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Climate change and its impacts on crop production: A case study in Khotang district of Nepal

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Credit

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Declaration

I, Kabindra Dhakal, declare that this thesis is a result of my research investigations and findings. Sources of information other than my own have been acknowledged and a reference list has been appended. This work has not been previously submitted to any other university for award of any type of academic degree.

Signature……………………………..

Date………………………………………

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Abstract

This research was carried out to study climate change and its impacts on major crops production in Khotang district of Nepal. The effect of climate variables on crops yield and farmers` respond to climate change in the last eight to ten years were studied and analyzed. Monthly precipitation data in Aiselukharka, Kuruleghat, Khotangbajar and Diktel; and monthly minimum and maximum air temperatures data in Okhaldhunga, Chainpur East and Udayapur Gadhi available from the Department of Hydrology and meteorology in Nepal were used to study their annual and seasonal trends. Time-series annual yield data in maize, paddy, wheat, millet and potato were collected from the District Agriculture Development Office Khotang. The linear trends in various sites were computed to study the climate variations whereas multiple regressions were used to study the relationships between climate variables and crop yields. Focal group discussions, key informants interviews, household survey and field observations were carried out in Bamrang Khola micro-watershed in Khotang district as an empirical survey.

Variations in temperatures and precipitations trends were observed in different sites. There was a tendency towards increased mean air temperature and a tendency towards a decreased yearly precipitation in Khotang district; however, these trends were not significant. Yields have increased for most crops and this is likely to be related with improved management practices, increased use of fertilizers and pesticides. The significant effects of climate variables were observed in maize and wheat yields. The yield of maize has a negative relationship with minimum air temperature and a positive relationship with maximum air temperature whereas the yield of wheat has positive relationships with maximum air temperature and precipitation, and a negative relationship with minimum air temperature.

Farmers' perceptions in Bamrang Khola micro-watershed revealed that the changes have been observed in frequencies, durations and intensities in monsoon and winter rainfall, fogs, snowfalls and storms. The impacts of these changes have resulted in increased attack of white grub in roots and maize smut in cobs, rice blast in panicle and stem, rust and blight disease and grain borer in wheat, red ants in potato. Farmers adapt to these changes by altering crop management practices as sowing time, sowing methods, weeding practices, varieties and in the methods of irrigation practices.

Key words: precipitation, temperature, management practices.

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Introduction

Emissions from burning fossil fuels and land use changes have emitted large quantity of green house gases (GHGs) in the earth`s atmosphere. Global GHGs emissions due the human interventions have increased with 70% from 1970 to 2004 (IPCC, 2007). The Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) also reported that human activities have changed the Earth surface and atmospheric compositions. This has impacted Earth's energy balance directly or indirectly (IPCC, 2013). This has led to the green house effect resulting in changes in local, regional and global climate. Increase in average global temperature (global warming), change in cloud cover and precipitation mainly over, melting of ice caps and glaciers and reduced snow cover, increase in ocean temperature and ocean acidity are the main characteristics of climate change (UNFCCC, 2007). Climate change can have both direct and indirect impact on the people. Agriculture is highly climate dependent and the impact of climate change on agriculture is mainly related to the variability and seasonality in precipitation and temperatures (Wreford et al., 2010). Changes in precipitation and temperature in any area result in altering land and water regimes and this directly impacts on the agriculture production system (Thapa & Joshi, 2010).

Climate change: An overriding issue

Intergovernmental Panel on Climate Change defines climate change as "a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. It refers to any changes in climate over time, whether due to natural variability or as a result of human activity" (IPCC, 2007). Many changes in geophysical, biological and socio-economic system will occur due to the impact of climate change. As the scientific consensus on significant changes in climate grew, there has also increased concerned on the effect of climate change on human beings (Thapa & Joshi, 2010).

Fourth Assessment Report on climate change (AR4) of the IPCC depicted that eleven of the last twelve years from 1995 to 2006 were the warmest years recorded since 1850. The 100-year linear trend on global average surface temperature from 1906 to 2005 showed that the earth surface temperature has increased by 0.7 [0.56 to 0.92] degree centigrade (^{0}C) (IPCC, 2007). Similarly, the linear trend on global averaged surface temperature (combining land

and ocean surface) from 1880 to 2012 period showed that the temperature on Earth has increased by 0.85 [0.65 to 1.06]^{0}C (IPCC, 2013). A number of climate models projections estimated the overall increase in global surface temperature. Based on the full range of 35 SRES scenarios for various climatic models, the global average surface temperature has been projected to increase by 1.4 to 5.8^{0}C over the period 1990 to 2100 (IPCC, 2001).

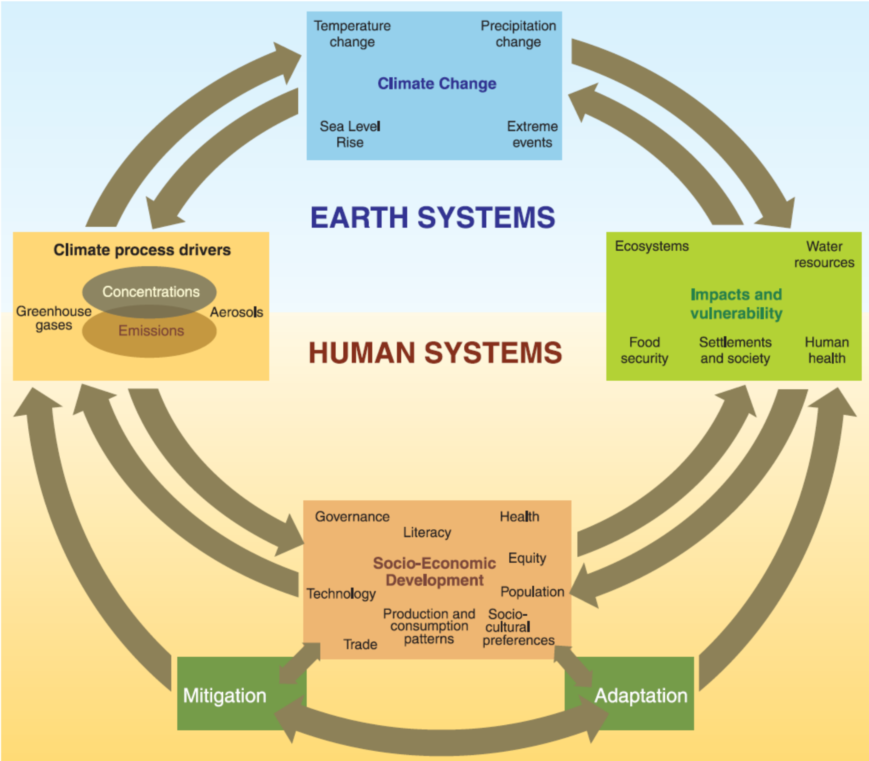


Figure 1: Schematic framework representing anthropogenic drivers, impacts and responses to climate change, and their linkages

Source: (IPCC, 2007)

The AR5 on climate change of the IPCC has reported a number of changes that were observed in the climate system of the earth from the last century. This report has revealed that number of cold days and nights has decreased whereas the number of warm days and nights has increased on global scale since 1950. The changes have also been observed in ocean temperatures, sea level and ice volume in global scale. According to the report by IPCC (2013), the ocean near the surface (upper 75 meters) has warmed by 0.11 [0.09 to 0.13]0C per decade over the period 1971 to 2010, the average rate of ice loss from glacier around the world over the period 1971 to 2009 was 226 [91 to 361] Gigatonnes per year (Gt/year) and the level of sea rose by 1.7 [1.5 to 1.9] millimeters per year (mm/year) from 1901 to 2010.

Food Productions in Nepal

Nepal`s economy is largely based on agriculture and provides employment for two thirds of the active populations. Agriculture accounts for 35% of the gross domestic product (GDP) of the country (MoEnv, 2012) and represents 13% of the foreign trade (MoSTE, 2013). Nepalese agriculture is mainly small scaled farming. Over fifty percent of the farmers in Nepal cultivate in less than 0.5 hectares of land (MoSTE, 2013). Rice, maize, millet are the major food crops in Nepal. Paddy is the main crop cultivated extensively in lowland areas (Terai) of Nepal while maize and millet are mostly cultivated in hills and mountains (MoAC & WFP, 2010).

Paddy, maize, and millet are the major summer crops in Nepal while wheat and barley are the major winter crops. Due to variations in topography, climate and culture in Nepal, cropping pattern varies across the country. Nearly one-third of the total crop production in Nepal comes from the central region and the rest followed by the Eastern and western regions (Regmi, 2007). Short duration crops like barley, potato, buckwheat and mustard are cultivated in high mountains (northern most part of the country). Rice and wheat are cultivated in the irrigated lands of middle mountains (middle parts of the country) while maize and millet or soybean are cultivated in non-irrigated land. Rice and wheat are cultivated as the most dominant crops in southern part (Siwaliks and Terai) of Nepal, and some crops like sugarcane, pulses, oilseeds and vegetables are also grown as cash crops in this area.

The Ministry of Agriculture Development (MOAD) under the Government of Nepal has reported that the yield on major crops in Nepal has increased except in millet. From 1990/1991 to 2012/2013, the yield of paddy, maize, wheat and potato have increased approximately by 40, 37, 48 and 300 kilograms per hectare (kg/ha) respectively while the yield of millet has decreased having no significant trend (MOAD, 2013). The trend on yield of these major crops grown in Nepal from 1990/91 to 2012/13 as given by MOAD (2013) has been shown in figures 2 and 3. Besides, Panta (2012) has also reported that the production rate of edible portion of rice, wheat, maize and millet in Nepal has increased by 1.81%, 3.93%, 2.36% and 1.12% per annum respectively from 1989/1990 to 2009/2010. This showed that the crop production rate in Nepal is still positive. However, the output growth rate in compared to other Asian neighboring is very less and has not kept up with the growing demand of the increasing population (MoAC & WFP, 2010).

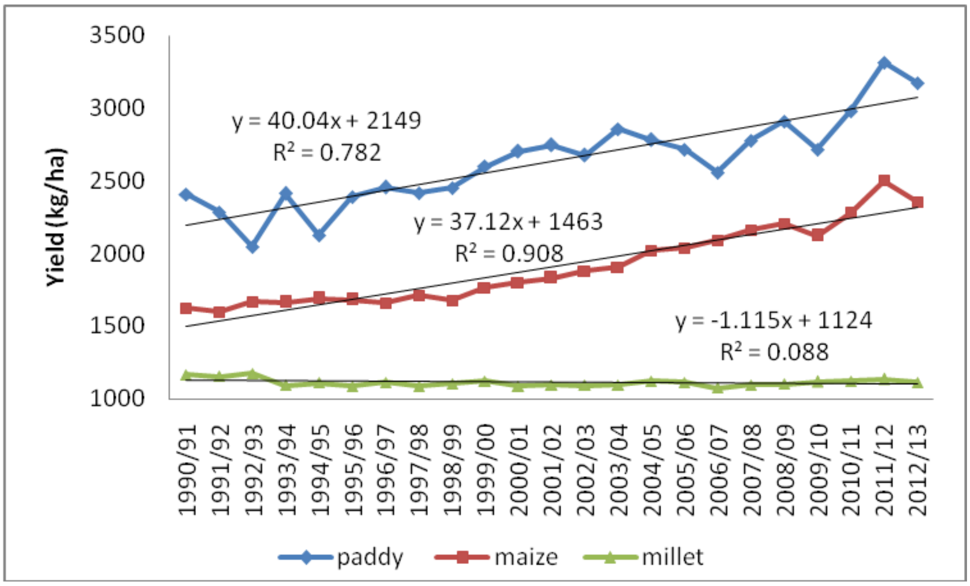


Figure 2: Yield of rice, maize and millet in Nepal

Source: (MOAD, 2013)

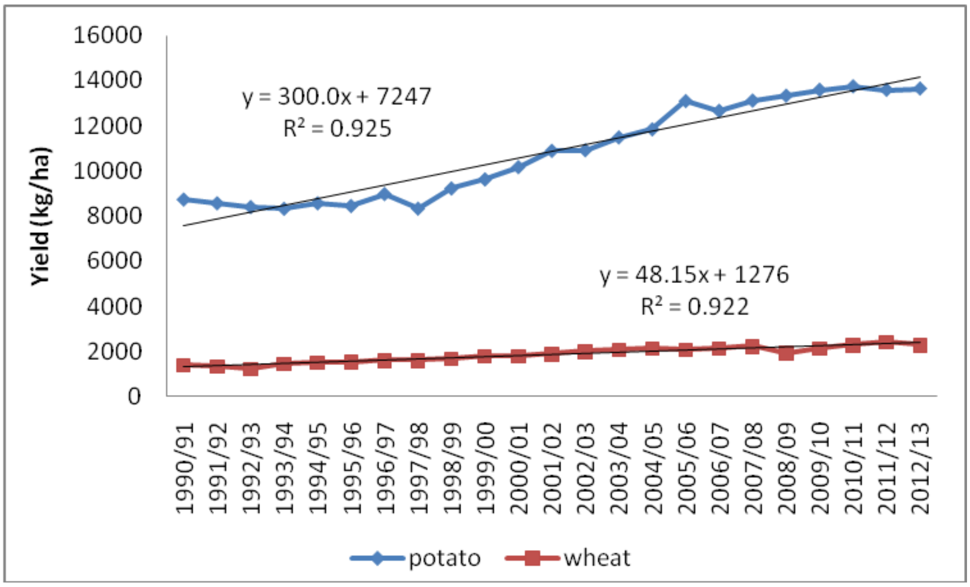


Figure 3: Yield of wheat and potato in Nepal

Source: (MOAD, 2013)

Climate of Nepal, observed variations and projections

Nepal is a small mountainous country which lies in the central Himalayas between 26^{0}22’ and 30^{0}27’N latitudes and 80^{0}40’ and 88^{0}12’E longitudes. It covers an area of 1, 47,181 square kilometers and the altitudes vary between 60 m in the south to 8,848 m (Mount Everest) in the north. The length of the country from east to west is about 850 km and the width is about 200 km from north to south. Its climate varies from the sub-tropical in the south and the alpine in the north. The climate of Nepal is characterized mainly in four distinct seasons viz., pre-monsoon (March-May), monsoon (June-September), post monsoon (October-November) winter (December- February).

Monsoon circulation system dominates the climate of South Asian countries; summer monsoon dominates the climate from May to September while winter monsoon dominates the climate from November to March (Shrestha et al., 2000). In Nepal, summer monsoon (June to September) which is governed by the southeasterly moisture containing air masses that comes from the Bay of Bengal and winter monsoon (December to February) which is cold and dry air masses that brings winter rainfall in Nepal from northwestern side. The monsoon rain starts from east towards west and is more abundant in eastern part while winter monsoon is higher in northwest and declines as it moves to south-east (MoEnv, 2010). About 13% of total annual rainfall falls in pre-monsoon, 80% in monsoon and 4% in post monsoon season while 3% falls in winter season (Practical Action Nepal, 2009). Temperature within Nepal varies with topographic variations; it increases from north (Mountain) to south (Terai) (FAO, 2008; Practical Action Nepal, 2009). The average temperature in Nepal decrease by 0.5^0C for every 100 m increase in altitude and the temperature tend to increase from east to west (FAO, 2008). The mean temperature in Nepal varied above 20^0C in southern part to less than 12^0C in the northwestern parts of the country (Practical Action Nepal, 2009). The highest temperature recorded in Nepal was 46^0C (at Chisapani in Bardiya district, western Nepal) and the lowest was -26^0C (at Thakmarpha in Mustang district, central Nepal) (FAO, 2008).

Temperature trend analysis from 1977-1994 in 49 meteorological stations across Nepal showed the average increase of temperature varies from 0.06^0C to 0.12^0C per year (Shrestha et al., 1999). Similarly, a study on trend of spatial and temporal temperature variation in Nepal from 1976-2005 showed the mean annual temperature is increasing and the warming has been observed more pronounced in the northern part of the country than its southern part (Practical Action Nepal, 2009). Temperature in cooler months (October to February) increased by 0.06^0- 0.08^0C per year across the country while in warmer months (March-September) it is increased by 0.02-0.05^0C per year (MoEnv, 2010).

Recent studies on temperatures using General Circulation Model (GCM) projects the temperature of Nepal is on an increasing trend. Mean annual temperature across Nepal is projected to increase by 0.5 to 2.0 ^{0}C in 2030, 1.7 to 4.1^0C in 2060 and 3.0 to 6.3^0C in 2090

(NCVST, 2009). The projection also revealed higher temperature increment in winter than in summer season and higher temperature increment in central and western part than eastern parts of Nepal (MoEnv, 2010).

The amount of precipitation varies significantly across the country because of the non-uniform and rugged terrain. Analysis on precipitation data recorded in all-Nepal (1948-1994) and sub-regions (within Nepal from 1959-1994) showed a large inter-annual and decadal variations (Shrestha et al., 2000). Similarly, a study conducted on the annual precipitation data from 1976-2005 from 166 stations across the Nepal revealed the overall an increasing trend of precipitation (Practical Action Nepal, 2009). Projected mean annual precipitation is -34 to +22% by 2030, -36 to +67% by 2060 and -43 to +80% by 2090 (NCVST, 2009). This shows the wide range of mean annual precipitation changes with no clear trends. Furthermore, the projection also revealed an increasing trend of rainfall intensity during monsoon and post monsoon while this showed a decreasing trend in winter (MoEnv, 2010).

Climate change impacts on Agriculture

Agriculture is directly or indirectly affected by the changing climate. Agriculture sector is very susceptible to climate variability like temperature and rainfall change, drought and flood (Shrestha et al., 2012). The rise in temperature influence the growth of crops; reduces moisture availability, increase in pest activities, reduce in water availability for irrigation (Pant, 2012) that eventually influence on agricultural production system. Up to 1^0C to 3^0C rise in temperature, the cereal production in low latitudes will decrease while it will increase in mid to high latitudes, and the production of all cereals will decrease in most regions if the temperature goes beyond these trends (IPCC, 2007). Change in temperatures and precipitation can affect the phonology of plants, length of growing season, occurrences in pests and diseases and water availability in the area that ultimately affects on the yields of crops (Shrestha et al., 2012). According to Malla (2008), increase in temperature and carbon dioxide emission is helpful in crops as it will enhance photosynthesis process and increase soil microbial activities to some extent. However, in the long run this will led to increase in pest occurrences, decrease in grain filling due to increase respiration, desertification, increase soil erosion and evapo-transpiration that ultimately led to increase in the use of pesticides and fertilizers (Malla, 2008). Variation on precipitation trend will also have significant effects on crops productivity (IWMI, 2010).

Projected surface warming and rainfall shifts in most Asian countries will induce a substantial decrease in food production negatively effecting subsistence farmers (IPCC, 2007b). The effects of climate change on Nepalese Agriculture mainly depend on changes in the monsoon and changes in snow and glacier melting (IWMI, 2010). Many studies based on climate change and agriculture in Nepal revealed that climate change and its associated impacts have direct impacts on crops production (MoEnv, 2010; Shrestha et al, 2012; WFP, 2009). Erratic and intense monsoon rainfall, reduced winter snowfall, shortened flowering and fruiting time in crops, increased landslide and river-cutting are some impacts of climate change in hills and mountains while frequent and hazardous flooding events, increase in crops pest occurrence are some notable impacts of climate change in Terai regions of Nepal (WFP, 2009).

More intense, erratic, period shifting in monsoon rainfall in Nepal is affecting summer crops due to increasing pest occurrences, reducing water availability and destroying ripen crops in the field; and the decline in winter rainfall is adversely affecting the winter crops (MoEnv, 2010). According to Regmi (2007), the drought during 2005/06 has caused rice and wheat production decreased in Nepal by 2% and 3% respectively and total crop production reduced by 12.5% on national basis. In the same period, the long dry spell during winter season affected subsistence hill and mountain farmers in the Mid-western and Far western regions of Nepal while mid western part of Terai faced heavy rain with floods that caused to reduce winter crop production by 30% (Regmi, 2007).

Statement of Problem

Climate change is unequivocal (IPCC, 2007) and it is affecting every corner of the world. However, the information regarding the trends and pattern of climate variables lacks at local and specific level (Practical Action Nepal, 2009). The IPCC`s fourth assessment report depicts Hindukush- Himalaya including Nepal as "white spot" where there is limited or lacking scientific information on climate change (NCVST, 2009).

The agriculture system in Nepal is mostly smallholder and subsistence and accounts for a large portion of Nepal`s annual GDP. Large population of the country is engaged in agriculture. Many studies show that climate change is affecting the agricultural production system in Nepal directly or indirectly. The livelihood of two-third of the labor force in rural areas of Nepal will be affected if the agriculture production is adversely impacted by climate change (Pant, 2012). Although the amount of precipitation varies significantly across the country, there is shift in monsoon periods, intense and unpredictable rainfall pattern. The temperature across the country shows tendencies towards increasing trend. Drying of water sources, erosion and landslides in hills and mountain regions of Nepal while flooding of cultivated lands in low-lying areas of hills and in Terai regions are the direct impacts of climate change in Nepalese agriculture. This alters the heat and water stresses on the crops (Pant, 2012). Small holders` farmers in Nepal are responding to changing climate.

This research was conducted to study trends on climate variables and the impacts of climate variations in major crops production system. The results of this study are expected improve understandings of climate change. This will facilitate to develop proper plans and policies for sustainable agriculture development. This can be useful for policy makers, researchers, community based organizations and the community people to implement effective measures to help smallholders to cope and adapt to climate change.

Objectives

The main objective of this research was to study climate change and the impact of climate change on major food crops production system in Khotang district of Nepal. Specific objectives of this research were:

1. To study climate variations using time series meteorological data in Khotang district.
2. To study the relationship between climate variables and yields of major crops (paddy, maize, wheat, millet, potato) in Khotang district.
3. To analyze the local farmers` responds to climate change in Khotang district.

Study Area Description

General Background

Khotang district is one of the seventy five districts of Nepal which lies in Sagarmatha zone of Eastern Development Region. It is located in $26^0$50’ to $27^0$28’ Northern latitude and $86^0$26’ to $86^0$59’ Eastern longitude and the elevation ranges from 152 to 3,620 meters above sea level (masl) covering the area of 1591 square kilometers (DADO, 2012). The total population in Khotang in 2011 was 206,312 (male- 97,092 and female- 109,220) with total household number 45,664 (CBS, 2012). The average number of member per households in Khotang district in 2011 was 4.84 (CBS, 2013).

The national population and housing census in 2011 in Nepal stated that the majority of caste/ethnic groups in Khotang district are dominated by Rai (36.6%) which is followed by Chettri (21.5%), Brahmin (7.2%) and Newar (5.4%) (CBS, 2013). Other castes groups residing in Khotang district are Magar, Kami, Tamang, Damai, Sarki, Gurung, Sherpa, Sunuwar and Majhi. Furthermore, the summary results in population census in 2011 disclosed that the population increase rate per year from 2001 to 2011 was -1.15% and the literacy population in and above 5 years age group was 68.83% (CBS, 2012). By religion type, the majority of the population in Khotang district is dominated by Hindus (58.7%) followed by Kirats (31.3%), Buddhists (7.3%) and Christians (2.01%). A very small population of the people belong to other religion types like; Islam, Prakriti, Bon, Jain, Bahai and Sikh.

Geography, climate and land use

The climate zone is Khotang district has been categorized based on the elevation range. The area of land with the climatic zone in Khotang district is classified as below;

Table 1: Climate zone with elevation range in Khotang district

Climate zone	Elevation range (masl)	% of Area
Lower Tropical	Below 300	0.7
Upper Tropical	300-1000	31.5
Sub tropical	1000-2000	4.1
Temperate	2000-3000	16.3
Subalpine	Above 3000	1.6

Source: (en.wikipedia.org)[1]

1 Accessed from http://en.wikipedia.org/wiki/Khotang_District in March 19, 2014

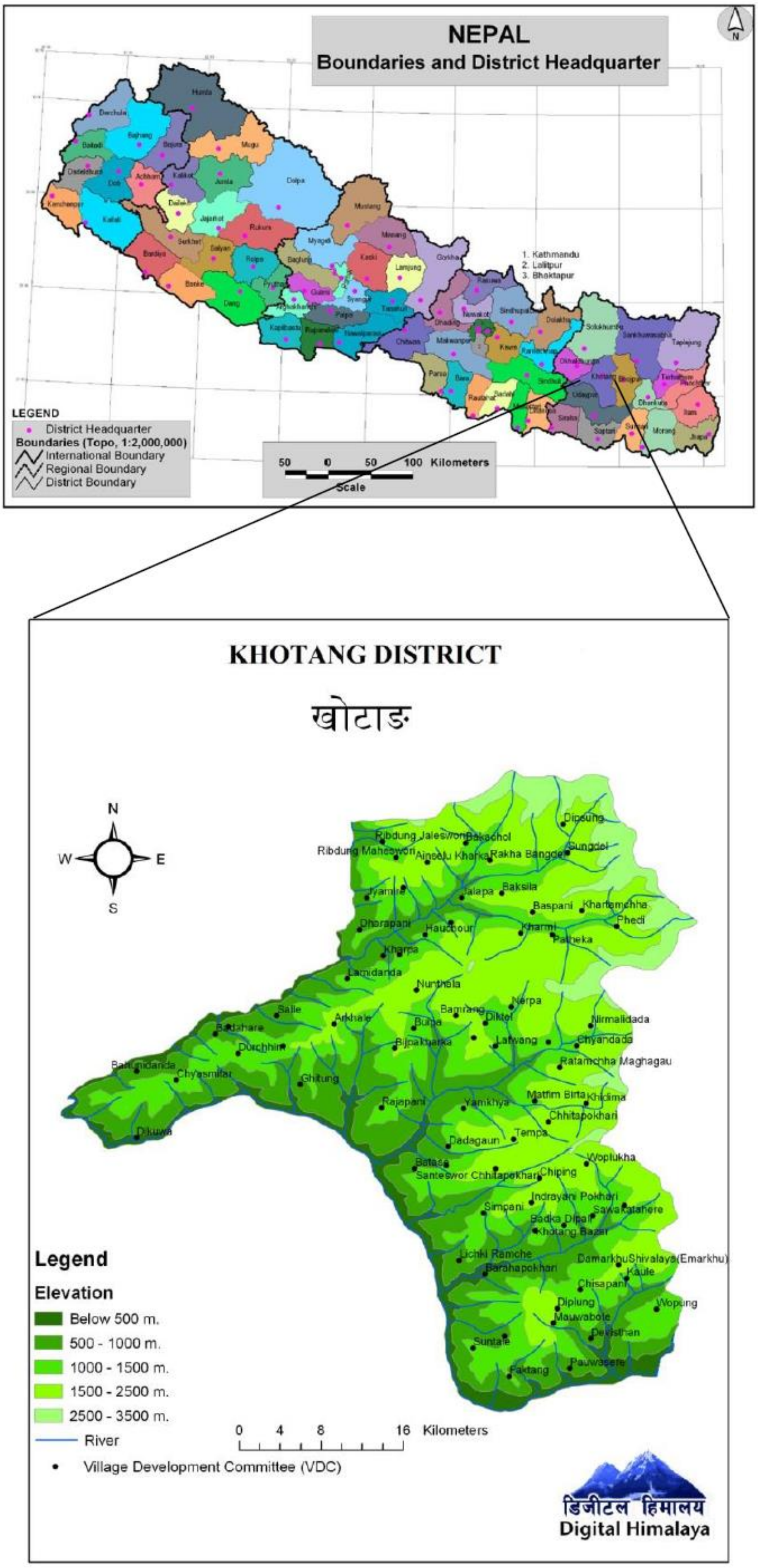


Figure 4: Khotang district in the map of Nepal

Based on the land use types, agriculture land covers the most of the area (47.51%) in Khotang district that is followed by forest land, underbrush land and sand (Table 2).

Table 2: Land covers by land use type in Khotang district

Land types	Area (km^2)	In percent (%)
Agriculture	755.85	47.51
Forest	669.28	42.07
Underbrush	116.60	7.33
Sand	25.44	1.6
Empty/ bare	8.73	0.55
Water	8.27	0.52
Landslides	6.69	0.42
Settlement	0.18	0.01
Total	1591.00	100.00

Source: (DADO, 2012)

Land ownership

The land ownership in Khotang district is categorized in Table 3. The majority of the households (45.6%) in Khotang district own land less than 0.5 hectare while the very few households (2.64%) owned land more than 10 hectares.

Table 3: Land ownership in Khotang district

SN	Land size (hectors)	Percent (%)
1	<0.5	45.6
2	0.5-1	22.52
3	1-2	12.07
4	2-3	5.22
5	3-4	4.13
6	4-5	4.03
7	5-10	3.79
8	>10	2.64
	Total	100

Source: (DADO, 2012)

Agriculture practices

Various crops are grown in Khotang district. The cropping systems also vary on different ecological zone. The main crops cultivated in Khotang district are paddy, maize, wheat, millet and potato. In additions, sorghum, black gram, soybeans, lentils, black-eyed peas and chickpeas are also cultivated in Khotang district. Various winter and summer fruits, various vegetables and oil seeds, cash crops like black cardamom, sugarcane, tea, coffee and tobacco are also grown in this district. Besides, livestock also constitutes an integral part of the agriculture system in Khotang district. The majority of the farmers own buffalos, cows, oxen and goats. In Khotang district, various crops are grown around the year (Table 4). The crop rotation type in Khotang district depends upon the farmers` land types.

Table 4: Crop cycle in Khotang district

Land Type	Crop rotation
Irrigated	Paddy-Paddy- Wheat Paddy- Wheat- Maize Paddy- Oil seeds- -Maize Paddy- Potato- Fallow
Partly irrigated	Paddy- Wheat- Barren Paddy- Fallow - Maize Paddy- Vegetables- Vegetables Maize- Vegetables- Vegetables Paddy- Oilseeds- Maize Paddy- Fallow
Non-irrigated (*rain-fed*)	Maize-Millet- Fallow Maize- Fallow Millet- Fallow Maize- Oilseeds- Fallow Buckwheat- Fallow

Source: DADO (2012)

Table 5: Various local and new verities of major crops cultivated in Khotang district

Crops	Types	Varieties
Paddy	New	*Lokatantra, Sabitri, Radha, Makawanpur1, Khumal 8 and 11*
	Local	*Bhotange, Attemars, Basmati local*
Maize	New	*Deuti, Manakamana 1 and 3, Sitala, Arun 1, Rampur Composite*
	Local	*Seto, Pahelo*
Wheat	New	*Gautam, LL 297 and 971, BL1473, Bijaya*
	Local	*Seto, Rato, Mudulle*
Millet	Local	*Dalle, Okhle, Kapre*
Potato	New	*Kuprijyoti, Cardinal, Dijire, Janakdev, Khumal while & red, TPS, PVS*
	Local	*Parkhadale, Sipiyas*

Source: DADO (2012)

Different varieties of crops cultivated in Khotang district are enlisted in Table 5. The time of sowing, planting and harvesting of the various crops depend on the altitude in Khotang district (Table 6).

Table 6: Time of cultivation practices for various crops in Khotang district

	Time	High hills (*Lekh*)	Mid hills	Lower regions
	Altitude			
Paddy	*Sowing/ planting*	June-July	June-July	June-July Feb-March
	harvesting	Oct-Nov	Oct-Nov	Oct-Nov June-July
Maize	*sowing*	Feb-March	Feb-March	Feb-March
	harvesting	Aug-Sept	June-July	April-May
Wheat	*sowing*	Oct-Nov	Nov- Dec	Nov-Dec
	harvesting	April-May	Feb-March	Feb-March
Millet	*Sowing/ planting*	June-July	July-August	-
	harvesting	Oct-Nov	Nov-Dec	-
Potato	*sowing*	Feb-March	Feb-March	Nov-Dec
	harvesting	July-August	July-August	Feb-March

Source: DADO (2012)

Methodology

Methodological Framework

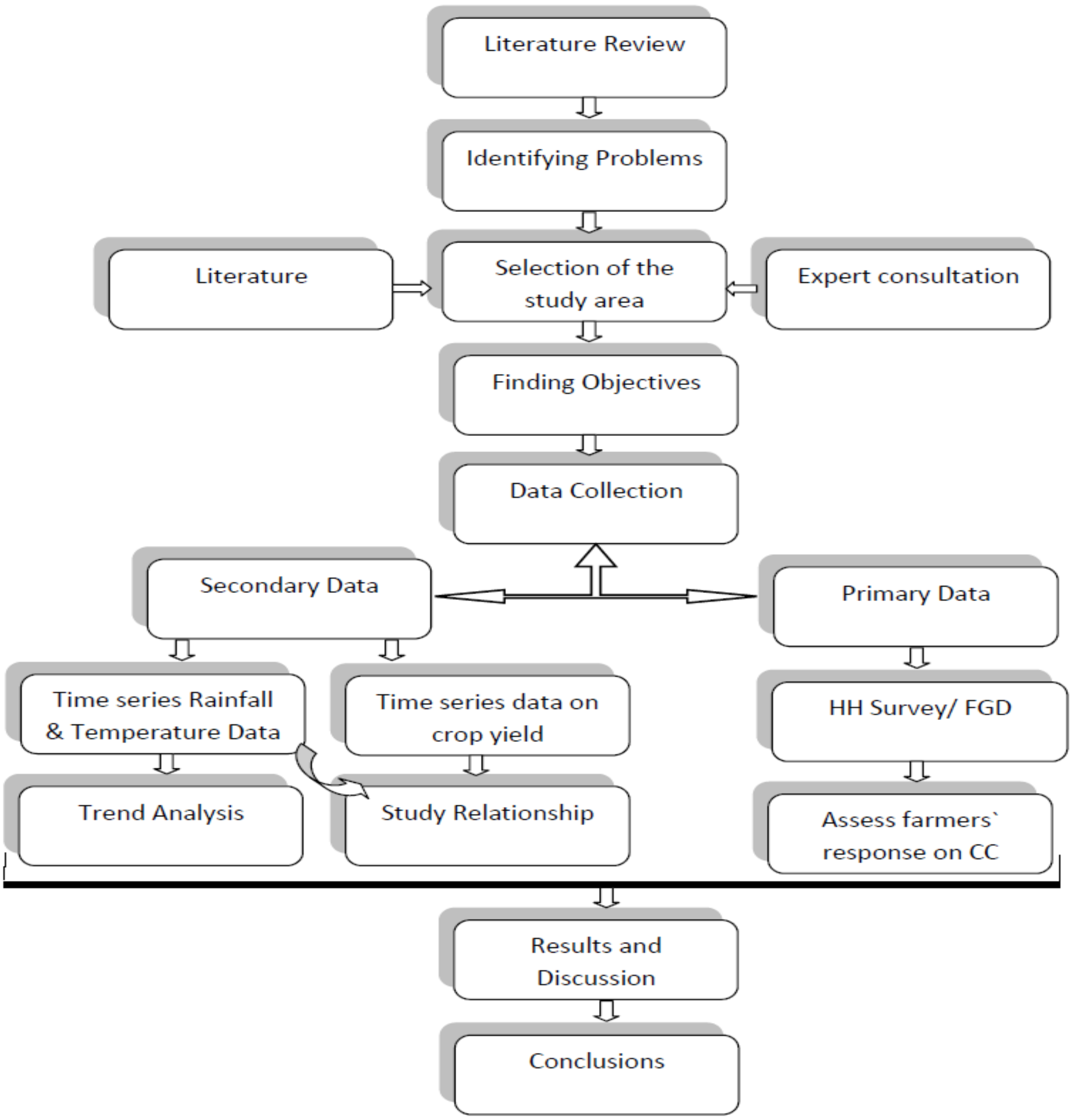


Figure 5: Methodology flow chart

Selection of the study area

Khotang district was selected as a study area. The area lies in Koshi River Basin in eastern Nepal. Ministry of Environment in its climate change vulnerability assessment report revealed that the trend of climate change in Khotang district is high and the risk associated with this change is also high (MoEnv, 2010). Many studies in Khotang district revealed an increasing trend in air temperature while declining trend in precipitation. In last 20 years of time, a long term dryness, and unpredictable rainfall were observed in Khotang district resulting in 75% drying up in water sources (Koirala & Bhatta, 2010). These changes in Khotang district may have resulted in changing crops yields. Majority (45.6%) of farmers in Khotang district have land holding size less than 0.5 hectare (DADO, 2012). This indicates that agriculture is vulnerable in Khotang district.

Besides, consultation was done with the institutions working in sectors of climate change. Discussion was held with climate change experts in Himalayan Climate Change Adaptation Program (HICAP) in International Centre for Integrated Mountain Development (ICIMOD), a policy relevant applied research program contributing to enhance resilience to climate change in Hindukush Himalaya (HKH) region.

Data collections and trend analysis

Available time series data on precipitation and air temperature from various meteorological stations were collected (Table 7). The data used in this study were monthly precipitation and monthly minimum and maximum air temperature that were published from the Department of Hydrological and Meteorology (DHM). DHM is the only an authentic institution under government of Nepal from where meteorological data can be collected. From these monthly precipitation and air temperature data, annual values were calculated as the average of January to December and the seasonal values were calculated based on four distinct seasons in Nepal, viz., pre-monsoon (March-May), monsoon (June-September), post monsoon (October-November) winter (December- following year February).

Table 7: Description of stations used in this study

Stations	Elevation masl	Latitude	Longitude	Data used	Data available
Kuruleghat	497	27^{0}13`	86^{0}43`	Precipitation	1960-2012
Khotangbajar	1295	27^{0}03`	86^{0}83`	Precipitation	1960-2012
Aiselukharka	2143	27^{0}35`	86^{0}75`	Precipitation	1960-2012
Diktel	1623	27^{0}22`	86^{0}8`	Precipitation	1973-2012
Okhaldhunga	1720	27^{0}32`	86^{0}5`	Temperature	1962-2012
Chainpur East	1329	27^{0}28`	87^{0}33`	Temperature	1987-2012
Udayapur Gadhi	1175	26^{0}93`	86^{0}52`	Temperature	1991-2012

In this study, years with missing monthly climate data were not considered for computing average annual air temperature and total precipitation values. Similarly, seasons with missing monthly climate data were also not considered while computing average seasonal air temperature as well as total seasonal precipitation. Linear trends were used to analyze the annual and seasonal trends on air temperature and precipitation.

Due to lack of time series air temperature data in Khotang district, data from nearby stations were used. Okhaldhunga, Chainpur East and Udayapur Gadhi stations were the nearest stations around Khotang district. The minimum and maximum monthly air temperatures data from these locations were used to compute the average yearly and seasonal trends. Besides, the mean annual and the mean seasonal trends on air temperature were also computed taking average monthly minimum and maximum air temperatures. Descriptive statistical tool was used to compute the mean value for these trends in three sites and established confidence interval at 95%.

Similarly, time series data on precipitation from various locations in Khotang district were used to study the precipitation trend. The monthly precipitation data for Aiselukharka, Kuruleghat, Khotangbajar and Diktel stations were used to study the trends on total annual precipitation and total seasonal precipitation. The mean for these trends in four stations was calculated and the confidence interval established at 95%.

Effects of climate variables in crops yield

Paddy, maize, wheat, millet, and potato are major food crops grown in Khotang district (DADO, 2012). The effect of climate variables has been analyzed in these major five crops yield grown in Khotang district. Data on yields on these crops were collected from annual publications by District Agriculture Development Office (DADO) Khotang in Diktel. DADO Khotang is a government institution working in the agriculture sector in Khotang district. The data on crops yields (in tons per hectare) were available from 1986 to 2011 and were used for this study. Linear trend on these data were computed to analyze the trends of yield for different crops.

Multi regression analyses were carried out between annual crops yield and climatic variables. The time series data on total precipitation, average minimum air temperature and average maximum air temperature for respective crops cultivation months were considered as explanatory variables and yield of crop as dependent variable. The cultivation period for same crop vary in Khotang district as this district extends from low to high altitude (below 300 to above 3000 masl). However, crop cultivation periods in this study were considered as given by DADO (2012) (Table 8). The output results on multiple regressions were interpreted for analyzing the effect of climate variables in crops yields.

Table 8: Crop cultivation periods used in this study

Crops	Cultivation period
Paddy	From June to November
Maize	From February to July
Wheat	From November to March
Millet	July to December
Potato	February to August

Farmers` respond in crop management practices

Empirical field survey was conducted in Bamrang Khola micro-watershed in Koshi Basin which covers Diktel Village Development Committee (VDC) ward no 1 & 2, Bamrang VDC ward 6 & 7 and Khalle VDC ward 9 in Khotang district. Four focus group discussions (FGD) were carried out during field survey. Besides, households' survey was also undertaken among 60 sample households on random sampling basis. Both qualitative and quantitative data were collected during empirical survey. Background information collected during this household survey includes the area of land they owned, food sufficiency months, number of cattle they have owned, annual income from agriculture production.

Table 9: Focus Group Discussions during field survey

SN	Locations	group discussions
1	DADO Khotang	field surveyors, members from each DADO divisions and representatives from different NGOs working in Khotang district
2	Diktel 1	farmers from Diktel 1 and 2
3	Khalle 9	farmers from Khalle 9
4	Bamrang 6	farmers from Bamrang 5 & 6

In FGD 1, discussions were focused on changes observed in Khotang district regarding agriculture practices in relations with ongoing climate variability. During FGD 2, 3 and 4 discussions mainly focused on effects of climate variations in major crops. Besides, information regarding changes in crop management practices to overcome the effects of climate variations in last eight to ten years, historic trend on major climatic events and their impacts on major crops were also collected.

Analysis Tools

The data were analyzed in MS Excel 2007. Linear regressions were carried out to compute the trends in climate variables and major crops yield. The model for linear regression line for fitted values used in this study was;

$$Y=a+ b X \text{..................................} (i)$$

In equation (i), Y is dependent variable, a is an intercept, b is slope of line and X is explanatory variable.

Similarly, multivariate analysis was conducted to study the effect of climate variables in major crops grown in Khotang district. The model for multiple linear regression line for fitted values,

$$Y=b_0+b_iX_i+b_{ii}X_{ii}+b_{iii}X_{iii}+\varepsilon \text{......................................} (ii)$$

In equation (ii), Y is dependent variable, b_0 intercept coefficient.

b_i, b_{ii} and b_{iii} are intercepts for X_1, X_2 and X_3 variables.

X_i, X_{ii} and X_{iii} are values for X_1, X_2 and X_3 variables.

ε is the deviation.

In this study, the regression equations were considered statistical significant cases at 95% and 99% significance level.

Results and discussions

Trend in precipitation

Total annual precipitation

Total annual precipitation for various locations in Khotang district were statistically analyzed. The total annual precipitation in Khotangbajar increased by 3.51 millimeters per year (mm/year) whereas in Aiselukharka, Kuruleghat and Diktel, it decreased by 9.62 mm, 2.09 mm and 3.11 mm per year respectively. Variation in precipitation is observed in Nepal within short distance (Shrestha et al., 2000). Practical Action Nepal (2009) revealed that the variation in spatial and temporal distribution of precipitation and its trend over Nepal is due to the interaction of the complex topography with monsoon and westerly disturbances system. However, there is a clear research gap in explaining spatial variability in annual precipitation in Nepal (Kansakar et al., 2004). In my study, the precipitation trend in Aiselukharka was found significant at 95% significant level.

A climate change study in Nepal from 1976 to 2005 conducted by Practical Action Nepal (2009) depicted an overall increased precipitation across Nepal. The report also revealed that the precipitation trend in different locations over Khotang district varies between -10 to +10 mm per year. A similar trend was also observed in my study. The trend in precipitation from the 1960 to 2012 in Khotang district varies between -9.62 to +3.51 mm per year. However, the measures of goodness of fit (R^2) for these linear equations were minimal (Figure 6, 7, 8 and 9). This illustrates that the model does not well explain the variations in total annual precipitation. However, the mean trend in precipitation computed for these four stations was -2.86 mm per year (Table 10). This illustrates a tendency towards decreased precipitation in Khotang district with 2.86 mm/year but this effect was not significant ($p>0.05$). More observations will be needed to conclude about changes in rainfall during the period.

The Third Assessment Report (TAR) on Intergovernmental Panel on Climate Change (IPCC, 2001) has revealed that over mid to high Northern hemisphere there was an increased precipitation by 0.5 to 1% per decade and a decreased precipitation (0.3% per decade) in sub-tropical regions (10^0 to 30^0 latitudes) during twentieth century. A study in 89 stations by Shrestha et al. (2000) revealed that long term trends on precipitation over Nepal do not show any significant trend. Similar study was also observed in a study over 274 locations across Nepal by Ichiyanagi et al. (2007).

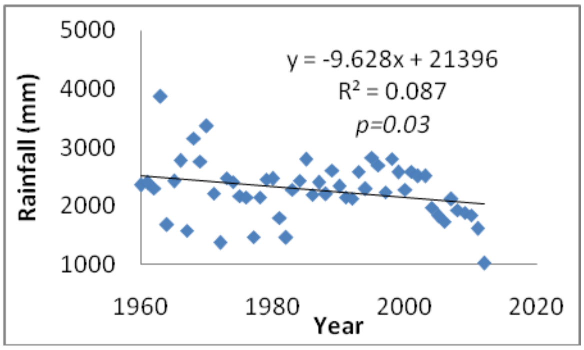


Figure 6: Total annual precipitation in Aiselukharka from 1960 - 2012

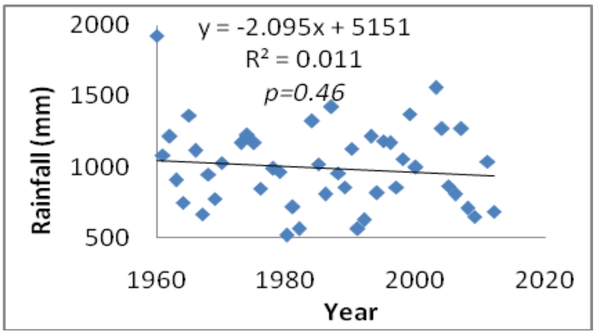


Figure 7: Total annual precipitation in Kuruleghat from 1960- 2012

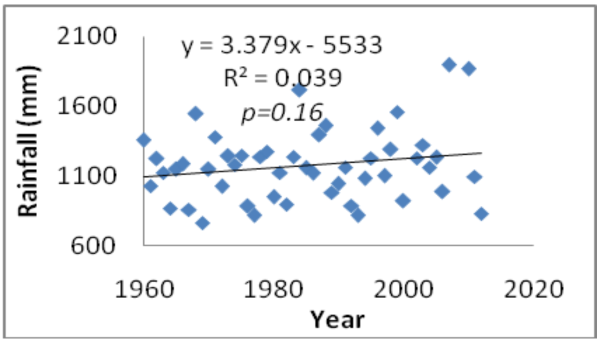


Figure 8: Total annual precipitation in Khotangbajar from 1960- 2012

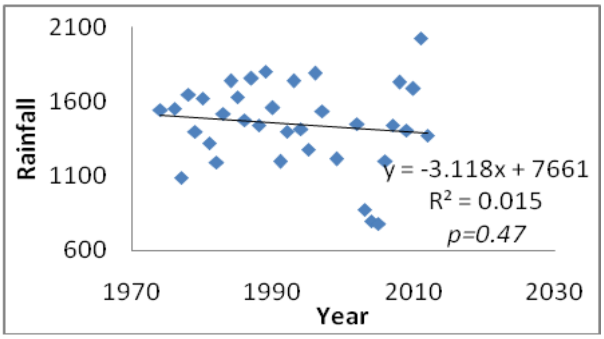


Figure 9: Total annual precipitation in Diktel from 1974- 2012

Table 10: Mean trend with confidence interval (CI) for the total annual precipitaion

Descriptive Statistics	
Mean	-2.86 mm per year
Confidence interval (95%)	-11.34, +5.61

South Asian climate is mainly predominated by summer (May to September) and winter monsoon (November to March) circulations systems (Shrestha et al., 2000). Many studies have related precipitation trend over Nepal with Indian subcontinent rainfall trend (Ichiyanagi et al., 2007; Shrestha et al., 2000). Studies on Indian precipitation revealed that there is not any clear increase or decrease trend in all-India average rainfall (Jain et al., 2013). However, all-India precipitation does not give a valid representation for the whole sub-continent because the precipitation pattern in northern part of subcontinent (Himalaya and its vicinity) is different than the southern part of this sub-continent (Shrestha et al., 2000). Wu et al. (2007) has depicted a high influence of mechanical and thermal forcing of Tibetan Plateau on Global and regional climate. The report revealed that during winter the cold ascending air masses above Tibetan Plateau along cold sloping surface is pumped causing winter monsoon in the surrounding surface and during summer the hot descending air masses above this plateau cause a high influence in global and regional winter and summer atmospheric circulation. There is a high influence of Tibetan Plateau in Asian monsoon (Wu et al., 2007). The mechanical and thermal forcing of Tibetan Plateau could influence atmospheric phenomena in Nepal.

A significant relationship has also been observed between precipitation in Nepal (both in eastern and western part) and Southern Oscillation Index (SOI) (Ichiyanagi et al., 2007; Shrestha et al., 2000). When SOI is low (El-Nino warm phases) then precipitation in Nepal is also low (Ichiyanagi et al., 2007). In the equatorial Pacific and Indian Ocean, a warmer sea surface temperature is produced during El-Nino warm phases that results to decline land-ocean thermal contrast that reduces the strength of the monsoon associated within these regions (Shrestha et al., 2000).

Total seasonal precipitation

The spatial and temporal distribution in seasonal precipitation study over Nepal was carried out by Practical Action Nepal (2009) and has depicted the seasonal precipitation trend varies across Nepal. The study revealed an increased precipitation trend in pre-monsoon season in eastern, central and western development regions of Nepal. In my study in Khotang district, pre-monsoon precipitation showed the tendencies towards increasing trend in all locations except in Aiselukharka (Table 11). But the trends were found significant only for Khotangbajar (+1.56mm/year; $p<0.05$) with low R^2 value. The mean trend across the four sites was +0.63 mm/year. However, the mean trend in pre-monsoon precipitation was not significant ($p>0.05$).

Further, the precipitation in monsoon showed the tendencies towards decreasing trend in all locations except in Khotangbajar. The highest declined in precipitation was observed in Aiselukharka with 6.9 mm/year while in Khotangbajar, it increased with 3.7 mm/year. However, no any significant trend was observed for this season across these locations. A study conducted by Practical Action Nepal in 2009 showed an average trend in monsoon rainfall increased in eastern Nepal, however the spatial distribution within the region illustrated a mixed results (-10 to +10 mm/year) for Khotang district. In Nepal, about eighty percent of the precipitation falls in monsoon season and this determines the total annual precipitation. The mean trend for the monsoon precipitation across the four sites in my study showed a decreased trend (-2.34 mm/year) though observed trend was found not significant.

The trend in post-monsoon precipitation showed a tendency towards decreasing trend in all locations except in Kuruleghat. However, the observed precipitation trend in this season was found significant only for Diktel (-1.7 mm/ year; $p<0.05$; $R^2= 0.1$). In winter season, no any significant trend was found across these locations. However, the precipitation showed a tendency towards an increasing trend in Khotangbajar while these were decreasing in other locations. The mean for post-monsoon and winter precipitation trend across the study sites were -0.68 and -0.04 mm/year respectively. However, the mean values calculated were not significant as $p>0.05$.

A study on climate change over Nepal from 1976 to 2005 by Practical Action Nepal in 2009 showed mixed results in post monsoon and winter precipitation trend across Nepal. According to the report, there was an increasing trend in post-monsoon precipitation in southern part of eastern, central and western development regions of Nepal whereas a decreasing trend in mid to northern part of these regions. The report also showed an overall increase in winter precipitation trend almost over the entire country. However, the trend in winter precipitation was decreased in some isolated pockets of northern part in eastern Nepal.

Table 11: Linear regressions, R-squared value, mean and CI for seasonal precipitation

Locations	Pre-monsoon	Monsoon	Post-monsoon	Winter
Aiselukharka	*Y=-1.779x+3824* R^2= 0.029 *p-value=0.2*	*Y=-6.94x+15612* R^2= 0.061 *p-value=0.07*	*Y=-1.176x+2456* R^2= 0.046 *p-value=0.12*	*Y=-0.256x+466.8* R^2= 0.017 *p-value=0.35*
Kuruleghat	*Y=0.96x-441.8* R^2=0.004 *p-value=0.62*	*Y=-2.273x+5271* R^2=0.018 *p-value=0.33*	*Y=0.148x-246.8* R^2=0.001 *p-value=0.80*	*Y=-0.235x+499.6* R^2=0.012 *p-value=0.46*
Khotangbajar	*Y=1.563x-2921* R^2=0.083 *p-value=0.03**	*Y=3.744x-6508* R^2=0.055 *p-value=0.08*	*Y=-0.003x+5942* R^2=9E-07 *p-value=0.99*	*Y=0.497x-948.1* R^2=0.039 *p-value=0.17*
Diktel	*Y=1.807x-3356* R^2=0.059 *p-value=0.14*	*Y=-3.908x+8897* R^2=0.032 *p-value=0.2*	*Y=-1.725x+3495* R^2=0.152 *p-value=0.01***	*Y=-0.186x+408.9* R^2=0.006 *p-value=0.6*
Mean (mm/year)	+0.63	-2.34	-0.68	-0.04
CI (95%)	(-4.16, +5.43)	(-16.46, +10.77)	(-3.32, +1.95)	(-1.08, +0.99)

(* indicates significant at 95% significance level, ** indicates significant at 99% significance level)

In this study, there was a tendency towards decreasing precipitation in overall seasons (except in pre-monsoon season) (Table 11); however, the means were found not significant ($p>0.05$). Although this result was comparable with the farmers` perception observed in focus group discussions during the field survey. Farmers stated that the winter rainfall (December to February) in Khotang district decreased in terms of frequency, intensity and duration instead this rainfall occurs in March.

The fluctuation and intensity of monsoon in Nepal are very much related to variations in the easterly currents (summer monsoon circulation), and these easterly current are weak during a weak monsoon year lying over 15^0 N in the Indian subcontinent (Nabhaya, 1980). In my study, a high variation in seasonal precipitation trends was observed across the sites in Khotang district. For this reason, the mean trends calculated for Khotang district were not found to be significant.

Trend in air temperatures

Minimum and maximum annual air temperatures

The minimum and maximum annual air temperatures for Okhaldhunga, Udayapur Gadhi and Chainpur East have been analyzed statistically. The minimum annual air temperature for Okhaldhunga showed an increased trend ($p<0.05$) whereas Chainpur East showed a decreased trend ($p<0.05$). The trend in minimum air temperature observed for Udayapur Gadhi was found to be not significant ($p>0.05$); however this temperature showed a tendency towards an increasing trend. Practical Action Nepal (2009) has reported that the trend in mean minimum air temperature in northern parts of Nepal showed a decreasing trend whereas in southern part showed an increasing trend. Similar results have also been observed in this study. Udayapur Gadhi (Udayapur district) lies in southern part whereas Chainpur East (Sankhuwasabha district) lies in northern part in eastern Nepal. Okhaldhunga (Okhaldhunga district) lies in the mid-hills region. The minimum annual air temperature in Okhaldhunga increased with 0.01^0C per year whereas it decreased with 0.1^0C per year in Chainpur East. The measure of goodness of fit of linear regressions (R^2) for these trend equations were 0.09 and 0.46 in Okhaldhunga and Chainpur East respectively. This indicates that the regressions models explained 9% and 46% of variations in minimum annual air temperature in Okhaldhunga and Chainpur East. The mean trend for minimum annual air temperature for these locations was calculated.

The maximum annual air temperature observed across locations showed an increasing trend. However, high variations in these trends were observed. The maximum annual air temperatures in Okhaldhunga and Udayapur Gadhi have increased by 0.05^0C and 0.1^0C per year respectively. The values of R^2 in linear equations were found 0.52 and 0.81 for Okhaldhunga and Udayapur Gadhi respectively. This shows that the linear model explained 52% and 81% of the variations in maximum annual air temperature in Okhaldhunga and Udayapur Gadhi respectively. The trends in maximum annual air temperature for both these locations were found highly significant (significant at 99% significance level). In Chainpur East, the maximum annual air temperature showed increased trend with 0.002^0C per year but the trend was not significant ($p>0.05$). Shrestha et al. (1999) analyzed the maximum air temperature for 49 stations over Nepal from 1971 to 1994. This study depicted the increasing maximum air temperature trend across Nepal after 1978. Besides, Practical Action Nepal (2009) also revealed the increasing trend in maximum annual air temperature almost in the entire country except few isolated places in Banke, Sunsari, Nawalparasi, Bardia districts (southern Nepal) and Sankhuwasabha district (north of eastern Nepal). This recent study in Khotang district resembles with the study by Shrestha et al. (1999) and Practical Action Nepal (2009) as the maximum annual temperature in all locations of this study showed an increasing trend.

The mean for the trends in minimum and maximum annual air temperature across these three locations were computed (Table 12). The mean for the trends in minimum air computed for Khotang district was found -0.004^0C per year which indicates no clear trend ($p>0.05$). More observations in minimum annual air temperature are needed to conclude about the trend clearly. The mean for the trends in maximum annual air temperature across these three locations was +0.08⁰C per year though the trend was found to be not significant ($p<0.05$). However, this indicates a strong increase in temperature in the long term. In a 100 year time this temperature would increase by 8.3⁰C. Temporal and spatial variability of climate change study over Nepal from 1976 to 2005 by Practical Action Nepal (2009) revealed that the trend in maximum annual air temperature in eastern Nepal was increasing (+0.02 to +0.08⁰C per year and resembles the recent study in Khotang district.

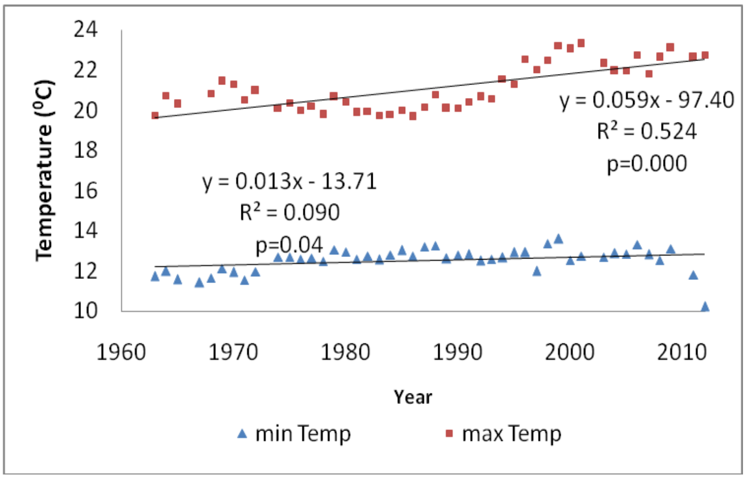


Figure 10: Minimum and maximum annual air temperatures in Okhaldhunga from 1963 – 2012

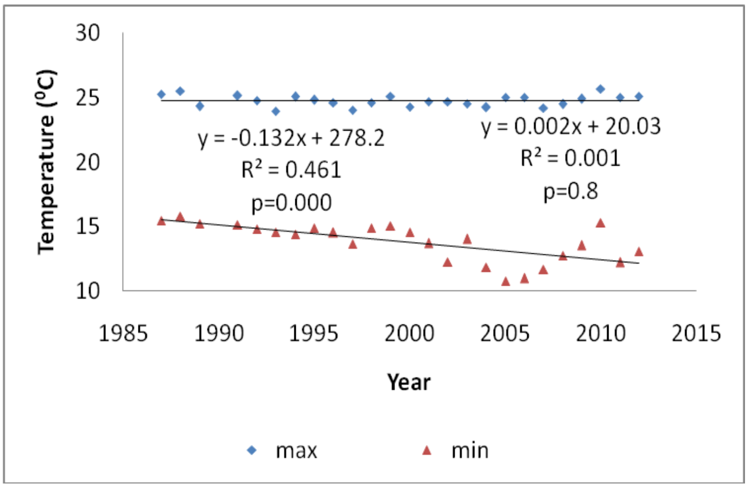


Figure 11: Minimum and maximum annual air temperature in Chainpur East from 1987-2012

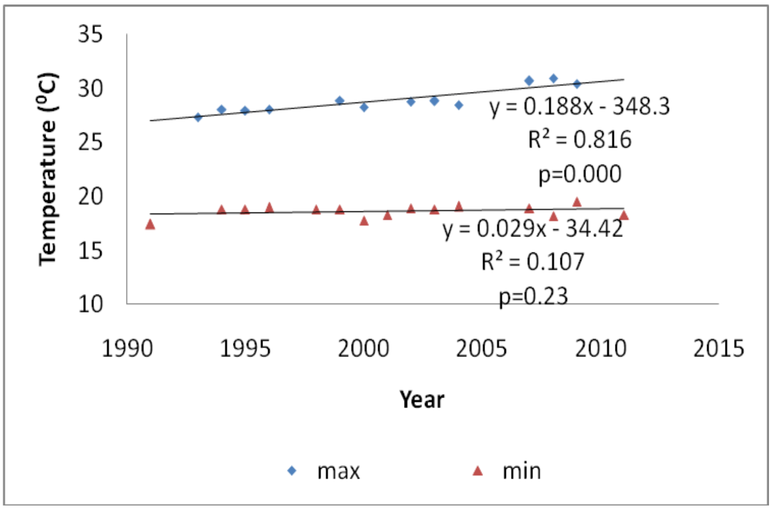


Figure 12: Minimum and maximum annual air temperatures in Udayapur Gadhi from 1991-2011

Table 12: Mean and confidence interval for minimum and maximum air temperature trends

	Minimum air temperature	**Maximum air temperature**
Mean trend (^{0}C/year)	-0.004	+0.083
Confidence interval (95%)	-0.30, +0.29	-0.15, +0.31

Mean annual air temperature

The mean annual air temperature in Okhaldhunga increased by 0.03^{0}C per year while in Chainpur East decreased by 0.06^{0}C per year and the trends were found highly significant. The value of R^2 for regression models in Okhaldhunga and Chainpur East were 0.55 and 0.36 respectively. This indicates that these models explain 55% of variations in mean annual air temperature for Okhaldhunga and 36% of variations in mean annual air temperature for Chainpur East. The mean annual air temperature in Udayapur Gadhi has increased by 0.053^{0}C per year. However, the trend observed for Udayapur Gadhi was found not significant ($p>0.05$). A short time series data was available for Udayapur Gadhi and the data from fewer years were available to compute the regression analysis. A long term air temperatures data are required to establish a significant trend in temperature in Udayapur Gadhi.

The mean trend in mean annual air temperature across these locations was +0.007^{0}C/year (Table 13). This indicates that the trend in mean annual air temperature in Khotang district increased by 0.007^{0}C per year. However, this trend was not statically significant ($p>0.05$).

High variations in mean annual air temperature trends were observed across the sites. There is a need for more observations to assess the trend in mean annual air temperature for Khotang district.

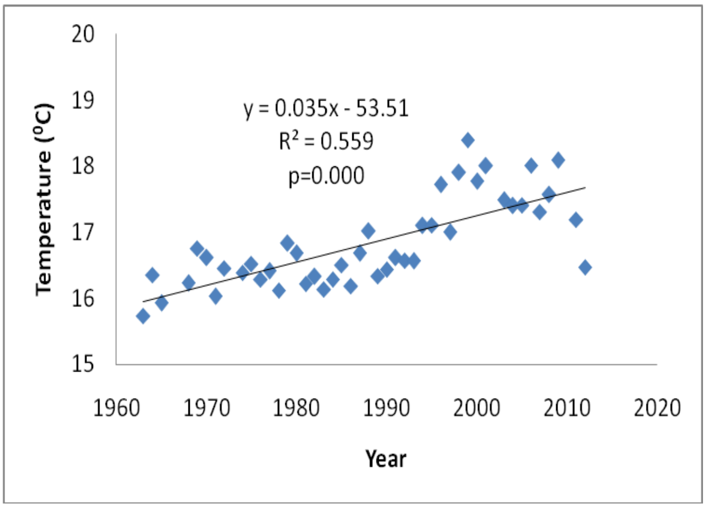


Figure 13: Mean annual air temperature in Okhaldhunga from 1963-2012

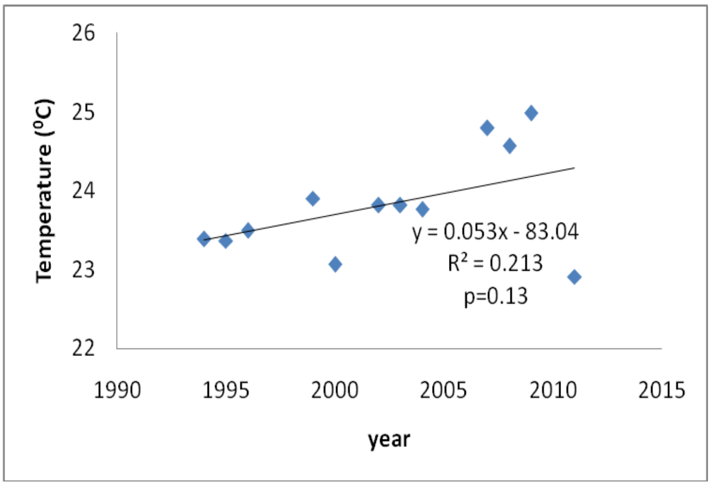


Figure 14: Mean annual air temperature in Udayapur Gadhi from 1994-2011

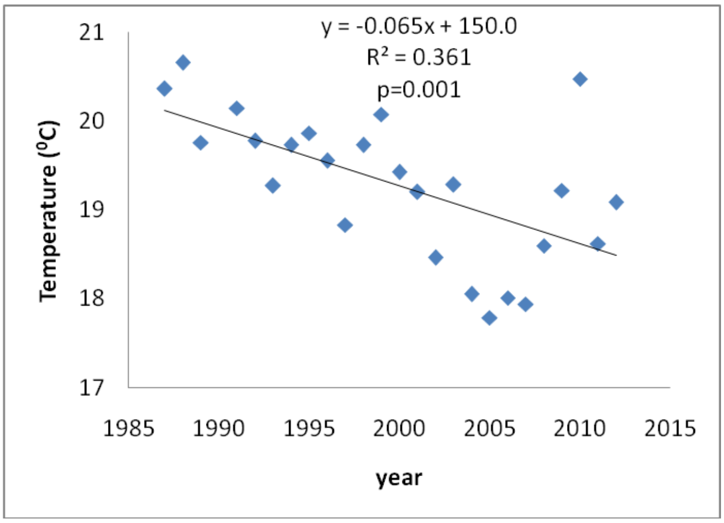


Figure 15: Mean annual air temperature in Chainpur East from 1987- 2012

Table 13: Mean with confidence interval in mean annual air temperature trends

Mean trend (^{0}C/year)	+0.007
Confidence interval (95%)	-0.15, 0.16

Seasonal air temperatures

Minimum and maximum air temperatures

The seasonal minimum and maximum air temperature for Okhaldhunga, Udayapur Gadhi and Chainpur East have been analyzed (Table 14). In pre-monsoon, there is a declining trend in minimum annual air temperature in Chainpur East by 0.13^{0}C per year ($p<0.05$). This linear model explained 30% of the variations in minimum annual air temperature (R^2=0.3). In Okhaldhunga and Udayapur Gadhi, the temperature increased with 0.01^{0}C and 0.03^{0}C per year but these trends were not significant. In monsoon season, Okhaldhunga showed a significant increase in minimum annual air temperature while Chainpur East showed a significant decrease in minimum air temperature. In Okhaldhunga, minimum air temperature in monsoon season increased by 0.01^{0}C per year whereas this was decreased by 0.12^{0}C per year in Chainpur East. The regression model explains 41% of variations in minimum air temperature in Chainpur East whereas R^2 value for Okhaldhunga was found very low (Table 14). However, the trend in both locations were significant ($p<0.05$). There was a decreasing trend of minimum air temperature in Udayapur Gadhi with 0.004 but this was found not significant.

Okhaldhunga and Udayapur Gadhi showed an increasing trend in minimum air temperature for the post- monsoon season while Chainpur East showed a decreasing trend. This temperature increased by 0.01^0C and 0.1^0C per year in Okhaldhunga and Udayapur Gadhi respectively. In Chainpur East, it decreased by 0.17^0C per year. However, this trend in temperature was significant only for Udayapur Gadhi and Chainpur East. The values of R^2 for Udayapur Gadhi and Chainpur East were 41% and 40% respectively. In winter season, minimum air temperature for both Okhaldhunga and Udayapur Gadhi showed an increasing trend by 0.02^0C per year while it showed a decreasing trend by 0.11^0C per year in Chainpur East. The value of R^2 for the linear regression observed for Okhaldhunga (R^2=0.11) was found very low in compare to Chainpur East (R^2=0.36). However, these trends in this temperature for these both locations were found significant ($p<0.05$).

Overall, the mean trend in minimum air temperature showed a decreasing trend (Table 14) though not significant. However, the trend of decrease in minimum air temperature was least (-0.006^0C/year) in post monsoon; thereafter, this decreasing trend continuously increased during winter season, pre-monsoon season and monsoon season (Table 14).

Table 14: Linear trend, R^2, p value and mean for minimum and maximum air temperature in different seasons

			Pre-monsoon	**Monsoon**	**Post-monsoon**	**Winter**
Okhaldhunga	*Min.*	*Trend*	+0.01	+0.01	+0.01	+0.02
		R^2	0.03	0.08	0.057	0.11
		p	0.2	0.04*	0.09	0.01**
	Max.	*Trend*	+0.05	+0.04	+0.07	+0.06
		R^2	0.41	0.40	0.50	0.40
		p	<0.001**	<0.001**	<0.001**	<0.001**
Udayapur Gadhi	*Min.*	*Trend*	+0.03	-0.004	+0.14	+0.02
		R^2	0.1	0.004	0.41	0.02
		p	0.1	0.8	0.003**	0.5
	Max.	*Trend*	+0.11	+0.13	+0.18	+0.16
		R^2	0.5	0.60	0.48	0.45
		p	0.001**	<0.001**	<0.001**	0.005**
Chainpur East	*Min.*	*Trend*	-0.13	-0.12	-0.17	-0.11*
		R^2	0.3	0.41	0.40	0.36
		p	0.001**	<0.001**	<0.001**	0.001**
	Max.	*Trend*	-0.0004	+0.006	-0.02	+0.01
		R^2	1.28E-05	0.01	0.05	0.01
		p	0.9	0.55	0.24	0.5
Mean (Confidence interval 95%)	*Minimum*		-0.03 (-0.24,+0.18)	-0.038 (-0.21,+0.13)	-0.006 (-0.39,+0.38)	-0.023 (-0.2,+0.16)
	Maximum		+0.053 (-0.08,+0.19)	+0.058 (-0.1,+0.21)	+0.07 (-0.17,+0.32)	+0.07 (-0.11,+0.26)

(* indicates significant at 95% significance level, ** indicates significant at 99% significance level)

The trend in maximum air temperature in pre-monsoon season has increased by 0.05^0C per year in Okhaldhunga whereas this was increased by 0.11^0C per year in Udayapur Gadhi. These both trends were found statistically significant ($p<0.05$) and the linear models explained 41% and 50% of the variations in maximum temperature in Okhaldhunga and Udayapur Gadhi respectively. In Chainpur East, the maximum air temperature observed for pre-monsoon season decreased by 0.0004^0C per year though insignificant ($p>0.05$).

In monsoon season, the maximum air temperature trends in Okhaldhunga and Udayapur Gadhi increased by 0.04^0C and 0.13^0C per year respectively. The trends in both the locations were found significant ($p<0.05$). The value of coefficient of determination (R^2) for Okhaldhunga and Udayapur Gadhi were 40% and 60%. The observed change in temperature in Chainpur East was 0.0006^0C, but this was found not significant ($p>0.05$).

Similarly, significant changes in the maximum air temperature were also observed for Okhaldhunga and Udayapur Gadhi in post-monsoon season. The observed trends were $+0.07^0$C per year for Okhaldhunga and $+0.18^0$C per year for Udayapur Gadhi with the coefficient of determination value 50% and 48% respectively. This temperature in Chainpur East showed a declining trend though insignificant ($p>0.05$). Similar trends have also been observed in maximum air temperatures in winter season. The winter maximum air temperature in Okhaldhunga increased by 0.06 per year ($p<0.05$) with the coefficient of determination 40% and this temperature increased by 0.16^0C per year ($p<0.05$) in Udayapur Gadhi with the coefficient of determination 45%. The maximum air temperature in winter season also showed a tendency towards an increasing trend in Chainpur East by 0.01^0C per year but this change was not significant ($p>0.05$).

The mean trends in maximum air temperature for the entire seasons were computed (Table 14). The spatial pattern of maximum air temperature trend in entire Nepal showed an increasing trend (Shrestha et al., 1999; Practical Action Nepal, 2009). Similarly, the maximum air temperature computed in this study for Khotang district showed tendencies towards an increasing trend. The trend in maximum air temperature was observed $+0.07^0$C per year in winter season. Thereafter, subsequent decrease in increasing trend ($+0.05^0$C/year) was observed during pre-monsoon and monsoon seasons.

The trends in seasonal maximum air temperature in this study were comparable with the studies by Shrestha et al. (1999) and Practical Action Nepal (2009). Shrestha et al. (1999) showed that the trends (from 1977 to 1994) in winter, pre-monsoon, monsoon and post-monsoon seasons in middle mountains regions were +0.059^{0}C, +0.05^{0}C, +0.055^{0}C and +0.094^{0}C per year respectively. Similarly, Practical Action Nepal (2009) depicted the variations in the trends in maximum air temperature from 1976 to 2005 across eastern Nepal. According to this report, the maximum air temperature in eastern Nepal has increased by 0.02^{0}C to 0.06^{0}C per year in pre-monsoon, 0.02^{0}C to 0.08^{0}C per year in monsoon, 0.02^{0}C to 0.1^{0}C per year in post-monsoon and 0^{0}C to 0.08^{0}C per year in winter seasons.

Mean seasonal air temperature

Then mean air temperature trend in various locations were computed (Table 15). The mean air temperature showed increasing trends in all seasons in Okhaldhunga and Udayapur Gadhi whereas this temperature in Chainpur East showed a decreasing trend. Practical Action Nepal (2009) illustrated that the trend in mean air temperature increase in the entire country except some pockets in northern part of eastern, central and far-western regions of Nepal. The results of this study in Khotang district are comparable with the study by Practical Action Nepal (2009). Chainpur East lies in northern part of eastern Nepal and showed the decreasing trend in mean air temperature. Similarly, Okhaldhunga lies in middle mountainous region and Udayapur Gadhi lies in southern Nepal.

In pre-monsoon season, the trends on mean air temperature across all locations were found significant. The mean air temperatures in Okhaldhunga and Udayapur Gadhi have increased by 0.03^{0}C and 0.05^{0}C per year while this has decreased by 0.06^{0}C per year in Chainpur East. Similar results were observed in monsoon season. The mean air temperature in monsoon season in Okhaldhunga and Udayapur Gadhi increased by 0.02^{0}C and 0.07^{0}C per year respectively while this has decreased by 0.059^{0}C per year in Chainpur East. In post-monsoon season, the highest increasing trend in this temperature was observed in Udayapur Gadhi by 0.1^{0}C per year whereas this has declined by 0.09^{0}C per year in Chainpur East. Udayapur Gadhi has the highest mean air temperature increasing trend in winter season. This temperature has increased by 0.1^{0}C per year in Udayapur Gadhi. In Chainpur East, this has decreased by 0.05^{0}C per year, though insignificant.

Table 15: Linear trend, R^2, p-value and mean with confidence interval for mean air temperatures in different seasons

Locations		Pre--monsoon	Monsoon	Post-monsoon	Winter
Okhaldhunga	*Trend*	+0.03	+0.02	+0.04	+0.04
	R^2	0.29	0.44	0.46	0.42
	p	<0.001**	<0.001**	<0.001**	<0.001**
Udayapur Gadhi	*Trend*	+0.05	+0.07	+0.1	+0.1
	R^2	0.38	0.53	0.52	0.44
	p	0.023*	0.001**	<0.001**	0.01**
Chainpur East	*Trend*	-0.06	-0.05	-0.09	-0.051
	R^2	0.21	0.34	0.39	0.14
	p	0.02*	0.001**	<0.001**	0.06
Mean (^{0}C) (CI at 95%)		+0.01 (-0.14,+0.16)	+0.01 (-0.15,+0.17)	+0.02 (-0.27,+0.32)	+0.03 (-0.15,+0.2)

(* indicates significant at 95% significance level, ** indicates significant at 99% significance level)

The mean across the study sites showed that the mean air temperatures are increasing in all seasons (Table 15). However, these trends were not found significant (p>0.05). The study on temporal and spatial variability of climate change over Nepal from 1976 to 2005 showed that the mean air temperature is increasing across the entire country (Practical Action Nepal, 2009). In my study the same trend was observed, but no significant effects could be found. From pre-monsoon to monsoon season, the trend in mean air temperature remained constant i.e., 0.01^{0}C per year. Thereafter, the trend slightly increased to 0.02^{0}C per year in post-monsoon season. In winter season, the trend in mean air temperature increased the most by 0.03^{0}C per year and the trend decreased with the beginning of pre-monsoon season. The correlation was computed between the mean trends in mean air temperature with the mean trends in precipitation in Khotang district. The correlation between these two variables was +0.29. This illustrates that the trend mean air temperature in Khotang district has small but positive effect with mean trends in precipitation.

Annual crops yield in Khotang district

The yields of paddy, maize, wheat, millet and potato produced in Khotang district were analyzed statistically. The linear trends on the annual yield of paddy, maize, wheat and potato in Khotang district showed significant increasing trends (figs. 16, 17, 18, 20). The yield of paddy, maize and wheat increased by 30, 46 and 44 kilograms per hectare (kg/ha) per year respectively. Linear equations explained 60.7% and 40.7% of total yield variations in maize and wheat respectively while it explained 21.2% of the total yield variations in paddy.

Similarly, the linear trend in millet showed a decreasing trend by 7 kg/ha, though significant ($p>0.05$).

Panta (2012) has studied food security status in Nepal at national and household level. He depicted that the yield of paddy, maize and wheat increased in Nepal. [2]From 1989/90 to 2009/10, the yield on paddy, maize and wheat increased by 1.18%, 2.36% and 3.93% per year respectively (Pant, 2012). Similarly, the trend on yields (from 1978 to 2008) of paddy, maize, wheat, millet and potato in Nepal was also studied by Joshi et al. (2011). This study showed a significant increase in the yield of major crops that are grown in Nepal. Results of my study in Khotang district were comparable with the studies by Joshi et al. (2011) and Panta (2012). Both the studies by Joshi et al. (2011) and Panta (2012) showed positive trends in the yield of major crops grown in Nepal. In my study, the trend on yield of millet showed a negative trend but it was found not significant ($p>0.05$).

In this study, the observed coefficient on potato yield was +0.319. This illustrates that the yield of potato increased by 319 kg/ha per year in Khotang district. This is an extremely high increase; although, it was found statistically significant ($p<0.05$). This linear equation in potato explained 47.7% of the total yield variations. Shrestha et al. (2012) explained such a big change by changes in crop management practices. The change in crop management practices might improve crop varieties, use of more fertilizers and pesticides and shifting in cropping patterns. The trend on the yield of potato in Khotang district of this study is comparable with the trend on the yield of potato for all-Nepal (from 1978 to 2008) as studied by Joshi et al. (2011); and for Makawanpur and Illam districts of Nepal (from 1978 to 2008) as studied by Shrestha et al. (2012). Both the studies showed a quite high trend in potato yield in comparison to other crops. A trend on the yield of potato in all-Nepal showed an increasing trend by 260 kg/ha per year; whereas the trends on the yield of potato in Makawanpur and Illam districts were 226.58 kg /ha and 220.65 kg/ha per year respectively.

2 growth rate in edible portion i.e., after milled

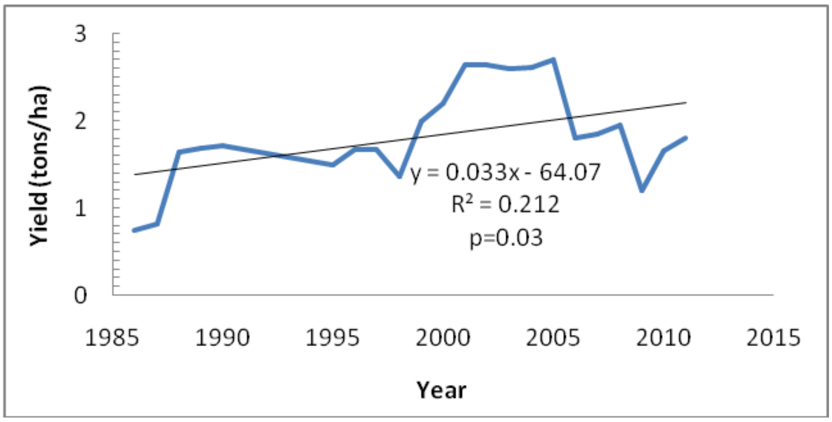


Figure 16: Annual paddy yield in Khotang district from 1986-2011

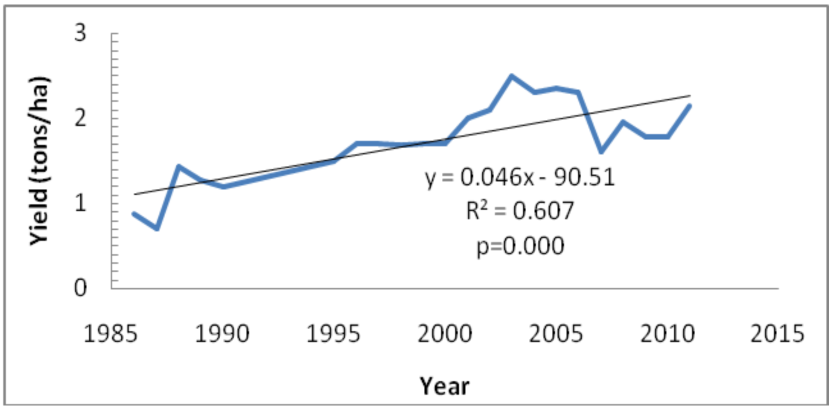


Figure 17: Annual maize yield in Khotang district from 1986-2011

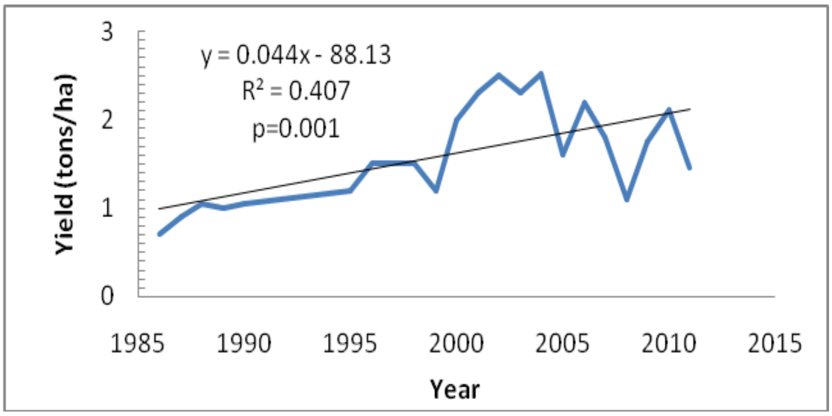


Figure 18: Annual wheat yield in Khotang district from 1986-2011

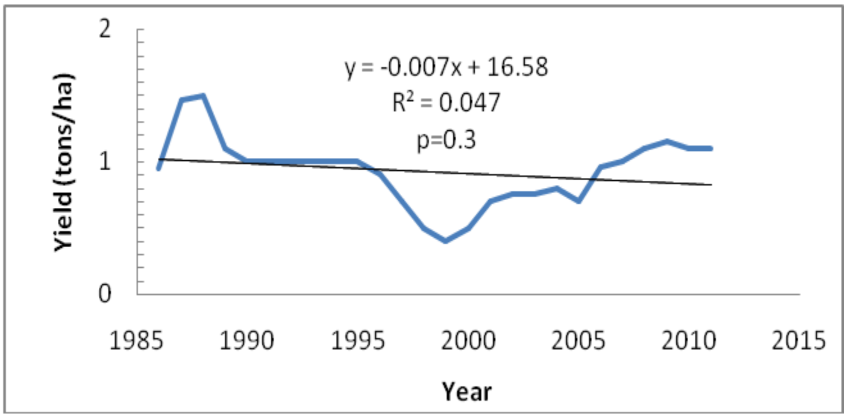


Figure 19: Annual millet yield in Khotang district from 1986-2011

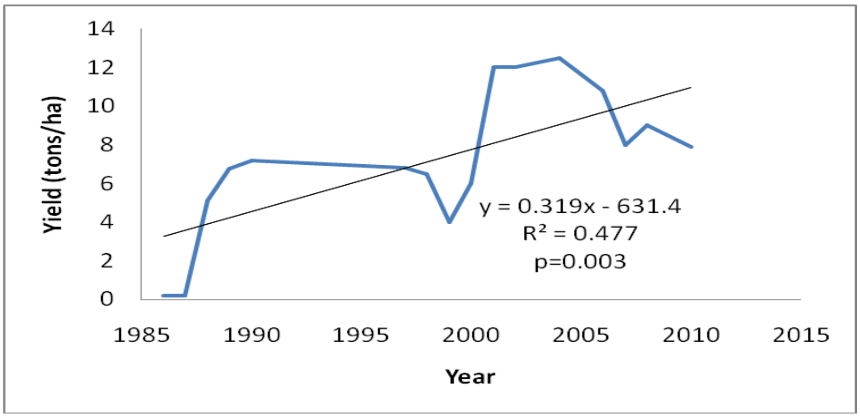


Figure 20: Annual potato yield in Khotang district from 1986-2011

Relationships between yield of crops and climate variables

Multiple regressions analysis were carried out to study the relationship between the annual yields (in tons per hectare) of major crops and climate variables in Khotang district (Table 16). The results showed that the effect of climate variables on yield of maize and wheat were found statistically significant at 99% significance level and these explained 60% and 79% of the variations on the yield of maize and wheat respectively. There is no significant effect of climate variables on the yield of paddy, millet and potato ($p>0.05$).

When examining the effect of actual climate variables, significant effects of minimum and maximum air temperatures were observed on the yield of maize ($p<0.05$). However, the effect of these two variables on yield of maize was opposite. The coefficient for minimum air temperature and maximum air temperature were -0.35 was +0.34 respectively. These indicate that the yield of maize has negative relationship with minimum air temperature and positive relationship with maximum air temperature. There is no significant effect of precipitation on the yield of maize (p>0.05). Similarly, all climate variables have statistically significant effect on the yield of wheat (p<0.05). The coefficient of minimum air temperature was -0.43 indicating the negative relationship between minimum air temperature and the yield of wheat. This illustrates that the yield of wheat decrease with increasing minimum air temperature. The coefficient for maximum air temperature and precipitation were +0.45 and +0.005 indicating that the yield of wheat increase with increasing maximum air temperature and so with increasing precipitation. The effect of precipitation in wheat yield was found weak in comparison to the effect of maximum air temperature; however, the effects were significant in both cases.

Table 16: Effect of climate variables on yield of major crops in Khotang district

Crops	*Intercept coefficient (p-value)*	Min. air temp.		Max. air temp.		Precipitation		R^2	*Sig. F*
		coefficient	*p-value*	*coefficient*	*p-value*	*coefficient*	*p-value*		
Paddy	-8.87 (0.90)	-0.08	0.55	0.21	0.43	0.0009	0.28	0.27	0.22
maize	-2.23 (0.51)	-0.35	0.004	0.34	0.01	0.0007	0.30	0.60	0.008
wheat	-4.11 (0.23)	-0.43	0.0003	0.45	0.02	0.005	0.04	0.79	0.002
Millet	+9.63 (0.06)	-0.02	0.8	-0.35	0.07	0.000	0.93	0.29	0.26
Potato	+9.49 (0.80)	-2.42	0.06	1.67	0.24	-0.006	0.46	0.64	0.08

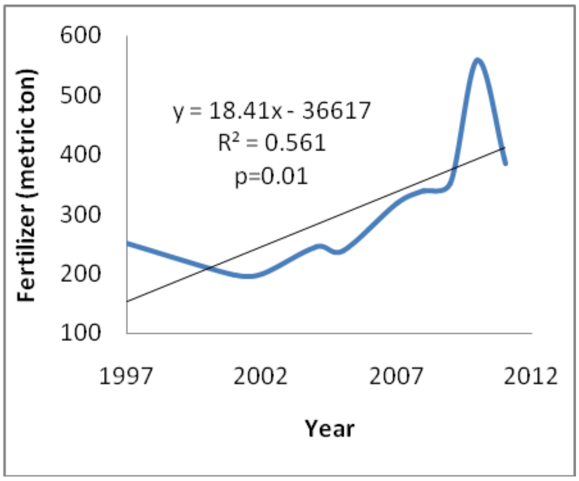
Several studies have been carried out to study the relationships between climate variables and the yields of major food crops in Nepal (Joshi et al., 2011; Shrestha et al., 2012). There are contradictory results on the effect of temperatures on crop yields in Nepal. The results of this study in Khotang district was compared with similar studies conducted in Nepal. Joshi et al. (2011) studied the effect of climate variables on the yield (1978-2008) of six major food crops (paddy, maize, wheat, millet, barley and potato) in Nepal. Further, Shrestha et al. (2012) also studied the relationship between climate variables and the yield (1978-2008) of similar crops in eastern (Illam district) and central (Makawanpur district) Nepal.

A study by Joshi et al. (2011) in all-Nepal and a study by Shrestha et al. (2012) in Illam district revealed that there is no significant effect of minimum air temperature on the yield of major food crops. While in the same study by Shrestha et al. (2012) in Makawanpur district showed that the effect of minimum air temperature was significant in paddy and maize; and the relationships were negative in both crops. In my study in Khotang district, the effect of minimum air temperature observed in the yields of maize and wheat were significant ($p<0.05$). Both crops yield showed negative effect in relation with minimum air temperature. The effect of maximum air temperature was statistically significant on the yield of maize in all-Nepal (Joshi et al., 2011) and in Illam district (Shrestha et al., 2012). However, the relation observed were opposite i.e., the effect of maximum air temperature on the yield of maize was negative in all-Nepal, and this effect was positive in Illam district. In my study, the effect of maximum air temperature was found significant in maize and wheat ($p<0.05$). The effect of precipitation on the yield of paddy was positive and significant in all-Nepal, and in paddy and wheat[3] in Illam district. A study by Shrestha et al. (2012) also revealed that the effect of rainfall in all crops were not significant in central Nepal (Makawanpur district). Assessing all these studies across Nepal, the effect of climate variables are not observed consistent in all locations.

The yields in paddy, wheat, maize and potato in Khotang district were increased. There might be other factors that have direct influences on the yield and production of crops. The effective adoption of improved technologies results in increasing productivity i.e., an improved farming system, instruction of farmers, supply of inputs and availability of markets are the four major requisites to increase the productivity (FAO, 1981).

The total fertilizers and pesticides distributed in Khotang district from DADO Khotang were also analyzed to observe the trends on their use. Urea $[(NH_2)_2CO]$ and Di-ammonium Phosphate (DAP) were found to be major fertilizers used in Khotang district. The trend of fertilizer use in Khotang district from 1997 to 2012 showed an increasing trend (Fig. 21). The use of fertilizer in Khotang district has increased by 18410 kilograms per year. Similarly, the use of pesticides use in Khotang district has also increased. The total quantity of powder and volume of liquid distributed from DADO office were used in analyzing the trend of pesticides use in Khotang district. The trend of using powder pesticides has increased by 10.39 kg per year and the trend of using liquid pesticides has increased by 14.94 liters per year (Fig. 22).

[3] significant at 90% significance level (Shrestha et al., 2012)



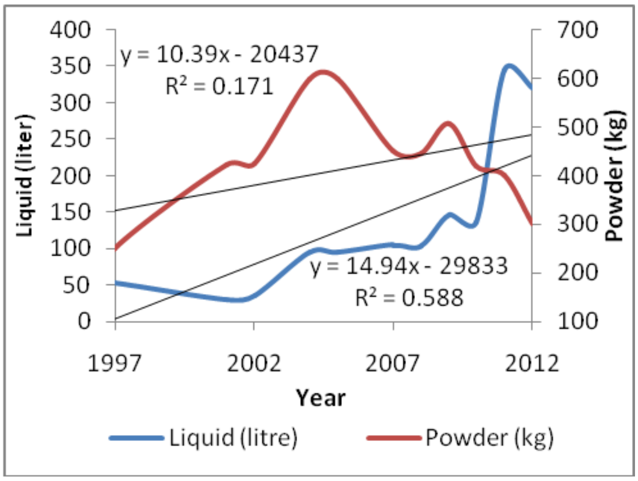


Figure 21: Annual fertilizer distributed from DADO Khotang

Figure 22: Annual pesticide distributed from DADO Khotang

Fertilizer and pesticides use increased with time. This effect is however confounded with the increasing temperature. The temperature effects that I have observed might not be related to a temperature effect but rather to changes in agronomic practices.

The effects of minimum and maximum air temperature on yield of wheat and maize showed significant effect. The minimum air temperature has negative effects while maximum temperature has positive effects. These temperatures might have significant physiological impacts on crop plant. Plant respiration goes up when the temperature increases and this might explain that yield go down as minimum temperature increases. However, the result in Khotang district showed high maximum temperature increase yield. This might be connected to higher radiation on a clear day when temperature is high. Considering the role of temperature rise in biophysical system of crops, Panta (2012) assessed the effect of average monthly temperatures during crop growing season on yield of crops in Kapilvastu district (southern part of central Nepal) and found a mixed result. It revealed that the effects of maximum temperature in April and June showed positive effect in maize yield while the effect is negative in the months of May and June. The same study also revealed that the effect of minimum air temperature in January and February was positive and negative respectively whereas the effect of maximum air temperature is negative for the months March and April. However, the crop growing season in Nepal vary with altitudes.

Farmers observations on climate change and observed changes in farming system in Bamrang Khola micro-watershed: A case study

Background information from sampled households (in total 60 households) was collected during field survey in Bamrang Khola micro-watershed in Khotang district. From the survey, it was found that the average area of total land owned per household was 0.75 hectare (Table 17). The average area of irrigated[4] and rain fed[5] land owned were 0.3 and 0.44 hectare per household respectively. It was also found that the average food secure months in farmers household was 9 months. In 40% of households (HH), the food that farmers produced in their own land in a year is sufficient for 12 months.

Table 17: Number of households with land holding size

Number of households with owned total land size (ha)				
Area of land owned (ha)	<0.5	0.5-1	>1.1-1.5	>1.5
Households (%)	25	60	10	5
Number of households with owned irrigated land size (ha)				
Area of land owned (ha)	0	<0.5	0.5-1	>1
Households (%)	13.3	61.7	25	0
Number of households with owned rainfed/non irrigated land size (ha)				
Area of land owned (ha)	<0.5	0.5-1	>1.1-1.5	>1.5
Households (%)	61.7	33.3	5	0

Source: Field survey in 2013

The average number of livestock raised per household was 2.27 (after conversion in standard tropical livestock unit -TLU)[6]. The highest livestock number owned in household was found 6.8 while the least livestock number found in household was 0.9. Households with the number of livestock owned in Bamrang Khola micro-watershed is given in Table 18.

Table 18: Households with number of livestock owned

Livestock (in TLU)	<1	1-2	2-3	>3
Household	8.3%	43.3%	30%	18.4%

Source: Field survey in 2013

4 including year round irrigated and partly irrigated

5 land that totally depends on precipitation for the cultivation

6 Standard used for one Tropical Livestock unit (TLU) is one cattle with a body weight of 250 kilograms and the exchange ratios for the livestock in Tropical Units is based on Metabolic Body weight. Conversion units for: cattle- 0.7, sheep/goat- 0.1, pig- 0.2, chicken 0.01- accessed from http://www.fao.org/ag/againfo/programmes/en/lead/toolbox/Mixed1/TLU.htm

The average annual income per household in the area was 1322 US$. The highest annual income found in household was 8638 US$ while the lowest was 101 US$. However, the average total annual income in 41.67% of the total households is less than 500 US$. Agriculture (selling crops, livestock and their products) contributes about 32% in average total annual income per household (Table 19). The remittance represents approximately 37% of average annual income in farmers household. The average annual income percent per household contributed by selling crops, livestock and their products in this area was found higher in comparison to the average annual income percent per household contributed from the farm in Nepal. [7]A survey in 2010/2011 reported that 27.75% of the total income per household in Nepal was contributed by agriculture while the remittance contributed 17.2% of the total annual household income (CBS, 2011).

Table 19: Average annual income (US$) per household in Bamrang Khola micro-watershed

	Selling crops and products	Selling livestock and products	Wage	Business and service	Remittance	Others
Average income (US$)	248	177	49	354	488	8
Income by percent (%)/HH	18.76	13.37	3.66	26.80	36.90	0.61

Source: Field survey in 2013

Average household size in Bamrang Khola micro-watershed was 5.9, ranging from 3 to 12. The average household size found for this area was more than the average family size in Nepal. CBS (2011) has reported that the family size in Nepal was 4.88. The average number of members per household in Bamrang Khola micro-watershed engaged in farming activities was found to be 1.34. On average, farmer's household in this area spent 13.1 days per month on farm works.

Farmers in Bamrang Khola micro-watershed use both old and new varieties of crops. The rotation and the time of cultivation of different crops in Khotang district varies in altitudes (Fig. 4 & 6). Farmers stated that the yield of crops in Bamrang Khola micro-watershed varies from year to year. Shiva Narayan Shrestha of Bamrang- 6 (a key informant) informed that if all the crop management practices were the same as eight to ten years ago, the production will decrease. However, the overall production in the area has been increased. This illustrates

7 The contribution of agriculture in total annual income per household constituted net value of total crops produced, livestock raised and their product selling and net income by renting farm assets (draft animal, tractor, thresher etc).

that despite of variations on climate in this area, changed in crop management practices have increased yield of crops.

Farmers` perception on climate change

Farmers have observed changes in the climate. These changes are related to local weather conditions, onset and end of monsoon, intensity and frequency of monsoon, start of crop growing season etc. in Bamrang Khola micro-watershed. Farmers` perceptions collected from focus group discussions were confirmed by key informants' information along with my own observations during field survey.

Farmers in Bamrang Khola micro-watershed have observed that the intensity of fog has decreased in higher altitude areas as compared to 10-12 years ago. The number of foggy days was more in the past as compared to recent years. Cold waves in winter season now occur seldom in this area. Farmers in this area have experienced a decrease in cold winter period and increase in hot summer period as compared to before. The Fifth Assessment Report of IPCC (AR5) has reported that the number of cold days and nights has decreased whereas the number of warm days has increased in global scale from 1951 to 2010.

Snowfall was intensive in high altitude areas before 8 to 10 years. Now, the snowfall has decreased tremendously. Farmers have related these changes with increased air temperature and decreased winter monsoon in this area. The study on the meteorological data for Khotang district showed that there is a tendency towards increased minimum air temperature and decreased winter precipitation; however, the trends were found no statistically significant.

Farmers have stated that the frequency and duration of summer monsoon in Bamrang Khola micro-watershed has decreased compared to 8-10 years ago, but the intensity of rainfall has increased. Erratic rainfall is more pronounced in these years. Farmers have stated that the onset and retreat time of summer monsoon is irregular in the area and this varies from year to year.

According to the farmers in Bamrang Khola micro-watershed, there was a maximum rainfall in May (pre-monsoon season) in 2012 and the actual monsoon rain was delayed for one month in the same year. Farmers have revealed that monsoon rainfall during first half of June is favorable for crops growing in summer season and if monsoon is delayed there will an effect on the whole cultivation system throughout that year. Normally, the monsoon starts from the second week of June in Nepal and retreats in September every year. The mean precipitation trend from four stations in Khotang district has also showed a tendency towards increased precipitation in pre-monsoon season while it showed a tendency towards decreased precipitation in monsoon season a, but this effect was not significant.

There is a renowned saying among farmers in the area*; Baishakh galos, Jeth balos, Asar ma pani paros*. This illustrates that if there is no rain in April and May it does not matter, but for good production there must be rainfall in the month of June. Furthermore, if there is good rain in June, paddy can be cultivated at normal time. During focus group discussions, farmers have stated that the distribution pattern of the monsoon rainfall in recent years is not even across the area. Eight to ten years ago, the distribution of monsoon rain was even in the region.

According to farmers, the precipitation in the months of January and February (*Maghe jhari*)[8] decreased in frequency and intensity in Bamrang Khola micro-watershed of Khotang district. January and February are the months that contributes winter monsoon in Nepal. Timely rainfall in winter is very good for winter crops (farmers' perception). However, this rainfall is higher in western part of the country than in the eastern part. Farmers have noted that the decreased winter rainfall results in low yield of winter crops like wheat. The time of wheat sowing in Khotang district varies depending on the altitude. In Bamrang Khola micro-watershed, wheat is sowed from first half of November (in higher altitude) to second half of December (in lower altitudes). Wheat sown in the month of December could not get sufficient water for its adequate growth if the rainfall during winter months decreases. Farmers have noted that there was no rainfall in 2005, 2008 and 2012 during winter months in Bamrang Khola micro-watershed. Farmers have observed very less growth of wheat in Bamrang Khola micro-watershed when there is no rainfall during winter months.

Box 1: A key informant`s perception on monsoon rainfall

Shiva Narayan Shrestha (age 62, a key informant and a farmer's leader) is an active farmer in Bamrang VDC-6 in Khotang district. He cultivates paddy, wheat, maize, potato as well as vegetables in his land. According to Shrestha, before he could well predict the monsoon rainfall and starts agriculture works accordingly. Now, the pattern of rainfall has changed. He cannot predict the rainfall. This has made farm operations more difficult.

8 commonly used word in Nepal for the prolonged rainfall during second half of January to first half of February

Many studies have revealed that drought conditions in Nepal have been severely affecting agriculture production (Regmi, 2007; Malla 2008). Regmi (2007) reported that the paddy and wheat production in Nepal were adversely affected by drought in the year 2005/2006. According to the report, the production of paddy and wheat declined by 2.0% and 3.3% respectively. Similarly, high intensity storms/windstorms were experienced in the month of April destroying large quantity of maize plants in the farm. Farmers have noted that the frequency, intensity and duration of storm have decreased now.

Farmers have reported that the water resources in the area have decreased notably. In recent years, most natural spout water tap totally dried up during winter (dry) season. Before, more or less water remained in all natural spout water taps during dry seasons also.

Box 2: A key informant`s perception on water resources

According to Uttar Khadka (age 46), a key informants in Diktel VDC-1, four out of six water sources including small and large water spouts in this area has already dried up in the last few years. The volume of the main watercourse *(Bamrang Khola)*[9] has also decreased almost by half as compared to 8-10 years back. Before, the water volume in this watercourse was sufficient for irrigating low lands in Bamrang khola micro-watershed.

The study on climate change by Koirala and Bhatta (2010) in eight village development committees in Khotang district has reported that 75% of the water sources in Khotang district have dried up. The water level in remaining 25% of the water sources in Khotang district has decreased drastically. Farmers have related this change with increased air temperature and decreased rainfall in this area.

Normally, mosquitoes were present from April to August in lower altitudes of Bamrang Khola micro-watershed. Farmers have noted that the period for mosquitoes observed has been prolonged in this area. Mosquitoes were not observed before in higher regions (cold climate) of this area. Normally, mosquitoes endure warm climates. But in these years, mosquitoes were frequent in higher altitudes of Bamrang micro-watershed. Farmers have related this change to the increased temperature in the area. Malla (2008) has also revealed that mosquitoes from lower tropical /tropical climate (Terai regions) and sub-tropical (mid-hills) are being able to survive in highlands (2000-3000 masl) in Nepal.

9 Rivulet that flows from the area and mix with Koshi river downstream.

Mangoes are tropical fruits and can only be grown in hot climates (average 27-30^{0}C). In Khotang district mangoes were grown only on lower altitude areas. But in recent years, mango can also be cultivated in higher altitudinal areas in Khotang district where the average maximum air temperature before was 20-22^{0}C (source: from field survey- FGD 1). Farmers have also disclosed that flowering of mango and apple started earlier than the normal period. Sometimes off-season flowering in fruits were also observed in recent years. Farmers have related these abnormalities in mango and apple with ongoing climate variability in the area.

Malla (2008) has revealed that a shifting of climatic zone has been observed in Nepal. The shift in climate zone from lower to higher altitudes in Nepal is also explained from the study on the seasonal and annual maximum air temperature data (1971-1994) across Nepal (49 stations). This showed that the warming trends after 1977 in higher altitude regions (hills and mountains) varies from 0.06 to 0.12^{0}C per year while the warming trend was less than 0.03^{0}C per year in lower altitude regions (Siwaliks and Terai). The higher warming trends in high altitude areas of Nepal clearly illustrates that the climate of lowland is gradually shifting towards the highland areas. Tropical fruits like banana, papaya and mango and other crops has been adopted in mid-hills (subtropical climate) of Nepal and observed off-season flowering in high altitudes regions (Malla, 2008).

Major climatic events

The time series major climatic events in Bamrang Khola micro-watershed were collected during FGDs and key informants' interviews in Bamrang Khola micro-watershed. The study was focused on the major impacts observed by the farmers due to these major climatic events. According to farmers in Bamrang Khola micro-watershed, drought and hailstorm are the major climatic events that frequently occurred in this area. Paddy, wheat, potato were mainly affected by these climatic events in this area. Major climatic events and the affected crops by these events are represented below (Table 20).

According to farmers, drought has been observed frequently the last 8 to 10 years. Drought has been observed frequently in every three years time since 2005. Farmers stated that droughts were experienced in 2005, 2008 and 2012 in this area. In the year 2005, meteorological drought was observed in most part of Khotang district in winter months (source from FGD1). The recorded precipitation data in Aiselukharka, Kuruleghat, Khotang and Diktel showed that there was no rainfall in winter months (December and following year January and February) in the year 2005. The impacts of the drought in 2005 have been observed in winter crops. The yield data published by DADO Khotang showed that the yield of wheat in Khotang district has decreased by 31% in 2005 compare to the earlier year. According to the farmers, droughts in 2008; and droughts and hailstorms in 2012 have reduced the yield on major crops in Bamrang Khola micro-watershed. The yield of paddy and wheat observed in Khotang district have decreased by 32% and 27% respectively in 2008 as compared to previous year.

Box 3: A key informant`s perception on climate event

According to Shiva Narayan Shrestha, a farmers' leader in Bamrang Khola micro-watershed, the drought in 2008 affected mainly the paddy cultivation in this area. Lands were left barren without cultivating paddy. During that time, paddy was cultivated using tank water through pipe supply by some farmers. Monsoon rain has started only from August. In that year, the yield of paddy was very low in Bamrang Khola micro-watershed.

Table 20: Major climatic events and affected crops in Bamrang Khola micro-watershed

Year	Major climatic events	Affected crops	Impacts
1977	Agricultural drought	paddy	Very low paddy production in Khotang and has resulted starvation in this area
1984	Excess hailstorm	paddy	Destroyed fully matured paddy plants in November- low yield of paddy
1987	Hailstorm	paddy and millet	Low yield- even bark of trees were destroyed in forests
1992	Hailstorm	Wheat and vegetables	Very less wheat production and vegetables were destroyed
1997	Hailstorm	wheat and pea	Yields on these crops were almost zero
2002	Hailstorm	paddy	Destroyed paddy plants just before harvesting
2005	Meteorological drought during winter months	Wheat	Low yield
2006	Excess rainfall	paddy	Landslides in paddy fields- destroyed paddy plants resulting low yield

2008	Meteorological and hydrological drought	Paddy	Water sources have dried up - low yields of paddy
	Hailstorm	wheat	Wheat plants destroyed- low yield
2012	Agricultural drought	Maize, millet, wheat and potato	Less production

Hailstorms were observed frequently in Bamrang Khola micro-watershed at every five to six years period. According to the farmers, hailstorms in 1984, 1987 and 2002 have affected seriously the summer crops in this area while hailstorms in 1992 and 1997 affected winter crops. Farmers stated that the impacts of these hailstorms were low yields in major crops like paddy and wheat.

Farmers` perceptions on pests and diseases

Farmers in Bamrang Khola micro-watershed have observed changes in the various pests and diseases in major crops that are cultivated in the area. Malla (2008) revealed that the development and distribution of pest and diseases in crops directly depends on the temperature, rainfall pattern and humidity of that area. In my study, the information regarding changes that occurred in frequency and occurrences of common pests and diseases as well as occurrences of new pests and diseases were collected during FGDs in Bamrang Khola micro-watershed. Besides, farmers' perceptions concerning the changes that occurred in pests and diseases in major crops grown in this area were also studied. This study also relates these changes with the ongoing climate variability in this area.

Drying of maize seedlings have been noted by most of the farmers in both new and traditional varieties in recent years. Similarly, the increased frequency and intensity of leaf drying has resulted in leaf fall problem in maize during the development phase. White grub[10] (*Phyllophaga spp.)* is an insect in soils occurring at approximately 20 cm depth (farmers' perception). Farmers have noted that these insects in recent years were seen in deeper soils layers during the maize cultivation period. Farmers have related this change with increased air temperature in that area. According to farmers, this insect goes much deeper into the soil in searching for moisture (adopting with increased temperature) and started cutting maize

10 Local name- *Khumre*

roots that cause root infections. This has resulted in falling maize plant in this area during pre-mature periods.

According to Om Karki, a farmer aged 55 years from Bamrang VDC-6, the attack of fungal pathogen maize smut[11] (*Ustilago maydis*) has increased in recent years in both old and new varieties of maize during maturity period. This has resulted decaying of the maize cob and rotting of maize seeds. Farmers` have related these abnormalities with increased air temperature and decreased rainfall during sowing and grain filling periods. Some farmers have also related rotting of seeds with untimely rainfall during maturity period. From meteorological data analysis in Khotang district, it was shown that there was a tendency for increased mean air temperature in winter and pre- monsoon season, but this effect was not statistically significant (Table 15). Similarly, the analysis also showed that tendency towards decreased precipitation in winter and increased precipitation in pre-monsoon period in Khotang district; however, these trends were also not significant statistically (Table 11). Besides, farmers have stated that the adventitious roots in maize plants were not well developed in recent years as compared to 8 to10 years ago. This might be related either with the shifting in cropping time or with the short cropping period than the normal period.

In paddy, farmers have observed swirling of leaves (*Beruwa*) in the last 8-10 years. In additions, farmers have noticed small pests (unknown name) that attack roots of paddy. This has caused drying of whole paddy patch or sometimes even has resulted in dead of plants (*Maruwa*). This trend has increased intensively in the area mainly in varieties during growth period. Farmers have stated that the frequency of rice blast (caused by a fungal pathogen- *Magnaporthe oryzae*) attack in the paddy panicle and stem has increased during flowering and seeding period in recent years. According to farmers, the fungal attack during this period has resulted in less seeds production in paddy. They have related this effect with high moisture content and low incidence of sunlight during flowering and seeding period of paddy plant. Farmers have experienced increased intensity in fog and clouds which are followed by prolonged rain during the month of September (*Ashoje jhari*)[12]. More clouds and fog that covered the atmosphere in this period cause high moisture content in atmosphere and low incidence of sunlight which might be favorable for fungal attack in paddy plants. Farmers revealed that occurrences of weeds in recent years are frequent and increased in intensity in

11 Local name- *Kalipoke*

12 low intensity but prolonged rain during the first half of September

the paddy field. This might be related with the overall decreased precipitation in monsoon season and increased use of fertilizers in the paddy field.

During farmers' group discussion in Khalle VDC-9, famers have revealed that yellow patches (unknown fungal diseases) and grain borer *(Prostephanus truncatus)* are frequent in wheat in recent years during seeding period. These were seen in both new and traditional varieties. According to farmers, these diseases were common; however, the frequency of these diseases has increased. They have related this with less winter rainfall. They also revealed that grain borer has the ability to be spread by air and this happens mainly during dry periods. The mean trend in precipitation for four stations in Khotang district has shown that winter rainfall (December to February) has been decreased while for the pre-monsoon rainfall there is a tendency towards increased precipitation; however, these effects were not significant.

Local varieties of millet were cultivated in Bamrang Khola micro-watershed. Farmers notified that the management practices used for the millet production in this area are traditional. Traditional diseases in millet are yellowish of leaf and death of plant (*Dadhuwa*) that reduces production. No new diseases and pests are noted in millet since it is one of the least prioritized cereals in this area. In case of potato, farmers change the seeds every year (prescribed by DADO Khotang). Farmers revealed that the attacks of red ants in potato during seeding periods in this area are more frequent than before. However, the occurrences of red ants in potato are usual in this area. Farmers have linked this increased frequency of red ants in recent years with ongoing climate variability. Farmers have observed these occurrences mainly after either too cold or too dry period. Dry and death of potato *(Dadhuwa)* plants were also observed by farmers during development phase in some years. Farmers have connected this change with high intensity of rainfall for short time followed with long dry winter days. However, less rainfall is supposed to be favorable for potato plants.

Changes in crop management practices

In Khotang district, farmers might have adopted various techniques to adapt with ongoing climate variability. During focus group discussions and key informants interviews in Bamrang Khola micro-watershed, information regarding changed crop management practices in major crops in the last 8 to 10 years was collected. In additions, farmers' perceptions concerning the cause for these changes in the management practices were also collected.

In Bamrang Khola micro-watershed, average maize sowing period in lower part (in irrigated land) has been shifted two to four weeks later. This has resulted in later maturity time of maize. Normally, maize seeds are sown in irrigated and partly irrigated lands during the month of February while in rain fed lands; these are sown during April. Farmers have revealed that the winter rain (January and February) has decreased in this area and this has resulted in drying of maize seedlings. To overcome this, farmers have started soaking the maize seeds in water for one whole night before sowing (seed priming) in irrigated and partly irrigated lands (practiced by some farmers) while in rainfed lands; farmers wait for the pre-monsoon rainfall (March to May). Coulibaly and Aune (2007) has defined seed priming as method which consists submerging seeds in water and the optimal soaking time varies on crops. The effects of priming on plants is shown in reduced germintion time, uniform growth, reduced cropping period, more resistant to pest and fungus attack with high outputs (Coulibaly and Aune, 2007). Ousman and Aune (2011) has studied the effect of priming and micro-dosing in ground nuts, cow pea and seasame for three years in on farm and on station experiments under rainfed lands in Sudan. According to this study, the combination of mocro dosing with seed priming has the potential to increase the productivity and improves the output in crops

Broadcasting as a maize sowing practice has been displaced by row sowing where the seeds are dropped in plough line and are buried. When broadcasting is practiced, seeds are broadcasted randomly after the plowing is done in the field. Farmers have revealed that the moisture content in seeds will be preserved when sowing maize in rows. Farmers have related this change in sowing practice with the adoption to changed rainfall during maize sowing period (February). According to farmers, the use of fertilizers in the maize field has increased to a great extent.

Both traditional and new varieties of paddy are used in Bamrang Khola micro watershed. *Tauli*, a local paddy variety is sowed in early May and transplanted in early monsoon. Farmers stated that the late monsoon in this area has resulted very less yield in *Tauli* variety. Nowadays, the use of this variety has disappeared. Similarly, due to increase in air temperature in hilly areas (colder regions), local and prescribed cold resistant varieties of paddy were demolished. *Pokhreli*, a new variety of paddy was introduced as a cold resistant variety to be grown in colder areas (1200 to 1400 masl). Later, this variety is not cultivated in these regions due to increased temperature in the areas (from FGD1). De Datta (1981) has revealed that variation in rainfall is more critical for upland rice cultivation than for lowland.

According to farmers, erratic and unpredictable precipitation pattern are pronounced in this area in recent years. Due to this reason, the time for seed sowing and transplanting of paddy is uncertain. Normally, sowing of paddy seed is done from last of May to beginning of June, if proper and timely precipitation occurs in this area. But this trend has been shifted to three to four weeks later that has resulted in 3 to 4 weeks late transplanting of paddy seedlings (in some early monsoon years, this practices has been shifted 1-2 weeks earlier from usual time). The yield of *Pahelo atela* (a type of local paddy variety) was found to decrease when cultivated during late monsoon while the yield of this variety increases when cultivated during timely monsoon. Farmers in this area have started replacing *Pahelo atela* by other new varieties of paddy. Farmers revealed that the reason behind replacing *Pahelo atela* with other varieties was untimely monsoon pattern in this area.

The trend of using pipe water supply irrigation was common in Bamrang Khola micro-watershed instead of direct channel irrigation (from my own observation). System of Rice Intensification (SRI) techniques have also been practiced by some farmers in this area. However, most of the farmers in this area were found unfamiliar with the practices used in SRI technique. In SRI technique, seed is moistened (seed priming) and sowed in dry and fine soil bed and then covered with straw to maintain moisture. [13]International Rice Research Institute (IRRI) has defined SRI techniques as an evolving set of practices aimed to increase the productivity of rice by changing the management practices in plants, soils, water and nutrients. Farmers in this area have observed comparatively fewer pests in paddy plants with this technique. Otherwise, the usual trend of sowing paddy in this area was sowing in wet and finely prepared soil bed without mulching. Farmers have related this change in practice with low precipitation in this area. They explained that they are using this technique to adapt to water deficit and to avoid excess evaporation from the seed sowing bed. [14]According to International Fund for Agricultural Development (IFAD), there is a significant reduction in the use of seed with SRI techniques; and SRI reduces water consumption in plants by 40 to 85%.

The trend of using fertilizers and pesticides in the paddy field has increased in Bamrang Khola micro-watershed. Farmers stated that they use more fertilizers and pesticides to increase crop growth. The distribution of fertilizers and pesticides in Khotang district from 1997 to 2012 also showed an increased trends (Figs. 21 & 22). More pesticides were used in

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13Source: http://irri.org/news/hot-topics/system-of-rice-intensification-sri; accessed in 5 May 2014.
14 Source: http://www.ifad.org/english/sri/index_full.htm; accessed in 5 May 2014.

crops to prevent and destroy pests and diseases that are new and frequent in this area. Traditional manual weeding has also been practiced in this area. However, the trend of using herbicides and other pesticides has increased. Farmers stated that weeds are more frequent and intense in paddy field in the recent years. Farmers in this area started weeding paddy field more frequently than usual (from key informant's interview). To control weeds in the paddy field, farmers in this area use herbicide 15 days after transplanting of paddy seedling (first caring) and this is followed with a first and second manual weeding which are done in 30 days and 45 days after transplantation of paddy seeding. According to farmers, the use of herbicides in the field after 15 days of paddy transplantation has controlled weeds significantly in the paddy field.

According to farmers in Bamrang Khola micro-watershed, late sowing seeds and late transplanting of seedlings prevailed in this area. Flowering and maturing time of paddy in this area were found to be earlier than the normal time. This illustrates that the paddy cropping period in this area has been reduced. This could be related with the increased temperature in Bamrang Khola micro-watershed. According to Malla (2008), the rising temperature and emissions of carbon dioxides enhances photosynthesis processes, shortening physiological period, increase water use efficiency in crops and increase microbial activities.

Both traditional and new varieties of wheat seeds are used in cultivating wheat in Bamrang Khola micro-watershed. According to farmers, fields need to be moistened few days before broadcasting wheat seeds in the field. Irrigation must be done in wheat field in 28 days of seed broadcasting and during the start of wheat flowering period. Generally, wheat is sowed in the field during November to December, one month after paddy harvest (in lower altitude regions). Farmers have explained that the rainfall has decreased during wheat sowing period in recent years. From the study of meteorological data, the mean trend on winter precipitation for four locations in Khotang district showed a tendency towards decreasing precipitation; however, this trend was not found significant. In areas where there is less or no irrigation facility, wheat is broadcasted immediately after harvesting paddy from the field (without leaving the land fallow for one month after paddy harvest). Farmers have explained this practice of early broadcasting of wheat to preserve the soil moisture content in the field. Farmers have related this with decreased precipitation and increased temperature during months of November and December (wheat sowing period). Farmers also stated that rainfall in January and February is very good for wheat cultivation. Some farmers in Bamrang Khola micro-watershed have used pipe water irrigation practice during the time of water needs in wheat fields.

In some colder regions (highland areas) of Khotang district where snowfall prevails in winter, wheat is broadcasted from beginning of September. Snowfalls are the source of water for wheat plants in these areas. Farmers in Bamrang Khola micro-watershed have noticed that the intensity and duration of snowfall in these areas decreased in recent years. This has resulted in water deficiency in wheat plants during the growth period. To adapt with this change, farmers in highland areas of Bamrang Khola micro-watershed are using new varieties of wheat. The time of wheat broadcasting in these areas has also been shifted one month later than before. *Gautam, LL297, LL971, BL1473* and *Bijaya* are new varieties of wheat that are grown in Khotang district (DADO, 2012). In Khotang district, trends on mean air temperatures in winter season showed a tendency towards increase while the precipitation in this season showed a tendency towards decrease (Tables 11 & 15). However, these trends were not found significant.

According to farmers, rust and blight were seen frequently in these years in wheat plants during flowering period. To overcome this change, *RR21* (an old improved variety of wheat) has been replaced by *Gautam* (a new variety of wheat). Grain borer (a disease during seeding period) was also frequent in recent years in Bamrang Khola micro-watershed. To adopt with this, farmers are using new varieties of seeds as prescribed by DADO Khotang.

Millet is normally cultivated from July to December in Khotang district in rainfed lands. According to farmers, varieties and management practices in millet cultivation are same as before in Bamrang Khola micro-watershed. Generally, millet transplantation in rainfed lands is done after the transplantation works of paddy is completed in irrigated lands. However, there was three to four weeks shift in sowing and planting time of millet as compared to before since the sowing and transplantation of paddy has also shifted three to four weeks later. Farmers stated that there is no effect of rainfall in millet production. However, less moisture is good for the production of millet. According to farmers, rainfall during millet flowering period results lower yield.

Potato is the fourth main food crops in the world after maize, paddy wheat and is mainly grows best at about 20^0C (Rykaezewska, 2013). Its growth does not perform well in hot climate. Potatoes are mainly grown in high altitude areas in Khotang district from February to August as a major crop (source: from FGD1). Farmers stated that the time of potato cultivation in this area is same as before. In Bamrang Khola micro-watershed, farmers have made some changes in potato management practices. Farmers use more Faradin (a type of pesticides) to control the attack of red ants. The attack of red ant in potato is common in the area. According to farmers, the frequency and intensity of red ant attack has increased in recent years. They have noted this change in occurrences of red ants mainly after the high intensity of rainfall followed with dry weather during seeding period. Mustard cake was also practiced to control red ant; however, this practice was traditional. In recent years, potatoes are sowed on a ridge bed instead of direct on flat land. Farmers have related this with decreased precipitation during potato sowing period. According to farmers, this new practice helps to maintain the soil moisture. In dry period, the amount of water in water sources is very low or even dry in recent year. Before eight to ten years, the level of water in sources was sufficient to irrigate potato field even in dry season. In recent years, water from the source is collected in deep pits and sprinkled in potato field. Farmers have related this change with increased air temperature with decreased rainfall in potato sowing month (February). Study on meteorological data for Khotang district revealed that the air temperature for winter season (December to February) showed a tendency towards increasing trend while the precipitation showed a tendency towards decreasing trend; however the effects were not found significant. Normally, the time period of potato cultivation (sowing to harvesting) is three months. Farmers in this area have noted that the cropping period in potato decreased approximately by 10 days in recent years as compared to eight to ten years ago. The changes that were observed by the farmers on climate and farming practices in Bamrang Khola micro-watershed is summarized in table 21.

Table 21: Summary on farmers` respond to climate change in Bamrang Khola micro-watershed

	changes in	**Observed changes in 8 -10 years**
Variations in climate	Intensity of fog and cold waves	Has decreased during winter months
	Cold winter period	Has decreased
	Hot summer period	Has increased
	Summer monsoon	unpredictable, decreased in frequency and duration in rainfall; intensity increased, shifted one month later
	Winter monsoon	Has decreased in intensity and frequency no rainfall in some years
	Storms/windstorms (in April)	Has decreased in frequency, intensity and duration
	Snowfall	Has decreased in frequency, intensity and duration
	Climatic zone/snowfall	Shifts in climate zone from lower to higher altitudes

Pests and diseases; and other changes	Drying of maize seedling and leaf drying during maize development period	Intensity and frequency has increased
	Attack of White grub in roots of maize	Resides much in deeper soils in recent years during maize cultivation period
	Attack of Maize smut (fungal disease) in maize cob	Has increased in both old and new varieties of maize
	Swirling of leaves and dead of paddy plants	Has increased in frequency
	Fungal attack of *Phyllophaga spp* in paddy	Has increased in frequency in old and new varieties
	Rust and blight in leaves; and grain borer in wheat	More frequent in both old and new varieties
	Attack of red ants in potato	More frequent during seeding period
	Dry and death of potato (*Dadhuwa*)	Has increased in intensity and frequency
Management practices in crops	Maize sowing period (in irrigated land)	Has shifted two to four weeks later due to late arrival of winter monsoon
	Seed priming in maize	Is practiced by some farmers during winter season
	Sowing of maize	Broadcasting practice has been displaced by row sowing
	Use of fertilizers and pesticides in paddy, wheat, maize and potato	Has been increased in great extent
	Tauli, a local variety of paddy	Has disappeared from this area due to late monsoon
	Pokhreli, a new variety of paddy introduced as a cold resistant variety grown in uplands	Has been replaced by other new varieties due to increase in temperature and rainfall variation
	Seed sowing and transplanting of paddy time	Has shifted 3 to 4 weeks later due to late arrival of monsoon
	Pahelo atela, a type of local paddy variety	Has been replaced with other new varieties due to untimely monsoon
	Irrigation practices	Pipe water supply irrigation were used by some farmers instead of direct channel irrigation practices
	Seed sowing practice in paddy	Old paddy sowing practice is replaced by new practice (SRI techniques)
	Weeding practice	Improved weed control by the use of herbicide followed with first and second manual weeding
	Wheat seed sowing practice	Broadcasted immediately following harvesting of paddy to preserve moisture content in the field in lowlands. Time of sowing has shifted one month later in highlands due to untimely snowfall.
	Varieties of wheat	Old verities have been replaced by other new varieties to overcome the attack of some new diseases
	Sowing and transplanting of millet	Has shifted three to four weeks later
	Use of pesticide in potato	Has increased to control the attack of red ants
	Sowing practice in potato	Sowed in ridges instead of sowing at flat
	Irrigation practice in potato	Water is collected by some farmers in a deep pit and sprinkled instead of direct water supply

Conclusions

The total annual precipitation, and average annual minimum and maximum air temperatures in various sites showed variations in their trends. There was a tendency towards decreased precipitation in Khotang district but this trend was found not significant. Similarly, the mean trends in maximum and mean annual air temperature showed tendencies towards increasing trends while minimum annual air temperature showed a tendency towards decreasing trend. However, the trends on these air temperatures were found not significant. More sites are needed in order to draw more clear conclusions on the changes in climatic parameters.

Similarly, the seasonal precipitations and air temperatures in various locations showed variations in their trends. The mean trends in precipitation in monsoon (-2.34 mm/year), post-monsoon (-0.68 mm/year) and winter seasons (-0.04 mm/year) showed the tendencies towards decreased precipitation except in pre-monsoon season (+0.63 mm/year). However, the mean trends in seasonal precipitations were found not significant. The trends in seasonal minimum and maximum air temperatures did not show any significant changes. The mean air temperatures computed for pre-monsoon, monsoon, post-monsoon and winter seasons have shown the tendencies towards increased temperature in Khotang district; however, these trends were also found not significant.

Significant yearly increases in the yields of paddy (30 kg/ha), maize (46 kg/ha), wheat (44 kg/ha) and potato (319 kg/ha) have been observed in Khotang district. This is likely to be related with improved management practices, increased fertilizers and pesticide use. Significant effects of climate variables were observed in maize and wheat yields in Khotang district. The yield of maize showed a negative relationship with minimum air temperature while a positive relationship with maximum air temperature. There is no significant effect of precipitation on the yield of maize. Similarly, the yield of wheat in Khotang district has positive relationships with maximum air temperature and precipitation while it has a negative relationship with minimum air temperature.

Despite the difficulties to prove significant changes in weather parameters, farmers have observed changes. According to the farmers in Bamrang Khola micro-watershed, the intensity and frequency of fogs and snowfalls have decreased in higher altitudes in the last eight to ten years. The cold winter period has decreased while the warm summer period has increased during this period. The frequency and duration of summer monsoon has decreased whereas the intensity has increased. Onset and retreat of monsoon rainfall varies from year to year and is unpredictable. According to the farmers' perceptions, the monsoon rainfall shifted one month later than before. Frequency and intensity of winter rainfall and windstorm have decreased. Drought and hailstorm were the major climatic events that frequently occurred in this area. The trends have shown that hailstorms occurred at every five to six years and drought occurred at every three to four years in this area.

Farmers have also stated that the frequency and occurrences of common pests and diseases and occurrences of new pests and diseases were observed in major crops grown in this area during the last eight to ten years due to the variations in climate in the area. The attacks of white grub in roots and maize smut in cobs maize plants, rice blast in panicles and stem of paddy plants, rust and blight disease and grain borer in wheat and red ants in potato plants have found to be increased in this area in last eight to ten years.

Farmers in Bamrang Khola micro-watershed have adopted various management practices to adapt to climate variability. Changes were observed in sowing practices, time of cultivation, weeding methods, use of varieties and irrigation methods for major crops. Maize sowing period has been shifted two to three weeks later. Seed priming are done in major crops like maize and paddy to overcome droughts. Uses of fertilizers and pesticides have increased to a great extent. Broadcasting as a maize sowing practice has been displaced by row sowing. The time of paddy broadcasting and transplanting is uncertain; although these have been shifted three to four weeks later than previously. SRI techniques were used by some farmers to cultivate paddy to cope with uncertain time in monsoon. Pipe water supply is dominated in this area instead of open irrigation channel.

Farmers are using new varieties of paddy and wheat as an adaptation measure to climate change. In areas where there is less water for irrigation or no irrigation facility, wheat is broadcasted immediately after harvesting paddy from the field without leaving the land fallow for one month after paddy. The time of sowing and transplanting of millet has been shifted three to four weeks later. Potatoes are sowed on a ridge beds instead on flats. Water is sprinkled in potato field instead of direct open irrigation from the source to adapt with less water for irrigation.

Conclusively, changes in climate variables pattern has occurred in Khotang district. More observations are needed to conclude the clear trends on these variables. However, the impacts of these changes are being felt in crop productions system in Khotang district in one or another way.

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Appendices

Appendix 1: Acronyms and Abbreviations

^0C	: Degree centigrade
AR5	: The Fifth Assessment Report on climate change
CI	: Confidence Interval
DHM	: The Department of Hydrology and Meteorology
FGD	: Focus Group Discussion
GCM	: General Circulation Model
GDP	: Gross Domestic Product
GHGs	: Green House Gases
HH	: household
IPCC	: Intergovernmental Panel on Climate Change
Kg/ha	: kilograms per hectare
masl	: meters above sea level
mm/year	: millimeters per year
MOAD	: The Ministry of Agriculture Development
R^2	: measure of goodness of fit of linear regression
SOI	: Southern Oscillation Index
SRI	: System of Rice Intensification
t/ha	: tons per hectare
TLU	: Tropical Livestock Unit
VDC	: Village Development Committee

Appendix 2: Annual yields on major crops grown in Khotang district

Years	Paddy	Maize	Wheat	Millet	Potato
1984	0.74	0.88	0.71	0.95	0.2
1985	0.82	0.7	0.9	1.46	0.11
1986	1.64	1.43	1.04	1.5	5.14
1987	1.68	1.28	1	1.1	6.74
1988	1.72	1.2	1.05	1	7.2
1993	1.5	1.5	1.2	1	-
1994	1.67	1.7	1.5	0.9	-
1995	1.67	1.7	1.5	0.7	-
1996	1.36	1.69	1.5	0.5	6.5
1997	2	1.7	1.2	0.4	4
1998	2.35	1.7	2	0.5	6
1999	2.64	2	2.3	0.7	12
2000	2.65	2.1	2.5	0.7	12
2001	2.68	1.9	2.3	0.75	
2002	2.64	2.3	2.52	0.8	12.5
2003	2.67	2.26	-	0.75	-
2004	2.1	2.31	2.2	0.96	10.6
2005	1.62	2.2	1.5	0.99	
2006	1.85	2	1.65	1	10
2007	1.78	2	1.65	1	-
2008	1.2	1.26	1.2	1	-
2009	1.65	1.9	1.2	1.1	-
2010	2.12	1.86	2.11	1.13	8.5
2011	1.99	1.54	2.13	1.11	9.98

(Source: DADO Khotang annual publications)

Appendix 3: Questionnaire for household survey

Name of the Respondent: Years of Residing:

Age:

a. What are the major crops that are you produced in your farm?
   Irrigated land (*khet*): ....
   Rain fed land (*bari*): ……………………………………………………….
b. Number of raising livestock:

Cattles	Numbers
Buffalo/ cow/ox	
Goat/sheep	
If others,	

c. How large is the farm (area) you owned to produce crops?
   i. Rain fed land (*bari*): …..
   ii. Irrigated land (*khet*): ....

d. If land is other than owned, area of land rented/ leased/share cropping arrangement..................
e. Total household members – and how many (male/female) do active work on farming- and other paid works?
   Total members: .... male/female: ……….
   Number of (male/female) doing work in farm actively: ..../...................
   Numbers of members doing other paid work: ....
f. Is the farm headed by a man or a woman? (Tick)
   i. man
   ii. women
g. Food that you produced are sufficient for:……….months
h. How is the household member's work divided between work on farm and other paid work?

Members	On farm works	Other paid works
Men		
Women		

i. What is the approximate costs you spend (yearly) on producing crops in your farm (NRs)? (including all costs of crop management and labor costs)
   i. below NRs 10000
   ii. NRs 10001-15000
   iii. NRs 15001-20000
   iv. Above 20000

j. What is your total average income expenditure (monthly in NRs) in
   i. Food not produced on your farm:____________
   ii. other consumer goods:_________
   iii. input to the farming in total:____________

k. What is your average annual income from:

Sources	Income (NRs)
selling food crops and cash crops and their products	
Selling livestock and their products	
Wage income	
Business	
Remittances	
If, other source.................	

Appendix 4: Focal group discussions checklist (Farmers' perception)

1. What are the changes you have observed in climate in the last 8 to 10 years?
2. What are the changes you have observed in this area due to the effects of climate change and its associated impacts?
3. What are the five major crops grown in this area?
4. What are the changes in major crops plants you have observed in the last 8 to 10 years? (In its growth and development, yields?) Enlist the major changes in major five crops? Is there any effect of climate variations in these changes observed in crops?
5. What are the changes in pests/diseases occurrences in major crops in the last 8 to 10 years (whether in new or traditional varieties of crop)? During which period of the crop growing season? Enlist the changes in major five crops? How could you relate this change with ongoing climate variations in this area?
6. What are the major climatic events in the area in the last 30 years? What are the impacts caused by these events?
7. How farmers are responding to climate change? What are the changes in crops management practices to adapt with ongoing climate variations? (In which crop, and which period of crop growing season?)

Appendix 5: Photo plates

Photo 1: An overview Bamrang Khola micro-watershed

Photo 2: A part of Koshi Basin in Khotang district

Photo 3: FGD 1 in DADO Khotang

Photos 4: FGD with the farmers

Photo 5: Maize Smut (a fungal disease) in maize cob

Photo 6: Information board in DADO Khotang for the Promotion of Agro-business

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