IMPACT OF CLIMATE CHANGE ON PADDY AND WHEAT PRODUCTION AND LIVELIHOOD OF SMALLHOLDER FARMERS IN NAWALPARASI, NEPAL

A
THESIS SUBMITTED TO
THE ORISSA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY,
BHUBANESWAR
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE
OF
MASTER OF SCIENCE
IN
AGRICULTURE (AGRICULTURAL ECONOMICS)

BY
ANKIT KOIRALA

DEPARTMENT OF AGRICULTURAL ECONOMICS
COLLEGE OF AGRICULTURE
ORISSA UNIVERSITY OF AGRICULTURE AND
TECHNOLOGY
BHUBANESWAR
2013

THESIS ADVISOR: Prof Dr. H.N. ATIBUDHI
(*Head of Department*)

DEDICATED
TO MY
BELOVED PARENTS & SISTERS

Orissa University of Agriculture & Technology
Bhubaneswar-751003

Prof. Dr. H. N. ATIBUDHI

Head of Department
Department of Agricultural Economics
College of Agriculture,
OUAT, Bhubaneswar – 751003, Orissa

CERTIFICATE

This is to certify that the thesis entitled **"IMPACT OF CLIMATE CHANGE ON PADDY AND WHEAT PRODUCTION AND LIVELIHOOD OF SMALLHOLDER FARMERS IN NAWALPARASI, NEPAL"** submitted in partial fulfillment of the requirements for the award of the Degree of **MASTER OF SCIENCE (AGRICULTURE)** in the subject of **AGRICULTURAL ECONOMICS** to the Orissa University of Agriculture and Technology, Bhubaneswar is an authentic record of bona fide research work carried out by **ANKIT KOIRALA** under my guidance and supervision. No part of the thesis has been submitted for any other degree or diploma.

The help and information availed during the investigation have been duly acknowledged.

Place: Bhubaneswar
Date:

Prof. Dr. H. N. ATIBUDHI
Chairman
Advisory Committee

CERTIFICATE OF APPROVAL

"IMPACT OF CLIMATE CHANGE ON PADDY AND WHEAT PRODUCTION AND LIVELIHOOD OF SMALLHOLDER FARMERS IN NAWALPARASI, NEPAL"

A THESIS SUBMITTED TO

ORISSA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY, BHUBANESWAR

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN AGRICULTURE

(AGRICULTURAL ECONOMICS)

2013

BY

ANKIT KOIRALA

APPROVED BY ADVISORY COMMITTEE

CHAIRMAN : **Prof. Dr. H. N. Atibudhi**
Head of Department
Department of Agricultural Economics
College of Agriculture
OUAT, Bhubaneswar

MEMBER : Dr. R. K. Mishra
Assoc. Professor
Department of Agricultural Economics
College of Agriculture
OUAT, Bhubaneswar

MEMBER : Dr. P. N. Pradhan
Assoc. Professor
Department of Agricultural Statistics
College of Agriculture
OUAT, Bhubaneswar

EXTERNAL EXAMINER :

ACKNOWLEDGEMENT

It is an exquisite occasion and unique opportunity to express my deep sense of gratitude and indebtedness to my esteemed guide Prof. Dr. H.N. Atibudhi, Head of Department, Department of Agril. Economics, College of Agriculture, OUAT, Bhubaneswar for his enduring interest, sincere guidance, inspiring suggestions and constructive criticism during the course of research and preparation of the manuscript, inspite of his multifarious engagement. His paternal and filial love, enduring patience coupled with facetious nature generated in me the impetus that led to completion of my work and preparation of the manuscript smoothly and successfully.

I further avail this opportunity and profound privilege to epitomize my deepest sense of gratitude and indebtness to Dr. R.K. Mishra, Department of Agril. Economics and Dr. P.N. Pradhan, Department of Agril. Statistics who acted like a lighthouse in my research activity as co-guides.

I owe a deep sense of obligation and gratefulness to all the faculties; Prof. Dr. S.N. Tripathy, Prof. Dr. M.A.A. Baig, Dr. D.C. Pradhan, Dr. A.K. Mishra, Dr. S.N. Mishra for their valuable suggestions, constant inspiration and frequent enquiry about the progress of the work. I would also like to express my gratitude to the staffs; R.K. Behera, S.C. Kalah, C. Nayak who helped me in many ways during my research work.

I gratefully acknowledge the assistance of Jeevan Lamichhane, Surya Adhikari and Dev Raj Bhusal in completing the work of statistical analysis of data and other course of research and survey. I am also thankful to Kamal, Rabindra, Laxman, Susma, Purnima and Bineeta for their guiding words, suggestions and good wishes throughout the research activity.

My hearfelt thanks are due to my department mates Subhadip, Manoj, Bibhuti, Soumya, DeepaRani, Ranjan, Gyano, Abhishake, Mukesh and Goura for hearty cooperation and encouragement during my study period. I would like to thank my friends Jerome, Kunja, Judge, Gerald, Harey, Hemant, Deva, Bhumiya and all others who helped me in many ways during my study period in OUAT. I would also like to thank my seniors Eric, Nirmal, Saurabh, Alok, Subhasis, Priyo, Namami, Shaily, Bipin and others for their guidelines and company and would like to acknowledge all my beloved juniors who have made my study period a moment of remember.

My sense of great gratitude and gratefulness to 'Mano' for great time, help and company during my study here at OUAT.

I bow down my head to my adorable father and mother, whose blessings, dedication and indessant inspiration have made me so today. My deep sense of respect to my beloved sisters whose blessings are armor in my life.

I solicit the benediction of "Almighty BholeNath" for his blessings.

Ankit Koirala

Date:

Ankit Koirala

Title of the thesis	**: IMPACT OF CLIMATE CHANGE ON PADDY AND WHEAT PRODUCTION AND LIVELIHOOD OF SMALLHOLDER FARMERS IN NAWALPARASI, NEPAL**
Author	**: Ankit Koirala**
Admission No.	**: 02/AE11**
Major Advisor	**: Prof. Dr. H. N. Atibudhi (Head of Department)**
Degree for which thesis submitted	**: Masters in Agricultural Economics**
Year of submission	**: 2013**

ABSTRACT

A study on impact of climate change on paddy and Wheat crop production and livelihood of samllholder farmers of Deurali and Hupsekot VDCs, Nawalparasi, Nepal was conducted. Altogether 80 households, 40 from each VDC were selected randomly for the study. Survey using questionnaire, direct observation, focus group discussion as well as secondary data from District Agriculture Development Office (DADO) Nawalparasi, Department of Hydrology and Meteorology (DHM), Kathmandu and Asian Precipitation-Highly-Resolved Observational Data Towards Integration Evaluation of the Water Resources (APHRODITE's) were done to collect the required information.

Before and after comparison of the major livelihood options showed that the dependency upon the agricultural has declined from 60.955 per cent to 24.46 per cent. The cropping pattern changed with the introduction of on season and off season vegetables and fruits to cope with the change in cropping calendar. The study also showed there was almost one or more than one month shift in the cropping calendar due to late rainfall.

It was found that that there was significant impact of climatic variables like temperature and rainfall in the production of both paddy and wheat. The Change in per unit percentage of temperature and rainfall changed the yield of paddy by 1.89 per cent and 0.39 per cent respectively. Similarly, the change in per unit percentage of tempreature and rainfall changed the yield of wheat by 1.79 per cent and 0.42 per cent respectively.

The study strongly supported the farmer's perception that summer was hotter and winter was less cold as compared to the past. The trend analysis also showed that total rainfall was increased with 12.63.mm per year in Dumkauli station.

Different adaptation strategies viz; zero tillage operation, use of high yielding hybrid varieties, use of plastic tunneling for vegetables and nursery management, use of mulching and composting of weeds to control water loss and conserving moisture in the field have been practiced by the farmers of the study area. The study revealed if the farmers receive formal or informal training and extension from different governmental and non-governmental organization, the probability to practice different adaptation strategies increases by 66 per cent.

CONTENTS

LIST OF TABLES

LIST OF MAPS AND FIGURES

CHAPTER-I

INTRODUCTION

1. INTRODUCTION

1.1 Background

Nepal is a land-locked country located in South Asia between India and China. It contains 8 of the 10 highest mountain peaks in the world, including Mount Everest (at 8848 m), although some of its low lying areas are only about 80 meters above sea level. Nepal is divided into five geographic regions: Terai plain, Siwalik hills, Middle Mountains, High Mountains (consisting of the Main Himalayas and the Inner Himalayan Valleys), and the High Himalayas. The climate in Nepal varies from the tropical to the arctic within the 200 km span from south to north. Much of Nepal falls within the monsoon region, with regional climate variations largely being a function of elevation.

"Climate change is the change in climatic condition over time occurred either due to anthropogenic or nature induced causes, which remains for decades or even longer period of time showing distinct variation in its mean" states International Panel for Climate Change (IPCC, 2007a). Similarly, Framework Convention on Climate Change (UNFCCC) defines climate change as a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods. Climate change is not only the gravest environmental threat of the 21st century but also the matter of National and Global security; it's a matter of life and death. Global climate change has been described as the 'mother' of all problems because of it complexity. Anyone who has attempted to understand the carbon cycle, the climatological interactions of CO_2 in the atmosphere, the effects of climate change on market and non-market activities, the technological options to abate carbon emissions, or how a market-based trading system of CO_2 permits might work usually comes away frustrated and hopelessly bewildered. This is a phenomenon occurring on earth due to anthropogenic activities such as emissions of greenhouse gases (GHGs) from fuel combustion, deforestation, urbanization and industrialization (Upreti, 1999) resulting variations in solar energy, temperature and precipitation. These GHGs are warming the earth at an unprecedented rate resulting rapid change in climatic parameters. There are predictions that by 2100, the temperature of Indian sub-continent may increase further by 3.5°C to 5.5°C due to global warming (Bajracharya *et al.,* 2007). IPCC (2004) reported that anthropogenic activities are the major contributors to emission of the GHGs such as forestry sectors (17.40%), waste and waste water (2.80%), energy supply (25.90%), transport (13.10%), industry (19.40%) and agriculture (13.50%). The concentration of CO_2 has increased from 280 ppm to 380 ppm after the industrial revolution (Karki, 2007a) and has recently been reported to reach the maximum level as high as 400 ppm for the first time since the measurement begin in 1958 at Key Obeservation Center at Hawaii. Climate Change affects water resources, agriculture, coastal regions, freshwater habitats, vegetation and forests, snow cover and melting and geological processes such as landslide, desertification and floods, and has long-term effects on food security and human health (Malla, 2008).

Water shortages will become endemic in some regions previously supplied by glacial streams affecting some two billion people in Asia. Rainfall patterns will change, drying up large parts of the most fertile agricultural lands, including in Africa. Water scarcity is likely to affect up to half the world's population by 2030. Sea levels will rise by more than a meter, some islands will disappear, and coastal cities - such as New York - which house more than 60 percent of humanity, will be increasingly at risk in storm surges, or even partially submerged. Storms will be more violent; rainfall more intense, heat waves and drought more destructive. Climate models are able to predict the general areas that will be affected by these changing weather patterns. Africa and the American

Southwest will be drier, the Arctic much warmer, with polar ice rapidly disappearing, and northeast Europe - at least temporarily - will be colder. And all of this in a world with a rapidly growing population and increased pressures on natural resources and energy sources. The UN is predicting 50 million environmental refugees by 2030, as regional climate-related stresses exacerbate existing political conflicts.

Agriculture is the largest employer in the world and the most weather dependent. Agriculture accounts for 24% of world output, employs 22% of world population and uses 40% of land area (FAO 2003a). Simultaneously agriculture is the most vulnerable to weather and climate risks. In developing countries, around 70% of total population is dependent on agriculture. Of total annual crop losses in the world agriculture are mainly due to direct weather impacts *viz.* droughts, floods, untimely rain, frost, hail, heat and cold waves and severe storms (Hay, 2007).

Agriculture is an important sector for Nepalese economy with about 32.35 percent contribution to its GDP, and engaging 65.7 percent of total population (MOAC, 2008). Agriculture in Nepal is mostly dependent on weather and climatic conditions. Increasingly, unusual changes in climate as rising temperature, irregular monsoon, intensity of rainfall and its patterns are being noticed in Nepal. As a result of temperature increase and change in precipitation pattern, increase in natural calamities is anticipated, the effect of which will be considerable in terms of agricultural productivity, water resource management and human health etc. Because of these and many other reasons, climate change is considered to be one of the important issues in the present world (MOPE, 2004). Nepal's physical characteristics, geographic position, topography and weak socio-economic vis-a vis political conditions make it one of the highly vulnerable countries of climate change.

Nepal has already witnessed a number of changes in its mean temperature and climate patterns. Rates of temperature rise has been observed from 0.06°C to 0.12°C/yr in most of the middle mountain and Himalayan regions whereas in the Siwalik and Terai regions, temperature seemed to be increasing by less than 0.03°C/yr (Shrestha *et al.,* 1999). Changes in rainfall patterns and occurrence of erratic monsoon have already been experience by the farmers in Nepal (Manadhar, 2009). Problem of frequent drought, severe floods, landslides and mixed type of effects in agricultural crops have been experienced in Nepal (Malla, 2008). An increase in forest fire due to higher temperature in different areas of Nepal may threat the survival of rare and indigenous species (Thapa, 2006). Local level impacts such as loss of local land races, plant and animal species, changes in cropping patterns, scarcity of water due to drying of wells/decrease in natural water tables, decrease in agriculture productivity have been noticed in Nepal (Regmi *et al.,* 2008).

1.2 Statement of Problem

Nepal is one of the LDC's depending on rain fed agriculture as a major source of livelihood thereby even a small change in the climatic condition for a short period could largely affect the food security in the country (Bhandari, 2007). The majority of Nepal's present population depends on agriculture for their subsistence but still about 63% of the agricultural lands are deprived of modern irrigation facilities (FAO, 2004). Studies showed that developing countries are more vulnerable to climate change and are expected to suffer more from the adverse climatic impacts than the developed countries (IPCC, 2001a). The annual average temperature over Nepal increased steadily at a linear rate of 0.4 °C per decade from 1975 to 2005 (APN, 2007). ICIMOD (2007) stated the temperature rise in Nepal was within a range of 0.2 to 0.6 °C per decade between 1951 and 2001 particularly during autumn and winter. Rise in temperature and temporal and spatial change in rainfall pattern have direct impacts while disturbances in water resources for irrigation and incidences of pests and diseases are the indirect impacts of climate change on agriculture (Gurung *et al.,* 2010). The majority of the farmers depend on the monsoon rain for crop cultivation. So, the changes in the rainfall pattern and intensity can become a matter of great concern for them. The extreme rainfall and downpour causes landslides, soil erosion and loss of lives. Due to the poor adaptation practices and weak institutional supports, lack of improved agricultural knowledge on crop diversification and lack of appropriate inputs and credit on right time, the poor, marginalized and disadvantaged people in risk prone areas are more vulnerable to the climate change impacts. Decreased winter rainfall and prolonged drought leads to the reduced production of wheat, changes the cropping calendar of wheat similarly the erratic monsoon and shift in the occurrence of monsoon is so vital for rice plantation which directly hits the economy of small scale farmers who solely depend on agriculture for their economy.

1.3 Rationale of the study

Off late the impact of climate change on crop production and livelihood has been duely emphasized worldwide. Eventually with the realisation, many organisations have started working on it. Effect of climate change engulfs all vital system supporting world populations hitting hard on Human health, agriculture, forest, water resources and biodiversity. If the increase in temperature exceeds by 1.5^0C to 2.5^0C, there will be the risk of extinction of plant and animal species by 20-30% (IPCC, 2007a).

Climate change and its impacts are now clearly visible on both ecosystem health and farmers livelihoods. Subsistence and Resource Poor farmers are highly vulnerable to its negative consequences. This study explain about what the likely impacts on agriculture are, to what extent these influence people's livelihoods, how people are responding to them, and what the potential roles of the local government and other development partners are in adaptation efforts in vulnerable sectors.

Studying the impacts of climate change experienced by small scale farmers could form the base for further research and development of adaptation measures for sustainability of agriculture. Also it helps in tackling the problem of food security from the grassroot level. This study aimed to estimate the impacts of climate change on wheat and rice production in Nawalparasi district of Nepal and also about the change in cropping patterns. This study would contribute towards existing knowledge gap, and help researchers and policy makers to respond to climate change by adjusting agricultural and environmental policies and practices as needed. This research will give a concluding idea about the farmers' perception on climate change, its major impacts in agriculture and livelihood of resource poor marginal farmers.

1.4 Objectives of the study

- To estimate the impact of Climate Change on the cropping intensity and Cropping pattern in Nawalparasi district, Nepal
- To estimate the impact of Climate Change in production and productivity of paddy and Wheat
- To estimate the impact of Climate Change on the Livelihood of farming community
- To study the adaptation measure for its mitigation

1.5 Limitation of the study

Despite having the great scope of this study, there are some limitations too which cannot be ignored. It does not consider the impact of climatic change on paddy and wheat production through CO_2, humidity and different features of soil due to non-availability of wide range of time series data. Several parameters are synthesized by analyzing the data on recall basis of the farmers, which might lead to some response errors. In addition, a Time constraint is a limiting factor too. Therefore narrow range of research coverage may not generalize wide array of the country.

1.6 Hypothesis of the Study

- The effect of Climate Change on cropping pattern is not significant.
- The effect of Climate change in the production and productivity of paddy and wheat is not significant.
- The effect of Climate Change on the livelihoods of farmers is not significant.
- The effect of adaptation measure for the mitigation of Climate Change is not significant.

CHAPTER-II

REVIEW OF LITERATURE

2. LITERATURE REVIEW

International Panel for Climate Change, 2001 defined weather as a fluctuating state of the atmosphere, characterized by the temperature, precipitation, wind, solar radiation, clouds, air pressure and humidity. Graedel and Crutzen, 1993 defined climate as average statistics of meteorological conditions. Weather and Climate have a very important influence on life on the earth. They are part of the daily experience of human beings and are essential for food, health and well-being (IPCC, 2001b).Climate is defined as average statistics of meteorological conditions (Graedel and Crutzen, 1993). It refers to the average weather in terms of the mean and its variability over a period of time ranging from months to thousands or millions of years. The classical period used as modern measures of climate is 30 years (IPCC, 2001). Climate on the earth varies in space and time because of natural as well as anthropogenic forcing factors (IPCC, 2001).

2.1 Greenhouse Gases and Greenhouse effect

Carbon dioxide is a greenhouse gas that regulates the rate at which the planet can radiate heat energy back to space. Greenhouse gases are transparent to incoming solar radiation, but largely opaque to the passage of infrared radiation back out into space. In effect, these gases form a type of greenhouse that traps solar heat near the earth's surface, causing global warming and other climate changes. Besides CO2, other greenhouse gases include halocarbons, nitrous oxide, methane, tropospheric ozone, and water vapor. Most of these greenhouse gases occur naturally and are essential for providing temperate conditions under which life on earth is possible.

Groom *et al.*, 2007 stated that without GHGs, the earth's surface temperature would be 60^0C cooler than it is today. Similarly IPCC, 2007 reported that available data show that air temperature near the earth surface rose by 0.74 ±0.18 °C (1.33 ± 0.32 °F) during 20th century and scientists estimate it could increase as much as 6.4 °C (11.5 °F) on average during the 21st century (Wigley 1999, IPCC 2007). The number of days with extreme heat in summer is increasing and winters are becoming warm and dry with less snow (Schiermeier 2008).

Wigley (1999) reports approximately a 0.5 degree Celsius or a 0.9 degree Fahrenheit increase in global mean temperature over the 1950–2000 period. It is estimated that CO2 has historically accounted for 53 percent of the anthropogenic forcings associated with greenhouse gases (IPCC, 2001). Greenhouse gases (GHG) are components of the atmosphere that contribute to the Greenhouse effect. Greenhouse gases include water vapor, carbon dioxide, methane, nitrous oxide, and ozone and they are responsible for causing 36-70%, 9-26%, 4-9%, 10-12% and 3-7% of the greenhouse effect respectively (IPCC, 2001c).

2.2 Agriculture as an emitter of GHGs

Organic Consumer Association, 2008 reported that agriculture is one of important contributors of GHG emissions at the global scale. Also, agricultural land use in the 1990s was responsible for approximately 15% of all GHG. Agriculture is believed to account for roughly two-thirds of the total man-made methane (CH_4) emissions; mainly from paddy rice fields, burning of biomass and ruminants (enteric fermentation and animal waste treatment). Similarly Smith et. al., 2007 reported that of the total GHGs emitted from Agriculture Rice Production, Manure, Soil emissions, Enteric fermentation and Biomass burning, respectively emits 11%, 7%, 38%, 32% and 12%.

2.3 Global climate change

IPCC, 2001 reported that climate has changed considerably throughout the history of the earth due to change in its forcing components, whether natural or anthropogenic. The climate system consists of five major components: the atmosphere, the hydrosphere, the cryosphere, the land surface and the biosphere. The average temperature of the earth's surface has risen by 0.74 degree Centigrade since the late 1800s (IPCC, 2007b). Observed temperature records of the earth have only been available since 1861. The Earth's temperature before the instrumental period has been reconstructed using different indirect tools and methods such as tree rings, coral, ice cores, ice sheets, borehole measurements, glaciers, ancient sediments, sea level changes etc (IPCC, 2001a). The long term temperature record derived from the palaeoclimatic records shows clear evidence of fluctuation in temperature resulting in glaciation and deglaciation periods in the history of the earth since its formation some 4 billion years ago (Coughlan *et al.*, 1991).

World Bank Report, 2013 reported that Communities around the world are already feeling the impacts of climate change today, with the planet only 0.8 °C warmer than in pre-industrial times. Many of us could experience the harsher impacts of a 2°C warmer world within our lifetimes – 20 to 30 years from now – and 4°C is likely by the end of the century without global action.

IPCC, 2001b reported that the observed global average surface temperature (the average of near surface air temperature over land and sea surface temperature) records from 1861 to 2000 show that the earth's temperature is increasing (See fig. 2.2) and most of the warming occurred during the second half of the twentieth century, especially in two periods, 1910 to 1945 and 1976 to 2000. Over the 20th century the increase has been 0.6±0.2° C.

UNFCCC, 2007 estimated that by 2020, up to 250 million people in Africa could be exposed to greater risk of water stress. The average atmospheric CO_2 concentration has increased from 280 ppm in 1850 to 400 ppm at present, and could exceed 700 ppm by the end of the present century if emissions continue to rise at current rates (IPCC, 2001d).

World Bank Report, 2013 also reports that in Sub-Saharan Africa, between 1.5°C-2°C warming, drought and aridity, will contribute to farmers losing 40-80 percent of cropland conducive to growing maize, millet, and sorghum by the 2030s-2040s, the researchers found.

Kothyari and Singh (1996) analyzed long term data for India as a whole on the monsoon and annual rainfall and annual temperature. They also analyzed these data for the Ganga basin. They found an increase in temperature and a decrease in precipitation since the mid of the 1960s.

IPCC, 2001a reported that Increasing global surface temperatures are very likely to lead to change in precipitation and atmospheric moisture, because of a change in atmospheric circulation, a more rapid hydrological cycle and an increase in the water holding capacity throughout the atmosphere. Despite the irregularity in the trends of precipitation in the last century (see fig 2.3), the annual average precipitation in mid and high latitudes was increasing while that in tropics and sub-tropics was decreasing.

World Bank Report, 2013 reported that, In a 4°C warmer world, around the 2080s, annual precipitation may decrease by up to 30 percent in southern Africa, while East Africa will see more rainfall, according to multiple studies. Ecosystem changes to pastoral lands, such as a shift from grass to woodland savannas as levels of carbon dioxide increase, could reduce food for grazing cattle. In South East Asia, coastal cities will be under intense stress due to climate change. A sea-level rise of 30 cm, possible by 2040 if business as usual continues, would cause massive flooding in cities and inundate low-lying cropland with saltwater corrosive to crops. Vietnam's Mekong Delta, a global rice producer, is particularly vulnerable to sea-level rise. A 30 cm sea-level rise there could result in the loss of about 11 percent of crop production. At the same time, storm intensity is likely to increase. The study also describes rising ocean acidity leading to the loss of coral reefs and the benefits they provide as fish habitats, protection against storms, and revenue-generators in the form of tourism. Warmer water temperatures and habitat destruction could also lead to a 50 percent decrease in the ocean fish catch in the southern Philippines, the report says. Water scarcity in some areas and overabundance of water in others are the hallmarks of climate change in South Asia, the researchers found. Inconsistencies in the monsoon season and unusual heat extremes will affect crops. Loss of snow melt from the Himalayas will reduce the flow of water into the Indus, Ganges and Brahmaputra basins. Together, they threaten to leave hundreds of millions of people without enough water, food, or access to reliable energy. Bangladesh and the Indian cities of Kolkata and Mumbai will be confronted with increased flooding, intense cyclones, sea-level rise, and warming temperatures.

2.4 Climate Change in Nepal Context

Mani, 1981 stated that the basic patterns of the climate in the Himalayan region are governed by the summer and winter monsoon systems of Asia. The central and eastern Himalaya receives most precipitation during summer and the western Himalayan region receives most of its precipitation in winter. For every 1000 m of altitude, there is generally about a 6°C temperature drop. Also, Chalise, 1994 reported that it is very difficult to identify an accurate change in the Himalayan climate because of its large size, inaccessibility and unavailability of systematic climatological data.

Ministry of Agriculture and Cooperatives, 2010 stated that Nepal stretches between $26^0 22'$ to $30^0 27'$ north and $80^0 4'$ to $88^0 12'$ east. The east-west length of the country is about 800 km, roughly parallel to the Himalayan axis, and the average north-south width is 140 km. Within the 1,47,181 km^2 area of the country, physiographic regions range from tropical forests with tropical climate in the south to the snow and ice covered Himalayas with alpine climate in the north. The topography generally progresses from altitudes of less than 100 m in the southern Terai, up to more than 8,848 m peaks in the north, Mt.Everest being the highest peak in the world. It has more than 6000 rivers drawn from North to South and about 40 % of its area under forests with a total projected population of 28.37 million.

Yogacharya, 1998 reported that generally, there are four seasons in Nepal: summer monsoon (June-September), post-monsoon (October-November), winter (December-February) and pre-monsoon (March-May). UNEP, 2001 reported that the climate of Nepal is dominated by monsoon and about 80 percent of annual precipitation occurs during the summer monsoon.

Scientific statements regarding changing climate of Nepal are pronouncedly focused on temperature rise at the rate of 0.06°C per annum (Gautam and Pokhrel, 2010). Also report shows that there is trend of decreasing total rainy days, and increasing number of drier days and days receiving over 100mm rain (MOE, 2010; Practical Action, 2009). Weather variability associated with rising temperature and changing pattern of precipitation is expected to have utmost adverse impacts on various components of agricultural systems (Pokhrel and Pandey, 2011).

Malla (2008) explained some evidences about impacts of climate change in Nepalese agriculture, they are: Adverse decline in yield of winter crops due to cold wave, upward shifting of tree lines (apple trees) and livestock (Chauri), shortening of the maturity days of the crops(Rice:- 6 days, Wheat: - 14 days), off season flowering was observed in horticultural crops (peach and pear), decreased rice production by30% in 2006 in eastern terai due to the drought, increase in number of dry days, increase in evapotranspiration and reduce moisture availability in Mid western Terai and mustang district, increase nitrogen content of rice by 16.3% due to rise in temperature but decreased by 9.8% due to the doubling of CO_2.

2.5 Tempreature trend in Nepal

Sharma *et al.* (2000) indicated that the increasing trend of average temperatures during that period was primarily due to the increasing trend of maximum temperatures and there was no increasing trend of minimum temperatures. Nepal's temperature has increased by 0.7^0 C during last 30 years (1975 to 2005). It means the average temperature increased as 0.06^0C per year and in particular, 0.04^0 C/year in Terai and 0.08^0C/year in Himalayas (Malla, 2007).

The temperature trends for 1971-1994 as analyzed by Shrestha *et al.* (1999) widely varied among the geographical regions and the seasons in Nepal. Low-elevation areas in the south showed a slower warming rate than the high mountain areas in the north. Similarly, the pre-monsoon season (March-May) showed the lowest warming rate of 0.03°C per year, while the post-monsoon season (October-November) showed the highest. The warming is found to be more pronounced in the high altitude regions of Nepal such as the Middle Mountain and the High Himalaya, while the warming is significantly lower or even lacking in the Terai and Siwalik regions.

2.6 Precipitation trends in Nepal

Shrestha *et al.* (2000) reported that there was no distinct long-term trend in the precipitation records in Nepal during 1948-1994, though there was significant variation on annual and decadal time scales. Precipitation is the main driver of variability in the water balance over space and time. Change in precipitation could have very important implications for hydrology and water resources (IPCC, 001).

Another study based on the precipitation records from 80 stations for the period 1981-1998 across Nepal revealed that the hills and mountains in the north showed positive trends while the plains in the south were experiencing negative trends (MoPE, 2004). The precipitation fluctuation in Nepal is not the same as the all-India precipitation trend; but it is well related with rainfall variations over northern India (Shrestha *et al.*, 2000; Kripalani *et al.*, 1996).

2.7 Climate Change and livlihoods

Smallholder farmers are the backbone of the rural economy – but they are bearing the brunt of climate change. Worldwide, there are 500 million smallholder farms supporting some 2 billion people. These farmers inhabit some of the most at-risk landscapes, including hillsides, deserts and floodplains. Climate change multiplies the threats facing smallholders, endangering the natural assets they depend on and accelerating environmental degradation. The increased frequency and extent of floods, droughts and land cutting has rendered the agriculture sector more vulnerable and reduced the productivity of land and of the potential for plant production. The case is much more severe in countries like Nepal where people have inadequate knowledge, weak governance systems and fewer resources to respond. Estimates of the annual cost of climate change adaptation in developing world agriculture range from US$7 billion to US$12 billion per year. But smallholders face significant risks and barriers that limit their access to climate finance, including their insecure land tenure and the high cost of implementing projects. Climate change is making smallholder development more expensive. Climate-resilient programs typically have higher up-front costs, including for infrastructure, skills development for farmers and strengthening of institutions. International climate finance is often linked to particular global policy goals, such as emissions mitigation, adaptation or efficient energy.

According to The International Fund for Agricultural Development (IFAD) *Rural Poverty Report 2001*, 75% of the world's 1.2 billion poor (defined as consuming less than one purchasing-power adjusted dollar per day) live and work in rural areas. Earlier IFAD figures suggest that almost 50% of the developing-country rural population were smallholders (farming 3 ha or less of crop land), and almost 25% were landless, which may have included some agricultural laborers, nonpastoralist livestock keepers, and poor people not engaged in agriculture.

In developing countries, 11% of arable land could be highly affected by climate change. There will be a reduction of cereal production in 65 countries and retardation of about 16% of agricultural GDP (FAO, 2007). There is a decrease of 30% in food production in South Asia. Climate change will have serious impacts on world economic output, human life and the environment throughout the world (IPCC, 2007c).

The impact of climate change on the livelihoods of the poorest of the poor in Nepal would be substantial (IPCC, 2001) because there is large income and consumption disparity in the country. For example, the poorest 20 percent of the population consume only 6.2 percent of the resources, whereas the richest 20 percent of the population consume about 53.3 percent of the resources (CBS, 2004).

2.8 Impact of climate change in Agriculture

IPCC, 2001c reported that the impacts of climate change on the livelihoods of the poorest of the poor in Nepal would be substantial. Similarly CBS, 2004 stated that there is large income and consumption disparity in the country. For example, the poorest 20% of the population consume only 6.2% of the resources; on the other hand, the richest 20% of the population consume about 53.3% of the resources.

MoPE, 2004 reported that the South Asian region has a strong linkage between monsoon activity and agricultural productivity. In the last decade (1990-2000), particularly Nepal and the Indo-Gangetic plains of India, just immediate south of the mountain region, experienced significant reduction in yield of winter crops due to severe sky overcast. Yield reduction in 1997/98 ranged from 11% to 38% compared to the average of the preceding 10 years.

Agriculture is extremely vulnerable to climate change in Nepal. The overall agriculture production system is very traditional, unmanaged and is too slow to adopt new technology. Changes in water availability in the monsoon, pre-monsoon and the post-monsoon season have direct impact on the Nepalese agriculture. Rice production is decreasing with a decrease in monsoon flow (Sharma *et al.*, 2006). A 4 °C temperature rise might cause a wheat yield reduction in Nepal of as much as 60% of the potential yield (Pradhan, 1997).

Climate change will have a significant impact on agriculture in many parts of the world (IPCC, 1998). Particularly vulnerable are subsistence farmers in the tropics, who make up a large portion of the rural population and who are weakly coupled to markets (IPCC, 2001). Temperature, precipitation, atmospheric carbon dioxide content, the incidence of extreme events and sea level rise are the main climate change related drivers which impact agricultural production.

Hulme (1996) describes four ways in which climate would have a physical effect on crops. First, *changes in temperature and precipitation* will alter the distribution of agro-ecological zones. Second, *carbon dioxide* effects are expected to have a positive impact due to, for example, greater water use efficiency and higher rate of photosynthesis. Third, *water availability (*or *runoff)* is a critical factor in determining the impact of climate change in many places fourth, agricultural losses can result from climatic variability and the increased frequency of *extreme events* such as droughts and floods or changes in precipitation and temperature variance. Rice, maize and wheat are the major cereal crops of Nepal that constitute about 38 percent, 17 percent and 14 percent of the total calorie supply respectively (FAO, 2004). MOPE, 2004 reported, the average optimum temperatures for rice, maize and wheat are 22-30°C, 25°C and 15-20°C respectively and there might be a substantial reduction in production when the temperatures exceeds the ranges.

Lobell and Field (2007) reported that there is sharp decline in the yield of wheat, maize and barley, as a result of the warming and increase in temperature. Increase in global temperature with altered soil moisture is projected to decline in yield of food crops over the next 50 years. Another projection by Murdiyarso (2000) estimate to decrease rice yield by 3.8% by the end of 21st century due to the combined effect of thermal stress and water scarcity. The livestock yield also decline due to the limited herbaceous production, heat stress from higher temperature and limited water intake due to poor rainfall and increased incidence of disease (Cruz et.al, 2007).

2.9 Impact of climate change in wheat

Climatic parameters like rain and temperature strongly affect the growth and productivity of wheat. Focusing on wheat, Lobell and Field (2007) perform an aggregated global study. They consider the period 1961-2002 and estimate the impact of average monthly minimum and maximum temperatures as well as precipitation on wheat yields. They find that 41 percent of the variance in year-to-year wheat yields is explained by weather during the growing season. Temperature appears to have a negative influence on wheat yields. The authors estimate that for an increase of 1°C in average monthly minimum and maximum temperatures, wheat yields decrease by 5.4 percent.

A negative relationship between maximum temperature and wheat yields is also observed by Nicholls (1997) in Australia. A 1 percent increase in rainfall leads to an increase of 0.03 percent in wheat yields. Additionally, according to Corobov (2002), temperature and precipitation are responsible for 75 percent of winter wheat yield fluctuations in Moldova.

There is positive role in percentage change in wheat yield in all the agro ecological zones. With doubling of carbon dioxide, wheat production is likely to increase with adoption of more heat tolerant varieties (Sharma, 2007). A rise in temperature and additional water can enhance wheat production in higher altitudes as wheat varieties grown in Nepal are more adaptive to heat stresses and elevated CO_2 than rice (NARC, 2007).

An experiment conducted in open top chamber at Khumaltar shows the increase of wheat yield by 8.63 and 9.74 % even at the increase of the temperature by 6.94°C and the doubling of CO_2 respectively. Greenhouse effect due to doubling of CO_2 was observed only by 0.18°C and produced 9.74% higher than ambient plots. Increase in the CO_2 level in the C_3 pathway in rice and wheat helped to increase the production. Wheat production was increased by 41.5 % in the Terai plain, 24.4 % in the hill and 21.2 % in the mountain under the elevated CO_2. The yield however decreased by 1.8% in the Terai but continued to increase by 5.3 % in the hill and 33.3 % in the mountain at 4°C rise in temperature under irrigated condition. The study conducted in India showed that, in subtropical region there will be small decrease in potential yield by 1.5-5.8% but in tropical zone the decrease will be 17-18% (Agrawal and Kalra, 1994). It indicates that rainfed wheat productivity is likely to suffer more in Terai as compared to the mid-hill's environment in a climate change scenario. The additional rains had favorable impacts on the wheat yield at all levels of temperature rise.

2.10 Impact of Climate Change in Paddy

Chahal, et al., 2007 reported that the rice yield is significantly influenced by temperature throughout the crop growth period and still more pronounced in the flowering period. Besides temperature, excessive rainfall during the growth period also affects the yield. With the shifting of planting dates of rice from higher to lower evaporative demand, there is an increase in grain yield of rice while there is reduction in evapotranspiration and irrigation water applied.

Sharma *et al.*, 2006 stated that Agriculture is extremely vulnerable to climate change in Nepal. The overall agriculture production system is very traditional, unmanaged and is too slow to adopt new technology. Changes in water availability in the monsoon, pre-monsoon and the post-monsoon season have direct impact on the Nepalese agriculture. Rice production is decreasing with a decrease in monsoon flow.

Wassmann, Jagadish, Sumfleth, et al. 2009 reported that the rice-wheat system in the Indo-Gangetic Plain, which meets the staple food needs of more than 400 million people, is a highly vulnerable regional system. The system, which covers an area of around 13.5 million hectares in Pakistan, India, Bangladesh, and Nepal, provides highly productive land and contributes substantially to the region's food production. Declining soil productivity, groundwater depletion, and declining water availability, as well as increased pest incidence and salinity, already threatens sustainability and food security in the region.

Using agro-meteorological crop modeling, Pathak et al. (2003) explain the observed rice yield decline in the IGP (1985–2000) as a result of the combined decrease in radiation and increase in minimum temperature.a Confirming this, Auffhammer, Ramanathan, and Vincent (2006) apply an agro-economic model over all of India and find that atmospheric aerosols and greenhouse gases, reducing radiation and increasing minimum temperatures, have contributed to the recent slowdown in rice harvest growth.

Asada and Matsumoto (2009) analyze the effects of variations in rainfall on rice production in the Ganges-Brahmaputra Basin in India and Bangladesh. This is one of the most important regions for rice production in South Asia and is responsible for about 28 percent of the world's total rice production. Their focus is on regional differences between the upper and the lower Ganges and the Brahmaputra Basin.

Based on climate and rice production data from 1961–2000, Asada and Matsumoto (2009) apply statistical modeling and find that the effect of changes in rainfall differs among the regions analyzed. While rice production in the upper Ganges Basin is strongly affected by rainfall variation and is vulnerable to rainfall shortages, rice production in the lower Ganges Basin is more strongly affected by floods. In the Brahmaputra Basin, in contrast, the drought effect is stronger than the flood effect as a consequence of increasing rainfall variation, though crops are vulnerable to both droughts and floods. These findings are highly relevant in the context of climate change as they provide a better understanding of regional differences and vulnerabilities to provide a stronger basis for adaptation and other responses (Asada and Matsumoto 2009).

Saseendran et al. (2000) showed that for every one degree rise in temperature the decline in rice yield would be about 6%. Saseendran, *et al.* (2000), explains on an average over the state with the climate change scenario studied, the rice maturity period is projected to shorten by 8% and yield increase by 12%. When temperature elevations only are taken into consideration, the crop simulations show a decrease of 8% in crop maturity period and 6% in yield. This shows that the increase in yield due to fertilization effect of elevated CO_2 and increased rainfall over the state as projected in the climate change scenario nearly makes up for the negative impact on rice yield due to temperature rise. The sensitivity experiments of the rice model to CO_2 concentration changes indicated that over the state, an increase in CO_2 concentration leads to yield increase due to its fertilization effect and also enhance the water use efficiency of the paddy. The temperature sensitivity experiments have shown that for a positive change in temperature up to 5°C, there is a continuous decline in the yield. For every one degree increment the decline in yield is about 6%.

2.11 Adaptation against climate change impacts

IPCC, 2001 stated that although a mitigation strategy is essential for reducing carbon molecules on air and soil, it is not sufficient to save us and our world from climate change related woes. It takes several years to remove CO2 molecules from the atmosphere, through sequestration by plants and natural geochemical processes, and maintain its level below the dangerous point.

Practical Action Nepal, 2008 reported that Nepal is poor in infrastructure and lacks resources to immediately and effectively practice any mitigation measures in the short term. Thus it will be prudent to increase peoples' ability to adapt to change while continuing our efforts to mitigate carbon emissions. Adaptation is mainly about warning people about certain events in advance and preparing them to deal with vulnerability and uncertainty. Effective predictability, awareness, provision of certain support systems and better planning are some of important things to consider in local preparedness for reducing vulnerability and enhancing resilience. Crop diversification, Zero tillage, Mulching, Water Harvesting, Plastic tunneling are some of the way for communities to cope with increased flooding and the threat to their land by growing a range of new and different crops that have a higher market-value. By introducing crops that are more resilient to the changes in rainfall patterns, crop diversification also allows alternative crops to be cultivated at different times of the year, despite changes to the weather.

Agrawala *et. al.*, 2003 reported that construction of watch towers; provision of emergency materials and emergency shelters; and considering risk free or low risk locations for new settlements and resettlement are important strategies to improve local adaptation capacity.

Selection of certain technologies over others such as small hydropower, drought-tolerant crop varieties, mixed cropping, Sloping Agriculture Land Technology (SALT) etc., is also important in the adaptation process. Another adaptation strategy might be enhancing connectivity of forests as suggested by Hannah *et al.* (2007). The connectivity between two or more forest patches by developing corridors is important to develop continuum of forests and facilitate migration of species from one environment to another. Forests provide a carbon reservoir as they contain about 60% of all carbon stored in terrestrial ecosystems (CIFOR 2007), and they serve as important adaptation buffers.

CHAPTER-III

MATERIALS AND METHODS

3. MATERIALS AND METHODS

This section includes different aspects of research procedure such as selection of the study area, sample size and sampling technique, source of information, method and technique of data collection and data analysis.

3.1 Geographic settings and climate of Nawalparasi

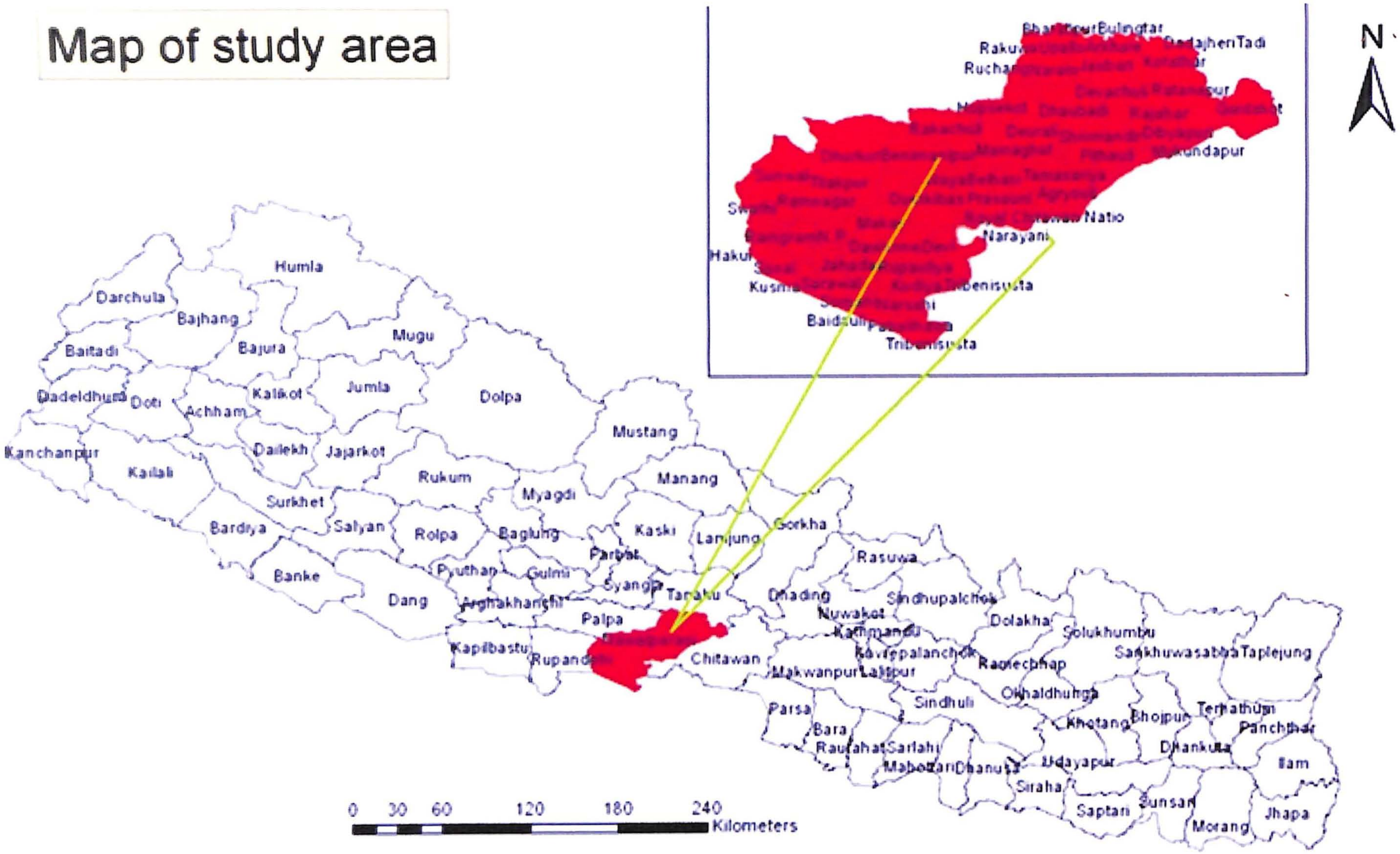
Nawalparasi district is bounded by Chitwan in east, by Rupandehi in west, by Palpa and Tanahu in north and by Uttar Pradesh and Bihar province of India in south. The district spreads from 27°21' to 27°47' north latitude and 83°36' to 84°25' longitude in east and elevation ranges from about 100 masl to 1936 masl and covering an area 2,01,587 hectares. The mean district minimum and maximum temperature are 5.0°C and 37.0°C, respectively. Mean annual precipitation of the district is 2145 mm (DADO, 2011).

3.2 Natural and historical resources

Nawalparasi district, naturally well endowed and historically famous district of Nepal, today, is one of the major tourism centers in western region of Nepal. The places of historical importance's in Nawalparasi district are Ramgram (maternal uncle's house of Lord Buddha, Trivenidham, Palhibhagwati Mandir, Daunnedevi, Devghat, Maulakalika Mandir. The Narayani is the main river in the district. There are small rivers (Turia, Girubari, Jharahi, Arunkhola, Bungdi, Kawasoti, Jayashree etc.) and lakes (Nandantaal, Gaidataal, Butahataal, Khusihawataal etc.

Among cultivated land only 21,880 ha is irrigated throughout the year while rest of the cultivated land is irrigated only partially and unirrigated. The soil in Nawalparasi is favorable for agriculture. The major crops grown in the district are paddy, wheat, maize, pulses, oilseed, spice and potato. Besides, commercial vegetables, buckwheat, millet, barley, bananas and sugarcane are grown. Cattle, buffalos and goats are major livestock

Map of study area



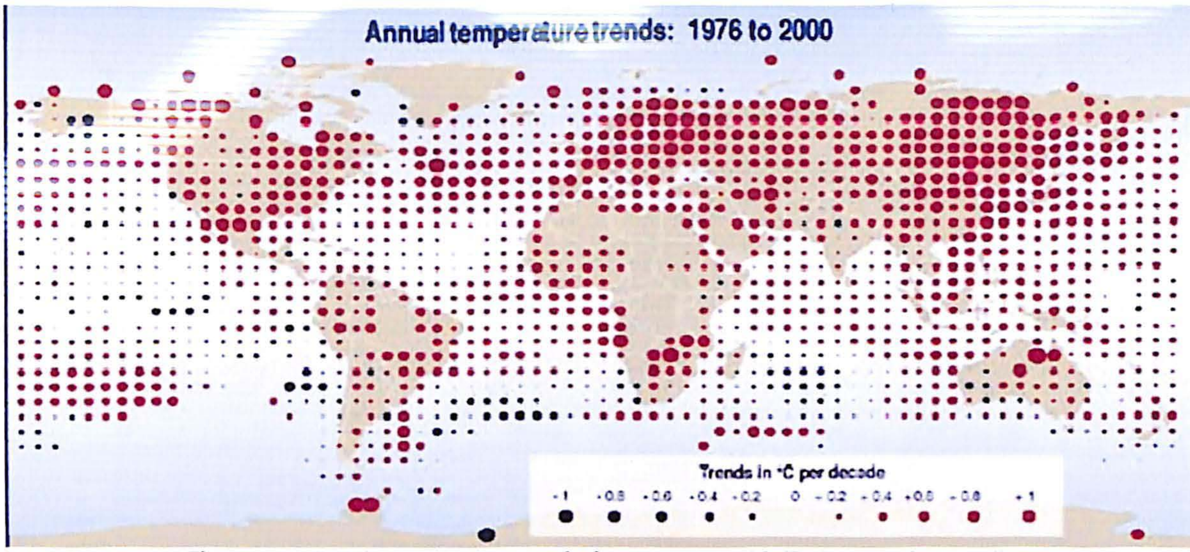


Figure 1. Annual temperature trends for 1976 to 2000 (IPCC, 2001a, p. 54)

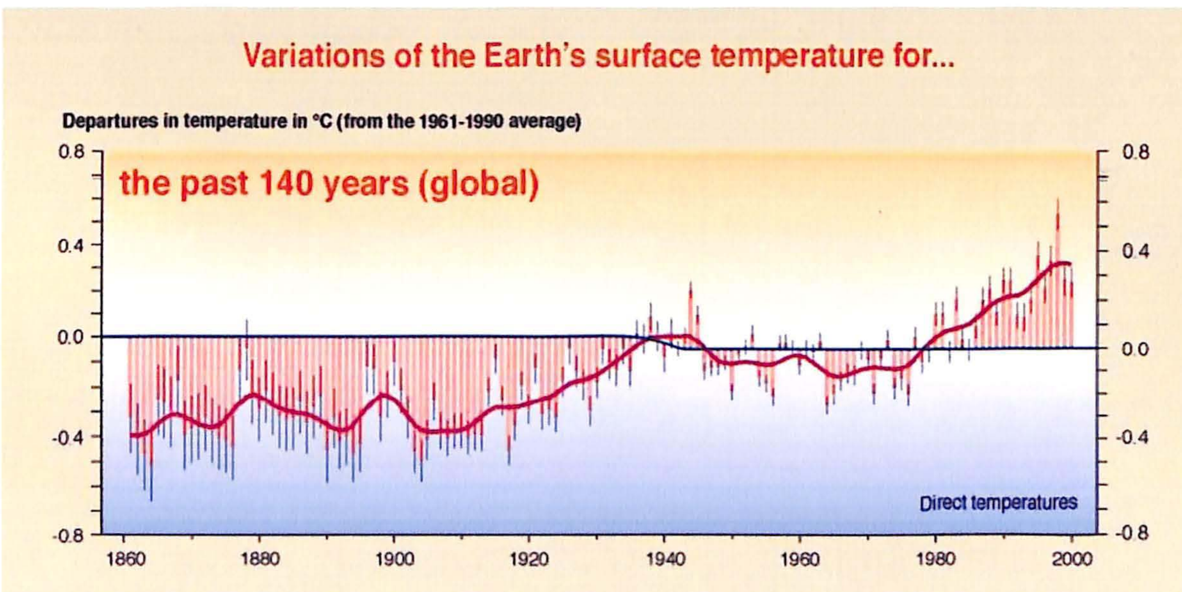


Figure 2. Variations of the Earth's temperature (IPCC, 2001b)

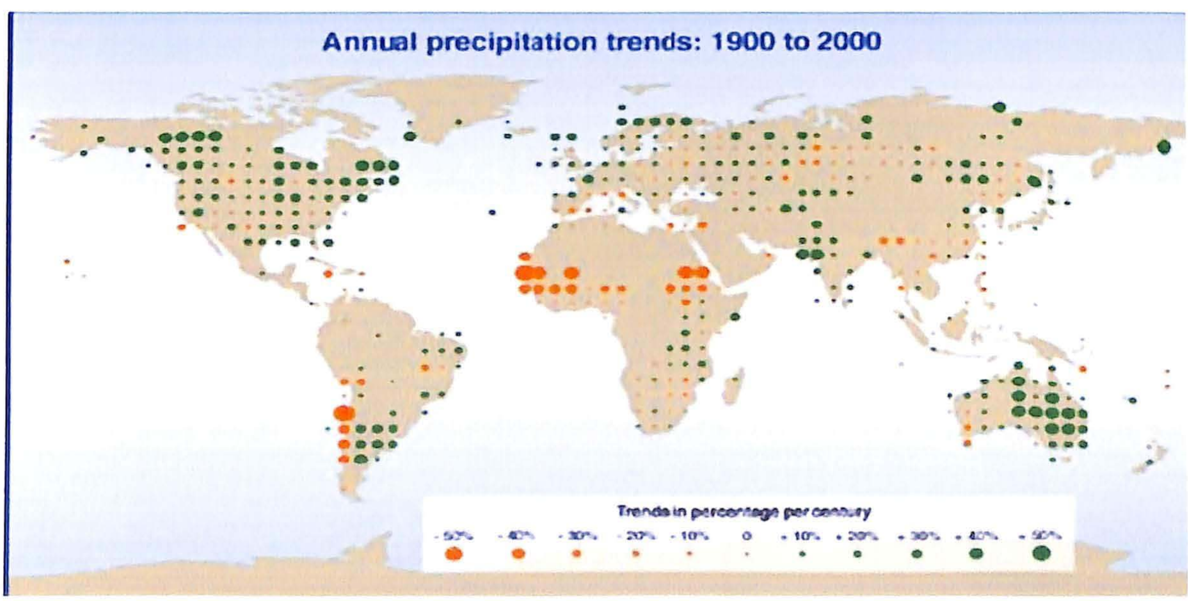


Figure 3. Annual precipitation trends for 1900 to 2000 (IPCC, 2001b)

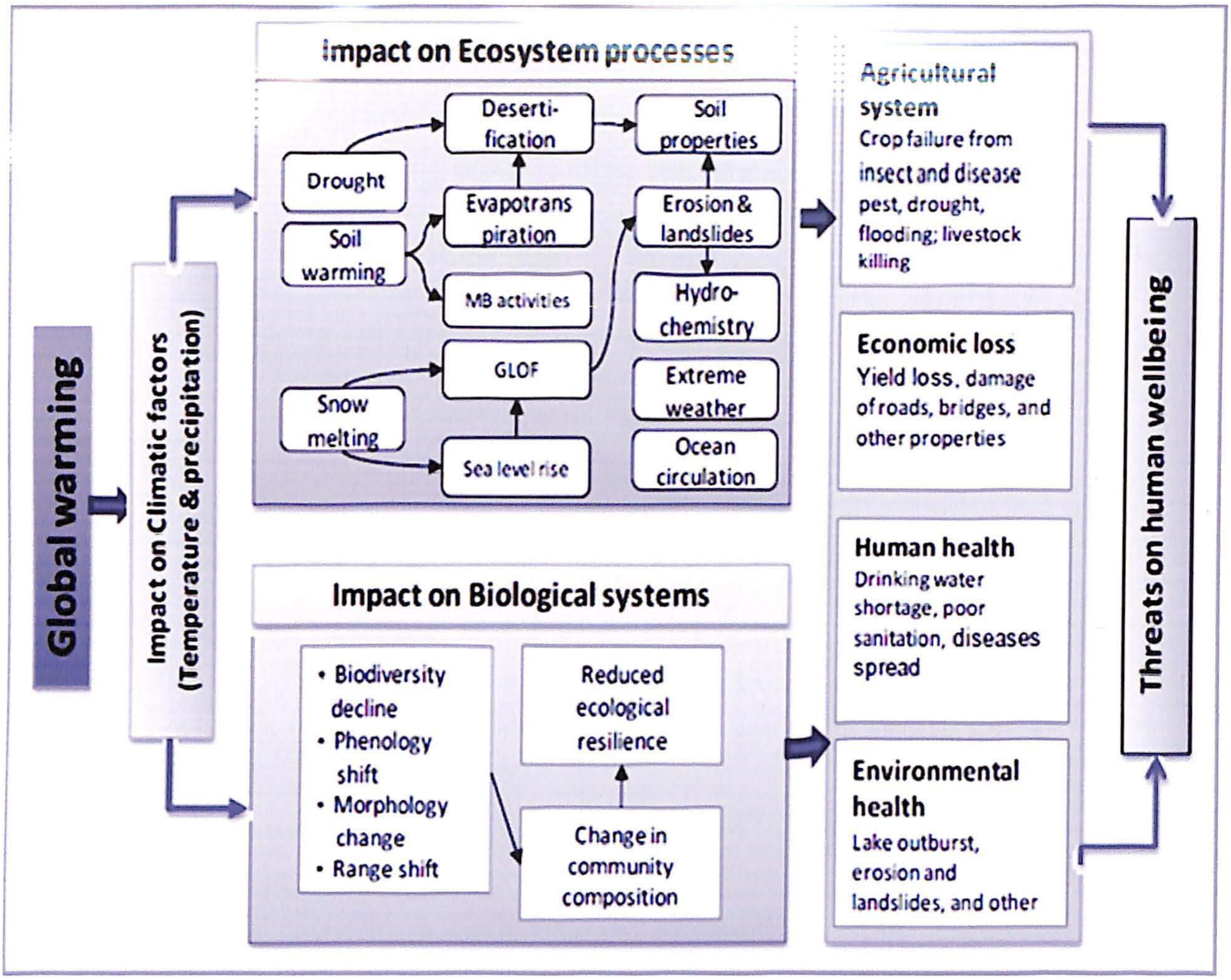


Figure 4. Schematic diagram showing the impact of global warming (Source: IPCC,2001)

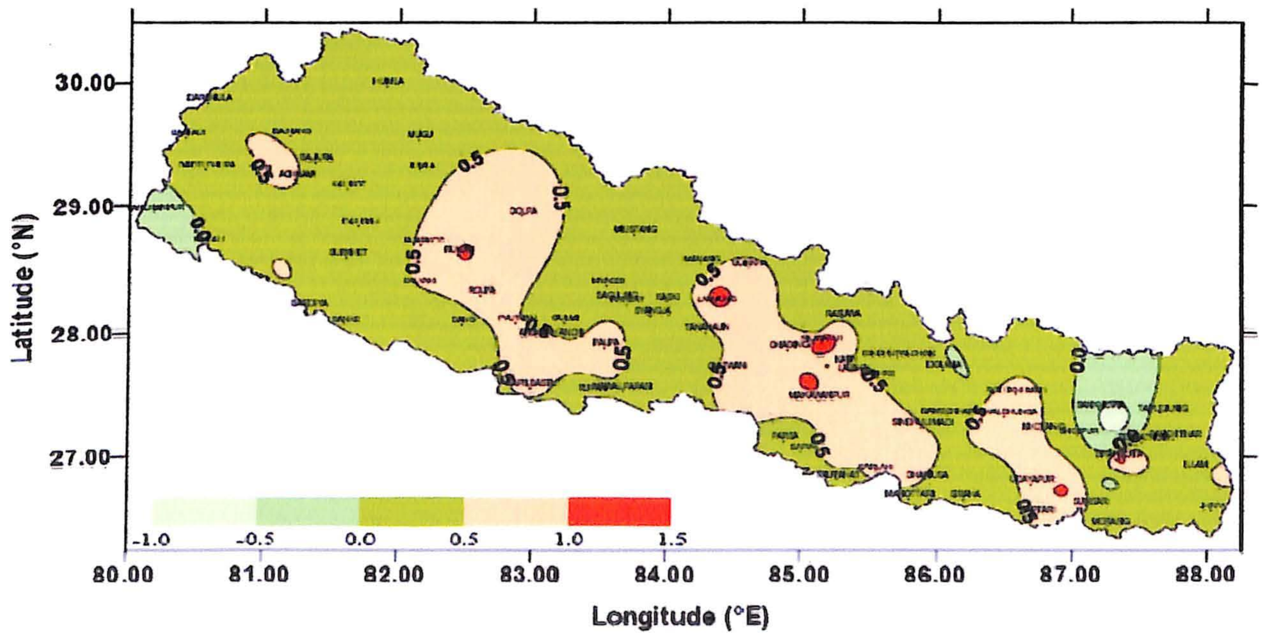


Figure 5. Observed mean annual temperature trend (°C) per decade for the period1981 to 1998 (MoPE, 2004)

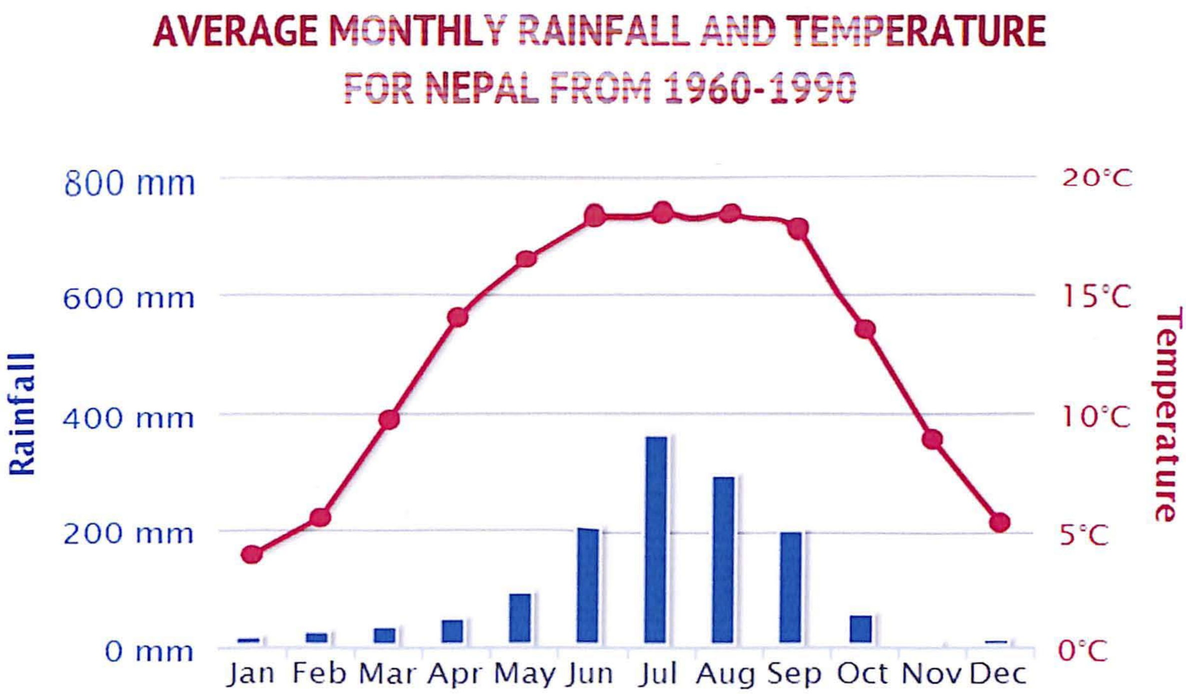


Figure 6. Graphical representation of average monthly rainfall and tempreature for Nepal from 1960 to 1990

(Souce: World Bank Data)

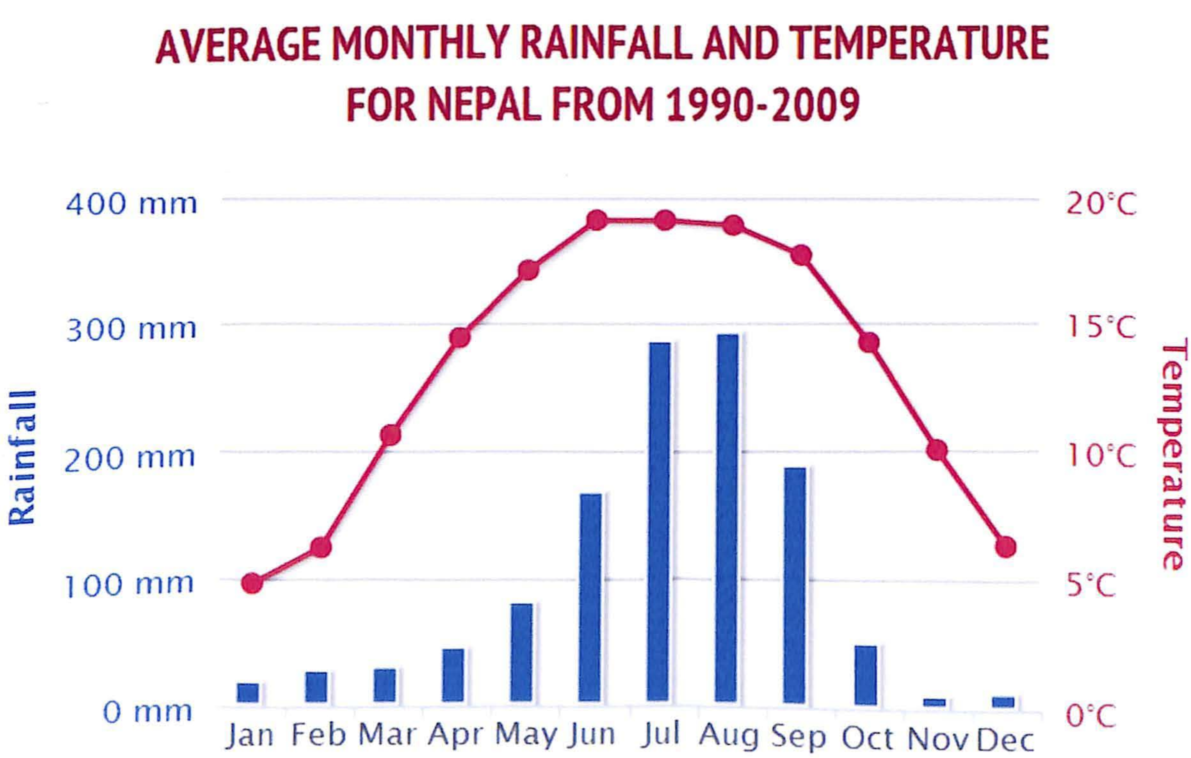


Figure 7. Graphical representation of average monthly rainfall and tempreature for Nepal from 1990 to 2009

(Souce: World Bank Data)

mainly raised for milk, meat and draft power. The economy of the district mostly depends upon the agriculture, and about 80.99% of workforces derive their income from this activity.

3.3 Social, demographic and economic settings

According to National Census 2011, the total population of Nawalparasi district is 643508 (2.42%), Male: 303675 and Female: 339833 with population growth rate of 2.55 per year and consists of 128760 households with population density of 298. Magar (17.21%), Brahmin (16.86%), Tharu (16.48%), Chetri (5.83%) and Musalman (3.91%) are the major caste/ethnic groups. Hinduism (88.18%), Buddhism (6.00%), Muslim (3.75%), Christian (1.73%) and others (0.34%) are the major religion of Nawalparasi. The average household size is 5.00. There are 73 VDCs and only one municipality in the district.

3.4 Land utilization pattern

The total area of district is 2,01,616 ha out of which only 15.43% is cultivated. Out of total land suitable for cultivation, only 63% is provided with irrigation facility in all round the year. The detail of land utilization pattern of Nawalparasi district is presented in Table 1.

Table 1. Land utilization pattern in Nawalparasi district

Land situation	Area (ha)	Percent
Cultivable land	70143	34.79
National Park	7500	3.72
Whole year irrigated	36797	10
Rivers and Streams	6699	3.32
Forests	104942	52.05
Pasture/vegetation	5816	2.89
Others	6516	3.23
Total	201616	100

Source: District profile, Nawalparasi (2010)

3.5 Selection of study area

The study was conducted in Nawalparasi District of Nepal. Since the purpose of the study was to assess the impact of Climate change on the wheat production and livelihood of marginalized community and their adaptation strategies, Giruwari Watershed Region was purposively selected for the study. Two VDCs namely Deurali and Hupsekot were selected.

3.6 Sampling and sample size

Farmers of these two VDCs were the target communities for this study. Care full attention was paid to make the sample more inclusive (i.e. inclusion of farmers from different wealth categories, different ethnic groups and occupation).By using simple random sampling technique farmers from each VDC were selected by applying simple random sampling method and in totality 80 farmers were selected.

3.7 Methods of data collection

Various sources and technique were used for collection of necessary information. In this study both the primary and secondary data were collected and analyzed.

3.7.1 Sources of information

3.7.1.1 Primary source of data

The local wheat growing farmers were the primary source of information. The interview schedule was administered to the respondents to collect primary information. These data were supplemented by information obtained from focus group discussion, and key informant interview

3.7.1.2 Secondary source of data

Secondary information were collected from the Department of Hydrology and Meteorology(DH&M) , District Development Committee (DDC), District Agricultural Development Office (DADO), National Wheat Research Centre, Bhairahawa (NWRC), International Centre for Integrated Mountain Development (ICIMOD), Central Bureau of

Statistics (CBS), Ministry of Agriculture and Cooperatives (MoAC), Village Development Committee (VDC), and from the various published materials like journals, research articles, proceedings of various NGOs and INGOs, annual reports of District Agriculture Development Office (DADO). The local political leaders, working agencies, was also the source of secondary information.

3.7.2 Interview

Interview schedule was prepared to collect primary information from farmers and marginalized people. A co-ordination schema was prepared to help and facilitate the questionnaire development and preparation of interview schedule.

Pre-testing of interview schedule was done by administering the designed interview schedule to the farmers of adjoint V.D.C. The final interview schedule was prepared by taking due consideration of the suggestion obtained during the pre- testing.

3.7.3 Field survey

The pre-tested interview schedule (questionnaire) was administered to the respondent to collect the primary data. The in-depth information on the various aspects of impacts of climate change was collected through face to face interview.

3.7.4 Key informant interview

The progressive farmers, local leader were interviewed with the preparation of Checklist about the various climate change and their perceptions will be collected.

3.7.5 Focus group discussion

One comprehensive focus group discussion was conducted in the study area after completing the field survey with help of the checklist to verify the result obtained from field survey. In the FGD, participants were farmers; both male and female and from all the ethnic groups and key informants residing locally.

3.8 Field survey

After the finalization of the interview schedule, the schedule of field visit was prepared to collect information with the help of enumerators. The enumerators were oriented about the set of questions. Respondents were interviewed by visiting their home. The interview timing was fixed as per the farmer's convenience. Regular checking and validation of the information was done immediately after filling the interview schedule. Focus group discussions, informal discussions and key informants interview were also done during the field survey.

3.9 Techniques of data analysis

3.9.1 Descriptive analysis

All the qualitative data collected from the survey and the secondary data were analyzed by mean, median, standard deviation.

3.9.2 Analytical statistics

Changes in the area allocation over the time, yield and production changes analyzed by estimating the trend line by using Microsoft excel, SPSS. Climatic data was analyzed by using the Microsoft excel, SPSS, STATA12 to obtain the estimated coefficient of the explanatory variables. Statistical tools like mean, standard deviation, and t-test and f-test were used to analyze the trend of rainfall and temperature.

3.10 Data processing

Data collected from both primary and secondary sources were processed for the desirable form.

3.10.1 Processing of primary information

Qualitative information from the survey questionnaire was quantified with the appropriate scaling method. Yes or no, increase or decrease or not noticed were changed to dummy for the further analysis.

3.10.2 Processing of secondary data

3.10.2.1 Climatic data

Climatic data were collected from the Department of Hydrology and Meteorology. Monthly time series data related to rainfall, and temperature from Dumkauli Nawalparasi was collected.

3.10.2.1.1 Temperature

Collected monthly temperature data for Dumkauli stations were processed in the desirable form as follows:

Monthly average temperature for each month was calculated as (T) = $(T_{max}+T_{min})/2$ where T_{max} and T_{min} represents maximum temperature and minimum temperature for particular month.

3.10.2.1.2 Rainfall

Collected monthly rainfall data for the station was processed for the desirable form as follows: $R = R_1+R_2+R_3+R_4+ \ldots\ldots\ldots\ldots\ldots + R_{12}$ Where R_1, R_2, R_3,...... , R_{12} refers to the rainfall from the month Jan to Dec.

3.11 Climate change impact analysis

The log linear regression analysis was done to study the effect of precipitation and temperature on wheat and paddy yield.

$$\text{Ln } YH_t = a + b_1 T + b_2 \ln A + b_3 \ln PRC_t + b_4 \ln TMP_t$$

where,

YH= yield for 't' years

T= Time (years)

A= Area (ha)

PRC_t = Cumulative Rainfall from CRI to Heading stage in year 't' (mm)

TMP_t = Mean Monthly Temperature during post anthesis period of wheat in year't' (^{0}C) a ,b2,b3=intercept and slope of the estimated regression line.

3.12 Scaling and indexing

Various problems and reasons were ranked with the use of index. Scaling techniques, which provides the direction and extremity attitude of the respondent towards any proposition (Miah, 1993) was used to construct index. The intensity of production problem being faced by the aromatic rice producers and traders, respectively were identified by using five point scaling technique comparing most important, somewhat important, important, and less important and least important using scores of 1.00, 0.80, 0.60, 0.40, and 0.20, respectively. The formula given below was used to find the index for intensity various problem/reasons.

$$I_{prob} = [\Sigma (S_i f_i)] / N$$

where,

I_{prob} = Index value for intensity of problem

Σ = Summation

S_i = Scale value of i^{th} intensity

f_i = Frequency of i^{th} response

N = Total number of respondents

3.13 Logit regression model

Logistic Regression has been used by the investigators in various fields of enquiry for quantifying and interpreting casual linear relationships. It is used when the outcome variable is dichotomous, a 'yes' or 'no', whether or not the subject has a particular characteristics.

The decision of farmers to practice different adaptation strategies were estimated through logit regression to derive the several factors that govern the probability to practicing adaptation strategies ($Y_i = 1$)

In the logit model, suppose Y_i be the binary response of the farmers and take only two possible values; Y = 1, if farmer practiced different adaptation strategies and Y = 0 if farmer did not practice any adaptation strategies. Suppose x was the vector of several explanatory variables affecting to practice different adaptation strategies and β, then thelogit transformation of the probability of the practicing adaptation strategies by farmers was represented as follows (Gujrati, 2003);

$$L_i = \ln \left[\frac{Pi}{1-Pi} \right] = z_i = \alpha + \sum_{i=1}^{n} \beta i \, xi \; + \; €i$$

where Y_i = a binary dependent variable (1, if farmers practicing stronger adaptation practices, 0 otherwise), x_i includes the vector of explanatory variables used in the model, β_i = parameters to be estimated, $€_I$ = error term of the model, exp (e) = base of the natural logarithms, L_i = Logit and $\left[\frac{Pi}{1-Pi} \right]$ = Odd ratios.

Thus, the binary logit regression model was expressed as;

$Y_i = f(\beta_i \, x_i)$ = f (Economically active family members, Education, Farm size, Annual household cash earning, Credit, Training & Extension Service).

Table No.1 Description of the variables used in the logit model

Variables	Description	Unit	Expected sign
Economically active members	Number of economically active(16-59years) family members in the household	Number	+
Education	Education of the household head	Year	+
Farm size	Total size of cultivated land	ha	+
HH annual cash earning	Annual household cash earning	Nepali Rs	+
Credit	Whether farmer have accessed to credit or not in reasonable interest rate(1/0)	=1 if access; 0 = otherwise	+
Training and Extension	Whether farmers received training from different governmental and non-governmental organization about climate change adaptation strategies(1/0)	= 1 if farmers received training and extension; 0 = otherwise	+

CHAPTER-IV

RESULT AND DISCUSSION

4. RESULTS AND DISCUSSION

4.1 Population and household characteristics in the study area

4.1.1 Gender of the study population

The total population of the sampled households was 538, In terms of gender, 46.20 % were male and 53.80 % were female in Deurali, Likewise 54.04 % were male and 45.96 % were female in Hupsekot (Table 2). Among the total population, 49.62 % were male and 50.38 % were female in the study area.

Table 2. Gender of the population in study area (2013)

Gender	VDCs		Total
	Deurali	Hupsekot	
Male	140(46.20)	127(54.04)	267(49.62)
Female	163(53.80)	108(45.96)	271(50.38)
Total	303(100)	235(100)	538(100.00)

Figure in the parantheses indicate percent

4.1.2 Educational status of the study population

Six categories, Illiterate (who cannot read and write) Informal literate (capable of read and write without school), Primary (formal education upto five class), Secondary (formal education upto ten class), Higher secondary (formal education upto twelve class) and University (formal education more than twelve class) were devised in order to assess the educational status of the family members of the sampled households. The survey revealed that large proportion of the members of the sampled households (23.04%) were illiterate and lower proportion of the population attained University level education (3.71%).The educational attainment of the members of the sampled household is presented in (Table 3).

Table 3. Educational level of the respondents in the study area (2013)

Educational Level	VDCs		Total
	Deurali	Hupsekot	
Illiterate	68(22.44)	56(23.82)	124(23.04)
Informal Literate	73(24.09)	51(21.70)	124(23.04)
Primary	67(22.11)	43(18.29)	110(20.44)
Secondary	74(24.42)	48(20.42)	122(22.67)
Higher Secondary	14(4.62)	24(10.22)	38(7.6)
University	7(02.32)	13(5.54)	20(3.71)
Total	303(100)	235(100)	538(100)

Figure in the parantheses indicate percent

4.1.3 Ethnicity of the respondent

Majority of the respondents were Brahmin and Magar followed by Tharu and Dalit and Newar in the study area. In total, 50.00 percentage of the respondent were Brahmin, followed Tamang (20.00%), Tharu (13.75%), Dalit (8.75%) and Newar (7.5%). In the Deurali V.D.C majority of the respondents were Brahmin (47.50%) and in Hupsekot V.D.C also majority of the respondents were Brahmin/Chhetri (52.50%).

The ethnicity of the respondent is presented in (Table 4).

Table 4. Ethnicity of the respondents in the study area (2013)

Ethnicity	VDCs		Total
	Deurali	Hupsekot	
Brahmin/Chhetri	19(47.50)	21(52.50)	40(50.00)
Tharu/Darai	0(00.00)	11(27.50)	11(13.75)
Newar	0(00.00)	06(15.00)	6(7.50)
Dalit	05(12.50)	02(5.00)	7(08.75)
Tamang/Magar	16(40.00)	00(00.00)	16(20.00)
Total	40(100.00)	40(100.00)	80(100.00)

Figure in the parantheses indicate percent

4.1.4 Distribution of the economically active population in the study area

Age of the family members was categorized in to three classes, less than 15 years, economically active age (15-59 year) and more than 59 year as in given Table 5. Majority of the population (57.24%) was of economically active age. The percentage of economically active population was higher (61.05%) in Deurali VDC than Hupsekot (52.34%).

Table 5. Distribution of economically active members in the study area (2013)

	Age groups	Deurali	Hupsekot	Total
	≤15	86(28.38)	64(27.23)	150(27.88)
Economically active members	16-59	185(61.05)	123(52.34)	308(57.24)
	≥60	32(10.57)	48(20.43)	80(14.88)
	Total	303(100)	235(100)	538(100)

Figure in the parantheses indicate percent

4.1.5 Family size of the respondents

The population distribution showed that the family size was greater in Deurali than Hupsekot (Table 6). The average family size of the surveyed sample was 6.79, particularly, 7.65, and 5.92 in Deurali and Hupsekot respectively.

Table 6. Family size of the respondents in the study area (2013)

Family Size	VDCs	
	Deurali	Hupsekot
Average size (Mean±SD)	7.65±3.66	5.92±1.86
Minimum	3	3
Maximum	19	12
Modal size	6	5

4.2 Number of economically active population (16-59 year) in different occupation in the study area

Agriculture was the major occupation for the economically active family members in the study area. Majority of the economically active population were living through Remmitance (31.25%) followed by Agriculture (23.75%) and Service (21.25%). Involvement in agriculture was more (30%) in Hupsekot V.D.C.s as compared with (17.5%) in Deurali (Table 7). Number of person in agricultural activity was declined from year after year because of the lower profit from agriculture as compared to other livelihood options like wage laboring, remittance and service. The detailed of the livelihood options of the sampled households was shown in the Table 7.

Table 7. Number of economically active population (16-59year) in different occupation (2013)

Occupation	V.D.Cs		Total
	Deurali	Hupsekot	
Agriculture	7(17.5)	12(30)	19(23.75)
Wage labor	4(10)	3(7.5)	7(8.75)
Service	9(22.5)	8(20)	17(21.25)
Business	3(7.5)	4(10)	7(8.75)
Remittance	15(37.5)	10(25)	25(31.25)
Others	2 (5)	3(7.5)	5(6.25)

Figure in parentheses indicate the percent

4.3 Change in major source of livelihood options in the study area

Before and after comparison of the major livelihood options showed that the dependency upon the agriculture as a primary means for sustaining their livelihood options has declined from 60.955 percent to 24.46 per cent. The farmers have now diversified the way of living from just farming to farming plus other activities. The before and after comparision also showed that the dependency on Farming+Remitence has increased from 12.33 per cent to 28.975 per cent.

Diao et al. 2007; Wiggins 2011 reported that small farmers tend to spend extra income locally, on construction materials, locally made furniture, entertainment, etc., thereby stimulating local (small-scale) business and job creation.

Table 8. Change in the Livelihood options of the population of the sampled households shown in the study Area (2013)

Livelihood options	Deurali		Hupsekot		Average		Mean difference	T-stat (P- Value)
	Before 10 years	At present	Before 10 years	At present	Before 10 years	At present		
Farming	167(55.11)	58(19.14)	157(66.80)	70(29.78)	(60.955)	(24.46)	2.76	2.13 (0.000)***
Farming +Wage labor	22(7.26)	15(4.95)	31(13.19)	20(8.51)	(10.225)	(6.73)	1.87	1.9(0.000)***
Farming +Service	39(12.87)	40(13.20)	12(5.10)	35(14.89)	(8.985)	(14.045)	1.47	1.14 (0.029)**
Farming+Business	7(2.31)	26(8.58)	12(5.10)	11(4.68)	(3.705)	(6.63)	0.98	0.84 (0.46)
Farming+Business+Remmittance	6(1.98)	32(10.56)	0(0)	11(4.68)	(0.99)	(7.62)	3.12	2.31 (0.000)***
Farming + Remittance	45(14.85)	115(37.95)	23(9.81)	47(20.00)	(12.33)	(28.975)	2.45	1.58(0.041)**
Farming + Business + Service	17(5.62)	9(2.97)	0(0)	12(5.10)	(2.805)	(4.035)	0.47	0.91 (0.35)
Farming +Remittance + Service	0(0)	8(2.65)	0(0)	29(12.36)	(0)	(7.505)	1.02	1.63(0.035)**
Total	303(100)	303(100)	235(100)	235(100)	(100)	(100)		

*** Significance at p= 1%; ** Significance at p = 5%, Figure in parenthesis indicate the percentage

4.4 Average size of holding

Average size of own holding was 0.59 ha before and 0.48 ha at present in Deurali V.D.C and 0.68ha before and 0.53 ha at present in the Hupsekot (Table 9). The study revealed that as the time passes farmer lose their ownership over the land. There was also decline in the average cultivated land in the study area. Paired t-test was done for Before After comparison on the combining the value of Before 10 years and at present of two VDCs.

Table 9. Average size of the holding in the study sites (2013)

	VDCs				Before after comparison by paired t- test	
	Deurali		Hupsekot			
	Before	Present	Before	Present	Mean difference	T-Stat (P- value)
Owned land holding	0.59±0.039	0.48±0.037	0.68±0.063	0.53±0.053	1.24	2.54 (0.047)**
Cultivated land	0.79±0.069	0.63±0.051	0.56±0.060	0.48±0.065	2.14	3.23 (0.000)***
Shared in land	0.36±0.070	0.22±0.028	0.19±0.035	0.1±0.017	1.84	1.67 (0.039)**
Irrigated land	0.57±0.044	0.39±0.044	0.47±0.048	0.39±0.055	2.67	2.87 (0.001)***
Unirrigated land	0.41±0.052	0.33±0.053	0.42±0.047	0.26±0.033	3.42	1.49 (0.013)**

*** Significance at p= 1%; ** Significance at p = 5%

4.5 Area and productivity analysis of wheat over the time in the study sites

The study revealed that both area and productivity was in declining trend over the time. The study found that the average area allocation for Wheat ($p<0.05$) across the study site has been decreasing significantly over last five years .The negative value of the slopes indicates the decreasing trend on area and productivity allocation over the time.

Sinha and Swaminathan (1991) showed that an increase of 2 ^{0}C in temperature could decrease the rice yield by about 0.75 ton/ha in the high yield areas; and a 0.5 ^{0}C increase in winter temperature would reduce wheat yield by 0.45 ton/ha. Similarly, Rao and Sinha (1994) showed that wheat yields could decrease between 28 to 68% without considering the CO_2 fertilization effects; and would range between +4 to -34% after considering CO_2 fertilization effects. Also, Aggarwal and Sinha (1993) using WTGROWS model showed that a 2 ^{0}C temperature rise would decrease wheat yields in most places in India.

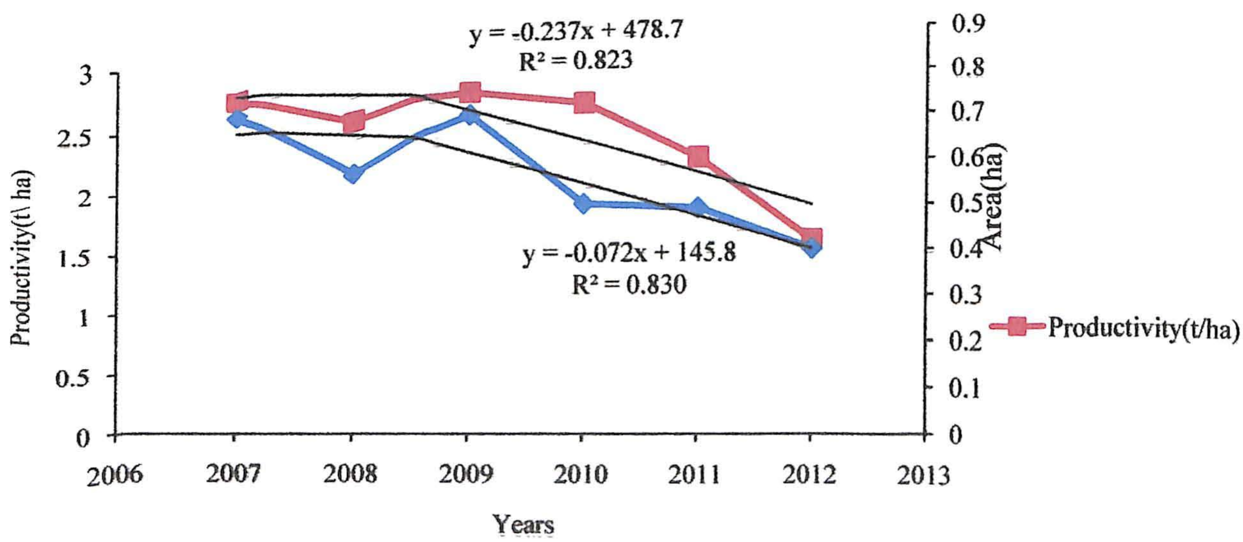


Figure 8. Trend of wheat productivity and area in the study sites

4.6 Crop rotation adopted by farmers

Various cropping pattern were found in the study area. Somewhat different cropping pattern was reported by the farmer as compared to the past. Almost all farmer planted paddy and wheat. New crop like rajma was cultivate in recent year. Farmers prioritized Rice crop in any situation at first, if rainfall was on time. Those farmers who establish the tube well for irrigation purpose did not change their cropping pattern; instead they cultivate different types of seasonal and off seasonal vegetables and fruit crops.

Table 10. Crop rotation adopted by farmers

	Before	Present
Irrigated medium-low land	Rice-Wheat-Maize Rice-Wheat+Potato-Maize Rice-Potato+Mustard-Maize Rice-Fallow-Maize Rice-Pea+Lentil-Maize Rice-Lentil+Wheat-Maize Rice-Mustard/Tori+Wheat-Maize Rice-Linseed-Maize Rice-fallow-Fallow	Rice-Wheat-Maize+Vegetable Rice-Potato-Maize Rice-Wheat-Maize Rice-Wheat+Potato-Maize Rice-Mustard-Maize Rice-Veg+Wheat-Maize Rice-Fallow-Maize Rice-Veg+Mustard-Maize Rice-Mustard+Wheat-Maize Rice-Pea-Maize Rice-Potato+Mustard-Maize Rice-Linseed+Lentil-Maize
Irrigated upland	Rice-Wheat-Maize Fingermillet-Fallow-Maize Rice-Wheat+Potato-Maize Rice-fallow-maize Rice-Mustard/Tori+Pea-Maize Rice-Wheat+Mustard-Maize Rice-fallow-Fallow Rice-Fallow-Blackgram Rice-Mustard-Maize	Rice-Wheat+Potato-Maize Rice-Vegetable-Maize Rice-Vegetable+Wheat-Maize Rice/Fingermillet-Fallow-Maize Rice-Wheat-Maize Rice-Mustard-Maize Rice-Fallow-Maize Rice –Lentil/Linseed-Maize Rice-Rajma-Maize Rice-Potato-Maize Rice-Pea-Maize Finger millet-Mustard-Maize Finger millet-Fallow-Maize
Unirrigated land	Finger millet-Fallow-Maize Finger millet-Mustard-Maize Rice+Fingermillet-Wheat+Mustard-Maize Maize-Lentil Rice-Wheat-Maize Maize-Black gram-Fallow maize-fallow-fallow	Rice-Lentil-Maize Finger millet-Rajma-fallow Sesame-Fallow Rice-Wheat-Maize Finger millet-Black gram Rice/Finger millet-Fallow-Maize Finger millet+Mustard-Fallow Rice-Mustard-Maize Rice+Finger millet-Mustard-Maize Finger millet-Mustard-Maize Maize-fallow-Fallow

4.7 Change in planting method and time

But due to the shift in the intensity and timing of monsoon, the planting of rice was delayed which consequently delayed wheat sowing too. With regards to paddy transplantation, the appropriate time schedule is in Nepal 15th June to mid July. Farmers used to plant wheat after harvest of rice in late November. Delayed wheat had to cope with drought and extreme hot wind that resulted in decreased yield. So, majority of the farmers have stopped the cultivation of wheat. Similarly, some farmers have adopted surface seeding of wheat at high soil moisture due to late monsoon that used to hinder land preparation and seed sowing on time. Most of the farmers were experiencing shift in monsoon season by more than one month. With regards to wheat cultivation, the appropriate time schedule is in Nepal 15th November but about 38% farmers in the study site were forced to plant rice by 15 days and 35 % farmers were able to plant rice by about one month delay

4.8 Availability of irrigation in the study sites

The availability of irrigation in the study site is scanty. Farmers depend on monsoon for the transplatation of rice.Because of the late onset of the monsoon farmers in the study sites have to depend on the irrigation and also face many problems due to unavailability of irrigation facility. Without the supplementary irrigation the yields would not have been increased. Respondents have perceived different views regarding irrigation. 68.75% of the respondents said that the availability of irrigation was high. 22.5% of the respondents replied that the availability of irrigation was medium and 8.75% of the respondents said that the availability of irrigation was low.

4.9 Changes in cropping calendar of Paddy and wheat

Onsets of timely rainfall are major factor for improving agricultural production. Changes in rainfall pattern adversely affect the normal cropping calendar of the farmer. There was almost one and more than one month shift in the cropping calendar of the farmer due to late rainfall.

Table 11. Changes in cropping calendar of paddy

Conditions	Seed Sowing	Harvesting
Normal Monsson	mid June to mid July	Late September to October
Late onset of Rainfall	July to early August	Late October to November

Table 12. Changes in cropping calendar of wheat

Conditions	Seed Sowing	Harvesting
Normal	2nd week of November	3rd week of March
Late onset of Rainfall	Last week of Nov to 1st week of December	Till 3rd week of April

4.10 Paired sample test on production of paddy before 10 years and at present

Studying the paired sample test on production of paddy before 10 years and now, there seems a significant effect. The value of mean difference is 1.278 which clearly indicates that there is a significant effect of some variables in the production of paddy. The p value of the effect on the production of paddy is 0.043 which shows it is significant at 5% level of significance.

Table 13. Analysis of the production of paddy before 10 years and at present

Statistics	Value
Mean difference	1.278
Standard deviation of mean difference	4.61728
Standard error mean	0.52280
t – value	2.127
Degree of freedom	79
Sig(2- tailed)	0.043**
Correlation	0.588

**Significance at 5% level of Significance

4.11 Paired sample test on production of wheat before 10 years and at present

Studying the paired sample test on production of wheat before 10 years and now, there seems a significant effect. The value of mean difference is 1.139 which clearly indicates that there is a significant effect of some variables in the production of wheat. The p value of the effect on the production of wheat is 0.038 which shows it is significant at 5% level of significance.

Table 14. Analysis of the production of wheat before 10 years and at present

Statistics	Value
Mean difference	1.139
Standard deviation of mean difference	4.61728
Standard error mean	0.52280
t – value	2.127
Degree of freedom	79

Sig(2- tailed)	0.038**
Correlation	0.588

**Significance at 5% level of Significance

4.12 Impacts of temperature and rainfall variation in paddy production

In this study, impacts of cumulative rainfall and temperature on paddy from tillering to milking stage were studied. With the observation of the 22 years of production data i.e. from 1990–2012, regression analysis was done and it was found that best fitted data in Ordinary Least Square (OLS). It was found that the model has R-square of 0.64 indicating 64 percent change in productivity of paddy in Nawalparasi district is affected by the variables area, rainfall, temperature and time trend.

Table 15. Impact of temperature and rainfall variation in paddy production

Variables	Coefficient	Std error	T-stat	P > |t|
Constant	-8.451708	5.060391	-1.67	0.113
Ln A	1.785782***	.3250815	4.26	0.001
Ln PR	0.396487	0.332004	0.89	0.384
Ln Temp	1.89885**	0.3372635	1.27	0.041
T	0.399055***	.0052595	5.12	0.000

***Significant at P = 0.001 **Significant at P = 0.05

The model becomes

$$LnYH = -8.451708 + 1.785782LnA + 0.396487LnPR + 1.89885LnTemp + 0.399055LnT$$

The study found that the productivity and area of paddy cultivation goes in same direction. The elasticity of Area is 1.78 indicating that 1% change in Area will change the productivity of paddy by 1.78%. Similarly 1% change in the Rainfall will change the productivity by 0.39%. Likewise the elasticity of temperature is 1.89 indicating that 1% change in Temperature will bring 1.89 % change in paddy productivity. The productivity of paddy will change by 0.39% per year.

Saseendran, *et al.* (2000), with the climate change scenario studied, the rice maturity period is projected to shorten by 8% and yield increase by 12%. When temperature elevations only are taken into consideration, the crop simulations show a decrease of 8% in crop maturity period and 6% in yield. This shows that the increase in yield due to fertilization effect of elevated CO_2 and increased rainfall over the state as projected in the climate change scenario nearly makes up for the negative impact on rice yield due to temperature rise. The sensitivity experiments of the rice model to CO_2 concentration changes indicated that over the state, an increase in CO_2 concentration leads to yield increase due to its fertilization effect and also enhance the water use efficiency of the paddy. The temperature sensitivity experiments have shown that for a positive change in temperature up to 5°C, there is a continuous decline in the yield. For every one degree increment the decline in yield is about 6%.

4.13 Impacts of temperature and rainfall variation in wheat production

In this study, impacts of cumulative rainfall from CRI to heading Period and temperature of post anthesis period on wheat was studied. With the observation of the 21 years of production data i.e. from 1990–2010, regression analysis was done and it was found that best fitted data in Ordinary Least Square (OLS). It was found that the model has R-square of 0.73 indicating 73 percent change in productivity of wheat in Nawalparasi district is affected by the variables area, rainfall, temperature and time trend.

Table 16. Impact of temperature and rainfall variation in wheat production

Variables	Coefficient	Std error	T-stat	P > |t|
Constant	-8.451708	5.060391	-1.67	0.113
Ln A	1.535782***	.3250815	4.26	0.001
Ln PR	0.426487	0.332004	0.89	0.384
Ln Temp	1.79885**	0.3372635	1.27	0.041
T	0.339055***	.0052595	5.12	0.000

***Significant at P = 0.001 **Significant at P = 0.05

The model becomes

$$LnYH = -8.451708 + 1.535782LnA + 0.426487LnPR + 1.79885LnTemp + 0.339055LnT$$

The study found that the productivity of Wheat and Area under wheat cultivation goes in same direction in Nawalparasi District. The elasticity of Area is 1.53 indicating that 1% change in Area will change the productivity of wheat by1.53%. Similarly 1% change in the Rainfall will change the productivity by 0.42%. Likewise the elasticity of temperature is 1.79 indicating that 1% change in Temperature will bring 1.79 % change in wheat productivity. The productivity of wheat will change by 0.33% per year.

Lobell *et al.* (2005) used CERES-Wheat simulation model for the climate trend effect on wheat production in the Mexico region. They studied the climate trend and wheat yield for the last two decades from 1988-2002. They found that the climate had favored during the two decades and resulted in 25% increase in wheat production. Piya *et al.* (2011) also found that the effect of increase in temperature and rainfall was positive for wheat production in case of Nepal.

4.14 Analysis of the change in maximum and minimum temperature for last 30 years in Dumkauli Meteorological Station, Nawalparasi

4.14.1 Analysis of the change in maximum temperature

For analyzing the trend of the maximum temperature, the temperature data of last 30 years was taken from the Dumkauli Meteorological Station, Nawalparasi. The trend analysis showed that there was no change in maximum temperature in the last 30 years but maximum temperature during wheat growing season decreases by 0.011°C per year. The trend analysis strongly support the farmer perception that summer was hotter and winter was less cold as compared to the past.

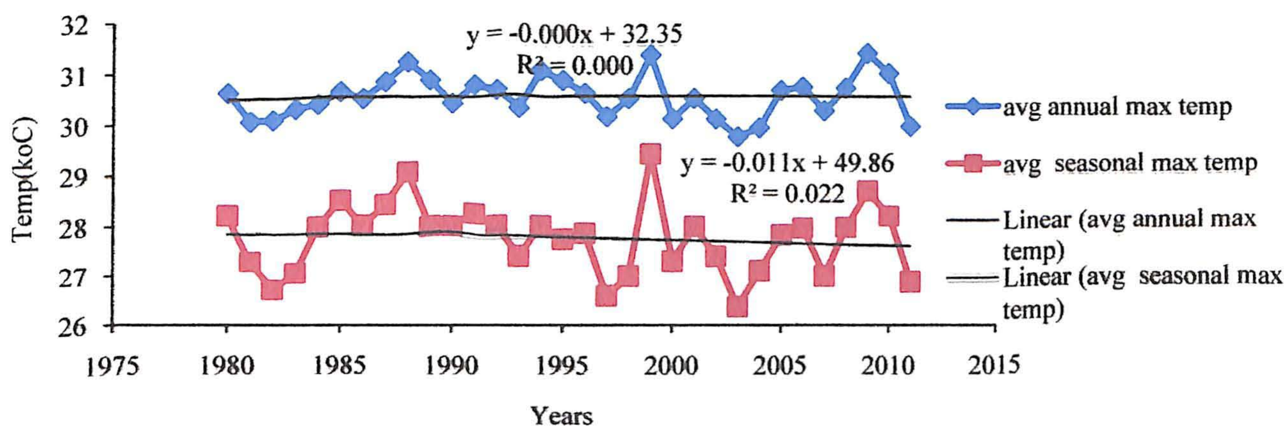


Figure 9. Trend analysis of the maximum temperature

Sharma *et al.* (2000) reported that the increasing trend of average temperatures during that period was primarily due to the increasing trend of maximum temperatures and there was no increasing trend of minimum temperatures. Similarly, Malla, 2007 also reported that Nepal's temperature has increased by 0.7^0 C during last 30 years (1975 to 2005). It means the average temperature increased as 0.06^0C per year and in particular, 0.04^0 C/year in Terai and 0.08^0C/year in Himalayas.

4.14.2 Analysis of the change in minimum temperature

The trend analysis showed that the minimum temperature in the last 30 years increased by 0.014 but during the average seasonal minimum temperature increased by 0.028°C per year as shown in figure 3. The trend analysis strongly support the farmer perception that summer was hotter and winter was less cold as compared to the past.

Sharma *et al.* (2000) reported that there was no increasing trend of minimum temperatures. While Malla, 2007 reported that Nepal's temperature has increased by 0.7^0 C during last 30 years (1975 to 2005).

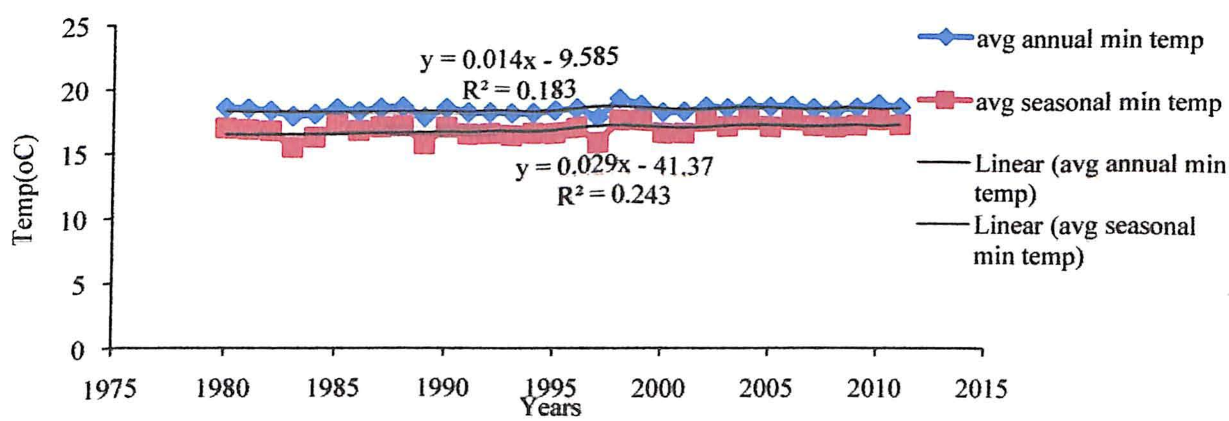


Figure 10. Analysis of the change in minimum temperature

4.14.3 Analysis of the change in the rainfall

Analysis of the rainfall data of last 30 years of the Dumkauli station shows that there was irregular pattern of rainfall as shown in figure 4. Total rainfall, pre-monsoon (March-May), monsoon (June-September), post monsoon (October-November) and winter (December-February) rainfall all were varied across the time horizon. Winter rainfall shows the decreasing trend (0.123mm per year) but the analysis of the all other rainfall showed the increasing trend over the years. The trend analysis shows that total rainfall was increased with 12.63.mm per year in Dumkauli station.

A study done by MoPE, 2004 based on the precipitation records from 80 stations for the period 1981-1998 across Nepal revealed that the hills and mountains in the north showed positive trends while the plains in the south were experiencing negative trends. Similarly, Shrestha *et al.,* 2000; Kripalani *et al.,* 1996 found that the precipitation fluctuation in Nepal is not the same as the all-India precipitation trend; but it is well related with rainfall variations over northern India.

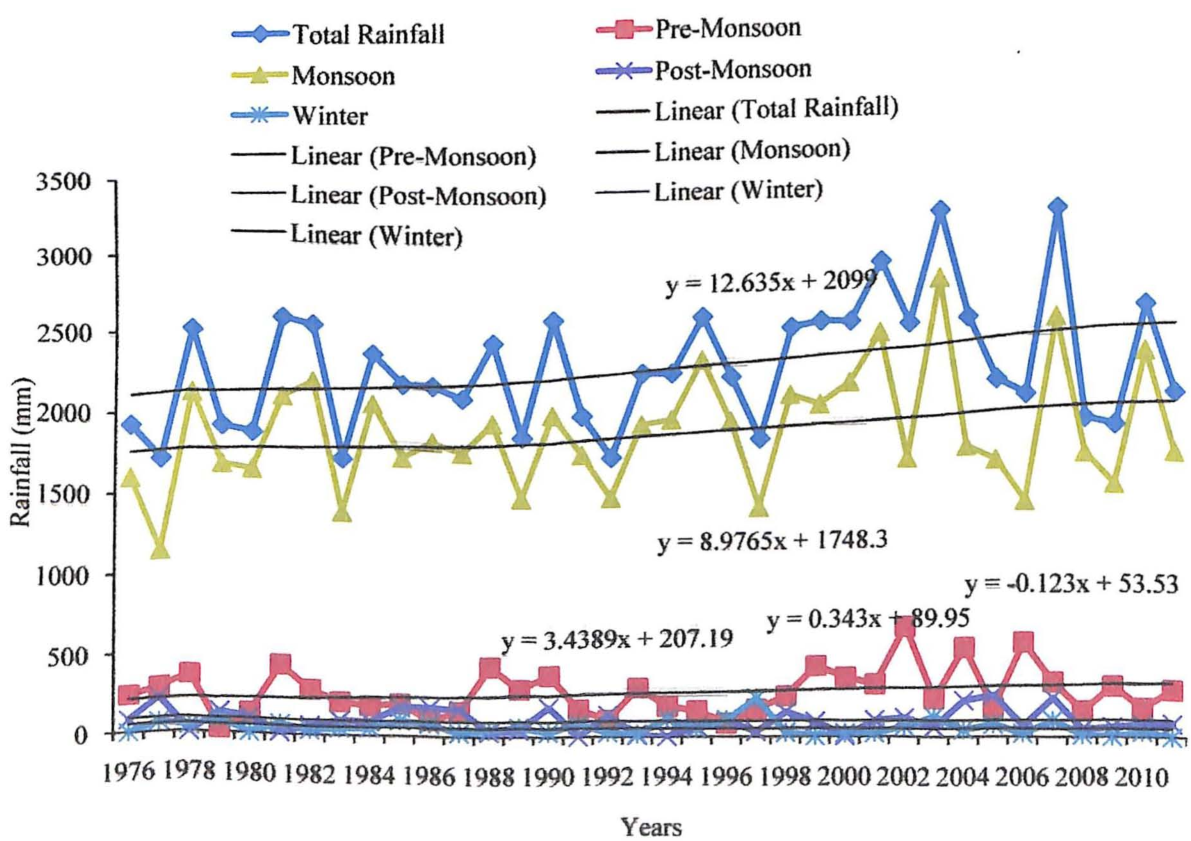


Figure 11. Analysis of the change in the rainfall

4.15 Adaptation measures undertaken by farmers

Farmers are also adapting the effects of climate change based on their local knowledge. Local knowledge and innovations can offer important insights to solve the big problems so they should be promoted instead of being ignored or subsided. Effects of gradual increase in temperature and erratic rainfall patterns have been increasing in agriculture and livelihood of farmers in Girubari watershed area. Most farmers have perceived changes and are trying their best to adopt the changes based on their local knowledge. Long term experiences in farming and interactions between the climate and crops helped farmers to shape their perception of climate change (Dahal, 2005).

4.15.1 Adoption of new varieties

Several modern varieties of rice have been introduced in Nepal to increase the productivity, fulfill the growing demand of increasing population and to adopt the changing environment. Besides the yield, farmers consider various characteristics such as drought tolerances, disease resistance and insect/pest resistance in adopting modern varieties (Joshi and Pandey, 2006). Farmers were used to cultivate local landraces of rice having specific requirements of rainfall and temperature that were highly affected by erratic rainfall resulting lower productivity. Due to continuous cultivation of improved varieties, local landraces of rice such as Ghaiya, Anadi, Mansar, Padheni, Dudharaj, Sattari, Thapachini, Batisara, Golaraj, Mansara, Achhami Masino, Kanchhi Masino etc. have been lost. Farmers adopted improved and hybrid crop varieties instead of local landraces to obtain more yield.

Similarly, several modern varieties of wheat have also been introduced to increase the productivity, fulfill the growing demand of increasing population and to adopt the changing environment. Adaptation of altered cultivars allows low-and mid-to high-latitude cereal yields to be maintained at or above baseline yields for modest warming (IPCC, 2007b). Farmers in the Girubari watershed area used to cultivate local variety of wheat having specific requirements of rainfall and temperature that were highly affected by erratic rainfall resulting lower productivity. As a result, farmers adopted drought and other stress resistant/tolerant improved varieties of wheat. Due to continuous cultivation of improved varieties, local landraces have been lost. Farmers adopted improved and hybrid crop varieties instead of local landraces to obtain more yield. Farmers replaced the variety for the improved and hybrid one due to poor productivity of the local variety.

4.15.2 Crop diversification

The erratic Climatic variation has affected regular crop cultivation in Girubari watershed area. Similarly, several farmers have started sugarcane farming instead of rice, wheat and maize. Similarly, some farmers started cultivating perennial fruits like banana and pineapple which are less sensitive to climate change. The farmers of the rice-wheat belt started to diversify agriculture by including short duration crops such as potato, soybean, bean, cowpea, pea, mustard and maize into different combinations.

4.15.3 Reforestation and afforestation on degraded land

In the past, increased frequency and intensity of floods used to destroy large areas of cultivated land in the Girubari watershed area which demanded the communities to protect their land from floods and landslides. Based on the needs of the communities, gabion wire boxes filled with rocks were placed in riverbanks to divert the stream flow during flood periods.

Communities has identified tree planting as an integral activity for coping and adaptation to prevent soil erosion and landslides in the future. So, tree planting has been done on both community and private lands. The preferred trees included fodder, timber and fruit species. The community members have also promoted grass species in plantations which effectively checked soil erosion. They have formed Community Forest User Groups to manage the existing forest, which didn't exist in the past. Moreover, they have controlled the intrusion by outsiders and locals to collect forest products illegally. Similarly, Sloping Agricultural Land Technology has been adopted in the area through which farmers have been producing multipurpose crop species including fodder while arresting the top soil from erosion and minimizing the possibility of landslides.

Slash and burn agricultural system was a common practice among many indigenous communities in the study area. Slash and burn practices for the expansion of agricultural land was one of the chief causes of deforestation and GHG emission and thus, discouraged though legal as well as technical measures to slow down the deforestation in the hills.

4.15.4 Application of pesticides and chemical fertilizers

Farmers perceive that there was increase incidence of disease, pest and weeds in the crop field. Appearances of weeds in crops field was more severe, they relate that drought and use of modern varieties and chemicals were responsible for the increased intensity of the weeds. In order to increase the agricultural production they apply more chemical fertilizers and pesticides in their crop field. Farmers use excessive amount of chemical fertilizers to increase the production. The use of Pesticides was mainly for masking the weeds those they were not appeared before.

4.15.5 Zero tillage operation

Results done in the study area showed that very few farmers have started practicing Zero tillage operation. This may be also due to the fact Excessive tillage destroy the structure of the soil and it also incur heavy cost to the farmer which forces them to adopt the moisture conserving practice from zero tillage operation. This operation also reduces the water requirement thus reduces the cost of irrigation.

4.15.6 Cropping calendar

There was almost one and more than one month shift in the cropping calendar of the farmer due to late rainfall. Farmers waited for onset of monsoon for sowing of crops but due to the lack of timely rainfall, they were compelled to change their usual cropping calendar. Farmers reported that, they were unable to transplant their rice crop in the 15^{th} Asar and they were compelled to transplant their crops even up to the first week of Bhadra (3rd week of August). Late onset of monsoon result in transplanting of old age seedlings with weak crop growth and resulted in poor harvest. Occurrence of dry spells was responsible for reduced soil moisture and stunted plant growth.

Farmers also changed their usual cropping calendar for wheat up to the first week of December, but there was poor yield if wheat was sown after November 15. Lack of winter rainfall was also one of the important reasons for declining the productivity of wheat.

4.15.7 Change in cropping pattern

Changing sowing/ planting date and using different variety of same crop or introducing new crop species are some adoption measures in agriculture (Reilly and Schimmelpfennig, 1999). Farmers follow rice-wheat-rice/maize cropping pattern in *Khet* at the time of normal rainfall in the past but due to the increasing incidence of drought and late rainfall, farmers were unable to follow the normal cropping pattern.

Moreover, farmers couldn't mange irrigation facilities during rice plantation and had to wait for the rain to occur which forced them to change the Cropping pattern. As they changed the cropping pattern from rice-wheat-maize to rice-wheat/maize in order to manage time and water for proper growth and development the crops. This helped them to get good harvest and cope with the effects of late rainfall. Nepalese farmers have also adopted the changes in cropping pattern and crop adjustments (Regmi *et al.,* 2008).

Table 17. Change in cropping pattern in Girubari catchment area over the last 10 years

Land type	Cropping pattern before 10 years	Cropping pattern at present
Pakho bari (Unirrigated land)	Maize – Finger millet – Potato Maize –Finger millet –Wheat	Maize – Finger millet Finger millet – Potato
Khet (Irrigated land)	Main season rice – Wheat – Maize Main season rice – Fallow- *Chaite* rice	Sugarcane as a whole year Main season rice- potato/ mustard- -maize

4.16 Analysis of the factors affecting adaptation strategies

Some farmers in the study area were seen to adapt the adaptation strategies while some others do not adopt any adaptation strategies. Those farmers who adopt the adaptation practices were assigned value 1 and those who do not adopt any strategies were assigned value 0. There were many factors influencing the adaptation strategies, such as economically active members, education, farm size, annual household cash earning, credit and training and extension.

Table 18. Statistical description of the different variables used in logit model

Variables	Mean	Standard error
Adaptation strategies	0.58	0.56
Number of economically active family members	3.35	.20
Education	4.4	0.47
Farm size	15.425	1.02
Annual household cash earning('000)	68.26	48.731
Credit	0.4125	0.56
Training and extension	0.425	0.56

Table 19. Logit regression results to identify the factor influencing for practicing more adaptation strategies to the climate change impacts in agriculture in the study area (2012)

Variable	Coefficients	Z	P>|Z|	Standard error	dy/dx[b]	S.E[b]	Z[b]	p>|Z|[b]
Economically active members	0.193	0.92	0.357	0.209	0.043	0.48	0.9	0.366
Education	1.065**	0.88	0.038	0.744	0.314	0.016	0.88	0.037
Farm size	0.293	2.13	0.578	1.077	0.303	0.143	2.12	0.114
Annual cash earning	0.512	1.43	0.038	0.015	0. 015	0.001	2.82	0.146
Credit	0.802	1.21	0.225	0.662	0.175	0.139	1.26	.208
Training/Extension	3.730***	4.32	0.000	0.864	0.661	0.90	7.29	0.000

Constant	-0.709	0.65	0.000	1.091	-	-

*** Significance at p= 1%; ** Significance at p = 5%

[b] Marginal change in probability (marginal effects after logit) evaluated at the sample means.

Table 20. Summary statistics

Number of observation(N)	80
Log likelihood	-33.035
LR chi2(6)	42.37(Prob>chi2 = 0.000)
Pseudo R^2	0.39

The Logistic regression analysis shows the variables training on adaptation practices and annual cash income was statistically significant for practicing adaptation strategies.

Training and extension activities (dummy) was statically significant ($P<0.01$) to practice different adaptation strategies. If the farmers receive formal or informal training and extension from different governmental and non-governmental organization, the probability to practice different adaptation strategies increases by 66%. Apata *et.al,(*2009) in South Western Nigeria and Maddison (2007) in Africa also reported that provision of extension facilities increases the probability of practicing different adaptation strategies by farmers.

The education level of the head of the household was positively significant ($P<0.05$) on the practicing adaptation strategies to climate change. According to the findings, keeping other factor constant, a unit increase in number of years of schooling would result in 31 % increase in the probability of adapting climate change. Deressa *et.al,*(2009) also reported that a unit increase in years of schooling would result in to the 1% increase in the probability of soil conservation and 0.6% increase in change in planting dates to adapt climate change.

CHAPTER-V

SUMMARY AND CONCLUSION

5. SUMMARY AND CONCLUSION

5.1 SUMMARY

Off late the impact of climate change on crop production and livelihood has been duely emphasized worldwide. In Nepal, Agriculture is the primary source of food and is greatly dependent on weather and nature. It is the mainstay of majority of population and source of livelihood for more than 65.6% of the people. Mainly the smallholders farmers who practice subsistence agriculture are heavily affected by the climate change.

80 respondents, 40 from each VDCs namely Deurali and Hupsekot were randomly selected. Secondary data regarding the temperature was obtained from DADO of Nawalparasi district, CBS, MoAC, Department of Hydrology and Meteorology, Kathmandu and precipitation data from APPRODITIEs (Asian Precipitation Highly Resolved Observational Data Towards Integration Evaluation of water resources).

Out of total land suitable for cultivation, only 63% is provided with irrigation facility in all round the year. Among the total population, 49.62 % were male and 50.38 % were female in the study area. The survey revealed that large proportion of the members of the sampled households (23.04%) were illiterate and lower proportion of the population attained University level education (3.71%). Majority of the respondents were Brahmin and Magar followed by Tharu and Dalit and Newar in the study area. Majority of the population (57.24%) was of economically active age. The percentage of economically active population was higher (61.05%) in Deurali VDC than Hupsekot (52.34%). Before and after comparison of the major livelihood options showed that the dependency upon the agricultural has declined from 60.955% to 24.46%. The study revealed that as the time passes farmer lose their ownership over the land. There was also decline in the average cultivated land in the study area. The cropping pattern has been found to change in recent year as compared to previous ones. Due to the shift in the intensity and timing of monsoon, the planting of rice was delayed which consequently delayed wheat sowing too.

The availabiltiy of irrigation faciltiy is scanty and farmers largely depend on monsoon for transplantation of rice. The change in rainfall pattern has adversely affected the normal cropping calendar of the farmer, in some case the shift in calendar being as big as one or more than one month. It has also been found that 64 percent change in productivity of paddy in Nawalparasi district is affected by the variables area, rainfall, temperature and time trend.

The elasticity of Area is 1.78 indicating that 1% change in Area will change the productivity of paddy by 1.78%. Similarly 1% change in the Rainfall will change the productivity by 0.39%. Likewise the elasticity of temperature is 1.89 indicating that 1% change in Temperature will bring 1.89 % change in paddy productivity. The productivity of paddy will change by 0.39% per year.

Similarly, it is found that 73 percent change in productivity of wheat is affected by the variables area, rainfall, temperature and time trend. The elasticity of Area is 1.53 indicating that 1% change in Area will change the productivity of wheat by1.53%. Similarly 1% change in the Rainfall will change the productivity by 0.42%. Likewise the elasticity of temperature is 1.79 indicating that 1% change in Temperature will bring 1.79 % change in wheat productivity. The productivity of wheat will change by 0.33% per year.

The trend analysis strongly support the farmer perception that summer was hotter and winter was less cold as compared to the past. The trend analysis shows that total rainfall was increased with 12.63.mm per year in Dumkauli station.

Farmers are also adapting the effects of climate change based on their local knowledge. Most farmers have perceived changes and are trying their best to adopt the changes based on their local knowledge. Farmers utilizes weeds and residues as mulching material to conserve moisture, plastic tunneling for vegetables, zero tillage operation, use of high yielding crop varieties, altering planting time in accordance with the onset of rainfall, increased use of chemicals in the field. they have also adopted the changes in cropping pattern and crop adjustments. The Logistic regression analysis shows the variables training on adaptation practices and annual cash income was statistically significant for practicing adaptation strategies.

5.2 CONCLUSION

The climate change issue is global, long-term and involves complex interaction between demographic, climatic, environmental, economic, health, political, institutional, social and technological processes. It has significant implications in the context of sustainable development. Climate change will impact on social, economic and environmental systems and shape prospects for food, water and health security especially of smallholder farmers. Climate change and variability may result in irreparable damage to arable land and water resources with serious local consequences for food production.

Smallholder and subsistence farmers will suffer impacts of climate change that will be locally specific and hard to predict. Small farm sizes, low technology, low capitalization, and diverse nonclimate stressors will tend to increase vulnerability, but the resilience factors—family labor, existing patterns of diversification away from agriculture, and possession of a store of indigenous knowledge—should not be underestimated.

Now there is dire need of a genuinely interdisciplinary attempt to apply the rapidly growing scientific knowledge of the effects of climate change on crops and livestock to the ''complex, diverse and risk-prone'' farming systems of developing countries. This will not only improve knowledge of impacts, but just as important, aid in building adaptive capacity at all levels including that of farmers themselves.

There is significant concern about the impacts of climate change and its variability on agricultural production. The impact of Climate change on smallholder farmers is grave. There is inadequate awareness even among the professionals working both at grass roots and at national level. There is a need to raise the awareness of climate change and its impact among all types of stakeholders.

The local community in, Nawalparasi has perceived climate change affecting the agriculture and livelihood of them. the frequency of natural disasters has increased affecting total cultivated area and productivity of both paddy and wheat. The farmers have started discounted their livelihood options from agriculture to the less risky and more return oriented occupation. These losses will be felt most profoundly in smallholder farmers with low capacity to cope and adapt.

Farmers have been using their indigenous knowledge and experiences in implementing adaptation measures at grassroot level. Various adaptaion strategies have been adopted. So, it is important to plan sustainable adaptation strategies based on scientific research and make farmers prepared to cope with the increasing impacts of climate change in coming days. Adaptation strategies, both on-farm and via market mechanisms, will be important contributors to limiting the severity of impacts.

5.3 POLICY SUGGESTIONS

The impact of climate variable is significant on crop production and livelihood of smallholder farmers. To add more to the grief, the ferquency of climatic hazards like drought, landslides, flood, flashflood, hurricanes, erratic rainfall are reported to be incresing. Therefore, to cope with the negative impact of climate change, policy makers in future both in global and local level need to focus their priorities on following:

- The negative impact of climate change can be minimised by adopting different resistant varieties. For eg heat resistant/tolerant varieties to cope with increasing tempreature, disease resistant varieties to fight with different disease attack, submergence varieties of rice in flood prone areas can be judiciously used to minimise the adverse effect of climate change.
- Technolgical adoption like Zero tillage, application of irrigation and other technological innovation should be made readily available to smallholder farmers to fight with the adversities of climate change.
- The provisions should be made to make quality variables inputs.
- Training related to adoption techniques under changed climatic condition should be given to the smallholder farmers.
- Awareness campaign about climate change should be organized time to time for better understanding in famers.
- Credit and insurance policies should be developed to cope with negative consequences of climate change mainly floods, landslides, cloudbrust, hailstorm, hurricanes etc.

- The provisions need to be madefor the farmers to aceess with short term weather forecast data that helps to reduce climatic uncertainities.
- Improved provisions of extension services should be made available for the farming practices.
- Development of catchment management plans should be made feasible to improve water availability for small scale irrigation system ysing pumps, intergrating conservation farming and agro-forestry
- Further research works should be carried out on regarding potential area under crop cultivation, future demand and supply of the product under the climate change.

CHAPTER-VI

BIBLIOGRAPHY

BIBLIOGRAPHY

Abrol, Y. P., and K. T. Ingram. 1996. Effects of higher day and night temperatures on growth and yields of some crop plants. *In*: F. Bazzaz. and W. Sombroek (eds.) Global Climate Change and Agricultural Production: Direct and indirect effects of changing hydrological, pedological and Plant Physiological Processes. John Wiley & Sons Ltd, West Sussex, England,UK. pp. 123-140.

Agrawala,K and M.Karla. 1994. Development and climate change in Nepal: Focus on water resources and hydropower. Website: http://www.oecd.org/dataoecd/6/51/ 19742202.pdf. (Retrieved on June 1, 2008).

Alford, D. 1992. Hydrological aspects of the Himalayan region. International Centre for Integrated Mountain Development. Water Resources (June) 12:15-25

Alkire, S. and M. E. Santos. 2010. Human development initiative and multidimensional poverty index. website: http://www.ophi.org.uk/wpcontent/uploads/Nepal.pdf (Retrieved August 8, 2010).

Anonymous, 2007. Greenhouse gases. Website http://www.solarnavigator. net/ greenhouse_ gases. htm. (Retrived on June 19, 2010).

Aydinalp, C. and M.S. Cresser. 2008. The effects of global climate change on agriculture. American-Eurasian Journal of Agriculture and Environment Science. 3(5): 672-676.

Baidya, K.S. and J. Karmacharya. 2007. Observed and Future Climate Change in Nepal. *In*: Climate Change and Human Health: Potential Impact, Vulnerability and Adaptation in Nepal. Proceeding of National Workshop held at Kathmandu, Nepal.19-21 December, 2007. pp.22-23.

Barker, V.A. and E. Siri. 2003. Mainstreaming adaptation to climate change in the development process. M.S. Thesis,Texas University. 150p.

Briggle, K.S., 1980. Climate change impacts in Asia. *In*: M..A. Toman and U.Chakravort (eds.) Asia and Global Climate Change. Yashahama University, japan. pp 110-125.

CEN, 2003. Climate Change: A Nepalese Perspective.Clean Energy Nepal , Kathmandu, Nepal.115p.

Crutzen, S.M., and S. Graedel. 1993. Cliamte change and disease management. Annual Review of Phytopathology. Website: www.climatechangepatho.org/html (Retrieved on February 1, 2009)

Cruz, R.V., H.Harasawa, M.Lal, S. Wu, Y.Anokhin,B. Punsalmaa, Y.Honda,M.Jafari,C. Li and N.Huu Ninh,2007: Asia. Climate Change 2007: Impacts Adaptations and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change., M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, United Kingdom and New Wor,USA. pp 496-506.

Curtin, P., S. Feierman, L.Thompson and Jan Vansina (1978). African History.London: Longman.

DADO. 2010. Annual Report. District Agriculture Development Office, Nawalparasi.82p.

Dahal, N and L. Khanal. 2010. Perceptions of climate change in Himalayas. Tiempo Bulletin. Issue number 26. pp 19-24. Website :www.tiempocyberclimate.org/ newswatch/feature050910.htm (Retrieved on August 2, 2010).

Dahal, N. 2005. Setting climate change adaptation policy in Nepal. *In*: G.R. Joshi (ed.), Nepal up in smoke: time for action on climate change. LIBIRD, Nepal.

Deressa, T., R. M. Hassan and C. Ringler. 2008. Measuring Ethiopian farmers' vulnerability to climate change across regional states, organized by Ethiopian Climate change concerned society,Vogar, Etiopia. 54 p.

DHM. 2004. Hydrological Records of Nepal. Department of Hydrology and meterology, Kathmandu, Nepal. 125p.

FAO. 1998. Mixed progress in hunger reduction in Asia and the Pacific: south Asia trails. FAO. Kathmandu, Nepal. Working Paper No. 04-10. Agricultural and Development Economics. FAO, Rome Italy.

FAO. 2001. Climate Change and Food Security: A Framework Document Summary, Interdepartmental working group on climate change. Website: http://www.fao.org/ clim/index_en.htm (Retrieved on July 27, 2008).

FAO. 2003. Strengthening coherence in FAO's initiatives to fight hunger (item 10). Conference Thirty Second session, 29 November to 10 December. Food and Agriculture organization of the Unites Nations, Rome.

FAO. 2004. World Agriculture: Towards 2015/2030. An FAO perspective. Bruinsma.ED. FAO, Rome and Earthscan, London. 520p.

FAO. 2007. Adaptation to climate change in agriculture, forestry and fisheries: perspective, framework and priorities, Food and Agricultural Organization of the United Nations, Rome. 30p.

FAO. 2008. Organic agriculture and climate change. Retrieved on Jan 10, 2009 from http://www.fao.org/DOCREP/005/Y4137E/y4137e02b.htm#89.

Gautam, A. K. and S. Pokhrel, 2010. Climate change effects on agricultural crops in Nepal and adaptation measures.Technical Working Group, Kathmandu; Nepal, Feb 23-24, 2010.

Gbetibouo, G.A., R.M. Hassan. 2004. Measuring the Economic Impact Of Climate Change On Major South African Field Crops: A Ricardian Approach. Global and Planetary Change 47. 9p.

Gurung G., 2008. Impacts of Climate Change:Website: www.practicalaction.org (Retreived on 17 march, 2009)

Gurung, G.B. and D. Bhandari. 2008. An Integrated Approach to Climate Change Adaptation. Magazine on Low External Input and Sustainable Agriculture. 24, 4. December, 2008.

Hulmes, J. 1996. Impacts of climatic change on world agricultural product market: estimation of macro yield functions. University of Manitoba,Canada. 23: 3-18.

IFAD (2001) *Rural Poverty Report 2001: The Challenge of Ending Rural Poverty* (International Fund for Agricultural Development, Rome)

IPCC. 2007a. Working Group II contribution to the Intergovernmental Panel on climate change fourth assessment report. Intergovernmental Panel on Climate Change Website: www.ipcc.ch/publications_and_data/ar4/wg2/en/contents.html (Retrieved on April 12, 2007).

IPCC. 2007b. Climate Change 2007: The physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Solomon.S., D.Qin, M.Manning,Z.Chen,M. Marquis,K..Averyt,M.Tignor and H.L.Miller(eds).Cambridge University Press, Cambridge, United Kingdom and New Work,NY,USA, , 996p.

IPCC. 2007c. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change., M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden.

IPCC. 2001a. Climate Change Summative Analysis. Intergovernmental Panel on Climate Change. Cambridge University Press. 23p.

IPCC. 2001b. Climate change 2001: Synthesis Report. In: R.T. Watson and T. Core (eds.), Contribution of Working Groups I, II and III to the Third Assessment Report of the Intergovernmental Panel on Climate Change'. Cambridge University Press, Cambridge.

IPCC. 2001c. IPCC special report: Land use, land-use change, and forestry.Website: http://www.ipcc.ch/pdf/special reports/spm/sres-en.pdf (Retrieved on May 2 2008).

IPCC. 2001d. The climate change 2001: The scientific basis. Cambridge University Press, Cambridge, United Kingdom. 881 p.

IPCC. 2001e. Climate change impacts in and around the globe. A review and analysis.

Ives, S. and K. Messerli. 1989. Fundamentals of weather in south Asia. Los Banos, Philippines, IRRI. pp. 269.

Joshi, N. P., K. Maharjan, and L. Piya. 2010. Poverty and food insecurity in Nepal: A review. Journal of International Development and Cooperation, 7: 1-19.

Kemp, D. (1994). Global Environmental Issues: A Climatological Approach. Chapter 3: Drought, Famine and Desertification. London & New York: Routledge.

Kemp,G., 1994. Climate change impacts on rice yield and production yield. Journal of Rural Development. 32: 17-29.

Lamichhane, R.B. and K.D. Awasthi. 2009. Changing climate in a mountain sub-watershed in Nepal. Journal of Forest and Livelihood. 8(1):9-105.

Lobell, D.B. and C.B. Field. 2007. Global scale climate–crop yield relationships and the impacts of recent warming. Climate of World. August 17: 20-35.

Maharjan, K. L., Joshi, N. P., and Piya, L. (2009): Sources of climate change, its impact, and mitigation issues in Nepal. International Conference on Climate Change, Livelihoods, and Food security. Institute of Development Studies, Jaipur, India.

Malla, G. 2008. Climate Change and its Impact on Nepalese Agriculture. The Journal of Agriculture and Environment. Government of Nepal, Ministry of Agriculture and Cooperatives. 9: 62-70

Malla, G.S. 2007. Climate Change and its Impact on Agriculture Sector in Nepal. *In*: Climate Change and Human Health: Potential Impact, Vulnerability and Adaptation in Nepal. Proceeding of National Workshop held at Kathmandu, Nepal. 19-21 December, 2007. pp 48-57.

Manandhar, S. 2009. Perception of and adaptation to climate change by farmers in different ecological zones of the western development region of Nepal. Thesis, M.Sc. Asian Institute of Technology (AIT), School of Environment Resources and Development, Thailand.

McCarl, B. A., R. M. Adams and B. H. Hurd. 2001. Global climate change and its impact on agriculture. A&M University, Texas, USA. 250p.

MoAC. 2010. Selected Indicators of Nepalese Agriculture and Population. Ministry of Agriculture and Cooperatives, Kathmandu, Nepal. 67p.

MoE. 2010. National adaptation program of action (NAPA) to climate change . Ministry of Environment, Kathmandu, Nepal. 12p.

MOEST. 2008. National Capacity Self –Assessment for Global Environment Management Nepal Stocktaking report: climate change: Jan, 2008. Ministry of Environment Science and Technology, Nepal.

MoPE. 2004. Initial National Communication to the Conference of the Parties of the United Nations Framework Convention on Climate Change. Kathmandu, Nepal. 69p.

Murdiyarso,D., 2000. Adaptation to climatic variability and change: Asian perspectives on agriculture and food securiy. McGraw-Hill Book Co.,New York,USA.63. 8p.

NARC. 2007a. Climate change and agriculture in Nepal. Environment Unit, Nepal Agriculture Research Council, Lalitpur, Nepal.

NARC. 2007b. Released and registered crop varieties in Nepal, Nepal Agricultural Research Council, Kathmandu.

NARC. 1999. Annual report. Nepal Agriculture Research Council, Khumaltar. 28 p.

Nawalparasi, 2006. District profile of Nawalparasi (*Jilla bastugat bibaran,Nawalparasi 2063*). 64 p.

Nayava, J.L., 1980. Climates of Nepal and their implications for Agricultural Development. Ph.D. Dissertation, The Australian National University, Canberra, Australia, pp 1-284.

Oliver, J and D. Hidore. 2003. An Integrated Approach to Climate Change Adaptation. Magazine on Low External Input and Sustainable Agriculture.24, 4. December, 2008.

Organic Consumer Association, 2008. Organic agriculture can help stabilize global climate change.Websitehttp://www.organicconsumers.org/organic/stabalize062404.cfm. (Retrieved on 10 Nov, 2008)

Pachauri, R.K., 1992. Global warming: impacts and implications for South Asia. *In*: J. Schmandt and J. Clarkson. (eds.) The regions and global warming: impacts and response strategies. Oxford UniversityPress, New York. pp. 140-167.

Piya, L., N.P. Joshi and K.L. Maharjan. 2011. Effect of Climate Variables on Yield of major Food Crops in Nepal. A Time Series Analysis. Journal of contemporary India Studies, Space and society,Hiroshima University. 1: 19-26.

Pokhrel, D. M. and B. Pandey, 2011. Climate change adaptation: strategic vision in agriculture. Journal of Agriculture and Environment. website: http://www.moac. gov.np/geed/art14.pdf. (Retreived on October 15,2011)

Practical Action, 2008. Fighting Salinity through Traditional Practices, Adapting Agriculture to Climate Change in SriLanka.Website: http://practicalaction.org/?id=climatechange_ricebiodiversity (Retrieved on July 23, 2008)

Practical Action, 2009. Temporal and Saptial Variability of Climate Change over Nepal (1976 – 2005. Website: www.practicalaction.org (Retreived on july 2, 2009)

Regmi, B.R., L. Sharma, S. Khadka. 2007. Climate Change Risk and Vulnerability in Nepal. *In*: Time for Action on Climate Change. Local Initiative for Biodiversity, Research and Development & Clean Energy (Nepal). pp 6-8.

Regmi, Bimal R., Thapa, Lalita., Sharma, Gyan B., & Khadka, Sudha. 2008. Climate Change Risk, Vulnerability and Adaptation Strategies at Community Level, LI-BIRD.

Schmidhuber, J. and F.N. Tubiello. 2007. Proceeding of the national level workshop on Global food security under climate change, organized by NAS, 20-26 july 2007. National Academy of Science, Kathmandu,Nepal. 5p

Sharma, A., 2007. Climate change scenario of Nepal. National Agricultural Research Council, Khumaltar, Nepal. 13: 124-131.

Shrestha, A. B., C. P. Wake, P. A. Mayewski and J. E. Dibbl. 1999. Maximum temperature trends in the Himalaya and its vicinity: An analysis based on temperature records from Nepal for the period 1971-94. 12: 277-278.

Shrestha, A. B., C. P. Wake, P. A. Mayewski and J. E. Dibbl. 2000. Precipitation Fluctuations in the Nepal Himalaya and its Vicinity and Relationship with Some Large Scale Climatological Parameters. International Journal of Climatology. Website:http://www3.intescience.wiley.com/journal/70500383/abstract?CRETRY=1&SRETRY0. (Retreived on June 25,2008)

Silwal, P. 2009. Assessment of Climate Change Vulnerabilities and Adaptation Option for Sustainable Livelihood. B.S. Thesis, Tribhuvan University, Institute of Forestry, Nepal. 98p.

Singh, I. L. 1985. Rainfall distribution. *In:* T. C. Majupuria (ed.) Nepal- Nature's Paradise. White Lotus Co. Ltd., Bangkok. pp. 56-58.

Smith, A.M., R.A. Brown, N.J. Rosenberg, R.C. Izaurralde and V. Benson. 2007. Climate change impacts for the conterminous in Florida USA: An integrated assessment. University of Oklahama. 69: 43-65.

Swaminathan, M.S. 2002. Climate change, food security and sustainable agriculture. Impacts and adaptation strategies. *In:* Climate change and India. Issues, concerns and opportunities [Shukla, P.R., S.K. Sharma and P. Venkata Raman (eds.)], Tata McGraw-Hill Publishing Companay Ltd, New Delhi, p.196-216.

Takhasaki,F. and E. Sekho. 1991. Change in Agricultural water demand and soil moisture in China over the last half-century and their effects on Agricultural production. Agri.Forest Meteorology. 118: 251-256.

TWG. 2010. Stocktaking report: Agriculture and Food Security. Thematic Working Group on Agriculture and Food Security (MOAC), National Adaptation Program of Action (NAPA) to Climate Change, Kathmandu, Nepal. 57 p.

UNFCC. 2007. Climate Change: impacts, Vulnerabilities and Adaptation in Developing Countries. United Nations Framework Convention on Climate Change. 65p.

Warrick, 1988. Economic Implication of Global Climate Change for World Agriculture. Journal of Agricultural and Resource Economics. 17 : 195-204.

Webersik, C. and M. Thapa. 2008. Nepal Climate Change and Security Factsheet, United Nations University- Institute of Advanced Studies, Climate Change Facts Sheets

Series 1. Website: http://www.ias. unu.edu/resource_centre/Nepal _Climate% 20 Change % 20 Facts%20 (Retrieved on June 21, 2010).

World Bank. 2002. World development indicators. Oxford University Press, New York. 6 p.

World Bank, 2008. Agriculture for development policy brief: Adaptation and mitigation of climate change in agriculture: website: http://siteresources.worldbank.org/ INTWDR2008/Resources/Brief_AdptMitClimateChng_web.pdf (Retrieved on Nov 8, 2008)

World Bank, 2009. Agriculture for Development, Overview. Website: http://siteresources.worldbank.org/INTWDR2008/Resources/27950871192111580172/WDROver2008-ENG.pdf (Retrieeved on Jan 10, 2009).

Xiao, G., Z. Qiang., Y. Yubi., Z. Hong., W. Runyuan. 2008. Impact of recent climatic change on the yield of winter wheat at low and high altitudes in semi arid northwestern China.Agriculture, Ecosystems and Environment, (XingXang University). 127: 5-24.

CHAPTER-VII

APPENDIX

APPENDIX

Appendix 1: Maximum temperature recorded in °C over the last 30 years (1980-2011) in Dumkauli Meteorological Station, Nawalparasi

Year (AD) /Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1980	22.5	25.8	30.6	38.3	35.5	33.6	33.4	32.8	32.4	30.7	27.9	24.3
1981	22.3	26.8	29.8	32.5	33.7	34.9	32.0	32.7	32.6	31.3	27.8	24.6
1982	23.6	24.2	29.0	33.7	37.2	33.6	33.4	33.9	32.0	30.8	26.6	23.2
1983	21.6	24.8	30.6	33.6	33.6	36.3	33.6	33.7	32.8	31.4	28.4	23.3
1984	21.7	24.9	32.2	37.2	34.1	32.6	32.4	34.2	31.6	32.0	28.0	23.8
1985	23.1	25.9	32.9	37.0	35.2	34.2	31.8	33.7	31.5	30.3	28.0	24.0
1986	23.3	25.5	32.0	35.2	34.5	36.2	32.5	33.1	31.6	30.1	27.8	24.1
1987	23.2	27.3	30.6	35.4	36.8	35.8	31.5	32.2	32.4	30.8	28.9	24.9
1988	24.6	27.5	30.7	35.8	34.9	34.1	32.6	32.4	33.4	33.0	30.1	25.4
1989	22.2	24.7	31.0	37.2	36.6	34.7	31.9	34.1	32.7	32.8	28.3	24.0
1990	24.2	25.0	29.1	34.4	33.8	34.8	32.4	33.1	32.3	31.0	29.8	24.8
1991	22.0	27.3	32.1	35.6	36.5	34.0	33.1	32.4	32.2	31.9	28.0	24.0
1992	22.2	23.5	32.6	37.8	35.6	36.3	32.8	32.7	32.1	30.5	28.0	23.5
1993	20.6	26.9	29.0	33.9	34.1	34.6	33.8	32.6	32.1	32.0	28.2	25.4
1994	23.2	24.9	31.3	35.9	37.1	34.9	34.4	34.2	32.5	31.6	28.4	23.9
1995	21.9	24.9	30.8	36.9	38.9	33.5	33.2	33.7	32.5	32.2	27.8	23.7
1996	21.4	25.0	31.3	36.1	37.2	33.9	32.9	33.3	32.9	30.0	28.3	24.6
1997	22.4	24.4	31.0	32.0	36.0	35.4	34.0	33.5	32.5	30.5	27.7	21.9
1998	20.2	25.6	28.4	33.7	36.1	36.5	32.3	32.6	33.6	32.8	28.7	25.1
1999	23.0	28.3	33.6	37.8	34.6	34.4	32.7	33.0	33.2	31.8	28.4	25.1
2000	21.6	24.0	30.8	34.6	33.5	33.6	32.9	32.7	32.1	32.6	27.9	24.5
2001	22.3	26.7	32.1	35.6	33.8	33.5	33.3	33.8	32.1	31.6	28	22.8
2002	22.5	25.8	31.1	33.6	33.1	34.3	32.5	33.4	32.5	30.9	27.8	23.2
2003	19	24.7	28.7	34.6	35.1	33.6	33.3	33.3	31.9	31.2	27.4	23.7
2004	20.7	25.6	32.8	33.0	34.3	33.7	31.9	33.8	32.4	30.2	26.7	23.5
2005	22.1	25.5	31.8	35.4	35.0	36.1	32.9	32.7	33.9	30.4	27.1	24.6
2006	22.5	28.1	31.8	34.2	34.7	33.8	34	34.5	32.3	31.7	27.1	23.6
2007	21.8	23.8	29.3	34.9	36	34.8	32.5	33.7	32.3	31.7	28.1	23.8
2008	22	24.4	31.7	36.1	35.7	33.7	33	32.8	33.6	31.9	28.5	24.7
2009	23.7	28.1	32.3	37.1	35.8	35.6	34.3	33	34.2	31.6	27.2	23.4
2010	20.1	25.9	33.2	38.3	36.2	36.4	33.5	33.1	32.1	31.5	27.6	23.7
2011	20.5	25.9	31.0	34.9	33.7	34.4	32.4	33.0	32.9	31.7	26.8	21.9

Appendix 2: Minimum temperature recorded in °C over the last 30 years (1980-2011) in Dumkauli Meteorological Station, Nawalparasi

Year (AD) /Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1980	8.9	11	14.7	20.2	23.6	25.5	26.3	25.8	24.6	20.1	13.7	11.1
1981	9.7	11.7	15.3	20.3	22.9	25.6	26	26.1	24.6	20.1	14	8.8
1982	9.7	10	14.8	19.7	22.4	24.7	26	26.2	24.6	19.7	15	10.6
1983	7.7	8.5	13.6	18.3	22.6	25.6	25.9	26.3	25.5	20.8	14.5	9.3
1984	7.6	9.8	14.9	19.5	24.4	25.4	25.3	25.9	23.6	21	12.8	10.4
1985	9.6	9.9	15.7	20.6	23.1	24.8	25.1	25.9	24.1	20.8	14.6	11.8
1986	9.9	11.2	14.7	18.6	22.1	26.2	25.4	25.4	24.1	19.5	15.2	10.8
1987	9.5	11.7	15.4	19	21.6	25.6	25.4	25.1	25.1	21.1	15.2	11.9
1988	9.6	12.1	15.4	19.6	23.4	25.2	26.1	25.7	25.2	20.8	13	11.7
1989	9	9.2	14.3	17	23.2	25.4	25.1	25.7	24.8	20.6	14.2	9.4
1990	10.2	11.7	14.5	19.1	23.3	26	25.8	25.8	24.8	19.9	14.8	10.6
1991	8.6	11.4	15.6	19.3	24.1	25.7	26	25.6	24.9	19.8	12.6	9.5
1992	9	10	14.6	19.6	22.8	25.1	25.2	25.7	24.3	20.9	14.6	10.6
1993	9.7	11.8	12.8	18.7	22.7	25.3	26.1	25.8	24.3	20.1	15.1	9.6
1994	10.3	10.4	16.3	18.5	23.3	25.6	26.2	26	24.4	19	13.1	9.9
1995	8.1	10.2	13.9	18.1	24.3	26.3	25.8	25.6	24.6	20.8	15.1	11.7
1996	9.9	11.6	16.3	17.8	23.3	24.7	25.9	25.7	24.6	20.3	14.8	9.6
1997	8	8.5	13.6	18.3	21.2	24.5	25.9	25.7	24.5	18.3	14.8	11
1998	9.3	11.1	14	19.2	24.1	26.5	25.8	25.8	25.4	22.9	17.5	10.7
1999	8.5	12.3	14	21.4	23.8	24.9	25.5	25.4	24.8	20.7	15.1	11.1
2000	9	9.3	13.4	19.3	23.9	25.1	25.7	25.5	24.2	20.6	16.5	9.5
2001	7.8	11	13.8	18.5	23.2	25.2	26	25.6	24.3	21.2	15.9	11
2002	9.5	11.8	15.2	20.4	23.2	25	25.7	25.9	24.1	20.2	15.4	11.4
2003	8.8	11.9	15.2	20.2	21.9	24.6	25.6	25.7	24.7	20.7	15.9	10.1
2004	9.6	11.2	17	21	23.2	24.6	25.4	25.7	24.3	19.7	14	11
2005	9.9	12.4	16.3	18.7	22.6	25.6	25.9	25.6	25.4	20.5	14.0	10.0
2006	9	14.4	14.5	19.5	23.5	24.7	26.2	25.9	24.2	20.3	15.1	11.6
2007	8.7	12.6	14.4	20.8	23.7	25.1	25.5	25.6	24.4	21.4	14.8	10.1
2008	9.3	8.9	15.7	19.9	22.9	25.1	25.7	25.4	24.3	20	14.9	12.8
2009	10.6	11.6	14.8	20.5	22.8	24.8	26.2	25.7	24.5	21	14.42	10.4
2010	9.3	10.9	17.2	21.1	23.7	25.5	26.0	25.9	24.7	21.1	16.7	9.5
2011	8.5	11.2	15.2	19.4	23.2	25.2	25.5	25.5	25.1	21.1	16.7	11.6

Appendix 3: Annual monthly rainfall measured in mm over last 34 years (1976-2011) in Dumkauli Meteorological Station, Nawalparasi

Year(AD) /Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1976	2.1	0	0	105.7	132.7	597.3	457.1	377.9	170.8	83.4	0	0
1977	24.5	8	9.5	70.6	206.4	152.4	451.9	410	130.4	180.9	38.7	32.5
1978	5.5	20.3	32	43.6	286.7	786.7	617.9	327.4	398.8	0	0	12.3
1979	4.1	20	0	18.6	6.9	219.1	840.8	398.8	230.8	124.9	7.1	58.4
1980	1.2	0	8.3	4.2	117.3	470.6	406.5	414.9	366.5	100.1	0	3.7
1981	58.3	0	42.3	193.6	198.2	319.7	827	568.4	419.2	0	12.8	3.7
1982	17.5	6.6	92.6	130.3	59.1	634.2	780.3	456.9	367.2	46.7	10	6.2
1983	18.2	0	3	34.7	170.1	123.5	700.2	362.3	216.6	93.2	0	25.6
1984	33.1	6.4	3.8	24	159.8	586.6	780.7	331.9	409.4	87.6	0	8.5
1985	6.8	10	0	3.2	197.2	395.7	591.6	319.3	459.3	178.7	0	77.9
1986	0	18.6	0	37	63.4	279.2	513.9	474.6	609.9	157.4	23.7	59.9
1987	1.8	10.3	43	42.4	71.1	382.7	792.8	445.7	191.8	169.3	0	11.5
1988	0	6	48.8	157.5	232.4	318.2	757	771.4	163.8	28.4	1.1	40.6
1989	54.7	0	15	0	280.4	321.6	776.5	123.9	300.8	39.9	1	2.2
1990	0	21.1	39.5	13.3	331.7	295.4	802.6	662.5	300.4	186.1	0	7.1
1991	33.6	6.3	22.2	14	132.3	305.7	735.4	344.2	417.3	0	0	38.4
1992	7.2	18	0	36.5	65.7	360.8	562.5	330	263.6	125.4	8.2	0
1993	0	15.3	34	69.9	199.4	280.6	383.4	1026.8	293.8	8.8	0	0
1994	56.4	23.3	4.6	10.8	171.8	442.9	443.8	545	579.8	0	0	29.5
1995	5	39.9	5.4	13	142.6	747.6	741.4	597.7	302.2	2.9	58.8	2.8
1996	60	43.6	0	3.8	78.8	586.1	621.6	452.8	331.6	99	0	0
1997	3.8	2.7	1	58.6	109	109	534.7	521.3	275.2	25.7	5.1	230.7
1998	10	13.6	64.9	40.9	145.6	312.9	646.4	925.3	271.3	150.5	1.5	0
1999	2	0	0	63.2	370.8	496	671.2	727.5	194.6	90.6	0	0
2000	6.5	11	45.5	63.2	255.7	763.7	729	432.8	301.2	3	0	0
2001	4	16.8	0	110.6	209.5	486.9	772.6	772.9	504.5	42.5	58.4	0
2002	35	28.4	70.2	99.8	507	381.4	828.6	263.7	261.4	65.1	50	0
2003	42.2	58.4	62.3	79.8	90.6	617.2	1225.8	673.9	348.7	60	0	21
2004	42.7	0	0	204.8	342.6	590.7	490.3	253.9	464.9	219.2	2	0
2005	76.5	0	10.2	83.4	81.4	267.8	457.7	796.6	188.7	251.5	0	0
2006	0	0	19	266	292.2	270.9	189.4	517.4	474	67.4	0	20.2
2007	0	98.5	38.3	103.3	194.1	226.6	794.4	510.8	1060.4	215.7	22	0
2008	4	8	0	27.4	129.4	389.3	422.2	651.4	289.5	45	0	0
2009	0	0	0	0	309.6	377.7	434.3	613.2	130.8	58.8	0	0
2010	8.3	22.1	0	9.0	167.2	388.8	744.5	729.7	521.7	76.6	0	0
2011	0.4	0	12	12	264.4	338.8	741.2	388.6	292.7	0	82	0

Latitude (deg/min): 2741
Longitude (deg/min): 8413
Elevation (m): 0154

Appendix 3: Annual monthly rainfall measured in mm over last 34 years (1976-2011) in Dumkauli Meteorological Station, Nawalparasi

Year(AD) /Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1976	2.1	0	0	105.7	132.7	597.3	457.1	377.9	170.8	83.4	0	0
1977	24.5	8	9.5	70.6	206.4	152.4	451.9	410	130.4	180.9	38.7	32.5
1978	5.5	20.3	32	43.6	286.7	786.7	617.9	327.4	398.8	0	0	12.3
1979	4.1	20	0	18.6	6.9	219.1	840.8	398.8	230.8	124.9	7.1	58.4
1980	1.2	0	8.3	4.2	117.3	470.6	406.5	414.9	366.5	100.1	0	3.7
1981	58.3	0	42.3	193.6	198.2	319.7	827	568.4	419.2	0	12.8	3.7
1982	17.5	6.6	92.6	130.3	59.1	634.2	780.3	456.9	367.2	46.7	10	6.2
1983	18.2	0	3	34.7	170.1	123.5	700.2	362.3	216.6	93.2	0	25.6
1984	33.1	6.4	3.8	24	159.8	586.6	780.7	331.9	409.4	87.6	0	8.5
1985	6.8	10	0	3.2	197.2	395.7	591.6	319.3	459.3	178.7	0	77.9
1986	0	18.6	0	37	63.4	279.2	513.9	474.6	609.9	157.4	23.7	59.9
1987	1.8	10.3	43	42.4	71.1	382.7	792.8	445.7	191.8	169.3	0	11.5
1988	0	6	48.8	157.5	232.4	318.2	757	771.4	163.8	28.4	1.1	40.6
1989	54.7	0	15	0	280.4	321.6	776.5	123.9	300.8	39.9	1	2.2
1990	0	21.1	39.5	13.3	331.7	295.4	802.6	662.5	300.4	186.1	0	7.1
1991	33.6	6.3	22.2	14	132.3	305.7	735.4	344.2	417.3	0	0	38.4
1992	7.2	18	0	36.5	65.7	360.8	562.5	330	263.6	125.4	8.2	0
1993	0	15.3	34	69.9	199.4	280.6	383.4	1026.8	293.8	8.8	0	0
1994	56.4	23.3	4.6	10.8	171.8	442.9	443.8	545	579.8	0	0	29.5
1995	5	39.9	5.4	13	142.6	747.6	741.4	597.7	302.2	2.9	58.8	2.8
1996	60	43.6	0	3.8	78.8	586.1	621.6	452.8	331.6	99	0	0
1997	3.8	2.7	1	58.6	109	109	534.7	521.3	275.2	25.7	5.1	230.7
1998	10	13.6	64.9	40.9	145.6	312.9	646.4	925.3	271.3	150.5	1.5	0
1999	2	0	0	63.2	370.8	496	671.2	727.5	194.6	90.6	0	0
2000	6.5	11	45.5	63.2	255.7	763.7	729	432.8	301.2	3	0	0
2001	4	16.8	0	110.6	209.5	486.9	772.6	772.9	504.5	42.5	58.4	0
2002	35	28.4	70.2	99.8	507	381.4	828.6	263.7	261.4	65.1	50	0
2003	42.2	58.4	62.3	79.8	90.6	617.2	1225.8	673.9	348.7	60	0	21
2004	42.7	0	0	204.8	342.6	590.7	490.3	253.9	464.9	219.2	2	0
2005	76.5	0	10.2	83.4	81.4	267.8	457.7	796.6	188.7	251.5	0	0
2006	0	0	19	266	292.2	270.9	189.4	517.4	474	67.4	0	20.2
2007	0	98.5	38.3	103.3	194.1	226.6	794.4	510.8	1060.4	215.7	22	0
2008	4	8	0	27.4	129.4	389.3	422.2	651.4	289.5	45	0	0
2009	0	0	0	0	309.6	377.7	434.3	613.2	130.8	58.8	0	0
2010	8.3	22.1	0	9.0	167.2	388.8	744.5	729.7	521.7	76.6	0	0
2011	0.4	0	12	12	264.4	338.8	741.2	388.6	292.7	0	82	0

Latitude (deg/min): 2741
Longitude (deg/min): 8413
Elevation (m): 0154

Appendix 4: Area and Production and yield of Wheat in Nawalparasi

year	Area(ha)	Production(MT)	yield (Kg/ha)
1990	14140	23150	1637
1991	13920	22690	1630
1992	14100	15280	1084
1993	17000	26350	1550
1994	19000	29040	1528
1995	19100	31515	1650
1996	19100	31500	1649
1997	17190	26640	1550
1998	19000	42750	2250
1999	19000	42150	2218
2000	19000	42750	2250
2001	18975	42087	2218
2002	18745	39364	2100
2003	18745	43113	2300
2004	18745	44240	2300
2005	18805	33034	2130
2006	18830	42609	2422
2007	18850	44805	2376
2008	18850	35844	1901
2009	18800	36250	1928
2010	18600	47000	2526
2011	18830	47350	2514

Source : DADO, Nawalparasi & CBS (2013)

Appendix 5: Area and Production and yield of Paddy in Nawalparasi

year	Area(ha)	Production(MT)	yield (Kg/ha)
1990/91	34660	92610	2672
1991/92	34700	87300	2516
1992/93	32960	74160	2250
1993/94	39000	92649	2376
1994/95	38000	83600	2200
1995/96	42100	104250	2476
1996/97	42500	110000	2588
1997/98	42500	109000	2565
1998/99	42600	119280	2800
1999/00	42652	122690	2877
2000/01	45152	130955	2900
2001/02	46947	140736	2998
2002/03	46977	141505	3012
2003/04	46507	141505	3043
2004/05	45507	137260	3016
2005/06	45500	131574	2892
2006/07	45490	116383	2558
2007/08	46490	149233	3210
2008/09	46490	165425	3558
2009/10	44590	138749	3112
2010/11	46690	180373	3863
2011/12	44890	191337	4262

Source : DADO, Nawalparasi & CBS (2013)

Appendix 5: Area and Production and yield of Paddy in Nawalparasi

year	Area(ha)	Production(MT)	yield (Kg/ha)
1990/91	34660	92610	2672
1991/92	34700	87300	2516
1992/93	32960	74160	2250
1993/94	39000	92649	2376
1994/95	38000	83600	2200
1995/96	42100	104250	2476
1996/97	42500	110000	2588
1997/98	42500	109000	2565
1998/99	42600	119280	2800
1999/00	42652	122690	2877
2000/01	45152	130955	2900
2001/02	46947	140736	2998
2002/03	46977	141505	3012
2003/04	46507	141505	3043
2004/05	45507	137260	3016
2005/06	45500	131574	2892
2006/07	45490	116383	2558
2007/08	46490	149233	3210
2008/09	46490	165425	3558
2009/10	44590	138749	3112
2010/11	46690	180373	3863
2011/12	44890	191337	4262

Source : DADO, Nawalparasi & CBS (2013)