



Climate Change Impact on Glacier Retreat and Local Community in the Langtang Valley, Central Nepal

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ABSTRACT

Global warming leading to climate change is a rapidly growing global threat to humanity and environment of the world. The present research in the Langtang Valley, Central Nepal attempts to find out the impact of climate change on glacier retreat and local community based on the studies of available long-term hydrological-meteorological data, satellite image analysis of glaciers from 1979 to 2009, and observation of local people and their experience on climate change issues. The high altitude areas of the Langtang Valley show a consistent trend of increase in temperature, a clear evidence of the global warming that has resulted in the fast melting of glaciers with both horizontal and vertical retreats. The Lirung Glacier and the Kimjung Glacier have retreated for over 900 metre and 400 metre, respectively, with an average retreat of about 40 metre/year and total vertical retreat in the snout position is 100 metre for both. The study also reveals that this glacier retreat is due to an increase in temperature and a change in patterns of precipitation and snowfall. The study also shades light on some socio-economic impacts of such changes on the livelihood of marginal communities residing downstream the affected areas.

JEL Classification: Q54, Q55

Keywords: Climate Change, Green House Gases Emissions, Langtang Glaciers, Glacier Retreat, Environment

Acknowledgment: Authors are extremely grateful to the Ministry of Environment, Government of Nepal for providing the grant support to conduct this research project. We would also express our sincere thanks to Dr. D. C. Devkota and Dr. G. R. Joshi for their encouragement supports and fruitful suggestions to complete this project.

Submitted: Nov. 12, 2016

Accepted: Jan. 3, 2017

Published: Feb. 28, 2017

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1. Introduction

Global warming leading to climate change is a rapidly growing global threat to humanity and environment. The major causes of the production of the Green House Gases (GHGs) emission are deforestation, careless farming, industrialization, urbanization, automobiles, infrastructures, and the burning of fossil fuels (IPCC, 2001). Lately, industrial farming in the world is considered to be a major contributing factor in producing GHG emissions which accounts for nearly 20% (Lappé, 2016). Nepal's contribution to the global annual GHGs emission is negligible (0.025%), out of total global emission (MoPE, 2004). In terms of volume of production, Nepal's share on total GHGs emission is estimated to be nearly 39,265 Giga gram (Gg) and per capita emission is 1,977 kg (MoEST, 2008) compared to the global average of 3,538 kg. Over the last century, the warming in the Himalayas has been much greater than the global average of an increase of 0.74°C (IPCC, 2007). The temperature trends in Nepal for the period of 1971-1994 record a continuous warming at an average rate of $0.06^{\circ}\text{C}/\text{year}$ varying spatially and seasonally (Shrestha et al., 1999) whereas the global average surface temperature rise of the last century was $0.6 \pm 0.2^{\circ}\text{C}$ (IPCC, 2007). Various studies in Nepal also indicate that the observed warming trend is not uniform across the country. Warming has been more pronounced in higher altitude areas and lower in low altitude Terai and Siwalik regions (MoENV, 2010). Similarly, Maplecroft (2010) has also ranked Nepal as the fourth most vulnerable country in the world in the context of climate change. According to Devkota & Bhattarai (2011), the major climate change impacts in Nepal's Himalayan region include rapid glacial melting in the Tibetan-Tethys Zone and wildlife habitat degradation in the Higher Himalayan Zone of the northern part of the country.

Due to the diverse topography and a varied range of ecological zones in Nepal, the overall impact of climate change is likely to vary depending on geographical location. With rising temperature, monsoon precipitation has undergone some changes with decreasing rainy days and increasing high-intensity rainfall events (Marahatta et al., 2009); as a result, water-induced disasters such as landslides, debris flows, Glacial Lake Outburst Flood (GLOF) and floods frequently occur with a loss of biodiversity and infrastructure each year.

The observed recent changes in climate have already had significant impacts on biodiversity and ecosystems, including changes in species distributions, population sizes, the timing of reproduction or migration events, and an increase in the frequency of pest and disease outbreaks (Xu et al., 2009; Malla, 2008). As reported in other parts of the world, vegetation regime in Nepal is expected to push northward to higher altitude, and if the present rate of warming continues for next couple of decades, plant species will not be able to migrate fast enough and could result into species extinction. Amid these projections, several plants and animals are already reported as threatened species together with noticeable biodiversity loss in Nepal (Thapa et al., 2013).

As the rainfall is becoming unpredictable in Nepal, water scarcity is projected to become one of the serious environmental stresses from climate change in mountainous region. Groundwater depletion, drying up of water sources in longer dry seasons, and irregular rains are some of the adverse impacts in mountains due to climate change. As temperature increases, evaporation also increases resulting in drought. In recent times, villages in mountains in Nepal have shown signs of vulnerability to environmental stress, particularly drought related stress (Thakur & Upadhyaya, 2014).

2. Climate Change Impact in Nepalese Glaciers

Since the end of the Little Ice Age (around 1850s, i.e., middle of the 19th century), glaciers in the world have been retreating with remarkable geomorphological changes.

Himalayan glaciers are the earth's largest freshwater reservoirs to feed the world's major rivers. The snow-fed Himalayan rivers originated from these glaciers are the main sources to the water supply of hundreds of millions of people downstream during dry season, including its use in irrigation, hydroelectricity and agriculture. The melted water drained from these glaciers to the Ganges Basin draws up to 80% of its water flow from Nepalese rivers. Nowadays, Himalayan glaciers are retreating at rates ranging from 10 to 60 metre/year, and retreat rates of 30 metre/year are common (Bajracharya et al., 2007). The intense impact of climate change on glaciers in the Himalaya results in retreating of the glacier, elimination of small glaciers, formation of new and enlarging the existing glacial lakes, and breaching some lakes resulting Glacial Lake Outburst Floods (GLOF). At present 26 glacial lakes (out of the 2,315 lakes in Nepal) are potentially dangerous to be GLOF in the near future (ICIMOD, 2011). The melting of the Himalayan glaciers can be considered as a reliable indicator of climate change. Studies have also shown that there is a rapid shrinkage of glaciers in the Nepal Himalaya during recent decades (Yamada et al., 1992; Kadota et al., 1997; Fujita et al., 1998; 2001). It is estimated that the rapid melting of the Himalayan glaciers will first increase the volume of water in rivers causing widespread flooding and rapid erosion but in a few decades later this situation will change and the water level in rivers will decline, meaning massive economic and environmental problems will arise threatening to environment and humanity.

A number of studies have been carried out in the Nepalese Himalayan region regarding climate change impact on various areas such as water resources, biodiversity, agriculture, glacial retreat (Shrestha et al., 1999; WWF, 2005; Bajracharya et al., 2007; Chhetri, 2008; Malla, 2008; Upreti et al., 2010a & b; Thapa et al., 2013; Bajracharya et al., 2016). Shiraiwa & Watanabe (1991) have dated the historic positions of the glaciers in the Langtang Valley of Nepal. The present study carried out in 2010 (hydrological and meteorological data, satellite image of glaciers collected from 1979 to 2009 and detailed field study in 2010) is focused to know the impact of the climate change on the glacier retreat in the Langtang Valley, Central Nepal in the recent decades (Figure 1). During this study, the hydrological data, temperature data, precipitation data, analysis of the snout positions of the glaciers, local people's observation and field visit were mainly used to interpret the impact of the climate change on glacier retreat and local community in the Langtang Valley.

3. Impact of Climate Change in Glaciers of the Langtang Valley

Himalayan Alpine zone is very much sensitive to the changing in temperature and precipitation. The mountainous habitants are threatened by the loss of the rich flora and fauna. Nepal, also has been severely affecting by the climate change impact on the health, agriculture, water resources, biodiversity, forestry, economy and environment. Langtang Valley is also highly affected by the climate change. The present research attempts to find out the impact of climate change on glacier retreat and local community based on the combined studies of available long-term hydro-meteorological data interpretation, satellite image analysis of glaciers and observation of the local people and their experience on climate change.

3.1 Data Analysis

(i) Temperature

Various analyses of temperature pattern in Nepal have shown that the high altitude mountains are highly affected by warming climate as compared to the lower altitude terrains (Gautam, 2014; Aryal et al., 2013; Upreti et al., 2010; ICIMOD, 2009; Shrestha et al., 1999). Temperature data of the Langtang Valley obtained from the Department of Hydrology and

Meteorology, Government of Nepal (GoN) for the years between 2003 and 2008 were analyzed to observe the temperature trend in Nepal. The annual average temperature between 2003 and 2008 shows fairly an increasing trend (Figure 2). The total increase in temperature is 0.9°C . This increasing trend is comparable to the trend analyzed by WWF (2005) between the years of 1988 and 2000 (Figure 3). Both slope coefficients demonstrate an increasing trend in temperature; yet, the rate of increase in the present study is slightly smaller than the rate of increase as calculated by WWF (2005). In general, the temperature data of the Langtang Valley between 1998 and 2008 shows a consistent trend of an increase in temperature. In addition to previous analyses, the average annual temperature calculated in this valley from 1993 to 2004 has been increased by $0.19^{\circ}\text{C}/\text{year}$ (Figure 4) as found by Aryal et al. (2013). Also, the annual mean temperature recorded from 1988 to 2008 is found to be of 4.2°C while the rate of temperature rise in this period was $0.116^{\circ}\text{C}/\text{year}$ as revealed by Bajracharya et al. (2016).

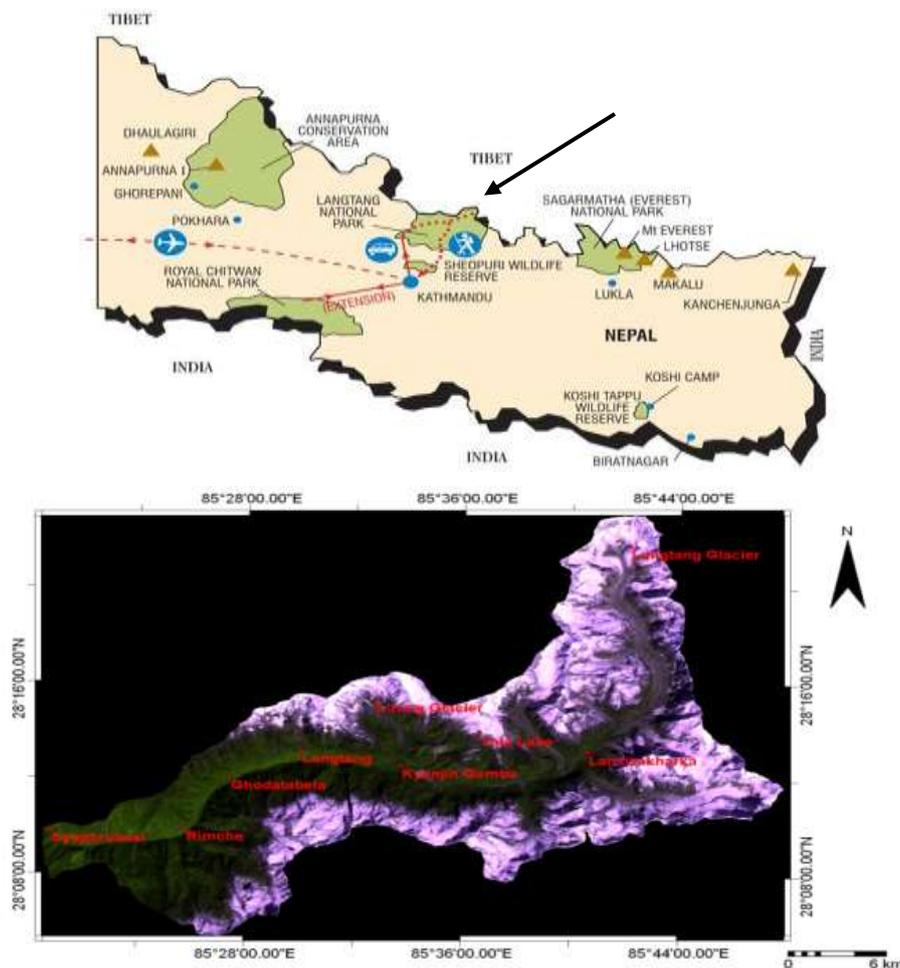


Figure 1: The study area, Langtang Valley, a part of Langtang National Park located in the northern part of the capital of Nepal, Kathmandu. In upper figure, the arrow shows the location of the study area. (Source: Langtang/besthike.com)

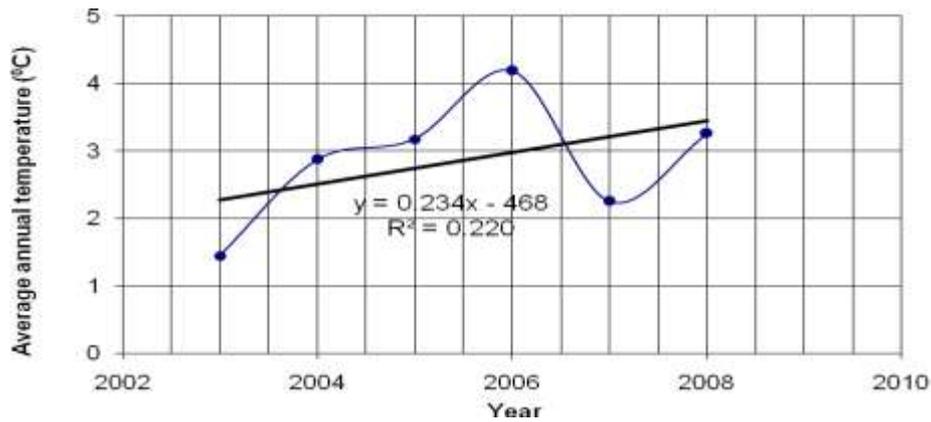


Figure 2: Variation of average annual temperature in the Langtang Valley (Kyanjin Gumba, 3,730 metre) between the years 2003 and 2008 (Data source: Department of Hydrology and Meteorology, Government of Nepal)

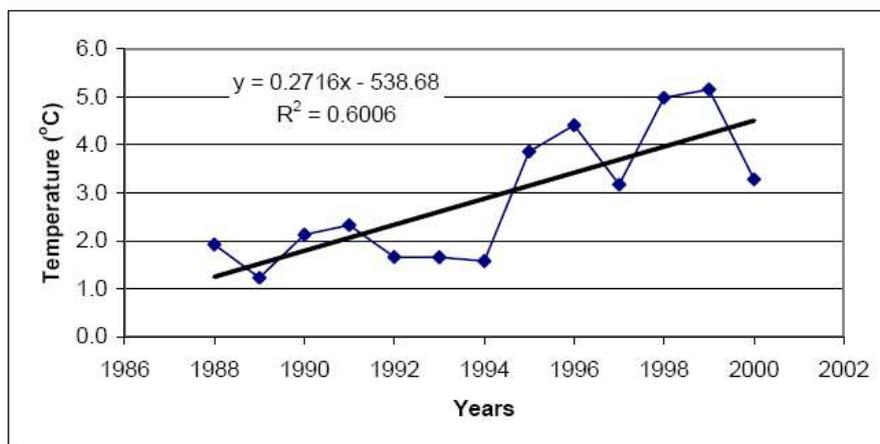


Figure 3: Variation of average temperature in the Langtang Valley (Kyanjin Gumba) area between 1988 and 2000 (WWF, 2005)

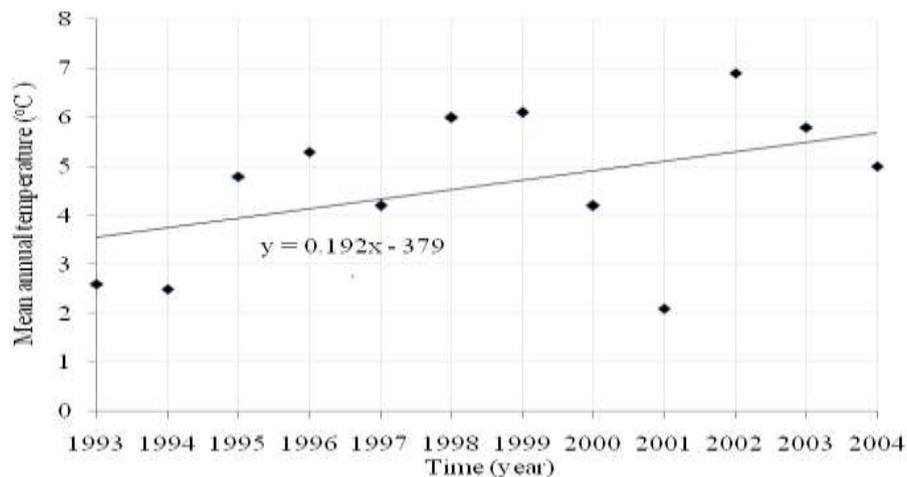


Figure 4: Variation of average annual temperature in the Langtang Valley from 1993 to 2004 (Aryal et al., 2013)

The temperature data analyzed from Dhunche station (2,030 metre), close to Syaphrubesi (1,460 metre) at lower altitude of the Langtang Valley (Figure 1) between the years 1995 and 2008 shows that the trend of the temperature is quite different than that of Kynajin Gumba (3,730 metre) station located at the higher altitude of the same valley. The trend of T_{\max} (maximum temperature) shows a very small increase over the years (Figure 5) whereas the T_{\min} (minimum temperature) on the contrary shows a trend of general decrease (Figure 6). The trend of average temperature shows that higher altitudes are showing a consistently higher rate of temperature change than in the lower altitudes in the Langtang Valley. The strongest correlations of enhanced warming with elevation are obtained for the daily minimum temperature during winter, with the largest increases found for the Tibetan Plateau/Himalayas because of proportionally greater increases in downward longwave radiation at higher elevations in response to increases in water vapor (Rangwala et al., 2013). Furthermore, the amplification of warming with elevation is greater for a higher GHGs emission scenario (Rangwala et al., 2013). The greater increases in downward longwave radiation at higher level in response to increases in water vapor in the higher altitude of the Langtang Valley could be reason for more warming in winter season to produce more GHGs emission.

Thus, the yearly temperature recorded at Kyanjin Gumba area shows a consistent rising trend since 1988, a clear indication of global warming. However, the temperature data from the lower altitude at Dhunche station shows much subdued rising trend indicating that higher altitudes are much more sensitive to temperature increase than at lower altitudes due to global warming.

(ii) Hydrological Indicators

The main discharge data analyzed from the Langtang Khola, a major river of the valley, between the years of 1990 and 2008 shows that there is a definite increasing trend in the average discharge over that period (Figure 7). However, a persistent rise and decline in the data shows a repetition of high or low discharge events occurring for few years interval. On the other side, the total precipitation in general, is in a decreasing trend (Figure 8). The precipitation increases for spring, summer and autumn whereas it decreases in winter determined by the National Centres for Environmental Prediction (NCEP) calibrated scenarios (Adhikari et al., 2014). But, in Figure 7, the overall discharge is in an increasing

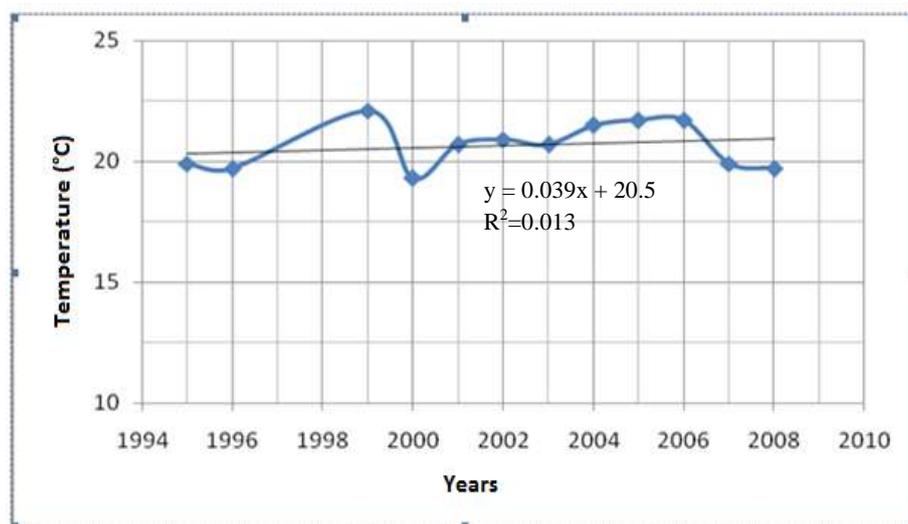


Figure 5: Variation of maximum temperature (T_{\max}) at Dhunche station, lower section of the Langtang Valley between the years 1995 and 2008

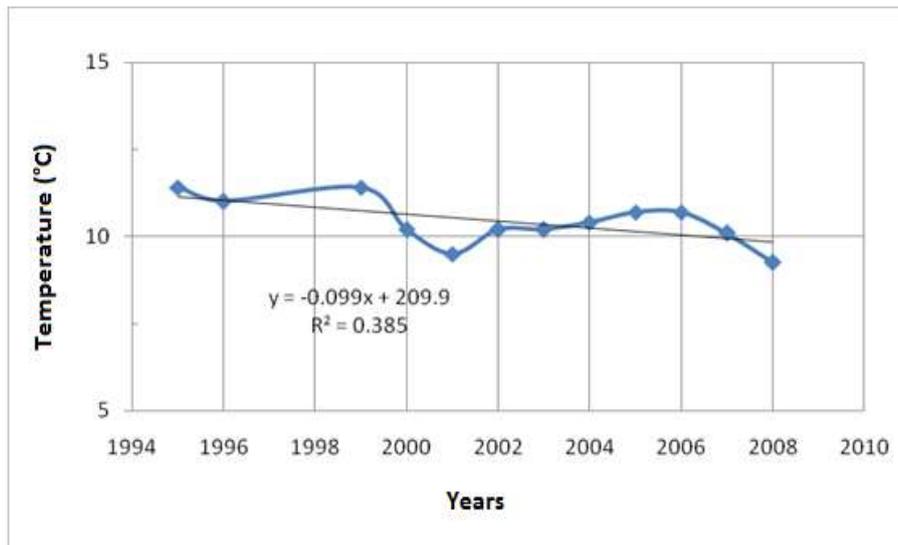


Figure 6: Variation of minimum temperature (T_{min}) at Dhunche station between the years 1995 and 2008

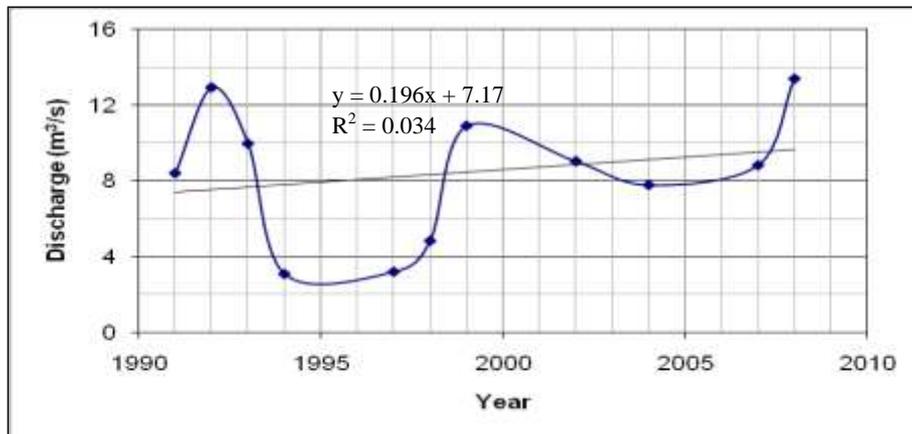


Figure 7: Variation of discharge in the Langtang Khola (Kyanjin Gumba village) from 1990 to 2008

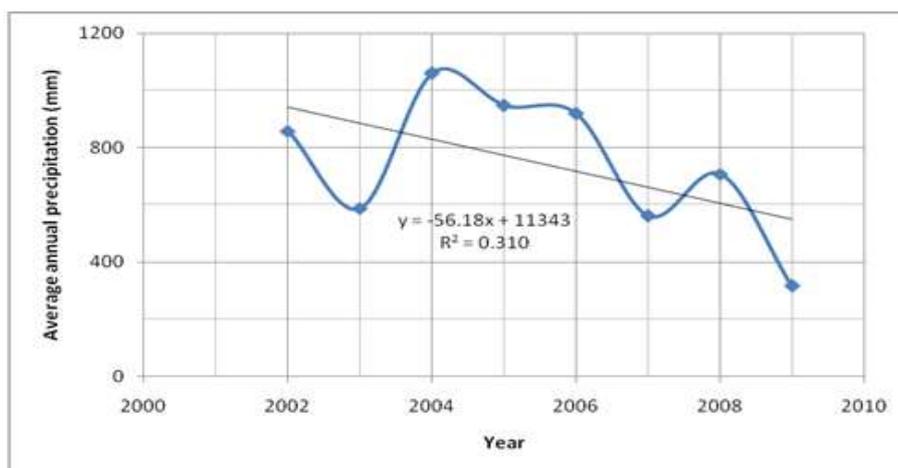


Figure 8: Variation of annual precipitation in the Langtang Khola (Kyanjin Gumba) between 2002 and 2009

trend. This result clearly demonstrates that such opposite trends in total annual discharge and total precipitation can only be possible in the case when the snow melts in higher amount to give higher discharge in the Langtang Khola despite the decreasing trend of annual precipitation (Figure 8).

(iii) Glacier positions

Landsat satellite images from 1970s to the recent past were investigated and analyzed to examine the changes in the aerial coverage and length of glaciers in the Langtang Valley (Figure 9), and was further verified on the ground by field visits investigating the Lirung Glacier (North- Northwest part of Kyanjin Gumba) and Kimjung Glacier, immediate eastern vicinity of the Lirung Glacier (Figures 10 and 11), to determine the changes in the snout positions of the glaciers at different dates and the current positions of the glacier snouts. Landsat Enhanced Thematic Mapper Plus (ETM+) was used to track the size and movement of glaciers.

The glacier study in the Langtang Valley shows a consistent trend of increase of temperature since late 1970s resulting in the rapid melting of glaciers and their horizontal and vertical retreats. In this study, the satellite images of four different points of time: 1979, 1989, 1999 and 2009 were examined to elicit the evidences of distinct changes in the snout positions of the glaciers, and their sizes during this period (Figures 9 and 11; Tables 1 and 2). Tables 1 and 2 show the total area covered by the glaciers during the period 1979 through 2009. The interpretation of satellite imageries of the glaciers shows clear horizontal retreat of most of the glacial snouts. Over the past 30 years between 1979 and 2009, the Lirung Glacier and the Kimjung Glacier have retreated for over 900 metre and 400 metre, respectively, with an average retreat of about 40 metre/year for both. Similarly, the total vertical retreat in the snout position of the both glaciers within the past 30 years is about 100 metre. This same vertical retreat for both glaciers might be because of having the same type of geomorphological features of the glaciers. When comparing the aerial extent of the glaciers in the Langtang Valley between 1979 and 2009 (within the same 30 years range); Lirung Glacier coverage area has shrunk by 62%. If this shrinking rate continues, this glacier might just melt away within another one or two decades. The total loss of glacial coverage area of the entire Langtang Valley watershed within the past 30 years is 24%. The study carried out by Immerzeel et al. (2012) is consistent with this result and shows that glaciers in this watershed has been retreating steadily and it is estimated that glacier area will be shrunk by

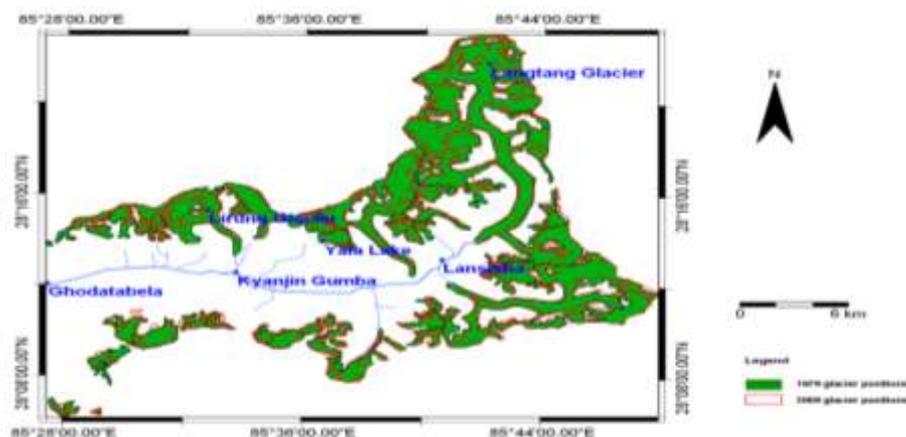


Figure 9: The glacier positions of the Langtang Valley between 1979 and 2009



Figure 10: A view of Lirung peak with glacier seen from south-east of Kyanjin Gumba village

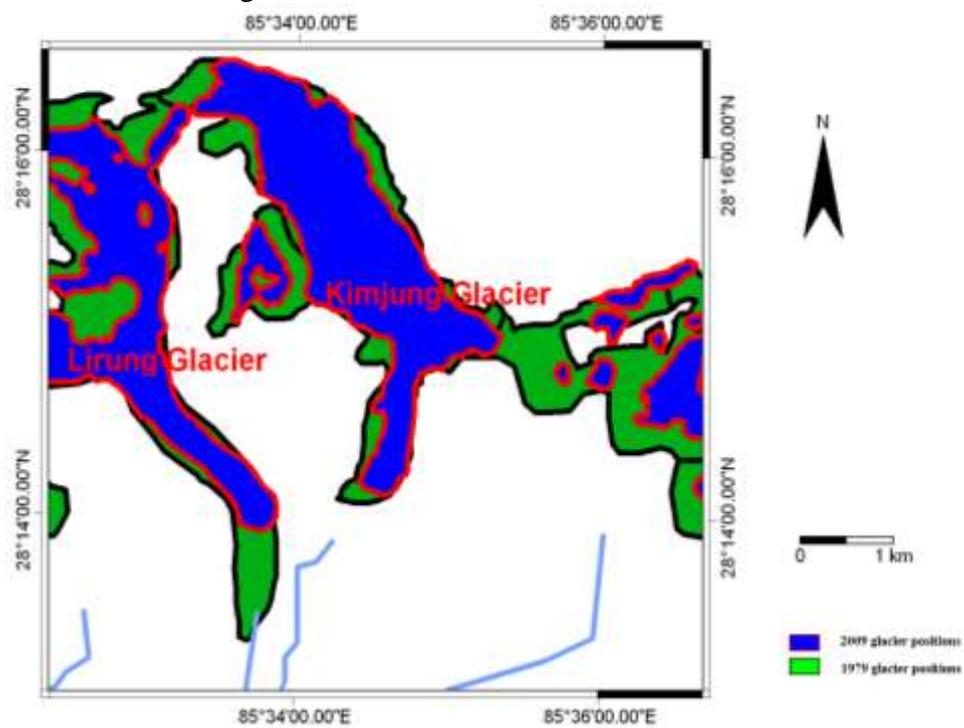


Figure 11: Close up view of retreat of the Lirung and Kimjung glaciers between the years 1979 and 2009

Table 1: Total area covered by all of the glaciers in the Langtang Valley between 1979 and 2009

Year	Total area of the glacier (km ²)
1979	192.13
1989	171.34
1999	152.22
2009	142.06

Table 2: Total area covered by the Lirung Glacier and Kimjung Glacier in the Langtang Valley between 1979 and 2009

Name of Glacier	Year	Total area of the glacier (km ²)
Lirung Glacier	1979	11.00
	1989	5.46
	1999	5.12
	2009	4.19
Kimjung Glacier	1979	5.04
	1989	4.44
	1999	4.16
	2009	4.09

32% by 2035. If such a melting process of glacier continues, about 75% of glaciers of this valley could be disappeared within next three to four decades (Chaulagain, 2009). In another study, the glacier area of the Langtang Valley has been decreased by 26% between 1976 and 2009 (Bajracharya et al., 2016).

(iv) Local people's observation

Local people at Kyanjin Gumba area were also interviewed to elicit their views about changing pattern of glaciers in their localities for the period of past 30 years. On the basis of their observation and their experience, the area covered by ice a decade ago is now converted into a barren land with a rapid retreat of glaciers. They also explained that they feel that summer is getting hotter and winter is warmer than in the past. The duration of winter is shrinking and extremely cold days are decreasing in number. The precipitation rate in the summer is decreasing. The water resources are being dried up and the local drinking water supply for Kyanjin Gumba village (3,730 metre) had to be channeled from its source about two kilometre away. The local people believe now that if such a rate of glacial melting continues, there will be no more glaciers at all in the near future.

Some people state that the agricultural production has decreased in recent time in this valley as shown by barely cultivable land in Figure 12. The use of land for agricultural purpose at lower section of the Langtang Valley is gradually decreasing due the climate and socio-economic transformation (Thapa, 2011). Such changes are also responsible for increasing pest and disease infestation on crops, loss of fertile soil and land degradation according to the study. Besides, most people believe that *nyaks* (yak family) are becoming sick more frequently and even are losing their hairs due to warmer climate.



Figure 12: High altitude agriculture threatened by climate change in the Langtang Valley

4. Socio-Economic Impact of Environmental Degradation

The climate change in the Langtang Valley has been creating severe problems in biodiversity, health, economy, water resources, tourism, infrastructure and environment. The people are facing problems of natural hazards such as big debris flows, as observed near Kyanjin Gumba where they lost many houses during past couple of years. Many disasters relating to mass movement of materials such as debris flows, increased erosion in the thin soil cover, landslides, avalanches and Glacial Lake Outburst Flood (GLOF) in this valley produce thousands of tons of the sediments and such materials take a route along Trishuli Khola and thereby to join Bhotekoshi River, then known as the Trishuli Ganga River after Syaphrubesi village downwards, creating havoc in many communities downstream. The sediments carried by the Trishuli Khola as well as Bhotekoshi River are creating problems in the dams and reservoirs in various hydropower projects in planning and implementation in river's coverage region by rapid deposition of sediments and corrosion of equipments of the projects which is creating uncertainties in projects' future life.

With regard to the retreat of glaciers and the changes in its phenomena, on the other hand, it is recommended that there is an urgent need of preparing a better guideline or policy prescription for adaptive measures. Such adaptive measures can help reduce the GHGs production and protect the natural resources and conserve the water resources in many ways. By launching community forestry and forest plantation programs, organic farming, population control, practice on biogas extension programs, and public awareness programs certainly help reduce the GHGs production; as a result, the goal of environment protection in Himalayan region could effectively be implemented to save the region from global warming threats.

The Nepalese economy and the livelihoods of its people are very much dependent on the region's climate: a large proportion of the country's Gross Domestic Product (GDP) is associated with climate-sensitive activities (IDS-Nepal et al., 2014). The Government of Nepal (2013) has endorsed the Environment-friendly Local Governance Framework aiming to incorporate the environment-friendly planning process in the nation taking into consideration the issues related to environment, climate change adaptation, disaster and waste management. Government of Nepal is currently working to address the issues of climate change by improving carbon sink and reduction of carbon emissions (mitigation), coping climate change with vulnerability to be strengthened (adaptation) and clearly defining research and policies supporting adaptation and mitigation (Chaudhary and Aryal, 2009).

Under the adaptive measure policy, public awareness programs should be developed to make people aware about the climate change and its impact on people's various socio-economic aspects. They include preparation of climate change adaption manual for the local community, encouragement in the adaptation of agro-ecology farming system - a process of reduction of GHG emission, and recommendation for the improvement in science curriculum in schools based on the outcome the study would reveal.

5. Conclusion

Although, Nepal has a negligible contribution to produce the Green House Gases (GHG)s emission, severe issues of climate change have been reflecting in the health, agriculture, water resources, biodiversity, irrigation, economy and environment in all parts of this country. The present study reveals the climate change issue in the high rate of the glacier melting and local community in the Langtang Valley. A trend of general increase of temperature in the valley is causing a faster melting of glaciers. Study of satellite image, analysis of hydrological and temperature data and the observation of the local people have shown that there is a clear retreat of the glaciers in the Langtang Valley during in recent

decades. Over the past 30 years between 1979 and 2009, the Lirung Glacier and the Kimjung Glacier have retreated for over 900 metre and 400 metre, respectively, with an average retreat of about 40 metre/year for both. Similarly, the total vertical retreat in the snout position of the both glaciers within the same period is about 100 metre. Lirung Glacier coverage area has found to be shrunk by 62% in the last 30 year between 1979 and 2009s. The total loss of glacial coverage area of the entire Langtang Valley watershed within the last 30 years is 24%. The study reveals that this glacial retreat is due to an increase in temperature and change in rainfall and snowfall patterns, indicating a definite sign of climate change. The researches on the retreat of glaciers with its phenomena should be carried out in details that could help to prepare better guidelines for adaptive measures. So, the adaptive measure policy helps to take a decision to reduce the GHGs production and to protect the natural resources and conservation of water. By launching community forestry and forest plantation program, organic farming, population control, practice on biogas extension program, and awareness program to the people certainly could help to reduce the GHGs production; as a result, our environment could be effectively saved from global warming threatening. The study also shades light on some socio-economic impacts of such changes on the livelihood of marginal communities residing downstream the affected areas.

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