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Global Warming in Nepal: Challenges and Policy Imperatives

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Abstract: Information on climate change is so far scattered and documents are written in technical language often obscured by sophisticated jargons and complicated mathematical models. As a result, information about causes and consequences of climate change is not understood by general public. The problem is particularly acute in developing countries such as Nepal where literature on climate change is too insufficient to make firm conclusion and develop adaptation and mitigation measures. Hence, we make an attempt to summarize available information to develop a conceptual framework with a view to make it easily accessible among wider audience. Impacts of global warming on ecological factors, ecosystem process and functions, and also on human wellbeing are outlined first for global context. The issues are then discussed for Nepal using available evidences, models, and predictions supplemented by some primary data on local perception and knowledge. Finally, outlooks for future action, research and policy are discussed.

Key words: climate change, global warming, ecosystems, human wellbeing, Nepal.

INTRODUCTION

There is a worldwide consensus that global warming is a real, rapidly advancing and widespread threat facing this century. Scientists have presented evidences and tested models to substantiate this truly alarming fact (Permesan 1996, Pounds *et al.* 1999, IPCC 2001, Woodward 2002, Klanderud and Birks 2003, Hall and Fagre 2003). The evidences confirm that man-made factors such as deforestation, agriculture, industries, automobiles, burning of fossil fuels, etc., are attributable to Greenhouse Gas (GHG) emission, a major cause of global warming (IPCC 2001). The warming has manifold impact on ecosystem and biological behaviors. Some widely discussed impacts include snow melting, glacier retreat, drought and desertification, flooding, frequent fire, sea level rise, species shift, and diseases incidence. These ecological and biological responses can consequently lead to serious consequences on human wellbeing (Easterling *et al.* 2000, Mehl and Karl 2000).

Amid the plethora of literature available on the subject, majority of people know very little about causes and consequences of climate change partially because the information is scattered and available mostly in science language obscured by jargons and sophisticated mathematical models. As a result, the information is beyond the reach for several concerned people. The information is even scantier for poor countries like Nepal although such regions are vulnerable to climate change because of persistent poverty, illiteracy, and ignorance.

GLOBAL WARMING AND GLOBAL CHANGE

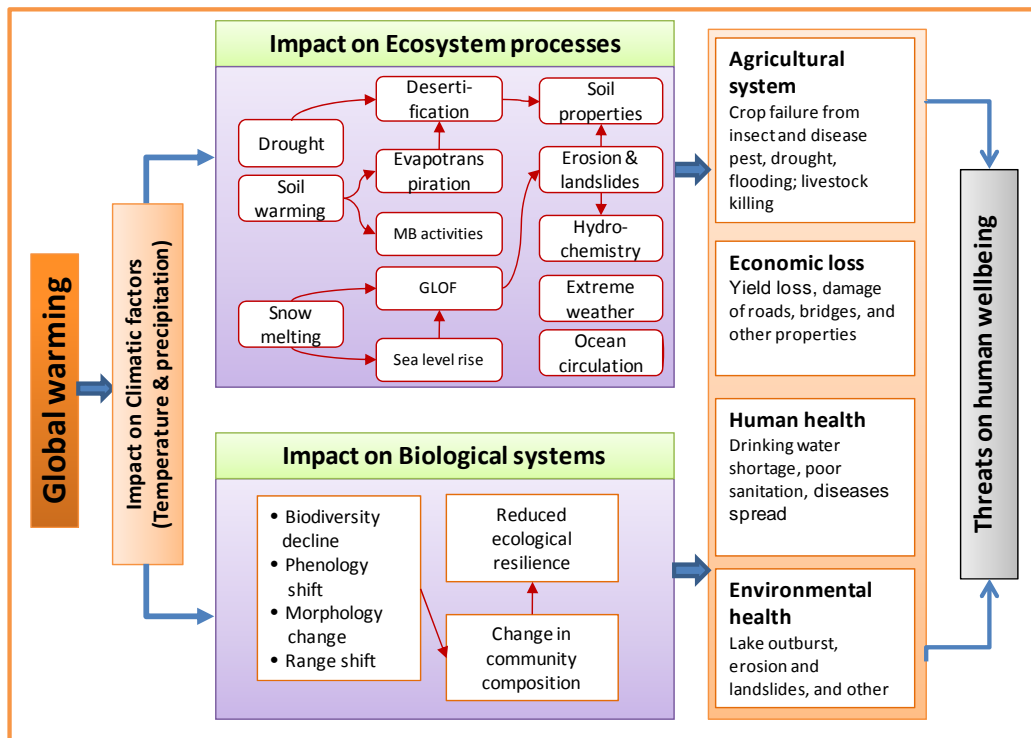
Before talking about Nepal, it is important to discuss theoretical underpinnings of global warming and cite some examples from other parts of the world. Global warming is a globally distributed challenge and its consequences are widespread and alarming, with the nature and intensity of impact varying with space and

The paucity of information impedes the task of policy formulation regarding adaptation and mitigation, making the poor countries more vulnerable. It is thus important to review current findings and develop such a conceptual framework that is easily understandable to general public, planners, policy makers and other non-science persons. Equally important is to explore how climate is changing, examine how these changes are affecting ecosystems and human wellbeing, and finally suggest the ways to enhance local ability to adapt change situation.

We intend to (a) illustrate the effects of global warming on ecological factors such as temperature and precipitation, (b) assess its impact on ecosystem processes and functions and ultimately (c) examine its consequences on human wellbeing. We first present the scenarios at global perspective and then analyze the destiny of Nepal based on available evidences, models, and predictions. This paper draws on a variety of literature from different regions throughout the world with particular emphasis on high altitude and latitude environments and then makes inferences for Nepal. In addition, we collected some primary data on local perception and knowledge about climate change in the hilly regions of eastern Nepal. The findings were validated with and supplemented by additional ideas, wherever necessary, gathered through focus group discussions, key informant surveys, direct observations and consultations with experts.

time. Global warming causes changes in climatic factors and affects ecosystem (ecological processes and functions) and biophysical system. Many of such changes consequently yield negative consequences on human wellbeing. This whole process is depicted in figure 1 and elaborated below.

Figure 1: Schematic diagram of impacts caused by global warming



Temperature and precipitation are two important climatic factors affected by climate change in general and global warming in particular. Although global average temperature has warmed and cooled many times in the past, it has been constantly rising since the mid-twentieth century and is likely to rise constantly in future mainly due to increased concentration of GHGs in the atmosphere. Without GHGs, the earth's surface temperature would be 60^o C cooler than it is today (Groom *et al.* 2007). Available data show that air temperature near the earth surface rose by 0.74 ± 0.18 °C (1.33 ± 0.32 °F) during 20th century (IPCC 2007) and might reach as high as 6.4 °C (11.5 °F) on average in worst case during the 21st century (Wigley 1999, IPCC 2007). The number of days with extreme heat in summer is increasing and winter is becoming warm and dry with less snow (Schiermeier 2008). Changes are also observed in nature, intensity and frequency of precipitation. Scientists have observed odd patterns of rainfall throughout the world, but the results are mixed and distribution is uneven. More rain in terms of amount and intensity is experienced in higher altitude regions during summer (Shrestha *et al.* 2000) and so is in the mid and high latitude regions of the Northern hemisphere, where frequencies of heavy precipitation events have already increased (Easterling *et al.* 2000).

Changed rainfall and temperature increasingly affect ecosystem processes and functions such as snow and ice melting, soil properties, and hydrological systems (IPCC 2001). Some years ago, nearly half of the volume of the glaciers or 30-40% of surface of Swiss Alps was lost in about 150 years. Likewise, Mt. Kenya and Mt. Kilimanjaro have lost 70% of snow in the last century and projection confirms it will be completely lost by 2020 (Hastenrath and Greischnar 1997). It is also confirmed that over two thirds of 150 glaciers in the Glacier National Park of Montana disappeared in 1850-1980 (Hall and Fagre 2003). While snow melting results in drought upstream, erosion and landslides arisen from floods destroy farm, forest and other sources of livelihoods downstream (IPCC 2001, Easterling *et al.* 2000). In coastal areas, sea level rise caused by warming-led snow melting is even more devastating (Wigley 2005). Since 1990 the sea level has increased several folds and it is unlikely to stop for several decades to come (Barnett 1984, Nicholls and Hoozemans 1996, IPCC 2001, Douglas 2001, Pirages and Cousins 2005). Projection indicates that sea level rise will reach 280-340 mm on average between 1990-2100 (Church *et al.* 2006), and nearly 30% change will be attributable to ice melting (IPCC 2001). Warming also causes more extreme weather conditions such as hurricane, storm, tornadoes, sea wave, tsunami, etc.

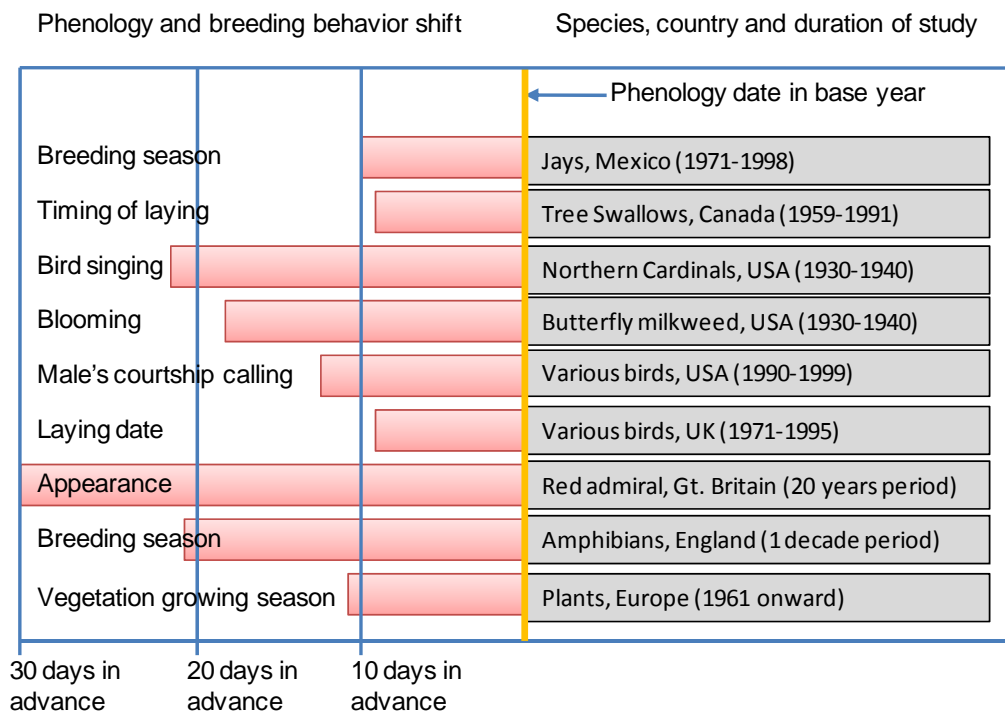


(Huang 2006). Drought and desertification, increased evapotranspiration, enhanced microbial activities, altered soil physical and chemical properties are other impacts most likely resulting from warming.

Altered temperature, precipitation and ecosystem processes also affect the biological fabric in a variety of ways (Pounds *et al.* 1999). Range shift, phenology change, extinction, morphology and behavior change are some of biological changes linked to warming-led ecosystem change. Certain plant species shift to higher altitude to escape the increased temperature (Woodward 2002, Klanderud and Birks 2003), making insects and herbivores to shift with them (Whittaker 1999) and forcing carnivores to co-migrate with their prey populations. During glacial period, when the earth was cooler than it is today, a large number of species were confined to the equator, but they slowly moved to higher latitudes as weather became warmer. Scientists have confirmed the latitudinal and altitudinal shift of

species at a rate of between 7 and 100km per decade (Thomas and Lennon 1999, Parmesan 1996, Parmesan *et al.* 1999). Studies have also found trees grown at altitudes 40 meters higher than 25 years ago (NGS 2002). The distribution shift is also obvious in marine fishes (Perry *et al.* 2005, Brander 2007). Global warming has remarkable effects on phenology of plants and breeding behavior of animals that are highly sensitive to photoperiod and heat. Several studies have already confirmed the change in breeding habits (e.g. courtship calling, laying, mating, bird singing) in animals and insects and blooming and flowering time, vegetative growth, etc., from a few days to as early as a month (Hersteinsson and MacDonald 1992, Grabherr *et al.* 1994, Parmesan 1996, Pounds *et al.* 1999, Crozier 2003, available in Groom *et al.* 2007). These studies are also illustrated in figure.

Figure 2: Examples of earliness in phenology and breeding behaviors in various plant and animal species (Adapted from Groom *et al.* 2007)



Several species may also become extinct due to gradual habitat loss caused by global warming, predominantly in tropical mountain biota above tree line and among nationally rare alpine species (Sætersdal and Birks 1997, Holten 1998, Molau 2004, Körner 2004) and in high latitude and altitude biomes (McCarthy 2001, Chapin *et al.* 2004, Rull and Vegas-vilarru 2006). In Australian snowy mountains, warmer winters with less snowfall are threatening 250 species of plants (NGS 2002). The loss of Golden Toad (*Bufo periglenes*) in Central America and

Bay checkerspot butterfly (*Euphydryas editha bayensis*) is also linked to global warming (Pounds and Crump 1994, McLaughlin *et al.* 2002). IPCC's 4th Assessment Report confirms 20-30% species became extinct between the years 1980-1999 and temperature went up on average by 1.5-2.5%. Thomas *et al.* (2004) suggest that 15-37% of known plants and animals will be extinct or "committed to extinction" by 2050.

Table1: Various Examples of Range Shift in Different Places around the World

Country	Species	Observed range shift	Reference
Costa Rica	Lowland bird	Began breeding on mountain slopes	Pounds <i>et al.</i> (1999)
Switzerland	Alpine flora	Expanded toward the summits	Grabherr <i>et al.</i> (1994)
Sierra Nevada, CA	Edith's checkerspot butterfly	Shifted upward by 105 meters	Parmesan (1996)
Canadian Rockies	Treeline	Upward movement	Parmesan (1996)
Canada	Arctic fox	Contracted toward Arctic ocean	Hersteinsson and MacDonald (1992)
USA	Sactrem skipper butterfly	Expanded from CA to WA	Crozier (2003)

Adapted from: Groom *et al.* 2006

Global warming is not only affecting climate and ecosystem, but it is also upon us. Warming affects various man-dominated eco and biophysical systems that support human wellbeing. Among all, agriculture is affected most when drought increases the reliance for rain-fed agriculture largely in developing countries where majority of farmers practice subsistence agriculture. The African continent will have to bear huge amount of yield loss from rain-fed agriculture in next decade or so. On the other hand, many other regions will face more intense and frequent flooding accompanied by landslides and erosion. As a result, soil carrying silt and debris can spoil valuable croplands (Preiser 2005, Pimental and Pimental 2006). Outbreak of insect and disease pests will also become more prevalent in agricultural crops. Livestock will not escape from this trouble. Drought has already destroyed livestock in past. History shows, millions of people and several millions of livestock in Pakistan were killed when a drought prolonged for 3 years in South Asia during 1999-2001.

Warming can cause both direct and indirect effects on human health. Morbidity and mortality due to vector-

borne and water-related diseases kill 1.5 million people every year (Eriksson 2006). Vectors carrying pathogens causing diseases like malaria, dengue fever, lyme disease and West Nile can very likely become more active and spread out to wider localities under temperature rise. Several people also die due to extreme heat waves, heat-related illness, intoxication and intake of polluted water and air as these events have already killed several people in different places around the world. Indirectly, human beings have to face problems of water shortage and poor sanitation. We have already used about 70% of all fresh water available worldwide (UNESCO 2001); by 2020, about 75-250 million people will face increased water stress (Pimental *et al.* 2004). As one-sixth of the global population relies on glacier and seasonal snow packs, the people living in mountains will face more severe water shortage problem (Barnett *et al.* 2005). Eventually, human being has to bear a huge economic loss due to reduced crop yield (Goswami *et al.* 2006) and damaged roads, bridges and other property. This can cause more food insecurity and hunger (UNWFP 2007) throughout the developing world.

GLOBAL WARMING IN THE CONTEXT OF NEPAL

The picture of Nepal is as bleak or even worse as compared to many other developing countries around the world, but it is little understood hitherto. Reviewing past is important for understanding future climatic changes and developing adaptation and mitigation plan. We intend to unfold past and offer ideas to carve the

path for sustainable future. Past warming-led events in Nepal based on scientific findings and local perception collected through surveys are presented below. Major impacts of warming are outlined and possible implications for human wellbeing are also discussed.

Major Scientific Evidences

Weather and Climatic Patterns

High altitude and latitude regions are likely to experience a higher rate of temperature rise compared to other regions (Beniston *et al.* 1997, Diaz and Bradley 1997, Shrestha *et al.* 1999, IPCC 2001), Himalayan countries like Nepal being no exception. Over 1977-1994, mean annual maximum temperature in Nepal increased by 0.06 degrees celsius (Shrestha *et al.* 1999, UNEP 2002, Ebi *et al.* 2007). Now, average temperature rise is estimated 0.5 degrees celsius per decade, which is way high compared to several other developing countries. Precipitation is also becoming unpredictable and more erratic than ever, with more droughts and shorter-period heavy rainfall (Shrestha *et al.* 2000). Several regions in the country are already vulnerable to unevenly distributed and erratic weather.

Snow Melting and Glacial Retreat

Glaciers are excellent indicators of climate change and global warming (Ageta and Kadota 1992, Oerlemans 1994). Warming-led glacier retreat in Nepalese Himalayas is widespread and alarming. According to a study carried out by the International Commission for Snow and Ice, snow in the Himalayas will disappear by 2035 if no proper initiative is taken to reduce warming. Khumbu glacier in Nepal has retreated about 100m on

average annually since 1953 (Shrestha *et al.* 1999). Some other glaciers of Nepal were also studied by Mool *et al.* (2001) and Bajracharya *et al.* (2007). Their satellite imagery data show the glaciers are retreating. Yamada *et al.* (1992) and Fujita *et al.* (2001) studied glaciers in Khumbu region and Shrong Himal of Nepal respectively for about 20 years and found the glaciers retreated by 30-60 meters in the entire period. Similarly, UNEP (2002) reveals that the Tradkarding glacier is retreating at a rate of over 20 meters a year and estimates it will reach 100 meters per year in some years. This is an alarm bell.

Glacial Lakes Outburst Flooding (GLOF)

Due to snow and glacial melting, several glacial lakes are under tremendous threat of flooding in Nepal (Oerlemans 1994, Agrawala *et al.* 2003, Bajracharya *et al.* 2007). Lakes either overflow or seep and dams are sometimes broken, sweeping lands, forests, houses and damaging valuable properties downstream. We are already experiencing an increase in GLOF with more intense and more frequent floods in several reasons. For instance, satellite imageries show 5 lakes were outburst between 1977 and 1998 and the floods had affected as far away as 100 kilometers downstream (Richardson and Reynolds 2000). There are still at least 20 glaciers in Nepal that are likely to outburst in next 5-10 years (UNEP 2002, Iyengararasan *et al.* 2002).

Table 2: Damages Caused by Glacial Lake Outbursts Floods (GLOF) in Nepal

Year	Glacial lake	Impacts and consequences	References
1977	Dudh Koshi	Killed 3 people; destroyed bridges for 35 km downstream; construction materials of a hotel swept away	Mool <i>et al.</i> 2001, Bajracharya <i>et al.</i> 2007, Ives 1986
1981	The Zhangzhangbo	Closed the China-Nepal highway for 1 year; destroyed Friendship bridge; damage worth USD 3 million	Mool <i>et al.</i> 2001, Bajracharya <i>et al.</i> 2007, WWF 2005
1991	Chilbung/ Chhubung lake	Damaged several houses in Beding village in Rolwaling valley	Mool <i>et al.</i> 2001
1985	Dig Tsho lake feeding Dudh Koshi and Bhote Koshi	Destroyed almost completed Namche Small Hydro Project (\$1.5 million); damaged 14 bridges, 30 houses and trails; killed 5 people; collapsed roads	WECS 1987, UNEP 2002, WWF 2005
1997	Dudh Koshi	Destroyed mini hydroplants	Mool <i>et al.</i> 2001, Bajracharya <i>et al.</i> 2007
1998	Sabai Tsho lake	Washed away fields, killed 2 people, damaged trekking trails	Mool <i>et al.</i> 2001
2003	Kawari glacial lake	Killed 5 people, destroyed wealth worth \$100,000	Dhakar 2003

Ecological and Biophysical Impacts

Ecosystem degradation often follows the floods, GLOF and droughts caused by snow melting and heavy rain. Floods carry debris downstream, affecting soil properties, hydrology, hydrochemistry, evapotranspiration, and microbial activities.

Water upsurge and debris flows triggered by GLOF have damaged forests, agricultural lands, walking trails, bridges, and rivers as far as hundred meters downstream (UNEP 2002, Dhakar 2003, Bajracharya *et al.* 2007). Several times, the outbursts were truly devastating and fatal as they claimed lives of several thousand people. For instance, discharge of water in 1995 Dudh Koshi lake



outburst was 4 times the magnitude (10-15 meters high or 2,000 m³/sec) of maximum monsoon flood in normal time. Likewise, 1982 disaster discharged water at the rate nearly 16,000 m³/sec (Bajracharya *et al.* 2007). Floods wash away forests and living creatures along with it, thus reshuffling composition of plant and animal species both up and downstream.

Livelihoods Crisis

Like in other regions in the world, climatic and ecological changes caused by global warming have resulted in several negative consequences on peoples' health, economy and livelihoods in Nepal (Eriksson 2006). Every year, diseases and natural calamities caused by such changes claim lives of several people, majority being poor women and children who lack capability to adapt to change. For instance, Diarrhea kills 28,000 people annually in Nepal and most of the affected are children below 5 (Eriksson 2006). It is likely that when weather gets warmer, microorganisms become more active and affect quickly on foods we eat. Since people in developing countries have poor sanitation at place and they have no choice but eat leftover foods, it is also likely to be affected by pathogens very easily. Floods following ice melting and lake outburst or river overflow also kill several people by adversely affecting water quality from debris carried along with flood. Between 2000 and 2005, more than 1300 people, mostly poor, were killed by floods and landslide related disasters (CBS 2006).

Agriculture - the mainstay of rural food and economy that accounts for about 96% of the total water use in the country - has to suffer a lot from erratic weather pattern such as heat stress, longer dry season and uncertain rainfall as 64% of the cultivated area fully depends on monsoon rainfall (CBS 2006). Declined yield due to unfavorable weather and climate will lead to vulnerability of food insecurity, hunger and shorter life expectancies (Ebi *et al.* 2007) and the rural poor will again be the hardest hit. Floods carrying rocks, sediments and debris increase the intensity of landslides and erosion; deteriorate soil and water; wash away houses and properties; cause human injuries and deaths; destroy

infrastructure such as schools, roads, and markets. Since hydropower electricity accounts for about 91% of total power production of the country, people will have to face problem in hydropower operation due to sediments carried along the floods. The effects will be pronounced more in higher altitude (Diaz and Bradley 1997, Shrestha *et al.* 1999) because of poor infrastructure and lack of resources to cope with the changes. As a result, dependency on firewood will increase and destruction of forest - carbon reservoir - is undeniable, which will further increase GHG emission and exacerbate global warming.

Himalayan glaciers and glacial lakes including those situated in Nepal are the sources of waters of many large rivers including Ganga, Brahmaputra, Indus, with Ganga only receiving about 70% of the summer flow from glaciers (Ebi *et al.* 2007). Only in India and Bangladesh, nearly 400 million people depend on rainfall and rivers arising from the Himalayas. Thus, when glaciers are retreating, 2.6 billion people in the region including Nepal, India and Bangladesh will fall short in water supply.

Local Perceptions

Several elderly people were met during transect walks to discuss the climate change issues. The walk was done along the ridge of Eastern Indo-Nepal border. A variety of responses were recorded based on their stories and past experiences. Local peoples' experiences broadly range from erratic weather pattern, ecological variability, biological change and their ill-effects on human wellbeing. However, they were not quite sure whether the changes are due to climate warming or some other reasons, but believe it might have association with warming. The respondents were from various locations with variation in altitude, climatic conditions and socio-economic backgrounds, giving mixed types of responses. Thus, the responses might hold true for one place and not for the others and are subject to validation and verification with the use of scientific tools and techniques. The perceived changes as reported by respondents are summarized in box 1 below.

Box 1: Local Knowledge on Climate Change (Indicators and Potential Impacts)**Major impacts****Weather and climate****Observed changes**

- The weather is becoming like *madhes* (Plain Terai region)
- Spring season is starting earlier
- Hotter weather, less snow, less rainfall in last 10 years; heavy snowfall last year; January and February (winter) has become warmer
- Less and shorter-duration cold during winter, requiring less amount of fuel wood
- Rains increasingly becoming unpredictable and erratic
- Used to receive rain every month, but now more drought but shorter-period and heavy rainfall experienced
- Some regions experience more drizzle and less downpours
- Haven't seen snow on the lower belts (*Chitre* village) for about 10 years, which indicates the lowest altitude receiving snow is moving upward
- Frost used to appear for about 15 days, now we barely see forest
- Cattle used to die due to heavy snow, but for last 10-12 years less snow is received except the last year's heavy snow

Biological responses

- New crops like mangoes, tomatoes, and other fruits and vegetables grow well, which was impossible few years ago due to cold
- Some fruits bear less fruits with poor quality taste due to warm climate
- Mosquitoes are seen for last few years (about 4-6 years on average)
- A disease - swelling of tongue in livestock seen. Possible cause is extreme heat. Livestock also suffer speedy breathing due to heat
- *Bake* flower started flowering little earlier, but used to flower during September/October (*tika*)
- Flowers (e.g., gladiolus) that were not grown before grow very well
- A tree species - *Korlinga*, used to blossom together with rhododendron (around the mid May (*Jestha*), but this year it flowered 15 days earlier (End of April (*Baisakh*) month)
- Fish species like *Asla* will be affected more than others because it grows well in cold water
- Wild boar give birth to their young earlier than before
- Maize gets dried due to heat, some mature early, new pest are also seen
- Marigold leaves become black and die out probably due to heat

We also tested several theories by collecting local perceptions on changes likely caused by global warming. Interesting but mixed results were found (Table 3). More than 50% (n=66) respondents responded they experience warmer climate, early onset of summer, early onset of monsoon, drying water source, species shift, new weeds, and mosquitoes in last few years (marked with symbol **). Few other changes are not experienced (column 4) by majority of them and few others shown in column 5

are under category 'not aware about'. The data shows while people have experienced some of changes, they still aren't aware of several other changes likely intrigued by a warming climate. The potential impacts of warming observed in various locations are divided into two categories—'weather and climatic conditions' and 'biological responses' and entire responses are then plotted under those categories. Statistical analysis is yet to be done and will follow soon.

Table 3: Local Perception on Various Global Warming Related Changes in their Localities

Major areas of impact	Responses	Yes	No	Don't know
Climatic conditions	Weather getting warmer	47 (71) **	12 (18)	7 (11)
	Early onset of summer	38 (58) **	25 (37)	3 (5)
	Early onset of spring	24 (36)	35 (53)	7 (11)
	Early onset of monsoon	53 (80)**	12 (18)	1 (2)
Ecosystem function and processes	More drought	5 (8)	55 (83) **	6 (9)
	More snow melting	9 (14)	7 (11)	50 (75) **
	Drying water source	39 (59) **	24 (36)	3 (5)
	New crop pests	28 (42)	32 (49)	6 (9)
	New diseases seen	1 (2)	25 (38)	40 (60) **
Biological systems	Early flowering	21 (32)	42 (63) **	3 (5)
	Species shift	43 (65) **	10 (15)	13 (20)
	New species seen	15 (23)	39 (59) **	12 (18)
	Change in species composition	25 (38)	20 (30)	21 (32)
	Early bird singing	14 (21)	35 (53) **	17 (26)
	Early bearing of wildlife	3 (5)	9 (14)	54 (81) **
	Early crop maturity	22 (33)	40 (61) **	4 (6)
	New weeds seen	35 (53) **	27 (41)	4 (6)
	Mosquitoes seen	57 (86) **	7 (11)	2 (3)
	New diseases seen	1 (2)	25 (38)	40 (60) **

Note: Figures in parentheses are percentage

**Indicates more than 50% respondents have agreed upon that response

FUTURE OUTLOOK FOR NEPAL

Simply, the earth has warmed and cooled several times as a natural process and will do so in future too. What concerns the global community is the alarming constant and yet unprecedented increase of temperature experienced in some regions. Scientists are now in agreement that human activities releasing GHGs into the atmosphere is responsible for the already observed and committed global warming causing climatic changes (IPCC 2007). Without proper attention, it is very difficult to bring temperature down as humans continue deforestation and investment in infrastructure and industries. Thus, inadvertent consequences are inevitable. The big sufferers of this will be mostly the ones who have done the least to cause climate change - poor nations and poor people - because they lack sufficient fund, skilled manpower and strong strategies to adapt and mitigate global warming. Nepal is no exception to this reality. However, a global level effort is necessary to combat this widespread problem. Major efforts required are three-fold. First, it is important to put efforts in improving carbon sink and reduction of carbon emission (mitigation). Second, local ability to cope with climate change or deal with vulnerability and uncertainty needs to be strengthened (adaptation). Third, clearly defined research and policies that support adaptation and mitigation endeavor should be in place. Below we discuss some mitigation and adaptation strategies and suggest some research and policy incentives to be adopted by Nepal government and all

concerned organizations working in climate change, conservation and development issues in the country.

Mitigation Measures

It is important to reduce the effects of climate change by restraining activities that produce carbon and other greenhouse gases. Certain mitigation measures as suggested by international community and as agreed upon in conventions can be followed to reduce carbon emission and enhance carbon sink. Forest ecosystem is a carbon reservoir as it contains about 60% of total carbon stored in terrestrial ecosystems (CIFOR 2007) and it serves important adaptation buffer. Since deforestation contributes about one-fourth of total global carbon emission, the first and foremost task is to curb deforestation and invest in forest plantation. This can be achieved by providing rural people with alternative energy sources such as biogas, solar power, and hydroelectricity and by adopting better land use management to improve carbon sink. If we preserve forest, it can store large amount of carbon and reduce warming substantially. Non-agriculture employment and other alternative income sources can also reduce the dependence of people on forest resources. Whereas, in farmland, better agricultural technologies including introduction of drought-tolerant (water-stress) cultivars that perform well in low external input (chemical fertilizer, pesticides) can also offset crop loss that might be caused by drought. These all require strong and

vibrant policies and commitment to international treaties such as facilitation of Carbon Development Mechanism (CDM) and carbon market place that facilitate payment for important environmental services.

Adaptation Strategies

Although mitigation strategy is essential for reducing carbon molecules on air and soil, it is not sufficient to save us and our world from climate change related woes. It takes several years to remove CO₂ molecule from the atmosphere through removal by plants and natural geochemical process and maintain its level below dangerous point (IPCC 2001). Moreover, Nepal is poor in infrastructure and lack resources to immediately and effectively practice any mitigation measures, which indicates the country will need even more years to remove the same amount of carbon molecules. It will be prudent to increase peoples' ability to adapt to change situation while we are putting our efforts to mitigate carbon emission. Adaptation is mainly about warning people about certain events in advance and preparing them to deal with vulnerability and uncertainty. Effective predictability, awareness, provision of certain support systems and better planning are some of important things to consider in local preparedness for reducing vulnerability and enhancing resilience. Construction of watch tower; provision of emergency materials and emergency shelters; considering risk-free or low risk locations for new settlement and resettlement (Richardson and Reynolds 2000, Agrawala *et al.* 2003) etc., are important strategies to improve local adaptation. Selection of certain technologies over others such as small hydropower, drought tolerant crop varieties, mixed cropping, Sloping Agriculture Land Technology (SALT) etc., is also important in adaptation process. Another adaptation strategy might be connectivity of forests as suggested by Hannah *et al.* (2007). The connectivity between two or more forest patches by developing corridors is important to develop continuum of forests and facilitate migration of species from one environment to another. If 'species shift' theory is real or if species move upward when climate gets warmer in lower altitudes, this proposition will be extremely vital.

REFERENCES

- Ageta, Y. & Kadota, T. 1992. Predictions of Changes of Glacier Mass Balance in the Nepal Himalaya and Tibetan Plateau: A Case Study of Air Temperature Increase for Three Glaciers. *Annals of Glaciology*, **16**: 89–94.
- Agrawala, S., Raksakulthai, V., Van Aalst, M., Larsen, P., Smith, J. & Reynolds, J. 2003. Development and Climate Change in Nepal: Focus on Water Resources and Hydropower 2003. France: Organization for Economic Co-operation and Development (OECD).
- 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*, **27**: 336–344.
- Barnett, T.P. 1984. The Estimation of Global Seas Level Change: A Problem of Uniqueness. *Journal of Geophysical Research*, **89**: 7980-7988.
- Barnett, T.P., Adam, J.C. & Lettenmaier, D.P. 2005. Potential Impacts of a Warming Climate on Water

Bagging Incentives from International Policies

International communities are very much concerned in 'Reduced Emission from Deforestation and Degradation' (REDD) and offsetting it with reasonable credits. There are tremendous potential for Nepal to earn economic benefits from such policies. Economic gains can be obtained not only from selling valuable woods and medicinal plants, but also trading carbon sunk in soil and standing forest biomass. Thanks to Forest Carbon Partnership Facility (FCPF) endorsed by Global Forest Alliance (GFA), Nepal is already selected for rewarding 'tradable carbon credit'. Nevertheless, some grave challenges also face the country. Proper valuation of carbon sink and emission needs to be done using more precise tools and techniques so that proper price is tagged for carbon reservoirs. It is also important to maintain the country's reputation in carbon emission so that it continuously receives credit. Promoting equity among poor and non-poor and among various other strata of society and economy is another incumbent need.

Further Research Needs

While we take initiatives in adaptation and mitigation, additional research is needed to verify what has been acclaimed by climate scientists. Exhausting assessment of available data and carefully designed research are required to analyze causal relationships between observed changes and climate warming, because several of the acclaims might have loose association with climate warming theories. On the other hand, in order to facilitate CDM and carbon market place, proper valuation of forests in terms of carbon sequestration and contribution to ecological resilience needs to be done. Strong environmental governance and involvement of civil society and private sectors along with NGOs are must for high-quality outcomes. Coordinated efforts, self-motivated local participation and leveraging policies are also essential to ensure the efficiency of any efforts we do to improve our climate and secure quality wellbeing.

- Availability in Snow-dominated Regions. *Nature*, **438**: 303-309.
- Beniston, M., Diaz, H.F. & Bradley, S.** 1997. Climatic Change at High Elevation Sites: An Overview. *Climatic Change*, **36**: 233-251.
- Brander, K.M.** 2007. Global Fish Production and Climate Change. *PNAS*, **104**(50): 19709-19714.
- CBS**, 2006. *Environmental Statistics of Nepal*. Kathmandu, Nepal.
- Chapin, F.S. III, Callaghan, T.V., Bergeron, Y., Fukuda, M., Johnstone, J.F., Juday, G. & Zimov, S.** 2004. Global Change and the Boreal Forest: Thresholds, Shifting States, or Gradual Change. *Ambio*, **33**: 361-365.
- Church, J. A., White, N.J. & Hunter, J.R.** 2006. Sea-level Rise at Tropical Pacific and Indian Ocean Islands. *Global and Planetary Change*, **53**: 155-168.
- Center for International Forestry Research (CIFOR)** 2007. Reducing emissions from deforestation. Carbon Forestry Research Program, online www.cifor.cgiar.org/carbofor
- Crozier, L.** 2003. Winter warming facilitates range expansion: cold tolerance of the butterfly *Atalopedes campestris*. *Oecologia*, **135**: 648-656.
- Dhakal, S.** 2003. One World South Asia.
- Diaz, H.F. & Bradley, R.** 1997. Temperature Variations during the Last Century at High Elevation Sites. *Climatic Change*, **36**: 253-279.
- Douglas, B.C.** 2001. An Introduction to Sea Level. In: B.C. Douglas, M.S. Kirney and S.P. Leatherman (Eds.) *Sea Level Rise: History and Consequences*. San Diego Academic Press.
- Easterling, D.R., Mehl, G.A., Parmesan, C., Changnon, S.A., Karl, T.R. & Mearns, L.O.** 2000. Climate Extremes: Observations, Modeling and Impacts. *Science*, **289**: 2068-2074.
- Ebi, K.L., Woodruff, R., Von Hildebrand, A. & Corvalan, C.** 2007. Climate Change-related Health Impacts in the Hindu Kush-Himalayas. *EcoHealth*, **4**: 264-70.
- Eriksson, M.** 2006. Climate Change and its Implications for Human Health in the Himalaya. *Sustainable Mountain Development in the Greater Himalayan Region*, **50**.
- Fujita, K., Kadota, T., Rana, B., Shrestha, R.B. & Ageta, Y.** 2001. Shrinkage of Glacier AX010 in Shorong Region, Nepal Himalayas in the 1990s. *Glaciological Research*, **18**: 51-54.
- Goswami, B.N., Venugopal, V., Sengupta, D., Mahusoodanan, M.S. & Xavier, P.K.** 2006. Increasing Trend of Extreme Rain Events over India in a Warming Environment. *Science*, **314**: 1442-1445.
- Grabherr, G., Gottfried, M. & Pauli, H.** 1994. Climate Change Effects on Mountain Plants. *Nature*, **369**: 448.
- Groom, M., Maffe, G.K. & Caroll, C.R. (Eds.)** 2006. *Principles of Conservation Biology-III Edition*. Sunderland, Massachusetts U.S.A.
- Hall, M.H.P. & Fagre, D.** 2003. Modeled Climate-Induced Glacier Change in Glacier National Park, 1850-2100. *BioScience*, **53**(2): 131-140.
- Hannah, L., Midgley, G., Anelman, S., Araujo, M., Hughes, G., Martinez-Meyer, E., Pearson, R. & Williams, P.** 2007. Protected Area Needs in a Changing Climate. *Frontiers in Ecology and the Environment*, **5**: 131-138.
- Hastenrath, S. & Greischnar, L.** 1997. Glacier Recession on Kilimanjaro, East Africa, 1912-89. *Journal of Glaciology*, **43**(145): 455-459.
- Hersteinsson, P. & Macdonald, D.W.** 1992. Interspecific Competition and the Geographical Distribution of Red and Arctic Foxes *Vulpes* and *Alopex Lagopus*. *Oikos*, **64**: 505-515.
- Holten, J.I.** 1998. Vertical Distribution Patterns of Vascular Plants in the Fennoscandian Mountains Range. *Ecologie*, **29**: 129-38.
- Huang, S.** 2006. 1951-2004 Annual Heat Budget of the Continental landmass. *Geophysical Research Letters*, **33**. <http://www.agu.org/journals/gl/g10604/2005GL025300/>
- IPCC** 2001. Climate Change 2001: The Scientific Basis, Contribution of Working Group to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press.
- IPCC** 2007. Working Group II Contribution to the Intergovernmental Panel on Climate Change Fourth Assessment Report. Climate Change 2007: Climate Change Impacts, Adaptation and Vulnerability. Summary for Policymakers. Available at: <http://www.ipcc.ch>; [Accessed April 12, 2007].
- Ives, J.D.** 1986. Glacial Lake Outburst Floods and Risk Engineering in the Himalaya. Kathmandu: ICIMOD.
- Iyengararasan, M.L., Tianchi, L. & Shrestha, S.** 2002. The Challenges of Mountain Environments: Water, Natural Resources, Hazards, Desertification and the Implications of Climate Change. Draft Background Paper E1 for the Bishkek Global Mountain Summit 2002.
- Klanderud, K. & Birks, H.J.B.** 2003. Recent Increases in Species Richness and Shifts in Altitudinal Distributions of Norwegian Mountain Plants. *The Holocene*, **13**: 1-6.
- Koerner, C.** 2004. Mountain Biodiversity, Its Causes and Function. *Ambio Special Report*, **13**: 11-17.
- McCarty, J.P.** 2001. Ecological Consequences of Recent Climate Change. *Conservation Biology*, **15**: 320-331.
- McLaughlin, J.F.; Hellmann, J.J.; Boggs, C.L. & Ehrlich, P.R.** 2002. Climate Change Hastens Population Extinctions. *PNAS*, **99**(9): 6070-6074.
- Mehl, G.A. & Karl, T.** 2000. An Introduction to Trends in Extreme Weather and Climate Events: Observations, Socio-economic Impacts, Terrestrial Ecological Impacts and Model Projections. *Bulletin of the American Meteorological Society*, **81**(3): 413-416.
- Molau, U.** 2004. Mountain Biodiversity Patterns at Low and High Latitudes. *Ambio Special Report*, **13**: 24-28.

- Mool, P.K., Bajracharya, S.R., & Joshi, S.P.** 2001. Inventory of Glaciers, Glacial Lakes and Glacial Lake Outburst Flood Monitoring and Early Warning System in the Hindu Kush-Himalayan Region, ICIMOD: Nepal. [pp 364-365]
- National Geographic News (NGS)** 2002. Mountain Ecosystems in Danger Worldwide, UN Says. From Wire Service.
- Nicholls, R.J. & Hoozemans, F.M.J.** 1996. The Mediterranean: Vulnerability to Coastal Implications of Climate Change. *Ocean and Coastal Management*, **31**(2-3): 765-766.
- Oerlemans, J.** 1994. Quantifying Global Warming from the Retreat of Glaciers. *Science*, **264**: 243-245.
- Parmesan, C.** 1996. Climate and Species' Range. *Nature*, **382**: 765-766.
- Parmesan, C., Ryrholm, N., Stefanescu, C., Hill, J.K., Thomas, C.D., Descimon, H., Huntley, B., Kaila, L., Kullberg, J. & Tammara, T.** 1999. *Nature*, **399**: 579-583.
- Perry, A.L., Low, P.J., Ellis, J.R. & Reynolds, J.D.** 2005. Climate Change and Distribution Shifts in Marine Fishes. *Science*, **308**: 1912-1915.
- Pimentel, D., Berger, B., Filberto, D., Newton, M., Wolfe, B., Karabinakis, E., Clark, S., Poon, E., Abbott, E. & Nandagopal, S.** 2004. Water Resources: Agricultural and Environmental Issues. *BioScience*, **54**(10): 909-918.
- Pimental, D. & Pimental, M.** 2006. Global Environmental Resources versus World Population Growth. *Ecological Economics*, **59**: 195-198.
- Pirages, D. & Cousins, K.** 2005. From Resource Scarcity to Ecological Security: Exploring New Limits to Growth. Cambridge, Massachusetts and London, England: The MIT Press.
- Pounds, J.A. & Crump, M.L.** 1994. Amphibian Declines and Climate Disturbance: The Case of the Golden Toad and the Harlequin Frog. *Conservation Biology*, **8**: 72-85.
- Pounds J.A., Fogden, M.P.L. & Campbell, J.H.** 1999. Biological Response to Climate Change on a Tropical Mountain. *Nature*, **398**: 611-615.
- Preiser, R.F.** 2005. Living Within Our Environmental Means: Natural Resources and an Optimum Human Population. <http://dieoff.org/page50.htm> [Accessed November 2, 2007].
- Richardson, S.D. & Reynolds, J.M.** 2000. An Overview of Glacial Hazards in the Himalayas. *Quaternary International*, **65/66**: 31-47.
- Rull, V. & Vegas-vilarru, T.** 2006. Unexpected Biodiversity Loss under Global Warming in the Neotropical Guayana Highlands: A Preliminary Appraisal. *Global Change Biology*, **12**: 1-9.
- Schiermeier, Q.** 2008. A Long Dry Summer. *Nature*, **452**: 270-273.
- Soetersdal, M., & Birks, H.J.B.** 1997. A Comparative Ecological Study of Norwegian Mountain Plants in Relation to Possible Future Climatic Change. *Journal of Biogeography*, **24**: 127-52.
- 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. *Journal of Climate*, **12**: 2775-2786.
- Shrestha, A.B., Wake, C.P. & Dibb, J.E.** 2000. Precipitation Fluctuations in the Himalaya and its Vicinity: An Analysis Based on Temperature Records from Nepal. *International Journal of Climate*, **20**: 317-327
- Thomas, C.D. & Lennon, J.J.** 1999. Birds Extend their Ranges Northwards. *Nature*, **399**: 213.
- Thomas, C.D., Cameron, A., Green, R.E., Bakkenes, M., Beaumont, L.J., Collingham, Y.C., Erasmus, B.F.N., De Siqueira, M.F., Grainger, A., Hannah, L., Hughes, L., Huntley, B., Van Jaarsveld, A.S., Midgley, G.F., Miles, L., Ortega-Huerta, M.A., Townsend Peterson, A., Phillips, O.L. & Williams, S.E.** 2004. Extinction Risk from Climate Change. *Nature*, **427**: 145-148.
- UNEP**, 2002. Global Environment Outlook 3. Nairobi, Kenya: United Nations Environment Program (UNEP).
- UNESCO** 2001. Securing the Food Supply. Paris: World Water Assessment Programme, United Nations. United Nations Education Scientific and Cultural Organization.
- UNWFP** 2007: Food Security Bulletin, Issue 16, Kathmandu, Nepal, 2007.
- WECS** 1987. Study of Glacier Lake Outburst Floods in the Nepal Himalayas, Phase I, Interim Report, WECS Report No. 4/1/200587/1/1, Seq. No. 251, Kathmandu.
- Whittaker, J.B.** 1999. Impacts and Responses at Population Level of Herbivorous Insects to Elevated CO₂. *Eur. J. Entomol*, **96**: 149-156.
- World Health Organization (WHO)** 2006. Human Health Impacts from Climate Variability and Change in the Hindu Kush-Himalaya Region: Report of an Inter-regional Workshop, Mukteshwar, India, New Delhi, India: Regional Office for Southeast Asia.
- Wigley, T.M.L.** 1999. *The Science of Climate Change*. Washington D.C.: Pew Center on Global Climate Change.
- Wigley, T.M.L.** 2005. The Climate Change Commitments. *Science*, **307**: 1766-1769.
- Woodward, F. I.** 2002. Potential Impacts of Global Elevated CO₂ Concentrations on Plants. *Curr. Opin. Plant Biol.*, **5**: 207-211.
- WWF** 2005. *An Overview of Glaciers, Glacier Retreat, and its Subsequent Impacts in Nepal, India and China*. Kathmandu: WWF, Nepal Program.
- Yamada, T., Shiraiwa, T., Iida, H., Kadota, T., Watanabe, T., Rana, B., Ageta, Y. & Fushimi, H.** 1992. Fluctuations of the Glaciers from the 1970s to 1989 in the Khumbu, Shorong and Langtang Regions, Nepal Himalayas. *Bulletin of Glacier Research*, **10**: 11-19.