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Global Warming in Nepal: Challenges and Policy Imperatives

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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 jargon and complicated mathematical models. As a result, information about the causes and consequences of climate change is not understood by the general public. The problem is particularly acute in developing countries such as Nepal where literature on climate change is insufficient to make firm conclusions and develop adaptation and mitigation measures. Hence, we attempt to summarize available information to develop a conceptual framework with a view to making it easily accessible among a wider audience. First, the impacts of global warming on ecological factors, ecosystem processes and functions, and also on human wellbeing are outlined in the global context. The issues are then discussed for Nepal using available evidence, 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, adaptation

INTRODUCTION

There is a worldwide consensus that global warming is a real, rapidly advancing and widespread threat facing humanity this century. Scientists have presented evidence 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 evidence confirms that man-made factors such as deforestation, agriculture, industries, automobiles, and the burning of fossil fuels, are contributing to Greenhouse Gas (GHG) emission, a major cause of global warming (IPCC 2001). The warming has manifold impacts on ecosystems and biological behaviours. Some widely discussed impacts include snow melting and glacier retreat, drought and desertification, flooding, frequent fire, sea level rise, species shifts, and heightened diseases incidence. These ecological and biological responses can consequently lead to serious consequences for human wellbeing (Easterling *et al*. 2000, Mehl and Karl 2000).

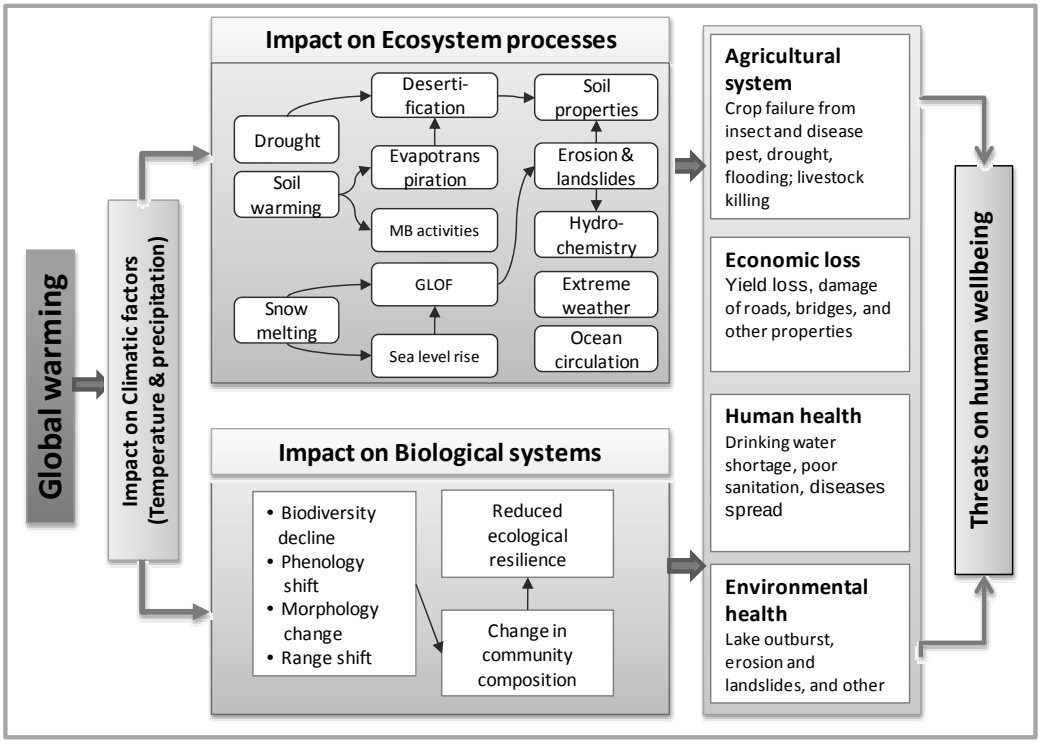
Amid the plethora of literature available on the subject, the majority of people know very little about the causes and consequences of climate change, partially because the information is scattered and produced mostly in scientific language, obscured by jargon and sophisticated mathematical models. As a result, the information is beyond the reach of many concerned people. The information is even more scant for poor countries like Nepal, although such countries are vulnerable to climate change because of persistent poverty, illiteracy, and ignorance. The paucity of information impedes the task of effective policy formulation regarding adaptation and mitigation, making the poor countries more vulnerable. It is thus important to review current findings and develop a conceptual framework that is easily understandable to the general public, planners, policy makers and other non-scientific audiences. It is equally important to explore how climate is changing, to examine how these changes are affecting ecosystems and human wellbeing, and finally to suggest ways to enhance local ability to adapt to the changing 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 for human wellbeing. We first present the scenarios from a global perspective and then analyze the destiny of Nepal based on available evidence, models, and predictions. This paper draws on a variety of literature from different regions throughout the world, with particular emphasis on high altitude and high latitude environments, and then makes inferences for Nepal. In addition, we collected some primary data on local perceptions 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.

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 impacts varying over space and time. Global warming causes changes in climatic factors and affects ecosystems (ecological processes and functions) and biophysical systems. Many of these changes consequently yield negative consequences for 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 the future mainly due to an 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 20^{th} century (IPCC 2007) and scientists estimate it could increase as much as 6.4 °C (11.5 °F) on average during the 21^{st} century (Wigley 1999, IPCC 2007). The number of days with extreme heat in summer is increasing and winters are becoming warm and dry with less snow (Schiermeier 2008). Changes are also observed in the 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 the summer (Shrestha *et al*. 2000) and in the middle and high latitude regions of the Northern hemisphere, where frequencies of heavy precipitation events have already increased (Easterling *et al.* 2000).

Changes in rainfall and temperature increasingly affect ecosystem processes and functions such as snow and ice melting, soil properties, and hydrological systems (IPCC 2001). Nearly half of the volume of the glaciers, or 30-40% of the surface of the Swiss Alps was lost over the past 150 years. Likewise, Mt. Kenya and Mt. Kilimanjaro have lost 70% of their snow cover 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 the 150 glaciers that existed in Glacier National Park in the United States in 1850 disappeared by 1980 (Hall and Fagre 2003). While snow melting results in drought upstream, erosion and landslides arising from floods destroy farms, forests and other sources of livelihoods downstream (IPCC 2001, Easterling *et al.* 2000). In coastal areas, sea level rise caused by warming-induced melting of ice and snow is even more threatening (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). Projections indicate that sea level rise will reach 280-340 mm on average between 1990-2100 (Church *et al*. 2006), and nearly 30% of this change will be attributable to ice melting (IPCC 2001). Warming also causes more extreme weather events such as hurricanes, storms, tornadoes, sea waves, tsunamis, etc. (Huang 2006). Drought and desertification, increased evapotranspiration, enhanced microbial activities, and

altered physical and chemical properties of soil are other impacts most likely to result from global 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 behaviour change are some of the biological changes linked to warming-led ecosystem change (Table 1). Certain plant species shift to higher altitudes with the increased temperature (Woodward 2002, Klanderud and Birks 2003), causing 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 the weather became warmer. Scientists have confirmed latitudinal and altitudinal shifts of species at a rate of between 7 and 100 km per decade (Thomas and Lennon 1999, Parmesan 1996, Parmesan *et al.* 1999). Studies have also found trees growing at altitudes 40 meters higher than 25 years ago (NGS 2002). The shift in distribution is also obvious in marine fish (Perry *et al.* 2005, Brander 2007). Global warming has remarkable effects on the phenology of plants and the breeding behaviour of animals that are highly sensitive to photoperiod and heat. Several studies have already confirmed the change in breeding habits (e.g. courtship calling, birthing, mating, bird singing) in animals and insects, and in the blooming and flowering time of plants, from a few days to as early as a month before historical precedents (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 2.

Several species may also become extinct due to gradual habitat loss caused by global warming, predominantly in tropical mountain biota above tree line, among rare alpine species (Sætersdal and Birks 1997, Holten 1998, Molau 2004, Ko¨rner 2004) and in high latitude and high altitude biomes (McCarthy 2001, Chapin *et al.* 2004, Rull and Vegas-vilarru 2006). In Australia's Snowy Mountains, warmer winters with less snowfall are threatening 250 species of plants (NGS 2002). The loss of the Golden Toad (*Bufo periglenes*) in Central America and the 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 that 20-30% of species became extinct between the years 1980-1999 and temperatures increased 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.

Global warming is not only affecting climate and ecosystem, but it is also impacting human wellbeing. Warming affects various man-dominated ecosystems and biophysical systems that support human wellbeing. Agriculture is affected most when drought adversely impacts rain-fed agriculture, largely in developing countries where the majority of farmers practice subsistence agriculture. The African continent will have to bear a huge loss in yield from rain-fed agriculture over the 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). Outbreaks of pests and disease 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.

Figure 2: Examples of Early Phenology and Breeding Behaviours among Various Plant and Animal Species (Adapted from Groom et al. 2007)

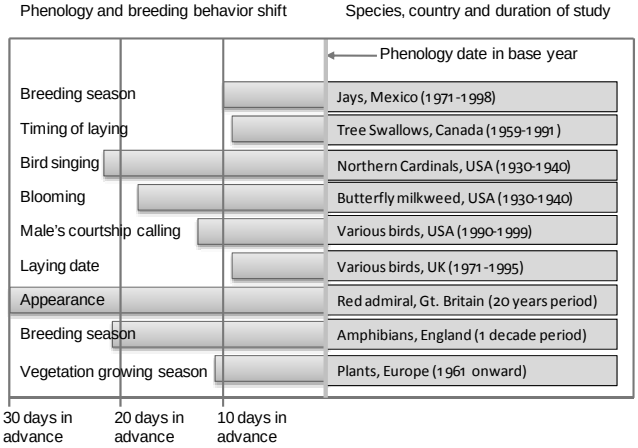


Table 1: Various Examples of Range Shift in Different Places around the World

Country	Species	Observed range shift	Reference
Costa Rica	Lowland bird	Begun breeding on mountain slopes	Pounds *et al.* (1999)
Switzerland	Alpine flora	Expanded toward the summits	Grabherr *et al.* (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

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 have also died due to extreme heat waves, heat-related illness, toxic contamination and intake of polluted water and air in different places around the world. Human beings also face problems of water shortage and poor sanitation. We have already used about 70% of all fresh water available worldwide (UNESCO 2001), and 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 glaciers and seasonal snow packs for their water supply, the people living in mountains will face more severe water shortage problem (Barnett *et al.* 2005). Eventually, human being will bear a huge economic loss due to reduced crop yield (Goswami *et al.* 2006) and damaged roads, bridges and other property. This may 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 than many other developing countries around the world, but it remains little understood. Reviewing the past is important for understanding future climatic changes and developing adaptation and mitigation plans. We intend to unfold the past and offer ideas to carve the path for a sustainable future. Past warming-led events in Nepal based on scientific findings and local perceptions collected through surveys are presented below. Major impacts of warming are outlined and possible implications for human wellbeing are also discussed.

Major Scientific Evidence

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. From 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 at 0.5 degrees celsius per decade, which is very high compared to several other developing countries. Precipitation is also becoming unpredictable and more erratic than ever, with more droughts and shorter periods of 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 the 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 risk 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 and houses, and damaging valuable property downstream (Table 2). We are already experiencing an increase in GLOF with more intense and more frequent floods. For instance, satellite imageries show 5 lakes were outburst between 1977 and 1998 and the floods had affected areas as far away as 100 kilometers downstream (Richardson and Reynolds 2000). Moreover, there are still at least 20 glaciers in Nepal that are likely to outburst in next 5-10 years (UNEP 2002, Iyngararasan *et al.* 2002).

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, evapo-transpiration, 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 of meters downstream (UNEP 2002, Dhakal 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 m^3/sec) of maximum monsoon flood in normal time. Likewise, 1982 disaster discharged water at the rate nearly 16,000 m^3/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.

Table 2: Damage Caused by Glacial Lake Outburst Floods 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 *et al.* 2001, Bajracharya *et al.* 2007, Ives 1986
1981	The Zhangzhangbo	Closed the China-Nepal highway for 1 year; destroyed Friendship bridge; damage worth USD 3 million	Mool *et al.* 2001, Bajracharya *et al.* 2007, WWF 2005
1991	Chilbung/ Chhubung lake	Damaged several houses in Beding village in Rolwaling valley	Mool *et al.* 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 *et al.* 2001, Bajracharya *et al.* 2007
1998	Sabai Tsho lake	Washed away fields, killed 2 people, damaged trekking trails	Mool *et al.* 2001
2003	Kawari glacial lake	Killed 5 people, destroyed wealth worth $100,000	Dhakal 2003

Livelihoods crisis

As in other regions of the world, climatic and ecological changes caused by global warming have resulted in several negative consequences for people's health, the economy and livelihoods in Nepal (Eriksson 2006). Every year, diseases and natural calamities caused by such changes claim the lives of several people, the majority being poor women and children who lack the capacity to adapt to change. For instance, Diarrhea kills 28,000 people annually in Nepal and most of the affected are children below age 5 (Eriksson 2006). It is likely that when the weather gets warmer, microorganisms become more active and act more quickly on the foods we eat. Since people in developing countries often have poor sanitation and lack refrigeration, and thus have no choice but to eat leftover foods, they are likely to be affected by such 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 the 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 - suffers a lot from erratic weather patterns such as heat stress, longer dry seasons and uncertain rainfall, since 64% of the cultivated area fully depends on monsoon rainfall (CBS 2006). Declined yield due to unfavourable weather and climate will lead to vulnerability in the form 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 hydro-electricity accounts for about 91% of total power production in the country, people will have to face problems in hydropower operation due to sediments carried along the floods. The effects will be more pronounced in higher altitudes (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 the Ganga, Bramhaputra and Indus, with the Ganga alone receiving about 70% of its summer flow from glaciers (Ebi *et al.* 2007). 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 of the people in the region including in Nepal, India and Bangladesh will fall short in water supply.

Local Perceptions

Several elderly people were met during transect walks to discuss their perceptions of climate change. The walk was done along the ridge of the Eastern Indo-Nepal border. A variety of responses were recorded based on their stories and past experiences. Local peoples' experiences range broadly from erratic weather patterns, ecological variability, biological change and their ill-effects on human well-being. However, they were not quite sure whether the changes are due to climate change or some other reason, but they believe it might have some association with warming. The respondents were from various locations varying 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.

Box 1: Local Knowledge on Climate Change (Indicators and Potential Impacts)

Major impacts	Observed changes
Weather and climate	— 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 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 fewer 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 is seen. A possible cause is extreme heat. Livestock also suffer speedy breathing due to heat — *Boke* flower started flowering a 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 said that they experience a warmer climate, earlier onset of summer, earlier onset of the monsoon, drying of water sources, species shifts, new weeds, and mosquitoes in the last few years (marked with symbol **). A few other changes were not experienced (column 4) by a majority of respondents and several others responded that they rae 'not aware about' specific changes (column 5). The data also shows that, while people have experienced some of changes, they still aren't aware of several other changes associated with 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 then plotted under those categories.

FUTURE OUTLOOK FOR NEPAL

The earth has warmed and cooled several times as a natural process and will do so in the future. What concerns the global community is the alarming constant, yet unprecedented, increase of temperature experienced in some regions. Scientists are now in agreement that human activities releasing GHGs into the atmosphere are responsible for the already observed global warming causing climactic changes (IPCC 2007). Without proper attention, it is very difficult to decrease temperatures as humans continue deforestation and investments in fossil-fuel dependent 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 effective strategies to adapt to and mitigate global warming. Nepal is no exception to this reality. However, a global effort is necessary to combat this widespread problem. Addressing climate change requires a three-pronged strategy. First, it is important to put efforts in improving carbon sink and reduction of carbon emissions (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

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 percentages

**Indicates more than 50% of respondents have given that response

adaptation and mitigation endeavours should be in place. Below we discuss some mitigation and adaptation strategies and suggest some research and policy incentives to be adopted by Nepal's government and all concerned organizations working on climate change, conservation and development 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 can be followed to reduce carbon emission and enhance carbon sinks, as suggested by the international community and agreed upon in conventions. Forests provide a carbon reservoir as they contain about 60% of all carbon stored in terrestrial ecosystems (CIFOR 2007), and they serve as important adaptation buffers. Since deforestation contributes about one-fourth of global carbon emissions, the first and most important task is to curb deforestation and invest in reforestation activities. 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 sinks. If we preserve forests, they can store large amounts of carbon and reduce warming substantially. Non-agriculture employment and other alternative income sources can also reduce the dependence of people on forest resources. In farming, better agricultural technologies, including introduction of drought-tolerant (water-stress) crops that perform well with low external inputs (e.g. chemical fertilizers, pesticides), can also offset crop losses that might be caused by drought. These measures all require strong and vibrant policies and commitment to international treaties such as facilitation of the Clean Development Mechanism (CDM) and carbon markets that facilitate payment for important environmental services.

Adaptation Strategies

Although a 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 CO_2 molecules from the atmosphere, through sequestration by plants and natural geochemical processes, and maintain its level below the dangerous point (IPCC 2001). Moreover, Nepal is poor in infrastructure and lacks resources to immediately and effectively practice any mitigation measures in the short term. Thus it will be prudent to increase peoples' ability to adapt to change while continuing our efforts to mitigate carbon emissions. 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 towers; provision of emergency materials and emergency shelters; and considering risk-free or low risk locations for new settlements and resettlement (Richardson and Reynolds 2000, Agrawala

et al. 2003) are important strategies to improve local adaptation capacity. 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 the adaptation process. Another adaptation strategy might be enhancing 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.

Bagging Incentives from International Policies

The international community is very much concerned with promoting forest carbon offsetting credits through 'Reduced Emission from Deforestation and Degradation' (REDD). There is 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 present in soil and standing forest biomass. Thanks to the Forest Carbon Partnership Facility (FCPF) endorsed by Global Forest Alliance (GFA), Nepal is already selected for promoting 'tradable carbon credits'. Nevertheless, the country also faces significant challenges for implementing such a scheme. Proper valuation of carbon sinks and emissions needs to be done using more precise tools and techniques so that a proper financial sum is given for carbon reservoirs. It is also important to maintain the country's reputation in low carbon emissions so that it continuously receives credit. Promoting equity among the poor and non-poor and among various other strata of society is another critical need.

Further Research Needs

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

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