EFFECTS OF CLIMATE CHANGE: THE GLOBAL CONCERN

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ABSTRACT

Background: Climate change which is the consequence of global warming is one of the major factors of hazards in Nepal and all over the world. Variable geo-climatic conditions, young geology, unplanned settlements, deforestation environmental degradation and increasing population are other causes of hazards. However, various researches have revealed that climate change is one of the key factors for the occurrences of multiple hazards.

Context: Geo-scientists have found that due to global warming, the number and volume of glacier-lake outburst flood hazards are on the rise. Considering the average vertical lapse rate of 6.5°C per kilometer, it was found that almost 20% of the present glaciated area above 5000 meter altitude are likely to be snow and glacier free area with an increase of air temperature by 1°C. Similarly, 3°C and 4°C rise in temperature could result into the loss of 58% and 70% of snow and glaciated areas respectively. The above figures and situation warn us on the effect of global warming and climate change in the GLOFs. The outburst of huge GLOFs may cause enormous loss not only in Nepal that will extend up to North India and Bangladesh. In addition to the threats of GLOFs, the major impacts of climate change are: increased variability of river runoff, increased sediments, increased evaporation from reservoirs and impacts on watershed. Obviously climate change will affect agriculture. While majority of the people of Nepal depend on agricultural crops like rice, maize and wheat. Higher temperatures, increased evapo-transpiration and decreased winter precipitation may result into droughts. It should be considered as an early warning for food security.

Conclusion: This is high time to realize that adverse impacts of climate change, variability and extremes are the common concerns of every nation. Greenhouse gases from human activities are among the major causes for the alarming situations. Although United Nations Framework on Climate Change and the Kyoto Protocol allow emission producers to offset their emissions by paying others to carry out emission reducing activities - it is to be noted that various studies show pressing need to calculate carbon appropriation, the basis for calculating the impact of ecological imbalance particularly - deforestation. Stopping deforestation and building healthy environment should be the key issues in climate change policy of every government. Then it will provide a way for millions of poor people in developing countries to benefit directly. In the same way, such policy will help to reduce deforestation, maintain ecological balance and allow the nations to sell credits for successful programs combating carbon dioxide. On the other hand, developed countries that pollute more than the allowed limits under the existing Kyoto accord would be able to buy the carbon credits to increase their emission levels and help to fund forest protection plan and programs.

Keywords: Hazards, potential, GLOFs, carbon, emission

EFFECTS OF CLIMATE CHANGE: THE GLOBAL CONCERN

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1. Background:

Nepal, a small and land locked country in South Asia is exposed to multiple hazards due to the variable geo-climatic conditions, young geology, unplanned settlements, deforestation environmental degradation and increasing population. Climate change is one of the key factors for the occurrences of various types of disasters. The vast altitudinal variation within a short span of about 193 km, ranging from 60 meters to 8848 meters above sea level makes the country an abundant storehouse of bio-diversity and ecological niches with diverse agro-climatic zones ranging from the sub-tropical to the alpine and tundra (Poudyal Chhetri and Bhattarai 2001). On the other hand, increasing population, rapid and unplanned urbanization and other economic activities in vulnerable areas are other contributing factors to increase hazards. Hence, Nepal is a global hot spot for several types of disasters.

The South Asian monsoon is one of the most important and influential phenomena of the earth's climate system. The modern large-scale, time averaged seasonal variations in the South Asian monsoon system are fairly well understood and are linked to the greater heat capacity of the ocean relative to the surrounding land masses. During summer in the Northern Hemisphere, the Tibetan Plateau warms rapidly relative to the Indian Ocean. The resulting low pressure over Asia and higher pressure over the ocean gives rise to the strong low-level atmospheric pressure gradient that, in turn, generates the south-west monsoon from the Indian Ocean. In years of low snowfall, the Tibetan Plateau is able to warm earlier and generate stronger monsoonal circulation. Deep snow and associated influences on albedo (reflected light or radiation) and soil hydrology delay and weaken the monsoon. The South Asian monsoon during the last glacial period was significantly weaker than at present, and was abruptly strengthened during the beginning of Holocene Period around 12,000 years ago (Overpeck and Cole 2007). In the winter, the continent cools relative to the ocean, the pressure gradient is completely reversed, and the dominant flow across the Arabian Sea becomes north easterly and, therefore, the South Asian region receives little precipitation. Arguments based on physical phenomena clearly indicate that global warming will cause an increase of evaporation from the ocean. A warmer atmosphere can carry more moisture, which can lead to larger amounts of precipitable water. Global warming will also induce higher temperature differences between land and sea surfaces, causing an increased transport of precipitable water to the continents and an increase in frequency of intense rainfall. Recent results from global coupled models generally agree with these scenarios. The global coupled ocean-atmosphere climate model of the National Centre for Atmospheric Research produces greater mean precipitation in the South Asian summer monsoon region (Lal et al. 1998).

2. The Context

Global warming has become a very serious concern due to its adverse effects in livelihood and environment. Global climate change is causing a rapid melt down of snow and glaciers in the Himalayan region and the water from the Himalayan river systems flows into water basins of nine major rivers serving a total population of almost 1.3 billion. Thus, this mountain range constitutes a major source of water for some of the most populous parts of the world. The region and its water resources play an important role in global atmospheric circulation, biodiversity, irrigated agriculture, potential hydropower, as well as for the production of commodities exported to markets worldwide. Moreover, glaciers are the coolers of the planet

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earth and the lifeline of many of the world's major rivers. They contain about 75% of the Earth's fresh water and are a source of major rivers. Yet, global warming is melting glaciers not only in Himalayan region, but also in every region of the world, putting millions of people at risk from floods, droughts and lack of drinking water.

The Hindu Kush-Himalayan region is the highest mountain range in the world. It extends more than 3500km through eight countries, from Afghanistan to Pakistan, India, Nepal, Bhutan, China and Myanmar. This area is covered by glaciers and permafrost outside the Polar Regions. The glaciers' retreat in this region is massive. Therefore, Himalayan glaciers are among the fastest retreating glaciers than elsewhere. The increasing temperatures and changing precipitation patterns are influencing the region's ecosystems and human populations.

3. Global Warming-The Cause of Climate Change:

Studies have shown that in the last 100 years the world's average temperature has risen rapidly than in the last 10,000 years. The scale of temperature rise is in increasing trend. Out of the 10 recorded warmest years in history, nine were recorded during the last decade. The global mean temperature is expected to increase between 1.4 to 5.8ºC over the next hundred years. The adverse effects of such change in global climate are seen in the Himalayas where glaciers and glacial lakes are posing catastrophic risks. Himalayan glaciers are retreating at rates ranging from 10 to 60m per year and many small glaciers (<0.2 sq.km) have vanished. The boundary of most of the high altitude valley glaciers in Bhutan, China and Nepal are diminishing quickly. Glaciers in the Himalaya are thinning faster than elsewhere in the world. If current situation prevailed, the glaciers could disappear by the year 2305. Thus, climate change is shrinking the mountain glacier and directly affecting the landscape and threatening water supplies all over the world. In such a way, the Himalayan glaciers can be considered as a reliable indicator of climate change. It is a matter of grave concern though.

For the last 10,000 years we have been living in a remarkably stable climate that has allowed the whole of human development to take place, now we see the potential for sudden changes of between 2 and 6 degrees Celsius (by the end of this century). We just do not know what the world is like at those temperatures. We are climbing out of the safe zone (Corell 2007).

4. Effects of Global Warming in the Nepalese Mountains and Beyond:

Mountain regions occupy about a quarter of the global terrestrial land surface and provide goods and services to more than half of the inhabitants. The rise of the Himalaya and Tibetan Plateau together that started about 50 million years before caused a tremendous impact on the regional and global climate of the world. The Himalayan region has long been recognized as extremely rich in animal and especially plant diversity. Himalayan watersheds harbor more diverse ecosystems than the Amazon. The rise of the Himalaya and Tibetan Plateau together caused a tremendous impact on the regional and global climate of the world. During the summer season warm moist wind blows from ocean to land. While in winter time, cold dry wind blows from land to ocean. Monsoon circulation involves a change of approximately 180 degree in the direction of wind between the summer and winter (Upreti, 2008).

Physiographically, the country is divided into five regions namely: the Tarai (flat and fertile southern plain land that extends from east to west of Nepal), the Churiya hills (very fragile small hilly region of Nepal), the Middle hills, the High hills and the Himalayas. Ecologically, the country is divided into three regions running from east to west, namely; *the Tarai, the Hills* and *the Mountains*. Nepal is influenced by monsoonic rainfall which starts from the middle of June and lasts until the middle of September. Nepal also experiences some amount of rainfall during the winter between January to March. However, about 85 percent of total precipitation occurs during the monsoon. The monsoonic rain first strikes the south eastern part of the country and gradually moves towards the west, with diminishing intensity. Thus the eastern part of the country generally experiences more rain than the western part during this season. On the contrary, the rain in winter, caused by western disturbances, enters Nepal from the west and gradually moves eastward with diminishing intensity. In both cases, the rainfall intensity is maximum in the Hilly regions of the central part of the country, particularly the southern flanks of the Annapurna Range goes on decreasing both on the Northern and Southern sides. This is mainly due to highly spatially varying topography resulting in varying orographic effects in the country. During the monsoon about 64 percent of the rainfall drains out immediately as surface runoff. Of the remaining 36 percent, some is retained in the form of snow in the high Himalayas, some percolates through the ground as groundwater, and some is lost by evaporation and transpiration. The retained water in the forms of snow and ground water acts as natural reservoirs which feed the rivers to keep them flowing during the dry season. In the Northern Himalayan region precipitation occurs in the form of snow. Glaciers and snow melt influence the hydrological behavior of the major rivers. Nearly 8 percent of the country's area is estimated to be under permanent snow cover. Snow fall is estimated to contribute about 10 percent of the total precipitation. The potential evapotranspiration (PET) ranges from over 1350 mm per year in the central and eastern Tarai regions to less than 750 mm in the Eastern Himalayas. In the mid-western and far western Tarai regions it is observed to be about 1150 mm per year (Poudyal Chhetri and Bhattarai 2001).

Studies show that rainfall patterns are influenced by climatological phenomena including the El Nino/Southern Oscillation as well as changes in regional-scale land and sea surface temperature (Mirza, 2003). Studies also indicate that local variations in rainfall amounts and timing can be high, with ridges receiving four to five times the amounts that valley do (Higuchi ET. Al. 1982; Barros and Lang, 2003).

Nepal's 83% land mass is mountainous terrain. The wide range in altitudinal variation along its width gives rise to a steep and rugged topography and extreme relief. Steep and unstable slopes, rugged terrain, active geodynamic processes and intense monsoon rains make the Himalaya an active and fragile mountain range. As the nature of the Himalaya suggests, landslides and debris flows and floods are the main types of water-induced hazards in the region and in Nepal. These hazards wipe out entire villages, wash out roads, bridges, canals and hydropower plants and damage hectares of valuable agricultural land during the monsoon season. Besides substantial economic losses, more than 320 people on average lose their lives in the Nepal Himalaya alone. Other losses from these hazards are on a rise every year. Many factors trigger debris mass movement or debris flows. Among the most common triggers in the Himalaya are prolonged or heavy monsoon rains. Rainfall can lead to mass movement of debris by reducing the internal or binding strength of soil and other materials through three different mechanisms. The saturation of soil materials increases the weight of slope materials and creates greater gravitational force. Saturation of soil materials can reduce the cohesive bond of individual soil particles and water can serve as a lubricant along the interface between soil and rock and along the weakness zones of rocks, such as joints, cracks and fault planes. The first two mechanisms often act in combination. Rainfall intensity and duration thresholds for triggering landslides have been widely identified in many different climates and geological settings. Caine and Mool (1982) estimate a threshold rain of 100 mm day-1 to trigger a landslide and lead to a debris flow such as had happened in the Kolphu Khola drainage basin area, central Nepal in 1980. The intensity and duration of rainfall that can initiate a landslide depends on many factors. However, most landslides and debris flows reported in the Nepal Himalaya are either associated with intense or sustained monsoon precipitation (Dhital 2003, Adhikari and Koshimizu 2005).

There is likely to be increased severity and frequency of monsoonal storms and flooding in the Himalayas, which are expected outcomes of climate change, may significantly alter the area's erosion, river discharge and sediment dynamics. Eventually, this may affect existing hydropower reservoirs, as well as those planned for construction in the Himalayas. Part of the generated sediment may be deposited on agricultural lands or in irrigation canals and streams, which will contribute to deterioration in crop production and in the quality of agricultural lands.

Geo-scientists have found that due to global warming, the number and volume of glacier-lake outburst flood hazards are on the rise. Some of these floods have produced discharge rates of up to 30,000 m3/sec and can run for distances of 200 km (Richardson and Reynolds, 2000). Considering the average vertical lapse rate of 6.5°C per kilometer, it was found that almost 20% of the present glaciated area above 5000 meter altitude are likely to be snow and glacier free area with an increase of air temperature by 1°C. Similarly, 3°C and 4°C rise in temperature could result into the loss of 58% and 70% of snow and glaciated areas respectively. Such changes are likely to contribute to the faster development of glacier lakes leading consequently to the increase in potential of glacier-lake outburst flood hazards. Also, increase in precipitation by more than 20% is likely to cause significant increase in sediment delivery and more than 20% increase in annual sediment deposit could be expected in a scenario of 50% increase in annual precipitation (MoPE, 2004). The above figures and situation warn us on the effect of global warming and climate change in the GLOFs. The outburst of huge GLOFs may cause enormous loss not only in Nepal that will extend up to North India, Bhutan and China.

Global climate change is affecting the Himalaya much faster than previously thought and mountaineers have been the first to notice the changes: more frequent avalanches, more crevasses and exposed rock faces where there used to be snowfields. Cho Oyu and Chomolungma (Mt. Everest) used to be considered the easiest to climb, but have become more difficult in the past 25 years. On the area leading up to the bottom of the Himalaya there are now small lakes and ice slush rivers forming during the spring season, says Brice. The ice walls of the 'Magic Highway' leading to Advanced Base Camp are now half the size of what they used to be 20 years ago. On the Nepal side, Chomolungma has also changed dramatically since Edmund Hillary and Tenzing Norgay first climbed it in 1953. "When my colleague Guy Cotter first guided an expedition to Everest the Hillary Step was completely covered in snow and ice in 2004 it was just rock," says Mike Roberts, who has led expeditions to Everest since 2002. "The entire stretch from the south summit to the true summit is now pure rock."

5. GHG Effects:

Global climate change –driven largely by human induced warming of greenhouse gases (GHG) – is a growing threat to humanity. The world experienced a surface temperature rise of 0.6°C on average during the 20th century, and the temperature by year 2100 is projected to go as high as 6.4°C relative to 1990 if GHG emissions are not reduced (IPCC 2007). But time has shown that given the dependence of global economic systems on fossil fuels, and the time required for new technologies that reduce or replace fossil fuels, to integrate into the global marketplace, significant reduction in GHG emissions is unlikely to occur soon enough to avoid climate impacts. Significant harm from observed climate change on the environment and on society is already occurring worldwide and more severe and widespread impacts lie ahead. Climate change impacts on the geo-environment of the Nepal Himalaya are significant.

Greenhouse gases (GHG) from human activities are among the major causes for this alarming situation. Although hazards do not necessarily lead to disasters unless the people are exposed, ill equipped to respond and incapable to cope with the hazard. While by the help of science and technology, most of the disasters can be predicted and mitigated, impacts reduced and communities protected. Nevertheless, due to the inability to reap the benefits of such scientific advancements, the people of Nepal are left with no choice other than facing it and trying to get prepared to minimize the negative impacts. People have to know about the characteristic of the hazard, self-exposure to the vulnerability and capability to plan and execute appropriate actions during disasters. Countries causing the majority of emissions should recognize their responsibility for climate change and help developing countries like Nepal to adapt to it to ensure their long-term sustainability. While adaptive measures and interventions to protect human health from the consequences of climate change need immediate attention, mitigation measures, such as reduced greenhouse gas emissions, are vital.

6. Can We Defuse The Global Warming?

Global warming has become a serious concern due to its adverse effects in livelihood and environment. Experts firmly believe that most glaciers worldwide are retreating inevitably to their final demise. Global warming is a scientific fact and ice melting is the indicator of disastrous consequences. Yet most gloom-and-doom climate scenarios exaggerate trends of the agents that drive global warming. Study of these factors has revealed that global warming can be slowed and stopped, with practical actions that yield a cleaner, healthier atmosphere, however.

7. Impact of Climate Change in Nepal:

Although Nepal is not contributing to global warming, it has tremendously impacted the glacier ecosystem in the Nepalese Himalayas. Climate change is not just an environmental phenomenon but also an economic, social and political issue in Nepal. From the point of view of climate change, Nepal is among the most vulnerable countries in the world. Himalayan Study is important because of the four reasons, namely; role of Himalaya on global climate, present impact of global warming in the water balance in high mountain areas, the impact of climate change in flora and fauna and the socio-economic impact of climate change in subsistence farming.

The major impacts of climate change in Nepal are: increased glacier-lake outburst flood (GLOF) hazards, increased variability of river runoff, increased sediments, increased evaporation from reservoirs and impacts on watershed. As a result glacier melt and precipitation patterns would occur. Nepal has wide variety of species. A study has found that 2.4% of biodiversity may be lost with climate change. Obviously climate change will affect agriculture. While majority of the people of Nepal depend on agricultural crops like rice, maize and wheat. Higher temperatures, increased evapo-transpiration and decreased winter precipitation may result into droughts. It should be considered as an early warning for food security.

The average maximum temperature in Nepal between 1977 and 1999 has increased by 0.9°C, at a rate of 0.03°C to 0.12°C per year, whereas the global average surface temperature rise of the last century was 0.6±0.2 °C. (Shrestha et al. 1999) and is estimated to have gone even higher since then. This is one of the highest registered rates of temperature rise in the world. The observed trend of rising temperature in Nepal is challenging the IPCC projections, as it seems that land areas will warm more rapidly than the global average.

As stated in earlier section, monsoon climate is predominant in Nepal. Torrential rains during the monsoon render the country highly susceptible to water induced natural disasters such as floods, landslides, flash floods, debris flows and slope failures. Although rainy days are decreasing, high-intensity rainfall events are increasing, resulting into increase in magnitude and frequency of water-induced disasters. On the other hand, potential threat of Glacier Lake Outburst Floods (GLOF) is also growing. GLOF occurs when the moraine damming of a glacial lake suddenly collapses and releases large quantities of water resulting in a high velocity surge, causing devastating floods and debris transport downstream.

In the Himalayan region of Nepal glacier lakes are common. Glaciers were formed in the Himalaya between the 15th and 19th century, during the Little Ice Age (Yamada, 1993). A glacier lake originates from a glacier and usually forms at its terminus. According to ICIMOD (2007), the Nepal Himalaya has more than 2323 glacier lakes with areas larger than 0.03 sq. km. As a glacier melts, melt water is stored within the lateral and end moraines creating a glacier ice or ice cores and moraines and will continue to grow as the ice melts. The Imja, for example, "was just a small pond in 1960s" but in recent, it has radius of 1 km. and stores 2.9 millions cubic metres of water (Watanabe et. al. 1994). The Koshi River Basin, the Gandaki

River Basin, the Karnali River Basin and the Mahakali River Basin contain 1,062, 338, 907 and 16 lakes respectively. Dudh Koshi Sub-Basin, the largest basin in Nepal, is also the most densely glaciated region of the country (Bajracharya et. al., 2007).

Out of the 2323 glacial lakes, 26 are potentially dangerous. The areas of Upper Barun, Lower Barun, Chamlangtsho, Tsho Rolpa, Sabou, Dudh Kunda, Majang, Imja, and Thulagi have been identified as dangerous glacier lakes. These lakes contain huge volumes of water and remain in unstable condition. As a result, they can burst any time and a natural catastrophe would cause loss of life and property. About 14 such glacier lake outburst floods have been experienced between 1935 and 1991. A GLOF of 1985 caused a 10 to 15 meter high surge of water and debris to flood down the Bhote Koshi and Dudh Koshi Rivers for 90 kilometers which swept away a hydropower plant. At its peak, 2,000 m3/sec was discharged (Poudyal Chhetri and Bhattarai 2001).

Almost 20% of the glaciated areas in Nepal above 5000 m are likely to be snow and glacier free area at an increase of air temperature by 1 °C. Two degree Celsius rise in temperature can cause the loss of almost 40 % of the areas. Similarly, 3 °C and 4 °C rise in temperature can result in the loss of about 58 % and 70 % of snow and glacier areas, respectively.

"The rapid melting of Himalayan glaciers will first increase the volume of water in rivers causing widespread flooding," said Jennifer Morgan, Director of WWF's Global Climate Change Program. "But in a few decades this situation will change and the water level in rivers will decline, meaning massive economic and environmental problems for people in Western China, Nepal, Pakistan and Northern India."

8. Effects of Climate change in Livelihoods:

The UN's Intergovernmental Panel on Climate Change (IPCC) reported that if current trends continue, 80 per cent of the Himalayan glaciers, the water source for a sixth of the world's population could disappear in 30 years if the current rate of emissions is not reduced. If, even the present rate of warming is continued for a 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. Like the water-induced disasters, intensity and frequency of drought is already on a rise and the projected change in temperature and precipitation pattern would result a further decline in crop yield.

With a predominantly agrarian economy where about 81 percent of the over 30 million people reside in rural areas in Nepal, traditional, self-sustaining hills and mountain farming systems have been disrupted owing to increased population and fertile top soil erosion combined with deforestation, so that migration from the hills and mountains to the fertile Tarai region and haphazardly developed urban centers are increasing at an unprecedented scale. Consequently, the poor, uneducated and unemployed people are compelled to make a living by settling in flood and land slide prone areas in the hills as well as the plains and the urban areas which are now became more vulnerable to disasters due to climate change and global warming. Lack of effective land use and settlement regulations have contributed to increased vulnerability to floods and other hazards caused by both natural and anthropogenic factors (Poudyal Chhetri and Bhattarai 2001).

On the other hand, forest area is significantly reduced in Nepal mainly due to human activities. Tarai forest has decreased at an annual rate of 1.3 %, while hill forest has decreased at the rate of 2.3 % from 1978/79 to 1994/95. In the whole of the country from 1978/79 to 1994/95, forest area has decreased at an annual rate of 1.7 %, whereas forest and shrub together have decreased at an annual rate of 0.5 % (FRISP, 1999).

9. Climate change and Health Hazard:

Climate change may aggravate the water quality. The possible increase in differences between wet and dry seasons may imply wetter wet seasons and drier dry seasons. Access to safe water is limited throughout the Himalaya. If dry seasons become even drier, this problem will grow.

It is a well known fact that unavailability of water leads to poor sanitation. As a result, the risk of water-borne diseases will increase. Climate change will also affect infectious diseases transmitted by insects, i.e., vector-borne diseases like malaria, yellow fever, and schistosomiases. Once temperatures increase beyond the comfort range of human tolerance, thermal stress will result in discomfort, physiological stress, ill health, or even death. Heat causes clinical syndromes, heatstroke being the most serious and occurring when body temperature exceeds 40.6 °C. While adaptive measures and interventions to protect human health from the consequences of climate change need immediate attention, mitigation measures, such as reduced greenhouse gas emissions, are vital.

Many vector-borne and water-borne infectious diseases are known to be sensitive to warm climatic conditions, and some of these effects, such as Japanese Encephalitis, Malaria and Kala-azar cases are already on a rise under the observed warming in Nepal. Nepal is especially vulnerable to climate change because a large share of their economies is in climate-sensitive sectors and its adaptive capacity is low due to limited human, financial and institutional and technological capacity.

10. <u>Conclusion:</u>

Due to climate change, glaciers are receding rapidly not only in the Himalayan region. The vast majority of all Himalayan glaciers have been retreating and thinning over the past 30 years, with accelerated losses in the last decade. Glaciers are receding in Africa, South Pacific, Arctic, North America, South America, Europe and Antarctica as well. Glacial retreat is the most visually convincing evidence of climate change which is not a myth but an unwanted scientific reality. This is high time to realize that adverse impacts of climate change, variability and extremes would be impeding factors to attain the set goals of the respective governments.

Although United Nations Framework on Climate Change and the Kyoto Protocol allow emission producers to offset their emissions by paying others to carry out emission reducing activities. It is to be noted that various studies show pressing need to calculate carbon appropriation, the basis for calculating the impact of ecological imbalance particularly - deforestation. Stopping deforestation and building healthy environment should be the key issues in climate change policy of every government. Then it will provide a way for millions of poor people in developing countries to benefit directly. In the same way, such policy will help to reduce deforestation, maintain ecological balance and allow the nations to sell credits for successful programs combating carbon dioxide. On the other hand, developed countries that pollute more than the allowed limits under the existing Kyoto accord should buy the carbon credits to increase their emission levels and help to fund forest protection plan and programs.

We need to work together on reducing CO2 emissions, increasing the use of renewable energy and implementing energy efficiency measures.

In the context of Nepal- disaster management system is basically limited to response – it needs to focus more on preparedness and mitigation by addressing adverse effects of climate change. Other plan and policies of the government should also be proactive in lieu of reactive approach. Disaster preparedness and improved agriculture is necessary and important to reduce the vulnerability to climate change and possible hazard and disasters.

Institutions in Nepal are facing several limitations in conducting modeling studies to assess the impacts of climate change in water resources. One of the biggest limitations is the lack of reliable observation data to verify the model results. Inadequate human and technical resource is another hindrance in this regards. Nepal feels that some of the gaps can be bridged by sharing of satellite data conducting regional trainings and real time sharing of observational data. It is imperative for the governments in the region to have good climate change policies with strong focus on impact adaptation. To avoid negative impacts on the socio-economy of the region planning for adaptation measures is essential. For adaptation planning, it is essential to understand how the climate of the region might change in the future and how the change might impact the hydrological regime of the river basins. Climate modeling has been an important tool to understand how the climate might evolve in the future while hydrological modeling can provide insights on how the projected climate might impact the hydrological regime of the river basins.

The performance can be greatly enhanced, if the activities can be conducted in close collaboration among the countries that are conducting their activities in isolated manner e.g. the climatic scenarios can be developed for regional scale while individual countries can generate higher resolution scenarios for national scales. Similarly, hydrological model can be run at basin scales, while higher resolution models can be run at catchment scales by individual countries. There is the opportunity of learning among the countries to develop regional climate change scenarios and basin-wide scenarios of water availability under the climate change situation.

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References:

Adhikari, D. P., (2003). Monitoring the Monsoon in the Himalayas: Observations in Central Nepal, Monthly Weather Review, Vol. 131, pp. 1408-1427, June, 2001.

Adhikari, D.P.; Koshimizu, S., (2005). 'Debris Flow Disaster in Larcha, Upper Bhotekoshi Valley, central Nepal'. In The Island Arc, 14 (4): 410-423.

Bajracharya, B., Shrestha, A. B., Rajbhandari, L., (2007). Glacial Lake Outburst Floods in the Sagarmatha Region: Hazard Assessment Using GIS and Hydrodynamic Modeling, Mountain Research and Development, Vol. 27, pp. 336-344, Kathmandu.

Bhattarai, D. and Poudyal Chhetri M. B. (2001), Mitigation and Management of Floods in Nepal, Ministry of Home Affairs, HMG/Nepal.

Caine, N.; Mool, P.K. (1982). 'Landslide in the Kolphu Khola Drainage, Middle Mountains, Nepal'. In Mountain Research and Development, 2: 157-67.

Corell, R., (2007). Chairman of the Arctic Climate Change Impact Assessment (ACCIA).

Dhital, M.R., (2003). 'Causes and Consequences of the 1993 Debris Flows and Landslides in the Kulekhani Watershed, Central Nepal'.

Higuchi, K., Ageta, Y. and Yasunari, T., (1982). Characteristics of Precipitation During the Monsoon Season in High Mountain Areas of the Nepal Himalaya, Hydrological Aspects of Alpine and High Mountain Areas, July, International Association of Hydrological Sciences, (IAHS), Publ. No. 138.

ICIMOD, (1996). Database of Key Indicators of Sustainable Mountain Development in Nepal, Mountain Environment and Resources Information Service (MENRIS), pp.85, ISBN 92-9115-516-0, Kathmandu.

ICIMOD, (2007). Disaster Preparedness for Natural Hazards, Current Status in Nepal, International Center for Integrated Mountain Development (ICIMOD), Kathmandu.

IPCC, (2007b). Climate Change 2007: The Physical Basis, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge: University Press, United Kingdom and New York, USA. URL: http://ipcc-wg1.ucar.edu/wg1/wg1-report.html.

Kansakar, S., Hannah, D., Gerrad, J., Rees, G., (2004). Spatial Patterns in the Precipitation Regime of Nepal, International Journal of Climatology, Vol. 24, pp. 1645-1659.

Lal, M., Whetton P.H., Pittock A. B., Chakraborty B., (1998) 'Simulation of Present-Day Climate Over the Indian Subcontinent by General Circulation Model.' In Terrestrial, Atmospheric and Oceanic Science, 9(1): 69-96

Mirza, M.Q., (2003). Three Recent Extreme Floods in Bangladesh: A Hydro-Meteorological Analysis, In Flood Problem and Management in South Asia, Mirza, M. Q. and Dixit, A. (eds.), pp. 35-64, Kulwer Academic Publishers, 3300 AZ Dordrecht, The Netherlands.

Mool, P. K., (1995). Glacier Lake Outburst Flood in Nepal, Journal of Nepal, Geological Society, Vol. 11, Special Issue, pp. 273-280, Kathmandu.

Ministry of Population and Environment, (2004). Annual Report, Kathmandu, Nepal.

Nepal Disaster Report: The Hazardscape and Vulnerability, (2009). Disaster Preparedness Network-Nepal.

Overpeck, J.T.; Cole, J.E. (2007). 'Climate Change Lesson from a Distant Monsoon.' In Nature, 445: 270-271

Richardson, S. D. and **Reynolds, J. M.** (2000a). An overview of glacial hazards in the Himalayas. *Quaternary International*, **65-66,** 31–47.

Roberts, M. and Brice, (2006). While Speaking With The Media in Kathmandu.

Shrestha, A.B.; Wake, C.P.; Mayewski, P.A.; Dibb, J.E. (1999) 'Maximum Temperature Trends in the Himalaya and Its Vicinity: An Analysis Based on Temperature Records from Nepal for the Period 1971-94. In Journal of Climate, 12: 2775-2787.

Upreti, B. N., (2008**).** Climate change and its Implication in the Himalayan region, A Paper Presented at the Queensland University of Technology, Australia.

Watanabe, T., Ives, I. D., and Hammond, J. E., (1994**).** Rapid Growth of a Glacial Lake in Khumbu Himal, Himalaya, Prospects for Catastrophic Flood, Mountain Research and Development, Vol. 14, No. 4, pp. 329-340.

Yamada, T., (1993). Glacier Lakes and Their Outburst Floods in the Nepal Himalaya, pp. 37, Published by the Water and Energy Commission Secretariat (WES), Kathmandu.