Journal of
Forest and Livelihood
ForestAction
Vol 8 (1) February 2009 ISSN 1684-0186

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Changing Climate in a Mountain Sub-watershed in Nepal

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Abstract: Nepal, as a part of the earth, cannot remain untouched by the global climate change. This study identifies the indicators of changing climate at local level, particularly at sub-watershed in the mid-hills of Nepal. It shows that considerable warming has occurred in the study area. The average temperature has risen by 1.5° C from 21.6° C during 1978-82 to 23.1° C during 2001-06. Annual rainfall is fluctuating; prolonged dry periods and short but intense rainfall during rainy season are being observed in recent years. The study also identifies non-climatic indicators of warming climate observed in the study area such as increase in insects and pests, spread of invasive species at higher elevations, change in flowering time and change in time of harvest etc.

Key words: climate warming, climate change indicator, temperature, rainfall, insects and pests

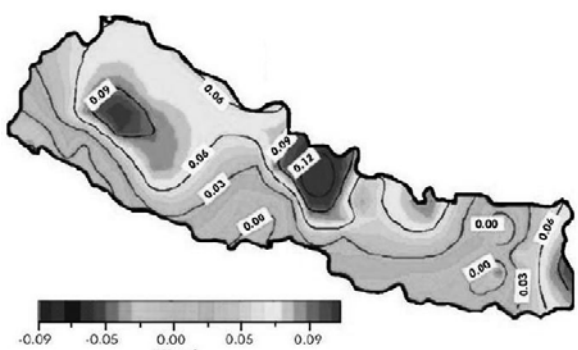
INTRODUCTION

Climate change refers to the variations in the earth's global climate or in regional climate over time. UNFCCC (1992) defines it as 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere'. IPCC (2007) concludes that increased global temperature since the twentieth century is very likely due to increased anthropogenic Greenhouse Gas (GHG) emissions from burning of fossil fuel and forest conversion. The climate change is real and happening now. The planet is already experiencing its impact on biodiversity, freshwater resources and local livelihood (WWF 2006). Using the current temperature trends, the average temperature may rise by 1.4-5.8° C by 2100 (IPCC 2001). This is certain disaster for a fragile ecosystem such as mountains (WWF 2006). Climate change is emerging as one of the most profound ecological and social concerns in our time (Y2Y 2007). The ecological axiom 'adapt, migrate or die' takes a particular relevance and urgency as scientists continue to study the potential scope of climate change. In the face of warming temperatures many species will be forced down to one of the three paths (Y2Y 2007).

Nepal, as a part of the earth, cannot remain untouched by this global phenomenon. Although Nepal is responsible for only about 0.025% of the total annual GHG emissions of the world (Karki 2007), it is already experiencing an increasing trend and the associated effects of climate warming. It is experiencing increase in dry periods, intense rainfall, floods, landslides, forest fires, glacial retreats and Glacier Lake Outburst Flood (GLOF) threats (Shrestha 2007). Temperature observations in Nepal from 1977 to 1994 show a general warming trend (Shrestha *et al*. 1999), as shown in Figure 1. The temperature differences are most pronounced during the dry winter season and least during the height of monsoon. The warming is significantly greater at higher elevations, i.e. mountainous region, in the northern part of the country than at lower elevations, i.e. Terai in the south (Agrawala and Berg 2002). This finding is reinforced by observations by Liu and Chen (2000) on the other side of the Himalayas, i.e. on the Tibetan Plateau (Figure 2). Being a developing country, Nepal is more vulnerable to the effects of climate change due to its high dependence on climate-sensitive sectors such as glaciers, agriculture and forestry, and its low financial adaptive capacity (Karki 2007).

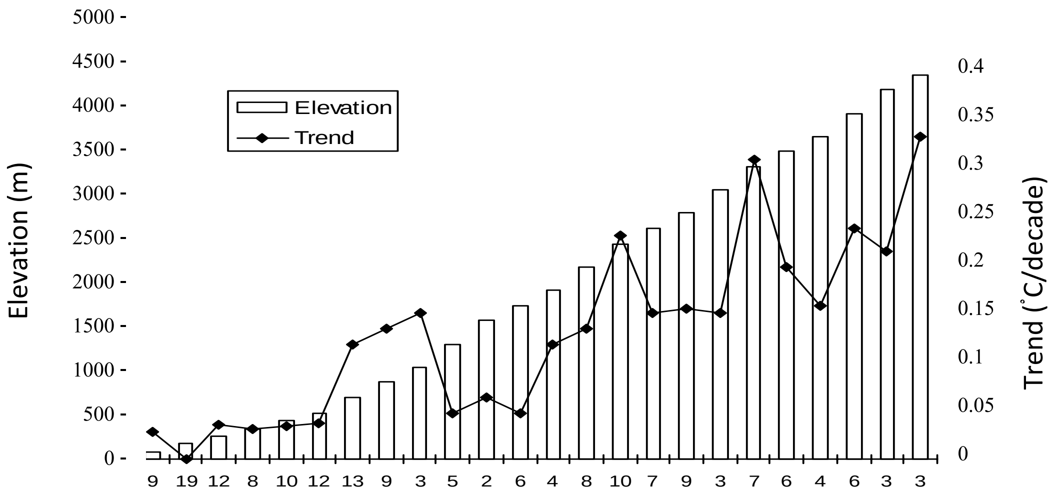
Although climate change is a very complex phenomenon and associated with many variables, simple measurements can be used as indicators of the whole process of climate change (or warming). Among the many variables of climate, temperature is a direct way of measurement of climate warming, and most of the other variables are associated in some way to it. Rainfall and humidity are other important variables of climate, after temperature. The life zone in the world is influenced basically by these two variables: temperature and humidity. Thus, evidence of climate change can be observed by analysing the instrumental measurements of temperature, atmospheric pressure, rainfall and humidity, etc. In this study, data on temperature and rainfall are used as the climatic indicators of climate change in a watershed area. Some associated effects or the non-climatic indicators of climate change are also documented.

Figure 1: Warming in Nepal from 1977 to 1994



Source: Shrestha *et al.* 1999

Figure 2: Variation in Temperature Increase at Different Elevations



Source: Liu and Chen 2000

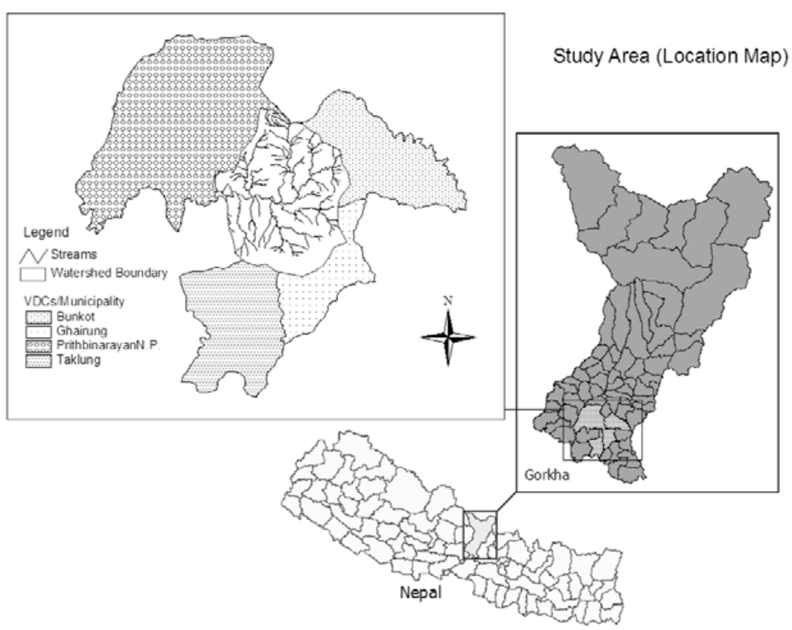
MATERIALS AND METHODS

Study Area

The sub-watershed area lies in the southern part of Gorkha district, located between 27°06'29" to 27°13'15" N and 85°00'00" to 85°06'30" E (Figure 3).

It is a typical example of the mid-hill region of Nepal, and lies in the Middle Mountain Ecological Zone (north to the Mahabharat range and south to the High Himalayas).

Figure 3: Lundi Khola Sub-watershed in Gorkha District



Altitude rises from 576 m to 1,560 m. Of the total watershed area, 61.43% is steep sloping land (30-60% slope), and the remaining 39.57% have less than 30% slope. The watershed encompasses an area of 35.18 sq. km., including Prithvi Narayan Municipality (ward no. 7 and 8), Taklung Village Development Committee (VDC) (ward no. 8 and 9), Ghairung VDC (ward no. 4 and 9) and Bunkot VDC (ward no. 1, 2 and 3). *Bari*[1] is the major land use type (42.7%), followed by forest (39.8%), *Khet*[2] (14.7%), shrub (2.5%) and grazing (0.3%) (DSCO 2006). The climate of the area varies from sub-tropical at lower altitudes to temperate at higher altitudes, with average annual rainfall of 1,972 to 2.000 mm and average daily temperature of 14.5°C.

Data Collection

Climatic data (monthly maximum and minimum temperatures and monthly precipitation [rainfall] of the time interval 1978 to 2006 [29 years]) from the agro-meteorological station, Laxmibazaar, Gorkha is used to analyse the trend in climatic change in the watershed area. The climatic data are collected from the Department of Hydrology and Meteorology. A reconnaissance survey was carried out in April 2008. Therefore, key informants' interview was carried out to know the people's perceptions and experiences of changing climate (warming) at local level during field visits in May 2008.

Data Analysis

Microsoft Excel 2007 was used to analyse the instrumental measurement of the temperature and rainfall. Five-year moving mean of each month as well as five-year average temperature of the area is calculated. Non-climatic climate change indicators are descriptively analysed based on the key informants' interview.

RESULTS AND DISCUSSION

Climatic Indicators

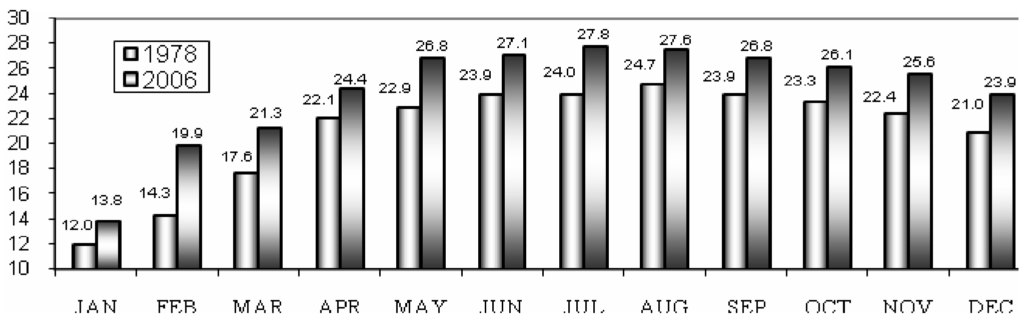
In this study, data on 'Maximum and Minimum Monthly Temperature' and 'Monthly Rainfall' are used as the climatic indicators of the changing climate change in the watershed area.

Temperature

Temperature change (increase) is the direct indicator of climate change. Figure 4 clearly explains the temperature rise within the sub-watershed area. Comparing the monthly average temperature of 1978 and 2006, each month shows considerable change. Although it cannot be concluded that climate has changed by comparing the monthly temperature of two single years, it can be an indicator of the process of change.

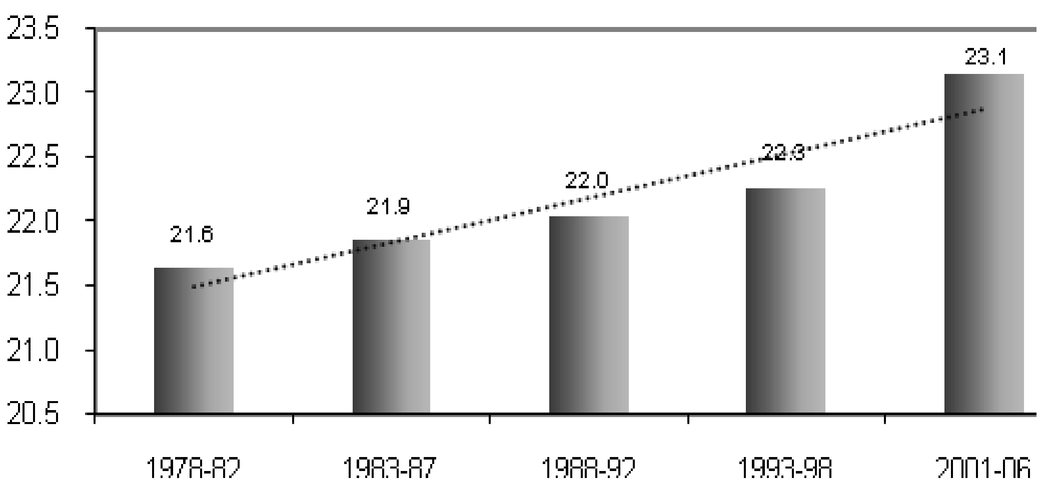
Figure 5 shows the change in average temperature of the area, which gives a clear picture of the warming trend in the area. The average temperature (23.1^o C) for the period 2001-06 is 1.5^{o}C more than (21.6^{o}C) for the period 1978-82. The increase in average temperature of the area is continuous.

Figure 4: Mean Monthly Temperature (^{o}C) of 1978 and 2006



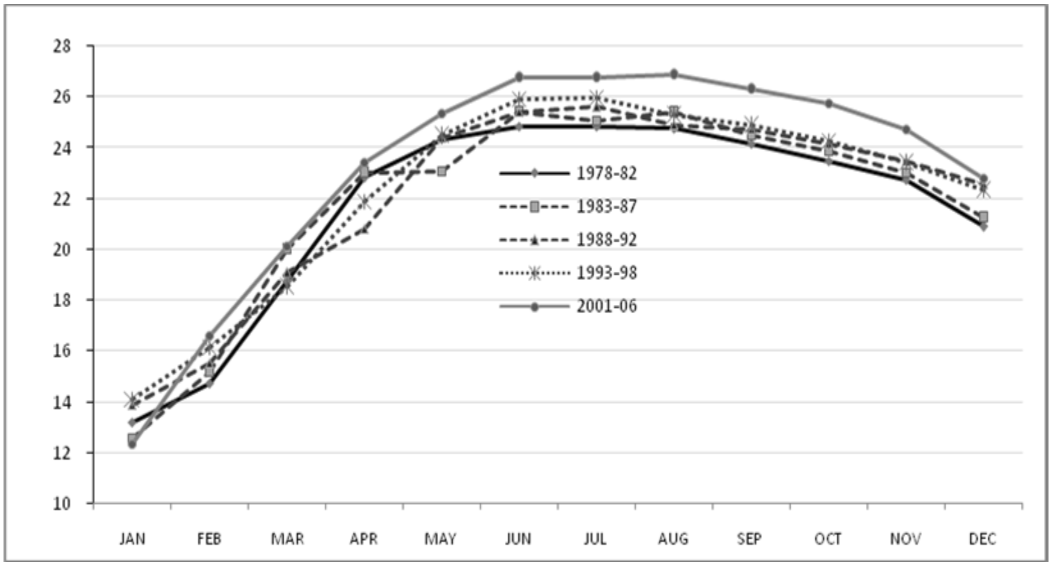
Source: Field Survey 2008

Figure 5: Average Temperature of Different Time Periods



Source: Field Survey 2008

Figure 6: Average Monthly Temperature for Different Time Periods



Source: Field Survey 2008

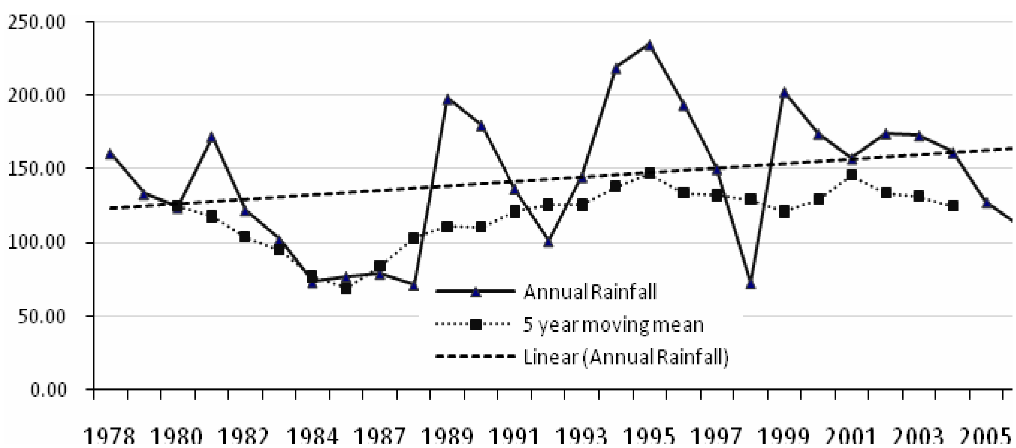
Figure 6 shows the increasing trend of monthly average temperature for different time intervals from 1978 to 2006. Temperature increase is more distinct for the time period 2001-06 compared to other time periods. The average monthly temperature of the time interval 2001-06 is higher for all months, with the highest variation in October (2.1^{o}C).

Rainfall

There is high fluctuation of annual rainfall in the study area, but five-year moving average annual rainfall shows an increasing trend in rainfall (Figure 7). This also explains the uncertain pattern of rainfall. But in recent years (2005, 2006 and 2007), annual rainfall is decreasing.

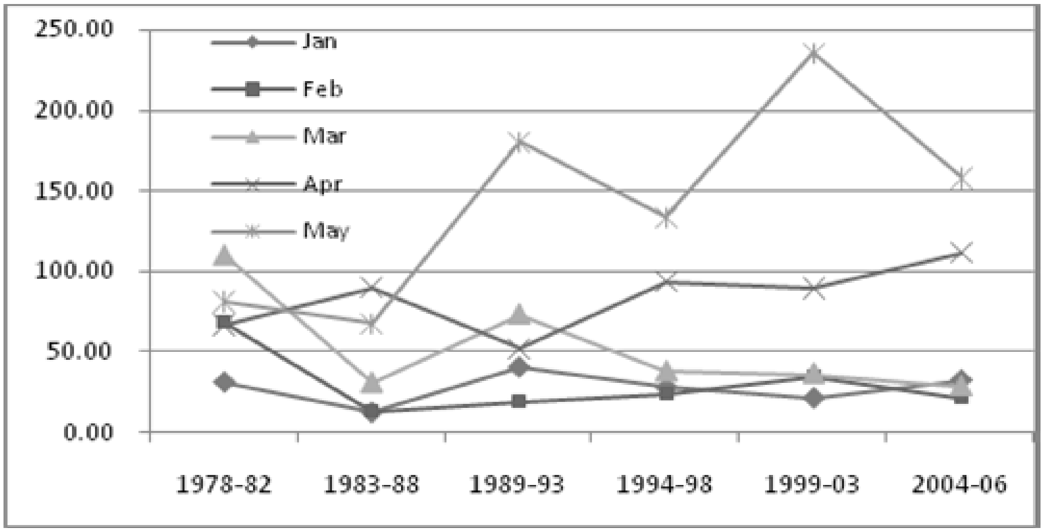
Figures 7, 8 and 9 show that annual precipitation is fluctuating every year, but the average (or five-year moving mean) shows decreasing rainfall till the mid-1980s and increasing rainfall during 1990-2004, which is again decreasing in recent years (2006/07). At the same time, although high annual precipitation is observed, very low and even decreasing precipitation in January, February and March indicates prolonged dry periods or droughts in recent years (1994-2006). Thus, there are more extreme events, both drought and short duration but high intensity rainfall.

Figure 7: Annual and 5-Year Mean Rainfall (cm)



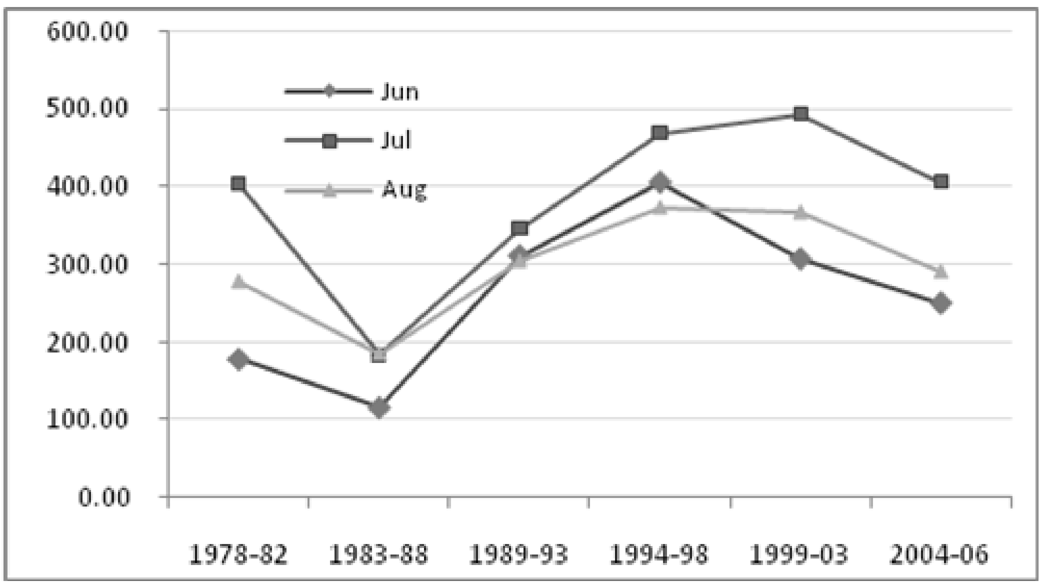
Source: Field Survey 2008

Figure 8: Monthly Rainfall during Pre-monsoon



Source: Field Survey 2008

Figure 9: Monthlly Rainfall during Monsoon



Source: Field Survey 2008

Non-climatic Indicators

As all the life forms are basically determined by climate, the living organisms as well as other non-climatic objects also respond in a specific way to the changing environment. The effects of climate change are seen not only on the extreme climatic events but also on different aspects of life. The following are some of the associated effects of climate change, which can be used as indicators of the changing climate of the area.

Insects and pests

Based on the key informants' interview, it can be said that insects and pests are increasing in recent years. Another aspect of this is that a few species of insects that were common to the area are gradually disappearing, but new species of insects and pests are being observed. One typical example is that, even those areas where mosquitoes were not found until thirty years ago are severely being invaded by them for the past few years.

Invasive species

Many new plants that have invasive character are being noticed in the watershed area in recent years. Some of the examples are *Ageratina adenophora (Kalo Banmara), Chromolaena odorata (Seto Banmara), Ageratum sps (Gandhe* with blue flower), *Thulo Chitlage* (slightly different from common *Chitlange*). At the same time, the common herbs of the area, such as *Ageratum conyzoids* (*Gandhe* with white flower), *Chitlange*, *Digitaria ciliaris (Chitre Banso), Cyperus compressus (Mothe),* etc. are disappearing from the area. An interesting fact found from the key informants is that invasive species are moving gradually to upper elevations (e.g., *Eupatorium odoratum [Kalo Banmara])* have been seen even at the elevation of 1,500 m, which was not common fifteen or twenty years ago), which can be correlated with the warming trend within the watershed.

Change in flowering time

During the fieldwork, some elderly people who had been observing the local environment of the study area shared their experiences about the change in flowering time of plants, giving examples of the seasonal vegetables they had been planting for a long time. The flowering time of some of these vegetables, *Cucumis sativus (Cucumber)*, *Luffa cylindrical (Chichinda)*, *Trichosanthes cucumerina (ghiraula)*, *Cucurbita moschata* (pumpkin) etc. is changing, i.e. it is about a week to up to two weeks earlier than it was twenty or twenty-five years ago. Similar phenomenon is observed in fruit trees such as *Citrus limonia*, *Pyrus calleryana*, *Magnifera indiaca,* etc.

Time of harvest

Although considerable change was not reported in the cropping pattern, time of plantation within the watershed area has undergone considerable change. They are planting crops later than it was twenty or twenty-five years ago, but the harvest time of crop is similar or even earlier. There may be two reasons for this: change in the species of crops, especially improved varieties of crops, and change in climate. Warming of the environment ultimately accelerates the metabolism of plants, which causes early ripening of crops. The regular crops being planted in the area are rice, maize and millet. For example, till a few decades ago millet planting used to start from mid June and harvest time was after mid-November. This trend has changed during the last decade. Planting starts in July and harvesting starts by the end of October. The early ripening is related with both the above-mentioned causes: change in species (from the traditional *Mangsire* to other species locally known as *kattike*) of millet and climate warming.

CONCLUSION

Based on the instrumental observations of temperature as well as the key informants' interview, indicators of changing climate are observed unambiguously. The average temperature has risen by 1.50^{o} C from 21.6^{o} C of 1978-82 to 23.1^{o} C for 2001-06. Rainfall shows irregular pattern; thus uncertain but higher annual rainfall but less rainfall during winter and spring indicates both extremes; intense rainfall during rainy season and longer dry periods (drought) during winter. The non-climatic indicators of changing climate such as increased insects and pests, spread of invasive plants to higher elevations, new herbs displacing the old, change in flowering time of crops, vegetables and fruits, change in time of harvest, etc. are observed.

ACKNOWLEDGEMENTS

I would like to express my gratitude for all who helped me in carrying out this study successfully. I especially would like to mention my advisor, Mr. Keshav Datt Awasthi, for his continuous support as well as critical and valuable comments and suggestions. I want to record my thanks to Mr. Sanam K. Aksha, Mr. Achyut Dahal, Mr. Bishnu Singh Thakuri, Mr. Rajan Subedi and Mr. Mohan B.K. for their help during fieldwork.

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[1] Rain-fed dry agricultural land.
[2] Lowland wet agricultural land.