Master's Thesis

Effect of Climate Change on Socio-Economy and Vulnerability of Farmers in Nepal

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Abstract

Climate change will have effect on all sectors, but will vary in degree according to sector and region. Climate change will adversely affect sectors like agriculture and water which are dependent on climatic variables. People that are dependent on these sectors for their livelihood will be the most adversely affected by climate change. Subsistence farmers in developing countries like Nepal where agriculture is mainly rain-fed, and have very little resources and are unable to cope with changing climatic condition will be more vulnerable to climate change. So, it is very important to identify the groups and regions that are more vulnerable for policy or developmental intervention.

This research was conducted in order to study how climate change is having effect on the socio-economy and vulnerability of farmers. It tries to analyse the trend of climatic variables and climatic extreme of the study area and find how climatic variables are affecting yield of major food crops using regression analysis. Further, it also tries to study the adaptive capacity of farmers in the study area and captures their vulnerability. To capture adaptive capacity a semi-structured questionnaire survey was administered in Chitlang village development committee (VDC) of Makwanpur district and Namsaling VDC of Ilam district. Furthermore, vulnerability was calculated using integrated indicator approach.

The study analysed the trend of climatic variables such as temperature and rainfall, climatic extremes and also the effect of climatic variables on yield of major food crops of Nepal in both districts for the period from 1978 to 2008. The trend analysis found that in both the districts, the maximum temperature is increasing for summer and winter seasons as well as overall while minimum temperature was found to be increasing in Makwanpur district while it was in decreasing trend 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 study showed that the effect of climate change on yield of major food crops except paddy in Makwanpur district had adverse impact. Similarly, in Ilam, except maize and potato, climate change had negative impact on all the food crops. Though the majority of climatic variables did not show any significant relation with yield, the analysis showed the direction in which the climate change has an effect. Further, trend analysis for yield of major crops was performed which 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 the use of improved seeds and fertilizers.

Also, trend analysis of natural disasters showed that they have been increasing from mid 1990s and also the casualties caused by natural disasters were increasing in both districts. Descriptive analysis of socio-economic characteristics showed that there are high income disparities among the sampled households in both VDCs. In Chitlang VDCs there were only two categories of farmers among the sampled households, marginal and small according to landholding, while in Namsaling VDC, there were three categories of farmers; marginal, small and large. Though infrastructure was better in Chitlang than Namsaling, the literacy rate and farmers association was better in Namsaling.

The vulnerability analysis showed that the poorest sampled farmers households that lack resources in both districts were most vulnerable. In Makwanpur district, the variables like agricultural income, landholding, irrigation and livestock holding played important part in determining the vulnerability. But, in the case of Ilam, time taken to reach the infrastructure like road, health facilities, school, agricultural services and livestock services played important part. This showed that adaptive capacity will not just depend on few factors, but will differ according to the region.

Though the majority of the respondents were not aware of the term climate change, they noticed changes in climatic variables, especially in Namsaling than in Chitlang. Also, the respondents have noticed changes like faster ripening of fruits, invasion of plant species in higher altitude that used to grow in lower altitudes only and also started to notice mosquitoes in higher altitudes.

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Abbreviations/Acronym

ADB:	Agriculture Development Bank
AR4:	Fourth Assessment Report
CBS:	Central Bureau of Statistics
CO2:	Carbon dioxide
DDC:	District Developmental Committee
DHM:	Department of Hydrology and Meteorology
DSSAT:	Decision Support System for Agrotechnology Transfer
FAO:	The Food and Agriculture Organization
GCM:	General Circulation Model
GDP:	Gross Domestic Product
ICIMOD:	International Center for Integrated Mountain Development
IPCC:	Intergovernmental Panel on Climate Change
m:	Meter
masl:	mean above sea level
MDNR:	Missouri Department of Natural Resources
MoAC:	Ministry of Agriculture and Cooperatives
MoE:	Ministry of Environment
MoPE:	Ministry of Population and Environment
NAPA:	National Adaptation Program Of Action
NGO:	Non-Governmental Organization
NRs.	Nepalese Rupees
PCA:	Principal Component Analysis
SEI:	Stockholm Environment Institute
sq. km:	Square Kilometre
TAR:	Third Assessment Report
TLU:	Tropical Livestock Unit
UN:	United Nation
UNFCCC:	United Nations Framework Convention on Climate Change

USEPA:	United States Environmental Protection Agency
VDC:	Village Developmental Committee
WICCI:	Wisconsin Initiative on Climate Change Impacts
WWF Nepal:	World Wildlife Fund Nepal
UNCED:	United Nations Conference on Environment and Development
yr-1:	per year

Chapter I Introduction

1.1 Background

Climate change is the change in climatic condition over the time, which is due to natural variability or as a result of human activity (IPCC, 2007a). It has been established that the temperature is rising rapidly over the past century due to anthropogenic activity which is causing climate change. This change in climate will have an effect on various natural as well as man-made process and structures. A climate change will effect natural resources, such as water, forests, etc. which will ultimately have effect on human being. The impact of climate change will be felt differently in different sectors like agriculture, water resources etc., where some sectors will be more adversely affected while some will be less adversely affected, and some will benefit from it. The effects will be both social as well as economical. The socio-economic effects of climate change arise from interactions among climate and society, and how these in turn affect both natural and managed environments (Ericksen, Ahmad and Chowdhury, 1997).

As climate is one of the main factors of agricultural production, there is significant concern in the world about the effects of climate change and its variability on agricultural production (Kaul, n.d.). Many believe that agriculture sector is more susceptible to climate change as it depends on climatic factors like temperature and precipitation (Deschenes & Greenstone, 2006). Impact of climatic variability is quite noticeable in the majority of small and marginal farmers that lack resources to adjust with climatic variations (Kaul, n.d.). 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 and may suffer significant disruption and financial loss for relatively small changes in crop yields and productivity (Parry et al. cited by IPCC, 2007b).

Nepal is a mountainous country where majority of people live in rural areas. In 2009 only 17.72% of people living in urban areas. The agricultural land in Nepal is 42100 sq. Km. as of 2009 (The World Bank, 2011). In rural area agriculture is the main livelihood option so economy of Nepal is significantly dependent on agriculture. Approximately 33.85% of GDP came from agriculture in 2009, down from 40% in 2000. Irrigation covers only 27.74% of the total agricultural land in Nepal (The World bank, 2011). Therefore people mostly rely on the rain-fed agricultural system. Further, irrigation is mainly the small type managed by the farmers' community itself (Bhandari and Pokharel, 1999). As farmers rely mainly on rain-fed system, climate change will have more effects on them.

1.2 Statement of the Problem

It has been established that the global temperature has increased over the past centuries due to human anthropogenic activities causing change in the climate, and many believe climate change is a threat to the world. As climate is an integral part of any systems, natural or man-made, any change in it will have an effect on the system. There have been numerous studies on how climate change will impact on different sectors, but still there remain uncertainties regarding the extent to which climate change will impact different sectors. The impact of climate change will be different in different sectors and will be felt at the local level. Climate change will put more stress on sectors like agriculture and water resources that are more dependent on climatic factors like temperature and precipitation particularly in certain localities that are more prone to these changes. In addition to the impacts, adaptation capacity of the people will also determine the vulnerability of people to 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. With rapid increasing population and vast climatic variation, Nepal is experiencing rapid changes and pressures from climate change. As agriculture is one of the sectors that are more dependent on climatic factor, farmers are more prone to have impact from any changes in the climate. The change in agricultural production due to climate change will have an effect on farmers both economically as well as socially, especially to those who have little adaptive capabilities. Though there are studies on how climate change will impact different sectors worldwide, in case of Nepal there is very less researches and less understanding of how climate change is having impact on the farmers at the local level, and also what are their adaptive capacity and vulnerability to climate change.

1.3 Rationale

Climate change will have different effects on different sectors. However, the degree of the effect is still debatable. Climate change will have more effect on sectors like water and agriculture which are more dependent on climatic conditions and especially to those people who have fewer resources to adapt to it. Further, developing countries are more vulnerable to climate change because very less research is being conducted in these areas and people are not well prepared for the changes in climatic variation. Though Nepal has vast ecological resources and diversity it is still one of the poorest countries in the world. In Nepal the majority of the people depend on natural resources for their livelihood. So, it becomes very important to understand the impact of climate change on the local level but in the case of Nepal there are limited researches on the impact of climate change on farmers, and their vulnerability.

As one of the developing countries, Nepal has to pursue its developmental needs and face and adapt to the changing climate though its effect is uncertain. It is important for everyone to understand climate change and its socio-economic impacts and adaptation strategies. Since capacity to adapt to climate change is unequal across and within societies (IPCC, 2007b), especially in developing countries like Nepal, where there is lack of financial resources to adapt to the changing condition, understanding the physical sensitivity and adaptive capacity of the farmers to climate change is important in determining their vulnerability. Further, studies done by different researchers have stressed the importance of studying the vulnerability at micro scales. Therefore, the identification and characterization of the vulnerable regions, sectors, and communities is a priority concern for addressing climate change issues in Nepal.

1.4 Objective

1.4.1 General Objectives

- Analyze the vulnerability of farmers to climate change

1.4.2 Specific Objectives

- To analyze the change in climatic factors; precipitation, temperature and occurrence of extreme weather.
- Find out the effect of climatic factors in yield of major food crops of Nepal in the studied area.
- Assess the socio-economic status of the studied area.
- Study the adaptive capacity of farmers.

1.5 Vulnerability Flowchart

For this study, the definition of vulnerability was taken from the IPCC (2001) in which it says that vulnerability is the function of three factors namely exposure, sensitivity and adaptive capacity. According to the IPCC (2001), vulnerability assessment is done through the integrated approach in which biophysical and socio-economic indicators are considered. This research is based on the IPCC vulnerability assessment approach. Figure 1.1. shows the conceptual framework for the study.

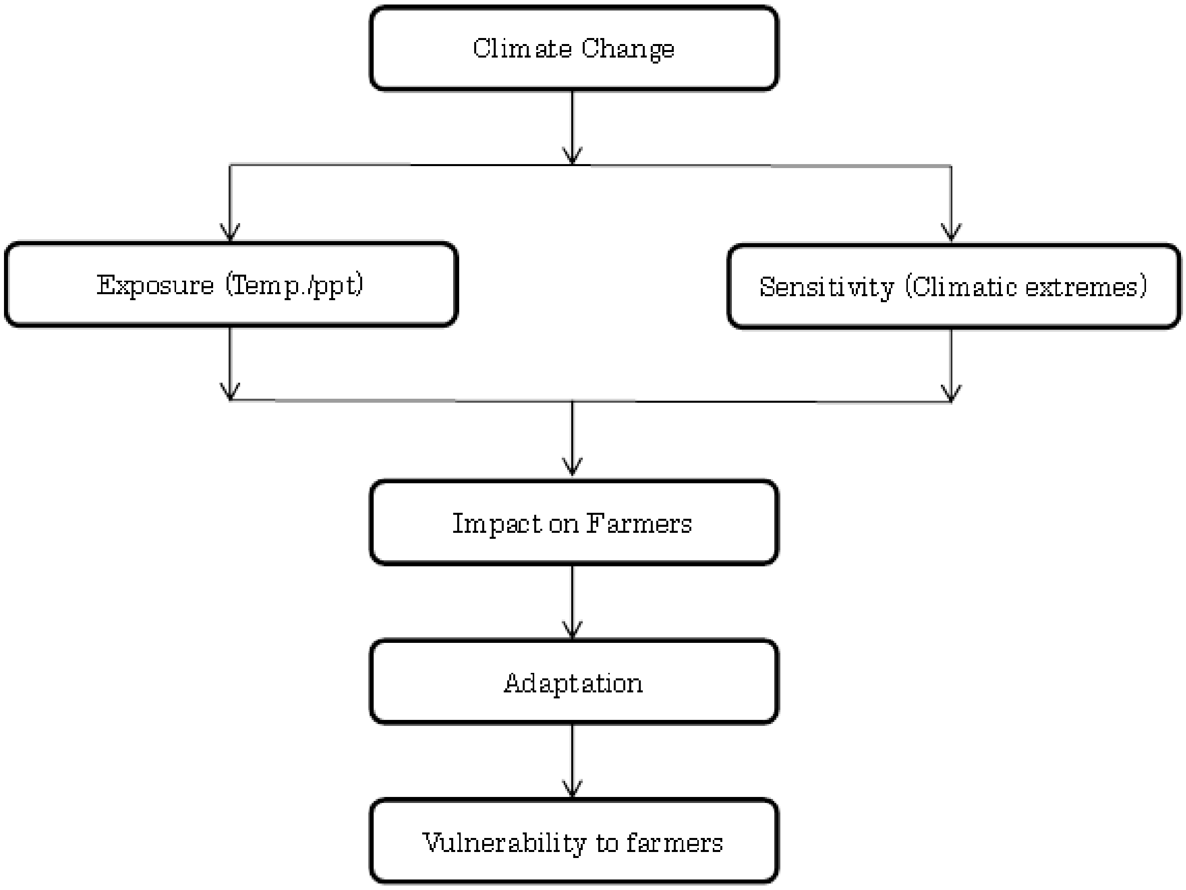


Figure 1.1: Conceptual framework of the study

In figure 1.1, the impact on farmers by climate change is basically by exposure (temperature and precipitation) and sensitivity (frequencies of climatic extremes and death, wounded, house destroyed by climatic extremes). The exposures also influence the sensitivity as sensitivity is the degree to which the system responds to exposure. The exposure and sensitivity will give the impact of climate change to farmers. The impact by climate change to farmers will be negated by the adaptive capacity of the farmers, which means higher the adaptive capacity of the farmers, lesser will be the impact of climate change. So, after considering exposure, sensitivity and adaptive capacity, the vulnerability of farmers can be determined.

1.6 Limitations of the Study

To study climate change phenomenon a long-term climatological data is required. In this study a 30-year period is used for the study due to the availability of the data. Further, due to the geographical nature of the area, the hydrological and meteorological stations may not cover all the areas of the district. Also, regarding the data of natural disaster, the reported cases of natural disasters in newspaper, and other sources were taken which may not represent the exact information on natural disasters in the area as there is no official record of natural disasters for 30 years period. Also, due to the time constraints this study covers one village development committee of each district which may not represent the whole district.

Chapter II Literature Review

2.1 Climate Change and Its Impact

2.1.1 Climate Change

Climate change, according to the IPCC (2007a) refers to the "Change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity." The United Nations Framework Convention on Climate Change (UNFCCC, 2007) states that "The main characteristics of climate change are increase in average global temperature (global warming), change in cloud cover and erratic precipitation particularly over land, melting of ice caps and glaciers and reduced snow cover, and increase in ocean temperatures and ocean acidity due to seawater absorbing heat and carbon dioxide from the atmosphere."

2.1.2 Evidences of Climate Change

Global mean surface temperatures have risen by 0.74°C ±0.18°C when estimated by a linear trend over the last 100 years (1906–2005). The rate of warming over the last 50 years (1956 to 2005) is almost double that over the last 100 years (0.10°C to 0.16°C) from 1906 to 2005. Over the past 12 years (1995-2006), 11 years have been among the 12 warmest years recorded since 1850. Since 1961, it has been shown that ocean temperature has increased to the depth of 3000 m and ocean is taking around 80% of the added temperature to the climate system. There is also consistent increase in the temperature along with global sea level rise of

3.1 mm per year from 1993 to 2003. Also, there is widespread reduction in the number of frost days in mid-latitude regions, an increase in the number of warm extremes and a reduction in the number of daily cold extremes observed in 70 to 75% of the land regions where data are available. Also, some extreme weather events intensity and frequency have changed since 1850 (IPCC, 2007a).

2.1.3 Impact of Climate Change

The effect of climate change will be felt on different systems like ecosystem, weather pattern, water resources and landscapes. Change in vegetation, species composition will have an impact on ecosystem (Beniston, 2003). Also, events like glacier retreating at a rate of 10-60 m per year (Bajracharya, Mool and Shrestha, 2007) have an impact on water resources and landscape. Further, natural and human systems are exposed to direct effects of climatic variations such as change in temperature and precipitation variability as well as frequency and magnitude of extreme weather events due to climate change. According to the IPCC (2001), future changes in weather patterns will affect different regions in different ways. Further, developing countries are the most vulnerable countries to climate change impacts because they have fewer resources to adapt: socially, technologically and financially (UNFCCC, 2007). Climate change is anticipated to have far reaching effects on the sustainable development of developing countries (UN, 2007 cited by UNFCCC, 2007). The impact of climate change will be due to the change in climatic conditions like temperature, precipitation which will have an effect on climate and weather of an area and ultimately have effect on the physical and biological condition. The net impact of climate change on different sectors will be due to its exposure, sensitivity and adaptive capacity to climate change (IPCC, 2007b).

2.1.4 Impact of Climate Change on Agriculture

In 2008, the world agricultural land is 38% of the total land surface (tradingeconomics.com). According to the IPCC (2007b), more people in the developing world are dependent on agriculture. Agriculture is very sensitive to climatic variability such as change in temperature, precipitation and also climatic extremes like drought, flood etc. (USEPA, 2011). Climatic variability will cause the decrease in the yield of the crop in the long run and also forces farmers to adapt the new agricultural practices.

The effect of climate change on agriculture will be direct as well as indirect (Gbetibouo and Ringler, 2009). The direct effect of climate change on agriculture will be through changes in temperature and precipitation (WICCI, 2009). The change in temperature and precipitation will affect the phenology and timing of crop development as well as through changes in atmospheric CO2 concentration (IPCC, 2007b). Also, changes in the global climate will affect temporal patterns of temperature and rainfall at the regional level (Houghton et al., 1997 cited in Alexandrov, 1999) which will have effect on agriculture. Further, due to climate variability there will be shortening of growing periods which will reduce potential yield (Peiris et al., 1995). Also climate change will have impact on extension of growing season in the subtropical regions because of impact of climate change on agricultural seasons by changing seasonal temperature and precipitation (Reilly and Schimmelpfennig, 1999). Seasonal temperature change could alter the growing season and could result in the regional redistribution of the agriculture growing pattern (MDNR, n.d.). Indirect effects will be detrimental changes in diseases, pests and weeds, decrease in water availability which will have negative impact on crop yield. Rain has become less predictable and dependable, both in distribution and amount. The changes in weather pattern can have direct influence on surface runoff and impact on agriculture, vegetation, and people's daily lives (ADB and ICIMOD, 2006).

In a research by Nelson et al. (2009) using the Decision Support System for Agrotechnology Transfer (DSSAT) model, it is stated that by 2050 climate change will have negative affect on well-being of humans and agriculture. It also states that crop yield in global agriculture context will decrease and production will be negatively affected (Nelson et al. 2009). The positive effect in agriculture will be basically due to the carbon dioxide CO_2 fertilization which will depends on the metabolism of the crops. According to Cline (2007) in 2080, crop yield will decrease in some parts of the world especially tropics where it will increase in some countries of temperate region. The reason for the decrease is attributed to increase in temperature but increases in some part due to the CO_2 fertilization effect. Wheat, for example, may virtually disappear as a crop in Africa, while experiencing substantial decline in Asia and South America.

The effect of climate change on agriculture will not just depend on the exposure and sensitivity of the area but also depend on the adaptive capacity which depends on the reach of people to the resources which is generally low in the case of developing countries, which are mainly in the tropics region. So, agriculture in developing countries will be especially at risk (Chhetri, 2008). In addition, the effect of climate change on the productive croplands is likely to threaten economic development and the welfare of the population in developing countries where poor soil covering the large areas have made land already unusable for agriculture, which makes them particularly vulnerable to potential damage from environmental changes

(Mendelsohn and Dinar 1999).

2.2 Climate Change and Nepal

2.2.1 Overview of Nepal

Nepal is a mountainous country situated in south Asia. The total area of Nepal is 147,181 sq. km. With an average width of only about 150 km, the altitude range varies from 161 meters above sea level (masl) to 8,848 masl (CBS, 2004). Northern part of Nepal consists of mountains covering one third of the total area of which only 2% is cultivable. The central region of Nepal covers about 42% of total area of which only 10% is suitable for farming and consists of middle hills, river basins and valleys. The southern region which consists 23% of the whole Nepal, is low lands, that is, Terai of which 40% is under cultivation (Maharjan, 2003). Nepal has tropical to tundra climate, and it receives about 80% of annual precipitation during a very short period of summer months from June to September, which produces a large number of small and big rivers in mountains. As of 2004, about 30.9% of Nepal's population is below the national poverty line, but poverty ratio headcount at $1.25 a day becomes 55.12% (The World Bank, 2011). Moreover, as much as 70% of the rural population is poor; local food production sometimes just covers three months of the annual households needs (FAO, 2004). In this context, the issue of food balance is extremely important for Nepal and more severe effects will arise under climate change conditions. The IPCC also states that the impacts of climate change on the livelihoods of the poorest of the poor in Nepal would be substantial (IPCC, 2001). Nepal is among the most vulnerable countries on earth with regard to climate change, yet the level of understanding and awareness on the issue is very limited as pointed out by the World Wide Fund for Nature Conservation (WWF Nepal 2006).

2.2.2 Climate Change Policies of Nepal

Nepal, along with over 150 other countries, signed the UNFCCC convention on climate change at the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in June 1992. Nepal ratified the convention on 2 May 1994, and this convention came into force on 31 July 1994. Nepal prepared the Initial National Communication as a party of non-annex 1 country (MoE, 2010).

According to the Ministry of Environment the climate change policy (2011) has been approved by the Government of Nepal on January 17, 2011 which goal is as follows:

"The main goal of this policy is to improve livelihoods by mitigating and adapting to the adverse impacts of climate change, adopting a low-carbon emissions socio-economic development path and supporting and collaborating in the spirits of country's commitments to national and international agreements related to climate change."

The climate change policy basically focused on

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
7. Climate-friendly natural resources management

2.2.3 Evidences of Climate Change in Nepal

Analyses of data from 1976 to 2005 indicate that Nepal temperature has increased by

1.6°C which is a fastest long-term increase (Maharjan, Joshi and Piya, 2011). In addition, warming trend in Nepal is more pronounced in autumn and winter. Nepal experiences monsoonal rains during June to September which is around 80% and very low precipitation during December to February (MoPE, 2004).

Analysis of hydrological, meteorological and glaciological data from the Nepal Himalayas has revealed that the climate in the Nepal Himalayas is changing faster than the global average. Also, there is higher temperature rise in higher altitudinal areas than lower altitudes as seen in the case of Rampur station which altitude is 286 m the rate of increase was seen 0.04°C yr-1 while those at Kathmandu (1136 m), Daman (2314 m) and Langtang (3920 m) were increasing by 0.05, 0.07 and 0.27 ºC yr-1 respectively (Chaulagain, 2006). An analysis of temperature trend from 1976 to 2005 found that maximum temperature was increasing faster in the higher altitude than in lower altitude while annual minimum temperature rend of the country was found to be decreasing in the northern (higher altitude) part while most of the southern lower altitude part was found to be in increasing trend (Practical Action, 2010). This shows that there is increasing temperature anomaly in the country. Further, in 2009, there was positive temperature anomaly of over 1°C recorded in the north-western part and some areas of Eastern, Central and Western part of Nepal (DHM, 2009). Additionally, Agrawala et al. (2003) the climate projection using general circulation model (GCM) to calculate change in area averaged temperature and precipitation over Nepal showed that there was significant increase in temperature projection for 2030, 2050 and 2100.

A study carried out by Chaulagain (2006) in four stations showed that there was decrease in the number of rainy days in three stations while there was positive trend on a number of rainy days from July to August in all stations indicating longer duration of drought period. Further, this type of longer duration of rainfall will increase floods and landslides in the area. According to Practical Action (2010), the data from 1976 to 2005 indicate no definite trend of rainfall due to large inter annual variation. In general, eastern, central, western and far western region of Nepal showed increasing trend while mid-western had decreasing trend of rainfall over the period from 1976 to 2005 (Practical Action, 2010). In 2009, during August, southern plains of Central, Western, Mid-western, and far-western received 140% of normal rainfall in the month whereas some part received 60% of the rainfall (DHM, 2009) showing disparity among rainfall distribution which will cause climatic extremes like flood and drought in the region. Further, the precipitation in different season will affect the water availability in different area, which is one of the main resources needed for agriculture. During summer monsoon, where there is plenty of precipitation, there will be plenty of water but in dry seasons, there will be significant water deficit since water availability in Nepal basically depends on monsoon precipitation.

2.2.4 Effect of Climate Change in Agriculture of Nepal

The effect of climate change in agriculture will mostly be adverse as it is highly dependent on weather condition due to extreme rainfall (Maharjan, Joshi and Piya, 2011). The variability in the rainfall will have very severe negative effect in agriculture especially in 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 Terai in 2006 due to drought (Regmi, 2007). Further, climatic extremities like flood and landslides will affect agricultural production. In the last decade (1990-2000), particularly Nepal and the Indo-Gangetic plains of India, just immediate south of the mountain region, experienced significant reduction in yield of winter crops due to severe sky overcast. 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 in will affect agriculture as there will be increase in incidence of pests and diseases and decreasing physiological performance. Additionally, some of the studies showing how climate change is having effect on agriculture in Nepal are as follows:

- A 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. The study concludes that the food crops are negatively affected by climate change except for paddy which thrives on water logging condition.
- In a 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. But, he 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.

- A study done by Giri (2009) found that disease infection trend has been increasing for maize, paddy and wheat which might have been due to favorable condition for pathogen with increasing temperature promoting the high use of pesticides. Further, Giri stresses the fact that the impact of climate change will be more pronounced in rain-fed farmland than irrigated farmland (Giri, 2009).
- A study done by Khadka (2011) points that there was change in flowering, fruiting and harvesting time of cash crops due to the snowfall and also decrease in survival of cash crops due to defective seedling and drought.

2.3 Vulnerability

2.3.1 Concept of Vulnerability

The ordinary use of the word ‘vulnerability’ refers to the capacity to be wounded, i.e., the degree to which a system is likely to experience harm due to exposure to a hazard (Turner II et al., 2003 cited by Fussel, 2007). Vulnerability is conceptualized in very different ways by scholars from different knowledge domains. Adger (1999) cited by Gbetibouo and Ringler (2009) defines social vulnerability as the exposure of groups or individuals to stress as a result of social and environmental change, where “stress” refers to unexpected changes and disruptions to livelihoods. Reilly and Schimmelpfennig (1999) define vulnerability as a probability-weighted mean of damages and benefits. The Intergovernmental Panel on Climate Change defines vulnerability to climate change as: “The degree to which a system is susceptible, or unable to cope with adverse effects of climate change, including climate variability and extremes, and vulnerability is a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity." (IPCC, 2001)

Different social groups have different level of vulnerability to climate change which is determined by both socioeconomic and environmental factors (The World Bank, 2010). The variations among socio-economic and environmental factors in different social groups are responsible for the differences in their levels of vulnerability to climate change (Deressa, Hassan and Ringler, 2008). Further, the sensitivity and adaptive capacity of the affected system in particular depends on a range of socio-economic characteristics of the system. Several measures of social well-being such as income inequality, nutritional status, access to lifelines such as insurance and social security, and so on can affect baseline vulnerability to a range of climatic risks (Agrawala et al., 2009).

2.3.2 Basic Components of Vulnerability

The IPCC Third Assessment Report (TAR) argues that vulnerability has three components mainly the exposure to climatic stress, its sensitivity, and its adaptive capacity (IPCC, 2001). Also, in IPCC Fourth Assessment Report (AR4), the definition of vulnerability is consistent with the TAR (IPCC, 2007b).

Exposure

Exposure can be conceptualized as the degree of climate stress upon a particular unit of analysis. Exposure is represented by either long-term changes in climate conditions or changes in climate variability (O'Brien et al., 2004). 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 and Stafford-Smith, 2009). According to the IPCC (2001), exposure can be interpreted as the nature and extent of changes a region is exposed to from the region’s climate variables (e.g., temperature, precipitation).

Sensitivity

Sensitivity refers to the responsiveness of a system to climate hazards. This is often represented conceptually as a dose-response model – the more sensitive a system, the larger the rate or magnitude of an adverse response to a given hazard. However, the nature of the response may often be secondary to the mechanisms by which it is realized (Preston and Stafford-Smith, 2009). Sensitivity may vary considerably from one system, sector or population to another. Sensitivity, according to Gallopín (2003) cited by Bruggeman (2010), 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 cited by Gbetibouo and Ringler, 2009). According to the IPCC (2001), sensitivity is to what extent or degree the system is affected either adversely or positively by the climatic stimuli.

Adaptive Capacity

Adaptive capacity refers to the ability of a system to 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 and Ringler, 2008). 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 behavior to better cope with existing or anticipated external stresses, and also changes in external conditions. The 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, the adaptive capacity is context-specific and varies from country to country, from community to community, among social groups and individuals, and over time (IPCC, 2001).

2.4. Vulnerability Assessment

According to Deressa, Hassan and Ringler (2008), there are basically three conceptual approaches for assessment of vulnerability namely:

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 and 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 and Ringler, 2008).

3. Integrated assessment approach: The integrated assessment approach combines both the approaches, socioeconomic and biophysical approaches (Deressa, Hassan and 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 and Ringler, 2008).

Further, the vulnerability assessment approaches tries to answer questions like who and what are vulnerable, to what are they vulnerable, their degree of vulnerability, the causes of their vulnerability, and what responses can lessen their vulnerability (Gbetibouo and Ringler, 2009).

2.5 Vulnerability to Climate Change

Vulnerability of the household, community, region, or country to climate change is very much essentially related to the social and economic development (Gbetibouo and 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. Some of the researches done by different researchers on vulnerability are as follows:

- The research done based on the integrated vulnerability assessment approach using vulnerability indicators in Ethiopia points out that the least developed, arid, and semi-arid areas where climate extremes are high are the most vulnerable places. It also indicates that vulnerability is highly related to the poverty (Deressa, Hassan and Ringler, 2008).
- According to Berry, Rounsevell, Harrison and Audsley (2009), the vulnerability of both

farmers and species is dependent on the scenario under consideration. They state that in agriculture, it is the socio-economic scenarios that particularly lead to different patterns of intensification, extensification and abandonment. For species, vulnerability is more related to climate change scenarios. In both cases, adaptation options and potential were associated with different socio-economic and policy intervention. Also, they have demonstrates the importance of cross-sectorial assessments of vulnerability, and highlights the importance of sectorial integration in policy development and implementation.

- The study done by Deressa, Hassan and Ringler (2009) on household vulnerability to climate change in the Nile basin of Ethiopia using econometric approach shows that farmers' vulnerability is highly sensitive to their minimum per day income requirement (poverty line) and agro-ecological setting. This shows that vulnerability to climatic extremes can be reduced by increasing their income and enabling them to meet their daily minimum requirement.
- Gbetitouo and Ringler (2009) calculated vulnerability as the net effect of sensitivity and exposure on adaptive capacity in South Africa. They show that South African farmers' vulnerability was characterized by the combination of medium-level risk exposure and medium to high levels of vulnerability. Also, greater wealth and high infrastructure and good access to resources increased the adaptive capacity of the area indicating that climate change will increase the burden of those who are already poor and vulnerable.
- A study by O'Brien, Sygna and Haugen (2004), indicates that at national level, though Norway may seem to benefit from climate change but regional and local level assessment

indicate that climate change will pose some challenges and threat to some regions and localities.

- O'Brien et al. (2004) stress that institutional support can help in adapting to climate change. Further, the study also reveal that though the macro scale studies help to evaluate the relative distribution of vulnerability in the country, but it will not capture different factors like differences between the farmers and between the villages.

There are very limited studies done regarding the vulnerability to climate change. According to the report by MoE (2010b) the identification of the vulnerable area to climate change is important in responding to climate change impact. Few studies regarding the vulnerability to climate change done in Nepal are as follows

- Lama and Devkota (2009) show that the adaptive capacity which is dependent on the socio-economic variable plays an important role in categorizing the vulnerability of the community or area. The study also points out that there have been changes in flowering and fruiting pattern in the area study.
- According to Bhusal (2009), the local people in Lumle were not aware of climate change, but just noticed the unpredictable nature of the weather and change in fruiting time of flower etc. Further, the adaptive measures that the locals adopted were response to observed risks and hazards which were mostly event specific based on local knowledge and innovations.
- Khatiwoda (2011) indicates that the Tharu communities in Kailali district vulnerabilities have increased due to the extreme events, especially floods and recommends that identification of local vulnerable groups is important in developmental plans.

Chapter III Methodology and Study Area

3.1 Study Area

3.1.1 Makwanpur District

Makwanpur district lies in the Central Development Region and is situated between 84°41’ and 85°31’ East longitude and 27°10’ and 27°40’ North latitude. The district is surrounded by Sindhuli, Lalitpur, Kavreplanchok, Kathmandu, Chitwan, Dhading, Rautahat, Bara and Parsa districts. It covers about 2426 square kilometer. The district ranges from 166 masl to 2584 masl. The district is broadly hilly and can be considered as Mahabharat hills in the north and Churia hills in the south. The slopes of Mahabharat hills are very steep. The climate of Makwanpur district ranges from tropical to temperate where tropical exist in the southern part and northern part comprise of temperature climate. The major river systems of the districts are Rapti and Bagmati. This district is known as an entry point to Kathmandu and two highway crosses from this district. The district is accessible by 47 km of East-West highway and 110 km of Tribhuvan highway and several district level roads. The population of this district according to 2001 census is 392604 and increasing by 2.22% (DDC, 2001). The population demography is shown in table 3.1.

Table 3.1: Population demography of Makwanpur District

Census year	Household	Family size	Population growth	Population density	Life expectancy	Male female ratio	Rural Population	Urban Population
1991	56091	5.6	2.6	129.7	58.5	1.02	82.9	17.1
2001	71112	5.7	2.2	160.5	55.75	1.02	82.6	17.4

(Source: DDC, 2010)

In table 3.1 though the population of Makwanpur district has increased within 10-year period, the percentage of population in rural and urban areas has not changed significantly. So, though the district is known for its industry, the majority of the people who lives in the rural areas are dependent on agriculture for their livelihood. For households sampling Chitlang village development committee (VDC) was selected as study area.

3.1.1.1Chitlang VDC

Chitlang lies in Makwanpur district that is hilly area and borders Phakhel, Bajrabarahi, Markhu VDCs and Kathmandu district. It has gently sloped agricultural land surrounded by mountains. The total area of the VDC is 33.2 square kilometre, and large area has favourable agricultural land with access to irrigation. The elevation of Chitlang ranges from 2000 masl to 2500 masl with sub-tropical to temperature climatic condition. The source of water supply and irrigation in the area is mainly the small rivulets/streams running across the VDCs (Pant, 2005).

The major occupation of Chitlang VDC is farming which is mainly subsistence in nature although cultivation of vegetables is one of the major income source of households in the area (Pant, 2005). The population demography is shown in table 3.2.

Table 3.2: Population demography of Chitlang VDC.

Year	Total Household	Male population	Female Population	Total population	Average household size
2001	1174	3935	3801	7736	6.603
2005	1366	4589	4549	9138	6.7

(Source: DDC, 2010 and Pant, 2005)

Table 3.2 shows that population of Chitlang VDC has increased from 2001 to 2005 having a growth rate of 4.5%, which is very high compared to the national growth rate. Also, the total households have increased from 1174 to 1366 and male-female ratio is nearly constant in the VDC. Chitlang is basically a Newar village with the highest population of

4668 (DDC, 2001). The population composition of Chitlang VDC in 2005 is shown in table 3.

Table 3.3: Population composition of Chitlang VDC

Ethnicity/caste	Household
Newar	841
Tamang	174
Chhetri	145
Bahun	113
Magar	54
Kami	20
Damai/Dholi	10
Thakuri	2
Gurung	1
Sarki	1
Rai	1

(Source: Pant, 2005)

The people that were literate in Chitlang in 2001 was 64.09% and illiterate was 35.91% whereas in 2005 literate was 63.43% and illiterate 36.57% which shows that it has not changed in four years' time.

Table 3.4: Literacy rate of Chitlang VDC

Year	Literate		Illiterate	
	Male (%)	Female (%)	Male (%)	Female (%)
2001	37.5	26.6	13.4	22.5
2005	38.2	25.2	12.0	24.5

(Source: DDC, 2001 and Pant, 2005)

Table 3.4 shows that literacy rate in the case of male population has increased from 2001 to 2005 slightly from 37.5% to 38.2% but has decreased in the case of female from 26.6% to 25.2%. But overall, the education status has not improved at all in four years' time instead it has worsened.

3.1.2 Ilam District

Ilam district lies in the Eastern development Region of Nepal. The Ilam district is situated between 26°40' to 27°08' north latitude and 87°40' to 88°10' east longitude

(Illamonline, 2011). The geography and climate of Ilam district varies greatly with altitude ranging from 150 masl in the south to 3700 masl in the north (Thakur, 2009). The area is generally hilly where the majority of people depend on agriculture. Its area is 1714 sq. km. with population of 282,822 (CBS, 2004). The climate of Ilam district is generally hot and wet summers and cold and dry winters. In Ilam district, two cash crops (ginger and broom grass) are getting popular with the paving of the main road (Takahatake, 2002). Ilam is one of the richest districts in Nepal because of its bio-cultural diversity, natural landscape and flourishing professionalism in agriculture (Ilamonline, 2011). Ilam is the second fastest developing district in eastern hills. Ilam population growth rate is 2.12%, and average family size is around 5.1 (Takahatake, 2002).

Table 3.5: Population demography of Ilam district

Year	House hold	Family size	Population growth	Male female ratio	Male population	Female Population	Total Population
1991	41450	5.5	2.12	1.01	115,377	229,214	229,214
2001	55619	5.1		1.02	142,535	140,287	282,822

Source: (Takahatake, 2002)

In table 3.5, it can be seen that population of Ilam district has increased from 229,214 to 282,822 from 1991 to 2001 with growth rate of 2.12. The male-female ratio has been nearly constant over the period, but family size has decreased from 5.5 to 5.1. Further, Namsaling VDC in Ilam district was taken as study area.

3.1.2.1 Namsaling VDC

Namsaling lies in Ilam district and borders Nayabazar VDC, Jogmai River, Mai River and Soyang River. It is situated at 26°53’45” and 26°57’03” North latitude and 87°57’03” and 88°71’54” East longitude. The altitude ranges from 500 masl to 2050 masl with generally temperate climate. The VDC covers an area of 2741.84 ha. The temperature ranges from 2°C to 35°C and annual rainfall is 375 mm. In Namsaling VDC, cash crops were introduced since the late 1980s (Takahatake, 2002). Table 6 shows the population demography of Namsaling.

Table 3.6: Population demography of Namsaling VDC

Year	House hold	Family size	Population growth	Male female ratio	Male population	Female Population	Total Population
1991	905	5.5	2.44	1.04	2435	2435	4978
1999	1113	5.4		1.09	3153	2884	6037

(Source: Takahatake, 2002)

In table 3.6, the population of Namsaling VDC has increased from 4978 from 1991 to 1999 with growth rate of 2.44. The male-female ratio has increased slightly from 1.04 to 1.09 but the family size has decreased slightly from 5.5 to 5.4. Further, Namsaling VDC population is mainly Hindu being 73.3% followed by Kirati 14.8%, and Buddhist 11.9% (Takahatake, 2002). The population composition of Namsaling in 1999 is given in table 3.7.

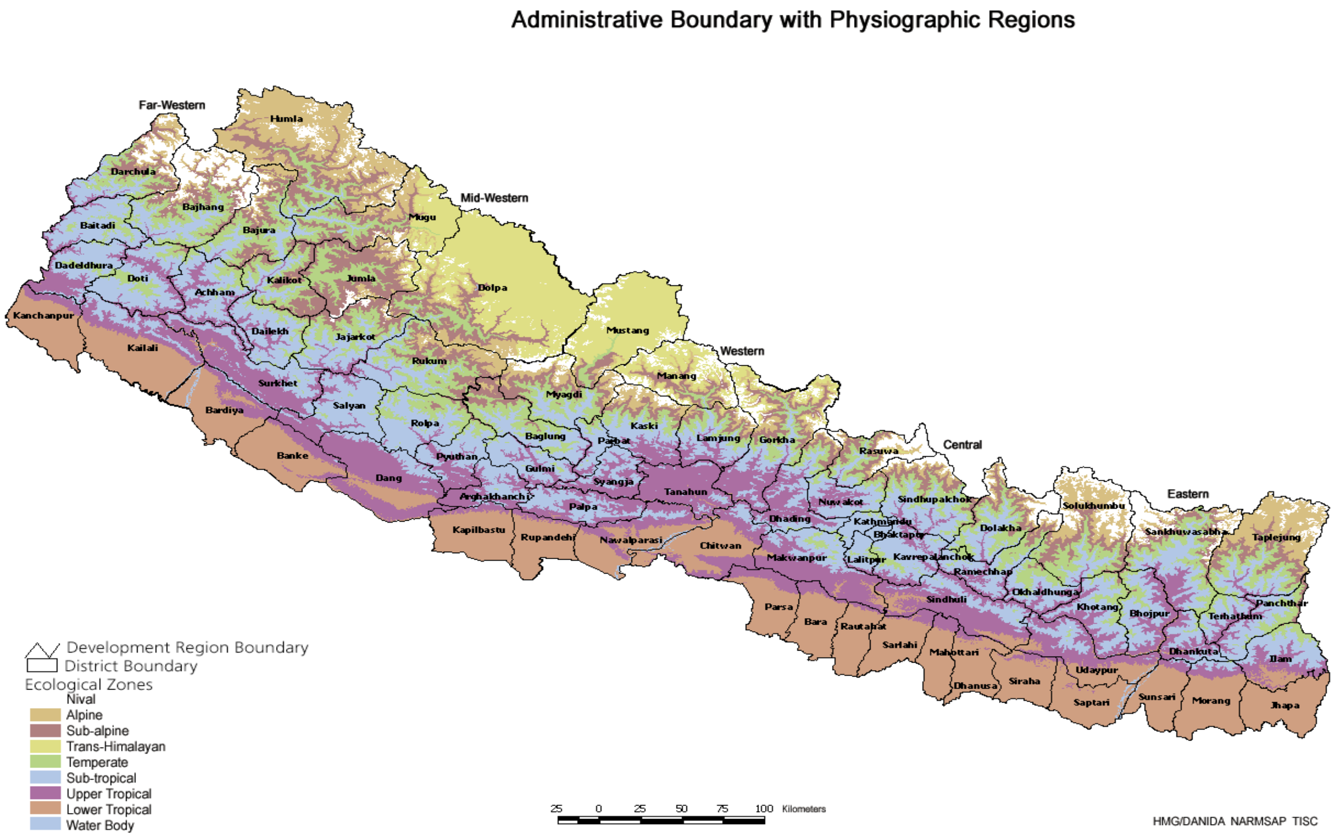
Table 3.7: Population composition of Namsaling VDC

Caste/ethnic group	Population
Bahun/Chhetri	2304 (38.2%)
Rai/Limbu	1806 (29.9%)
Tamang	497 (8.2%)
Magar	470 (7.8%)
Newar	401 (6.6%)
Occupational caste	468 (7.8%)
Others	91 (1.5%)

(Source: Takahatake, 2002)

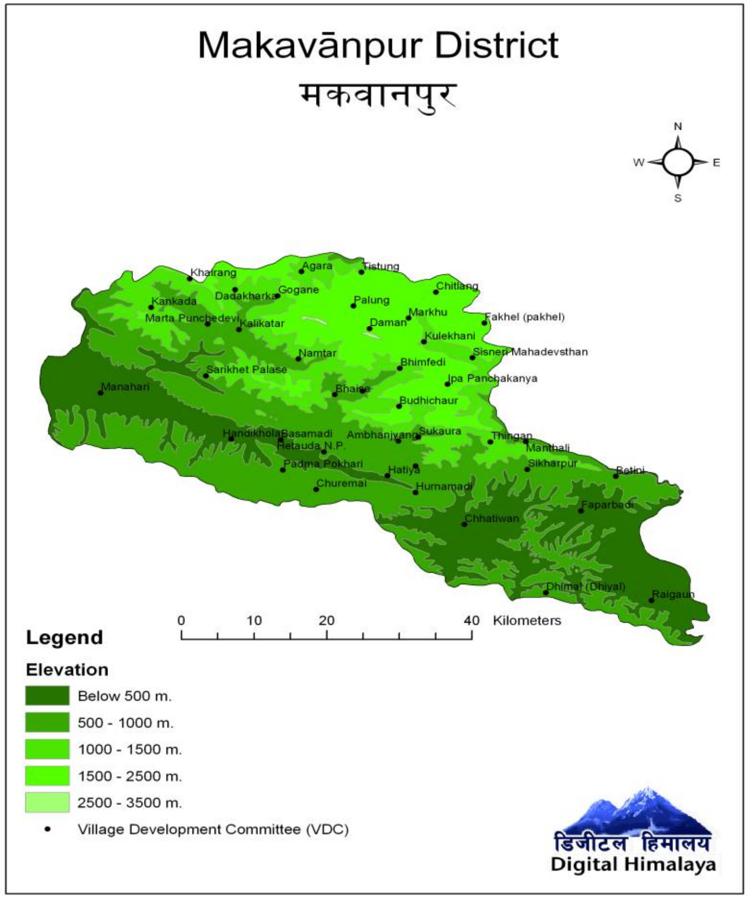
From table 3.7, it can be seen that Namsaling VDC is dominated by the Bahun and Chhetri primarily followed by Rai and Limbu. As being the former trade route to India it has developed more of a uniform culture in the area.

3.1.3 Map of Study Area



(Source: Lilleso et al., 2005)

Figure 3.1: Map of Nepal



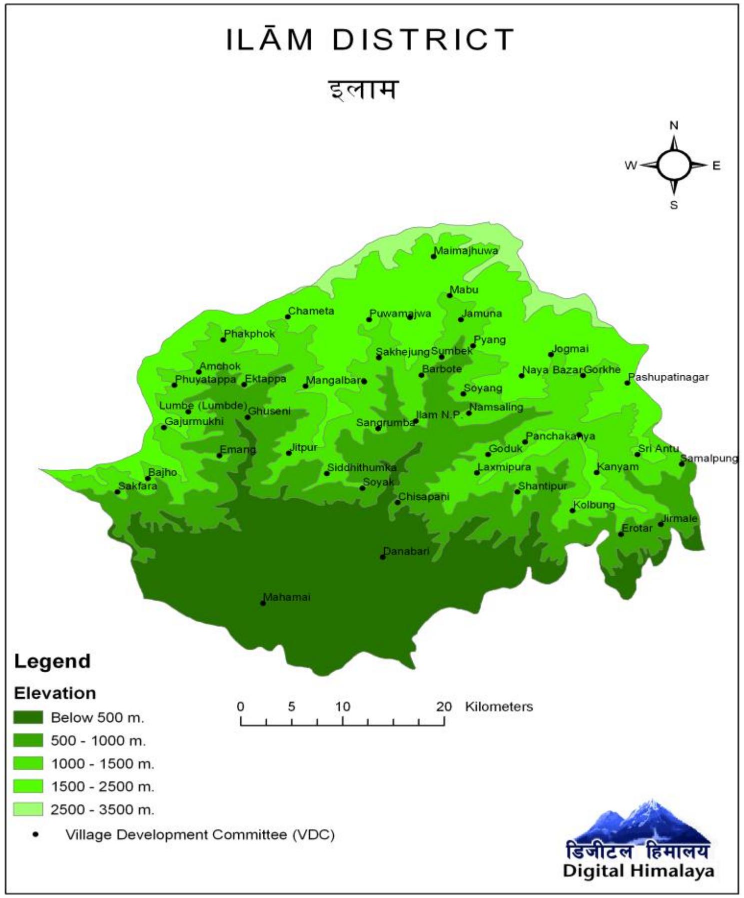
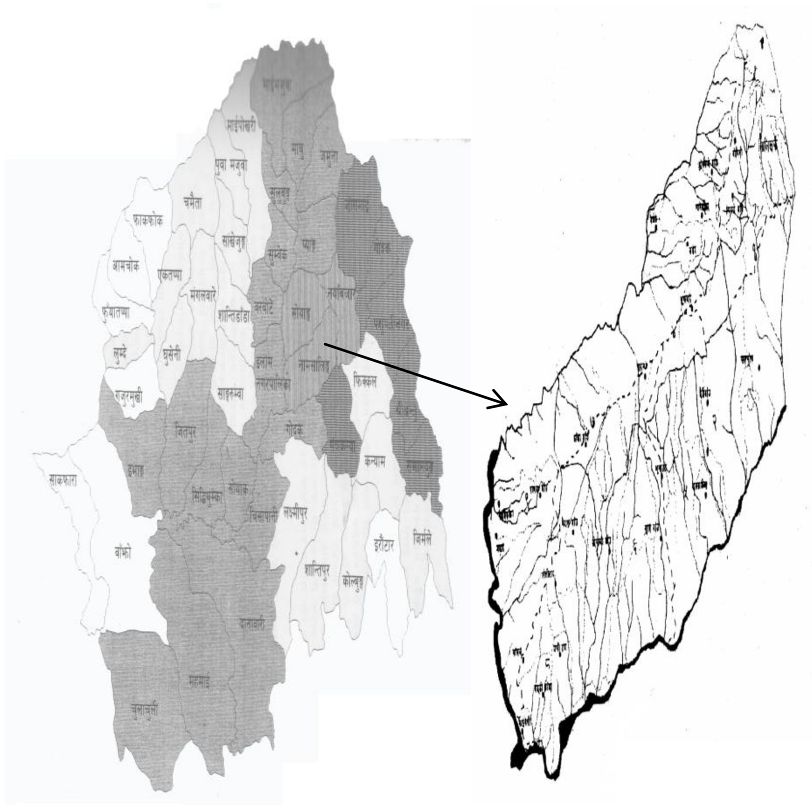


Figure 3.2: Map of Makwanpur and Ilam Districts

Chitlang

Namsaling



(Source: Pant, 2005 and Namsaling VDC, 1996)

Figure 3.3: Map of Chitlang and Namsaling VDC

3.2 Methodology

The study is based on primary data as well as secondary data. So, the methodology includes both quantitative and descriptive method.

3.2.1 Literature Review

Literature review is done to build the knowledge of past studies relevant to the sectors which are very essential to the study. The literature review helped to understand the importance, gaps and necessity of the research. Different relevant literatures were reviewed such as books, reports, journal articles, papers, web sites and other relevant sources.

3.2.2 Field Visit and Primary Data Collection

Field visit was carried out primarily in two VDCs, namely Chitlang and Namsaling for primary data collection. The field visit included consultation with various stakeholders and household surveys. The consultation with various stakeholders included key persons, concerned authorities, related non-governmental organizations (NGO) like Namsaling Community Development Centre, PLAN Nepal etc. This was done to get the information needed for the study and to have a holistic view. Semi-structured questionnaire survey was administered in both VDCs and random household survey was done. Sixty samples from each VDC covering 6 wards in each VDC, around 10 households from each ward were taken. Further, group discussions were held with the locals in the area to gain the local perspective of the farmers.

3.2.3 Secondary Data Collection

Secondary data were collected from various sources like Department of Hydrology and Meteorology (DHM), Ministry of Agriculture and Cooperatives (MoAC), websites, NGOs etc.

3.2.4 Research Instruments

3.2.4.1 Simple Regression Analysis

Simple regression analysis was done using the MS-EXCEL to see the relations between maximum temperature, minimum temperature, and precipitation of summer (May-August) and winter (November-February) seasons of Ilam and Makwanpur district from 1978 to 2008. The summer and winter seasons were taken according to the cropping season of Nepal as given by Joshi, Maharjan and Piya (2011). Also simple regression model was run to see the changes in the yield of the major food crops of Nepal in Ilam and Makwanpur district namely, paddy, maize, wheat, millet, barley and potato. Further, simple regression model was run to see the scenario of average maximum and minimum temperature, precipitation and disaster scenario of both the districts from 1978 to 2008.

3.2.4.2 Multiple Regression Analysis

To see the effect of climate change on the yield of the major crops of Nepal in Ilam and Makwanpur district, regression analysis was used as given by Nicholls (1997). This study uses the historic data of climate variables such as change in temperature and precipitation and yield data (Joshi, Maharjan and Piya, 2011). To capture the differential effect of day and night temperature, minimum and maximum mean air temperature is used as given by Peng et al. (2004). The multiple regression analysis used to see the effect of climate change on yield is given by (Nicholls, 1997).

$$\delta W = \beta_1 \delta R + \beta_2 \delta T_{max} + \beta_3 \delta T_{min}$$

Here, δW = Change in yield

δR = Change in rainfall

δT_{max} = Change in maximum temperature

δT_{min} = Change in minimum temperature

β_1, β_2 and β_3 are the coefficient of rainfall, maximum temperature and minimum temperature respectively.

In the above equation, detrending of the yield and climatic variables was done by using residuals to calculate quantitative relationships between variations in climate and yields to remove non-climatic influences like new cultivars, changes in management practices of crops. For this first difference, time-series for yields and climate variables, that is, year to year changes of yield and climate variables, are taken (Nicholls, 1997).

In this study, the major food crops of Nepal, paddy, maize, millet, wheat, barley and potato, as stated by Subedi (2003) are taken. Further, paddy, maize, potato and millet are taken as summer crops grown from May to August, and wheat and barley are taken as winter crops cultivated from November to February (Joshi, Maharjan and Piya, 2011). Also, due to the availability of the data and its consistency the period from 1978 to 2008 was taken for the analysis. The data for temperature and rainfall was taken from the Department of Hydrology and Meteorology (DHM), whereas yield data was taken from different publications of the Ministry of Agriculture and Cooperatives (MoAC).

3.2.4.3 Vulnerability Assessment

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. Also, it is used to develop the understanding of the contribution of socio-economic and biophysical factors to vulnerability (Hebb and Mortsch, 2007). The indicators were undertaken based on a review of the literature. The indicators were based on exposure, sensitivity and adaptive capacity and are given in table 3.8.

Table 3.8: Indicators of Vulnerability

Vulnerability components	Determinants of vulnerability	Description of indicators	Unit of measurement	Remarks
Adaptive Capacity	Wealth	Land holding Radio/mobile holding Livestock ownership Microfinance (credit) Agricultural cash income Non-agricultural cash income	Hectare (ha) Number Number Rupees Rupees Rupees	Higher the wealth lesser the vulnerability
	Technology	Use of fertilizer, pesticides and improved seed	Money spent	Higher the use of technology lesser is the vulnerability
	Irrigation	Irrigated landholding	Hectare	Higher the irrigated landholding lesser the vulnerability
	Literacy	Highest education attain in the household	Highest schooling year in HH	Higher the education attained lesser the vulnerability
	Human capital	Dependency ratio		Higher the dependency ratio higher the vulnerability
	Infrastructure	Time taken to reach facilities (road, school, health post, agriculture services, livestock services)	Minutes	Lesser the time taken to reach to these services lesser the vulnerability.
Sensitivity	Extreme climate	Frequency of natural disasters Death due to natural disasters Wounded due to natural disasters Houses destroyed and affected by natural disasters	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

From the conceptual framework, vulnerability depends on exposure, sensitivity and adaptive capacity where exposure and sensitivity give impact of climate change, whereas adaptive capacity gives the resilience of the society. So, vulnerability may be formulated mathematically as follows (Gbetibouo and Ringler, 2009):

V = f (I – AC)

where V is vulnerability,

I is potential impact,

AC is adaptive capacity.

A higher adaptive capacity is associated with a lower vulnerability, while a higher impact is associated with a higher vulnerability.

After considering theoretical determinants and indicators, we now standardize the indicators to ensure indicators are comparable (Vincent, 2004). All of the variables in the vulnerability indices are normalized to a range of 0 to 100. The values of each variable are normalized to the range of values in the data set by applying the following general formula:

$$Index\ Value = \frac{(Actual\ Value - Minimum\ Value)}{Maximum\ Value - Minimum\ Value} * 100$$

To ensure that low index values indicate high vulnerability in all cases, we reverse the index values by using [100 – index value] for indicators hypothesized to increase vulnerability. After standardizing, weight was attached to the vulnerability indicators. The literature indicates that there are three methods used to assign weights to indicators: (1) expert judgment (Brooks et al., 2005); (2) arbitrary choice of equal weight (Lucas and Hilderink, 2004) and (3) statistical methods such as principal component analysis or factor analysis (Cutter, Boruff and Shirley, 2003).

Here, household vulnerability to the exposure from temperature and precipitation for a community in a particular location will be the same which is taken from the district level data and for the sensitivity data is taken from the district level disaster scenario due to its availability issues so equal value was given to all the three determinants of vulnerability as per the report by the National Adaptation Programme of Action (2011). Then the principal component analysis (PCA) was used to generate weights for indicators of each determinant separately. Also, simple regression model was run to get year wise change in exposure and sensitivity and its coefficient is taken as proxy for its net effect. Further, within determinants PCA was done to see the variability of different indicators in exposure, sensitivity and adaptive capacity.

PCA is a technique used to extract few orthogonal linear combinations of variables which most successfully capture information from a set of variables (Gbetibouo and Ringler, 2009). According to Filmer and 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.

Following the methodology from Gbetibouo and Ringler (2009), PCA is explained as following.

Here it is supposed that for a set of N-variables (a^*1j to a^*Nj) that represents the N-variables (indicators) of each households. PCA starts by specifying each variable normalized by its mean and standard deviation, i.e, $a1j = (a^*1j – a^*1)/s^*1$, where a^*1 is the mean of a^*1j across households and s^*1 is its standard deviation. The variables that are selected are expressed as linear combinations of a set of underlying components for each household j:

$$a1j = \gamma 11\ A1j + \gamma 12A2j + \ldots + \gamma 1NANj$$

$$j= 1 \ldots J$$

$$aNj = \gamma N1A1j + \gamma N2A2j + \ldots + \gamma NNANj\ , (1)$$

where ,

A’s are the components

γ’s are coefficients for each variable on each component (do not vary among households). PCA overcomes this indeterminacy problem by finding a linear combination of variables with maximum variance (normally the first principal component W1*j*), then finding a second linear combination of variables orthogonal to the first and with maximal remaining variance, and so on. Technically, the procedure solves the equation

$(R - \lambda nI)\ \mathbf{v}n = 0$ for λn and $\mathbf{v}n$,

Where, R is the matrix of correlations between the scaled variables (the a's)

$\mathbf{v}n$ is the vector of coefficients on the nth component for each variable.

Solving the equation yields the following

R **(**the characteristic roots of),

λn (also known as eigenvalues)

$\mathbf{v}n$ (associated eigenvectors),

The final set of estimates is produced by scaling the **v***n*s to make sure that sum of their squares sums to the total variance; this is another restriction imposed to achieve determinacy of the problem.

The scoring factors from the model are achieved by inverting the system implied by equation (1) which yields a set of estimates for each of the *A*-principal components:

$A1j = f11\ a1j + f12\ a2j + \ldots + f1N\ aNj$

$j = 1 \ldots J$

$ANj = fN1\ a1j + fN2\ a2j + \ldots + fNN\ aNj$ (2)

Where, f's are the factor scores.

Therefore, the first principal component, expressed in terms of the variables, is an index for each household based on the following expression:

$A1j = f11\ (a^*1j - a^*1)/(s^*1) + \ldots + f1N\ (a^*Nj - a^*N)/(s^*N)$ (3)

After getting the weight from the PCA using STATA, we selected the positively associated indicators with PCA for adaptive capacity and then the normalized value by mean and standard deviation was multiplied with the weight for adaptive capacity. For exposure and sensitivity weight from PCA was multiplied with the coefficient which is taken as proxy for net effect. Finally, the vulnerability was calculated after applying the value in the vulnerability function given as

Vulnerability = Exposure + sensitivity – adaptive capacity

Chapter IV Results and Discussion

4.1 Trend Analysis of Climatic Variables

4.1.1 Trend Analysis of Climatic Variables of Makwanpur District

The trend analysis of climate variables was done as per the growing season of the major food crops of the districts. For the analysis of temperature trend data from two stations namely Daman station and Hetauda station were taken. For rainfall trend analysis, data were taken from Daman, Hetauda, Chisapani Gadhi, Markhu Gaun, Makwanpur Gadhi and Beluwa stations.

4.1.1.1 Temperature Trend of Makwanpur District

The average maximum and minimum temperature trend of Makwanpur was analysed for the period from 1978 to 2008. In figure 4.1 it can be seen that average maximum temperature was increasing with coefficient of 0.10 having R square value of 0.68. Similarly, average minimum temperature is also increasing with coefficient of 0.08 and R square value of 0.43. The p-value for both average maximum and minimum temperature was 0.000 showing 1% level of significance.

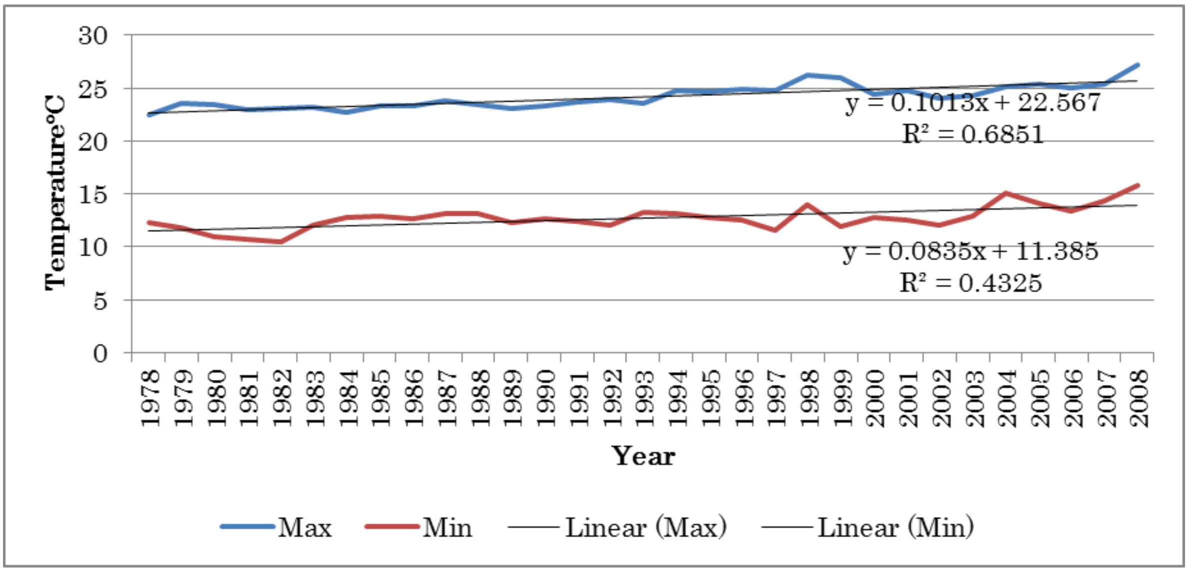


Figure 4.1: Temperature trend of Makwanpure district (1978-2008)

Further the average maximum and minimum temperature according to summer and winter seasons was also analysed from 1978 to 2008. Figure 4.2 shows the trend analysis of maximum and minimum temperature of summer season of Makwanpur district.

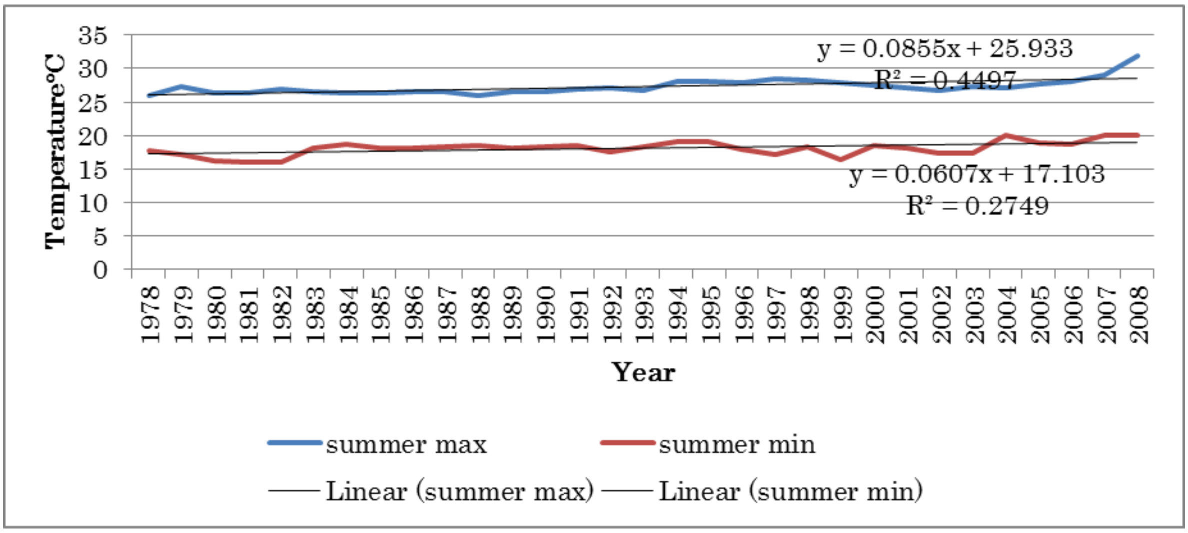


Figure 4.2: Summer temperature trend of Makwanpur district (1978-2008)

In figure 4.2 it can be seen that the average maximum and minimum temperature of summer season is increasing slightly with R square value of 0.44 and 0.27 respectively. The average maximum temperature is increasing with coefficient of 0.085, whereas average minimum temperature is increasing with coefficient of 0.060. The average maximum summer temperature is increasing at a higher rate than that of the average minimum. Though both average maximum and minimum was increasing, it is lesser compared to average maximum and minimum temperature of the district.

Also, trend analysis of the winter maximum and minimum temperature was also done from 1978 to 2008 to be consistent. Fig 4.3 shows that the winter average maximum and minimum temperature is also in increasing trend. The average maximum temperature is increasing with coefficient of 0.136 with R square value of 0.51. The average minimum temperature is rising with coefficient of 0.0854 with R square value of 0.27. Figure 4.3 shows that winter temperature average maximum and minimum temperature is increasing faster than that of summer temperature, and also of the average district temperature. This indicates that winter is getting warmer faster than the summer in Makwanpur district.

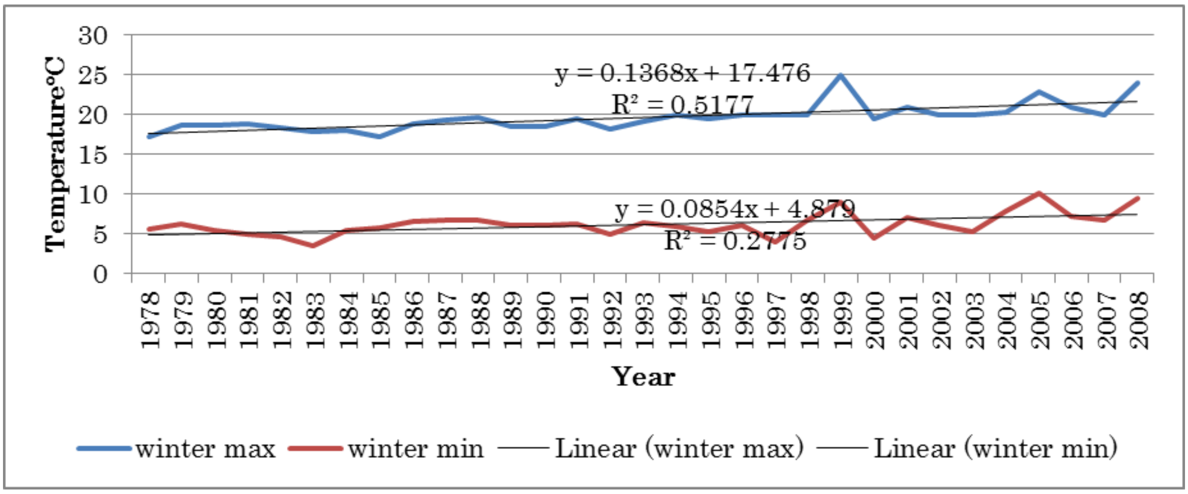


Figure 4.3: Winter temperature trend of Makwanpur district (1978-2008)

4.1.1.2 Rainfall Trend of Makwanpur District

The trend analysis of average summer and winter rainfall of Makwanpur district for 1978 to 2008 was done from the data collected from six stations. The trend analysis as presented in figure 4.4 shows that the average rainfall in Makwanpur district is increasing with coefficient of 1.69 and R square value of 0.19. A p-value for this is 0.18, which shows that it is not significant. Further, it is shown that the rainfall is erratic over the years. Also, it is shown that in 2008 the rainfall decreased, but the temperature increased in the district.

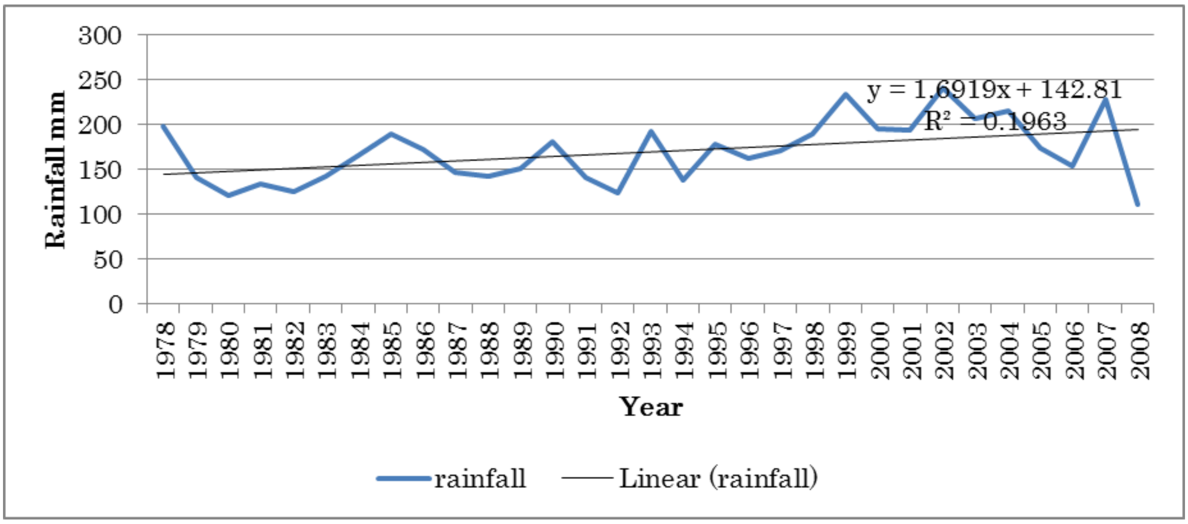


Figure 4.4: Rainfall trend of Makwanpur district (1978-2008)

Additionally, the trend analysis of the summer and winter average rainfall was performed for 1978 to 2008. Figure 4.5 shows the summer and winter average rainfall trend of Makwanpur district.

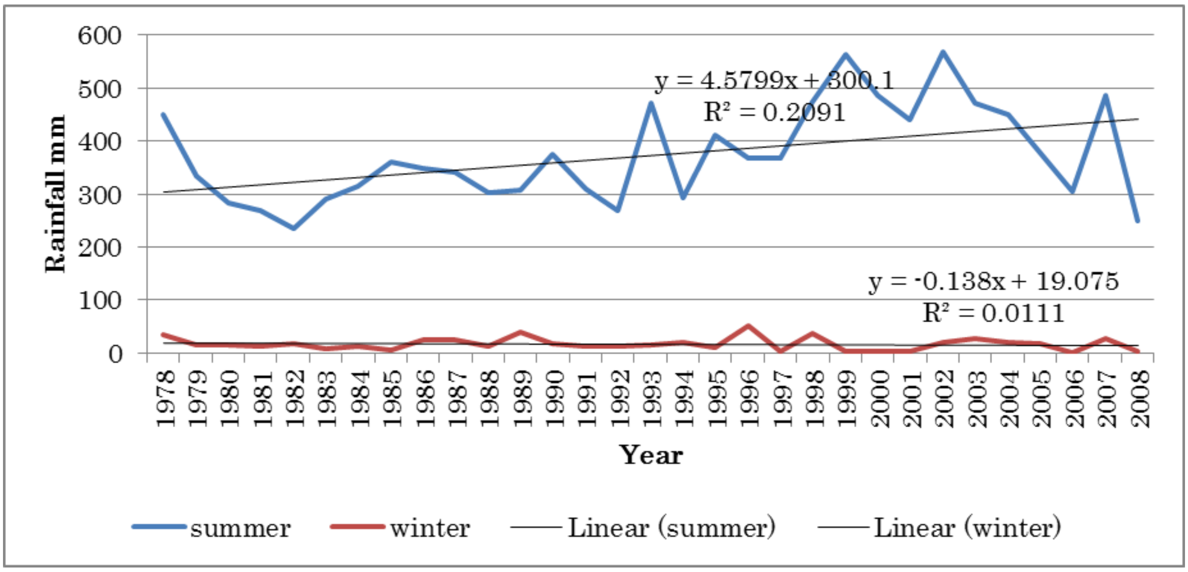


Figure 4.5: Summer and winter rainfall trend of Makwanpur district (1978-2008)

Figure 4.5 shows the trend analysis of average summer and winter rainfall in Makwanpur district from 1978 to 2008. The average summer rainfall over the analysed period is very erratic and is increasing with coefficient of 4.57 having R square value of 0.20. But, in the case of average winter rainfall, it is seen to be decreasing with coefficient of -0.13 and R square value of 0.01. As summer season is the main season where farmers grow majority of main crops any change in it will have great effect on farmers. Since average rainfall is erratic with some year having very high rainfall and some having very lean period, this will increase the chances of natural disasters like floods and droughts which will hamper agriculture production and affect farmers. Further, winter crops are facing water deficiency as it is in decreasing trend bringing more damage to the farmers.

4.1.2. Trend Analysis of Climatic Variables in Ilam District

Trend analysis of summer maximum and minimum temperature of Ilam was done using the data from the DHM. The analysis was done for the period from 1978 to 2008. For temperature trend analysis, data from two stations, Ilam Tea state and Kanyam tea state stations were used. Similarly, for rainfall trend analysis, data from three stations Ilam Tea state, Kanyam tea state and Himali gaun stations were used.

4.1.2.1 Temperature Trend Analysis of Ilam District

Average maximum and minimum trend of Ilam district was analysed using simple linear regression analysis. The trend is shown in figure 4.6.

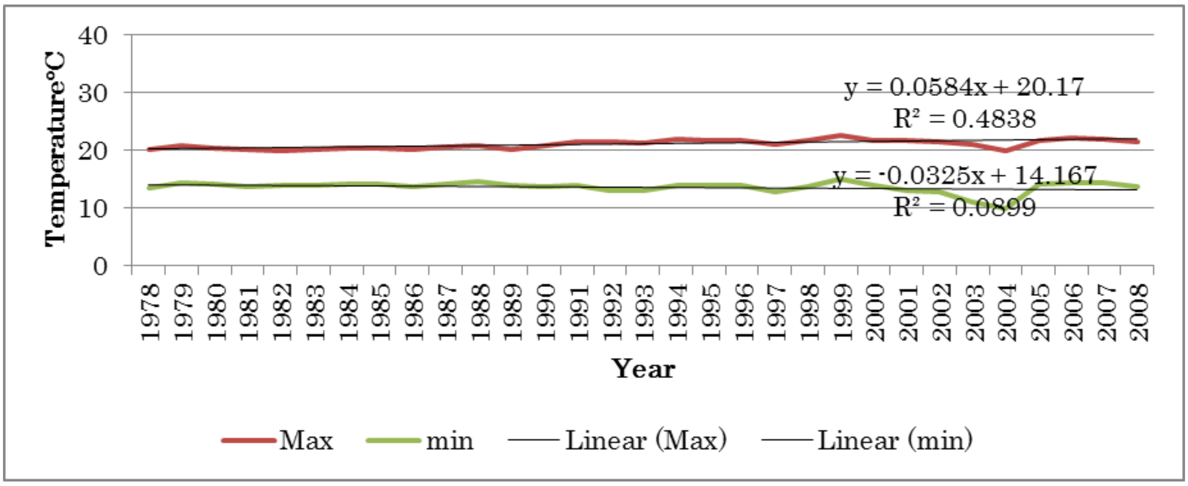


Figure 4.6: Maximum and minimum temperature trend of Ilam district (1978-2008)

Figure 4.6 shows that the average maximum temperature of Ilam district is increasing with coefficient of 0.05 having R square value of 0.48. However, the average minimum temperature is decreasing slightly with coefficient of 0.03 having R square value of 0.08. The p-value for average maximum temperature is 0.000 which shows that it is significant at 1% level of significance while p-value for average minimum temperature is 0.101 indicating that it is not significant.

Additionally, in Ilam district summer and winter average maximum and minimum temperature was analysed. Figure 4.7 shows the summer average maximum and minimum temperature trend from 1978 to 2008 in Ilam district. The average maximum temperature is increasing slightly with coefficient of 0.05 having R square value of 0.41, whereas average minimum temperature is decreasing with coefficient of -0.03 with R square value of 0.11. Though R square value for both average maximum and minimum temperature is not that significant, it indicates that summer temperature is varying with days becoming hotter and nights becoming colder.

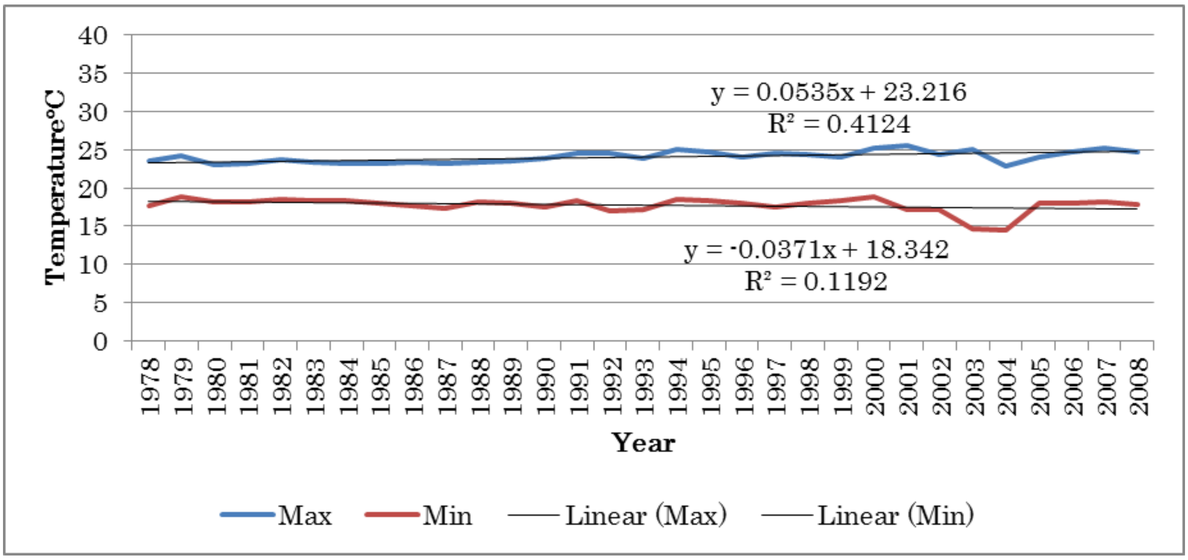


Figure 4.7: Summer temperature trend of Ilam district (1978-2008)

. Figure 4.8 shows the winter average maximum and minimum temperature trend for 1978 to 2008. The winter average maximum winter temperature is increasing with coefficient of 0.06 having R square value of 0.36. The winter average minimum temperature is decreasing with coefficient of -0.032 having R square value of 0.07. Though, R square value is not significant for both maximum and minimum temperature, it increases in maximum temperature and decrease in minimum temperature, which indicates that there is high chance of increase in climatic extreme like droughts.

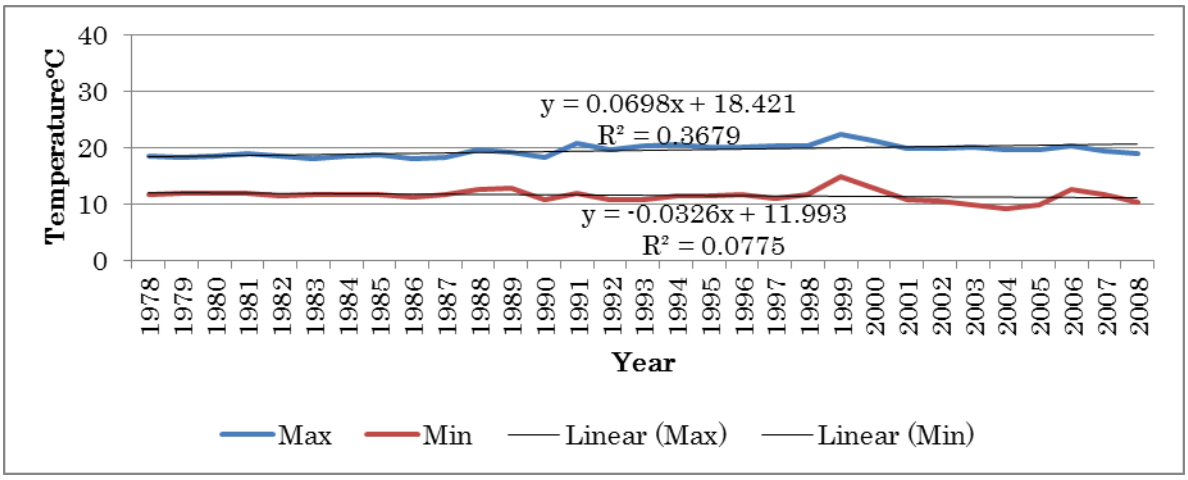


Figure 4.8: Winter temperature trend of Ilam district (1978-2008)

4.1.2.2 Average Rainfall Rrend of Ilam District

The average rainfall trend of Ilam district was analysed for 1978 to 2008 using data from three stations. The analysis shows that rainfall is in decreasing trend with coefficient of -0.86 having R square value of 0.06 as shown in figure 4.9. The p-value is 0.18 which is not significant. Further, rainfall is very erratic in Ilam district.

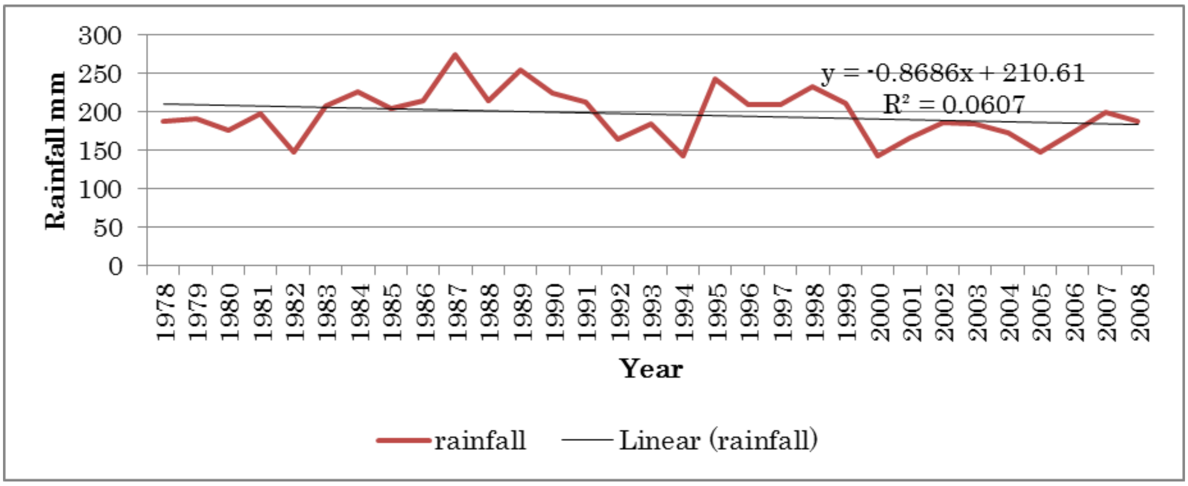


Figure 4.9: Rainfall trend of Ilam district (1978-2008)

The trend of average summer and winter rainfall was also analyzed from 1978 to 2008 using data from three stations. Figure 4.10 gives the trend analysis of summer and winter rainfall of Ilam district.

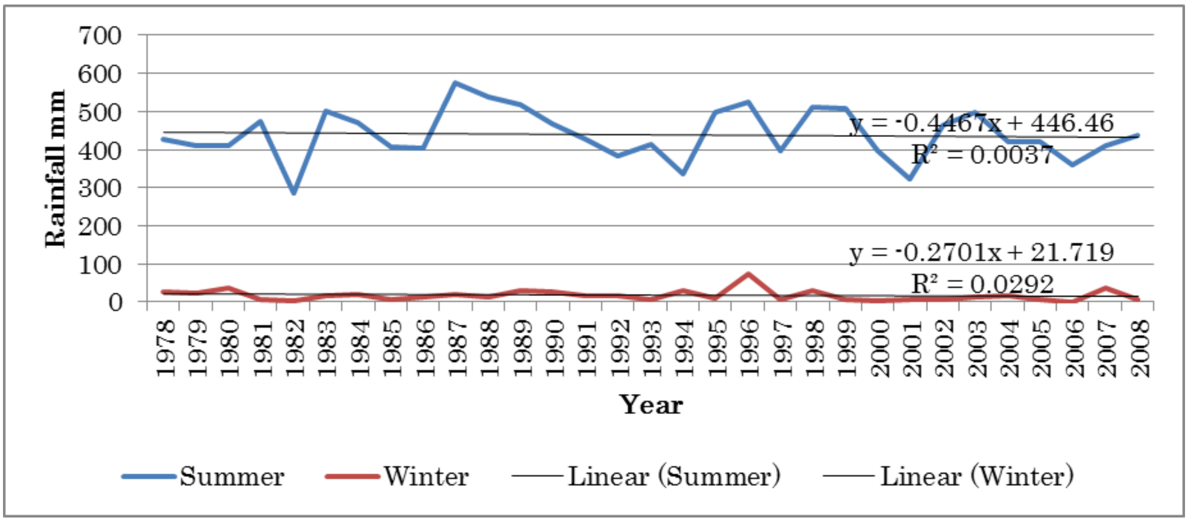


Figure 4.10: Summer and winter trend of Ilam district (1978-2008)

Figure 4.10 shows the average summer and winter rainfall of Ilam district. The average summer rainfall is decreasing with coefficient -0.44 having R square value of 0.003. Similarly, average winter rainfall is decreasing with coefficient -0.27 having R square value of 0.02. The rainfall is erratic mainly in summer season than in winter which also points to the increase in climatic extremes in summer. Further, change in rainfall in summer will have more effect for farmers as majority of the crops are summer crops which depend on rainfall. Also, decrease in rainfall is the indication of more long lasting drought in the region which is very harmful to farmers.

4.2 Effect of Climate Change on Yield of Major Food Crops of Nepal

4.2.1 Effect of Climate Change on Yield of Major Crops in Makwanpur District

The effect of climate change on the yield of major crops of Nepal was analyzed using the multiple regression analysis given by Nicholls (1997). The major crops of Nepal are paddy, wheat, maize, millet, barley and potato. Climate change effect was seen on these major crops. Detrending was done so that the management practices can be removed and only the effect of climatic variables on these crops can be calculated. The effect of climate change on the yield of major crops of Makwanpur district is given in table 4.1.

Table 4.1: Effect of climatic variables on yield of major food crops in Makwanpur

Crops	Max temp coefficient	P value	Min temp coefficient	P value	Rainfall Coefficient	P value	Change in Yield
Maize	-27.88	0.70	-129.83	0.01***	-0.00	0.99	-311.63
Paddy	81.18	0.29	-93.11	0.05**	0.69	0.24	214.54
Wheat	17.46	0.72	-63.43	0.20	3.27	0.27	-331.06
Millet	-60.44	0.16	23.81	0.36	-0.00	0.99	-124.93
Potato	-666.78	0.21	5.97	0.98	1.97	0.62	-4603.67
Barley	-9.57	0.60	-19.25	0.30	-0.37	0.74	-197.70

*** 1% level of significance, ** 5% level of significance

In table 4.1, except paddy, climate change will have negative impact on all other major food crops. Climate change has positive impact on yield of paddy where it increased by 214.52 kg/ha from 1978 to 2008 whereas yield of maize, wheat, millet, potato and barley decreased by -311.63 kg/ha, -331.06 kg/ha, -124.92 kg/ha, -4603.67 kg/ha, -197.69 kg/ ha respectively due to climate change from 1978 to 2008. While analysing the effect of different climatic variables on yield of crops it was seen that maximum temperature have positive relationship with yield of paddy and wheat at 81.17 and 17.45 respectively, whereas yield of maize, millet, potato and barley have negative relationships with coefficient of -27.88, -60.43, -666.783 and -9.56 respectively. Further, minimum temperature has negative relationship with yield of maize, paddy, wheat and barley with coefficient of -129.82, -93.10, -63.42 and -19.25 respectively and has only significant relationship with yield of maize at 1% level of significance and yield of paddy at 5% level of significance but other crops does not have significant relationship. Also, analysis shows that minimum temperature has positive relationship with the yield of millet and potato having coefficient of 23.80 and 5.97 respectively. Analysis also shows that the rainfall has negative relationship with yield of maize, millet and barley with coefficient of -0.0001, -0.001, and -0.373 respectively but are not significant. Though the majority of the value did not have significant p-value, this analysis showed the direction in which climate change is having effect on the yield of major food crops of Nepal. As potato is most negatively affected by climate change, farmers in hills and mountains will be more affected where it is major food crop.

4.2.2 Effect of Climate Change on Yield of Major Food Crops in Ilam District

The major crops of the Ilam district include cash crops like tea, broom grass and food crops like paddy, maize (Takahatake, 2002). The impact of climatic variables on yield of major food crops was seen. Following Nichols (1997), the multiple regression analysis was done to see the impact of climate change, where detrending was done to remove the impact of management practices so that the impact of climatic variables on yield of food crops can be calculated. Table 4.2 shows the effect of climate change on the major food crops of Nepal in Ilam district.

Table 4.2: Effect of climate change on yield of major food crops of Nepal in Ilam district

Crops	Max temp coefficient	P value	Min temp coefficient	P value	Rainfall Coefficient	P value	Change in Yield
Maize	89.46	0.04**	12.45	0.66	0.07	0.84	28.59
Paddy	-60.79	0.26	54.85	0.14	1.18	0.01***	-246.96
Wheat	24.38	0.70	51.82	0.25	2.93	0.061*	-136.25
Millet	-19.58	0.56	9.58	0.67	-0.07	0.80	-5.40
Potato	-88.23	0.88	-147.76	0.71	-3.11	0.50	508.37
Barley	-17.03	0.75	-2.30	0.95	0.65	0.61	24.74

* 1% level of significance, ** 5% level of significance, *** 10% level of significance

Table 4.2 shows the impact of climatic variables on the yield of major food crops of Nepal in Ilam district. Climate change had the positive impact on maize, potato and barley in increasing the yield by 28.59 kg/ha, 825.2264 kg/ha, 24.74 kg/ha respectively whereas paddy, wheat, and millet decreased by -246.961 kg/ha, -136.251 ha/kg, -5.399 kg/ha from 1978 to 2008. The maximum temperature had positive relationship with yield of maize, wheat and potato having coefficient of 89.46, 24.38 and 239.10 respectively. Only maize had significant p-value with maximum temperature at 5% level of significance whereas in the case of other crops there was no significant p-value. The minimum temperature had negative relationship with yield of potato and barley having coefficient of -246.231 and -2.298 respectively; whereas yield of maize, paddy, wheat and millet had positive relationship with coefficient of 12.45, 54.84, 51.82, and 9.57 respectively, but none had significant p-value. Furthermore, rainfall had negative relationship with yield of millet and potato having coefficient of 0.06 and -3.15 respectively while yield of other crops maize, paddy, wheat and barley had positive relationship with coefficient of 0.06, 1.18, 2.92 and 0.64 respectively. Only yield of paddy and wheat have significant relationship with rainfall at 1% level of significance and 10% level of significance respectively while yield of other crops did not have any significant p-value. Though climatic variables did not have any significant relationship with the change in yield of the major food crops in both the districts, the analysis shows the direction in which the climate change is having effect on major food crops of Nepal in both districts.

4.3 Trend Analysis of Yield of Major Food Crops in Nepal

4.3.1 Trend Analysis of Yield of Major Food Crops of Nepal in Makwanpur District

The major food crops of Nepal namely Paddy, wheat, maize, millet, barley and potato yield from 1978 to 2008 was analysed using simple linear regression model. The analysis is as follows:

4.3.1.1 Trend Analysis of Paddy Yield in Makwanpur District (1978-2008)

In figure 4.11, the yield of paddy is slightly decreasing with coefficient of -12.56 and R square value of 0.16 having p-value of 0.02 significant at 5% level of significance. Some of the reasons for the decline in the yield of paddy could be deteriorating soil condition, impact of decreasing rainfall in the district, increase in pest and diseases in the crops etc.

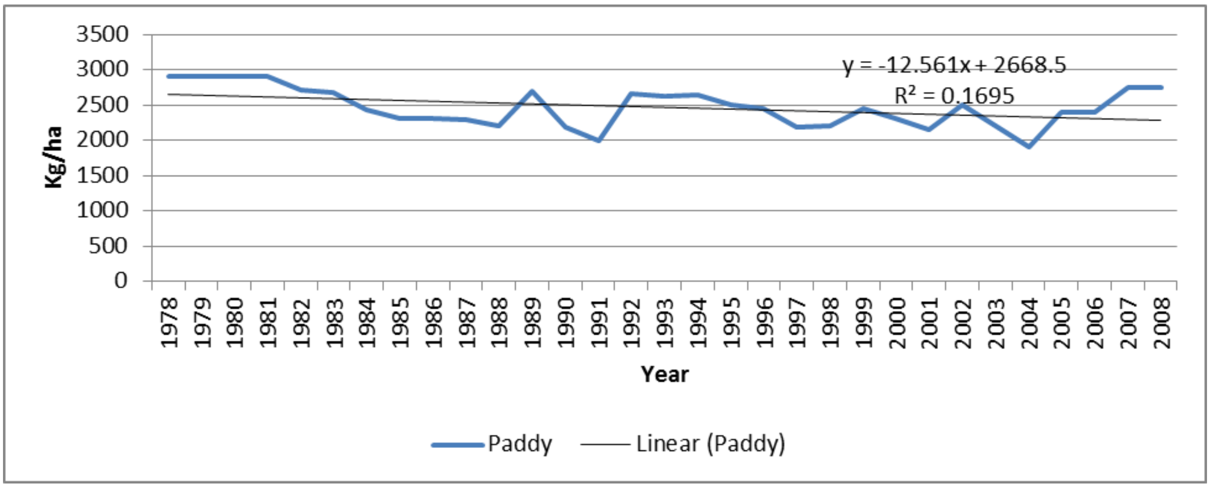


Figure 4.11: Trend of paddy yield in Makwanpur district (1978–2008)

4.3.1.2 Trend Analysis of Maize in Makwanpur District (1978-2008)

The simple linear regression analysis for yield of maize with was done from 1978 to 2008. In figure 4.12, maize yield has been decreasing steadily with R square value of 0.112 and coefficient of -10.047. The p-value of 0.06 is significant at 10% level of significance. As maize is the main food crop in hills and mountains, decrease in its yield will harm the people more. The factors that might have affected the yield adversely are the increase in diseases and pests, climate change etc.

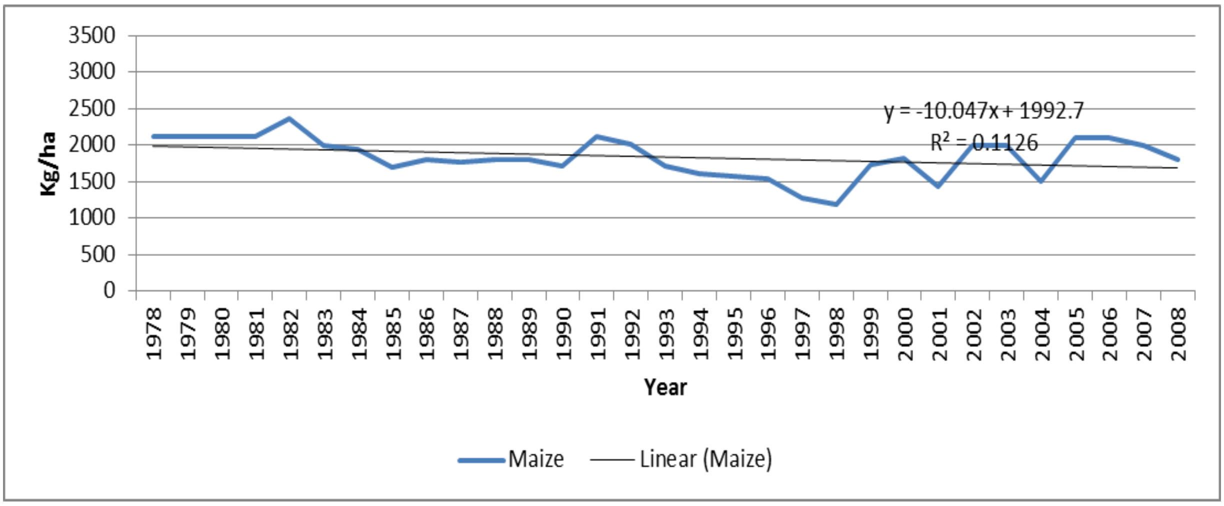


Figure 4.12: Trend of maize yield in Makwanpur district (1978-2008)

4.3.1.3 Trend Analysis of Millet Yield in Makwanpur District (1978-2008)

Millet is a summer crop which is one of the major crops mainly in the hills and mountains of Nepal. The trend analysis of millet yield from 1978 to 2008 is shown in figure 4.13.

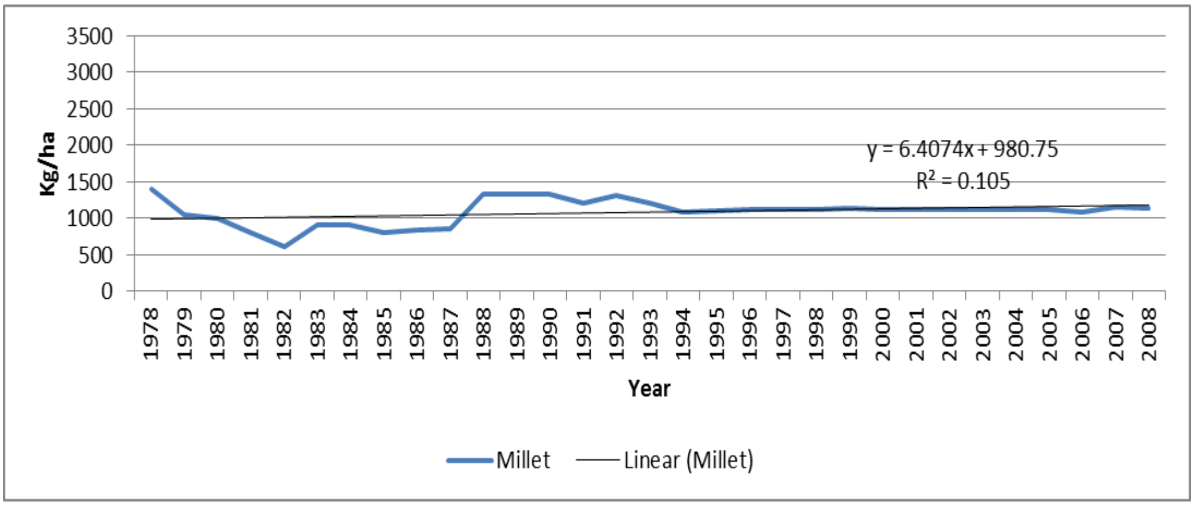


Figure 4.13: Trend of millet yield in Makwanpur district (1978-2008)

Figure 4.13 shows that millet has been increasing slightly over a 30-year period from 1978 to 2008 with coefficient of 6.40 and R square value of 0.105. The p-value from regression analysis is 0.07 which indicates that it is significant at 10% level of significance. The millet yield decreased drastically in 1982, which may be due to many factors in which the decrease in rainfall is one of the contributing factors.

4.3.1.4 Trend Analysis of Potato Yield in Makwanpur District (1978-2008)

Potato is one of the major food crops in the hills and mountains of Nepal. The time series analysis of yield of potato is shown in figure 4.14.

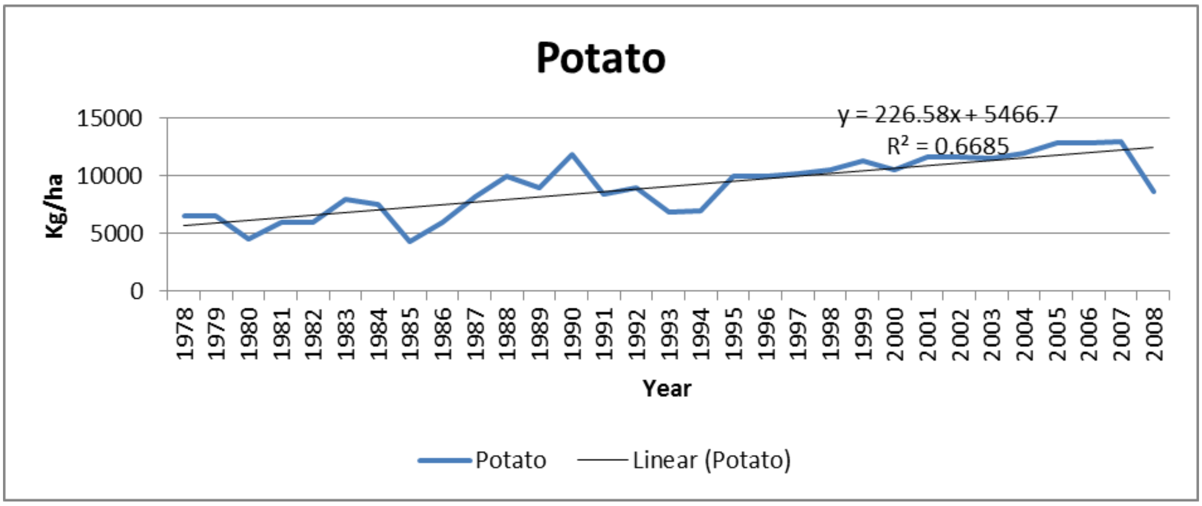


Figure 4.14: Trend of potato yield in Makwanpur district (1978-2008)

Figure 4.14 shows that yield of potato is increasing significantly over a 30-year period from 1978 to 2008 with coefficient of 226.58 and R square value of 0.66. The p-value from the regression analysis is 0.000 which indicates that it is significant at 1% level of significance.

4.3.1.5 Trend Analysis of Wheat Yield of Makwanpur District (1978-2008)

Wheat is the world's most cultivated food crop and is also one of the major food crops of Nepal. The time series analysis of wheat from 1978 to 2008 is shown in figure 4.15. Figure 4.15 shows that it is increasing with coefficient of 34.4 with R square value of 0.60. The p-value from regression analysis is 0.000 indicating that it is significant at 1% level of significance. The increase in wheat yield may be attributed to the increase in temperature and rainfall in the region and also other factors like improvement in management factors, that is, use of fertilizers, seeds etc.

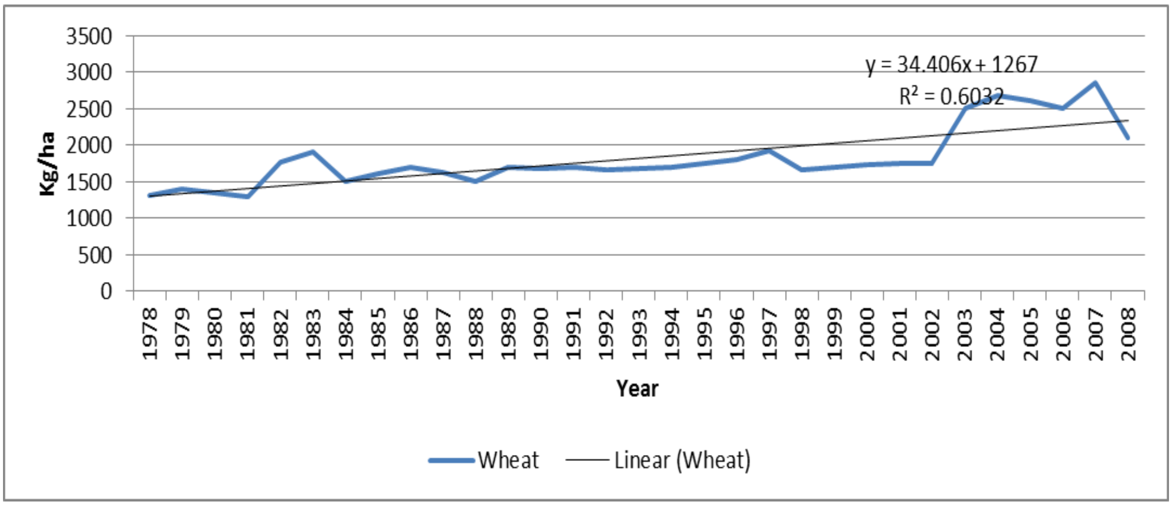


Figure 4.15: Trend of wheat yield in Makwanpur district (1978-2008)

4.3.1.6 Trend Analysis of Barley Yield in Makwanpur District (1978-2008)

Barley, normally grown in the cold places, is also one of the major food crops of Nepal and is grown mainly in the higher hills and mountains. Barley is important food crop especially to the people in the higher hills and mountains. The time series analysis of yield of barley in Makwanpur district is shown in figure 4.16.

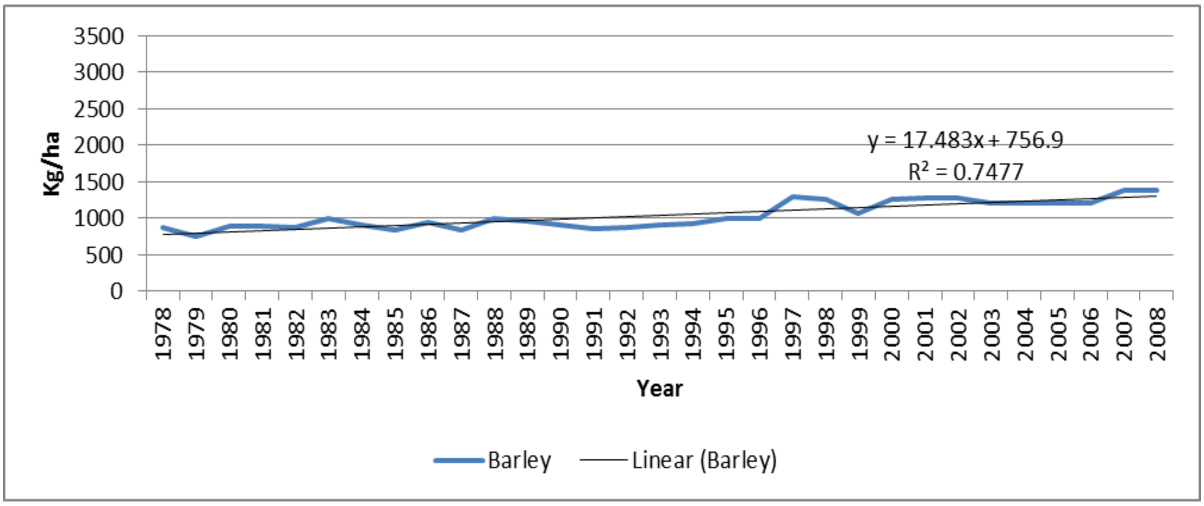


Figure 4.16: Trend of barley yield in Makwanpur district (1978-2008)

Figure 4.16 shows that the yield of barley is gradually increasing with coefficient of 17.48 having R square value of 0.74. The p-value from the regression analysis is 0.000 indicating that it is significant at 0% level of significance. Also, in the case of barley the yield increase can be attributed to better management practices like increase in fertilizers and pesticides use and also to climatic factors like increase in rainfall and temperature.

In Makwanpur district, the yield of food crops like paddy and maize is in decreasing trend while other crops are in increasing trend. Though all of them have significant p-value at different significance levels, the affecting factors for different food crops may be different factors like management, climate, market, infrastructure, natural disasters etc. In the case of potato, the yield is increasing very rapidly which is mainly because of factors like commercialization, use of high yielding varieties, and increase in the use of fertilizers and pesticides.

4.3.2 Trend Analysis of Yield of Major Food Crops of Nepal in Ilam District

Ilam lies in the eastern part of Nepal, and is one of the areas where cash crops and commercial agriculture has grown. The trend analysis of yield of major food crops of Nepal in Ilam district are as follows:

4.3.2.1 Trend of Paddy Yield in Ilam District (1978-2008)

Paddy is one of the important crops of Ilam (Takahatake, 2002). It normally grows well in high temperature and with plenty of water, but the temperature should not go beyond certain limit and the water should be managed properly. The time series analysis of paddy of Ilam district is shown in figure 4.17.

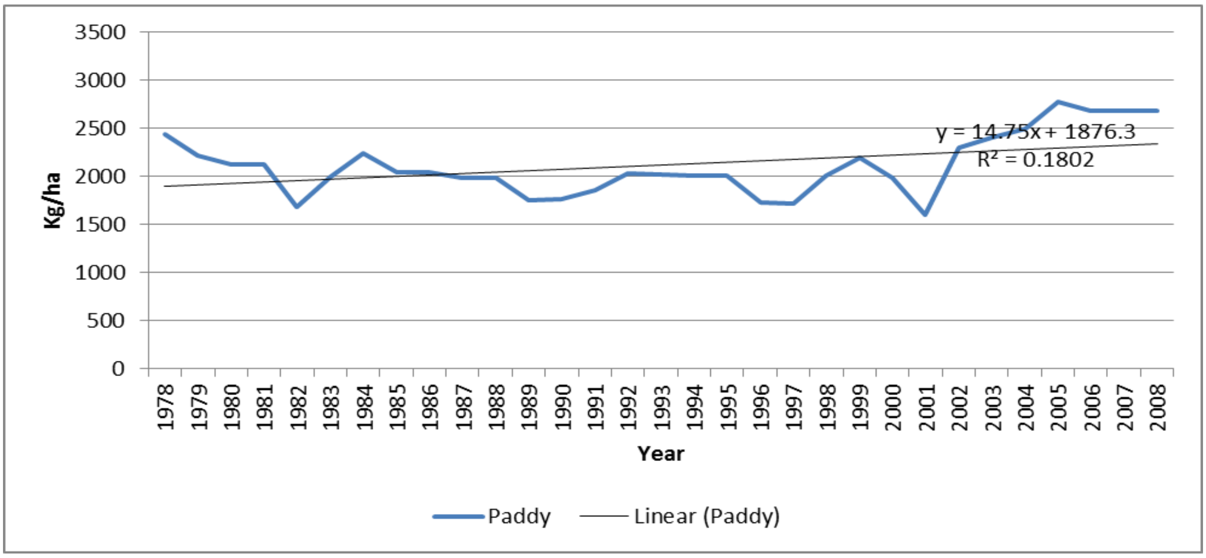


Figure 4.17: Trend of Paddy in Ilam district (1978-2008)

Figure 4.17 shows that paddy is increasing slightly with coefficient of 14.75 and R square value of 0.18. The p-value from regression analysis is 0.01 indicating that it is significant at 1% level of significance. As the district is slowly being moved to commercialization, management practices played important role in increasing the yield of paddy in the Ilam district.

4.3.2.2 Trend of Maize Yield in Ilam District (1978-2008)

Maize, which is C4 crop, is one of the major food crops especially in the hills and mountain regions. The time series analysis of the maize yield of Ilam district is shown in figure 4.18. The maize yield is decreasing slightly with coefficient of -12.53 and R square value of 0.38. The p-value from regression analysis is 0.000 which indicates that it is significant at 1% level of significance. The factors affecting the decrease in yield may have been the increase in temperature, and also other factors like management practices.

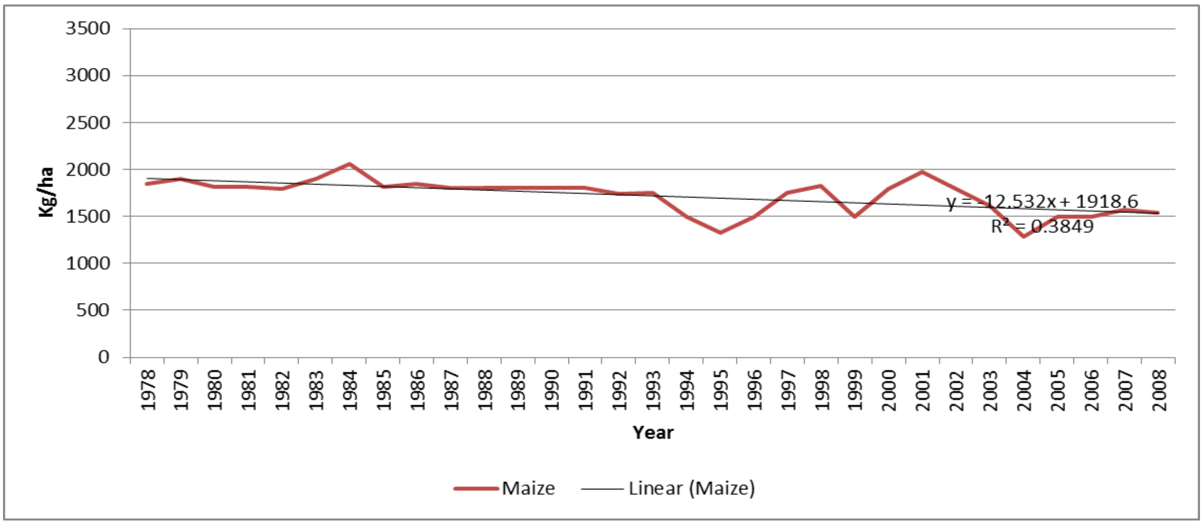


Figure 4.18: Trend of maize in Ilam district (1978-2008)

4.3.2.3 Trend of Millet Yield in Ilam District (1978-2008)

Millet is also one of the major crops of Nepal. Figure 4.19 shows that millet yield in Ilam district is decreasing slightly with coefficient of -1.10 with R square value of 0.007. The p-value from regression analysis shows that the change in yield of millet was not significant at 0.65. The yield of millet has decreased drastically in 1980, and after that it has increased slightly and remains nearly constant.

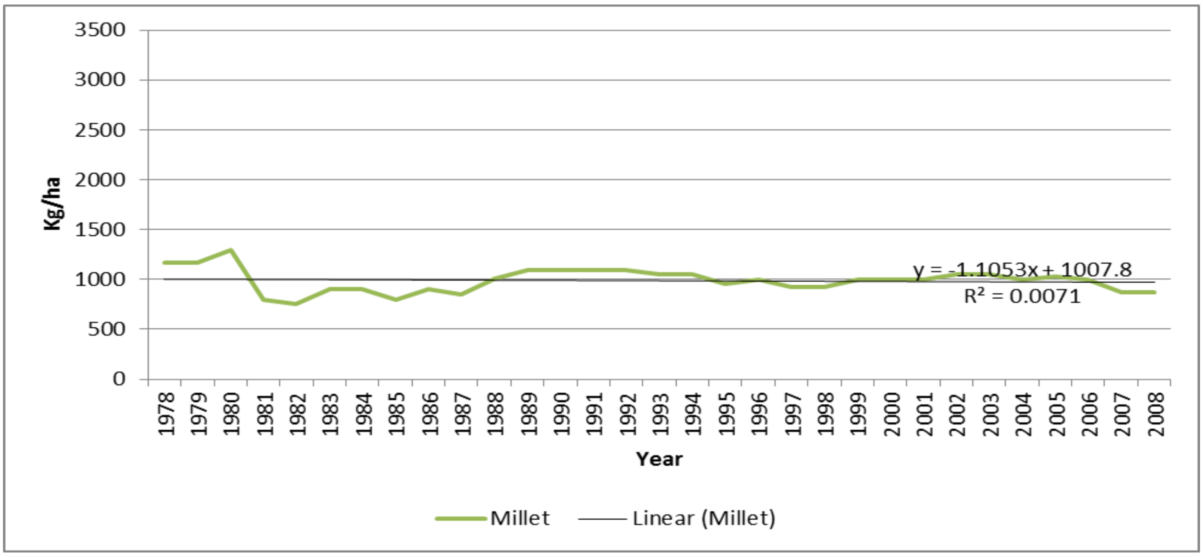


Figure 4.19: Trend of millet in Ilam district (1978-2008)

4.3.2.4 Trend of Potato Yield in Ilam District (1978-2008)

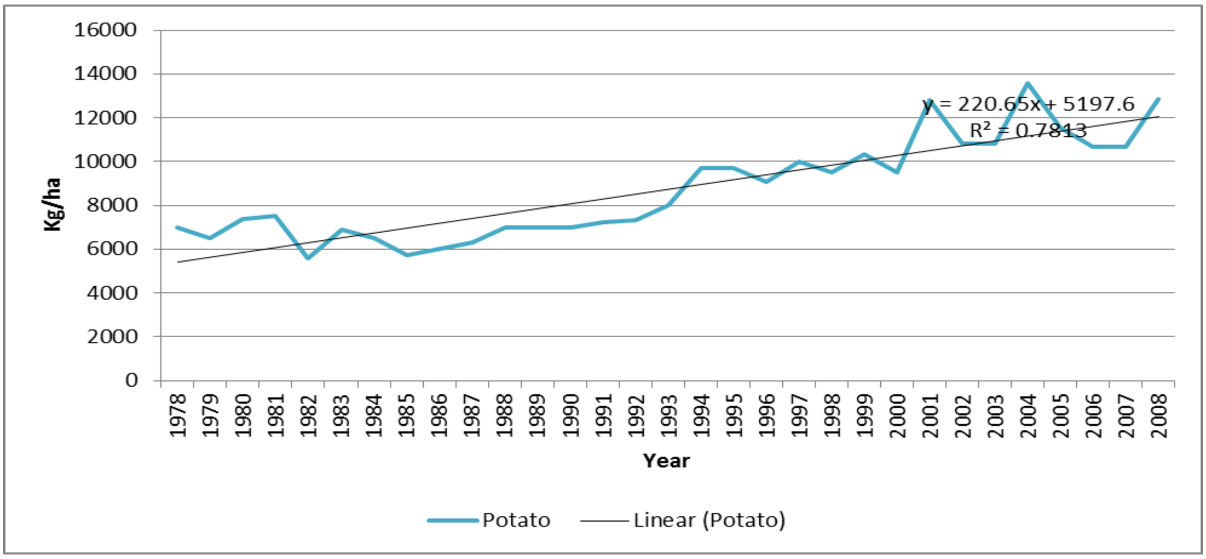


Figure 4.20: Trend of potato in Ilam district (1978-2008)

Figure 4.20 shows that the yield of potato from 1978 to 2008 is increasing with coefficient of 220.65 and R square value of 0.78. The p-value from the regression analysis shows that the increase in yield of potato is significant at 1% level of significance having value of 0.000. This high increase in yield of potato is mainly due to the change in management practices like improved seeds, fertilizers, and it is being adopted as one of the cash crops in the area.

4.3.2.5 Trend of Wheat Yield in Ilam District (1978-2008)

Wheat, a winter crop, is one of the major food crops of Ilam district. The time series analysis of the wheat is shown in figure 4.21.

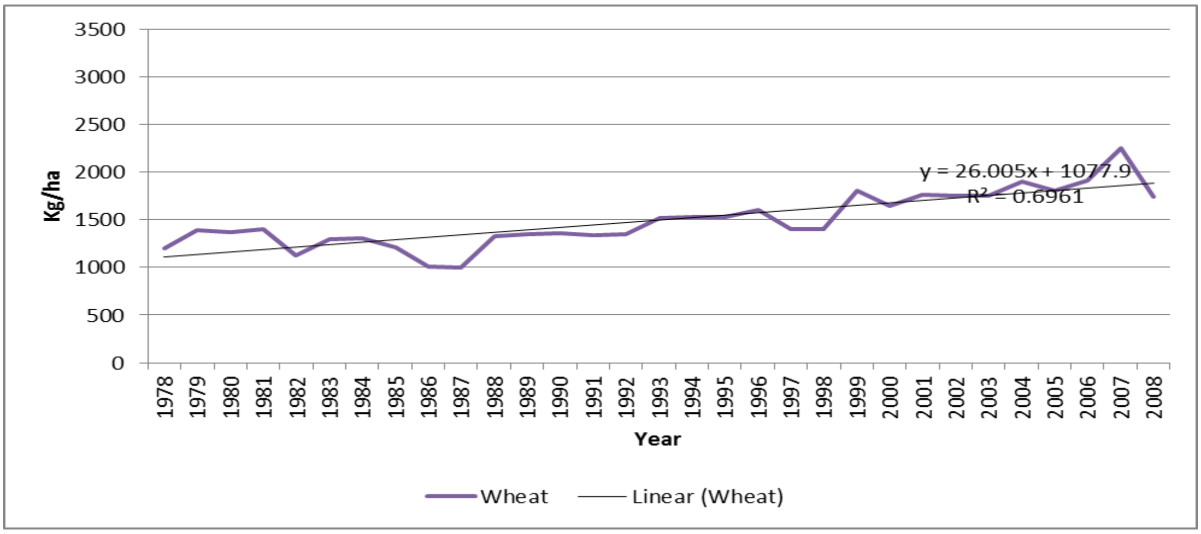


Figure 4.21: Trend of wheat in Ilam district (1978-2008)

Figure 4.21 gives the trend analysis of wheat from 1978 to 2008 which shows that wheat is increasing steadily having coefficient of 26.005 and R square value of 0.696. The regression analysis showed that the increase in wheat is significant at 1% level of significance having p-value of 0.000. There is a sharp decrease in 2008 as it was one of the driest years in Nepal. Further the improvement in management practices has attributed to the increase in its yield as well as climatic factors.

4.3.2.6 Trend of Barley Yield in Ilam District (1978-2008)

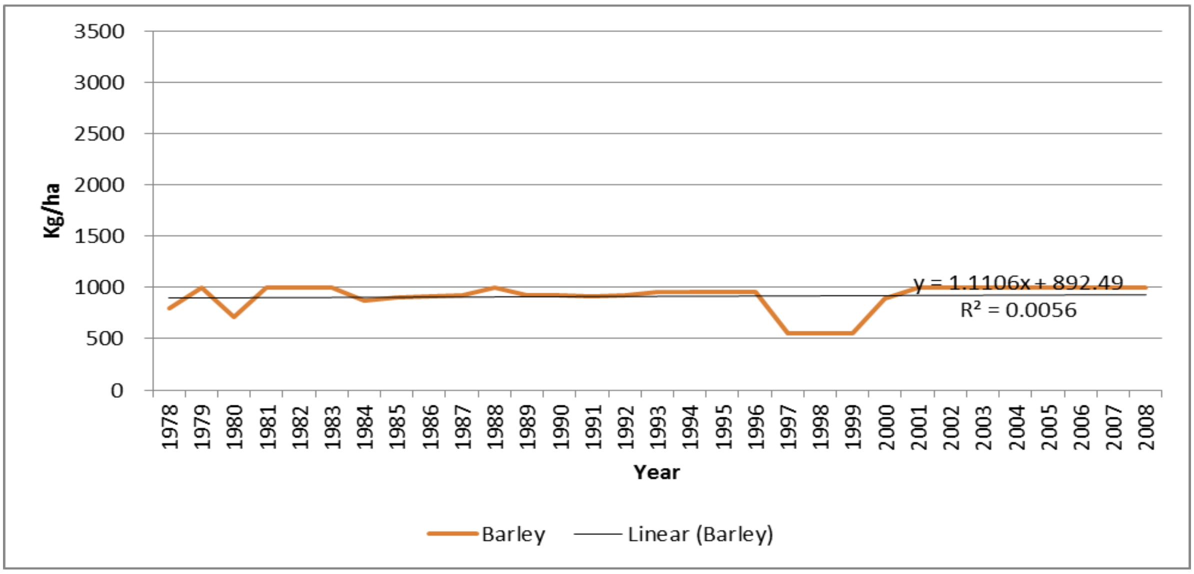


Figure 4.22: Trend of barley in Ilam district (1978-2008)

Figure 4.22 shows that the trend of barley yield is slightly increasing with coefficient of 1.110 and R square value of 0.005. The p-value from regression analysis shows that it is not that much significant having value of 0.688. The yield of barley has increased very slightly in 30-year period which can be attributed to factors like improvement in management practices and change in climatic factors.

The yield of major food crops in Makwanpur and Ilam district were analyzed using simple regression model. This shows that in the case of Makwanpur except for maize and paddy yield of all food crops are increasing within the 30-year period whereas in the case of Ilam district except maize and millet, yield of all other food crops are increasing within the 30-year period. The major concern in both the districts is the decrease in the yield of maize which is the major food crop in hills and mountains.

4.4 Natural Disaster Scenario

The natural disaster considered in this study are floods, landslides, electrical lightning, storms, hailstorms, hurricanes, heatwaves, coldwaves, rainfall, frosts, fog, droughts, forest fire, snowfall and famines which are all climate related disasters. The data of natural disasters were obtained from newspapers gathered by “www.desinventar.org” as in Nepal there is no proper data of natural disaster recorded over a 30-year period. The data were taken from the websites Desinventar that have been gathering information from various newspapers from 1978 to 2007, and for the 2008 data was taken from the Red Cross Society of Nepal. So data used for analysis are from 1978 to 2008. The time series regression analysis was done to see how natural disasters are occurring from 1978 to 2008.

4.4.1Natural Disaster Scenario in Makwanpur District

Makwanpur district altitude varies greatly from 166 masl to 2584 masl, and it has very steep slopes, so it is more prone to natural disasters. The major river systems in Makwanpur district are Rapti and Bagmati. The major climate related disasters that occurred in Makwanpur district are floods, landslides, hailstorms, and droughts.

4.4.1.1 Frequency of Occurrence of Natural Disaster in Makwanpur district (1978-2008)

The different climate related natural disasters like landslides, floods etc. reported were summed up according to the year and then a simple linear regression analysis was done. Figure 4.23 shows that the frequency of occurrence of natural disasters has started to increase in the last decades. The highest number of disasters was in 1993 where there were large number of floods and landslides in the central development region of Nepal where Makwanpur lies. The regression analysis shows that the frequency of occurrence is increasing with coefficient of 0.60 having R square value of 0.20 and p-value of 0.01 indicating it to be significant at 10% level of significance.

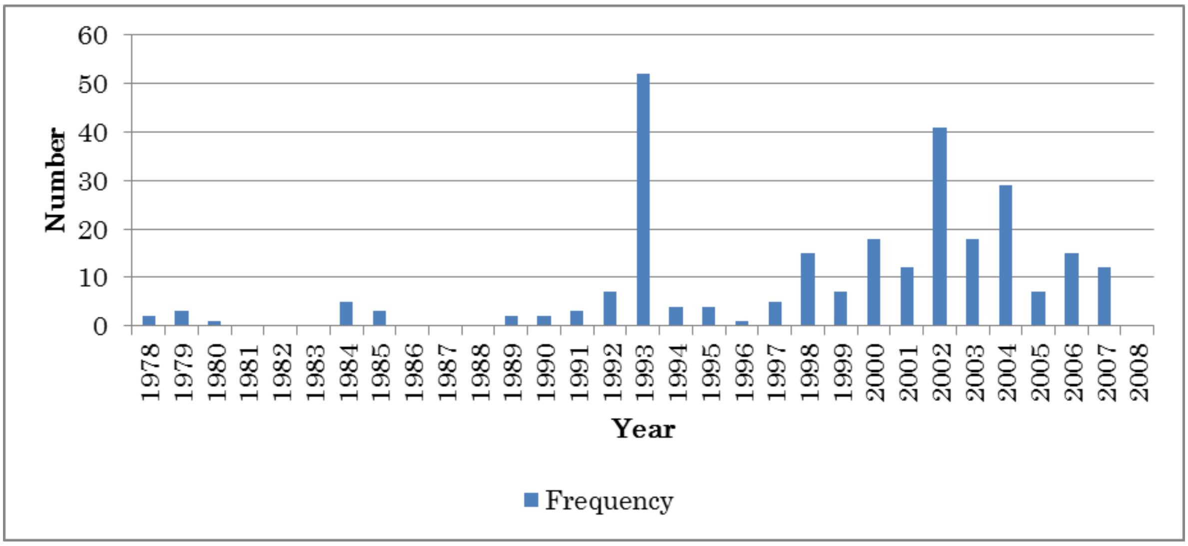


Figure 4.23: Frequency of natural disaster in Makwanpur district (1978-2008)

4.4.1.2 Death due to Natural Disaster in Makwanpur district (1978-2008)

Natural disasters like floods and landslides take a number of lives each year in Nepal. If any house member dies especially the economically active group, this will have negative affect on the household capacity to adapt to the changing climate by weakening the capacity of the house economically as well as psychologically. Figure 4.24 shows the number of deaths that occurred due to various natural disasters in the Makwanpur district. Figure 4.24 shows that the number of deaths due to natural disasters has been increasing in the last decade with the highest number of deaths in 1993. From simple regression analysis, it was found that the deaths due to natural disasters are increasing with coefficient 0.53 with R square value of 0.008 and p-value of 0.49 which is not significant.

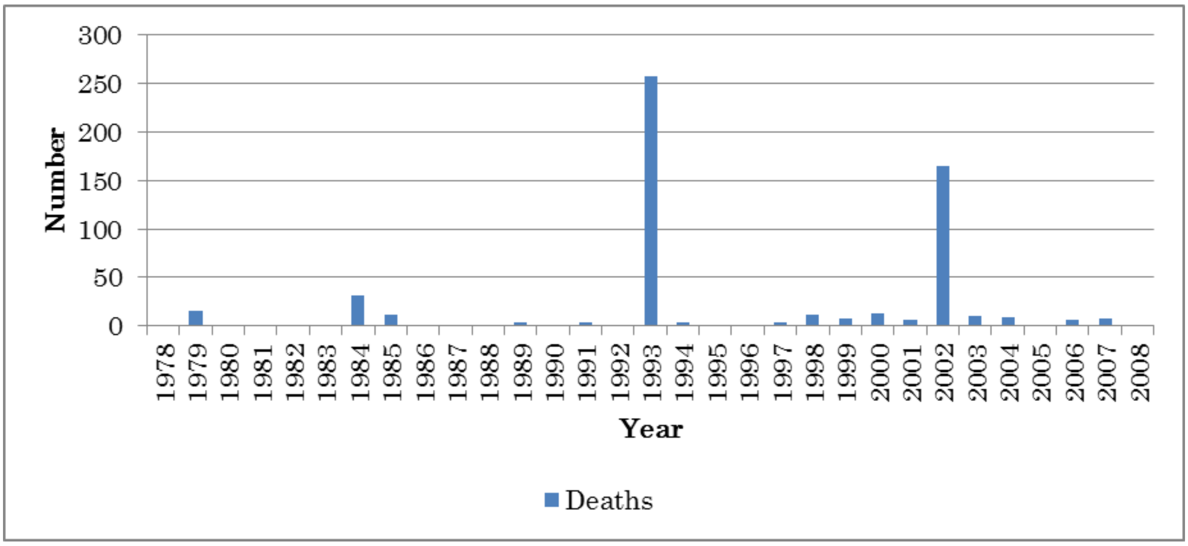


Figure 4.24: Number of people died due to natural disaster in Makwanpur district (1978-2008)

4.4.1.3 Wounded by Natural Disaster in Makwanpur District (1978-2008)

The scenario of people being wounded by the natural disaster in Makwanpur district is shown in the figure 4.25.

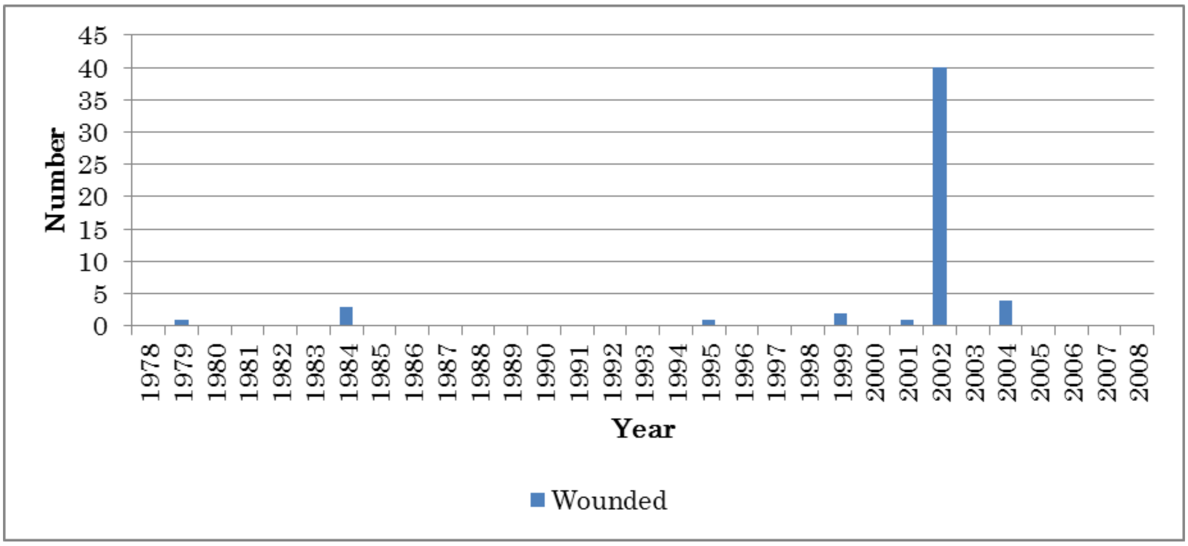


Figure 4.25: People wounded by natural disaster in Makwanpur district (1978-2008)

Figure 4.25 shows that the wounded numbers were more in 2002 but there are only few years where there are reported cases of people being wounded by the natural disaster. This can be mainly attributed to poor record keeping. However, the cases of the wounded increased significantly since 1999. The regression analysis shows that it is increasing with coefficient of 0.15 with R square value of 0.04 and p-value of 0.29 which is not significant.

4.4.1.4 Houses Destroyed and Affected by Natural Disaster in Makwanpur District (1978-2008)

The houses destroyed and affected by the natural disaster will also have tremendous effect on the livelihood of the people and their adaptive capacity, especially those people that have very less resources. The trend analysis of the houses destroyed and affected by natural disaster from 1978 to 2008 is shown in figure 4.26.

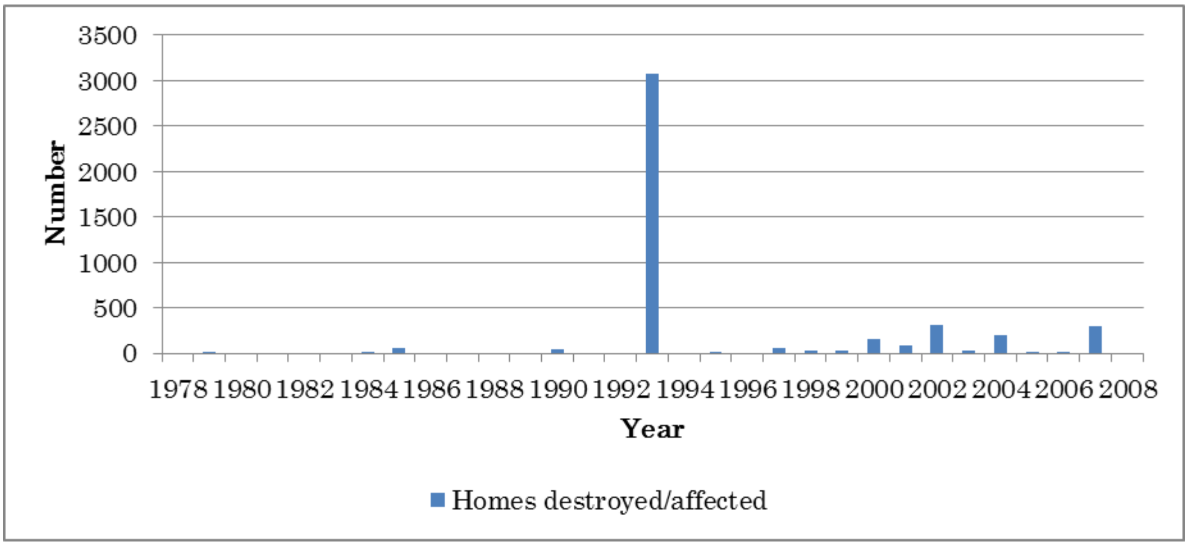


Figure 4.26: Houses destroyed and affected by natural disaster in Makwanpur district (1978-2008)

Figure 4.26 shows the houses destroyed and affected each year from 1978 to 2008. The number of houses destroyed and affected by the natural disaster has increased since 1997. The highest number of houses destroyed was in 1993, the year when a large number of landslides and floods occurred in Makwanpur district. The regression analysis shows that the houses destroyed and affected by natural disasters are increasing with coefficient of 3.30 with R square value of 0.01 and P-value of 0.46 which is not significant.

4.4.2 Natural Disaster Scenario in Ilam District.

According to the Ministry of Environment (MoE) (2010b), Ilam district is not as prone to natural disasters as other districts in Nepal. Still, the households in Ilam district are significantly affected by natural disasters. The scenario of natural disasters in Ilam district is shown below.

4.4.2.1 Frequency of Occurrence of Natural Disaster in Ilam District (1978-2008)

The frequency of the occurrence of the natural disasters is shown in figure 4.27.

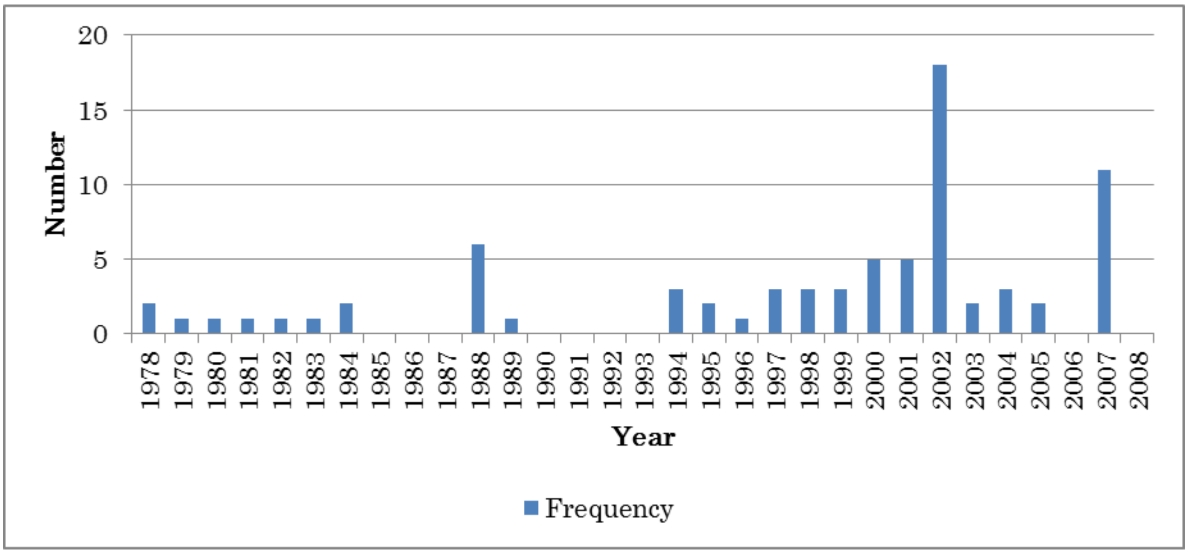


Figure 4.27: Frequency of occurrence of natural disaster in Ilam district (1978-2008)

The graph above shows the frequency of the occurrence of the natural disasters in Ilam district. The reported cases of the frequency of the occurrence of natural disasters started to increase since 1994. The frequency of the occurrence is increasing with coefficient of 0.15 having R square value of 0.14 and p-value of 0.03 which is significant at 5% level of significance.

4.4.2.1 Death due to Natural Disaster in Ilam District (1978-2008)

Figure 4.28 shows the death of people due to natural disasters in Ilam district from 1978 to 2008. The death numbers are increasing since 1994 and are highest in 1997 claiming 23 lives. The regression analysis showed that the death of people due to natural disasters is increasing with coefficient of 0.10 having R square value of 0.03 and p-value of 0.33

indicating that it is not significant.

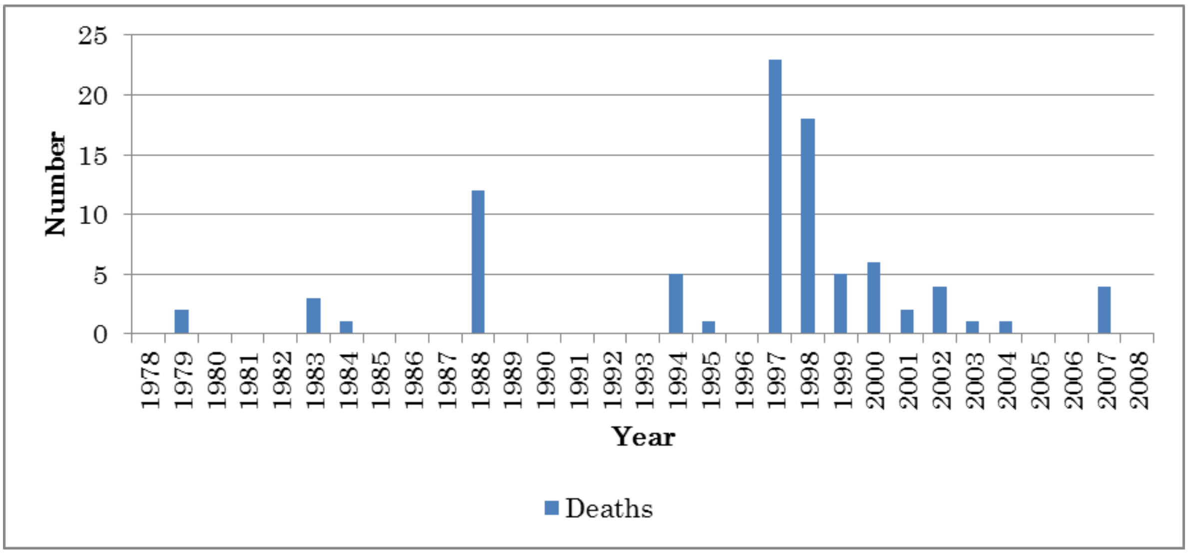


Figure 4.28: Death due to natural disaster in Ilam district (1978-2008)

4.4.2.3 Wounded due to Natural Disasters in Ilam District (1978-2008)

The trend analysis was done for people being wounded by natural disaster from 1978 to 2008. Figure 4.29 shows the number of people wounded each year from natural disaster from 1978 to 2008.

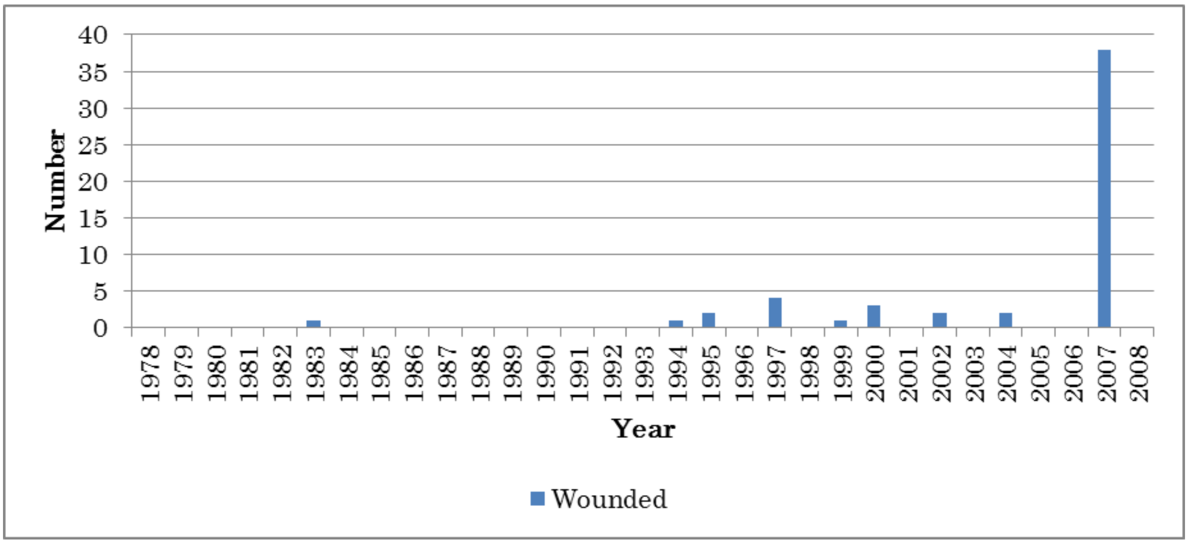


Figure 4.29: Wounded due to natural disasters in Ilam district (1978-2008)

In figure 4.29 the reported cases of people wounded from natural disasters started to increase since 1994. As frequency of natural disasters is higher in 2007, the wounded cases are higher but the death has decreased showing people are able to cope better to natural disasters. The regression analysis shows that the people being wounded by natural disasters are increasing with coefficient of 0.24 having R square value of 0.10 and p-value of 0.07 indicating that it is significant at 10% level of significance.

4.4.2.4 House Destroyed and Affected by Natural Disaster in Ilam District (1978-2008)

Houses are one of the important assests of the people's livelihood and when they are lost, it will have a negative effect on people for a longer period of time. Figure 4.30 shows the houses destroyed and affected by natural disasters over the period from 1978 to 2008.

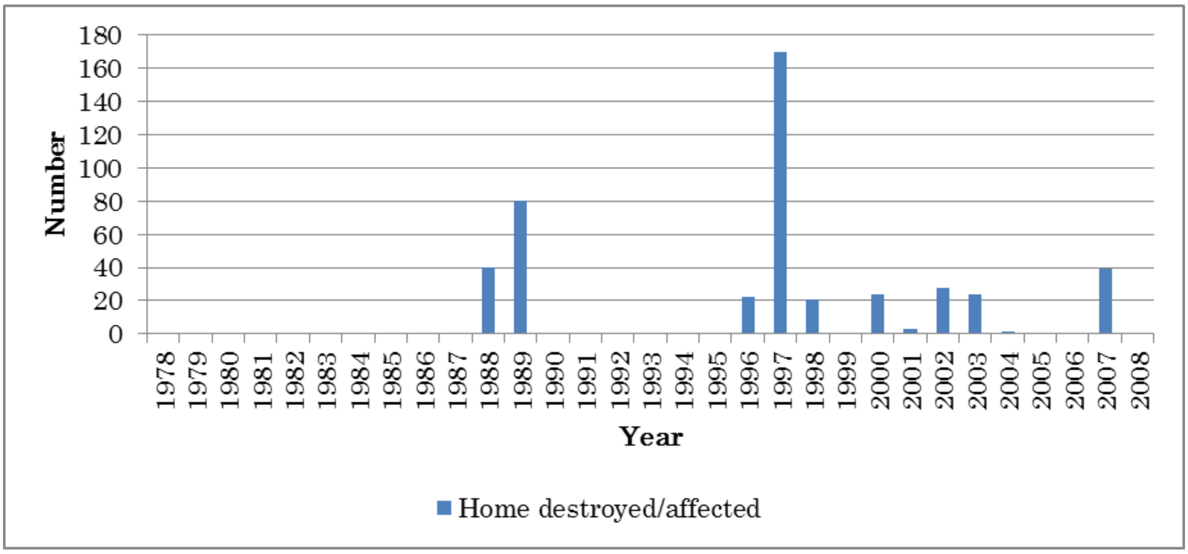


Figure 4.30: Houses destroyed and affected by natural disasters in Ilam district (1978-2008)

Figure 4.30 shows that the damage of houses by natural disasters since 1996 has increased. In 1997, natural disasters were the highest. The regression analysis shows that the houses destroyed by natural disasters were increasing at 0.63 with R square value 0.02 and p-value of 0.36 which is not significant.

Natural disasters in both the districts have been increasing steadily since the 1990s. This shows that the weather in both districts is getting more extreme, and humans are adversly affected by natural disasters. The increase in the extreme events in both districts is very damaging to the people especially the farmers as their occupation is hit hard by the these extremes. Futher, these extreme events will not just have a short term effect but will also have long term effect.

4.5 Socio-Economic Status of the Study Area

It is very important to understand the adaptive capacity of the farmers to determine their vulnerability. To study the adaptive capacity, we need to study the socio-economic parameters that govern their adaptive capacity. So, in order to study the adaptive capacity of farmers in two study areas which are Chitlang VDC of Makwanpur district and Namsaling VDC of Ilam district, a simple random household survey was carried out.

4.5.1 Household Income Distribution

The sampled households were divided into five quintiles groups according to their annual cash income. The average income of sampled households was divided into five quintiles and poorest group having <20% of income and richest group having >80% of income which is shown in table 4.3:

Table 4.3: Household income according to quintiles

VDC	Income (NRs.[1])				
	<20%	**20%-40%**	**40%-60%**	**60%-80%**	**>80%**
Chitlang	30075	81666	118608	163180	349617
Namsaling	30663	54647	90300	131524	229936

In table 4.3, it can be seen that there is income disparity among the sampled households in Chitlang with the highest group earning around 349,617 while the lowest having an average income of 30,075. Also, in Namsaling, there is high disparity among the income groups with the highest income group earning around 229,936, while the lowest earning 30,663 annually. The disparity in the case of Namsaling is lower than in the case of Chitlang.

4.5.2 Income Composition in Different Quintile

The income source of the sampled households is mainly from two sources, that is, cash income from agriculture, which includes crops and livestock and non-agriculture income

[1] US$1 = NRs. 72

which includes labour, shops, services, and remittance. The income distribution among different income groups is shown in figure 4.31.

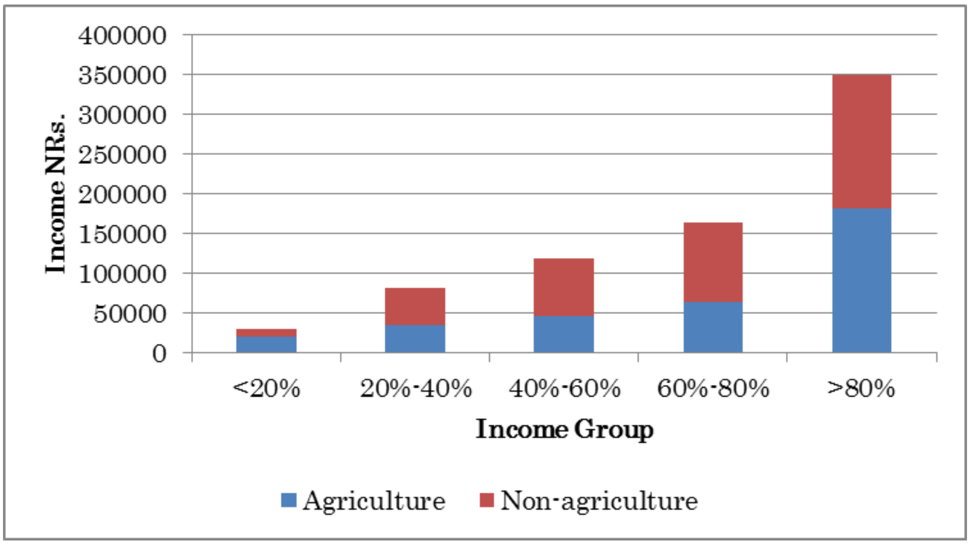


Figure 4.31: Average income composition of Chitlang according to quintiles

The above graph shows that the agricultural income plays a very important part in the case of the lowest income group, whereas with increase in income group the non-agricultural sources increases, which is mainly due to the jobs like services, remittance, and businesses like shop. In the case of highest income group contribution from agricultural income and non-agricultural income is almost same as they rely on commercial farming of vegetables and also rely on business, remittances, and services that are non-agricultural income source. Also, in the case of income group from 40%-60% to 60%-80%, the agricultural income has not increased significantly but non-agricultural income played an important part which is mainly due to the income from remittances which is higher for the people in 60%-80% group.

Figure 4.32 shows that in Namsaling, the agricultural cash income has been increasing steadily from lower income group to higher income group. Since in Namsaling, agricultural practices are moving towards commercialization, the agricultural income plays an important part in their annual income, whereas non-agricultural income has little share which increases from the group 60%-80% and higher where the remittance and income from the services plays major part, whereas in the lower income group like <20%, the non-agricultural income group, labour plays important source of income for their livelihood.

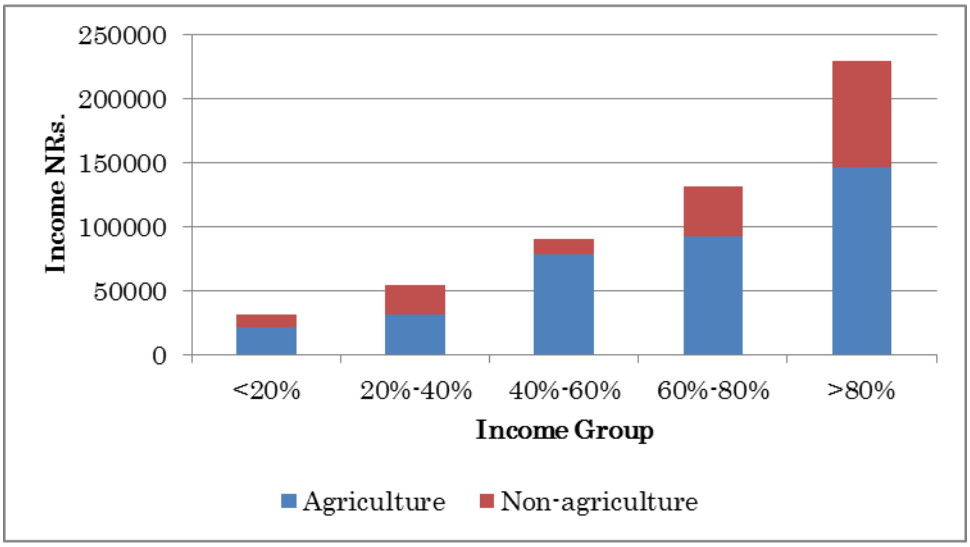


Figure 4.32: Average income composition of Namsaling according to quintiles

It was observed that in the case of Chitlang, the non-agricultural income played a major part in their annual income source as it is closer to Kathmandu where they generally go in search of work. Also the disparity among the income groups is higher in case of Chitlang. In the case of Namsaling agricultural cash income play a major part in all the groups as commercial farming is getting popularity and there are more farmers associations who are actively working for the betterment of agriculture in the area.

4.5.3 Land Distribution in Chitlang and Namsaling VDC.

To see how the land is distributed among the sampled households farmers in the Chitlang and Namsaling VDCs households were divided according to landholding as marginal famers, small farmers and large farmers based on Sharma (1999). The land distribution characteristics of the sampled households is shown in Table 4.4

Table 4.4: Landholding among farm household

VDC	Sampled Household	Land holding		
		Marginal <0.5 ha	Small 0.5-2.0 ha	Large >2.0
Chitlang	Total Land (ha)	10.06(27.4)	26.66(72.6)	-
	Household	31(51.7)	29(48.3)	-
Namsaling	Total Land(ha)	3.2(5.6)	46.36(80.3)	8.14(14.1)
	Household	11(18.3)	46(76.7)	3(5)

In table 4.4, it can be seen that in Chitlang 51.7% of the sampled households are marginal farmers while 48.5% are small farmers. Here, 51.7% hold 10.06 ha of land while 48.3% holds 26.66 ha of land. In the case of Namsaling, 18.3% of the households were marginal farmers which hold 3.2 ha of land while 46 households were small farmers that hold 46.36 ha of land, and finally, 5% of households were large farmers that hold 8.14 ha of land.

4.5.4 Household Landholding Type of Chitlang and Namsaling VDC

In this study land is generally classified as irrigated and non-irrigated land. Figure 4.33 shows the landholding type according to farm category.

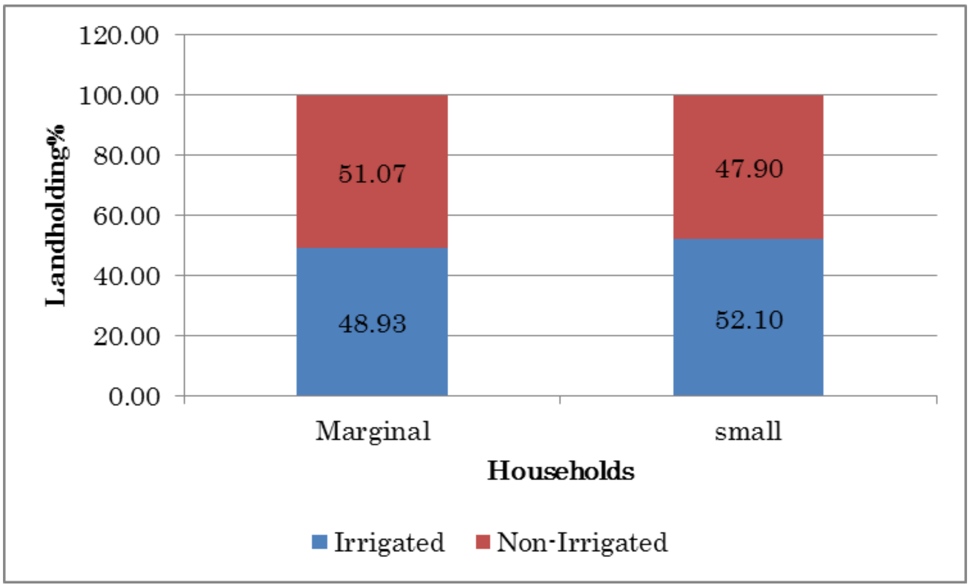


Figure: 4.33: Household landholding type in Chitlang

In figure 4.33, in the case of Chitlang, marginal farmers hold 48.93% of irrigated land, while 51.07% of land is not irrigated. While in the case of small famers, they hold 52.1% of the irrigated land, while 47.9% of the land is not irrigated. This shows that the irrigated landholding is more in the case of small farmers than in the case of marginal farmers indicating that marginal farmers have less access to resources than small farmers.

In the case of Namsaling, among the sampled household, there are three categories of farmers; marginal, small, and large farmers. The landholding types according to the irrigation availability in Namsaling among the different farmers groups is shown in figure 4.34

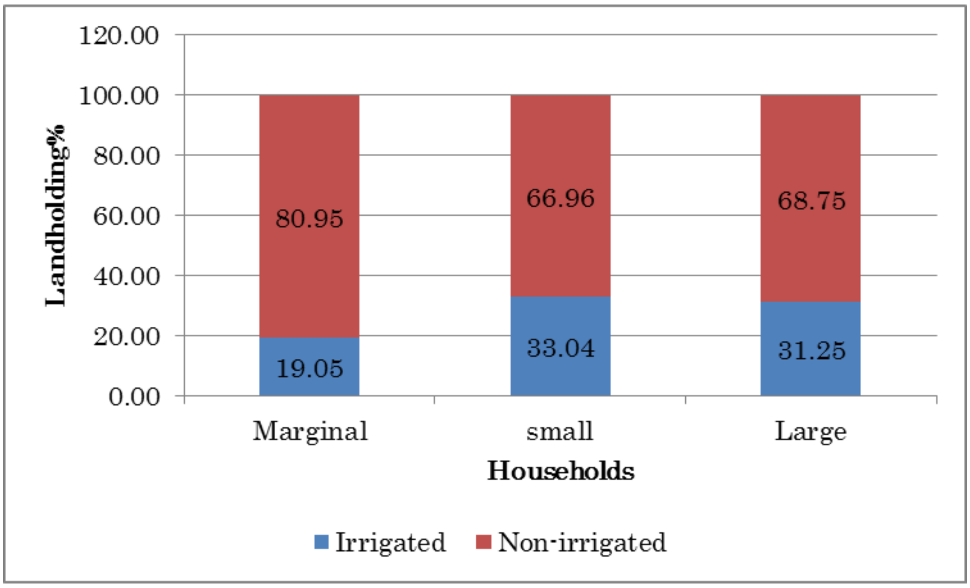


Figure: 4.34: Household landholding type in Namsaling

Figure 4.34 shows that among the sampled households, marginal farmers have only 19.05% of irrigated land, while they own 80.95% of non-irrigated land, but in the case of small farmers, irrigated landholding increases to 33.04% while non-irrigated landholding is 66.96%. Finally, in the case of large farmers, the irrigated landholding is 31.25% whereas non-irrigated landholding is 68.75%. In the case of large farmers, irrigated landholding decreased because they had large area of non-irrigated landholding. Finally, the irrigated landholding percentage is higher in the case of Chitlang than Namsaling among all the farmers.

4.5.5 Other Socio-Economic Characteristics of Chitlang and Namsaling VDCs

The other socio-economic characteristics include family size, literacy rate, dependency ratio, livestock holding, population, credit, radio/mobile holding, landholding, irrigated landholding, microfinance, amount of money spent on seed, pesticides, fertilizer and average amount of time required to reach services such as roads, health facilities, schools, markets, livestock services, agriculture services as shown in table 4.5.

Table 4.5: Socio-economic characteristics of Chitlang and Namsaling VDCs

Variables	VDC	
	Chitlang	Namsaling
Population of Sample HH		
Male	175(46.8%)	169(54.9%)
Female	199(53.2%)	131(45.9%)
Family size	6.18	4.62
Dependency ratio[2]	0.39	0.52
Literacy rate	60.9%	83.3%
Average livestock holding (TLU[3])	1.6	2.4
Average landholding (ha)	0.61	0.96
Average irrigated landholding (ha)	0.31	0.31
Average radio holding (No.)	0.98	0.77
Average mobile holding (No.)	0.98	0.78
Average Credit (NRs.)	16683.33	58866.67
Average time to reach (min)		
Road	12.57	28.5
Health	32.25	36.83
School	19.9	27.67
Market	26	30.83
Agriculture services	29.92	37.92
Livestock services	34.83	40.58
Average amount spend on (NRs.)		
Seed	3282.05	2240
Fertilizer	6808.33	3381.93
Pesticides	1481.67	1757.14

In the above table, the population of the sampled households of Chitlang VDC was found to be 374 of which 46.8% are male and 53.2% are female, but in the case of Namsaling where the population of sampled households was 300, male population was higher at 54.9% than female at 45.9%. The family size of Chitlang was higher in comparison to that of Namsaling at 6.18 and 4.62 respectively. But in the case of dependency ratio, in Chitlang, it was found to be lower than in Namsaling indicating that there are higher groups of people which are considered economically active in Chitlang. Also, the literacy rate of sampled households of Chitlang was lower at 60.9% which was consistent with the 2005 data showing no improvement in the education status in Chitlang. Whereas in the case of Namsaling, it is

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[2] Dependency ratio is the ratio of economically non-active member to economically actively member (calculated as Dependency ratio = $\frac{\text{(Number of aged 1-14) + (Number of aged 65 and over)}}{\text{(number of aged 15-64)}} \times 100$

[3] Tropical Livestock Unit (TLU) used are as follows cattle=0.07 sheep and goat = 0.10, pigs = 0.20 and chicken = 0.10 (source: Maltsoglou and Taniguchi, 2004)

83.3% indicating that the education in Namsaling is better than that of Chitlang, and also that it is higher than the previous data. Also, livestock ownership in Namsaling was much higher than in Chitlang at 2.4 and 1.6 respectively, which also indicates that in Namsaling, people are more agriculture based whereas in the case of Chitlang they preferred non-agriculture activities. Further, the average landholding was lower in Chitlang than Namsaling indicating that there are more small and marginal farmers in Chitlang. All the farmers according to the farm landholding in both districts have equal amount of irrigated and non-irrigated land indicating that irrigation facility was distributed equally among the farmers. Also, the people getting benefits from microfinance in Namsaling was higher than in Chitlang showing a higher and better network of farming association in Namsaling. Furthermore, in Chitlang the average time taken to reach infrastructure was less showing that infrastructure is developed than in Namsaling. Similarly, in Chitlang, money spent on fertilizers and improved seeds were higher than in Namsaling as in Chitlang the vegetable farming was more pronounced.

4.6 Vulnerability of Farmers

Vulnerability is the function of exposure, sensitivity and adaptive capacity. To analyse the vulnerability of households of Makwanpur and Ilam district the weight for different indicators was given by principal component analysis which was calculated separately for exposure, sensitivity and adaptive capacity The weight of indicators is shown in table..

Table: 4.6 Principal component score of Makwanpur and Ilam districts

Indicator	**Weight**	
	Makwanpur	**Ilam**
Adaptive Capacity		
Education	0.1346	0.0611
Dependency ratio	0.1356	-0.0726
Agricultural Income	0.4328	0.185
Other Income	-0.0649	0.0714
Land holding	0.4571	0.1258
Livestock	0.4523	0.0637
Radio	-0.0495	0.0604
Mobile	-0.0115	0.0371
Irrigation	0.4758	0.0353
Road	0.0295	0.3889
Health	0.0197	0.3867
School	-0.0128	0.3827
Market	0.1196	0.3811
Microfinance	-0.1354	0.0766
Agricultural Service	0.1558	0.381
Livestock service	0.161	0.3876
Seed	0.0074	-0.0726
Fertilizer	0.2059	0.1109
Pesticides	0.0524	0.119
Exposure		
Max temp	0.6552	0.589
Min temp	0.658	0.7785
Rainfall	0.3712	0.217
Sensitivity		
Death	0.5794	0.5563
Wounded	0.3245	0.3941
Frequency	0.5026	0.5643
House destroyed/affected	0.5535	0.4656

In the case of Makwanpur district, the results of principal component analysis for adaptive capacity show seven components having Eigen value greater than 1 accounting for

70.71% of the total variance. The first component has Eigen value of 3.31 which accounts for 17.46%. While in the case of Ilam district five components have Eigen value greater than 1 accounting for 71.39% of the total variance. The first component has Eigen value of 5.29 which accounts for 31%. The first component scores of the first component were only used for weighing the variables. The component scores are shown in the table above.

The analysis of the vulnerability shows that in the case of Makwanpur district, the first quintile of the income, which is the most poorest one, have average vulnerability of 4.68 which goes on decreasing as income group increases slightly in the second quintile (4.23) and third quintile (4.07) but starts to decrease sharply in the fourth (3.19) and fifth quintile (2.10). This is shown in figure 4.35.

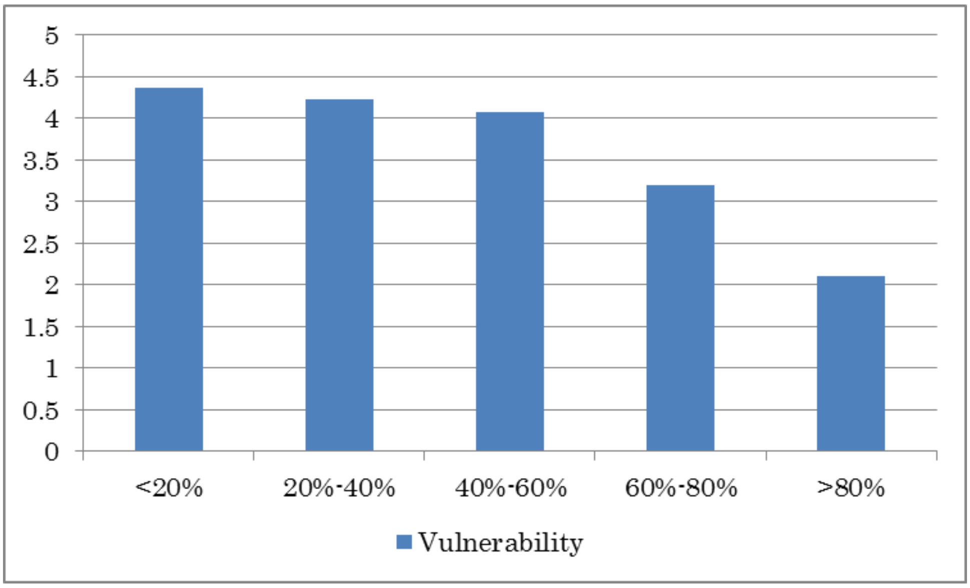

Figure 4.35: Household vulnerability of Makwanpur district

In Makwanpur district, the vulnerability is high as the climate extreme is higher as the geography of the district is quite fragile with steep slopes being prone to floods and landslides.

In the case of Ilam district also, the vulnerability is highest among the groups having the least income that is the first quintile (2.30) which gradually decreases in the second quintile (1.86), third quintile (1.05), fourth quintile (0.06) and finally fifth quintile (-1.08).

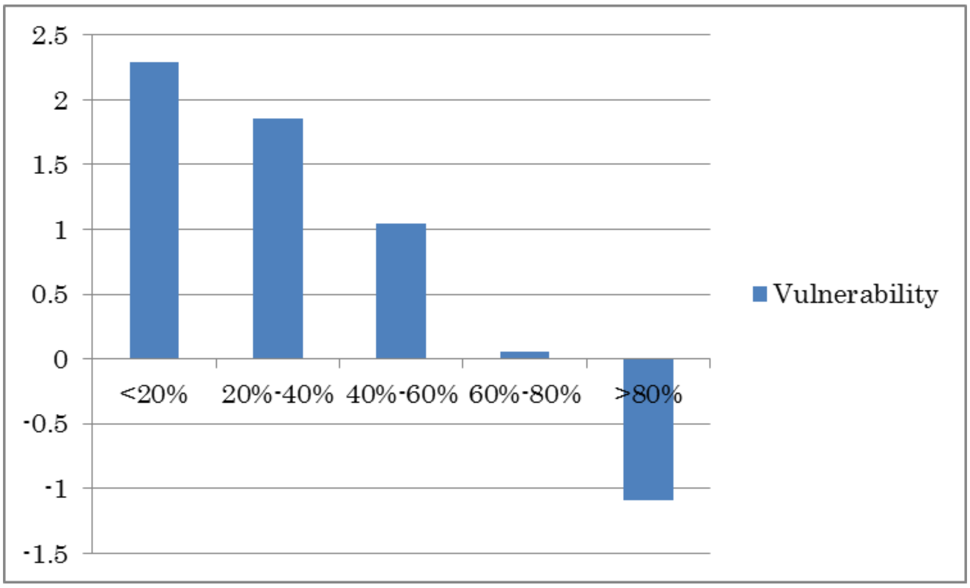

Figure 4.36: Household vulnerability of Ilam district

The analysis of the vulnerability shows that the adaptive capacity of the different regions depends on different variables. In the case of Makwanpur district, the income from agriculture, landholding, livestock holding and irrigation played a major part in adaptation while in the case of Ilam district, the reach to infrastructure such as roads, health facilities, schools, markets, agricultural services and livestock services played major role in determining their vulnerability.

4.7 Perception of Local People to Climate Change

The majority of both VDCs sampled households did not have any information regarding climate change except 4 households of Namsaling VDC. Further, regarding the changes in their environment and their perceptions towards change in climatic parameters like change in rainfall during summer and winter, change in temperature during winter and summer, increase in plant disease was noticed.

4.7.1 Perception of Household in Chitlang VDC

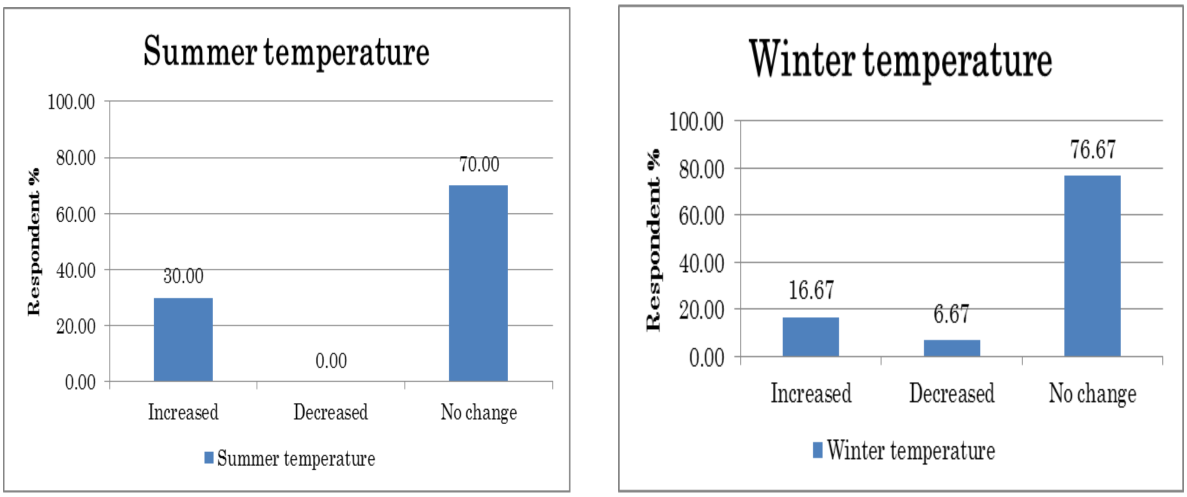

Figure 4.37: Perception of summer and winter temperature in Chitlang VDC

Figure 4.37 shows the perception of the respondents' perception of summer and winter temperature in Chitlang. In Chitlang, 70% of the people did not feel any increase in summer temperature, whereas 30% felt that summer temperature has increased and nobody felt temperature has decreased. Also, 76.67% of people felt that there is no change in winter temperature and 16.67% said that it has increased. Also, 6.67% felt that winter temperature has decreased, which they said is mainly due to the effect of the Kulekhani hydropower dam.

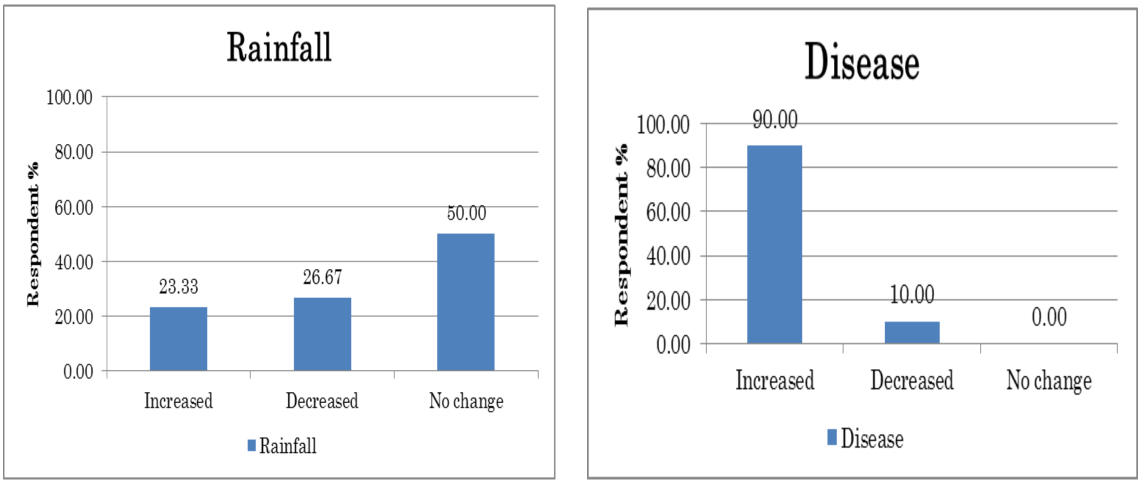

Figure 4.38: Perception of rainfall and disease in plant in Chitlang VDC

Figure 4.38 shows the perception of the respondents to rainfall and diseases in plants in Chitlang. Fifty percent of the people in Chitlang did not notice any changes in rainfall while 23.33% noticed increase in rainfall whereas 26.67% noticed decrease in rainfall. As the

Chitlang area has good irrigation facility, people may have not noticed change in rainfall. Further, 90% of the people noticed increase in plant diseases while 10% noticed decrease in the plant diseases which they said is due to the use of pesticides. Further, the sampled households have noticed that the harvesting period of maize has shifted around one month late which may be attributed to change in monsoon which for the past few years has been coming late in the country.

4.7.2 Perception of Household in Namsaling VDC

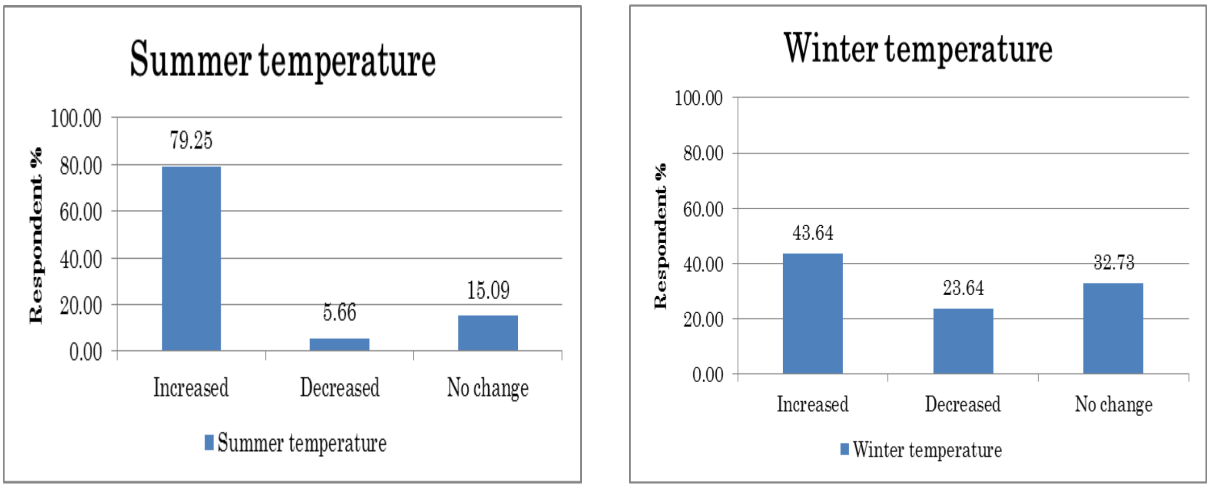

Figure 4.39: Perception of summer and winter temperature in Namsaling VDC

Figure 4.39 shows the perception of the respondents towards summer and winter temperature in Namsaling. In Namsaling, 79.25% of sampled households have noticed increase in summer temperature whereas 5.66% noticed decrease in summer temperature and 15.09% have not seen any change. Also, in the case of winter temperature, 43.64% have noticed increase, whereas 23.64% noticed decrease in winter temperature and 32.73% have not noticed any change. Also, from the analysis of temperature trend in the area, it is in increasing trend.

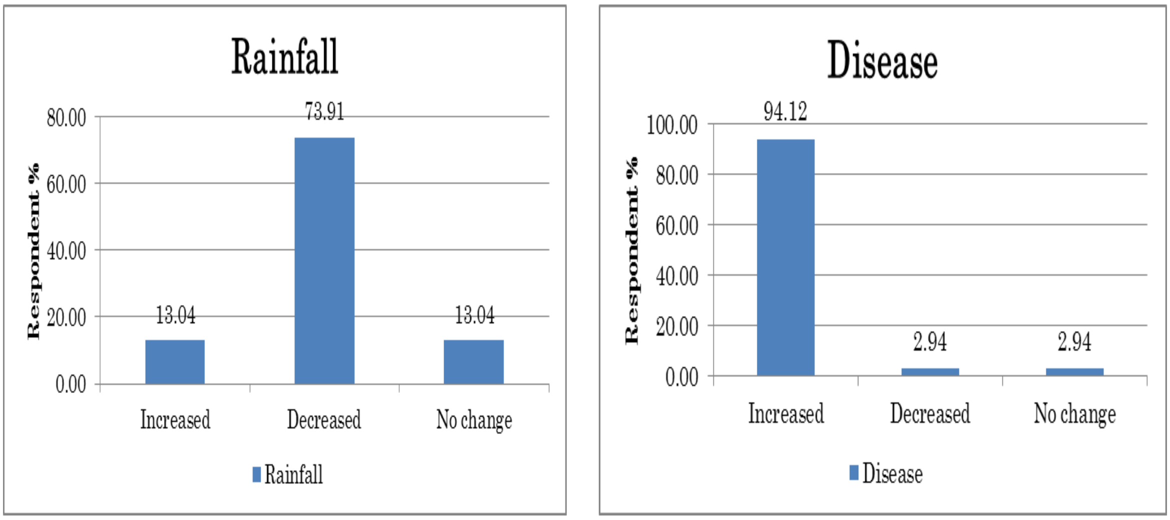

Figure 4.40: Perception of rainfall and disease in plant in Namsaling VDC

Figure 4.40 shows the respondents' perception of rainfall and diseases in plants in Namsaling VDC. In Namsaling, 73.91% of the respondents noticed the decrease in rainfall whereas 13.04% noticed an increase in rainfall and 13.04% noticed no change, which is in decreasing trend in the area. In the case of plant disease around almost all (94.12%) the respondents noticed increase while 2.94% noticed decrease and 2.94% did not notice any change. Further, in the case of Namsaling, the respondents have also noticed changes in ripening of the fruits 15 days earlier. Also, they noticed that broom grass has also ripened earlier than it used to. Further, respondents said that they have started to notice mosquitoes in the higher altitude whereas it was not seen previously. In addition, people have started to notice that fruits like oranges which used to grow in the lower altitude have also started to grow in higher areas.

Chapter V Conclusion and Recommendation

5.1 Conclusion

The effect of climate change on farmers and their vulnerability in two districts, Makwanpur and Ilam, was analyzed. First of all, the trend analysis of climatic variables in both the districts was carried out to see the overall picture of how climatic variables are changing in the study area. The analysis shows that the summer maximum and minimum temperature of Makwanpur district is increasing with the coefficient of 0.085 and 0.060 showing the warming trend of summer temperature, and also winter maximum and minimum temperature was increasing with coefficient of 0.136 and 0.085 showing increasing trend which is higher in winter than summer. The summer rainfall in Makwanpur district was found to be increasing with coefficient of 4.57 though it was quite erratic, while winter temperature was decreasing slightly with coefficient of -0.13. As temperature is increasing faster in winter, rainfall is decreasing indicating that drought is increasing in Makwanpur especially during the winter season. In the case of Ilam district, the summer maximum temperature was increasing with coefficient of 0.05, but summer minimum temperature was decreasing with coefficient of -0.037. Similarly, the winter maximum temperature was increasing with coefficient of 0.06 and minimum temperature was decreasing with coefficient of -0.03. The increase in maximum temperature and decrease in minimum temperature indicate that days are becoming warmer and nights cooler, and also indicate that the weather in the area are becoming more extreme. Further, summer and winter rainfall of Ilam district was in decreasing trend with coefficient of -0.44 and -0.27 respectively, and also erratic. This increase in summer and winter maximum temperature and decrease in rainfall indicate that the weather in the area is becoming harsher.

The effect of climate change on the yield was analysed and showed that in Makwanpur district, the climate change had negative impact on yield of all the major food crops of Nepal except for paddy. While in the case of Ilam district, climate change had negative impact on yield of all the major food crops except maize and potato. The increase in paddy in Makwanpur and the decrease in Ilam can be attributed to increase in rainfall in Makwanpur district and decrease in Ilam district. Only the minimum temperature had significant relationship with yield of maize and paddy in Makwanpur district. Similarly, maximum temperature had significant relationship with maize, and rainfall had significant relationship with paddy and wheat in Ilam district. In addition, the majority of the climatic variables did not have significant p-value, but this analysis showed the direction in which climate change has effect.

The yield trend was also analysed to see how yield of major food crops of Nepal in Makwanpur and Ilam district are changing. The simple regression analysis showed that in Makwanpur district, yield of paddy and maize is decreasing with coefficient of -12.56 and -10.04 respectively while millet, potato, wheat and barley are increasing with coefficient of 6.40, 226.58, 34.40 and 17.48 respectively. The decrease in yield of paddy can be attributed to drought and also management practices not improving over the course of time. Also, there was sharp increase in the yield of potato which is mainly attributed to the new varieties of potato and the use of fertilizers and pesticides. In the case of Ilam district the yield of maize and millet was found to be in decreasing trend with coefficient of -12.53 and -1.10 respectively while paddy, potato, wheat and barley were found to be in increasing trend with coefficient of 14.75, 220.65, 26.00 and 1.11 respectively. Also in Ilam district, potato was found to be increasing sharply which can also be attributed to the use of high yielding varieties, fertilizers and pesticides, and also to the development of potato as a cash crop in the area.

After seeing how climate is changing and how it is effecting the yield of the crop, the frequency and intensity of climatic extremes like floods, landslides, forest fire, storms, hailstorms etc. which are related to climatic conditions were analysed using the simple linear regression analysis from 1978 to 2008 and it was seen that the frequency of natural disasters has been increasing over the last decades from mid 1990s. Also, it was seen that landslides and floods are the main two natural disasters that are occurring more frequently and the casualties that they cause are increasing indicating that the higher intensity natural disasters are also recurring faster than expected. In Makwanpur district, it was seen that the frequency of natural disasters was increasing with coefficient of 0.60, deaths due to natural disasters, wounded due to natural disasters and houses destroyed and affected were increasing with coefficient of 0.53, 0.15 and 3.30 respectively. Similarly, in Ilam the frequency of natural disaster was increasing with coefficient of 0.15. Also, the deaths, wounded, and houses destroyed and affected by natural disasters were also increasing with the 0.10, 0.24 and 0.63 respectively. Only the increase in the frequency of the occurrence of natural disasters in both districts and wounded due to natural disasters in Ilam district were significant, but this showed that natural disasters are increasing in both districts.

The descriptive analysis revealed that there is a huge difference of income disparity among the income quintile groups in both VDCs. In the case of Chitlang VDC of Makwanpur district, the income disparity was seen higher than in the case of Namsaling VDC of Ilam district which is mainly due to the higher people involvement in non-agricultural income in Chitlang VDC, which is nearer to the Kathmandu district and have more opportunity to earn from non-agricultural income sources than in the case of Namsaling VDC. Also, in Chitlang, it was found that non-agricultural income was one of the major sources of income for the households and cash income from agricultural and non-agricultural sources were important source of income. While in the case of Namsaling VDC, the cash income from agricultural sources were dominant than the non-agricultural income source. This is mainly due to the fact that people in Chitlang have more opportunities from non-agricultural income sources but in the case of Namsaling VDC, they have limited opportunities and also that the farmers in Namsaling VDC are more organized and agriculture is being commercially developed.

In Chitlang VDC, it was found that marginal farmers and small farmers were found in the equal proportion according to the landholding while in Namsaling VDC, the proportion of small farmers were more than 75%, while others were marginal farmers and larger farmers in the area. Also, in the case of Chitlang higher percentage of marginal farmers' land was not irrigated while in the case of small farmers' land higher percentage was irrigated though the difference was not that significant. But in the case of Namsaling 80% of marginal farmers' land were not irrigated while in the case of small and large farmers, around 67% of land was not irrigated.

Descriptive analysis of other socio-economic characteristics found that the average literacy rate of sampled households in Namsaling was higher than in Chitlang, but the average dependency ratio in Chitlang was found to be lesser compared to Namsaling. This indicates that there is higher number of economic active people in Chitlang than in Namsaling who are more involved in labour works, which is reflected by their less literacy rate, and also a high non-agricultural income. Further, it was found that infrastructure in Chitlang VDC was developed than in Namsaling VDC.

After seeing the exposure, sensitivity and adaptive capacity of the study area, households' vulnerability was measured and it was found that the average vulnerability of the first quintile, which belongs to the poorest income group, is highest in both districts. Also, the impact from climatic variables was higher in Makwanpur district than in Ilam. In Makwanpur, the sensitivity to natural calamities were higher than Ilam due to its fragile geographic nature with steep slopes. Also, it was found that the adaptive capacity of the household depends on different factors according to the region as seen in Chitlang where agricultural land, landholding, livestock holding, and irrigation played important role in determining their adaptive capacity whereas in the case of Namsaling the time taken to reach the infrastructure like roads, health facilities, schools, agricultural services and livestock services played important role.

Finally, the descriptive analysis for the perception of the respondents was done and nearly all the people in both VDCs have not heard about the term climate change. Further, regarding the changing climatic variable, it was found that in Chitlang VDC, majority of people did not noticed much change in the summer or winter temperature which may be because of their access to non-agricultural income sources and having irrigation facilities. In Namsaling, majority of respondents felt that both summer and winter temperature are rising and also rainfall is decreasing in the area, which coincides with the trend analysis. Further, in Namsaling VDC, respondents have started to notice changes in ripening of fruits, which is normally earlier; new invasion of species in the area that were generally found in the lower altitude and invasion of mosquitoes in higher altitudes. Further, in both VDCs people have noticed increase in agricultural disease and pests in the area.

5.2 Recommendation

It has been established that climate change is occurring at faster rate due to the human anthropogenic activities and that the most vulnerable will be those people who have less resources to adapt to climate change and especially the sector that relies mostly on climatic factors like agriculture. It was seen that climate change will have negative impact on yield of major food crops in Nepal for which we need to give more importance by introducing new varieties and suitable technology so that farmers are able to adapt to the situation.

It is very important to identify the vulnerable group for policy or development intervention. Also, the adaptation program to climate change should be incorporated in the development program and policies of the area. As vulnerability does not depend on only few variables for all the regions but depend on different variables according to the region, proper identification of need of the people in certain areas is needed to launch program related to climate change. Also sensitizing people of the impact of climate change and how to adapt to the situation are needed and should be addressed in future policies.

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Annex

Principal Components of Adaptive Capacity

Chitlang Adaptive capacity

Principal components/correlation	Number of obs	=	60
	Number of comp.	=	1
	Trace	=	19
Rotation: (unrotated = principal)	Rho	=	0.1746

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	3.31651	.982223	0.1746	0.1746
Comp2	2.33429	.142292	0.1229	0.2974
Comp3	2.192	.339044	0.1154	0.4128
Comp4	1.85295	.422258	0.0975	0.5103
Comp5	1.43069	.203441	0.0753	0.5856
Comp6	1.22725	.146024	0.0646	0.6502
Comp7	1.08123	.0812787	0.0569	0.7071
Comp8	.999949	.108468	0.0526	0.7597
Comp9	.891481	.167607	0.0469	0.8066
Comp10	.723874	.0928173	0.0381	0.8447
Comp11	.631057	.0332737	0.0332	0.8780
Comp12	.597783	.175204	0.0315	0.9094
Comp13	.422579	.0456983	0.0222	0.9317
Comp14	.376881	.0501543	0.0198	0.9515
Comp15	.326726	.0885541	0.0172	0.9687
Comp16	.238172	.0771617	0.0125	0.9812
Comp17	.161011	.0319277	0.0085	0.9897
Comp18	.129083	.0625919	0.0068	0.9965
Comp19	.0664909	.	0.0035	1.0000

Principal components (eigenvectors)

Variable	Comp1	Unexplained
Education	0.1346	.9399
Dependency ratio	0.1356	.939
Agriculture Income	0.4328	.3788
Non-agricultural Income	-0.0649	.986
Landholding	0.4571	.3069
Livestock holding	0.4523	.3216
Radio	-0.0495	.9919
Mobile	-0.0115	.9996
Irrigation	0.4758	.249
Time to Road	0.0295	.9971
Time to Health	0.0197	.9987
Time to School	-0.0128	.9995
Time to market	0.1196	.9526
Microfinance	-0.1354	.9392
Time to Agiculture Service	0.1558	.9195
Time to Livestock Service	0.1610	.914
Spent on Seed	0.0074	.9998
Spent on fertilizer	0.2059	.8594
Spent on pesticides	0.0524	.9909

Namsaling Adaptive capacity

Principal components/correlation	Number of obs	=	60
	Number of comp.	=	1
	Trace	=	19
Rotation: (unrotated = principal)	Rho	=	0.3116

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	5.92009	3.12758	0.3116	0.3116
Comp2	2.79251	.88385	0.1470	0.4586
Comp3	1.90866	.383745	0.1005	0.5590
Comp4	1.52492	.106821	0.0803	0.6393
Comp5	1.4181	.446622	0.0746	0.7139
Comp6	.971476	.102208	0.0511	0.7650
Comp7	.869268	.0771832	0.0458	0.8108
Comp8	.792085	.134984	0.0417	0.8525
Comp9	.657102	.18468	0.0346	0.8871
Comp10	.472422	.0611611	0.0249	0.9119
Comp11	.411261	.0452208	0.0216	0.9336
Comp12	.36604	.0777459	0.0193	0.9528
Comp13	.288294	.0532571	0.0152	0.9680
Comp14	.235037	.0858372	0.0124	0.9804
Comp15	.1492	.0587298	0.0079	0.9882
Comp16	.0904701	.0266593	0.0048	0.9930
Comp17	.0638108	.019671	0.0034	0.9964
Comp18	.0441399	.0190316	0.0023	0.9987
Comp19	.0251083	.	0.0013	1.0000

Principal components (eigenvectors)

Variable	Comp1	Unexplained
Education	0.0611	.9779
Dependency ratio	-0.0726	.9688
Agriculture Income	0.1850	.7974
Non-agricultural Income	0.0714	.9698
Landholding	0.1258	.9063
Livestock holding	0.0637	.976
Radio	0.0604	.9784
Mobile	0.0371	.9918
Irrigation	0.0353	.9926
Time to Road	0.3889	.1047
Time to Health	0.3867	.1148
Time to School	0.3827	.1328
Time to market	0.3811	.14
Microfinance	0.0766	.9653
Time to Agiculture Service	0.3810	.1404
Time to Livestock Service	0.3876	.1107
Spent on Seed	-0.0726	.9688
Spent on fertilizer	0.1109	.9272
Spent on pesticides	0.1190	.9162

Principal Component of Disaster

Makwanpur disaster

Principal components/correlation Number of obs = 31
Number of comp.= 1
Trace = 4
Rotation: (unrotated = principal) Rho = 0.7131

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	2.8525	1.89442	0.7131	0.7131
Comp2	.958087	.776975	0.2395	0.9526
Comp3	.181112	.172812	0.0453	0.9979
Comp4	.00829965	.	0.0021	1.0000

Principal components (eigenvectors)

Variable	Comp1	Unexplained
Death	0.5794	.04238
Wounded	0.3245	.6997
Homes Destroyed/affected	0.5026	.2795
Frequency	0.5535	.126

Ilam Disaster

Principal components/correlation Number of obs = 31
Number of comp. = 1
Trace = 4
Rotation: (unrotated = principal) Rho = 0.5121

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	2.04839	.897125	0.5121	0.5121
Comp2	1.15126	.620157	0.2878	0.7999
Comp3	.531103	.261853	0.1328	0.9327
Comp4	.269251	.	0.0673	1.0000

Principal components (eigenvectors)

Variable	Comp1	Unexplained
Death	0.5563	.3662
Wounded	0.3941	.6818
Homes Destroyed/affected	0.5643	.3476
Frequency	0.4656	.556

Principal Component of Climatic Variables

Makwanpur climatic variable

Principal components/correlation Number of obs = 31
Number of comp. = 1
Trace = 3
Rotation: (unrotated = principal) Rho = 0.5857

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	1.757	.877901	0.5857	0.5857
Comp2	.879101	.515203	0.2930	0.8787
Comp3	.363898	.	0.1213	1.0000

Principal components (eigenvectors)

Variable	Comp1	Unexplained
Maxtemp	0.6552	.2458
Mintemp	0.6580	.2393
Rainfall	0.3712	.7579

Ilam Climatic variable

Principal components/correlation Number of obs = 31
Number of comp. = 1
Trace = 3
Rotation: (unrotated = principal) Rho = 0.4168

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	1.25051	.0457223	0.4168	0.4168
Comp2	1.20479	.660079	0.4016	0.8184
Comp3	.544706	.	0.1816	1.0000

Principal components (eigenvectors)

Variable	Comp1	Unexplained
Maxtemp	0.5890	.5662
Mintemp	0.7785	.2422
Rainfall	0.2170	.9411