1.871	.069	0.29	.084	.060	11.333	10.517
Rampur	.006	.007	.125	.780	.440	0.125	.016	-.010	11.750	2.719
Summer Total Rainy Days										
Jomsom	.470	.213	.337	2.204	.034	0.337	.113	.090	11.152	0.241
Lumle	.538	.612	.141	.879	.385	0.141	.020	-.006	11.725	0.037
Rampur	.074	.337	.036	.221	.826	.036[a]	.001	-.025	11.836	0.017
Autumn Maximum Temperature										
Jomsom	1.095	.162	.739	6.761	.000*	0.739	.546	.534	7.979	-0.015*
Lumle	7.440	1.278	.687	5.820	.000*	0.687	.471	.457	8.611	0.063
Rampur	8.768	1.714	.659	5.115	.000*	0.659	.435	.418	8.719	0.032
Autumn Minimum Temperature										
Jomsom	3.057	.445	.745	6.875	.000*	0.745	.554	.543	7.906	0.034
Lumle	.964	4.423	.035	.218	.829	0.035	.001	-.025	11.836	0.001
Rampur	5.683	1.182	.636	4.809	.000*	0.636	.405	.387	8.948	0.089
Autumn Extreme Maximum Temperature										
Jomsom	.916	.136	.737	6.724	.000*	0.737	.543	.531	8.003	-0.019*
Lumle	7.224	1.666	.575	4.336	.000*	0.575	.331	.313	9.687	0.045
Rampur	8.214	1.871	.601	4.389	.000*	0.601	.362	.343	9.267	0.025
Autumn Extreme Minimum Temperature										
Jomsom	6.094	1.048	.686	5.816	.000*	0.686	.471	.457	8.615	0.036
Lumle	4.412	2.242	.304	1.968	.056	0.304	.092	.069	11.283	0.021
Rampur	5.356	.967	.689	5.538	.000*	0.689	.474	.459	8.410	0.102

Autumn Total Precipitation										
Jomsom	.003	.035	.015	.092	.927	0.015	.000	-.026	11.842	0.068
Lumle	.003	.010	.044	.272	.787	0.044	.002	-.024	11.832	0.721
Rampur	.010	.018	.090	.554	.583	0.09	.008	-.018	11.796	0.809
Autumn Total Rainy Days										
Jomsom	.778	.485	.252	1.603	.117	0.252	.063	.039	11.462	0.081
Lumle	-.269	.303	-.142	-.887	.381	0.142	.020	-.006	11.723	-0.075
Rampur	-.184	.386	-.077	-.477	.636	0.077	.006	-.020	11.808	-0.032

*Statistically Significant Change (Increase) as the value is <0.04

Appendix 11: Changes in Altered Temperature by Months and Stations

(Rates of Change = °C/year)

Station /Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Winter - Summer Altered Temperature
Jomsom	0.058	-0.094	0.012	-0.034	-0.004	-0.091	-0.070	-0.010	-0.040	-0.050	-0.072	0.005	0.062
Lumle	0.054	-0.026	-0.021	0.030	-0.001	-0.013	-0.009	-0.035	-0.012	0.040	0.045	0.012	0.002
Rampur	-0.029	-0.006	-0.048	-0.082	-0.045	-0.031	0.013	-0.052	-0.276	-0.309	-0.224	-0.199	0.011

Note: Calculated from Maximum and Minimum Extreme Temperatures

Appendix 12: Proportions of Households with Changed Share of Livelihood Contribution of different Sectors in last Decade (2002-2012)

Places	Changed Proportions	Agro Livestock	Employment	Business/ Enterprises	Remittance	Wage Labour
Tarai	- >75%	1.31	0.65	0.00	0.00	0.65
	- 50 and 75%	1.96	0.65	0.00	0.65	0.00
	- 25 and 50%	26.14	1.31	0.65	3.27	0.65
	- Up to 25%	18.30	1.96	0.00	1.96	5.23
	+ Up to 25%	3.27	5.23	3.92	5.88	7.19
	+ 25% and 50%	1.31	3.92	6.54	15.69	5.23
	+ 50% and 75%	0.65	0.65	1.96	6.54	0.65
	+ Over 75%	0.00	0.00	1.31	0.65	0.00
Middle-Mountain	- >75%	2.84	1.42	0.00	1.42	0.00
	- 50 and 75%	7.09	1.42	1.42	0.00	1.42
	- 25 and 50%	13.48	3.55	0.00	3.55	4.26
	- Up to 25%	24.11	2.13	2.13	5.67	5.67
	+ Up to 25%	6.38	5.67	4.96	9.93	7.80
	+ 25% and 50%	2.13	4.26	4.96	14.18	2.84
	+ 50% and 75%	0.71	0.00	1.42	7.09	0.71
	+ Over 75%	0.71	1.42	3.55	4.26	0.71
Trans-Himalaya	- >75%	0.00	0.00	0.00	0.00	0.00
	- 50 and 75%	4.55	0.00	0.00	0.00	3.03
	- 25 and 50%	7.58	1.52	1.52	0.00	4.55
	- Up to 25%	16.67	0.00	1.52	1.52	3.03
	+ Up to 25%	0.00	0.00	3.03	6.06	6.06
	+ 25% and 50%	0.00	0.00	9.09	9.09	0.00
	+ 50% and 75%	0.00	0.00	6.06	1.52	0.00
	+ Over 75%	0.00	0.00	1.52	0.00	0.00
Total	- >75%	1.67	0.83	0.00	0.56	0.28
	- 50 and 75%	4.44	0.83	0.56	0.28	1.11
	- 25 and 50%	17.78	2.22	0.56	2.78	2.78
	- Up to 25%	20.28	1.67	1.11	3.33	5.00
	+ Up to 25%	3.89	4.44	4.17	7.50	7.22
	+ 25% and 50%	1.39	3.33	6.39	13.89	3.33
	+ 50% and 75%	0.56	0.28	2.50	5.83	0.56
	+ Over 75%	0.28	0.56	2.22	1.94	0.28

Source: Field Survey, 2013

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