Climate Change Vulnerability, Impacts and Adaptation of Agriculture in a Mountain region of Western Nepal

A DISSERTATION

SUBMITTED IN THE

PARTIAL FULFILMENT OF THE REQUIREMENTS FOR

THE MASTER OF SCIENCE DEGREE IN ENVIRONMENT AND NATURAL RESOURCES

BY

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DHULIKHEL, NEPAL

"September, 2013"

DEDICATION

TO THE NUBRI PEOPLE: WHO LIVE IN TRANQUILITY INSPITE OF THEIR HARDSHIPS.

ACKNOWLEDGEMENTS

I would like to extend my gratitude to those individuals whose assistance helped to make this thesis possible. First of all, I would like to thank my academic advisors Prof. Dr. Roshan Man Bajracharya and Asst. Prof Dr. Bed Mani Dahal for their committed guidance throughout the research process. I would also like to thank Prof. Dr. Subodh Sharma, Head of Department/ Department of Environment Science and Engineering (HOD/DESE) for his suggestions and guidance during this research. I am thankful to the staffs and research assistants of Aquatic Ecology Centre (K.U.) for their assistance in laboratory analysis.

Thank you Dr. Dinesh Bhuju the team leader of a Nepal Academy of Science and Technology/ Nepal Climate Change Knowledge Management Centre (NCCKMC/NAST) for instructions during this research. This research would not have been possible without the financial assistance, trainings and logistic supports of Climate and Development Knowledge Network (CDKN). I am very thankful to Mr. Pawan Neupane program officer of NCCKMC for his help during field visit.

Thank you to Mr. Madhu Chettri, project coordinator Manaslu Conservation Area Project/ National Trust for Nature Conservation (MCAP/NTNC) and Mr. Keshab Raj Khanal conservation officer MCAP/NTNC for facilitating the field visit inside the Manaslu Conservation Area. Thank you Mr. Rikjin Dorje Lama, Nubri teacher of Nurbi Primary School for help in translating the interview. I am also thankful to Mr. Maheshwor Dhakal, principal of Nubri Primary School for his help during field work in Prok Village Development Committee (VDC).

My sincere thanks to Mr. Dorje Thakuri and Mrs. Kshring Lhomo Lama for their hospitality during my stay in Prok village. I would also like to express my appreciation to all the Nubri farmers in the Prok VDC who participated in the research interviews, group discussions and informal discussions. At last I am very thankful to my friends and family for their support and inspiration.

ABSTRACT

Agriculture is one of the sectors most vulnerable to climate change impact. The impact is even stronger in Mountain region of Nepal, where the topography is fragile and agriculture is important for the daily subsistence. Therefore, it is crucial to increase the understanding of the actual climate change dynamics on agricultural activities at the household level. This study uses the Prok Village Development Committee in western mountain region of Nepal, as a case study to examine the local climatic trends and its impacts, vulnerability and adaptation in the agriculture sector. The study uses semi-structured interview and participatory appraisals methods to garner the socio-economic data and filed based observation and laboratory analysis of soil samples for study of soil vulnerability. Socio-economic status of farmers in the villages of Prok VDC is found very poor and they are vulnerable to climate change. Soil of this region is stony and sandy loam and the crop yield is lower than national average. Trend analysis of temperature and precipitation over 30 years indicates that this region is experiencing various weather variability. The result shows a trend of gradual, erratic and extreme weather changes where farming system is constrained. Farmer perceptions on climate change generally agree with the weather station trend. Erratic changes in rainfall pattern, temperature variation and gradual reduction in snowfall are some of the main constraining factors on farming. Drought, delay in monsoon and heavy and unseasonal rain are major challenges on agriculture. Majority of the farmers believe that crop failure, crop damage, degradation of pasture, low quality fodder and forage are due to the increase in temperature, erratic precipitation pattern and windstorms in their village. The changing scenario has forced local people to find measures to secure their livelihoods. To cope with the impacts the societies use re-sowing, cultivating catch crops and short seasoned crops, shifting of animal shed to less landslide risk area, planting fodder tress and practicing agroforestry, saving of grains and money, on land diversification, off-farm activities and credits as a strategy. The existing local and institutional strategies are not sufficient and sustainable to cope with climatic vagaries. It is very important to address the problems in this region with institutional support and through a long-term policy perspective.

Key Words: *Climate change, impact, socio-economic vulnerability, soil vulnerability, adaptation*

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ABBREVIATIONS

BD	Bulk Density
CBS	Central Bureau of Statistics
CCVI	Climate Change Vulnerability Index
CEC	Cation Exchange Capacity
DADO	District Agriculture Development Office
DFID	Department for International Development
DHM	Department of Hydrology and Meteorology
DLS	Department of Livestock Services
GDP	Gross Domestic Product
GON	Government of Nepal
FAO	Food and Agricultural Organization
HH	Household
IPCC	Intergovernmental Panel on Climate Change
LAPA	Local Adaptation Programme of Action
MACP	Manaslu Area Conservation Project
MOAC	Ministry of Agriculture and Cooperatives
MOAD	Ministry of Agriculture and Development
MoE	Ministry of Environment
NAPA	National Adaptation Programme of Action
NAST	Nepal Academy of Science and Technology
NCCKMC	Nepal Climate Change Knowledge Management Center
NCVST	Nepal Climate Vulnerability Study Team
NPR	Nepali Rupees
NTNC	National Trust for Nature Conservation
SPSS	Statistical Package for Social Sciences
TN	Total Nitrogen
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
VDC	Village Development Committee
WFP	World Food Programme
WMO	World Meteorological Organization

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CHAPTER 1: INTRODUCTION

1.1. Background

The Nepalese economy is largely based on agriculture which accounts for around 35% of GDP (MOAD, 2012). About 65% of the total population is engaged in Agriculture (CBS, 2011). Nepalese farming systems are typically integrated and livestock is an essential component (DLS, 2009/10). Over 50% of Nepalese farmers are small holders cultivating less than 0.5 ha (CBS, 2011).

Climate change has increased the risk of disaster in Nepal. Nepal is at high risk of adverse impacts due to climate change and is one of the 20 most disaster-prone countries in the world (DFID, 2011). Climate change is becoming a major issue in Nepalese agriculture sector and has already lost valuable arable land to flood and erosion. It has seen changes in the monsoon affecting agricultural production and has experienced water shortages and drought. There is also the growing and potentially deadly threat from GLOFs, outbreaks of diseases, and a sustained decline in food security (Regmi et.al, 2009). Hence, climate change has become serious threat to Nepalese agriculture.

Nepalese agriculture is predominantly small-scale farming, around half of which is dependent on natural rainfall. Rainfall and other climatic factors are critical to crop yields because only 46.5% of overall cultivated area is irrigable of which 69.5% is actually irrigated (MoA, 2012). Empirical study in recent years indicate that 70% of the performance of crop production can be explained by the climatic variability linked with the temporal weather conditions (Sherchand et.al, 2007). Agriculture sector has been affected by floods, droughts and erratic rainfall. Climate change is expected to lead to increasing dryness in drought-prone areas and to wetter conditions in wet areas and there have already been alarming signs of sharp and sustained decline in food security in Nepal. For example, winter food crop harvests for 2009 in all regions of Nepal have declined (Regmi et.al, 2009).The extreme weather phenomenon, including droughts and floods, is expected to induce food vulnerability to the already food insecure 3.4 million people in Nepal and this will affect adaptation measures (WFP, 2009). The projected changes in climatic conditions of Nepal will adversely affect agriculture production.

Scientific statements regarding changing climate of Nepal are pronouncedly focused on temperature rise at the rate of 0.06°C per annum (Dahal et.al., 2011). Such a rise in average temperature is variable across the country, being higher in the mountains and Himalaya (0.08°C) as compared to low-lying terai (0.04°C) (Gautam and Pokhrel 2010). Climate change scenarios indicate that warming at higher elevations will lead to a reduction in snow and ice coverage, which in turn will lead to an increase in the frequency of climate-related disasters, including floods and droughts, as well as cause changes in precipitation at a regional scale (Sherchand et al., 2007).Changing climate will also likely shift the geographic range of crop pests, weeds, and diseases (Rosenzweig et al., 2001), as well as plant pathogen life cycles, requiring new crop management strategies (Chakraborty et al., 2000). Mountain regions of Nepal are facing severe impacts of climate change on the agriculture sector. The effects of climate change are most severely felt by those who depend on the environment and natural resources for livelihood, especially resource poor farmers because they lack alternatives to provide adequate coping mechanisms. This inevitably indicates that the general economic wellbeing of the majority of farmers in the mountain region of Nepal will be affected due to climate change.

Geographically over 75% of Nepal is composed of rugged hills and mountains. Increased occurrences of intense rains concentrated during the monsoon season and compounded by frequent occurrences of glacial lake outburst floods has increased soil erosion, floods and landslides in the region (Shrestha et al, 1999). As a result, soil quality has significantly declined in the mountain region and destruction of agricultural fields and crops have become common. The degree of vulnerability of agriculture and farming communities to climate change is higher in mountain region of Nepal due to its rugged terrain with steep topography, and fragile geological conditions, and vulnerability of soil.

The socio-economic status of the people in mountain region limit institutional capacity and greater reliance on climate-sensitive sectors like agriculture increase the degree of vulnerability (Regmi & Adhikari, 2007; World Bank, 2008). Hence, exposure to risks and low adaptive capacity to cope with those risks are major factors contributing to the vulnerable situation of the people in the mountain region of Nepal. Their risks and exposure to food insecurity and malnutrition are greatly increased in the event of any change in rainfall patterns leading to declining crop yields and crop variety. This justifies the strong need of understanding climate change at the regional scale and its relationship with socio-economic and biophysical context in order to develop mitigation and adaptation programs and minimize the risk at farm level in mountain region of Nepal.

Nepal has prepared its National Adaptation Programme of Action (NAPA) for adapting to extreme climate events and variability through an extensive country-driven consultative process. The document was shared with Parties to the UNFCCC in November 2010. Nepal has also prepared a National Framework for Local Adaptation Plan for Action (LAPA) with the twin objectives of implementing adaptation actions, and integrating climate change into local development planning and implementation. The LAPA Framework ensures that the process of integrating climate change resilience from local-to-national planning is bottom-up, inclusive, responsive and flexible. Both NAPA and LAPA would be very important to help grass root communities in local level.

1.2. Rationale for the study

Mountain agriculture of Nepal has been subjected to climate variability in the form of irregular precipitation and gradual increase in temperature. Mountain people are socially background and the topography is very fragile. Farmers of this region cultivate most subsistence crops. Maize is the major crop of the mountain agriculture system and has been affected by unpredictable rainfall during the sowing time and other critical periods of moisture requirement (Gautam et al., 2008). Farmers have been experiencing the loss of most of the winter crops in the system – wheat production in particular have been found to be very sensitive to decrease in snowfall and prolonged drought (Gautam et al., 2010). Several factors like loss of biodiversity and common property resources, growing water stress for irrigation, recurrent crop damage due to natural hazards (such as floods and droughts), soil vulnerability, poor infrastructure (especially transport systems), and inadequate institutional support, such as credit, crop insurance, and storage and processing facilities, have contributed to the undermining of agricultural production in the Mountain region of Nepal. Therefore, mountain communities need to be helped to improve their current adaptation and coping strategies at both the autonomous or local level and at the community level, taking into full consideration the mountain perspective framework defined by fragility, marginality, multi-level vulnerability, and poor accessibility (Gautam et al., 2010).

Climate change will likely shorten the growing season and alter conditions; higher temperatures will enhance the transpiration of plants which will lead to increase in water demand; soil texture and the organic content of soil can change; and the incident of diseases and trans-boundary movement of species will introduce new challenges in mountain region of Nepal. Soil fertility management is an important requirement for sustainable farming. The Nepalese farming system is strongly interlinked among livestock, forestry and agriculture. So, this research will measure the soil fertility status of the region and access if the soil of the region is vulnerable to the climate change. Farmers have unknowingly used different adaptation and coping measures to adopt such consequences like by changing sowing time, cultivating catch crops, double sowing, adopting more drought varieties etc. They use different adaptation strategies by practice and experience. However, such practices have not been found to be adequate. So, it is very important to identify the current adaptation practice of farmers in household level.

The rationale for the choice of Prok VDC for the study is based on its wide range of agro-ecological conditions, its good representation of mountain ecology and high hill area where pastoralism and integrated farming systems exist. Further, this region lacks research on climate change impact, vulnerability and adaptation on agriculture. No any policies and programs have been formulated for adaptation strategy in mountain region (Tiwari et. al, 2010).This research identifies a number of dimensions of climate change and adaptation strategy on agriculture. It examines how rising annual temperature is affecting crop calendar and changing crop yield and productivity. It will also analyse if any climatic hazard like increases in frequency and intensity floods, and changes in monsoon patterns triggering physical loss of fertile soil etc. Extreme events change like change in land use patterns contributing to desertification and acidification, change in patterns of crop and variety use; Outbreaks and extension of minor diseases, pests and unwanted weeds, major problems in crop and livestock sectors are the factors that is analysed in the research. Research will identify the most appropriate adaptation strategies like use of traditional knowledge, indigenous seeds and the local institutional approaches for combating climate change impacts and vulnerability.

1.3. Objectives

Main Objective:

To assess the current climate change vulnerability, impacts and adaptation strategies of agriculture at the household and community level in Prok VDC of Manaslu Conservation area.

Specific Objectives

- To assess the socio-economic vulnerability of the rural people to climate change
- To document the vulnerabilities of climate change on soil/land resources
- To identify the trends of climate change and farmer's perception of these changes
- To evaluate the impact of climate change on agricultural production
- To identify choices for adaptation measures that farmers are using to mitigate potential impacts of climate change on agriculture

1.4. Research Questions

- What are the socio-economic vulnerabilities of the rural people?
- What is the status of soil resources and land management?
- What are trends of climate change and farmer's perception of the change?
- What is the impact of climate change on agriculture in the study area?
- What are the adaptation practices to climate variability that local farmers are adopting?

1.5. Limitation of the study

This research was conducted in remote part of Nepal which takes 4 days walk from district headquarter of Gorkha district. This area lacks baseline data and previous data on crop productivity was not accessible. Similarly no soil fertility data were available. During the transport of sample from field to lab, soil sample might have been subjected to some error. Only two climatic parameters (temperature and rainfall) were analysed for assessing the climate change occurring scenario in the study area. There was no weather station in Prok VDC. Hence, weather data was obtained from the nearest VDC, i.e., Sirdibas VDC. Currently measured rainfall, which is mainly based on measurements of rainfall in the valley bottoms (1200 m asl), may not be representative for the area, and the use of these data can be someway different from real situation at higher altitude (1800 – 3800 m asl). VDC level crop yield data have not been documented yet. So, the district crop yield data used in order to analyse the trend of crop yield.

CHAPTER 2: REVIEW OF LITERATURE

2.1. Climate Change in Nepal

Climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity (IPCC, 2007). It is a long-term change in the statistical distribution of weather pattern, including average temperature and rainfall over periods of time. Climate change is increasingly accepted as the major issue facing the globe. Climate change is a phenomenon due to emissions of greenhouse gases from fuel combustion, deforestation, urbanization and industrialization (Upreti, 1999) resulting variations in solar energy, temperature and precipitation.

According to the measurement taken by thousands of weather stations all over the world, global temperature has been increased by 0.7^{o}C on an average since 1960s (Friis-Christensen et.al.1991). During last 32 years temperature of Nepal has been increased by 1.8^{o}C and the average temperature increase was recorded as 0.06^{o}C per year (Baidya et.al., 2008). The rainfall pattern across Nepal has been experienced as inconsistent with higher intensities of rain and less number of rainy days (Malla, 2008) creating long drought for some time and heavy rain in some other periods. In the context of climate change Nepal is facing major challenges like changes in hydrological cycles and depletion of water resources.

Nepal is the fourth most vulnerable countries in the world to the climate change based on Climate Change Vulnerability Index (CCVI) (Global risks advisory firm Maplecraft, 2010). Observed data indicates consistent warming and rise in maximum temperature at an annual rate of 0.04 – 0.06^{o} C (MoE, NAPA 2010). Warming trend is not uniform all over the country and it is higher in mid hills and mountains compared to the Terai (Practical Action, 2009). The local people have experienced rise in temperature with hotter days, longer summer and shorter winter seasons (Practical Action, 2009). Unlike temperature trends, precipitation data for Nepal does not reveal any significant trends (Practical Action 2009, NAPA 2010), however the shifting of monsoon is experienced in many regions. Frequency of long drought events, especially during winter is increasing and winter drought of 2008/09 is considered as a signature event of climate change (NCVST, 2009). The 2009 monsoon experienced a significant delay: it started on the 23rd June and became active only after the 25th July. It remained active till the 15th October extending the retreat period by more than 20 days (MoAC/WFP 2009/10). Mean annual temperature across Nepal is projected to increase by 0.5 – 2.0 º C with the multimodel mean of 1.4 º C by 2030s and 1.7-4.1 º C with a multi-model mean of 2.8 º C by 2060s (NCVST 2009).

Similarly, Mean annual temperature of Eastern Nepal is projected to increase by 0.5 – 1.8 º C with the multi-model mean of 1.4 º C by the 2030s and 1.7-3.3 º C with a multimodel mean of 2.7 º C by the 2060s.

In Nepal, Climate Change is predominantly having its impact on Agriculture and Food Security, Forest and Biodiversity, Water Resource and Energy, Climate Induced Disasters, Public Health, and Urban Settlements and Infrastructure (NAPA, 2010). Shifting of monsoon pattern, prolonged drought, rise in temperature, increase in frequency and severity of wind and hailstorm, incidence of disease and pests, etc are heavily affecting the nature based agricultural system of Nepal. The impact is going to be more severe in coming years if the climate change scenario continues without any adaptation measures. For developing countries like Nepal, climate change is not just an environmental phenomenon but also an economic, social and political issue.

2.2. Climate Change and Mountain Agriculture

Mountain region of Nepal is most vulnerable to climate change in comparison to other parts. Past studies on climate change in Mountain region of Nepal has suggested significant warming in higher elevations leading to reduction in snow and ice coverage with increased frequency of extreme events like landslides and droughts (Gautam et al., 2010).The inhabitants of the Himalayan region depend heavily on subsistence agriculture as the mainstay and primary source of livelihood (Bajracharya & Sherchan, 2009). Studies on temperature trend in Nepal have identified increasing trend in annual mean and annual maximum temperature in high altitude more than that of lower altitude (Baidya et al 2008). Even an insignificant change in climatic variables can cause amplified and devastating impacts in these ecologically fragile mountains. The impact of climate change can be much greater for indigenous communities living in the more remote and ecologically fragile zones and relying directly on their immediate environments for subsistence and livelihood (UNFCCC, 2004). Mountain farming systems are composed of upland and rainfed cultivation of potato, maize, buckwheat, barley and other minor millets, as well as livestock rearing. The integrated farming system is characteristic of Mountain region of Nepal. Lower terraces, known as *khet* lands in mountain region, generally have access to the irrigation that is necessary for rice-based cropping systems whereas rainfed terraces located higher on the hill slopes, known as *bari* lands, are often used for maize-based cropping systems. The peculiarity of this type of farming system is that it is mixed, diverse and subsistence oriented, since it has a close interaction between crops, animals and forests, which makes it very similar to the highland mixed and/or rainfed mixed farming system category of the Food and Agriculture Organization of the United Nations (FAO) (Regmi and Adhikary, 2007).

2.3. Climate Change Impacts on Agriculture

A number of negative effects of Climate change like change in Agricultural Calendar, vegetation shifts, change in routine activities like grazing, harvesting and storing etc. have been observed in Agriculture in Nepal. Over the past three years, the delay in monsoon season experienced in Nepal has changed the cropping pattern and crop maturity period which has delayed the planting and harvesting season by a month, which has in turn affected rotation practices (Dahal et. al. 2011). The delay in monsoon season has also made thousands of hectares of farm land fallow and reduced production due to lack of water (Regmi and Adhikary, 2007). A drought in the Eastern region of Nepal decreased the rice production by 30% in 2006 and heavy flooding in the mid-Western and far-Western regions in 2006 and 2008 destroyed crops in many places and there is also evidence that the vector borne diseases in livestock are increasing, forcing the livestock population to move to higher altitudes (Practical Action, 2008).

Gautam and Pokhrel (2010) have predicted temperature rise of 0.06°C per annum but the Global Climate Models (GCM) project the increase in temperature by 0.5-2.0°C with a multimodal mean of 1.4 °C by the 2030s, rising to 3.0-6.3 °C with a multimodal mean of 4.7 °C, by the 2090s (NCVST, 2009). In addition, it has been suggested that warming of more than 2.5°C could reduce global food supplies and contribute to higher food prices (UNEP & UNFCCC, 2002). For precipitation GCMs project a wide range of changes, especially in monsoon: -14 to 40 % by the 2030s increasing -52 to +135 % by the 2090s (NCVST, 2009). These projections suggest that Nepal's agriculture will face many challenges over the coming decades due to climate related variability. Existing problems such as soil degradation and increasingly limited water resources are likely to be exacerbated by climate change, increasing the difficulty of achieving food security for the growing population. The recently observed extreme severe weather events between 2006-09 including droughts and floods have significantly affected food production in Nepal (WFP, 2009).

Climate change such as rising annual temperature, delayed monsoon season, increased annual rainfall resulting from increased glacial melting and increased occurrence of intense rainfall (Regmi and Adhikari, 2007) among others has affected many rainfed farmer communities in Nepal and it is forecasted by the United nations Framework Convention on Climate Change and Inter governmental Panel on Climate Change to create even more damage to agricultural production in the coming 20 years (IPCC third assessment report, 2001; UNFCC report 2000).

2.4. Climate Change Vulnerability of Agriculture

The term vulnerability is used loosely in many different contexts, from medicine to poverty and development literature. In global environmental change studies, the concept of vulnerability is often derived from the social sciences (Chambers, 1989; Liverman, 1992). In hazard research, Chambers (1989) introduced the concept that vulnerability has an internal and external dimension and these relate to the capacity to anticipate, cope, or recover from the impacts of a hazard, and to the exposure to risks of the hazard, respectively. Kasperson and Kasperson (2001) also recognized that interactions exist between the internal capacity of humans to withstand or respond to a risk and the external dimension (risk). Similar interactions occur between the social and economic vulnerability of populations and the degree of resilience of ecological systems. He suggested, therefore, that an integrated approach to both human and natural systems is needed if significant progress is to be made in understanding the different vulnerability of regions, places and people. A widely accepted methodological framework to analyse vulnerability arising from these two concepts of the internal and external dimensions (and their interplay) has yet to be fully developed.

The Intergovernmental Panel on Climate Change (IPCC), in its Second Assessment Report, defines vulnerability as "the extent to which climate change may damage or harm a system" and it adds that vulnerability "depends not only on a system's sensitivity, but also on its ability to adapt to new climatic conditions" (Watson et al. 1996: 23). Looking at vulnerability from the food security point of view, the FAO publication, The State of Food Insecurity in the World (1999), defines vulnerability as "the presence of factors that place people at risk of becoming food insecure or malnourished." Clearly, this definition encompasses causes of food insecurity other than climate change (e.g., armed conflict, landlessness, etc.). Nevertheless, the concept of vulnerability includes hunger vulnerability—which refers to the vulnerability of individuals or households rather than that of regions or economic sectors. A common theme in the climate change impacts and vulnerability literature is the idea that countries, regions, economic sectors and social groups differ in their degree of vulnerability to climate change (see, for example, Bohle et al. 1994). This is due partly to the fact that changes in temperature and precipitation will occur unevenly and that climate change impacts is unevenly distributed around the globe. It is also due to the fact that resources and wealth are distributed unevenly.

Crop lands in Mountain region of Nepal is environmentally marginal and are likely to be at increased risk of land degradation and biodiversity loss as a result of climate trends. Nepalese farmers are largely poor with limited access to external resources and are likely to be particularly vulnerable to climate change. Vulnerability to climate change is closely related to poverty, as the poor are least able to respond to climatic stimuli (Olmos, 2001). Besides, bio-physical features of the region further increases the vulnerability.

2.5. Climate Change Impacts and Vulnerability of Soil

Soil is an important natural resource which directly or indirectly supports all forms of life on the planet earth. According to Reale et al. (1985) soil is holistically defined as a social good; it represents the physical, chemical, biological base of the agricultural production. The decline in agricultural productivity may be related to influences changes in climate elements have on soil quality, especially its overall ability to support life and suitability for sustainable alternative uses. There is a strong inter-dependence between climate factors and soil quality (Jenny, 1980). Some climatic factors that influence land degradation have been reported by WMO (2005). These include rainfall, floods, solar radiation, temperature, evaporation and wind. The vulnerability of soil to climatic influence depends on both the physical and chemical characteristics of soils. Such properties as texture, mineralogy, population and activities of soil determine the extent of changes in soil characteristics that will occur in response to changing soil forming factors (i.e. climate) (Brady and Weil, 1999).

The impacts of climatic variations and climate change on soils of mountain region of Nepal could be examined in their implication on floods, droughts, desertification, soil erosion etc. The top layer of the soil is one supporting most of the plant growth, and also part with higher direct interactions with climate and vegetation, and more influenced by human activities. Climate is probably the main variable that influences, directly or indirectly the topsoil, and particularly the surface layer. Other surface processes are caused by the properties of the soil itself (Pla, 2002). Land degradation is the loss of utility or potential utility of land or decline in soil quality caused through misuse by human (Barrow, 1992).

High rainfall and temperature arising from climate change will increase rock and mineral weathering, as well as leaching of the basic cations (Ca^{2+}, Mg^{2+}, Na^{2+}, and K^{+}) thereby leaving the acidic cations (Al^{3+} and H^{+}), thus increasing soil acidity. Acid rainfall which is a consequence of climate change with its implications of greenhouse gases add to the acidity of the soil. The availability of micronutrient cations is increased by low pH, even to the extent of toxicity to plants and microorganisms (Brady and Weil, 1999). Soil temperature is the primary determinant of microbial processes and so, increase in temperature will exacerbate the rate of mineralization leading to a decrease in the soil organic carbon pool (SOCP). With climatic change peat and other organic soils are converted to mineral soils. Lal (2004) noted that an increase in temperature would deplete the SOCP in the upper layers by 28% in the humid zone, 20% in the sub humid zone and 15% in the arid zone.

Declining soil fertility has been considered one of the major problems in the hill and mountain areas of Nepal as a result of recent changes in agricultural practices and increasing resource constraints. Hartemink *et al.* (2008) documented several constrains in soil fertility management in Nepal because of deforestation and other land use changes. These changes include non-agricultural uses of fertile land, land fragmentation and cultivation in marginalized areas, cultivation on the slopes, overgrazing, burning of crop residues, imbalanced use of agrochemicals, and declining use of organic manure. In South and South-East Asia, the principal soil degradation processes associated with land use changes include accelerated erosion by water and wind, salinization, flooding, water logging, and soil fertility. The pace of soil degradation issue is the highest in mountains because of the fragile environment and the steep slopes (Acharya and Kafle, 2009). Moreover, due to rugged mountainous topography, active tectonics and concentrated monsoon precipitation, Nepal is naturally highly vulnerable to soil erosion on slopes and flooding in the low-lands

2.6. Climate Change Adaptation of Agriculture

Adaptation is the responsive adjustment in natural or human managed systems to minimize the impacts, effects or expected changes. IPCC has categorized adaptations in two types; spontaneous and planned. Spontaneous adaptation occurs at the level of individual whereas planned adaptation need involvement of society with guiding policies (Berry et. al. 2006). According to Smit & Skinner (2002) adaptation on agriculture can be categorized as: technological, on-farm adjustment practices, government policy including insurance as well as diversifying household income sources as financial management strategies. In fact, the farmers who have the resources and access should be able to adapt better as compared to resource poor marginal farmers (Esterling & Apps 2005). Famers can adopt to climate change to some extent by adjusting planting time and input use, by altering soil management practices as well as diversifying their farm enterprises (Smit et. al. 1996). Lobell et al. (2008) has stressed that agricultural systems in Southern Africa and South Asia face decreases in crop production if sufficient adaptation strategies are not implemented.

In South Asian countries, particularly India, Nepal and Bangladesh, farmers are already adapting to changing conditions by using traditional seed exchange practices that are part of established seed systems (Gautam et al., 2008). Farmers can also use their knowledge of abiotic stress tolerance and adaptability in their materials and work with plant breeders to develop varieties that are adapted to changing local conditions and possess improved yields and quality (Jarvis et al, 2007). Many adaptation practices involving crops and livestock have been reported (e.g. Reid and Swiderska, 2008).

Climate variability and risks have always been a part of agriculture, due to which farmers have developed many ways of managing risks. Searching and exchanging drought-resistant seeds and other abiotic stress-tolerant crop varieties and adopting and practicing specific soil and water management practices for marginal areas have long been core activities of the farming communities (Gautam et al., 2010). Climate change introduces a new dimension to the problem. The continued availability and use of agro-biodiversity in Nepalese farming, particularly by smallholder farmers, is likely to play an important role in adaptation to climate change. Communities maintain rich species and intra-specific crop diversity both to help manage climatic adversity and meet their other needs (Jarvis et al., 2008). The farming in Nepal is characterized by mixed farming and livestock production systems, which have rich diversity. Forest, home gardens, agroforestry (with richness of fodder trees) and productive fields all embed diversity rich maintenance and use practices that increase adaptability and reduce vulnerability.

Traditional farming system management practices and farmers' innovations are clearly a key element in local adaptation to climate change. While scientists and policymakers work to find solutions, local farmers have already amassed considerable experience of how to cope, based on their observation and experimentation in the field (Reid and Swiderska, 2008). So, it is very important to document the adaptation practices that have been evolved in the farmers' fields.

CHAPTER 3: MATERIALS AND METHODS

3.1. Study Area

3.1.1. Prok VDC

Prok Village Development Committee (VDC) is located in the northern part of Gorkha district (See Fig. 1). This VDC is situated in Nubri Valley (Sama, Lho, Prok and Bhi VDC). The VDC is one of most remote VDC situated inside the Manaslu Conservation area and inhabited by poor and vulnerable communities. This VDC doesn't have access to motor road and the only modes for transporting goods is through Mules. It's a 4 days walk to reach the district headquarter *Arughat Bazar*. The VDC is situated between latitudes of 28° 36' 46.5" North to 28° 26' 53.0" South and longitudes of 84° 51' 45.9" East to 84° 41' 11.4" West (Source: MCAP[1]). This VDC has five villages Prok, Gaap, Kaap, Chaak and Namrung. Since, this VDC lies north to the middle mountain of Nepal, it has a cool temperate climate. Though the region lies in the world's highest mountain range of western Nepal, it receives the monsoon rains from east, i.e., from Bay of Bengal. As a result the landscape is lush and green. The VDC has steep slopes which are almost entirely composted of rocky surfaces and rocky gorges. Less than a quarter of the total land is found to be level and used for agriculture purpose. These level areas are in most cases terminal moraines and tiny alluvial plains where black alpine soils are found. The VDC is inhabited by 378 households with total population of 575 of which 273 are males and 302 are females (CBS, 2011). According to the same census the population density is 5.06 persons per square km and population growth rate is -0.10.The VDC has about 40% area as grassland (CBS, 2002). Hence, this VDC has great prospect for livestock farming. Forest is covered by 35% of the total area whereas 10% of the area is marginal and very rugged and barren (CBS, 2002). Total area of Prok VDC is 144.69 km^2. Only 15% of the total land (i.e. 227 ha) land cultivable (CBS, 2002).

[1] Manaslu Conservation Area Project run by National Trust For Natural Conservation (NTNC)

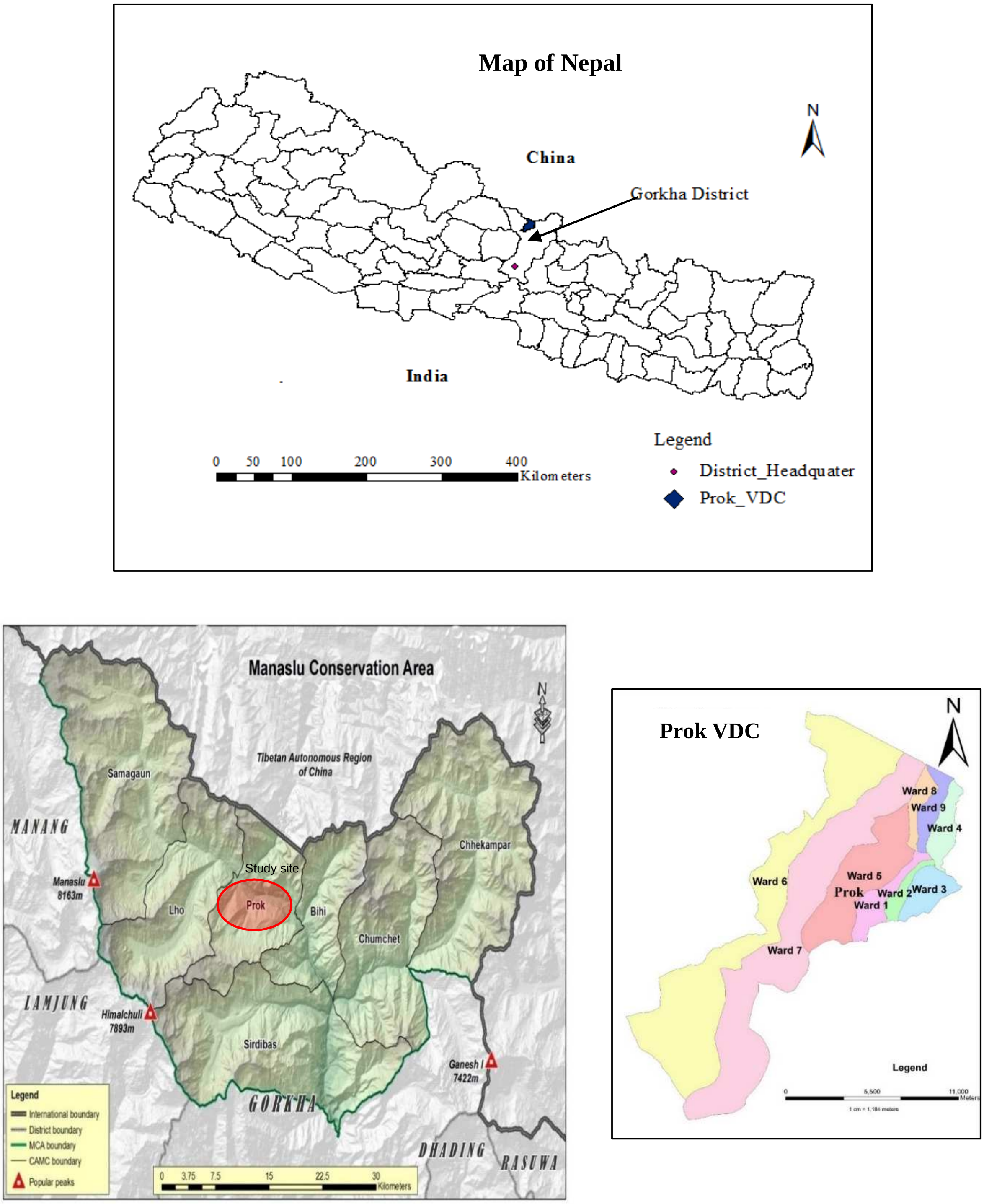


Figure 3.1 Study area (Prok VDC shown in Gorkha district, Nepal)

3.2. Methods

For the examination of current climate change vulnerability, impacts and adaptation strategies of agriculture at the household and community level case study strategy (Yin, 2003) and methodological triangulation approaches (Bryman, 2008) are used. The case study strategy incorporated in the study is both 'qualitative and quantitative'. Methodological triangulation; obtaining data from different sources, such as observations, documentations and interviews, helps to harness diverse ideas about the same issue and assist in cross-checking the results, and consequently helps to increase the validity, reliability of the findings and eases data analysis (Bryman 2008; Rialp & Rialp 2006). So, this strategy would be very helpful in order to validate the data obtained from different sources. This study obtains data from primary sources (field observation, household survey, laboratory analysis, interview with Manaslu Conservation Area Project Officers and Livestock Service Centre Officers) and secondary data sources (government documents, meteorological data and crop production data).

3.2.1. Vulnerability, Impact and Adaption Assessment

Informal semi-structured and formal structured surveys (Bryman, 2008 & Yin, 2003) based on individual interviews, key informant interviews, group interviews and focus group interviews of randomly selected farmers and other stakeholders (Manaslu Conservation Area Project Officers and Livestock Service Centre Officers) were used to describe and comprehend the realities of farming systems and households in the study areas. This was done to ascertain the vulnerability of farmers to prevailing negative conditions and strategies adopted to ensure livelihoods.

Key Informant Interview

In order to identify the local issues related with the climate change vulnerability, impact and adaptation on agriculture and get the overall information of the VDC monk of the monastery, VDC secretary and headmasters of local school were interviewed. All the activities in the villages are directed by the monk of the village and they are most respected. Similarly, school headmasters are the most literate person in the village and VDC secretary are the political representative of the village. Hence, these people are the good source for knowing overall information about the village.

Household Survey

Key informants survey was used for sampling frame. Farmers were selected after key informant's survey. Out of 378 households in the VDC, about 25% (48 households) were selected by random sampling method. Selected households were interviewed for information on food security, household income, yield trend, soil nutrient management, farm inputs and outputs, climate change perception, weather variability and their impact on agriculture and their adaptation strategies. Before data collection, a face to face interview for pre-testing the questionnaire was done in Gorkha district with four respondent.

Focus Group Discussion

Focus group discussion were organized in Prok, Gaap, Kaap, Chaak and Namrung village each. Focus group discussion was organized using participatory based appraisal (Yin, 2003 & Bryman, 2008). Focus group discussions were organized for qualitative information on climate change vulnerability, impact and adaptation of agriculture. Monks, VDC officials, progressive farmers and women group were chosen for the group discussion. In the FGDs, crop calendar, major disaster calendar were also constructed.

Transect Walk

Transect walk (Yin, 2003) was done in order collect the information about the land use system, cropping pattern and other information related to climate change impact vulnerability, impacts and adaptation on agriculture sector. Field observation methods were also applied to collect primary data on cropping pattern, use of agrochemicals and input self-sufficiency for farming by local farmers.

3.2.2. Soil Sampling and Analysis

Before the fieldwork, a topographic map (scale 1:25,000) and google satellite images were used to delineate the area and land uses. Total 18 random composite samples were collected from the five villages. Soil samples were collected from the cultivated field during spring season. These cultivated land includes wheat/karu field and maize field. 5 samples were taken from Prok village, 5 from Gaap village, 4 samples from Kaap and Chaak and 4 from Namrung Village.

Composite soil samples were collected from the plough layer surface (0-15 cm) for the purpose of quantifying soil nutrient reserves and soil quality. In the same sites, samples were collected for determining bulk density by using metallic core samplers. Samples were kept in sealed plastic bags and returned to the laboratory for analysis. At each observation point, soil properties such as soil colour, field texture, soil structure, soil consistence were recorded.

Physical soil properties were determined as follows: soil texture by the Bouyoucous hydrometer method (Gee & Bauder, 1986), bulk density (BD) using soil cores (Blake & Hartge, 1986). Chemical properties determined included: soil organic carbon (SOC) by dry combustion method (Nelson and Sommers, 1982), total nitrogen (N) by Kjeldahl (Bremner & Mulvaney, 1982) available phosphorous (P) by a modified Olsen's method (Olson & Sommers, 1982), available potassium (K) and cation exchange capacity (CEC) by ammonium acetate extraction (Rhoades, 1982) and pH using a digital pH meter with 1:1 soil water ratio (McLean, 1982).

3.2.3. Productivity Trend Analysis

Productivity data of the Prok VDC has not been documented yet. So, the district level crop yield data from 1981 to 2011 was obtained from Ministry of Agriculture and Development (MOAD), Statistics Section, Kathmandu; for productivity trend analysis. Crop yield data of previous year for the soil sampled farm was recorded from interview for the documentation of major crop yield of the VDC.

3.2.4. Climate Change Trend Analysis

The temperature and rainfall scenarios of the study site were accessed by analysing the thirty to forty years weather data from the nearest weather station, (i.e., Jagat station located in Sridibas VDC, Gorkha district). Similarly, discharge data of Buri Gandaki River obtained from Jagat station was also analysed in order to see how the volume of water discharged in the region is changing. Buri Gandaki River is the main river system of that region that provides water supply to the VDC. Climate change trend graph was constructed suing more than 30 years rainfall and temperature data obtained from Department of Hydrology and Metrology (DHM, 2012) based on Jagat station of Gorkha district.

3.2.5. Data Collection

For primary data collection different techniques such as household interview, group discussion, and informal interaction and field observation were used. Secondary information was collected from Central Bureau of Statistics, Ministry of Agriculture and Development (MOAD) and Department of Hydrology and Meteorology. Soil quality data were obtained from filed observation and laboratory analysis of soil samples. Some additional information was obtained from National Trust for Nature Conservation (NTNC)/Manaslu Conservation Area Project (MCAP).

3.2.6. Statistical analysis

The collected data was analysed using both descriptive tools like mean, standard deviation, percentage etc. and inferential statistical tools. Data was tabulated and statistically analysed using Microsoft Office Excel 2010 and SPSS 16. The descriptive statistics were used to describe the respondents' socio-economic characters such as sex, age, farm size, education; knowledge level etc. Missing weather data were replaced by linear interpolation method in SPSS. Multiple regression analysis was done in order to interpret farmer's socio-economic status. The annual precipitation and temperature trends and discharge rate of Buri Gandaki River were analysed using SPSS statistical techniques. Soil analysis data was analysed by calculating means and standard deviation. Qualitative information such as farmers' perception regarding climate change and adaptation measures taken on their farmland collected key informants interviews and group discussions were analysed manually and interpreted to complement and supplement the quantitative information collected from household interviews and the meteorological stations. The relationship between productivity and climatic parameters (temperature and rainfall) was studied by using correlation analysis.

CHAPTER 4: RESULTS AND DISCUSSIONS

4.1. Socio-economic Vulnerability

4.1.1. Socio-economic and Demographic Characteristics

Agriculture is the main occupation of Prok VDC. Besides agriculture, labour work and remittance supports livelihood of the people to some extent in the region. Tourism is slowly increasing which is impacting on livelihood of people. Like most part of Nepal integrated farming dominates the livelihood of the region. Land is an important asset of household for production of crops and rearing livestock. Livestock serves as a source of manure and fuel. Oxen are the only means of ploughing the land. Due to the strong inter-linkage between crop production and livestock it is difficult to consider the two livelihoods separately.

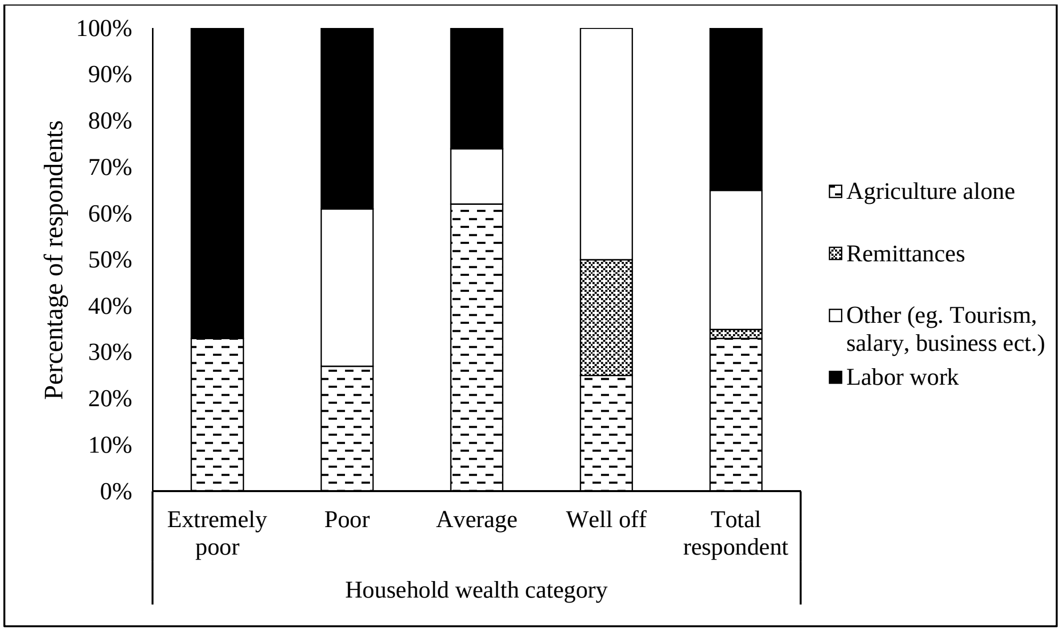


Figure 4.1 Source of income of respondents in different wealth groups (Source: Household Survey, April 2012)

From focus group discussions with the farmers, monks, women groups and VDC officials, four different wealth categories of farmers were determined. Nubri people emphasised mainly on total annual income, livestock holding and cultivable land holding for the wealth categorization. They think that household with less than NPR 50,000 annual income; less than 2 livestock and less than 0.2 ha of cultivable land should be categorized as extremely poor. Household with NPR 50,000 to NPR 80,000 annual income; 2 to 5 livestock; 0.2 – 0.5 ha of cultivable land were accepted to be categorized as poor. Similarly, Household with NPR 80,000 to NPR 100,000; 5 to 8 livestock and 0.5 – 0.8 ha of cultivable land was chosen for average. Farmer with more than NPR 100,000 annual income, more than 0.8 ha of cultivable land and more than 8 livestock were considered as well off farmers. Large populations of the villages were below the poverty with average annual NRs. 68,229 (equivalent to $ 802). Around 6% household were found to be extremely poor. Just less than 3 quarter of the respondent were found poor. About 16% of the respondents were found to be average and less than one tenth of the respondent were found to be well off. The bar graph (fig. 4.1) shows the income of respondent in different wealth groups. About 35% of the household income comes from labour works and around 30% of household income comes from other sources (like tourism, local trade of non-timber forest products (NTFPs). For some well off people of the village remittances and other sources like tourism and trade was major source of income (about 75%). For the extremely poor labour work was the major source of income (around 67%).

The average size of the households in the study site was found to be 4.90 (HHs survey, 2012). The educational status of the area is very poor since 70% of the respondents were literate. About 17% got education in 'lama school', and only 13 % had a primary education in formal school. There is Buddhist education in Lama School which includes Nepali and English subjects in their monasteries which provide residence for monks and nuns.

The average land holding size for permanent crop per household of respondents is only around 0.418 hectare (HHs survey, 2012). Most of other land are left barren or used for livestock grazing and sometime for cultivation of minor crops that have low productivity and are not consumed as staple food, i.e. millet and buckwheat. System of agriculture in the VDC is integrated agriculture with agro-pastoral system. They grow maize, barley, wheat and potato as crops and apple, pear, peach, plum and walnut as fruits.

4.1.2. Ethnicity and Religion

Entire population of the VDC are Buddhist (CBS, 2012). Prok VDC is inhabited by the Bhote Lama ethnic group known as *Nubri* people. Nubri people live in the northern part of Gorkha District. It includes Bihi, Prok, Lho and Sama Village Development Committees. They have culture and religion resembling with Tibetan culture. There are around 50 monasteries and stupas in the VDC. *Gumbas* (monasteries) of this village have owned in the village where villagers work there and give some part of harvest to monastery.

4.1.3. Regression analysis of Annual Income against Household Size and Livestock Holding

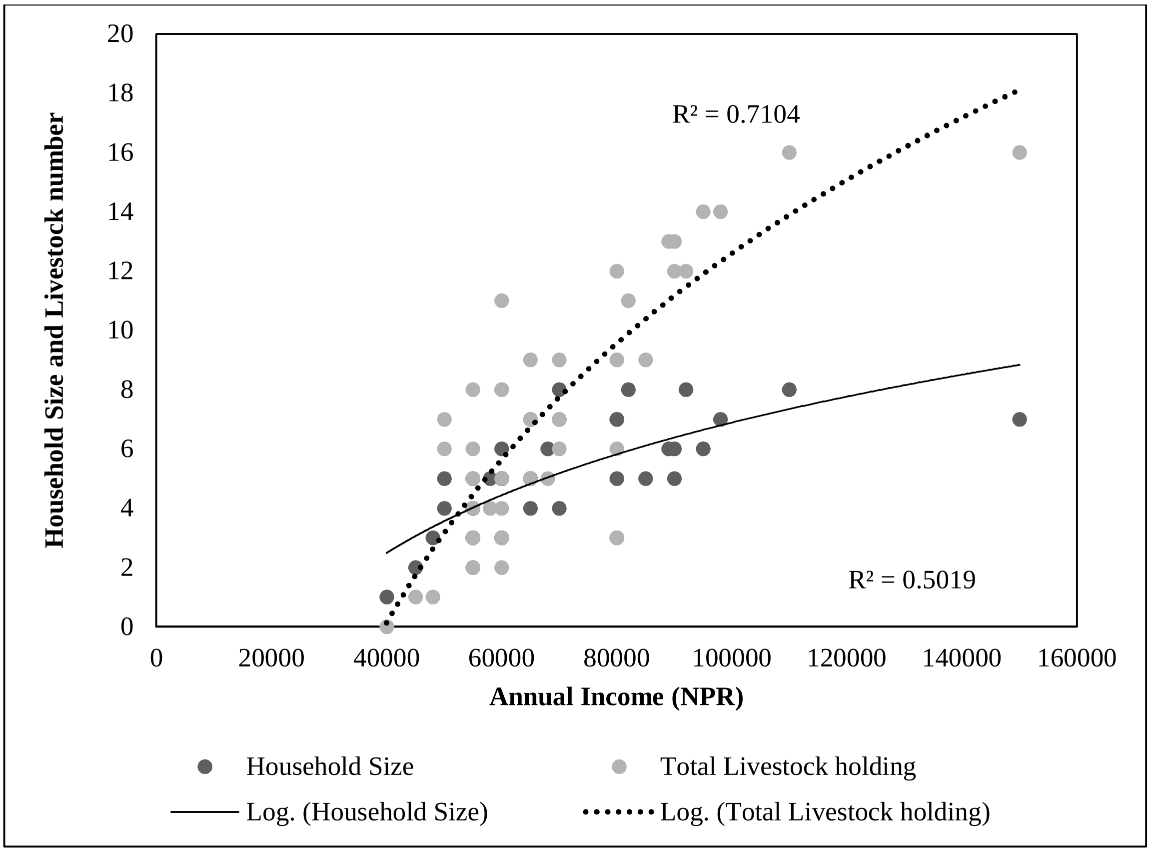


Figure 4.2 Scatter plot showing relation between annual income (NPR) and household size and livestock holding.

The plot diagram (fig. 4.2) shows the relation between annual income and household size and livestock holding. Logarithmic trend lines shows significant correlation between household size, livestock holding and annual income. That means farmers with more livestock holding and large household size have more annual income. Household with large number of livestock holding were found to have higher annual income among the surveyed farmers. Regression analysis of annual income (NPR) against household size and livestock holding shows positive correlation (R^2 = 0.667) at 95% level of significance (See Appendix, II). It means annual income of the household is positively correlated with the number of household size and livestock holding. The situation is like, the more animals a household can manage to keep, the more farm yard manure (FYM) for crops to be grown. Thus, there is a balance between the size of animal herds and acreage under cultivation. Hence, rich farmer has many animals in the village. Similarly, more family members in household means more labour for farming and off farm activities. Hence, both household size and livestock number is positively correlated with annual income.

4.1.4. Food Security

From the household survey it was found that 44% of the respondent of the village could produce crops sufficient to feed just for 3-6 months. Only 3% of the surveyed households were found to be food self-sufficient during the study. Above 30% of the respondent were found to have local products sufficient for only three months. Around 45% of the respondent were found to have sufficient food only for 3 to 6 months and for 22% their yield was sufficient for 6 to 9 months. People used to eat *dhido* (porridge) with salt and hot pepper before 40 years. But, at present people have habit of eating rice. Food grains are sold by Food and Agriculture Organization (FAO) on subsidy to the villagers during shortage months. For 9 months they import food from Tibet and Arughat. Since, only 3% of the respondents have food sufficiency for 9-12 months it can be inferred that the food security situation of the VDC is poor.

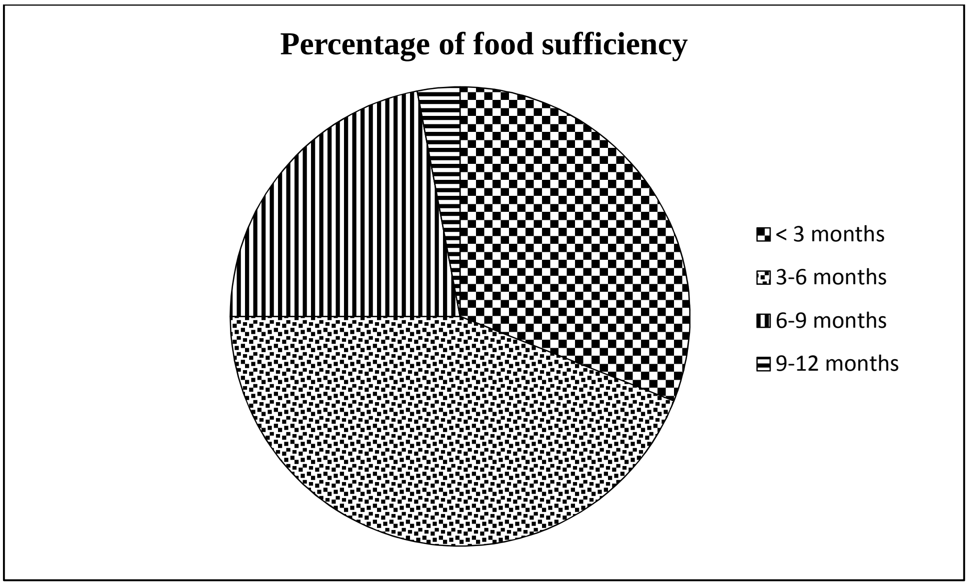


Figure 4.3 Status of food sufficiency of farmers of Prok VDC (Source: HH Survey, April 2012)

Insufficient food production from farm means that people will have to rely more on purchase of food and are therefore more vulnerable to rising food prices. Those with more assets such as land and livestock and more importantly, off-farm incomes are in a better position to buy food. However, for the families interviewed, off farm income is limited to casual labour either locally (on other people's farms or as porters), in Arughat in Gorkha (often as the porter and manual worker) or further away either in Nepal or India (including agricultural and construction labour, as guards etc.).

4.1.5. Farming System

The most typical cropping pattern in the Prok VDC is the rotation of maize and wheat with *karu*[2] and buckwheat. There is still some millet but farmers don't prefer and it's a minor crop. Wheat is very important, and this plant has been cultivated many years. Besides maize wheat and *karu*; potatoes, summer vegetables are also grown. In the summer, animals are taken to high mountain pastures where they are allowed to graze on village common pasture. Every spring, men from each village go to herd the animals throughout the summer. From November to February the villages are covered in snow and livestock has to be fed in the stable. The supply of winter fodder is a very important in case of livestock farming in the village. Mostly, fodder is supplied by crop residues, which are dried and stored for use in winter. Various herbs and grass species, including wild oats (*Avena* spp.) are also collected from common village land along footpaths, on uncultivated land in the valley bottom around the bank of river Buri Gandaki and from the forest nearby villages.

Maize is a summer crop where soybeans and beans are mixed. Vegetables like onion, broad leaf mustard, cabbage, cauliflower, radish etc. are cultivated during summer season. Wheat and barley are major winter crops and pea is mixed in the wheat farm. Table 4.1 shows the crop calendar of major cultivated crops in Prok VDC.

Table 4.1 Crop Calendar of main cultivated crops in Prok VDC

Crop	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Season**
Maize			P	P				H	H	H			Summer
Millet				P	P					H	H		Summer
Wheat					H	H					P	P	Winter
Karu				H	H						P	P	Winter

P = Planting; H = Harvesting

(Source: Household survey, April 2012)

[2]six-row naked *Barley*

4.1.6. Land Use and Management Practices

The land use are broadly classified into forest land, pasture land and agricultural land. The forest land covers about 75 % of the VDC. The dominant forest types are Sal forest, Rhododendron and Juniper forest. Forest is an integral part of the farming system. Only *bari* land (unirrigated upland) is found in the study area. Prok villagers take their livestock to pasture land (*kaltal)* for pasture grazing (*lek)*. They take their livestock to pastureland for three months (i.e. June, July and August) during summer season. During this period they preserve their grass. Farmers collects grass, dry them and save for the lean period i.e. winter season. Farmers have experienced that in many areas, the disappearance of fallows and the shrinking of pastures have led to overgrazing, which has equally devastating consequences on land resources.

4.1.7. Agricultural Inputs

Farmers in the Prok VDC don't have access to chemical fertilizers and other agricultural inputs. It takes around 4 days to reach the nearest road. Hence, the problem of maintaining soil fertility is solved by the use of manure. Animal husbandry is thus an integral part of the farming system as nothing can be cultivated without manure in mostly marginal sandy loam soil of the region. For the Prok farmers manure is so valuable. They collect manure form the summer pasture at higher elevation and carry in baskets down to the farmsteads nearby settlement area. In winter, pine needles and juniper branches are collected from the forest on the north-facing slope and used for animal bedding. After two months the bedding is mixed with dung and urine and finally added to the manure heap.

Prok farmers do not have access to improved seed varieties for their major crops. For all the respondents own saved seeds are main source of seeds for their crops. Around 46 percent of respondent reported that they get some seeds from their relatives. Around 67 percent of the respondent said that they get summer vegetables from Manaslu Conservation Area Project (MCAP). Only 20% of respondent reported that they get some vegetable seeds from Non-Governmental Organization and International Non-Governmental Organization.

Farmers do not have access to improved varieties are totally dependent on local seeds for cereal crops. So, the cereal crops of this regions are entirely local varieties. The local varieties have low yield potential and are not as productive as improved varieties available in other regions. The risks of crop failure are high due to the frequency of droughts, landslides and other yield-reducing factors such as pests, diseases and weeds. Besides, the poor road infrastructures and access to markets in these rural areas make both physical and economic access to improved sees is a major problem. Some of the traditional seeds of the major crops are listed below in the local Nubri language.

Table 4.2 Traditional crop varieties

Crops	Local varieties (Nubri name)
Maize	*Asri, Korcha, Sherpu*
Karu (Barley)	*Changta, Nheje*
Jhi jhi (wild sesame)	*Jhi Jhi*
Potato	*Marpo, Karpo*
Latte (*Amaranthus sps.*)	*Nana*
Wild rice	*Tongren*

(Source: HH Survey, April 2012)

The inaccessibility of farmers to improved varieties of seeds is constraining the productivity of crops. The socio-economic status of farmers and the remoteness of their village is depriving farmers from access to agricultural inputs. Unless farmers have sufficient access to agricultural inputs they cannot produce good harvest from their farm. The socio-economic data obtained from the surveyed villages reflects the overall socio-economic vulnerability of farmers in agricultural sector. Aase et. al. (2009) has also similar condition of farmers in Manang district in western mountain region of Nepal. For 200 years, *Mananges* (people of Manang) have managed to develop from being one of the most miserable peoples of Nepal, suffering extreme poverty and regular famines (Aase et. al., 2009). Nubri communities in Prok VDC are also living in the similar condition as the *Mananges* does. Hence, Farmers of this regions need strong support from government administration in order to develop infrastructures in their villages and to uplift their socio-economic status.

4.2. Status of Soil/Land Resources

4.2.1. Soil resources and land management

The soils in of the Prok are inherently fragile and prone to degradation. Only 15.42 % of total land in this region is cultivable (CBS, 2002). Soils of this region are coarse grained and have high gravel content which varies from 5% to more than 25%. It makes farming very difficult. The composition of many soils in the Prok VDC (high levels of sand (52.17±13.73 %) and silt (34.5±13.65), and low levels of clay (14.39±5.88) makes them highly prone to wind erosion and landslides. Farmers uses abundant organic manures (around 2.5 tons/ha) to make their farm fertile. Among five villages of VDC soil erosion is very evident in Kaap village. Water runoff causes losses of huge amounts of fertile topsoil during the pre-monsoon and monsoon season in Kaap village. People from Kaap village have opined that because of the absence of trees wind erosion is causing more soil loss in their village. The loss of the topsoil (which contains most of the plant nutrients) through water and wind erosion is a major setback to agricultural sustainability and food security in Kaap village. Prok village has productive flat land and erosion problem is negligible.

4.2.2. Physiochemical Properties

Soils in all five villages were found to be mostly black in colour and slightly alkaline in nature (pH= 7.38±0.63).The sand and silt dominates with more than 80% in all the samples. The texture of soil was found sandy loam and silt loam dominant by USDA system (See table 4.3). Bulk density of soil samples ranges from 0.92 – 1.38 Mg/m^3 (See fig.4.4). Generally, soils with high sand content tend to have a higher bulk density due to high specific gravity of quartz, principle component of sand (USDA, 2008). Soils with high silt and clay tend to have lower bulk densities. However, organic matter, which is of much lower density, also affects soil bulk density despite its relatively low proportions in mineral soils. So, high organic matter contents of the soil found in this region could be the cause of lower bulk density.

Table 4.3 Physical properties of soil in Prok VDC

Name of Village	Plot nos.	Sand (%)	Silt (%)	Clay (%)	USDA textural class	Structure	Consistency
Prok	1.	49	15	36	SiL	weak, moderate, fine, granular, subangular	very friable
	2.	34	56	10	SiL	weak, fine, granular, subangular	very friable
	3.	61	25	9	SL	weak, medium, granular, subangular	friable
	4.	71	18	15	SL	weak, fine, medium, subangular	very friable
	5.	58	27	15	SL	weak, fine	very friable
	Mean ±SD	54.6 ±13.94	28.2 ±16.30	17 ±10.97			
Gaap	1.	63	25	12	SL	weak, fine, medium, granular, subangular	very friable
	2.	36	50	14	L	moderate, fine, granular	friable
	3.	27	55	18	SiL	weak, fine, subangular	very friable
	4.	40	48	12	L	weak, fine, subangular	very friable
	5.	58	27	15	SL	weak, fine	very friable
	Mean ±SD	44.8 ±15.19	41 ±13.95	14.2 ±2.49			
Kaap and Chaak	1.	46	40	14	SiL	weak, fine, medium, granular	very friable
	2.	72	18	10	LS	weak, medium, granular	very friable
	3.	46	38	16	L	weak, medium, granular, subangular	friable
	4.	62	26	12	SL	weak, medium, granular	very friable
	Mean ±SD	56.5 ±12.79	30.5 ±10.37	13 ±2.58			
Namrung	1.	65	23	12	SL	weak, fine, medium, granular	Very friable
	2.	64	35	11	SL	weak, fine, subangular	very friable
	3.	53	42	15	L	Weak, fine, medium, granular, subangular	friable
	4.	34	53	13	SiL	weak, fine, medium, granular, subangular	very friable
	Mean ±SD	54 ±14.40	38.25 ±12.58	12.75 ±1.71			

Table 4.3 shows the soil of the Prok VDC are mostly sandy loam, silt loam and loam type. The structural types of soils are mainly weak, fine, granular to sub-angular blocky. Such types of soil have lower water holding capacity and are more liable to nutrient losses due to leaching. The bar charts (fig. 4.4) indicate standard deviations about the mean of the SOC and Organic Carbon % in five different villages of Prok VDC. Organic carbon content in Gaap village is

found to be the highest followed by Namrung and Prok village. Similarly, the bulk density of soil from prok village is highest. Soils from Chaak and Kaap had lowest organic carbon. Soil from Prok VDC had the highest organic carbon percentage which ranges from 3.44% to 11. 34%. Baumler et al. (1994) also have found high carbon percent in soil of the mountain region of Nepal.

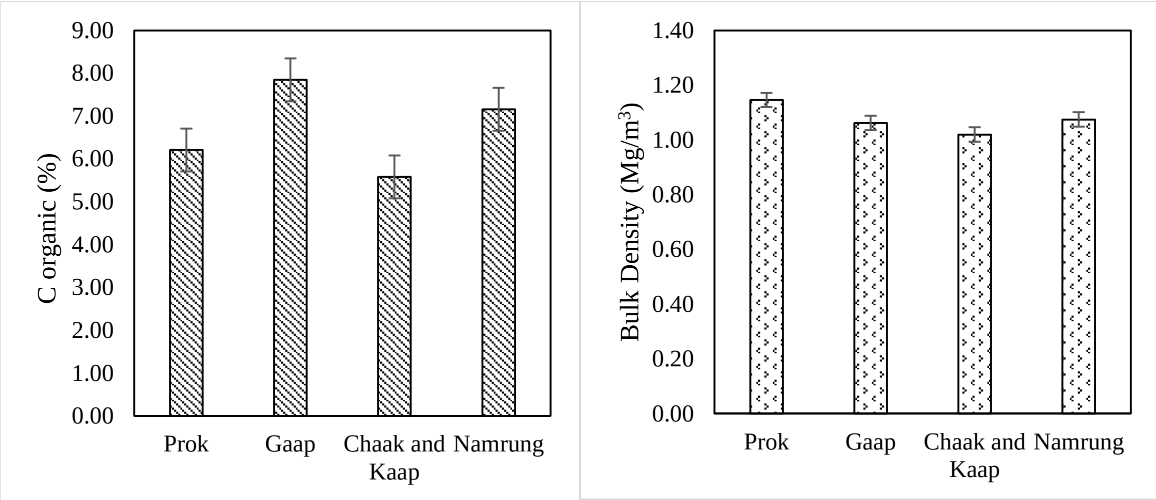


Figure 4.4 Organic Carbon percentage and Bulk Density (Mg/m^3) of soils

4.2.3. Nitrogen, Phosphorus, Potassium (NPK) and Cation Exchange Capacity (CEC)

The results of the analyses of soil for total nitrogen TN, available phosphorus P, and exchangeable potassium, K are shown in fig. 4.5. Total Nitrogen in Prok VDC ranges from 0.23 % to 0.76 % with standard deviation of 0.19 %. Total Nitrogen percent was found to be highest for Prok Villages followed by Chhak and Kaap. Available phosphorous content of sampled soils varied from 27 ppm to 104 ppm. Phosphorous content was highest for Prok village and almost similar in remaining villages. Exchangeable potassium ranges from 87 ppm to 636 ppm. The major macro nutrients of sampled soils were high. This could be due to higher amount of organic manure application. Bajracharya *et al.* (2009) data have recalculated from numerous studies in mountain region of Nepal shows similar results as above. The nitrogen, phosphorous and potassium were high in this region likely due to the fact that upland sloping terraces generally receive high levels of compost. A similar study conducted in western Nepal also showed high phosphorus level in upland areas (Tuladhar 1995).

Cation exchange capacity of the soil of ranges from 26.2 m.e/100gm to 56.5 m.e./100gm (see fig.4.5). CEC of Prok village was highest in comparison to soils from other village. It means soil from Prok village is more negatively charged in comparison to other soils, thus making it capable to hold more nutrients and avoid rapid changes in soil solution.

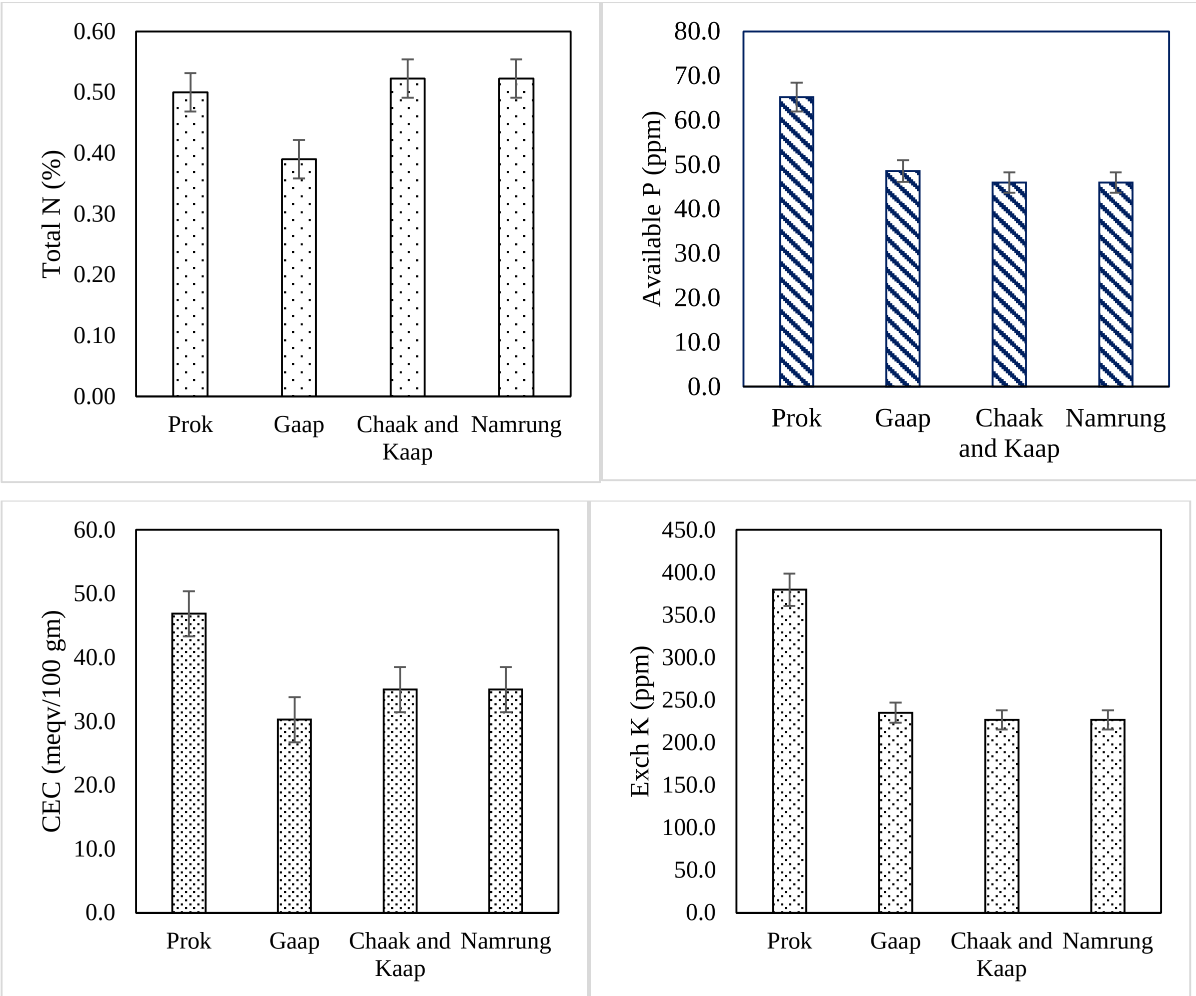


Figure 4.5 Total Nitrogen (N) percent, Available Phoshorous (P) (ppm), Exchangeable Potassium (K) (ppm) and Cation Exchange Capacity (CEC) (meqv/100gm) of soil in different villages of Prok VDC

From the soil analysis data it is evident that the nutrient status of most of the cultivated land is good. Farmers use only farm yard manure and compost on their farmland. And, the maintenance of soil fertility is the key to sustainable agriculture in this region. Traditionally, farmers in the Nepal hills have relied upon compost or farmyard manure (FYM, made of forest litter, crop residues and animal manure) to replenish crop lands, and in the past, the less intensive 2-crop with fallow farming systems had been sustainable for generations (Bajracharya & Sherchan, 2009).

4.2.4. Major Crop yield in Prok VDC

Major crops of the Prok VDC are maize, wheat and barley (*karu*). The crop yield data obtained from the household survey conducted in April 2012 revealed that in all five villages of the VDC crop yield was lower than the national average yield (MOAD, 2012). National average of maize, wheat, barley are 2053.4 kg/ha, 2501 kg/ha, 2412 kg/ha respectively (MOAD, 2012). Bar graph (fig. 4.6) shows that among the five villages in the VDC, Prok village has maximum crop yield, followed by Gaap village. Chaak, Kaap and Namrugn village have comparatively lower yield of major crops maize, wheat and *karu ((*six-row naked *Barley*). Among five villages Prok VDC has very well managed farm land. In Prok VDC yield of maize and wheat were 2053.4 kg/ha and 1864.6 kg/ha, respectively, which are considerably less than the national average yield. Yield of *karu* (six-row naked *Barley*) in Prok village is 1708.2 kg/ha in the villages is higher than the national average yield (1245 kg/ha) (MOAD, 2012). This may be because of the agroecological zone being more favourable for this crop than for other crops like maize or wheat.

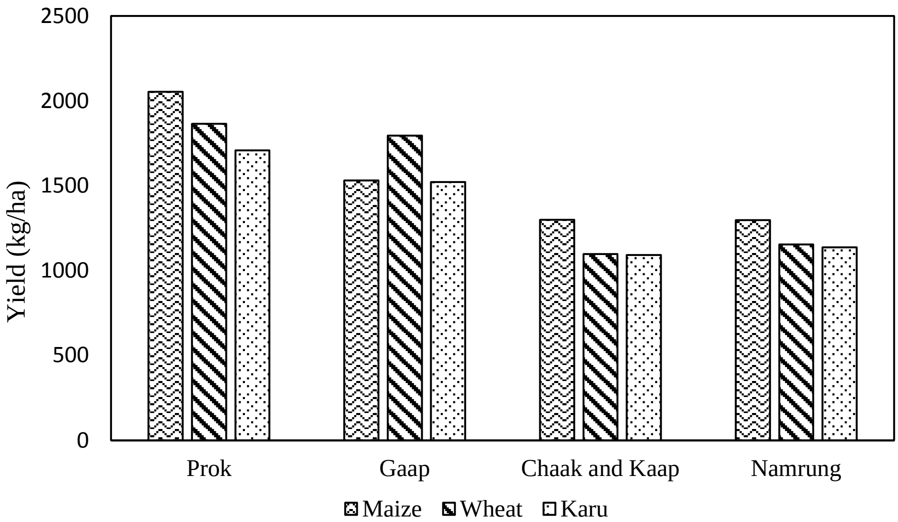


Figure 4.6 Major cereal crop yield in different villages (Data source: HHs survey, April 2012)

In spite of good nutrient status crop productivity is very low in all the surveyed villages (fig. 4.6). It could be due to the poor physical properties of the soil. High gravel content and less amount of clay in the soil of this region makes soil of this region more vulnerable. Similarly, this region lacks access to irrigation and farming is completely rainfed. Though farmers make their great effort to maintain nutrient status of soil factors like agricultural inputs and agroecological condition undermine crop yield.

4.3. Local Climate Change Scenario

Strong signals of climate change were detected when the weather station data nearby Prok VDC were examined over recent history (1971-2010) (fig. 4.7 to 4.9). There were significant changes in most annual and seasonal climate variables examined in this study. First, the significant increase in minimum and maximum temperatures and significant decrease in precipitation at annual and seasonal temporal scales were observed. The maximum mean annual temperature of this region has been increased by 0.085ºC (fig. 4.7.I) and the minimum mean annual temperature of this region has increased by 0.025 ºC (fig. 4.7.II).

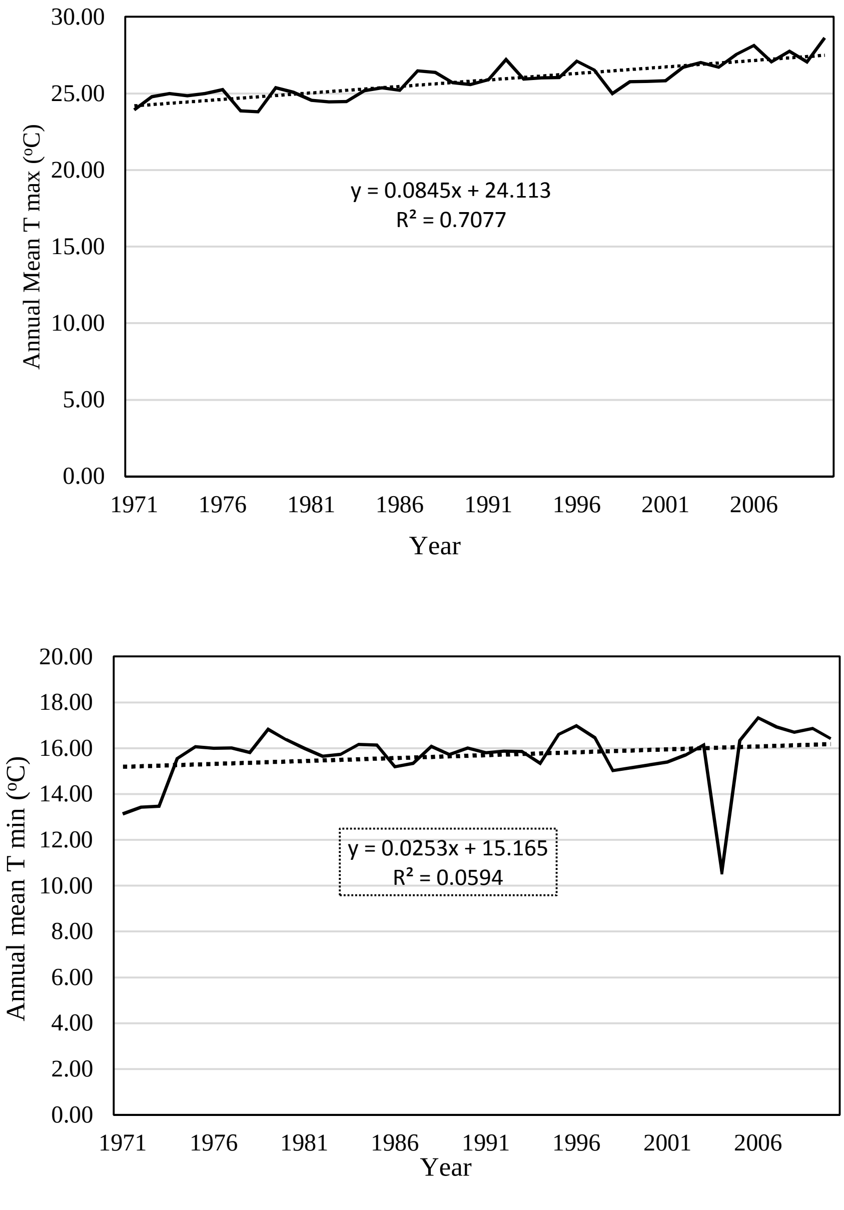


Figure 4.7 I. Time series of annual mean maximum temperature values (ºC), II. Time series of annual mean maximum temperature values (ºC)for Jagat station between 1971 and 2010; (Data Source: DHM, Kathmandu, 2013).

The biggest changes in precipitation were observed during the monsoon season. Monsoon precipitation trend in the time series was found to be decreasing which is -3.32 mm yr^{-1} (Figure 4.8), which is equivalent to a decrease in 132.8 mm in monsoon rainfall over the entire study period. There has been a very erratic trend of monsoon precipitation ranging from around 400 mm to just below 1800 mm. This high variation in monsoon rainfall totals is clearly unfavourable for the agriculture systems of this region.

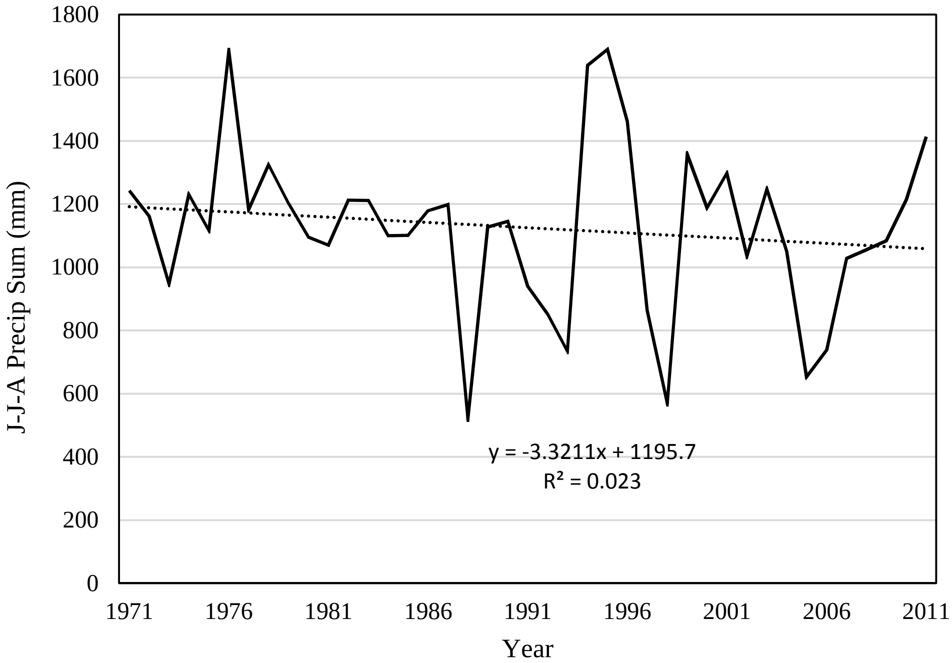
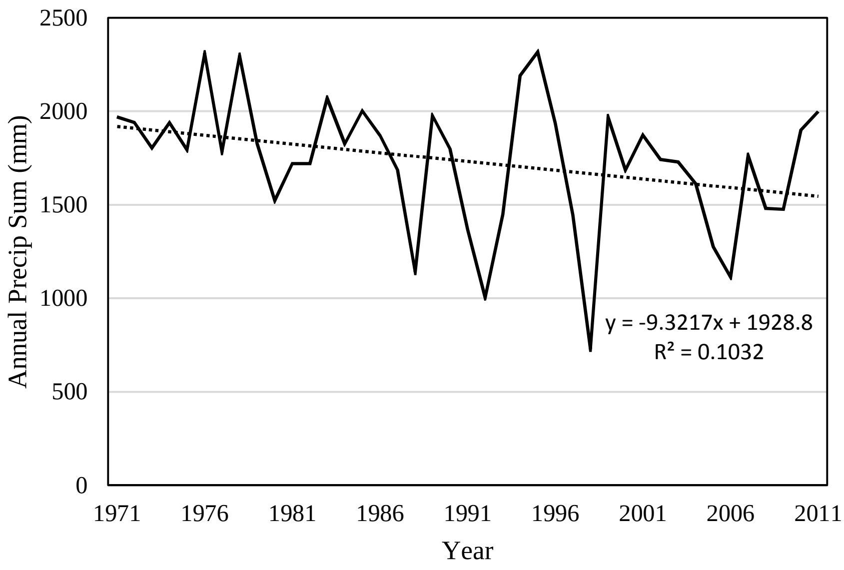


Figure 4.8 Time series of June–July–August precipitation totals (mm) from 1973 to 2010 for the Jagat station; (Data source: DHM, Kathmandu, 2013).

When these recent change in the temperature, precipitation and river discharge was compared over 30 to 40 years time series data from the weather station in Jagat, it is apparent that regions' climates exhibits fluctuations over time, many of the changes are very erratic. Annual mean temperature is found to be increasing by 0.06^0Cyr^{-1} which is equal to 2.4^0C warming over the course of time. The annual total precipitation of the region appears to be significantly decreasing. This decrease in total annual precipitation for the region is 9.32 mm yr^{-1} (fig. 4.9). Average annual discharge in Buri Gandaki river shows decreasing trend which is 0.18 m^3/yr (fig. 4.9).



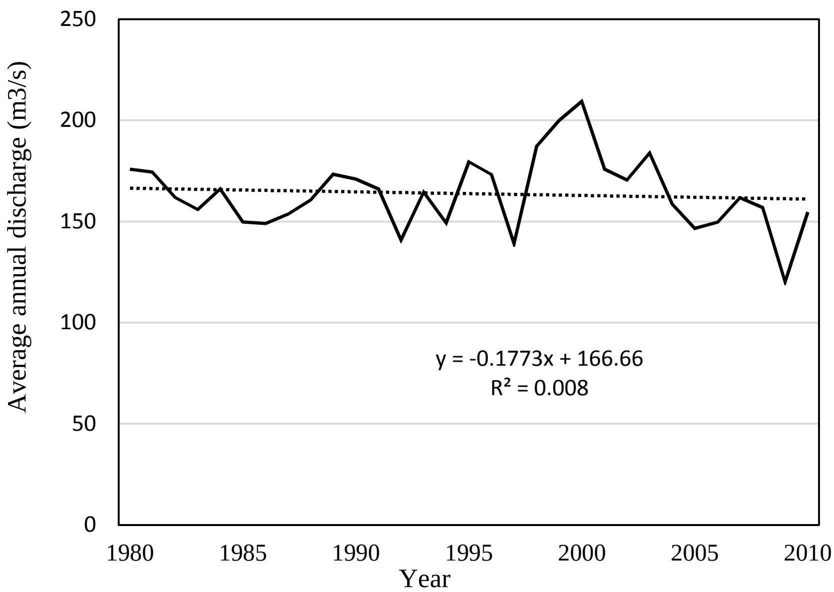


Figure 4.9 Time series of annual mean temperature average (°C) and annual precipitation sum (mm) and average annual discharge (m3/s) in Buri Gandaki River at Jagat station. (Data source, DHM, Kathmandu, 2013)

From the above analysis of temperature and precipitation trends over 30 to 40 years data it can be concluded that this region experiencing high weather variability and the trend is erratic. Similar results have been reported by Baidya et. al. (1993) from their studies done in various parts of the country. There has been late monsoon or pre-monsoon, unusual precipitation patterns, decreasing rainy days and increase in intense rainfall events throughout the country

(Malla, 2008). Shrestha et. al. (1993) have reported an average of 0.08^0C/yr rise in maximum temperature in the Himalayan region of Nepal which is very close to 0.085^0C/yr of Jagat temperature rise trend. From the temperature, precipitation and river discharge trend over 30 years period shows this region is experiencing climate change variabilities.

4.3.1. Major Cereal Crop Productivity Trend in Gorkha District

Data on productivity at VDC level was not available, so data for the whole district was used for analysis. The productivity trend for last 30 years showed fluctuation in productivity of maize, and wheat and whereas the productivity of barley is almost stagnant over the years. Productivity of maize is positively correlated with time and positive trend. Both for the Maize and Wheat the productivity trend has been found to be decreasing after 2005. This could be due to the weather unfavourable weather pattern.

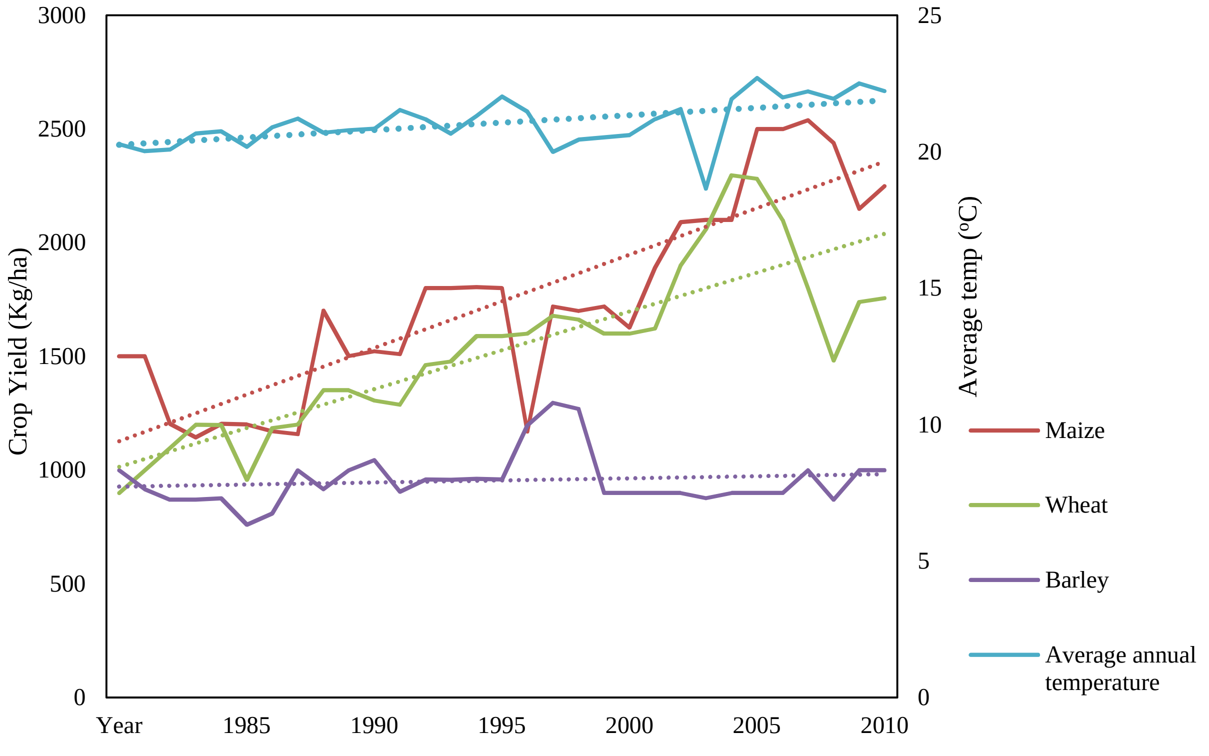


Figure 4.10 Productivity of major cereals and average annual temperature (ºC) in Gorkha District (Source, Ministry of Agricultural Development, Statistics Division, Singha Durbar, Kathmandu, Nepal (June, 2013)

The year 2007 was most favourable for maize production in Gorkha District. Productivity trend of maize has been very erratic during the 30 years period. Figure above shows erratic pattern for the productivity of wheat as well. From 2004 the productivity of wheat has been decreasing.

Productivity trend of barley is almost constant from 1981 to 2011. In 1998 productivity of barley was highest, but the following year it began to decline and continued the same trend. There is no significant correlation with temperature change on crop productivity in Gorkha District productivity data. But, changes in weather pattern including temperature, precipitation, humidity and solar radiation have detrimental role in crop productivity.

4.4. Farmer’s Perception of Climate Change

Farmers from Prok VDC haver reported weather of this region has been very erratic and unpredictable. Figure 4.11 show the perception of climate change parameter reported by farmers from five villages of Prok VDC. In the household survey, about 75 per cent of respondents answered that they have observed decrease in annual precipitation. About 73 per cent of the total respondents answered that they have observed a reduction in the rainfall during rainy season. About 68 per cent of the farmers have seen a reduction in the total winter rainfall. The condition is similar regarding total number of rainfall days, which is observed to be reduced by about 65 per cent of the respondents.

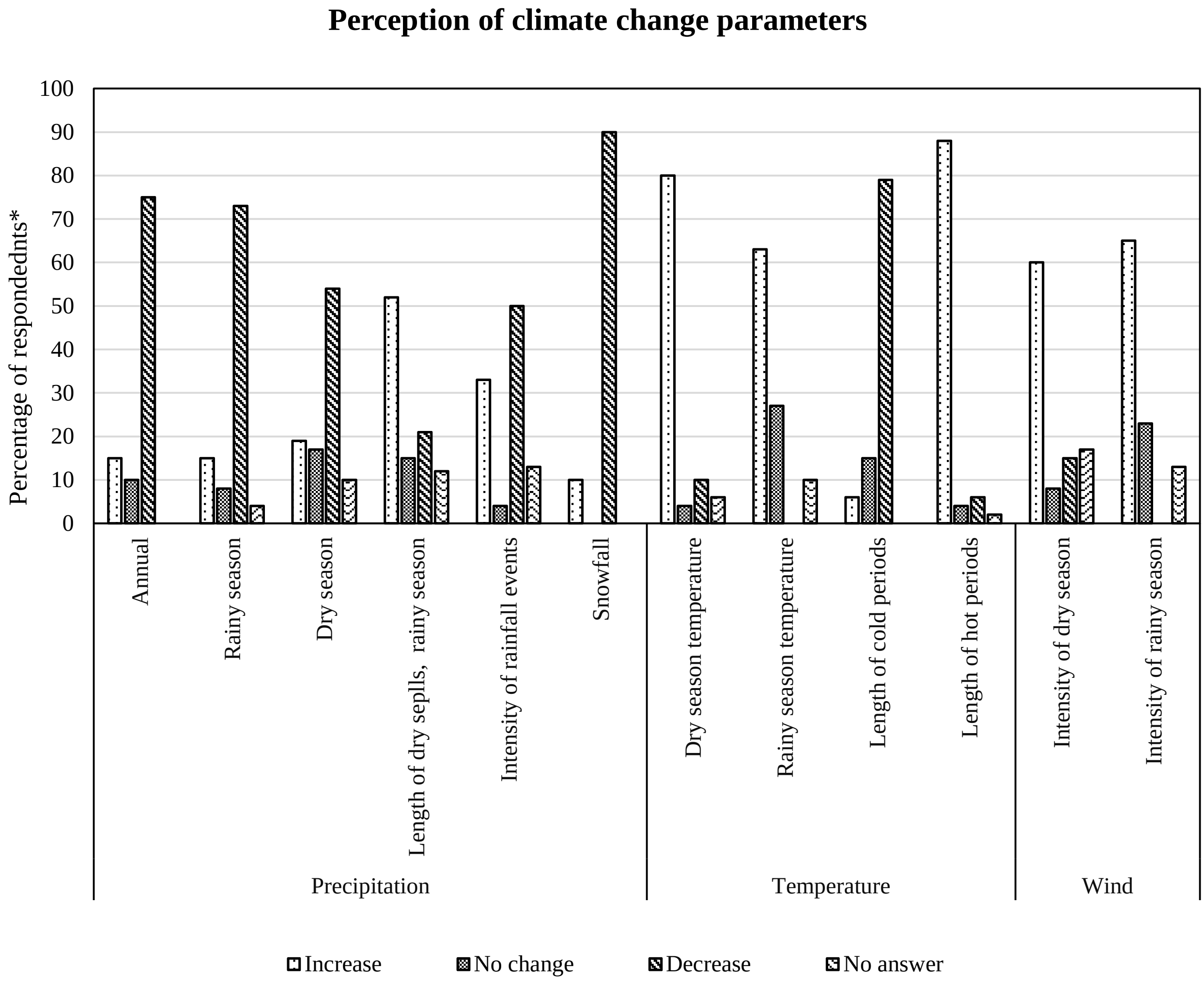


Figure 4.11 Perception of climate change parameters by households in Prok VDC during the last 30 years (Source: HHs survey, May 2012)

* Percentage are rounded to whole numbers

All of the respondents believed that there has been a considerable decrease in snowfall during recent decades. Similar results were also reported by Tiwari et. al. (2010) in the mountain region of Nepal. According to Tiwari et. al. (2010) snowfall has been severely decreasing during winter months in the mountain region of Nepal. According to Macchi (2011) farmers in the hilly regions of western Nepal and north-western India are reported perceived reduced snowfall and warmer winters in recent years. The lack of snowfall means less precipitation for winter crops, but also less soil moisture as snow percolates into the ground gradually improving the soil moisture content. Hence, a decrease in snowfall has a detrimental impact on winter crops. Around 60 per cent of the total respondents answered that the problem of windstorms during dry season has increased in recent years. According to farmers such windstorms cause harm to their crops and livestock.

Box 1 An experience of decreasing snowfall in Prok VDC-5, Namrung village (source: author's interview)

Kalden Dhoma Lama, 64 years old resident from Prok VDC-9, Namrung village, still has memory of winter year in around Buri Gandaki River when she was during her first and second decade. When she was young, there used to be snowfall even up to a meter around the river. But, nowadays it's less than half meter. This has impacted on the growth of our Karu (Six rowed barley). High snowfall helps to have good harvest of Karu and its declining because of less snowfall.

In all the villages farmers reported delayed and erratic rainfall during the rainy season followed by prolonged dry periods. Study carried out from April to May 2012 farmers reported that weather patterns had changed over the past 10 years and that weather was becoming more extreme and erratic; and many farmers have noted that the summer rains have been delayed and that they lasted for a shorter period but were more intense than those they remember from previous times.

Table 4.4 Statements on change in climate parameters by focused group discussion in different villages of Prok VDC

Weather parameters	Prok Village	Kaap and Chaak Village	Namrung Village
Rain	Less rain, erratic pattern Rainfall is late during monsoon	Longer dry spells during rainy seasons No rainfall during monsoon	Less rain
Temperature	Heat is more intense Heat is more intense during August and September	Cold spells reduced in length and intensity	Intensity of cold spells reduced Intensity of heat during dry months increased
Snowfall	Snowfall has considerably decreased	Snowfall used to be half meter high in the bank of Buri Gandaki river but now a days up to few centimetres	Snowfall has decreased considerably leading to decrease in the yield of *Karu* (Barley)
Wind	Winds are very strong during March/ April and the intensity of wind has increased	Clouds bring more wind than rain in rainy season	Wind is sometime so strong that sometime house roof are blown and livestock sheds are completely damaged

4.4.1. Climate risk and hazards

Climatic stresses and frequencies of such stresses were analysed using past 30 years timelines of the VDC. During the participatory appraisal farmers had revealed how their communities are affected by climate stress over the years. Respondents suggested that climate risks and hazards are increasing in terms of magnitude and frequency and severity of impacts are high in recent decades. While discussing and drawing timeline with the farmers in the five villages, almost 90% of the respondents perceived that risks and uncertainty of the climate has increased. The timeline showed that occurrence of climatic stresses like flood, drought, river bank erosion, windstorm increased in recent years as compared 25 - 30 years back, even drought and 2 - 3 times flooding in a single season. Drought was prominent even during mid-monsoon season. According to the timeline drawn during the focus group discussions (FGDs) landslide, drought, windstorm, floods and decrease in snowfall were found to be major climatic stress.

In the villages of the Prok VDC landslide comes in first places as the hazards occurrence in the study area. (Table 4.5). Agriculture and livestock are the mostly affected sector in the VDC due to irregular weather pattern as more than 95% of the people engaged in this sector for their subsistence, which is followed by forestry, infrastructure, human casualties and water sources.

Climate change has increased the variability of the run-offs of the rivers leading to shortages of water in dry season.

During the focus group discussion risk and hazard ranking was done in different vulnerability sectors. Farmers have identified agriculture as the most vulnerable for them. They have identified landslide as one of the most challenging climatic threat followed by drought and rock fall. They have reported livestock sector is more affected by climatic risk after agriculture followed by human casualties and water resources.

Table 4.5 Climatic risks and hazards seen in Prok VDC and its impacts on different vulnerability sectors

Threats/Sectors	Agriculture	Livestock	Forest	Human casualties	Infrastructures	Water Sources	Total	Rank
Floods	3	2	2	3	1	1	12	3rd
Landslides	4	3	4	3	3	3	20	1st
Riverbank erosion	3	2	2	1	1	2	11	4th
Rock Falls	2	3	1	2	2	2	12	3rd
Drought	4	3	2	1	-	4	14	2nd
Wind Strom	3	2	2	2	3	2	14	2nd
Epidemics	1	3	1	4	1	-	10	5th
Total	20	18	14	16	11	14		
Rank	1st	2nd	4th	3rd	5th	4th		

1- low/no impact, 2-medium impact, 3-high impact, 4-severe impact

(Source: HH Survey, May 2012)

Farmer’s perception on climate change generally agree with the weather station data. Extreme changes in rainfall pattern, temperature variation and gradual reduction in snowfall are some of the main climate change events perceived by famers from the surveyed villages. From the above analysis it is clearly evident that farmer are experiencing climate changes events. These climate changes events have caused several risks and hazards. These risks and hazards are directly linked with the socio-economic aspects of farmers. Threats like landslides, riverbank erosion, and drought and wind storms have direct impact on farming activities. From the Nubri farmer’s perspectives it evident that climate changes have brought various risks and uncertainties in their farming system.

4.5. Climate Change Impact on Agriculture

The household surveys and focus groups discussions conducted in the villages of Prok VDC have found that farmers have perceived several changes in their local weather pattern. Farmers have noted occasional drought, less snowfall and have perceived warming in ambient temperatures. A close agreement between the weather changes reported by the farmers and data from the meteorological stations was observed. The farmers themselves correlated weather changes with crop production. Farmers correlated weather events with the productivity of traditional crops (such as wheat, maize, and *karu*) that are not irrigated and reported a decrease in productivity. They noted that crops are failing due to drought during the growing stage and intense, heavy rainfall later in the season which flattens and floods crops when they are close to maturity.

Farmers are aware of decrease in snowfall, gradual rise in the temperature of the region, severe windstorms during dry seasons. They have also recognized the decrease in the amount of cold days in winter, and experience more hot days at present than in the past. Because of this, farmers have perceived the consequences of weeds and insect pests, which used to be a severe problem in lower altitudes. More than 60% of the farmers have reported new weeds have become more prominent during recent decade. They have also noticed the increased frequency of extreme events in recent years, such as landslides caused by heavy downpours, as well as very long dry periods. The shortening and shifting of the monsoon season has also been recognized in the way that it commences and ends one month earlier. The prolonged winter droughts induced by the sparse rainfall and the changing weather trends in general have led to drier springs, challenging effective water resource management.

Farmers in *Gaap* and *Chaak* village reported a loss of agricultural production as a result of changing environmental conditions. Farmers from Prok and Namrung have said that crop losses of up to 50% were due to problems of erratic rainfall and increased drought. Farmers in *Gaap* and *Namrung* village correlated changing weather patterns with a trend of early ripening of fruits such as wild pear (*Prunus sps.*) fifteen days to one month earlier than in previous years. They reported the same for fruit trees, such as apple, peach and linked this with degrading fruit quality during recent decade. Another general observation by the inhabitants of these areas was that local drinking water sources seemed to be drying up; and on average, they reported a 50% decrease in drinking water sources. But, they have found increase in discharge level of water in *Buri Gandaki* river during spring implying more ice melting from the Himalayas.

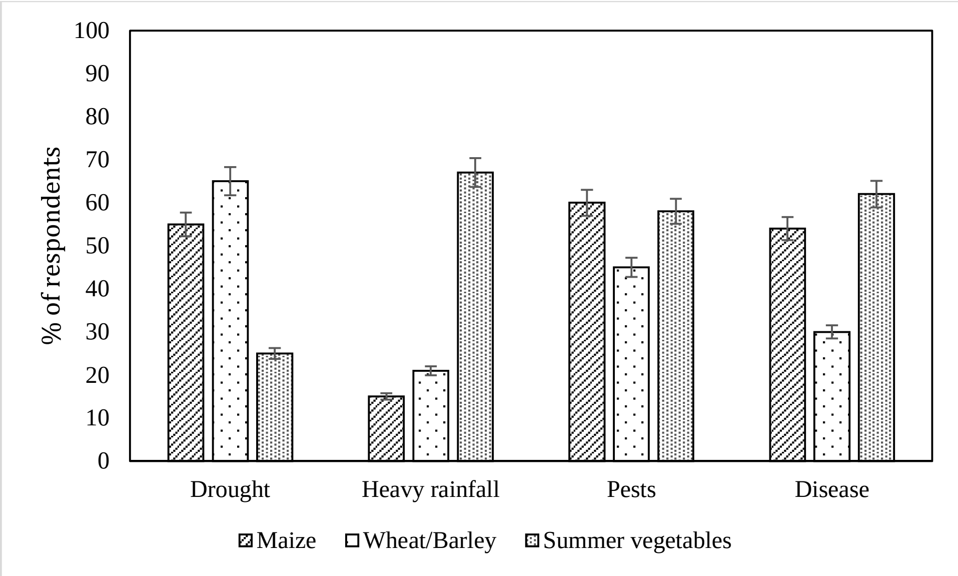


Figure 4.12 Reason for crop damage (Source: Household survey, 2012)

In the household interview farmers have find four main causes that are harming their crops (fig. 4.12). More than 50% of the respondents reported that drought is creating damaging their cereal crops maize, wheat and barley. Heavy rainfall was really problematic for summer vegetables because more than 70% of the farmers have reported that heavy rainfall is causing damage to their summer vegetables. Farmer finds during recent decade pests and diseases are becoming more pronounce in their farm. More than 50% of respondents believes than their crops and vegetables have been damaged by pests and diseases more during this decade.

4.5.1. Livestock Diseases

Farmers have reported incidence of livestock diseases have been increasing in recent decades. Farmers mentioned that they had noticed the emergence of new diseases to the increase in temperature, and they also suffer from the problem of animal infertility. Above 80% of the farmers think this was due to the changes in the weather pattern, rise in temperature during summer season. Table 4.6 shows the cattle disease and their toll number reported by the villagers during focus group discussion in different villages of Prok VDC. Villagers have reported new livestock diseases are appearing and are becoming more severe during this decade. Livestock diseases were not used to be more severe during past time. Such situation could be due to change weather variability mainly temperature of this region.

Table 4.6 Reported disease of Cattle

Village	Disease	Number of Outbreak	Number of affected	Number of Dead
Prok	Foot and Mouth disease Liver Fluke / Distomatosis Blackquarter	2 1 2	7 4 5	3 0 3
Chhak	Foot and Mouth disease Haernorrhagic septicaemia	1 5	4 3	2 2
Kaap	Foot and Mouth disease Liver Fluke / Distomatosis	3 2	4 3	2 3
Namrung	Foot and Mouth disease Liver Fluke / Distomatosis Haernorrhagic septicaemia	1 1 4	4 2 3	2 2 0

(Source: FGD, May 2012)

4.5.2. Perceived Impacts and Adaptation of Agriculture

Famers have reported many indictors of climate change impact on agriculture in Prok VDC. Table, 4.7 shows the major climate change impacts observed by farmers and their adaptation strategies. Majority of the farmers believes that crop failure, crop damage, low quality apple and decrease in harvest of apple is due to the increase in temperature, erratic precipitation pattern and windstorms in the region. From the household interview climate change impacts in major crops their causes and the existing adaptation strategies were documented. Farmers believe that crop failure is due to lack of rain, untimely rain and erratic rain. More than 50% of the respondent have reported that they re-sow their crops unless it is too late. Just above 30% of the respondent were found to plant catch crop or short seasoned crops if their crop is damaged by bad weather.

Table 4.7 Perceived impacts of climate related parameters and adaptation measures of farmers of Prok VDC.

Category	**Impact**	***No.**	**(Climate) Cause**	***No.**	**Adaptation**	***No.**
Cultivation	Crop failure	28	Lack of rain, untimely rain and erratic rain	32	Re-sowing	24
	Damage to crops	21	Heavy wind,	8	Cultivating catch crops (short seasoned crops)	9
			Insect pest from lowland	10		
	Low quality apple	8	Early fruiting and maturity of apple	23	Growing peach	14
	Decrease in harvest of apple	17	Increase in insects and pests of apple	10	Growing peach	5
					Other off farm activities	18
Livestock	Poor animal health	11	Vector borne diseases	21	Use of local herbs	20
	Death of Livestock	9	Landslide	17	Shift animal sheds to less landslide risk area	5
	Fodder shortage	10	Drought	19	Plant fodder tress/ Practice agroforestry	6
Soils	Low moisture availability	14	Prolonged droughts	23	Use more farm yard manure	19
	Soil erosion	16	Wind erosion	13	Mulching	17
Water resources	Blockage and pollution in the water streams and springs	28	Mass failure during heavy rainfall	18	Making proper drainage system	21
	Less water, or drying of water sources	8	Prolonged drought	14	Tree plantation	21
	Drying of natural springs	13	Prolonged drought	21	Tree plantation	14

(Source: Household interview survey, May 2012)

Responses are based on household interviews and the most frequent.

* Indicates frequency of the responses. Some household had many responses in each category, others very few or none.

Around 35% of the interviewed farmers believes that harvest of apple is decreasing and they believe it is due to increase in insects/pests of apple. Farmers have started planting peach in due to decrease in harvest of apple. Farmers have noticed more livestock diseases during this decade. Around 45% of farmers reported that vector borne diseases of their livestock is due to climate change. They use local herbs found around *kaltal* (pastureland) region in order to cure their livestock. Similarly, farmers have climate change impacts in soil moisture and water resources.

Farmers were reported that degradation of the grass land and low grass production they have reduced the livestock numbers as well as practiced rotational grazing. Some respondent reported that hardship of the livestock and agriculture farming they were either changed the occupation such as hotel business or migration from that place.

4.6. Farmer's coping strategies to climate change

From the participatory appraisal tools, focus group discussions and key informants interview, various local coping strategies of the farmer to climate change were identified. In all the surveyed villages farmers feel there is a critical need to address their vulnerability by diversifying their cash generation options. In the absence of non-farm income diversification, communities have started adaptation by summer vegetable cultivation. Thus, cereal crops are being replaced rapidly by crops that offer potential opportunities for cash returns. Re-sowing, cultivating catch crops (e.g. buckwheat) and short seasoned crops, growing peach instead of apples, using bio-pesticides, shifting of animal shed to less landslide risk area, planting fodder tress and practicing agroforestry are the adaptation strategies taken by farmers. Some signs of adaptation have been noticed among the farmers like saving of fire woods, fodders and food grains, depending on plant physiology for crop calendar, on land diversification, seasonal migration, off-farm and non-farm activities and credits.

On average of 40% of the respondents were found using savings of food and money for climate related risk. About 32% of respondents were practicing land diversification as their main coping strategy. Selling of herbs and Non-timber Forest Products (NTFPs) is the third most significant coping mechanisms, for average of 28% respondent. Practicing off-farm and non-farm activity also helps farmers to retain assets or to withstand climatic shocks. On average 14% of the respondents reported that they were planning to migrate to the district headquarter in order to escape from different climate related risks.

4.6.1. Indigenous knowledge

Farming communities in Prok VDC are coping with climate change with their traditional skills and local knowledge. But, many factors make their efforts futile. Farmers in *Gaap* and *Namrung* village have traditional culture of adjusting their cultivation time according to change in climate. Farmers from Chaap and Kaap village waits for flowering on the tree of *Prunus sps.* to sow maize seeds. Such practice makes some scientific senses because in order to attain reproductive phase tree need to get appropriate temperature and moisture. Such practice matches the requirement moisture and temperature requirement for maize. This is very important traditional knowledge of the farmers of that region. Farmers from Gaap villages reported that they noticed flowering of *Prunus sps.* is 15 days ahead than in past. So, their sowing calendar has also been shifted 15 days ahead.

Nubri farmers don't have access to improved seeds that is suitable for higher temperature. Farmers are using their own indigenous seed varieties for cultivation. More than fifty percent of the surveyed Nubri farmers were found to be consulting with their monks for every agricultural acitivities. Their crop calendar is based on Tibetan Calendar. Hence, they don't change the calendar of crop planting and harvesting with changes in weather situation. Other than crop calendar farmers are using their traditional adaptation skills in insect pest management by the use of local herbs to tackle with new insects and pests and soil conservation and fertility maintenance in their agriculture land.

Box 2 Use of Indigenous way of practicing agriculture calendar in Prok village (Source: author's interview, Jun 2012)

Rikjin Dorje Lama (Lama teacher in Nubri Primary School) 32 years old resident from Prok VDC-5, Gaap village opine about traditional knowledge on agriculture calendar in Prok VDC. "When there is white flowering in Mail tree (Prunussps.) potato is sown." Some villager's stills wait for of sun shine from Mount Manaslu to cultivate Maize. But, majority of the villagers follow the date for sowing and harvesting of crop fixed by Lama in the monastery. The Lama follows Tibetan Calendar in order to fix date for sowing and harvesting of crops. Lama is also called during unfavourable climatic events for religious ritual. "Last year we didn't have rainfall during monsoon season but when our Lama did religious ritual at kaaltaal (lake) raining occur."

4.6.2. Saving

Farmers need to save their resources in order to cope with the difficult situation brought up by the climate change. They save firewood, fodders and seeds for unexpected calamities. They save in two way one being pro-active and other after the climatic hazards. They are using less amount of available resource during climatic crisis; they eat less food, use less feed and don't go to district headquarter to buy necessary goods. In case of proactive type of saving sufficient households keep sufficient assets (like crop, forage, livestock, money or other form of asset) which could help them during the time of hardship. In past years, farmers used to use higher amount of their grains for fermenting alcohols but now they are becoming more cautious because last year they had acute food shortage due to less harvest of maize and *Karu (Barley).*

4.6.3. On-land diversification

Farmers of Prok VDC are slowly moving toward on-farm diversification practices, where farmers grow cabbage, summer vegetables, green leafy vegetables and legumes. In past they don’t used to grow green leafy vegetables, *Amaranthas sps.* grew on its own in their fields. But, these days they cultivate different species of green leafy vegetables. They cultivate short seasoned crops as catch crop in order to avoid losses due to no rainfall or heavy rainfall. Livestock plays and important food source during the time of crisis.

4.6.4. Seasonal migration

During the winter season when the livestock are brought back to the homestead male from the household goes to the nearest city for the labour work and brings back daily essential goods when they are back to their home. This is the trend of youth in the study area for many years and this has been very helpful in climate change adaptation.

4.6.5. Credits

Farmer are practicing credit activities at the time of crop failure and less harvest. They borrow seeds, livestock and grains from their relatives and neighbours at the time of food shortage and crop damage. Credit from better-offs informal social organizations increase the adaptation capacity of farmers.

4.6.6. Off-farm and non-farm activities

Number of tourist in Manaslu conservation area is growing these years. People of this village are opening new hotels and lodges and some people are involving in tourism business. Household survey in different villages of VDC shows that around 37% of adults have left the village for jobs in district headquarter or abroad. At present farmers are more attracted to off-farm activities to support their living. Off-farm activities would be very helpful to support economy of farmers and such activities have indirect role in climate change adaptation.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

Mountain region of Nepal is vulnerable to impacts of climate change due to topographic adversity, climatic complexity, agriculture based economy and poverty. Farmers of Prok VDC are vulnerable to climate change because of their socio-economic status, geographical inaccessibility and fragile topography. Household surveys showed that farmers of this region have poor economic status with lower economic capacity to cope with climate change. Majority of the poor people in Prok VDC are dependent on Agriculture sector for their livelihood. Their only assets are farm and their livestock which are prone to climate change. Socio-economic status of surveyed villages shows vulnerability of people to climate change in the region is very high.

The soils in the Prok VDC are inherently fragile and prone to degradation. Most of the lands in the villages are marginal lands. Only less than one fourth of the VDC is cultivable. Soils of this region have high gravel content and high content of sand and silt. Low amounts of clay in soil make them highly prone to wind erosion and landslides. Farmers use abundant amounts organic manure to make their farm fertile. Hence, nutrient content of cultivated soil is good. Although the nutrient content in cultivated land is high, the productivity is lower than national average crop productivity. So, in spite of the farmers' tireless efforts to make their lands fertile the productivity level is low. This could be due to a combination of poor physical properties of soil and the low yielding crop varieties.

Trend analysis of temperature and precipitation have shown changing scenarios in Prok VDC. Weather data of over 30 years obtained from the nearest weather stations of the VDC indicates that this region is experiencing various types of weather variability and trend is erratic. There is noticeable change in rainfall pattern. Similarly, average annual discharge in the Buri Gandaki River is also decreasing. Total annual rainfall is decreasing and the pattern is becoming unpredictable. This is associated with long droughts and calamities such as landslides. Trend of temperature shows an increasing trend in maximum temperature and in minimum temperature.

Farmer's perceptions on climate change agree in general with the weather station data trends. Farmers have reported late pre-monsoon, unusual precipitation, decreasing rainy days, intense rainfall and decrease in snowfall in the region. People are aware of decrease in snowfall, gradual rise in temperature and severe windstorms during dry seasons. They have also recognized the decrease in the amount of cold days in winter, and experience more hot days at present than in the past. Because of this farmers have perceived the consequence of weeds and insects pests which used to be problematic in lower altitude.

Famers have reported many indictors of climate change impact on agriculture in Prok VDC. Survey indicated that primary impacts of climate change were seen in agriculture and livestock. Farmers have reported a number of negative effects of climate change like change in routine activities in grazing, harvesting and storing etc. Degradation of the grass land and low grass production have reduced the livestock numbers as well as practiced rotational grazing. Due to hardship of the livestock and agriculture farming some farmers have either changed their occupation to non-farming activities or planning for migration to other place. A majority of the farmers believe that crop failure, crop damage, low quality apple and decrease in harvest of apple is due to the increase in temperature, erratic precipitation pattern and windstorms in the region. Most of the farmers have reported a loss of agricultural production as a result of changing climatic condition. Some farmers have correlated changing weather pattern with a trend of early ripening of apple. The climatic and non-climatic stressors in the village are found to be continually increasing; leading to the degradation of land resources and are more likely to exacerbate the society's vulnerability.

The changing scenario has forced local people to find measures to secure their livelihoods. Local knowledge, resources and innovations are important for community based adaptation strategies. They have started adapting in these conditions knowingly or unknowingly. Few examples of adaptation strategies were found in the study areas. Farmers are cultivating their crops fifteen days earlier as an adaption to unfavourable weather. They do this by noticing flowering in wild pear (*Prunus sps.*). There is great scope of documentation of these evidence, impacts and local adaptation strategies to cope the changing scenario. Re-sowing, cultivating catch crops (e.g. buckwheat) and short seasoned crops, growing peach instead of apples, using bio-pesticides, shifting of animal shed to less landslide risk area, planting fodder tress and practicing agroforestry are the adaptation strategies taken by farmers. Some signs of adaptation have been noticed among the farmers like saving of fire woods, fodders and food grains, depending on plant physiology for crop calendar, on land diversification, seasonal migration, off-farm and non-farm activities and credits.

The government administration is not adequate in the villages of this region. Farmers are needed to be supplied with credit services, awareness raising and use of technology and emergence aid. Poor and vulnerable farmers alone cannot face the situation brought up by the vagaries of climate change but it is always important to look for solution based on their own knowledge and resources. It is very urgent that the Nepal government and policy makers should support the farmers to generate long-term and location-specific adaptation strategies in order to prevent themselves from become more miserable and even to protect land resources of the region. However, the current adaptation strategies are not sufficient. The institutional coping mechanisms are very urgent. Recommended adaptations strategies for the farmers of Prok VDC are listed in the table below:

Table 5.1 Possible adaptation strategies for farmers in Prok VDC

S.N.	Possible adaptation strategies
1.	Improvement of economic status of farmers.
2.	Building on indigenous knowledge to develop local specific long-term adaptation strategies.
3.	Changing input such as crop varieties and/or species and using inputs with increased resistance to heat shock and drought.
4.	Using seasonal climatic forecasting to reduce production risk and in determining best times for farm operations.

There is very limited understanding about climate change and its impacts in remote mountain region of Nepal. Institutional actions are required to prepare the local people and the whole country to face the unavoidable impacts of climate change. There should be improvement in climate and crop forecasting system. Sufficient number of meteorological stations should be established to monitor the climatic conditions. Major part of crop cultivation is rain fed so irrigation investments are required to help farmers to adapt the long and unpredictable droughts. Awareness program in community level, inclusion of climate change related issues in planning and designing of developmental activities, crop insurance program and strengthening agriculture research centres can be good strategy for fighting climate change. More specific studies like regional climate modelling, adaptation studies etc. should be conducted to document and validate the climate change vulnerability, impact and adaption of Agriculture in Mountain region of Nepal.

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ANNEXES

Appendix I: Soil Laboratory Analysis table

Table 1 Chemical properties of soil samples of Prok village (Prok VDC ward number 1, 2 and 3)

Sample ID	Colour	pH	C Organic %	BD (Mg/m^3)	Total N (%)	Total P (ppm)	Total K (ppm)	CEC (meqv/100 gm)
P1	7.5YR 2.5/1	7.86	3.44	0.92	0.76	103.9	636.6	30.4
P2	10YR 3/1	7.4	5.08	0.97	0.32	27	149	48.5
P3	2.5Y 3/1	7.65	10.2	1.38	0.42	57.8	347.9	56.5
P4	10YR 2/1	7.88	7.04	1.20	0.41	39.1	311	51.1
P5	10YR 2/1	7.19	5.30	1.26	0.59	98.2	453.6	47.8
Average		7.60	6.21	1.15	0.50	65.20	379.62	46.86
S.D		0.30	2.57	0.20	0.18	34.58	180.56	9.82

Table 2 Physical properties of soil samples of Prok village (Prok VDC ward number 1, 2 and 3)

Sample ID	Particle Size Distribution			Texture	Structure	Consistency	Gravel %	Other features
	Sand	Silt	Clay					
P1	49	15	36	SiL	weak, moderate, fine, granular, subangular	Very friable	5-10%	Black, Silt Loam
P2	34	56	10	SiL	weak, fine, granular, subangular	very friable	5-10%	very dark grey silt loam
P3	61	25	9	SL	weak, medium, granular, subangular	friable	10-15%	very dark grey sandy loam
P4	71	18	15	SL	weak, fine, medium, subangular	Very friable	10-15%	Black sandy loam (Dry colour: 10 YR 4/1 (Dark grey)
P5	58	27	15	SL	weak, fine	very friable	10%	Black sandy loam

Table 3 Chemical properties of soil samples of Gaap village (Prok VDC ward number 4 & 5)

Sample ID	Colour	pH	C Organic %	BD (Mg/m3)	Total N (%)	Total P (ppm)	Total K (ppm)	CEC (meqv/100 gm)
G1	10 YR 2/2	6.42	4.3	1.22	0.18	65.1	154.7	11.9
G2	10YR 2/1	7.94	6.32	1.16	0.36	70.8	231.5	17.3
G3	10YR 3/1	7.87	8.07	0.96	0.46	31.7	87.73	32.4
G4	10YR 3/1	7.4	11.34	0.92	0.41	42.2	350	53.7
G5	10YR 2/1	7.77	9.22	1.05	0.54	33	351.7	36
Average		7.48	7.85	1.06	0.39	48.56	235.13	30.26
S.D.		0.63	2.69	0.13	0.13	18.27	117.25	16.52

Table 4 Physical properties of soil samples of Prok village (Prok VDC ward number 4 & 5)

Sample ID	Particle Size Distribution			Texture	Structure	Consistency	Gravel %	Other features
	Sand	Silt	Clay					
G1	63	25	12	SL	weak, fine, medium, granular, subangular	Very friable	5-10%	very dark brown, course sandy loam
G2	36	50	14	L	moderate, fine, granular	friable	15-20%	Black loam, gravelly
G3	27	55	18	SiL	weak, fine, subangular	very friable	20-25%	very dark grey gravelly silt loam
G4	40	48	12	L	weak, fine, subangular	Very friable	10-15%	Very dark grey Loam
G5	58	27	15	SL	weak, fine	very friable	5%	Black sandy loam; Dry colour: 10YR 4/1 (dark grey)

Table 5 Chemical properties of soil samples of Kaap and Chhak village (Prok VDC ward number 6 & 7)

Sample ID	Colour	pH	C Organic %	BD (Mg/m3)	Total N (%)	Total P (ppm)	Total K (ppm)	CEC (meqv/100 gm)
KC 1	10YR 2/1	6.54	6.56	1.00	0.76	37.3	136	46.8
KC 2	10YR 2/1	6.32	3.42	1.03	0.23	46.2	114.9	14.6
KC 3	10YR 3/1	6.03	7.03	0.97	0.39	36.8	400.7	52.3
KC 4	10 YR 2/1	7.38	5.32	1.08	0.71	63.7	254.7	26.2
Average		6.57	5.58	1.02	0.52	46.00	226.58	34.98
S.D.		0.58	1.61	0.05	0.25	12.57	131.38	17.63

Table 6 Physical properties of soil samples of Kaap and Chhak village (Prok VDC ward number 6 & 7)

Sample ID	Particle Size Distribution			Texture	Structure	Consistency	Gravel %	Other features
	Sand	Silt	Clay					
KC 1	46	40	14	SiL	weak, fine, medium, granular	Very friable	15-20%	Black loamy sand gravelly
KC 2	72	18	10	LS	weak, medium, granular	very friable	15-20%	Black gravelly loamy sand
KC 3	46	38	16	L	weak, medium, granular, subangular	friable	20-25%	Very dark grey gravelly Loam
KC 4	62	26	12	SL	weak, medium, granular	Very friable	20-25%	Black sandy loam

Table 7 Chemical properties of soil samples of Namrung village (Prok VDC ward number 8 & 9)

Sample ID	Colour	pH	C Organic %	BD (Mg/m3)	Total N (%)	Total P (ppm)	Total K (ppm)	CEC (meqv/100 gm)
NA 1	2.5Y 2.5/1	7.95	8.63	0.96	0.76	37.3	136	46.8
NA 2	10YR 2/1	7.89	3.68	1.11	0.23	46.2	114.9	14.6
NA 3	10YR 3/1	7.86	11.02	1.24	0.39	36.8	400.7	52.3
NA 4	10YR 2/2	7.42	5.32	0.99	0.71	63.7	254.7	26.2
Average		7.78	7.16	1.08	0.52	46.00	226.58	34.98
S.D.		0.24	3.29	0.13	0.25	12.57	131.38	17.63

Table 8 Physical properties of soil samples of Namrung village (Prok VDC ward number 8 & 9)

Sample ID	Particle Size Distribution			Texture	Structure	Consistency	Gravel %	Other features
	Sand	Silt	Clay					
NA 1	65	23	12	SL	weak, fine, medium, granular	Very friable	15-20%	Black sandy loam (Dry colour: 2.5 Y 6/2)
NA 2	64	35	11	SL	weak, fine, subangular	very friable	15-20%	Black gravelly loamy sand
NA 3	53	42	15	L	Weak, fine, medium, granular, subangular	friable	10-15%	Very dark grey loam (Dry colour: 10YR 5/2, greyish brown)
NA 4	34	53	13	SiL	weak, fine, medium, granular, subangular	very friable	8-10%	Very dark greyish brown silt loam

Appendix II Regression Table

Table 9 Regression statistics of Annual Income against Household Size and Livestock Holding

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	38477.999	5120.030	7.515	0.000
Household Size	846.538	1464.852	0.578	0.566
Total Livestock holding	3691.050	614.540	6.006	0.000

Regression Statistics	
Multiple R	0.826
R Square	0.682
Adjusted R Square	0.667
Standard Error	11335.022
Observations	48

Appendix II: Questionnaires

Introduction

My name is Niranjan Phuyal. I am studying Environment and Natural Resources at Kathmandu University. I am doing my master's thesis on Climate change vulnerability, impact and adaption on agriculture in western mountain region of Nepal. Thus I appreciate your cooperation to give me your time for the success of my research. Your information would be used for educational purpose only and your name will not be disclosed unless you agree for the disclosure.

Interview question: local households

1. Name …………………………… Sex …………………….. Age …………………..
2. Marital status Married …….. Not married ………… other specify …………
3. What is your educational level? Illiterate…… Lama School….. Primary school … Secondary Schoo….
4. Do you have children? Yes/no If yes, how many …… ………....
5. How do you make your life? Cattle rearing……… Crop production …….. Other (specify)…………
6. How much money you spend per year (approximately)? ……..
7. Do you or your family member have another source of livelihood other than agriculture? Yes/No, if yesspecify ……………………………………….
8. Do you own land? …. If yes how much? …..
9. For how many months of the year do your family have enough food? < 3 months … 3-6 months ……. 6-9 months ….. > 9 months……
10. How many livestock do you own?
11. How do you characterize the weather of this area in terms of its temperature and precipitation? Is there any change? If yes, how?
12. Have you ever faced any climate related impact in your life time? If yes, what type of climatic shock?
13. If the answer to Q13 is yes, did it affect your cattle or/and crop? Yes/No, if yes how much? ....
14. Have you observed any new diseases affecting your livestock and crops over the past 10/20 years? Which one? When did they occur for the first time? Any casualties?
15. What type of seeds do you use mostly? Where do you get seeds for your crops?
16. What are the major risk factors to climate change in farming?
15. What type of climate related impacts you have observed in agriculture and what are you adaptation strategies?
17. How did the government, GOs and NGO's responded to reduce the impact?
18. Which type of climatic shock is your main concern?
19. What are the major constraints you have that hinders your coping mechanisms in farming?

Thank you!

Interview questions: District Agriculture Development Office and Agriculture and Livestock Service Centres

Name of the Respondent: Name of the organization: Address:

1. What observations have you observed resulting from climate change, and what are the impacts on agriculture?
2. What are the impacts of climate change on livelihood of farmers in mountain region of Gorkha District (MCA)?
3. What are the major challenges for farmers in alleviation of the problem and what should be done?
4. What concrete role does your organization play in supporting the local people in their efforts to adapt to, or cope with, climate and socioeconomic change?
5. What kind of concrete support do you offer (extension services, knowledge transfer, technological support, income opportunities, loans, and so on)?

6 Who is directly benefitting from your organization's services? Who participates in your initiatives? How do they benefit from your initiatives?

7. What are farmers in MCA, doing to adapt?
8. Do your organization has launched adaptation program to improve adaptation in that region?
9. Based on your experiences, what are the perceptions of local farmers on climate change? And what are they doing to tackle with the problems?

Thank you!

VDC officials and Manaslu Conservation Area Project Office officials

1. Name ………………….. Position/profession …………………
2. What is the factors that makes agriculture of this site vulnerable to climate change?
3. Is there any form of climate change in in this site? If your answer is yes, please can you explain?
4. If the answer to Q2 is yes, please would you like to explain the extent of climate change and variability? Impact on crop and livestock of this area?
5. What is the impact of climate change and variability on agriculture sector of this region?
6. Who is more vulnerable to the impacts? Why?
7. What are the local adaptation strategies to reduce the impacts on agriculture?
8. What is the institutions effort to reduce future impacts?
9. What are the main challenges and how do you think they can be improved?

Thank you!

Appendix III: Photos

Picture 1 Wheat and *Karu* field of Prok Village and Maize filed of Ghaap Village

Picture 2 Landslides in Kaap village and gully erosion in Kaap village

Picture 3 Household interview in Prok Village and Namrung Village

Picture 3 Focus group discussions with villagers and monks

Picture 4 Transect walk and interview with farmer

Picture 5 I. Soil core sampler II. Drying of soil samples in shed

Picture 6 I. Soil in Oven to determine Bulk Density II. Soil Ph Determination

Picture 7 Soil texture determination steps, (I), soil sample soil mixed with sodium hexa-meta-phosphate and water (II), texture determination

Picture 8 Soil organic matter determination steps, (I) weighting sample, (II) hot air oven drying sample, (III) muffling and (IV) cooling in desiccator