Doctoral Dissertation

Climate Change Resilience and Vulnerability of Farmers in Nepal

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Summary of Dissertation

Climate change refers to any change in climatic condition over the long period of time. Scientists are now more certain that climate change is due to anthropogenic activities. International and scientific community have general consensus that climate change will impact mostly the least developed countries which have limited capacity to adapt to it. Climate change will have adverse impact on socio-economy systems especially of those people whose livelihood directly depend on natural resources, such as those that depend on agriculture and forestry for their livelihood. As climate change will have impact on the society, it is very much necessary to understand the climate change from the social perspective. So this study analyses impact of climate change from vulnerability and resilience perspective.

The study focuses on the temporal and spatial dimension of climate change impact at national level and then focuses on analyzing climate change vulnerability and resilience at household level. Due to limitation in availability of meteorological data, only temperature and rainfall are taken from 1978 to 2011 to represent changes in climatic factor. Trend analysis is used to analyze how temperature, rainfall and occurrence of natural hazard are changing over time. Seemingly unrelated regression is used to see the impact of climate change on occurrence of natural hazards. Also temperature and rainfall

data are interpolated using ArcGIS for trend analysis. Further, trend analysis of climate extremes using daily rainfall data from 202 to 2011 is used to see the variability in the climate. The result shows that there has been increasing temperature trend while rainfall is in decreasing trend and erratic in nature. The analysis shows that rainfall is increasing in the monsoon season especially in August increasing the probability of occurrence of natural disasters. The change in the climatic pattern has exacerbated the occurrence of natural hazards in the country which is also increasing rapidly. Also, climate extremes are in increasing trend over the period of 2002 to 2011 exacerbating occurrence of natural hazard. Landslide and flooding is found to be two most disastrous natural hazards in Nepal with flooding being most destructive of all. Hence seemingly unrelated regression analysis is used to analyse impact of climate change on occurrence of flooding. The result shows that increasing temperature will significantly increase the occurrence of heatwave. Similarly any increase in rainfall, especially in the monsoon season will significantly increase the occurrence of flooding while decrease in rainfall will increase occurrence of natural hazards like forest fire and drought.

As climate change impact is location specific, analysing impact of climate change from spatial perspective is important in Nepal where topography plays a major role. So, the study analyses and produces maps to show district wise climate change vulnerability

in Nepal. The study uses interpolated temperature and rainfall data for mapping district wise change temperature, rainfall and natural hazard. Vulnerability is measured as function of exposure, sensitivity and adaptive capacity as stated by Intergovernmental Panel on Climate Change Fourth Assessment Report. Principal component analysis is used to give weights to the indicator since using expert judgment and giving equal weights has limitation of cognitive biases and being too subjective. The result shows that adaptive capacity plays an important role in determining the overall vulnerability of an area. The occurrence of natural hazards further exacerbates the exposure and will increase the vulnerability. The result is found to follow the pattern of district wise vulnerability according to NAPA by showing western part of the country comparatively more vulnerable than eastern part. But, the result is also able to show the difference in the vulnerability of district more properly. For example, Kathmandu district is found to be least vulnerable as it has high adaptive capacity while the result of NAPA shows it being most vulnerable.

Climate change is a global phenomenon but its impact will be felt at local level. The least developed countries can do little about mitigation so have to adapt to the climate change. Hence the study analyses the households' adaptation practices and their perception to climate change. Further, the study also analyses impact of climate change from vulnerability and resilience perspective at household level. The analysis uses the Heckman Selection Model for understanding the factors affecting households' perception and their adaptation. Also temperature and rainfall of household is analysed using the interpolated data. Resilience is analysed as the function of ability to absorb shocks and vulnerability. Further, determinant of resilience is analysed using multiple regression analysis. The result shows that most of the households does not know the term climate change but has perceived some changes in climate. Households are more sensitive to notice changes in the rainfall than change in temperature. They have been adapting to these changes through reactive adaptation practices that they are practicing traditionally. Eighteen different adaptation practices are identified in the study area mainly for conservation of soil and water. It is seen that majority of the farmers adopt practices like agroforestry, conservation of water by building water tanks and rain water harvesting. The adaptation practices like prioritizing livestock is least favoured among households as there has been decrease in the availability of grass in forest. The result of Heckman Selection Model shows that there is correlation between perception of farmers and their adoption of adaptation practices. The result shows that information source has positive influence on households to perceive any changes in the climatic change. Households' adoption of adaptation practices are significantly influenced by their possession of assets

as well as the infrastructure present in the area.

The analysis shows that adaptive capacity and exposure is the major contributor for determining the households' vulnerability. Jhyaku has the highest vulnerability compare to Nalang and Dalchowki which is mainly attributed to lack of adaptive capacity as well as frequent occurrence of natural disasters. The factors like infrastructure contributed mainly to vulnerability. However, vulnerable households are also seen to be practicing more adaptation practices to cope with it. Thus the results points out that the households are not just mere sufferer but also have capability to overcome the adverse impacts. Further, the analysis shows that most of households belong to the group of low to moderate resilience which can be mainly attributed to addition of new challenges from climate change. Also, the result shows that access to extension service center, possession of livestock and higher number of crops planted played are significant factors determining the resilience of the households.

Overall the study indicated temperature is rising and rainfall is erratic in Nepal which has increased the occurrence of natural hazards. So, mitigation of natural hazards like landslide and flood should be given prioritization. In addition to flood and landslide, there is need to give emphasis on the mitigation of the forest fire as it has been increasing steadily and also damaging the livelihood options in the rural areas. Also, there is need to improve climatic data management to capture micro-climatic variation of the area. This could help in reducing the casualties from natural hazards by providing early warning as well as in adaptation. Infrastructure being a significant factor for determining the vulnerability, its development should be given more prioritization. Developmental programs and policies should give more emphasis on the vulnerable area and households by capturing their capability to adaptation. Further, households should not just be seen as sufferer but also their capability to cope with changing condition should be understood. Additionally, climate change has added new challenges to households by reducing their resilience. So, climate change policy and developmental programs should focus on improving the households' resilience and decreasing their vulnerability.

This dissertation is divided into eight chapters. Chapter one, two and three deals with introduction and conceptualization where as other chapters deal with analytic analysis. Chapter four analyses the impact of climate change from temporal aspect by analysing climatic trend and its relationship with natural hazard at national level. Chapter five deals with spatial impact of climate change by analysing vulnerability at national level. Chapter six and seven analyses the adaptation practices, vulnerability and resilience at the household level. Finally the study is concluded in chapter eight with some recommendation.

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Suman Lal Shrestha

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Abbreviations/Acronym

˚C	degree centigrade
BAP	Bali Action Plan
BAPA	Buenos Aires Plan of Action
CDM	Clean Development Mechanism
COP	Conference of Parties
GCM	General Circulation Model
GDP	Gross Domestic Product
GEF	Global Environment Fund
GIS	Geographic Information System
GLOF	Glacial Lake Outburst Flood
HDI	Human Development Index
HHH	Household Head
H.R	High Resilience
H.V	High Vulnerable
ICCA	Initiative for Climate Change Adaptation
IPCC	Intergovernmental Panel on Climate Change
km	kilometre
LAPA	Local Adaptation Plan for Action
LDC	Least Developed Countries
LDCF	Least Developed Countries Fund
LULUCF	Land Use, Land Use Change and Forestry
L.R	Low Resilience
LSU	Livestock Unit

L.V	Low Vulnerable
m	meter
masl:	mean above sea level
mm	millimeter
MCCICC	Multistakeholder Climate Change Initiative Coordination Committee
M.R	Moderate Resilience
M.V	Moderate Vulnerable
NAPA	National Adaptation Program of Action
NCCC	National Climate Change Committee
NCCKMC	Nepal Climate Change Knowledge Management Centre
NCSA	National Capacity Self-Assessment
NGO	Non-Governmental Organization
NMS	Nepal Meteorological Service
NRs.	Nepalese Rupees
NSTs	National Study Teams
PC1	First Principal Component
PCA	Principal Component Analysis
RCM	Regional Circulation Model
REDD	Reducing emission from forest deforestation and forest degradation
SAR	Second Assessment Report
SCCF	Special Climate Change Fund
SNC	Second National Communication
SUR	Seemingly Unrelated Regression
TWGs	Thematic working groups

UN	United Nation
UNDP	United Nation Development Programme
VDC	Village Developmental Committee
WMO	World Meteorological Organization
UNFCCC	United Nations Framework Convention on Climate Change
V.H.R.	Very High Resilience
V.H.V	Very High Vulnerable
V.L.R	Very Low Resilience
V.L.V	Very High Resilience

Chapter I

1. Introduction

1.1 Background

People face potential disasters from number of sources which are natural as well as man-made. People have continued to live through these disasters by adapting to changes and building resilience. It has been established that climate change is one of the major environmental challenges that people are facing. Climate change has been defined differently by different institutions and scholars. The Intergovernmental Panel on Climate Change (IPCC) defines the climate change as

"*Climate change refers to a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer). Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use*" (IPCC, 2001).

According to United Nations Framework Convention on Climate Change (UNFCCC) article 1.2. climate change is defined as "*change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods*"

(UN, 1992).

Climate change will effect positively as well as adversely, The article 1.1 of UNFCCC states that

"*Adverse effect of climate change" means changes in the physical environment or biota resulting from climate change which have significant deleterious effects on the composition, resilience or productivity of natural and managed ecosystems or on the operation of socio-economic systems or on human health and welfare"* (UN, 1992).

Climate change will have adverse impact on socio-economy systems especially of those people whose livelihood directly depend on natural resources, such as those that depend on agriculture and forestry for their livelihood. Socio-economic effects of climate change arise from interactions between climate and society and how these in turn affect both natural and managed environments. As climate change will have impact on the society and the social well-being of the humans it is very much necessary to understand the climate change from the social perspective. Further, climate change occurs globally but its impact will differ according to the region and sector. The direct impact of the climate change is usually context specific to a local scale (Kassam, Baumflek, Ruelle, & Wilson, 2011). So understanding impact of climate change especially at local context, analysis of vulnerability and resilience are very important (Kassam, Baumflek, Ruelle, &

Wilson, 2011).

According to the Fourth Assessment Report, the IPCC defines the vulnerability as "*degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity"* (Barker, et al., 2007).

The analysis of impact of climate change only from the perspective of vulnerability may only represent humans as passive victims of climate change only and will not incorporate their innovativeness and their resilience towards climate change (Kassam, Baumflek, Ruelle, & Wilson, 2011). So it becomes very necessary to look at the impact of climate change from the perspective of resilience also.

Resilience is defined as "*ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for selforganisation, and the capacity to adapt to stress and change*" in The Fourth Assessment Report of IPCC (Baede, Linden, & Verbruggen, 2007).

Vulnerability and resilience is interlinked and cannot be viewed differently. The human knowledge and their practices within their communities can reduce their vulnerabilities to adverse impact of climate change which are their resilient qualities

(Kassam, Baumflek, Ruelle, & Wilson, 2011). For example community that knows to build homes that can withstand rare flood events, for instance, is less vulnerable to increases in the frequency and intensity of flooding resulting from climate change (Kassam, Baumflek, Ruelle, & Wilson, 2011).

Adaptation to the climate change has been focused by many scholars since 1990s (IHDP, 2009). The strategy in climate change normally focuses on the mitigation and adaptation. The IPCC defines mitigation as

"*Technological change and substitution that reduce resource inputs and emissions per unit of output. Although several social, economic and technological policies would produce an emission reduction, with respect to Climate Change, mitigation means implementing policies to reduce greenhouse gas emissions and enhance sinks."* Whereas adaptation is defined as "*Initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects*" (Baede, Linden, & Verbruggen, 2007).

This shows that mitigation generally addresses the cause of climate change whereas adaptation deals with the effect.

According to the Resilience Alliance (2002) resilience has three distinct characteristics, i.e., system capacity to undergo change and still be in the same state, have capability of self-organization and have ability to build and increase capacity of learning and adaptation. Further, resilience can be viewed as layered concept which ranges from individual to household, community, ethnic group and global level (Jordan, 2009). Further, resilience is recognized as complex, context specific, and highly dynamic in nature (Schwarz, et al., 2011). The resilience of the community or household will increase its adaptation potential and will help to lessen the impact from climate change. Also, the resilient community or household that are resilient are less vulnerable to the climate change, i.e., they are less prone to suffer the same magnitude as the non-resilient group from the climate change (Speranza, 2010).

In addition to this, effects of climate change will vary according to region and is very hard job to predict it, but the societies that are already suffering severe development stress will be the most heavily effected and in particular, the most vulnerable sections of those societies (Jordan, 2009). So, climate change will have negative impact on the people living in the least developed countries that have little resources. Further, many of the communities in these countries can do little about the mitigation and must adapt to the local impact of climate change (Kassam, Baumflek, Ruelle, & Wilson, 2011).

Nepal is a one of the least developed countries with annual GDP per capita of NRs. 57,726 (US$1 = NRs. 82) as of April 2012 (CBS, 2012). It has population of 26,494,504 having growth rate of 1.35% since 2001 with majority of people living in rural areas (CBS, 2012). According to national census of 2011 only 17% of people live in urban area, that is, 58 municipalities (CBS, 2012). Agriculture is the main livelihood option in rural area that contributes 31.75% in 2011 of the country's gross domestic product GDP (WB, 2013). Further, agriculture is mainly subsistence in nature and farmers mainly rely on rain-fed agricultural system with irrigation covering only 27.42% of the total agricultural land in Nepal as of 2008 (WB, 2013). In addition to this, irrigation is mainly the small type managed by farmers' community itself (Bhandari & Pokharel, 1999). Agriculture provides employment opportunities to 66% of population (DoA, 2014) indicating that majority of people are dependent on agriculture which is mainly rain-fed in nature and thus climate change will have more effects on them. As Nepal lack economic resources to deal with climate change, it is very essential to understand the farmers' resilience and vulnerability. Thus, this study deals with farmers' resilience and vulnerability to the climate change in Nepal.

1.2 Statement of Problem

Climate change will have an effect on all sectors like water, agriculture, energy and so on. The impact of climate change differs according to sectors and will be felt at local level. Climate change will put more stress on sectors like agriculture and forestry which are more dependent on the natural resources and climatic factors. The impact of climate change does not depend on the biophysical characteristics only but also depends on the society and how they interact with the climate. As agriculture is one of the sectors that will be impacted adversely more, farmers with limited financial resources and farming systems with few adaptive technological opportunities available to limit or reverse adverse climate change are more vulnerable towards it (IPCC, 2007). The IPCC Second Assessment Report states that socio-economic systems "typically are more vulnerable in developing countries where economic and institutional circumstances are less favourable" (IPCC, 1996) and also continues that vulnerability is highest where there is "the greatest sensitivity to climate change and the least adaptability." IPCC (2007) states that climate change is directly affecting the livelihood of the people especially in the developing countries more so in least developed countries through increasing variability and uncertainty of the condition. Also with climate change the climate related hazards are becoming more frequent and intense which increases the tragedies due to death, injuries and disease that ultimately affect the livelihood of the people (Cannon & Muller-Mahn, 2010). These raises the question of how people can be more resilient to the climate change so that they become less vulnerable to the natural hazards with increase in their adaptive capacity as well as focusing on the mitigation options for climate change.

Nepal though being rich in biodiversity, is one of the poorest countries in the world with the majority of the people dependent on agriculture and mostly living in the rural areas. As agriculture is one of the sectors that are more dependent on climatic factor, people in the rural settings are more prone to impact from any changes in the climate. The change in agricultural production due to climate change will have an effect on rural communities both economically as well as socially, especially to those who have little adaptive capabilities. In addition to this, Nepal being mountainous country is prone to natural hazards like landslides and flood, and climate change will further exacerbate the frequency and intensity of these natural hazards. So, climate change will further add to the vulnerability of farmers especially in the countries like Nepal where people have less economical capabilities to deal with it.

Climate change will further impact different localities differently especially in Nepal, where there are many small pockets of areas that shows different climatic trend (Practical Action, 2009). In Nepal as different localities have different climatic trend, the adaptation practices, vulnerabilities and resilience of the people in these localities also differs. Further within the community, people that have less capability for adapting to climate change will be more vulnerable and hardest hit by its impact. Also, for any intervention in the local area it is important to have knowledge regarding how the communities react to changing environmental condition and how resilient they are. But, there are limited studies on climate change impact on local regions in Nepal.

1.3 Rationale

Nepal being least developed country has to adapt to climate change and also has to pursue its development needs. It is important to understand the impact of climate change according to sector and region and also how these sectors and regions react with such changes. Further, vulnerability, resilience and adaptation strategy of different people differs according to the region and their socio-economic condition. So, there is need of studying the needs, impact, vulnerabilities, and resilience at the local level that will help for any policy implementation as stressed by different researches.

After the Fourth Assessment Report of IPCC, the focus of the researches has been shifted to climate change mitigation and adaptation which brings in researches on vulnerabilities of the specific places that have centered on analysis of human welfare (Ibarraran, Malone, & Brenkert, 2008). Focusing only on the vulnerability can give wrong impression that communities are only mere victims of climate change but may not account communities capacity to be resilient to these changes (Kassam, Baumflek, Ruelle, & Wilson, 2011). There are semantic differences between resilience and vulnerability

(Cutter, et al., 2008) where vulnerability is the function of exposure, sensitivity and their coping capacity. Whereas in case of resilience it is the ability of the system to respond and cope with the disaster, events and also the adative measure after the post event and how they in turn can reorganize, turn and learn fom the disaster itself (Cutter, et al., 2008). In addition to this adaptive capacity is ability of system to change, lessen the effect and cope with disturbances (Brooks, Adger, & Kelly, 2005) while mitigation is any action taken to avoid the risk of damage (Godschalk, 2003). Therefore, the identification and characterization of impact of climate change from the perspective of vulnerability and resilience of different regions, sectors, and communities is a concern for addressing climate change. Without taking into all these into consideration the local issues and their reaction to climate change impact will not be properly addressed. But these types of researches are lacking focusing on local areas especially in the least developed countries. Also, IPCC has stressed that the priorities should be given for advancing understanding of potential consequences of climate change for human society and the natural world, as well as to support analyses of possible responses (IPCC, 2001). This emphasizes need for research from perspective of vulnerability and resilience in Nepal since it is more vulnerable to climate change. The research should also focus on climate change impact in relation to natural hazards and how local communities interact with it. Thus this research will tries to study the resilience and vulnerability to climate change and their relationship to climate change in Nepal.

1.4 Objective

General objective:

Analyze the resilience and vulnerability of households to climate change of Nepal.

Specific Objective

- Analyse relationship between climatic variables and natural hazards
- Map district wise vulnerability of Nepal
- Analyze factors affecting households perception of and adaptation to climate change
- Determine the households vulnerability and resilience to climate change
- Study the determinants of resilience to climate change

1.5 Limitation of the study

The study limitations have been grouped in the three major categories as follows:

1. *Lack of data*: Nepal is mountainous country, and its climatic condition is largely affected by its topography. Therefore, it is necessary to establish more number of

metrological stations to capture data to reflect variations according to the topography of the country. Unfortunately, Nepal has not yet been able to establish required number of metrological stations to capture the climatic data representing its topography. It has limited technical and financial resources to establish necessary infrastructure and facilities to collect numerical data and conduct researches and modeling related to climatic change. Given the country's available infrastructure and facilities, collecting metrological data, the study is able to use the data collected over 34-year period from the stations established at limited and scattered areas, which do not capture the micro-climatic variations appropriately.

2. *Data reporting:* In Nepal, proper collection and management of natural hazards data started only from 1990s onwards. The remoteness of the areas and poor information & communication systems in the past limited the data availability and in some cases did not receive exact information about natural hazards. The data were often distorted and there were no proper means to verify those reports. In general, the reports about natural hazards are different in the recent years compared to the past due to the development of information and communication systems. In the recent years, information about natural hazards is accurate, and easy to verify. In absence of proper information and communication system in the past, the study used natural hazards

data that are reported in the national daily, local newspapers and other various reports. Further, natural hazards reported by the households may not actually represent occurrence of all natural hazard, as information is basically collected form selected memories, which could have been biased. There is a high possibility that some of the cases, which are reported by the households, might have selective memory biases (remembering or not remembering events that occurred in some point in time).

3. *Use of cases study:* Only one VDCs from each districts are chosen as the case study due to limitation of time and resources..

Chapter II

2. Literature Review

2.1 Climate Change and its impact in Nepal

2.1.1 Climate Change in Nepal

Climate change is a serious global issue which demands prompt response as shown by numerous scientific evidences (Stern, 2006). Climate change has both beneficial as well as detrimental effect, but mostly negative, as shown by many research findings. Climate change will exacerbate the problems of natural hazards like drought, flood, tornadoes etc. The degree of impact of these hazards varies according to its geography, environment and its capacity to cope with these hazards. The intensity of impact will be higher for Nepal as it has little capacity to cope with it and thus will be more vulnerable to climate change.

In Nepal the first systematic and regular monitoring system was established in 1965 in the name of Nepal Meteorological Service (NMS) with the help of United Nation Development Programme (UNDP) and World Meteorological Organization (WMO) (Mool, Bajracharya, & Joshi, 2001). According to the analysis of temperature trend done by Shrestha et al. (1999) for 1971-1994, temperature trend was different according to the geographical area and seasons in Nepal. The warming was slow in the low-elevation Tarai with annual average of 0.04 ºC/yr than in north high mountains with annual average of 0.08 ºC/yr (Shrestha et al. 1999). In case of seasonal difference the highest one was in post-monsoon season (October-November) at 0.08ºC/yr while lowest warming rate was for pre-monsoon season (March-May) at 0.03ºC/yr (Shrestha et al., 1999). Similarly, the trend analysis done by the Practical Action found that for the period of 1976-2005 the maximum temperature was increasing at 0.05 ºC/yr while minimum temperature was increasing at 0.03 ºC/yr (Practical Action, 2009). Also the maximum temperature was found to be in decreasing trend in Tarai region during winter season which was mainly due to cold waves resulting foggy conditions (Practical Action, 2009). According to Practical Action (2009) in Nepal due to high inter annual variation in rainfall there was no significant trend observed over the years. However, the rainfall trend was increasing at average annual rainfall of 4 mm/year over the period of 1976-2005 (Practical Action, 2009). Also there were some small pockets of area that has decreasing rainfall trend over the period of 1976-2005 (Practical Action, 2009). Similarly, the pre-monsoon, monsoon, post monsoon and winter seasons average rainfall was increasing at 9mm/year, 30 mm/year, 7 mm/year and 2.8 mm/year respectively except few pockets area where it was in decreasing trend (Practical Action, 2009).

There are limited number of studies that have projected temperature and precipitation by General Circulation Model (GCM) / Regional Circulation Model (RCM) in Nepal but confidence in projection is low as they are biased (NCVST, 2009). The study done by Agrawala et al. (2003) using GCM estimates that by 2100 both temperature and precipitation will increase as shown in Table 2.1.

Table 2.1 Climate Change in Nepal

Year	Mean temperature increase (ºC)			Mean precipitation increase (mm)		
	Annual	Winter	Summer	Annual	Winter	Summer
Baseline average				1433	73	894
2030	1.2 (0.27)	1.3 (0.4)	1.1 (0.2)	71.6 (3.8)	0.6 (9.9)	81.4 (7.1)
2050	1.7 (0.39)	1.8 (0.58)	1.6 (0.29)	104.6 (5.6)	0.9 (14.4)	117.1 (10.3)
2100	3.0 (0.67)	3.2 (1.00)	2.9 (0.51)	180.6 (9.7)	1.5 (25.0)	204.7(17.9)

Source: Agrawala, et al., 2003

Note: Figures in parenthesis indicate standard deviation.

2.1.2 Impact of climate Change in Nepal

As Nepal is covered mostly by fragile mountains, climate change will further exacerbate the occurrence of natural hazards like floods and landslides and will affect the various sectors. According to the National Adaptation Programme of Action, climate change will impact mainly the agriculture, water resources, climate-induced disasters, forests and biodiversity, health, and urban settlement and infrastructure in Nepal (MoE, 2010).

According to the Maharjan, Joshi and Piya (2011) effect of climate change in agriculture will mostly be adverse as it is highly dependent on weather condition due to extreme rainfall. The variability in rainfall will have severe negative impact in agriculture especially in least developed countries like Nepal where agriculture is primarily rain-fed and farmers are mainly subsistence in nature. According to Regmi (2007), in 2005, there was 2% and 3.3% decrease paddy and wheat production as country experienced drought. Also, paddy decreased by 27-39% in Eastern Tarai in 2006 due to drought (Regmi, 2007). There was significant reduction in the yield of winter crops due to severe sky overcast condition in particularly Nepal and the Indo-Gangetic plains of India that lies south of mountain region between 1990 to 2000 (Shrestha, 2007). According to MoPE (2004), there was Yield reduction in 1997/98 ranged from 11% to 38% compared to the average of the preceding 10 years (MoPE, 2004). Sharma and Shakya (2006) state that changes in water availability in the monsoon, pre-monsoon and the post-monsoon season and shifting of the hydrograph have a direct impact on Nepalese agriculture. According to Maharjan, Joshi and Piya (2011) the rise in temperature will impact agriculture as there will be increase in incidence of pests and diseases and decreasing physiological performance. The study done by Joshi, Maharjan and Piya (2011) to see effect of climatic variables on the yield of the major food crops of Nepal using the multivariate regression model showed that the increase in wheat and barley yield is contributed by the current climatic trends whereas increased summer rainfall and temperature suppressed the growth of yield of maize and millet. Also, in the case of change in yield of potato the positive impact of increased summer rainfall and increased minimum temperature is surpassed by negative impact of increased maximum temperature (Joshi, Maharjan, & Piya, 2011). In the study done by Malla (2008) on climate change and its impact on Nepalese agriculture taking into account only the biological factors it was found that enriched CO_2 has shown positive impact on yield of major crops in all geographical zones. Malla (2008) also emphasized that increase in temperature and CO_2 levels also may have hidden-hunger problem in human by lowering essential nutrients contents in food crops. According to Alam and Regmi (2004)**,** due to rising temperature in Nepal there could be longer drier phases during dry season and higher chances of flooding and landslides during rainy seasons that will subsequently impacts agriculture and livelihoods. The food production in Nepal from 2006-2009 has been significantly affected by extreme events that include droughts and floods (Hobbs, 2009).

The study by Shrestha, Maharjan and Joshi (2012) analyses the relationship of climate variable and yield of food crops in Makwanpur and Ilam district of Nepal. It analyses the trend of climatic variables and yield of major food crops of Nepal from 1978 to 2008 and analyses how climatic variables are affecting yield of major food crops using regression analysis. The study shows that in both the districts, the maximum temperature trend is increasing for summer and winter seasons while minimum temperature was found to be increasing in Makwanpur district but decreasing in Ilam district. Similar trends were found in the case of rainfall in both districts where it was found to be increasing in summer and decreasing in winter seasons. The trend analysis for yield of major crops showed that in Makwanpur district, the yield of paddy and maize was decreasing while other crops like millet, potato, wheat and barley was increasing. Similarly in the case of Ilam district, except yield of maize and millet, yield of other food crops was found to be in increasing trend. The potato was found to be rapidly increasing in both districts, which is mainly due to management practices such as use of improved seeds and fertilizers. The study showed the effect of climate change on yield of major food crops except paddy in Makwanpur district had adverse impact. In case of Ilam, except maize and potato, climate change had negative impact on all the food crops.

According to LFP (2009) Nepal forestry ecosystem distribution will shift due to the climate change and Himalayan forest are expected to be most vulnerable as increased temperature will cause decreased soil moisture causing drought resistant trees or grassland replacing current forest. Also the recent forest fire in Nepal which was unusually for the long time raised the issue of climate change impact on the forest of Nepal. Further according to the MoPE (2004) under doubling of CO_2 tropical wet forest and rain forest will disappear and cool temperate forest will move into warm temperate forest. According to Thakur (2009) Uttis (*Alnus nepalensis*) in Ilam district is severely affected by defoliating insect outbreak (*Scarabaeidae coleopteran*) which according to local resident was related mostly to temperature rise and decrease rainfall due to shorter hibernation period.

2.2 Adaptation to climate change

There are many uncertainties regarding the impact of climate change though there are studies regarding future change in precipitation and temperature. Changes in rainfall pattern are likely to lead to severe water shortages and/or flooding. The increase in temperature and irregularities in the precipitation pattern will have impact on environment and socio-economic sectors like agriculture, forestry, water resources, health etc. (UNFCCC, 2007). The impacts of climate change are expected to become more intense in the near future (Harley, Horrocks, Hodgson, & Minnen, 2008). To cope with the uncertain future, societies need to cope with the change, which is adaptation (UNFCCC, 2007). Despite of strict stabilizing greenhouse gas mitigations measures, impacts of climate change are likely to be large for which all countries need to adapt to it (Harley, Horrocks, Hodgson, & Minnen, 2008). For adapting to climate change, appropriate measures for lessening its impact should be prioritized mainly by adjusting to it and making changes that includes the developing technological options, behaviour changes, better management of natural resources, improved risk management etc. (UNFCCC, 2007). A major challenge for dealing with climate change is to determine how, where and in what form the projected impacts will occur which is complicated by a number of factors such as relationship between changes in climatic variables, impacts and system response and many others which are not clear (Harley, Horrocks, Hodgson, & Minnen, 2008). After the publication of IPCC Third Assessment Report in 2001, there has been substantial work done on the adaptive capacity to climate change. Initially many of the studies focused on adaptive capacity at national level (Adger & Vincent, 2005; Adger et al., 2004; Brooks, Adger, & Kelly, 2005) which purpose was to identify the countries with lowest adaptive capacity. Later on few studies focused on subnational level (Nelson, et al., 2009; Gbetibouo & Ringler, 2009) which tried to identify the regional variations within the country.

2.2.1 Importance of Traditional and Local Knowledge in Adaptation

Traditional Knowledge

The policy makers, planners and managers rely heavily on the scientific knowledge to inform decisions as it provides important insights and shapes the world we live in today (MacKendrick, 2009) and often neglect traditional and local knowledge. Gilligan et al. (2006) state that though scientific knowledge has numerous benefits it is not free from flaws and is subject to certain limitations (cited by MacKendrick, 2009). Traditional ecological and local knowledge gives important insight in understanding environmental and social change (Riewe and Oakes 2006 cited by MacKendrick, 2009). According to Berkes, Colding, & Folke (2000) traditional ecological knowledge is "a cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment." Traditional ecological knowledge emphasizes knowledge accumulated over a long time about an area or species (Gilchrist, Mallory, & Merkel, 2005). It is based on tradition and passed from generation to generation (Gilligan et al. 2006 cited by MacKendrick, 2009). So, in responding to the impacts of climate change already occurring, as well as preparing for and mitigating those projected for the future, requires integrating different knowledge systems and decision making processes in order to improve understanding of the issue and manage risk (Gilligan et al. 2006 cited by MacKendrick, 2009). Further, Gilchrist, Mallory & Merkel (2005) emphasizes that in case of lack of scientific information and data, other knowledge system provides insight for decision making. Also, traditional knowledge is vital in providing a human viewpoint about environmental management and change beside scientific knowledge (Gilligan et al. 2006 cited by MacKendrick, 2009).

Local Knowledge

According to the MacKendrick (2009) local knowledge is different from traditional ecological knowledge in timescale and it provides important insight to addressing climate change. Local knowledge is "acquired more recently over the lifetime of individual" instead of through oral history and offers a mixture of current experience with the land and traditions passed down through generations (Gilchrist, Mallory, & Merkel, 2005). Local knowledge adds up to the traditional ecological knowledge due to influencing factors like technology and other current factors (Mallory et al. 2006 cited by MacKendrick, 2009). Local knowledge provides information that can be useful in environmental decision making, as a compliment to scientific knowledge, particularly in areas where extensive scientific knowledge may not exist (Gilchrist, Mallory, & Merkel, 2005). Integrating local knowledge into scientific research offers opportunity to benefit the groups of people who hold it by engaging them in projects and assisting them in developing the end-products (Riewe and Oakes 2006 cited by MacKendrick, 2009).

2.2.2 Adaptation practices in Nepal

Agriculture is the main source of livelihood in Nepal. The major threats by climate change in Nepal seems to be disturbance of livelihood which is mainly by natural disasters like flood and landslide, decrease in water sources, long drought period, increase in plant diseases and decrease in productivity.

Table 2.2 Climate change impact and adaptation practices

Impact	Local Adaptation measures
Landslides	Stonewalls Afforestation
Food security	Skill development for alternative income activities Market facility
Drought	Local irrigation canal (Kulo) Adoption of drought resistant cultivars
Appearance of mosquitoes and other harmful insects and related disease	Mosquito nets
Decrease in agriculture production	Adoption of high yielding varieties Develop skill for alternative livelihood Cultivation of cash crops (Cardimom)
Incidence of plant diseases	Local pesticides Synthetic pesticides Disease resistant varieties
Incidence of animal disease	Veterinary facility

The changes in different sector due to climate change has forced people to find measures in securing their livelihoods by adapting knowingly and unknowingly to these changes (Sharma & Dahal, 2011). According to Sharma and Dahal (2011), few of the adaptation practices adapted by the people in Shankhuwasabha district to the impact of climate change are shown in Table 2.2. The adaptation practices mention in Table 2.2 adopted by the people of Sankhuwasabha may not all be the response of the climate change but may be response to both climate change as well as to the development factor occurring in the area.

2.3 Vulnerability and Resilience

2.3.1 Vulnerability

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

2.3.2 Resilience

The concept of resilience is a complex and multi-interpretable which has contested definitions and relevance (Jordan, 2009). Resilience in general sense means the system ability to deal with stresses and disturbances and also maintaining its basic structure and ways of functioning, capacity for self-organisation, and capacity to learn and adapt to change (Speranza, 2010). So, resilience is about managing the changes and adapting to the test of current and future climate risks (Speranza, 2010). According to the Fourth Assessment Report of IPCC, resilience is defined as "ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for selforganisation, and the capacity to adapt to stress and change" (Baede, Linden, & Verbruggen, 2007). Further, Adger (2000) differentiates resilience as social and ecological. The social resilience result due to social, political and environmental changes and it is the ability of groups or communities to cope with external stresses and disturbances. While ecological resilience is the characteristic of ecosystems to maintain themselves in the face of disturbance (Adger, 2000). According to the Resilience Alliance (2002) resilience has three distinct characteristics, i.e., system capacity to undergo change and still be in the same state, have capability of self-organization and have ability to build and increase capacity of learning and adaptation. Further, resilience can be viewed as layered concept which ranges from individual to household, community, ethnic group and global level (Jordan, 2009).

2.4 People's Perception to Climate Change

2.4.1 Importance of perception of climate change

Perception can be stated as the process by which individual notices and understand the environmental stimuli. Also human perception do not just solely respond to the environmental stimuli but go beyond the information present in the environment and pay selective attention to some aspects of environment and ignore others elements that are relevant to people (Carpenter, Bauer, & Erdogan, 2009). So, perception plays an important part in the human for any action towards the change in the environment. According to the Speranza (2010) awareness and perception of a problem, shapes action or inaction for climate change problems. In light with this Gbetibouo (2009) states that farmers having access to extension services are likely to perceive changes in the climate as extension services provides information about climate and weather. This emphasizes the perception of the people changes with the different services and the immediate need or risks.

2.4.2 Perception towards natural hazard risk

According to the Wachinger & Renn (2010) risks perception process involves collecting, selecting and interpreting signals about uncertain impacts of events, activities or technologies. He also states that perception may differ depending on the type of risk, the risk context, the personality of the individual, and the social context (Wachinger & Renn, 2010). Further he adds that people evaluate risk according to their subjective perception which is governed by psychological mechanisms for processing uncertainty, intuitive heuristics for reaching generalisations and conclusions and additional contextual characteristics (Wachinger & Renn, 2010). Poumadere, Mays, LeMer, & Blong (2005) state that the societal and contextual aspects are linked with the perception of disaster impacts. There are literatures indicating that perception about the impacts of disaster depended on many factors. The study done by Medina, Iglesias, & Mateos (2007) about risk perception among organic farmers in Spain indicated that risk perception depended on many variables such as type of culture, the zone of cultivation etc. Further Wachinger & Renn (2010) state that wider social, economic and political contexts at local, regional and national levels are important factors that influence risk perception.

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

2.4.3 Relationship between perception of climate change and socio-economic status

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

2.4 Climate Change Policy and Programs

2.4.1 Climate Change in International Regime

Climate change has been actively on discussion as one of the major challenges for human since 1990s. The United Nations Framework on Climate Change is an international treaty joined by different countries to limit the increase in global temperature rise, deal with resulting climate change and cope with whatever the impacts.

Table 2.3 UNFCCC Conference of Parties events

Date	Event	Place	Main outcomes/Comments
1995	COP-1	Berlin, Germany	Berlin Mandate adopted to develop a Protocol on emission reduction.
1996	COP-2	Geneva, Switzerland	Geneva ministerial Declaration supporting climate change science endorsing IPCC second assessment report
1997	COP-3	Kyoto, Japan	Kyoto Protocol adopted
1998	COP-4	Buenos Aires, Argentina	Buenos Aires Plan of Action (BAPA) on negotiation to prepare the Kyoto Protocol to come into force
1999	COP-5	Bonn, Germany	Progress on rules and guidelines for Kyoto market-based mechanisms
2000	COP-6	Hague, Netherland	Final decisions on BAPA; negotiation failed to conclude and COP-6 suspended
2001	COP-6 COP-7	Bonn, Germany; Marrakesh, Morocco	Bonn Agreements adopted on final details of BAPA, apart from land use, land use change and forestry (LULUCF). Established three new fund: Special Climate Change Fund, Least Developed Country Fund, Adaptation Fund Marrakesh Accord to the Bonn Agreements adopted
2002	COP-8	New Delhi, India	Delhi declaration on climate change and sustainable development adopted

2003	COP-9	Milan, Italy	Decisions on LULUCF adopted, final piece of BAPA negotiation completed
2004	COP-10	Buenos Aires, Argentina	Adaptation was equally featured as mitigation (also known as adaptation COP)
2005	COP-11	Montreal, Canada	Finally adopted the Marrakesh accords, which enable operation of special climate change fund (SCCF), least developed countries fund (LDCF), adaptation fund
2006	COP-12	Nairobi, Kenya	Conference made little measurable progress.
2007	COP-13	Bali, Indonesia	Roadmap for post-2012 climate regime was agreed, comprising the Bali Action Plan (BAP)
2008	COP-14	Poznan, Poland	Focused on paving road from Bali to Copenhagen, details on operationalization of Adaptation Fund discussed
2009	COP-15	Copenhagen, Denmark	Copenhagen accord drafted. Later submitted emission reduction pledges or mitigation action pledges
2010	COP-16	Cancun, Mexico	Cancun Agreement was drafted. Agreed to establish the Green Climate Fund for developing countries and also Cancun adaptation framework, reducing emission from forest deforestation and forest degradation (REDD) plus mechanism and Technology mechanism.
2011	COP-17	Durban, South Africa	Durban platform for enhanced action accepted and also agreed on formation of National Adaptation Plan
2012	COP-18	Doha, Qatar	Doha Amendment to the Kyoto Protocol was adopted. Agreed to look at the possibility of looking into mechanism for Loss and Damage in future.
2013	COP-19	Warsaw, Poland	Decision on advancing Durban platform, Green-Climate Fund, and Long-term finance, Warsaw Framework for REDD+ and the Warsaw International Mechanism for Loss and Damage

Source: Compiled from UNFCCC (2014) and Kashyap (2009).

In May 1992 UNFCCC was adopted and entered into effect in March 1994. Kyoto Protocol was adopted in 1997 as a result of negotiation in response to strengthen the UNFCCC which they realized was not enough for emission reduction. Now in Kyoto Protocol there are 192 countries and 195 countries in the UNFCCC (UNFCCC, 2014). The Conference of Parties (COP) event and the key elements are described in Table 2.3.

2.4.2 Climate Change Initiative in Nepal

Nepal has been member of UNFCCC since its beginning. Nepal signed the UNFCCC in Rio de Janerio in 1992 and later ratified the convention on May 1994 and came into force in 31st July 1994 (MoPE, 2004). Nepal prepared Initial National Communication report based on COP2 guidelines and setup National Climate Change Committee (NCCC) and four separate National Study Teams (NSTs) to prepare country response to climate change (MoPE, 2004). Nepal has been participating in the COP meetings regularly but was not been able to raise national issue effectively in international arena due to initial lower priority to climate change issue, lack of awareness, and inadequate capacity for climate negotiation (ADAPT-Nepal, 2014). Role of Nepal since COP-17 has been more active as they made a submission in National Adaptation Plan, organized side event on Mountain Initiative and also opted for LDC coordinator in the UNFCCC process for the year 2013 and 2014 (MoE, 2012). In January 2013, Nepal became chair for Least Developed Countries (LDC) Group at United Nation (UN) Climate Change negotiation.

One of the major challenges for Nepal is implementation of Rio convention for which government began process of assessing institutional and individual capacity (MoEST, 2008) and prepared National Capacity Self-Assessment (NCSA) for Global Environment Management in 2008. Nepal also developed National Adaptation Programme of Action (NAPA) in 2010 and climate change policy in 2011 and now also is making Local Adaptation Plan for Action (LAPA). The focus of NCSA project was identifying the priority issues for action and capacity needs within thematic area of biodiversity conservation, combating climate change and combating land degradation. For the preparation of NCSA three thematic working groups were formed based on working area with the help of Global Environment Fund (GEF) and UNDP (MoEST, 2008). The major outcome of NCSA project is that it was able to bring representative from different concerned authorities together (MoEST, 2008). It also pointed out the strength, weakness, opportunity and threat in the capacity to address biodiversity conservation, adapt to and mitigate impacts of climate change and to combat land degradation.

2.4.3 National Adaptation Programme of Action

Nepal prepared NAPA in 2010 as a requirement of UNFCCC for accessing the LDC Fund for most urgent and immediate adaptation needs. NAPA was developed with three components namely preparation and dissemination of NAPA document, development of Nepal Climate Change Knowledge Management Centre (NCCKMC) and Multistakeholder Climate Change Initiative Coordination Committee (MCCICC). For preparation of NAPA US$ 1,325,000 was allocated of which US$ 250,000 was used for preparation and dissemination of NAPA document and remaining amount was used for other two purposes (GoN & UNDP, 2008). NAPA process was signed on November 14, 2008 but the process began only from May 2009 and completed in September 2010 (GoN & UNDP, 2008; MoE, n.d.). NAPA is strategic tool that assess climate vulnerability and identifies the immediate needs to adaptation and was formed by consultative process (MoE, 2010). For the preparation of NAPA six thematic working groups (TWGs) were formed and were led by line ministries. The TWGs identified the nine integrated project as urgent and immediate national adaptation priority which are as follows (MoE, 2010):

1. Promoting community-based adaptation through integrated management of agriculture, water, forest and biodiversity.
2. Building and enhancing adaptive capacity of vulnerable communities through

improved system and access to service for agricultural development.

3. Community-based disaster management for facilitating climate adaptation.
4. Glacial Lake Outburst Flood (GLOF) monitoring and disaster risk reduction.
5. Forest and ecosystem management in supporting climate-led adaptation innovations.
6. Adapting to climate challenges in public health.
7. Ecosystem management for climate adaptation.
8. Empowering vulnerable communities through sustainable management of water resource and clean energy supply.
9. Promoting climate-smart urban settlements.

NAPA is the first comprehensive climate change dedicated government document (HELVETAS, 2011). NAPA tried to link the governmental policies and communities needs by identification of need to prepare LAPA. NAPA was successful in generating discussion on immediate needs for adaptation to climate change but also has some gaps. NAPA prioritized the adaptation program for natural hazards by focusing on its management and need for monitoring Glacial lake outburst flood (GLOF). NAPA was also successful in emphasizing the need for better data management but has not raised issue of extensive research requirements on climate change. NAPA has prioritized on infrastructure from the view point of adaptation to natural hazards but has not thought from the view point of increasing resilience. It does not clarify on the implementation strategy of the adaptation and fails to identify implementation partner but only identifies communities as major beneficiaries. Further, it seems to identify the communities more from the perspective of sufferer but does not consider increasing community capabilities for adaptation. Also NAPA fails to acknowledge private sector as one of the important partner for implementing adaptation technologies. The broader criticisms of the NAPA document seems that its process is mainly dominated by centre level government agencies, national NGOs, donor organizations representatives and relevant UN agencies (HELVETAS, 2011). This raises the question of participation of stakeholders at community level and their subsequent needs.

2.4.4 Climate Change Policy

In the past climate change was addressed in 2003 sustainable development agenda for Nepal and 2001 millennium development goals. Nepal being signatory to UNFCCC for implementing the convention between 2007 and 2009 initiated projects like NCSA, Clean Development Mechanism (CDM) project approval, NAPA, second national communication (SNC), and strengthening capacity for managing climate change and environment (GoN, 2011). In this regard, on March of 2011 Government of Nepal formulated Nepal climate change policy 2011 in need to address the urgent response to climate change and in response to international climate regime (HELVETAS, 2011).

In the climate change policy first three sections deals with Nepal initiatives and efforts in the international climate change regime. The fourth section deals with the problems and challenges from climate change while fifth section gives the reasons for formation of climate change policy, its vision and mission. The sixth section deals with vision, mission and goals of climate change policies. The vision of the climate change policy (GoN, 2011) is

"*This policy envisions a country spared from the adverse impacts of climate change, by considering climate justice, through the pursuit of environmental conservation, human development, and sustainable development—all contributing toward a prosperous society.*"

Further, main goal of climate change policy is to improve the livelihood by mitigating and adapting to the adverse impact of climate change. For achieving the main goal it gives the quantitative targets with timeline which are as follows:

1. Establishment of climate change center
2. Initiation of LAPA
3. Preparation of national strategy for carbon trade

4. Formulation and implementation of low carbon economic development
5. Assessment of losses and benefits from climate change
6. Promotion of climate adaptation
7. Development of reliable impact forecasting system

In accordance to the goals, section seven describes the objectives of climate change. Further, section eight deals with various policies in detail to meet the desired policy objectives which are as follows:

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

Section nine of climate policy deals with the strategy and working policies, while later sections deal with institutional structure, financial aspect, legal aspect, monitoring and evaluation, plans and risks.

In climate change policies local communities are seen as the major stakeholders for adaptation and mitigation. Also, it is mentioned that local communities are entitled to 80% of the climate fund but its modality of implementation is still not clear and is in discussion. The policy also stresses on lack of the scientific researches and fact regarding the impact of climate change. The policy governs the immediate activities listed in NAPA document and also recognizes natural hazards management as immediate need. The policy also stresses upon development of infrastructure along with adaptation. There are few gaps that exist in the climate change policy especially in its implementation part. Till April 2014 there has not been any separate laws and regulation for facilitating in the implementation of climate change policies. Climate change policy fails to give detail about working procedure in the community though it gives some implementing strategy and working policy in section 9 (HELVETAS, 2011). The policy defines Ministry of Environment as the coordinating organization at functional level but does not talk about coordination with other ministries since Ministry of Environment does not have local organization at district and village level. Also policy fails to recognize the implementing partner at the ground level. Though it recognizes the risks associated with the implementation of policy, it does not talk about managing those risks. Though the policy documents are for implementing the climate change adaptation programs that are directed towards local community, there is information gap regarding climate change policy at local level. The policy also sees the people from the view point of sufferer but does not stresses on possibility of enhancing their local resources and knowledge. The few programs that have been implemented go in different direction undermining the focus of climate change programs. Thus looking from these perspectives, the policy documents seem to be driven from top to bottom and do not seem much accountability at local level along with significant gap in the implementation.

2.4.5 Local Adaptation Plan for Action

From the recommendation of NAPA document 2010 and with the view of supporting implementation of adaptation fund to local level Nepal Government has developed national framework for LAPA (GoN, 2011b). According to GoN (2011b) LAPA framework basically supports integration of climate resilience into local to national development planning process and outcomes. This is insured by bottom-up, inclusive, responsive and flexible approach. Basically the purpose of LAPA can be described as follows (MoE, n.d.):

1. Enable communities to understand climate change and engage them in developing adaptation priorities.
2. Implementing climate-resilient plans.

3. Informing sectoral programmes and catalysing integrated approaches between various sectors and sub-sectors.

LAPA framework has identified VDC and municipalities as the appropriate unit for integrating climate resilient local-to-national development planning process (GoN, 2011b). It has been piloted in 10 districts and made 70 LAPA as of February 2014 that includes 69 VDC and 1 municipality. LAPA process involved seven steps for integrating climate change resilience into local-to-national planning process (GoN, 2011b).

1. Climate change sensitization
2. Climate vulnerability and adaptation assessment
3. Prioritization of adaptation options
4. Developing Local Adaptation Plans for Action
5. Integrating Local Adaptation Plans for Action into planning processes
6. Implementing Local Adaptation Plans for Action
7. Assessing progress of Local Adaptation Plans for Action

Each of these steps involves activities at the local level where it went down to VDCs and ward level for integrating climate change resilience in the development planning (HELVETAS, 2011). LAPA documents are inclusive, comprehensive and community centric but there implementation is still questionable as there has not been much progress after the formation of 70 LAPAs. Further, there has been addition of new dimension from many developmental organizations by making community based adaptation plan. This community based adaptation plan has focused communities more but has also added challenges of how it is going to be integrated in LAPA.

2.4.6 Foreign assistance in Nepal

Nepal started to receive the foreign assistance since 1952 after joining Colombo Plan Cooperative, Economic and Social Development in Asia and Pacific (Bista, 2006). Foreign aid has been a vital component in the development of socio-economic development and representing on average around 6.57% of total GDP till 2009 and around 26% of total budget in the fiscal year 2010/11 (Foreign Aid Coordination Division, n.d.; Bhattarai & Sharma, 2013). Nepal has received most of the foreign aid from 1975 till 2009 in the sector of transportation, power and communication followed by agriculture and social service (Bhattarai & Sharma, 2013). But recently there has been increase in the proportion of donor grant in the field of climate change in Nepal. Nepal started to receive foreign aid from 2007 onwards. It received around 20.7% proportion of donor grant in 2007/2008 which increased to 40.4% in 2011/2012 (Regmi & Bhandari, 2012). Currently, there are 13 projects that have disbursed the financing in support of climate change programs in Nepal (Table 2.4).

Table 2.4 Current climate change projects in Nepal

Project Title	Donors	Commitment US $	Disbursed US $
Capacity Building for Strategic Planning for Municipal Solid Waste Management including understanding of Climate Change and CDM	United Nations Human Settlements Programme	90,624	63,437
Strengthening Capacity for Managing Climate Change and the Environment	Asian Development Bank	1,275,000	1,125,407
Improved capability to respond to increased risk of natural disasters related to climate change	Finland	645,245	691,592
Nepal Climate Change Support Programme	European Union, DFID	16,571,528	4,820,467
Cities and Climate Change Initiatives	United Nations Human Settlements Programme	26,000	9,441
REDD-Forestry and Climate Change	World Bank Trust Funds	3,400,000	1,422,912
Enhancing Capacities for Climate Change Adaptation and Disaster Risk Management for Sustainable Livelihoods in the Agriculture Sector	United Nations Development Programme	103,890	241,385
Initiative for Climate Change Adaptation (ICCA)	U.S. Agency for International Development	2,000,000	750,000
Multilateral climate change mitigation	WorldBank AusAid	1,430,930	1,430,930
Capacity Development for Mainstreaming Climate Change Risk Management in Development	Asian Development Bank	7,163,000	881,023
South Asia Water Initiative - Climate Change and Water	AusAid	101,276	101,276
NCCSP	MoSTE, DFID	4,299,623	1,635,417
NCCSP: Building Climate Resilience in Nepal	DFID, European Union	22,564,557	11,041,158

Source: (MoF, 2014)

Understanding importance of climate change impact, Nepal government has taken initiatives to address it by allocating 10.3% of its budget in the year 2013/14 (IIED, 2014). Besides these there has been US$ 236.62 from the international source for the period of 2009-2012 (IIED, 2014). The foreign assistance in Nepal is implemented by different developmental organizations by taking non-governmental organization, community based organizations and governmental bodies as their implementation partners. The developmental organization is working basically focusing on two aspects:

- Nature focused
- Community focused

Nature focused programs mainly focuses on the knowledge generation and disaster risk reduction programs. The nature focused programs are also aimed at maintaining the ecosystems and natural resource management for the betterment of the communities. Communities focused programs mainly focuses on improvement of livelihood and dissemination of information regarding climate change to the people. For implementation of the climate change adaptation programs organizations are mainly taking three approaches

- Ecosystem based approach
- Community based approach

- Integrated approach

Ecosystem based approach

The ecosystem based approach give priority for using biodiversity and ecosystem services for helping people to adapt to climate change. In Nepal management of water resources, disaster risk management, REDD, forestry management and wetland programs are the common programs which is implemented from ecosystem based approach. This approach is mainly delivered by knowledge generation like researches, capacity development and conservation activities.

Community based approach

The community based approach gives priority for strengthening the communities by improving their livelihood and building on local practices for adapting to climate change. The programs such as Nepal climate change support program, initiatives for climate change adaptation, increasing resilience of communities to cope with climate change and so on. The community based approach depends mainly on how the community group organize themselves to adapt to climate change (Bryan & Behrman, 2013).

Integrated approach

In integrated approach both the ecosystem as well as community based approach are taken together. In Nepal programs like Hariyo Ban uses this approach. This approach takes into account both preservation of ecosystem and strengthening the communities, since without participation of communities ecosystem cannot be preserved.

With these approaches different developmental, non-governmental and governmental organizations are implementing different programs. For example the pilot program for climate resilience which looks into different aspect like natural hazards management, climate data management, watershed management, involving private sectors for adaptation, mainstreaming climate change in development and so on. These programs are being prioritized by the developmental organizations based on the adaptation programs identified by the NAPA and climate change policy. Further, with issue of climate change getting more recognized internationally, the developmental organizations are planning more and more programs incorporating the climate change issues. Further there has been shift on development of infrastructure to reduce vulnerability as well as adaptation by the international donors. There has been improving coordination among the donor organizations and government agencies but still there exists some gaps such as

- Lack of coordination between government agencies has been one of the major problems for implementation of adaptation organization[1].

- The developmental organization blames government of not having the capacity for adaptation program where as government authorities think too much bureaucracy while working with the donor organization.
- Though the focus of climate change programs is adaptation, but different developmental organization are implemented differently.
- Development organization sees that there has been lessening interest in the governmental agencies for climate change.

Chapter III

3. Research Design and Study Area

3.1 Introduction

This chapter describes the conceptual framework for analysing the vulnerability and resilience of farmers in Rural Nepal. The concept is developed based on the existing literatures and IPCC Fourth Assessment Report definition of vulnerability. Also, this chapter highlights the study area and methodology for gathering the data.

3.2 Conceptual Framework

There are basically three conceptual approaches for assessment of vulnerability (Deressa, Hassan, & Ringler, 2008).

1. Socio-economic approach: The socio-economic approach mainly focus on socioeconomic and political variations within the society, but not environmental factors, so it basically tries to identify the adaptive capacity of the individual and communities based on their characteristics (Deressa, Hassan, & Ringler, 2008).
2. Biophysical approach: The biophysical approach basically tries to capture the damage done by environmental factors on the social and biological systems and mainly focuses on the physical damages like change in yield, income, etc. (Deressa,

Hassan, & Ringler, 2008).

3. Integrated assessment approach: The integrated assessment approach combines both the approaches, socioeconomic and biophysical approaches (Deressa, Hassan, & Ringler, 2008). Though the integrated approach tries to correct the limitations of the other two approaches, it has its own weakness as there is no standard process of combining socioeconomic and environmental indicators, and also this approach does not account for dynamism in vulnerability (Deressa, Hassan, & Ringler, 2008).

This study adopts the integrated assessment approach and uses the indicator method to assess the vulnerability and resilience of farmers in Rural Nepal. The main issue in this research is what are the factors that determining the vulnerability and resilience at both district as well as household level? This study tries to identify the different factors that are determinant for climate change vulnerability and resilience of farmers. First the study tries to identify the determinant factors of vulnerability at national level (district) and finally also looks at the factors effecting vulnerability and resilience at local level (household).

3.3 Components of Framework and relationship between them

There are numerous conceptual models, frameworks, and assessment techniques that have been developed to understand vulnerability and resilience both theoretically and from point of application (Cutter, et al., 2008). According to IPCC vulnerability can be explained by exposure, sensitivity and adaptive capacity. Exposure to climate change is change in temperature and rainfall pattern in the area over the years and also occurrence of natural hazards. With increase in exposure, i.e., increase in the change in temperature and rainfall and also increase in the occurrence of natural hazards the people will be more vulnerable to climate change, especially farmers as their livelihood depends on it. Sensitivity increases the effect of exposure on the people and will have more negative impact on them. Sensitivity will include the factors like casualties and damaged caused by the natural hazards as well as human and environmental factors that makes them more susceptible to the natural hazards and climate variability. The combined effect of exposure and sensitivity will increase the vulnerability while adaptive capacity will decrease it. Ford et al. (2006) suggest while defining adaptive capacity based on resource and risk management decision is influenced by human system like social, economic, cultural, experience and so on. Adaptive capacity includes the factors like buffering capacity, self-organization and capacity of learning and adaptation which will improve their capacity of adaptation. The buffering capacity includes the variables like demography, wealth, infrastructure, and livelihood options, while self-organization will include institute and information. The capacity of learning means the management and openness for learning which will be given by their perception to climate change.

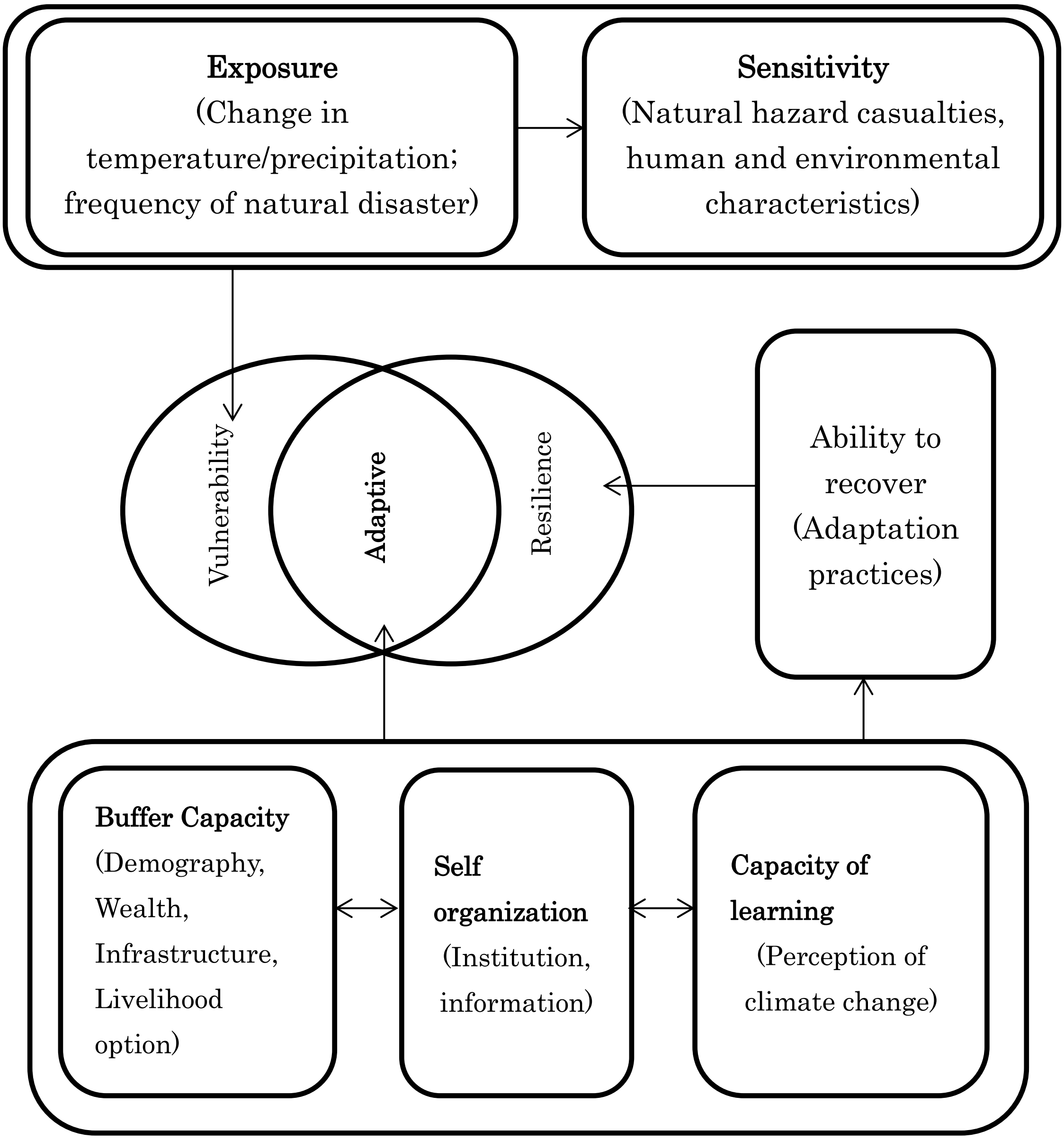


Figure 3.1 Conceptual frame work of study

The households that have more wealth and better excess to the infrastructure like road, health post and have diverse livelihood option can accommodate changes in the climatic variables. Further, the institution like micro-credit, access to technology and information and their perception to climate change will further enhance the household's ability of adaptation. The adaptive capacity will decrease the vulnerability due to the combined effect of exposure and sensitivity and also increases the resilience of the households to climate change as a whole. Adaptive capacity is the major factor contributing to resilience of famers to climate change but also resilience is governed by the factors like their capacity to absorb shocks. Furthermore, vulnerability and resilience depends on the geographic as well as social condition, so indicators of vulnerability and resilience will also change based on it as well as unit of study, i.e., national level or local level study.

3.4 Study Area

Government of Nepal in 2010 did analysis of vulnerability of Nepal at district level and produced NAPA by overlying climate risk/exposure maps, sensitivity maps, and adaptive capacity maps. According to NAPA vulnerability of different districts of Nepal were generally classified into five different categories namely:

1) Very High Vulnerable

2) High Vulnerable

3) Moderate Vulnerable

4) Low Vulnerable

5) Very low vulnerable

Based on this NAPA classified vulnerability on different scenarios such as natural hazards like landslides, flood, GLOF and drought, socio-economic, forest and others and also overall vulnerability. Study districts are selected based on vulnerability and also accessibility of the area. The study districts are presented in Table 3.1

Table 3.1 Vulnerability level of the study districts

	Very High Vulnerable	High Vulnerable	Low Vulnerable
Vulnerability	Dolakha	Dhading	Lalitpur

Dolakha District

Dolakha district lies in the central developmental region and mountainous district of Nepal. The district extends from 27˚28” to 28˚ North latitude and 85˚50” to 86˚32” East longitude. The elevation ranges from 732 masl to 7148 masl. The district is surrounded by China in the north, Ramechhap and Kavrepalanchok district in south, Ramechhap and Solukhumbu district in the east, and Sindhupalchok district in the west. The mean annual temperature of the district is 8˚C with annual mean rainfall of 2043.5mm. The district covers 2191 square kilometre with agricultural land of 56683ha (DDCDolakha, 2013). The population of district is 186,557 with population density of 85 (CBS, 2012).

Dhading District

Dhading district lies in the central developmental region and one of the least developed districts among hilly districts of Nepal (DDCDhading, 2003). The district extends from 27˚40” to 28˚14” North latitude and 84˚ to 85˚1” East longitude. The elevation ranges from 488 masl to 7409 masl (DDCDhading, 2003). The district is surrounded by Gorkha district in the west, Kathmandu and Nuwakot district in the east, Makwanpur and Chitwan district in the south and Rasuwa district in north and also has border with China. It has total area of 192,487ha (DDCDhading, 2003). The district climate ranges from sub-tropical zone below 1000 masl to alpine zone above 3000 masl. The average annual rainfall is 2121.2 mm (DDCDhading, 2003). The population of Dhading district as of 2010 is 336,067 with population density of 174.

Lalitpur District

Lalitpur district lies in the central developmental region and is situated between 27˚22" to 28˚50" North latitude and 85˚14" to 85˚26" East longitude. The elevation ranges from 457 masl to 2831 masl. One-third of the district lies within Kathmandu valley where as two-third are hilly remote areas. The district is surrounded by Kathmandu district in south, Bhaktapur district in north, Kavrepalanchok district in east and Makwanpur districts in west. The Lalitpur district covers 385 square kilometres. Lalitpur district has 152.16 kilometre of agricultural land. The district has sub-tropical to cool temperate climate and mean annual maximum temperature is 23.6˚C and mean annual minimum temperature is 10.7 ˚C and mean annual rainfall is 1232.6mm (DDCLalitpur, 2013). The population of district is 468,132 as of 2010 having population density of 1216 (CBS, 2012).

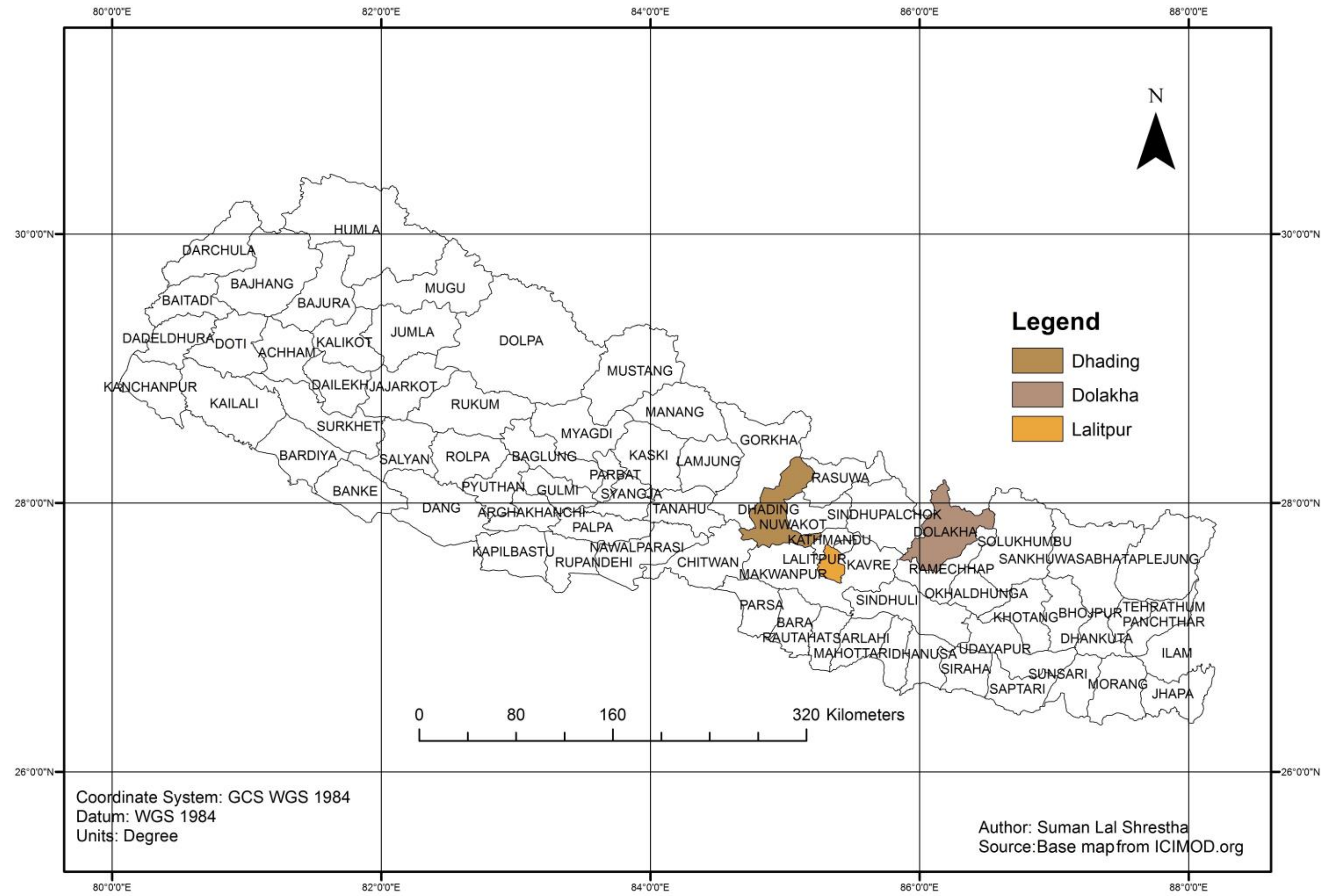


Figure 3.2 Map of Nepal showing study districts

a

b

c

Figure 3.3 Map of Dolakha (a), Dhading (b) and Lalitpur (c) district with VDC (highlited)

Chapter IV

4. Climate Change and Natural Hazards

4.1 Introduction

Climate is becoming more erratic in nature globally with increasing global temperature. Climate change will not just affect the average temperature but also increase the weather-related climatic hazards (Przyborski, 2013). Natural hazards is the physical phenomena which occurs naturally and is caused by rapid or slow onset events which can be geophysical, hydrological, climatological, meterological, or biological (IFRC, 2013). There are growing evidences on changing natural cycles and variation in global climate system and also strong evidences that these changes are unusual and do not fit into natural pattern (Anderson, 2006). The changing climatic pattern will increase the possibility of extreme climatic events like heatwave, coldwave, flooding and other climate related natural hazards. According to Heltberg, Siegel, & Jorgensen (2008) there is growing evidence that natural hazards related to climate are increasing in frequency and intensity. It has been predicted that with climate change there is large range of consequences, some of long term like sea level rise while some have immediate impacts such as flooding (Anderson, 2006). The combination of increased temperatures, decreased equator-versus-pole temperature difference, and increased humidity might have impact on increasing intense cycles of droughts and floods as more precipitation falls in a single large storm than series of small ones (Przyborski, 2013). These natural hazards are the principal cause of the hazards that results in the casualties to human life and damages to the economic property. In the fifth assessment report of IPCC hazard is defined as "occurrence of a natural or human- induced physical event that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, and environmental resources" (Lavell, et al., 2012). The natural hazard and its impact will differ according to country and further will be location specific. As stated by Lal, Singh, & Holland (2009) geographic condition is very important determinant to which country is exposed to different type of natural hazard.

Nepal being mountainous country is characterized by rugged topography with high relief, complex geological feature, and concentrated rainfall (Pradhan, 2007). Nepal is one of the hazardous areas in world as its mountains are young and fragile with steep slopes and experiences heavy monsoon rainfall (Pradhan, 2007). Nepal regularly experiences the natural hazards such as floods, landslides, intense rains, hailstorms, droughts, and coldwaves and heatwaves (MoAC, 2011) which are in increasing trend with climate change. The increasing trend of natural hazard like floods, the characteristics like high local level vulnerability that is associated with poverty levels, depleted natural resources, fragile land and infrastructure and increasing intensive risk as urbanization, has increased the impacts from these natural hazards (Practical Action, 2010). Nepal is ranked 30th globally in terms of water-induced hazards such as landslide and flood (MoHA, 2009). In Nepal the high intensity rainfall during the monsoon makes the country highly vulnerable to water induced natural hazards like flood and landslides (MoAC, 2011). Flooding is frequent in monsoon season in Nepal and drought is also not uncommon in some areas of Nepal with prolonged breaks in summer monsoon (MoAC, 2011). According to United Nations Nepal Information Platform (2013) the natural hazard in Nepal is increasing with global climate change further exacerbating the vulnerability of Nepalese people. According to Khanal, Shrestha, & Ghimire (2007) in the context of increasing global warming phenomenon there will consequent increase in the intensity of the extreme events. There has been increase in the recent undesired climatic events like increase in the frequency of extreme events flooding, landslides, droughts, heat stress, hot winds, cold waves, hailstones, and snowfall (Prasai, 2010). In Nepal from 1971 to 2007 more than 50,000 people were reported injured, 3,000 people missing and more than five million people affected by natural hazards (UNISDR, 2009). Floods and landslides are the most overwhelming natural hazards accounting for most loss of life and livelihoods that regularly affect Nepal, and claimed about 211 lives on average annually between

1998 and 2008 (MoHA, 2009). For example the flood of 1993 in the central region of Nepal caused deaths of around 1336 people (Pradhan, 2007). Also huge landslides in Durbang about 200 km west of Kathmandu in the year 1988 killed 109 people and in only half the monsoon period (June 10 to August 15) in the year 2009 killed 50 people (Dahal, 2012). Besides flood and landslides there are other natural hazards that have significant impact like drought and hailstorm. Also extreme events of coldwaves and heatwaves affected number of people lives. In 2007 southern plains were reported to record temperature around 12˚C below normal and same year in February Kathmandu received its first snowfall in 63 years (Prasai, 2010). In 1997/1998 winter cold reduced the winter crop yield by 11-38% compared to the average of the preceding 10 years (Prasai, 2010). In addition to this, hills that accounts for 56.2% of total land mass of Nepal accounted for highest number of hazard event from 1900 to 2005 (Aryal, 2012).

Nepal ranks fourth on the list of 'extreme risk from climate change over the next 30 year out of 16 countries globally (UN, 2012). The hydrological, meteorological and glaciological data from Nepal Himalayas shows that Nepal Himalayas is changing faster than the global average. According to Maharjan, Joshi and Piya (2011) analysis of data from 1976 to 2005 shows that temperature in Nepal has increased by 1.6°C. The warming trend in Nepal is more distinct in autumn and winter and mostly rainfall is in monsoonal season, June to September, around which 80% of rainfall occurs and there is very low rainfall during December to February (MoPE, 2004). The trend analysis done by Practical action (2009) found that average temperature of Nepal was increasing at 0.04ºC per year. According to Practical Action (2009) in Nepal due to high inter annual variation in rainfall there is no significant trend observed over the years. Also there were some small pockets of area that has decreasing rainfall trend over the period of 1976-2005 (Practical Action, 2009). The impact of climate change in Nepal will differ according to region as well as sector.

World is now more warm than it was for the past two millennia (Jones & Mann, 2004). With increasing global climate and increasing extreme weather there is need to link climate change and the extreme weather. According to Anderson (2006) establishing link between weather extremes and climate change has now become a pressing and political concern and understanding the science to establish it very important especially if political decisions are based on it. As Nepal is vulnerable to natural hazard, it is important to analyse the climatic pattern and trend of natural hazard and their relationship with each other in order for proper management of natural hazards. Climatic variables are the major determinants for occurrence of natural hazards. Any change in climatic variable due to climate change will increase the occurrence of natural hazards. But still the effect of climate change on occurrence of natural hazard, in empirical equations, is still very unclear. The effect of climate change on occurrence of natural hazard in Nepal is still yet to be established. There are very few literatures that try to see empirical relationship between natural hazards and climatic variables in Nepal like Dahal & Hasegawa (2008) which studies rainfall threshold for landslides in Nepal. Many of the literature regarding natural hazard like landslides mainly focuses on the loss of life and wealth, physical properties of landslides, and recommendation of environmental friendly preventive measures (Dahal & Hasegawa, 2008). In addition, whatever the source of hazards occurrence might be their impacts include loss of life, injury to persons, damage to property and destruction of assets (Lal, Singh, & Holland, 2009). So, there is need of analysing effect of climate change in with the impact of natural hazard also. This paper first tries to analyse trend of climatic variable like temperature and rainfall and occurrence of natural hazards and their impacts such as casualties and damages over the period of 1978 to 2011. Also the paper tries to analyse effect of climatic variables on occurrence of natural hazards and their impacts.

4.2 Methodology

The study uses the climatic data taken from department of hydrology and meteorology of Nepal for the period of 1978 to 2011. The natural hazard data were taken from DesInventar (Disaster Information Management System) for the period of 1978 to 2011. The DesInventar collects the data from various sources like newspapers, disaster review series from 1993 to 2002. The total number of natural hazards and the casualties and damages caused by it taken for the study may not be the actual representative of all the natural hazards but only the reported cases during the study period. The climatic data are analysed annually as well as seasonally. In regards to climate change, annual average rainfall and temperature trend gives the overall characteristics of changing climatic pattern while change in trend of temporal standard deviation gives the variation over the area as well as time. It is also important to analyse the seasonal trend as it shows occurrence of more extreme weather pattern of the study area. Nepal season is divided into four season namely: Pre Monsoon (Mar.-May), Summer Monsoon (Jun – Sep), Post Monsoon (Oct.-Nov.) and Winter (Dec – Feb) (Kansakar, Hannah, Gerrard, & Rees, 2004).

The monthly temperature and rainfall trend of Nepal is analysed from 1978-2011 to see the overall temperature and rainfall pattern, while daily average rainfall is analysed from 2002 to 2011 to see relationship with the climate extremes. For seeing the climate extreme rainfall indices are used as shown in Table 4.1.

Table 4.1 Rainfall Indices

Indicator	Indicator definition	Units
Number of heavy rainfall days	Annual count when precipitation ≥ 10mm	Days
Number of very heavy rainfall days	Annual count when precipitation ≥ 20mm	Days
Consecutive dry days	Maximum number of consecutive days when rainfall < 1mm	Days
Consecutive wet days	Maximum number of consecutive days when rainfall ≥ 1mm	Days

Source: Zhang, et al. (2011)

Further, linking climate change and extreme weather is important but establishing it is complicated. According to Anderson (2006) there are three main ways of linking:

1. Empirical (by comparing current data of natural hazard with historical record),
2. Theoretical (through simulation using such as GCMs and RCMs).
3. Indirect proxy – examining data on damage from extreme events, including the frequently cited rise in insurance claims.

Every method has its own advantages and disadvantages, in the empirical method the data quality and quantity changes over the time (Anderson, 2006). He also stated that theoretical methods are not suited well for examining the specific geographical location. Further, he added that measurement of impacts are complex since the amount of insured property keeps changing and element of chance in the location damaging event and infrequent repetition to allow comparison is simply difficult to use them as evidence. As climate change make specific event more likely it might have happened under unchanged circumstances, so linking between natural hazard and climate change will thus have to refer to statistically significant trend (Anderson, 2006). So this study uses the empirical method by taking historical data trend to see effect of climatic variable on natural hazard.

In order to see the effect of climatic variable on natural hazard, trend analysis and seemingly unrelated regression (SUR) analysis is used. The climatic variables like average rainfall and temperature and temporal standard deviation are taken. Similarly, natural hazards like flood, landslides, storm, snowstorm, heatwave, coldwave, forest fire, and drought are taken. Also the number of people died, number of house affected/destroyed, number of people injured and area of crop land affected by these natural hazards are used for analysis. SUR analysis is used as it is expected that the equations for prediction will be interrelated. SUR estimator developed by Zellner (1962) is useful for estimating models with submodels more than 1 dependent variables that allow for different regression matrices in each equation and account for contemporaneous correlation. To simplify, all equations are stacked into a single equation and can be written as:

$$Y = X\beta + U \quad \ldots\ldots\ldots\ldots 4.1$$

Where $Y = (Y'_1, Y'_2, \ldots, Y'_n)$ is a vector of all stacked dependent variable

X is a block diagonal design matrix

$\beta = (\beta'_1, \beta'_2, \ldots \beta'_n)$ is a vector of the stacked coefficient vectors of all equations

$U = (U'_1, U'_2, \ldots U'n)$ is a vector of the stacked error vectors of all equation.

4.3 Result and Discussion

4.3.1 Trend analysis of temperature and rainfall

The 91 available temperature stations of Nepal are taken for the yearly as well as seasonal analysis. Figure 4.1 shows the average temperature trend of Nepal from 1978 to 2011 and is seen to be increasing with the coefficient of 0.046 and R^2 value of 0.615. The increasing temperature trend is similar to the analysis done by Practical Action (2009). This shows that temperature trend in Nepal is increasing faster than global temperature trend. Further trend analysis of temporal standard deviation for the period of 1975 to 2011 shows that it is in decreasing order though not significantly indicating that temperature in higher cold places like higher altitude is increasing faster.

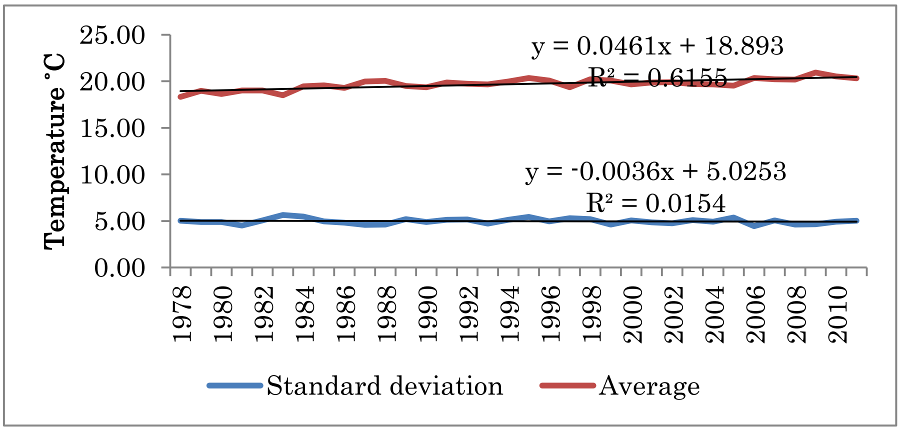


Figure 4.1 Temperature and rainfall trend of Nepal from 1978-2011

Further, seasonal trend analysis is done to see the variation among the seasons. Figure 4.2 shows that average temperature for all the season is increasing and is highest in pre-monsoon and post-monsoon season having the coefficients of 0.063 (R^2 value of 0.429) and 0.047 (R^2 value of 0.437), respectively.

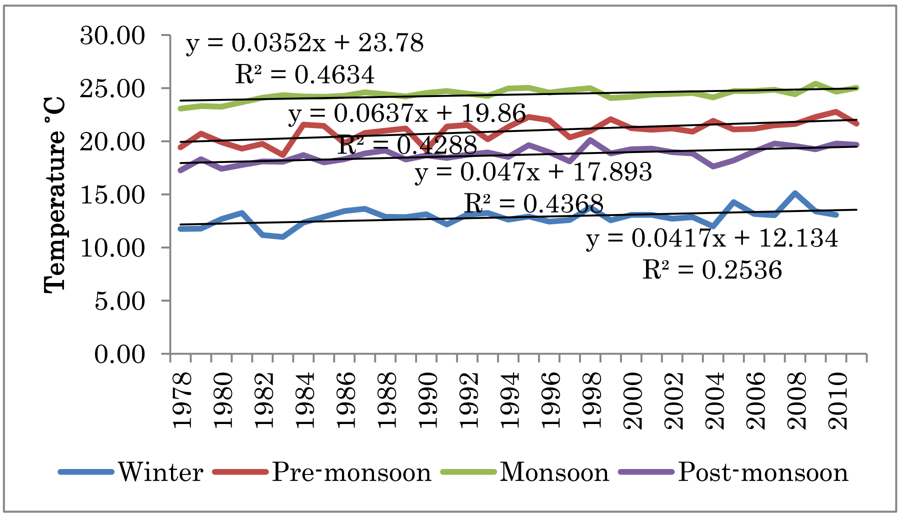


Figure 4.2 Seasonal temperature trend of Nepal from 1978-2011

This is closely followed by winter season which is increasing with the coefficient of 0.0417 having R^2 value of 0.25. This shows that there is increase in temperature continuously from post-monsoon to pre-monsoon. This increase in temperature in the drier period (winter) will make natural hazards like drought more severe.

The monthly average rainfall trend was analysed using the available data of 234 rainfall stations of Nepal. In Figure 4.3, rainfall has no significant trend but is seen to be slightly decreasing with coefficient of -0.027 having R^2 value of 0.0006. Rainfall is seen to be very erratic in nature with some years having very low rainfall and the immediate following years having high rainfall as seen in year from 2004 to 2006 where rainfall is very low but suddenly increases in 2007. The continued lesser amount of rainfall for consecutive years can be associated with the hazards like drought that have significant impact on the farmers, where people depend mostly on rain-fed agriculture. Additionally, standard deviation trend for rainfall is analysed from 1978 to 2011 and it is seen to be in increasing trend having coefficient of 0.216 and R^2 value of 0.019. Though standard deviation trend is not significant, it indicates that rainfall is getting more erratic in nature.

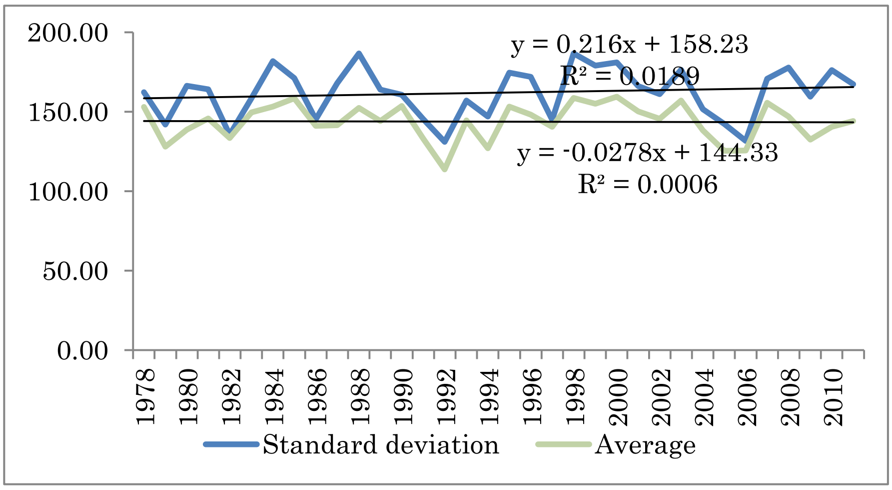


Figure 4.3 Rainfall trend of Nepal from 1978-2011

The seasonal monthly average rainfall trend is analysed for the period of 1978 to

2011. Figure 4.4 shows that there is no significant rainfall trend in all the season, but it shows the direction of rainfall. Rainfall is slightly increasing in monsoon season with coefficients of 0.188, while is decreasing in pre-monsoon, post-monsoon and winter season with coefficients of -0.04, -0.11 and -0.25, respectively. The increase in rainfall in monsoon season during which it already receives around 80% of total rainfall indicates that rainfall intensity is increasing over the short period. The decreasing rainfall in the pre-monsoon, post-monsoon and winter along with increase in the temperature in same season indicates that drier periods are getting more severe. This increase of rainfall in the monsoon season and decrease in winter season both could increase the probability of increasing natural hazards like flooding in monsoon season and drought in winter season.

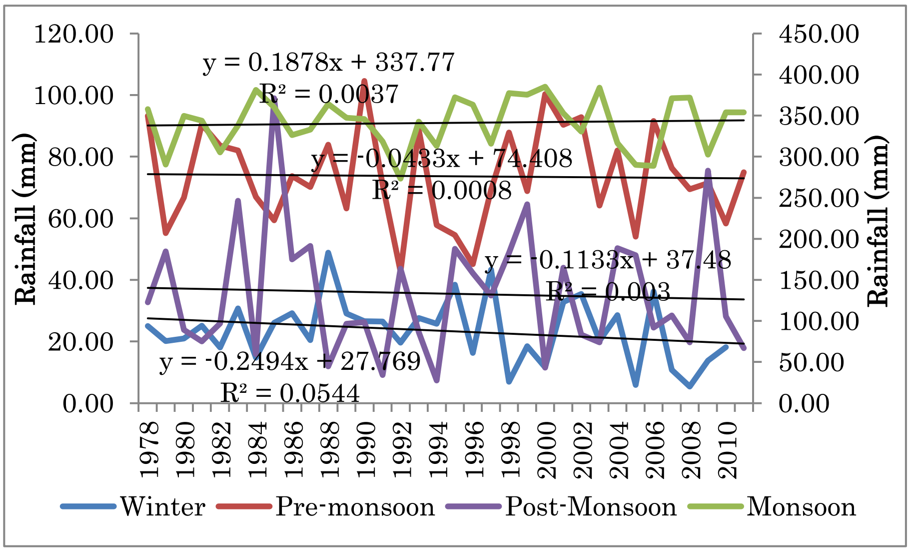


Figure 4.4 Seasonal rainfall trend of Nepal from 1978-2011

4.3.2 Occurrence of climatic extremes

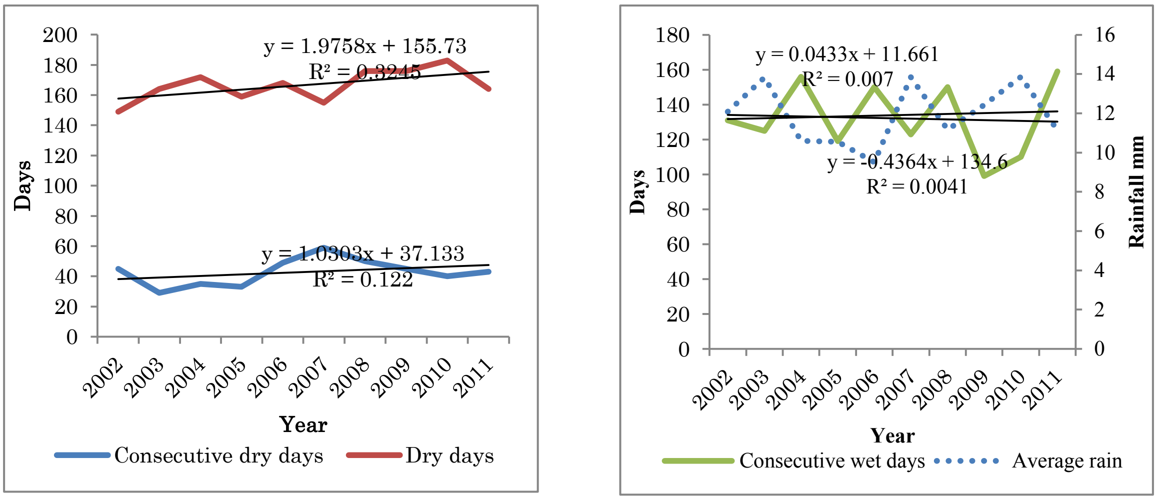
Nepal being prone to different kinds of natural hazards which is season specific, it is very important to analyse the climatic variability. So, month wise temperature and rainfall trend for the period of 1978 to 2011 is analysed. The analysis shows that temperature is increasing in all the months with the fastest in March having the coefficient of 0.08 (R^2 value of 0.38) followed by February with the coefficient of 0.07 (R^2 value of 0.27). The least increasing trend is in December with the coefficient of 0.02 (Annex I). Further, standard deviation trend for temperature is found to be in decreasing order for all the months though not significant (Table 4.2).

Table 4.2 Temperature and rainfall coefficient for each month

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. temp	Trend coeff	0.04	0.07	0.08	0.06	0.05	0.03	0.04	0.03	0.04	0.05	0.05	0.02
	R^2 value	0.16	0.27	0.38	0.24	0.28	0.20	0.38	0.38	0.47	0.33	0.34	0.04
	SD coeff	-0.02	-0.02	-0.03	-0.04	-0.06	-0.02	-0.01	-0.02	-0.02	-0.01	-0.03	-0.02
	R^2 value	0.11	0.02	0.19	0.16	0.52	0.13	0.04	0.19	0.16	0.07	0.10	0.06
Avg. rainfall	Trend Coeff	-0.20	0.17	-0.16	0.09	0.39	0.35	-0.42	1.58	-0.76	-0.06	-0.17	-0.69
	R^2 value	0.01	0.01	0.07	0.00	0.02	0.00	0.01	0.09	0.02	0.00	0.19	0.11
	SD coeff	-0.16	0.06	-0.33	0.13	0.05	-0.02	0.00	0.03	-0.68	0.33	0.02	-0.23
	R^2 value	0.02	0.00	0.09	0.02	0.00	0.00	0.00	0.00	0.07	0.02	0.00	0.12

Rainfall analysis shows that there is no significant trend in all the months but the direction in which month rainfall is mostly decreasing while increasing in few months. It is seen that rainfall is decreasing in January, March, July, September, October, November and December while it is increasing in February, April, May, June and August. The continuous decrease in rainfall from September to January indicates that drier periods are getting drier in nature. Further, during monsoon season there is decrease in rainfall in July while high increase in the month of August. This shows that rainfall is getting more extreme in nature and there is high probability of occurrence of flood in the August and drought in July.

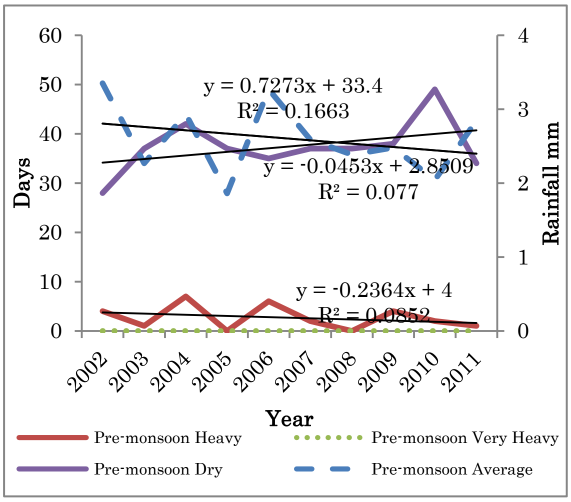
In addition to this, extreme rainfall trend for 2002 to 2011 are analysed using the daily average data. It is seen that number of total dry days in a year has been increasing with coefficient of 1.97 with R^2 value of 0.32 and consecutive dry days are increasing with coefficient of 1.03 and R^2 value of 0.12 (Figure 4.5a). Further, it is seen that consecutive wet days are decreasing over the same period with coefficient of -0.43 and R^2 value of 0.004 (Figure 4.5b). Also, the average daily rainfall over these continuous wet days is increasing with coefficient of 0.043 and R^2 value of 0.007 (Figure 4.5b). This trend analysis shows that overall rainfall is getting more extreme in nature, i.e, drought is becoming more severe and frequent, and rainfall is getting more intense over the short period of time.



a b

Figure 4.5 Trend analysis of dry days (a) and wet days (b) from 2002 to 2011

Further, number of days of extreme rainfall trend according to season is analysed using daily average rainfall for period of 2002 to 2011 (Figure 4.6). The analysis shows that in pre-monsoon season average rainfall is decreasing with the coefficient of -0.045 while dry periods are increasing with the coefficient of 0.727. In pre-monsoon season heavy rainfall is decreasing with the coefficient of -0.236 indicating that it is getting drier. This decrease in the average rainfall as well as increase in the dry periods in pre-monsoon season, exacerbates the problem of water shortage. In monsoon season the average rainfall, heavy rainfall, very heavy rainfall and dry periods is increasing with coefficient of 0.004, 0.97, 0.16, and 0.24, respectively.



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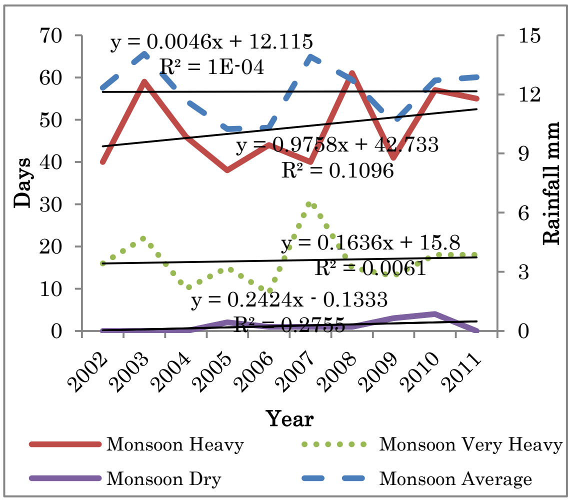

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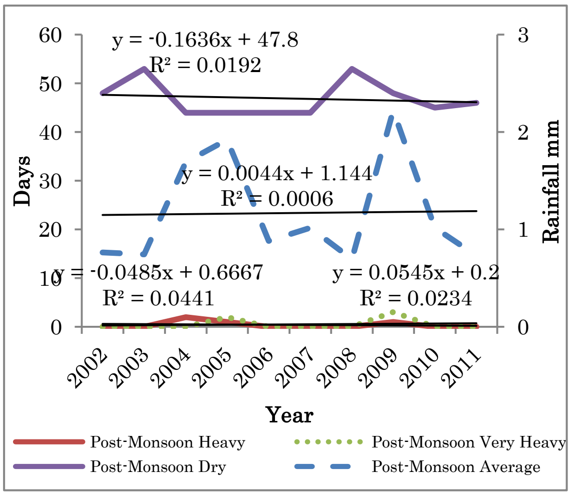

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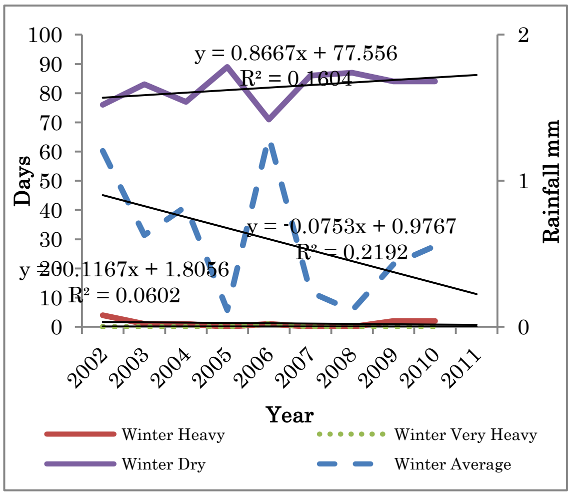

d

Figure 4.6 Trend analysis of average rainfall and extreme rainfall days for pre-monsoon (a), monsoon (b), post-monsoon (c) and winter (d)

Since most of the rainfall comes in monsoon season, the increase in daily average rainfall and increase in the intensity of heavy and very heavy rainfall increases the probability of natural hazards occurrence like flood and landslide. In case of post-monsoon season the average daily rainfall and very heavy rainfall is increasing with coefficient of 0.004 and 0.05, respectively; while dry period and heavy rainfall is decreasing with the coefficients of

-0.16 and -0.045, respectively. The increase in the average rainfall can be attributed to increase in very heavy rainfall and is more disastrous as it will increase the occurrence of flood and landslides. In winter season the average rainfall and heavy rainfall is decreasing with the coefficients of -0.07 and -0.12, respectively, but dry period is increasing with the coefficient of 0.86. As winter season is normally dry, increasing trend of dry period will further exacerbated occurrence of drought. Figure 4.8 also shows that the climatic extreme are increasing especially in the last few years. It is seen that with increasing natural hazards there is also increase in the casualties and damages caused by them.

4.3.3 Occurrence of Natural Hazards

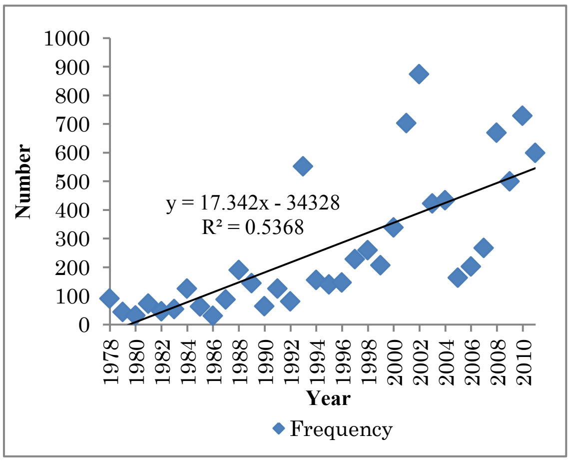

Figure 4.7 Trend of natural hazard occurrence from 1978 to 2011

The analysis shows that natural hazard is increasing for the period of 1978 to 2011 having coefficient of 17.32 with R^2 value of 0.537 (Figure 4.7). The frequency of natural hazard occurrence seems to be increasing very rapidly since 1990s. The occurrence of the natural hazard in 1993, 2001 and 2002 is high compared to other years indicating that return period of natural hazards is getting shorter.

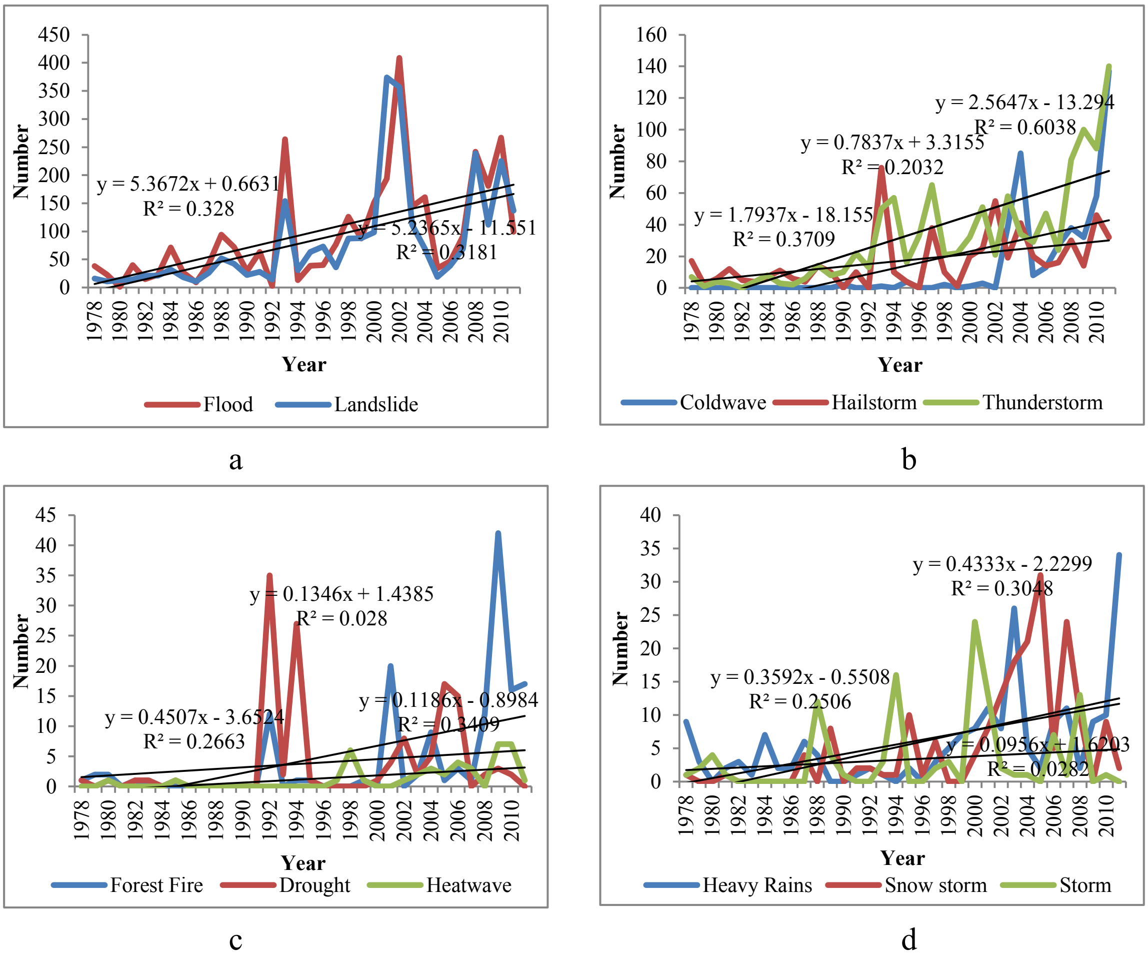

Figure 4.8 Different types of natural hazard trend

Further, trend of occurrence of different type of natural hazard are analysed in Figure 4.8. Flood and landslides are increasing very rapidly with coefficient of 5.367 and 5.236, respectively. It is seen that in 1993 there is huge number of flood and landslide and also in 2001 and 2002 (Figure 4.8.a). Also there is increase in the occurrence of natural hazards especially from 1990s onwards (Figure 4.8). Further, incidence of coldwave has been increasing sharply from 2002 onwards (Figure 4.8.b). There has been increase in the number of heavy rains that caused the casualties and damages since 2000 (Figure 4.8.d). The trend shows that occurrence of natural hazards is highest for flood and landslide. Also it is seen that hailstorm, coldwave, forest fire, drought and heavy rains that causes damages are also occurring frequently. Mostly flood and landslide occurs in monsoon season when there is high rainfall in Nepal followed by post-monsoon season (Table 4.3). In winter season there is high occurrence of coldwave and snowstorm while in pre-monsoon season there is high occurrence of forestfire, hailstorm, heatwave, storm and thunderstorm (Table 4.3).

Table 4.3 Occurence of natural hazard according to season

Natural Hazard	Pre-monsoon	Monsoon	Post-monsoon	Winter
Coldwave	3(6)	3(6)	19(18)	355(50)
Drought	14(21)	107(47)	3(9)	5(9)
Forest fire	122(47)	5(9)	0(0)	15(21)
Flood	68(56)	3039(100)	99(50)	9(18)
Hailstorm	420(88)	32(35)	95(65)	31(41)
Heatwave	15(26)	24(24)	0(0)	1(3)
Heavy rain	22(32)	137(71)	25(32)	11(21)
Landslide	72(65)	2519(100)	81(74)	45(47)
Storm	95(50)	14(29)	3(6)	0(0)
Snowstom	24(35)	2(6)	11(24)	145(62)
Thunderstorm	523(94)	472(91)	25(35)	54(44)

Note: Figures in parenthesis shows the occurrence percentage[1] of natural hazards over the period of 1978 to 2011.

[1] Occurrence percentage= $\frac{\text{(No. of years X natural hazard occurred in different season)}}{\text{(Total No. of years)}}$ x 100

While in monsoon season there is high occurrence of drought, flood, landslide and heavy rain. Also, there is increase in the occurrence of forest fire in pre-monsoon season from 2000 onwards. Further, occurrence of drought in monsoon season is high which may be due to significant increase in the heavy rainfall and decrease in consecutive wet days in monsoon.

4.3.4 Casualties due to natural hazards

Figure 7 shows the trend of casualties and damages caused by natural hazards for the period of 1978 to 2011. The trend analysis shows that all the casualties and damages caused by the natural hazards are increasing rapidly. The deaths caused by the natural hazards are increasing with coefficient of 7.94 having R^2 value of 0.097 (Figure 4.9a). The injured person by natural hazards are increasing with coefficient of 9.996 having R^2 value of 0.68 (Figure 4.9b). While, houses destroyed have great yearly variation and are increasing with coefficient of 140.6 and R^2 value of 0.0825 (Figure 4.9c). Further, crops damaged by natural hazards are also increasing with coefficient of 1254.4 and R^2 value of 0.12 (Figure 4.9d). The analysis shows that injuries due to natural hazards are increasing very rapidly while there is large variation in the numbers of houses destroyed/damaged by the natural hazards.

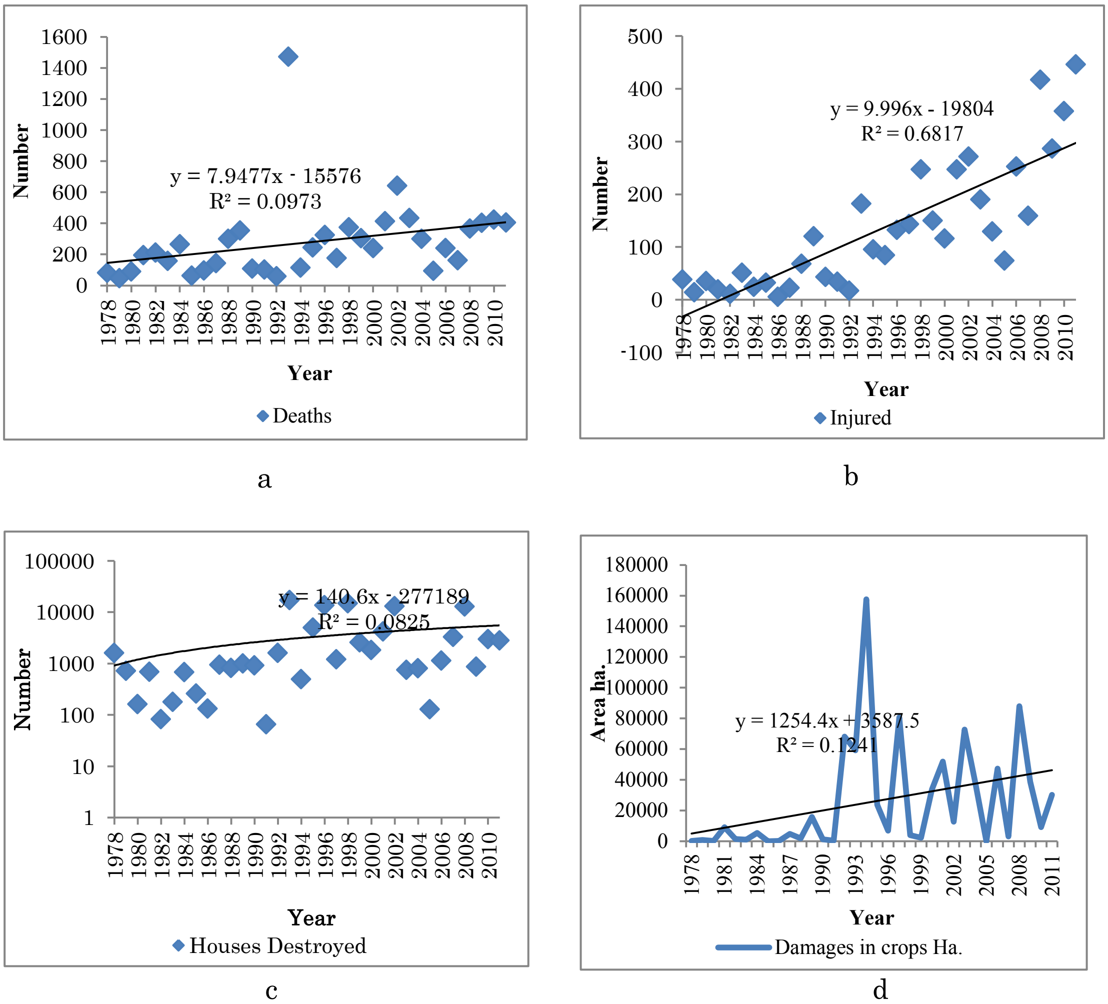

Figure 4.9 Occurrence of natural hazards (a) and casualties (b,c and d) of Nepal from 1978-2011

Landslide and flood are the two major natural hazards followed by hailstorm and coldwave over the period of 1978 to 2011(Table 4.4). Further, landslide and flooding is causing maximum casualties and damages among all the natural hazards. Casualties and damages caused by coldwave are increasing rapidly over the period of 1978 to 2011 (Table 4.4). Flooding is seen as the most destructive natural hazards event that destroys/damages the houses. Drought is also causing significant damages to crops.

Table 4.4 Natural hazards and casualties/damages caused by it from 1978 to 2011

Natural Hazards	**Frequency**	**Deaths**	**Injured**	**Houses Destroyed/Affected**	**Damages in crops Ha.**
Cold wave	450	596	83	0	20906.5
Drought	129	0	0	0	392353.00
Flood	3216	3157	502	87180	218175.00
Forest Fire	143	61	55	15914	38629.41
Hailstorm	580	32	88	207	132372.40
Heat wave	40	41	20	0	0.00
Landslide	2723	4359	1499	19261	182037.00
Heavy Rains	194	57	40	743	69966.60
Snow Storm	182	89	46	168	1900.00
Storm	112	43	269	1021	87.00
Thunderstorm	1074	1011	1925	291	2.00

4.3.5 Effect of climatic variable on natural hazards

Table 4.5 Result of SUR between climate variables and natural hazards

V.	Cold-wave	Flood	Forest Fire	Drou-ght	Hail-storm	Land-slide	Thunder-storm	Heat-wave	Heavy-rain	Snows torm	Storm
1	**2.04** ***	**5.81** ***	**0.28** *	0.12	**1.29** ***	**5.48** ***	**2.62** ***	**0.07** *	**0.47** ***	**0.65** ***	0.09
2	-0.04	**1.61** *	**-0.18** **	**-0.39** ***	0.05	1.58	-0.31	0.00	0.12	0.00	0.04
3	-8.08	-12.50	5.29	0.03	**-16.80** **	-6.00	-2.38	**1.73** *	-3.64	**-7.28** **	0.12
4	-3879.35	-11474.30	-642.37	-175.09	-2231.41	-10961.45	-5108.08	-165.21	-884.39	-1149.81	-191.51

Note: V. Variables, 1 year, 2 Average annual rainfall, 3 Average annual temperature, 4 constant. * Significant at 10%, ** Significant at 5%, *** Significant at 1%

SUR analysis is used to analyse the effect of climatic variables on natural hazards. Time trend is included as additional explanatory variable to capture change in dependent variables over time. It is found that coldwave, flood, forest fire, hailstorm, landslide, thunderstorm, heavy rain and snowstorm are increasing significantly with the coefficient of 2.04, 5.81, 0.28, 1.29, 5.48, 2.62, 0.07, 0.47, and 0.64, respectively (Table 4.5). The result shows that flood and landslide are increasing fastest for the period of 1978 to 2011. The analysis shows that increase in rainfall will significantly increase the flood with the coefficient of 1.61, while decrease in rainfall will significantly increase forest fire and drought having the coefficient of -0.18 and -0.39, respectively (Table 4.5). With increase in temperature there will be significant increase in the heatwave having the coefficient of 1.73, while decrease in temperature will significantly increase hailstorm and snowstorm with the coefficient of -16.80 and -7.28, respectively (Table 4. 5).

Flooding is the major natural hazard affecting life of people in Nepal as shown by Table 4.3 and 4.4. Analysis shows that pre-monsoon and monsoon flooding are correlated to each other. So, SUR analysis is used to see the effect of climatic variables on occurrence of pre-monsoon and monsoon flooding. The analysis shows that pre-monsoon and monsoon flood are increasing significantly over the period of 1978 to 2011 with the coefficients of 0.149 and 6.365, respectively (Table 4.6).

Table 4.6 Result of SUR between occurrence of flood and seasonal climatic variables

Variable	Pre-monsoon Flood		Monsoon Flood	
	Coeff.	P-value	Coeff.	P-value
Year	0.149***	0.001	6.365***	0.001
Pre-monsoon temperature	1.092**	0.038	10.907	0.61
Monsoon temperature	-0.763	0.527	-82.085*	0.094
Pre-monsoon rainfall	0.067***	0.004	1.534	0.107
Monsoon rainfall	-0.004	0.666	0.133	0.719
Constant	-304.085	0.000	-10960.1	0

Note: * Significant at 10%, ** Significant at 5%, *** Significant at 1%

Pre-monsoon flooding significantly increases with increase in pre-monsoon temperature and rainfall having coefficient of 1.092 and 0.067, respectively (Table 4.6). This is mainly because with increase in temperature there will be increase in rainfall which causes flooding (Seneviratne, et al., 2012). This adds to the fact that flooding has significant increase in pre-monsoon season with increasing temperature as seen in Figure 4.2. The result shows that decreasing monsoon temperature significant increase monsoon flooding. With decrease in temperature, moisture content of soil in general increases, saturating the soil faster and with continuous precipitation there will be rapid increase in stream flow (Fernandez, Karem, Norton, & Rustad, 2007) and thus there will be higher probability of flooding. Further, simple linear regression is run for post-monsoon flooding and winter flooding with post-monsoon and winter climatic variables which shows no significant result.

4.4 Conclusion

The average temperature of Nepal over the period of 1978 to 2011 is rising while rainfall is decreasing. The seasonal trend shows that temperature is increasing in all season while rainfall is increasing in monsoon season and decreasing in pre-monsoon, post-monsoon and winter season. In Nepal there is increase in extreme weather pattern as shown by increasing trend of natural hazards. Flooding and landslides are causing most casualties and damages which have the highest increasing trend and occur throughout the year. There has been increase in extreme weather pattern such as increasing trend of heavy and very heavy rainfall and increase in dry periods. SUR analysis is used to see the effect of climatic variables on the occurrence of different types of natural hazards. The analysis shows that natural hazards are increasing significantly over the period of 1978 to 2011. It shows that any change in rainfall and temperature significantly increase natural hazards like flood, forest fire, drought, heatwave, hailstorm and snow storm. Further, SUR analysis is used for understanding effect of seasonal climatic variables on occurrence of flooding. The analysis showed the flooding is increasing significantly in pre-monsoon and monsoon season. Also, with increase in temperature and rainfall of pre-monsoon, there is significant increase in flooding while any decrease in monsoon temperature significantly increases the flood. Thus climatic variables significantly affect occurrence of natural hazards. This emphasizes with climate change there is further need to understand the relationship between climatic variables and occurrence of natural hazards, so that local communities can better understand the later and increase their resilience. Understanding seasonal pattern of temperature and rainfall might be helpful for understanding future natural hazards pattern which might be useful in better management of natural hazards. Future study should focus on analysing local temperature and rainfall pattern and the associated natural hazards. This will help in reducing uncertainty related to natural hazards so that local communities can prepare for it.

Chapter V

5. Climate Change Vulnerability in Nepal

5.1 Introduction

The anthropogenic climate change is predicted to have negative impact on least developed countries where livelihood of most people dependent on natural resources (Heltberg & Bonch-Osmolovskiy, 2011). The impact of climate change will not just depend on the biophysical characteristics but will also depend on the society and how they interact with the climate. The IPCC Second Assessment Report (SAR) states that socio-economic systems “typically are more vulnerable in developing countries where economic and institutional circumstances are less favourable” (IPCC, 1996). Also SAR describes that vulnerability is highest where there is “the greatest sensitivity to climate change and the least adaptability.” Further in the Fourth Assessment Report, the IPCC defines the vulnerability as “degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes”. After the Fourth Assessment Report of IPCC, the focus of the researches has been to mitigation and adaptation to climate change which brings in researches on vulnerabilities of the specific places that have centered on analysis of human welfare (Ibarraran, Malone, & Brenkert, 2008).

Kelly and Adger (2000) defines the vulnerability as “ability or inability of individuals or social groupings to respond to, in the sense of cope with, recover from, or adapt to, any external stress placed on their livelihoods and well-being”. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity (Barker, et al., 2007). There are numerous conceptual models, framework and assessment techniques that have been developed to understand it better both theoretically and practically (Cutter, et al., 2008). According to Adger (2006), “The concept of vulnerability has been a powerful analytical tool for describing states of susceptibility to harm, powerlessness, and marginality of both physical and social systems, and for guiding normative analysis of actions to enhance well-being through reduction of risk”. This paper conceptualizes the vulnerability as a function of exposure, sensitivity and adaptive capacity as per the definition of IPCC.

Exposure can be explained as the degree of climate stress upon a particular unit of analysis (Comer, et al., 2012). Further, exposure can be defined as the experiences of disturbances in the internal and external system (Abson, Dougill , & Stringer, 2012). Sensitivity refers to the responsiveness of a system to climate hazards (Preston & Stafford-Smith, 2009). Sensitivity may vary considerably from one system, sector or population to another. Sensitivity, according to Gallopin (2003), is the degree to which a system is changed or affected by an internal or external disturbance or set of disturbances. The measure that shows the responsiveness of a system to climatic influences is shaped by both socio-economic and ecological conditions and determines the degree to which a group will be affected by environmental stress (SEI, 2004). According to the IPCC (2001), sensitivity is to what extent the system is affected either adversely or positively by the climatic stimuli. Adaptive capacity refers to the ability of a system in a way that makes it better prepared to manage its exposure and/or sensitivity to climatic influences (Preston and Stafford-Smith, 2009). Capacity is often measured in terms of resource availability. The institutional and governance networks that exist to deploy those resources are also essential, and any number of socio-political barriers may exist that impede successful adaptation (Deressa, Hassan, & Ringler, 2009). Adaptive capacity is a significant factor in characterizing vulnerability. According to Brooks (2003), the adaptive capacity of a system or society generally reflects its ability to modify its characteristics or behaviour to better cope with existing or anticipated external stresses, and also changes in external conditions. IPCC (2001) describes adaptive capacity of a system, region, or community as its potential or ability to adapt with the effects or impacts of climate change (including climate variability and extremes). Also, adaptive capacity is context-specific and varies from country to country, community to community, among social groups and individuals, and over time (IPCC, 2001).

Climate change vulnerability of the household, community, region, or country is very much related to the social and economic development (Gbetibouo & Ringler, 2009). Further, the vulnerability to climate change varies from one place to another depending upon different factors like its exposure, sensitivity and adaptive capacity. The study done by Gbetitouo & Ringler (2009) calculated vulnerability as the net effect of sensitivity and exposure on adaptive capacity in South Africa and shows that vulnerability is characterized by the combination of medium-level risk exposure and medium to high levels of social vulnerability. In addition to this, O'Brien et al. (2004) stressed that institutional support can help in adapting to climate change. Deressa, Hassan & Ringler (2009) analysed the household vulnerability to climate change in the Nile basin of Ethiopia using econometric approach and shows that farmers' vulnerability is highly sensitive to their minimum per day income requirement (poverty line) and agro-ecological setting. This emphasizes that there is need for identification and characterization of climate change impact from the perspective of vulnerability. Also, IPCC has stressed that priorities should be given for advancing understanding of potential consequences of climate change for human society and the natural world, as well as to support analyses of possible responses (IPCC, 2001). Further for increasing resilience and adapting to climate change, it is important to understand the nature of vulnerability and reflect it in various development strategies formulated at different levels (UNDP, 2010). Furthermore, it is imperative to address the issue of climate change vulnerability at all levels of decision-making through different policies and measures for increasing resilience to climate change. In addition to this, the impact of climate change will be felt at the local level and mapping climate change vulnerability will facilitate in conveying the information about vulnerability and adaptive response to concerned authorities by down-scaling global climate change to local level (Benjamin, Emma, & Richard, 2011). Identifying and mapping the vulnerable area is one of the important steps in developing climate resilient development plans and strategies for making society resilient in the face of climate change (UNDP, 2010). Further, there has been increase in the importance of spatially-explicit vulnerability assessments as instrument for environmental policy formulation and development debates (Metzger & Schroter, 2006). Also, spatial information regarding climate change will help in spatial planning taking into account the future changes in environment and social context (NRC, 2007).

In Nepal there have been very few studies done regarding climate change vulnerability. Few of the studies on vulnerability focuses on the local region, society and household such as Khatiwoda (2011) which indicates that the vulnerability of Tharu communities in Kailali district have increased due to extreme events, especially floods. In addition to this, NAPA by the government of Nepal categorized vulnerability according to districts. NAPA categorized districts like Kathmandu, Bhaktapur, Dolakha as most vulnerable while districts like Ilam, Banke, Palpa are termed as least vulnerable districts (MoE, 2010). NAPA uses the expert judgment to give weights to the indicators and also gives equal weightage to exposure, sensitivity and adaptive capacity in vulnerability analysis. The use of expert judgment to give the weights may not properly determine the climate change vulnerability as using the expert judgment may have biases due to cognitive limitations (Kirkebøen, 2009). Vulnerability analysis will be clearer and sound if both socio-economic and biophysical indicators are used (Johnson, Stanforth, Lulla, & Luber, 2012). While it is difficult for policymaker to indicate vulnerability according to area by taking large number of discrete indicators, there is significant value to capture multiple aspects of climate change vulnerability in smaller number of aggregate indices by spatially-explicit measures (Abson, Dougill, & Stringer, 2012). So, this chapter identifies district wise climate change vulnerability of Nepal using both socio-economic and biophysical indicators. Further, it uses Principal Component Analysis (PCA) to give weights to the indicators of climate change vulnerability to lessen the biases that may arise due to cognitive limitations. Also, the chapter maps climate change vulnerability using Geographic Information System (GIS) to provide visual spatial information of climate change vulnerable districts in Nepal.

5.2 Methodology

Nepal is one of the least developed countries whose livelihood mostly dependent on natural resource. According to Maplecroft climate change vulnerability index 2011, Nepal is the fourth extremely vulnerable country in the world (Maplecroft, 2011). Nepal is generally mountainous with steep topography. Its terrain can be divided into three parts, namely; Tarai - southern plain region, Hills - mid hilly region and Mountains - northern high mountains. Its climate varies from tropical in the south to alpine in the north. The country climate is mainly influenced by Himalayan mountain range and South Asian monsoon (NCVST, 2009). There has been increasing trend in the occurrence of natural hazards since 1990s onwards in Nepal (Aryal, 2012) which will further increase the climate change vulnerability. Further, Nepal is susceptible to geological and climate-related disasters due to its topography, which is further exacerbated by lack of effective response mechanisms and strategies to deal with them (WB, 2011). It has low literacy rate (53%), hunger (30-40% of the Nepalese suffered from hunger in 2007), and widespread poverty (WB, 2011). Nepal ranks 157th out of 187 countries in world in terms of human development index (HDI) (Budden, Collins, Rahman, & Salinas, 2012) with districts from eastern and central part having higher HDI than western part of Nepal. Furthermore, districts from western part of Nepal are mostly ranked at the bottom of Socioeconomic and Infrastructure Development Index (CBS, 2003). This indicates that there is development disparity among the districts in Nepal emphasizing need for analysing climate change vulnerability according to districts.

Sub-national level analysis of climate change vulnerability is important as they play important role for implementation of adaptation programs (UNDP, 2010). In this chapter districts are taken as sub-national level for analysis of climate change vulnerability. The study uses the raw climatic data taken from department of hydrology and meteorology of Nepal for the period of 1978 to 2011. Natural disaster data are taken from DesInventar for the period of 1978 to 2011. The total number of natural hazards and the casualties and damages caused by them, taken for the study may not be the actual representative of all the natural hazards but only the reported cases in newspaper and disaster review report. Socio-Economic data are collected from various sources such as National Population and Housing Census 2011 (CBS, 2012), Annual Report Department of Health Services 2010/2011 (MoHP, 2012), Statistical Information on Nepalese Agriculture 2011/12 (MoAD, 2012) and Statistics of Strategic Road Networks 2011/12 (DoR, 2012)

The study uses the integrated assessment approach using indicator to analyse vulnerability. For quantifying the vulnerability, the integrated assessment approach using indicator is one of the most common methods. According to IPCC Fourth Assessment Report vulnerability may be formulated as:

Vulnerability[2] = Exposure + Sensitivity – Adaptive Capacity

A higher adaptive capacity is associated with the lower vulnerability while a higher exposure and sensitivity is associated with higher vulnerability. The vulnerability indicators were standardized to ensure indicators are comparable (Vincent, 2004). The values of each variable are normalized to the range of values in the data set by applying the following general formula:

$$Index\ Value = \frac{(Actual\ Value - Minimum\ Value)}{Maximum\ Value - Minimum\ Value} \quad \text{……..5.1}$$

After standardizing, weight is attached to the vulnerability indicators using PCA. PCA is a technique used to extract few orthogonal linear combinations of variables which most successfully capture information from a set of variables (Gbetibouo & Ringler, 2009). According to Gbetibouo & Ringler (2009), PCA is explained as following.

In this case set of N-variables (X^*_{1j} to X^*_{Nj}) represents the N-variables (indicators) of each households. PCA normalizes each variable by its mean and standard deviation, i.e,

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[2] The study measures the relative vulnerability between different districts of Nepal

$X_{1j} = (X^*_{1j} - X^*_1)/s^*_1$, where X^*_1 is the mean of X^*_{1j} across households and s^*_1 is its standard deviation. The selected variables are expressed as linear combinations of a set of underlying components for each household $_j$:

$X_{1j} = \beta_{11} A_{1j} + \beta_{12}A_{2j} + \ldots + \beta_{1N}A_{Nj}$

$j = 1 \ldots J$

$X_{Nj} = \beta_{N1}A_{1j} + \beta_{N2}A_{2j} + \ldots + \beta_{NN}A_{Nj}$, …………… 5.2

where ,

A is the component

β is coefficient of each variable on each component. PCA solves the problem of indeterminacy by linear combination of variables with maximum variance (normally the first principal component W_{1j}) followed by second linear combination of variables orthogonal to the first with maximal remaining variance, and so on. Technically, the procedure solves the equation

$(R - \lambda nI)\, vn = 0$ for λn and vn,

Where, R is the matrix of correlations between the scaled variables (X)

vn is the vector of coefficients on the nth component for each variable.

Solving the equation yields the following

R (the characteristic roots),

λn (also known as eigenvalues)

vn (associated eigenvectors),

The vns is scaled to total variance to make the final set of estimates, which is done to achieve determinacy of the problem. The system is inverted to get the scoring factors from the model as implied by Equation 2 that gives set of estimates for each of the *A*-principal components:

$A_{1j} = f_{11} X_{1j} + f_{12} X_{2j} + \ldots + f_{1N} X_{Nj}$

$j = 1 \ldots J$

$A_{Nj} = f_{N1} X_{1j} + f_{N2} X_{2j} + \ldots + f_{NN} X_{Nj}$ ………….. (5.3)

Where, f is the factor score

There are number of ways that can be used for retaining principal component score. According to Filmer & Pritchett (2001), the first principal component defines the linear index of all the variables from a set of variables which captures the largest amount of information common to all the variables. While according to Sharma (1996) principal component to be retained from PCA is based on the Kaiser's rule of thumb that is Eigenvalues of component should be more than 1. This will help to capture the highest variability in the data. Further, the heaviest loading of principal component expressed in terms of the variables, is an index for each household which will capture largest amount of information (Abson, Dougill , & Stringer, 2012). Further, Principal component score is based on the following expression:

$$A_{1j} = f_{11}\,(X^*_{1j} - X^*_{1})/(s^*_{1}) + \ldots + f_{1N}\,(X^*_{Nj} - X^*_{N})/(s^*_{N}) \quad \ldots\ldots\ldots\ldots \quad (5.4)$$

Climate Change Vulnerability Indicators

Exposure

Exposure is represented by either long-term changes in climate conditions or changes in climate variability (O'Brien, et al., 2004). Further, communities are often exposed to natural calamities through natural climate variability which does not relate to the future changes in the climate system. Still, climate change may change the nature of those hazards, potentially increasing future exposure (Preston & Stafford-Smith, 2009). According to the IPCC (2001), exposure can be interpreted as, nature and extent of changes a region is exposed to/from the region's climate variables. Furthermore, exposure can be expressed as direct threat and changes in the climatic variables of the area like temperature, precipitation and extreme weather events (Gbetibouo & Ringler, 2009).

Sensitivity

Sensitivity to climate change depends on both the impact from natural phenomenon as well as the social factors. According to Deressa, Hassan, & Ringler (2008), people that suffer more from the impacts of natural hazards will be more sensitive to climate change. Also, people that are more dependent on the natural resource for their livelihood are more sensitive to climate change (Marshall, Fenton, Marshall, & Sutton, 2007). For example people using fuel wood will be affected more if there is decrease in forest resources as consequences of climate change. Further, sensitivity to climate change also depends on human factors like household head, (HHH) disabled people and population density. According to Gbetibouo & Ringler (2009) in the area with high population density, large number of people will be exposed to risks which will need larger assistance.

Adaptive Capacity

Adaptive capacity is determined by different factors like social, infrastructure, wealth, and information. People that have better excess to the information regarding the climate will be better prepared and can better adapt to any changes that may befall (Marshall, et al., 2010). Availability of wealth (remittance and houses in the area) can increase the adaptive capacity of the people as it provides flexibility to change (Marshall, et al., 2010; Deressa, Hassan, & Ringler, 2008). Similarly, the infrastructure like health institutes, road network, school, irrigation, electricity and drinking water plays important role in increasing the adaptive capacity which facilitate in resources availability (Deressa, Hassan, & Ringler, 2008; Marshall, et al., 2010; Nhemachena & Hassan, 2007).

Table 5.1 Indicators of Vulnerability

Vulnerability components	Determinants of Vulnerability	Description of indicators	Unit of measurement	Expected sign
Adaptive Capacity	Social	Literacy	Number	+
		Dependency Ratio	Percentage	-
	Infrastructure	Health Institute	Number	+
		School	Number	+
		Road	Kilometer	+
		Irrigation	Area	+
		Electricity	Number	+
		Drinking Water	Number	+
	Wealth	House	Number	+
		Away population	Number	+
	Information	Radio	Number	+
Sensitivity	Human	Disable Population	Number	+
		Population density	Number	+
		Female household head	Number	+
	Ecological	Use Fuelwood	Number	+
	Shocks due to Natural hazards	Death	Number	+
		Injured	Number	+
		Houses damaged/destroyed	Number	+
		Crop damaged	Hectare	+
Exposure	Climatic Variables	Change in temperature	Coefficient	+
		Change in rainfall	Coefficient	+
	Natural Hazards	Frequency of natural hazards	Number	+

Social capital like literacy rate increases the adaptive capacity and decreases the vulnerability by increasing people's ability to cope with adverse effects (Gbetibouo & Ringler, 2009) while lesser dependency ratio in the household will increase its adaptive capacity (Barr, Fankhauser, & Hamilton, 2010).

GIS being a powerful tool that can store, manage, analyse, manipulate and present spatial data, it is very useful for presenting data in a placed-based format and helps in identification of highly vulnerable area (UNDP, 2010). ArcGIS software is used in this study to map climate change vulnerability of Nepal. The yearly average temperature and rainfall is analysed using data from 91 and 234 stations, respectively, from 1978 to 2011. All the districts do not have the sufficient number of temperature and rainfall stations to represent its temperature and rainfall. So, interpolation by Kriging method is used to represent each districts temperature and rainfall. Kriging method in general is based on spatial dependence which is based on generalized least square regression method and allows for knowing spatial dependence between known points (Goovaerts, 2000) The kriging takes into account spatial autocorrelation which is calculated into semivariance, and plotted against distance in semivariogram for optimal prediction (Park, 2009). The semivariance is calculated as

$$\delta^{(h)} = {}^{1}/_{2}\,[z(a_i) - z(a)] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ 5.5$$

Where, $\delta^{(h)}$ is semivariance between two known points $z(a_i)$ and $z(a_j)$ with distance h. After interpolation of temperature and rainfall data for each year, they are converted to the point data, which later is averaged to get the data of whole districts.

Coefficient from simple linear regression is used to represent change in temperature and rainfall for each district in vulnerability analysis. After analysing the vulnerability, GIS is used for mapping it according to different districts of Nepal.

5.3 Result and Discussion

5.3.1 Results of Climate Variables Interpolation and occurrence of natural disaster

The Figure 5.1 shows the change in temperature in 75 districts of Nepal. The analysis shows that increasing temperature trend is highest in the eastern districts of the country and some western districts like Manang and Mustang. The mean temperature trend is increasing the fastest in Mustang district with the coefficient of 0.195 while it is increasing slowly in Dang district with the coefficient of 0.002. In few districts like Kailali, Banke and Bardia the mean temperature trend is also in decreasing trend and is decreasing fastest in Banke district with the coefficient of -0.038.

Figure 5.2 shows the change of rainfall trend in different districts of Nepal. The highest increasing trend of rainfall is in the eastern districts and some western hilly districts. The rainfall is in decreasing trend in Tarai districts which is taken as the food basket for the country.

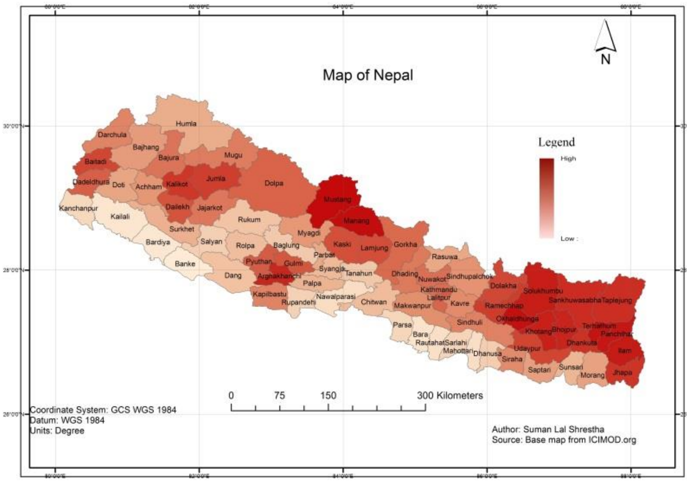


Figure 5.1 Map of Nepal showing temperature trend

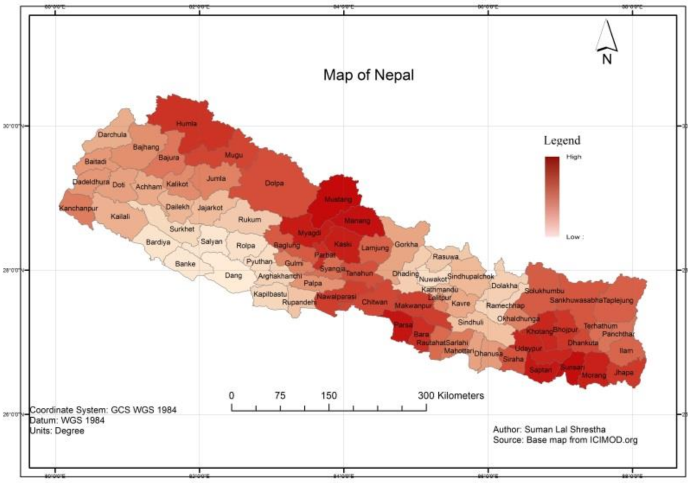


Figure 5.2 Map of Nepal showing rainfall trend

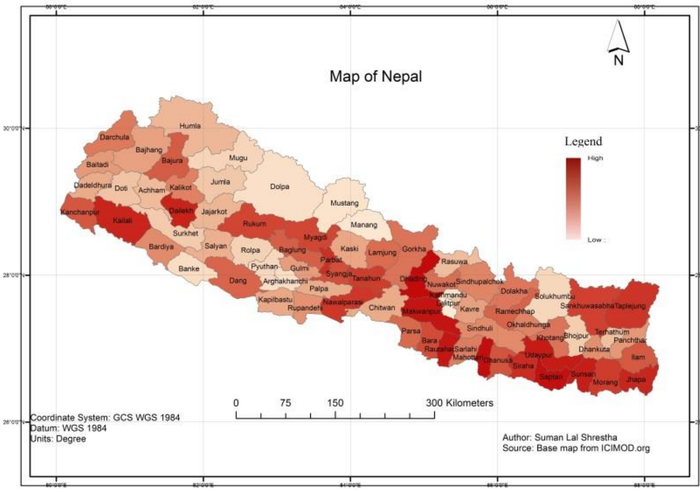


Figure 5.3 Map of Nepal showing natural hazard trend

The decrease in rainfall is very much harmful for agriculture sector, especially when farming is mainly rain-fed in nature. The highest increase in rainfall trend is noticed in Mustang district with the coefficient of 0.83, while the least increasing trend is for Syangja district with the coefficient of 0.005. Further, the highest decreasing trend of rainfall was noticed in Dang district with coefficient of -0.931.

Figure5.3 shows the change in trend of Natural hazards, which is highest in the central part of country mainly and is lowest in some higher mountain district like Dolpa and Mugu. Generally the increasing trend is higher in eastern districts of the country than the western districts. The highest increasing trend is found in Dhading district with the coefficient of 0.945 while the least increasing trend is found in Lalitpur district with the coefficient of 0.024. Overall, the natural hazards are in increasing trend all over the country.

5.3.2 Vulnerability to Climate Change in Nepal

Table 5.2 shows the weight of the variable for adaptive capacity, sensitivity and exposure from PCA. PCA shows six components having Eigen value greater than 1 and accounting for 81.99% of total variance. The first principal component (PC1) has the highest variance around 44% (Figure 5.4).

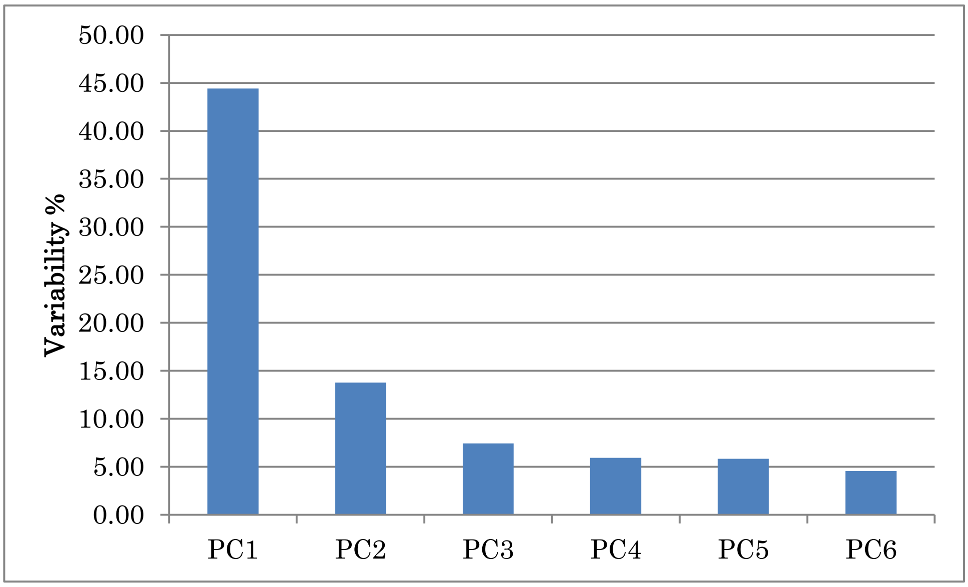


Figure 5.4 Principal component having Eigenvalue more than 1

Table 5.2 Weight of variables from PCA

Component	Variables	Weight	Component	Variables	Weight
Adaptive Capacity	Health	0.2024	Sensitivity	Disability	0.2865
	Literacy	0.3049		Fuel Wood	0.2815
	Road	0.5266		Population density	0.2365
	Irrigation	0.2818		Female Household Head	0.2917
	Drinking Water	0.3091		Deaths	0.3581
	Electricity	0.2935		Injured	0.5953
	Radio	0.2940		Houses destroyed	0.4777
	House	0.3067		Crop damaged	0.3301
	Away population	0.2801	Exposure	Frequency	0.3973
	Dependency ratio	0.4095		Temperature	0.3673
	School	0.2779		Rainfall	0.6953

The heaviest loading from PCA is used as weight for the variables. It is seen that adaptive capacity can be categorised as income and infrastructure, education, road and agricultural facilities. Similarly, sensitivity can be categorised as casualties, physical damage, environmental and social. While exposure can be categorised as climate extremes due to rainfall, increasing temperature and natural hazards. Further the principal component scores are shown in Table 5.2.

Exposure

The exposure is highest in Mustang and Dhading district with the score of 1.01 and 0.89, respectively while is lowest in Syangja and Sarlahi district with the score of 0.14 and 0.17, respectively.

Table 5.3 Categorizing different districts according to exposure

Very Low (Below-0.31)	Syangja, Sarlahi, Baglung, Chitwan, Mugu, Palpa, Lalitpur, Kanchanpur, Dolpa, Lamjung, Rautahat, Bajhang, Tanahu, Doti, Jumla, Bajura, Humla, Terhathum, Solukhumbu, Nawalparasi, Gulmi, Dhanusha, Panchthar
Low (0.31- -0.48)	Achham, Dadeldhura, Siraha, Kavrepalanchok, Dhankuta, Ilam, Bhojpur, Gorkha, Baitadi, Bara, Taplejung, Kalikot, Darchula, Makwanpur, Sankhuwasabha, Okhaldhunga, Parbat, Bhaktapur, Kathmandu, Mahottari, Jhapa, Sindhupalchok, Rupandehi, Parsa, Morang, Kailali, Jajarkot
Moderate (0.48 - 0.66)	Kaski, Sindhuli, Rasuwa, Myagdi, Khotang, Surkhet, Rukhum, Rolpa, Dailekh, Sunsari, Udayapur, Saptari, Kapilbastu, Pyuthan, Dolakha
High (0.66 - 0.83)	Arghakhanchi, Manang, Bardiya, Nuwakot, Salyan, Ramechhap, Banke, Dang
Very High Above 0.83	Dhading, Mustang

Kathmandu being the capital of the country has the low exposure, while study districts like Lalitpur has very low exposure and Dolakha has moderate exposure (Table 5.3). Exposure is high especially in the Southern Tarai districts, which is mainly in the western part because of high occurrence of natural hazards (Annex VII). Also, exposure is highest in Mustang and Dhading district which is mainly due to high change in rainfall and high occurrence of natural hazards. Further, exposure is high especially in western districts like Bardiya, Banke, and Dang (Table 5.3).

Sensitivity

Sensitivity is very high in Kailali, Dhading, Jhapa and Sunsari district with the score of 1.55, 1.49, 1.31, and 1.30, respectively which is mainly due to high population density as well as high number of casualties due to natural hazards. Sensitivity is very low in Manang, Mustang, Mugu and Dolpa districts with score of 0.25, 0.28, 0.32, and 0.34 respectively mainly due to low population density. Kathmandu having high population density has the high sensitivity. The study district like Lalitpur has very low sensitivity and Dolakha has low sensitivity (Table 5.4). The sensitivity is mostly low in the mountainous district while moderate to high in Tarai districts (Annex VII). Further, sensitivity is high in the Central and Tarai districts where there is high population density.

Table 5.4 Categorizing different districts according to Sensitivity

Very Low (Below 0.51)	Manang, Mustang, Mugu, Dolpa, Humla, Rasuwa, Myagdi, Solukhumbu, Sindhuli, Jumla, Darchula, Terhathum, Arghakhanchi, Taplejung, Panchthar, Lalitpur, Okhaldhunga, Dadeldhura, Kalikot
Low (0.51- 0.77)	Bhojpur, Sankhuwasabha, Salyan, Bhaktapur, Bajura, Lamjung, Parbat, Sindhupalchok, Rolpa, Nuwakot, Jajarkot, Achham, Doti, Kapilbastu, Parsa, Bajhang, Dolakha, Surkhet, Banke, Palpa, Rautahat, Pyuthan, Ilam, Baglung, Baitadi, Syangja, Kanchanpur, Gorkha, Dhankuta, Gulmi, Bardiya, Sarlahi, Rukhum, Rupandehi, Khotang
Moderate (0.77 - 1.03)	Ramechhap, Bara, Tanahu, Kavrepalanchok, Udayapur, Siraha, Dailekh, Dang, Kaski, Chitwan, Dhanusha, Saptari
High (1.03 - 1.29)	Morang, Mahottari, Makwanpur, Nawalparasi, Kathmandu
Very High 1.29-Above	Sunsari, Jhapa, Dhading, Kailali

Adaptive Capacity

The adaptive capacity of Kathmandu districts is highest with the score of 2.98 while that of Mugu is the least with the score of 0.17 followed by Humla and Dolpa with the score of 0.25 and 0.27 respectively (Table 5.5). Most of the districts have very low to low adaptive capacity. Comparatively, Tarai districts have higher adaptive capacity than mountainous districts (Annex VII). The adaptive capacity is highest in Kathmandu and some district like Jhapa, Morang, and Rupandehi as these districts have high economic transaction of and also has good infrastructure facilities. The reasons for mountainous districts to have less adaptive capacity are their topography as well as lack of infrastructure facilities. Further, it is also seen that adaptive capacity is high in those area where sensitivity is also high. This is mainly because with increase in population density, there will be development in infrastructure and other facilities to meet their demands.

Table 5.5 Categorizing different districts according to Adaptive Capacity

Value	District
Very Low (Below 0.73)	Mugu, Humla, Dolpa, Bajura, Kalikot, Rasuwa, Jumla, Bajhang, Jajarkot, Solukhumbu, Darchula, Myagdi, Manang, Dadeldhura, Achham, Okhaldhunga, Taplejung, Rolpa, Ramechhap
Low (0.73 - 1.29)	Rukhum, Doti, Pyuthan, Terhathum, Parbat, Mustang, Sankhuwasabha, Bhojpur, Salyan, Lamjung, Parsa, Baitadi, Dolakha, Dhankuta, Khotang, Dailekh, Rautahat, Arghakhanchi, Panchthar, Dhading, Nuwakot, Sindhupalchok, Gorkha, Udayapur, Baglung, Gulmi, Bhaktapur, Mahottari, Sindhuli, Bara, Palpa, Kanchanpur, Tanahu, Surkhet, Kapilbastu, Syangja, Siraha, Bardiya, Banke, Kavrepalanchok
Moderate (1.29- 1.86)	Lalitpur, Ilam, Sarlahi, Makwanpur, Saptari, Dhanusha, Kaski, Nawalparasi, Dang, Chitwan, Sunsari, Kailali
High (1.86- 2.42)	Rupandehi, Morang, Jhapa
Very High 2.42 Above	Kathmandu

Vulnerability

Vulnerability to climate change is found to be the highest in western part of the country, especially in mountainous districts. Also vulnerability is high in some of the central districts where there is high exposure and low adaptive capacity. The highest vulnerable district is Dhading with score of 1.36 while the lowest is found to be in

Kathmandu with score of -1.28 (Table 5.6). Districts like Ramechhap, Jajarkot, Rukhum, and Kalikot are found to have high vulnerability with score of 0.77, 0.57, 0.54, and 0.52, respectively (Table 5.6). Dhading is very highly vulnerable because it has very high exposure and sensitivity and low adaptive capacity. Further, majority of the districts that have very low adaptive capacity and high exposure like Ramechhap, Jajorkot, Kalikot, Bajura have high vulnerability.

Table 5.6 Categorizing different districts according to Vulnerability

Value	District
Very Low (Below -0.75)	Kathmandu
Low (-0.75 - -0.23)	Lalitpur, Rupandehi, Chitwan, Morang, Sarlahi, Syangja, Ilam, Palpa, Dhanusha, Sindhuli, Kanchanpur, Jhapa, Baglung, Panchthar
Moderate (-0.23-0.30)	Tanahu, Kaski, Nawalparasi, Bhaktapur, Gulmi, Kavrepalanchok, Terhathum, Rautahat, Siraha, Lamjung, Surkhet, Bara, Gorkha, Dang, Sindhupalchok, Kapilbastu, Bhojpur, Saptari, Solukhumbu, Dhankuta, Sunsari, Sankhuwasabha, Arghakhanchi, Baitadi, Makwanpur, Doti, Bardiya, Taplejung, Dadeldhura, Banke, Parbat, Okhaldhunga, Parsa, Jumla, Kailali, Darchula, Nuwakot, Myagdi, Manang, Achham
High (0.30 - 0.83)	Dolpa, Khotang, Udayapur, Dolakha, Mugu, Humla, Salyan, Mahottari, Bajhang, Rasuwa, Rolpa, Mustang, Dailekh, Bajura, Pyuthan, Kalikot, Rukhum, Jajarkot, Ramechhap
Very High (0.83 Above)	Dhading

Further, vulnerability is less especially in those districts where there is high adaptive capacity like Kathmandu, Rupandehi and Morang. Also, it is seen that vulnerability is high in the western mountainous district (Annex VII) which is mainly due to their low adaptive capability. Further, Lalitpur has low vulnerability while Dolakha has high vulnerability. This result showing the western part of Nepal being more vulnerable is in line with the NAPA report, but the analysis also shows the contrary result in case of Kathmandu as having very low vulnerability. This is mainly due to high adaptive capacity of Kathmandu district. Further, PCA gives weighted index value and reduces congnitive and subjective biases which is limitation in case of NAPA report.

5.4 Conclusion

As the effect of climate change is more pronounced in Nepal, understanding vulnerability to climate change needs to be well understood before introducing any development and adaptation intervention. Since the local authorities play important role in the implementation of strategies for adapting to climate change, this study analyses and produces maps to show district wise climate change vulnerability in Nepal. Results of this study show that climate change vulnerability in Nepal depends mainly on adaptive capacity. It is also seen that natural hazards increases the overall vulnerability. It is observed that western districts are more vulnerable because of low adaptive capacity and higher natural hazards. Especially, districts like Jajarkot, Rukhum and Kalikot from west have the high climate change vulnerability mainly due to low adaptive capacity. In addition, districts like Dhading, where there is high occurrence of natural hazards has the highest vulnerability. So, in order to enhance resilience to climate change in Nepal, it is necessary to prioritize measures which increases adaptive capacity but mitigates natural hazards. For that, it is necessary to map vulnerability using more robust indicators denoting land-use change and topography through the use of satellite images. It is also imperative to understand the disparity of climate change vulnerability even within a district in order to identify social groups, communities, and households who are prone to adverse impact of climate change.

Chapter VI

6. Adaptation to Climate Change

6.1 Introduction

Climate change is a serious global issue which demands prompt response as shown by numerous scientific evidences (Stern, 2006). Agriculture is one of the sector that is seriously affected by climate change, especially in the least developed countries where it is the main livelihood option for vast majority of the people. Any change in weather pattern such as rainfall, temperature and associated natural hazards will have detrimental impact on agriculture. Climate change will affect yield of crops, which will threaten food security and livelihood of the people. Nepal is a sub-tropical and mountainous country where majority of people live in rural areas and are highly vulnerable to climate change. Around 74% of Nepal population engaged in agriculture as their main occupation (MoAC, 2011). Agriculture accounts for about one-third of the gross domestic product (WB, 2011). It is mostly subsistence in nature due to its rain-fed nature, low yield of major crops and rapidly increasing population (Joshi, Maharjan, & Piya, 2011). Some of the major factors that contribute to low yield include soil degradation (caused by over grazing and deforestation), poor complementary services (extension, credit, marketing, and infrastructure) and climatic factors (Devereux, 2000; Alene, 2003; Yirga, 2007).

There are many uncertainties regarding the impact of climate change though there are studies regarding future change in precipitation and temperature. The increase in temperature and irregularities in the precipitation pattern will have impact on environment and socio-economic sectors, like agriculture, forestry, water resources, health and so on (UNFCCC, 2007). The impacts of climate change are expected to become more intense in the near future making it more uncertain under business as usual scenario (Harley, Horrocks, Hodgson, & Minnen, 2008). To cope with the uncertain future, societies need to cope with these changes (UNFCCC, 2007). Further, Harley, Horrocks, Hodgson, & Minnen (2008) states that despite strict stabilizing greenhouse gas mitigations measures, impacts of climate change are likely to be substantial for which countries needs to adapt. Fussel (2007) reasoned that since climate change is mainly anthropogenic, adaptation should be emphasized. He also emphasized that there is a need to focus on adaptation as it can be done at local or national level without being dependent on others' actions like emission reduction or mitigation that will take several decades for its impact.

According to Maddison (2007) adaptation to climate change has two-steps, firstly the farmers have to perceive that there is climate change and secondly they need to act through adaptation. There are studies that have tried to see perception and adaptation to climate change separately. The study done by Admassie & Adenew (2007) in Ethiopia gave information on people's perception of climate change and the adaptation strategies. Also, there have been few researches that have tried to see perception of people to climate change in Nepal and explore adaptive measures to climate change. According to Sharma and Dahal (2011) climate change has forced people to find measures in securing their livelihoods by adapting knowingly and unknowingly to these changes. This study identified the adaptation measures adopted by farmers but did not identify the factors affecting it. Study done by Piya, Maharjan, & Joshi (2012) showed different factors like access to information and extension services which played important role in determining the perception of communities to climate change. The study identified the different factors that affect the perception of the communities but did not consider the factors that determine the adaptation to climate change. Majority of the study in Nepal either analyses how the perception of climate change are formed or how they adapt to climate change but do not consider the factors affecting adaptation of those people that perceive the changes. So the objective of this study is to identify the factors that influence the farmers' perception of climate change and their adaptation to climate change.

6.2 Methodology

There are number of ways for measuring the factors affecting the farmers' perception of climate change and their adaptation. In case of analysis of agricultural technology adoption, Probit and Logit models are the most commonly used, and binary method is used when choices are two and multivariate method is used when choices are more than two (Deressa, Hassan, & Ringler, 2011). For example, Nhemachena & Hassan (2007) employed the multivariate Probit model to analyse factors influencing the choice of climate change adaptation options in Southern Africa. Deressa et al. (2009) used the multinomial Logit model to analyse factors that affect the choice of adaptation methods in the Nile basin of Ethiopia. Piya, Maharjan, & Joshi (2012) used the Probit model to analyze the factors affecting the community perception of climate change in Chepang community of Nepal.

When adoption of a new technology is done through the farmer's choice which is more than one step, models with two-step regressions are used for correcting selection bias created during the decision-making processes (Deressa, Hassan, & Ringler, 2011). For correcting the sample biases they used Heckman Probit Selection model to analyse factors affecting perception of and adaptation to climate change. Also, Yirga (2007) and Kaliba, Verkuijl, & Mwangi (2000) used Heckman's Selection model to analyse the processes of agricultural technology adoption and the intensity of agricultural input use.

6.2.1Empirical model and model variables

According to different literatures it is found that household ability to notice changes in climate will facilitate adaptation (Nhemachena and Hassan, 2007). According to Deressa, Hassan, & Ringler (2011) adaptation is sub-sample to perception of climate change and that adaptation may not be non-random and not necessarily different from the first thus creating a sample selection bias. For correcting the sample bias Heckman Selection model which consists of two equations is used. The first equation is the selection which selects those people that perceive the climate change and second equation is outcome equation which analyses determinants of adaptation strategies. Using maximum likelihood method two equations are simultaneously run as it is more efficient than two-step procedure (Khanal, 2012). To separate these two equations information listen regarding weather is used as an identifier in the selection equation. According to Heckman (1979) maximum likelihood procedure assumes that there is an underlying relationship which has latent equation as:

$Y_1{}^* = \beta X + U_1$ ·· · · · · · · · · · · · · · · · · · (6.1)

$Y_2{}^* = \gamma Z + U_2$ · · · · · · · · · · · · · · · · · · · (6.2)

Where, X and Z are the vectors for independent variables, U_1 andU_2 are errors. The dependent variable Y_1^* is observed only if the observation Y_2^* is observed. Here, Equation 2 is whether a farmer has perceived climate change or not. The outcome model (Equation 1) represents the farmers who have adapted to climate change and is conditional that climate change has been perceived by the same farmers.

In selection equation of Heckman Selection model farmers' perception of climate change is the dependent variable while socio-economic variables are independent variables. Similarly, in case of outcome equation adaptation index, i.e. adaptation practices adopted by the farmers, is the dependent variable while socio-economic variables are independent variables. The weighted adaptation index is created using Principal Component Analysis (PCA) based on number of adaptation practices they choose for adapting to climate change. Description of the people perception to climate change and adaptation practices will be elaborated in the next section. Twelve socio-economic variables are taken as explanatory variables in this model and additional one variable is used as selection variables. These explanatory variables are based on literature review and characteristics of the locality.

Different studies show that socio-economic and demographic factors affect farmers' perception of climate change and their decision for adoption of new technology for adaptation. Studies by Sampei & Aoyagi-Usui (2009) and Akter & Bennett (2009) shows that people who have exposure to mass media have higher probability of being aware regarding climate change damages. The factors like higher income level, gender and membership of groups have positive impact on individual perception regarding climate change (Semenza, et al., 2008; Leiserowitz, 2006). According to Maddison (2007) and Gbetibouo (2009) factors like education, extension service have positive impact on perception of climate change. Piya, Maharjan, & Joshi (2012) showed that access to information and extension services played important role in facilitating the perception of climate change. Also, Hassan & Nhemachena (2008) indicated that factors like access to markets, extension service, credit service and information about adaptation to climate change influences adaptation. The availability of services like extension and inputs will increase the adoption of adaptation strategies as well as help to perceive climate change (Maddison, 2007; Hassan & Nhemachena, 2008; Deressa, et al., 2009; Below, et al., 2012). In this study, distance to market, livestock service centers and road is taken as proxy for the availability of services and inputs which is hypothesized to improve farmers' perception of climate change and adoption of adaptation practices. According to Piya Maharjan, & Joshi (2012) formal education will reduces the ability to perceive the climate change. The impact of household age (taken as proxy for experience) and education on farmers' perception of climate change and their adaptation has a mixed result with literature showing both positive as well as negative result (Nhemachena and Hassan 2007; Hassan and Nhemachena 2008; Deressa et al. 2009). In this study, it is hypothesized that household head age (proxy for experience) and education are likely to help in perceiving climate changes and adaptation. Further, impact of livestock possession, landholding and total income, which is taken as proxy for asset, influences the farmers' perception of climate change and adaptation positively (Gbetibouo 2009; Below et al. 2012). In this study, it is hypothesized that households with higher assets are likely to have more information on climate change and are better able to adapt to various adaptation practices. The information sources like listening to information regarding climate will have positive influence on farmers' perception of climate change (Hassan and Nhemachena 2008; Deressa et al. 2009, Gbetibouo 2009). Further, access to micro credit facilities such as credit and saving will facilitates in adaptation as well as perception by enabling investments as well as providing information (Hassan and Nhemachena 2008; Deressa et al. 2009, Gbetibouo 2009; Below et al. 2012). The variable listening information on radio regarding climate information is taken as identifier in selection variable. It is expected that if the people listen to information regarding climate they will perceive climate change more.

Table 6.1 Variables selected for models

Variables	Mean	Expected sign	
		Adaptation	**Perception**
Dependent			
Adaptation Index			
Perception			
Independent			
Gender (male 1, female 0)	0.7	+/-	+/-
Age (years, continuous)	50.6	+	+
Livestock (LSU, continuous)	1.7	+	+
Landholding (hectare, continuous	0.8	+	+
Education (schooling year, continuous)	2.2	+/-	+/-
Irrigation Land (hectare, continuous)	0.3	+	-
Total Income (NRs, continuous)	151778.9	+	+
Distance to Road (hour, continuous)	0.7	-	-
Distance to Market (hour, continuous)	1.7	-	-
Distance to Livestock Service(hour, continuous)	1.7	-	-
Distance to drinking water (hr, continuous)	0.2	-	+
Micro credit facility (dummy; if has loan/saving 1 otherwise 0)	0.8	+	+
Listen to climate information (dummy; if hear 1 otherwise 0)	0.5		+

6.3 Study Area and household characteristics

Household survey is conducted in Jhyaku, Nalang, and Dalchowki village development committee (VDC) of three districts Dolakha, Dhading and Lalitpur, respectively, in two phases, first in September and October of 2012 and second in December and January of 2012/2013. First phase of survey is conducted to get the socio-economic status of the household while second phase is conducted to get the perception of climate change and their adaptation. The three VDCs are chosen based on occurrence of natural hazards and vulnerability by discussion with the local authority of the respective districts as well as accessibility from Kathmandu.

Jhyaku VDC

Jhyaku VDC lies in the Dolakha district towards 50 kilometre North from the district headquarter Charikot and 2.5 hour walk from Singhati market. The VDC is surrounded by Suri and Shyama in the east, Laduk and Lamidada in the west, Suri in the north and Jugu in the south. The district extends from 27˚40" to 27˚44" North latitude and 86˚10" and 86˚15" East longitude with elevation ranges from 1200 masl to 3000 masl. The VDC covers 3134ha of land and nearest market is Singhati and Maipokhari. The temperature of the VDC varies according to altitude with mean minimum temperature ranges from 0˚C to 3 ˚C while mean maximum temperature ranges from 20˚C to 22˚C with annual mean rainfall of 2000mm (VDCJhyaku, 2012). There are 8067 people residing in 1876 households in VDC with male population of 3674 and female population of 4393 (CBS, 2012).

Nalang VDC

Nalang VDC lies in Dhading district and one of the most prone VDC to natural hazards in the district. The VDC is surrounded by Maidi, Dhola and Muralibhanjyang in the north, Muralibhanjyang and Sunaulabazar in the east, Kampur and Salang in the south and Salang and Maidi in the west. The elevation of district ranges from 550 masl to 1200 masl. The VDC covers 1234ha of total land and Dhading bazaar is the nearest market place. The VDC has seasonal motorable road across all the wards and farming is the primary occupation in the area. The population of VDC is 8067 residing in 1876 households having male population of 3574 and female population of 4393 as of 2010 (CBS, 2012).

Dalchowki VDC

Dalchowki VDC lies in central part of Lalitpur district covering 630ha of land and is bordered by Lele and Nallu VDC in north, Chaughare and Sakhu in the east, Sakhu in the south and Bhattedada in the west. The nearest market is Lele, Chapagaun and Patan city. The population of the VDC as of 2010 is 1167 living under 269 households with 537 male and 630 female (CBS, 2012). The VDC altitude ranges from 1200 masl to 2300 masl. Development of gravelled road across the wards of VDC has gained some momentum recently but all the parts of the VDC are still not connected by the motorable roads. Farming is the primary occupation in the area.

Socio-Economic Characteristics of Households

In total 195 households (Jhyaku 64, Nalang 64, Dalchowki 67) are surveyed in three VDCs.

Table 6.2 Socio-economic characteristics of the households

Socio-Economic Variable	Jhyaku	Nalang	Dalchowki
Age of HH (Years)	54.67	48.75	48.37
Livestock (LSU)	1.87	1.58	1.72
Total landholding (ha)	1.32	0.73	0.50
Education of HH (Years)	2.11	1.63	2.69
Irrigated landholding (ha)	0.57	0.32	0.004
Total Income (NRs.)	63995	141887	245081
Time taken to reach road (hr)	1.59	0.17	0.44
Time taken to reach market (hr)	2.24	0.54	2.36
Time taken to reach livestock service center (hr)	2.39	0.75	2.00
Time taken to reach drinking water (hr)	0.23	0.21	0.08
Time taken to reach school (hr)	0.27	0.27	0.48
Time taken to reach health post (hr)	1.13	0.55	0.81
Time taken to reach agricultural service center (hr)	2.35	1.02	1.75
Non-farm income (NRs.)	61023	126815	137805

Source: Field survey 2012

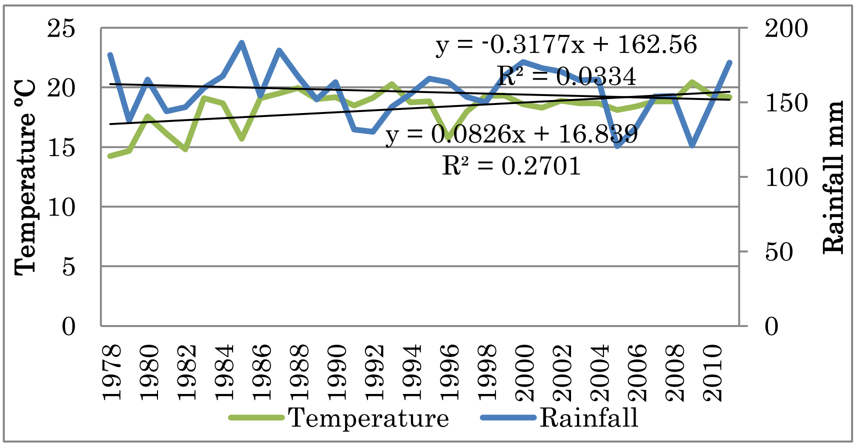
Jhyaku being the largest VDC among three study area has the largest landholding per household compared to Nalang and Dalchowki. Education of household head is very low in all the VDC. Among three VDCs education is higher in Dalchowki though not much different. Similarly, the total income and non-farm income is higher in case of Dalchowki followed by Nalang and Jhyaku. Further, Nalang being more low lying VDC has better infrastructure facility compared to other two VDCs as seen by time taken to reach the facility. Among three VDC time taken to reach the infrastructure like road, agricultural service center is highest in Jyanku due to its topographical as well as being remote than other two VDCs. Dalchowki though is near to capital city Kathmandu has less infrastructure development than Nalang which is mainly due to it topography. Further, in all the VDCs there are no agricultural or livestock service center and much of the information is provided through non-governmental organization working in their respective areas. Household uses the agricultural and livestock service center facility from nearby area, but very limited services are provided by them. In all the three VDCs there are farmers' group and mothers' group which are helping them by providing micro-credit facilities. Further all the VDCs have community forest group users which are protecting the forest in their respective areas.

6.4 Result and discussion

6.4.1 Climatic trend of study households

It is important to understand the actual climate trend in the study area and how farmers perceive these changes. As there are no meteorological stations in the study area ArcGIS is used for determining the temperature and rainfall of each household. Kriging method is used for interpolation of temperature and rainfall data from 1978 to 2011. Kriging method in general is based on spatial dependence which is based on generalized least square regression method and allows for knowing spatial dependence between known points (Goovaerts, 2000).

Figure 6.1 shows that temperature in all the VDCs are increasing rapidly while rainfall is in decreasing trend. The temperature is increasing fastest in Jhyaku with the coefficient of 0.08 while it is increasing at 0.0505 and 0.0506 in Nalang and Dalchowki, respectively. Rainfall is found to be very erratic in nature in all the VDC and is found to be decreasing fastest in Nalang followed by Jhyaku and Dalchowki with the coefficient of -0.56, -0.32, and -0.07, respectively. The trend analysis shows that all the households are experiencing increase in the climatic extremes as rainfall is erratic in nature with increasing temperature.



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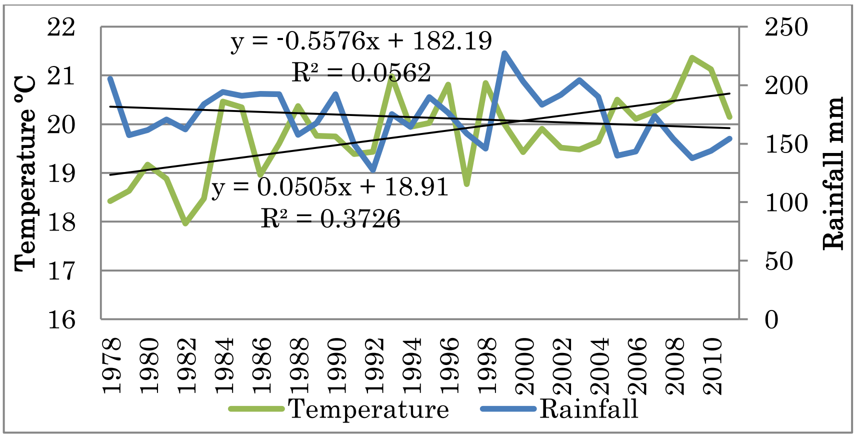

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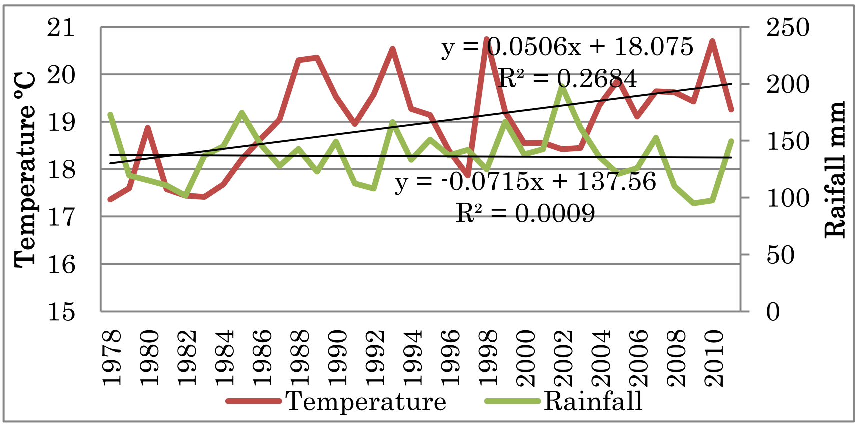

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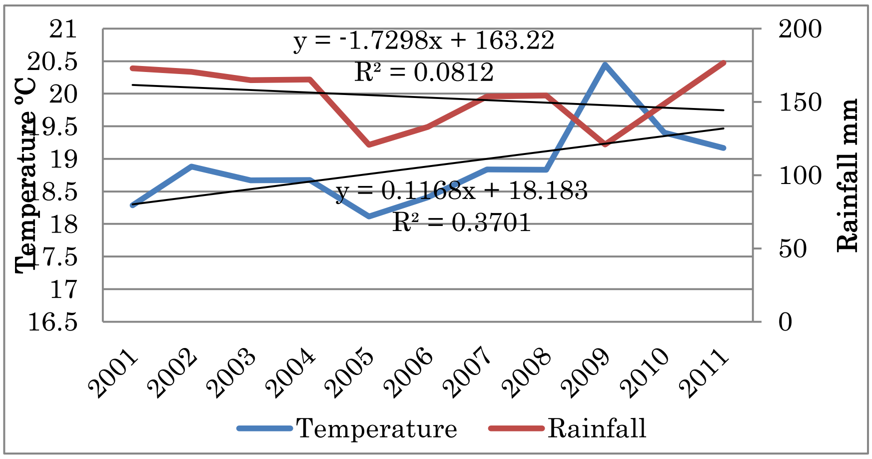
Figure 6.1 Temperature and rainfall trend of Jhyaku (a), Nalang (b) and Dalchowki (c)



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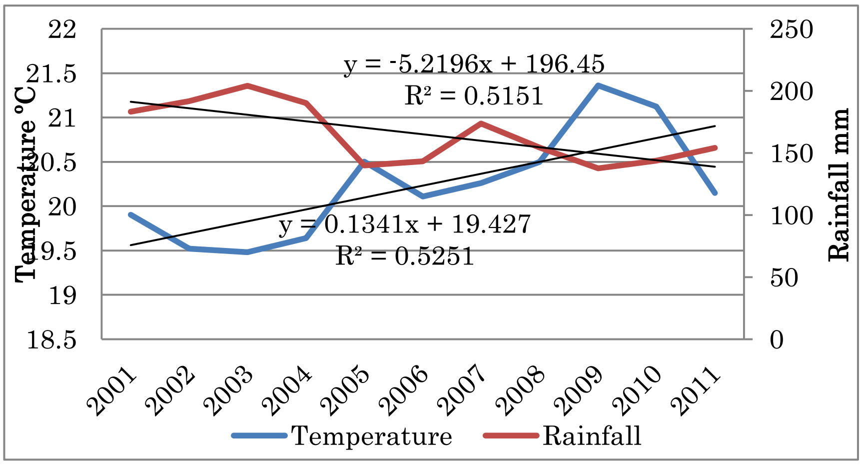

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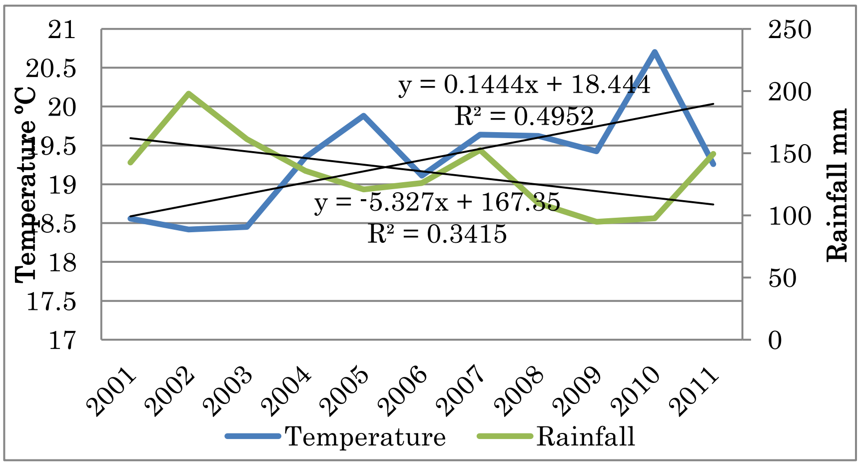


c

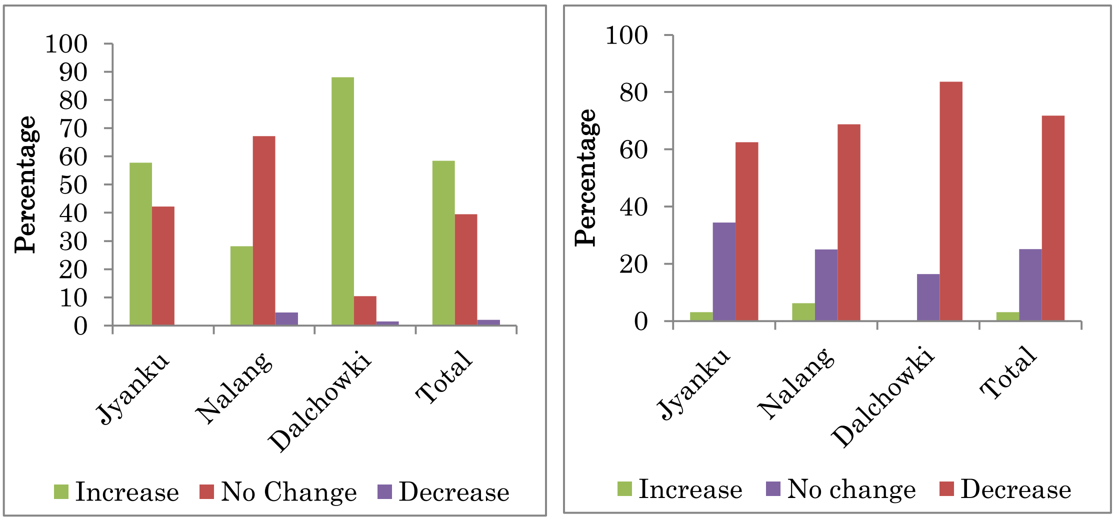
Figure 6.2 Rainfall trend of Jhyaku (a), Nalang (b) and Dalchowki (c) from 2001-2011

Further study also analyses the temperature and rainfall trend for the past 10 years (2001 to 2011) in order to see if there is any change in the recent climatic pattern which might influence the people perception. The study uses the interpolated temperature and rainfall data of households. The analysis shows households are experiencing increase in temperature in all the VDC (Figure 6.2). Temperature is increasing fastest in Dalchowki with the coefficient of 0.14 (R^2 value of 0.49) followed by Nalang with the coefficient of 0.13 (R^2 value of 0.53) and Jhyaku with the coefficient of 0.12 (R^2 value of 0.37). Similarly rainfall is decreasing fastest in Dalchowki with the coefficient of -5.33 (R^2 value of 0.34 followed by Nalang with the coefficient of -5.22 (R^2 value of 0.53) and Jhyaku with the coefficient of -1.73 (R^2 value of 0.08). The direction of increase in temperature and decrease in rainfall is similar to the long term change for all the VDCs. Further in Dalchowki, temperature is increasing fastest for the last 10 years compared to other two VDC. Similarly, rainfall is also found to be decreasing fastest in Dalchowki for the last 10 years.

6.4.2 Perception of Climate Change

Out of 195 surveyed households around 58% of household indicated that temperature is rising, while around 39% stated there is no change and around 2% indicated decrease in temperature. In addition to this, around 72% indicated that there is decrease in rainfall, while around 25% stated that there is no change in rainfall and 3% indicated increase in rainfall in the study area. This shows that majority of the households' perception regarding temperature and rainfall are in line with the temperature and rainfall trend of the area as revealed by the data of local observation of meterological and hydrological station.

In case of Jhyaku VDC, 58% indicated that there is increase in temperature while 42% indicated no change in temperature. Also 63% indicated decrease in rainfall, 34% stated no change in rainfall and 3% indicated increase in rainfall. In case of Nalang VDC, 28% stated increase in temperature, while 67% indicated no change and 5% indicated decrease in temperature. In addition to this, 25% indicated increase in rainfall, 6% indicated no change in rainfall and 69% stated decrease in rainfall. In case of Dalchowki VDC, 88% indicated increase in temperature, 10% indicated no change and 1% indicated decrease in temperature. Further, 88% reported decrease in rainfall, while 12% indicated no change in rainfall. As temperature and rainfall is increasing fastest in the last 10 years, higher numbers of households in Dalchowki are able to perceive changes in temperature and rainfall in line with the trend. The results showed that households are more able to grasp changes in rainfall than temperature as majority of people are able to perceive changes in rainfall in line with the actual trend as agriculture is mainly rain-fed in nature and their main livelihood option. This finding can be said to be in line with the similar findings by Piya, Maharjan and Joshi (2012).



a b

Source: Field Survey 2013

Figure 6.3 Perception of people to temperature (a) and rainfall (b) in study area

Households also identified some of the impacts due to change in the current climatic pattern as shown in Table 6.2. The 53.8% of households in the study VDCs states that monsoon is coming late which is affecting their agriculture season. Further, 80% of households states that there has been decrease in winter rainfall, especially in Dalchowki (94%), and also there has been increase in the drought. In addition to this, 58.5% households also states that there has been increase in the mosquito in the area, especially in Nalang (79.7%). The 49.7% of the households in study area indicate that plantation day has been changed especially of maize by one month (from end of March to beginning of May). The change in plantation day of maize has decreased the production of maize in the study area. Further 26.7% of households states that there has been change in the flowering day few plants like mustard and plump. The change in flowering period will increase the incidence of pest infestation and will impact the agricultural production. There has been increase in the incidence of crop disease especially in vegetables as stated by 37.9% of the households. According to 54.4% of the households, there has been decrease in the availability of forest grass. In addition to decrease in the availability of grass, there has also been incidence of invasion from new species like *Ageratina adenophora* especially in Nalang VDC which they mainly attribute to increasing temperature. Additionally, the people also identified that there has been gradual decrease in the availability of water resources in the area which they attributes to both increase in temperature as well as deforestation.

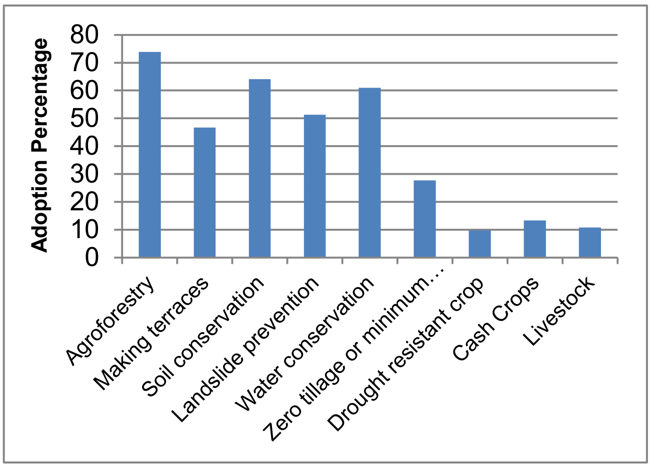
Table 6.3 Household perception of Climate Change Impacts

Events	Jyanku			Nalang			Dalchowki			Total		
	Yes	No	Don't know	Yes	No	Don't know	Yes	No	Don't know	Yes	No	Don't know
Late Monsoon	28.1	71.9	0.0	50.0	46.9	3.1	82.1	17.9	0.0	53.8	45.1	1.0
Decreased Winter rain	82.8	10.9	6.3	62.5	20.3	17.2	94.0	0.0	6.0	80.0	10.3	9.7
Increased Mosquito	42.2	51.6	6.3	79.7	9.4	10.9	53.7	25.4	20.9	58.5	28.7	12.8
Change in plantation day	35.9	64.1	0.0	45.3	54.7	0.0	67.2	32.8	0.0	49.7	50.3	0.0
Change in Flowering day	29.7	70.3	0.0	21.9	78.1	0.0	28.4	71.6	0.0	26.7	73.3	0.0
Increase in Disease	34.4	65.6	0.0	43.8	54.7	1.6	35.8	64.2	0.0	37.9	61.5	0.5
Decrease in forest grass	59.4	40.6	0.0	56.3	42.2	1.6	47.8	25.4	26.9	54.4	35.9	9.7

Source: Field Survey 2013

6.4.3 Adaptation practices in the Study Area

This section of paper deals with the various adaptation practices that households are adopting in their farming activities. Since the mid hills are prone to natural hazards like landslides, soil conservation practice is a must (Piya, Maharjan & Joshi, 2012). Also climate change will have significant impact on water resources, so water conservation practices are a must for adapting to climate change as also identified by the households. Based on these two adaptation practices, surveyed households identified 18 different types of adaptation practices. It is seen that around 90% of the households are adopting at least one of the adaptation practices and around 10% of households did not have any adaptation practices. The 18 different adaptation practices are categorized into 9 different adaptation practices in this study. The most common practice that most of the households implemented is agroforestry (74%), since there has been decrease in the availability of grass in the forest as well as for prevention against soil erosion. Followed by this few of the adaptation practices that households implemented are soil conservation (64%) by planting legumes and covering soil from erosion, water conservation (61%) by building water tank, rain water harvesting. The reason for high number of households practicing water conservation practices is mainly due to scarcity of water due to erratic rainfall and increase temperature. It is seen that prioritizing livestock (11%) and drought resistant crop (10%) are the least favoured adaptation practices as there has been decrease in the availability of grass in the forest.



Source: Field Survey 2013

Figure 6.4 Adaptation practices adopted by households

Most of the adaptation practices identified by the households are traditional practices which are in response to changes in their daily life due to climatic and non-climatic factors. Further these practices are based on local knowledge and are event specific in nature. The common barriers for adoption of adaptation practices identified by the households are lack of knowledge, financial sources and water resources.

6.4.4 Socio-economic Factors Affecting Adaptation to Climate Change

For determining the factors affecting perception of and adaptation to climate change Heckman Selection model is run for its appropriateness and the result indicated that the Likelihood test of independence of error terms is accepted (Wald X^2 4.55, with $p = 0.033$).

Also, the likelihood function of Heckman selection model is significant (Wald X^2 19.12, with p = 0.095) indicating high explanatory power.

The result from the regression analysis shows that explanatory variables like landholding, time taken to reach market significantly explains the adoption of adaptation practices as expected except time taken to reach the livestock service. The increase in the unit landholding size will significantly increase the adoption probability of adaptation practices by 0.173 (Table 6.2). The result is in line with the argument that with increase in the possession of assets like landholding, there will be higher adoption probability of adaptation practices as they will have better assess to resources (Gbetibouo 2009; Below et al. 2012). Further, unit decrease in time taken to reach the market will increase the adoption probability of adaptation practices by 0.130 (Table 6.2). With decrease in time taken to reach the market the farmers will have more access to market which will increase the adoption probability of adaptation practices. This finding is similar to Hassan & Nhemachena (2008) which states that with increase in access to market, farmers will have more accessibility of inputs and information which will help in adoption of adaptation practices. Also with improvement in the market farmers can diversify their livelihood strategies and also able to increase their income source (IFAD, 2003). With diverse livelihood option and increase income, farmers will have more financial resources which will help in adoption of adaptation practices as financial resource is identified as one of the major barriers for adaptation. Though micro-credit facility does not have significant relationship with adaptation index, the positive relationship shows that it can be one of the sources for improving saving and investment resource of the farmers.

Table 6.4 Result of Heckman Selection model

Variables	Adaptation Model		Perception Model	
	Coefficient	P-value	Coefficient	P-value
Gender	-0.068	0.66	-0.748***	0.01
Age	0.002	0.70	0.013	0.14
Livestock	-0.039	0.54	-0.093	0.28
Landholding	0.173*	0.07	0.061	0.70
Education	0.008	0.70	-0.062**	0.05
Irrigated Land	0.198	0.27	-0.624**	0.03
Total Income	-0.020	0.43	0.139***	0.00
Distance to Road	0.066	0.40	0.213	0.19
Distance to Market	-0.130*	0.10	0.151	0.39
Distance to Livestock service	0.190*	0.06	-0.311	0.14
Distance to Drinking water source	0.003	0.99	2.372**	0.02
Micro-credit facility	0.260	0.17	-0.269	0.47
Listening to weather information			0.669**	0.02
Constant	0.956	0.04	-0.436	0.58

Wald chi (12)=19.12, Log likelihood statistics = -251.52, p=0.085, Likelihood ratio test =4.55, p=0.033, rho = -0.73 sigma = 0.82, lamda = -0.60, No. of observation = 194, censored = 35, unceoncosred = 159

Note: *, ** and *** indicate significance at 10%, 5% and 1%, respectively.

The time taken to reach the livestock service center with adoption of adaptation practices is not as expected. This is mainly because there is no livestock service center in the study area and also services provided by nearby VDCs are not adequate. In addition to this, there are non-governmental organizations (NGOs) working in agriculture and livestock services which provide information and knowledge for adaptation in the study areas. As expected time taken to reach drinking water source, information heard about weather in radio and female are significantly more likely to perceive changes in climate having coefficients of 2.372, 0.669 and -0.748, respectively (Table 6.2). Listening to weather related information plays important role for farmers to perceive the change in the climate, as seen in case of Deressa et al. (2009) and Deressa, Hassan, & Ringler (2011). The result also indicates that female will perceive change in climate more than male. This is mainly due to the fact that female are responsible for household chores like fetching the drinking water especially in rural area of Nepal. So, if there is water scarcity due to changing climate they need to travel far and will perceive change in climate better. Also with increase in the time taken to reach the drinking water source, the probability of perceiving climate change increases. As expected farmers having facility of irrigation will perceive less about the climate change (having coefficient of -0.613). As farmers have irrigation facilities they will be more resilient to climate change and hence will care less about it which is in line with the study done by Gbetibouo (2009). Further, as expected any unit increase in the income of farmers will increase the probability of farmers perceiving climate change by 0.138 which is in line with Semenza, et al. (2008). With increase in the income level farmers will have more access to information, inputs and resources for adopting new adaptation practices. In contrary to the expected result education has negative relation with the perception of climate change (having coefficient of -0.061). This may be because with increase in education level people will have more opportunity to work in different sectors and have diverse livelihood strategies, so they will pay less attention to climate (Piya, Maharjan, & Joshi, 2012).

6.4 Conclusion

Understanding the actual climatic condition and the perception of farmers in the area is important as they have to adapt to the changing condition. The temperature is in increasing trend where as rainfall is in decreasing trend in the study area. Farmers are more sensitive to notice change in the rainfall than change in temperature. Eighteen different adaptation practices (categorised to nine) are identified which are being practised by farmer to adapt to climate change. It is seen that majority of the farmers adopt locally available practices like agroforestry and soil conservation strategy to prevent against natural hazards like landslide, soil erosion. Also another important adaptation strategy that farmers are adapting more is conservation of water by building water tanks and rain water harvesting to cope with water stress during the dry season.

The study uses the Heckman Selection method for analysing the factors guiding the farmers' perception of climate change and their adaptation. The analysis shows that for farmers to adapt to climate change they first need to perceive the change. The result indicated that listening to weather information, time taken to reach drinking water source, female, total income have positive relationship with the farmers' perception of climate change. Farmers' adaptation practices are determined by the factors like landholding and time taken to reach market. This result indicated number of measures to be considered while planning any adaptation program in the area like investing for increasing the income and other assets, developing access to market. Also, there is need to raise the awareness of farmers to climate change by providing information regarding the climate for them to perceive the change which will help in adoption of adaptation practices. Finally for farmers to adapt to climate change, developmental plans along with the information and awareness regarding climate change should be emphasized.

Chapter VII

7. Climate Change Vulnerability and Resilience of Farmers

7.1 Introduction

Climate change is posing challenges to human as well as natural system especially in the least developed countries. The impact of climate change differs according to different regions and environmental condition. The developing countries are more vulnerable to climate change as they lack resources for adaptation (UNFCCC, 2007). Vulnerability is not only dependable on the effect of climatic stress but also on socio-economic structure, which mainly contributes to adaptive capacity and sensitivity (Tesso, Emana, & Ketema, 2012). There has been number of studies regarding vulnerability in different sectors such as water, agriculture and taking different aspect such as socio-economic, environmental and so on. To understanding local level vulnerability, there is need to take account the household level vulnerability which will help to tackle climate change problems by better understanding their needs (Tesso, Emana, & Ketema, 2012). On the other hand resilience to climate change is important issue to understand the farmers' ability to deal with the climatic stresses and disturbances. The study uses the integrated assessment approach which combines both socio-economic vulnerability as well as biophysical vulnerability.

There are different methods and practices for combining socioeconomic and environmental indicators. For first instance it is considered that all indicators of vulnerability has equal importance and thus equal weight (Cutter, et al., 2008). The second approach includes using different weights for different indicators. This approach includes different methods like expert judgment, PCA and so on. Principal component analysis is used in this study as it identifies the similarities and differences in the data (Smith, 2002). The analysis of vulnerability to climate change in this research is based on integrated assessment method taking into consideration of both soico-economic and environmental aspect.

7.1.1 Relation between Resilience and Vulnerability

Resilience and vulnerability are very much interlinked with each other in context of climate change. As climate change is overlying and interacts with non-climatic factors, taking its impact as starting point of analysis has serious limitations (Speranza, 2010). This is mainly due to the fact that the impact of climate change is uncertain, with GCM sending confusing signals and treating mainly the symptoms and not the cause, especially by focusing just the impact (Speranza, 2010). So, for measuring the impact of climate change another approach has to be taken, i.e., vulnerability and resilience approach. So for this we need to understand the relationship between vulnerability and resilience.

According to Turner II (2010) in coupled human-environment systems resilience and vulnerability at its fundamental level constitute different but complimentary framing. The vulnerability tries to identify the most affected negatively of system to disturbances while resilience tries to identify the characteristics that make systems more robust to disturbances (Turner II, 2010). Further in coupled human-environment systems framework, resilience is employed as coping capacity in vulnerability research (Turner II, et al., 2003), whereas according to Folke et al. (2002) resilience views vulnerability as an antonym for its label. In addition to this, Adger (2006) states that vulnerability and resilience "have common elements of interest - the shocks and stresses experienced by the social-ecological system, the response of the system, and the capacity for adaptive action." He recognizes three features of social-ecological systems: biological and biophysical processes of natural systems; rules and institutions of social systems; and knowledge, experience, and ethics that bond the social to the natural system. Further, he states that elements of socio-ecological resilience, "the ability to absorb the shocks, the autonomy of self-organisation and the ability to adapt both in advance and in reaction to shocks," will impact vulnerability. According to Folke (2006) resilience considers adaptation, learning, and self-organization and provides adaptive capacity. Also Folke (2006) implies that beyond adaptation resilience also considers responding to a current situation, transformation that implies improving social-ecological systems through adaptive governance. Further resilience and vulnerability also has some differences as given by Speranza (2010):

Resilience factors

- Moderating impacts and outcomes

– Protective factors and processes

Resilience approach

– Reflecting strengths

– Recognising capacities and competencies (actors as competent social agents)

– Reflecting sustained competence / functioning

Vulnerability factors

– Exacerbating impacts and outcomes

– Fostering exposure (risks)

Vulnerability approach

– Emphasises problems or deficits

– Emphasises dependencies on others for survival and development

As there are some differences among the factors and approach, it becomes very important to consider both in climate change researches. Also, the literature on vulnerability and resilience can give insights which are very important for adaptation and mitigation to climate change.

7.1.2 Importance of assessing vulnerability and resilience at local level

It is important to assess vulnerability and resilience at local level as impact of climate change will be felt at local level. The assessment of climate change impact at local level offers opportunity to understand how any change in ecosystem has an effect on human communities culturally, socially, economically, and politically (Duerden, 2004). Duerden (2004) describes that human activity will change with their experience of climate change impact felt at local level. In addition to this Smit and Wandel (Smit & Wandel, 2006) describe that human takes action and strategies to reduce vulnerability at the local level or 'community scale'. Further, Duerden (2004) states that “While many prognoses about change are made on a large scale, human activity is highly localized, and impacts and responses will be conditioned by local geography and a range of endogenous factors, including demographic trends, economic complexity, and experience with 'change' in a broad sense”. Also, according to Adger (2006) communities recognize risk or vulnerability in terms of their specific cultural, economic, social, environmental, and political characteristics.

Understanding and assessing vulnerability and resilience from the multi-sector view and combining them is very important for any policy intervention or planning for the adaptation to climate change impact in the local level. According to Wesche and Armitage (2006) communities offer understanding of change in environment based on multiple knowledge systems, including local and traditional knowledge, and how these have impact on their ability to adapt to changes (cited by MacKendrick, 2009). Ford and Smit (2004) describe how indigenous communities of the Arctic that follow traditional lifestyles have been shown to be disproportionately vulnerable to climate change; however, they have also been shown to possess considerable capacity, or adaptability, to address climate change. "Studies that are highly localized can identify community specific concerns that may be overlooked in regional scale analyses and serve as a valuable tool for local empowerment and information exchange" (Duerden and Beasley, 2006 cited by MacKendrick, 2009). Also, it is important to understand impact of climate change at local level due to social differentiation (Ford, Smit, Wandel, & MacDonald, 2006) since the ones that can use resource more efficiently can adapt more to the climate change and be more resilient.

7.1.3 Vulnerability to climate change in Nepal

There are very limited literatures that have focused on understanding local level vulnerability to climate change in Nepal. The study done by Piya, Maharjan & Joshi (2012) states that vulnerability mainly dependent on the adaptive capacity. Similarly, according to Lama and Devkota (2009) adaptive capacity plays crucial role in categorizing the vulnerability of the community or area.

Cases of Chitlang and Namsaling

Vulnerability of Chitlang of Makwanpur district and Namsaling of Ilam district is assessed for conceptualizing how vulnerability differs according to region and community. The objective of this vulnerability assessment is to conceptualize difference in vulnerability of farmers to climate change according to different area and also understand how farmers perceive changes in climate. The study uses the indicator method and assesses based on IPCC definition of vulnerability. The study uses PCA to give weights to the indicators. The assessment of vulnerability in both the study area showed that poorest people are the most vulnerable group and as income increases the vulnerability decreases. Further, it is seen that in Chitlang, vulnerability is high due to higher extreme climate since geography of the district is quite fragile and is prone to floods and landslides. The assessment of vulnerability shows that the adaptive capacity of the different regions depends on different socio-economic variables. In the case of Chitlang, the income from agriculture, landholding, livestock holding and irrigation played a major part in adaptation. While in the case of Namsaling VDC, reach to infrastructure such as roads, health facilities, schools, markets, agricultural services and livestock services played major role in adaptation and their overall vulnerability.

For understanding vulnerability, it is very imperative to acknowledge the perception of households as it determines the adaptation process. It is observed that the majority of households do not have any knowledge regarding the term climate change in both VDCs. But, when asked about how temperature and precipitation are changing in the area farmer do feel some changes on it. In Chitlang, majority of surveyed households do not feel any changes in temperature of summer and winter. But in Namsaling majority of households perceive increase in summer and winter temperature. This difference in perception of two VDCs may be due to households in Namsaling are dependent on farming only while in case of Chitlang they have prospect for other livelihood opportunities being closer to Kathmandu. Further, in Chitlang households perceive that winter temperature has decreased which they attributed to change in micro-climate due to the effect of the Kulekhani hydropower dam. Similarly, regarding perception of changes in rainfall half of the surveyed households do not notice any changes in Chitlang while in Namsaling only majority perceived changes in rainfall pattern. This difference may be due to availability of better irrigation facility in Chitlang than Namsaling. In addition to this, households in study area noticed change in harvesting period of maize which has shifted around one month late. Also farmers noticed change in ripening of fruits 15 days earlier along with broom grass which also ripened earlier. Further, households started to notice mosquitoes in the higher altitude where they were not seen previously.

7.2 Methodology

Resilience and vulnerability is interlined with each other and can be embedded in one another. This means ones component can be embedded into another. So there is need to understand how changes in the climate will have an impact for which we need to consider vulnerabilities. Resilience means reducing the vulnerabilities but it also adds other dimensions of time and dealing with uncertainties (Gitz & Meybeck, 2012). According to IPCC Fourth Assessment Report vulnerability may be formulated as:

Vulnerability[3] = Exposure + Sensitivity – Adaptive Capacity ………7.1

In this study adaptation practices adopted by the farmers are taken as the ability to

[3] The study measures the relative vulnerability among households in the study area.

absorb shocks which they have been practicing for long period. Further vulnerability to climate change will cover the aspect of self-organization and adaptive capacity. Hence resilience is measured as:

Resilience Index = Ability to absorb shocks – Vulnerability ……………7.2

PCA is used to give weights to the indicators. To ensure that high index values indicate high vulnerability in all cases, we reverse the index values by using [1 – index value] for indicators hypothesized to increase vulnerability. The indicators of vulnerability are taken from literature review and shown in Table 7.1.

Table 7.1 Indicators for Vulnerability

Vulnerability components	**Vulnerability Determinants**	**Indicators Description**	**Measurement Unit**	**Remarks**
Adaptive Capacity	Buffering Capacity	**Wealth**		
		Land holding	Hectare (ha)	Higher the value lesser the vulnerability
		Radio/mobile holding	Number	
		Livestock ownership	LSU[4]	
		Agricultural cash income	Rupees	
		Non-agricultural cash income	Rupees	
		Total Income	Rupees	
		Irrigated landholding	Hectare	
		Human Capital		
		Dependency ratio		
		Education	Highest Education of HHH	
		Infrastructure		
		Time taken to reach	Hour	

[4] Livestock Unit (LSU); conversion factor: cattle (0.5), buffalo (0.5), sheep and goats (0.10), pigs (0.20) and poultry (0.01). Source: FAO (2005)

		facilities (road, health post, agriculture services, livestock services, agrovet, market)		Lesser the time taken to reach to these services lesser the vulnerability.
	Self organization	Saving No. of Crops	Rupees Number	Higher the self capacity lower the vulnerability
	Capacity to learn	Perception to climate change		If notices changes vulnerability decreases
Sensitivity	Extreme climate	Frequency of natural disasters Land damaged due to natural hazard Agricultural production damaged due to natural hazard Livestock killed due to natural hazard	Coefficient from trend analysis	Higher the frequency and casualties from natural disaster higher the vulnerability
Exposure	Change in climate	Annual change of temperature Annual change of precipitation	Coefficient from trend analysis	Higher the annual change of temperature and precipitation higher the vulnerability

Households were classified into five different groups depending upon vulnerability for descriptive analysis as:

1. Very High Vulnerable (V.H.V)
2. High Vulnerable (H.V.)
3. Moderate Vulnerable (M.V.)
4. Low Vulnerable (L.V)

5. Very low vulnerable (V.L.V)

Further resilience of household is analysed as a function of absorption of shock and vulnerability. The absorption of shock is taken as function of adaptation index. The adaptation index implies how they are adapting to the current changes after they have absorbed the shocks of natural hazards. Also, households were classified into five different classes based on their resilience as:

1. Very High Resilience (V.H.R)
2. High Resilience (H.R.)
3. Moderate Resilience (M.R.)
4. High Resilience (H.R.)
5. Very High Resilience (V.H.R.)

Determinants of Resilience

Multiple regression analsyis is used to identify the determinants of households' resilience to climate change.

$$Y_j = \alpha + \beta_1 X_1 j + \ldots\ldots\ldots\ldots + \beta_k X_{kj} + U_j \qquad \ldots\ldots\ldots\ldots 7.3$$

Y_j is the level of resilience. The X_{ij} are the explanatory variables for resilience while β are the coefficient of the explanatory variables and α is the constant and U_j error term.

7.3 Result and Discussion

7.3.1 Vulnerability and Resilience of Farmers

The integrated vulnerability assessment approach here focused on both the social as well as climatic factors. As individual differ from each other from perspective of both being affected by climate change as well as socio-economic factors, their vulnerability also differs from households to households. The PCA analysis for vulnerability shows that nine components having Eigen value greater than 1 and accounting for around 67% of the total variance (Figure7.1). The heaviest loading from these nine components are used to give weights to the variables for vulnerability analysis.

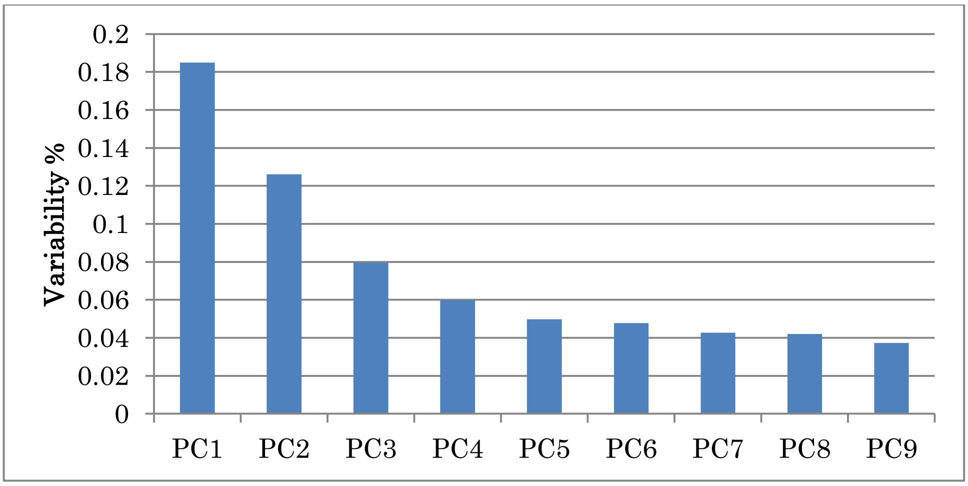


Figure 7.1 Principal component having Eigenvalue more than 1

Further based on the nine principal component scores adaptive capacity can be categorized as infrastructure, income, resources and information, education, asset possession and agricultural diversification, institution, school, perception. Similarly sensitivity can be categorized as sensitivity due to damages to resources and sensitivity due to food security. Further, exposure can be categorized as climatic extremes due to rainfall, and increasing natural hazards with temperature.

Table 7.2 PCA score of indicators for vulnerability

Variables	**Vulnerability PCA Score**
Education (No. of years of education of HHH)	0.4494
Livestock (LSU)	0.3154
Irrigated Land (Hectare)	0.3698
Total Landholding (Hectare)	0.3394
Mobile (Yes/No)	0.3181
Radio (Yes/No)	0.5235
Total saving (NRs.)	0.4746
Off-farm Income (NRs.)	0.179
Total Income (NRs.)	0.3238
Agricultural income (NRs.)	0.3929
Time taken to reach road (Hour)	0.3194
Time taken to reach water source (Hour)	0.417
Time taken to reach school (Hour)	0.4973
Time taken to reach health service (Hour)	0.3869
Time taken to reach agriculture Service centre (Hour)	0.3645
Time taken to reach livestock service centre (Hour)	0.3634
Time taken to reach agrovet centre (Hour)	0.3412
Time taken to reach market (Hour)	0.3083
Dependency ratio	0.2148
Climate change perception (Yes/No)	0.1526
No. of Crops (Number)	0.3118
Temperature (Coefficient)	0.059
Rainfall (Coefficient)	0.403
Frequency of Natural hazard (Total number)	0.1581
Damage to Land (Hectare)	0.2873
Damage to agricultural production (Kg)	0.6242
Livestock lost (LSU)	0.162

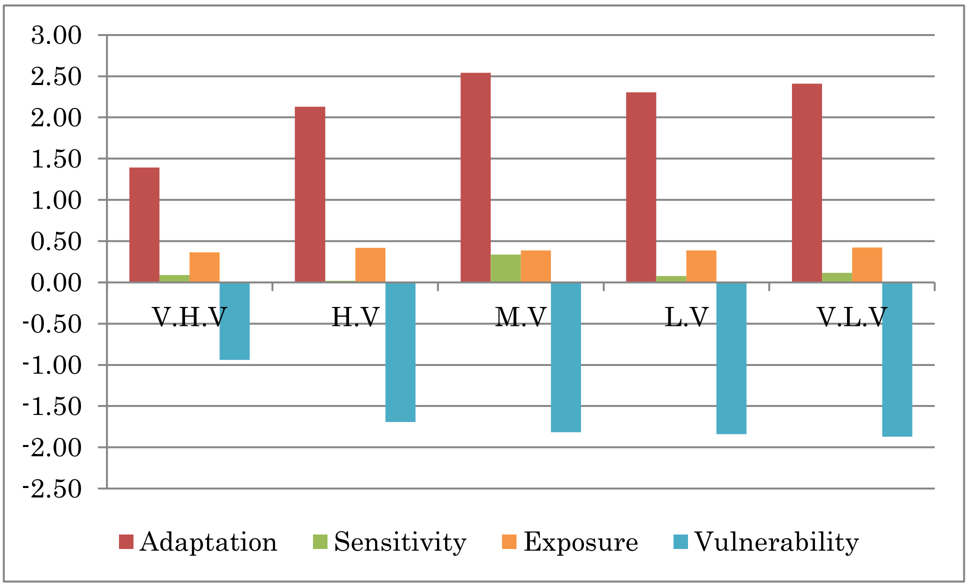


Figure 7.2 Vulnerability of households according to different categorizes

After obtaining the weight from PCA vulnerability is calculated as the function of exposure, sensitivity and adaptive capacity. From PCA it is seen that infrastructure like school and water resources and saving played an important role in increasing the household adaptive capacity as it has higher weights. Further, the study categorized the households into five different groups according to their vulnerability (Figure 7.2). The analysis shows that vulnerability mainly dependent on the adaptive capacity of the households as well as their exposure (Figure 7.2).

In addition to this, the analysis shows that around 22% of households have relatively very low vulnerability while only one household belongs to very highly vulnerable in the study area (Figure 7.3). The majority of households are in the group ranging from low vulnerability to moderate vulnerability.

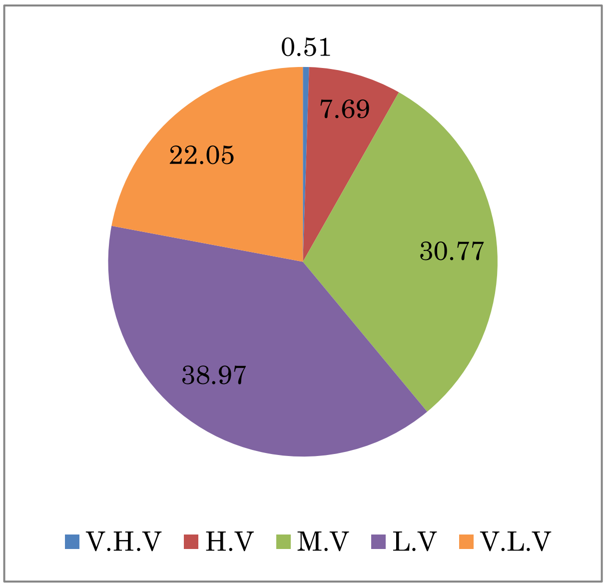


Figure 7.3 Percentage of Households in different category of vulnerability

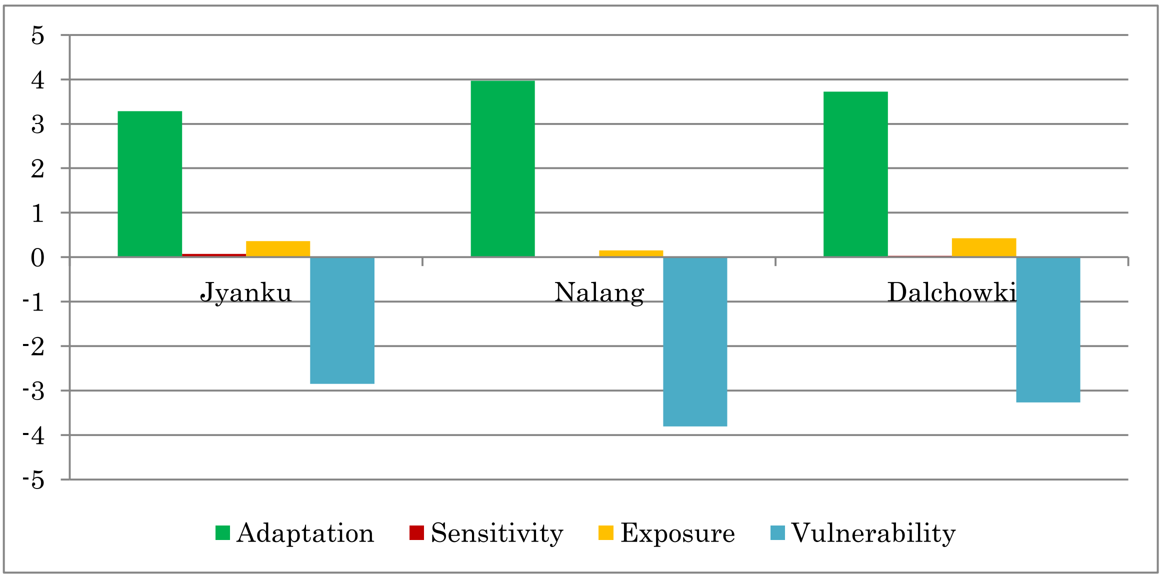


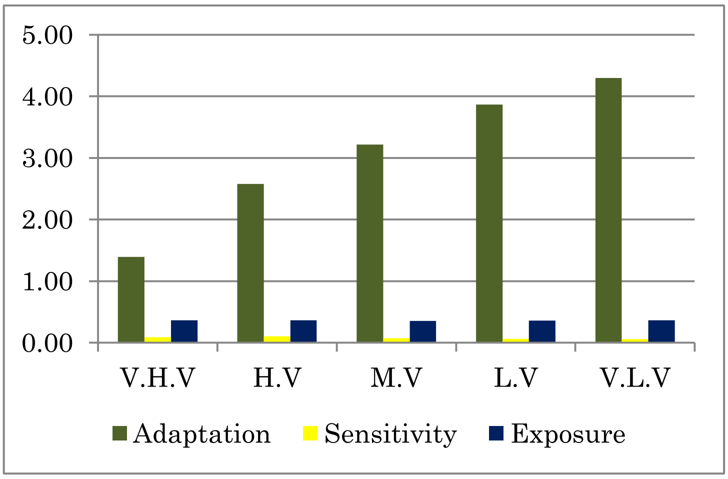
Figure 7.4 Adaptive capacity, exposure, sensitivity and Vulnerability of households according to study VDC

In Figure 7.4, it is seen that vulnerability is highest for Jhyaku since it has the lowest adaptive capacity and high exposure. Nalang has the lowest vulnerability as it has the highest adaptive capacity and the lowest exposure (Figure 7.4). Vulnerability of

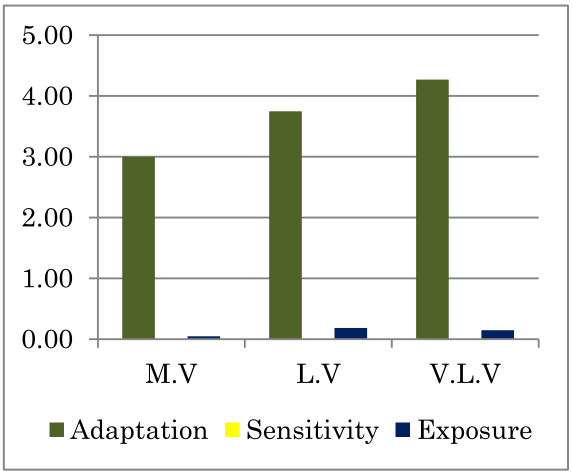
Dalchowki lies between Jhyaku and Nalang as it has moderate adaptive capacity and highest exposure VDCs (Figure 7.4). This further adds to the earlier finding that vulnerability is determined mainly by adaptive capacity, while exposure also plays a crucial role.

In addition to this, households are classified according to vulnerability in each VDC. In Nalang there are no households that fall in the category of very high vulnerable and high vulnerable while in Dalchowki there are no households that fall in cateogory of very very high vulnerability (7.5). The analysis shows that with increasing vulnerability there is steady decrease in adaptive capacity in all the VDCs while exposure also plays an important role.

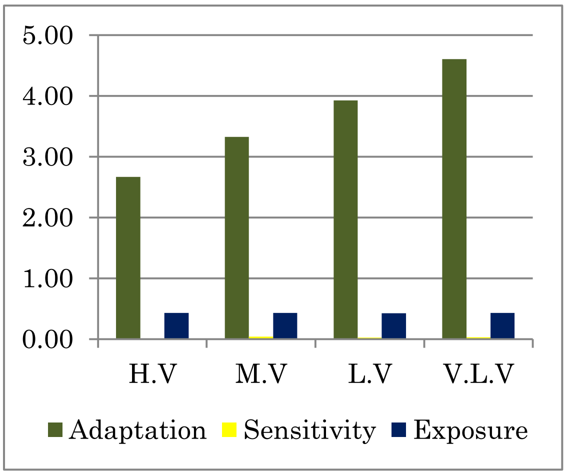
The adaptation index is classified according to different vulnerable groups. It is seen that adaptation index is the highest for households that have modearate vulnerability and increases slightly with decerasing vulnerability. This indicates that housholds adaptation practices are helping farmers to decrease their vulnerability (Figure 7.6). As most of the households are mainly practicing the traditional adaptation practices, with additional burden of climate change they might not be able to cope in the future.



a



b



c

Figure 7.5 Category wise household vulnerability of Jhyaku (a), Nalang (b), Dalchowki (c)

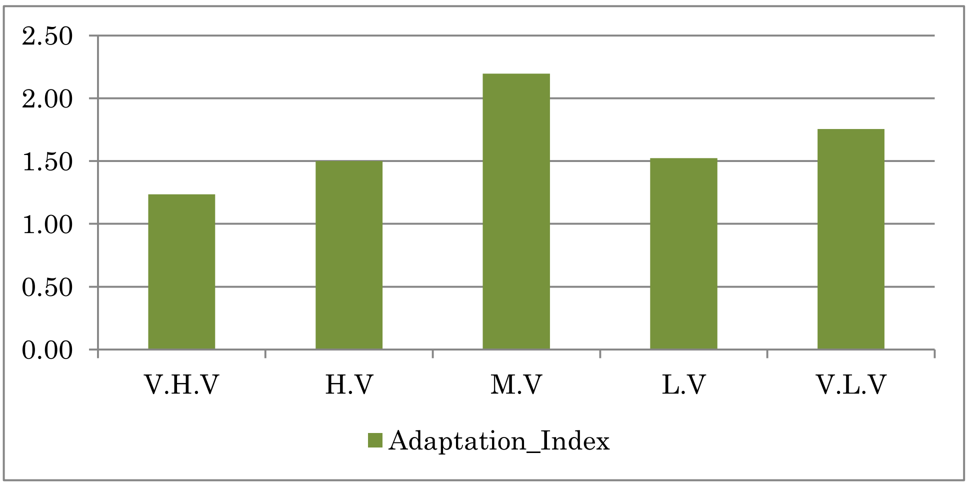


Figure 7.7.6 Adaptation index according to vulnerable groups

Further, analysis shows that only 2.05% of households have very high resilience while around 8.21% has very low resilience to climate change (Figure 7.7). Most of the households belong to the group of low resilience to moderate resilience.

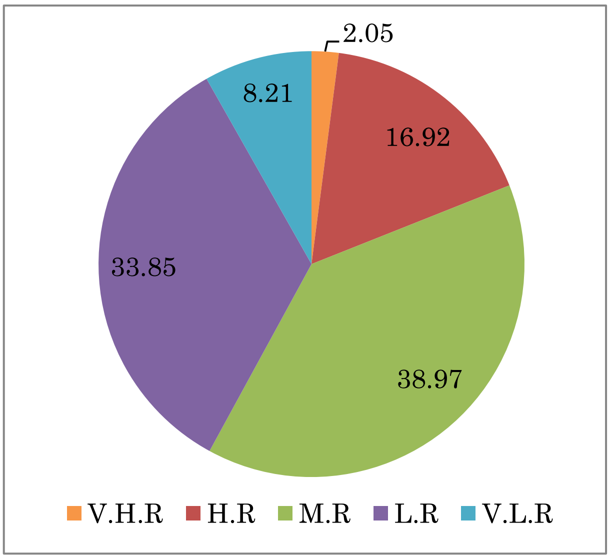


Figure 7.7 Households according to resilience category

In addition to this, households in the study area also stated that they have been able to cope with small scale natural hazards but with recent increase in natural hazard, they are not able to manage it properly. This shows that climate changes has added additional challenges, increasing their vulnerability while reducing their resilience.

7.3.2 Determinants of Resilience

The analysis used the multiple regression analysis to find the determinants of resilience. From the analysis it is found that education, livestock, irrigation, saving, infrastructure like school and market significantly increases the resilience. The increase in education will increase the resilience with the coefficient of 0.04 having p-value of 0.03.

Table 7.3 Determinants of Resilience

Variables	Coefficient	P-value
Education	**0.04**	**0.03****
Livestock	**0.09**	**0.05***
Irrigated Land	**0.28**	**0.01*****
Total Income	0.02	0.26
Total Saving	**0.03**	**0.06****
Climate Change perception	-0.04	0.82
Time taken to reach road	-0.05	0.46
Time taken to reach school	**-0.58**	**0.00*****
Time taken to reach livestock service center	-0.03	0.73
Time taken to reach market	**-0.23**	**0.00*****
Total no. Crops	0.01	0.42
Constant	4.40	0.00

The education will improve the information and knowledge which will help in increasing the resilience of the households. Similarly, livestock possession will significantly increase the resilience with the coefficient of 0.09 having p-value of 0.05 as it gives the opportunity for diversifying their income and as an alternative source of income during hazards. Saving will significantly increases the resilience with the coefficient of 0.03 and p-value of 0.06, as it provides safety net to absorb the shocks. Additionally, any decrease in the time taken to reach the infrastructure like school and market will significantly increase the resilience with the coefficient of -0.58 and -0.23, respectively. Availability of infrastructure close to dwelling will increase their access to information, inputs and resources which will help to absorb shocks as well as decrease the vulnerability.

7.4 Conclusion

The vulnerability of the households is determined mainly by adaptive capacity as it is observed that vulnerability increases especially with decrease in adaptive capacity. Exposure is also important factor in determining overall vulnerability. In addition to this, geographic factors are crucial factors determining the overall vulnerability as impacts of natural hazards and climatic factors differ according to area. This is particularly seen in Jhyaku whose majority of households are more vulnerable than in Nalang and Dalchowki. Further, vulnerability also differs within the same geographic location due to adaptive capacity which is mainly contributed by the socio-economic condition as well as exposure to natural hazards. It is found that adaptation practices is highest for moderately vulnerable households, indicating that households are able to overcome negative affect of hazards to some extend by using traditional adaptation practices. Also with increase in vulnerability, adaptation index decreases slightly. This indicates that climate change has added additional challenges to households by increasing their vulnerability and affecting their ability to cope with it.

Similarly, resilience mainly depends on the socio-economic condition and also on the geographic location. The resilience is significantly impacted by their education, livestock, irrigation, saving, and infrastructure. Resilience significantly increases with increase in the saving which acts as safety net to absorb shocks as well as increase resources and inputs availability. Further, infrastructure plays crucial role in increasing the resilience as it will increase their reach to information as well as inputs. Further livestock possession will help households to diversify their income as well as to absorb shocks.

Finally the analysis shows that analysing only from the perspective of vulnerability will only show the households as mere sufferer but will not capture their capability. Further understand from resilience point of view will also capture their capability to observe those shocks. This emphasizes that for planning any development or adaptation program there is need to understand households' vulnerability as well as their resilience for better planning and implementation.

Chapter VIII

8. Conclusion and Recommendation

Climate change has been pressing issue in the world since 1990s onwards. With the increase in global temperature, there has been number of researches on its science and impact. According to IPCC Fifth Assessment report, scientists are 95% certain that climate change has been primarily due to the anthropogenic activities. Also in international and scientific community there is general consensus that climate change will impact mostly the least developed countries which have limited capacity to adapt to it. Understanding the climate change at country level and planning for adaptation at local level has been a challenging issue as climate change impacts differ from sector wise as well as location wise. So, there is need to understand the climate change impact from the country as well as adaptation characteristics at the local level. Nepal being least developed country is facing challenges from the climate change in different sectors especially agriculture, water resource and energy, climate induced disaster, forestry and biodiversity, public health and urban settlements, and infrastructure as identified by NAPA. As climate change will impact different sectors differently, it is very difficult to assess impact of climate change on all the sectors in one research. So, this study assesses the impact of climate change from the point of natural hazards and households' vulnerability and resilience.

Analysis shows that there has been increase in temperature trend from 1978 to 2011, while rainfall is in decreasing trend and erratic in nature. This change in climatic pattern has further exacerbated the occurrence of natural hazards in the country. The study shows that natural hazards have been increasing rapidly for the period of 1978 to 2011. The increase in natural hazards will further increase the vulnerability of people. Further, establishing the empirical relationship between the occurrences of natural hazards with climatic variable is very important for mitigating the impacts of natural hazards. It is seen that increasing temperature trend will significantly increase the occurrence of heatwave. Also, increasing rainfall especially in the monsoon season will significantly increase the occurrence of flooding while decrease in rainfall will increase occurrence of natural hazards like forest fire and drought. As rainfall has been erratic in nature with some years experiencing sudden increase while some years experiencing very low rainfall, there is increase in natural hazards like flood, forest fire and drought. Furthermore, it is seen that pre-monsoon temperature and rainfall will significantly increase the occurrence of pre-monsoon flood while decrease in temperature in monsoon season will increase the monsoon flood. Also, it is found that flood and landslides are the two major natural hazards that have been occurring over the whole country. There has been increase in other natural hazards also like forest fire which has been one of the major issues for the people but has not been given proper consideration in climate change adaptation programs. This change in climatic variable and increase in the natural hazard will directly impact the households' livelihood by mainly affecting agriculture sector as it is mostly rain-fed in nature.

As climate change impact is more pronounced in Nepal, understanding climate change vulnerability is important before any development and adaptation intervention. Also it is important to understand vulnerability from the perspective of location, since local authorities are responsible for implementing any development and adaptation strategies to climate change. So, this study analyses and produces maps to show district wise climate change vulnerability in Nepal. In the study it is seen that adaptive capacity plays an important role in determining the overall vulnerability of an area. The occurrence of natural hazards further exacerbates the exposure and will increase the vulnerability. The result is found to follow the pattern of district wise vulnerability according to NAPA by showing western part of the country comparatively more vulnerable than eastern part. But, the result also shows the difference in the vulnerability of district more properly. Kathmandu district is found to be least vulnerable district as it has high adaptive capacity while the result of NAPA shows it has most vulnerable. This is mainly due to the factors giving equal weights to exposure, sensitivity and adaptive capacity and cognitive errors due to expert judgment. Further in this study, this limitation is refuted by giving weights using PCA.

In addition to this, the study focused on the understanding the perspective of the households to climate change. It is seen that households perceive the changes in the climatic factor but are not aware of climate change terminology. Households are more sensitive to notice change in the rainfall than change in temperature. They have been adapting to these changes through reactive adaptation practices that they are practicing traditionally. Eighteen different adaptation practices are identified which are being practised by farmer to adapt to climate change. It is seen that majority of the farmers adopt locally available practices like agroforestry and soil conservation strategy to prevent against natural hazards like landslide and soil erosion. Also another important adaptation strategy that farmers are adapting more is conservation of water by building water tanks and rain water harvesting to cope with water stress during the dry season. The adaptation practices like prioritizing livestock is least favoured among households as there has been decrease in the availability of grass in forest. Further the study uses Heckman Selection method for analysing the factors guiding the farmers' perception of climate change and their adaptation. The analysis shows there is correlation between perception of farmers and their adoption of adaptation practices. It is seen that information source is important factors for households to perceive any changes in the climatic change. Further, households that are more dependent on climatic factors or whose daily lives are dependent on natural resources perceive more changes in climate. Furthermore, it is seen that households' adoption of adaptation practices are determined by their possession of assets as well as the infrastructure present in the area.

For proper implementation of policy and programs, understanding the local vulnerability and resilience is important as climate change will impact locally. So, households' vulnerability and resilience is analysed. PCA is used to give weights to the indicator. The result shows that households' vulnerability to climate change is determined especially by adaptive capacity and exposure. It is seen that Jhyaku has the highest vulnerability in compare to other two areas which is mainly attributed to lack of adaptive capacity as well as frequent occurrence of natural disasters. In addition, the haphazard constructions of road without giving proper consideration of climate change impact have increases the occurrence of natural hazards. This shows that there is need of proper planning for investing in any infrastructure developmental programs as infrastructure plays important role in increasing adaptive capacity of the households. For example, preparing the area specific vulnerability assessment of infrastructure and vulnerability reduction measures before implementation increase the resilience as well as reduces the vulnerability due to infrastructure. Further, it is also seen that those households that are more affected by the natural hazards are practicing more adaptation practices to cope with the changes. This emphasizes that households are not just mere sufferer but they also have capability to overcome the adverse impacts. But, the analysis also shows that most of households have low to moderate resilience. This is mainly due to addition of new challenges from climate change like increase in the frequency of natural disaster and erratic weather pattern due to which households are not being able to cope with it. In addition to this, resilience of households is significantly determined by the access to market, school as it provide informations to adapt to climate change. Also possession of livestock, irrigation facilities and education significantly affect the resilience as they provide resources, opportunity for livelihood diversification and alternative income source to adapt to climate change.

Overall the study indicated that management of natural hazards like landslide and flood should be given priority to decrease the casualties caused by changing climatic pattern. In addition to flood and landslide, there is need to give emphasis on the mitigation of the forest fire as it has been increasing steadily and also damaging the livelihood options in the rural areas. As impact of climate change differs according to area, there is need to improve the climatic data management for better understanding of impact of climate change in pocket area. Also more focused should be provided for improving the information and knowledge about impact of climate change on social systems at both the district as well as community level. Along with this more emphasis should be given to western part of the country and also increasing the adaptive capacity to reduce vulnerability of an area. Further, steps for identification of potential impact of climate change from the view point of households concerns should be given priority. For example, need for raising the awareness regarding impact of climate change, conservation of water resources, diversification of income source, prevention of natural hazards, providing technical and financial support and so on. One of way to increase the awareness could be incorporate the information regarding climate change in the education system itself. As vulnerability of the households is found to be dependent more on the accessibility to infrastructure, there is need to invest more for its development. Also the developmental programs should also incorporate the impact of climate change before planning and implementation. In addition to this, there is need to understand the local level adaptation capability and their practices for planning and implementation of any climate change policy and programs. For example, mapping the indigenous knowledge about drainage of the rain water during the monsoon season will help in reducing the casualties due to flooding and subsequent landslide. The resilience analysis further emphasizes this point as it shows that those moderately vulnerable households are practicing more adaptation practices. This shows that climate change has added new challenges to households. So we need to understand the local knowledge which will aid in adaptation to climate change and if possible replicate the knowledge in other areas.

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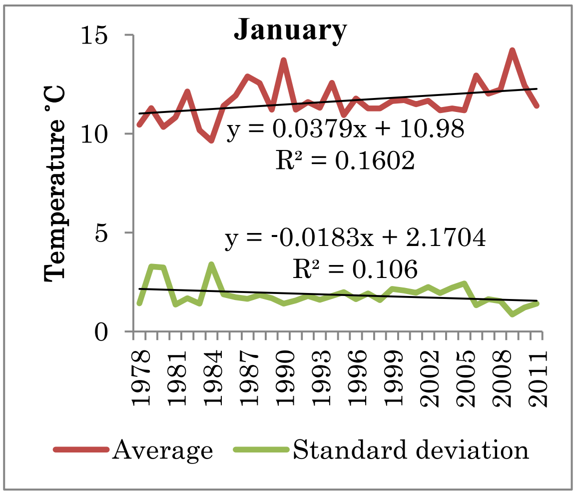
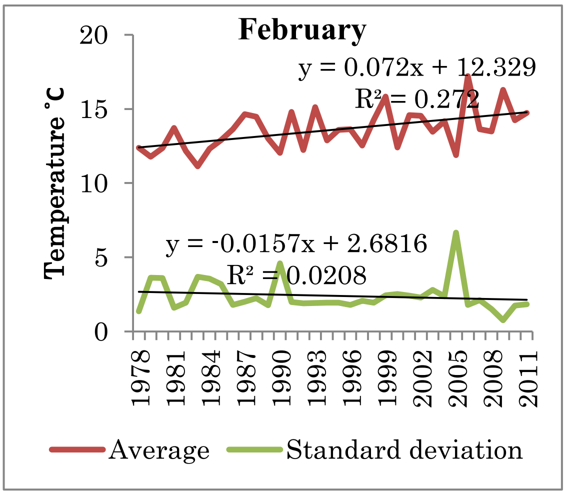
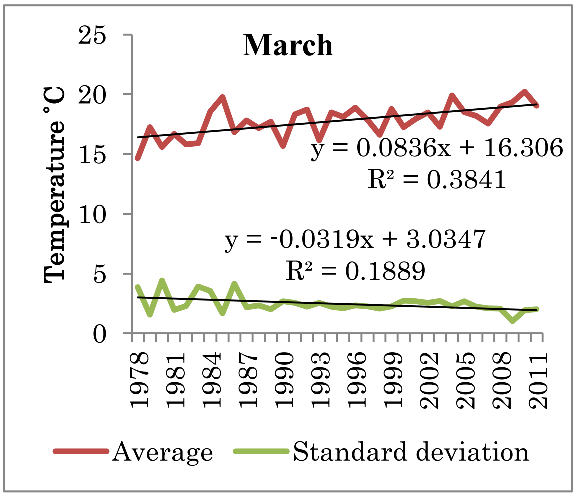
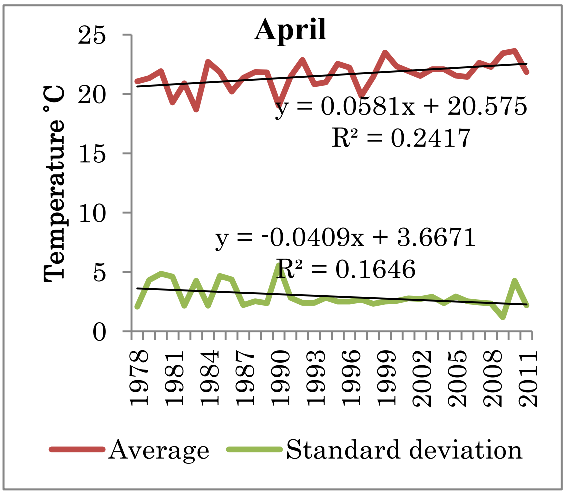
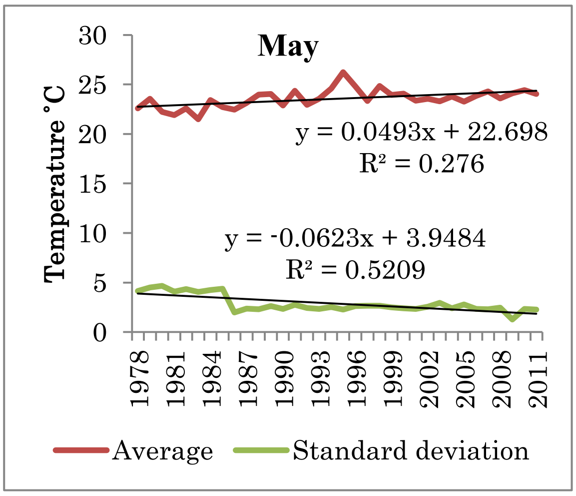
Annex I

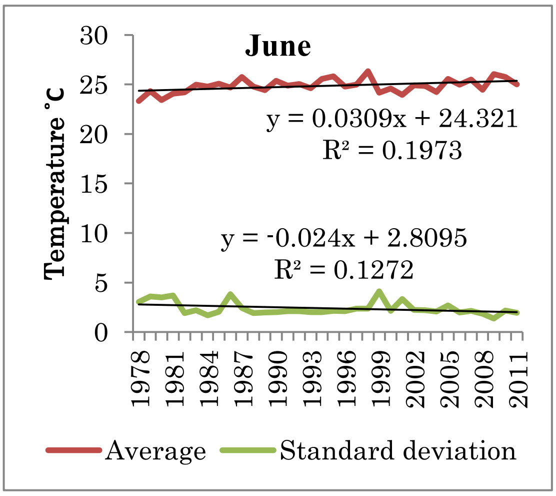

January
Temperature °C
15
10
5
0
y = 0.0379x + 10.98
R² = 0.1602
y = -0.0183x + 2.1704
R² = 0.106
1978 1981 1984 1987 1990 1993 1996 1999 2002 2005 2008 2011
Average
Standard deviation

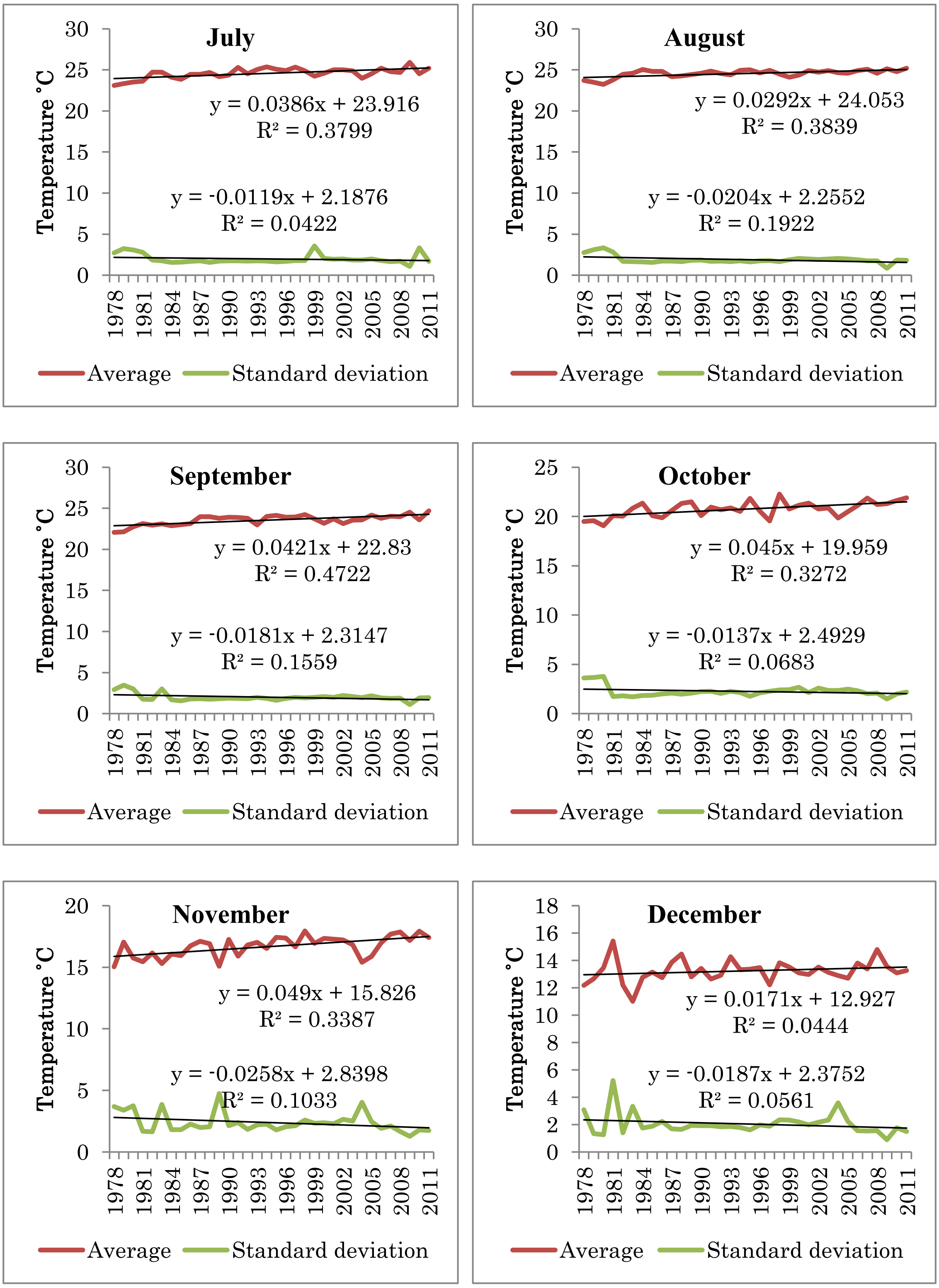

February
Temperature °C
20
15
10
5
0
y = 0.072x + 12.329
R² = 0.272
y = -0.0157x + 2.6816
R² = 0.0208
1978 1981 1984 1987 1990 1993 1996 1999 2002 2005 2008 2011
Average
Standard deviation


March
Temperature °C
25
20
15
10
5
0
y = 0.0836x + 16.306
R² = 0.3841
y = -0.0319x + 3.0347
R² = 0.1889
1978 1981 1984 1987 1990 1993 1996 1999 2002 2005 2008 2011
Average
Standard deviation


April
Temperature °C
25
20
15
10
5
0
y = 0.0581x + 20.575
R² = 0.2417
y = -0.0409x + 3.6671
R² = 0.1646
1978 1981 1984 1987 1990 1993 1996 1999 2002 2005 2008 2011
Average
Standard deviation


May
Temperature °C
30
25
20
15
10
5
0
y = 0.0493x + 22.698
R² = 0.276
y = -0.0623x + 3.9484
R² = 0.5209
1978 1981 1984 1987 1990 1993 1996 1999 2002 2005 2008 2011
Average
Standard deviation

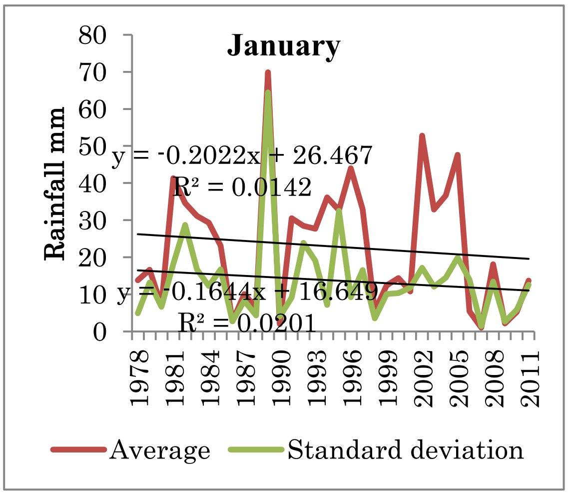

June
Temperature °c
30
25
20
15
10
5
0
y = 0.0309x + 24.321
R² = 0.1973
y = -0.024x + 2.8095
R² = 0.1272
1978 1981 1984 1987 1990 1993 1996 1999 2002 2005 2008 2011
Average
Standard deviation

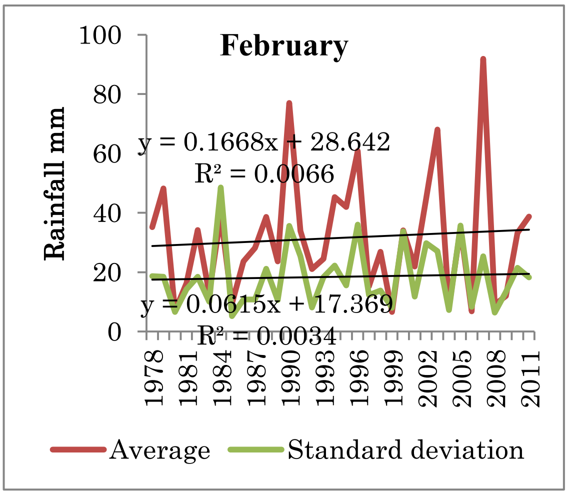


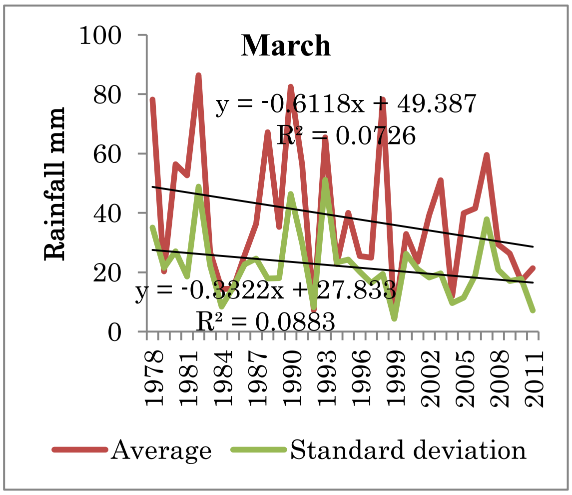
Source: Raw data from Department of Hydrology and Meterology

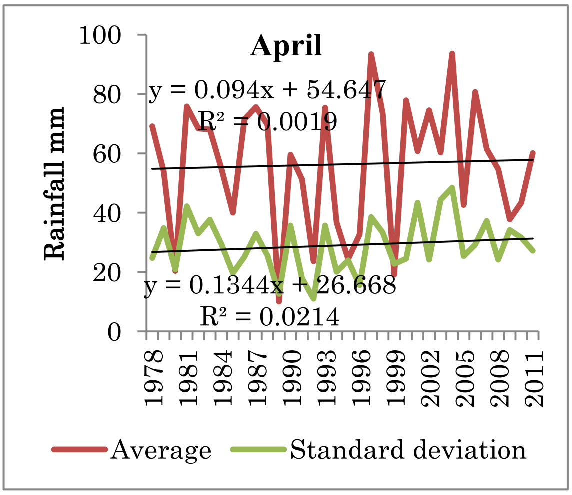
Month wise average temperature and standard deviation trend from 1978 to 2011

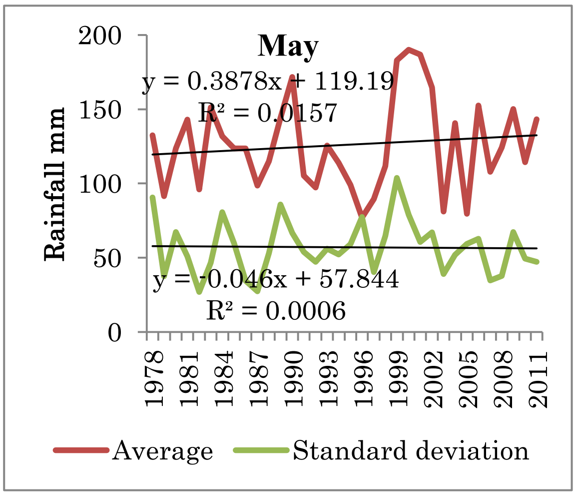
Annex II

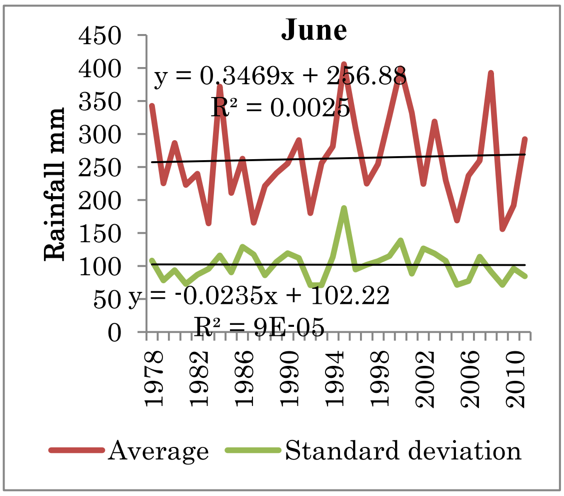

January
Rainfall mm
80
70
60
50
40
30
20
10
0
y = -0.2022x + 26.467
R² = 0.0142
y = -0.1644x + 16.649
R² = 0.0201
1978
1981
1984
1987
1990
1993
1996
1999
2002
2005
2008
2011
Average
Standard deviation

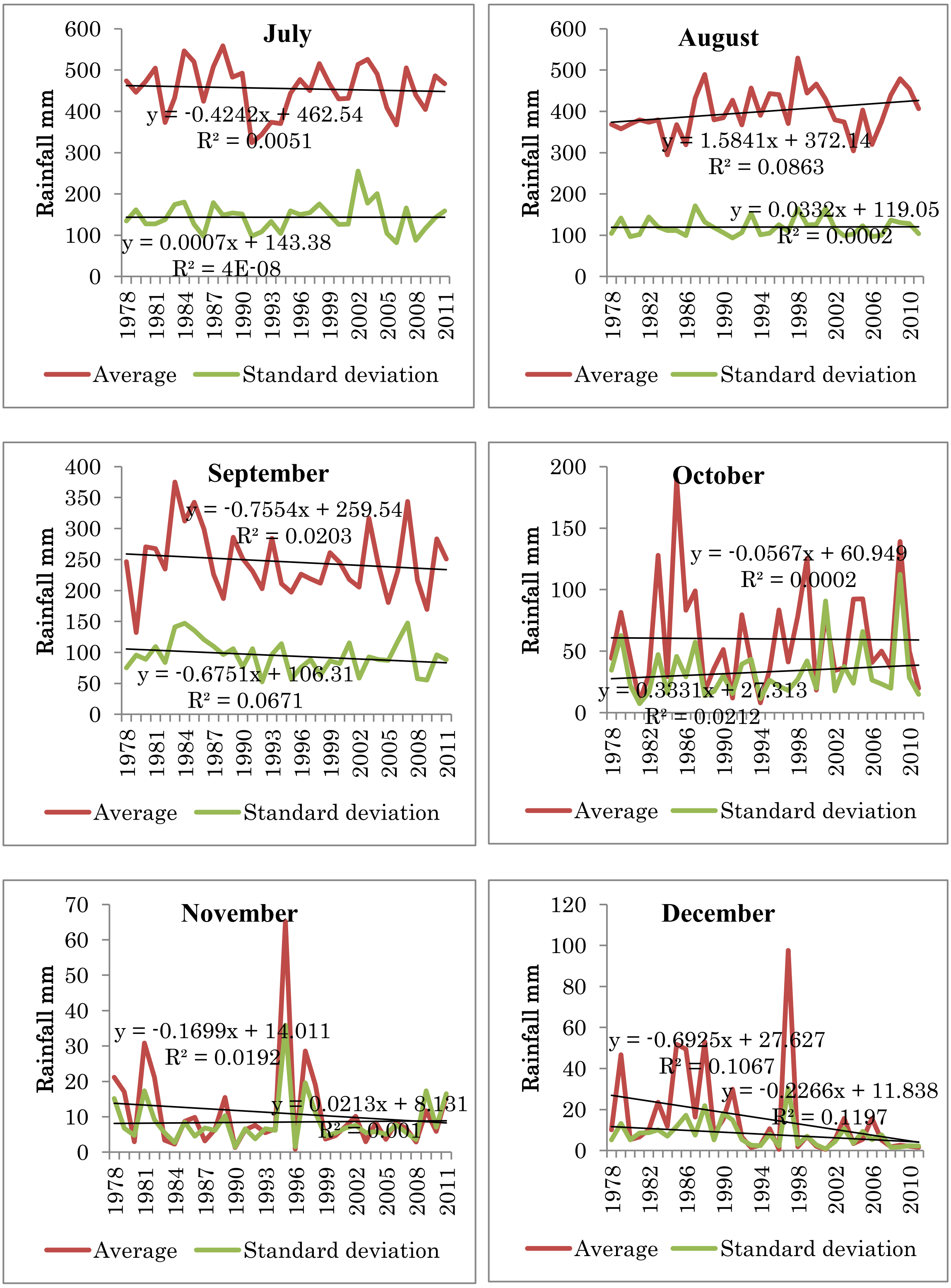

February
Rainfall mm
100
80
60
40
20
0
y = 0.1668x + 28.642
R² = 0.0066
y = 0.0615x + 17.369
R² = 0.0034
1978
1981
1984
1987
1990
1993
1996
1999
2002
2005
2008
2011
Average
Standard deviation


March
Rainfall mm
100
80
60
40
20
0
y = -0.6118x + 49.387
R² = 0.0726
y = -0.3322x + 27.833
R² = 0.0883
1978
1981
1984
1987
1990
1993
1996
1999
2002
2005
2008
2011
Average
Standard deviation


April
Rainfall mm
100
80
60
40
20
0
y = 0.094x + 54.647
R² = 0.0019
y = 0.1344x + 26.668
R² = 0.0214
1978
1981
1984
1987
1990
1993
1996
1999
2002
2005
2008
2011
Average
Standard deviation


May
Rainfall mm
200
150
100
50
0
y = 0.3878x + 119.19
R² = 0.0157
y = -0.046x + 57.844
R² = 0.0006
1978
1981
1984
1987
1990
1993
1996
1999
2002
2005
2008
2011
Average
Standard deviation


June
Rainfall mm
450
400
350
300
250
200
150
100
50
0
y = 0.3469x + 256.88
R² = 0.0025
y = -0.0235x + 102.22
R² = 9E-05
1978
1982
1986
1990
1994
1998
2002
2006
2010
Average
Standard deviation



Source: Raw data from Department of Hydrology and Meterology

Month wise average rainfall and standard deviation trend from 1978 to 2011

Annex III

Definition of natural hazards as given by http://desinventar.org

Coldwave

Drop of atmospheric average temperature well above the averages of a region, with effects on human populations, crops, properties and services.

Drought

Unusually dry season, without rain or with rain deficit. As a whole, these are long periods (months, years, and even decades) typical in limited continental areas or on regional scales.

Flood

Water that overflows river-bed levels ("riverine flood") and runs slowly on small areas or vast regions in usually long duration periods (one or more days).

Forest fire

The event includes all open-air fires in rural areas, natural forests, plains, etc.

Hailstorm

Precipitation of hail. Frozen raindrops of varying sizes that fall violently in the form of hard pellets.

Heatwave

Rise of atmospheric average temperature well above the averages of a region, with effects on human populations, crops, properties and services.

Landslide

All mass movements other than surface erosion of a hillside. This event includes terms such as precipitation of earth, settling, horizontal land thrust, rock falls, (slow or quick) detachment of soil masses or rocks on watersheds or hillsides.

Rains

Precipitation. Includes punctual, persistent or torrential rain, or rain exceeding the rainfall averages of a specific region; also, unusual long rain periods. Rain includes terms such as downpour, cloudburst, heavy shower, deluge, etc.

Storm

Heavy rain accompanied by strong winds and/or electric discharges (lightning).

Snowstorm

Anomalous fall and accumulation of snow, especially when it occurs in zones not subject to seasonal changes. This term refers to events where precipitation exceeds the average multi-annual values, causing especially serious effects.

Thunderstorm

Occurrence of atmospheric static discharges (lightning) with effects on people, cattle, domestic properties, infrastructure (power networks, for example, causing blackouts), and the environment. It is different from “storm” in that thunderstorms are not accompanied by rain and gusty winds. The key differentiator is that damage is caused explicitly by lightning.

Annex IV

Seemingly unrelated regression between climatic variable and natural hazard

Equation	Obs	Parms	RMSE	R-sq	chi2	P
Coldwave	34	3	22.79	0.38	20.64	0.00
Flood	34	3	72.29	0.38	20.99	0.00
Forest fire	34	3	6.74	0.38	21.02	0.00
Drought	34	3	5.94	0.43	25.95	0.00
Hailstorm	34	3	14.34	0.29	14.09	0.00
Landslide	34	3	72.38	0.37	19.85	0.00
Thunderstorm	34	3	19.99	0.62	55.25	0.00
Heatwave	34	3	1.53	0.41	23.54	0.00
Rains	34	3	5.75	0.33	16.90	0.00
Snowstorm	34	3	6.05	0.38	21.13	0.00
Storm	34	3	5.49	0.04	1.27	0.74

Result of Effect of climate variables on occurrence of natural hazards

Variables	Coldwave		Flood		Forest Fire		Drought		Hailstorm		Landslide		Thunderstorm		Heatwave		Heavy rain		Snowstorm		Storm	
	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value
Year	2.04	0.00	5.81	0.00	0.28	0.09	0.12	0.42	1.29	0.00	5.48	0.00	2.62	0.00	0.07	0.08	0.47	0.00	0.65	0.00	0.09	0.49
Rainfall	-0.04	0.90	1.61	0.10	-0.18	0.05	-0.39	0.00	0.05	0.78	1.58	0.11	-0.31	0.24	0.00	0.88	0.12	0.11	0.00	0.96	0.04	0.60
Temperature	-8.08	0.54	-12.50	0.77	5.29	0.18	0.03	0.99	-16.80	0.04	-6.00	0.89	-2.38	0.84	1.73	0.05	-3.64	0.28	-7.28	0.04	0.12	0.97
Constant	-3879.35	0.00	-11474.30	0.00	-642.37	0.02	-175.09	0.48	-2231.41	0.00	-10961.45	0.00	-5108.08	0.00	-165.21	0.01	-884.39	0.00	-1149.81	0.00	-191.51	0.41

Annex V

Seemingly unrelated regression between seasonal flood and climatic variables

Equation	**Obs**	**Parms**	**RMSE**	**R-sq**	**chi2**	**P**
Pre-monsoon flood	34	5	1.61	0.60	50.57	0
Monsoon Flood	34	5	65.33	0.46	29.10	0
House destroyed/affected	33	9	3893.215	0.362	18.72	0.0277
Crop Damaged (ha)	33	9	27780.02	0.3858	20.73	0.0139

Relationship between climate variables and casualties and damages caused by natural hazards

Variables	Pre-monsoon flood		Monsoon Flood	
	Coefficient	P-value	Coefficient	P-Value
Year	0.149	0.001	6.36	0.00
Pre-monsoon rainfall	1.092	0.038	10.91	0.61
Pre-monsoon temperature	-0.763	0.527	-82.09	0.09
Monsoon rainfall	0.067	0.004	1.53	0.11
Monsoon temperature	-0.004	0.666	0.13	0.72
Constant	-304.085	0.000	-10960.10	0.00

Annex VI

Number of observation = 75

Number of components = 22

Trace = 22

Rotation: (unrotated = principal) Rho = 1

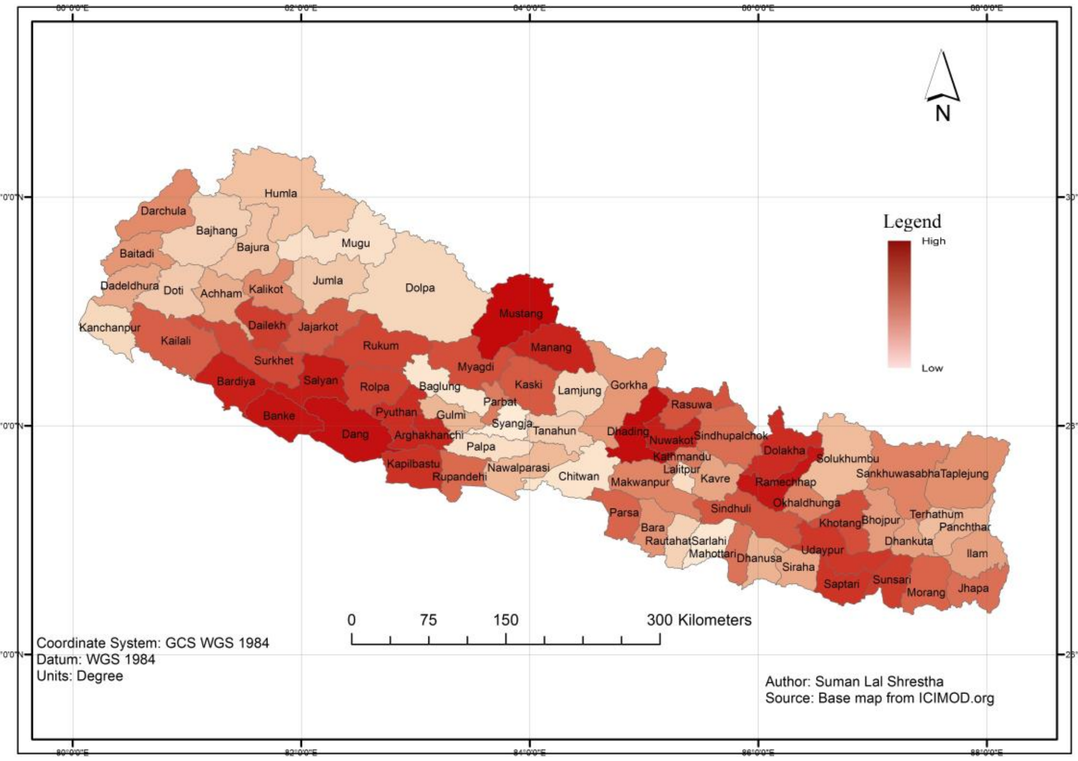
Principal Component analysis of Nepal

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	9.77	6.74	0.44	0.44
Comp2	3.03	1.40	0.14	0.58
Comp3	1.63	0.33	0.07	0.66
Comp4	1.31	0.03	0.06	0.72
Comp5	1.28	0.27	0.06	0.77
Comp6	1.01	0.32	0.05	0.82
Comp7	0.69	0.02	0.03	0.85
Comp8	0.67	0.07	0.03	0.88
Comp9	0.61	0.06	0.03	0.91
Comp10	0.54	0.16	0.02	0.93
Comp11	0.39	0.06	0.02	0.95
Comp12	0.33	0.13	0.02	0.97
Comp13	0.20	0.04	0.01	0.98
Comp14	0.16	0.05	0.01	0.98
Comp15	0.12	0.02	0.01	0.99
Comp16	0.09	0.01	0.00	0.99
Comp17	0.09	0.05	0.00	1.00
Comp18	0.03	0.02	0.00	1.00
Comp19	0.02	0.01	0.00	1.00
Comp20	0.01	0.01	0.00	1.00
Comp21	0.00	0.00	0.00	1.00
Comp22	0.00	.	0.00	1.00

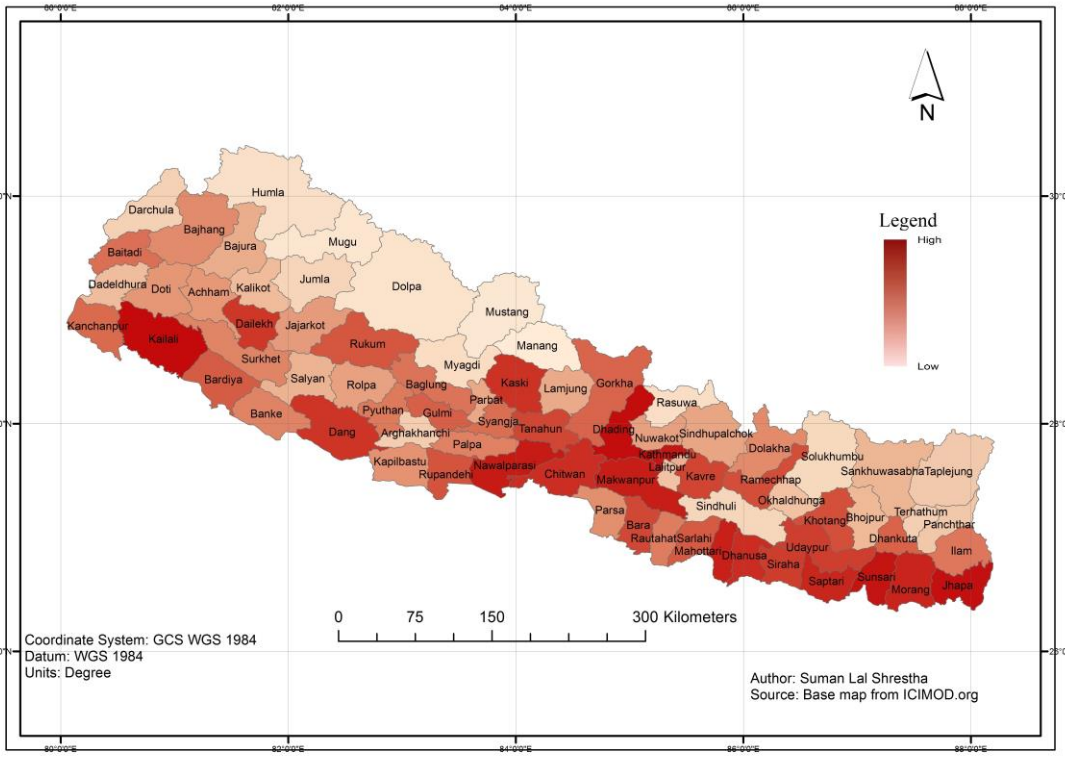
Principal component having Eigenvalue more than 1 of Nepal

Variable	Comp1	Comp2	Comp3	Comp4	Comp5	Comp6
			Adaptive capacity			
Health Institute	0.20	0.18	-0.21	0.03	-0.10	-0.18
Drinking water	0.31	-0.05	-0.08	-0.12	0.03	0.02
Electricity	0.29	-0.18	0.00	-0.13	-0.04	0.10
Radio	0.29	-0.18	0.04	-0.05	-0.09	0.09
House	0.31	-0.10	-0.07	-0.12	-0.02	0.07
Away population	0.28	-0.02	-0.02	-0.01	-0.03	-0.14
School	0.28	-0.02	0.05	0.10	-0.25	-0.03
Literacy	0.16	-0.28	0.30	0.27	0.14	-0.28
Road	0.19	0.13	0.05	0.53	0.07	0.03
Dependency ratio	0.13	-0.31	0.27	0.06	0.41	-0.06
Irrigation	0.20	0.21	-0.24	-0.12	0.28	-0.23
			Sensitivity			
Disable population	0.29	0.13	-0.10	0.07	-0.06	-0.05
Female household head	0.29	-0.17	0.04	-0.02	-0.07	0.07
Injured	0.05	0.19	0.60	0.17	-0.29	0.11
Use Fuelwood	0.22	0.28	-0.06	0.28	0.01	-0.25
House damaged/destroyed	0.12	0.23	-0.01	-0.19	0.48	0.12
Crop damaged	0.11	0.29	0.10	-0.12	0.33	-0.05
Population density	0.20	-0.30	-0.02	-0.26	-0.07	0.24
Death	0.10	0.25	0.27	-0.33	-0.01	0.36
			Exposure			
Frequency	0.10	0.40	0.36	-0.12	-0.03	0.05
Temperature	-0.12	-0.21	0.31	-0.04	0.37	-0.15
Rainfall	0.03	0.00	-0.20	0.46	0.27	0.70

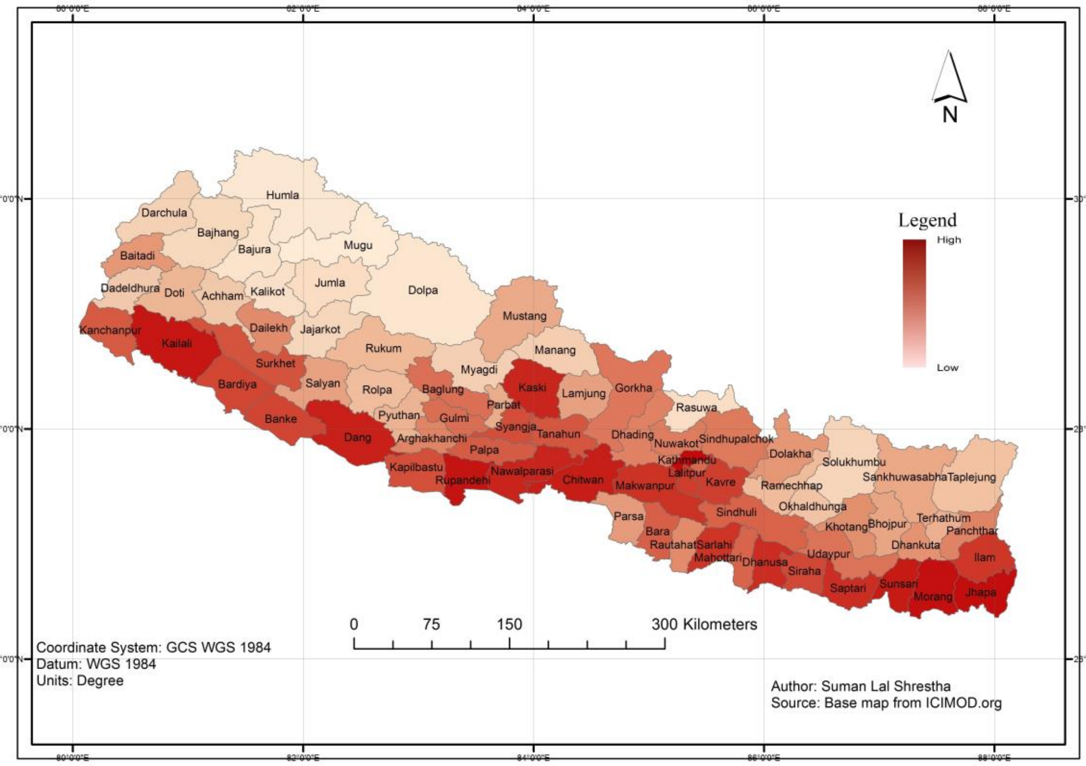
Annex VII



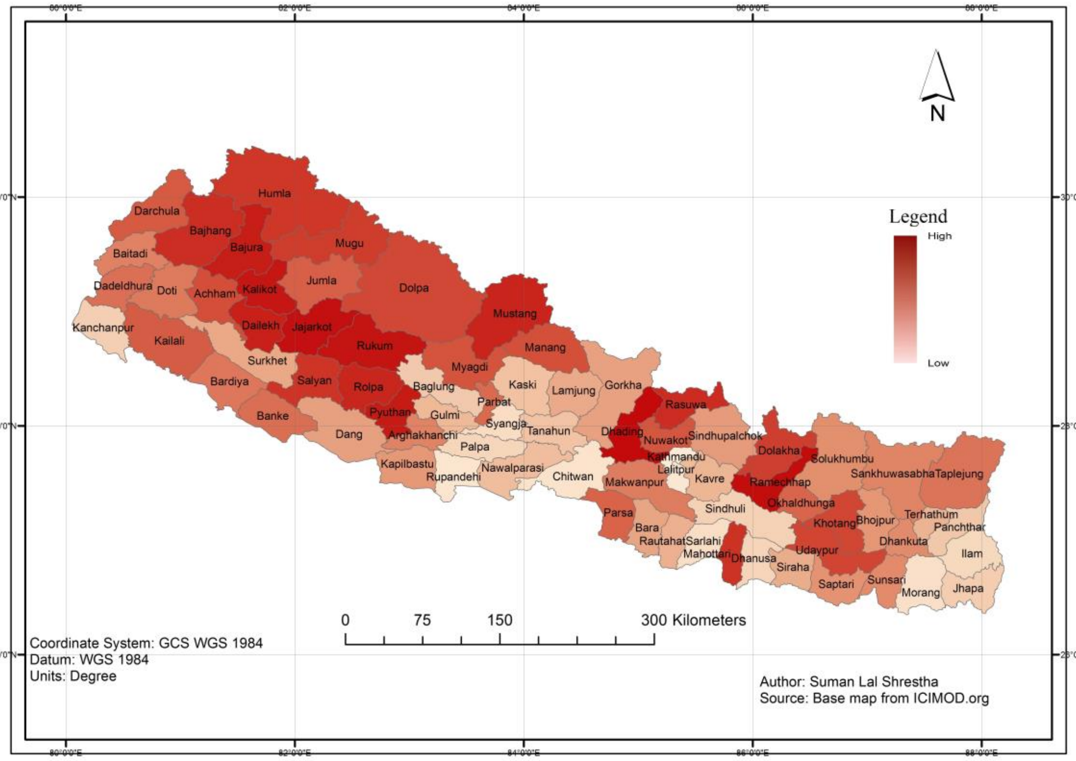
Map of Nepal showing exposure due to climate change



Map of Nepal showing sensitivity to climate change



Map of Nepal showing adaptive capacity to climate change



Map of Nepal showing vulnerability due to climate change

Annex VIII

Vulnerability Index Value and Relative Rank

Districts	Adaptation	Sensitivity	Exposure	Vulnerability	Rank
Achham	0.67	0.62	0.31	0.26	21
Arghakhanchi	0.99	0.44	0.66	0.11	38
Baglung	1.13	0.67	0.17	-0.29	62
Baitadi	0.93	0.67	0.37	0.12	37
Bajhang	0.48	0.63	0.25	0.40	12
Bajura	0.30	0.55	0.26	0.50	7
Banke	1.27	0.64	0.78	0.15	31
Bara	1.20	0.77	0.38	-0.05	49
Bardiya	1.25	0.71	0.67	0.13	34
Bhaktapur	1.13	0.54	0.41	-0.18	57
Bhojpur	0.84	0.52	0.37	0.05	44
Chitawan	1.71	0.93	0.18	-0.60	72
Dadeldhura	0.66	0.49	0.32	0.15	32
Dailekh	0.96	0.86	0.58	0.48	8
Dang	1.69	0.88	0.79	-0.01	47
Darchula	0.58	0.41	0.38	0.22	25
Dhading	1.02	1.49	0.89	1.36	1
Dhankuta	0.94	0.70	0.33	0.09	41
Dhanusha	1.54	0.93	0.30	-0.30	66
Dolakha	0.93	0.63	0.64	0.34	17
Dolpa	0.27	0.34	0.23	0.31	20
Doti	0.75	0.62	0.25	0.12	35
Gorkha	1.08	0.69	0.37	-0.01	48
Gulmi	1.13	0.71	0.29	-0.13	56
Humla	0.25	0.36	0.26	0.37	15
Ilam	1.39	0.67	0.33	-0.38	68
Jajarkot	0.50	0.59	0.48	0.57	3
Jhapa	2.06	1.31	0.46	-0.29	63
Jumla	0.43	0.38	0.26	0.21	27
Kailali	1.82	1.55	0.48	0.21	26
Kalikot	0.36	0.51	0.38	0.52	5
Kanchanpur	1.22	0.69	0.22	-0.30	64

Kapilbastu	1.23	0.63	0.62	0.02	45
Kaski	1.55	0.88	0.49	-0.19	59
Kathmandu	2.98	1.25	0.45	-1.28	75
Kavrepalanchok	1.28	0.83	0.33	-0.11	55
Khotang	0.96	0.76	0.53	0.33	19
Lalitpur	1.37	0.48	0.22	-0.68	74
Lamjung	0.86	0.56	0.24	-0.06	51
Mahottari	1.15	1.10	0.45	0.40	13
Makwanpur	1.41	1.14	0.40	0.12	36
Manang	0.65	0.25	0.66	0.26	22
Morang	2.05	1.05	0.48	-0.52	71
Mugu	0.17	0.32	0.20	0.35	16
Mustang	0.81	0.28	1.01	0.47	9
Myagdi	0.60	0.36	0.49	0.25	23
Nawalparasi	1.61	1.14	0.29	-0.18	58
Nuwakot	1.04	0.59	0.69	0.23	24
Okhaldhunga	0.69	0.49	0.40	0.20	29
Palpa	1.20	0.65	0.21	-0.34	67
Panchthar	1.02	0.47	0.31	-0.23	61
Parbat	0.81	0.56	0.41	0.17	30
Parsa	0.91	0.63	0.48	0.20	28
Pyuthan	0.78	0.66	0.63	0.51	6
Ramechhap	0.72	0.77	0.73	0.77	2
Rasuwa	0.41	0.36	0.49	0.44	11
Rautahat	0.98	0.66	0.25	-0.08	53
Rolpa	0.72	0.58	0.58	0.44	10
Rukhum	0.74	0.73	0.55	0.54	4
Rupandehi	1.86	0.74	0.47	-0.65	73
Salyan	0.84	0.53	0.69	0.37	14
Sankhuwasabha	0.82	0.52	0.40	0.11	39
Saptari	1.50	0.96	0.61	0.07	43
Sarlahi	1.40	0.71	0.17	-0.52	70
Sindhuli	1.15	0.37	0.49	-0.30	65
Sindhupalchok	1.06	0.58	0.46	-0.01	46
Siraha	1.25	0.85	0.32	-0.08	52

Solukhumbu	0.56	0.37	0.28	0.09	42
Sunsari	1.80	1.30	0.59	0.10	40
Surkhet	1.23	0.64	0.53	-0.06	50
Syangja	1.24	0.68	0.14	-0.43	69
Tanahu	1.22	0.77	0.25	-0.20	60
Taplejung	0.69	0.45	0.38	0.14	33
Terhathum	0.79	0.42	0.27	-0.10	54
Udayapur	1.12	0.85	0.61	0.34	18

Annex IX

Number of observation = 195

Number of comp. = 27

Trace = 27

Rotation: (unrotated = principal) Rho = 1

Principal Component analysis of Households

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	4.99	1.59	0.19	0.19
Comp2	3.41	1.25	0.13	0.31
Comp3	2.15	0.54	0.08	0.39
Comp4	1.62	0.27	0.06	0.45
Comp5	1.35	0.06	0.05	0.50
Comp6	1.29	0.13	0.05	0.55
Comp7	1.15	0.02	0.04	0.59
Comp8	1.13	0.13	0.04	0.63
Comp9	1.01	0.07	0.04	0.67
Comp10	0.93	0.06	0.03	0.70
Comp11	0.87	0.06	0.03	0.74
Comp12	0.81	0.03	0.03	0.77
Comp13	0.78	0.06	0.03	0.80
Comp14	0.72	0.04	0.03	0.82
Comp15	0.68	0.06	0.03	0.85
Comp16	0.62	0.10	0.02	0.87
Comp17	0.52	0.03	0.02	0.89
Comp18	0.49	0.03	0.02	0.91
Comp19	0.46	0.04	0.02	0.93
Comp20	0.42	0.03	0.02	0.94
Comp21	0.38	0.05	0.01	0.96
Comp22	0.33	0.03	0.01	0.97
Comp23	0.30	0.06	0.01	0.98
Comp24	0.24	0.05	0.01	0.99
Comp25	0.19	0.06	0.01	0.99
Comp26	0.14	0.14	0.01	1.00
Comp27	0.00	.	0.00	1.00

Principal component having Eigenvalue more than 1 for households

Variable	Comp1	Comp2	Comp3	Comp4	Comp5	Comp6	Comp7	Comp8	Comp9
					Adaptive capacity				
Road	0.32	0.04	0.09	0.06	0.12	0.03	0.23	0.04	0.18
Agricultural service	0.36	-0.13	-0.03	0.05	0.04	0.03	-0.08	-0.08	-0.09
Livestock service	0.36	-0.21	-0.01	0.01	0.04	0.03	-0.12	-0.03	-0.01
Agrovet	0.34	-0.20	0.04	0.02	0.07	0.03	-0.03	-0.01	-0.02
Market	0.31	-0.26	0.04	-0.01	0.00	0.01	-0.13	0.09	-0.11
Off-farm income	0.12	0.18	0.17	-0.64	-0.15	-0.11	0.00	0.04	-0.05
Total Income	0.14	0.32	0.19	-0.51	-0.12	-0.02	0.00	-0.01	-0.06
Agricultural Income	0.08	0.39	0.09	0.17	0.04	0.17	-0.01	-0.12	-0.03
Irrigated	-0.10	-0.24	0.37	-0.03	-0.18	0.13	0.08	-0.24	-0.01
Total Land	-0.13	-0.18	0.34	0.04	-0.24	0.19	0.13	-0.29	-0.02
Mobile	0.05	0.12	0.32	0.21	-0.01	-0.44	-0.22	0.05	-0.06
Dependency ratio	0.07	0.10	0.21	0.19	-0.12	-0.47	-0.03	0.12	-0.34
Education	0.01	0.09	0.23	-0.06	0.45	-0.14	-0.23	-0.28	0.30
Livestock	-0.02	0.04	0.30	0.24	-0.27	0.32	-0.02	0.10	-0.32
Drinking water	0.03	0.14	0.10	-0.02	0.39	0.42	0.01	0.15	-0.19
No. of Crops	0.09	0.22	0.23	0.10	-0.05	0.31	-0.42	0.15	-0.01
Total Saving	0.04	0.21	0.08	0.24	0.16	-0.15	0.47	-0.03	-0.12
Health	0.26	-0.05	0.16	0.05	0.16	0.08	0.39	-0.03	0.17
School	0.01	-0.18	0.14	-0.14	0.04	-0.06	0.37	0.50	-0.15

Radio	0.02	-0.01	0.32	0.11	-0.23	-0.11	0.09	-0.04	0.52
Climate change perception	0.05	0.14	-0.31	0.06	-0.41	0.02	0.12	-0.06	0.15
	Sensitivity								
Damage to land	-0.23	-0.08	0.07	0.00	0.29	-0.17	-0.07	0.05	-0.07
Livestock lost	-0.19	-0.06	0.15	-0.15	0.16	0.11	0.15	0.05	0.09
Damage to agricultural production	-0.05	0.06	0.04	0.10	-0.10	0.05	-0.11	0.62	0.43
	Exposure								
Rainfall	-0.13	0.40	-0.01	0.09	0.09	0.07	0.14	-0.06	0.00
Temperature	-0.32	-0.19	0.06	-0.07	0.05	-0.03	0.00	-0.01	-0.15
Frequency of natural hazard	-0.23	-0.19	0.16	-0.03	0.11	0.04	-0.11	0.13	0.11