Analysis of Climate Change Impacts on Food Security and Livelihoods in the Mountainous Region of Nepal: A Case Study of Lamjung District

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Analysis of Climate Change Impacts on Food Security and Livelihoods in the Mountainous Region of Nepal: A Case Study of Lamjung District

A Dissertation Submitted in Fulfillment of the Requirements of the Doctor of Philosophy in Global Environmental Studies

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ABBREVIATIONS

APP- Agriculture Perspective Plan

COP- Conference of Parties

DADO- District Agriculture Development Office

DDC- District Development Committee

DHM- Department of Hydrology and Meteorology

EM-DAT- Emergency Events Database

FAO- Food and Agriculture Organization

GCM- Global Circulation Model

GEF- Global Environmental Fund

GEM- Global Environment Management

GLOF- Glacial Lake Outburst Flood

HHs- Households

IFPRI- International Food Policy Research Institute

IPCC- Intergovernmental Panel on Climate Change

INGOs- International Non Governmental Organizations

KIIs- Key Informant Interviews

LAPA- Local Adaptation Program of Action

LDCs- Least Development Countries

LVI- Livelihood Vulnerability Index

MCCICC- Multi-stakeholder Climate Change Initiative Coordination Committee

MDGs- Millennium Development Goals

MOAD- Ministry of Agricultural Development

MOE- Ministry of Environment

MOSTE- Ministry of Science, Technology and Environment

NAP- National Agriculture Policy

NAPA- National Adaptation Program of Action

NARC- Nepal Agricultural Research Council

NAST- National Academy of Science and Technology

NCCC- National Climate Change Committee

NCCKMC- Nepal Climate Change Knowledge Management Center

NCSA- National Capacity Self- Assessment

NDHS- National Demographic and Household Survey

NGOs- Non Governmental Organizations

NMS- Nepal Meteorological Service

NOAA- National Oceanic and Atmospheric Administration

NST- National Study Team

ODA- Official Development Assistance

PPP- Public, Private Partnership

RCM- Regional Circulation Model

SDGs- Sustainable Development Goals

SWOT- Strength, Weakness, Opportunity and Threat

TAR- Third Assessment Report

TWG- Thematic Working Group

UN- United Nations

UNDP- United Nations Development Program

UNFCCC- United Nations Framework Convention on Climate Change

VDC- Village Development Committee

WB- World Bank

WMO- World Meteorological Organization

EXECUTIVE SUMMARY

Background

The Intergovernmental Panel on Climate Change (IPCC 2014) projects that the average annual temperature will increase as much as 6°C in high altitudes under a high-emission scenario and will rise as much as 3°C under a low-emission scenario by the end of 21th century. It is anticipated that the increasing rate of the average temperature in the Himalaya will be greater than the global average. The increasing temperature may affect the timing and quantity of precipitation, which consequently change the water availability. Furthermore, it can alter weather trends such as wind patterns, intensity and frequency of extreme weather conditions such as droughts, rainfall, storms, *etc*. that are the triggering factors for several catastrophes such as floods, avalanches, landslides *etc*. Thus, climate change affects all sectors of the economy. Among them agriculture could be the one of the most affected sector that eventually affects the livelihoods and food security at the global and local level.

Climate change impacts all the dimensions of food security - food availability, food accessibility, food utilization and stability. These effects are already being felt in global food markets, and are likely to be particularly significant in some rural areas where, agricultural practices are mainly depended on whether condition. Moreover, impacts are experiencing in both rural and urban locations where supply chains disrupted, market prices increased, purchasing power fell, assets and livelihood opportunities lost, and affected people are unable to cope with the changes. The population living in the remote mountainous areas and depending on the subsistence livelihood on agriculture with minimum resources have the least capacity to adapt and therefore are likely to be the most vulnerable (IPCC 2001, IPCC 2014). Impacts from recent climate-related extremes, such as heat waves, droughts, floods reveal significant vulnerability and exposure of many human systems to current climate variability IPCC (2014).

Research Objectives and Questions

Food security and rural livelihoods are highly sensitive to climatic risk. However, the ways in which livelihoods and specific vulnerabilities are linked to climate have not been well studied. The purpose of this research is to quantitatively and qualitatively assess climate impacts on food security and livelihoods. Therefore, this research builds on the notion that assessing the climate change impact on food security and livelihoods, and identifying the priority areas of intervention to manage climatic risk can enhance the food security and strengthen the resilience of the households.

The study has three main objectives:

- ❖ Understand the climatic variables trends, their impacts on crop yield and relationship.
- ❖ Analysis of climate change impacts on food security and livelihood vulnerability to climate change.
- ❖ Identification of priority areas of intervention for adaptation plan to combat against changing climate.

Research Questions

- How is crop yield in a mountainous region affected by climate variability?
- What are the climate change impacts and consequences on food security and livelihoods?
- What are the priority areas of intervention for adaptation plan to strengthen the resilience of the mountainous household with changing climate?

Research Locations

Lamjung district is located in the western mountainous region of Nepal. Climate of Lamjung ranges from tropical/subtropical in the south to temperate in the north. Due to the heterogeneous topography and elevation variations, it is ranked one of the highly vulnerable districts in climate change and climate induced natural disasters in Nepal (NAPA 2010).

Structure of the Research

Table 1 gives the structure of the research with four major components: background, methodology, results and findings, and discussion and conclusions.

Chapter 1 introduces a brief description of the overall research framework and its key points.

Chapter 2 provides a detail overview of climate variability and food security situation of Nepal. Particularly, it presents the evidences and impacts of climate change in Nepal, climate change vulnerability, climate change adaptation practices, and climate change and food security programs and policies in Nepal.

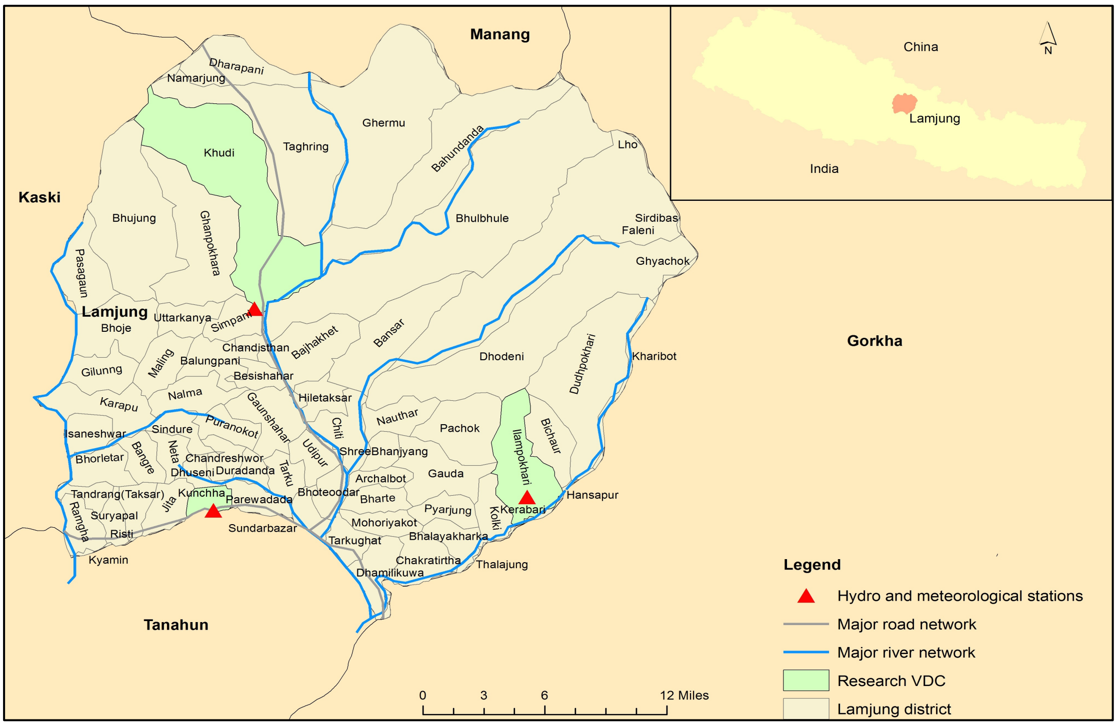

Figure 1 Map of the study area, Lamjung district Nepal

Chapter 3 deals with the relationship between climate variables and crop yield in Lamjung district Nepal based on the historical data. This chapter particularly describes the trend of climate variables and crop yield, and their relationship through correlation and multivariate regression analysis.

Chapter 4 explores the household perception of climate change and its impacts on food security in three VDCs of Lamjung. In particular, it focuses on changes in food production, availability, accessibility and utilization, and changes in daily/economic activities of the households to ensure food security amidst of changing climate during the last twenty years. It also presents the findings of a household survey.

Chapter 5 presents the livelihood vulnerability of the mountainous households with changing climate. This chapter specially describes the livelihood vulnerability of the households based on locations, well-being status and gender of the household`s head through vulnerability composite index and VI-IPCC approaches.

Table 1 Structure of the Research

Background	**Methodology**	**Results and findings**	**Discussion and conclusions**
❖ Changes in climate variables	Quantitative analysis	Identification of climate-crop yield relationships	Mixed trend in climate variables and crop yield, Few significant relationship between climate and crop yield.
❖ Crop yield	Qualitative analysis		
Case study of 3 VDCs of Lamjung ❖ Kunchha ❖ Khudi ❖ Ilampokhari	Key informant interviews	Identification of the underlying causes of changes in food security	Climatic factors and socio-economic status both play imperative role in changes in food security situation of the households.
Climate change and changes in food security	Household questionnaire survey		
Livelihood vulnerability to climate change	Focus group discussions	Identification of vulnerable households	Very poor, poor and female-headed households are more vulnerable to climate change.
Managing climate risks Identification of priority areas of intervention for adaptation plan	Stakeholders workshop	Identification of priority areas for adaptation planning for the resilience of the households	Economic intervention Technical intervention Socio-behavioral intervention Development of infrastructure play vital role to manage climatic risk and enhance the food security.

Chapter 1 Introduction **Chapter 2** Climate change and food security scenario of Nepal	**Chapter 3** The relationship between climate variables and crop yield **Chapter 4** Analysis of climate change impacts at household level food security **Chapter 5** Assessment of households` livelihood vulnerability to climate change	**Chapter 6** Synopsis

Chapter 6 stresses on the key findings and the achieved results, their practical implications and provides recommendation on priority areas of intervention for

adaptation plan in Lamjung district Nepal. It draws key suggestions for future research on the vulnerable households.

Key Findings

This research tried to explore the climate change impacts on food security and livelihoods of the mountainous households. Particularly, research focused on understanding of the trend of climate variability and its impacts on crop yield. Then, it analyzed households` food security and livelihood vulnerability to climate change in Lamjung district Nepal. The key findings derived from this research are summarized below.

1. Climate Variability Trends

The seasonal and annual trends analysis of precipitation showed increasing trend during summer, decreasing trend in winter and mixed trend in spring and autumn. While both minimum and maximum temperature showed increasing trend from 1980 to 2012. Although both the minimum and maximum temperatures increased, the increasing rate of the minimum temperature was more than three times faster than that of the maximum temperature. And all seasons maximum and minimum temperatures increased significantly except spring season.

2. Crop Yield Trends

The major crops rice, maize wheat, millet and barley were selected and analyzed from the period of 1980 to 2012. The yield trend of summer crops (maize) and winter crops (wheat and barley) showed that the yield of these crops has changed significantly over time. Production trends for the main crops in Lamjung relatively stable increase in area cultivated, production and yields except in the context of barley and millet.

3. Climate-Crop Yield Relationship

The relationship between climatic variability and major crop yields (kg/ha) was derived from correlation analysis. The results revealed that there was a strong and positive relationship between the climatic variability and the yield of millet and wheat, whereas there were no or negligible relationships between climatic variability and the yields of rice, maize and barley. A multivariate regression model was performed to confirm the impact of climate change on crop yield. Though the regression results show very few significant relationships between yield and climate variables, these coefficients can be used to assess the real effects of climate variables in the changes of the food crop yields considered in this study. In addition, the sign of the coefficients indicates the direction of change in the yield *versus* climate variable change. Precipitation in winter was an important factor that can increase yield potential for wheat and barley. Similarly, summer precipitation had a positive impact on rice, while maize and millet showed negative effects. Therefore, increasing maximum temperature has positive impacts on all summer crops, and decreases in temperature have negative impacts.

4. Local People Perception of Climate Change

The mountainous households were familiar about climate change, and they have experienced and noticed the changes in recent decades. Majority of the households experienced increased temperature, less rainfall in winter and increased frequency of natural disasters in the study areas.

5. Changes in Food Security of the Mountainous Households

Food security situation of the mountainous households was analyzed through changes on food production, availability, accessibility and utilization during the last twenty years. Food availability changed because of changes in crop production, income, food price *etc*. Food accessibility of the mountainous households increased during the last 20 years because of distance to the nearest market decreased and access to road increased. However, in some area of Lamjung, food accessibility decreased because of climate impact *i.e*. seasonal road disturbance by landslides and floods. As far as the food consumption pattern and utilization is concerned, it was improved during the last two decades. The reasons behind improved food consumption pattern were awareness about the utilization of food along with increased income and access to sources of nutritional food.

6. Most Impacted Livelihood Options and Resources

The changing climatic variables have affected livelihood of the households who solely depends on the subsistence agriculture. Erratic rainfall, floods, GLOFs, droughts and emergence of insects/diseases were considered as the major hazards in Lamjung. And the most impacted livelihood resources in order were winter crops, orange farming, rice cultivation, livestock rearing, migration and labor. Similarly, landslides were considered as the major hazards particularly, by poor families living in the slope hills and riversides. Additionally, drying water resources increased livelihood vulnerability due to scarcity of drinking water, insufficient water for irrigation.

7. Most Vulnerable Households

Climate change vulnerability of the households was analyzed to examine the vulnerable communities according to their well-being status, location of the households (Kunchha, Khudi and Ilampokhari) and gender of the household head. The overall LVI was higher for Khudi VDC (0.351) as compared to Kunchha VDC (0.310) and ILampokhari VDC (0.309) and indicating that households of Khudi are more vulnerable as compared to two other VDCs. The vulnerability factors varied according to well-being status of the households. The adaptive capacity of the households is significantly difference ($P < 0.05$) according to well-being status**.** LVI analysis depicted that climate change vulnerability varied according to the gender of household head. The analysis revealed that female-headed household had slightly higher exposure, sensitivity and lower adaptive capacity in comparison to male-headed households. The adaptive capacity of the households is significantly difference ($P < 0.05$) according to gender of household head.

Practical Implication of the Achieved Results

The findings of this research can help to the development planners and national policy makers. Any organization working in the field of climate change and food security also benefit from the findings of this study. It has implication on local, national and global level and implication on climate change policies and programs. Specially, the findings of this research are aimed to the local government, and targets developing favorable climate change policy, programs and physical environment to foster climate resilient food system and livelihoods in rural mountainous region.

Based on the findings of the results, the development of improved varieties of crops particularly fertilizer-responsive high yielding, heat and drought tolerance is necessary in the Lamjung district. Winter crops such as barely is highly vulnerable with decreased precipitation in winter therefore, new variety, resilient to the drought is suggested to enhance the food security. And water management techniques such as rainwater harvesting can help to overcome the problem in drought and less rainfall seasons in Khudi VDC. It is imperative to develop early warning tools that help to monitor, detect, forecast risks and issue alerts on forthcoming hazards since almost all the households did not receive early information of the natural hazards in the study areas. Similarly, alternative employment generation for the poor and women is highly recommended to ensure their food security and livelihoods in Kunchha and Ilampokhari VDCs. Formation of farmers cooperative is suggested for Kunchha VDC. Finally development of infrastructural facilities is highly recommended for all study areas and groups because Lamjung lacks the development of transportation facilities, proper market, cold storage facilities, seed bank *etc*. Therefore, significant development is required from the local/district government by creating markets and other infrastructural facilities to ensure the food security and enhance the resilience of the mountainous households.

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1 Chapter 1 Introduction

This chapter provides a brief description of the overall research framework, including the problem statement, objectives, hypothesis, research questions, and methodology. The context of changes in climate variables and food security is discussed, along with an in-depth review of the historical trends of climate variables and climate risk, crop production, and livelihood vulnerability in the mountainous region of Nepal. The chapter concludes with a brief summary of the subsequent chapters.

1.1 Background of the Study

Climate refers to the characteristic conditions of the earth's surface atmosphere at a specific location over a long period, while weather refers to the instantaneous conditions at the same location. The variables that are commonly used by meteorologists to measure daily weather phenomena include air temperature, precipitation (*e.g.,* rain, snow, and hail), atmospheric pressure, humidity, wind, sunshine, and cloud cover (FAO, 2008). When weather phenomena are measured systematically at a specific location over several years, a record of observations is accumulated, from which averages, ranges, maximums, and minimums can be computed for each variable, along with the frequency and duration of extreme events (Magawata, 2014).

Climate change is defined differently by different organizations and institutions. The Intergovernmental Panel on Climate Change (IPCC) defines climate change as "a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer). Climate change may be due to natural internal processes or external forces, or to persistent anthropogenic changes in the composition of the atmosphere or in land use" (IPCC, 2001). According to article 1.2 of the United Nations Framework Convention on Climate Change (UNFCCC), climate change is defined as a "change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods" (UNFCCC, 1992). Climate change has both adverse and positive effects. Article 1.1 of the UNFCCC states that adverse effects of climate change are changes in the physical or biological environment resulting from climate change that have significant harmful effects on the composition, resilience, or productivity of natural and managed ecosystems, the operation of socio-economic systems, or human health and welfare" (UNFCCC, 1992).

According to the 5th assessment report of the IPCC (IPCC, 2014), the average annual temperature will rise by more than 2°C in most of South Asia by the mid-21st century compared to the 20th century. By the late 21st century, the temperature increases will exceed 3°C and will reach as high as 6°C at high altitudes under a high-emission scenario. Under a low-emission scenario, the average temperature could rise by less than 2°C in the 21st century, but at higher altitudes, the temperatures will rise by as much as 3°C.

It is anticipated that the increasing rate of average temperature in the Himalayas will be greater than the global average. Figure 1.1 shows the global land and ocean temperature anomalies from 1980 to 2016. There has been variation in global temperature, which has had an increasing trend at a rate of 0.18°C per decade. The increasing temperatures may affect the timing and quantity of precipitation, which would consequently change water availability (Mishra et al., 2014a). Furthermore, they will alter weather trends such as wind patterns and the intensity and frequency of extreme weather conditions, such as droughts, floods, storms, and avalanches. Climate change also affects all factors of the economy. Among them, agriculture is badly affected by climate change (Eriksson et al., 2009), which consequently affects the livelihoods and food security at global and local levels.

Food security is achieved 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" (FAO 1996). Climate change impacts all the dimensions of food security, namely food availability, food accessibility, food utilization, and stability. These effects are already being felt in global food markets and are likely to be particularly significant in some rural areas where agricultural yield is declining. Impacts are being experienced in both rural and urban locations where supply chains are disrupted, market prices have increased, purchasing power has fallen, assets and livelihood opportunities are lost, and affected people are unable to cope with the changes (Shrestha, 2014).

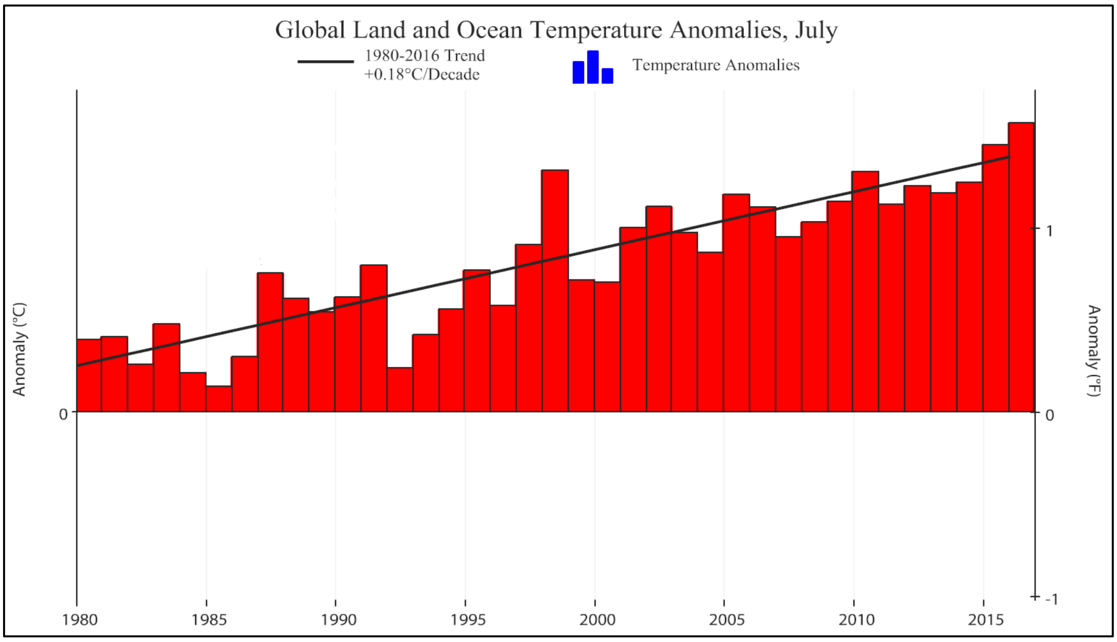

Figure 1.1 Global land and ocean temperature anomalies from 1980 to 2016

Source (NOAA, 2016)

The possible impacts of climate change on food security have tended to be viewed with most concern in locations where rain-fed agriculture is still the primary source of food and income (FAO, 2008). Climate change will have adverse impacts on food security especially for people whose livelihood directly depends on natural resources. Climate change impacts society and social wellbeing, and it is necessary to understand it changes from a local perspective. Although climate change occurs globally, its impact is realized at the local level, and it varies with respect to the region and sector. The direct impact of climate change is subject to a local scale (Kassam et al., 2010). Thus, understanding the changing climate is imperative to strengthen the resilience of local people, especially the local impacts on food security and livelihoods (Kassam et al., 2010).

The effects of climate change are very hard to predict, but those who are already experiencing the effect are the most vulnerable (Jordan 2009). Many communities in developing countries are experiencing difficulty with taking appropriate actions for climate change mitigation and adaptation (Kassam et al., 2010). The potential impacts of climate change on the food security must therefore be viewed within the larger framework of changing climate and observable changes in multiple socio-economic and environmental variables. This research seeks to elucidate the impacts of climate change on food security while considering changes in the dimensions of food security (food availability, accessibility, and utilization). The particular focus is on changes in climate variables and then impacts on crop yield, household-level food security, and livelihood vulnerability to climate change at the local level in a mountainous environment.

Nepal is one of the least developed countries, and 49% of the households are already experiencing food insecurity (NDHS, 2011). Agriculture is the main occupation of around 60% of the population and contributes 32.8% of the country's gross domestic product (GDP) (World Bank, 2016a). Furthermore, agriculture is mainly subsistence-oriented in nature, and farmers mainly rely on rain-fed agricultural systems, with irrigation covering only 27.42% of the total agricultural land in Nepal as of 2010 (World Bank, 2016a). Due to the huge dependency on the agricultural sector and the majority of agricultural fields being rain-fed, climate change will have more effects in Nepal. The heterogeneous topography, limited economic opportunity, and lack of access to basic services can make living in the rural mountainous parts of Nepal miserable.

Approximately 1.9 million people are estimated to be highly vulnerable to climate change, and an additional 10 million are at increasing risk in Nepal (NAPA, 2010). In addition, Nepal is ranked as the fourth most vulnerable country (Maplecroft, 2010). The National Adaptation Program of Action (NAPA, 2010) prepared a vulnerability map of Nepal and identified agriculture, forestry, and water resources as the sectors most vulnerable to climate change. Landslides, droughts, and glacial lake outburst foods (GLOFs) are major hazards induced by climate change. The risk of flash floods, landslides, and GLOFs is high in mountainous areas. Therefore, climate change will likely have a significant impact on the livelihoods of households, and the vulnerability is even greater in the hilly and mountainous parts of Nepal.

Climate change vulnerability is a function of character, magnitude, climate change exposure, sensitivity, and adaptive capacity (IPCC, 2001). The state of exposure is mainly based on geographical location rather than individual and social characteristics (Adger, 1999; Gentle et al., 2014). The adaptive capacity of individuals and society varies according to social dimensions and inequity related to factors such as gender and socio-economic status (Ribot, 2009). The poor and marginalized are severely affected by the impacts of climate change due to limited livelihood options, such as dependency on climate-sensitive livelihoods, inequitable access to productive assets, education, limited skills, and inadequate access to services (Adger et al., 2003; Gentle and Maraseni, 2012; Paavola and Adger, 2005). Therefore, it is essential to understand climate change's impacts on crop production, livelihoods, and household food security. Thus, this study focuses on the relationship between climate variables and crop yield, households' perception of climate change, household food security, and livelihood vulnerability in Nepal.

1.2 Statement of Problem

Climate change is a major threat to rural livelihoods in Nepal, especially in the mountainous region, and it eventually affects the state of food security. A majority of the population depends on agriculture, which is mainly rain-fed and dependent on climate. People in a rural environment are more sensitive to the impact of any climate variations. Changes in agricultural production affect the food security and economic activities of rural communities, especially those with low adaptive capacity. As a mountainous country, Nepal is prone to natural hazards like landslides and floods. Due to its heterogeneous topography, climate change will further exacerbate the frequency and intensity of these natural hazards. Therefore, climate change will make rural households vulnerable, especially in countries like Nepal where people have less economical resources to cope with it.

Although all the people in Nepal are affected by climate change, the poor households living in rural mountainous areas are the most vulnerable. Their agricultural system and livelihood strategies are not reliable due to the uncertainty of rainfall and water availability, along with other affects. Because of their low income, technological skills, and awareness, these households have limited options for adaptation. Therefore, rural households are the least capable of coping with the adverse effects of climate change (Shrestha, 2014). For any adaptation intervention in local areas, it is important to have knowledge of how the communities react to changing environmental conditions, their food security situation, and their livelihood vulnerability. However, there are limited studies on the impact of climate change on food security and livelihoods at the local level.

Formulating new adaptation plans may be necessary for rural communities to properly adapt to the changing scenario. Thus, climate change poses new challenges for farmers, policy makers, and the government to strengthen the resilience of local households. Before implementing any adaptation measures, it is necessary to understand climate variability and its consequences. In the second stage, it is necessary to explore the impacts on food security and livelihoods. Vulnerability analysis may be necessary for rural communities to implement appropriate adaption programs for the target population. The development of effective adaptation plans is necessary to strengthen the resilience of the vulnerable community to the impacts of climate change.

1.3 Objectives, Questions and Hypothesis

The aim of this research is to explore the consequences of the impacts of climate change on food security. The particular focus is on understanding the trends of climate variability and its impacts on crop yield. Furthermore, household food security and livelihood vulnerability are explored in the higher mountainous regions of Nepal. Finally, recommendations on priority areas of intervention are provided for adaptation plans to enhance food security and reduce vulnerability. In this context, the relationship between climate variables and crop yields are examined, as well as its consequences on household-level food security in the Lamjung district. Finally, livelihood vulnerability to climate change is assessed, and recommendations are provided to improve the resilience of rural mountainous households. The major objectives include:

- Understanding trends of climatic variability, as well as their relationships with and impacts on crop yield
- Understanding the perception of climate change among local people and its impacts on food security in rural households
- Assessing the vulnerability of household livelihood to climate change
- Identifying priority areas of intervention for adaptation plans to enhance food security and improve livelihoods

Therefore, the following research questions are addressed:

- How is climate changing in the mountainous region of Nepal?
- How is crop yield in mountainous area affected by climate variability?
- What are the underlying causes of changes in household food security?
- Is there any change in daily/economic activities to ensure household food security?
- Which livelihood options do households consider as the most vulnerable?
- Who are the most vulnerable to the impacts of climate change?
- What are the priority areas for adaptation plans to strengthen the household resilience and enhance food security with changing climate?

The research focuses on determining the consequences of climate change on food security in the mountainous region of Nepal. The targeted groups are local community farmers, development planners, and national policy makers. The research was conducted within a conceptual framework and is illustrated by a case study based on surveyed data from the mountainous district of Lamjung, which is one of the highly vulnerable districts to climate change in Nepal.

1.4 Research Methodology

Both qualitative and quantitative methods were used to achieve the research objectives and to answer the research questions. The overall methodology is presented in Figure 1.4.

1.4.1 Review of Literature

The literature on climate change and food security was extensively reviewed. The focus included changes in climate variables, crop production, food security, and livelihood vulnerability. Publications from several organizations were reviewed to develop the conceptual framework of this research.

1.4.2 Collection of Secondary Data

Secondary data were collected from different organizations in different stages of the research. The climatic data (temperature and precipitation data) were collected from the Department of Hydrology and Meteorology (DHM). Crop production data were collected from the Ministry of Agricultural Development (MOAD) of Nepal and the District Agriculture Development Office (DADO) of Lamjung. Other data related to natural hazards were collected from the district profile of Lamjung, village development committee (VDC) profile, and other sources. Secondary data were also collected from published books, scientific journals, reports, and various websites.

1.4.3 Key Informants Interviews

A field survey was conducted in Lamjung through key informant interviews (KIIs) (Appendix 10). Each interview was designed to collect qualitative information on climate change and experiences of extreme weather events, such as erratic rainfall, floods, droughts, and landslides. The interviews were conducted with selected representatives from the Nepal Agricultural Research Council (NARC), DADOs, MOAD, DHM, non-governmental organizations (NGOs), local leaders, women's groups, and farmers' groups. The interviews provided ideas in each stage of the research.

1.4.4 Household Questionnaire Survey

Household level questionnaires were used to determine the local perceptions of climate change, natural hazards, household food security, and livelihood vulnerability (see Appendix 6 and 8). A total of 150 households were interviewed from three VDCs of Kunchha, Khudi, and Ilampokhari (Figure 1.2).

The VDCs were selected based on the hydrological and meteorological stations. The household survey was successfully completed with the help of local assistants just after the Gorkha earthquake in Nepal. The survey findings are presented in chapters 4 and 5.

Figure 1.2 Conducting the households` questionnaire survey

1.4.5 Focus Group Discussions and Workshop with Stakeholders

After obtaining the results for the first objective (the relationship between climate variables and crop yield in Lamjung), a workshop was conducted to disseminate the results to the local government offices in Lamjung (Figure 1.3).

Figure 1.3 Group photo taken after workshop and focus group discussions in Lamjung, Nepal

The workshop involved different stakeholders and helped to obtain an idea of how the food security and resilience of vulnerable households can be enhanced in the study area. Nine focus group discussions were conducted to obtain the perception of natural hazards, food security, and wellbeing of different groups in different locations.

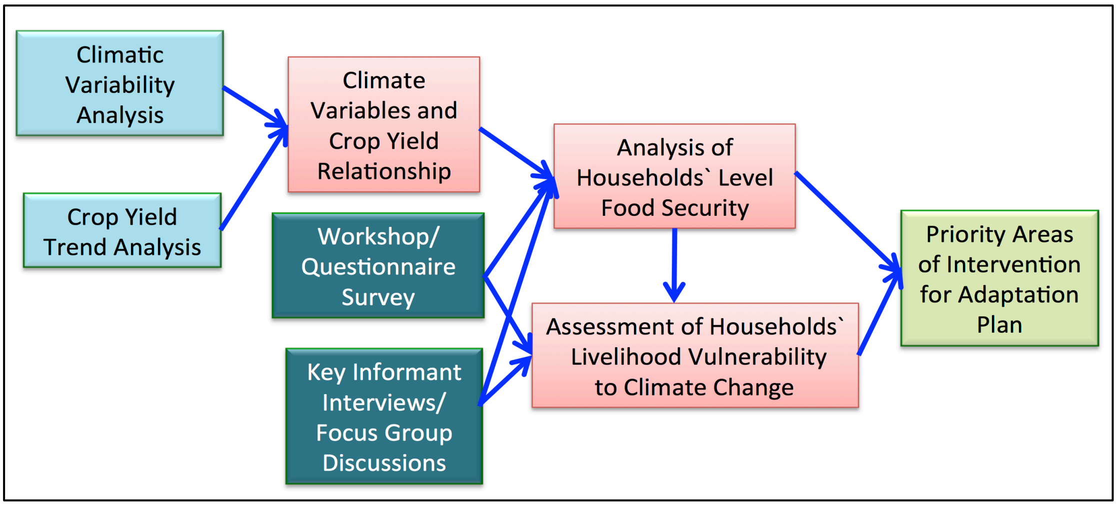

Figure 1.4 Overall research methodology

1.5 Overview of the Study Location

The Lamjung district is located in the western mountainous region of Nepal. It is situated between 27°55′N and 28°25′N latitude and between 85°00′E and 85°50′E longitude. Its elevation varies from 596 m to 7893 m above sea level (masl). It has an area of 1692 km^2 and a population of 167,724 (CBS, 2012). Lamjung is a good representative of a mountain landscape because it presents an interesting scenario of a complex coupled human-ecological system. It covers three ecological zones: the Himalayas cover 18%, high mountains cover 39%, and middle hills and mountains cover 43% of the total area (Shrestha, 2015). The eastern, southern, and western borders are respectively shared with the Gorkha, Tanahun, and Kaski districts, while the north is the Himalayan border with the Manang district. Broadly, five types of land-cover patterns are found in Lamjung. A land-cover map developed from Landsat images taken in 2014 is presented in Figure 1.5.

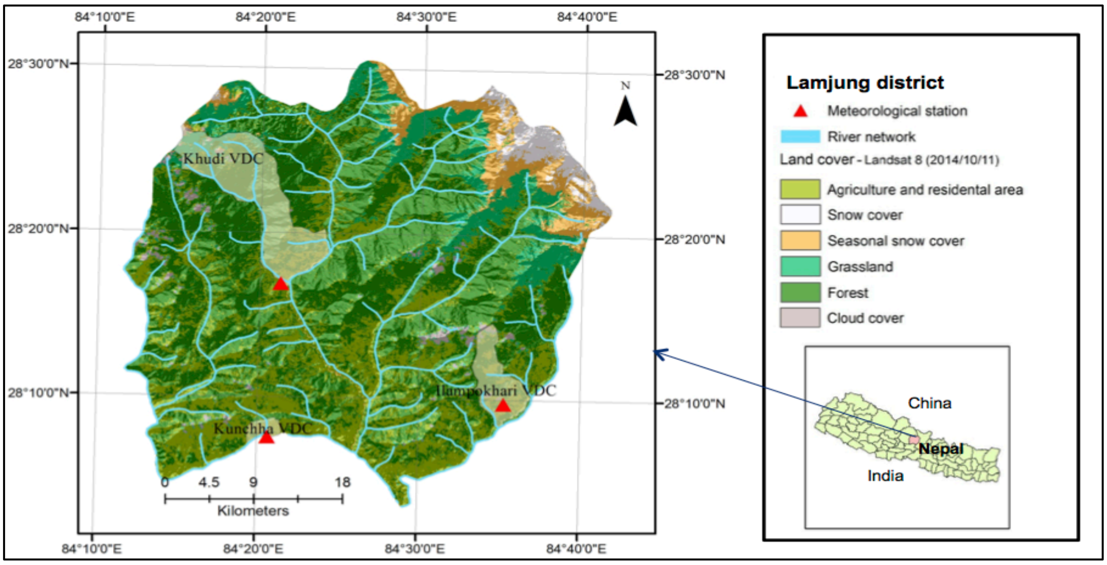

Figure 1.5 Map of the study area

Geology and Climate:

The climate of Lamjung ranges from tropical or subtropical in the south to temperate in the north. The physiography of the southern side is fertile plains, while the northern side is very rugged with permanent snow-covered peaks. It comprises five climatic zones: tropical climate (up to 1,000 m), sub-tropical climate (1,000-2,000 m), temperate cold climate (2,000-3,000 m), sub-alpine climate (3,000-4,000 m), and alpine and tundra climate (above 4,000 m) (DCEP, 2014). The total number of households is 42,079, and the average household size is 3.99. According to the latest census, the population density of the study area is 99/km^2 (CBS, 2013).

The government of Nepal has ranked Lamjung district as one of the highly vulnerable districts to climate change and climate-induced natural disasters (NAPA, 2010). It has 61 Village development committees, and we chose three of them based on hydrological and meteorological stations. The district partly covers two of the major Himalayan ranges: Manaslu and Annapurna-Lamjung Himal, where the major peaks are Nyaagdichuli (7,513 m), Himalchuli (7,893 m), Buddha Himal (6,672 m), and Lamjung Himal (6,986 m). Dudhpokhari (Milk Lake), which comprises two sacred glacier lakes, is located at the base of these peaks. These peaks are also the source of rivers, such as the Ngadi, Khudi, Dordi, Maadi, and Chepe Khola. Marsyaandi is the biggest river of Lamjung. It originates in the adjoining northern district of Manang and enters Lamjung through the deep gorge between the Nyaagdichuli and the Lamjung Himal peaks, dividing the district almost into two halves.

Figure 1.6 (a) Southern part of Lamjung (b) Northern part of Lamjung (c) Terraced agricultural field in Kunchha VDC (d) District headquarters Beshishahar, Lamjung

Due to the heterogeneous topography and elevation variations, the temperature and precipitation vary seasonally and spatially. The summer (June–August) is hot, and the maximum temperature in the lower part of the district can reach 40°C or higher. The minimum temperature during winter (December–February) is below freezing in most of the area. The distribution of precipitation also depends on the spatial location and time of the year. Monsoons contribute approximately 80% of the annual precipitation during the summer season, and westerly winds deliver winter precipitation. Precipitation is in the form of rain at lower elevations and snow at higher elevations, although there is no clear separation line due to the seasonal variations in temperature.

During autumn (September–November) and spring (March–May), the region receives occasional precipitation. These precipitation events are often in the form of hailstorms or snowstorms. The key natural calamities in the study area are occasional frosts and hailstorms during the spring and autumn, as well as floods and landslides caused mostly by the heavy monsoon season. Over the last two decades, long-term dry spells and unpredictable rainfall have been observed several times in this area (Koirala and Bhatta, 2010).

Demography

One of the most important components of Lamjung is its impressive socio-cultural diversity found in different elevation zones. The district has eight major ethnic and caste groups and five distinct language groups. The census data of 2011 report that Gurungs are the dominant ethnic group in the district (32%), followed by Chhetris (16%) and Brahmins (15%). About 15% are Dalits (*i.e.,* occupational caste groups, such as Kami, Sarki, and Damai). The other major ethnic and caste groups are Tamangs (7%) and Newars (3%). Magars and Duras are a native ethnic group of the district and constitute about 2% of the total population (CBS, 2012), as shown in Figure 1.7(a).

Although it is hard to make generalizations due to increasing diffusion, Gurung settlements are dominant in the northern side of the district. The southern part, in contrast, is heterogeneous in terms of ethnic composition. Regarding languages, 56% of the population speaks Nepali, which was originally called *Khas Bhasa* and is by far the most widely spoken language in the district. This is followed by the Gurung language (32%). Other major language groups are Tamang (6%), Dura (2%), Newar (2%), and others (2%), as shown in Figure 1.7(b).

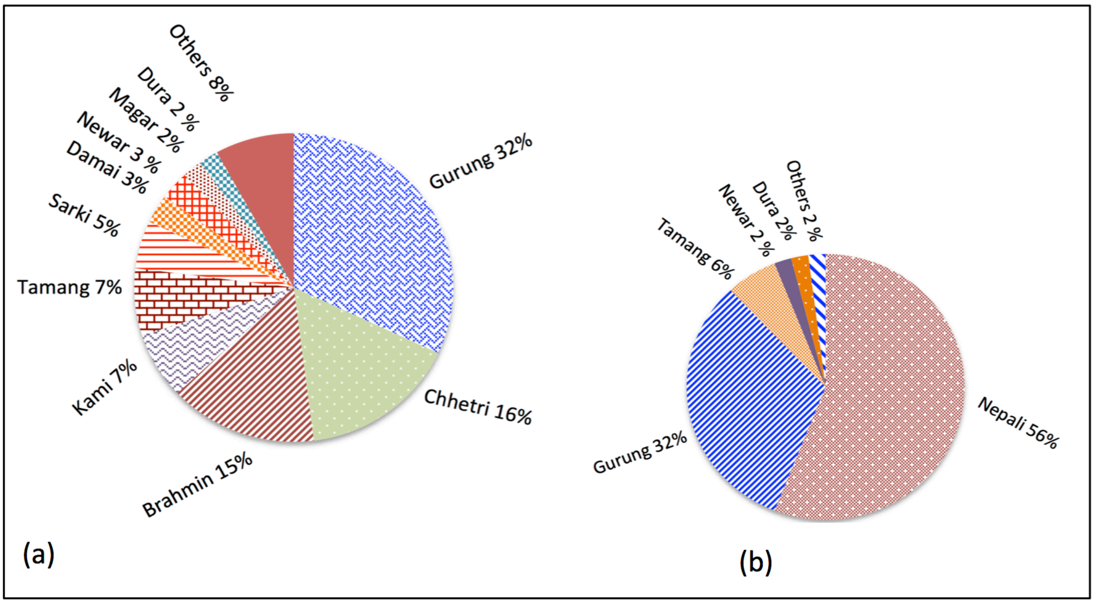

Figure 1.7 (a) Major castes and ethnic groups (b) Major languages

Source: (CBS, 2012)

Nepali is the native tongue of Brahmins, Chhetris, and Dalits, but almost all people can speak Nepali. This is not surprising because *Khas Bhasa* has received the nation state's exclusive patronage and promotion as the national language over the last 200 years.

Agriculture and Livelihoods

According to the district profile of Lamjung (2008), agricultural land covers approximately 61,819 ha in Lamjung, which is about 25% of the total area. Around 89% of this agricultural land (55,080 ha) is located in the middle mountain region. Irrigation facilities are available in only 42% (26,272ha) of the total agricultural land. Cultivation is possible on moderate to steep slope terrains, and there are four different types of agricultural terraces: sloping terraces (74.5 km^2), level terraces (257.9 km^2), foot slopes (87.4 km^2), and valley floors (7.7 km^2) (Shrestha, 2015). Among them, land in lowland valleys and foot slopes are the "main lands," and their market value is higher than that of slope terraces since they have the highest productivity.

The agricultural system is highly intensified, and specialization on staple and cash crops is preferred in these lands. Thus, rice is the most dominant and preferred crop, followed by maize, wheat, millet, oilseed (*e.g.,* mustard, sesame), potato, and pulses. They share several similar characteristics to the wetland rice cultivation that is prevalent in the plains. The plains of Lamjung district are limited to areas along the banks of rivers and foothills. According to the slope gradients of the district, 35.2% of the total land is less steep with slope less than 20^o. This area has minimum soil erosion and is suitable for cultivation. The remaining two-thirds of the total land has steep slopes of more than 20^o and is highly prone to soil erosion. Areas at higher elevations above 2000 masl with relatively steep slopes are leveled to form sloping terraces, which are not as valuable as the valley floors and foot slopes. These two agricultural land categories cover about 78% of the cultivated lands and stretch throughout the northern part. Even though there are only one or two harvests per year on average for such lands, they support very diverse agriculture and provide livelihoods for a majority of the inhabitants. Other major crops include barley, legumes, and citrus fruits.

The livelihood system of Lamjung district has changed over the past few decades. Traditionally, agro-pastoralism was the main livelihood source of local people for centuries. For off-farm income sources, they used to serve in the armies of the Indian and British Gurkha regiments or worked as seasonal traders. Agro-pastoralism has almost disappeared, with some exceptions in remote northern Gurung villages. That system has been replaced by the increasing mixed-mountain agricultural system in the middle hill region and rice-dominated agricultural intensification in the foot-slopes and valley floors. Many have migrated to the Terai plain region after the eradication of malaria during the 1960s. While agriculture remains the main source of livelihood in recent years (83% of total employment), many are working as laborers in the Gulf countries, India, Malaysia, and beyond (Shrestha 2007).

Research Sites

Kunchha, Khudi, and Ilampokhari are the three VDCs selected as representative cases of climate change and food security in mountainous households, as shown in Table 1.1. The main settlement of Kunchha is located at lower altitudes and has easy access to roads and markets. It has a cereal-dominated agricultural intensification system. The main ethnic and caste groups are Gurungs, Chhetris, Brahmins, and Dalits. Nowadays, vegetable and cash crop transactions are increasing as a result of expanding agricultural extension services provided by governmental and non-governmental organizations. In recent years, there has also been a growing trend among the youth to seek jobs abroad.

Khudi is the village nearest to the district headquarters among the three selected. Its landscape is characterized by a mixed-mountain agricultural system with some agro-pastoralism. The majority of the population is predominantly Gurung, followed by Brahims and Chettris. Cultivated lands are located mostly at the bottom of a hill. Forest area also stretches along all the slopes of this area.

Ilampokhari is remote and far from the district headquarters in comparison with Kunchha and Khudi. The main ethnic and caste groups are Gurungs, Magar, Tamangs, and Chhetris. The agricultural production is consumed within the village rather than sold in the market because of the poor road network connected to the market. Traditionally, most of the male population enlists in the British or Indian armies for work. However, in recent years, there is also a growing trend among the youth to seek jobs in other countries.

Table 1.1 Profile of research sites

Factor Details	Kunchha	Khudi	Ilampokhari
Coordinates	28.14°N 84.34°E	28.40°N 84.31°E	28.18°N 84.59°E
Area	7.22 km^2	64.23 km^2	33.11 km^2
Access to district headquarter (Beshishahar)	14.4 km road network	5.4 km road network	21.6 km road network
Total population	1855	3401	2650
Population density	256.92 km^2	55.88 km^2	80.03 km^2
Total number of households	514	826	608
Family size (Lamjung = 3.99)	3.61	4.12	4.36
Landholding size (ha)	0.79	0.49	0.77
Household food sufficiency (months)	9.06	5.91	8.94

Source: (CBS, 2012)

1.6 Relevance of the Study

It is now widely accepted that Nepal is one of the vulnerable countries to climate change and climate-related natural hazards. Therefore, it is imperative to understand the impact of climate change at the household level and its consequences on food security and livelihoods. The impact of climate change is realized differently in different regions, sectors, and groups. Furthermore, the climate change exposure, vulnerability, resilience, and adaptation strategies of different people differ according to the region and their socio-economic conditions (Gentle et al., 2014). Thus, there is a need to study the changes in climate variables at a local scale and the perceptions of the local people. Similarly, the impacts on crop production, household livelihoods, and food security at the local level need to be assessed. This will help to identify the priority areas of intervention for adaptation plans at the local level.

One focus of the IPCC is climate change mitigation and adaptation, which has attracted researchers to examine the vulnerability of the specific places (Ibarrarán et al., 2008). Therefore, the identification and characterization of climate change impacts from a vulnerability perspective in different regions, sectors, and communities are a concern for addressing climate change. Without considering all of these, the local issues and their reactions to climate change impacts may not be addressed properly. However, there is not enough research on local areas, especially in developing countries. The IPCC has also stressed that the priorities should be directed toward advancing the understanding of potential consequences of climate change for human society and the natural world, as well as to support analyses of possible responses (IPCC, 2001). This emphasizes the need for research at the local level. Therefore, the research focuses on climate variables and crop yield relationships, climate impacts on food security, and livelihood vulnerability to climate change in the mountainous region.

1.7 Limitations of the Study

The study draws its conclusions on climate change and climate-induced natural hazards, and its impacts on crop yield, food security and livelihood from limited cases of three VDCs of Lamjung.

Lack of Data: There was insufficient data for the climate variables. Precipitation data were available from all three stations of Lamjung (Kunchha, Khudi, and Gharedhunga), but temperature data were available from only one station (Khudi). It is necessary to establish a meteorological station to capture data to reflect variations of the highly heterogeneous topography in Lamjung. Unfortunately, such stations have not yet been established in Nepal.

Regarding crop yield data, the aggregated production of the district was examined to find the relationship with climate variables. Therefore, it is difficult to obtain information on crop production of these particular villages. Datasets with better spatial resolution on primary production data from the village should be used.

Data Reporting: Due to a lack of access and poor information and communication systems, the data availability was limited and in some cases did not reveal exact information about natural hazards. However, the reports of natural hazards have in improved in recent years due to the development of information and communication systems. Information about natural hazards for last few years is accurate and easy to verify. However, natural hazards reported by households may not actually represent the occurrence of all natural hazards since the information is collected from selected memories.

Inclusion Criteria

- Climate variable data were collected from the available three hydrological and meteorological stations in Lamjung district (Kunchha, Khudi, and Gharedhunga).
- Major crop production data were collected from MOAD, which collects crop production data from districts.
- The respondents of Key informant interviews included the head of villages, members of farmers' and women's groups, community leaders or representatives, NGO workers, scientist of NARC, District Agriculture Development Officials (DADO), and MOAD officials.
- Local households from three VDCs were considered as respondents based on the hydrological and meteorological stations.

Reference period: The field-based survey data were collected from the study area during the period of October 2014 to January 2016.

1.8 Structure of Thesis

The remainder of this thesis is structured as follows. Chapter 2 provides a brief review of relevant literature on climate change, its evidence, impacts, livelihood vulnerability in Nepal, adaptation plans and policies, and their implementations. In addition, the food security situation of Nepal and policy related to agriculture and food security are also reviewed. Chapter 3 deals with analyses of climate variables and crop production in Lamjung district. The trends of climate variables and crop yield are investigated based on the historical temperature and precipitation data provided by the DHM and crop yield data provided by MOAD. The relationship between climate variables and crops is explored through multivariate regression analysis.

Chapter 4 presents the local perceptions of climate change and changes in the overall food security situation of households from the Kunchha, Khudi, and Ilampokhari VDCs. Changes in households` food security are analyzed from the perspective of food production, food availability, food accessibility, and consumption patterns. Changes in daily and economic activities and the role of climate change are also presented.

Chapter 5 deals with households' livelihood vulnerability to climate change. Households are categorized based on wellbeing status, gender of the household head, and locations. Climate-related hazards, the most impacted livelihood resources, and livelihood options are further elaborated. Finally, the most vulnerable households are identified.

Chapter 6 provides a synopsis of the dissertation. The key findings of the research are emphasized. Implementations and key recommendations for priority areas of intervention for adaption plans are presented to strengthen the resilience of mountainous households in the face of changing climate.

2 Chapter 2 Climate Variability and Food Security Scenario of Nepal

This chapter provides a detail overview of climate variability and food security scenario of Nepal. In detail, this chapter deals with evidences and impacts of climate change in Nepal, climate change vulnerability, local people perception about climate change, natural disasters trends and impacts, climate change adaptation practices in Nepal, climate change programs and policy, and food security program and policy in Nepal.

2.1 Overview of Nepal

Nepal, officially, Federal Democratic Republic of Nepal (in local languages: *Sanghiya Loktantrik Ganatantra Nepal*), where, agriculture is the mainstay of around 60% of the population that contributes 32% of the country's gross domestic product GDP (World Bank, 2016a). Income inequality is widespread throughout the country, the difference between urban and rural populations is huge and per capita GDP is $2,500 (PPP) (CIA, 2016). Most of the populations living in rural areas rely on climate sensitive resources, such as agriculture for their livelihoods. Thus, changing climate threatens the livelihoods and food security of many rural households. Agriculture system in rural Nepal is dominated by rain-fed, and therefore, even small changes in precipitation pattern may have big negative impacts on their income as well as the local food system. From a policy perspective, building rural households' adaptive capacity and strengthen the resilience from climate change is of importance to the development of the country.

2.1.1 Demography

Nepal has a population of 29,033,914 (July 2016 est.) with 49% male and 51% female. The population growth rate is 1.24% per year and population density 180 people per square kilometer (CIA, 2016) (Table 2.1). It is the 42th largest country in the world in terms of population, the population increased twofold from 1971 to 2001 (From 11,555,983 to 23,151,423). Currently more than 82% of people lives in rural area, 49 % population live in mountain and hill (CBS, 2014a) and 25% population are under the poverty line. Similarly, the literacy rate of male and female are 75.1% and 57.4% giving on average of 65.9%.

Table 2.1 Nepal demographic (2016 estimates, unless stated otherwise)

Population	29,033,914
Age structure	
0-14 years	30.93% (male 4,646,048/female 4,333,105)
15-24 years (youth)	21.86% (male 3,176,158/female 3,169,721)
25-54 years	35.99% (male 4,707,264/female 5,740,985)
55-64 years	6.22% (male 877,288/female 927,202)
65 years and over	5.02% (male 723,523/female 732,620) (2016 est.)
Median age	
Total	23.6 years
Male	22.4 years
Female	24.8 years
Population growth rate	1.24% (est. 2016)
Birth rate	19.9 births/1,000 population (2016 est.)
Death rate	5.7 deaths/1,000 population (2016 est.)
Net migration rate	-1.9 migrant(s)/1,000 population (2016 est.)
Urbanization	
Urban population	18.6% of total population (2015)
Rate of urbanization	3.18% annual rate of change (2010-15 est.)
Sex ratio	
Total population	0.95 male(s)/female
Life expectancy at birth	
Total population	70.7 years
Male	70.1 years
Female	71.3 years (2016 est.)
Total fertility rate	2.18 children born/woman (2016 est.)
Ethnic groups	Chhettri 16.6%, Brahman-Hill 12.2%, Magar 7.1%, Tharu 6.6%, Tamang 5.8%, Newar 5%, Kami 4.8%, Muslim 4.4%, Yadav 4%, Rai 2.3%, Gurung 2%, Damai/Dholii 1.8%, Thakuri 1.6%, Limbu 1.5%, Sarki 1.4%, Teli 1.4%, Chamar/Harijan/Ram 1.3%, Koiri/Kushwaha 1.2%, other 19%
Religions	Hindu 81.3%, Buddhist 9%, Muslim 4.4%, Kirant 3.1%, Christian 1.4%, other 0.5%, unspecified 0.2% (2011 est.)

Source: (CIA, 2016)

In reference to Human Development Report 2014 of the United Nations Development Program (UNDP), Nepal's Human Development Index (HDI) is 0.490.

The total life expectancy is 70.7 year with 70.1 years for male and 71.3 years for female. Nepal is diversified in cultures and ethnic groups, 125 castes/ethnic groups and 123 languages were reported to be used in the 2011 census (CIA, 2016). Though, an official national language is Nepali.

2.1.2 Geography and Climate

Nepal is located between China, in the north, and India, in the south, east, and west in Asian continent. It is the mountainous and landlocked country covering 147,181 km^2 (CBS 2014). It extends from 26°22′N to 30°27′N and 80°40′E to 88°12′E. Nepal is divided into three main geographical regions: high mountain, hill, and Terai. High Mountain covers 35% of total area, and Hill or Middle Mountain and Terai cover 42% and 23%, respectively. Mt. Everest (8848 m) is the highest peak in the country, which is the highest peak in the world as well, while the lowest point is in the Terai, named Kechana Kalan (70 m) in Jhapa district (FAO, 2010).

Nepal can be broadly divided into five ecological zones with respect to the altitude (Figure 2.1): the tropical zone below 1,000 m, the subtropical zone between 1000 m and 2000 m, the temperate zone between 2,000 m and 3,000 m, the alpine zone between 3,000 m and 5,000 m, and the arctic zone above 5,000 m (CBS, 2013) (Table 2.2).

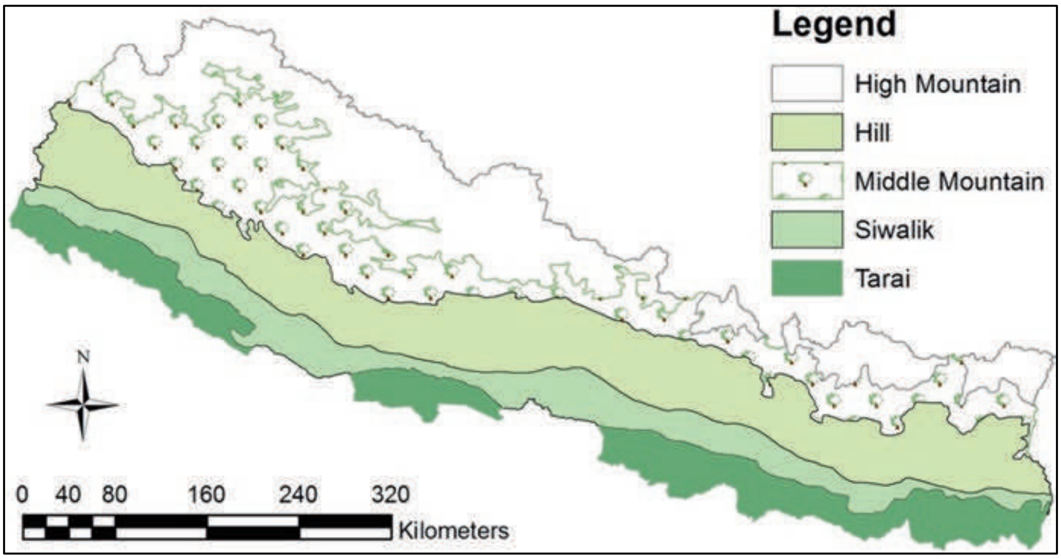

Figure 2.1 Topography of Nepal

Source: (GoN, n.d.)

Similarly, Nepal experiences four distinct climatic seasons: spring/pre-monsoon

(March–May), summer/monsoon (June–September), autumn/post-monsoon (October–November), and winter (December–February). The average rainfall is about 1800mm/yr (MoE, 2010).

Table 2.2 Physiography and bioclimatic zones of Nepal

Physiographic zone	Area (%)	Elevation (m)	Bioclimatic zone
High Himal	23	Above 5,000	Artic and Tundra
High Mountains	19	4,000-5,000	Alpine
		3,000-4,000	Sub-alpine
Middle Mountains	29	2,000-3,000	Montane (Temperate)
		1,000-2,000	Subtropical
Siwalik	15	500-1,000	Tropical
Terai	14	Below 500	Tropical

The mountain ecosystem of Nepal provides several important goods and services such as habitat diversity and protection, water resources, food and fiber production, *etc*.(Poudel and Shaw, 2017). The mountain environment is fragile to change, such as land use dynamics, which can have a large impact with the small changes in climatic and environmental factors in this region (Houet et al., 2010). The main agents of the environmental change in the mountainous area of Nepal are changes in land use pattern, climate change, rapid urbanization, and population dynamics. These agents have made the mountain people more vulnerable to economic and environmental aspects and threaten the livelihoods and food security of rural households (Poudel and Shaw, 2015). Changes in land cover from forest to other uses such as construction of buildings, roads, and agricultural activities have been widespread all over Nepal. Due to climatic and geographic conditions, most of the land is threatened by degradation and desertification. Eventually, that leads to decrease in agricultural production and environmental degradation.

Present Status of Land Use Pattern in Nepal

Land is one of the most important sources of livelihoods for human being and one of the most important natural resources where many development activities are dependent. Infrastructure development, rapid population growth with the growing demand of water resources, food, and agricultural land are creating pressure on the land resources (Poudel and Shaw, 2017). Although Nepal has a large area of abundant land, due to the lack of proper management (FAO, 2010), there is a scarcity of cultivable land. Current land use pattern is depicted in Figure 2.2. Majority (39.5%) of the land area is covered by forest followed by agricultural land (27%), and snow cover (17.2%). According to the Central Bureau of Statistics of Nepal, in 2008 there was 0.6 ha land availability per household, while it was 0.8 ha in 2001 (MoHA, 2011). Due to the increasing population and occurrence of natural disasters, land availability of per-capita is declining. Hence, land use pattern has changed during the last few decades.

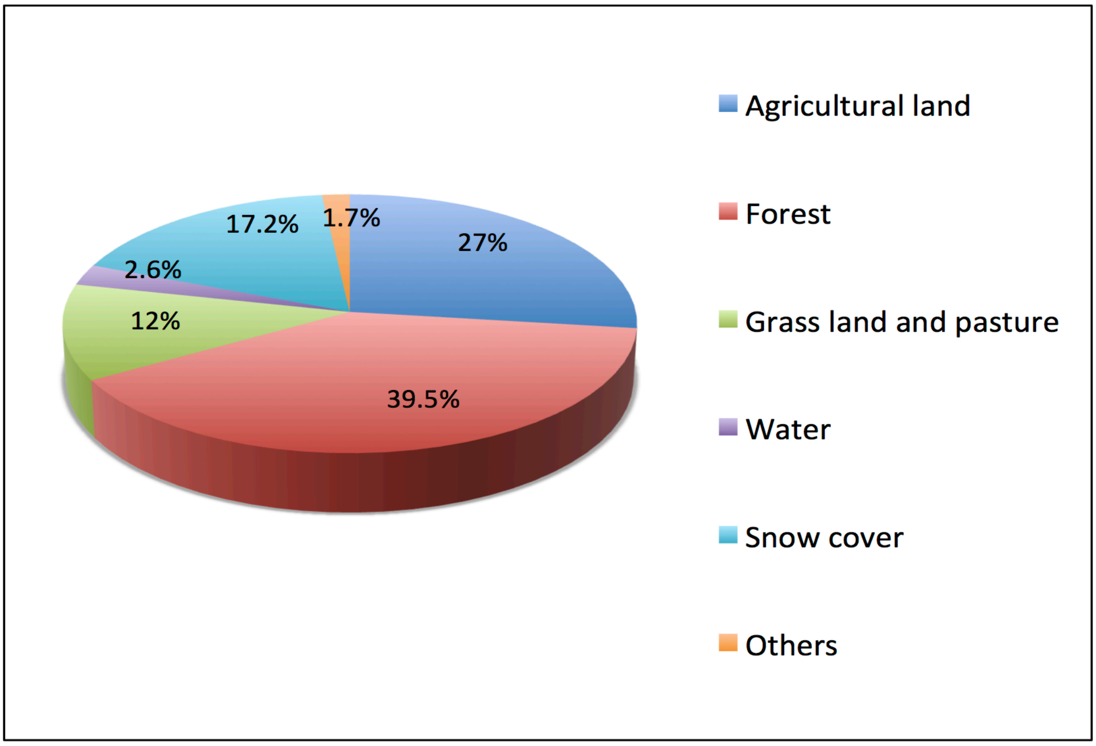

Figure 2.2 Land use/cover pattern of Nepal

Source: (FAO, 2010; MOLRM, 2012)

2.2 Evidences of Climate Change in Nepal

Though, Nepal does not contribute much in climate change, it is highly vulnerable to climate change impacts. The population of Nepal is less than 0.4% of the world population and is responsible for only about 0.025% of annual greenhouse gas emissions (NAPA, 2010). In Nepal the first systematic and regular monitoring of hydrological and meteorological system was established in 1965 in the name of Nepal Meteorological Service (NMS) with the help of UNDP and World Meteorological Organization (WMO) (Bajracharya and Mool, 2009). According to the analysis of temperature trend done by Shrestha (Shrestha et al., 1999) for 1971-1994, trend was different according to the geographical area and seasons in Nepal. The warming was slow in the low-elevation Terai with annual average of 0.04°C/yr than in north high mountains with annual average of 0.08°C/yr (Shrestha et al., 1999). In case of seasonal difference the highest one was in Autumn (October-November) at 0.08°C/yr while lowest warming rate was for Spring (March-May) at 0.03°C/yr (Shrestha et al., 1999). Similarly, the trend analysis done by the Practical Action found that for the period of 1976-2005 the maximum temperature was increasing at 0.05°C/yr while minimum temperature was increasing at 0.03°C/yr (Practicle Action, 2009). Also the maximum temperature was found to be in decreasing trend in Terai region during winter season that was mainly due to cold waves resulting foggy conditions. The rainfall trend increased at average annual rainfall of 4mm/yr over the period of 1976-2005. However, in some areas of Nepal decreasing rainfall trend was observed over the period of 1976-2005 (Practicle Action, 2009). Similarly, the Spring, Summer, Autumn and Winter seasons average rainfall increased by 9mm/yr, 30mm/yr, 7mm/yr and 2.8mm/yr respectively except few area where it decreased (Practicle Action, 2009).

Climate Change trend analysis showed that national temperatures since 1962 has significant variations between years, but a progressive increase in maximum temperatures is evident in line with global and regional records. Shrestha (Shrestha et al., 2012) reported that increasing trend of temperature is higher in Himalayan region compared to other regions and annual increasing trend is 0.06°C and trend is higher than globally (0.02°C). It is reported that all Nepal temperature is increasing steadily and 32 years temperature data analyzed showed about 1.8°C increase from 1975 – 2006 and 2006 was reported warmest year in record (Shrestha et al., 2012). Ministry of Environment (MoE, 2010) projected that temperature will increase 1.2°C by 2030, 1.7°C by 2050, and 3.0°C by 2100 (Table 2.3). Temperature rise in higher areas leads to increase the rate of snow and glacier melt, releasing a higher volume of water flow into lower region (Practicle Action, 2009). All-Nepal and regional precipitation series showed significant variability on annual and decadal time scales (Shrestha et al., 2000). From the trend observed between 1976 and 2005 it is expected that the regions with already high precipitation will receive more rainfall and those with low precipitation will see further decrease (Practicle Action, 2009). It is also reported that over the past decades rainfall has become more intense, highly variable, longer gaps of no rain and delayed monsoon.

Figure 2.3 depicts temperature and precipitation trends between 1980 and 2012. The average temperature was maximum in 2009 and minimum in 2012 over the period of time. There was the lowest precipitation in 2010, while the highest precipitation was in 2011. It shows that there was a great variation in temperature and precipitation pattern over the period of time. These types of variations create uncertainty to the weather dependent livelihood in the rural areas of Nepal.

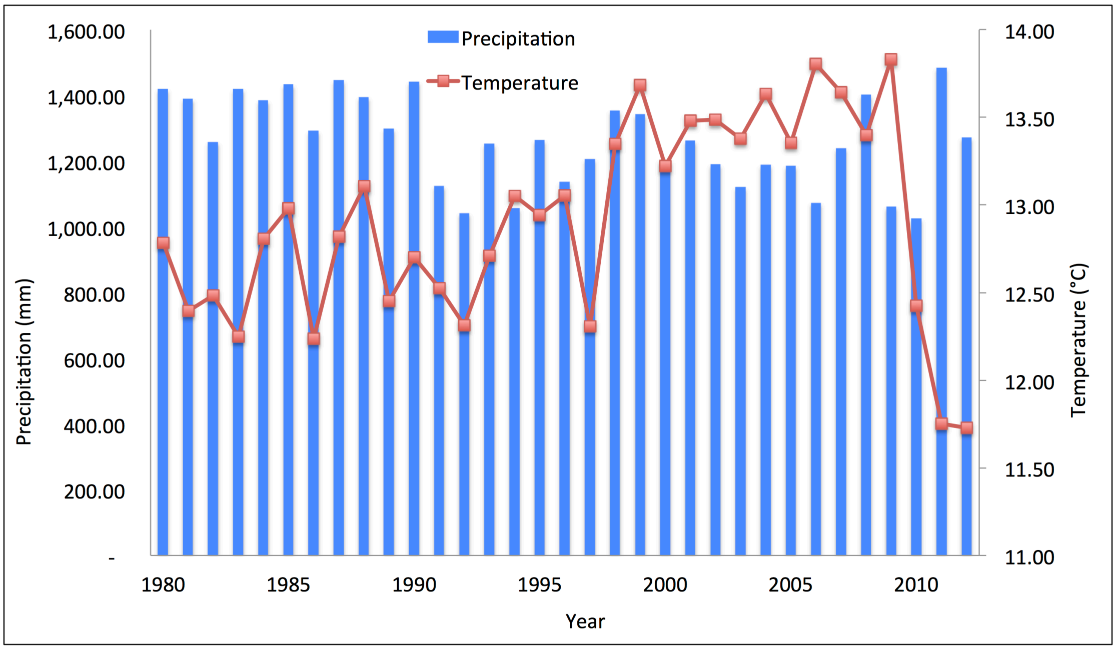

Figure 2.3 Average temperature and precipitation trend of Nepal between 1980 and 2012

Source: (World Bank, 2016b)

There are a few numbers of studies that have projected temperature and precipitation by General Circulation Model (GCM) / Regional Circulation Model (RCM) but confidence in projection is low as they are biased (Shrestha, 2014). The study done by Agrawala (Agrawala et al., 2003) using GCM estimates that by 2100 both mean temperature and mean precipitation will increase by 3°C and 180.6 mm respectively as shown in Table 2.3.

Due to the changing climatic patterns, land cover and use patterns are also likely to change in several parts. As the land use pattern in the mountainous region of Nepal is highly vulnerable to the changing climate, changes in climatic factors may contribute to change a distribution of vegetation in sub-alpine and alpine regions. The snow cover area is also changing into grassland apparently in the Higher Himalayas region (Mishra et al., 2014b), while forest to other classes, such as agricultural land and built-up area, is common all over the hills and the Terai region. Rapid urbanization, global environmental change, population growth, and encroachment for the agricultural land are the major agents of such changes. Figure 2.4 shows the land cover map of Nepal based on the Moderate-Resolution Imaging Spectroradiometer (MODIS) product MOD11Q1 in 2001 and 2012. The increment of the vegetation in the northern part of Nepal is clearly visible from East to West. Several researches (Dahal, 2005; Mishra et al., 2014b) have also reported the similar results in the higher altitude of Himalayas.

Table 2.3 Projection of climate change in Nepal

Year (Baseline 2000)	Mean temperature increase (°C)			Mean precipitation increase (mm)		
	Annual	Winter	Summer	Annual	Winter	Summer
2030	1.2 (0.27)	1.3 (0.4)	1.1 (0.2)	71.6 (3.8)	0.6 (9.9)	81.4(7.1)
2050	1.7 (0.39)	1.8 (0.58)	1.6 (0.29)	104.6(5.6)	0.9 (14.4)	117.1(10.3)
2100	3.0 (0.67)	3.2 (1.00)	2.9 (0.51)	180.6(9.7)	1.5 (25.0)	204.7(17.9)

Source: (MoE, 2010) *Note: Figures in parenthesis indicate standard deviation*

The increment of vegetation in the higher altitude is the evidence of the receding of the snow cover area, which is the widely accepted fact in this region and is one of the most visible effects of the global warming. Similarly, the cropland to built-up area in the southern plain, Terai region is also increased considerably during the period of 12 years even though, this fact is not very visible in the map.

Mountain region soil is prone to erosion because of steep slopes. It is colder than plain Terai region therefore; soil formation and vegetative growth rate are slow. It may be irreversible or reversible only over a long period of time, if once damage to mountain soil or vegetation (Jansky et al., 2002). Mountain region is in the risk of climate change such as excessive rainfall and relatively low temperature as well as natural disaster such as avalanches, earthquakes *etc*. (Pal, 2015).

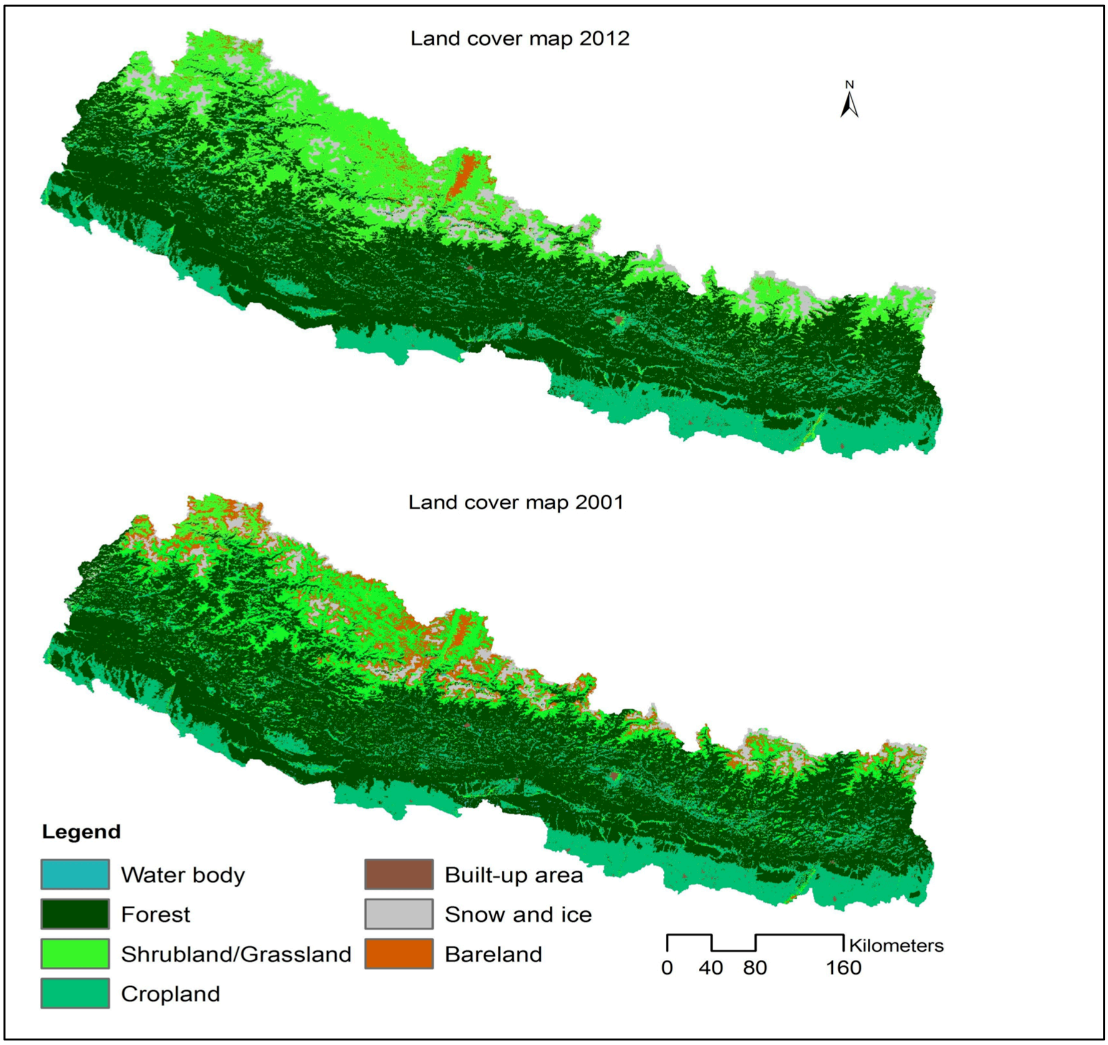

Figure 2.4 Land cover map of Nepal, developed from MODIS Land product MOD12Q1
Source: (Poudel and Shaw, 2017)

2.3 Impacts of Climate Change

There is no doubt that, climate of Nepal is changed affecting the biophysical and socio-economic sectors. The overall temperature is increasing and precipitation has become erratic. Nepal`s landscape is covered mostly by fragile mountains; climate change will further exacerbate the occurrence of natural hazards like floods and landslides, and will affect the various sectors. Climate change impact is realized mainly on the agriculture, water resources, climate-induced disasters, forests and biodiversity, health, and urban settlement and infrastructure in Nepal (MoE, 2010).

Other types of change are also noticed such as depletion of local water sources, increasing risks of glacial lake outburst floods (GLOFs) Figure 2.5 (a), upward shifting of agro ecological belts and tree/snow lines Figure 2.5(b). Similarly, encroachment, rapid growth and distribution of exotic species, change in flowering behavior of some plant species, and increased prevalence of disease and pests observed in forest and food crop species.

Figure 2.5 (a) Moraine dammed lake formation (b) Climbing the vegetation line and appearances of new species in higher altitudes

Photo Source: (Mishra, 2011).

Erratic rainfall and rising temperatures could lead to delayed planting, shortened growing seasons, withered crops and increased incidences of pest infestations and disease outbreaks (Jansen, 2013). Some previous literatures (Joshi et al., 2011; Maharjan and Khatri Chheri, 2006) mentioned that effect of climate change in agriculture would mostly be adverse as it is highly dependent on weather condition because of extreme rainfall. Due to rising temperature there could be longer drier phases during dry season and higher chances of flooding and landslides during rainy seasons that will subsequently impacts agriculture and livelihoods (Alam and Regmi, 2004). The food production from 2006-2009 has been significantly affected by extreme events that include droughts and floods (Hobbs, 2009).

Himalayan forest is expected to be most vulnerable as increased temperature would decrease soil moisture causing drought or grassland replacing current forest (Dahal et al., 2009). Also the recent forest fire in Nepal raised the issue of climate change impact on the forest of Nepal that was unusual in the past. The eastern part of Nepal was severely affected by defoliating insect outbreak. According to local resident that was related mostly to temperature rise and decrease rainfall due to shorter hibernation period (Thakur, 2009).

The most critical impacts of climate change in Nepal are expected on its water resources, particularly glacial lakes, and its hydropower generation. Water supply infrastructure and facilities are at risk from the increased flooding, landslides, sedimentation and more intense precipitation events (particularly during the monsoon) expected to result from climate change. Greater unreliability of dry season flows poses a potentially serious threat to water supplies in the lean season. Hydroelectric plants are highly dependent on predictable run-off patterns. Therefore, increased climate variability, which can affect frequency and intensity of flooding and droughts, could affect lives and livelihood of Nepalese.

As Nepal is a highly vulnerable country, there are more likely adverse impacts of climate change in the coming days. Therefore, adaptation to climate change must be a priority for the country. However, without understanding the changing climate, adaptation planning will not be effective due to the diverse climatic variation in Nepal. For effective adaptation planning, special climate change scenarios and their special impacts are crucial to understand.

2.4 People`s Perception of Climate Change

Perception can be stated as the process by which individual notices and understands changes in their surroundings. Also human perception do not just solely respond to the environmental stimuli but also go beyond the information present in the environment and pay selective attention to some aspects of environment and ignore other elements that are relevant to people (Shrestha, 2014). So, perception plays an important role for any action towards the change in the environment. According to the Speranza (Speranza, 2010) awareness and perception of a problem, shapes action or inaction for climate change problems. The risks perception process involves collecting, selecting and interpreting signals about uncertain impacts of events, activities or technologies (Wachinger et al., 2010). They also stated that perception might differ depending on the type of risk, the risk context, the personality of the individual, and the social context. And the societal and contextual aspects are linked with the perception of disaster impacts (Poumadère et al., 2005). There are literatures indicating that perception about the impacts of disaster depended on many factors. Further, Wachinger (Wachinger et al., 2010) states that wider social, economic and political contexts at local, regional and national levels are important factors that influence risk perception.

This emphasizes the importance of perception in order to know how people react to the certain risks and cope with the distresses. Also in another study (Nyanga et al., 2011), it mentions that the smallholder farmers' perceptions related to floods and droughts were significantly related with adoption of conservation agriculture. Similarly, there should be inclusion of climate change communication, which helps to exchange the climatic information so farmers can relate to conservation agriculture as an adaptation strategy to climate change (Nyanga et al., 2011).

2.4.1 Relationship between Perception of Climate Change and Socio-economic Status

People can think about climate change adaptation when they perceive changes, which is mainly related to their individual beliefs and practices. The study by (Bang, 2008) shows that socioeconomic and cultural factor guides the risk perception of people. The socio-economic condition may have influence on the individual beliefs and attitudes (Bayard and Jolly, 2007). Diekmann and Franzen (Diekmann and Franzen, 1999) argued that in richer countries there is higher willingness to give priority to environment and thus environmental behaviors are positively correlated with per capita gross national product. In contrast to this, different literatures urge differently and state that poor people are highly concerned about environmental degradation. The different studies (Brechin and Kempton, 1994; Dunlap et al., 1993) show that people in both developing and developed countries are concerned about the environmental degradation. Also in the study by Dunlap, Gallup Jr., & Gallup, (Dunlap et al. 1993) and Brechin and Kempton (Brechin & Kempton 1994) state that despite the resource limitation and distribution of the poor in the developing world, there is a strong tendency for improving the environment. In another study by Cordell and Tarrant (Cordell and Tarrant, 1997) mention that there is a higher correlation between attitude and behavior for low-income than the high-income individuals. Furthermore, Vogel (Vogel, 1996) proposes that farmers whose livelihood is harsher may have more knowledge about environmental problems. So, it can be said that the perception of the people depends on various factors like social, cultural and economic which is location specific in nature.

2.5 Climate Change Vulnerability and Resilience

2.5.1 Vulnerability

Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity (Barker T. et al., 2007). In this context, the vulnerability is taken as described by the IPCC. Further, vulnerability concept is an analytical tool that describes state of susceptibility to harm, powerlessness, and marginality of both physical and social systems, and it is a guiding analysis for enhancing well-being by reducing the risk (Adger, 2006). So for understanding the vulnerability to climate change we need to understand multi-scale and interdisciplinary issues. Kelly and Adger (Kelly and Adger, 2000) defines the vulnerability as "ability or inability of individuals or social groupings to respond to, in the sense of cope with, recover from, or adapt to, any external stress placed on their livelihoods and well-being".

Vulnerability to climate change has become a hotly debated and increasingly researched subject with climate change research shifting from an impacts-led approach, to a vulnerability-led approach (Turner II et al., 2003). The subject of vulnerability to climate change overlaps with many different disciplines (Brooks, 2003), from ecology, to sociology, to health sciences, economics, climatology and beyond. The number of definitions, concepts of vulnerability and related terms are explaining by some researchers arguing that vulnerability cannot be defined at all (Brooks, 2003). According to the Third Assessment Report (TAR) of the Intergovernmental Panel on Climate Change (IPCC), vulnerability is described as a function of exposure, sensitivity and adaptive capacity (IPCC, 2001). Where 'exposure' is defined as the degree to which a system experiences climate change stresses; 'sensitivity' is the degree to which a system responds to climate related stimuli; and 'adaptive capacity' is the ability of a system to adjust to actual or expected climate stresses or to cope with the consequences (IPCC, 2001). Since TAR, this definition of vulnerability and its sub-components have been utilized by many researchers (Adger, 2006; O`Brien et al., 2004; Panthi et al., 2015; Piya et al., 2016). This is not to say that all vulnerability research has accepted this definition as many others, including Turner (Turner II et al., 2003), view vulnerability as a function of exposure, sensitivity and resilience, or view vulnerability simply in terms of exposure and sensitivity. The lack of coherent, consistently defined terminology has led to numerous issues (Adger, 2006; Wolf et al., 2010) including preventing clear communication across disciplines (O`Brien et al., 2004) making difficult to compare studies, increasing confusion among policy makers (O`Brien et al., 2004), and has just generally slowed overall progress in this field. On the other hand, Ghimire (Ghimire et al., 2010) argues that the diverse approaches to vulnerability are essential to address the complex nature of the concept to the social-environmental system, and can even be viewed as complementary to one another.

The way vulnerability is defined is of critical importance to multidisciplinary research, as it directly affects how climate change research is designed, carried out and understood by all involved parties (O`Brien et al., 2004). Vulnerability can either be viewed as a 'starting-point' where vulnerability is caused by numerous environmental and social processes, and exacerbated by climate change, or as an 'end-point', where one considers the residual impacts of climate change after adaptation efforts have been made (Kelly and Adger, 2000). Viewing vulnerability as a starting point allows for an understanding of how climate change impacts will be distributed and is used to identify how vulnerability can be reduced (O`Brien et al., 2004). In viewing vulnerability as a 'starting-point' climate change acts as a "magnifying glass" where populations that already exist at the margins of society are likely to experience climate change more acutely. This further prevents them from participating equally in any solution or accessing necessary adaptation measures (Mitchell et al., 2009). The mounting evidence that vulnerability to climate change is closely tied to other deprivations, climate change has emerged as not only an urgent environmental issue, but as an urgent development issue as well (Skinner, 2011).

Vulnerability Assessments

The scopes of vulnerability assessments are varied based on scales, purposes and targeted audiences. Vulnerability assessments may look only at social vulnerability, a term that is often associated with adaptive capacity (Fussel, 2007) only at environmental vulnerability, or consider the interplay of both human and environmental vulnerability (Fussel, 2007). Vulnerability assessments can also be classified by purpose and may be carried out with the intent to: 1) compare between communities, nations, or regions, 2) assess future threat, or 3) enhance the understanding of factors that cause vulnerability so that vulnerability may be reduced (Adger, 1999). Recent advances in vulnerability research emphasize the importance of considering climate change effects on the human- environment coupled system (Fussel, 2007; Turner II et al., 2003). Analysis of vulnerability can be performed at many different scales including at a regional or country level, a sub-national level, a community level and even a household or individual level. Each study must consider the scope, purpose, scale and audience for their research.

Measuring Vulnerability Using Indicators

However there is not an absolute way to measure vulnerability, vulnerability assessments by using indicators is a common tool. While they have proven useful for identifying vulnerable communities, regions, or groups of people (Hinkel, 2011), developing vulnerability indicators poses a major set of challenges. There are various number of indicators that may be used to measure vulnerability (Hutchinson and Campbell, 2007). To narrow down this list, a defined criteria has to follow (Adger et al., 2003);

a. decide whether the focus is future, or present-day vulnerability,
b. ensure that the indicator is robust, precise, objective and transparent,
c. confirm that stakeholders recognize the indicator as valid, and
d. make sure the indicator is appropriate for the scale at which one is working.

To add to the complexity of designing vulnerability indicators, indicators must be sensitive enough to display clear variation and yet broad enough to be transferable (Vincent, 2004). Just as with many other facets of vulnerability, there is no clear consensus in the literature for the validity of used vulnerability indicators. Hinkel

(Hinkel, 2011) believes that vulnerability indicators are only useful at the local level, but many studies use them in regional and national assessments (Adger, 1999; Madhuri et al., 2014; O`Brien et al., 2004; Thornton and Cramer, 2012; Vincent and Cull, 2010).

Vulnerability of the Population

Poor people are often considered the most vulnerable to climate change. According to the World Bank, at the household level, poverty is the single most important factor determining vulnerability. In part reflecting location of housing (e.g., on steep slopes, floodplains, riverbanks), level of access to basic services (e.g., waste management) particularly for illegal squatters; sources of livelihood; and level of access to financial and other assets and resources. In the case of Nepal, linkages between poverty and vulnerability to climate related natural hazards are clearly evident (Gentle and Maraseni, 2012). Nepal has a high incidence of poverty, with 25 percent of the population living below the poverty line (Table 2.4).

Table 2.4 Population below the poverty line in South-Asian countries

Country	Population below the poverty line (%)	Year
Afghanistan	36	2009
Bangladesh	32	2010
Bhutan	12	2012
India	30	2010
Maldives	NA	NA
Nepal	**25**	**2011**
Pakistan	22	2006
Sri Lanka	9	2010

Source: (CIA, 2014)

In South Asia, Nepal is just ahead of Afghanistan, Bangladesh and India in the ranking. Poverty is largely a rural phenomenon in Nepal. Causes of poverty include high dependence on agriculture and per capita economic growth is low. Lack of adequate social safety nets, especially for poor women and children, and lack of educational attainment in terms of school dropouts and low educational quality *etc*. exacerbate the vulnerability (Fernandez, 2015). Population pressure and a declining natural resource have exacerbated these problems. In Nepal, land is a major asset for the majority of population. Seventy-four percent of households own agricultural land and roughly two percent don't own land but depends on agriculture. A majority of agricultural households (53%) operate less than 0.5ha of land (small farmer) and 4 percent operate 2ha or more (big farmers) (CBS, 2014b). Small farmers and landless agricultural households are bound to cultivate even on the unsuitable marginal lands and rely on forest resources for their livelihoods. Additionally, rapid expansion of urban areas in Nepal has resulted in unsystematic development leading to the escalation of unplanned, informal, and overcrowded settlements.

Moreover, being a mountainous country, Nepal is considered as among the countries most likely to be adversely affected by climate change risks (Maplecroft, 2010). According to the NAPA report (NAPA, 2010) only 5 districts out of 75 districts are ranked very low vulnerable in Nepal.

2.5.2 Resilience

According to the fourth assessment report of IPCC, resilience is defined as "ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organization, and the capacity to adapt to stress and change" (IPCC, 2007). In general resilience means the system ability to deal with stresses and disturbances, and also maintaining its basic structure and ways of functioning, capacity for self-organization, and capacity to learn and adapt to change (Speranza, 2010). So, resilience is about managing the changes and adapting with current and future climate risks (Speranza, 2010). Further, Adger (Adger, 2000) differentiates resilience as social and ecological. The social resilience result due to social, political and environmental changes and it is the ability of groups or communities to cope with external stresses and disturbances. While ecological resilience is the characteristic of ecosystems to maintain themselves in the face of disturbance (Adger, 2000).

According to the Resilience Alliance (2002) resilience has three distinct characteristics, i.e., system capacity to undergo change and still be in the same state, have capability of self-organization, and have ability to build and increase capacity of learning and adaptation. Further, resilience can be viewed as layered concept that ranges from individual to household, community, ethnic group and national level (Jordan, 2009).

2.6 Food Security

2.6.1 Food Security Situation of Nepal

Different views have been given focusing the food security situation of Nepal. Some literatures mentioned a serious problem of food security while some other report Nepal has sufficient food to feed its population. The proper food balance sheet is yet not prepared by the government of Nepal, and only food grains are included in the Food Balance Sheet prepared to judge the state of food availability; this shows food insecurity in Nepal. Nepal Demographic and Health Survey-2011 states that only 49% of HHs in Nepal is food secure and has access to food throughout the year (NDHS, 2011). This shows half of the populations are food insecure. The food insecurity is rooted in poverty and leads to poor health, low productivity, low income and inability to cope with the changing environment.

According to Food Balance Sheet of Nepal 2013, 33 out of 75 districts were estimated to be food deficient in that year, though total domestic cereal production was higher by 8% than total national demand (MOAD, 2013). However total domestic cereal production is able to meet national demand during the year of good harvest, the distribution system is affected by lack of good transportation and storage facilities. Food production varies based on the geographical regions and districts. The plain Terai region is food surplus and considered the food bowl of the country. The other two areas, the Hills and Mountains are both generally food deficit. Food is not available in the inaccessible rural mountainous communities in an affordable price due to high transportation cost. On the other hand, Nepal has not been able to produce agricultural products to its potential due to low quality inputs, traditional technology, and inadequate input subsidy and rain-fed farms (MOAC, 2011).

Based on NDSH (2011), approximately 12% of households (HHs) are mildly, 23% moderately and 16% severely food insecure. Rural households (46%) are less food secure compared to urban households (67%). And households in the highest wealth quintile are much more likely to be food secure (82%) than those in the lowest wealth quintile (18%) (Ghimire, 2014). The report prepared by the International Food Policy Research Institute (IFPRI) mentioned that the Global Hunger Index of Nepal in the year 2013 was 17.3 indicating the serious problem of food security. The underlying causes of food insecurity in Nepal are complex.

Due to the increasing population, increasing climate-induced calamities and uncertainty in agricultural production, Nepal has been considered a food deficit country since the 1990's. There are very less opportunity for employment within the country so most of the youth are in abroad for seeking job. The people involved in agriculture farming almost do not have any knowledge about the scientific agriculture farming. On the other hand, lack of irrigation facility and changes in weather pattern put the agriculture productivity to a low value. Additionally, Nepal is vulnerable to various types of natural disasters; this is also the next cause for food insecurity in Nepal. The trends of haphazard settlement in the productive areas and increasing investment in the land plotting are minimizing the productive agricultural lands in Nepal. Similarly, the political turmoil in Nepal is further putting the situation beyond the limits of solution, causing high fluctuation in food prices during a strike.

2.6.2 Climate Change Impacts on Food Security

Climate change has both positive and negative impact on crop production and food security. The study done by Malla (Malla, 2008) on climate change and its impact on Nepalese agriculture considered only the biological factors. It was found that enriched CO_2 has shown positive impact on yield of rice in all geographical zones. Similarly, Dahal (Dahal, 2005) mentioned the positive impacts of climate change in the high mountains. He explained that farmers were growing vegetables such as cauliflower, cabbages, tomato and cucumber that were not possible few years back.

Some researchers (Brown and Funk, 2008; Magawata, 2014; Wlokas, 2008) emphasized that some of the most profound impacts of climate change over the coming years will be on agriculture and food systems. And the extent to which households have the capacity to respond or adapt to these changes has critical implications for human development at the household, community, national and global level.

Changes in climate variables such as temperature and precipitation will have negative impact in agriculture. In 2005, there was 2% and 3.3% decrease rice and wheat production due to the prolonged drought. Similarly in 2006, rice production decreased by 27-39% in Eastern Terai due to drought (Regmi, 2007). There was significant reduction in the yield of winter crops due to severe sky overcast condition particularly in Nepal and the Indo-Gangetic plains of India that lies south of mountain region between 1990 to 2000 (Shrestha, 2007). The yield reduction in 1997/98 ranged from 11% to 38% compared to the average of the preceding 10 years (MoPE, 2004). Sharma and Shakya (2006) state that changes in water availability in the spring, summer and autumn seasons have a direct impact on agriculture. The loss of agricultural land and crops due to climate change induced disasters from 1971 to 2007 is presented in Table 2.5.

Table 2.5 Loss of agricultural land and crops as a result of climate-related extreme events in Nepal from (1970- 2007)

Events	**Loss of crops (hectares)**
Droughts	329,332
Floods	196,977
Hailstorms	117,518
Rains	54,895
Strong wind	23,239
Cold waves	21,794
Others (forest epidemic, snow storm, fire, storm, thunderstorm, avalanches *etc*.)	83,336
Total	**827,091**

Source: (Shrestha, 2014)

The rise in temperature will impact agriculture, as there will increase the incidence of pests and diseases and decreasing physiological performance (Maharjan et al., 2009). The increase in wheat yield is contributed by the current climatic trends whereas increased summer rainfall and temperature suppressed the growth of yield of maize and millet. Also, in the case of change in yield of potato the positive impact of increased summer rainfall and increased minimum temperature is surpassed by negative impact of increased maximum temperature (Joshi et al., 2011).

2.7 Natural Disaster Trend and Impacts

Different regions of Nepal face different types of natural disasters. Some regions are prone to seismic hazards, and some are prone to floods, droughts, landslides and health hazards (Figure 2.6). In Figure 2.6 more than 55 districts out of 75 districts are prone to more than three types of hazards. Eastern Terai is prone to earthquake, floods and diseases hazards. Eastern mountains and hills are susceptible to rainfall landslides and earthquake-triggered landslides. Similarly, central region is prone to earthquake, landslides and diseases, and western region is prone to droughts, earthquake and landslides. There was a great earthquake in 2015 damaging around 9000 lives and million-dollars property in the history of Nepal (GoN, 2015).

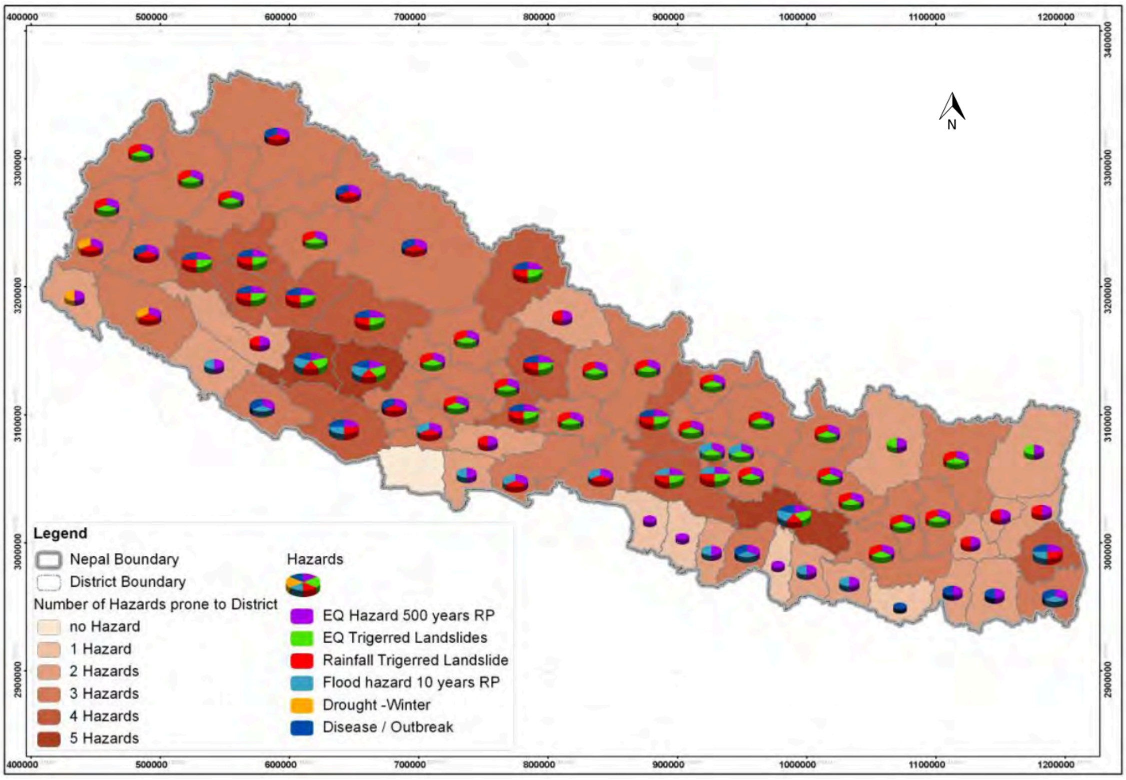

Figure 2.6 Natural hazards risk map of Nepal

Source: (World Bank, 2014)

An average annual loss of US$14.7 million was caused by floods, droughts and landslides, in between 2001 and 2007 (World Bank, 2014). These events are triggered by rapid snow and ice melt in the mountains as well as extreme, heavy rainfall episodes in the foothills during the summer (June-September). Droughts are becoming more frequent in Nepal, particularly during the winter months and the western Terai plains is already characteristically dry because of the late arrival of the monsoons. According to the UN's 2007 common country assessment for Nepal, epidemics such as cholera and diarrhea (diseases manifested from poor water quality) take the largest human toll every year. Water borne diseases are compounded by a lack of health facilities and medicines, widespread poverty, and a common lack of hygiene awareness (World Bank, 2016a).

Most of the top 10 disasters were caused by hydrological meteorological hazards with some of them occurring in the past decade (Table 2.6).

Table 2.6 Top 10 natural disasters in Nepal from 1980 to 2015 based on number of causalities

Rank	Disasters	Date	Number of causalities
1	**Earthquake**	**2015 April 25**	**8,831**
2	Epidemic	1991 June 15	1,334
3	Flood	1993 August 23	1,048
4	Flood	1996 July 12	768
5	Earthquake	1988 August 20	709
6	Flood	1981 September 29	650
7	Epidemic	1992 April 10	640
8	**Landslide**	**2002 July 15**	**472**
9	**Epidemic**	**2009 May 1**	**314**
10	**Flood**	**2014 August 11**	**294**

Source: (CRED, 2016)(as of September 27, 2016)

Most of the top 10 disasters with highest number of affected people were climate induced natural hazards, with three of them occurring in the past decade Table 2.7. There is a need to develop local climate change adaptation and mitigation strategies to strengthen the resilience of local people. Four of the top 10 economically most expensive disasters between 1980 and 2016 happened in the last decade (Table 2.8). Seven of these disasters were caused by climate related hazards. Millions of dollars in disaster losses can wipe out development gains and have significantly interfered with efforts for achieving the sustainable development goals, particularly reducing the extreme poverty and zero hunger mission by 2030.

Table 2.7 Top 10 natural disasters in Nepal from 1980 to 2015 based on number of people affected

Rank	Disasters	Date	Number affected
1	**Earthquake**	**2015 April 25**	**5,639,722**
2	Flood	2004 July 4	800,015
3	**Flood**	**2007 July 23**	**640,706**
4	Flood	1993 August 23	553,268
5	Flood	1987 August 10	351,000
6	**Drought**	**2009 December**	**303,000**
7	Earthquake	1988 August 20	301,016
8	Landslide	2002 July 15	265,865
9	**Flood**	**2009 October 4**	**257,786**
10	Earthquake	1980 July 29	240,600

Source: (CRED, 2016) (as of September 27, 2016)

Table 2.8 Top 10 natural disasters in Nepal from 1980 to 2015 based on economic damages

Rank	Disasters	Date	Total damage ('000 US$)
1	**Earthquake**	**2015 April 25**	**5174,000**
2	Earthquake	1980 July 29	245,000
3	Flood	1993 August 23	200,000
4	Flood	1987 August 10	95,490
5	Earthquake	1988 August 20	60,000
6	**Flood**	**2009 October 4**	**60,000**
7	Flood	1998 July 4	22,000
8	**Landslide**	**2014 August 2**	**15,000**
9	Flood	1983 September 1	10,000
10	**Flood**	**2000 June**	**6,300**

Source: (CRED, 2016) (as of September 27, 2016)

As Nepal is prone to seismic hazards, Nepal earthquake 2015 was one of the deadliest natural disasters in the history affecting huge number of people and inflicting the greatest economic losses. This is a true reality that a single disaster can affect hundreds thousands of people and billions of dollars and overwhelm national disaster management capacities. Hence, there is a need to develop and strengthen local disaster prevention, mitigation and recovery capacities to complement national capacities.

2.8 Adaptation to Climate Change

Adaptation is defined as “Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities” (IPCC, 2001). In other words, adaptation is a response to global warming and climate change, that seeks to reduce the vulnerability of social and biological systems to relatively sudden change and thus offset the effects of global warming (FAO, 2008). Adaptations vary according to the system in which they occur, who undertakes them, the climatic stimuli that prompts them, and their timing, functions, forms, and effects. In unmanaged natural systems, adaptation is autonomous and reactive; it is the process by which ecosystems respond to changed conditions. Adaptation depends greatly on the adaptive capacity of an affected system, region, or community to cope with the impacts and risks of climate change. The adaptive capacity of communities is determined by their socioeconomic characteristics. Enhancement of adaptive capacity represents a practical means of coping with changes and uncertainties in climate, including variability and extremes. In this way, enhancement of adaptive capacity reduces vulnerabilities and promotes sustainable development (Smit and Pilifosova, 2003). Adaptation is becoming complicated in practice as climate change and its impacts are faster than the natural process can sustain and they are interlinked with and embedded into a range of social, economic and political processes (Ayers and Huq, 2009). Hence, vulnerable communities need to respond to climate change without delay to enable them and their ecosystem to keep up with the on- going and potential changes in climate system. The ultimate goal of adaptation is to build long-term resilience of communities so that they are capable of sustaining their livelihoods even in extreme shocks and stresses.

Traditional and local knowledge is imperative while formulating adaptation plan at the local level. However, the planners and policy makers often neglect it heavily relying on the scientific knowledge. Traditional, ecological and local knowledge gives important insight in understanding environmental and social change (MacKendrick, 2009). Local knowledge adds up to the traditional ecological knowledge due to influencing factors like technology and other current factors (MacKendrick, 2009). Local knowledge provides information that can be useful in environmental decision-making, as a compliment to scientific knowledge, particularly in areas where extensive scientific knowledge may not exist (Gilchrist et al., 2005). Integrating local knowledge into scientific research offers opportunity to benefit the groups of people who hold it by engaging them in projects and assisting them in developing the end-products (MacKendrick, 2009).

2.8.1 Adaptation Practices in Nepal

Building adaptive capacity is now becoming the center of focus amongst adaptation and development communities. There is still no clarity on the direction to climate change adaptation, particularly on how it should happen and what the appropriate measures are. Different adaptation practices are followed by the people to combat with the changing climate using their traditional knowledge and skills. In the case of Nepal, agriculture is the main source of livelihood for more than half of the population. The major threats by climate change in Nepal seems to be disturbance of livelihood which is mainly by natural disasters like floods and landslides, decreases in water sources, long drought period, increase diseases in plant and livestock, and decrease in productivity.

The changes in different sector due to climate change has forced people to find measures in securing their livelihoods by adapting knowingly and unknowingly to these changes (Sharma and Dahal, 2011). In general, the adaptation practices followed by local people in Nepal is presented in Table 2.9 but this may not all be the response of the climate change but may be response to both climate changes as well as to the development factor occurring in the area.

The role of policy and institutions is crucial in enabling communities to use appropriate measures and access appropriate technologies, and to achieve adaptation and mitigation objectives. Similarly, policy and institutions play decisive roles in enhancing knowledge and skills for the successful use of approaches, processes and technologies. Climate change policy and program issued and implemented by Nepal will be discussed in the following sections.

Table 2.9 Climate change impacts and adaptation practices followed by local people in Nepal

Impacts	Local adaptation measures
Landslides	Stonewalls, afforestation
Droughts	Local irrigation canal *(Kulo),* Drill irrigation, Adoption of drought resistant cultivars
Decrease in agriculture production	Adoption of high yielding varieties, Develop skill for alternative livelihood, Cultivation of cash crops (Cardamom).
Food Security	Skill development for alternative income activities, Market facility
Appearance of mosquitoes and other harmful insects and related disease	Mosquito nets
Incidence of plant diseases	Local pesticides, Synthetic pesticides, Disease resistant varieties
Incidence of animal disease	Veterinary facility

Source: (Sharma and Dahal, 2011) and field observation 2014 - 2016

2.9 Climate Change Policy and Programs

2.9.1 Climate Change in International Regime

Addressing climate change issues is a critical for international law, which already is complicated to negotiate and difficult to execute. The foundation for the international climate change regime is the United Nation Framework Convention on Climate Change (UNFCCC), a treaty with practically global participation by governments. The UNFCCC was opened for signature in 1992 and assemble a sufficient number of ratifications to enter into force in 1994. It currently has 189 parties (Danish, 2007). The UNFCCC is the first step in the evolution of the climate change regulation, serving as a constitution. The UNFCCC does not set up a limit on GHG emissions for any countries; rather it forms a framework for further action and cooperation on the issue of climate change. The Kyoto protocol is a direct and formal outgrowth of the UNFCCC. The Kyoto protocol is the powerful point of international efforts to address global climate change and a significant milestone in the evolution of international environmental law. The Conference of Parties (COP) event under UNFCCC and the key elements are described in Table 2.10.

In sum, the UNFCCC is an international treaty joined by different countries to limit the rate of global temperature increase, deal with resulting climate change and cope with the impacts.

2.9.2 Climate Change Initiative in Nepal

Nepal has been the member of UNFCCC after signing in the Rio de Janerio in 1992 and later ratified the convention on May 1994. Then it came into force on 31st July 1994 (NAPA, 2010). Nepal prepared Initial National Communication report based on COP2 guidelines and setup National Climate Change Committee (NCCC) and four separate National Study Teams (NSTs) to prepare country response to climate change (MoPE, 2004). However, Nepal has been participating in the COP meetings regularly, it was not been able to raise national issue effectively in international arena due to initial less priority to climate change issue, lack of awareness, and lack of capacity for climate negotiation (Adapt-Nepal, 2014). Since COP-17, role of Nepal has been more active as they made a submission in NAPA, organized side event on Mountain Initiative and also opted for LDC coordinator in the UNFCCC process for the year 2013 and 2014 (MoE, 2010). In January 2013, Nepal became chair for Least Developed Countries (LDC) Group at United Nation (UN) climate change negotiation.

One of the major challenges for Nepal is implementation of Rio convention for which government began process of assessing institutional and individual capacity (MOSTE, 2014). Nepal prepared National Capacity Self-Assessment (NCSA) for Global Environment Management in 2008. In addition to that Nepal developed NAPA in 2010, climate change policy and Local Adaptation Plan for Action (LAPA) in 2011.

Table 2.10 UNFCCC conference of parties events

Date	Event	Place	Main outcomes/Comments
1995	COP-1	Berlin, Germany	Berlin Mandate adopted to develop a Protocol on emission reduction
1996	COP-2	Geneva, Switzerland	Geneva ministerial Declaration supporting climate change science endorsing IPCC second assessment report
1997	COP-3	Kyoto, Japan	Kyoto Protocol adopted
1998	COP-4	Buenos Aires, Argentina	Buenos Aires Plan of Action (BAPA) on negotiation to prepare the Kyoto Protocol to come into force
1999	COP-5	Bonn, Germany	Progress on rules and guidelines for Kyoto market-based mechanisms
2000	COP-6	Hague, Netherland	Final decisions on BAPA; negotiation failed to conclude and COP-6 suspended
2001	COP-6 COP-7	Bonn, Germany; Marrakesh, Morocco	Bonn Agreements adopted on final details of BAPA, apart from land use, land use change and forestry (LULUCF). Established three new fund: Special Climate Change Fund, Least Developed Country Fund, Adaptation Fund Marrakesh Accord to the Bonn Agreements adopted
2002	COP-8	New Delhi, India	Delhi declaration on climate change and sustainable development adopted
2003	COP-9	Milan, Italy	Decisions on LULUCF adopted, final piece of BAPA negotiation completed
2004	COP-10	Buenos Aires, Argentina	Adaptation was equally featured as mitigation (also known as adaptation COP)
2005	COP-11	Montreal, Canada	Finally adopted the Marrakesh accords, which enable operation of special climate change fund (SCCF), least developed countries fund (LDCF), adaptation fund

2006	COP-12	Nairobi, Kenya	Conference made little measurable progress
2007	COP-13	Bali, Indonesia	Roadmap for post-2012 climate regime was agreed, comprising the Bali Action Plan (BAP)
2008	COP-14	Poznan, Poland	Focused on paving road from Bali to Copenhagen, details on operationalization of Adaptation Fund discussed
2009	COP-15	Copenhagen , Denmark	Copenhagen accord drafted. Later submitted emission reduction pledges or mitigation action pledges
2010	COP-16	Cancun, Mexico	Cancun Agreement was drafted. Agreed to establish the Green Climate Fund for developing countries and also Cancun adaptation framework, reducing emission from forest deforestation and forest degradation (REDD) plus mechanism and Technology mechanism
2011	COP-17	Durban, South Africa	Durban platform for enhanced action accepted and also agreed on formation of National Adaptation Plan
2012	COP-18	Doha, Qatar	Doha Amendment to the Kyoto Protocol was adopted. Agreed to look at the possibility of looking into mechanism for loss and damage in future
2013	COP-19	Warsaw, Poland	Decision on advancing Durban platform, Green-Climate Fund, and Long-term finance, Warsaw Framework for REDD+ and the Warsaw International Mechanism for Loss and Damage
2014	COP -20	Lima, Peru	Accepted the Kyoto protocol Doha Amendment, New Climate action launched as part of Lima Climate Action Agenda
2015	COP-21	Paris, France	Adoption of the Paris Agreement, Reaffirm the goal of limiting global temperature increase will below 2 degree Celsius, while urging efforts to limit to the increase to 1.5 degrees

Source: Compiled from (UNFCCC, 2016) and (Shrestha, 2014)

The focus of NCSA project was identifying the priority issues for action and capacity needs within thematic area of biodiversity conservation, combating climate change and combating land degradation. For the preparation of NCSA three thematic working groups were formed based on working area with the help of Global Environment Fund (GEF) and UNDP (MOSTE, 2014). One of the main outcomes of NCSA project is that it was able to bring representative from different concerned authorities together (MOSTE, 2014). It also got an opportunity for the analysis of strength, weakness, opportunity and threat (SWOT analysis) in the capacity to address biodiversity conservation, adapt to and mitigate impacts of climate change, and to combat land degradation.

2.9.3 National Adaptation Program of Action (NAPA) 2010

As a requirement of UNFCCC for accessing the LDC fund for the most urgent and immediate adaptation needs, Nepal prepared NAPA in 2010. NAPA was developed with three components namely preparation and dissemination of NAPA document, development of Nepal Climate Change Knowledge Management Centre (NCCKMC) and Multi-stakeholder Climate Change Initiative Coordination Committee (MCCICC). NAPA process was began from May 2009 and completed in September 2010 though it was signed on November 14, 2008 (NAPA, 2010). NAPA is a strategic tool that assess climate vulnerability and identifies the immediate needs for adaptation and was formed by consultative process (MoE, 2010). Six thematic working groups (TWGs) were formed and were led by line ministries for the preparation of NAPA. The TWGs identified the nine integrated projects as an urgent and immediate national adaptation priority that are as follows (MoE, 2010).

1. Promoting community-based adaptation through integrated management of agriculture, water, forest and biodiversity.
2. Building and enhancing adaptive capacity of vulnerable communities through improved system and access to service for agricultural development.
3. Community-based disaster management for facilitating climate adaptation.
4. Glacial Lake Outburst Flood (GLOF) monitoring and disaster risk reduction.
5. Forest and ecosystem management in supporting climate-led adaptation innovations.

6. Adapting to climate challenges in public health.
7. Ecosystem management for climate adaptation.
8. Empowering vulnerable communities through sustainable management of water resource and clean energy supply.
9. Promoting climate-smart urban settlements.

NAPA is the first comprehensive climate change dedicated government document (HELVETAS, 2011; Shrestha, 2014). NAPA tried to link both the governmental policies and communities' needs by identifying the need of LAPA. NAPA is successful in generating discussion on immediate needs for adaptation to climate change, though there are some gaps. NAPA has prioritized on infrastructure from the viewpoint of adaptation to natural hazards but has not thought from the viewpoint of increasing resilience. It only identifies communities as major beneficiaries but does not clarify on the implementation strategy of the adaptation and fails to identify implementation partner. Additionally, it seems to identify the communities more from the perspective of sufferer but does not consider increasing community capabilities for adaptation. Also NAPA fails to acknowledge private sector as one of the important partner for implementing adaptation technologies. The broader criticisms of the NAPA document seems that its process is mainly dominated by center level government agencies, national NGOs, donor organizations representatives and relevant UN agencies (HELVETAS, 2011). This raises the question of participation of stakeholders at community level and their subsequent needs.

2.9.4 Climate Change Policy 2011

In March 2011, Government of Nepal formulated Nepal climate change policy 2011 in need to address the urgent response to climate change and in response to international climate regime (HELVETAS, 2011). Before formulating the policy, climate change was addressed in 2003 sustainable development agenda for Nepal and 2001 millennium development goals.

The vision of the climate change policy is "to envision a country spared from the adverse impacts of climate change, by considering climate justice, through the pursuit of environmental conservation, human development, and sustainable development—all contributing toward a prosperous society."

Further, main goal of climate change policy is to improve the livelihood by mitigating and/or adapting the adverse impact of climate change. For achieving the main goal it has the following targets.

- Establishment of climate change center.
- Initiation of LAPA.
- Preparation of national strategy for carbon trade.
- Formulation and implementation of low carbon economic development.
- Promotion of climate adaptation.
- Assessment of losses and benefits from climate change.
- Development of reliable impact forecasting system.

Further it deals with various policies in detail to meet the desired policy objectives, which are as follows:

- Climate adaptation and disaster risk reduction.
- Low carbon development and climate resilience.
- Access to financial resources and utilization.
- Capacity building, peoples' participation and empowerment.
- Study and Research.
- Technology development, transfer and utilization.
- Climate-friendly natural resources management.

In climate change policies, local communities are seen as the major stakeholders for adaptation and mitigation. However, it is also mentioned that local communities are entitled to 80% of the climate fund, its modality of implementation is still not clear and is in discussion. The policy is also suffering from the lack of the scientific researches regarding the impact of climate change. The policy governs the immediate activities listed in NAPA document and also recognizes natural hazards management as immediate need. There are few gaps that exist in the climate change policy especially in its implementation part. There has not been any separate laws and regulation for facilitating in the implementation of climate change policies until present. Climate change policy fails to give detail about working procedure in the community though it gives some implementing strategy and working policy (HELVETAS, 2011). The policy defines Ministry of Environment as the coordinating organization at functional level but does not talk about coordination with other ministries since Ministry of Environment does not have local organization at district and village level (Shrestha, 2014). Though it recognizes the risks associated with the implementation of policy, it fails to talk about managing those risks. However the policy documents are for implementing the climate change adaptation programs that are directed towards local community, there is information gap regarding climate change policy at local level. Thus looking from these perspectives, the policy documents seem to be driven from top to bottom and do not seem much accountability at local level along with significant gap in the implementation.

2.9.5 Local Adaptation Program of Action (LAPA) 2011

Nepal government has developed national framework for LAPA from the recommendation of NAPA with the view of supporting implementation of adaptation fund to local level (GoN, 2011). LAPA framework basically supports integration of climate resilience into local to national development planning process and outcomes. This is insured by bottom-up, inclusive, responsive and flexible approach. Basically the purpose of LAPA is described below. Each of these steps involves activities at the local level where it went down to VDCs and ward level for integrating climate change resilience in the development planning (HELVETAS, 2011; MoE, 2010).

- Enable communities to understand climate change and engage them in developing adaptation priorities.
- Implementing climate-resilient plans.
- Informing sectoral programmes and catalyzing integrated approaches between various sectors and sub-sectors.
- Climate vulnerability and adaptation assessment.
- Prioritization of adaptation options.
- Developing local adaptation plans for action.
- Climate change sensitization.

- Integrating local adaptation plans for action into planning processes.
- Implementing local adaptation plans for action.
- Assessing progress of local adaptation plans for action.

LAPA documents are inclusive, comprehensive and community centric but the implementation is still questionable as there has not been much progress after the formation of LAPA. Further, there has been addition of new dimension from many developmental organizations by making community based adaptation plan. This community based adaptation plan has focused communities more but has also added challenges of how it is going to be integrated in LAPA. LAPA framework has identified VDC and municipalities as the appropriate unit for integrating climate resilient local-to-national development planning process (GoN, 2011).

2.9.6 Foreign Assistance to Address Climate Change in Nepal

Foreign assistance plays an important role in the socio-economic development of Nepal. Nepal has been receiving the foreign assistance since 1952 after joining Colombo plan Cooperative, Economic and Social Development in Asia and Pacific (Bista, 2006; Sharma and Bhattarai, 2013). The major portion of Official Development Assistance (ODA) was received in the sector of transportation, power and communication till 2009 (Sharma and Bhattarai, 2013). But there has been increased in the proportion of ODA in the field of climate change and agriculture. There are 13 projects in operation in support of climate change programs in Nepal Table 2.11. The foreign assistance in Nepal is implemented by different developmental organizations in partnership with non-governmental organization, community based organizations and governmental bodies.

2.10 Food Security Policy and Programs

Number of policies have been formulated and implemented for development of agricultural sector and food security in Nepal. It has a comprehensive range of policies, strategies and initiatives to promote agriculture such as Agriculture Perspective Plan (APP) 1995, National Agriculture Policy (NAP) 2006, Agricultural Biodiversity Policy (2007) and Agri-Business Promotion Policy (2007). The government policy in regards to food security is to provide food items, in particular, rice to the food deficit area.

Table 2.11 Current climate change projects in Nepal

Project Title	Donors	Committed	Disbursed
Capacity building for strategic planning for municipal solid waste management including understanding of climate change and CDM	United Nations Human Settlements Programme	90,624	63,437
Strengthening capacity for managing climate change and the environment	Asian Development Bank	1,275,000	1,125,407
Improved capability to respond to increased risk of natural disasters related to climate change	Finland	645,245	691,592
Nepal climate change support programme	European Union, DFID	16,571,528	4,820,467
Cities and climate change initiatives	United Nations Human Settlements Programme	26,000	9,441
REDD-Forestry and climate change	World Bank Trust Funds	3,400,000	1,422,912
Enhancing capacities for climate change adaptation and disaster risk management for sustainable livelihoods in the agriculture sector	United Nations Development Programme	103,890	241,385
Initiative for climate change adaptation (ICCA)	U.S. Agency for International Development	2,000,000	750,000
Multilateral Climate change mitigation	World Bank AusAid	1,430,930	1,430,930
Capacity development for mainstreaming climate change risk management in development	Asian Development Bank	7,163,000	881,023
South Asia water initiative - climate change and water	AusAid	101,276	101,276
NCCSP	MoSTE, DFID	4,299,623	1,635,417
NCCSP: building climate resilience in Nepal	DFID, European Union	22,564,557	11,041,158

The interim constitution of Nepal 2007 has acknowledged food sovereignty as the fundamental right of people. Notably, promotion of agro-biodiversity and technologies for climate change is considered for long-term food security. It is also notable that MDG had given a high priority to invest in increasing food production and improving food security (United Nations, 2015). And currently sustainable development goal is also focusing on zero hunger strategy to enhance the food security of the poor and deprived population in the remote areas. Similarly, a Three Year Interim Plan (TYIP 2010/11-12/13) and the National Agriculture Sector Development Priority Plan (NASDP 2011-2015) have the following objectives for the agriculture and food security.

- To ensure food and nutrition security.
- To make agriculture sector competitive and business-oriented, with increased production and productivity.
- To reduce poverty by increasing employment and income generating opportunities in agriculture sector.
- To minimize adverse effects of environment, climate variability and climate change in the agriculture sector.
- To develop cooperatives for agriculture development.
- To develop human resources for the management of a sustainable agriculture development process.

2.10.1 Agriculture Perspective Plan (1995-2015)

The main policy document to modernize farming in Nepal is the Agriculture Perspective Plan (APP) (1995-2015). It focuses on poverty reduction, sustainable agricultural growth and a strong emphasis on technology inputs. It aims to increase agricultural growth by 3 percent per year. This growth is expected to stimulate non-agricultural growth in employment-intensive goods and services in both urban and rural areas. This would create job opportunities for the poor, particularly poor women, and thereby help increase incomes of rural households. The overall objectives of APP are as follows:

- Accelerate the growth rate in agriculture through increased factor productivity.
- Alleviate poverty and achieve significant improvement in the standard of living through accelerated growth and expanded employment opportunities.
- Transform agriculture from subsistence to commercial orientation through diversification and realization of comparative advantage.
- Expand opportunities for overall economic transformation by fulfilling the preconditions of agricultural development.
- Identify immediate, short-term and long-term strategies for implementation, and provide clear guidelines for preparing future periodic plans and programmes.

APP has emphasized the role of private sector in agricultural market. Its main strategy is to identify suitable production pockets in district level and concentrating all production inputs in the form of a single package. Even though APP is a long-term plan in agriculture, it has not made specific provision with respect to access of disadvantaged groups to productive resources particularly the land and other agricultural resources. Additionally, it has recommended extensive use of capital-intensive technologies such as hybrid seeds and improved breeds, chemical fertilizer in agriculture that leads to further marginalization of resource poor households. It has not paid much attention to conservation and promotion of traditional knowledge of farmers' which is the true strength of disadvantaged ethnic groups. Besides that, there are serious faults in implementation of this plan at district level due to lack of coordination and funding. Consequently, the impact of APP in terms of food security is disappointing at national as well as local level.

2.10.2 National Agriculture Policy 2004 (Rastriya Krishi Niti 2061)

National Agriculture Policy (NAP) is an official policy framework for all interventions. And it is supplemented and magnified by a range of specific sector policies. The NAP is seen as a means to achieve the goals of APP, rather than as a new strategic document, and focuses mainly on (i) increased productivity through technology improvements, (ii) a gradual shift towards commercialization of production, and (iii) natural resource base protection and disaster risk management. Although not explicitly stated, there is a strong emphasis in the NAP towards the creation of an enabling environment through improvement of Government capacity for service delivery. The NAP is supplemented by a number of specific sector policies and individual commodity policies, some of which are: (a) National Seed Policy 2000), (b) National Fertilizer Policy 2002, (c) National Irrigation Policy (2003), (d) National Water Plan (NWP 2005), (e) Agri-business promotion policy (2006), (f) Agriculture Bio-diversity Policy (2007), (g) Nepal MDG Progress Report (Draft 2010) by NPC, and (h) Nepal Master Plan for the Forest Sector (25 year plan 1989 – 2014) (i) Sustainable Development Goals (SDGs) (2015-2030).

The main objectives of the policy are:

- to accelerate agricultural growth through increased use of improved technology,
- to develop commercial and competitive agriculture production system,
- to promote, utilize and conserve biodiversity and natural resources.

The main emphasis of the policy is on commercialization of agriculture. Like APP this policy is also has not mentioned about the access of land and other natural resources to poor and disadvantaged communities. Disparity in land distribution between rich and poor, conflict on land ownership, lacks of responsive land use policy are posing challenges to ensure access and control of land and land based resources by the poor households. But both of these policy documents fail to adequately realize this fact. As a result, both APP and Agriculture Policy 2004 seem to be ineffective to tackle growing food insecurity problems of the country particularly due to poor commitment of the government to bring genuine reforms in this sector.

2.10.3 National Agriculture Sector Development Priority Plan (NASDP) (2011-2015)

Nepal government developed a National Agriculture Sector Development Priority Plan (NASDP) in 2010 acknowledging the need to expand the level of detail of the NAP covering the medium term period from 2011 to 2015. The NASDP also covers analysis of key issues and challenges confronting agriculture as articulated in the TYIP (2010/11-12/13). The NASDP focuses on seven priority outcomes.

- Enhanced food and nutrition security.
- Improved agricultural technology.

- Improved market orientation and competitiveness.
- Improved enabling environment.
- Sustainable natural resource conservation and use.
- Improved infrastructure support facilities.
- Adaptation to the effects of out-migration including feminization of agriculture.

The NASDP also supports the achievement of the millennium development goals and attempts to harmonize technical services related to MDG1 and MDG 7.

2.10.4 Nepal Constitution 2015

Nepal Constitution 2015 is the main legal and political document that governs all policies, practices and programs in the country. The constitution includes provisions that protect economic, social and cultural rights of citizens. Article 34 of the constitution under fundamental rights and duties, emphasizes on right to food as follows.

1. Each citizen shall have the right to food.
2. Every citizen shall have the right to be protected from a state of starvation, resulting from lack of foodstuffs.
3. Every citizen shall have the right to food sovereignty as provided for in law.

Besides, constitution protects the right to clean environment, right to employment and social security of the citizens. It emphasize that each person shall have the right to live in a healthy and clean environment. Similarly, under the directive principles, policies and responsibilities of the state, increasing investment in the agricultural sector by making necessary provisions for sustainable productivity, supply, storage and security, while making it easily available with effective distribution of food grains by encouraging food productivity that suits the soil and climate conditions of the country in accordance with the norms of food sovereignty.

Despite the fact that the constitution has several progressive provisions that safeguard the rights of the citizens to be food secured, the government has yet to make concrete strategy or institutional framework to address the recurrent problems of food insecurity and hunger.

3 Chapter 3 Climate Variables and Crop Yield Relationships

This chapter identifies the relationship between climate variables and crop yield in Lamjung district Nepal. For this purpose temperature, precipitation and crop yield data of last thirty years were analyzed. This chapter essentially describes the research findings of climate variables trends, crop yield trends and key informants interviews. The research process starts with KIIs to understand the changes in rainfall, temperature, snowfall and crop production in the study area. Then trends of climate variables and crop yields were identified through Man Kendall and Sen`s Slope method, correlation and multivariate regression analysis were preformed to find the relationship between climate variables and crop yields.

3.1 Introduction

In the mountainous country of Nepal, more than 60% of the population is dependent on agriculture, which contributes 35% of the gross domestic product (CBS, 2013). Based on this statistic, it is clear that growth and development in the agricultural sector has a direct contribution on the national economy and livelihood of the people. Several crops can be cultivated in Nepal; however, five major crops, *i.e.*, rice, maize, wheat, millet and barley, dominate the agricultural sector (Gumma et al., 2011). These crops represent more than 90% of the total grain production and cultivated area in Nepal (Gumma et al., 2011) however there is a variation in the yield of these crop during the last few decades Figure 3.1. Rice and millet are the major summer crops, maize is a spring/summer crop, and wheat and barley are the winter crops (Appendix 1). Among them, rice and maize are the primary crops that contribute more than half of the total food grain production of Nepal and are grown from the lowlands in the Terai (70 meters above sea level) through high hills (2830 meters above sea level) (MOAC, 2010). Thus, the study of the various impacts of climate change on these crop yields is urgently required for planning the future food availability in the country.

According to 5th assessment report of the Intergovernmental Panel on Climate

Change (IPCC, 2014), compared to the 20th century, the average annual temperature will rise by more than 2°C in most of the South Asia by the mid of 21st century, and by the late of 21st century, the temperature increases will exceed 3°C and as much as 6°C in high altitudes under a high-emission scenario. Similarly, under a low-emission scenario, the average temperature will rise by less than 2°C in the 21st century, but at higher altitudes, the temperatures will rise by as much as 3°C. It is anticipated that the increasing rate of the average temperature in the Himalaya will be greater than the global average. The increasing temperatures may affect the timing and quantity of precipitation, which would consequently change the water availability (Mishra et al., 2014a).

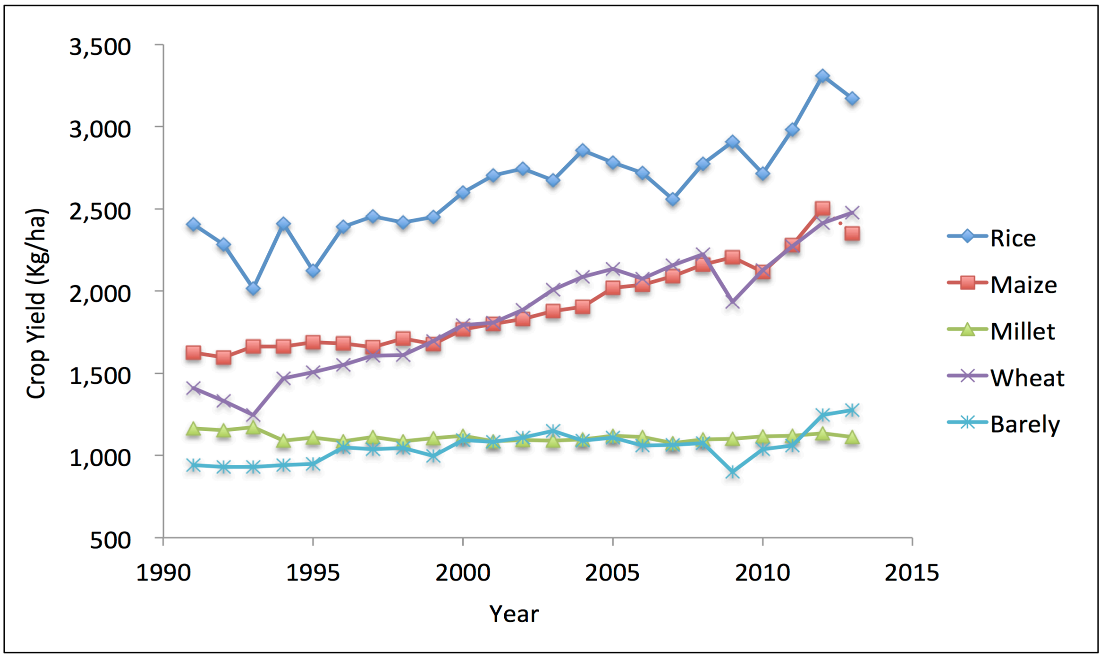

Figure 3.1 Major agricultural crop yields from 1990 to 2013 in Nepal

Source: (MOAD, 2013)

Several studies have shown that the rate of temperature increase is higher at higher altitudes (Baidya et al., 2008; Chaulagain, 2009; Immerzeel, 2008). Changing temperatures and erratic rainfall pattern are affecting crop production in Nepal (Malla, 2008). Similarly, the loss of local crops and domestic animals, changes in cropping patterns, scarcity of water due to the drying up of water resources, and increasing incidences of diseases and pests have also been observed (Panthi et al., 2015; Regmi and Adhikari, 2007). Due to its heterogeneous topography, there is a high risk of natural disasters, such as GLOFs, avalanches, landslides, *etc.*, in the higher altitudes and floods in the lower region. Hence, mountainous countries such as Nepal are more vulnerable to climate change (Maplecroft, 2010).

There is ample evidence to link the increase in extreme weather events, such as droughts and floods, with agricultural production. Due to the winter drought in 2008/2009, there was a huge loss in agricultural production in Nepal (Sheikh et al., 2015). Because of the erratic monsoon weather conditions in India during 2009, the production of the main crops decreased, resulting in food crises in neighboring countries (MOAC, 2010). Wassmann (Wassmann et al., 2009) also argued that small household farmers, especially in marginalized regions of Asia, experience most of the negative effects of climate change because agriculture is adversely impacted in this region (Poudel and Shaw, 2015).

In Nepal, a majority of the area is covered by hills, high mountains and lowland areas; therefore, there is a huge variation in weather. Similar changes can have different consequences at different altitudes. As the temperature increases, the higher mountainous areas may benefit, whereas lowland areas may suffer badly. Some studies have shown that the impact of global warming in the mountainous area could have a positive impact for some vegetables and crops, such as tomato, cauliflower, wheat, maize, and rice (Dahal, 2005; Mishra et al., 2014a). However, the decreasing winter precipitation may have an adverse impact on winter crops, which need more water or irrigation facilities.

Shrestha (Shrestha et al., 2012) said that the growth and development of plants, outbreaks of pests and diseases, and water availability could be affected by changes in the temperature and precipitation patterns, thereby eventually affecting crop yields. Climate change will have a significant impact on agriculture, primarily through its effect on crop yields (Alexandrov and Hoogenboom, 2001; Wang et al., 2014). Most of these studies seeking to understand the physical effects of climatic variables on crop yield were conducted through crop simulation models. However, small changes in the climatic variables, specifically in temperature, are often excluded (Schlenker and Roberts, 2008). Therefore, regression models based on historical yield data and climate data are relatively accurate for the prediction of changes in the yield due to climate change (Boubacar, 2012; Lobell et al., 2005; Lobell and Field, 2007).

Based on the climate change vulnerability, overall risk exposure and sensitivity data provided by the Nepal Government, Lamjung district, one of the 75 districts of Nepal, was selected. Lamjung is ranked as high risk in terms of climate change impacts (MoE, 2010). High risk in the sense that minimum and mean temperature-increasing trend was higher in all seasons in Lamjung from 1976 to 2005 (Tables 3.1 and 3.2). According to the report, the risk of flash floods, landslides, and GLOFs in Lamjung is also very high.

Table 3.1 Districts with high increasing and decreasing trends in annual temperature from 1976 to 2005

Annual temperature	**High increasing trend**	**High decreasing trend**
Maximum	Dhankuta, Dadeldhura and Okhaldhunga	Sankhuwasabha, Sunsari, Nawalparasi, Banke, Bardia
Minimum	**Lamjung,** southern parts of Nuwakot, Chitwan and Dhanusa	Doti, Sankhuwasabha and Nuwakot
Mean	Dhankuta and **Lamjung**	Sankhuwasabha, Doti and Nuwakot

Source: (Practicle Action, 2009)

Therefore, climate changes will also likely to have a significant impact on the crop yield in this district; thus, a detailed study is required for this region. Hence, this study focuses on understanding how the climate is changing and discusses its impact on crop yields in a mountainous region of Nepal. The objectives of this study, therefore, include time series analysis of precipitation, temperature and yield of selected crops. Similarly, to explore the impact of climate change on crop yield, the relationship between yield and climatic variables are also analyzed through a regression model of climate and crop yield anomalies.

Table 3.2 Regions with high increasing and decreasing minimum temperature trend in different seasons from 1976 to 2005

Seasons	High increasing trend districts/areas	High decreasing trend districts
Spring	**Lamjung**, Manang, Dhanusa	Doti, Nuwakot, Sankhuwasabha
Summer	**Lamjung**, Dhankuta	Doti, Manang, Nuwakot, Sankhu- wasabha
Autumn	Southern Nuwakot, **Lamjung,** Makawanpur, Syangja, Morang	Doti, Sankhuwasabha, Gorkha, northern Nuwakot
Winter	Southern Nuwakot, **Lamjung,** Banke, Makawanpur, Kailali, Dhanusa	Doti, Sankhuwasabha, Dolakha, northern Dang, Dadeldhura, Manang

Source: (Practicle Action, 2009)

3.2 Data and Method

3.2.1 Data

The research primarily depends on datasets that were obtained from several government departments and local agencies. Similarly, key informant interviews (KIIs) were conducted with local people and relevant government and non-governmental organizations regarding climate change and impacts on crop yield in Lamjung.

Climatic Datasets

Data from one meteorological and two rainfall stations are available in Lamjung. The meteorological station records the daily maximum temperature, minimum temperature, and accumulated precipitation; the rainfall stations also record daily-accumulated precipitation. All the data were available from 1980 to 2012. These datasets were obtained from the Department of Hydrology and Meteorology of the Government of Nepal. The summary of the climatic datasets is depicted in Table 3.3.

Table 3.3 Considered climatic data

Stations	Elevation (m)	Latitude (N) and longitude (E)	Climate variables	Duration (Monthly)
Gharedhunga	1,120	(28°28`, 84°35`)	Precipitation (mm)	1980-2012
Khudi	855	(28°12`, 84°34`)	Precipitation (mm) and temperature (°C)	
Kunchha	823	(28°15`, 84°55`)	Precipitation (mm)	

Source: Department of Hydrology and Meteorology, Nepal

Agricultural Datasets

Five major crops—rice, maize, millet, wheat and barley—were selected for this study because these crops contribute more than 80% of the total grain production in Lamjung. These data were obtained from the Ministry of Agricultural Development, Nepal. They collected the data from the District Agriculture Development Office Lamjung, Nepal. The crop cultivation, growth and harvesting periods presented in Table 3.4 were provided by the (MOAD, 2013).

Table 3.4 Considered crops and cropping period

Crops	Cultivation period	Frequency	Data available
Rice	From June to November	Annual	1970-2013
	April to August		
Maize	From May to August		
Wheat	From November to March		
Millet	From July to December		
Barley	From November to March		

Source: Ministry of Agricultural Development, Nepal

Key Informant Interviews

The field survey in Lamjung was conducted through KIIs. Each KII was designed to collect qualitative information on the community`s perception of climate change and experience of extreme weather events, such as erratic rainfall, floods, droughts, landslides, and so on. It was conducted with a selected representative from the Nepal Agricultural Research Council (NARC), District Agriculture Development

Offices, Ministry of Agricultural Development, Department of Hydrology and Meteorology, non-governmental organizations, local leaders, women's groups, and farmer groups.

3.2.2 Trend Analysis

The seasonal and annual trends were analyzed for the following climate variables:

- Temperature (seasonal and annual maximum and minimum at Khudi station).
- Precipitation (seasonal and annual accumulated quantities at Gharedhunga, Khudi, and Kunchha stations).
- Yield of rice, maize, millet, wheat and barley.

The existence of positive or negative trends among all the considered variables was determined using nonparametric trend test methods. The Mann–Kendall trend test is a nonparametric rank-based procedure, robust against the influence of extremes. In particular, this technique can be adopted in cases with non-normally distributed time series data, that is, data containing outliers and nonlinear trends (Karpouzos et al., 2010; Partal and Kahya, 2006). A Mann–Kendall test with a 90% confidence limit was used as a monotonic trend test. In the testing process, the null hypothesis (H_0) is that there is no trend in the population from which the dataset is drawn. The alternate hypothesis (H_1) is that there is a trend in the population. The H_0 will be rejected if $p \leq 0.1$.
Similarly, the trend was quantified using Sen's slope method. Sen's slope is another index to quantify the trend using the nonparametric procedure developed by Sen (Sen, 1968). The slope is computed using Equation 3.1.

$$Q_i = \frac{x_j - x_k}{j - k} \qquad \text{for i = 1,2,3....N} \qquad (3.1)$$

Where x_j and x_k are data values at time j and k (j > k), respectively. The median of these N values of Q_i is Sen's estimator of slope. If N is odd, then Sen's estimator is computed by Q_{med} = Q (N + 1)/2, and if N is even, the Sen's estimator is computed by Q_{med} = [QN/2+ Q (N + 2)/2]/2. Finally, Q_{med} is tested by a two-sided test at a 100% (1 – α) confidence interval, and the true slope is obtained.

3.2.3 Climate-Crop Yield Relationship

Correlation coefficient and multivariate regression analyses have been performed to determine the climate-crop yield relationship using the Statistical Package for Social Sciences (SPSS). The Pearson's correlation coefficient was used to measure the strength of the association between crop yield and climatic variability. This produced a linear association. The range of correlation coefficients is −1 to +1. The complete dependency between two variables is expressed by either −1 or +1, and 0 represents the complete independency of the variables. The calculation of the correlation coefficient is performed using Equation 3.2, in which *x* represents the independent variable and y represents the dependent variable.

$$r = \frac{\Sigma(x - x)(y - y)}{\sqrt{\Sigma(x - x)^2 \ (y - y)^2]}} \qquad (3.2)$$

Multivariate regression analysis of climate anomalies and crop yield anomalies has been performed to confirm the percentage of the response variable variation from the predictor variable that is explained by a linear model in Equation 3.3:

$$\Delta Y = \text{constant}+(\alpha \times \Delta Ppt) + (\beta \times \Delta Temp_{min}) + (\gamma \times \Delta Temp_{max}) \qquad (3.3)$$

Where ΔY is the observed change in the yield due to temperature and precipitation in the same season as crop growth and α, β, and γ are coefficients of the precipitation, minimum temperature and maximum temperature during the season, respectively. Similarly, Δppt, $\Delta Temp_{min}$, $\Delta Temp_{max}$ are the observed changes in precipitation, and minimum and maximum temperatures of the seasons, respectively, during the study period. The overall workflow diagram for this study is presented in Figure 3.2.

3.3 Results and Analysis

The seasonal and annual trend analysis of accumulated precipitation and seasonal and annual maximum and minimum temperatures have been analyzed using Sen's Slope and Man–Kendall methods. Similarly, trend analysis of the crop yield and the relationship with the climatic variables has been performed. Regression analysis was carried out between annual crop yield anomalies and climate anomalies. The detrended time series data for seasonal maximum temperature, seasonal minimum temperature and seasonal precipitation for respective crop cultivation seasons were considered the explanatory variables, and detrended crop yield was considered the dependent variable.

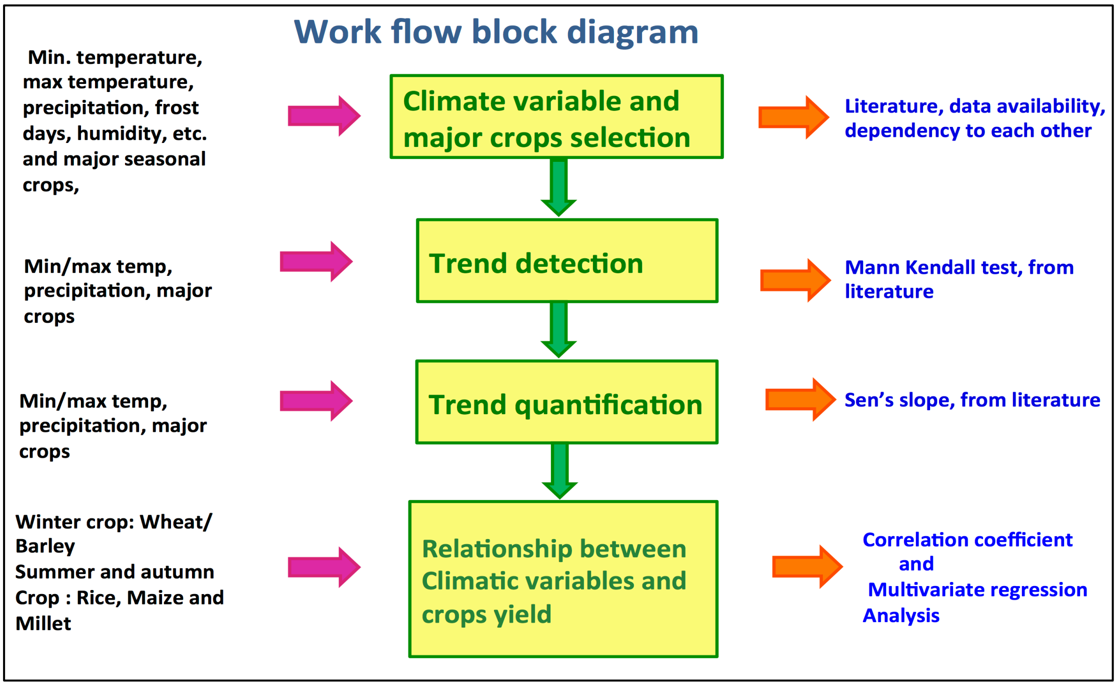

Figure 3.2 Overall workflow diagram

3.3.1 Precipitation Trend

The total annual precipitation from 1980 to 2012 for three stations was analyzed using the Mann–Kendall and Sen's slope tests. The total annual precipitation at the Kunchha and Gharedhunga stations increased by 10.48 mm/yr and 4.42 mm/yr, respectively, whereas at the Khudi station, it decreased by 3.47 mm/yr (Figure 3.7). Table 3.5 depicts the Sen's slope value of seasonal precipitation for all three stations in Lamjung. The result is somewhat similar to the results obtained in the Kaligandai basin, the basin next to Lamjung (Mishra et al., 2014a). Additionally, several other studies have revealed that the precipitation trend in Nepal varies due to the interaction of heterogeneous topography with the monsoon and westerly wind systems (Practicle Action, 2009).

Precipitation exhibited a decreasing trend during winter (Figure 3.3), at all three stations, mixed trends during the spring (Figure 3.4) and autumn (Figure 3.6), and an increasing trend during summer (Figure 3.5). The negative trend results in December precipitation were significant ($p < 0.1$), reflecting the changes in the winter precipitation.

Table 3.5 Sen`s slope value of seasonal precipitation of three stations

Season	Gharedhunga			Kunchha				Khudi		
	Sen's slope	P-value	Significance	Sen's slope	P-value	Significance	Sen's slope	P-value	Significance	Alpha value
Winter	0.4313	0.0004	Yes	0.4165	0.0120	Yes	0.4314	0.0221	Yes	0.1
Spring	1.5212	0.0914	Yes	2.1332	1.2755	No	1.6916	0.8807	No	0.1
Summer	2.9624	0.0717	Yes	4.4342	0.0557	Yes	5.7511	0.9701	No	0.1
Autumn	1.1888	0.2227	No	1.4964	0.4092	No	1.5178	0.0181	Yes	0.1

90% confidence level

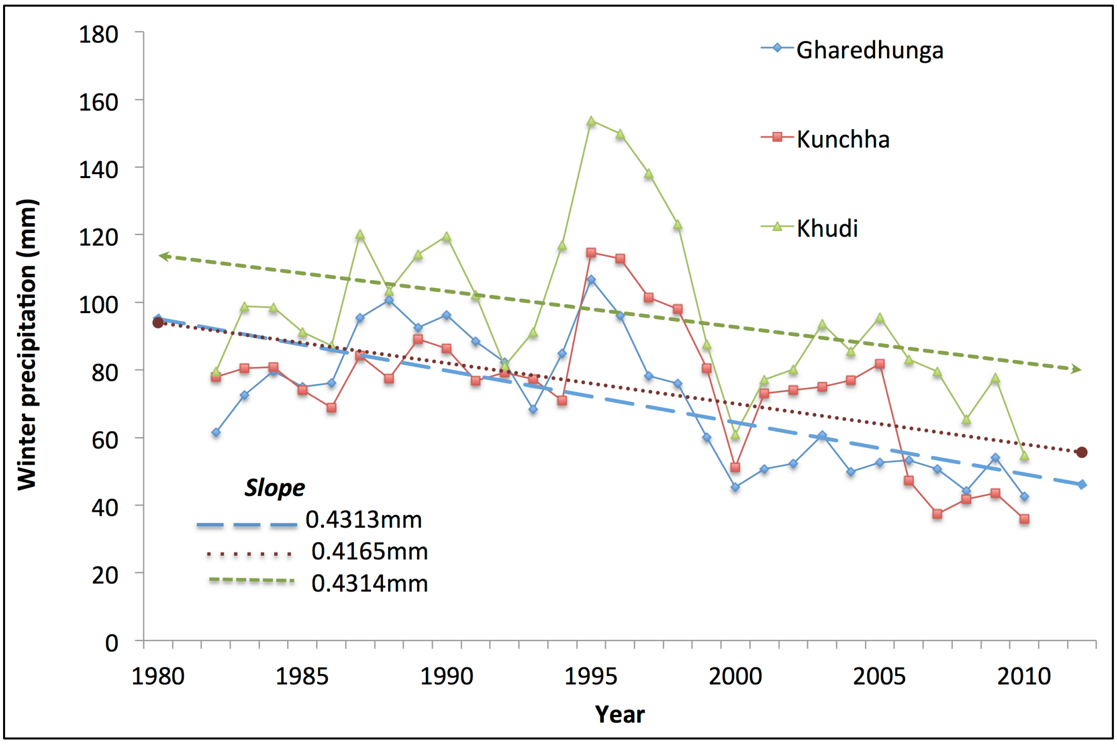

Figure 3.3 Winter precipitation trends at Gharedhunga, Kunchha and Khudi stations from 1980 to 2012

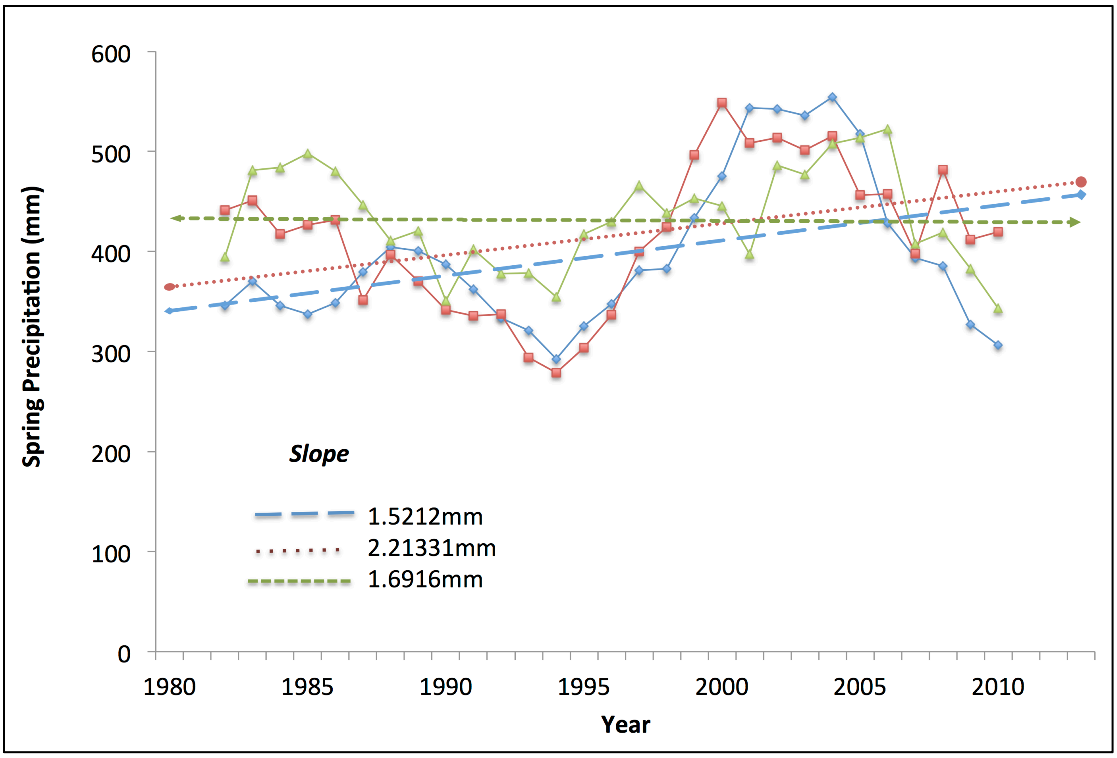

Figure 3.4 Spring precipitation trends at Gharedhunga, Kunchha and Khudi stations from 1980 to 2012

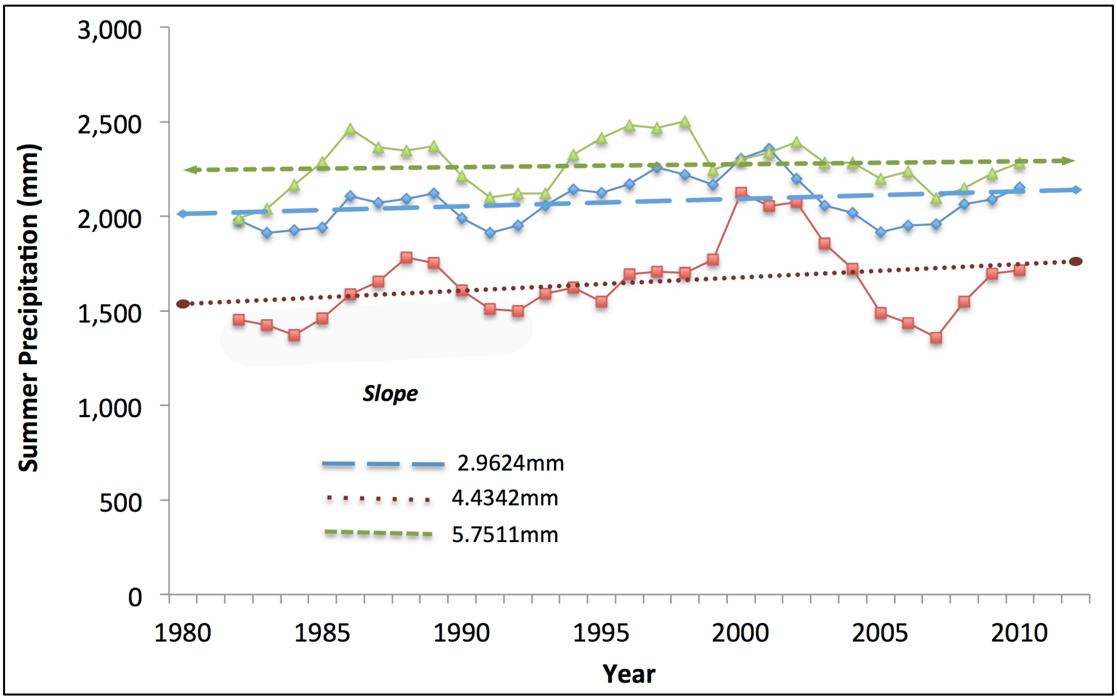

Figure 3.5 Summer precipitation trends at Gharedhunga, Kunchha and Khudi stations from 1980 to 2012

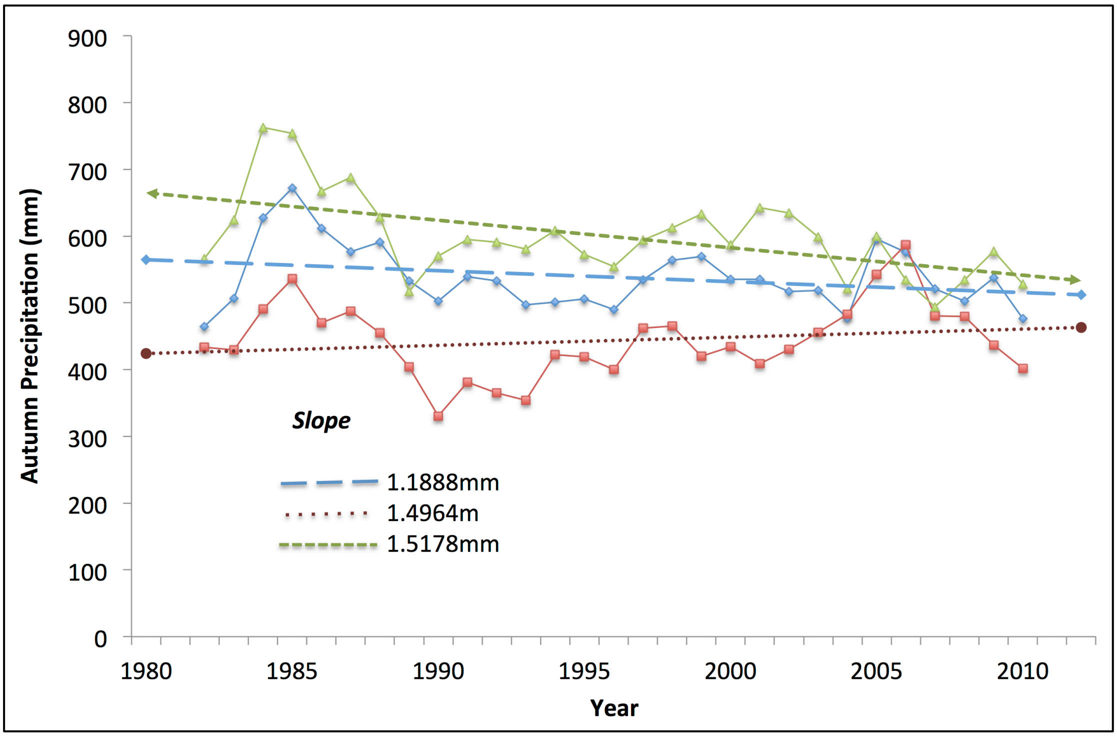

Figure 3.6 Autumn precipitation trends at Gharedhunga, Kunchha and Khudi stations from 1980 to 2012

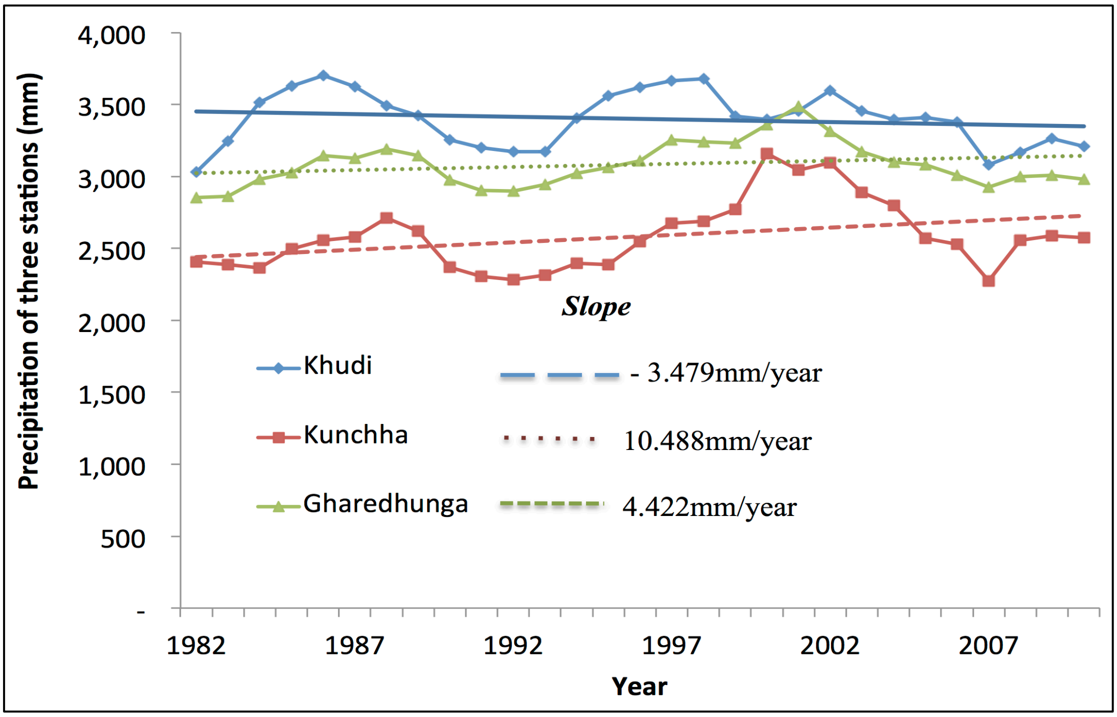

Figure 3.7 Annual precipitation trends at Gharedhunga, Kunchha and Khudi stations from 1980 to 2012

3.3.2 Temperature Trend

The minimum and maximum values of the seasonal and annual temperatures of Khudi station have been analyzed in this study. The widely used nonparametric method (Man–Kendall test) was adopted to determine the significance of the trend, and it was quantified using Sen's slope. The overall results are presented in Table 3.6. The maximum annual temperature increased by 0.02°C/yr, whereas the minimum annual temperature increased by 0.07°C/yr between 1980 and 2012. Although both the minimum and maximum temperatures increased, the increasing rate of the minimum temperature was more than three times faster than that of the maximum temperature. The slope of the rate and the value of the change in seasonal and annual maximum and minimum temperatures are shown in Figures 3.8 and 3.9, and Table 3.6. According to Shrestha (Shrestha et al., 1999), the maximum air temperature has increased since 1978, based on an analysis of 49 stations across Nepal from 1971 to 1994. Similarly, Practical Action Nepal (Practicle Action, 2009) found an increasing trend in maximum air temperature across almost the whole country.

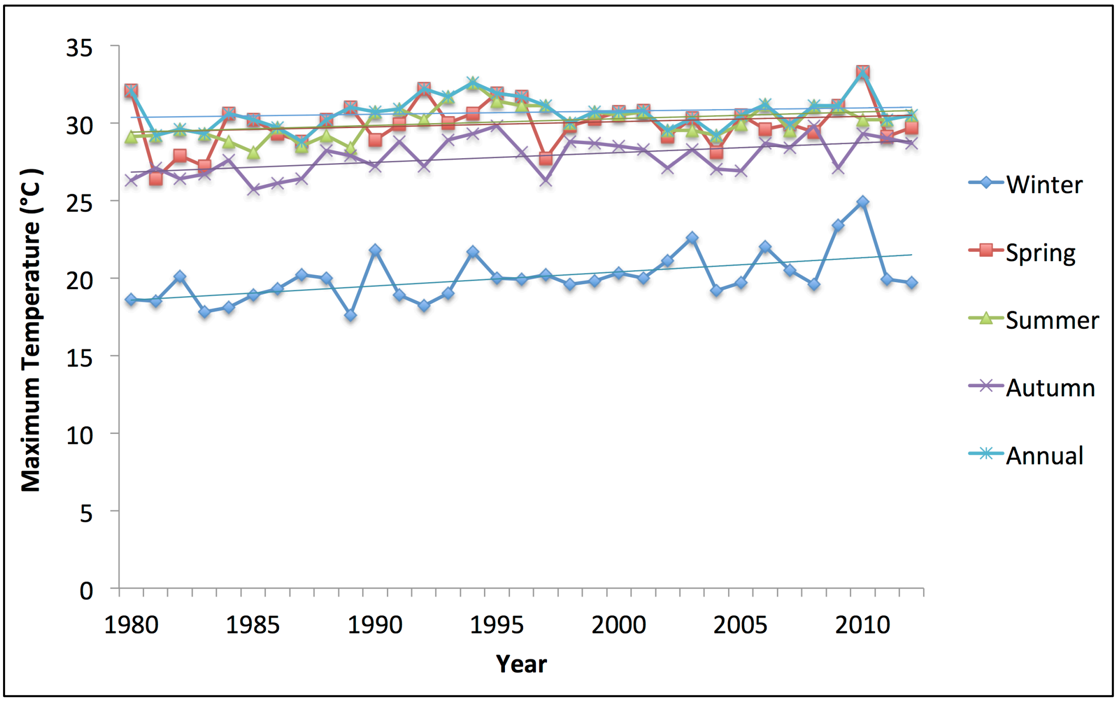

Figure 3.8 Seasonal and annual maximum temperature trends at the Khudi stations from 1980 to 2012

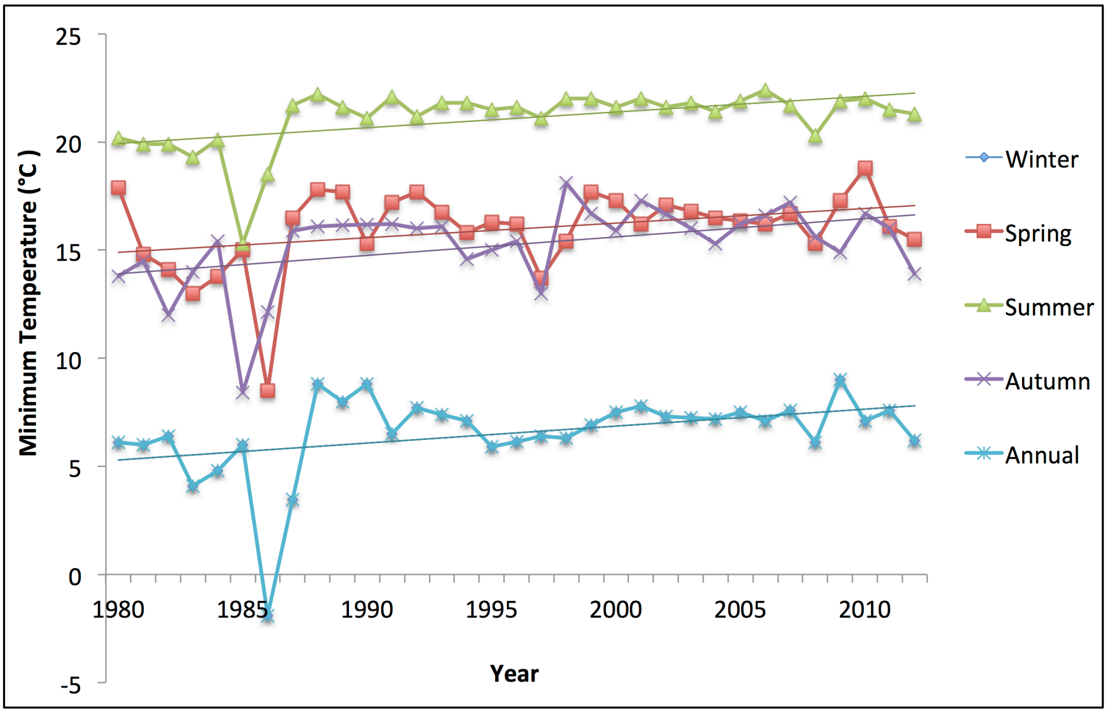

Figure 3.9 Seasonal and annual minimum temperature trends at the Khudi station from 1980 to 2012

Table 3.6 Sen`s slope value of the seasonal and annual temperature of the Khudi station

Season	Maximum temperature			Minimum temperature			Alpha value
	P-value	Sen's slope	Significance	P-value	Sen's slope	Significance	
Winter	0.004	0.079	Yes	0.053	0.051	Yes	0.1
Spring	0.212	0.039	No	0.119	0.057	No	0.1
Summer	0.082	0.039	Yes	0.024	0.04	Yes	0.1
Autumn	0.010	0.06	Yes	0.036	0.055	Yes	0.1
Annual	0.133	0.02	No	0.0001	0.07	Yes	0.1

90% confidence level

3.3.3 Crop Yield Trend

The yield trend of summer and winter crops, *i.e.*, maize, wheat and barley, showed that the yield of these crops has changed significantly over time ($p < 0.05$). However, the yield has fluctuated over time. Wheat had the highest regression coefficient *versus* time. The yield of wheat increased 26.83 kg/ha every year. In contrast, barley decreased (1.20 kg/ha) every year. Similarly, maize yield increased ($p < 0.05$) 16 kg/ha every year, whereas rice and millet yield increased 4.71 kg/ha and 0.26 kg/ha every year, but these changes were not significant ($p > 0.05$) with respect to the time variable. Figure 3.10 shows the trends and Table 3.7 indicates the Sen's slope value of the crop yields in Lamjung.

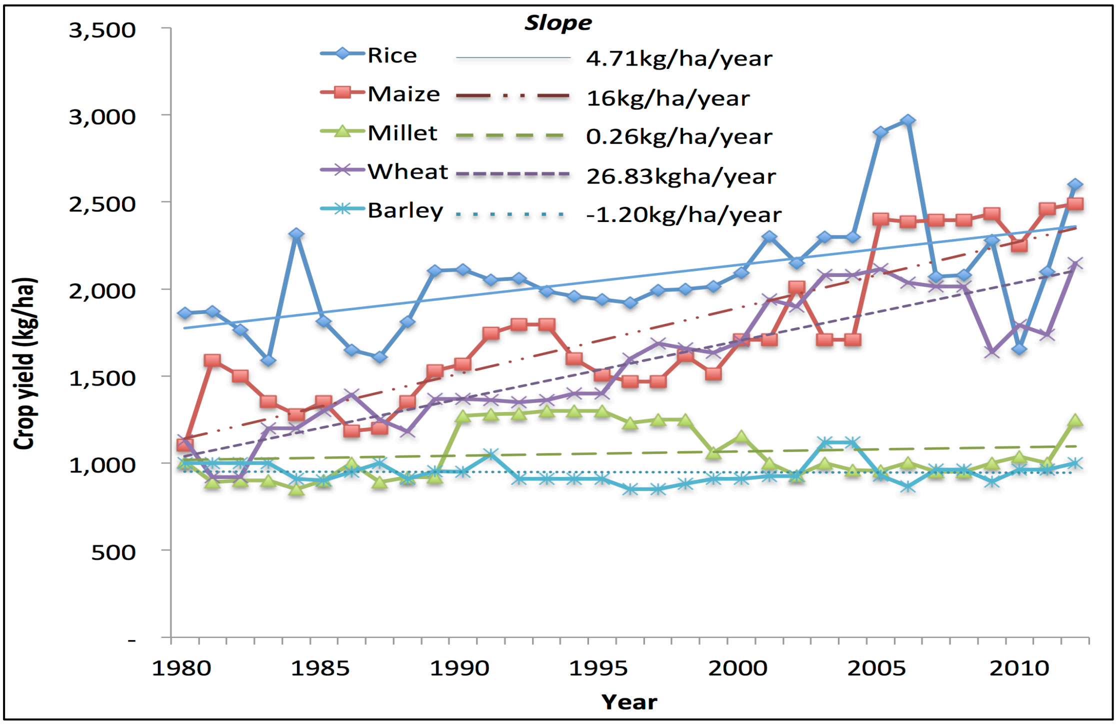

Figure 3.10 Crop yield trends for rice, maize, millet, wheat and barely from 1980 to 2012

The pattern of the crop yield in Lamjung appears to be very similar to the pattern throughout the whole country. Pant (Pant, 2012) revealed that the yield of rice, maize and wheat increased by 1.18%, 2.36% and 3.39%, respectively, from 1990 to 2010 all over the country. Similarly, Joshi (Joshi et al., 2011) detected a significant increasing trend for rice, maize and wheat. Hence, the yields of the major crops are increasing in Nepal. In addition to climate change, several influential factors, such as introduction of new seeds and agriculture technology, better irrigation, and better crop management practices, might be responsible for the increased crop yield. Therefore, we have tried to determine the climate-yield relationship and yield variation due to climate change in the following section through correlation and multivariate regression analysis.

Production trends for the main crops in Nepal show a relatively stable increase in area cultivated, production and yields except in the context of barley and millet. Millet yields have been relatively stable after reaching a peak in 1999 with cultivated area and production largely unchanged. In contrast, barley production has been decreasing consistently since 1996 due to a combination of two factors. On the one hand, a number of recurring winter droughts in key production areas which have forced farmers to identify alternative crops (Regmi, 2007). On the other hand, barley is less preferred crop compared with other crops, so farmers have diversified into other crops as soon as alternatives become viable (WFP, 2010).

Table 3.7 Quantification of the crop yield trend with Sen`s slope value

Crops	P-value	Sen's slope	Significance	Alpha value
Rice	0.297	4.71	No	0.05
Maize	0.003	16	Yes	0.05
Millet	0.761	0.267	No	0.05
Wheat	0.0001	26.837	Yes	0.05
Barley	0.029	-1.203	Yes	0.05

95% confidence level

3.3.4 Climate-Crop Yield Relationship

To determine the relationship between climatic variability and major crop yields (kg/ha), a correlation analysis was performed. The results reveal that there was a strong and positive relationship between the climatic variability and the yield of millet and wheat, whereas there were no or negligible relationships between climatic variability and the yields of rice, maize and barley. While testing the effects of seasonal minimum and maximum temperatures, a significant relationship was observed in the yield of millet. There was a strong correlation between millet and the seasonal maximum temperature (r = +0.734), and a normal correlation with minimum temperature (r = +0.336). The yield of millet increases with increasing maximum and minimum temperatures. There was no significant effect of precipitation on the yield of millet (r = +0.069). Similarly, the coefficient of maximum temperature was +0.4023, indicating a positive relationship between the annual maximum temperature and the yield of wheat. The coefficients for minimum temperature and precipitation were +0.2539 and −0.033, respectively. The correlations between the climatic variables and the crop yields are depicted in Appendix 2.

3.3.5 Changes in Yield due to Climate Trends

To test whether there is a direct relationship between climatic variables and crop yields in Lamjung, a multi-linear regression analysis between anomalies of mean yields for maize, rice, wheat, barley and millet, and precipitation and air temperature during the current climatic conditions (1980 to 2012) was performed. The anomalies of each climatic variable and crop yield were computed using the first-difference time-series, *i.e.*, the difference in values from one year to the next. Figure 3.11a shows the summer crop yield anomalies, and Figure 3.11b depicts the winter crop yield anomalies.

A multivariate regression model was used to confirm the impact of climate change on crop yield. The anomalies in climate variables and crop yields can be used to estimate the quantitative relationships between climate change and crop yield. The non-climate influences, such as introduction of agro-technology, better seeds, better crop management practices, use of fertilizer, *etc.*, were omitted when computing the respective anomalies.

Linear relationships between detrended crop yield, *i.e.*, yield anomalies in Lamjung, and anomalies in climate variables, such as air temperature and precipitation, were developed to determine the crop yield change due to changes in climate variables during the study period. These relationships were derived as follows:

$$\Delta Y = \text{constant} + (\alpha \times \Delta Ppt) + (\beta \times \Delta Temp_{min}) + (\gamma \times \Delta Temp_{max}) \quad (3.4)$$

Where, ΔY is the observed change in the yield due to temperature and precipitation in the same season as crop growth, and α, β, and γ are the coefficients of precipitation, minimum temperature and maximum temperature in that season, respectively. Similarly, Δppt, $\Delta Temp_{min}$, and $\Delta Temp_{max}$ are the observed changes in precipitation and minimum and maximum temperatures of the season, respectively, during the study period.

The multi-linear regression analysis results are shown in Table 3.8 for rice, maize, wheat, barley and millet. The results suggest that the model is able to describe the variations in the yields of food crops ranging from 37% (0.372) in the case of millet to only 7.8% (0.078) in the case of rice (see Table 3.8). Though the regression results show very few significant relationships between yield and climate variables, these coefficients can be used to assess the real effects of climate variables in the changes in the food crop yields considered in this study.

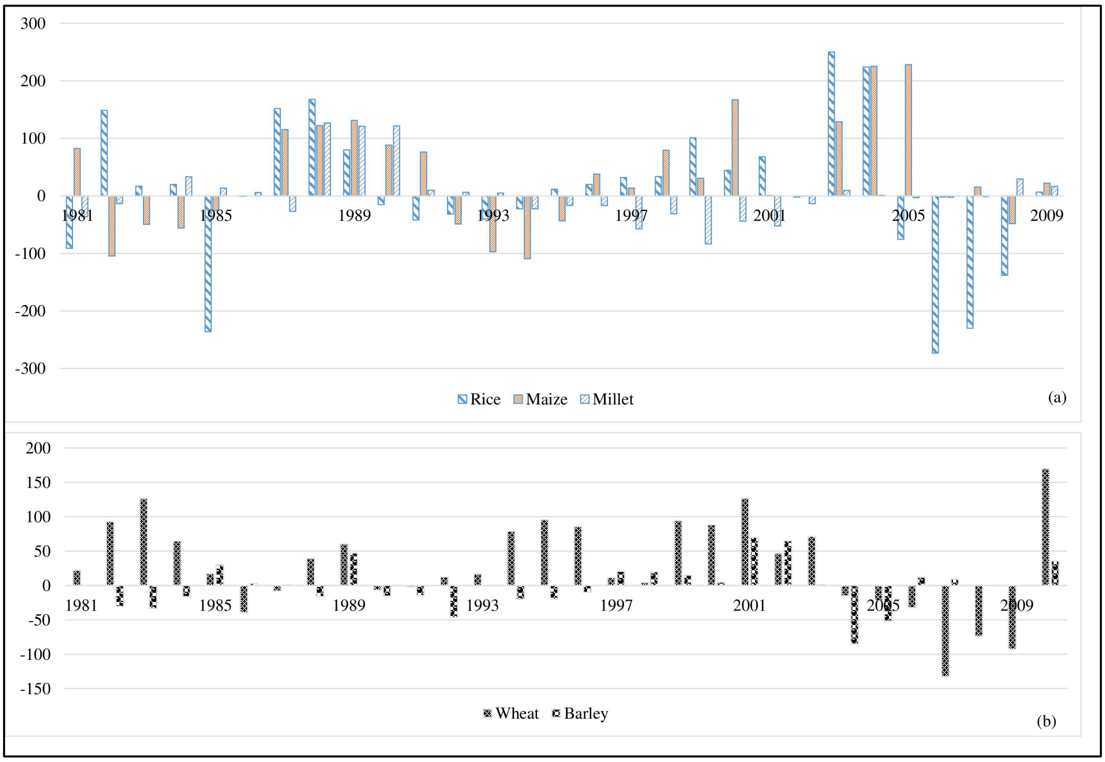

Figure 3.11 (a) Anomalies of summer crops yield (b) Anomalies of winter crops yield from 1980 to 2012

In addition, the sign of the coefficients indicates the direction of change in the yield *versus* climate variable changes (Nicholls, 1997). In the case of maize yield, climate variables account for only 34.7% of the yield changes, whereas 65.3% of the variation in maize yield is explained by other influential factors, such as better seeds, better crop management practices and introduction of new agro-technology. Similarly, the regression analysis indicates an R-squared value of 0.249, implying that the impact of climate variables accounts for only 24.9% of the wheat yield changes, while 75.1% of the variation in wheat yield is explained by other factors, such as the use of fertilizers, *etc.* Additionally, only 37.2% of the variations in millet yield are controlled by the climatic variables.

Precipitation in winter was an important factor that can increase yield potential for wheat and barley. Extreme temperatures had adverse effects on the yield, as increases and decreases in the maximum and minimum temperatures have negative impacts. Similarly, summer precipitation had a positive impact on rice, while maize and millet showed negative effects. Therefore, increasing maximum temperature has positive impacts on all summer crops, and decreases in temperature have negative impacts. Increases in temperature up to 2°C will help to increase the crop production in Nepal (Malla, 2008). Therefore, the average increase in temperature during the period from 1980 to 2012 of less than 2°C must have been favorable to the growth and yield of crops.

Table 3.8 Multivariate regression analysis of detrended yield of crops

Crop		**Ppt_ S**	**Tmax_ S**	**Tmin_ S**	**Ppt_ W**	**Tmax_ W**	**Tmin_ W**	**R2**
Rice	Coeff.	1.179	22.0	-21.7	-	-	-	0.078
	P-value	0.186	0.735	0.596	-	-	-	
Maize	Coeff.	-0.27	17.2	12.1	-	-	-	0.347
	P-value	**0.003**	0.669	0.632	-	-	-	
Millet	Coeff.	-0.01	76.0	-10.8	-	-	-	0.372
	P-value	0.811	**0.001**	0.421	-	-	-	
Wheat	Coeff.	-	-	-	0.39	-6.5	-29.1	0.249
	P-value	-	-	-	0.187	0.613	**0.014**	
Barley	Coeff.	-	-	-	0.027	-2.19	-9.68	0.11
	P-value	-	-	-	0.86	0.751	0.116	

where, Coeff. = coefficient, S = summer and W = winter

Tmax= Maximum temperature, Tmin= Minimum temperature, Ppt= Precipitation

3.3.6 Key Informants Interviews

As described in section 3, the KII was employed as one of the methods in this study to collect qualitative data regarding climate change and crop production in Lamjung. The results summarized in this section are based on the responses provided by 16 key informants (two informants from each organization/group). They were the representatives of NARC, District Agriculture Development Offices, Ministry of Agriculture, Department of Hydrology and Meteorology, non-governmental organizations, local leaders, women groups, and farmers groups.

Changes in Temperature

The perception of global warming has been reported based on their experience. The respondents mentioned that both summer and winter seasons are warmer at present and were not as warm 20 years ago. Similarly, the emergence of mosquitoes and pests at the altitude of 2016masl (Ghalegaun of Lamjung—a village of nearly 500 households located in the central part of Lamjung) was noted during the survey. The local people accept it as a consequence of the increased temperature.

Changes in Rainfall Pattern, Snowfall and Water Availability

The key informants were asked to provide information on changes in precipitation and water availability compared with the last 20 years. They reported that the precipitation pattern has changed and that they are experiencing untimely and heavy rainfall, winter drought, and other phenomena more frequently than before. In particular, summer rainfall is more intense in comparison to earlier years, and they mentioned that previously there used to be heavy snowfall almost every winter and that the local people in the middle-elevation hill areas used to harvest the snow for use as household water, but now the amount of precipitation has decreased and falls mostly as rain.

Changes in Crop Production

Different opinions were provided by the key informants regarding crop production changes over the last 20 years. Some reported that production has increased significantly in comparison to earlier years, whereas most of them are experiencing more pests and frequent droughts in the middle-elevation hills and floods in the lower regions. Several informants happily explained that they are now able to cultivate some vegetables, such as tomato, chilies and cauliflower, in the middle-elevation hills that were not possible to grow previously.

In summary, a changing trend in climatic variables has been found. Similarly, the timing, intensity and frequency of snowfall and rainfall have also changed over the last 20 years. In the high region of Lamjung, people previously had observed a consistent snow cover during the winter, and the greatest snow accumulation often occurred during January–February. However, currently, the snowfall pattern has changed, and heavy snowfall occurs in the late autumn or early spring, no-snow conditions prevail during winter, and the persistence of the snow has also decreased (Koirala and Bhatta, 2010; Mishra et al., 2014a). The duration of summer has increased during this period, and the number of chill days has decreased. Similarly, the occurrence of existing pests and the emergence of new pests and diseases have been observed over the last 20 years. These experiences agree with the results obtained from several studies in the region (Maharjan et al., 2009).

3.4 Discussion

The increasing trend of global warming is more evident in the mountainous areas than in the plains. Climate change is also likely to change the monsoon precipitation patterns in ways that could affect the current agricultural production of Nepal. After analyzing the data from the Lamjung district and conducting KIIs, this study found that there is a changing trend in the climatic variables. Additionally, the intensity and frequency of snowfall and rainfall have decreased in the higher altitudes over the last 20 years. The duration of summer has increased during this period, and the number of cold days has decreased. Similarly, the occurrence of existing pests and the emergence of new pests and diseases have been observed over the same period. These experiences agree with the results obtained from several studies in the region, as discussed in earlier sections.

The seasonal precipitation at various stations exhibited variation in trends. The precipitation in Lamjung is concentrated in the summer, with almost 80% of the annual precipitation falling then. The decreasing trend in winter precipitation and the increasing trend in summer precipitation indicate that precipitation in summer is becoming more intense. This could have a negative impact on crops due to water-induced disasters, such as floods and landslides, which eventually affect the crop yields. The total annual precipitation has increased at the Kunchha and Gharedhunga stations, but decreased at the Khudi station. In summary, the annual summer precipitation increased and the winter precipitation decreased in Lamjung. Joshi (Joshi et al., 2011) also revealed the same trends across Nepal, where summer precipitation increased and winter precipitation decreased from 1978 to 2008. The temperature data recorded at the Khudi station revealed that the maximum annual temperature and minimum annual temperature increased by 0.02 °C/yr and 0.07 °C/yr respectively, between 1980 and 2012.

The five crops studied here are grown in two seasons, with no autumn or spring crops in Lamjung. The yields of rice, maize and wheat increased by 4.71 kg/ha/yr, 16 kg/ha/yr and 26.83 kg/ha/yr, respectively, but the increases fluctuated over the years. Similarly, the yield of millet increased steadily, whereas the yield of barley decreased. These two crops are the major food crops in the mountainous region of Nepal. The growth yield of barley was suppressed by the increased minimum and maximum temperatures and decreased precipitation. However, the increased summer temperature contributed positively to millet yield.

3.5 Conclusions

This study concludes that climate variables have differential impacts on the yield growth of different crops. However, winter crops are adversely affected by the current climate trends. The yield of barley, one of the staple foods in the mountainous region of Nepal, is decreasing due to increased temperatures and decreased precipitation. On the other hand, though temperature is increasing in summer, the increases in precipitation have contributed positively to the yield growth of summer crops except maize. Thus, it is recommended that any programs that are working to minimize the adverse impact of climate change on food crops production should first consider the crop, such as barley and millet, that is being most affected by the higher temperatures relative to the other food crops. Moreover, these two crops are important staple foods in Nepal, especially in the mountainous and hill regions that are also exposed to higher degrees of vulnerability to climate change. However, overall crop yield found increased in the study areas, the increased in crop yield not necessarily determine the food security of the households at the local level. Therefore, the impacts of climate change on overall food security of the households, and the underlying causes of changes in food production, food availability, food accessibility and utilization pattern will be discussed in the next chapter.

The results of this research can be used by organizations and researchers to assess the current climate variability and fluctuations and their impact on food crops. The main shortcoming of this study is the examination of the entire district as one unit, despite the huge diversity existing within it. Therefore, further investigation with better spatial and temporal resolution is highly recommended to better understand the patterns and consequences of extreme weather affecting agriculture in mountainous regions.

4 Chapter 4 Household Perceptions about the Impacts of Climate Change on Food Security in the Mountainous Region of Nepal

This chapter describes the underlying causes of changes in the dimensions of food security (food availability, accessibility, and utilization pattern) in three VDCs of Lamjung. In particular, it focuses on changes in daily or economic household activities to ensure food security amidst changing climate during the last twenty years. For this purpose, a household survey (n=150) and four focus group discussions (FGDs) were conducted at the studied sites. During the survey, households were asked to express their perceptions about climate change. The three most experienced changes during the last twenty years were increased temperature, less rainfall in winter, and the frequency of natural disasters. Underlying causes of changes in food production included the introduction of new seeds, irrigation facilities, use of fertilizers, climate change, and less priority on agriculture. The main reasons for deterioration in the overall food security are decreased income, decreased crop production, and deteriorated food consumption patterns.

4.1 Introduction

The IPCC (2014) report explains that climate change is already having visible impacts, especially in developing countries like Nepal, which are more vulnerable due to their inability to cope against it. It is anticipated that the increasing rate of the average temperature in the Himalayas will be greater than the global average. The increasing temperatures may affect the timing and quantity of precipitation and change water availability (Mishra et al., 2014a). Furthermore, with changes in precipitation patterns, there is a greater possibility of climate-induced disasters such as landslides, floods, and droughts. This may affect the agriculture sector and eventually food security.

Climate change and increasing numbers of natural disaster are directly impacting food security in several parts of the world. In the last decade, more than 200 million people were affected annually by natural disasters (Parvin and Ahsan, 2013), which is seven times more than those affected by conflict. Natural hazards become disasters when the severity affects livelihoods and become a challenge for survival (Parvin and Ahsan, 2013). Frequent natural disasters due to changing climate make global food security system even worse, which is already in crisis for meeting basic demands.

According to the IPCC's Fourth Assessment Report and other scientific studies, it is clearly understood that climate change has a direct impact on agriculture, livestock, and fishing, especially in developing countries where people are living below the poverty line, and it will affect not only local but also global food security (Bals et al., 2008). Climate change can have serious impacts on the four dimensions of food security: food availability, food accessibility, food utilization, and food system stability. Effects are already being felt in global food markets (FAO, 2008), and they are likely to be particularly significant in specific rural locations where crops fail and yields decline. Impacts will be felt in both rural and urban locations where supply chains are disrupted and market prices increase. Similarly, assets and livelihood opportunities are lost, purchasing power falls, human health is endangered, and affected people are unable to cope. The possible impacts of climate change on food security have tended to be viewed with most concern in locations where rain-fed agriculture is still the primary source of food and income.

The Food and Agriculture Organization (FAO, 1996) defines food security as a "situation that exists 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." This definition addresses the four aforementioned key components of food security (Schmidhuber and Tubiello, 2007). Climate change affects food security in a complex way. A food system is vulnerable when one or more of the four components is uncertain and insecure.

Food Availability: Food availability is measured by the physical availability of food that is produced, stored, processed, distributed, and exchanged. A change in the production of food resulting from changing climatic conditions could impact food availability.

Food Accessibility: Food accessibility is a measure of the ability to secure entitlements that an individual requires to obtain access to food (Stamoulis and Zezza, 2003). Until the 1970s, food security was measured through national food production (Devereux and Maxwell, 2001), but since then, the concept has expanded to include households` and individuals` access to food, since only the presence of an adequate food supply does not ensure that a person can obtain and consume food. Increased risk of exposure resulting from climate change may reduce people`s access to food and undermine food security.

Food Utilization: Food utilization refers to the use of food and how a person is able to consume the required level of food. It includes the composition and methods of preparation, the social values of foods, the quality, and the hygiene and safety of the food supply.

Food System Stability: Food system stability focuses on the stability of the above-mentioned three components of food security – food availability, accessibility and consumption. Changes in food production, accessibility, and utilization with climate variability threat threaten to food stability and could bring about food insecurity.

According to the FAO definition, climate change has a direct impact on food production systems through changes in agro-ecological conditions. It indirectly affects food distribution, accessibility, and price, and it creates local food crises. For example, changing rainfall patterns due to climate change increase the possibility of floods in lowland areas and landslides at higher altitude. Due to its heterogeneous topography, Nepal has high risk of natural disasters such as glacial lake outburst floods (GLOFs), avalanches, and landslides at higher altitudes, as well as floods in lower regions. The number of climate-related disasters and the number of people affected during the last 30 years are presented in Figure 4.1. A large number of the population was affected by floods followed by droughts and landslides between 1980 and 2014. Hence, mountainous countries such as Nepal are more vulnerable to climate change (Maplecroft, 2010) and its effects on food security.

Several studies on the impacts of climate change on food security have focused on crop models, which indicate where yield might increase or decrease due to global warming (Arnell et al., 2002; Fischer et al., 2002; Parry et al., 2004). However, the models do not consider the local household level food security. Moreover, focusing solely on changes in crop yield ignores the important issue of food access, especially market-dependent, poor, or food-insecure households. To systematically analyze the impacts of climate change on food security, it is important to integrate all four components of food security (*i.e.*, food availability, access, utilization, and stability). Several studies explain that increased incidences of erratic precipitation, landslides, floods, and droughts have decreased agricultural production and deteriorated food security (Yu et al., 2013; Rasul and Hussain 2015; Bhatt et al., 2014). Therefore, this study explores whether these scientific findings are reflected in local people`s perceptions of climate change and household food security.

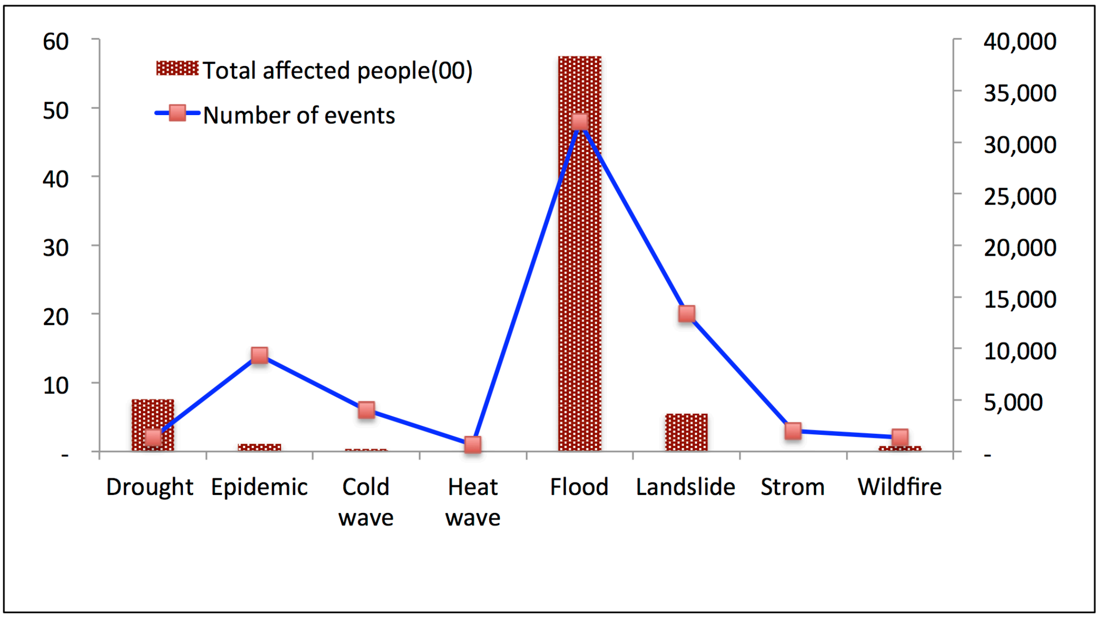

Figure 4.1 Number of climate-related natural disasters and affected people in Nepal from 1980 to 2014

Source: (CRED, 2016)

Therefore, this study analyzes the impacts of climate change on the food security of mountainous households while considering all the factors that contribute to food availability, accessibility, and consumption patterns in the Lamjung district of Nepal. Possible measures are provided to mitigate the impact of climate change on food security in the region. Some of the main goals are:

- To understand local perceptions of climate change
- To find the underlying causes of changes in food availability, accessibility, and utilization
- To understand changes in daily activities of local people

- To provide recommendations for policy makers to mitigate the impact of climate change on local food security

4.2 Climate Change and Food Crisis in Nepal

Changing temperatures and erratic rainfall patterns are affecting crop production in Nepal (Malla, 2008). The have also been observations of a loss of local crops and domestic animals, changes in cropping patterns, water scarcity due to water resources drying up, and increasing incidences of diseases and pests (Regmi and Adhikari, 2007). Climate change accelerates the deterioration of food production and other livelihood assets, and persistent poverty and increasing population exacerbate food insecurity. According to the FAO (2002), the size of the food-insecure population increased from 3.5 million (19% of the population) to 5 million (23%) between 1995 and 2002.

More than 60% of the population depends on subsistence agriculture (CBS, 2013), and heavy dependence on agriculture makes Nepal`s economy very sensitive to climate variability. Food production changed remarkably in 2007, with an overall reduction by 3.35% of cereals and other crops compared with 2001 (CBS, 2007). There is great regional variation, and people in mountainous areas suffer more due to lack of access because of poor development infrastructures, such as road networks and warehouses to store food for food lean seasons. In addition, crop yields have strong associations with the amount of rain received at the right time. The reduction of rice production in earlier years can be closely linked to the abnormal rainfall received in those years. Based on statistics until 2010, about 29.75% of agricultural land was irrigated (World Bank, 2016a), which leads to vulnerability, and up to 80% of the population could be affected badly by a change in precipitation (CBS, 2014b). In the early 1960s, Nepal had the highest level of agricultural productivity in South Asia, but by the early 1990s, its agricultural productivity was the lowest in the subcontinent (Tiwari et al., 2002). However, there are also other factors that affect the end result of production (Bhandari, 2007).

This study was conducted in the three VDCs of Kunchha, Khudi, and Ilampokhari of Lamjung district (Figure 4.2). Detailed information about the selected VDCs is given in Table 1.1. In Kunchha, the majority caste and ethnic groups are Brahmins, Chettris, whereas in Khudi and Ilampokhari, the majority are Gurungs and Tamangs. These sites are fairly representative of the mid-hill and mountain villages as they have relatively high climate change issues and high percentages of abandoned land, which has high potential for agricultural production.

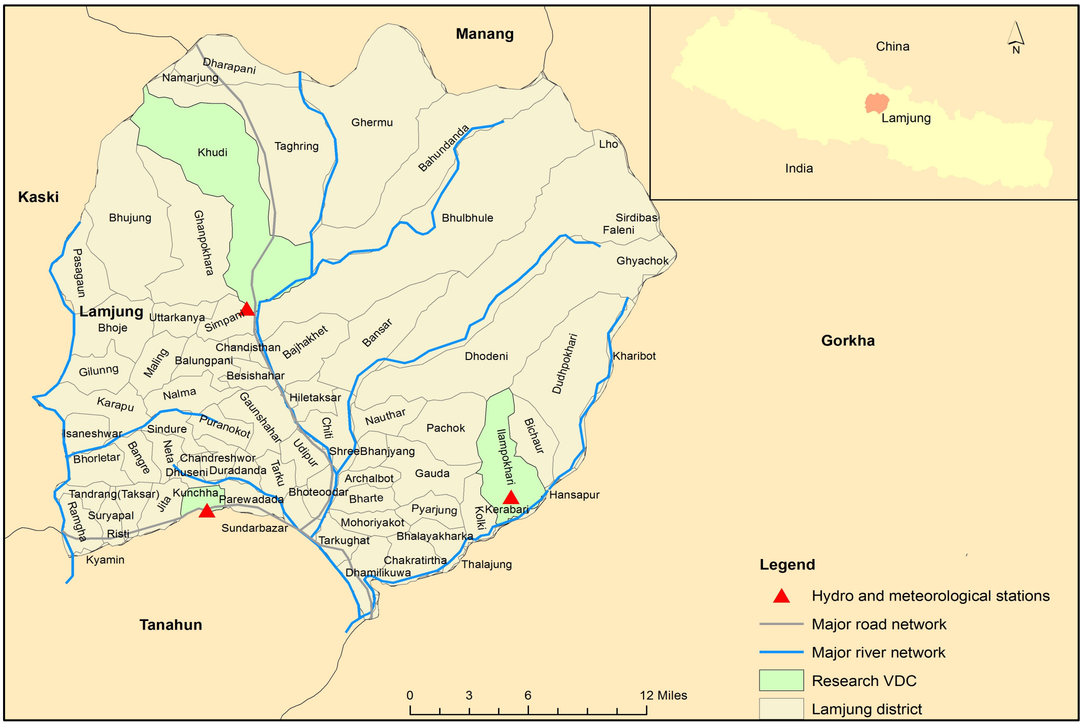

Figure 4.2 Map of the study area in Nepal

4.3 Methodology

The extent of the problems related to climate change and food security was conceptualized based on an intensive literature review and hydrological and meteorological stations. A total of 150 respondents were selected through a systematic random sampling method for a household survey. Each household head was interviewed to assess impact of climate change on their food security. In addition, participatory exercises such as FGDs, local workshops, and key informant interviews (KIIs) were performed. The results were analyzed using SPSS. The questions were focused broadly on issues of climate change; perceptions of local people of climate change; changes in crop production, food availability, accessibility, and utilization; and changes in daily or economic activities to ensure food security. The data collected may not be a true representative of the whole district. Thus, caution is warranted for the generalization of these household-level results. The detailed procedure of the research methodology is given below:

Sampling Scheme for the Survey in Lamjung

- Two-stage sampling was used with the district as the domain, the village as the primary sampling unit, and the households as the secondary unit.
- Three VDCs were selected after consultation with local stakeholders and based on the hydrological meteorological stations.
- The three VDCs represent the three distinct characteristics of Lamjung: lower hills, middle hills, and high mountains

Selection of Households

- The household lists of the VDC were obtained from each VDC office for the selection of 150 households in total.
- Each VDC has nine wards, so 150 households were selected from the 27 wards.
- Based on the numbers of households in each ward, six households were selected from each of the 15 high-density wards (90 households), and five households from each of the 12 low-density wards (60 households).
- The reference point was the VDC office. A random number *n* from 1 to 10 was drawn, and the *n*th house to the right of the reference point was the first household interviewed.
- The next respondent was the tenth house to the right of the first respondent, and so on.
- If the household was not in the house or refused to be interviewed, then the next 10^{th} house was interviewed.

Key Informant Interviews

A field survey in Lamjung was also conducted through Key informant interviews. Each interview was designed to collect qualitative information on the community`s perception of climate change and experience of extreme weather events, such as erratic rainfall, floods, droughts, landslides, and so on. It was conducted with a selected representative from the Nepal Agricultural Research Council, DADOs, MOAD, DHM, NGOs, local leaders, women's groups, and farmer groups.

Focus Group Discussions

Four FGDs were conducted: one in each VDC and one in the district headquarters. A total of 24 people participated in the FGDs (six people in each FGD). The questions focused broadly on issues of climate variables; perceptions of climate change; changes in crop production, food availability, accessibility and utilization; and changes in daily activities to ensure food security.

Type and Nature of collected Data

Both quantitative and qualitative data were collected and analyzed for this study. The quantitative data were household size, family income, and other sources of income besides agriculture. Qualitative data were the perception of households on climate change and changes in food availability, accessibility, and their daily or economic activities. Some of the important points about the nature of the data are clarified as follows:

a. The reported climate change experienced by the households (Figure 4.3) is for the past 20 years.
b. Changes in crop production, food availability, accessibility, utilization, and changes in daily or economic activities attributed to climate change are the average changes perceived by households in the past 20 years.
c. Although perception of climate change may vary across the households, it still provides some strong evidence about the incidence of extreme events attributed to climate change and their impacts on food security. Regardless of the limitations, perception-based data are useful for comparison with the findings of scientific research.

4.4 Findings and Discussions

4.4.1 People`s Perception of Climate Change

When it comes to peoples' understanding of changes and responses to them, relying on science alone is not enough. The overview of how people see the changes regulates their reactions to them. The majority of the households in all three VDCs were familiar with the term “climate change” and they had experienced changes during the last two decades. Their experiences included increased temperature, changes in rainfall patterns, increasing frequency of natural disasters, emergence of insects, prolonged winter droughts, and more intense rainfall in the summer. During the survey, households were asked to rank the changes in their areas in comparison with the last 20 years. Altogether, 97% of the respondents ranked increased temperature as number one, followed by less rainfall in winter (79%), and increased number of natural disasters (29%). A summary of the survey is presented in Figure 4.3 for each VDC, and a detailed analysis is presented in subsequent sections.

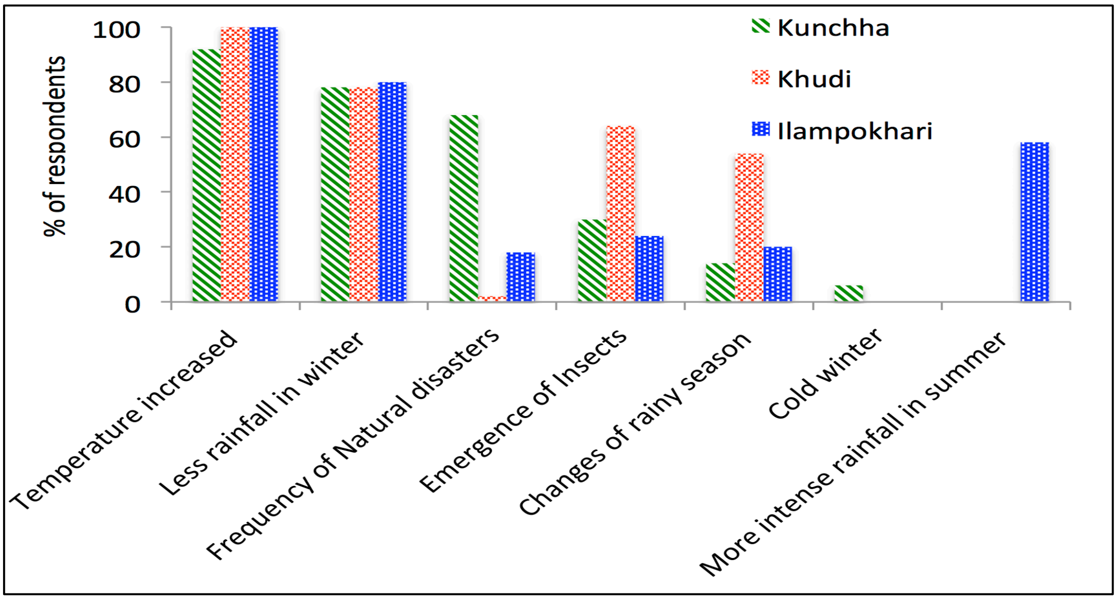

Figure 4.3 Local people’s perception of climate change from Kunchha, Khudi and Ilampokhari VDCs of Lamjung

Precipitation

People`s perception of changes in precipitation varied across the study areas. A majority of the respondents (79%) claimed that there was less rainfall in winter, 29% mentioned that there were some changes in quantity and duration, and 19% mentioned that the rainfall was more intense in summer. All the respondents of the three VDCs had similar perceptions about the decreased rainfall during winter (December–February) and intense rainfall in summer (June–August). According to 14% of respondents in Kunchha, 54% in Khudi, and 20% in Ilampokhari, the quantity and duration of the summer precipitation had changed and rainfall was more intense in the summer. Similarly, 58% of the respondents from Ilampokhari reported more intense rainfall in summer, whereas no respondents reported more intense rainfall in summer from Kunchha and Khudi. The survey results match with the recorded precipitation at the respective stations (1980-2013). According to the observed precipitation record, Kunchha and Gharedhunga (Ilampokhari) showed increasing trends of precipitation, and Khudi showed a decreasing trend (Poudel and Shaw, 2016).

Local communities from the mountain region reported that there has been a significant decrease in the stream flow during the winter, which was not noticed in the past. The trend in the annual discharges of the Marsyangdhi and Khudi river basins indicate that the discharges in these major basins are decreasing annually (MOSTE, 2014). Khadka and Pathak (2016) also found similar observations that natural springs in the mountain region, wells, and water sources have dried up due to insufficient rainfall and variation in the precipitation patterns. The impact on water resources was found to be very high, which ultimately affects all sectors, such as agricultural production, drinking water supply, hydropower, water-induced disasters, forests, and biodiversity. Anthropogenic activities as well as climatic uncertainties in this region suggest that there will be more water stress in all sectors in the future during winter, as well as flooding, landslides, and river bank erosion in summer. They also suggested that precipitation is likely to be more uncertain and that storm intensity will increase (NCVST, 2009). This changing precipitation pattern indicates that the drought period is becoming longer and the monsoon season is delayed. However, there was no definite trend in the annual precipitation amount (WECS, 2011). More intense rainfall in summer may cause floods and landslides, which affect summer crops. Similarly, less rainfall in winter affects the winter crops and consequently changes the state of food security.

Temperature

In Lamjung, local people have been experiencing hotter weather in the last twenty years. Altogether, 97% of the respondents believed the temperature had increased. Among them, 92% of the respondents from Kunchha and 100% from Khudi and Ilampokhari mentioned hotter days in summer and longer warm days in winter in the last two decades. On the other hand, they mentioned that extremely cold days were also increasing during winter. As a result, the cropping patterns can be disturbed (Joshi et al., 2011). However, increased temperature has also been reported to have positive impacts, such as opportunities to plant fruit and vegetables at higher mountain elevations.

Consultation with local stakeholders in Lamjung district revealed some plant species shifted to higher elevations, which might be due to increased temperature. A few respondents mentioned that they could grow some vegetables (tomatoes and cauliflowers) at higher altitude in recent years due to warming trends. These perceptions are supported by the historical records at Khudi station, which show that the minimum temperature increased 0.07^{o}C/yr and the maximum temperature increased 0.02^{o}C/yr from 1980 to 2012. Shrestha (Shrestha et al., 1999) reported a similar observation that the mean annual temperature is estimated to increase by 0.06°C annually and is projected to increase by another 1.2°C by 2030, 1.7°C by 2050, and 3.0°C by 2100 in Nepal (MoE, 2010).

Frequency of Natural Disasters

Altogether, 29% of the respondents noticed both increased severity and frequency of natural disasters in the last twenty years. Among them, a higher percentage of the respondents (68%) were from Kunchha, followed by Ilampokhari (18%) and Khudi (2%). Most of the respondents reported increasing numbers of landslides at higher altitude and floods in the lowland. The government of Nepal has also ranked Lamjung district as the one most prone to landslides in the country (NAPA, 2010). The increasing numbers of natural disasters impose threats on people's lives and livelihoods.

Emergence of Insects

The emergence of new insects or increasing numbers of existing pests and diseases to crops and livestock was noticed by 39% of the respondents. Around 64% of the respondents from Khudi, 30% from Kunchha, and 24% from Ilampokhari noticed increased numbers of existing insects and the appearance of new insects in their surroundings. Common insects and diseases mentioned included *gabaro* (stem borers) in maize, *patero* (rice bugs) in paddies, *lie* (aphids) on legumes and green vegetables, and blight on winter crops. They believed that it was due to the increasing warming trend in the hilly regions. Particularly, households in Kunchha reported more damage to orange trees due to warming compared to the previous decade.

Due to the emergence of new diseases with increasing temperature, most of the orange trees were damaged, as shown in Figure 4.4. The remaining trees also have few fruits, and the taste is not as good (MOAC, 2011). Most of the households reported that both quality and quantity of the orange decreased in comparison with the last twenty years. These changes directly impact their livelihoods since orange farming is the main source of income for some of the respondents.

Figure 4.4 Damaged orange trees in Kunchha VDC of Lamjung

Most of the households reported that both quality and quantity of the orange decreased in comparison with the last twenty years. These changes directly impact their livelihoods since orange farming is the main source of income for some of the respondents.

4.4.2 Changes in Food Availability, Accessibility and Utilization

Food availability (production and distribution), access (affordability and location), and utilization are the core elements of food security. Climate change can affect these different dimensions of food security in various ways. A majority of the respondents (60%) reported decreased crop production in comparison to the last twenty years. The decreased rate varied across the three VDCs. Decreased crop productions was reported by 78% of the respondents from Khudi, 58% from Ilampokhari, and 44% from Kunchha. Altogether, 24% of the households reported increased crop production, and 15% reported unchanged production. Among the households with increased crop production, 54% were from Kunchha, 18% were from Khudi, and 2% were from Ilampokhari. Among the unchanged households, 40% were from Ilampokhari, 4% were from Khudi, and 2% were from Kunchha. The results are summarized in Figure 4.5.

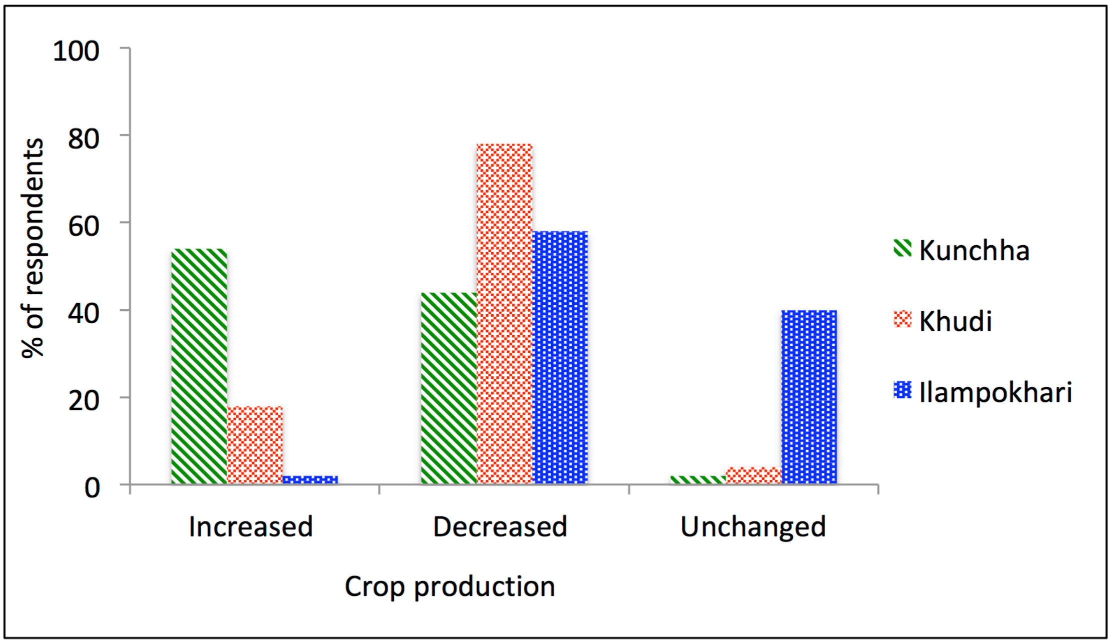

Figure 4.5 Percentage of respondents reporting changes in crop production from Kunchha, Khudi, and Ilampokhari

The agricultural sector is highly dependent on weather in this region, particularly precipitation. A majority of the farmers depend on rain-fed farming, which can be heavily affected by climate variability. Small changes in climate can induce large changes in agricultural risk in the mountainous region. Extreme weather conditions such as floods, droughts, frosts, and hail could be disastrous for agricultural production. Local consultation at the district and community levels revealed delayed and shorter monsoon seasons, as well as high variability, long droughts, decreased winter rainfall, and increased uncertainty, which have resulted in negative impacts on the production of both summer and winter crops.

Local communities reported one to two weeks of delay of the monsoon season and that it ends one week earlier, which affect both rice planting and harvesting. Additionally, upland farmers from the mid-mountain region were highly sensitive to the winter and pre-monsoon rainfall. Rain-fed crops like barley and winter vegetables are severely affected by low rainfall during winter and spring. MOAD (MOAD, 2013) also reported that the delay in the monsoon and low rainfall resulted in only 70-80% of the paddy cultivation for the whole country in 2012. The households of Ilampokhari mentioned that unpredictable and untimely precipitation in recent years in the months of May and October resulted in considerable damaged to several crops such as maize and rice at harvesting time.

During the survey, households were asked to rank the reasons or contributing factors for changes in crop production. Altogether, 66% of the respondents indicated the introduction of new seeds behind increasing crop production, and 58% indicated the use of fertilizer. Regarding the reasons behind decreased food production, 78% of the respondents indicated climate change, followed by less priority given to agriculture, abandoned land, and lack of manpower. The rankings of all contributing factors in each VDC are presented in Table 4.1.

Table 4.1 Ranking of reasons behind changes in crop production in Kunchha, Khudi and Ilampokhari

Production Increased	**Ranked by the respondents**		
Reasons	**Kunchha**	**Khudi**	**Ilampokhari**
a. Use of fertilizers	**2**	**2**	**2**
b. Introduction of new seeds	**1**	**1**	**1**
c. Irrigation facility	**3**	**4**	**3**
d. Use of agro equipment	4	5	4
e. Others	5	3	5
Production Decreased			
a. Climate change	**4**	**1**	**1**
b. Fallow land	**2**	**4**	**1**
c. Less priority to Agriculture	**1**	**2**	**3**
d. Lack of manpower	3	3	2
e. Others	5	5	5

Ranking: 1 indicates high contribution, 5 indicates low contribution

Regarding the crop production, the yield of barley (a staple food in the mountainous region of Nepal) decreased in the last 30 years (Poudel and Shaw, 2016). This decrement was mirrored in the response of households from Khudi and Ilampokhari. The government of Nepal has started giving subsidies to farmers for different types of seed varieties such as drought-tolerant wheat and flood-resistant rice to minimize agricultural loss from extreme climate. Similarly, high-quality, fertilizer-responsive, improved maize seeds are targeted for mountainous farmers. This is reflected in the historical crop yield data of rice, maize, and wheat since the yield of these three crops increased in the last 30 years in Lamjung district (Poudel and Shaw, 2016).

Changes in Food Availability

Food availability can be measured through production and the distribution of food to all people. It can be determined by local or national agricultural production and the ability to trade and transport essential food supplies from surplus areas to deficit areas. Regarding food availability, 34% of the respondents reported increased availability, 12% reported decreased availability, and 54% reported unchanged availability in the last 20 years. A higher percentage of respondents from Kunchha (48%) reported increased food availability, while a higher percentage of respondents from Khudi (24%) reported decreased availability, and 54% respondents from Ilampokhari reported unchanged availability (Figure 4.6).

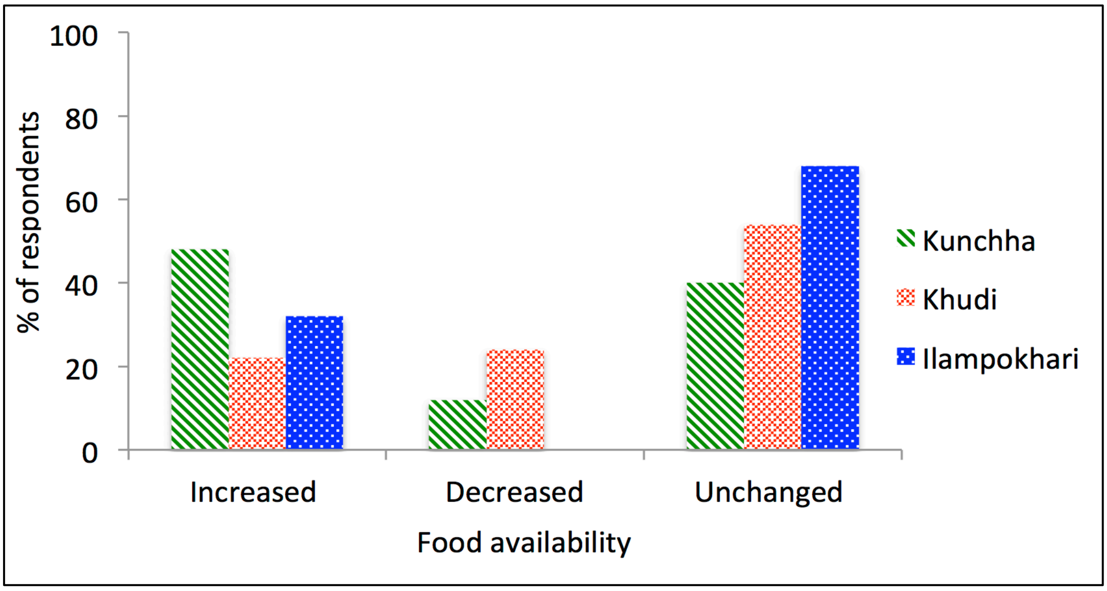

Figure 4.6 Percentage of household perceptions of changes in food availability in Kunchha, Khudi, and Ilampokhari VDCs of Lamjung

The main contributing factors for increased food availability in Kunchha were increased crop production, increased income, and access of road networks. In contrast, the reasons for decreased food availability in Khudi were decreased crop production and increased household burdens, such as family illness and diseases. No respondents from Ilampokhari noticed increased or decreased household burden in the last 20 years (Table 4.2). A majority of the households perceived a role of climate change in decreased crop production, decreased dairy production, increased food prices, and increased household burden (Table 4.3).

Table 4.2 Underlying causes of changes in food availability

Reasons of changes in food availability	% of respondents		
	Kunchha	Khudi	Ilampokhari
Crop production increased	77	35	6
Crop production decreased	**23**	**48**	**19**
Income increased	97	39	87
Income decreased	**3**	**13**	**0**
Dairy product increased	87	9	6
Dairy product decreased	7	48	6
Food price increased	**87**	**44**	**50**
Food price decreased	0	4	0
Other household burden increased	**6**	**35**	0
Other household burden decreased	86	0	0

Note: Percentage is not 100% due to multiple responses.

Table 4.3 Household perceptions of the role of climate change in changes in food availability from Kunchha, Khudi, and Ilampokhari

Reasons of changes in food availability	Responses about role of climate change (%)					
	Kunchha		Khudi		Ilampokhari	
	Yes	No	Yes	No	Yes	No
Crop production increased	**21**	**79**	**100**	**0**	**100**	**0**
Crop production decreased	71	29	100	0	100	0
Income increased	**0**	**100**	**33**	**67**	**7**	**93**
Income decreased	0	100	67	33	0	0
Dairy product increased	4	96	100	0	0	100
Dairy product decreased	**100**	**0**	**55**	**45**	**100**	**0**
Food price increased	**8**	**92**	**90**	**10**	**100**	**0**
Food price decreased	0	0	100	0	0	0
Other household burden increased	**100**	**0**	**50**	**50**	**0**	**0**
Other household burden decreased	0	100	0	0	0	0

Changes in Food Accessibility and Utilization

Food is allocated through markets and non-market distribution mechanisms. Factors that determine whether people have access to sufficient food through markets are considered in this section. These factors include distance of the food market from the homes and road access to reach to the nearest market. Altogether, 50% of the respondents reported increased food accessibility, only 2% mentioned decreased accessibility, and 48% indicated unchanged accessibility (Figure 4.7).

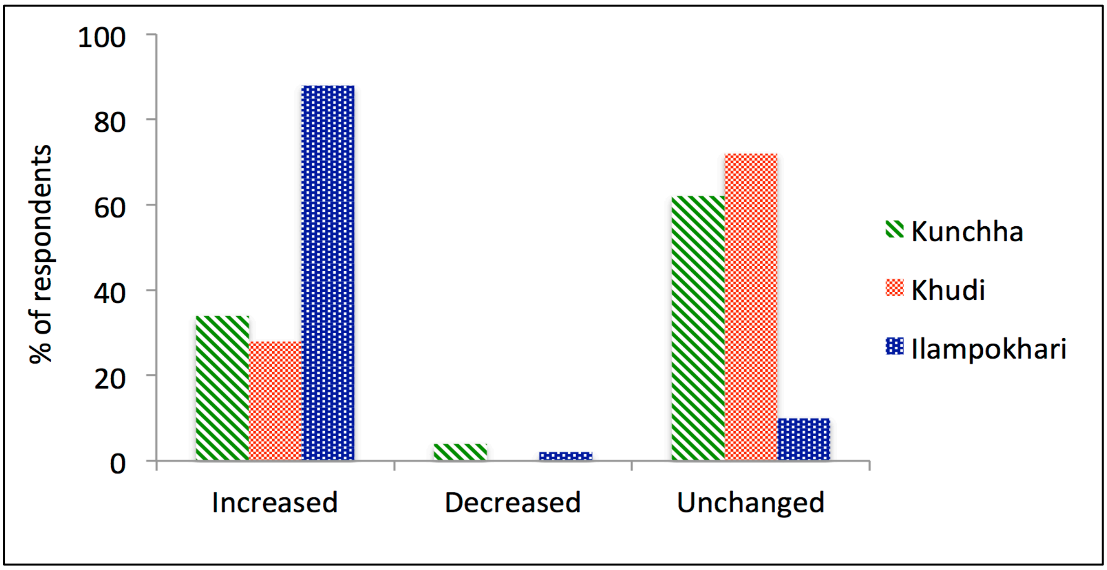

Figure 4.7 Percentages of household perceptions of changes in food accessibility in Kunchha, Khudi, and Ilampokhari VDCs of Lamjung

Food accessibility was measured through the distance from the local market and the time taken to reach it. In this case, 94% of the respondents reported that the distance of local market had decreased with the development of roads, and 96% mentioned increased road access to reach to the local market in the study area. The development of road infrastructure in rural areas of Nepal has increased rapidly in the last twenty years, which has facilitated the transportation of food from surplus areas to deficit areas. Among the households with decreased food accessibility, only 1% mentioned that it was because of climate impacts (i.e., seasonal road disturbances by landslides and floods).

As for food consumption patterns and utilization, 70% of the respondents explained that it had improved, 3% mentioned deterioration, and 27% mentioned it was unchanged for last two decades (Figure 4.8). The reasons behind improved food consumption patterns were awareness about the utilization of food along with increased income and access to sources of nutritional food. Several local, national, and international organizations are working in the sector of food security in Lamjung in collaboration with the government of Nepal. They provide training and awareness programs to the local people about hygiene and sanitation. This eventually helps with the consumption of nutritional food and enhances food security.

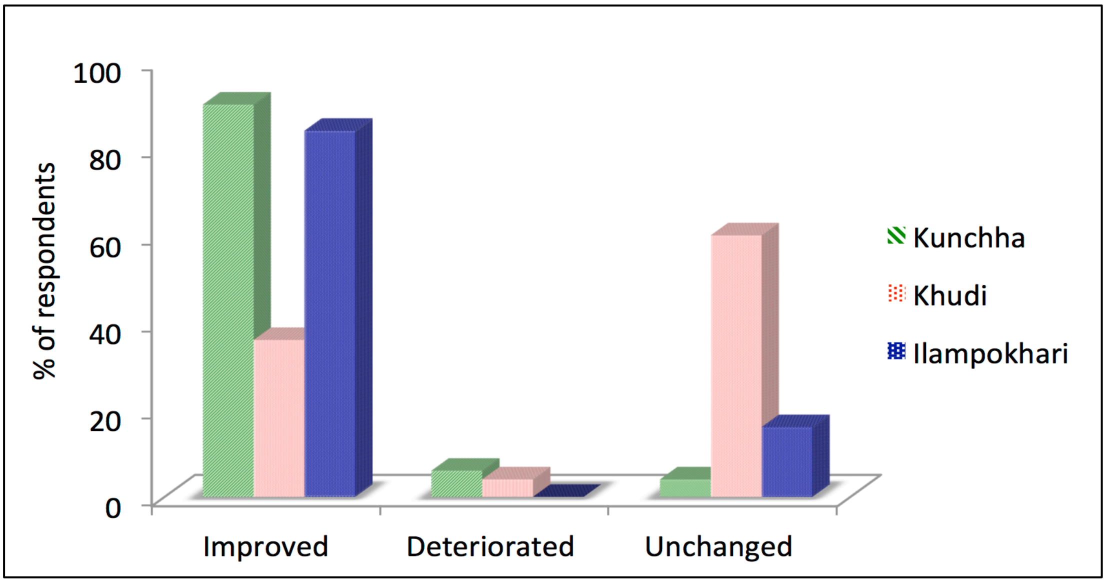

Figure 4.8 Percentage of household perceptions of changes in food consumption patterns in Kunchha, Khudi, and Ilampokhari VDCs of Lamjung

4.4.3 Changes in Households` Daily Activities

The results show that the daily activities of local people had changed in the last twenty years. A majority of the respondents (83%) reported that their daily activities were changed to ensure food security, while 98% of the respondents mentioned that the time to collect and process food (seedling to harvesting) had increased due to climate change. As most of the agricultural land is rain-fed, changes in rainfall patterns affected crop cultivation patterns as well. Most of the respondents witnessed the winter droughts of 2006, 2008, and 2009. They explained that food prices increased during that time and that they were in a difficult situation.

Increased time to collect fodder due to climate change impact was perceived by 78% of the respondents (Tables 4.4 and 4.5). They mentioned that there was no longer any grazing land and that it took a longer time to grow grass due to less rainfall and prolonged winter drought. Local species of grass disappeared in the study area due to warming. The time for collecting cooking fuel and household water was decreased in the study sites. Most of the local people have started to buy firewood from the market or use biogas and liquefied petroleum gas for cooking in recent years with increasing income and lack of manpower to collect firewood from the forest.

Table 4.4 Responses regarding changes in daily activities from Kunchha, Khudi, and Ilampokhari

Changes in daily activities	**Percentages of respondents**		
	Kunchha	**Khudi**	**Ilampokhari**
Time to process food increased (from seedling to harvesting	67	65	79
Time to process food decreased (from seedling to harvesting	4	3	2
Time to earn money increased	33	69	35
Time to earn money decreased	0	4	6
Time to collect fodder for livestock increased	50	30	84
Time to collect fodder for livestock decreased	7	4	2
Time to collect cooking fuel increased	40	4	80
Time to collect cooking fuel decreased	4	4	8
Time to collect water increased	80	8	0
Time to collect water decreased	2	15	81

Note: Percentage is not 100% due to multiple responses.

Table 4.5 Household perception of the role of climate change in daily activities

Changes in daily activities	**Responses about role of climate change (%)**					
	Kunchha		**Khudi**		**Ilampokhari**	
	Yes	**No**	**Yes**	**No**	**Yes**	**No**
Time to process food increased (from seedling to harvesting)	67	33	100	0	100	0
Time to earn money increased	33	67	100		100	0
Time to collect fodder for livestock increased	50	50	100	0	85	15
Time to collect cooking fuel increased	40	60	0	100	71	29
Time to collect water increased	80	20	100	0	0	0

Few respondents (5%) mentioned that the time increased for water collection. The reason is the use of pipelines to bring household water from main water resources rather than obtaining it by themselves. According to field observations, consultations with local stakeholders, and a literature review, water resources have decreased in natural springs and streams flowing in the study area. However, it is very difficult to analyze the impact on water resources at the field level and whether it is due to climate change or anthropogenic activities, such as haphazard construction of rural roads by heavy excavators, deforestation, forest degradation, or excess use of resources due to urbanization.

4.4.4 Changes in Households` Economic Activities and Livelihoods

Changes in lifestyles and economic activities of local people and their response to the impacts of climate change were also examined. Local people are involved in various types of economic activities for their livelihood, such as fruit farming, livestock rearing, and agribusiness. About 41% of the respondents mentioned that their lifestyle and economic activities have changed in the last twenty years. The majority of the respondents from Kunchha (73%) mentioned decreased fruit farming, in contrast to Khudi (40%) and Ilampokhari (36%). Among them, 100% of the respondents from Ilampokhari and Khudi and 78% of the respondents from Kunchha perceived an impact of climate change on decreased fruit farming in the study sites (Tables 4.6 and 4.7).

Table 4.6 Responses regarding changes in economic activities and lifestyle in Kunchha, Khudi, and Ilampokhari

Changes in economic activities and lifestyle	**Percentage of respondents**		
	Kunchha	**Khudi**	**Ilampokhari**
Increased working hours on economic activities	66	35	64
Decreased working hours on economic activities	33	0	36
Increased family member migration	96	85	100
Decreased family member migration	3	0	0
Increased poultry farming	53	0	18
Decreased poultry farming	20	0	10
Increased fruit farming	13	0	0
Decreased fruit farming	73	40	36
Increased agribusiness	37	5	28
Decreased agribusiness	23	0	10
Increased livestock rearing	27	5	18
Decreased livestock rearing	27	5	0

Note: Percentage is not 100% due to multiple responses.

Table 4.7 Household perception of the role of climate change in changes in economic activities and lifestyle in Kunchha, Khudi, and Ilampokhari

Changes in economic activities and lifestyle	**Response about role of climate change (%)**					
	Kunchha		**Khudi**		**Ilampokhari**	
	Yes	**No**	**Yes**	**No**	**Yes**	**No**
Increased working hours on economic activities	**20**	**80**	**86**	**14**	**86**	**14**
Decreased working hours on economic activities	0	100			0	100
Increased family member migration	**55**	**45**	**88**	**12**	**100**	**0**
Decreased family member migration	0	100				
Increased poultry farming	12	87			0	100
Decreased poultry farming	**83**	**17**			**100**	**0**
Increased fruit farming	75	25				
Decreased fruit farming	**78**	**27**	**100**	**0**	**100**	**0**
Increased agribusiness	0	100	0	100	67	33
Decreased agribusiness	**71**	**29**			**100**	**0**
Increased livestock rearing	0	100	100	100	50	50
Decreased livestock rearing	**75**	**25**	**0**	**0**		

Migration increased heavily during the last twenty years. Altogether, 93% of the respondents mentioned increased migration for several reasons, such as study abroad, jobs, and natural disasters. Among them, 73% of the migration was due to natural disasters such as floods and landslides. According to a living standard survey of Nepal (NDHS, 2011), 55% of households receive remittances from abroad, in contrast to 23% in 1995. There is no doubt that the inflow of remittances from migrants is a potential source for improving local food security and livelihoods through increasing economic access to food and enhancing local small businesses for local skilled and unskilled labor. But migration has also added challenges in the mountain areas. Increased migration and decreased interest by the youth in farming also add to low production in agriculture (Hussain et al., 2016). Households in all three VDCs face frequent labor shortages, which together with water shortages is leading to increased amounts of fallow agricultural land. This also imposes household burdens on women, children, and elderly people, and it has exacerbated many social problems and family fragmentations.

4.5 Adaptation to Climate Change

Climate variability has major impacts on lives and livelihoods. Households have adopted various practices to cope with changing climate that strengthen their resilience. Some of them changed their profession from agriculture to others professions with changing climate. Changes in farming practices include water conservation methods, changes in sowing time, and introduction of new cash crops such as black cardamom and coffee, which are more resilient to water stress and have higher market value (Hussain et al., 2016). Some of the households gave up rearing certain livestock. Climate change has resulted in significant degradation of pastures and rangelands, which are free sources of grazing for livestock. Some of the households gave up planting crops, which were highly vulnerable to water stress. Some households introduced new crops on their farms. In Nepal, farmers are shifting their cropping patterns from highly water-consuming crops (e.g., rice) to fruits and vegetables that are high-value crops (Gurung and Bhandari, 2009; Hussain et al., 2016). Some of them started new off-farm income activities to support their food security and livelihoods because of high vulnerability to landslides and floods.

The majority (60%) of the respondents from Khudi, 38% from Kunchha, and 22% from Ilampokhari VDC changed their farming practices, changed professions from agriculture to others, or changed from food crops to cash crops (Figure 4.9).

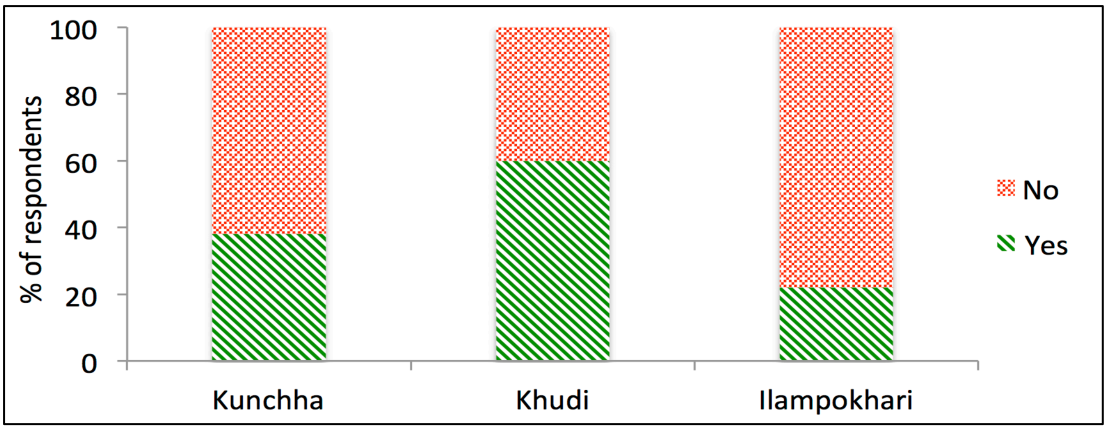

Figure 4.9 Households that changed profession in Kunchha, Khudi, and Ilampokhari VDCs of Lamjung

Among the households that changed professions, 80% from Khudi, 62% from Kunchha, and 10% from Ilampokhari perceived a role of climate change in changing profession (Figure 4.10). They mentioned that they were unable to feed their families while doing food crop agriculture, so they started cash crop agriculture. It helped to increase their income, and they could buy food from a nearby market. It is also reflected in food accessibility of the households, with very few respondents reporting decreased food accessibility (only 2%).

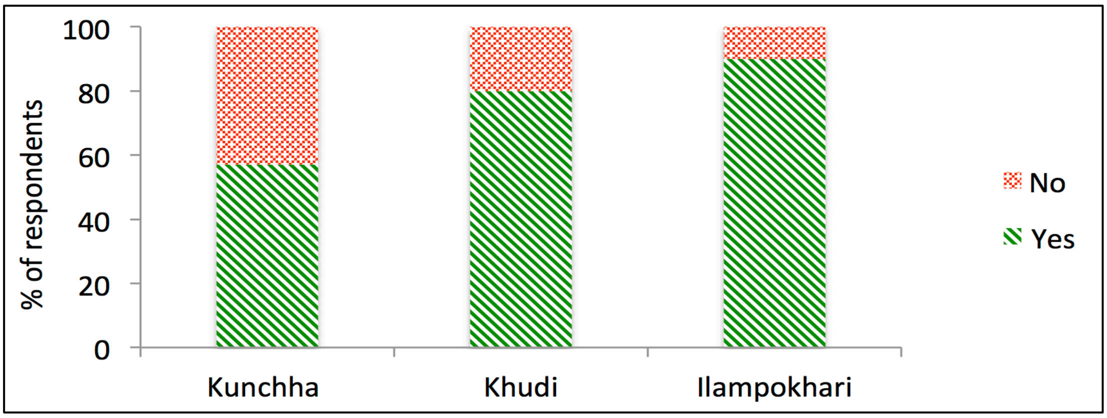

Figure 4.10 Respondents that changed profession due to climate impacts from Kunchha, Khudi, and Ilampokhari VDC of Lamjung

4.6 Conclusions

A majority of the mountainous households were aware of climate change, and they experienced hotter days, less rainfall, droughts, floods and landslides for the last twenty years. The perception of climate change by households seems to relate to the direction to which climate variables actually change. The higher percentage of the household from Ilampokhari VDC perceived intense rainfall in summer where precipitation increased from 1980 to 2012. Similarly, the higher percentage of household from Khudi perceived drought where precipitation decreased from 1980 to 2012 (Poudel and Shaw, 2016). The mountainous households do have varying levels of perception and attitudes towards climate change and its impacts.

Most of the respondents perceived impact of climate change on decreased food production, decreased dairy production, food price increased and increased households burden. This study found that the overall food security of Khudi households` was deteriorated in comparison with Ilampokhari and Kunchha for the last twenty years due to decreased income, decreased crop production and deteriorated food consumption pattern. It is now widely recognized that rural mountainous households are most affected due to the extreme climate events because of the highly dependency on natural resources.

The mountainous households already started autonomous adaptation practices to combat with the changing climate. These include changes in farming practices such as use of fertilizer responsive high yielding crops, abandoning certain highly water consuming crops and giving up rearing certain livestock, which are vulnerable to water and fodder stress. In addition, households invested in preparedness for climate-induced hazards such as floods and landslides. Some of them took on new off- farm activities due to the increased vulnerability of agriculture and decided to migrate as an adaptation measure to find off-farm income opportunities.

From the view of the study`s findings, the following policies are suggested to minimize the impacts of climate change and to ensure the households food security in the mountainous region of Nepal.

- ❖ Climate change has brought both opportunity and challenges for the mountainous households. It is crucial to enhance their understanding of risk related to climate change so that they are better prepared not only for the potential negative impacts but also for taking advantages of any opportunity comes from climate change. For examples some of the households reported production of cauliflower, tomatoes and cabbages in the higher altitude that was not possible twenty years back. National and local planning process should take into account such rising opportunities while preparing adaptation plan in Lamjung.
- ❖ Nepal government need to identify specific zones for high value crops such as fruits, cardamom, coffee since orange trees are damaged in Lamjung because of virus in the recent years that was one of the main sources of income for the households. Decreased orange farming has impacted on the livelihoods of the mountainous households.
- ❖ Local and national government should invest in development infrastructure facilities such as roads, markets, and extension services in partnership with

private sectors (Hussain et al., 2016). Capitalizing on local potential and opportunities will also help to control out-migration and lack of manpower in agriculture sector.

- Nepal government needs to establish different food security policies for the mountainous households based on geographical and spatial variation because of differential impact of climate change and differential vulnerability of the households. There is also a need to make an amendment on climate change policies and agricultural policies under the projected changes in climatic conditions. Some policies seem to be inappropriate. For example, the Nepalese government promotes cultivation of rice and pulses in mountainous areas, although these crops are resource-intensive and very sensitive to water stress (Hussain et al., 2016).

5 Chapter 5 Assessment of Households` Livelihood Vulnerability to Climate Change

This chapter analyses the livelihood vulnerability of mountainous households amidst climate change. It starts with identifying the major climate-related hazards and the most impacted livelihood options and resources in Lamjung. The chapter characterizes the livelihood vulnerability of households based on locations, well-being status, and gender of the household's head through a vulnerability composite index and VI-IPCC approaches. It identifies the contributing factors for exposure, sensitivity, and adaptive capacity of the households. Based on the research findings, the chapter identifies that the state of exposure is mainly based on geographical location rather than individual and social characteristics, and the adaptive capacity of individuals and society varies according to social dimensions and socio-economic status. Therefore, differences in the adaptive capacity determine vulnerability. Hence, very poor, poor, and female-headed households are more vulnerable to climate change in the study areas.

5.1 Introduction

Based on spatial variation and time, climate change has various levels of impacts on different communities (Bellard et al., 2012; Lejeusne et al., 2009; Mearns and Norton, 2009; Wagener et al., 2010) and sometimes on the state of development as well. The rural mountainous communities that depend on natural resources for subsistence livelihoods and agriculture are mostly affected by climate change (Poudel and Shaw, 2015). International and national organizations have focused on two major policy responses to address climate change. They focus on reducing the emission of greenhouse gases to slow down the rate of change and increasing the coping capacity of countries, sectors, and communities with the adverse impacts of climate change through adaptation (Ford and Smit, 2004). The identification of adaptation needs to start with vulnerability assessment, which is the state of susceptibility to harm from exposure to environmental change. This vulnerability is influenced by socio-economic profile, resource use, and other factors. Therefore, not all the communities are equally vulnerable (Fussel, 2007).

Several studies have identified several vulnerable groups in underdeveloped and developing countries (Ayers and Huq, 2009). They include households dependent on natural resources for their and geographically remote areas (Kohler et al., 2010; Mirza, 2011; Terry, 2009). In addition, poor households and women are highly vulnerable (Gentle et al., 2014; Wang et al., 2013). The households dependent on natural resources for their livelihoods are the most vulnerable communities in Nepal (Gentle and Maraseni, 2012; MoE, 2010). The Ministry of Environment (MoE, 2010) reported that Nepal has witnessed erratic rainfall, unpredictable onset of monsoon seasons, and increasing temperatures. The average annual temperature is increasing by 0.06°C/yr with a higher rate of warming at higher altitude (Ebi et al., 2007; Mishra et al., 2014a). Precipitation is becoming more unpredictable and more erratic with prolonged droughts. Similarly, monsoon and pre-monsoon precipitation has become heavier than historical records (Duncan et al., 2013; Poudel and Shaw, 2016; Shrestha et al., 2000). These have all led to an increasing vulnerability to droughts, flash floods, landslides, and GLOFs.

In addition, Nepal is ranked as the fourth most vulnerable country based on its extremely vulnerable situation (Maplecroft, 2010). The National Adaptation Program of Action (NAPA, 2010) identifies agriculture, forestry, and water resources as the most vulnerable sectors to climate change. Landslides, droughts, and GLOFs are the major related hazards. The risk of these hazards is also very high in mountainous topography. Therefore, climate change will also likely have a significant impact on the livelihoods of households. This will eventually increase the vulnerability of households living in the hilly and mountainous parts of Nepal, and a detailed study is urgently needed.

The causes of vulnerability can be different at different social, geographical, and temporal scales, but vulnerability is always experienced locally (Ribot, 2009). Few suitable adaptation policies and programs have already been formulated and implemented in some developing countries (Mertz et al., 2009). Nevertheless, only limited knowledge is available on livelihood vulnerability in Nepal at the regional, national (MoE, 2010), and household levels (Ghimire et al., 2010). Therefore, the assessment of household vulnerability to climate change is very necessary in the context of Nepal, especially to explore how climate change is impacting groups with different wellbeing in the community and different communities in the same territory. Thus, this study analyzes the vulnerabilities at the local level in-depth by integrating quantitative data with qualitative information obtained from a field survey. This was done by analyzing micro-level climate change vulnerability at the household level. This makes it easy to understand the perception of different wellbeing groups in response to major hazards and to identify hazard-induced risks, vulnerability, the most impacted livelihood resources, and the most vulnerable population. Social exclusion and marginalization remain a major challenge for the overall development of poor and marginalized people, so micro-level vulnerability analysis is important in Nepal (World Bank, 2006).

This study focuses on understanding how climate change is impacting the livelihood resources of different wellbeing groups in different communities. This chapter analyses the impacts of climate change and vulnerability in the mountainous region of Nepal to understand more about the following:

1. Perceptions by local people of major climate-related hazards and their impacts on livelihoods resources.
2. Livelihood options that are considered as the most vulnerable for households.
3. The most vulnerable household to the impacts of climate change.

The following sections present the theoretical background of climate change vulnerability, a description of a case study in Nepal where a vulnerability assessment was done, and the methods used to determine the theoretical and policy implications.

5.2 Climate Change Vulnerability

The intergovernmental panel on climate change has developed a holistic approach to climate change vulnerability that combines various methods related to ecological, biophysical, and social vulnerability (Panthi et al., 2015; Piya et al., 2016). The IPCC defines vulnerability as “the degree to which a system is susceptible to, or unable to cope with the adverse effects of climate change, including climate variability and extremes" (IPCC, 2001). In the Fifth Assessment Report (AR5), the IPCC defines vulnerability as "the propensity or predisposition to be adversely affected." Vulnerability encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt (IPCC, 2014).

Vulnerability is a function of the character, magnitude, and exposure to climate variation, as well as sensitivity and adaptive capacity (IPCC, 2001). This definition considers that exposure is the magnitude and duration of the climate-related exposure due to climate-induced disasters and variability such as landslides, droughts, floods, and variability in average annual temperature and precipitation. Sensitivity is defined as the degree to which a system or its major components are affected by exposure, such as sensitivity to water, food, and health. Adaptive capacity is defined as the system`s ability to withstand or recover from exposure, which his mainly based on the social network, livelihood strategies, and socio-demographic profile. The state of exposure is mainly based on geographical locations rather than individual and social characteristics (Adger, 1999; Gentle et al., 2014). The adaptive capacity of individuals and society varies according to social dimensions and inequities, such as gender and socio-economic status (Ribot, 2009). Particularly, the poor and marginalized populations in the developing world are already facing the impacts of climate change-induced extreme events, and they are more likely to suffer from them (Adger et al., 2003; Hedger et al., 2012). This is due to several deep-rooted factors in developing countries. For example, the livelihoods of a large population are dependent on agriculture and are very sensitive to climate change, most of the populations are poor with lower adaptive capacity, and it is difficult to adapt to climate change due to the low economic and technical capacity of developing countries (Mertz et al., 2009).

Climate change-related hazards such as droughts and floods create stress on rural livelihood by reducing existing livelihood options and creating volatility and unpredictability in streams of livelihood benefits (Conway and Schipper, 2011; Wang et al., 2016). The poor and marginalized are severely affected by the impacts of climate change due to limited livelihood options, such as dependency on climate-sensitive livelihoods, inequitable access to productive assets, education, limited skills, and inadequate access to services (Adger et al., 2003; Gentle and Maraseni, 2012; Paavola and Adger, 2005). Institutional constraints such as lack of property rights and social protection further prevent poor people from investing their scarce resources in managing climate risks (Ribot, 2009).

Most of the analyses are based on the IPCC's definition of vulnerability as a function of exposure, sensitivity, and adaptive capacity (Aryal et al., 2014; Ebi et al., 2007; Hahn et al., 2009; O`Brien et al., 2004; Piya et al., 2016; Vincent and Cull, 2010). More specifically, vulnerability is a positive function of the system`s exposure and sensitivity, as well as a negative function of the system`s adaptive capacity (Aryal et al., 2014; Ford and Smit, 2004). These dimensions are dynamic and specific to the system (Macchi, 2011; Smit and Pilifosova, 2003). Adaptive capacity is an important element in most conceptual frameworks of vulnerability and risk. It refers to the positive features of people`s characteristics that may reduce the risk posed by certain hazards. Improving capacity is often identified as the target of policies and programs based on the belief that strengthening capacity will eventually lead to reduced risk and vulnerability (Cardona et al., 2012). Climate change vulnerability is often placed in direct opposition to capacity. Measured vulnerability has been seen as the remainder after capacity has been taken into account (Cardona et al., 2012).

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

5.3 Materials and Methods

Both quantitative and qualitative methods were used based on pragmatism using an interpretivist perspective for this research (Johnson et al., 2007; Tashakkori and Teddlie, 2003). This perspective links quantitative data collection methods with social science-based qualitative methods that often deal with individual actions and their relationship with society. Data were collected through a mixed method involving quantitative and qualitative approaches. A household survey of 150 households was conducted for the quantitative data, while key informant interviews (KIIs) (n= 20 key informants), focus group discussion (FGDs) (n= 9 events), and participant observations were used to obtain qualitative data. The three VDCs, Kunchha, Khudi, and Ilampokhari were selected based on the availability and the proximity of the observed climatic datasets. The secondary data were collected from different organizations. Temperature and precipitation observations from 1980 to 2013 from stations in these VDCs were obtained from the Department of Hydrology and Meteorology (DHM). Climate-related hazard data were collected from the District development committee (DDC) of Lamjung and the International Disaster Database (EM-DAT).

Households were categorized into four wellbeing groups of well-off, medium, poor, and very poor (Table 5.1). To categorize households, participatory wellbeing ranking was applied to the research sites based on the relative wellbeing status of households in the community using local criteria (Mosse, 1994). Different researchers have tested the empirical validity of this method as a means of socio-economic stratification of households in Nepal and abroad (Gentle et al., 2014; Gentle and Maraseni, 2012; Richards et al., 2003; Sharma, 2010). The most common criteria used were landholding size, quantity and quality of land, house quality, food sufficiency, income sources, educational status of family, and involvement in saving and credit cooperatives.

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

Social Sciences (SPSS). Analysis of variance (ANOVA) and the chi-squared test were performed to test the significance of mean values between groups.

Table 5.1 Local criteria of well-being developed and applied in this research

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

5.3.1 Participatory Analysis of Climate Vulnerability and Rural Livelihoods

The participatory rural appraisal (PRA) was applied to understand climate-related hazards, rural livelihoods, and climate vulnerability. This technique has been commonly applied to assess livelihood vulnerability to climate change (Chambers and Conway, 1991; Dazé et al., 2009). The PRA helps improve understanding of the implications of climate change on people`s livelihood, it examines both hazards and socio-economic status, and it promotes multi-stakeholder analysis.

Focus group discussion (FGD) is one of the main PRA techniques often used to identify problems and causes of climate change along with possible mitigation and adaptation strategies (Uddin and Anjuman, 2013). The methodology comprises several participatory tools, including history of climatic hazards, seasonal calendars, historical timeline of livelihood activities, and ranking of the most impacted livelihood options and resources. Households were encouraged to share their experience of climate-related disasters and impacts on their livelihood through the FGDs. The results and findings were presented in a plenary of community members to validate and confirm the information. FGDs were performed in all three VDCs with different wellbeing groups and genders of the household head.

5.3.2 Concept of Livelihood Vulnerability Index (LVI)

The LVI was used to understand the contribution of demographic, social, and physical factors to climate change vulnerability. It was originally designed as a practical tool to provide the required vulnerability information to development organizations, policy makers, and planners. It is a flexible approach where development planners can focus their analysis to match the needs of each geographical location and wellbeing group. From the overall composite index, sectorial vulnerability indices can be segregated to identify potential areas for intervention for adaptation planning (Hahn et al., 2009). Furthermore, vulnerability indicators developed to estimate livelihood vulnerability in two districts of Mozambique (Hahn et al., 2009) were modified to fit the context of Nepal and applied according to wellbeing status, gender of the household head, and location of the respondents. Descriptive information generated from the survey based on 19 sub-components was grouped into eight major components: climate variability, natural disasters, heath, food, water, socio-demographic profile, livelihood strategies, and social networks (Table 5.2).

Table 5.2 Major components and sub-components, information sources and their functional relationship

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

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

Selection of indicators was based on stakeholder consultations and a literature review (Aryal et al., 2014) (Gentle et al., 2014) (Hahn et al., 2009) (Panthi et al., 2015) (Piya et al., 2016).

5.3.3 Livelihood Vulnerability Index Calculation

Calculating the LVI: Composite Index Approach

All eight major components of the LVI comprise several indicators or sub-components, and their functional relationship is presented in Table 5.2. The sub components within the major components of vulnerability were customized to the local context by consultation with several field-level experts and stakeholders and based on previous literature. Many authors have used a similar approach in various contexts because this assessment tool is accessible to a diverse set of users in resource-poor settings (Aryal et al., 2014; Etwire, 2013; Panthi et al., 2015; Shah et al., 2013). The LVI applies equal weights to all major components. Each of the sub-components was measure on a different scale, so it was first necessary to normalize them for comparability. The equation for normalization is given below:

$$Index\ S_V = \frac{S_V - S_{min}}{S_{max} - S_{min}} \quad (5.1)$$

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

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

$$M_V = \frac{\sum_{i=1}^{n} indexS_{V_i}}{n} \quad (5.2)$$

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

$$LVI_V = \frac{\sum_{i=1}^{8} W_{mi} M_{vi}}{\sum_{i=1}^{8} W_{mi}} \tag{5.3}$$

This equation can be expressed in an expanded form as:

$$LVI_V = \frac{W_{CV}\, CV_V + W_{ND}\, ND_V + W_H\, H_V + W_F\, F_V + W_w\, W_V + W_{SDP}\, SDP_V + W_{LS}\, LS_V + W_{SN}\, SN_V}{W_{CV} + W_{ND} + W_H + W_F + W_W + W_{SDP} + W_{LS} + W_{SN}} \tag{5.4}$$

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

LVIv is the livelihood vulnerability index for *VDCv*, and it equals the weighted average of the eight major components. The weights *Wmi* of each major component are determined by the number of sub-components that make up the component and are included to ensure that all sub-components contribute equally to the overall LVI (Hahn et al., 2009; Panthi et al., 2015; Sullivan, 2002). The overall LVI was scaled from 0 (least vulnerable) to 0.8 (most vulnerable). For illustrative purposes, a detailed example of calculating the LVI is given in Appendices 3 and 4. A similar method was applied to calculate the LVI of different wellbeing groups and of male- and female-headed households.

Calculating the VI-IPCC: IPCC Framework Approach

Another method is applied for calculating the LVI based on the IPCC vulnerability definition, which focuses on exposure, sensitivity, and adaptive capacity. Table 5.2 shows the organization of the eight major components in the VI-IPCC framework. Exposure is measured by the climate variability and natural disasters. Climate variability is measured by the mean standard deviation of the monthly average of average maximum and minimum daily temperature and precipitation. The numbers of natural disasters that occurred in the past 30 years were considered. In addition, the value of the precipitation subcomponent was derived from averaging the mean standard deviation of the monthly average precipitation of the three stations for the wellbeing status and sex of the household head. Similarly, sensitivity was measured by assessing the current state of a VDC`s food security, water resources, health, diseases, and emergence of insects. Adaptive capacity is quantified by the demographic profile of households and VDCs (e.g., male-headed households), types of livelihood strategies (% of households with other sources of income), and strength of social network (involvement in saving and credit cooperatives).

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

The same components outlined in Table 5.2 and Equations 5.1, 5.2, and 5.3 were used to calculate the VI-IPCC. The index value is different from the LVI in how the major components are combined. Instead of merging the major components into the LVI in aggregate, they are first combined according to the categorization into exposure, sensitivity, and adaptive capacity:

$$CF_V = \frac{\sum_{i=1}^{n} W_{mi} M_{vi}}{\sum_{i=1}^{n} W_{mi}} \quad (5.5)$$

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

Vulnerability = Exposure + Sensitivity –Adaptive Capacity (5.6)

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

5.4 Results and Discussions

5.4.1 Climate-related Hazards and Most Impacted Livelihood Resources

During the survey, households were asked to choose the major climate-related hazards and to relate these to the most impacted livelihood resources. Households chose temperature increases, changes in rainfall, droughts, and the emergence of insects or diseases as the major hazards. The most impacted livelihood resources were winter crops, orange farming, rice cultivation, livestock rearing, migration, and labor. Hazards related to farm productivity included increasing incidence of crop damage from insects and crop diseases, as well as increasing incidence of livestock diseases. Furthermore, there were more extreme hot and cold days, which threaten agricultural products and livestock. Regarding the perception of households to changing climate, most of them were aware of the climate change, and they have noticed hotter days in summer and fewer cold days in winter. This perception was compared with hydrology and meteorological data (1980-2013) available from the nearby Khudi station. The analysis showed that maximum and minimum temperatures increased by 0.02^{o}C/yr and 0.07^{o}C /yr, respectively (Poudel and Shaw, 2016).

Altogether, 39% of the respondents reported drought as a the most common hazard, as it affects water availability and consequently delays crop plantation, growth, and production, and it eventually increases the uncertainty in agricultural productivity. Drought was a major cause of winter crop damage in the district over the last 30 years, such as decreased barley yield (Poudel and Shaw, 2016). A majority of the respondents expressed that the incidences of drought increased and are linked with decreased water resources over the past few years at the study sites. Additionally, high mountain communities reported that there used to be good snowfall in high-altitude areas, which had been up to 2 to 2.5 feet in the past. However, it had been negligible for the last 5-6 years. It was also reported that inhabitants of the upper mountain area had migrated due to drying-up water sources. Furthermore, local people in high mountain areas also noticed spectacular changes in their surroundings in the last couple of decades: hillsides that used to be covered in snow throughout the year are now bare and dry.

Insect infestations, and crop and livestock diseases are also major hazards reported by 20% of the respondents. Common insects and diseases in the farmlands were reported as *lie* (aphids) in legumes and green vegetables, *gabaro* (stem borers) in maize, *patero* (rice bugs) in rice paddies, and blight in other winter crops. Similarly, landslides and avalanches were reported as another major hazard by 20% of the respondents. Particularly, poor families living on hill slopes and landslide-prone areas reported that they were stressed during the rainy season because of landslides. Flood is another major hazard in the research area according to 9% of the respondents, especially for households who live in lowland areas and who have cultivable land along rivers. Similarly, 8% of respondents believed that erratic rain and snowfall are the most common hazards in high-altitude villages. Higher percentages of respondents in the Khudi VDC reported erratic rainfall (14%), insects or livestock diseases (22%), and droughts (52%). The percentage of respondents was higher in the Kunchha VDC for floods (16%) and landslides (42%), whereas the percentage of respondents from Ilampokhari was higher for glacier lake outburst floods (GLOFs) (4%; Figure 5.1).

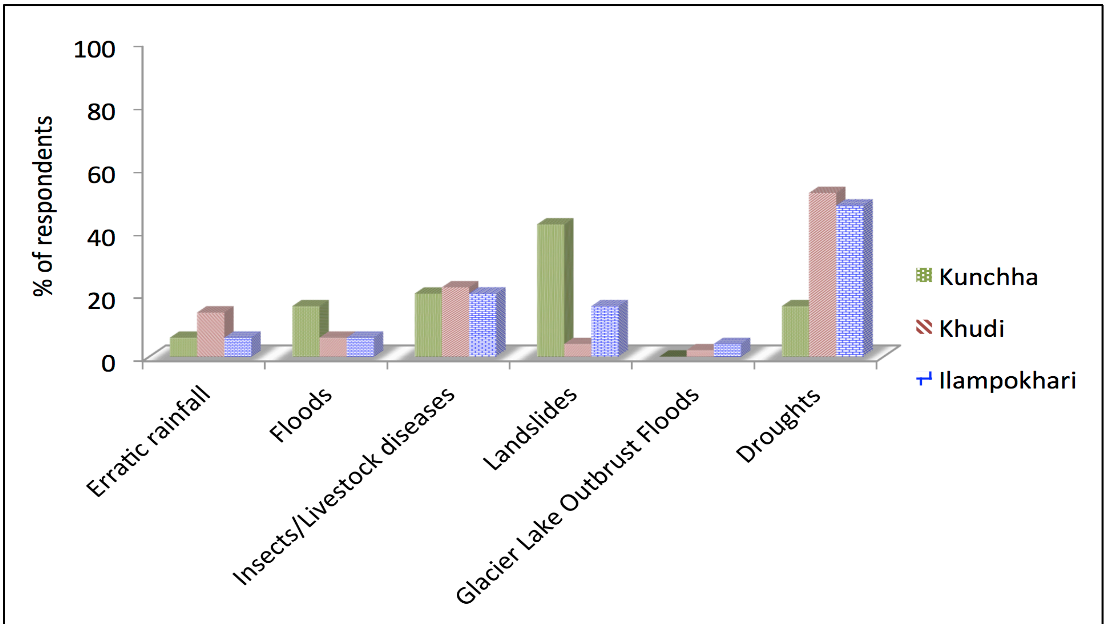

Figure 5.1 Percentage of respondents regarding climate-related natural hazards in Kunchha, Khudi, and Ilampokhari VDCs of Lamjung

5.4.2 Most Vulnerable Livelihood Options

Households were asked to rank the vulnerable livelihood options from the most vulnerable (significant climate impact=4) to the least vulnerable (no impact=0). Altogether, winter crops were ranked the first most vulnerable livelihood option by 65% of the respondents, as there was decreased winter crop production due to insufficient rainfall in winter (Table 5.3). Each VDC also showed similar results, (66% in Kunchha, 62% in Khudi, and 68% in Ilampokhari. The most impacted winter crop was barely, which decreased in yield from 1980 to 2013 in the study areas. Similarly, 36% of the respondents ranked rice cultivation as the second most vulnerable livelihood option as there was uncertainty in planting time due to erratic rainfall, inadequate water following the planting of seedlings, and damage to the crops by insects and diseases. One of the respondents from a very poor household reported, "We have to wait for rainfall for paddy cultivation as there is no irrigation facility." The availability of irrigation facilities was found to be crucial in determining crop loss in the face of erratic rainfall. Survey data revealed that 50% of all respondents had irrigation facilities to grow their primary crops, including 81% of well-off, 40% of medium, 42% of poor, and 23% of very poor households. Irrigation facilities to produce primary crops had a significant association with wellbeing status ($P < 0.01$) of the respondents.

Table 5.3 Most impacted livelihood resources ranked by the respondents from Kunchha, Khudi and Ilampokhari VDCs

Rank	Most vulnerable livelihood options	% of respondents
I	Winter crops	65
II	Rice cultivation	36
III	Orange farming	38
IV	Migration	47
V	Labor	47

Scores: High impact=4 to low impact=0.

Note: percentage is not 100% due to multiple responses.

Orange farming was the third most vulnerable livelihood option according to 38% of the respondents ranked. Due to the emergence of new citrus fruit diseases (MOAD and FAO, 2011), most of the orange trees had died, bore decreased numbers of fruits, and small fruit with poorer taste than previously. One of the well-off families of the Kunchha VDC reported, "I used to sell oranges at around 200,000 Nepalese rupees per year, but now there are no fruits on the orange tree or the size is smaller and the taste is not as good as in previous years" (1 USD=106 NPR as of November 4, 2016). Drying-up water levels in traditional sources such as spring-fed ponds and streams was indicated by 59% of the respondents. Drying water resources increased stress and caused livelihood vulnerability due to a scarcity of drinking water, inadequate water for irrigation, and increased internal migration.

The study revealed that almost all households have already experienced climate change and its impacts on their livelihoods. However, the impacts of climate change mentioned by the households varied according to their wellbeing status, occupations, and geographical locations. For example, the emergence of new insects or increasing number of pests and diseases on farms were reported as a major problem by households residing in high-altitude villages, while droughts and floods were reported by households in downstream villages. Furthermore, scarcity of drinking water resulting from gradually drying water resources was more commonly found in the uplands. Hence, it can be concluded that vulnerability to the impacts of climate change varies due to the geographical locations, wellbeing status, and occupations. The results confirm that the poor within the communities are disproportionately affected by the impacts of climate change due to settlement on marginal lands, high dependence on climate-sensitive livelihoods, limited livelihood options, inequitable access to productive assets, limited information, poor education, and limited skills.

5.4.3 Most Vulnerable Households

The analysis results of identifying the most vulnerable communities are presented in two different ways. First, the results obtained from the assessment of individual major components and sub-components` contributions to each major component are presented together with the overall LVI (Figure 5.2, Appendix 4). Second, the estimated values for the different dimensions (exposure, sensitivity, and adaptive capacity) of the climate vulnerability index are presented (Figures 5.3, 5.4, 5.5, and Table 5.4). Climate change vulnerability was tested to examine the vulnerable communities according to their wellbeing status, location of the households (Kunchha, Khudi, and Ilampokhari), and gender of the household head. Exposure was measured in terms of climate variability and natural disasters; sensitivity was measured in terms of impacts on health, food, and water; and the adaptive capacity was measured in terms of socio-demographic profile, livelihood strategies, and social network of the households.

5.4.3.1 Livelihood Vulnerability Index

The overall LVI was higher for Khudi VDC (0.351) as compared to the Kunchha VDC (0.310) and ILampokhari VDC (0.309), indicating that households of Khudi are more vulnerable. The results for major components are presented in a spider diagram in Figure 5.2. Khudi households were rated more vulnerable in terms of climate variability, natural disasters, health, food, and water. Kunchha was more vulnerable in regard to socio-demographic profile and social network. The livelihood strategies component had the highest value in Ilampokhari. The Khudi VDC is more exposed to extreme climate conditions, and the mean standard deviation of the monthly average of precipitation is higher than in Ilampokhari and Kunchha. However, the mean standard deviations of the monthly average minimum and maximum temperatures are the same for all study sites. Temperature data were available from only one station in the study areas.

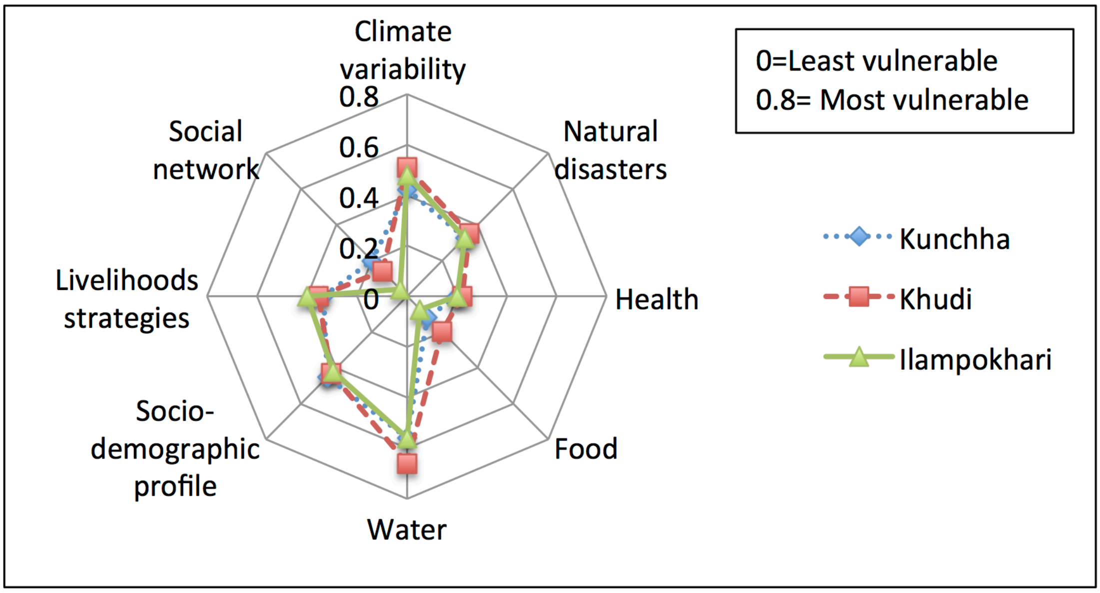

Figure 5.2 Vulnerability spider diagram for the major components of the livelihood vulnerability index (LVI) for the Kunchha, Khudi, and Ilampokhari VDCs

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

The Kunchha VDC is more vulnerable in regard to the socio-demographic profile and social network in comparison with Khudi and Ilampokhari (as indicated by the LVI value). Most of the subcomponents were highest in this VDC, including the average numbers of floods, and the percentage of households with decreased food accessibility and deteriorated food consumption patterns. The percentage of female-headed households was also highest in this VDC, which reflects that the majority of the population is from ethnic groups where most of the male counterparts go abroad for employment (Gurungs, Magars, Tamangs, marginalized groups, *etc*.).

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

5.4.3.2 Vulnerability Index- IPCC

The VI-IPCC score indicates vulnerability on a scale of -1 to +1. The results are similar in that households of Khudi (0.042) are the most vulnerable, followed by Kunchha (-0.077) and Ilampokhari (-0.085). The indexed values are calculated for each dimension of exposure, sensitivity, and adaptive capacity (Appendix 4, Table 5.4).

The results show that Khudi is more exposed (0.421) to climate variability and natural disasters than Ilampokhari (0.392) and Kunchha (0.368). Similarly, accounting for current health status and the availability of food and water, Khudi (0.277) was also more sensitive to climate change impact than Kunchha (0.204) and Ilampokhari (0.175). Kunchha (0.650), Khudi (0.656), and Ilampokhari (0.653) all had similar adaptive capacity, although there was a difference in exposure and sensitivity. In the VI-IPCC approach, the adaptive capacity is higher than the exposure, sensitivity, to climate change in all three VDCs (Figure 5.3). However, the Khudi VDC had the highest value in two major factors of vulnerability (exposure and sensitivity).

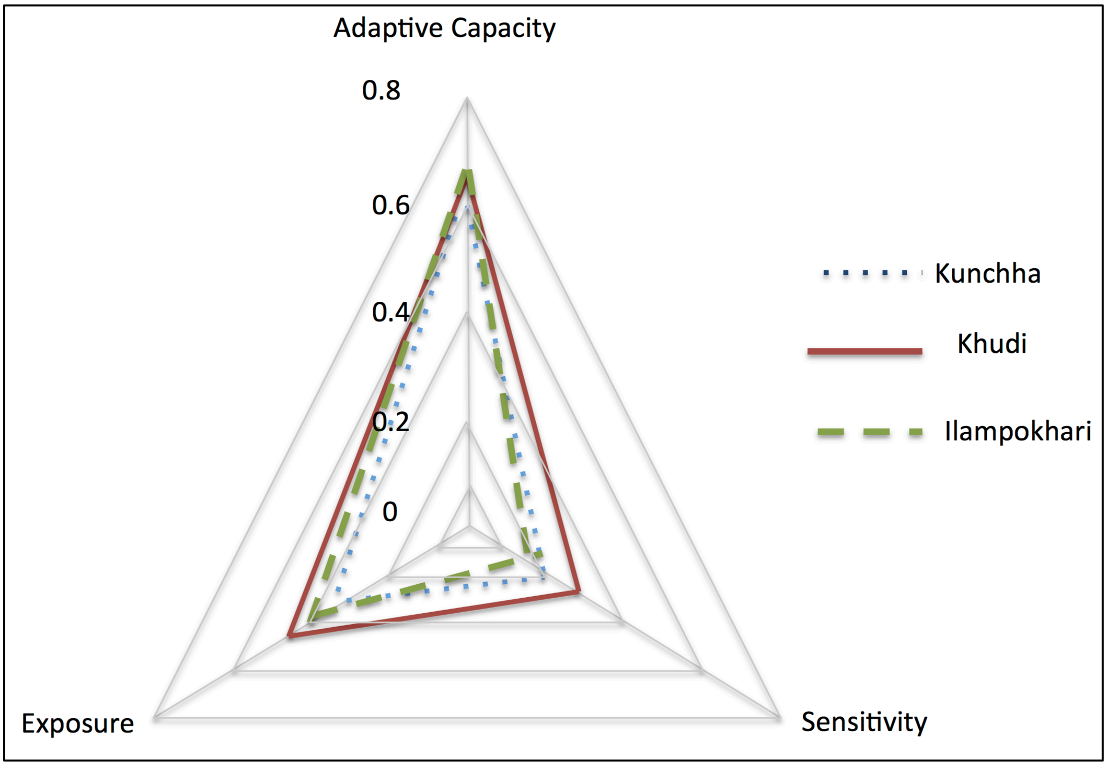

Figure 5.3 Vulnerability triangle diagram of the contributing factors of the livelihood index-IPCC (VI-IPCC) for Kunchha, Khudi, and Ilampokhari VDCs of Lamjung

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

Regardless of the similar adaptive capacity, the Khudi VDC is considered more vulnerable than the Kunchha and Ilampokhari VDCs due to higher exposure and higher sensitivity. However, no significant relationship was observed between the vulnerability of the three VDCs and exposure (P > 0.05), sensitivity (P > 0.05), and adaptive capacity (P > 0.05) as major factors of vulnerability.

The analysis shows that there was a uniform pattern or trend between vulnerability factors and components within the three VDCs. Although the three VDCs varied according to altitude, livelihood opportunities, distance from district headquarters, and ethnicity of the households, the differences were neither significant nor decisive factors in defining the level of vulnerabilities.

Table 5.4 Vulnerability of the respondents according to location, wellbeing status, and gender of the household head

Vulnerability contributing factors	Well-being status				Location			Gender of household head	
	Well off (n=42)	Medium (n=62)	Poor (n=33)	Very Poor (n=13)	Kuncha (n=50)	Khudi (n=50)	Ilam pokhari (n=50)	Male (n=89)	Female (n=61)
Exposure	0.374	0.384	0.387	0.390	0.368	0.420	0.392	0.390	0.395
Sensitivity	0.157	0.214	0.269	0.318	0.204	0.277	0.175	0.217	0.296
Adaptive capacity	0.773	0.653	0.585	0.435	0.65	0.656	0.653	0.716	0.549
VI- IPCC	-0.241	-0.054	0.072	0.272	-0.077	0.042	-0.085	-0.109	0.142

Livelihood Vulnerability According to Well-being Status of the Households

Livelihood vulnerability was analyzed according to wellbeing status of the households. The results reveal that the vulnerability factors (exposure, sensitivity, and adaptive capacity) varied according to the wellbeing status of the households (Figure 5.4). Very poor and poor households are more exposed to natural disasters, as they reported more events of natural disasters such as landslides and droughts. In the remote areas of Nepal, mostly poor households are concentrated on slopes and steep hills for their livelihood due to the lack of access to the lowland areas. Sensitivity is also higher for very poor and poor households, followed by medium and well-off households. The differences in the food component are mainly higher due to (i) higher average food-insufficient months of very poor and poor households, (ii) higher percentage of decreased in food availability or accessibility, and (iii) higher percentage of deterioration in food consumption patterns.

The adaptive capacity of the households is significantly different ($P < 0.05$) according to wellbeing status. The differences are mainly due to (i) a higher percentage of household heads who did not attend school among very poor and poor households, (ii) higher percentage of households that did not have alternative sources of income besides agriculture among very poor and poor households, and (iii) small landholding size and rarely irrigated land among very poor and poor households in comparison with well-off and medium households. However, there was no statistically significant difference between wellbeing status, exposure ($P > 0.05$), and sensitivity ($P > 0.05$).

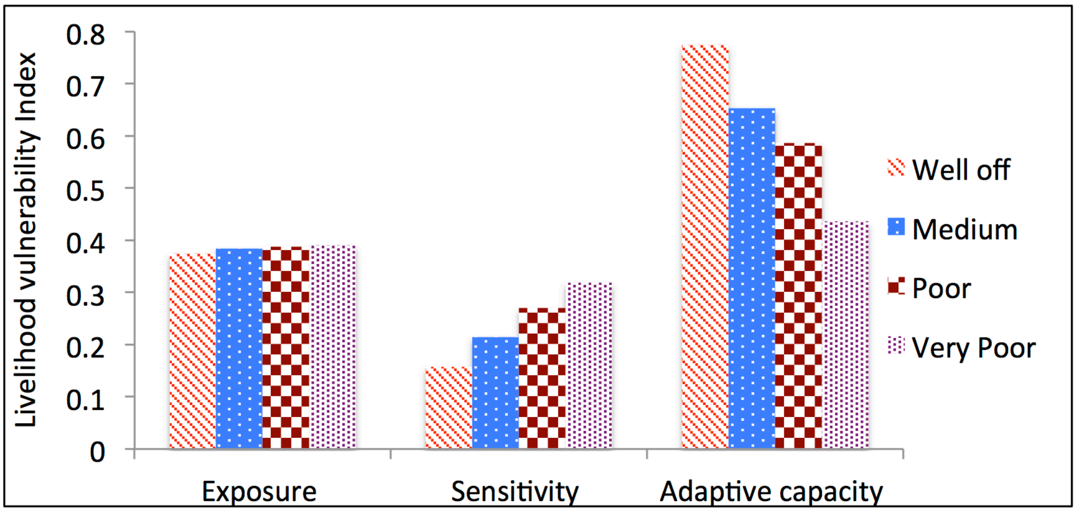

Figure 5.4 Livelihood vulnerability according to wellbeing status of the households in Lamjung

LVI value of 0 indicates the lowest, while 0.8 indicates the highest

Livelihood Vulnerability According to Gender of Household Head

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

According to the wellbeing status, well-off households had the highest percentage (41%) of female-headed households, followed by poor (39%), very poor (38%), and medium households (35%). The analysis shows that female-headed households had slightly higher exposure and sensitivity, as well as lower adaptive capacity in comparison to male-headed households (Figure 5.5). Similar results were derived by previous researchers (Gentle et al., 2014; Mainlay and Tan, 2012; Panthi et al., 2015). The exposure was slightly higher among female-headed households, as higher numbers of natural disasters such as landslides and floods are reported by female-headed households. Females are traditionally bound to housework, but in recent years, they have been facing increased burdens of household work along with agricultural activities due to the absence of their male counterparts.

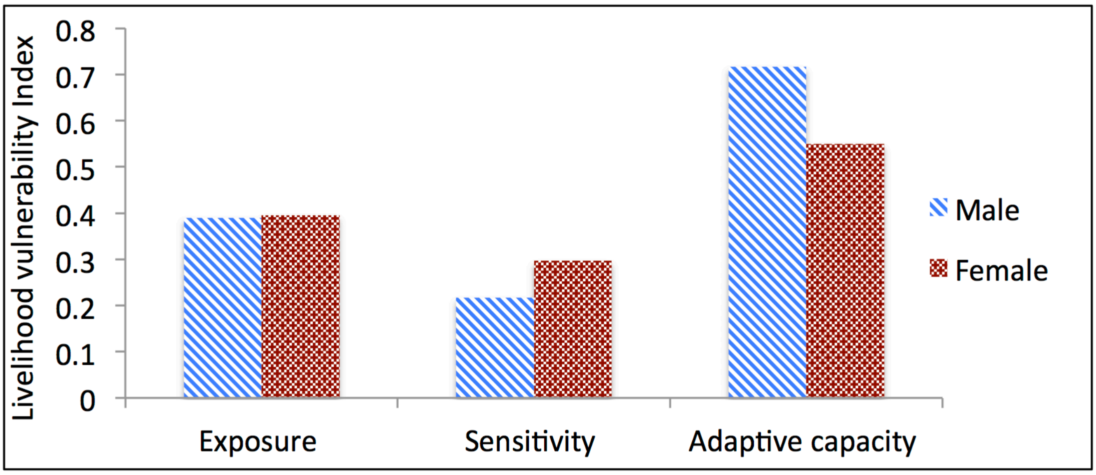

Figure 5.5 Livelihood vulnerability according to gender of the household head

LVI value of 0 indicates the lowest, while 0.8 indicates the highest

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

The adaptive capacity of the households is significantly different ($P < 0.05$) according to the gender of the household head because male-headed households (0.716) had more adaptive capacity than female headed (0.549) households. The differences were mainly due to a lower percentage of landlessness among male-headed households and higher percentages of households involved in social organizations. However, despite these huge differences, there is no significant difference between the male-headed households and female-headed household in exposure ($P > 0.05$) and sensitivity ($P > 0.05$).

Overall, Khudi had a higher LVI than the Kunchha and Ilampokhari VDCs, indicating greater vulnerability to climate change impact. The results of the major component calculations are presented collectively in a spider diagram (Figure 5.2). The scale of the diagram ranges from 0 (less vulnerable) to 0.8 (more vulnerable). The figure shows that Khudi is more vulnerable in terms of climate variability, natural disasters, health, food, and water, while Kunchha is more vulnerable in terms of socio-demographic profile and social network, and Ilampokhari is more vulnerable in terms of livelihood strategies. Similarly, very poor and poor households are more vulnerable, followed by medium and well-off households. Female-headed households are more vulnerable than male-headed households due to the higher exposure and sensitivity and lower adaptive capacity.

5.5 Implication of the Findings

The findings of this research can help to understand the contributing factors to vulnerability and enhance adaptive capacity of the rural households. Income and livelihood diversification options are essential for reducing the vulnerability of the local community (Ghimire et al., 2010; Panthi et al., 2015). The development of water infrastructure, rainwater harvesting, and water storage at the VDC level and district level would help reduce water problems in Lamjung. In addition, microfinancing could help communities through livelihood support and preparedness against risk during climatic extremes in Lamjung district, similar to other areas indicated by different studies (Heltberg et al., 2009; Panthi et al., 2015). This method can also be applied to calculate and compare vulnerable communities in other rural areas because the method is flexible, and indicators and subcomponents can be changed or replaced to calculate the vulnerability of sectors, regions, or communities (Aryal et al., 2014). This type of research is very important for focusing on reducing the impacts of climate change and vulnerability (Rosenzweig and Wilbanks, 2010). In determining the vulnerability of rural and remote areas in Nepal, it is important to consider the role of socio-economic changes, such as changing professions from agriculture to business or food crops to cash crops, and labor migration.

The findings have an implication for Nepal's climate change policies and programs, such as national adaptation programs of action (NAPA) 2010, local adaptation programs of action (LAPA) 2011, and climate change policy 2011, which ignored the concept of differential vulnerability in terms of analysis and adaptation planning. The findings suggest that the local communities as a unit of vulnerability analysis and the most vulnerable communities should be prioritized as groups for adaptation planning. Similarly, the findings have practical implications in vulnerability analysis and adaptation planning in consideration of geographical area, wellbeing status, and gender of the household head. Both NAPA and LAPA are oriented towards addressing climate hazards, overlook socio-political and underlying causes of vulnerability, and lack a process to identify and address the most vulnerable populations (Gentle et al., 2014). This process may result in inaccurate vulnerability analysis and further hinder identification of the adaptation needs of the most vulnerable communities.

Furthermore, the indexes used in this study are free of duplication and the limitation of secondary data problems. Furthermore, the index values for sub-components would be useful in assessing the impact of programs or policies by substituting the value of indicators (sub-components) that are expected to change and recalculating the overall vulnerability (Aryal et al., 2014; Hahn et al., 2009). Similarly, future vulnerability under some policy or program interventions could be calculated to see whether the planned activities can reduce vulnerability.

5.6 Conclusion and Recommendation

Based on the findings of this research, we can conclude that the households in the mountainous areas of Nepal are already experiencing the impacts of climate change on their livelihoods. The households that solely depend on rain-fed agriculture are mostly impacted. The trend of drying water resources, erratic rainfall, and increasing numbers of pests show that subsistence farming and livelihoods in the Kunchha and Khudi VDCs of Lamjung are becoming more challenging with the impacts of climate change. The overall vulnerability greatly varies according to occupation, gender of the household head, and wellbeing status of the households within the study areas. Because of the higher sensitivity of the very poor, poor, and female-headed households to the food, water, and health components and the lower adaptive capacity in terms of poor socio-demographic status, limited livelihood diversification strategies create large differences in vulnerability. Several researchers (Gentle et al., 2014; Gentle and Maraseni, 2012; Ribot, 2009) show similar results that describe the socio-economic, institutional, and policy dimensions of the households and communities govern sensitivity and adaptive capacity as components of vulnerability. The major determining factors causing vulnerability are access to resources and services, access to and control over natural resources such as land and water, as well as affordability of basic services such as food, water, and health. The outcomes of this research are consistent with previous research (Adger et al., 2003; Gentle et al., 2014; IISD, 2003; Paavola and Adger, 2005), which indicates that the poor within the communities are affected more by the impacts of climate change.

The LVI and VI–IPCC are related methods for assessing the aggregate relative vulnerability of communities to the impacts of climate change. Both approaches provide a detailed depiction of several factors affecting household livelihood vulnerability. Both of these indices varied across the three VDCs, different wellbeing groups, and gender of the household head. The results indicate that the households of the Khudi VDC, very poor households, and female-headed households in Lamjung were the most vulnerable to climate change. The indexed values for each component and subcomponent varied notably across sites, which provided insights for the design and implementation of site-specific coping strategies for the rural households.

This research suggests that climate change vulnerability is a complex process that requires analysis that considers multiple scales (location, timeframe, and population units), multiple disciplines (actors, institutions, and roles), and multiple causes (underlying causes related to structure, policy and systems), as indicated in some previous studies (Adger, 2006; Gentle et al., 2014; Ribot, 2009). A micro-level analysis of vulnerability may help in understanding the complexities and in designing adaptation plans at the local level. However, the accuracy is based on the relevancy of indicators and the reliability of local responses, including wellbeing ranking and stratification of households.

6 Chapter 6 Synopsis

This chapter highlights the progress achieved, their practical implications, and provides recommendation on priority areas of intervention for adaptation plan in Lamjung district, Nepal by incorporating specific research findings and recommendation in the previous chapters. This chapter principally focuses on the resilience of the mountainous households in the context of climate change and food security.

6.1 Introduction

Climate change is one of the most important global issues in the agendas of development and the environment. The IPCC (2014) report explains that climate change is already having visible impacts, especially in developing countries like Nepal, which are more vulnerable due to their inability to cope. Nepal is also confronted with issues like poverty, food insecurity, environmental degradation, and natural resource depletion (Schid, 2008). Climate change is expected to have serious environmental, economic, and social impacts in places where people`s livelihoods depend on resources such as agriculture, water, and forestry (Tiwari et al., 2012). Climatic variability therefore threatens the food security and livelihood of rural people in Nepal.

Climate change has different impacts on different locations because of Nepal’s remoteness, fragile landform, and diverse landscapes (Gentle et al., 2014). The situation is worsened by poverty, population pressures, land degradation, food insecurity, and deforestation. As one of the most vulnerable countries to climate change, it is become crucial for climate change adaptation plans and policy in Nepal to be centered on vulnerable groups to minimize the risk and strengthen resilience. To enhance food security and to improve the adaptive capacity of households, understanding the climatic impact on food production and the risk of households is essential (Heltberg et al., 2009). Therefore, assessment of the impacts of climate change on crop production, household food security, and livelihoods is urgently needed to develop intervention of adaptation plans. In this study, the impacts of climate change on crop yield, household food security, and livelihood vulnerability to climate change in Lamjung district were analyzed.

6.2 Achieved Results

This research focuses on understanding the trends of climate variability and their impacts on crop yield. Household food security and livelihood vulnerability were analyzed in the Lamjung district of Nepal. In this context, the relationship between climate variables and crop yield were examined with the consequences on household-level food security. Finally, the livelihood vulnerability of the mountain households was assessed.

6.2.1 Climate Variability Trend

Man-Kendall's and Sen`s slope methods were used to analyze seasonal and annual trends of accumulated precipitation along with seasonal and annual maximum and minimum temperatures from 1980 to 2012. The total annual precipitation at Kunchha and Gharedhunga stations increased by 10.48 mm per year and 4.42 mm/yr, respectively, whereas at Khudi station, it decreased by 3.47 mm/yr. Similarly, precipitation showed an increasing trend during summer in all three stations, a decreasing trend during winter, and mixed trends during spring and autumn. The negative trends in December precipitation were significant and reflect the changes in the winter precipitation.

Temperature data were available from only Khudi station, and the minimum and maximum values of seasonal and annual temperatures were analyzed. The maximum annual temperature increased by 0.02°C/yr, whereas the minimum annual temperature increased by 0.07°C/yr between 1980 and 2012. Although both the minimum and maximum temperatures increased, the rate of increase of the minimum temperature was more than three times higher than that of the maximum temperature. In all seasons, the maximum and minimum temperatures increased significantly ($p < 0.1$) except during spring.

6.2.2 Crop Yield Trend

The major crops rice, maize, wheat, millet, and barley yield trends were analyzed for the period of 1980 to 2012. The yield trends of summer and winter crops (maize, wheat, and barley) changed significantly over time ($p < 0.05$). Wheat had the highest regression coefficient versus time. The yields of wheat (26.83 kg/ha) and maize (16 kg/ha) increased, and that of barley (1.20 kg/ha) decreased significantly ($p < 0.05$). Similarly, rice (4.71 kg/ha) and millet (0.26 kg/ha) yield increased, but these changes were not significant ($p > 0.05$) with respect to time. Production trends for the main crops in Lamjung show a relatively stable increase in area cultivated, production, and yields, except for barley and millet.

6.2.3 Climate Crop Yield Relationship

The relationship between climatic variability and major crop yields (kg/ha) was derived from correlation analysis. The results revealed that there was a strong and positive relationship between the climatic variability and the yield of millet and wheat, whereas there were no or negligible relationships between climatic variability and the yields of rice, maize, and barley. When testing the effects of seasonal minimum and maximum temperatures, a significant relationship was observed with the yield of millet. There was a strong correlation between millet and the seasonal maximum temperature ($r = +0.734$), and there was a normal correlation with minimum temperature ($r = +0.336$). The yield of millet increased with increasing maximum and minimum temperatures. There was no significant effect of precipitation on the yield of millet ($r = +0.069$). Similarly, the coefficient of maximum temperature was +0.4023, which indicates a positive relationship between the annual maximum temperature and the yield of wheat. The coefficients for minimum temperature, precipitation, and the yield of wheat were +0.2539 and −0.033, respectively.

A multivariate regression model was used to confirm the impact of climate change on crop yield. Although the regression results show very few significant relationships between yield and climate variables, these coefficients can be used to assess the real effects of climate variables on the changes in food crop yields. In addition, the sign of the coefficients indicates the direction of change in the yield versus climate variable change. For example, in the case of maize yield, climate variables account for only 34.7% of the yield changes, whereas 65.3% of the variation in maize yield is explained by other influential factors, such as better seeds, better crop management practices, and introduction of new agro-technology.

Precipitation in winter was an important factor that can increase the yield potential of wheat and barley. Extreme temperatures had adverse effects on the yield, and increases and decreases in the maximum and minimum temperatures have negative impacts. Similarly, summer precipitation had a positive impact on rice, while maize and millet showed negative effects. Therefore, increasing maximum temperature has positive impacts on all summer crops, while decreases in temperature have negative impacts.

6.2.4 Climate Change Perception of Local People

Local people's perceptions about climate change were derived from the experience of changes in local climate variability related to temperature and precipitation. The mountainous households were familiar with climate change, and they noticed changes in recent decades. A majority of the households experienced increased temperature, less rainfall in winter, and increased frequency of natural disasters in the study areas. All the respondents of the Kunchha, Khudi, and Ilampokhari VDCs had similar perceptions about decreased rainfall during winter (December–February) and intense rainfall in summer (June–September). They believed that the quantity and duration of the summer precipitation had changed, and that rainfall was more intense in the summer.

Similarly, households were experiencing hotter days in the last twenty years. On the other hand, extremely cold days were also increasing during winter. As a result, the cropping patterns can be disturbed. Increased temperature has also been reported to have positive impacts such as opportunities to plant fruit and vegetables at higher elevations. Local perceptions of increased temperature are supported by the historical records from Khudi station, which showed that the minimum temperature increased by 0.07°C/yr, and the maximum temperature increased by 0.02°C/yr from 1980 to 2012.

6.2.5 Changes in Food Security of the Mountainous Households

Food security situation of the mountainous households was analyzed through changes in food production, availability, accessibility, and utilization during the last twenty years. Household perceived the change in food availability because of changes in crop production, income, and food price, among other factors. The increase and decrease of crops varied across the three VDCs. There were several underlying causes of the changes in crop production. The main reasons of increased crop production were the use of new cultivars, the use of fertilizers, and irrigation facilities. In contrast, the reasons for decreased crop production included climate change, fallow land, less priority on agriculture, and a lack of manpower. However, the number of households with decreased food availability was not higher than the number households with increased and unchanged availability. The majority of the household perceived the impact of climate change on decreased crop production, decreased income, decreased dairy production, increased food prices, and increased household burden.

Food accessibility of the mountainous households increased during the last twenty years as the distance to the nearest market decreased and access to roads increased. However, in some areas of Lamjung, food accessibility decreased because of climate impacts through seasonal road disturbances by landslides and floods. The food consumption patterns and utilization improved during the last two decades due to awareness about the utilization of food along with increased income and access to sources of nutritional food.

6.2.6 Changes in Daily and Economic Activities

The daily and economic activities of the households have been changed to ensure food security in the studied VDCs for the last twenty years. The time needed to collect and process food (seedlings to harvest) increased due to climate change. Similarly, the time needed to collect fodder was increased because of decreased grazing land and the longer time required to grow grass due to decreased rainfall and prolonged winter drought. Due to warming, local species of grass disappeared in the study area. The time for cooking fuel collection and the collection of household water decreased in the study sites. Field observations and the experience of local people showed that water resources decreased in natural springs and streams flowing in the study area. However, it is very difficult to analyze the impact on water resources at the field level and to determine whether it is due to climate change or anthropogenic activities.

The local people are involved in various types of economic activities for their livelihoods, such as fruit farming, livestock rearing, and agribusiness. Thus, their lifestyles and economic activities have also been changed in the last decades. Fruit farming decreased in Kunchha compared to Khudi and Ilampokhari. The local people have already started some coping strategies through alternate crop patterns, using different varieties, or sometimes changing professions from agriculture to other sources of livelihood to combat against climate change. Migration increased heavily for several reasons, including natural disasters induced by climate change during the last twenty years. Remittances help to increase the income of households and eventually improve food security, but they impose household burdens on women, children, and elderly people. It has also created many social problems and family fragmentations.

6.2.7 Most Impacted Livelihood Options and Resources

The changing climatic variables have affected the livelihood of households who solely depend on subsistence agriculture. Erratic rainfall, floods, GLOFs, droughts, and the emergence of insects or diseases were considered as the major hazards in Lamjung. The most impacted livelihood resources were winter crops, orange farming, rice cultivation, livestock rearing, migration, and labor. Landslides were also considered as major hazards, particularly by poor families living on the slopes of hills and riversides. Additionally, drying water resources increased livelihood vulnerability due to the scarcity of drinking water, insufficient water for irrigation, and increased internal migration. The study revealed that almost all households have already experienced climate change and its impact on their livelihoods. However, the impacts of climate change varied according to the wellbeing status, occupations, and geographical locations.

6.2.8 Most Vulnerable Households

The climate change vulnerability of households was analyzed to examine the vulnerable communities according to their wellbeing status, location of the households (Kunchha, Khudi, and Ilampokhari), and gender of the household head. The analysis showed that the overall LVI was higher for Khudi VDC (0.351) as compared to Kunchha VDC (0.310) and ILampokhari VDC (0.309). This indicates that households of Khudi are more vulnerable compared to the two other VDCs. Khudi households were rated more vulnerable in terms of climate variability, natural disasters, health, food, and water, while Kunchha showed more vulnerability in terms of socio-demographic profile and social networks. Only the livelihood strategies component had the highest value in Ilampokhari.

The VI-IPCC score indicates the vulnerability on a scale from -1 to +1. The results showed similar results in that households of Khudi (0.042) are the most vulnerable, followed by Kunchha (-0.077) and Ilampokhari (-0.085). All of the VDCs had similar adaptive capacity, although there were differences in exposure and sensitivity. Livelihood vulnerability was also analyzed according to wellbeing status of the households and gender of the household head. The results revealed that the vulnerability factors varied according to wellbeing status of the households. Very poor and poor households are more exposed to natural disasters, as they reported more events of natural disasters such as landslides and droughts. Sensitivity is also higher for very poor and poor households, followed by medium and well-off households. The adaptive capacity of the households differs significantly ($P < 0.05$) according to wellbeing status. However, there is no statistically significant difference between wellbeing status, exposure ($P > 0.05$), and sensitivity ($P > 0.05$).

Similarly, LVI analysis showed that climate change vulnerability varied according to the gender of the household head. The analysis revealed that female-headed households had slightly higher exposure, sensitivity, and lower adaptive capacity in comparison to male-headed households. The adaptive capacity of the households differs significantly ($P < 0.05$) according to the gender of the household head. The differences were mainly due to the lower percentage of landlessness among male-headed households and higher percentages of households involved in social organizations. Despite these huge differences, there is no significant difference between the male-headed household and female-headed households in exposure ($P > 0.05$) and sensitivity ($P > 0.05$).

Overall, the households of Khudi had a higher LVI than Khunchha and Ilampokhari, indicating greater vulnerability to climate change impacts. Very poor and poor households were more vulnerable, followed by medium and well-off households. Female-headed households were more vulnerable than male-headed households due to higher exposure, higher sensitivity, and lower adaptive capacity.

6.3 Practical Implication of the Achieved Results

The findings of this research can help development planners and national policy makers. Any organization working in the field of climate change and food security would also benefit from the findings of this study. Combatting changing climate and feeding the increasing population are great challenges of the 21st century. To meet the target of sustainable development goals and reducing hunger to zero by 2030, it is necessary to identify the underlying causes of food insecurity and livelihood vulnerability of target populations.

6.3.1 Implication on Local, National and Global Level

To set long-term goals of eventually achieving food security and reducing livelihood vulnerability, it is necessary to identify the vulnerable populations and most affected livelihoods. Such information is critically important for all local, national, regional, and global decision-makers for formulating effective policies and programs that address the problems. The findings of this research can help to understand the contributing factors to food insecurity and livelihood vulnerability, as well as to enhance the adaptive capacity of rural households. The method used in this research can be applied to calculate the vulnerability index and identify vulnerable communities in other areas or regions. The method is flexible, and the indicators and subcomponents can be adapted to other sectors, regions, or communities.

6.3.2 Implication on Climate Change Policies and Programs

The findings have implications for climate change policies and programs such as NAPA, LAPA, and climate change policy that ignored the concept of differential vulnerability in terms of analysis and adaptation planning. The findings suggest that local communities should be prioritized for adaptation planning as a unit of vulnerability analysis and as the most vulnerable communities. The findings also have practical implications for vulnerability analysis and adaptation planning in consideration of geographical area, wellbeing status, and gender of the household head. Both NAPA and LAPA in Nepal are oriented to address climate hazards, but they overlook socio-political and underlying causes of vulnerability, and they lack a process to identify and address the most vulnerable populations. This process may result in an inaccurate vulnerability analysis and further hinders identification of the adaptation needs of the most vulnerable communities. The index values for sub-components would be useful in assessing the impact of programs or policies by substituting the values of indicators (sub-components) that are expected to change and then recalculating the overall vulnerability. Similarly, future vulnerability under some policy or program intervention could be calculated to see whether the planned activities can reduce vulnerability.

6.4 Recommendation

It has been found that climate change has different impacts on the yield of major food crops, food security, and livelihood in Nepal. In light of the changing climatic conditions, the following key recommendations are developed based on information received from KIIs, surveys, FGDs, field observations, and analysis. They would help to manage climate risk, enhance food security, and reduce vulnerability of the households. Among the three VDCs, Khudi could be developed using a number of strategies to reduce vulnerability, especially in food security, water availability, and natural disasters. Kunchha needs to increase income diversification along with social networks, and Ilampokhari needs to initiate education and awareness programs since it has a larger percentage of household heads who never attended school. Similarly, economic empowerment, social empowerment, and awareness will play crucial roles in strengthening the resilience of the poor and women within society.

The recommendations presented in this research are aimed at the local government and target the development of favorable climate change policy, programs, and physical environments to foster climate-resilient food systems and livelihoods in the region. During the workshops, it was mentioned that the local government is the most important stakeholder for implementing such adaptive actions. Therefore, it remains imperative for the local government to endorse the following adaptive interventions to enhance the resilience of the rural mountainous households. Particularly, the district agricultural development office, livestock service center, agriculture research center, local NGOs or INGOs, farmers unions, and local media can be agents that suggest adaptive actions to deal with changing climate at the local scale.

6.4.1 Priority Areas of Intervention for Managing Climatic Risk

During the participatory exercises, the following interventions were identified as highly important for enhancing food security and increasing the resilience of household livelihoods in the Lamjung district of Nepal (Table 6.1).

a. Technical Intervention

❖ **Introduction and Development of Crop Variety**

Based on the findings of the study, the development of improved varieties of crops is necessary in the Lamjung district, particularly fertilizer-responsive, high-yielding, heat, and drought-tolerant crops. The introduction of new seeds and the use of fertilizers are perceived as the most contributing factors to increased production in the study areas. The changing climatic variability is posing threats to the production of existing local crops. Winter crops such as barley are highly vulnerable to decreased precipitation in winter, so a new variety that is resilient to the drought is suggested to enhance food security. Although the government of Nepal has also started promoting a few varieties of wheat, rice, and maize with high yield, they are not enough to meet the increasing food demand of the region.

❖ **Water Resource Management and Development**

The results indicate that the studied areas are vulnerable to erratic rainfall and declines in winter precipitation. One of the key implications of this finding is that water management should be in a priority for adaptation strategies in the Khudi VDC, where precipitation is becoming more intense during the summer months and scarce during the winter months. One such strategy might be supported through the installation of irrigation infrastructure and water optimization practices. Local government advocacy and efforts to increase irrigated areas through rainwater harvesting will play an important role. Specific priorities should be given in the context of increasing climate variability to incorporating a water management component, including the expansion and installation of irrigation facilities. The development of water infrastructure, rainwater harvesting, and water storage at the VDC level would help to reduce water problems in the studied VDCs. Nevertheless, water resource management and development remain challenging in this region, where natural streams are declining and the risk of GLOFs prevails

❖ **Establishment of Early Warning Systems for Climate Extremes**

During the participatory rural appraisal, almost all of the households from the studied VDCs mentioned the unavailability of early warning systems during extreme climate and natural disasters. Early warning information should alert about forthcoming hazards, cropping systems and planning, disease, and pest problems. An effective early detection and warning system for severe or abrupt climate variability would be an important tool for minimizing the risk and damage. People need to be informed in order to prepare and cope with imminent threats affecting agriculture, livestock, and forestry. It is imperative to develop tools that help to monitor, detect, and forecast risks and issue alerts on forthcoming hazards. Early warning alerts help local organizations to mobilize and act for early prevention of humanitarian and natural disasters. They would help households to be prepared against potential damage in the studied VDCs.

b. Economic Intervention

❖ **Support to Livelihood and Income Diversification**

The study found that major crops are sensitive to climatic variability. Strategies for livelihood and income diversification are critical for ensuring resilience of the households who solely depend on farm activities for their livelihoods, particularly in the Ilampokhari VDC. Alternative employment generation for the very poor, poor, and other households of the Ilampokhari VDC is urgently needed. Poor women need to be trained for alternative income-generating activities to ensure their food security and livelihoods. Support for additional income sources, such as wage labor and skilled non-farm activities can lead to improved livelihoods.

c. Social Behavioral Intervention

❖ **Formation of Farmers' Cooperatives**

Cooperatives can help communities through livelihood support and preparedness against risk and during the climatic extremes. However, the access and scope of farm mechanization and increasing agricultural productivity with technological adaptation measures is largely restricted due to a lack of sizeable landholding of the households in the studied areas. The survey data showed that nearly 76% of the farmers hold less than 1 ha of land. Hence, individual household capacity is heavily restricted. Farmer cooperatives need to be developed, especially in the Kunchha VDC, and they should target female-headed households. Although some cooperatives currently exist, the region is lacking in farmer cooperatives compared to other regions of Nepal. The local government can play a vital role in facilitating such cooperatives by providing incentives, such as loans for buying agricultural instruments, development of localized irrigation facilities, and group insurance.

d. Development of Infrastructural Facilities

In general, Lamjung district lacks the development of infrastructural facilities such as roads and markets, which affects the livelihoods of the local people. Particularly, the households from Ilampokhari VDC face the problem of road disconnection from the district's main market every summer because of landslides. During the workshop and

FGDs, stakeholders and the local community mentioned that livelihood-supporting infrastructures play crucial roles in the agricultural development and enhancement of food security in the studied VDCs, such as good transportation networks, proper market facilities, cold storage, seed banks, and soil testing facilities. The lack of supportive infrastructure has been restricting the productivity and market sustainability of agricultural products. Due to the shortage of adequate storage facilities, farmers are forced to sell their products at lower prices, and they are suffering from post-harvest loss. For example, in the entire region, there is no soil testing laboratory, and if farmers are not aware of their soil quality, it is difficult to promote adaptation options such as intercropping, dual use of agricultural land, or cultivation of high-yield varieties.

Table 6.1 Priority areas of intervention for adaptation plan and managing climatic risk

Interventions Areas	Well-being Status				Location			Gender of Household Head	
	Well off	Medium	Poor	Very Poor	Kunchha	Khudi	Ilam pokhari	Male	Female
1. Technical Intervention									
❖ Introduction and Development of Crop Variety	○	○	○	○	○	○	○	○	○
❖ Water Resource Management and Development	○	○	○	○	○	○	○	○	○
❖ Establishment of Early Earning System	○	○	○	○	○	○	○	○	○
2. Economic Intervention ❖ Support to Livelihoods and Income Diversification	△	△	○	○	○	△	○	○	○
3. Social Behavioral Intervention ❖ Promotion of Farmers` Cooperatives	△	△	△	△	○	△	△	△	○
4. Development of Infrastructural Facilities	○	○	○	○	○	○	○	○	○

○ = Highly Recommended
△ = Moderately Recommended

Therefore, significant development is required by the local or district governments to create markets and other infrastructural facilities. Furthermore, the local government should create a strong network of agricultural facilities, including seed banks and quality cultivars. National and international NGOs can collaborate with the local government. In addition, national-level research organizations such as NARC and the National Academy of Science and Technology (NAST) need to disseminate their research findings in a more proactive way so that findings from the laboratory are properly implemented in agricultural lands.

Overall, it is recommended that crops such as barley and millet first be considered in any programs that are working to minimize the adverse impact of climate change on food crop production. These crops are the most affected by the higher temperatures and intense rainfall. The aggregated crop production of the district was considered to find the relationship between yield and climate variables. Therefore, it is difficult to obtain information on the food production of the particular villages studied. It is recommended to use datasets with better spatial resolution, especially production data from the villages. More studies on Nepal's climate change are required at the local level, as the generalized information is not applicable for local-level adaptation. The complex topography and microclimates in Nepal make understanding climate change more complicated. Therefore, further studies are required on climate science because there are opposite trends in climate variables within a small geographic region, which are important to understand.

National programs and policies are needed to strengthen the resilience of the people and minimize the loss and damage, such as crop calendars or alternate crops. This would help ensure food security amidst changing climate. The main shortcoming of this study is the examination of the entire district as one unit, despite the huge diversity within it. Therefore, further investigation with better spatial and temporal resolution is highly recommended to better understand the patterns and consequences of extreme weather affecting food security and livelihoods in mountainous regions.

6.5 Further Research Scope

Assessing the impacts of climate change on food security and livelihood is a difficult task and needs to consider several underlying components. Considering this fact, every possible precaution has been adopted in this research. Both qualitative and quantitative research methodologies were adopted. PRA tools such as FGDs, semi-structured interviews, and participatory observations have also been used. However, the results might have some systematic bias because of the inherent limitations of these tools. Similarly, the lack of village-level crop production data is another limitation of this research. Additionally, the small sample size may not allow for conclusions about the entire VDC or district. In exploring household food security and livelihood vulnerability, detailed analysis of the local adaptation strategies used by local people could not be included, which may be another shortcoming of this research. The main shortcoming is considering the whole district in a single basket despite the huge diversity. Regardless of the limitations, this study explores the idea of differential vulnerability on food security and livelihood within one district by comparing different groups. The study has the following future scope:

1. Climate Crop Relationship

The research can be a milestone for future research in similar environments, such as the Hindu Kush Himalayas region. The study analyzed the climate and crop yield relationship while considering temperature and precipitation. It would be better to consider other climatic factors such as humidity, drought days, and heavy rainfall days to find the impacts of climate variables on crop production. It is also recommended to use crop yield data of the respective VDCs and climate variables for spatial variation. Additionally, the impacts of climate change on land cover or use change and the consequences in agricultural production can be explored in future research.

2. Household Food Security

This research explored the household food security while considering dimensions of food availability, accessibility, and utilization patterns. However, it lacks an analysis of food security in regard to calorie intake and nutritional status of the household members. However, the changes in crop yield do not necessarily change the household level food security. There might be several other influential factors behind the changes, so it is recommended that market variables, food prices, and nutritional status of the households be considered in future research.

3. Climate Change Vulnerability

The methodology adopted in this study comparatively evaluates vulnerability of the households in three VDCs within one district. Specific strategies for the most vulnerable households in the case of extreme climate could be worked out in future research. These strategies could be adopted by the local government to enhance the resilience amidst changing climate. Assessing vulnerability to climate impacts might require longer time scales to incorporate changes in livelihoods, water or food storage practices, and other long-term activities.

4. Vulnerability Index

The indicators of livelihood vulnerability in this study have been categorized into fewer categories to analyze livelihood vulnerability. These indicators can be applied in other sectors after modifying them for the needs of the locations. Both national and subnational vulnerability assessment can be conducted, and the regions could be ranked based on the assigned scores. Regional influences on climate vulnerability are recommended for consideration when determining the appropriate scale for vulnerability assessment. In the household-level analysis, household livelihood profiles should be viewed within the context of larger regional social and economic processes while developing the vulnerability index.

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LIST OF APPENDICES

Appendix 1- Crop Calendar for Major Crops in Nepal

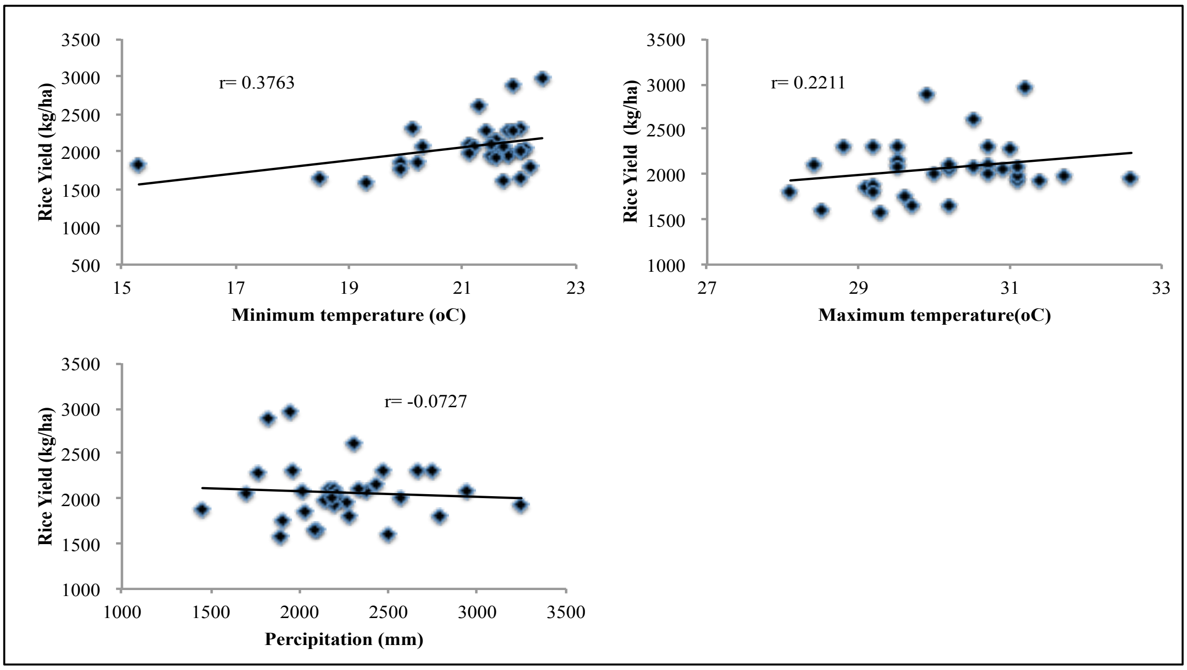
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Season
Mountain (Rainfed)												
		Mai-P	Mai-P				Mai-H	Mai-H	Mai-H			Summer
			Mil-P	Mil-P					Mil-H	Mil-H		Summer
				Whe-H	Whe-H					Whe-P	Whe-P	Winter
			Bar-H	Bar-H						Bar-P	Bar-p	Winter
Hills (Partial Irrigation/Rainfed)												
				Rice-TP	Rice-TP			Rice-H	Rice-H			Summer
		Mai-P	Mai-P				Mai-H	Mai-H				Summer
					Mil-P	Mil-P			Mil-H	Mil-H		Summer
		Whe-H	Whe-H	Whe-H					Whe-P	Whe-P	Whe-P	Winter
		Bar-H	Bar-H						Bar-P	Bar-P	Bar-p	Winter
Hill (Irrigated)												
		Rice-TP	Rice-TP			Rice-H	Rice-H					Spring
	Mai-P	Mai-P			Mai-H	Mai-H						Spring
		Whe-H	Whe-H	Whe-H					Whe-P	Whe-P	Whe-P	Winter
Terai (Rainfed)												
					Rice-TP	Rice-TP		Rice-H	Rice-H	Rice-H		Summer
			Mai-P	Mai-P			Mai-H	Mai-H				Summer
	Whe-H	Whe-H							Whe-P	Whe-P		Winter
Terai (Irrigated)												
						Rice-TP	Rice-TP			Rice-H	Rice-H	Summer
	Mai-P	Mai-P			Mai-H	Mai-H						Spring
		Rice-TP	Rice-TP			Rice-H	Rice-H					Spring
	Mai-H	Mai-H							Mai-P	Mai-P		Winter

Mai-Maize, Whe-Wheat, Mil-Millet, Bar-Barley, P-Plantation, TP-Transplantation, H-Harvesting.

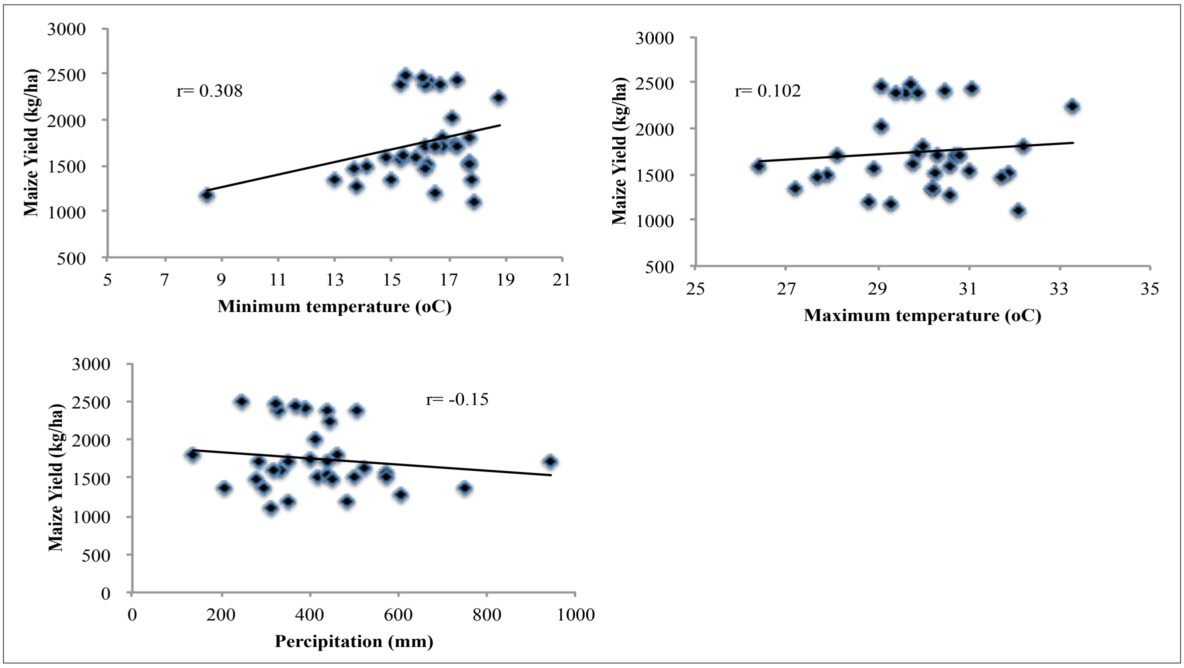
Plantation/Transplantation   Crop growing phase   Harvesting

Source: Food and Agriculture Organization & World Food Programme (2007), http://www.lanra.uga.edu/potato/asia/nepal.htm.

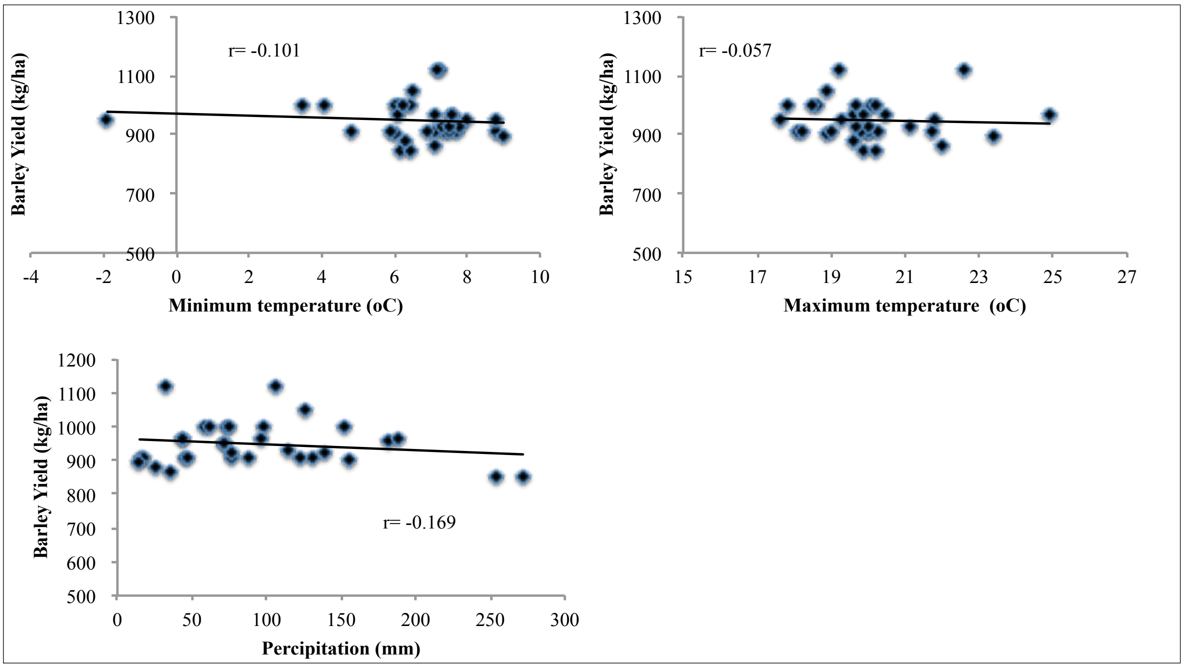
Appendix 2- Correlation between Climate Variables and Crop Yields



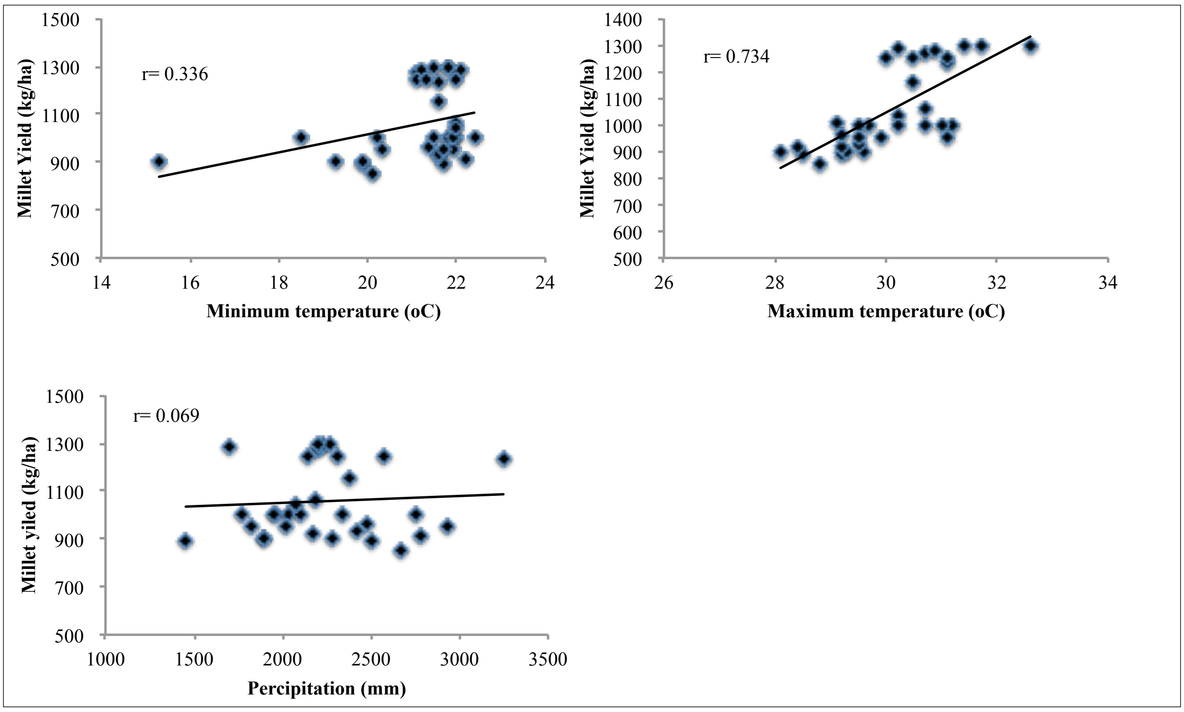
(**a**) Correlation of rice with maximum temperature, minimum temperature and precipitation.



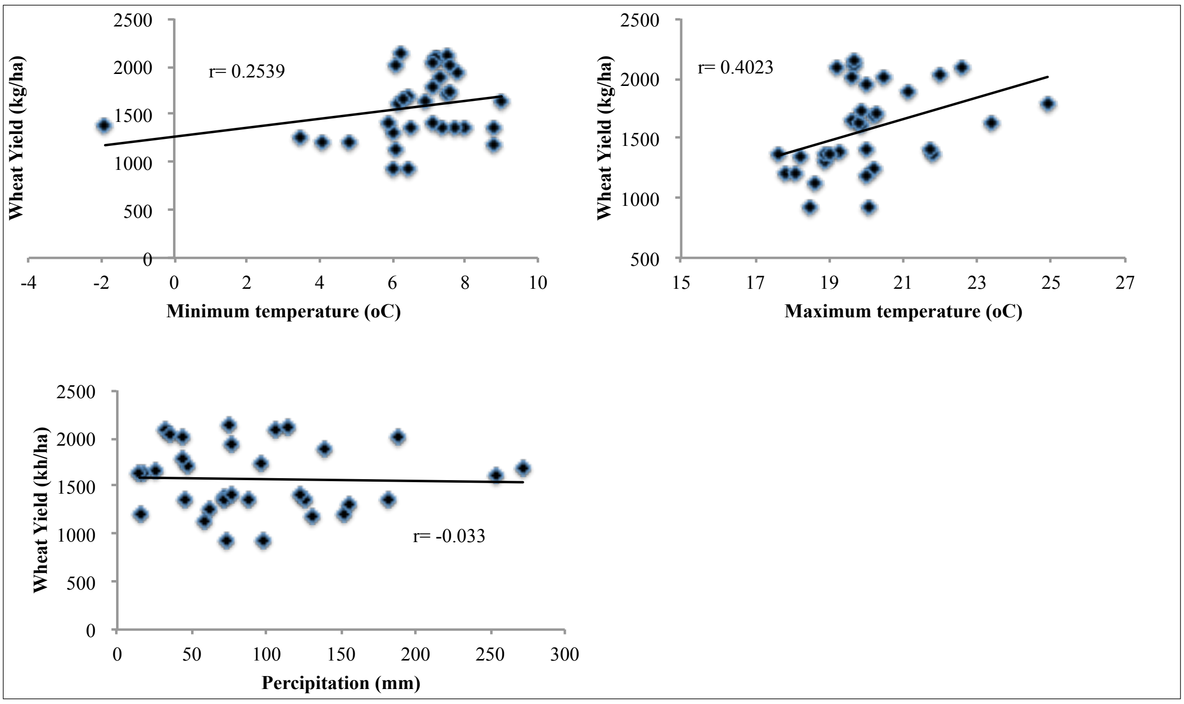
(**b**) Correlation of maize with maximum temperature, minimum temperature and precipitation.



(**c**) Correlation of barley with maximum temperature, minimum temperature and precipitation.



(**d**) Correlation of millet with maximum temperature, minimum temperature and precipitation.



(**e**) Correlation of wheat with maximum temperature, minimum temperature and precipitation.

Appendix 3- Livelihood Vulnerability Index (LVI) sub-component values

Major components	Sub-components	Units	Observed value for Index									Max. Value	Min. Value
			Well-being status				Location of Households			Sex of household head			
			Welloff (n= 42)	Medium (n= 62)	Poor (n= 33)	Very poor (n= 13)	Kunchha (n= 50)	Khudi (n= 50)	Ilamp okhari (n=50)	Male (n=89)	Female (n= 61)		
Climate variability	Mean standard deviation of monthly average of average maximum daily temperature (1980-2013)	Celsius	4.120	4.120	4.120	4.120	4.120	4.120	4.120	4.120	4.120	4.719	3.315
	Mean standard deviation of monthly average of average minimum temperature (1980-2013)	Celsius	5.472	5.472	5.472	5.472	5.472	5.472	5.472	5.472	5.472	7.189	4.703
	Mean standard deviation of monthly average of precipitation (1980-2013)	Millimeters	266.28	266.283	266.28	266.28	247.657	341.12	310.062	266.283	266.28	463.96	115.12
Natural disasters	Average numbers of floods in the past 30 years	Events	0.466	0.433	0.333	0.266	0.5	0.266	0.166	0.466	0.5	5	0
	Average numbers of landslides in the past 30 years	Events	1.666	2.333	2.5	2.666	2	2.666	1.833	2.333	2.5	15	0
	Average numbers of droughts in the past 30 years	Events	0.2	0.26667	0.333	0.366	0.333	0.366	0.3	0.333	0.366	2	0
	Percent of households that did not receive a warning about recent natural disasters	Percent	100	100	100	100	100	100	100	100	100	100	0
Health	Percent of households with emergence insects health problems/diseases	Percent	14.28	20.96	24.24	30.76	20	22	20	20.43	66.66	100	0
Food	Average food insufficiency months of households (0-12)	Months	1.34	3.45	6.35	10	2.94	6.09	3.06	3.9	4.1	12	0
	Percent of households with food availability decreased	Percent	4.76	14.51	18.18	7.69	12	24	0	16.12	5.26	100	0
	Percent of households with food accessibility decreased	Percent	0	1.61	3.03	7.69	4	0	2	1.07	3.5	100	0
	Percent of households with food utilization deteriorated	Percent	2.38	3.22	6.06	7.69	6	4	2	4.3	3.5	100	0
Water	Percent of households with decreased water resources	Percent	61.9	59.67	57.57	53.84	56	66	56	55.91	64.91	100	0
Socio-demographic status	Percent of male headed households	Percent	59.52	64.51	60.6	61.53	42	70	74	100	0	100	0
	Percent of household with school attended household head	Percent	73.8	50	33.33	30.76	68	44	42	50.53	52.63	100	0
Livelihood strategies	Percent of no landless households (above 0.1 ha)	Percent	100	100	87.87	38.46	94	90	92	93.54	89.47	100	0
	Percent of households not depend on agriculture as a main source of income	Percent	52.38	45.16	42.42	23.07	42	64	44	41.93	63.15	100	0
	Percent of households with irrigation facility to grow primary crops	Percent	80.95	40.32	42.42	23.07	64	40	48	48.38	54.38	100	0
Social network	Involvement in saving and credit cooperatives/social groups	Percent	90.46	87.09	84.84	84.61	80	86	96	94.62	75.45	100	0

Appendix 4- LVI Sub-component Indices, Major Components and Overall LVI

Major components	Sub-components	Units	Observed value for Index								
			Well-being status				Location of Households			Sex of household head	
			Well-off (n= 42)	Medium (n= 62)	Poor (n= 33)	Very poor (n= 13)	Kunchha (n= 50)	Khudi (n= 50)	Ilampo khari (n=50)	Male (n=89)	Female (n= 61)
Climate variability	Mean standard deviation of monthly average of average maximum daily temperature (1980-2013)	Celsius	0.5732	0.5732	0.5732	0.5732	0.5732	0.5732	0.5732	0.5732	0.5732
	Mean standard deviation of monthly average of average minimum temperature (1980-2013)	Celsius	0.3094	0.3094	0.3094	0.3094	0.3094	0.3094	0.3094	0.3094	0.3094
	Mean standard deviation of monthly average of precipitation (1980-2013)	Millimeters	0.4333	0.4333	0.4333	0.4333	0.3799	0.6478	0.5588	0.4333	0.4333
	Climate variability		**0.4386**	**0.4386**	**0.4386**	**0.4386**	**0.4208**	**0.5101**	**0.4805**	**0.4386**	**0.4386**
Natural disasters	Average numbers of floods in the past 30 years	Events	0.09334	0.08666	0.0666	0.0533	0.1	0.0533	0.0333	0.0933	0.1
	Average numbers of landslides in the past 30 years	Events	0.1111	0.1555	0.1667	0.1778	0.1333	0.1778	0.1222	0.1555	0.1667
	Average numbers of droughts in the past 30 years	Events	0.1	0.13335	0.1666	0.1833	0.08325	0.1833	0.15	0.1666	0.1833
	Percent of households that did not receive a warning about recent natural disasters	Percent	1	1	1	1	1	1	1	1	1
	Natural disasters		**0.3261**	**0.3438**	**0.3499**	**0.3536**	**0.3291**	**0.3536**	**0.3263**	**0.3538**	**0.3625**
Health	Percent of households with emergence of insects health problems/diseases	Percent	0.1428	0.2096	0.2424	0.3076	0.2	0.22	0.2	0.2043	0.6666
	Health		**0.1428**	**0.2096**	**0.2424**	**0.3076**	**0.2**	**0.22**	**0.2**	**0.2043**	**0.6666**
Food	Average food insufficiency months of households (0-12)	Months	0.1116	0.2875	0.5291	0.8333	0.245	0.5075	0.255	0.325	0.3416
	Percent of households with food availability decreased	Percent	0.0476	0.1451	0.1818	0.769	0.12	0.24	0	0.1612	0.0526
	Percent of households with food accessibility decreased	Percent	0	0.0161	0.0303	0.0769	0.04	0	0.02	0.0107	0.035
	Percent of households with food utilization deteriorated	Percent	0.0238	0.0322	0.0606	0.0769	0.06	0.04	0.02	0.043	0.035
	Food		**0.0457**	**0.1202**	**0.2004**	**0.4390**	**0.1162**	**0.1968**	**0.0737**	**0.1349**	**0.1160**
Water	Percent of households with decreased water resources	Percent	0.619	0.5967	0.5757	0.5384	0.56	0.66	0.56	0.5591	0.6491
	Water		**0.619**	**0.5967**	**0.5757**	**0.5384**	**0.56**	**0.66**	**0.56**	**0.5591**	**0.6491**
Socio-demographic profile	Percent of Female headed households	Percent	0.4047	0.3548	0.3939	0.3846	0.58	0.3	0.26	0	1
	Percent of household with school not attended household head	Percent	0.2619	0.5	0.6667	0.6923	0.32	0.56	0.58	0.4946	0.4736
	Socio-demographic profile		**0.3333**	**0.4274**	**0.5303**	**0.5384**	**0.45**	**0.43**	**0.42**	**0.2473**	**0.7368**
Livelihood strategies	Percent of households with land less than 0.1 ha	Percent	0	0	0.1212	0.6153	0.06	0.1	0.08	0.0753	0.0877
	Percent of households without other source of income	Percent	0.4761	0.5483	0.5757	0.7692	0.58	0.36	0.6	0.5584	0.4562
	Percent of households with no irrigation facility to grow primary crops	Percent	0.1905	0.5967	0.5758	0.7692	0.36	0.6	0.52	0.5161	0.4561
	Livelihood strategies		**0.1984**	**0.3333**	**0.4242**	**0.7179**	**0.3333**	**0.3533**	**0.4**	**0.3832**	**0.3333**
Social network	Percent of households not involve in saving and credit cooperatives/social groups	Percent	0.0952	0.129	0.1515	0.1538	0.2	0.14	0.04	0.0646	0.2281
	Social network		0.0952	0.129	0.1515	0.1538	0.2	0.14	0.04	0.0646	0.2281
	Overall LVI		**0.2628**	**0.3214**	**0.3589**	**0.4528**	**0.3107**	**0.3511**	**0.3094**	**0.3023**	**0.3814**

Appendix 5 – Test statistics

Analysis of Variance and Chi-square test

Test statistics of ANOVA

Null Hypothesis: There is no significant difference between locations of households, well-being status and gender of the household's head.

Exposure			
Categories	F-ratio value	P-value	Test-Results (at 95% confidence level)
Households location	0.026	0.975	Accept Null Hypothesis
Well-being status	0	1	Accept Null Hypothesis
Gender of household`s head	0	0.99	Accept Null Hypothesis

Sensitivity			
Categories	F-ratio value	P-value	Test-Results (at 95% confidence level)
Households location	0.396	0.679	Accept Null Hypothesis
Well-being status	1.258	0.316	Accept Null Hypothesis
Gender of household`s head	0.667	0.433	Accept Null Hypothesis

Adaptive Capacity			
Categories	F-ratio value	P-value	Test-Results (at 95% confidence level)
Households location	0.001	0.998	Accept Null Hypothesis
Well-being status	17.006	0.0001	Reject Null Hypothesis
Gender of household`s head	8	0.018	Reject Null Hypothesis

Test statistics of Chi Square

Null Hypothesis: There is no association between well-bing status and irrigation facility

Irrigation Facility			
Categories	Chi-Square value	P-value	Test-Results (at 95% confidence level)
Well-being status	22.922	0.0017	Reject Null Hypothesis

Appendix 6 - Questionnaire for Households Food Security

Questionnaire

Analysis of climate change impacts on food security in the mountainous households: A case study of Lamjung district of Nepal.

Households Questionnaire Survey

This survey is conducted by the Graduate School of Global Environmental Studies Kyoto University, JAPAN.

The objective of this questionnaire is to assess a socio-economic impact of climate change on food security at the households level in the mountainous areas of Nepal. The results of this survey will help to formulate strategies for the rural communities to lessen the socio-economic impact of the climate change in the context of food security and recover from its impacts. The expected beneficiaries of this result will be the rural farmers, local community, Local Government, Ministry of Agriculture Development, Nepal Food Corporation and Non-Government Organizations (NGOs).

All the information collected will be strictly used for the academic purpose.

This questionnaire survey will take 30 minutes approximately.

Please tick (□) the appropriate option where applicable.

PART A

Demographic and Household Information

1. Name of the respondents (Optional)…………
2. Address: VDC/Municipilaty………………….. …….Ward…………
3. Gender □Male □Female □Other
4. Age of the respondents (Optional) ………Years
5. Education level of the respondents…………..
6. Occupation of the respondents……………..
7. Average monthly income of the respondents (Rs)………….
8. Household size……….
9. Condition of house □ Kutcha □ Semi-pucca □ Pucca

PART B

Nature of Income and Occupation and Perception about climate change

1. Information about occupation and income of the household.

The household is primarily depends on: □Agriculture, □Livestock rearing □Poultry farming, □Business, □Fruit farming □Remittance □Service □Job □Other (specify)…………	
Mention about any other source of income:	Income (per month):

2. What was the household main occupation in the last 20 years?

   □Agriculture □Livestock rearing □Poultry farming □Business □Fruit Farming
   □Remittance □Service □Job □Others (Specify).....................

3. Is there any change in the occupation of your family members in the last 20 years?

   □Yes □No

4. If yes, how many times?

   □Once □Twice □Three times □Four to five times □Often
   Please mention the reasons for each time……………………

5. Do you think climate or environment is somehow related with this reason?

   □Yes □No

6. Do you know about climate change?

   □Yes □No
   If yes, what do you mean with it……………………………

   How……………………………………………………………………….

7. What type of changes have you noticed in your area? (Multiple response) (Please choose top three)

Type of changes	Type of changes
a) Temperature increased	f) Change of rainy season
b) More cold in winter	g) Water availability
c) Short winter	i) Frequency of natural disaster
d) More rainfall	j) Emergence of Insects
e) Less Rainfall	j) Other (specify

PART C

Impact of climate change on food security of the household

1. Is there any change in food production in your farmland in the last 20 years?

   □Yes, □No

   If yes, what is the extent of change?

   □Significantly increased, □Increased, □Decreased □Significantly decreased

2. What are the main reasons behind this change? (Multiple choice) (Please rank 1-5 and, 5 is the highest)

Production Increased	Rank	Production Decreased	Rank
a) Use of fertilizer		a) Climate change	
b) Introduction of new seeds		b) Fallow land	
c) Irrigation facility		c) Less priority to agriculture	
d) Use of agro-equipment		d) Lack of manpower	
e) Others (Specify)		e) Others (Specify)	

3. Is there any change in availability of food in your family in the last 20 years?

   □Yes □No

   If yes, what is the extent of change?

   □Significantly increased, □Increased, □Decreased □Significantly decreased

4. What are the responsible factors behind this change? (If answer is `No` in Q. 3, ignore this question) (Multiple response).

Causes	**Role of climate change behind this**
a) Crop production i) Increased i) Decreased	Yes/No, if yes, How
b) Income i) Increased ii) Decreased	Yes/No, if yes, How
c) Dairy product i) Increased ii) Decreased	Yes/No, if yes, How
d) Food price i) Increased ii) Decreased	Yes/No, if yes, How
e) Other burden to household (e.g. disease, medicine etc.) i) Increased ii) Decreased	Yes/No, if yes, How

5. Is there any change in the accessibility of food in your family in last the 20 years?

□Yes □No

If yes, what is the extent of change?

□Significant increased □Increased □Decreased □Significant decreased

6. What are the responsible factors behind this change? (If answer is 'No' in Q. 5, ignore this question) (Multiple responses)

Causes	Role of climate change behind this
a) Distance of Food Market or Shops i) Increased ii) Decreased	Yes/No, if yes, How
b) Access of Road to the Food Market or Shops i) Constructed/improved ii) Deteriorated	Yes/No, if yes, How
c) Other (specify)	Yes/No, if yes, How

7. Is there any change in the food consumption pattern of your family in the last 20 years? (Quality and Quantity of food consumption)

□Yes □No

If yes, what is the extent of change?

□Significantly improved, □Improved □Deteriorated, □Significantly deteriorated

8. What are the responsible factors behind this? (If answer is 'No' in Q. 7, ignore this question) (Multiple response)

Causes	Role of climate change behind this
a) Income i) Increased ii) Decreased	Yes/No, if yes, How
b) Grain production i) Increased ii) Decreased	Yes/No, if yes, How
c) Dairy product i) Increased ii) Decreased	Yes/No, if yes, How
d) Food price i) Increased ii) Decresed	Yes/No, if yes, How
e) Other burden to household (e.g. disease, medicine etc.) i) Increased ii) Decreased	Yes/No, if yes, How

9. Is there any change in the daily work of household to ensure food security in the last 20 years?

□Yes □No

If yes, what is the type of change?

Type of Changes	Role of climate change behind this
a) Working Hours to Collect/process food (including seedling to harvesting) i) Increased ii) Decreased	Yes/No, if yes, How
b) Working Hours to Earn Income for food i) Increased ii) Decreased	Yes/No, if yes, How
c) Working hours to collect grass for livestock i) Increased ii) Decreased	Yes/No, if yes, How
d) Working Hours to collect cooking fuel i) Increased ii) Decreased	Yes/No, if yes, How
e) Working hours to collect water i) Increased ii) Decreased	Yes/No, if yes, How
f) Other (specify) i) Increased ii) Decreased	Yes/No, if yes, How

10. Is there any change in the life style and economic activities of household to ensure food security in last 20 years?

□Yes □No

If yes, what is the type of change?

Types of Changes	Role of climate change behind this
a) Working hours in economic activities i) Increased ii) Decreased	Yes/No, if yes, How
b) Number of family members migration i) Increased ii) Decreased	Yes/No, if yes, How
c) Agriculture to poultry farming i) Increased ii) Decreased	Yes/No, if yes, How
d) Agriculture to fruit farming i) Increased ii) Decreased	Yes/No, if yes, How
e) Agribusiness i) Increased ii) Decreased	Yes/No, if yes, How
f) Livestock rearing i) Increased ii) Decreased	Yes/No, if yes, How
g) Consumption of luxurious goods i) Increased ii) Decreased	Yes/No, if yes, How
h) Other (specify)…….. i) Increased ii) Decreased	Yes/No, if yes, How

Name of data collector:

Area of data collection:

District:

VDC:

Ward No.:

Appendix 7- Questionnaire in Nepali

ग्रामीण परिवारमा खाद्य सुरक्षामा जलवायु परिवर्तनको सामाजिक आर्थिक प्रभावको लेखाजोखा
व्यक्तिगत प्रश्नावली

यो सर्वेक्षण जापानको विश्वव्यापी वातावरणीय अध्ययन क्योटो विश्वविद्यालय द्वारा सचांलित हो । यस प्रश्नावलीको उदेश्य नेपालको पहाडी तथा हिमाली भेगमा रहेका ग्रामीण परिवारहरुमा खाद्य सुरक्षामा जलवायु परिवर्तनको सामाजिक आर्थिक प्रभावको निर्क्योल गर्नु रहेको छ ।यस सर्वेक्षणको नतिजाले ग्रामीण समुदायमा खाद्य सुरक्षामा जलवायु परिवर्तनको सामाजिक आर्थिक प्रभाव कम गर्न तथा यसका असरबाट बच्न रणनिति निर्धारण गर्न मद्दत गर्नेछ।यस सर्वेक्षणको नतिजाले ग्रामीण किसानहरु, स्थानिय समुदाय, स्थानिय सरकार, कृषि विकास मन्त्रालय, नेपाल खाद्य संस्थान र गैर सरकारी संस्थाहरु लाभान्वित हुने अनुमान गरिएको छ।

सम्पुर्ण सकंलित विवरण तथा सुचनाहरु शैक्षिक प्रयोजनको लागी मात्र प्रयोग गरीनेछन।

कृपया उपयुक्त विकल्पमा ठिक (भ) चिन्ह लगाउनु होला ।

भाग – क

जनसाख्यिक/व्यक्तिगत तथा पारिवारिक विवरण :

१. उत्तरदाताको नाम(ऐच्छिक) : ....
२. ठेगाना : जिल्ला......................................गा.वि.स...वार्ड नं............
२. लिगं : ☐ पुरुष ☐ महिला ☐ अन्य
३. उमेर (ऐच्छिक) : .... वर्ष
४. शैक्षिक स्तर : ....
५. पेशा : ....
६. औषत मासिक आम्दानी(रु.) : ....
७. पारिवारिक संख्या :
८. घरको अवस्था : ☐ कच्चा ☐ अर्धपक्की ☐ पक्की

भाग – ख

आम्दानी तथा पेशाको प्रकृति र जलवायु परिवर्तनको अनुभव :

१. परिवारको आम्दानी र पेशा विवरण :
परिवार प्राथमिक रुपमा ☐ कृषि, ☐ पशुपालन, ☐ कुखुरापालन, ☐ व्यवसाय, ☐ फलफुल खेती, ☐ वैदेशीक रोजगार, ☐ सेवा, ☐ नोकरी, ☐ अन्य .... मा निर्भर छ।
आम्दानीको अन्य स्रोत भए उल्लेख गर्नुहोस। आम्दानी (प्रति महिना): रु.................................

२. विगत २० वर्षमा परिवारको मुख्य पेशा के थियो ?

☐ कृषि, ☐ पशुपालन, ☐ कुखुरापालन, ☐ व्यवसाय, ☐ फलफुल खेती,
☐ वैदेशीक रोजगार, ☐ सेवा, ☐ नोकरी, ☐ अन्य

३. विगत २० वर्षमा परिवारको सदस्यको पेशामा कुनै परिवर्तन भएको छ ?

☐ छ, ☐ छैन ।

४. यदी छ भने कतिपटक ?

☐ १ पटक, ☐ २ पटक, ☐ ३ पटक, ☐ ४ वा ५ पटक, ☐ प्राय:

कृपया प्रत्येक पटकको कारण उल्लेख गर्नुहोला ।

....

५. तपाईलाई के लाग्छ यी कारणहरुसाग जलवायु वा वातावरणको केही सम्बन्ध छ?

☐ छ, ☐ छैन ।

६. जलवायु परिवर्तनको वारेमा तपाईलाई थाहा छ ?

☐ छ, ☐ छैन ।

यदी छ भने के होला यसको अर्थ...

....

कसरी ....

७. तपाईको क्षेत्रमा कस्ता कस्ता प्रकारको परिवर्तन सुचित गर्नु भएको छ ? (बहु उत्तर)(कृपया मुख्य ३ वटा छान्नुहोस।)

परिवर्तनका प्रकार		परिवर्तनका प्रकार	
क	तापक्रम वृद्धि	च	वर्षायाममा परिवर्तन
ख	हिउदमा ज्यादै चिसो	छ	पानीको उपलब्धता
ग	छोटो हिउदको समय	ज	वारम्वारको प्राकृतिक प्रकोप
ध	अधिक वर्षा	झ	किराहरुको फैलावट
ङ	कम वर्षा	ञ	अन्य(खुलाउने)

भाग– ग

पारिवारिक खाद्य सुरक्षामा जलवायु परिवर्तनको प्रभाव:

१. विगत २० वर्षमा तपाईको जमिनमा अन्न उत्पादनमा केही परिवर्तन भएको छ ?

☐ छ, ☐ छैन ।

यदी छ भने परिवर्तनको मात्रा के छ ?

☐ सापेक्षिक वृद्धि, ☐ वृद्धि, ☐ ह्रास, ☐ सापेक्षिक ह्रास

२. यो परिवर्तनको पछाडी मुख्य कारण के होला ? (वहु उत्तर)(कृपया १ देखी ५ सम्म क्रम मिलाउनुहोस, अधिकतम ५)

उत्पादन वृद्धि		क्रम	उत्पादन ह्रास		क्रम
क	मलको प्रयोग		क	जलवायु परिवर्तन	
ख	नयाा विउको प्रयोग		ख	वााफो जमिन	
ग	सिचााई सुविधा		ग	कृषिमा न्युन प्राथमिकता	
घ	कृषि औजारको प्रयोग		घ	जनशक्तिको अभाव	
ङ	अन्य(खुलाउने)		ङ	अन्य(खुलाउने)	

३. विगत २० वर्षमा तपाईको परिवारमा खाद्यान्न उपलब्धतामा कुनै परिवर्तन भएको छ ?

☐ छ, ☐ छैन ।

यदी छ भने परिवर्तनको मात्रा के छ ?

☐ सापेक्षिक वृद्धि, ☐ वृद्धि, ☐ ह्रास, ☐ सापेक्षिक ह्रास

४. यस परिवर्तनको कारण के के हुन सक्छन्?(यदी छैन भने प्रश्न न. ४ लाई वेवास्ता गर्नुहोस)(वहु उत्तर)

कारणहरु	यसको पछाडी जलवायु परिवर्तनको भुमिका
क) वाली उत्पादन : अ) वृद्धि आ) ह्रास	छ/छैन, यदी छ भने कसरी
ख) आम्दानी : अ) वृद्धि आ) ह्रास	छ/छैन, यदी छ भने कसरी
ग) दुग्ध उत्पादन : अ) वृद्धि आ) ह्रास	छ/छैन, यदी छ भने कसरी
घ) खाद्यान्नको मुल्य : अ) वृद्धि आ) ह्रास	छ/छैन, यदी छ भने कसरी
ङ) अन्य पारिवारिक भार : (जस्तैःरोग व्यादी औषधी आदी) अ) वृद्धि आ) ह्रास	छ/छैन, यदी छ भने कसरी

५. विगत २० वर्षमा तपाईको परिवारमा खाद्यान्नको पहाुचमा केही परिवर्तन भएको छ?

☐ छ, ☐ छैन ।

यदी छ भने परिवर्तनको मात्रा के छ ?

☐ सापेक्षिक वृद्धि, ☐ वृद्धि, ☐ ह्रास, ☐ सापेक्षिक ह्रास

६. यस परिवर्तनको कारण के के हुन सक्छन्?(यदी छैन भने प्रश्न नं. ६ लाई वेवास्ता गर्ने)(बहु उत्तर)

कारणहरु	यसको पछाडी जलवायु परिवर्तनको भुमिका
क) खाद्यान्न बजार वा पसलको दुरी : अ) वृद्धि आ) ह्रास	छ/छैन, यदी छ भने कसरी
ख) खाद्यान्न बजार वा पसलसम्म बाटो–घाटोको पहाुच : अ) निर्मित/सुधारिएको आ) बिग्रिएको	छ/छैन, यदी छ भने कसरी
ग) अन्य(खुलाउने) :	छ/छैन, यदी छ भने कसरी

७. विगत २० वर्षमा तपाईको परिवारमा खानेकुरा प्रयोग गर्ने तरिकामा कुनै परिवर्तन भएको छ? (गुणस्तर र उपभोगको मात्रा)

☐ छ, ☐ छैन

यदी छ भने परिवर्तनको मात्रा के छ ?

☐ सापेक्षिक सुधार भएको, ☐ सुधारीएको, ☐ बिग्रीएको, ☐ सापेक्षिक रुपमा बिग्रीएको

८. यस परिवर्तनको कारण के के हुन सक्छन्?(यदी छैन भने प्रश्न नं. ८ लाई वेवास्ता गर्नुहोस)(बहु उत्तर)

कारणहरु	यसको पछाडी जलवायु परिवर्तनको भुमिका
क) वाली उत्पादन : अ) वृद्धि आ) ह्रास	छ/छैन, यदी छ भने कसरी
ख) आम्दानी : अ) वृद्धि आ) ह्रास	छ/छैन, यदी छ भने कसरी
ग) दुग्ध उत्पादन : अ) वृद्धि आ) ह्रास	छ/छैन, यदी छ भने कसरी
घ) खाद्यान्नको मुल्य : अ) वृद्धि आ) ह्रास	छ/छैन, यदी छ भने कसरी
ङ) अन्य पारिवारिक भार : (जस्तै:रोग व्यादी औषधी आदी) अ) वृद्धि आ) ह्रास	छ/छैन, यदी छ भने कसरी

९. विगत २० वर्षमा खाद्य सुरक्षा निश्चित गर्नको लागी घरायसी दैनिक कामकाजमा केही परिवर्तन भएको छ?
यदी छ भने कस्तो किसिमको परिवर्तन भएको छ :

परिवर्तनको किसिम	यसको पछाडी जलवायु परिवर्तनको भुमिका
क) खाद्यान्न सकंलन/ उत्पादन गर्दा लाग्ने समय (विउ छर्ने देखी थन्क्याउने सम्म) : अ) वृद्धि आ) ह्रास	छ/छैन, यदी छ भने कसरी
ख) खाद्यान्नको लागी आम्दानी गर्न लाग्ने समय : अ) वृद्धि आ) ह्रास	छ/छैन, यदी छ भने कसरी
ग) पशुपालनको घाास सकंलन गर्दा लाग्ने समय : अ) वृद्धि आ) ह्रास	छ/छैन, यदी छ भने कसरी
घ) खाना पकाउने इन्धन सकंलन गर्दा लाग्ने समय अ) वृद्धि आ) ह्रास	छ/छैन, यदी छ भने कसरी
ङ) पानी सकंलन गर्दा लाग्ने समय : अ) वृद्धि आ) ह्रास	छ/छैन, यदी छ भने कसरी
च) अन्य(खुलाउने) : अ) वृद्धि आ) ह्रास	छ/छैन, यदी छ भने कसरी

१०. विगत २० वर्षमा खाद्य सुरक्षा निश्चित गर्न पारिवारिक जिवनशैली र आर्थिक क्रियाकलापमा कुनै परिवर्तन भएको छ?

☐ छ, ☐ छैन।

यदी छ भने कस्तो किसिमको परिवर्तन भएको छ :

परिवर्तनको किसिम	यसको पछाडी जलवायु परिवर्तनको भुमिका
क) अर्थिक क्रियाकलापमा लाग्ने समय : अ) वृद्धि आ) ह्रास	छ/छैन, यदी छ भने कसरी
ख) वसाईसरी जाने परिवारको सदस्यहरुको संख्या : अ) वृद्धि आ) ह्रास	छ/छैन, यदी छ भने कसरी
ग) कुखुरापालन : अ) वृद्धि आ) ह्रास	छ/छैन, यदी छ भने कसरी
घ)फलफुल खेती : अ) वृद्धि आ) ह्रास	छ/छैन, यदी छ भने कसरी
ङ) कृषि व्यवसाय : अ) वृद्धि आ) ह्रास	छ/छैन, यदी छ भने कसरी
च) पशुपालन व्यवसाय : अ) वृद्धि आ) ह्रास	छ/छैन, यदी छ भने कसरी
छ) सुविधायुक्त सामानको उपभोग : अ) वृद्धि आ) ह्रास	छ/छैन,यदी छ भने कसरी
ज) अन्य(खुलाउने) : अ) वृद्धि आ) ह्रास	छ/छैन,यदी छ भने कसरी

तथ्याङ्क सकंलन कर्ताको नाम :...

तथ्याङ्क सकंलन गरिएको क्षेत्र :

जिल्ला :..

गा.वि.स. :..

वार्ड नं. :..

Appendix 8- Questionnaire for Livelihood Vulnerability

Questionnaire

Assessment of household`s livelihoods to climate change vulnerability in the mountainous regions of Nepal: A case study of Lamjung district of Nepal.

This survey is conducted by the Graduate School of Global Environmental Studies Kyoto University, JAPAN.

The objective of this questionnaire is to assess the climate change vulnerability of the households in the mountainous areas of Nepal. The results of this survey will help to identify the vulnerable communities and to lessen the climate change impacts on the livelihoods. The expected beneficiaries of this result would be the rural farmers, local community, local government, program and policy makers and Nepal government.

All the information collected will be strictly used for the academic purpose.

This questionnaire survey will take 15 minutes approximately.

Please tick (□) the appropriate option where applicable**.**

1. How much land does your family own?

   □Landless □0.1-0.5 ha □0.6-1 ha □ 1.1-1.5ha □1.6-2ha □2.1-2.5ha □ 2.6ha or more

2. What type of land does your family own?

   □Non-irrigated □Partially- irrigated □Fully irrigated

3. How many family members are dependent on family head`s income?

   □1-3 □4-6 □7-9 □ 10 or above

4. Who is the head of your family?

   □Male □Female

5. Food sufficiency produced on your own farm.

   □0-3 months □3-6 months □6-9 months □6-9 months □ 12 or months

6. How many times do you cultivate crops on your farmland in a year?

   □Once □Twice □Three times

7. Do you sell the produced vegetables/grain in the market?

   □Yes □No

8. Climate related natural disasters in your area in the last 20 years?

□Drought □Floods □Livestock diseases □Avalanches □Glacier Lake out burst flood

9. Level of ground water resources such as tap, well, tube well, pond, rivers etc.

□Increase □Decrease

10. What is the most vulnerable livelihood due to climate change? Please rank. 4 for high impact and 0 for no impact

Major Hazards / Livelihood options	Temperature Increases	Changes in rainfall pattern	Droughts	Insects outburst/ damages crop and livestock	Rank
Rice cultivation					
Winter crops					
Other crops					
Orange farming					
Other fruit farming					
Livestock (Forage and grazing)					
Wage Labor					
Migration					

11. Education level of your family

□All family members are educated □Partially educated □Few family members are educated □Family members are rarely educated

12. Children education

□ Go to urban/private English school □ Go to public school

□ Go to public school or dropped

13. Are you involved in saving and credit cooperatives? If yes, why?

□Yes □No

Appendix 9- Questionnaire in Nepali

प्रश्नावली

यो सर्वेक्षण जापानको विश्वव्यापी वातावरणीय अध्ययन क्योटो विश्वविद्यालय द्वारा सचांलित हो । यस प्रश्नावलीको उद्देश्य नेपालको पहाडी तथा हिमाली भेगमा रहेका ग्रामीण परिवारहरुको जीविकोपार्जनमा जलवायु परिवर्तनको प्रभावको निक्र्योल गर्नु रहेको छ ।यस सर्वेक्षणको नतिजाले ग्रामीण समुदायमा जलवायु परिवर्तनको प्रभाव कम गर्न तथा यसका असरबाट बच्न रणनिति निर्धारण गर्न मद्दत गर्नेछ। यस सर्वेक्षणको नतिजाले ग्रामीण किसानहरु, स्थानिय समुदाय, स्थानिय सरकार, कृर्षि विकास मन्त्रालय, नेपाल खाद्य संस्थान र गैर सरकारी संस्थाहरु लाभान्वित हुने अनुमान गरिएको छ।

सम्पुर्ण सकंलित विवरण तथा सुचनाहरु शैक्षिक प्रयोजनको लागी मात्र प्रयोग गरीनेछन।

कृपया उपयुक्त उत्तरमा (✓) चिन्ह लगाउनुहोस ।

१. तपाईको परिवारको आफ्नै कति जमिन छ ?
☐ जमिन छैन ☐ ०-३ हे ☐ ३-६ हे ☐ ६-९ हे ☐ ९-१२ हे ☐ १२ हे वा धैरै

२. तपाईको जमिन कस्तो प्रकारको छ ?
☐ सिचांई असुबिधा ☐ आशिंक सिचांई ☐ पुरा सिचांई

३. परिवार प्रमुखको आम्दानीमा कतिजना सदस्य भर पर्नुहुन्छ ?
☐ १-३ ☐ ४-६ ☐ ७-९ ☐ १० वा धैरै

४. तपाईको परिवारको प्रमुख व्यक्ति को हुनुहुन्छ ?
☐ पुरुष ☐ महिला

५. तपाईको आफ्नै खेतको उत्पादनले कती समय खान पुग्छ ?
☐ ०-३ महिना ☐ ३-६ महिना ☐ ६-९ महिना ☐ ९-१२महिना ☐ १२ महिना वा धैरै

६. तपाईले एक वर्षमा खेतीयोग्य जमिनमा कति पटक वाली उब्जाउनु हुन्छ ?
☐ एक पटक ☐ दुई पटक ☐ ३ पटक

७. तपाईले उत्पादित अन्न/तरकारी बजारमा बिक्री गर्नुहुन्छ ?
☐ गर्छु ☐ गर्दिन

८. विगत २० वर्षमा तपाईको क्षेत्रमा जलवायु सम्बन्धी प्राकृतिक विपत्ति ?
☐ अनावृष्टि ☐ बाढी ☐ पशु रोगहरु ☐ पहिरो ☐ हिम ताल फुटेर बाढी ☐ खडेरी

९. धारा, ईनार, कल, पोखरी, नदीहरु आदी जस्ता जलस्रोतहरुमा पानीको सतह ?
☐ बढेको ☐ घटेको ☐ यथाबत

१०. जलवायु परिवर्तनको कारणले सबैभन्दा धेरै प्रभावित जिविका/पेशा कुन छ ? कृपया धेरै असरलाई ४ र असर नपरेको लाई ० क्रममा राख्नुहोला ।

मुख्य कारक तत्व/ जिविकाका विकल्प	बढ्दो तापक्रम	वर्षात शैलीमा परिवर्तन	बाढी	किराहरुको फैलावट/ अन्न वाली र पशुको नाश	क्रम
धान उब्जनी					
हिउदे अन्नवाली					
अन्य अन्नवाली					
सुन्तला खेती					
पशुपालन(घास र चरन)					
ज्याला श्रम					
बसाईसराई					

११.तपाईको परिवारको शैक्षिक स्तर ?
☐ सबै परिवारका सदस्यहरु शिक्षित ☐ आंशिक शिक्षित ☐ केही शिक्षित ☐ अति कम शिक्षित

१२. वालवच्चाको शिक्षा ?
☐ शहरी/निजि विद्यालय जान्छन् ☐ सार्वजनिक विद्यालय जान्छन् ☐ सार्वजनिक विद्यालय जान्छन् वा जान छोडे

१३. के तपाई बचत तथा ऋण सहकारीमा आबद्ध हुनुहुन्छ ? यदी हुनुहुन्छ भने किन ?
☐ छु ☐ छैन

Appendix 10- Key Informant Questionnaires

All the questions were asked by assuming the average of 1980's as a standard value/frequency.

1. What are some of the most important changes you have seen in your lifetime, your village?
2. Do you think a particular land cover change has decreased or increased over the decades?
3. What about the productivity of particular crop over the year? Increase or decrease? How much?
4. Is there any change in the number of harvest you can get in one year compared to 1980's?
5. Have you observed changes in rainfall pattern and intensity of rainfall?
6. What are the significant climate change impacts you could see on agriculture?
7. What is the impact of climate change on your daily life?
8. Do you feel any changes in temperature over the period of time?
9. Is there any change in the cropping pattern due to climate change?
10. How many crops, farmers grow in their fields?
11. Do farmers use any inputs (Fertilizer for cultivation)? Before and now.
12. What are the major crops grown in your area?
13. What is the average farm size in Lamjung district?
14. What are the types of field? Khet, Bari, Tari, Pakho etc.
15. Any serious outbreaks of endemic pests? Increase or decrease has been observed due to climate change?
16. Your observation in disaster frequency and intensity? Is it increased, decreased or remain same.
17. Does the agricultural area increase, decrease or the remain same?
18. Local interpretations of each land-use types? Which ones are preferred and highly valued?
19. Is there any reason to modify land use type?
20. What is the irrigation system in Lamjung district?
21. What are the different kinds of agricultural system? Advantages and disadvantages of each agricultural system.
22. What is the main income source of the local people?
23. What is the percentage of population dependent on agriculture?
24. Local people involvement in other sectors rather than agriculture.
25. What is the seed network and exchange system in Lamjung district?

Based on the above-mentioned questionnaires, Questionnaire matrix has been prepared as follows to interview the respective stakeholders

Key informant questionnaire Matrix

Stakeholders	Environmental changes	Social changes	Climate change impact	Information	Market access	Alternative livelihood
Department of Agriculture, Nepal	2. Land cover change	23. Population dependent on agriculture	6. Impact on agriculture	13. Average farm size 14. Types of fields 17. Changes in Agricultural land		
Department of Hydrology and Meteorology (DHM)	16. Natural disasters		5. Changes in rainfall pattern 8. Changes in temperature 16. Natural disasters			
District Agriculture Office	2. Land cover change 19. Reason to modify land	23. Population dependent on agriculture	3. Crop productivity 4. Changes in number of harvests 6. Climate change impact on agriculture 9. Changes in cropping pattern 15. Outbreaks of insects	10. Types of crops 11. Use of fertilizer 12. Major crops grow 13. Average farm size 17. Change in agricultural land 20. Irrigation systems	25. Seed network and exchange system	21. Types of agricultural system
Village leaders	1. Changes in village 16. Natural disasters 19. Reason to modify land	1. Changes in lifetime	5. Changes in rainfall pattern 7. Climate change in daily life 8. Changes in temperature		18. High value land	22. Income source 24. Involvement in other sector
Farmers group	1. Changes in village 16. Natural disasters 19. Reason to modify land type	1. Changes in lifetime	3. Crop productivity 4. Changes in number of harvests 5. Changes in rainfall pattern 6. Climate change impact on agriculture 7. Climate change impact in daily life 9. Changes in cropping pattern 15. Outbreaks of insects	10. Types of crops 12. Major crops grow 13. Average farm size 14. Types of fields 20. Irrigation systems	11. Use of fertilizer 18. High value land 25. Seed network and irrigation	21. Types of agricultural system
Women group	1. Changes in village 16. Natural disasters	1. Changes in lifetime	7. Climate change impact in daily life			24. Involvement in other sectors

Appendix 11- Questionnaire for Focus Group Discussions

Focus Group Discussion on Climate change, Food Security and Households` Livelihood Vulnerabilities

1. Have this community experienced any changes in temperature in the last 20 years?

2. How temperature is changing? (Promote by following points)

a. Extreme hot summer days
b. Extreme cold winter
c. Winter are less cold and frosty
d. Days are becoming hotter,
e. Others

3. Then what do you think the impact of climate change?

In agriculture, in food security

a. Food production
b. Food availability
c. Food accessibility
d. Food consumption pattern
e. Fruit production (orange farming etc.)
f. Emergence of insects, diseases spreading
g. Water resources etc.

4. What are the coping mechanisms you are following to combat with this change?

5. Have you experienced any changes in rainfall/snowfall within last 20 years?

If yes then, what type of change?

a. Rainfall/Snowfall increasing
b. Rainfall/Snowfall is decreasing
c. I don't know

6. What are the consequences of changed rainfall pattern in agriculture? (In Agriculture production)

a. Increased
b. Decreased

7. What are the consequences of changed rainfall pattern in Water Resources?

a. Water availability increased/ decreased
b. Flood frequency increased/decreased
c. Landslides increased/decreased etc.

8. What are you doing to cope with these changes in rainfall?

a. Delay cropping
b. New variety of plantation etc.

9. What are the most significant natural disasters in this community? And numbers of disasters per year?

a. Landslides
b. Floods
c. Droughts
d. Avalanches

10. Do you receive early warning before these natural disasters?

a. Yes
b. No

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