Impacts of Climate Change as Evident in the Langtang Catchment

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Abstract: Nepal has felt the adverse impact of climate change even though its contribution to global greenhouse gases (GHGs) is negligible. Many scientists have expressed concern that the general rise in temperatures at high altitudes poses a serious environmental and humanitarian threat in Nepal as many glaciers and glacial lakes are located in the high Himalayas. For this study, I have observed rising temperatures in the Langtang catchment and compared the proportional rise of high altitude and low altitude temperatures as these will have serious implications for glaciers and glacial lakes in the region. As well, conducted a time series observation of water flow and noted that the river flow in the Langtang catchment are decreasing. Given these findings, Nepal may be facing increasing water scarcity while also keeping more serious watch on glacial melt.

Key words: Climate change, greenhouse gases, Langtang catchment, glacial melt, Nepal

Introduction

Climate can be defined as the average weather. Scientifically, climate is the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years (IPCC 2008). The classical period for averaging these variables is 30 years as defined by the World Meteorological Organization (WMO).

Climate change refers to a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer (IPCC 2008). Climate change may be due to anthropogenic causes or natural processes. The United Nations Framework Convention on Climate Change (UNFCC) also defines climate change in Article 1 as follows: "A change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods" (IPCC 2008).

Global warming is considered as one of the major factors causing climate change. Even a conservative estimate of 1°C increase could have dramatic effects for all aspects of human life. For example, during the medieval warming period (1200-1500 AD), and during the little ice age (1600-1700AD) the average temperatures were 0.5°C higher and 0.5°C lower respectively than they are today (Khaliq et al. 1997).

Anthropogenic climate change refers to climatic change resulting from human activity. Human activity that could possibly change the climate include emission of gases into the atmosphere, industrial activities, development of extensive cities, pollution of water ways and cities, diversion of water, creation of thousands of dams and lakes, conversion of grassland or forest to cropland, agricultural activities (Piechota and Garbrecht 2006).

Scientific studies have shown that due to a higher concentration of GHGs in the atmosphere, global warming has intensified. The higher carbon dioxide concentration has resulted from the burning of fossil fuels (coal, oil and natural gas) and deforestation. The global carbon dioxide (CO_2) concentration increased from 316 parts per million (ppm) in 1959 to 389 ppm in 2008 (Gautam 2010).

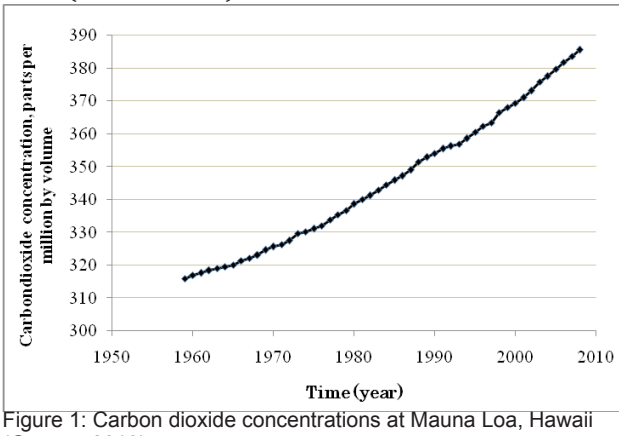

Figure 1: Carbon dioxide concentrations at Mauna Loa, Hawaii (Gautam 2010)

Climate is dynamic and changes through cycles influenced natural events such as continental drift, volcanoes, the earth's tilt, and ocean currents. These changes are being studied through historical evidence of tree-rings, pollen samples, ice-cores, and sea sediment.

Physiographic and Climate Change of Nepal

Nepal is a mountainous and landlocked country having an area of 147, 181 square kilometers. The country is located between 26o22' to 30o27' north latitudes and 80o04' to 88o12' east longitudes. It occupies about 0.03 percent of the total land of the earth and about two-thirds of its land is hills and mountains. It extends approximately 885 km east to west and about 193 km north to south. Elevation of the country starts from 61m to 8848 m within a span of less than 200 km.

The World Wildlife Fund (2005) reports that the Nepal Himalaya contains 3,252 glaciers and 2,323 lakes above 3,500 m above mean sea level (amsl). Glaciers cover an area of 5,323 km2 with an estimated ice reserve of 481 km3. By basin, the Koshi River contains 779 glaciers and 1,062 lakes; Gandaki River basin consists

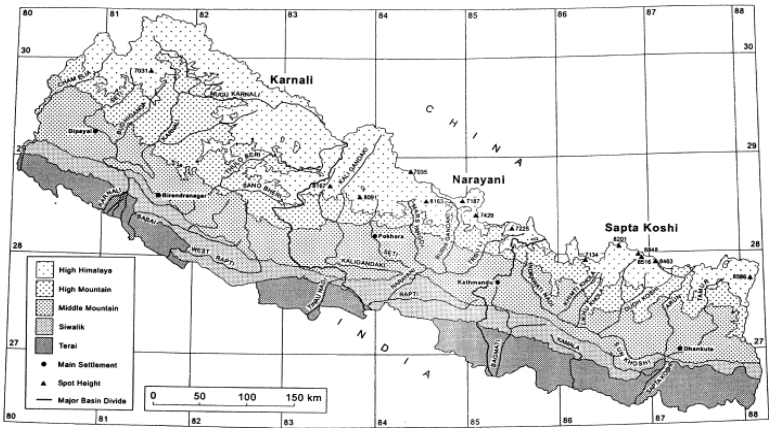

Figure 2: Physiographic condition of Nepal with its river systems (Hannah et al. 2005)

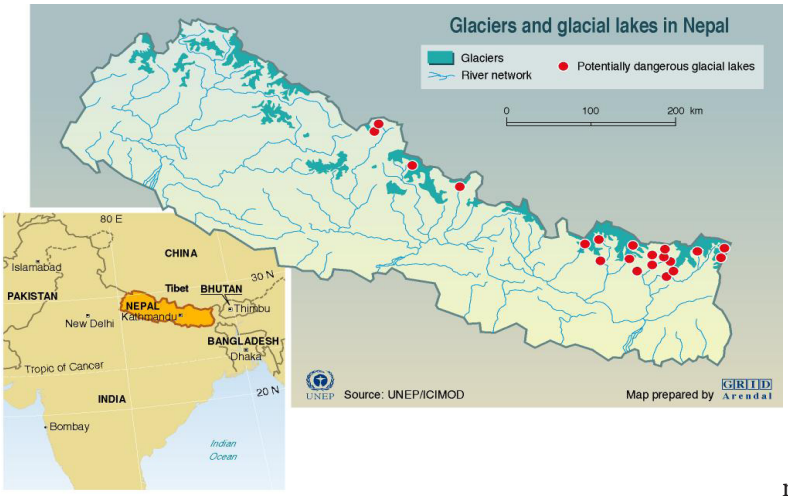

Figure 3: Glacier and glacial lakes in Nepal (Grid2009)

of 1,025 glaciers and 338 lakes; the Karnali River basin consists of 1,361 glaciers and 907 lakes; and, the Mahakali basin (within Nepal), consists of 87 glaciers and 16 lakes.

Glaciers are an important means of freshwater storage in Nepal as they accumulate water in monsoon and winter seasons at higher altitudes and provide melt-water at lower elevations during the dry seasons. The importance of glaciers extends beyond Nepal: the Ganges Basin draws up to 80% of its water flow from Nepali rivers (World Bank 2012).

Nepal is divided into five characteristic climatic zones in a span of less than 200 km (south to north), which are categorized as follows (ICIMOD 2002).

- Hot monsoon climate in the Terai, inner Terai, and Siwalik regions with a hot and wet summer, and mild and dry winter.
- Warm temperate monsoon climate in the Middle Mountains up to a height of about 2,100 meter above mean sea level (amsl).
- Cool temperate monsoon climate in the Middle Mountains and the High Mountains between 2,100 and 3,300 amsl.
- Alpine climate in the High Mountain region up to a height of about 4,800 amsl.
- Tundra type of climate above the snow line, that is, 5000m (WECS 2011) where there is perpetual frost and cold desert conditions.

Impacts of Climate Change: Global, Asian and Nepalese Contexts

Impacts of climate change can be categorized both positively and negatively. In a positive sense, winters will be less cold and more vegetation can be produced in high altitudinal areas. However, the rise in mean temperatures, currently projected to be as high as 5.8°C (Bajracharya *et al.* 2007) over the next century, may produce several of the negative consequences listed in table 1 (IPCC 2008).

In global context, 2009, ranked as the fifth warmest year on record since the beginning of instrumental climate records around 1850. On the decadal scale, the 2000s (2000-2009) were warmer than the 1990s, which in turn were warmer than the 1980s and earlier decades (WMO 2009).

Water distribution is uneven in Asia and it has a large and dense population with a fast growth rate. In this setting, it is expected that climate change will intensify water scarcity in Asia, adding to already present socio-economic stresses (IPCC 2008).

The Himalayan regions are located in the northern part of Indian sub-continent. The Himalayan region contains many rivers and the abundance of water in the area influences meteorological and hydrological conditions

Observed effect	Observed / possible impacts
Increase in atmospheric temperature	• Reduction in water availability in basins fed by glaciers that are shrinking, as observed in some cities along the Andes in South America
Increase in surface water Temperature	• Reductions in dissolved oxygen content, mixing patterns and self-purification capacity • Increase in algal blooms
Sea–level rise	• Salinization of coastal aquifers
Shifts in precipitation patterns	• Changes in water availability due to changes in precipitation and other related phenomena (e.g. groundwater recharge, evapotranspiration)
Increase in inter-annual precipitation variability	• Increase the difficulty of flood control and reservoir utilization during the flooding season
Increased evapotrans piration	• Water availability reduction • Salinization of water resources • Lower groundwater levels
More frequent and intense extreme events	• Floods affect water quality and water infrastructure integrity, and increase fluvial erosion, which introduces different kinds of pollutants to water resources • Droughts affect water availability and water quality

Table 1: Observed effects of climate change and its observed/possible impacts on water services in global perspectives (IPCC 2008)

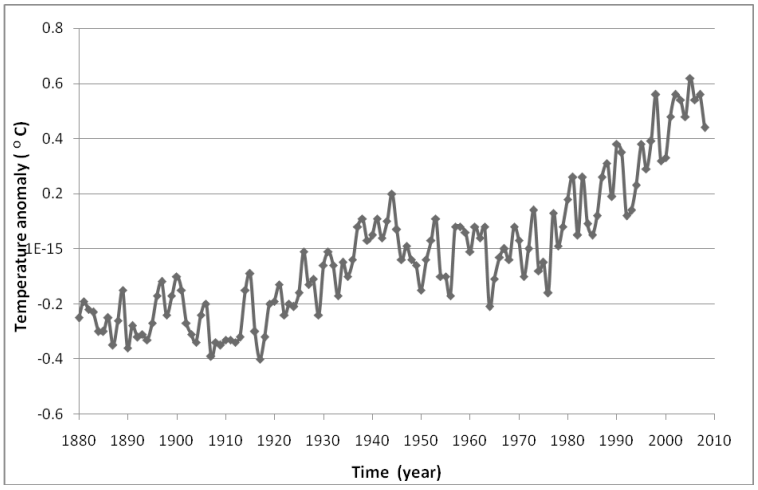

Figure 4: Trend of global average surface temperature (Gautam, 2010)

in the Indian sub-continent. It is assumed that even a minor change in the climate of the Himalayas could cause disastrous consequences on the socio-economic condition of millions of peoples living downstream of the river systems (Bhutiyani *et al* 2007).

Although Nepal's carbon emissions are negligible in the global context, it has been facing several adverse impacts of climate change. One climatic studies of Koshi basin of Nepal has shown that there is a high population pressure in the region (Sharma *et al.* 2000). The study indicated that the population of the basin grew at the rate of one percent per annum during the past four decades. It signified that the anthropogenic factors are increasing to enhance climate change in the Koshi basin, the eastern part of Nepal.

For an alternative perspective, we can divide the impacts of climate change in Nepal among various sectors: water resources, health, forestry, agriculture, biodiversity, economy, tourism and so on.

- **Water.** In Nepal, people consider *monsoon* as 'life giving rain'. More than 80% of the population depends on agriculture, which is predominantly fed by monsoon rain. Any change in the monsoon system directly affects the production of food. In recent years, concern for monsoon rains has been legitimated by increasing rainfall intensity and droughts throughout the country.
- **Health.** Climate change may be intensifying the spread of mosquito-related diseases such as malaria, dengue fever, Ross River virus, and West Nile virus (Climate Institute 2013). Gautam (2005) has shown that a mosquito problem has emerged in the high Jomsom valley of Nepal (2,700m). Aryal *et al.* (2013) found that the average annual temperature has increased by 0.13°C in the upper Mustang region, a rate faster than temperature increases in the central Himalayas of Nepal and the Tibetan Plateau.
- **Forestry.** Gaire et al (2005) studied dynamics of Abiesspectabilisin relation to climate change at the tree line eco tone in Langtang National Park. They collected tree core sampling and found that upward advancement of tree line should be expected in the coming decades. They further concluded that the general increase of winter minimum temperatures might be responsible for the upward advancement of the tree line and early melting of snow.
- **Biodiversity.** Chaudhary and Bawa (2011) conducted field surveys in Darjeeling and West Bengal of India and in the Ilam district of Nepal to analyze local perceptions of climate change. Respondents reported changes in biodiversity

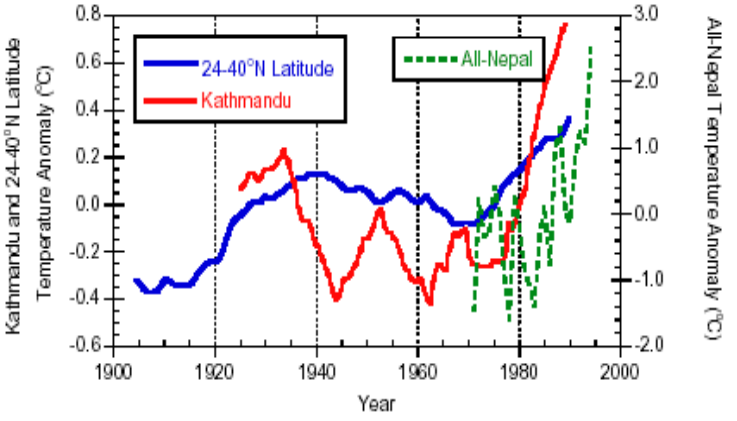

Figure 5: Comparison of temperature trends for Kathmandu with all-Nepal and global pattern (WWF 2005)

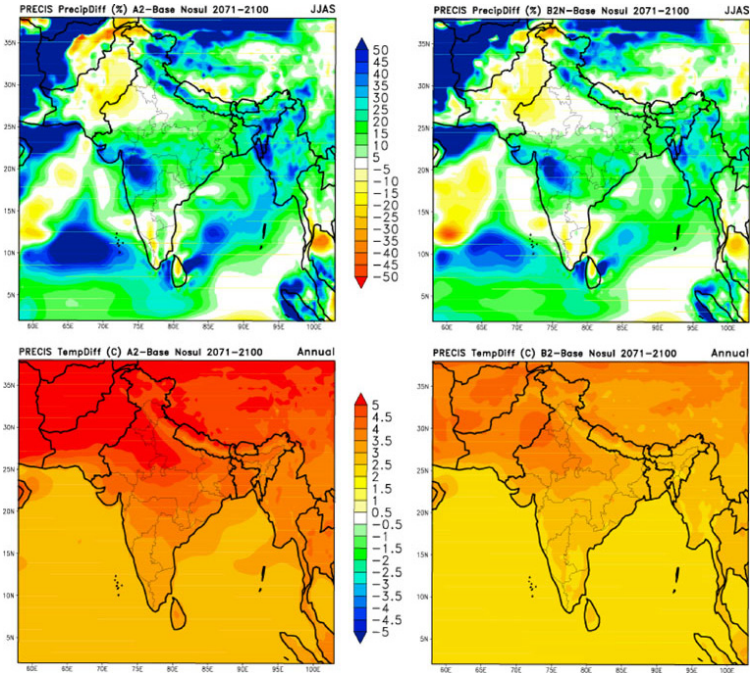

Figure 6: Projections of changes in monsoon precipitation (top) and average annual temperature (bottom) by the end of the twenty-first century for emission scenario SRES-A2 (left) and B2 (right) (Shrestha and Aryal 2011)

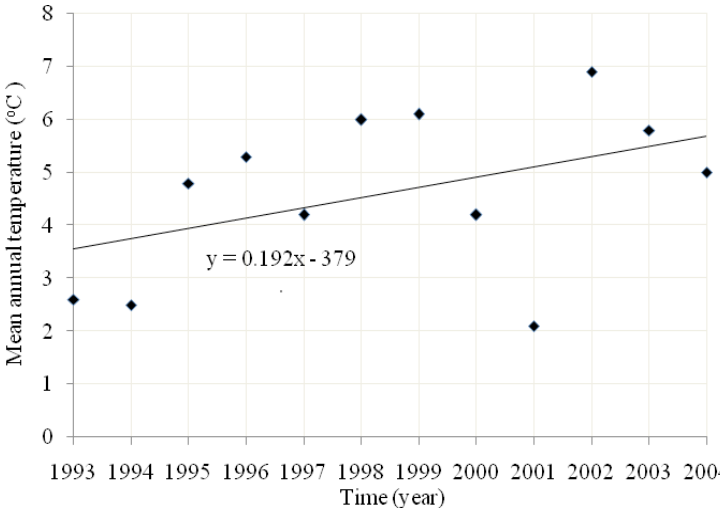

Figure 7: Average annual temperature at Langtang of Langtang cathchment from 1993-2004

such as early budburst and flowering, new agricultural pests and weeds, and the appearance of mosquitoes. They also reported that temperature increases appeared to be more rapid at higher altitudes.

- **Agriculture output.** Nepal Agricultural Research Council (NARC) has warned that the effect of a rise in temperature due to global warming will be greater on winter crops like wheat and millet. The vegetative state of those crops would be shorter with higher temperatures, thus lowering productivity (Upreti 2013). All these scenarios are showing that cropping systems could change with climate change.
- **Temperature.** The average number of 'hot' nights per year in Nepal increased by 9 and the average number of 'cold' days per year has decreased by 19 of days between 1960 and 2003 (UNDP 2008). 'Hot' day or 'hot' night is defined by the temperature exceeded on 10 % of days or nights in current climate of that region and season (UNDP 2008).
- **Precipitation.** A general circulation model (GCM) projection has shown that mean annual temperatures are projected to increase by 1.3 to 3.8oC by the 2060s and 1.8 to 5.8oC by the 2090s (UNDP 2008). Figure 6 illustrates the projection of changes in monsoon precipitation and average annual temperature in Nepal and neighboring countries.

Impact of Climate Change in Glaciers of Nepal Himalayas

Several temperature analyses in Nepal have shown that warming is occurring at much higher rates in the high altitudinal regions than in the low altitudinal regions (Aryal *et al.* 2013; ICIMOD 2009). In the Langtang catchment (figure 7), temperatures have risen 0.19°C per year from 1993 to 2004 (Aryal *et al.* 2013).

The rate of warming in Nepal is significantly higher than the global average, which is 0.74° C over the last hundred years (ICIMOD 2009). Most of the Hindu Kush-Himalayan (HKH) region is situated in the northern part of the Indian sub-continent. The HKH temperature increase is also outpacing global averages. The central Himalayas (Nepal) and the Tibetan plateau also reflect this sharp warming trend: 0.04 to 0.09° C per year and 0.03 to 0.07°C per year respectively (ICIMOD 2009). As a result, the number of glacial lakes has increased precipitously, creating additional concern for the potential of GLOF (figure 8).

Figure 8 shows that the Dig Tsho and Imja lake areas have been increasing rapidly in size. Tsho Rolpa Glacier Lake can also be considered a vulnerable lake, meaning it has a high likelihood of bursting. The volume of Tsho Rolpa is being reduced by human means to prevent any possible outburst. Tsho Rolpa appeared in 1950 and its size and depth have increased markedly each

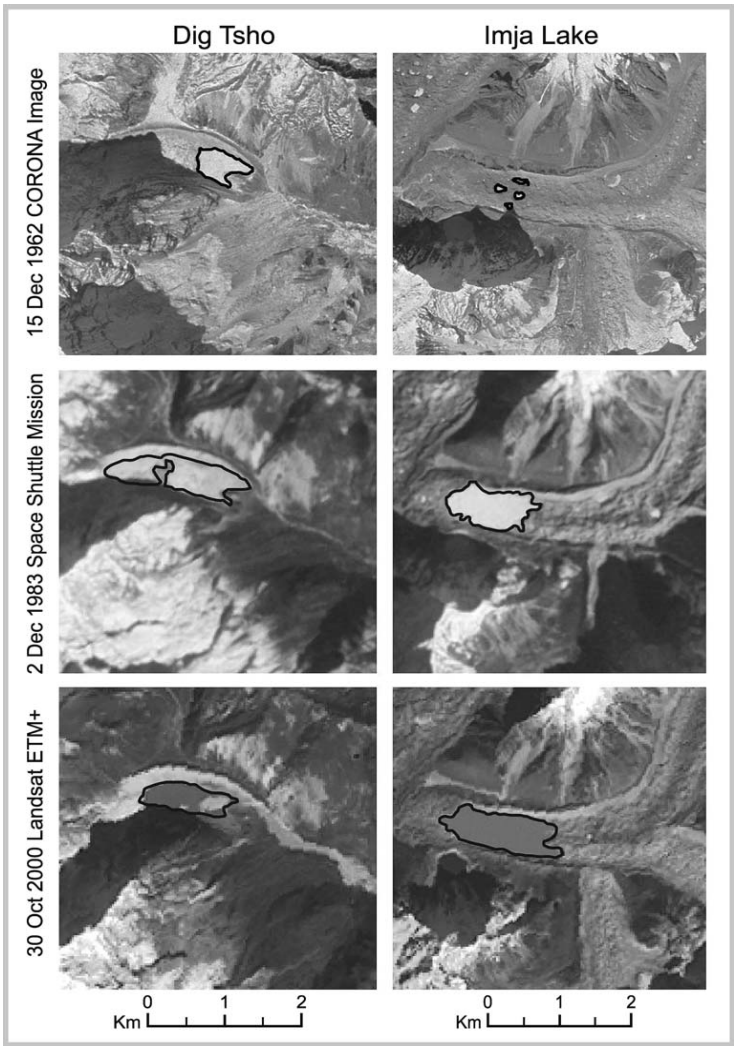

Figure 8: Growth of Dig Tsho and Imja lakes, Nepal (Bajracharya et al., 2007)

Date	River basin	Name of lake
450 years ago	Seti Khola	Machhapuchhare
August, 1935	Sun Koshi	Taraco, Tibet
21 September, 1964	Arun	Gelaipco, Tibet
1964	Sun Koshi	Zhangzangbo, Tibet
1964	Trishuli	Longda, Tibet
1968	Arun	Ayaco, Tibet
1969	Arun	Ayaco, Tibet
1970	Arun	Ayaco, Tibet
3rd September, 1977	Dudh Koshi	Nare, Tibet
23rd June, 1980	Tamur	Nagmapokhari, Nepal
11th July, 1981	Sun Koshi	Zhangzangbo, Tibet
27th August, 1982	Arun	Jinco, Tibet
4th August, 1985	Dudh Koshi	Dig Tsho, Nepal
12th July, 1991	Tama Koshi	Chubung, Nepal
3rd September, 1998	Dudh Koshi	SabaiTsho, Nepal

Table 2: List of GLOF events recorded in Nepal (WWF 2005)

Figure 9: Tsho Rolpa glacier lake area expansion (German watch 2009)

year due to melting glaciers (figure 9). The Trakarding glacier above the Tsho Rolpa Lake is retreating at a rate of 20 meters per year (Shrestha et al. 2011).

A rapid retreating glacier in the Himalayan region is a clear indication of global warming and the climate change. It also shows the growing likelihood of GLOF and events occurred in Nepal (Table 2).

Most hydropower projects in Nepal are built on snow fed rivers like Kali Gandaki, Marsyangdi, and Trishuli. The large amount of glacier melt can impede these projects and dampen their ability to produce electricity, as well as pose serious environmental and humanitarian potentials in the case of dam collapse. It is expected that after glaciers recede to a certain point, river flows will diminish and will not be sufficient to generate electricity. This research at Langtang supports the mentioned claim. Average annual flow obtained at Langtang village in the Langtang catchment and its diagrammatic representation has been given in Figure 10. In a recent study glaciers in the Langtang catchment were observed to be retreating steadily and by 2035 the glacier area will reduce by 32% (Immerzeel et al. 2012).

Studies have shown that about 20% of the

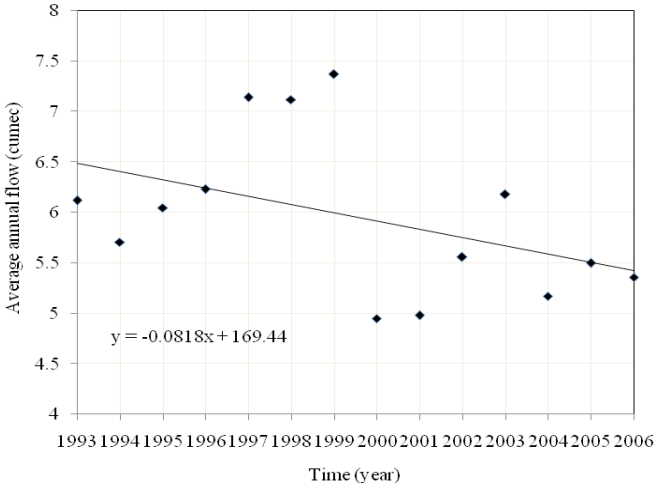

Figure10: Average annual flow at Langtang village of Langtang cathchment from 1993-2006

glaciated area above 5,000 meters is likely to become snow–and-glacier-free if air temperatures increase by 1oC (NAPA 2008). Around 70% of the snowcapped area above 5000 meters would be severely affected by an increase of 4oC (NAPA 2008). A study from 1988 to 2004 of temperature recorded in the Langtang catchment shows that the total number of days per year below 0oC has been decreasing (figure 11).

Glacier AX010 in the Shorong Himal in the eastern

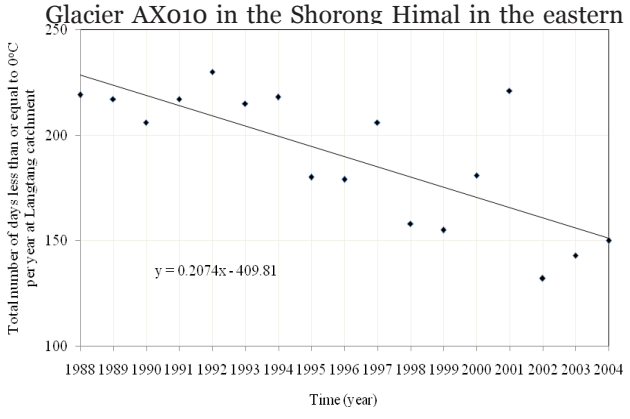

Figure 11: Total number of days less than or equal to 0oC per year at Langtang from 1988-2004

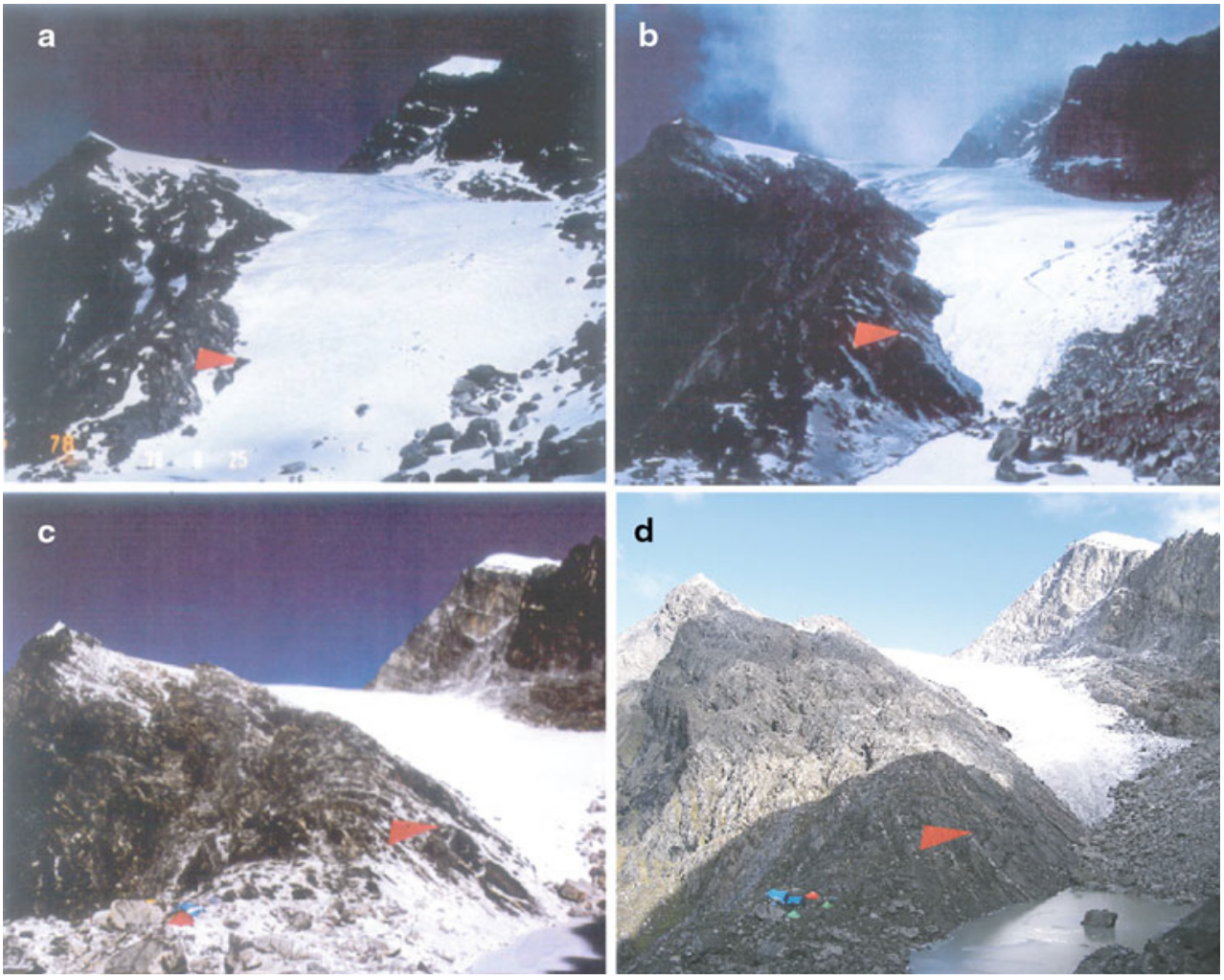

Figure 12: Glacier AX010 in a 1978, b 1989, c 1998 and d 2004 (Shrestha and Aryal 2011)

part of Nepal is one of the most highly studied glaciers. Figure 12 of the glacier AX010 illustrates the retreating condition of the glacier from 1978 to 2004.

In a recent study conducted on Himalayan glaciers in Nepal and Bhutan, Bajracharya et al. (2011) found that the glaciers are retreating at rates ranging from 10 meters to 60 meters per year and many small glaciers (<0.2 sq. km.) have already disappeared.

Chaulagain (2009) studied glaciers in Langtang Himalayas and found that they may disappear within two centuries at current temperature rates. Seventy-five percent of Langtang glaciers will disappear within 3-4 decades and only 24% of in the basin may remain by 2100 AD even without any further warming.

Concluding Remarks

Although Nepal has negligible contribution in global greenhouse gases (GHGs), adverse impacts of climate change are already seen in many parts of the country on water, health, agriculture, forestry, biodiversity and economy. Nepal Himalayas are the main source for the major rivers of the country and most hydro-power projects of Nepal have been constructed on snow fed rivers. Using evidence collected in Langtang, this study indicates that average annual temperature is increasing while annual river flows are decreasing. (It is) also found that the numbers of cold days are decreasing in the catchment. It is worthwhile to mention that further rising temperatures in Himalayan regions of Nepal could exacerbate water scarcity in the nation, which would have serious implications for economic development.

Although the impacts of climate change are found on global scale, Nepal should promote eco-friendly works to reduce the emission of GHGs. Forest conservation, use of renewable energy (including micro-hydro plants), scientific means for realizing urbanization, and waste management are just a few examples of the eco-friendly works that should be enhanced for the good of the nation. Last but not the least, more detailed research on climate change is needed in the Nepal Himalayas to provide policy makers with the best information possible to support effective mitigation and adaptation programs for the country.

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