AN ASSESSMENT OF CLIMATE CHANGE IMPACTS OAGRICUTURE AND LIVELIHOOD OF FARMERS: A CASE STUDY OF SIRIDIBAS VDC, MANASLU CONSERVATION AREA, GORKHA

A Dissertation Submitted to

CENTRAL DEPARTMENT OF ENVIRONMENTAL SCIENCE

Institute of Science and Technology

Tribhuvan University

Kirtipur, Kathmandu, Nepal

In Partial Fulfillment of the Requirements for the Award of Degree of

M.Sc. in Environmental Science

By

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April, 2012

DECLARATION

I hereby declare that the work presented in this dissertation is a genuine work done originally by me and has not been submitted elsewhere for the award of any degree. All sources of information have been specifically acknowledged by reference to the author(s) or institution(s).

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Ashish Rai

April 10, 2014

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RECOMMENDATION

This is to certify that Mr./Ms Ashish Rai has completed this dissertation work entitled *"An Assessment of Climate Change Impacts on Agriculture and Livelihood of Farmers: A Case Study of Sirdibas VDC, Manaslu Conservation Area, Gorkha"* as a partial fulfillment of the requirements of M.Sc. in Environmental Science under our (my) supervision and guidance.

To our (my) knowledge, this research has not been submitted for any other degree, anywhere else.

We (I) therefore, recommend the dissertation for acceptance and approval.

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LETTER OF APPROVAL

On the recommendation of supervisor "Prof. /Dr. /Mr. Deepak Kumar Rijal" this dissertation submitted by "Mr. /Ms Ashish Rai is approved for the examination and submitted to the Tribhuvan University in partial fulfillment of the requirements of M.Sc. in Environmental Science.

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CERTIFICATE OF ACCEPTANCE

This dissertation entitled "*An Assessment of Climate Change Impacts on Agriculture and Livelihood of Farmers: A Case Study of Sirdibas VDC, Manaslu Conservation Area, Gorkha*" submitted by " Mr. /Ms Ashish Rai." is examined and accepted as a partial fulfillment of the requirements of M.Sc. in Environmental Science.

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ACKNOWLEDGEMENT

This research has been granted by the NCCKMC, NAST program. I therefore acknowledge NCCKMC for providing me with the grant. Also, I would like to heartily acknowledge to the research grantee selecting committee member for selecting my research proposal to come through. I am very acknowledged to dear sir, academician, Dr. Dinesh Raj Bhuju for providing all possible help, tips and code of ethics needed for research work. This research grant program has been possible by his effort.

I duly would like to acknowledge Prof. Dr. Kedar Rijal, Head of Department at Central Department of Environmental Science, TU for the necessary support that I needed from the department. He has left not a penny in supporting me as department head.

Most importantly, I am grateful to supervisor Dr. Deepak Kumar Rijal who helped me work with this report ever since from initial research proposal writing and editing phase; supervised, assisted and supported me till the final shape of the thesis report. Also, I should be much thankful to my co-supervisor Jagannath Aryal, for his stupendous support and assistance in this research to give final form. Their comments, suggestions, directions were much worth throughout my work. I would like to remember Katherine Pasteur (UK) who kept mentoring me during research.

I moreover feel grateful and equally wish to acknowledge to Mrs. Tsheni Gurung, president of Ama Samuha; Ram Prashad Sakya, JTA; Balaram Pant, VDC secretary, Norbu Gurung, Deepak Karki, Sushil Gurung and all those people who were informative.

I would like to thank all our team members for making the research tour immortally memorable. A very special thanks to Pawan Neupane and Janak Sapkota who handled the overall program, made all our preparations for field and guided us to our destination.

I would not forget thanking Deputy Director Sarju Kumar Baidhya (DHM), Upen K.C., Birendra Gautam, Sagun Parajuli and Somnath Gautam for their small effort in this work.

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ABSTRACT

Farming in hill and mountain is subsistence type. This research and intends to assess the impact of climate change in agriculture and livelihood of MCA. FGD, KII, field observation methods was used for information collection, cross validation and verification with the secondary source of information. Household survey was done with pre-structured questionnaire. FGD was done between local Mothers Group (ama samuha) and Farmer's group. KII was done personally with JTA, VDC secretary, president of Mother's group and some modal farmers. The research is perception based verified by data. Perception was sorted out age wise so as to know age wise knowledge in climate and agriculture. This study reveals mean temperature, mean minimum temperature and mean maximum temperature is increasing at the rate of 0.05°C/yr, 0.96°C/yr and 0.002°C/yr respectively. Also, mean annual rainfall is increasing at rate of 0.995mm/ year where pre-monsoon, monsoon, post-monsoon is increasing at rate of 0.714, 2.88 and 0.293mm/yr respectively while winter monsoon is decreasing at rate of 0.236mm/yr. Though change in cropping season is unaltered there regarding varying climate, the harvesting period has decreased in maize, wheat, barley due to the increased temperature. 32-year crop production data of Gorkha district shows productivity of maize, wheat, and millet has increased at overall trend but at last few years to a decade, this productivity have decreased. This decreased productivity may be because of untimely rainfall in unnecessary amount. Untimely rainfall during pollination, flowering and increased temperature during grain filling with decreased rainfall causing dry spell have negative effects in crops yield. Climatic hazards like water logging are caused due to intense rainfall during Jestha/Ashad affecting summer crops. Also, increased temperature with less or no rainfall in Falgun-Baisakh caused dry spell problem affecting summer crops. Intense rainfall may be responsible landslides ultimately affecting agriculture production. External factors like government policy of food supply through its depot might have caused to divert people profession of farming to non-farming business contributing to decrease crop production. People with lesser hope in subsistence farming have changed their livelihood from alternate source like going abroad for earning. Thus, along with climate change impacts on farming, food distribution policy and changed livelihood source has affected the farming side by side.

Key Words: Adaptation, Crop Calendar, Crop Production, Temperature and precipitation

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Abbreviation

APP:	Agriculture Perspective Plan
ASC	Agriculture Service Center
CEN	Clean Energy Nepal
CDES	Central Department of Environmental Science
CDKN	Climate and Development Knowledge Network
CH_4	Methane
CBS	Central Beauro of Statistic
CO_2	Carbon dioxide
COP	Conference of Party
DADO	District Agricultural Development Office
DHM	Department of Hydrology and Meteorology
FAO	Food and Agriculture Organization
FGD	Focus Group Discussion
GDP	Gross Domestic Product
GHGs	Green House Gases
GoN	Government of Nepal
GtC	Gigaton of Carbon
Ha	hectare
HH	Household
HHS	Household Survey
HKH	Hindu Kush Himalaya
HM	His Majesty
IPCC	International Panel for Climate Change
ICPD	International Conservation and Development Program
IPM	Integrated Pest Management
JTA	Junior Technical Assistant
KII	Key Informants Interview
LAPA	Local Adaptation Program of Action
MCA	Manaslu Conservation Area
MCAP	Manaslu Conservation Area Project
MHPP	Micro Hydro Power Plant

MoAC	Ministry of Agriculture Cooperatives
MoAD:	Ministry of Agriculture and Development
MoE:	Ministry of Environment
MoLD:	Ministry of Local Development
MoPE:	Ministry of Population and Environment
NAPA:	National Adaptation Program for Action
NARC:	Nepal Agriculture Research Council
NAST:	Nepal Academy of Science and Technology
NCCKMC:	Nepal Climate Change Knowledge Management Center
NCVST:	Nepal Climate Vulnerability Study Team
NDC:	National Development Council
NGOs:	Non Governmental Organizations
NTNC:	National Trust for Nature Conservations
Ppm:	Parts per Million
SALT:	Sloping Agriculture Land Technology
SPSS:	Statistical Package for Social Survey
UNEP:	United Nation Environment Program
UNFCCC:	United Nation Framework for Climate Change Conference
VDC:	Village Development Committee
WFP:	World Food Program
WWF:	World Wildlife Fund

CHAPTER I

1. INTRODUCTION

1.1 Background

Nepal is a mountainous country consisting of the three ecological regions running north to south: Mountain, Hills and Tarai. According to the CBS (2011) about 18 % i.e. 2.6 million hectares of the total land area of country is arable for agriculture. Nepal is an agricultural country and is richly endowed with numerous agricultural crops and plants. The variation in temporal, altitudinal, topographical aspects has made agricultural diversity possible in Nepal (Shrestha, 2007). Agriculture is the mainstay of Nepalese economy and around 74% of Nepal's population is engaged in agriculture (CBS, 2011) pre-dominantly of subsistence nature which provides food and livelihood security to a substantial section of the Nepalese population accounting 40% of GDP (Gurung *et.al*, 2010). Nepal's agriculture is largely rain fed and their contribution to the GDP and food security is dependent on the characteristics of the monsoon rain. Any extent of change in climatic variables therefore directly affects agriculture performance. However, change in climatic variability and uncertainty has been posing increasing threats on agriculture.

Climate change refers to the variation in the earth's global climate or in regional climates over time. It is change of climate which attributed directly or indirectly to human activity that alters the composition of the global atmosphere (UNFCC, 2001). Climate change is a phenomenon due to emissions of greenhouse gases from fuel combustion, deforestation, urbanization and industrialization (Upreti, 1999) resulting variations in solar energy, temperature and precipitation. Climate change is an emerging environmental challenge to date is a natural process and has been considered through increased variability and uncertainty of precipitation. Greenhouse gases (GHGs) mainly CO_2, N_2O and CH_4 majorly emitted from the energy sector is the major contributing agents of climate change. Emission of Carbon Dioxide (CO_2) is the major element which forms more than 80 % of the total GHG. GHG have created a greenhouse effect which subsequently altered precipitation patterns and global temperatures. According to the National Communication Report prepared by MoE/GoN, net CO_2 emission was about 9.747 tons and the net CH_4 emission was estimated to be 0.948 tons in 1994. Nepal's contribution to

the global GHG emissions is 0.025%. Several basic indicators in our surroundings, such as steady rise in temperatures, increasing concentration of greenhouse gases in the atmosphere, and growing weather or climatic uncertainties, show the aggregate effects of these changes. IPCC (1995) reported that the global mean surface air temperature has increased by 0.6±0.2°C over 20th century. MoE/NAPA (2010) indicated the rise in Nepal temperature is 0.04-0.06°C. Tiwari (2009) showed that average temperature of Nepal has increased from 0.06 to 0.098°C over last 30 years and precipitation is characterized by large inter annual variability with substantial decrease in amount over last 5 years. Climate change affects agriculture in a variety of ways. Temperature, solar radiation, rainfall, soil moisture and CO_2 concentration are all important variables that determine agricultural productivity, and their relationships are not simply linear. The interaction of temperature increase and changing precipitation patterns determines the availability of soil moisture. With rising temperatures, both evaporation and precipitation are expected to increase. The resulting net effect on water availability makes agriculture and livelihood of the people more vulnerable. The livelihood of the Nepalese depends on forest, grassland and mostly agriculture for which reason, Nepal is identified a highly vulnerable country to Climate Change (Silwal, 2009). The agriculture in Nepal is vulnerable for two reasons. First, the existing system of food production is highly climate sensitive because of its low level of capital investment and adoption of modern technological options. Second, agriculture is the main source of livelihoods for a majority of the population i.e. 74% population depends on agriculture (CBS, 2011). This will put greater number of people at risk when agriculture is impacted due to climate variability and uncertainty (Dahal *et al.,* 2010). Climate change impacts on agriculture are very vague that climate change may have increased productivity in some region while it to be decreased in other region. So, it is a complex problem to the world (Pathak *et al.,* 2003). The impacts of climate change in Nepal, most cultivable land area is rain-fed and therefore productivity is dependent on form, intensity, distribution and timing of precipitation. Agriculture will be adversely affected not only by an increase or decrease in the overall amounts of rainfall but also by shifts in the timing of the monsoon rain. Agriculture Perspective Plan (APP, 1995) stated that the current irrigation facilities may not have sufficient water during dry seasons in the future due to climate change. This change in climate has been shifting the cropping calendar. Summer rainfall accounts for almost 80% of the total annual rainfall over Nepal and is crucial to Nepalese agriculture. Nepal experiences extreme monsoonal rainfall during Shrawan- Bhadra and low during

Poush- Fagun (Shrestha, 2007). Increase in temperature and increasing number of events of erratic rainfall directly affect agriculture and food supply through their effects on crops. Insufficient rain and increasing temperature cause drought whereas intense rain in short period reduces ground water recharge by accelerating runoff resulting floods. Both these situations induce negative effects in agriculture. The climate change also causes disruption in normal weather pattern, intensity and duration of monsoon. The impact of climate change as witnessed in recent times has adversely affected agriculture in a variety of ways. Any change in rainfall patterns poses a serious threat to agriculture, and thereby national economy and rural livelihood. Climate change impacts lives and livelihoods, particularly of economically poor and climatically (Downing *et al.,* 2007), sensitive countries like Nepal (Annex II, Table 1).

1.2 Problem Statement and Justification

The average land holdings decreased by 0.17 ha from 0.96 ha in 1991/92 to 0.79 ha in 2001/02 (CBS, 2002). Such trend has seriously threatened the livelihood and food security of those who depend on agriculture (Thapa *et al.,* 2008). The situation is even worse in mid-hills where landholdings of farmers are small and the opportunities for them to have other source of income from non-agricultural activities are also limited. In Gorkha Distirct, the arable land of 15.43% is used under different land use systems including forest, shrubs, grasslands and snow areas, rocks, rivers, housing etc. The Manaslu Conservation Area (MCA) is a food deficit area as the cultivable land area is only 2% (39.5sq.km) out of total area of MCA. These arable lands of MCA are also fragile and fragmented. The crop being produced in the area will not be sufficient even for 4 months (NTNC, 2004/5). Since, the agriculture in MCA depends largely on monsoon rain therefore agricultural production is marginal. Climate change has affected rainfall pattern, rainfall amount and temperature harming crop calendar and productivity. Overall, climate change has already started altering growing seasons, planting and harvesting, water availability, pest, weed and disease in the Tarai, hill and also in high hill. MoPE (2004) analyzed the impacts of climate change in crops yield in different physiographic regions of Nepal. While increasing attention has been placed on glacial lake outburst floods in Nepal, less attention has been given to other effects of climate change on local communities in terms of changes in water availability, agriculture, forest resources as well as on economy and livelihood (Pandit, 2009). Though much research at government and non-governmental level has been done and our knowledge in climate

change has increased significantly, research in climate change impact in agriculture is still very limited. Because of inadequate research understanding climate change impacts in agriculture in Nepal has been very limited. This is due to lack of knowledge and information about climate change first and how it affects agriculture by our society. Therefore, studies to assess the degree to which climate change has been effecting agriculture at different scales have been carried out. There is a lack of accurate database neither on climate not on longer term production data base of the climate sensitive sectors that are required to formulate or reformulate national policies and strategies. This study will contribute to create database of local climate knowledge base on these critical and globally valued issues of climate change upon agriculture at village level for the policy makers in addressing climate change impacts and for policy making in adaptation and mitigation in agriculture. This policy can be valuable for agricultural testimonial combating against climate change.

1.3 Research Questions

Some pertinent questions being researched in this study are formulated as follows. Do the climatic parameters of study area have changing trends? Does climate change have any impacts in agriculture of the study area? Does climate change have affected production? Does climate change effected in livelihood**?**

1.4 Objectives

The main objective of the research is to assess the impacts of climate change in agriculture and livelihood of farmers in Manaslu Conservation Area.

To achieve the main objective, following specific objectives are:

- To analyze climatic data (precipitation and temperature) of study area
- To identify key indicators to assess the impact of climate change in agriculture
- To document crop varieties, cropping system, crop production, their cropping time and their shifting calendar due to climate change
- To assess the impact of climate change in livelihood of the farmers of study area
- To identify adaptation measures to be adopted by the community in agriculture

1.5 Scope of the Study

This study was carried out with its prescribed objectives will help to access on following scopes.

- Crop variety documentation of study area
- Provide data base on agriculture and climate change for further study
- Documentation of local mitigation and adaptation measures
- Increased people perception on climate change
- Climate data analysis provides climatic trend
- Prepare local adaptation strategic plan in combating climate change impact in agriculture

1.6 Overview of the Content

This thesis consist of seven chapters each having with respective contents. Chapter I contains the introduction part including the background, problem statement, research question, objectives, scope of study, contents overview and limitation of study. Chapter II contains findings of literatures reviewed carried out to create a reference and testimonials of results for discussion in the later part. Chapter III contains the methodology used in the study. Chapter IV contains brief introduction of study area. Chapter V contains results of the study. Chapter VI contains the discussion regarding results. Chapter VII contains conclusion and recommendations part of the study.

1.7 Limitation of the Study

- The study on climate change impact on agriculture is a long term study and would require plenty of resources, time and scientific instruments and methods. This study was constrained in a variety of ways including the limitation of the funds, timing for the studies and adequate prior research training.
- Not all crucial aspects of climate change impacts could be captured even within the agriculture. Some factual data could not be obtained especially on phenology of the plants of food and agriculture importance. Data on livestock, birds and fisheries were not included in the study. Also, impacts studies were not carried out on fruits and vegetable. Without a detail and disaggregated data sets conclusions drawn from this study have limitation on generalization.

CHAPTER II

2 LITERATURE REVIEW

2.1 Temperature

IS92a, a scenario developed by IPCC predicted the GHGs and total radioactive force continues to increase through simulation period of 1990-2100. During it CO_2 increases as 6GtC to 36GtC, CH_4 as 540-1170Tg per year, NOx as 14-19Tg per year. This scenario assumes 2°C rise in global mean surface temperature between 1990-2100 (IPCC, 2001b).

General Circulation Models run with SRES B2 scenario show the mean annual temperature to increase by an average of 1.2°C by 2030, 1.7°C by 2050 and 3°C by 2100 compared to pre 2000 baseline. Also, recent study that used General and Regional Circulation Models projects the mean annual temperature to increase by 1.4°C by 2030, 2.8°C by 2060 and 4.7°C by 2090. The projection shows higher temperature rise in winter than in the summer seasons. Also, higher temperature increments are projected over western and central than eastern Nepal for 2030, 2060 and 2090. Similar, projections are done for the frequency of hot days and nights for 2060 and 2090.

DHM, Government of Nepal reveals that average temperature in Nepal is increasing at the rate of nearly 0.06°C/year between the period of 1977 and 1994. Another temperature analysis from 1976 to 2005 has revealed that the average temperature in Nepal has increased by 0.0597°C/year. The projected figures for Nepal further show that average increase in temperatures of 1.2°C for the year 2030, 1.7°C for 2050 and 3.0°C for 2100.
IPCC, 2001b assessment report showed that the global mean surface air temperature has increased by 0.6±0.2°C over 20th century.

Meteorological records showed that a warming of 0.3-0.6°C in global average temperature since 1860. Moreover, the global temperature has increased by 0.74° C during the period of 1906 to 2005. It is also recorded that 1990s was the warmest decade of the global surface temperature since 1850. The studies further reveal that the global temperature will rise between 1.5°Cto 4.5°C by sometime in the 21st Century. In addition, it has been suggested that warming of more than 2.5°C could reduce global food supplies and contribute to higher food prices (UNEP & UNFCCC, 2002).

World Bank, 2007 showed the average increase in mean annual temperature of earth surface between 1977 and 1994 was by 0.06°C annually.

Cited in CEN fact sheet, 2007 prepared by European Commission and WWF Nepal, the global average temperature has increased by 0.74°C during the period of 1906-2005. Eleven of the last twelve years (1995-2006) rank among the warmest years in the instrumental record of global surface temperature since 1850.

Cline, 2008 in his study with climate models under IPCC's scenario A23, predicted CO_2 concentration would increase to 735ppm by 2085 from current level of 380ppm and global temperature would rise by 3.3°C. Land area would become warmer than the ocean.

Tiwari, 2009, showed that the average temperature of Nepal has increased from 0.06-0.098°C over the last 30 years.

Shrestha *et al*., 1999 and Gautam and Pokharel, 2010, showed that in Nepal the average temperature increase was recorded as 0.06°C/yr and that in Terai and Himalayas was 0.04°C and 0.08°C/yr respectively. This indicates that the warming rate in Himalayas is higher than in the lowland areas.

MoE/NAPA, 2010 indicated consisting warming and rise in maximum temperature at the rate of 0.04-0.06°C annually

2.1.2 Rainfall

IPCC, 2007 projects that there will be a general increase in the intensity of heavy rainfall events in the future, and an overall decrease as many as 15 days in number of rainy days over large part of South Asia. This will cause significant warming particularly at higher elevations, leading to reduction in snow and ice coverage, increased frequency of extreme events like flood, drought, and increased precipitation (NAPA/MoE report, 2010).

Baidhya *et al.,* 2007 have shown more erratic pattern (unusual high intensity, less rainy number of days) of rainfall in the country. Such events increase possibility of climatic extremes like irregular monsoon, droughts and floods.

According to Malla, 2008, the heavy monsoon has shifted to the end period of monsoon. Traditional rainfall of Ashar and Bhadra has been shifted towards Shrawn and Bhadra in Kathmandu affecting negatively in paddy production.

Winter drought of 2008/9 in Nepal was the worst drought ever had happened with less than 50% rainfall which had significantly impacted crop production across Nepal. The hill and mountain agriculture were more impacted than terai (MoAC/WFP/FAO, 2009).

NCVST, 2009 revealed frequency of long drought events, especially during winter is increasing and winter drought of 2008/09 is considered as a signature event of climate change

Gurung, 2009, mentioned that precipitation not much varying in total amount but are being erratic and ill timed.

According to MoAC/WFP, 2009/10 the monsoon in 2009 experienced a significant delay: it started on the 23rd June and became active only after the 25th July. It remained active till the 15th October extending the retreat period by more than 20 days.

MoE, 2010; Practical Action, 2009, reported that total rainy days are decreasing and number of drier days are increasing. Days receiving over only 100mm rain are reported.

Moench, 2010 has reported that annual variation in precipitation has increased so far that has increased flooding and erosion and affecting agriculture.

2.2 Effect of Climate Change in Agriculture

Overall crop yield (wheat, maize and rice) could decrease in South Asia by up to 30% by the end of this century compared with an increase of up to 20% in East and South East Asia (Practical Action, 2010). In Nepal, the predicted decrease in precipitation during the winter months will reduce winter and spring crop production. Temperature increases are also expected to reduce wheat and maize yields, whilst increased variability in both temperature and precipitation will pose significant challenges to farming practices. Irrigation fed agriculture will be increasingly threatened as water resources deplete.

Landslides and flash floods have already reduced the area of cultivable land are likely to continue to reduce productivity in the future.

NARC in an experiment conducted in open top chamber showed that the wheat yield increased by 8.63 and 9.74% at 6.94°C temperature increase and doubling of CO_2. Greenhouse gas effect due to doubling of CO_2 was observed only by 0.18^0C and produced 9.74% higher than ambient plots. Physiological growth stages like panicle initiation, heading, flowering, milking and physiological maturity decreased by 14, 5, 9, 6 and 14 days respectively. This is due to increase in temperature. This indicates increase in temperature increase wheat production and also decreases physiological growth stages helping in rapid grain production and harvesting.

According to Robert *et al.,* 1987 temperature is known to affect the rate of development in crop plants during their entire growing cycle. Generally, higher temperature rise will increase the developing rate.

Also Vincent *et al.,* 1989 has cited soil temperature as important factor for crop development, leaf appearance, and shoot development. Higher temperature enhances phonological function in crop plants.

Agrawal and Kalra, 1994 in their study in India showed that there will be small decrease in potential yield by 1.5-5.8% in subtropical region while in tropical zone will have large decline in potential yield of crops by 17-18%. This shows in similar to another study that higher altitude crops will have less negative impacts from increased temperature (Serchand, 2007).

According to NARC annual reports, cold wave in Nepal in 1997/98 had negative impacts on agricultural productivity and showed reduction in the production of crops by 27.8, 36.5, 11.2, 30, 37.6 and 38 % in potato, toria, sarson, rayo, lentil and pea respectively from 1987/88 to 1997/98,). Also, Early Maturity of the crops due to increase in temperature may help to have more crops in the same crop cycle.

Reilly *et al.,* 2001 showed that increase in the temperature and changes in the precipitation pattern have potential to affect crop yields either in negative or positive way but the negative effects will be more.

Chang, 2002 estimates crop yield response models and finds negative effects associated with some climate changes. Physical effects of temperature rise on crop yield are feared more damaging in tropical and subtropical countries than in the temperate countries. The patterns of pests and diseases may change with climate change, leading to reductions in agricultural production. Moreover, agricultural productivity will be depressed by increased climate variability and increased intensity and frequency of extreme events such a drought and floods.

According to Rees *et al.,* 2004 water shortage during the dry season reduces yields from irrigated crops and threatens the food security of the region.

Alan and Regmi, 2004 predicted the decrease in precipitation from Nov to Apr would adversely affect the winter and spring crops threatening food security. Higher temperatures, increased evapo-transpiration and decreased winter precipitation may bring about more droughts in Nepal.

Kurukulasuriya *et al.,* 2006 using Ricardian Analysis revealed that highest damage from climate changes is predicted to be in agricultural sector in sub Saharan Africa. The study examined dry land and irrigated farms separately. Dry land farms are especially climate sensitive. The elasticity of net revenue with respect to temperature is -1.6 for dry land farms but 0.5 for irrigated farms. The elasticity of net revenue with respect to precipitation is 0.5 for dry land farms but only 0.1 for irrigated farms.

Sharma *et al.,* 2006 states 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 the Nepalese agriculture.

Literature on economics of climate change suggests that although global crop production may be boosted slightly by global warming in the short term before 2030, it will ultimately turn negative over the longer term (IPCC 2007). Climate change impacts on agriculture are unlikely to be evenly distributed. Low latitude and developing countries are expected to suffer more (Zhai and Zhuang, 2009).

According to Regmi, 2007 eastern tarai faced rain deficit in the year 2005/06 by early monsoon and crop production reduced by 12.5% on national basis. Nearly 10% of agriland were left fallow due to rain deficit but mid western terai faced heavy rain with floods, which reduced production by 30% in the year.

Serchand *et al.,* 2007 observed wheat productivity is likely to suffer more in Terai as compared to hills and mountains. In the study, wheat production increased by 41.5% in tarai, 24.4% in hill and 21.2% in mountain under elevated CO_2. The yield however decreased by 1.8% in tarai but increased 5.3% in hill and 33.3% in mountain at 4°C rise in temperature but in irrigated condition. In case of maize he found that temperature response to maize crop is more favorable in mountains than in tarai and hills. In elevated CO_2, maize production increased by 9% in terai. 4.9% in hills and 15.5% in mountains. However, temperature increase by 4°C, yield declined by 26.4% in tarai, -9.3% in hills but increased by 26.8% in mountain. This indicates that temperature increase has its affects based on the geomorphologic location.

Malla, 2008 showed the development and distribution insects and pest-diseases are impacted by climate change parameters: temperature, rainfall pattern and humidity. Increase in temperature will have an initial increase in production of rice, maize and wheat but will decrease after a certain temperature is reached. 4°C temperature rise in mountains are favorable for maize and wheat yield. Increase in temperature will lead to an increase in population of pests and severity of diseases in presence of host plant. Incidence of pest and diseases would be severe in tropical region which may gradually shift to hills and mountains. For instance, pathogens like rust and foliar blight of tarai has adapted in hills and mountains. Shifting of climatic zones has been observed in the country. Extinction of natural vegetation: local basmati rice varieties, some local wheat, maize and other agricultural crops was also observed.

Cline, 2008 showed that rain fed agriculture mostly practiced by the poor is likely to get affected adversely by the changing climate. The rising temperature results in increases of the rainfall and evapo-transpiration but this rainfall is not regular where evapo-transpiration is more thus affecting crops. By 2080, global agricultural productivity would decline by about 3% due to climate change

Khanal, 2009 in his study found that increase in temperature at the same time may affect lower altitude crops of Nepal i.e in tarai and foothills where temperature is already high. High temperature as heat stress affects both physical and chemical properties in soil; affects physiological development, maturation and finally yield of cultivated crops. Increased temperature accelerates transpiration to cause moisture stress which during flowering, pollination and grain filling stages is harmful to most crops. High temperature also provides conductive environment for the majority of insects pests. Lower growing seasons, higher night temperatures and warmer winters help insects pests undergo multiple life cycles and increase the chances of affecting plant production. Night temperature is higher than days (IPCC, 1995).

Craufurd *et al.,* 2010 reported warmer temperature shortens development stages of crops that will most probably reduce the yield of a given crop variety.

Gurung *et al.,* 2010 reported the intensity and distribution of rainfall in time and space affects maize yield. High rainfall during maturity period caused disease like rust and foliar blight that affects yield. He also reported that maize and wheat can increase production at 1°C temperature rise in all agro ecological zones. 2°C rise with doubling CO_2 can decrease yield in terai while hill is not impacted. Doubling of CO_2 with 4°C temperature rise can increase yield of these C_4 crops in mountains. CO_2 doesn't impact to productivity.

Koirala *et al*., 2010 revealed there is change in harvesting period of maize, wheat and barley due to increased temperature at mid region of Nepal.

Patel *et al*., 2010 experimented that warmer temperature reduces the harvesting period in crops. According to him warming soil greatly affected crops phenology during early stages of crop growth. Wheat in heated plots reached leaflets stages 44 days earlier than of non heated plots. This has reduced the harvesting period from 7-12 days in wheat.

2.3 Adaptation to Climate Change

Adaptation is a planned or active approach that deals with modifying impacts or vulnerability of systems to climate change and its subsequent effects (Smit *et al*., 1999). According to IPCC, 2007, adaptation consist of adjustment in natural or human system in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. According to Barnett (2001) adaptation to climate change can be implemented through modifying systems to accommodate long term incremental change and through resilience which consists of modifying systems to enable them to absorb and respond to short term changes without passing critical threshold limits and switching to alternative states of equilibrium. According to MoPE (2004) adaptation measures in agriculture are irrigation management, change in cropping pattern, diversification of crops, and introduction of drought resistant varieties.

CHAPTER III

3. METHODOLOGY

The study is primarily based on people perception with heavily relied review of secondary data relating to agriculture, socio-economic and climatic data recorded over time and space. Furthermore, supplementing review was done from different published and unpublished journal, articles, papers, e-papers, newsletter etc.

Selected Participatory Rural Appraisal tools (Fowler, 1998; Babbie, 1990) like questionnaire survey, Focus Group Discussion and Key Informant Interview supplemented by further field observation were used to collect field data The PRA tools like FGD and KII were done in the village level only. Two FGD, one in Pathi village and another in Philim were done. KII was also done among selected candidates thereafter. Pre-designed checklist was used during organized FGD and KII in order to ensure that relevant aspects of the research are adequately covered. Sample questionnaire is presented in Annex I. The seasonal crop calendar of the study area was prepared depending on their sowing, flowering, ripening or harvesting periods of the crops. The respondents' response was sorted out age wise to know the level of their understanding of climate change impacts on agriculture. Secondary data were collected from different sources. Rainfall and temperature data were collected from Department of Hydrology and Meteorology. Crop productivity data of Gorkha district was extracted from MoAD (2011/2012). Climatic data available at the district levels were used. These rainfall, temperature and productivity data were collated with the peoples' perception data for triangulation and cross validation of the research findings. The information gathered were processed, tabulated, analyzed and expressed in different pictorial devices.

3.1 Research Design

Designing is the initial step of a study in which the research topics and research issues are identified and presented in a systematic manner. The research objectives were set along with the activities and methodology for data collection. To collect perception data some checklist and questionnaires were designed to achieve against each objective through primary data collection. These check lists were used to cross validate and extract

information from the community. Secondary data are collected from different published and unpublished journals, articles, newsletter, papers and e-papers which were tabulated, processed, collated, analyzed for reference to compare and contrast with the present research findings. After a brief review of the literature on the content, research methodology and previous research findings, a draft proposal was drafted to discuss and further refine the framework with the supervisors and other professionals. Review of literature is done throughout the work. Final report is submitted and paper is presented. Figure1 shows research design of the research.

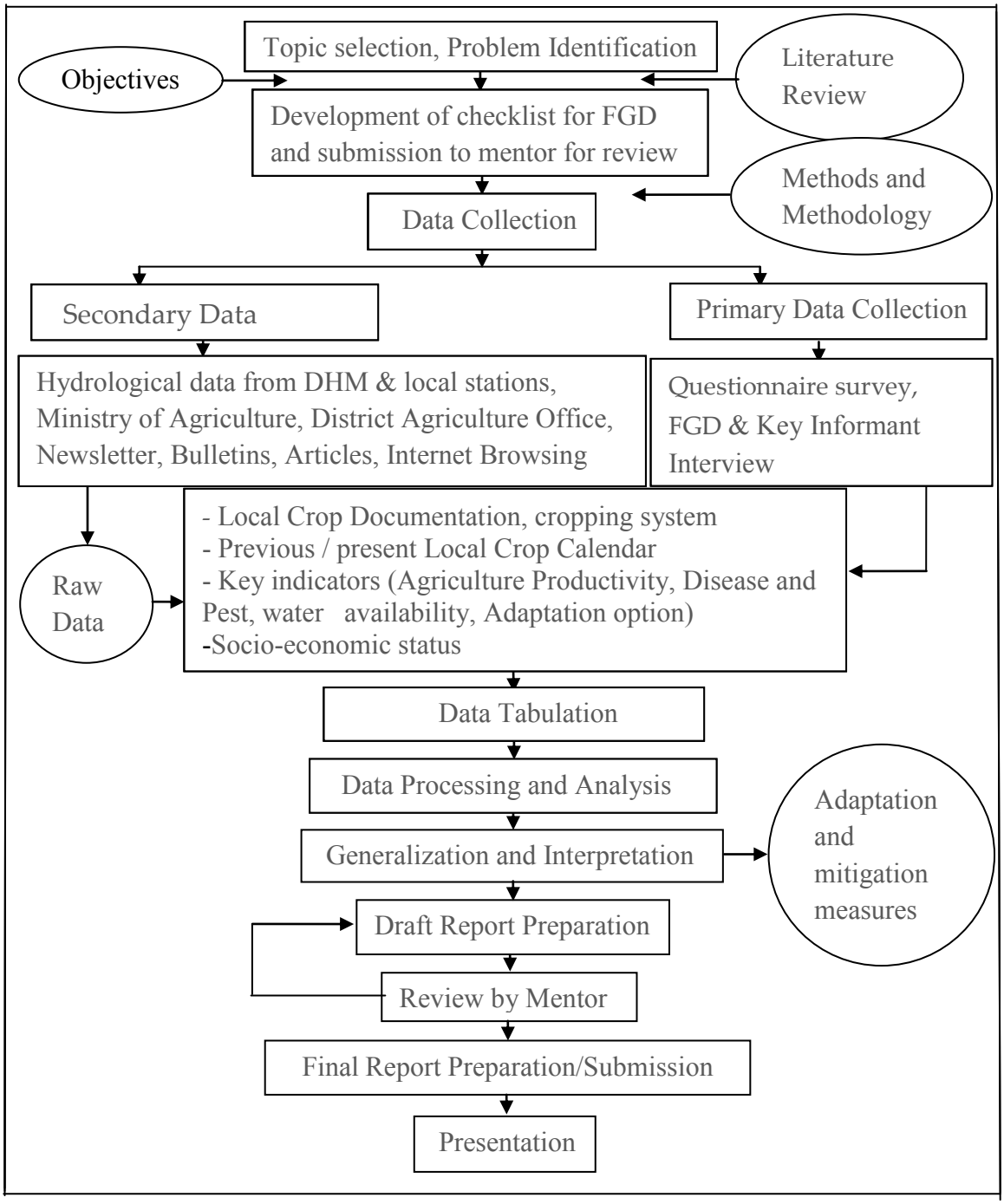

Figure 1: Research Design

3.2 Methods of Data Collection

3.2.1 Primary Data Collection

Household Survey

Of the total 559 household from 9 wards, 72 households were surveyed (Arkin and Colton, 1966). The households were randomly selected following appropriate random method of sampling. The questionnaire survey was focused in three different broad categories i.e. socio-economic parts, climate change in different forms of rainfall and temperature affecting agriculture and livelihood of farmers. Information on climate change impact in agriculture, agriculture production trend, seasonal crop calendar, water availability, incidence of crops diseases and pests and crop diversity, cropping system, and local practices adopted to adjust the impact of climate change. The number of sample households was determined according to the level of desirable precision the researchers normally expect.

***Sample size*:** The number of households to be surveyed will be calculated by using the formula given by Arkin and Colton, 1966 which is,

$$\textbf{Sample size (n)} = NZ^2.\ P\ (1\text{-}P)/[Nd^2 + Z^2.\ P\ (1\text{-}P)]$$

Where, n = Sample size N = total number of households Z = confidence level (at 25% level Z= 1.96) P = estimated population projection D = error limit

Focus Group Discussion

Focus group discussion was carried out between two groups in two different places regarding climate change, its impacts and coping strategies, fuel status and options and agriculture status. FGD was necessary to understand the impact of climate change on resources and agriculture based upon their experiences. FGD with Ama Samuha was done in Shree Buddha Ma Vi in Philim while another FGD was done with male farmer group in Pathi along with the Juntara Youth Club, Sirdibas. Checklist was used for FGD.

Key Informants Interview

To develop further idea of the study site, informal discussion and interview with key informant was conducted. KII was done with JTA (Junior Technical assistant) Ram Pd. Sakya of Krishi Sewa Kendra,Sirdibas; President of Ama Samuha and conservation farmer Mrs. Tsheni Gurung; VDC secretary Balaram Panta and with some nodal farmers both old and young. The interview was focused on the general description of the research site along with extraction of ideas on the change in climatic pattern, hazards associated

with climate change, effects of climate change in agriculture etc. Check list was used for KII.

Observation

Direct field observation was carried out around the research sites for additional information and for field verification.

3.2.2 Secondary Data Collection

Secondary data were extracted from published and unpublished documents, newsletter, journal, bulletins, annual reports and relevant articles from different agencies including Ministry of Agriculture Development (MoAD), District Agricultural Development Office (DADO), MCAP and NAST library. VDC profile was collected from the VDC lesion office, Gorkha. Rainfall and temperature (1971-2011) data were collected from Department of Hydrology and meteorology (DHM) of the station PA 080171in Jagat.

3.3 Data Analysis

Data analysis includes collation of primary and secondary data. Primary data were interpreted using secondary data to authenticate the finding of primary data. The data and information collected were tabulated in the MS-Excel-2007, SPSS 16.0 and MS-Word-2007 and was used for data processing, data analysis and interpretation of information collected. Missing rainfall and temperature data were obtained by using SPSS 16.0 tool. The results were then presented in a variety of forms including tables, graphs, charts and pictorially. The data were analyzed by using different statistical tools. Regression analysis was done to see the trends in temperature, rainfall and productivity. Also, the crop productivity trend was analyzed combined with the rainfall data disagreed by different seasons - pre-monsoon, monsoon, post-monsoon and winter monsoon and temperature for cropping period from sowing to maturation. The relationship between productivity and climatic parameters (temperature and rainfall) was studied by using correlation. The results thus obtained were presented pictorially in charts, diagram, graphs etc.

CHAPTER IV

4. STUDY AREA

4.1 Biophysical of Study Area

Gorkha district has an area of 3610 sq.km and lies at altitude from 228 to 8163 msl. It has average annual rainfall of 1492 mm and temperature of 25°C (max), 14°C (min). The study site of Sirdibas is 160 km away from the Gorkha Bazar. Sirdibas VDC is one among seven VDCs occurring under Manaslu Conservation Area Project (MCAP) of Gorkha district. Sirdibas VDC is the gateway village of the conservation area. The VDC has a total area of 314.91km^2. VDC is located between 28°19'45"N to 28°45'10"N latitude and 84°29'00" E to 85°12'15" longitude. The settlement lies between heights 1370m to 2200 m above sea level while the highest landscape remains at 7893m above sea level. Sirdibas VDC has 17 settlements. VDC is bounded by Keruja VDC (East), Uhiya VDC (West), Chumchet and Bihi VDC (North) and Keruja and Uhiya VDC (South). Jagat is the lowest and the gateway to the MCA and of the study site. The research area is mountainous area ranging from lower 1370 msl to highest 7893msl and has rocky terrain.

MCA lies in the upper region of Gorkha district and is bounded by Tibet Autonomous Region (TAR) of China to the north and east, Manang district to the west and Gorkha district to the south. MCA project was established on December 28, 1998 under NTNC management. Manaslu is a mountainous region in northern part of Gorkha District, has a fragile but diverse natural resource base and a rich cultural environment. MCA encompasses a 1,663 sq. km. area with 7 VDCs i.e. Sirdibas, Chhekampar, Chumchet, Bih, Prok, Lho and Sama. Sama is the highest settlement (3,830m) while Jagat is the lowest (1,370m). There are about 9,000 inhabitants living in MCA and 2,000 species of plants, 33 mammals, 110 birds, 3 reptiles and 11 butterflies in 11 types of forest have been reported from the area. The eighth highest Manaslu Range lies in MCA region. At the lowest altitude in MCA is Sirdibas VDC which is the research VDC. Figure 2 shows the landuse map of study area.

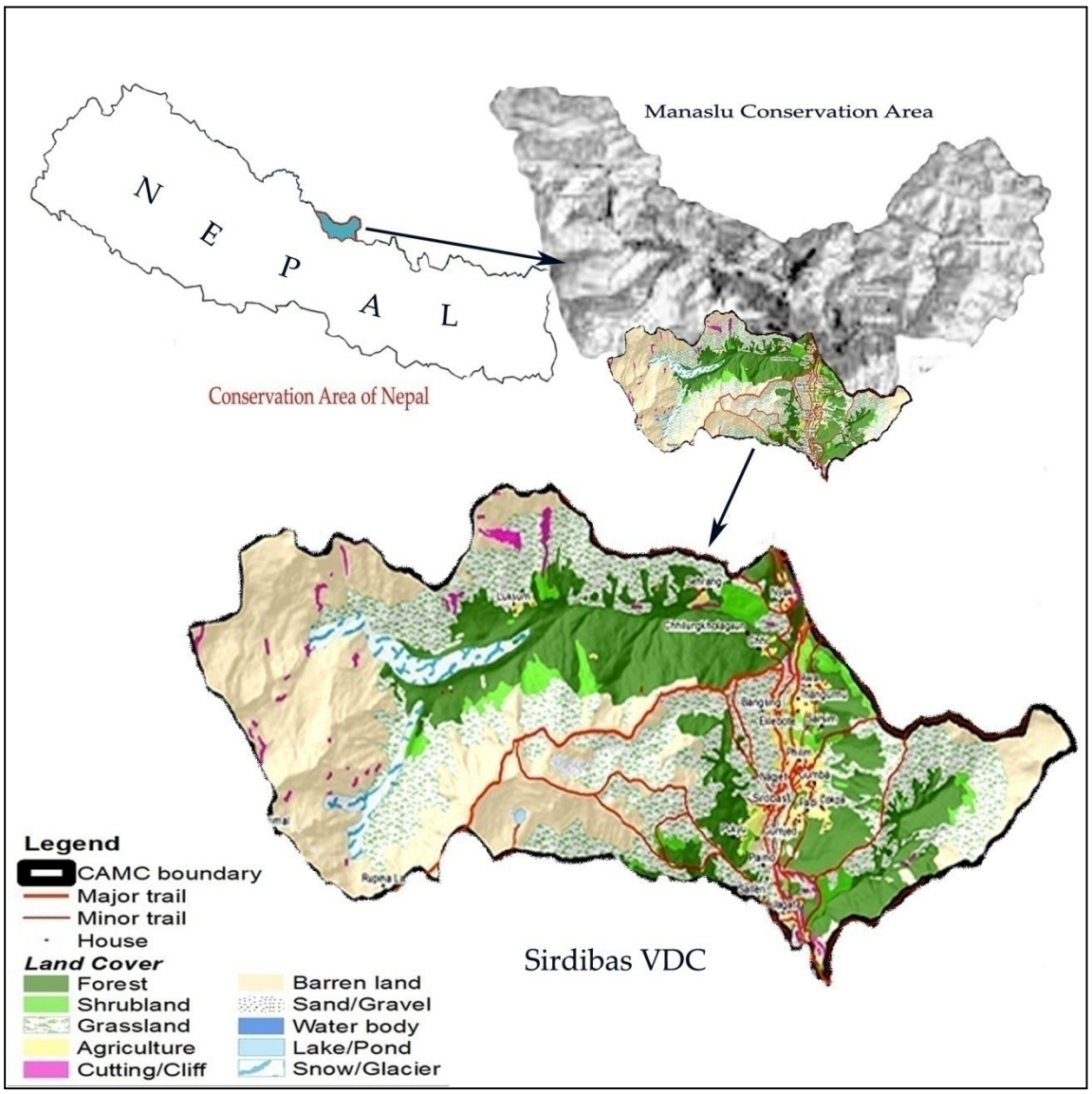

Figure 2: Map of Sirdibas VDC (Source: NTNC, 068)

Landuse of Sirdibas VDC comprise forest, grass land, shrubland, barren land, snow covered land, rocks, rivers-rivulets, lakes ponds and agricultural land. Total cultivable land area of the VDC is 889 ha. Annex II, Table 2 shows the land use of Sirdibas VDC.

There are 11 rivers and rivulets in the VDC. These are Budigandaki, Bhaluwan, Dudhpokhari river, Yawang River, Yayu river, Sano Philim river, Dhungang river, Angjung river, Ghattekhola, Lokpa river, Chirlang river. Dudh Pokhari is the major lake and is the tourism destination. There are five different forests in the VDC. They are Ghattekhola forest, Aanga Sirsium forest, Pangsing Forest, Nyak forest and Yayu forest.

The whole MCA is a food deficit area having only 2% cultivable land. The study area is within MCA, is therefore also food deficit area. The farmland of the study site is fragile and marginal. People here owned small parcels of land that are rain-fed type. So, farming

is subsistence type and therefore climate change is affecting agriculture here too. Also, the study site is within the conservation area that carries the conservation value so, the study area was selected for the research.

4.2 Socio-Economic of Study Area

The total population of the VDC is 2788 and the total household is 559. Male population is 1377 and female population is 1411(Annex II, Table 3). Gurung, Ghale, Kami are the ethnic group inhabitant to the place. Gurung is the dominant ethnic group. Literacy rate of the place is just below 26%. Nepali and Gurung are the major languages spoken there. Budhist, Hindhu, Christian are the major religions recorded from the study site. Different festivals like *Loshar, Dashain, Tihar, Sankranti* are celebrated by people according to their religious faith.

The major occupation here is agriculture, animal husbandry, labor, abroad etc. Food crops like maize, millet, wheat, barley, buckweet, soyabean are grown here. Varieties of vegetables are being practiced as well (Table 4). Major livestock of the people are cattle, buffalo, sheep, goat, pig, and poultry. Orange, pear, banana, apple, peach are the different fruits there. Besides, people have out migrated from the valley to earn for better living. Countries of destination for earning are Malaysia, Qatar, Kuwait, Iraq, Dubai, Korea etc.

4.3 Agriculture in Sirdibas

There is subsistence type of farming in Sirdibas. Agriculture land here is fragile and fragmented. Also, the arable land is very limited and distributed into small parcels. Out of total VDC area of 31,491Ha, only 889 Ha are cultivable (NTNC, 068/72) and 418 Ha (DADO, Gorkha). Out of whole MCA's area (1,663 sq. km i.e. 1, 66, 300 ha) only 1838 Ha (1.1%) is cultivable. The cultivable land area in MCAP is shown in Annex II, Table 4. The production is also subsistence that produces less food enough to sustain their family just for few months. Agriculture land here is rainfed "bari". Varieties of food crops and vegetables are grown here. But, people here are not totally dependent on their local productions. They majorly depend on the staple imported food rice and pulse available in food depot. NTNC distributed the varieties of vegetables seeds to 468 households at Rs 2/pack in fiscal year 2009/10 (2066/67B.S.).

CHAPTER V

5. RESULTS

5.1 Socio Economic of Study Area

5.1.1 Education

Education status of the study site is poor. The literacy rate of the study site is found to be 30% which on 2065 was 26% (MCAP, Management Operational Plan 2068-2072). The illiteracy rate of the people is found to be 70%. This literacy share is due to the young children of primary level. The understanding of climate change, adaptation to climate change is dependent on education. Only 3 respondents were familiar to climate change term while others have general knowledge in climate from their sense but didn't know the term climate change. These 3 respondents were a teacher, local staff at NTNC and a student.

5.1.2 Land holdings

Land holdings of people were categorized into landless, 1-5 hall, 6-10 hall and more than 10 halls. 76% sample owned 1-5 halls of land. 15 % owned 6-10 halls land while 3% owned more than 10 halls land. 6% were landless and victims of landslides. Figure 3 shows the people % holding lands. **1hall=2 ropani*

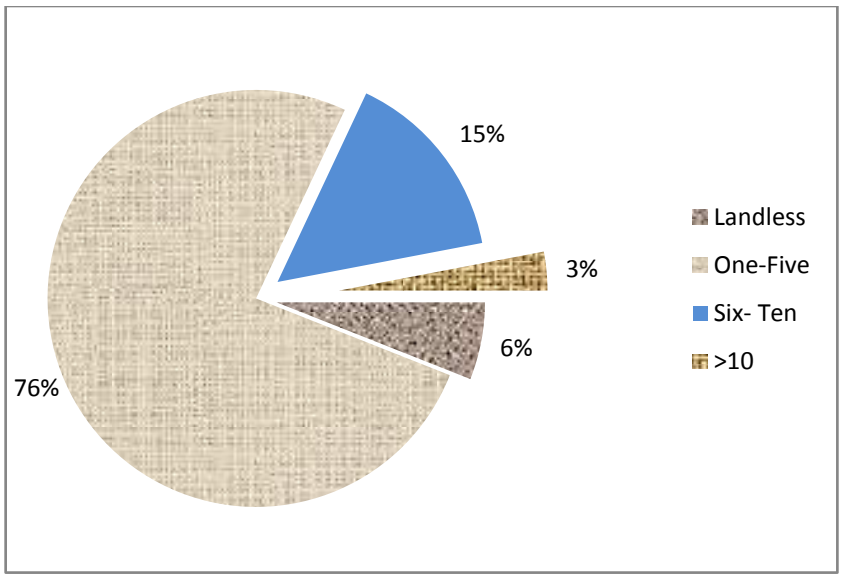

Figure 3: Land Holdings by People

5.1.3 Income Source

The major occupation is farming. The share of income from agriculture is 26.6% while remittance from abroad job shares high percentage of income (35.7%). Besides these, people are engaged in government service, hotel /cafe, trekking, wage labor (agriculture, potter), local construction in/outside of the valley. People with good income have more choices of better livelihoods. Figure 4 shows the percentage share of income of people of study site.

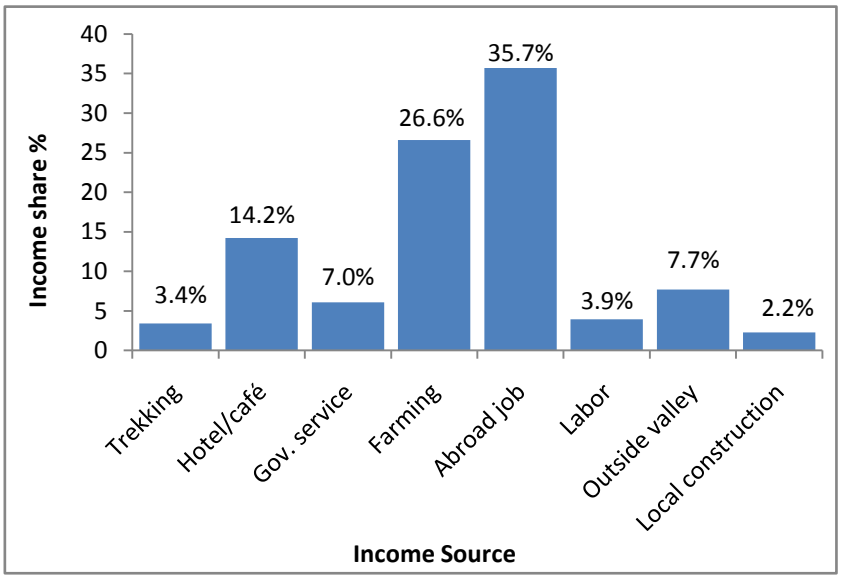

Figure 4: Income Share of the People

5.2 Climatic Analysis of Study Area

5.2.1 Temperature Analysis

The statistical record of 32-years temperature data of station no. 0809, Gorkha showed that the temperature trend of the study area is increasing. The linear trend line shows mean annual temperature is increasing at rate of 0.05°C/year, maximum temperature at rate 0.96°C/year and minimum temperature at rate 0.002°C/year. The mean annual temperature was highest in the year 2008 with value of 22.913°C. The maximum temperature of 28.616°C is in the year 2010 while minimum temperature till now recorded was in the year 2004 of 10.53° C. Maximum temperature increase is more than minimum temperature. The Figure 5 shows the temperature trend of the station number 0809 that represent study site (Annex II, Table 5).

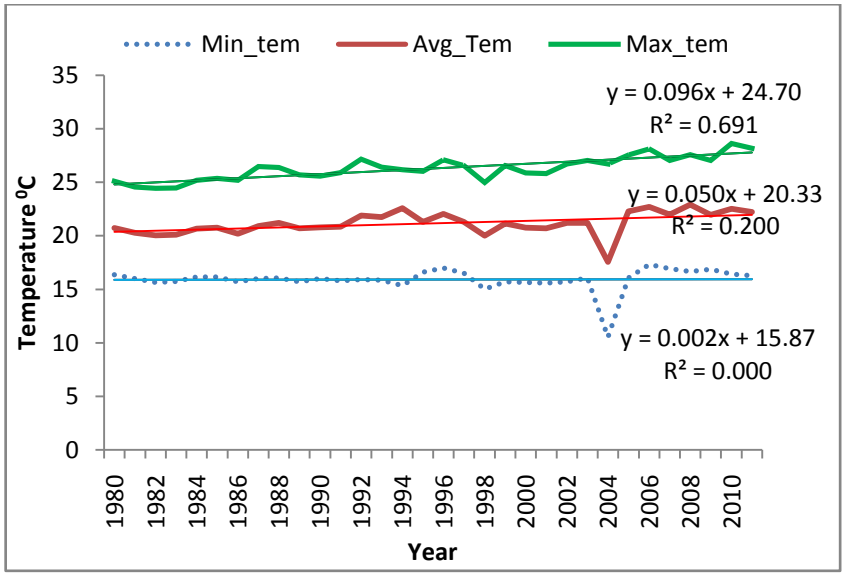

Figure 5: Temperature Trend of Study Area (DHM, 1980-2011)

5.2.2 Rainfall Analysis

The 40-year meteorological data of station no. PA080171 (Annex II, Table 6), Jagat showed irregularities in rainfall. Trend however shows increasing rate of 0.995mm/year. In the first twenty years of the period i.e. from 1971-1990, the curve shows irregularly decreasing rainfall while in another twenty years between 1991-2011, the curve shows the irregularly increasing rainfall. The minimum average annual rainfall occurred is 11.916mm in 1991. The maximum average annual rainfall occurred was 166.58mm in 2011. The meteorological record showed maximum rainfall of 496.25 mm occurred in July with total rainfall of 1948.9mm in 2008 (2065 B.S.). This year landslide in Dewal was triggered. Figure 6 shows rainfall trend of study area.

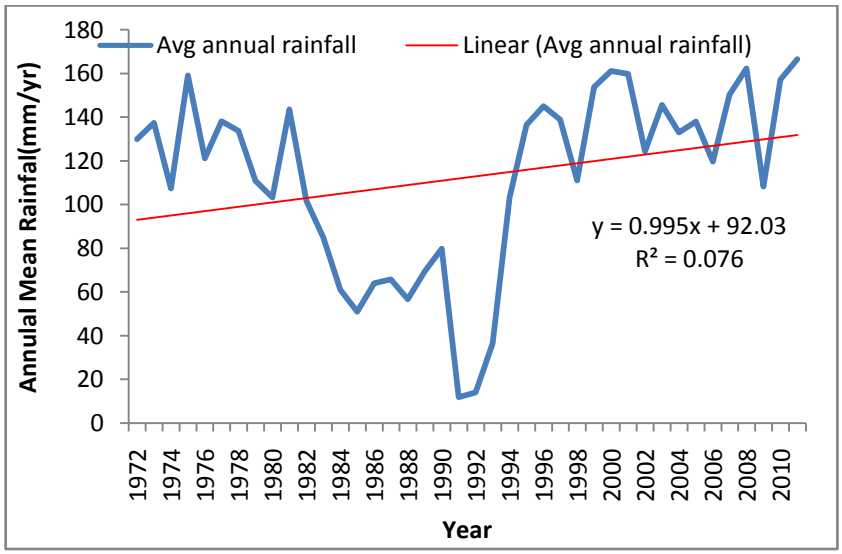

Figure 6: Annual Mean Rainfall of Study Area (DHM, 1971-2010)

The linear trend analysis of pre monsoon, monsoon, and post monsoon shows the rainfall is increasing at 0.714mm/yr, 2.88mm/yr and 0.293mm/yr respectively. The winter monsoon is decreasing at 0.236mm/yr. The maximum rainfall occurred during monsoon was 496.25mm in 2008 (2065, Asadh). The data showed that 72.43% of the monsoon occurred during Ashad- Bhadra (Jun – Sep). Figure 7, 8, 9 and 10 shows the linear trend of rainfall of Sirdibas.

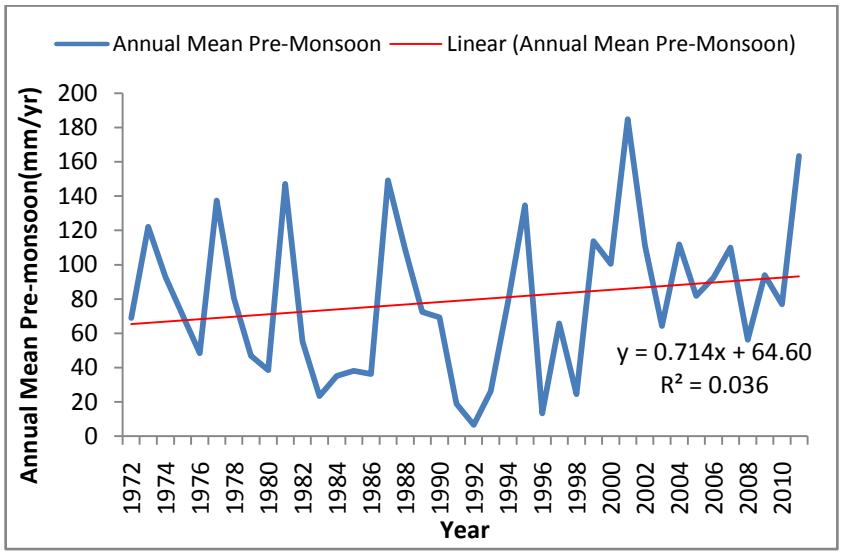

Figure 7: Annual Mean Pre-Monsoon (DHM, 1970-2011)

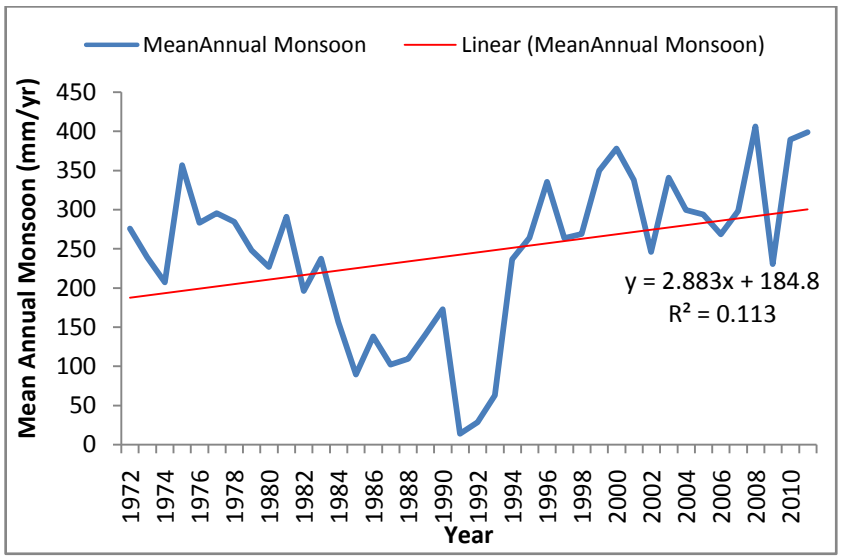

Figure 8: Mean Annual Monsoon (DHM, 1970-2011)

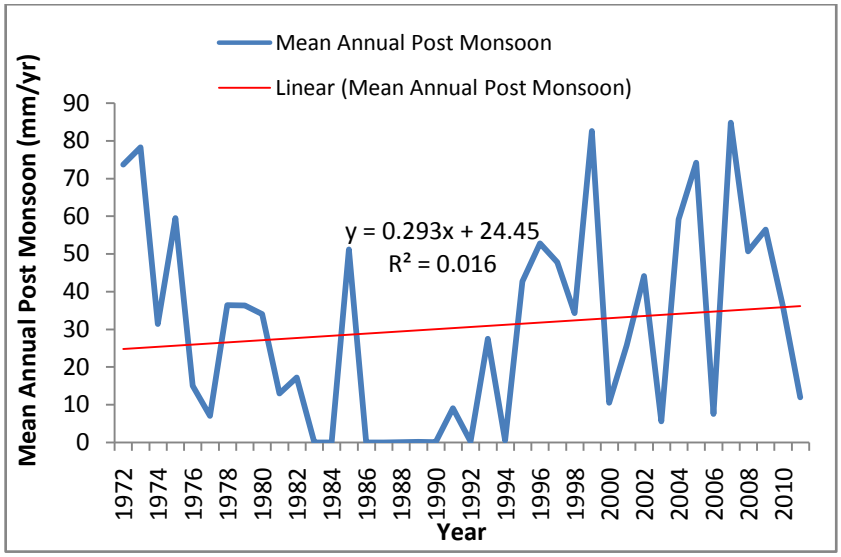

Figure 9: Mean Annual Post-Monsoon (DHM, 1970-2011)

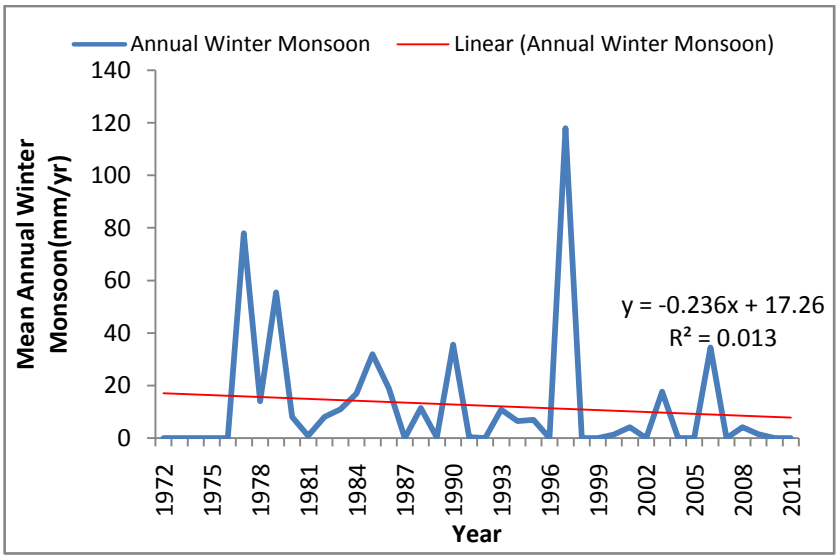

Figure 10: Mean Annual Winter Monsoon (DHM, 1970-2011)

5.2.3 People Perception on Climate Change

Temperature

The majority of the respondent responded that temperature has increased since few years. They felt summers are being hotter as before. 44 out of 72 responded that the summer temperature has been increasing. 24 responded for increased winter temperature also. 24 responded that temperature is same. 15 responded they have no idea in winter temperature and 8 responded they have no idea on summer temperature.

Age group 31-60 yr perceived increasing minimum temperature more than other age group in study area. Similarly, increasing maximum temperature is also experienced by

age group 31-60 yr majorly. 100% respondent of age group 61-90yr responded for increasing both maximum and minimum temperature which is 6% responses of total. People perception on temperature is shown in the Figure 11. Table 1 shows age wise temperature perception % of study site.

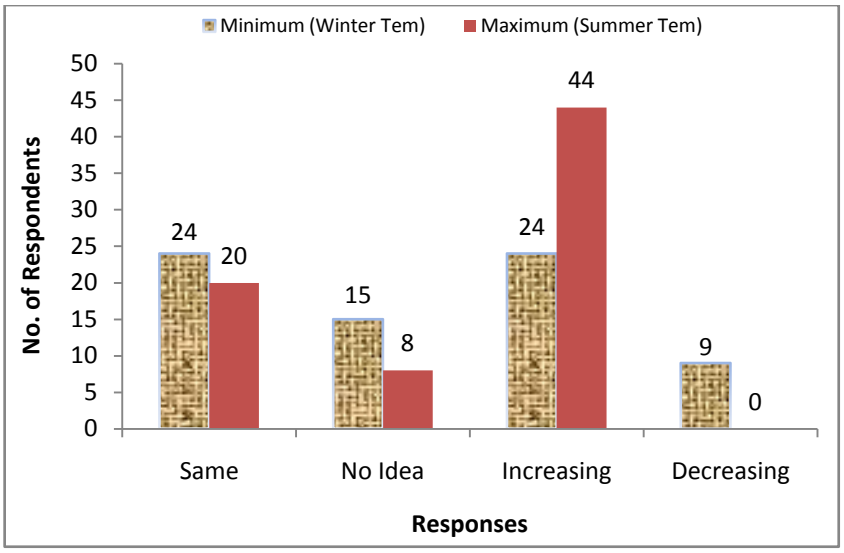

Figure 11: People Perception on Temperature

Table 1: Age wise Perception % on Temperature

Age wise Perception for Minimum Temperature (%)

Age Group	Same	No Idea	Increasing	Decreasing
1-30	18	7	3	11
31-60	18	11	25	1
61-90	0	0	6	0

Age wise Perception for Maximum Temperature (%)

Age Group	Same	No Idea	Increasing	Decreasing
1-30	6	18	15	0
31-60	11	4	40	0
61-90	0	0	6	0

Source: *Field Data, Apr 27, 2012*

Rainfall

The monsoon rainfall starts from Ashad and normally lasts by Aswin here. Of the total respondents surveyed, the majority of them responded that rainfall is increasing both in terms of amount and timing. 38 respondents shared that amount of rainfall is increasing and 33 responded the timing of rainfall is expanding but erratic. Rainfall is untimely but

increasing. Age wise too, rainfall is increasing. Age group 31-60 yr perceived increasing rainfall more than other age group in study area.100% respondent of age group 61-90yr responded for increasing rainfall amount and timing which is a 6% response of the total. Table 2 shows age wise perception % on rainfall. Figure 12 shows the people perception on rainfall amount and timing.

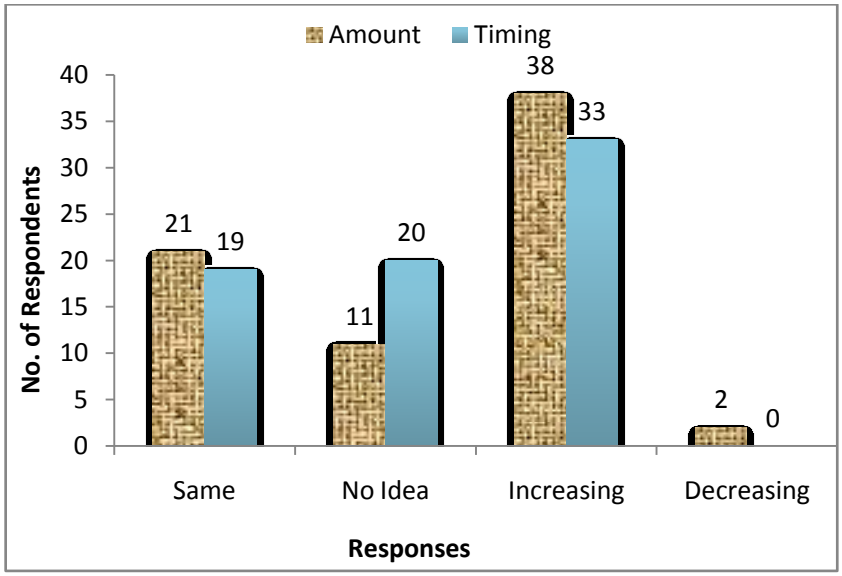

Figure 12: People Perception on Rainfall

Table 2: Age wise Perception % on Rainfall

Age wise Perception on Rainfall (%)				
Age Group	**Same**	**No Idea**	**Increasing**	**Decreasing**
1-30 yr	12	5	21	0
31-60 yr	17	10	26	3
61-90 yr	0	0	6	0

Source: *Field Data, Apr 27, 2012*

Snowfall

Of the 17 settlements, 2 settlements Anga and Nyak above 2200 m altitude received small (2-5 inches) amount of snowfall. Snowfall duration is uncertain most probably decreasing and amount too is decreasing. Snowfall timing is also uncertain. Lower Philim recorded snowfall once in past 12 years ago. Of the total respondents, only 21 respondents responded that the snowfall is decreasing in amount as before and has irregular snowfall. Figure 13 shows the perception of people on snowfall.

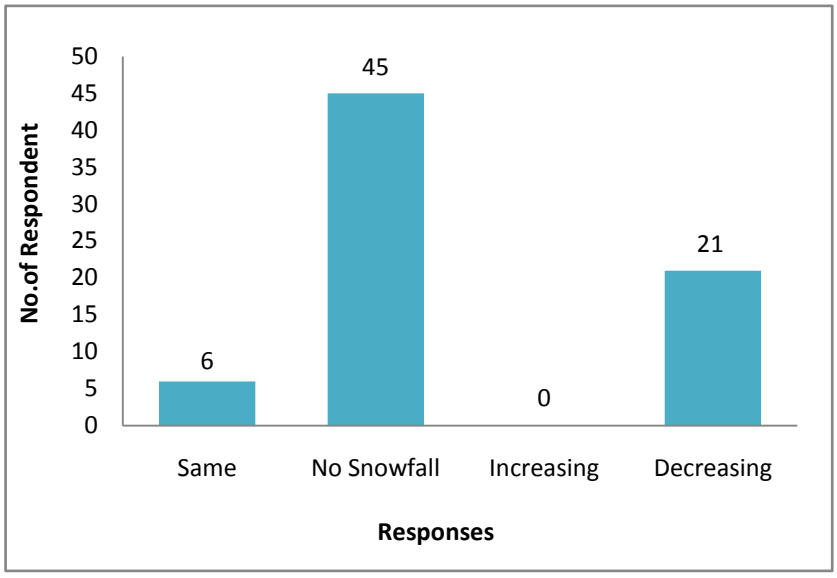

Figure 13: People Perception on Snowfall

5.3 Agriculture in Sirdibas

5.3.1 Crop Documentation

Despite the fragility and marginality of land in Sirdibas, varieties of crops both local and improved are being practiced. Varieties of vegetables have also been practicing since 2009/10 (066/67B.S.). Table 3 and 4 shows the food crops and vegetables being practiced in Sirdibas VDC.

Table 3: List of Food Crops Grown in Sirdibas

Common Name	Local Name	Scientific Name	Varieties
Maize	Makai	*Zea Mays*	Manakamana-1(seto) Khumal Pahelo
Wheat	Gahu	*Triticum aestivum*	Annapurna-3, R-R 21
Barley	Jau	*Hordeum vulgare*	Local
Millet	Kodo	*Eleusine corocana*	Dalle, Pangdur
Soyabean	Bhatmas	*Glycine max*	Local
Buckwheat	Phapar	*Fagopyrum tataricum*	Local
Karu	Uwa		Local

Source: *Field Data, Apr 27, 2012*

Table 4: List of Vegetables Practiced in Sirdibas

Common Name	Local Name	Scientific Name	Varieties
Cabbage	Banda Kobi	*Brassica oleraceae capitata*	Green coronet/ kordio
Cauliflower	Phool kobi	*Brassica compestris botrytis*	Snow mistic, Kathmandu local
Raddish	Mula	*Raphanus sativus*	Minu early, 40 days, Tokonasi
Onion	Pyaj	*Allium cepa*	N-53
Garlic	Lasun	*Allium satuvum*	Local
Bean	Simi	*Phaseoulus vulgaris*	Chaumase, Local round
Potato	Aalu	*Solanum tuberosum*	Potato
Pea	Kerau	*Pisum sativum*	Arkel
Tomato	Tamatar	*Lycopersicum esculutum*	Srijana, Surukchha
Cucumber	Kakro	*Cucumis sativa*	Bhaktapur local
Spinach	Rayo	*Brassica sps.*	Manakamana
Spinach	Palungo	*Spinicha oleracea*	Kande
Carrot	Gaajar	*Daucus carota sativus*	New Koroda
Coriander	Dhaniya	*Cortandrum satuvum*	Kathmandu Local
Pumpkin	Farsi	*Cucurbita pepo*	Local
Brinjal	Vanta	*Solanum melongena*	Hybrid
Mustard	Tori	*Brassica compestris*	Local
Amaranth	Lattey	*Amaranthus caudatus*	Local

Source: *Field Data, Apr 27, 2012*

5.3.2 Crop Calendar

Majority of the respondents (62 of 72) responded to unchanged cropping time. Flowering and fruiting was not noticed by majority of respondents (42 of 72) while 30 of 72 responded shared the same. Also, the sowing period is not exactly known, though they said they haven't altered sowing time. Ripening time is however decreasing as responded by majority of the respondents (33 of 72). Wheat, maize, millet and barley are taking lesser time to be harvested then before. Figure 14 show people perception on cropping calendar of Sirdibas.

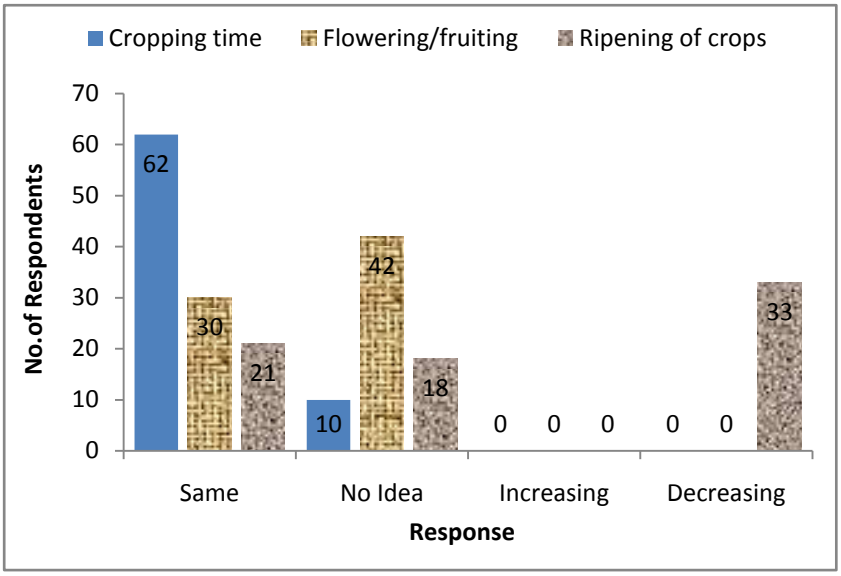

Figure 14: People Perception of Cropping Calendar

Figure 15 shows the crop calendar of Sirdibas VDC (Annex II, Table 7). In the figure 15, Hv= Harvesting, Sw= Sowing, Fl =Flowering, Rpn= Ripening.

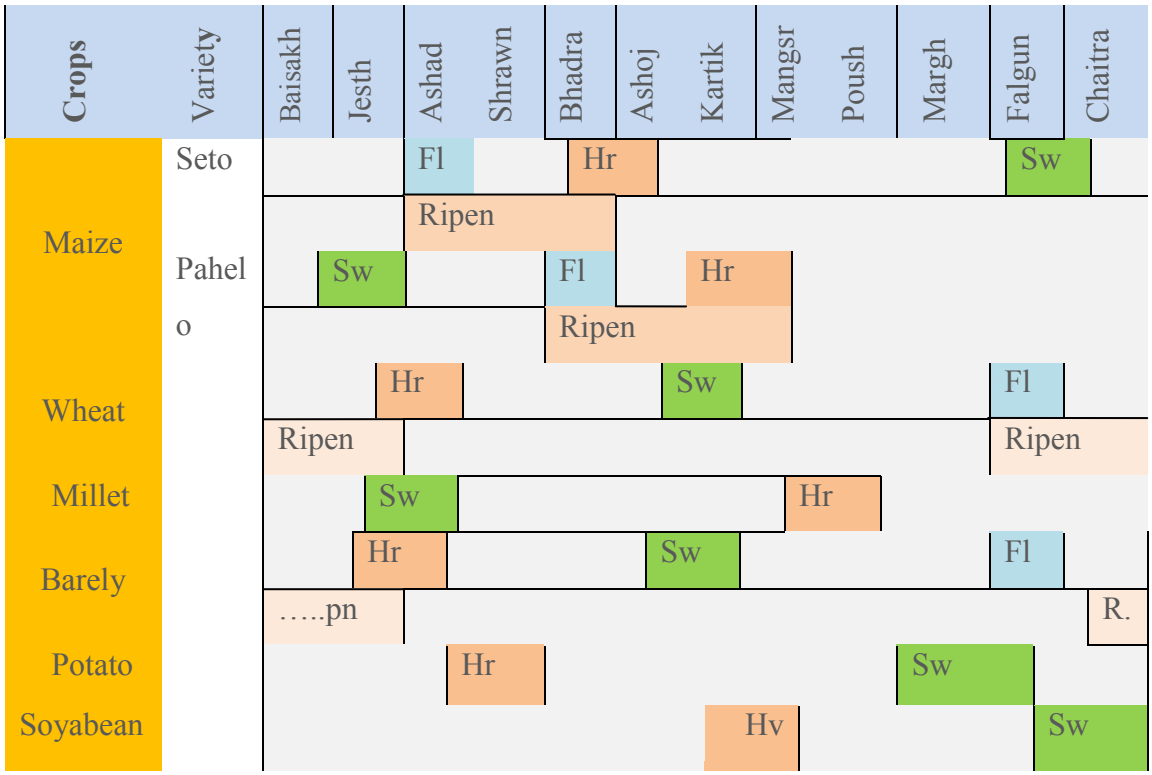

Figure 15: Cropping Calendar of Sirdibas

5.3.3 Ripening Period

People are unaware of flowering and fruiting exact time but they felt that maturation and harvesting of some crops has shortened. Crops have been taking less time to mature and harvest. The effect of increased temperature seems to pose this decreased senescence day of crops. To see this, temperature trend of crops growing period is analyzed. Temperature trend of following crops are given in figure 16, 17, 18 and 19. Flowering and fruiting is not sensed by people. Table 5 shows the temperature trend and senescence period of crops.

Ripening Period of Maize

The linear trend of 32 year maximum temperature of month Falgun-Aswin (Feb-Oct) shows the temperature is increasing at 0.112°C/yr. Falgun-Aswin is the growing to maturation period of maize (white) and Baisakh- Kartik (May-Nov) is the growing periods of maize (yellow). This increased temperature has possibly reduced maize ripening/ harvesting period by 5-15days at present

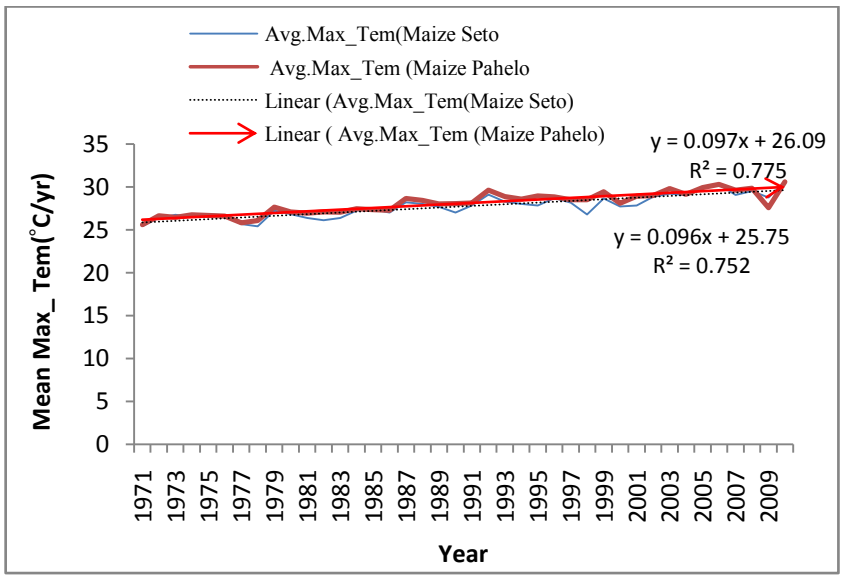

Figure 16: Temperature Trend of Maize Growing Period

Ripening Period of Wheat

The linear trend of 32 year maximum temperature of month Aswin-Jestha (Sep-May) shows the temperature is increasing at the rate of 0.078°C/yr. Aswin-Jestha is the growing to maturation period for the wheat crop. This has possibly reduced the wheat ripening/harvesting time by 5-10 days at present.

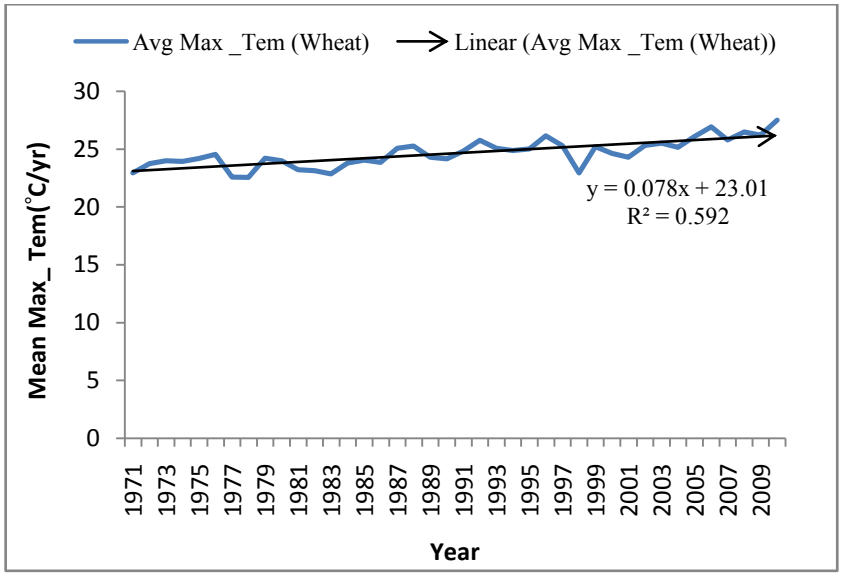

Figure 17: Temperature Trend of Wheat Growing Period

Ripening Period of Millet

The linear trend of 32 year maximum temperature of month Jestha-Poush (May-Jan) shows the temperature is increasing at 0.086°C/yr. Jestha-Poush is the growing to maturation period of millet. This increased temperature has possibly reduced millet ripening/harvesting period by 5-10 days at present

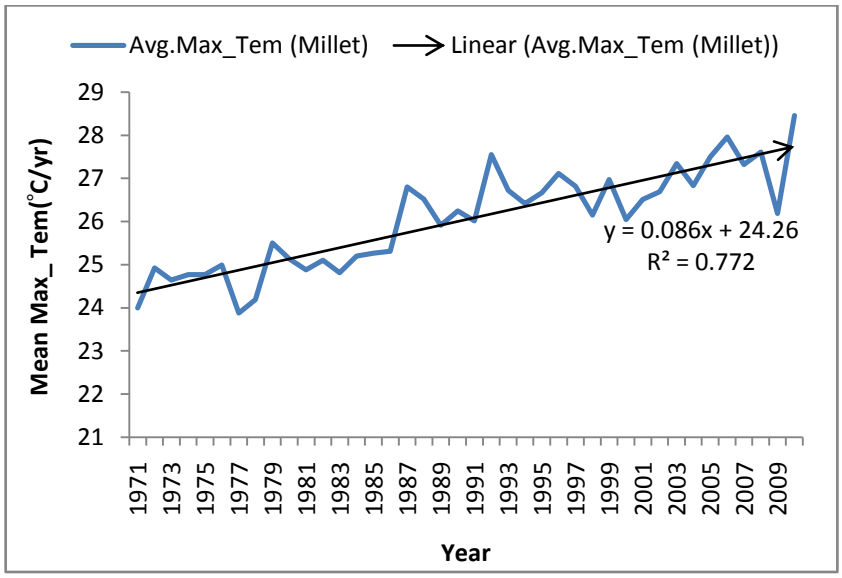

Figure 18: Temperature Trend of Millet Growing Period

Ripening Period of Barley

The linear trend of 32 year maximum temperature of month Aswin- Ashad (Sep-Jun) shows the temperature is increasing at 0.081°C/yr. Aswin- Ashad is the growing to

maturation period of Barley. This increased temperature has possibly reduced barley ripening/harvesting period by 5-10 days at present.

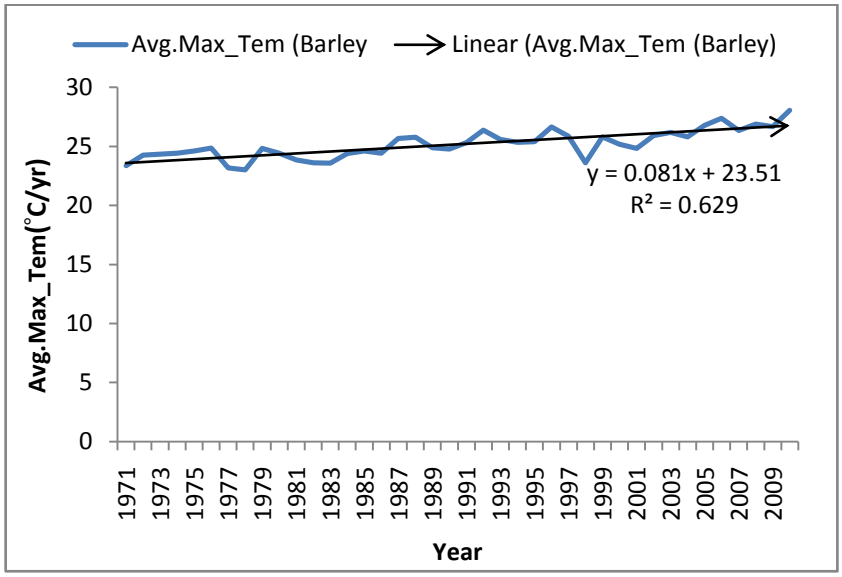

Figure 19: Temperature Trend of Barley Growing Period

Table 5: Increased Temperature and Decreased Senescence Period

Crops	Increased Avg. Max. Temp (^{0}C/yr)	Senescence Period (Months)	Decreased Senescence (day)
Maize (white)	0.096	9	10-15
Maize (yellow)	0.097	7	10-15
Wheat	0.078	9	5-10
Millet	0.086	9	5-10
Barley	0.081	10	5-10

5.3.4 Crop Production

Crop Production Perception

Majority of respondent responded that crops like maize, wheat, millet, barely and karu (local wheat variety)are decreasing in productivity. 68 of 72 responded that karu is refrained from the area now because of decreased productivity. Figure 20 shows the people perception on crop production. Age group 31-60yr has the highest response of 25% on decreasing production. Table 6 shows age wise production perception (%).

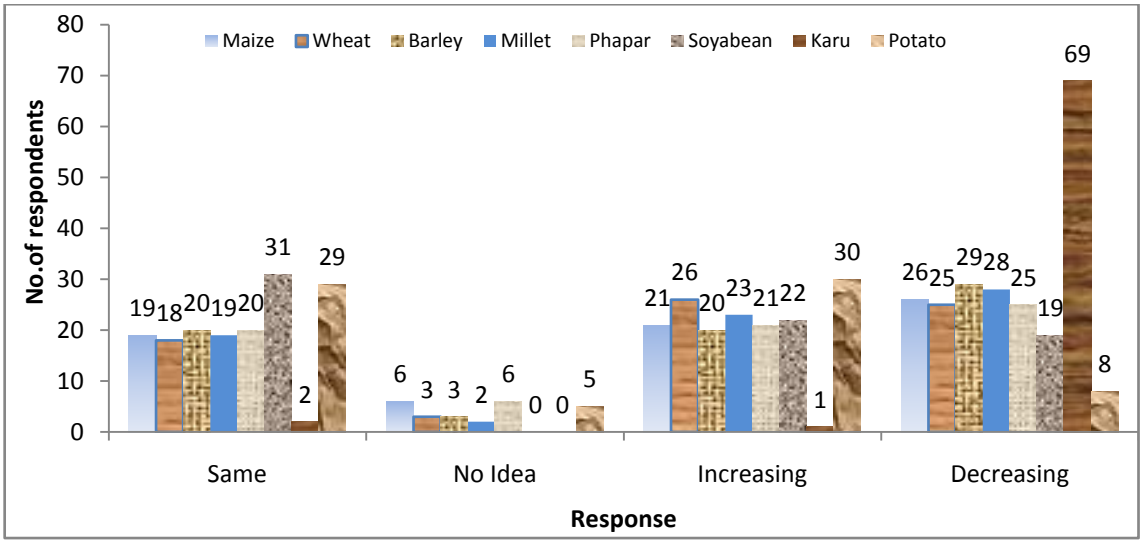

Figure 20: People Perception on Crop Production

Table 6: Age wise Crop Production Perception (%)

Age Group (Yr)	Age wise Perception on Crop Production (%)			
	Same	No Idea	Increasing	Decreasing
1-30	9	3	13	13
31-60	14	3	14	25
61-90	0	0	2	4

Of the total respondents, 41% said their overall agricultural production is decreasing, 28% responded increasing, 24 % responded same while 7% responded no idea. Figure 21 shows the percentage of people responding for crop production.

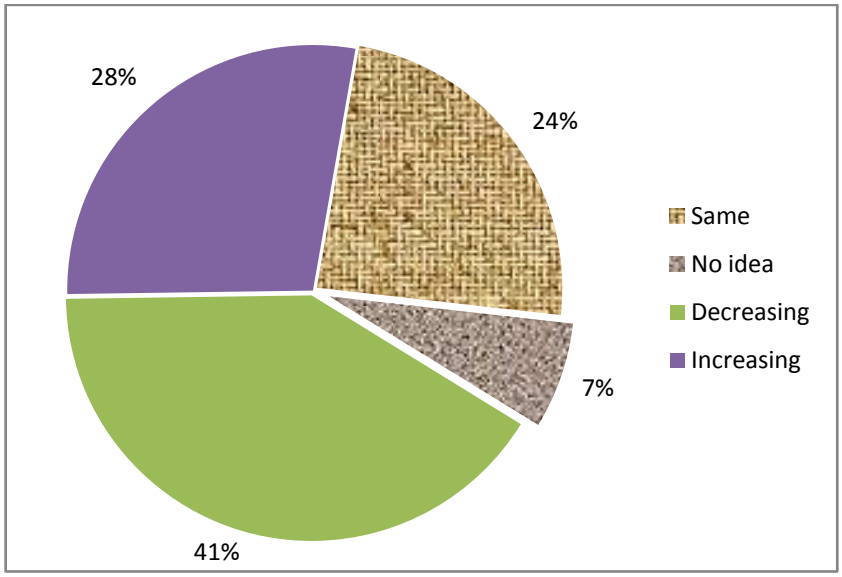

Figure 21: People Percentage Responding Crop Production

Crop Production Trend

The overall linear trend of 32-year crop production data for Gorkha District shows increasing production for maize, millet and wheat while barley production is decreasing (Annex II, Table 8). Maize showed highest increase rate of 1196metric ton/yr, millet at rate of 386.6 metric ton/yr, wheat at rate 165.5metric ton/yr and barley decrease rate of 1.755 metric ton/yr. However, their production since few years has been decreasing. The blue trend line in the curve shows the increasing trend of crops in maize, wheat, millet at overall while barley shows decreasing trend. The red trend line in curves of maize, wheat, millet shows decreasing trend since last decade. The field survey also showed the production is decreasing in the study site since a decade. In the figure 22, 23, 24 and 25 below, the red marked line shows the decreasing production. Table 7 shows the overall production trend for maize, wheat, millet and barley.

Table 7: Crop Production of Gorkha District

Crops	Overall Production (metric ton/yr)	Decreasing Production (metric ton/yr)	Periods Decreasing from in year
Maize	1196	-1926	6 yr
Wheat	165.5	-358.3	8 yr
Millet	386.1	-627.1	10 yr
Barley	-1.755	-1.755	32yr

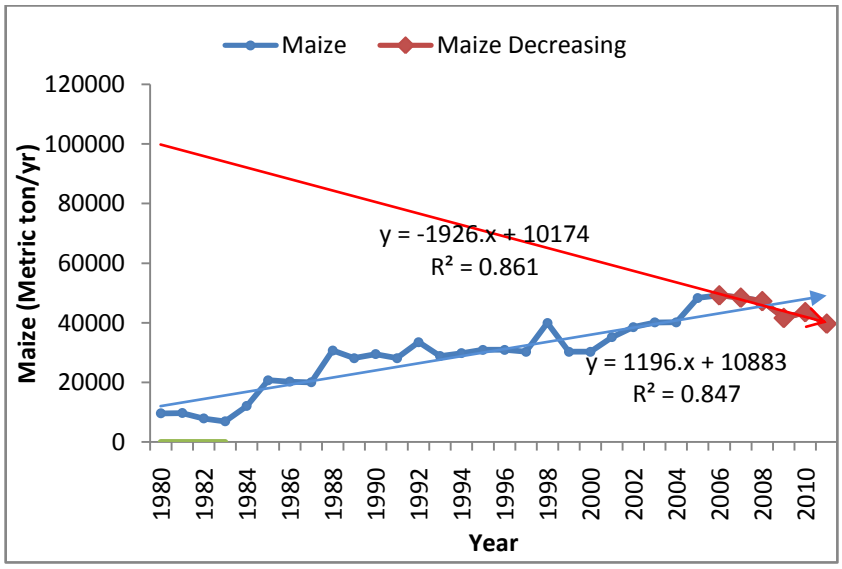

Figure 22: Production Trend of Maize in Gorkha District (MoAD, 2011/12)

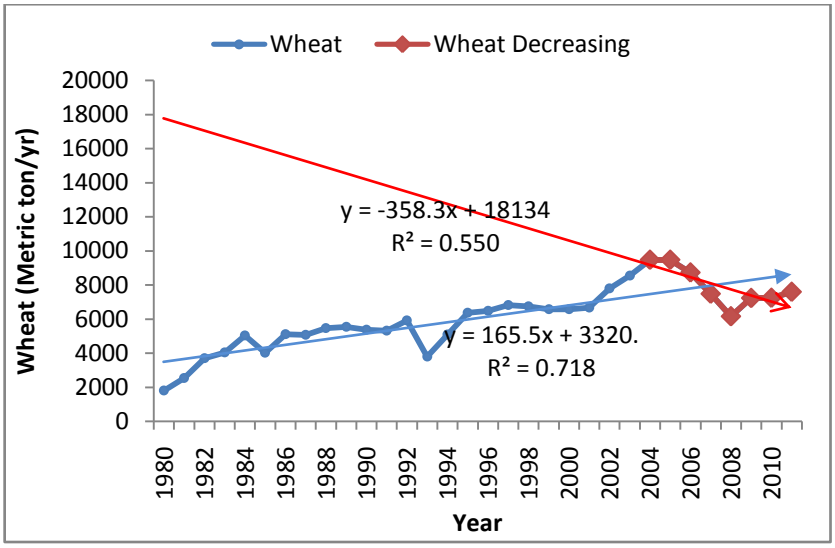

Figure 23: Production Trend of Wheat in Gorkha District (MoAD, 2011/12)

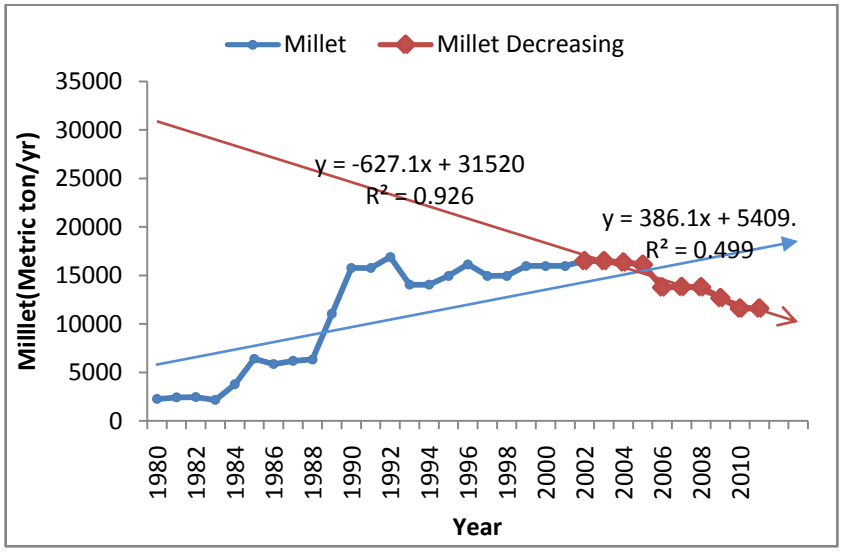

Figure 24: Production Trend of Millet in Gorkha District (MoAD, 2011/12)

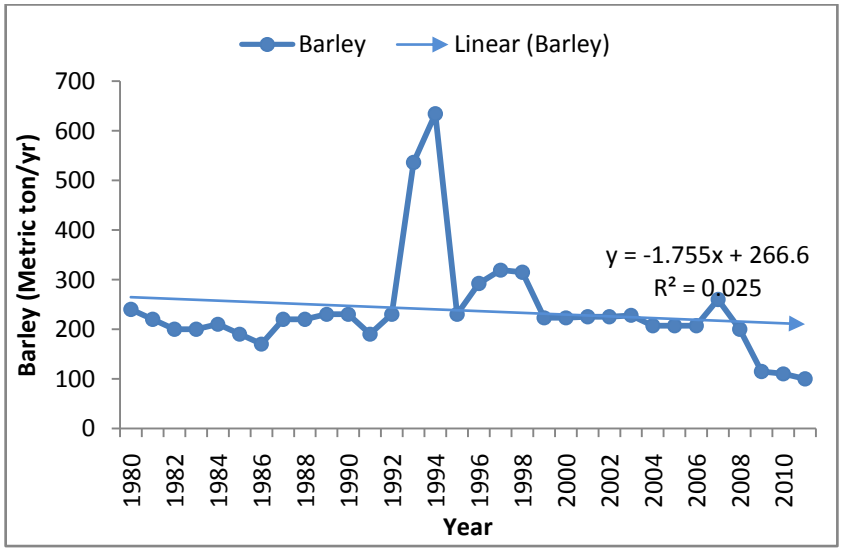

Figure 25: Production Trend of Barley in Gorkha District (MoAD, 2011/12)

Table 8 shows the correlation of productivity and time at *0.01*level of significance. Productivity of maize, wheat and millet show stronger degree of positive correlation with time. Barley shows negative correlation with time.

Table 8: Statistic of Crop Productivity and Time

Crops	r	p-value	r-Range	Remarks
Maize	0.921	0.001	-1 to 1	Strongly +v Correlated
Wheat	0.848	0.001	-1 to 1	Strongly +v Correlated
Millet	0.707	0.001	-1 to 1	Strongly +v Correlated
Barley	-0.159	0.384	-1 to 1	-V Correlated

Correlation between Productivity and Temperature

Maize productivity with temperature shows a stronger degree of positive correlation which means maize production increases with increasing temperature. Correlation for productivity of wheat, millet and barely with temperature shows a weaker degree of positive correlation. Table 9 shows the statistical correlation value of crop productivity with temperature at *0.01*level of significance. Figure 26, 27, 28 and 29 shows linear trend of productivity and temperature.

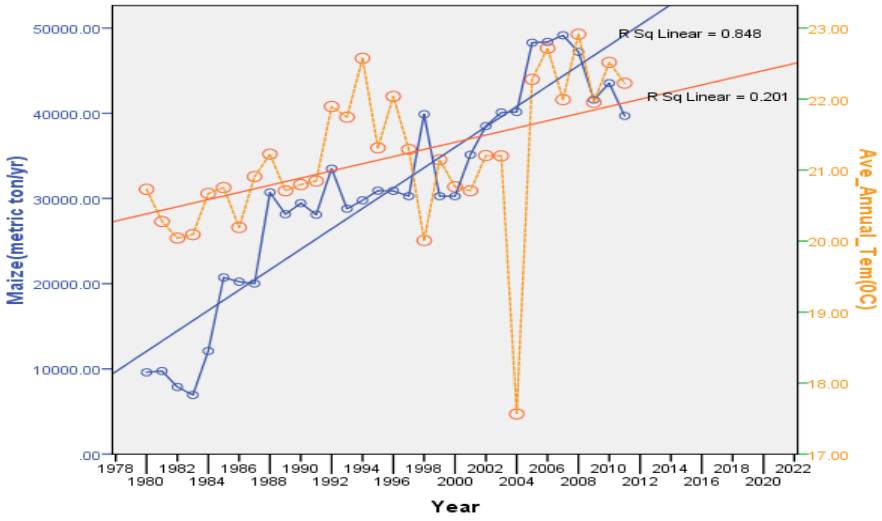

Figure 26: Production Correlation of Maize with Avg. annual Temperature

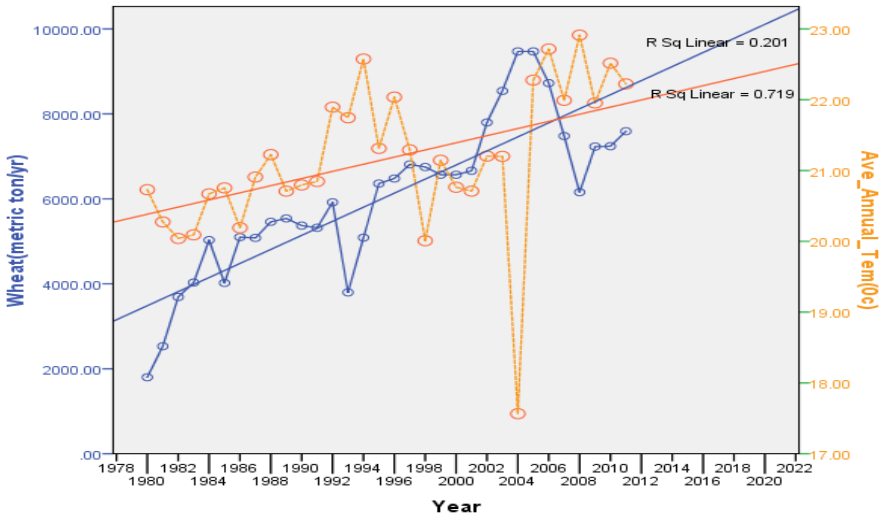

Figure 27: Production Correlation of Wheat with Avg. annual Temperature

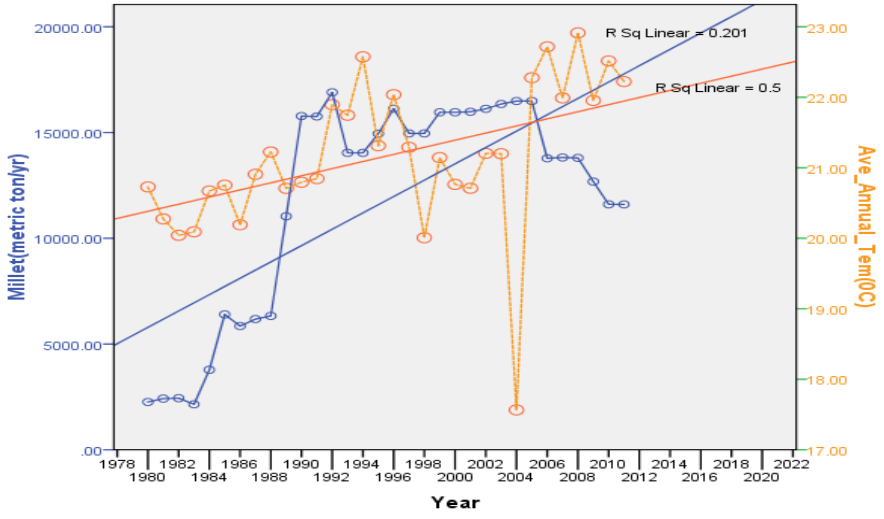

Figure 28: Production Correlation of Millet with Avg. annual Temperature

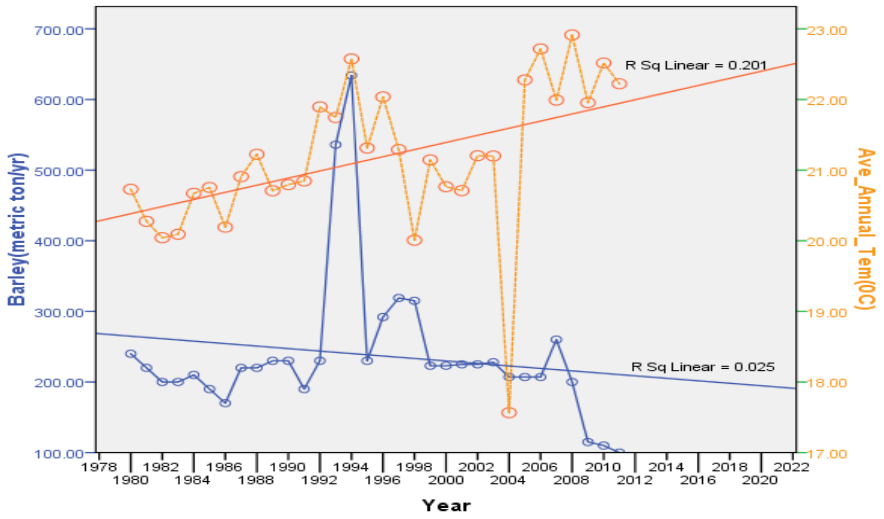

Figure 29: Production Correlation of Barley with Avg. annual Temperature

Table 9: Statistic of Crop Production and Annual Mean Temperature

Crops	r	p-Value	r- Range	Remarks
Maize	0.472	0.006	-1 to 1	Moderately +v correlated
Wheat	0.180	0.324	-1 to 1	Weakly +v correlated
Millet	0.278	0.123	-1 to 1	Weakly +v correlated
Barley	0.146	0.427	-1 to 1	Weakly +v correlated

Correlation between Productivity and Rainfall

Productivity of maize and wheat with rainfall shows moderate degree of correlation which means maize and wheat production is moderately increasing with increasing temperature. Productivity of millet with rainfall shows the weaker degree of positive correlation. Barley shows negative degree of correlation with rainfall which means that production of millet is decreasing with rainfall increase. Table 10 shows the statistical correlation value of crop productivity and rainfall at *0.01*level of significance. Figure 30, 31, 32 and 33 shows linear trend of productivity and temperature.

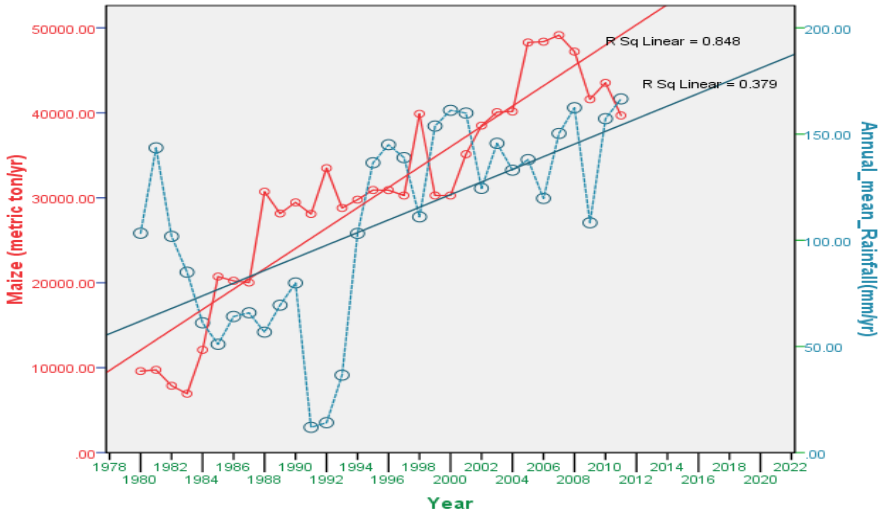

Figure 30: Production Correlation of Maize with Avg. annual Rainfall

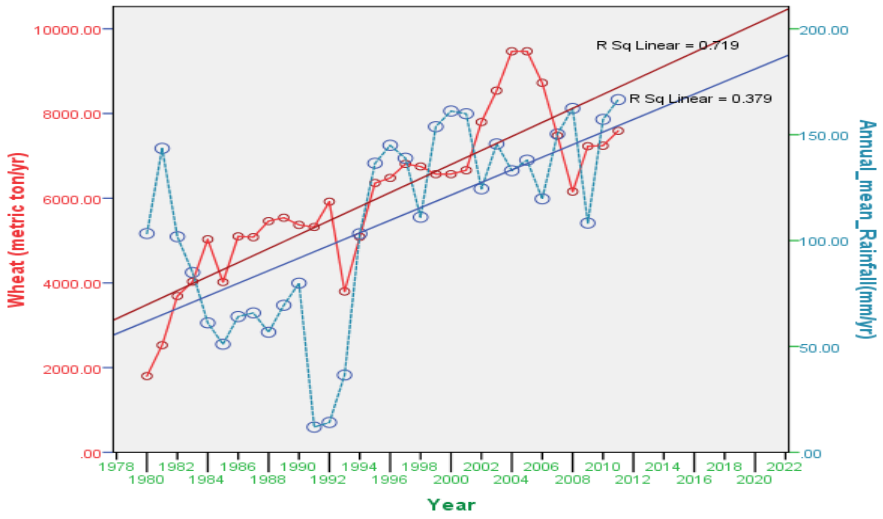

Figure 31: Production Correlation of Wheat with Avg. annual Rainfall

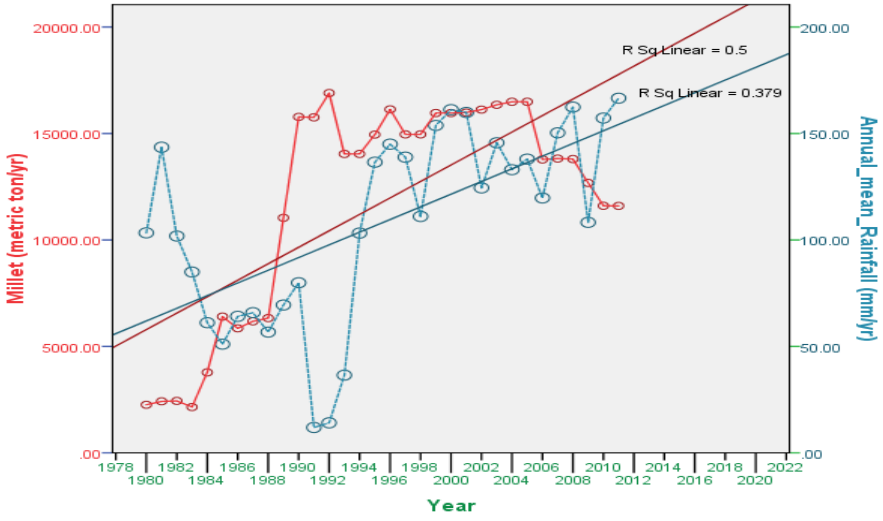

Figure 32: Production Correlation of Millet with Avg. annual Rainfall

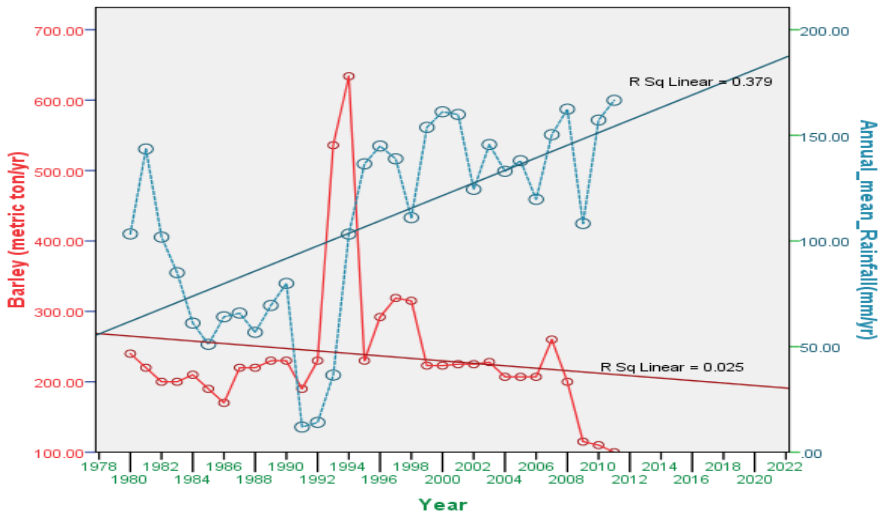

Figure 33: Production Correlation of Barley with Avg. annual Rainfall

Table 10: Statistic of Crop Production and Annual Mean Rainfall

Crops	r	p-Value	r-Range	Remarks
Maize	0.418	0.017	-1 to 1	Moderately +v correlated
Wheat	0.469	0.007	-1 to 1	Moderately +v correlated
Millet	0.281	0.120	-1 to 1	Weakly +v correlated
Barley	-0.165	0.367	-1 to 1	-v correlated

5.3.5 Agriculture Practice

79% respondents responded that there has been change in agriculture practice and all agreed that the cropping pattern has changed over time. Traditional practices have been replaced with new practices especially sowing methods, variety types, crop intensity and cropping practices, use of tools and technique in watering, weed clearing etc. Some small scale agriculture tools are used in farming including tongs and spades for weeding, watering can and sprinkles for watering. Sowing of maize seeds are done at distance of 25cm gap presently. Before, sowing seeds were randomly done. However, farmers still supply soil nutrients through locally made compost and manure. No advanced technology has been used so far in agriculture. Table 11 shows the perception percentage in agriculture practice in Sirdibas.

Table 11: Response for Agriculture Practice

	Response (%)		**Remarks**
Practice	**Changed**	**Same**	
Response %	79	21	Seed sowing, weeds clearing, watering plants, diversified crops and crops cycle, Improved varieties crops and vegetables One time farming (before), more than one cycle farming (present)

5.3.6 Food Supply and Consumption

Local production never meets total food demand of a family, and their production would be sufficient only for about seven months a year. The majority (53%) responded that food would be enough not more than four months. These responses were by family holding more lands. 6% respondents with no land or having small area of land responded that food enough for 2 months only. 3 % have enough food supply for 7 months. They are the people with more farmland. More than 89% respondents said they consume their local

food product. Such respondents are poor and landless or hold only a very small area of land. 7% family consume and as well sale their surplus foods. This family group is from more land holding group. 4% family consumes and buys needed food for livelihood. Table 12 below shows the respondents responses for food supply and consumption.

Table 12: People Response on Supply and Consumption of Food.

People Response	**Food Supply Periods in Months (M)**					
On Food	**2M**	**3M**	**4M**	**5M**	**6M**	**7M**
Supply %	6	53	26	3	6	3
			Consumption			
	Consume		**Consume + Sale**		**Consume + Buy**	
Consumption %	89		7		4	

5.3.7 Forest Status

The forest cover of the Sirdibas has been significantly depleted within about a decade. Until the last 6 years people used to have adequate timber, firewood and forage in nearby forest, but at present they have to go 2/3 hrs walk to acquire these services. This is a perception based point to clear that deforestation is occurring. Forest area of Sirdibas is reported to be 7,552ha (VDC profile, 2012).

5.3.8 Climatic Hazards in Agriculture

Climatic hazards in agriculture can be categorized into rainfall hazards and temperature hazards. Climatic parameter (temperature and rainfall) pose positive and negative effects however the negative effects are likely to be seen more than positive ones due to varying extreme climatic events and variability (Reilly *et al*., 2001). Temperature has senescence affect in growing, flowering, fruiting and ripening affecting in production. Rainfall also affects crops through its excess and deficit condition. Increased temperature with deficit rainfall cause dry spell affecting crops. Only rainfall in right amount and in right timing can be favorable for crops growth, development and yield. Climatic hazards are described below.

Temperature Hazards

Senescence

Increased temperature affects flowering, fruiting, ripening. Temperature change has shifted the senescence period of crops altering in their crop calendar. In the study area, 33 of 72 respondents responded that they have felt the early ripening of their crops.

Pest and Disease

Almost all respondents shared that they have not seen any diseases in their crops. But the field observation showed that their then wheat crop was infected with loose smut disease (*Ustilago tritici.* In case of vegetable, 26 % respondents said that their vegetables like rayo, cabbage, cauliflower are damaged by some insects like aphids (lai kira) and khumle kira. 74 % responded that they have not noticed their vegetables infected from any disease or pests. No chemical pesticide is used so far. Tobacco extract found used as pesticide. Weeds are uprooted with the help of spade and tongs.

Wilting

Temperature increase caused wilting from evapo-transpiration. This excessive heating causes the plant moisture to lose through evapo-transpiration resulting wilting on plants. This becomes severe in dry months. Maize, beans suffer wilting during Falgun/Chaitra/Jesth and even causing them to die.

Drought

Chaitra and Baisakh are totally dry causing drought in agricultural land as responded by whole respondents. The then crops like maize are affected by this dryness causing the maize plants wilt and dry. This has increased the uncertainty in production. However, no such event of drought in Sirdibas has been noticed till now that has caused famine.

Rainfall Hazards

Water logging

During Baisakh/ Jestha in maize, water logged field from pre monsoon caused stalk rot in the injured wounds occurred during weeds cleaning. Millet is also found to be affected in same way. However, water logging hasn't been a too much bothering factor in agriculture.

Landslide

Most of the land in Sirdibas VDC is fragile and sloppy. There have been major landslides in Dewal and Paiyu village which swept away agricultural land area. Dewal landslide had occurred in 2065 B.S. DHM meteorological records shows maximum rainfall of 496.25 mm occurred in July month 2065 which destabilized the Nausila settlement by the same landslide that had happened in Dewal. There are several opinions about such mass destruction of the agriculture lands. Local people belief that thing happens when Sime-vume, the god of land somehow become unhappy with peoples' actions such as killing animals for their own interest. This excessive rainfall during that period (2065 B.S.) probably induced the local Lokpa khola to madly help the landslide. The landslide destroyed infrastructures like 13 houses, a newly constructed micro hydro power plant (MHPP), several ropanies (some 40-50 ropanis as local estimated) and 3 lives (one from Pathi village and two from Dewal village). Paiyu landslide destroyed 11 houses and some 25-30 ropanis of land with no human casualties probably because people were awake and got chance to escape when it occurred during the daytime. The major landslides occurred are in sloping agricultural land. Deforestation might also be the reason for these landslides.

Snowfall

Most settlement of Sirdibas VDC is below 1800m. Only 2 settlements like Aanga and Nyak are above 2200 m which receives small amount of snowfall during winter. Lower settlement like Sirsium, Dewal and Pangsing receives trace amount of snow which are the source for moisture to winter crops like wheat and karu. However, snowfall amount and duration is decreasing as before. Philim had snow fall before 10 or 12 years ago. It is not considered damaging to winter crops instead helpful for irrigation of wheat and barley.

5.4 Impact on Livelihood

Livelihood of the farmers seems to be affected in the study site. The field study showed that the livelihood of the people is affected with the unsustainable farming. Table 13 shows the indicators of unsustainable farming in Hindu Kush Himalayan region which are the indicators of unsustainable farming in Sirdibas VDC as well.

Table 13: Indicators of Unsustainable Farming

Indicators	Rates	Score for Sirdibas Farming
Soil erosion rates on sloping lands	+	+
Deforestation on sloping lands	+	+
Limited size of land parcel	+	+
Steep slope cultivation	+	+
Lack of irrigation (rainfed farming)	+	+
Decreasing food grain production	+	+
Increasing population	+	+
Food grain supply by government	+	+
Out migration	+	+

Source: Indicators for Unsustainable Farming adapted from Pratap (1998).

The + sign in the table indicates presence of indicators in the study area. The existence of all mentioned indicators comply farming as unsustainable and of subsistence type there. Due to this subsistence and low production and poor resources, many people have gone outside the valley for their livelihoods. They have made their destiny to different parts of the country specially Kathmandu, and countries abroad like Kuwait, Qatar, Dubai, Arab, Korea, UK, Iraq, Bahrain, India etc temporarily or permanently. 10.32% of total population has out migrated from the VDC. People with no land or little land parcels are most likely affected due to climate change impacts. Annex II, Table 9 shows the out migrant from the VDC.

De-electrification of the VDC: The Lokpakhola MHPP of 21KW in Dewal and MHPP in Jagat electrified 450 households in the VDC. The recent landslide in Dewal destroyed the Lokpakhola MHPP de-electrifying the VDC and more than 200 household leaving them in the darkness since Chaitra. The Dewal landslide occurred in 2065 sweeping Nausila settlement at Dewal with 3 lives and more than 40-50 ropanis of agricultural land.

5.5 Adaptation to Climate Change Impacts in Agriculture

Climate change is a forever occurring fact which cannot be stopped but the process can be slowed down through mitigation measures. The effects of climate change have already been visible in some key sectors including ecosystem and biodiversity. Agriculture has been greatly affected by the climate change more negatively than positively creating the

food security issue. Countries like Nepal which are too poor to adapt to climate change impacts are becoming more and more vulnerable to climate change. Poorer people face more challenges for adapting to climate change than those well off households. Increasing adaptive capacity through community-based adaptation measures and improved access to information and skills, effective institutions, access to technology and opportunities to raise incomes are the challenges for the poorer to adapting climate change. Reducing vulnerability to climate change requires protection of existing assets including the ecosystems on which communities depend, improved risk management, increased assets and broadening the available range of livelihood options.

5.5.1 Adaptation Measures Adopted in Community

The farmers have been adopting a variety of options and technologies to adapt to the impacts of climate change also in agriculture. These measures include changing crop varieties, use of improved seeds of vegetables and food crops, changing cropping patterns, practicing intercropping system, terracing slopping lands to halt land slide and erosion, practicing the organic fertilizer to improve soil fertility instead of chemical fertilizers, irrigating vegetables and some crops with watering can. In many cases, these terraces are big sized in slope and terrace less in some others. Agriculture practices have been changed in the study site. 79% responded this change is in the form of sowing grains and other agriculture technique. Unlike random sowing of maize seed people in recent years sow seeds systematically in lines at gaps of 25cm. Farmers practice multiple crops. Multiple crops of maize, soyabean, bean or maize/ millet is done. Also, multiple crops of potato/ maize/ bean are done. They have been practicing maize, wheat, barley, millet, soyabean, bean, mustard, potato, karu and few vegetables. But now the crop pattern has also changed with practicing of varieties of seasonal/unseasonal vegetables. Due to this vegetable practice in the village, the existing traditional crop cycle has also changed. The crop cycle has also changed with the practice of vegetable farming as shown in below. Vegetables practice started widely in 066/067 three years before. Before a decade, farming was done only one season but now 3 seasons farming is done with following crop cycle.

Crop Cycle

Maize- wheat/ barley- empty

Maize/millet- wheat/barley-empty

Maize/ bean/ soyabean-wheat/barley-empty

Maize- Oil crops- wheat

Potato-wheat-empty

Potato/maize/bean- wheat/barley-empty

Maize- vegetable –vegetable Maize- wheat-vegetable

Crops have been switched from local to improved varieties that can tolerate drought and are more productive. Similarly, different varieties of vegetables have been started growing in Sirdibas. Watering can, sprinkler are used for irrigating their crops to escape from drought. Agricultural lands are terraced as a means to soil conservation. Livestock manures are used as fertilizer to increase soil fertility. As pesticides, solution from soaked tobacco; garlic solution etc was found to be used in vegetables. No chemicals fertilizers and pesticides are found to be used. National Trust for Nature Conservation in Jun 2008, organized agriculture and livestock development program in Sirdibas VDC. The organization trained the conservation farmers with techniques of organic farming, making compost and also providing improved vegetables seeds with farming tools, watering can, sprinkler etc.

5.5.2 Adaptation Measures Needs to be Adopted by Community

Agriculture is hardly impacted by changing climate as increased and unusual rainfall in the form of landslide in hills and mountain. So, soil conservation techniques are most important to conserve farming land. Deforestation rate in the VDC is very high. As said by locals, before five or six years, their resource of firewood, timber and fodder was nearby the settlement but now these resources are available only at two or three hours walk distance which is primarily due to the overuse of the resource. Thus, most importantly aforestation is necessary or agro forestry must be practiced. Shrubs or perennial grasses can be best grown in the contour to conserve soil loss. SALT technique can be used for soil conservation in sloping land. During dry seasons, irrigation in the crop field has become very important. The existing small irrigation through water can is tedious and time consuming. Long-run type promising adaptation measures for combating drought (Annex II, Table 10) are therefore necessary. Building water harvesting pond with channels for irrigation can be constructed for irrigating farmland.

IPM technology can be used for the disease and pest control in the future. The disease and pest in Sirdibas is at starting phase of spreading so IPM can be used to eradicate disease and pests preventing from being spread.

CHAPTER VI

6. DISCUSSION

6.1 Climate Change

Deressa *et al.,* 2011 reported that farmers have significant positive effects on climate change perception than non farmers. Maddison (2007) reported that subsistence farmers are better able to perceive rainfall. The respondents here though are business persons or engaged in any other off-farm jobs but are subsistence farmer. Thus these respondents have felt the increasing temperature and rainfall with variations. The analysis for temperature data of Gorkha district shows that average annual temperature is increasing at rate 0.050 $^{\circ}$C/year which is closely related to temperature increase at hill and mountain 0.08°C/year (Shrestha *et al*, 1999). The rainfall analysis of Jagat shows 0.995mm/year. The analysis of rainfall data for pre-monsoon, monsoon, post-monsoon and winter monsoon showed that rainfall in pre, post and monsoon has increased while winter monsoon has decreased. Decrease in winter monsoon means winter dryness is increasing. NCVST, 2009 has shown winter dryness is increasing due to decreasing winter monsoon. Monsoon here is unusual and seems no delay or shift but is ill-timed and irregular as also found by (Gurung, 2009). This is the evident that there is climate change in terms of variability which has increased uncertainty both on temperature and precipitation over time and space.

Age wise, all age groups mainly 31-60yrs and 61-90yrs group experienced temperature rise. 6% of 1-90yrs responded rise in temperature. This 6% is 100% responded of this group. Also, all age group experienced increasing and untimely occurring rainfall. Age group of 61-90yrs (6%=100% respondent) responded increasing rainfall.

6.2 Impact Assessment on Agriculture

6.2.1 Crop Calendar

The study showed that the crop calendar is changed in terms of crops harvesting period only. Sowing period is unchanged whereas flowering/fruiting behavior is unnoticed. Crop harvesting period has been reduced by 10-15 senescence days. Patel *et al*., 2010 in his experiment of warming of soil temperature effect in wheat showed the harvesting/

ripening days decreased by 12 days. According to him, temperature increase affects the penology of crops during early stage of growth. This indicates that the increased temperature has been affecting the crops growth. At mid region, harvesting time of some crops like maize, wheat, barley has been shifting due to increasing temperature (Koirala & Bhatta, 2010). Also Robert & Summerfield (1987) reported as temperature is known to affect the rate of development in crops plant during their entire growing cycle, generally with higher temperature increasing development rate. The increased temperature increases the soil temperature which is important for crop development, leaf appearance, shoot development, flowering and fruiting (Vincent & Gregory, 1989). A research conducted in NARC revealed that an increased temperature potentially affects physiological growth of crops across different stages especially panicle initiation, flowering, milking and maturity reduced by 14, 5, 6 and 14 days, respectively. Though flowering/fruiting period was not sensed by people, this increased temperature might have impacted on their phonological behavior. These all research shows that temperature increase is responsible for decreasing in ripening/ harvesting days by week or two weeks. Also, alteration in sowing and harvesting period is not exactly known. People responded as unchanged sowing and harvesting time in study site. This might be because crops like maize, wheat, barley, millet can grow with available soil moisture. Only rainfall dependent crops like rice have alteration in cropping time. If there is early monsoon, rice cultivation is done earlier and if monsoon is late, cultivation will be late too altering in cropping time.

6.2.2 Crop Production

Crop production in the study site is decreasing as perceived by respondents. The VDC level productivity data was unavailable so a district level productivity data was analyzed which at overall trend showed the increasing productivity. But within the last decade, this productivity in the district level is decreasing which may be due to the climate change impacts or decrease in productivity at the VDC level. The use of improved varieties of seeds, changed agriculture practice though has increased production at 32 years period, but last few years from, this has decreased. With 4°C temperature increased in mountain, both maize and wheat increased its productivity by 27 % and 33 % respectively but in irrigated condition (Serchand *et al*., 2007). This indicates that the temperature increase has positive effects in crops like maize and wheat in mountain in irrigated condition which means that wheat and maize production should have been increased here. But the

production has decreased here. This may due to increasing rainfall and temperature affecting negatively. Both lack and access of water might affect different stages of crop production. Moisture stress or dry spell during pollination, flowering, fruiting and grain filling stages is much harmful to most crops affecting yield (Khanal, 2009). Craufurd *et al.,* 2010 mentioned the warmer temperature shortens development stages of crops that will probably reduce the yield of given crops. Maize (yellow) due to drought in Falgun/Chaitra at its germinating phase might kill most of the plants. Millet due to excessive water during Jestha/Ashad at its initial growth stage might have caused for root rooting. Similarly, for wheat and barley, the dry spell from decreasing amount of winter monsoon might be the reason for the decreasing production. Shortage of water during the dry season reduces yields from irrigated crops and threatens the food security of the region (Rees *et al.,* 2004). Summer and winter crops are affected with dry spells. Only millet which is planted during Jestha/Ashad is affected with increased rainfall through water logging problem. Most probably untimely erratic rainfall can be destructive to crops. And such erratic and untimely rainfall are much frequent at present (Gurung, 2009; Baidhya *et al*., 2007). Rainfall in right amount and right timing can be helpful for crops to develop good physiological functions. Monsoon arrival during flowering, pollination can wash away flower and destroy pollination thus affecting fruiting and yield. This can be among one climatic factors affecting in crop yield of the study area.

The government policy of food supply through its food supply depot at reasonable price might have caused to divert people from farming to non-farming business contributing less to agriculture. The income source from the non farming covers 73.39% while farming covers only 26.61% income source. Remittance contribute highest 35.7%income source.

6.2.3 Climatic Hazards

The decreasing crop productivity and landslides occurrence has been due to climatic hazards of increasing rainfall and temperature. Summer crops like maize, millet might suffer heat stress during pre monsoon period and get negatively impacted in flowering and fruiting during excess rainfall in June/July (Ashad/Shrawn) during their flowering/fruiting time. Winter crops like wheat, barley may be affected by decreasing winter monsoon in lower settlements while in higher snowfall is beneficial for them as water source. Excess rainfall cause water logging problem in crops killing crop plants.

Increased temperature impacts the plants physiology and hence impacts production. Wilting can also effect the crops production through increased temperature and reduced soil moisture. Summer temperature from Falgun/Chaitra to Bhadra/Ashoj has been increased above 30°C to maximum of 33.5°C. This range of temperature is normal for irrigated agriculture but can be problematic to rain fed type agriculture. Drought and wilting are major problem to rain fed type agriculture. Increased temperature increases both rainfall and evapo-transpiration but this rainfall is not regular where temperature exceeds rainfall increasing evapo-transpiration and affecting crops (Cline, 2008). Higher temperatures, increased evapo-transpiration and decreased winter rainfall may cause more droughts (Alan & Regmi, 2004).

The major landslide in Dewal that swept Nausila settlement occurred in 2065B.S. The DHM record of 2008(2065 B.S.) showed that maximum rainfall (496.25mm) occurred in July of this year. This indicates occurrence of major landslide from this rainfall and deforestation is another reason for this.

6.2.4 Pest and Disease

Wheat in the field was infected with loose smut caused by *Ustilago tritici* while vegetables like rayo, cabbage, and cauliflower were infected by pests like aphids (lai kira) and khumle kira. The respondent have not observed any extent of crop diseases The responses of people and the observation of loose smut in the wheat can indicate that disease has just unnoticeably started and is unseen by them. This appearance of disease might be due to the increasing temperature. Aphids and grubs were also seen recently in vegetables. Malla (2008) showed the development and distribution of insects and pest-diseases are impacted by increasing temperature, rainfall and humidity. The tropical diseases and pest gradually shifts to hills and mountain. The presences of mosquito in the study site also suggest the climate has changed favoring insects and pest growth. This shows little evidence of climate change in here with favoring disease existence. There might be disease in winter crops like wheat as well. However, these diseases don't pose danger at present but in near future may threat the food security.

6.3 Impact on Livelihoods

Changing rainfall pattern or variation of rainfall intensity and duration is increasing (Baidhya *et al.,* 2007). The pattern of monsoon is changed into more erratic and intense

of short duration with decreased number of rainy days as before. This type of monsoon has increased the frequency of landslide in the hilly region. Deforestation and slope factors are the aid for intense rainfall to create landslide. People, those subsistence farmers have limited land and incomes are impacted more. Marginal or subsistence farmers are those having marginal farmland, typically less productive, small land parcel, steep topography, un-irrigated and unfertile land or are sharecroppers or landless agriculture labor (Tiwary, 2005). Their production is unpredictable depending upon monsoon for irrigation. If monsoon is favorable, they have production otherwise their production is hopeless. They have hardly food supply for few months. People have also become landless because of the nature disaster called landslide. This has made the farming unsustainable there because of which people who are landless have become agriculture labors in others farmland and most of them suffered from unsustainable farming have chosen to out migrate for better earning. This out migration is yet another factor for unsustainable farming. Unsustainable farming is clearly a push factor from undeveloped place while opportunities outside are pull factor (Gill, 2003). The good remittance from the abroad and within from the country has led to abandon the agriculture profession because of their improved living standard. They are now able to buy rice and daal instead of the traditional food ‘dhido’. Climate sensitive unsustainable farming impacts the livelihood and livelihood impacts back again to farming leaving agriculture more unsustainable.

CHAPTER VII

7. CONCLUSION AND RECOMMENDATIONS

7.1 Conclusion

Thus study concludes that the impact of climatic change has been assessed with increasing temperature and increasing unusual rainfall at rate of 0.096°C/yr (max), 0.05°C/yr (min) and 0.995mm/yr respectively. Pre-monsoon, monsoon, post-monsoon is found to be increasing at the rate of 0.714mm/yr,2.883mm/yr,0.293mm/yr respectively while winter monsoon is found to be decreasing at the rate of -0.236mm/yr. The climatic data shows the ups and down values indicating climatic variability and uncertainty have been increasing. Monsoon rain in Sirdibas has been unusual and seems irregular and uncertain. Snowfall is decreasing at higher altitude areas while at lower altitude there is no snowfall.

No change noticed in climate affected sowing and harvesting but the ripening and maturation period has been found to be reduced by a week or two in crops like maize, wheat, millet, barley. The harvesting period of maize has decreased to 5-15 days, harvesting period for wheat, barley and millet has decreased by 5-10 days. This might be due to increased temperature that affects crops physiological functions. Sowing and harvesting are dependent on time variable. Though, respondent had no idea on flowering and fruiting time but the decrease in harvesting period of wheat, maize, millet and barley prior to previous years clears that flowering and fruiting must have also changed.

The crop production has been found to be effected with inconsistent production. The overall district production for maize, wheat, millet is though increased at rate 1196 MT/yr, 165.5 MT/yr and 386.1Mt/yr respectively; it is decreasing in production since the last 10 years. Decrease production for maize, wheat and millet has been accounted since from 6 yrs, 8 yrs and 10 yrs at rate -1926MT/yr, -358.3MT/yr and -627.1MT/yr respectively. Barley production has been found to be decreasing at rate -1.755MT/yr. In the study site, 41 % responded for decreasing production, 28 % increasing production, 24% same and 7 % for no idea. Productivity data at VDC level is unavailable so the public response for decreasing at study site and the decreased production of crops at

district level can be referred to as crop productivity is decreasing at study area. This decreased productivity may be because of untimely rainfall in unwanted amount. Untimely rainfall during pollination, flowering and increased temperature during grain filling with decreased rainfall causing dry spell have negative effects in crops yield. Climatic hazards like water logging are caused due to intense rainfall during Jestha/Ashad affecting summer crops. Also, increased temperature with less or no rainfall in Falgun-Baisakh caused dry spell problem affecting summer crops. Intense rainfall may be responsible landslides ultimately affecting agriculture production.

Also, the external factor like food supply policy of government at reasonable price through its food depot has caused to divert their profession of farming to non-farming business contributing to decrease crop production.

Crops have been switched to improved varieties from local to increase production. Despite the improved varieties and use of organic manure, the production has been decreasing. Chemical fertilizer use was not known. According to perception, there is no diseases and pest in their crops. But the presence of loose smut in wheat and aphids, khumle in vegetables from field observation can be evidence for changing climate in study area.

Poor people are mostly challenged by climate change. People have become homeless: and landless due to landslides. Agricultural lands have been lost by landslide and these poor have become a labor in others farmland, gone outside valley and abroad for earning. 10.32% has out migrated from the valley for earning (VDC). Also, people with lesser hope in subsistence farming, is compelled to choose alternate source of earning for their livelihood. Marginal subsistence agriculture is thus affected by climate as well as food availability and change in livelihood of people side by side.

7.2 Recommendations

Successful adaptation depends upon technological advances, institutional arrangements, availability of financing and information exchange. So, following recommendations are made to the local and national level organizations for the successful adaptation to agriculture. These organizations are policy level institutions like Nepal Planning Commission (NPC), National Development Council (NDC), Ministry of Local

Development (MoLD), District Agriculture Development Office (DADO), Ministry of Agriculture and Development (MoAD), Ministry of Forests and Soil Conservation (MoFSC, Ministry of Water Resources (MoWR) as well as INGOs. These institutions should facilitate local institutions and communities to following recommendations.

- The soil conservation technique or runoff/erosion management systems must be applied to stop the probable danger of landslide in Sirdibas. SALT can be applied in slopes for soil conservation.
- Terraceless slope agriculture land should be avoided of farming and planted with trees instead.
- Agroforestry is much recommended in the sloppy farmland. Almost all farmland are in slope.
- Chemical fertilizer must be used as supplement to organic manure.
- Construction of irrigation channels is necessary to combat dryness in dry months like Chaitra, Baisakh. Constructing channel though is not feasible but plastic pipes can be used for improved water supply system from upstream.
- Further integrated research and monitoring including cooperative efforts between national, international and multi-lateral institutions be essentially conducted to further improve local and regional scale climate projections on agriculture.
- Concerned authority should promote organic vegetable farming by creating market and generating insurance. This will motivate the farmers and bring hope in their subsistence agriculture.

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Annex I

An Assessment on Climate Change Impact in Agriculture and Livelihood of the Farmers: A Case Study of Manaslu Conservation Area
Household Questionnaire

GPS readings: Northing…… Easting……..…..
Date: ……..... Time: ……
Name of the Respondent: ……..……..VDC:…….
Ward No: …... Tole: ……
Sex: …… Age: …… Ethnicity: ……..……. Occupation:……
Number of family: ……

A. Socio-Economic

1. Family Composition

Age Group (Years)	*Male*	*Female*	*Married*	*Unmarried*
< 14				
15-45				
45-60				
>60				
Total				

2. Education

Education Level	*Male*	*Female*	
Primary			
Secondary			
High			
Graduate			

2. Income

Income Source	*Income (Annum)*
Tourism	
Job abroad	
Government service	
Farming	
If others (Specify)	

3. Do you have land? Yes: ..... No: .....
If No, why and how you became landless?

……

If Yes, fill below

Land holding of Household

Kind of land	*Area (Ropani)*	*Own use*	*Used by others*
Khet (irrigated)			
Bari(rainfed)			
Pasture land			
Forest (private)			

B.Climate Change

1. Have you experienced any of the following changes in recent 10 years please tick (√)

Climatic Parameters		*Same*	*No Idea*	*If yes*		Other
				Increasing	*Decreasing*	
Temperature	Winter					
	Summer					
Rainfall	Amount					
	Extreme					
Snowfall	Volume					
	Extreme					

2. Precipitation (rainfall)

Rainfall Before(Tick)												*Rainfall Now (Tick)*											
Baisakh	Jestha	Ashad	Shrawn	Bhadra	Ashoj	Kartik	Mangsir	Poush	Margh	Falgun	Chaitra	Baisakh	Jestha	Ashad	Shrawn	Bhadra	Ashoj	Kartik	Mangsir	Poush	Margh	Falgun	Chaitra

3. Snowfall

Snowfall Before(Tick)												*Snowfall Now (Tick)*											
Baisakh	Jestha	Ashad	Shrawn	Bhadra	Ashoj	Kartik	Mangsir	Poush	Margh	Falgun	Chaitra	Baisakh	Jestha	Ashad	Shrawn	Bhadra	Ashoj	Kartik	Mangsir	Poush	Margh	Falgun	Chaitra

4. Disastrous event you have noticed/seen.

Event	*No*	*Yes*	*When*	*Damage /Loss*			
				Human	*Livestock*	*Agricultural land*	*Infrastructure*
Flood							
Landslide							
Drought							
Snowfall							
Others							

5. Major hazard affecting agriculture. Please rank them

Hazards	*Rank*	*Remarks*
Drought		
Rainfall (flood)		
Landslide		
Frost and snow		
Can be assessed impacts of climatic hazard		
Soil fertility		
Water logging		
Traditional crops		
Disease		

C. Climate change Assessment

1. Crop Documentation

a. Crops Varity in MCA

Crops before	*Crops now*	*Use*

b. Vegetable varity in MCA

Vegetable before	*Vegetable now*	*Use*

2. Have you felt the shifting of cropping time? Yes: ..... No :.....

If Yes, Please tick below in table.

a.Cropping Calendar

Crops	*Earlier cropping time (Tick)*												*Present cropping time (Tick)*											
	Baisah	Jestha	Ashad	Shrawn	Bhadra	Ashoj	Kartik	Mangsir	Posuh	Margh	Falgun	Chaitra	Baisakh	Jestha	Ashad	Shrawn	Bhadra	Ashoj	Kartik	Mangsir	Poush	Margh	Falgun	Chaitra

b.Vegetable Calender

Vegetable	*Earlier cropping time (Tick)*												*Present cropping time (Tick)*											
	Baisakh	Jestha	Ashad	Shrawn	Bhadra	Ashoj	Kartik	Mangsir	Posuh	Margh	Falgun	Chaitra	Baisakh	Jestha	Ashad	Shrawn	Bhadra	Ashoj	Kartik	Mangsir	Poush	Margh	Falgun	Chaitra

3. Is there change in flowering, fruiting, ripening, harvesting of crops? Yes: …….. No: ……..

If Yes, Please tick below in table

Crop	Karu								Phapar																											
	Before				*After*				*Before*				*After*				*Before*				*After*				*Before*				*After*				*Before*				*After*			
Month	Grm	Flw	Frt	Hrv	Grm	Flw	Frt	Hrv	Grm	Flw	Frt	Hrv	Grm	Flw	Frt	Hrv	Grm	Flw	Frt	Hrv	Grm	Flv	Frt	Hrv	Grm	Flw	Frt	Hrv	Grm	Flw	Frt	Hrv	Grm	Flw	Frt	Hrv	Grm	Flv	Frt	Hrv
Baisakh																																				
Jestha																																				
Ashad																																				
Shrawn																																				
Bhadra																																				
Ashoj																																				
Kartik																																				
Mangsir																																				
Poush																																				
Margh																																				
Falgun																																				
Chaitra																																				

Note: Grm=Spike Germinating Flw=Flowering Frt=Fruiting Hrv=Harvesting

Is there change in the production of Crops in last 10 year? Yes: …… No: …….

If Yes, Please tick below in table.

Change in Crop Production

Production(Tick)			*Production (in local unit)*		*Remarks What do you think is the reason?*
Dec	*Same*	*NI*	*Earlier*	*Present*	

b. Change in Vegetable Production

Vegetable	*Production(Tick)*				*Production (in local unit)*		*Remarks What do you think is the reason?*
	Inc	*Dec*	*Same*	*NI*	*Earlier*	*Present*	

Is your production enough for your family? Yes ……. No ……..

For how long duration does it last? …… month

If your production is enough and you sale your production, please refer affect on livelihood section.

If No, how do you supplement to your food needs?

.....

4. Cropping Pattern

Crops	*Traditional*	*Improved(Technology)*	*Fertilizer*
Vegetables			

5. Disease and Pest

a. crops

Crops	*Disease Past (Insects/pest)*	*Disease present (insects/pest)*

b. vegetable

Vegetable	Disease Past (Insects/pest)	Disease present (insects/pest)

What do you think the reason for these diseases? Your perception about this

……

C. Affect on livelihood

1. Basic resource availability

Resource	*Condition before*	*Condition now*	*Remarks*
Drinking water			
Food			
Fuel wood			
Fodder			
Timber			

2. Do you sale/ consume yourself your agricultural production? Consume / Sale
If you sale/consume your production, please tick

Crops/vegetable	**Consume**	**Sale**	**Price /kg (only if sale)**

3. Do you think that farming is sustainable for your livelihood? Yes ..... No.....
If No, why?.....

What is the another profession you want to engage in/ engaged/engaging?(eg.tourism, business, abroad etc)

.....
...

Any significant observation made by interviewer nearby, please note here**…….....**
.....
.....
.....

Interviewer's comments:
……
……
…….

Thank you

Annex II

Table 1: Climate Change Effects and Impacts

Climate Change Component	**Effect**	**Impact**
Increased temperature	Faster floral growth; increased transpiration, reduced runoff and GW recharge; higher water demand.	Changes in water yield; reduced crop yield.
Change in seasonal precipitation	Change in soil moisture; change in river runoff and GW discharge, change in water stress, change in peak runoff.	Change in agriculture yield; change in HP yield; change in water quality.
Change in water availability	Water scarcity; stress in agricultural production.	Food production decline
Change in flood hazard	Increased rainfall will increase runoff, GLOF.	Increased erosion, sedimentation flow, landslides
Loss of biodiversity	Temperature and pcpn range out optimal for biodiversity	Native plants loss; animal migration.
Proliferation of invasive spp	Changed climate favors invasive species	Native plants cannot survive
Spread of pests and diseases	Changed climate favors pests and diseases	Damage crops, cause harm to human

Source: Adapted from Downing *et al.,* 2007.

Table 2: Land use Of Sirdibas VDC

Landuse	**Area(Km^2)**	**Landuse**	**Area(Km^2)**
Barren land	106.04 (10,604Ha)	Agricultural land	8.89 (889Ha)
Grassland	95.52 (9,552Ha)	Rocks	4.01 (401Ha)
Forest	75.66 (7,552Ha)	River-rivulets	2.51 (251Ha)
Shrubland	12.65 (1,265Ha)	Ponds/lakes	0.18 (18Ha)

Snow-cover land	9.45 (945Ha)		
Total Area	314.91 (31,491Ha)		

Source: VDC profile, Sirdibas VDC lesion Office, Gorkha

Table 3: Household and population size of Sirdibas VDC.

Sirdibas VDC	**HH**	**Sex**		**Population**	**Population by Religion**	
		Male	**Female**			
Ward 1	61	146	136	282	**Religion**	**Population**
Ward 2	58	159	146	305	Buddhist	2649
Ward 3	36	92	98	190	Christian	112
Ward 4	37	87	96	183	Hindhu	27
Ward 5	45	92	120	212		
Ward 6	39	113	111	224		
Ward 7	122	296	308	604		
Ward 8	69	161	158	319		
Ward 9	92	231	238	469		
Total	559	1377	1411	2788	Total	2788

Source: VDC profile, Sirdibas VDC lasion office, Gorkha

Table 4: Arable Land and Productivity of Sirdibas, Illaka No.13 (covered 7 VDC)

Crop Covered Land	**Area (ha)**	**Productivity(Mt-ton)**
Maize	500	10-11
Wheat	350	2.00
Potato	350	10-11
Local Bean	345	8.5
Millet	100	1.00
Karu (local), Latte	90	0.90
Seasonal/unseasonal vegetable	30	5-10
Apple, Pears and others fruits	20	3.10
Others food crops and vegetables and fruits	50	3-5

Source: Agriculture Service Center (ASC), Sirdibas, 2068/69

Of this, mixed crops (soyabean, bean, potato, oil plants) covers 240 ha.

Table 5: 32- year Temperature trend of Sirdibas

Year	Min Temp	Mean	Max Temp
1980	16.375	20.729167	25.083333
1981	15.991667	20.275	24.558333
1982	15.641667	20.041667	24.441667
1983	15.725	20.091667	24.458333
1984	16.166667	20.670833	25.175
1985	16.141667	20.754167	25.366667
1986	15.183333	20.191667	25.2
1987	15.341667	20.908333	26.475
1988	16.075	21.225	26.375
1989	15.716667	20.708333	25.7
1990	16.016667	20.795833	25.575
1991	15.8	20.845833	25.891667
1992	16.263636	21.895455	27.527273
1993	15.858333	21.745455	27.045455
1994	15.333333	22.575	27.425
1995	16.6	21.3125	26.025
1996	16.975	22.0375	27.1
1997	16.5053	21.290909	26.569
1998	15.025	20.008333	24.991667
1999	15.7161	21.1448	26.5736
2000	15.655	20.7645	25.8741
2001	15.5939	20.709	25.825
2002	15.7	21.204167	26.708333
2003	16.0723	21.2	27.025
2004	10.538	17.565	26.7
2005	16.0723	22.277778	27.541667
2006	17.316667	22.716667	28.116667
2007	16.933333	21.991667	27.05
2008	16.646	22.913636	27.559
2009	16.858333	21.954167	27.05
2010	16.416667	22.516667	28.616667
2011	16.275	22.223	28.17

Source: (DHM, 1980-2011)

Table 6: 40- year Mean-Rainfall of Sirdibas

Year	Avg. annual rainfall
1972	129.666
1973	137.25
1974	107.083
1975	158.7533
1976	120.83333
1977	137.89667
1978	133.166

1979	110.54
1980	103.325
1981	143.55
1982	101.825
1983	84.95
1984	61.125
1985	51.454545
1986	64.116667
1987	65.85
1988	56.733333
1989	69.45
1990	79.89833
1991	11.916667
1992	14.108333
1993	36.49623
1994	103.24672
1995	136.51
1996	144.98333
1997	138.89167
1998	111.03333
1999	153.78333
2000	161.18333
2001	159.88333
2002	124.43333
2003	145.65
2004	133.00833
2005	137.98333
2006	119.70833
2007	150.325
2008	162.40833
2009	108.24167
2010	157.25833
2011	166.5833

Source: (DHM, 1972-2011)

Table 7: Crop Calendar of Sirdibas VDC

Crops	**Sowing**	**Flowering/Fruiting**	**Ripening (Days)**	**Harvesting**
Maize Seto	Falgun/Chaitra	Ashad	180-200	Bhadra/ Ashoj
Maize	Jestha	Bhadra	180	Ashoj/Kartik

Pahelo				
Wheat	Ashoj/Kartik	Falgun	240-260	Baisakh/Jestha
Millet	Jestha/Ashad (along with maize pahelo)		200-210	Mangsir/Poush
Barley	Ashoj/Kartik	Chaitra/Falgun	240-260	Jestha/Ashad
Potato	Margh/Falgun		180-200	Ashad/Shrawan
Soyabean	Chaitra/Baisakh (along with maize seto)		200-240	Kartik/Mangsir
Bean	Chaitra/Baisakh (along with maize seto)	Shrawan	160-180	Ashoj
Cabbage	Ashoj		160-180	Margh/Falgun
Cauli	Poush/Margh		160-180	Margh/Falgun
Garlic	Poush/Margh		160-180	Ashad/Shrawan
Pumpkin	Baisakh	Ashad/Shrawan	160-180	Ashad/Shrawan
Radish	Bhadra/Ashoj	Poush	160-180	Falgun

Source: DADO, ASC, Gorkha,2068/69

Table 8: Crop Production of Gorkha District

Year	Maize Production	Wheat Prodcution	Millet Production	Barley Production
1980	9600	1800	2260	240
1981	9750	2530	2420	220
1982	7880	3690	2440	200
1983	6940	4030	2150	200
1984	12100	5030	3780	210
1985	20730	4020	6400	190
1986	20230	5100	5850	170
1987	20020	5080	6180	220
1988	30720	5460	6330	220
1989	28150	5540	11040	230
1990	29460	5370	15780	230

1991	28100	5320	15760	190
1992	33490	5920	16900	230
1993	28800	3798	14040	536
1994	29783	5088	14040	634
1995	30915	6360	14948	230
1996	30900	6480	16130	292
1997	30270	6811	14960	319
1998	39886	6750	14960	315
1999	30270	6568	15960	223
2000	30270	6568	15960	223
2001	35135	6661	15984	225
2002	38500	7799	16490	225
2003	40090	8541	16490	228
2004	40154	9470	16350	207
2005	48285	9470	16122	207
2006	49150	8725	13781	207
2007	48375	7479	13821	260
2008	47212	6157	13800	200
2009	41602	7230	12679	115
2010	43537	7240	11605	110
2011	39692	7592	11601	100

Source: MoAC, 2012

Table 9: Out- Migrant form different wards of Sirdibas VDC.

Sirdibas VDC	Population	Out migrant
Ward 1	282	36
Ward 2	305	48
Ward 3	190	1
Ward 4	183	10
Ward 5	212	4
Ward 6	224	14
Ward 7	604	82
Ward 8	319	43

Ward 9	469	50
Total	*2788*	*288*

Source: Sirdibas VDC, 2010

Table 10: Promising Technologies for Combating Climate Change Impacts in Agriculture

Technologies	**Practices**
Improved soil use and water resource	Water harvesting microcatchments, planting and building bunds on contour, drainage practices, terracing, minimum tillage, mulching
Improving soil fertility	Biological nitrogen fixation, manuring, commercial fertilizer
Small Irrigation	Channeled systems
Improved cropping practice	Intercropping, agroforestry
Genetic improved	Hybrid or improved seeds
IPM	Quarantine, host resistance seeds/plants, cultural/biological control, pesticides

Source: *US Office of Technology Assessment (OTA), 1988*

Annex III

Photo Gallery

Photo1. Study Site and Varieties of Crops Practice

Photo2. Marginal and vulnerable crop land to landslide

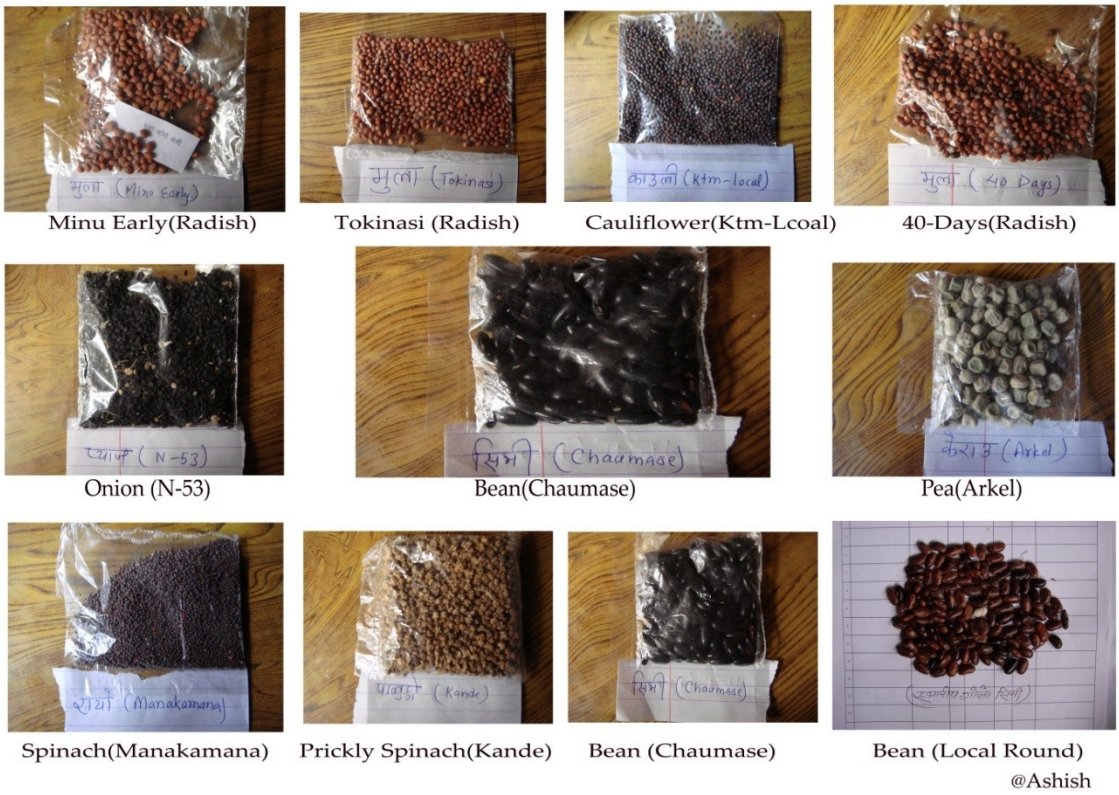

Photo3. Varieties of vegetable seeds being practiced in study site (Krishi Sewa Kendra)

Photo4. Food Depot, Research Team, KII and Activities

Photo5. Landslides of Study Site

Photo6. Disease in Vegetables and Crop