# Biodiversity in the Himalayas – Trends, Perception and Impacts of Climate Change

*Eklabya Sharma, Karma Tse-ring, Nakul Chettri and Arun Shrestha

International Centre for Integrated Mountain Development
Kathmandu, Nepal
*Email: esharma@icimod.org

## Abstract

Mountains are remarkably diverse and globally important as centers of biological diversity. Mountains' greatest values may be as sources of all the world's major rivers, and those of the Himalayas are no less important in terms of provisioning the ecosystem services that has thus far sustained huge population of people and high levels of biodiversity. The survival of these ecosystems and wildlife sustained are now threatened by human activities like timber harvesting, intensive grazing by livestock and agricultural expansion into forestlands, and above all climate change. This paper presents our findings in the Eastern Himalayas that have reconfirmed earlier studies that temperature will continue to rise and rainfall patterns will be more variable projecting both localized increases and decreases. However, the magnitude of climate change is predicted to be greater for the Eastern Himalayan region than that projected by IPCC for the Asia region. People have perceived changes taking place within their environment and have responded to such changes although the tenor differed. However, people's perceptions are limited to human memory and blur the distinction between climate variability and climate change. The altitudinal shift in vegetation belts is expected to be around 80m-200m per decade with greater shifts at the higher altitudes since the rate of warming increases with altitude. Glaciers, snowfields, and high-altitude ecosystems with biodiversity therein will the most impacted by climate change. At present, there is limited and imprecise knowledge with scientific evidence on how climate change affects biodiversity and human wellbeing. However, the impact is going to be severe as people have limited adaptive capacity considering the economic, socio-political and technological shortcomings in the region. There is a need of consistent data generation for which landscape and transect approaches are conceived by ICIMOD for bridging the gap in medium- and long-term timescale.

## Introduction

Climate and natural ecosystems are tightly coupled, and the stability of that coupled system is an important ecosystem service. Chapter 13 of Agenda 21 established an official and explicit recognition that mountains and uplands are a major component of the global environment. It sets the scene by stating the role of mountains within the global ecosystem, and expresses serious concerns related to the decline in the general environmental quality of many mountains. Beyond their common characteristics of having high relative relief and steep slopes, mountains are remarkably diverse (Ives *et al.* 2004) and globally important as centres of biological diversity.

The Himalayas is recognized for its ecosystem services to the Asian region as well as to the world at large for maintaining slope stability, regulating hydrological integrity, sustaining high levels of biodiversity and human wellbeing. Mountains, due to their exclusive and inimitable biodiversity, are recently receiving priority for biodiversity conservation in global agendas. The Hindu Kush-Himalayas (HKH) is a dynamic landscape with a rich and remarkable biodiversity (Pei 1995; Guangwei 2002). Stretched over an area of more than four million square kilometres, the HKH region is endowed with a rich variety of gene pools and species, and ecosystems of global importance, the region hosts parts of the four Global Biodiversity Hotspots; namely, the Himalayas Hotspot, the Indo-Burma Hotspot, the Mountains of South-West China Hotspot, and the Mountains of Central Asia Hotspot (Mittermeier *et al.* 2004). The region, with its varied landscapes and soil formation, and variety of vegetation types and climatic conditions, is well known for its unique flora and fauna, and has a high level of endemism (Myers *et al.* 2000) and numerous critical ecoregions of global importance (Olson *et al.* 2001; Olson and Dinerstein 2002).

Approximately 39% of the HKH is comprised of grassland, 20% forest, 15% shrub land, and 5% agricultural land. The remaining 21% is made up of other types of land use such as barren land, rock outcrops, built-up areas, snow cover, and water bodies. Elevation zones across the HKH extend from tropical (<500m) to alpine ice-snow (>6000m), with a principal vertical vegetation regime comprised of tropical and subtropical rainforest, temperate broadleaf deciduous or mixed forest, and temperate coniferous forest, including high altitude cold shrub or steppe and cold desert (Pei 1995; Chettri *et al.* 2008a,b).

The survival of the mountain ecosystems and biodiversity sustained are now threatened by various drivers of change such as human activities like timber harvesting, intensive grazing by livestock and agricultural expansion into forest lands, and above all the climate change. Problems associated with modernization like GHG emission, air pollution, land use conversions, fragmentation, deforestation and land degradation have already crept into the HKH region. The landscapes and communities in the HKH region are being simultaneously affected by rapid environmental and socioeconomic changes. Identification and understanding of key ecological and socio-economic parameters of the mountain ecosystems, including their sensitivities and vulnerabilities to climate changes, have become crucial for planning and policy making for environmental management and sustainable development of the mountain regions as well as the downstream areas. Besides, the welfare of some 1.3 billion people downstream is inextricably linked to the state of natural resources of the HKH region (Schild 2008).

This paper provides a concerted review of climate change assessment with specific focus on biodiversity impact areas on the mountain ecosystems of the Eastern Himalayas. The information content is based on credible sources as well as current level of understanding advanced through application of science in climate change and biodiversity assessment. The paper follows a logical sequence from climate change exposure to biodiversity resource sensitivity in determining the potential impacts followed by assessment of vulnerability to climatic stresses. It concludes with the possible options and mechanisms for adaptation in addressing the threats and vulnerabilities associated with climate change attributions. Finally, gaps in our current knowledge and understanding are translated into recommendations for research agendas in the Eastern Himalayas.

## The Eastern Himalayas

As a globally significant region for ecosystems diversity and rich biodiversity, and considering the enormity in geopolitical, demographic and socio-economic terms, the Eastern Himalayas is the focus of this paper. The Eastern Himalayan (hereafter EH) region covers an area of 524,190 $Km^2$ stretching from Eastern Nepal to Yunnan in China; whose country wise area percentages are given in Table 1. The region is physiographically diverse and ecologically rich in natural and crop-related biodiversity. The region is significant in many respects from geopolitical to environmental, cultural, ethnicity, ecosystems and tectonic orogeny of its encompassing Himalayan system, and together with all other associated issues and concerns.

Table 1: Percent share of the area of Eastern Himalayan region by country. The EH falls between 82.70$^0$E-100.31$^0$E latitude and 21.95$^0$N-29.45$^0$N longitude.

| Country | Areas | % of EH Area |
|---|---|---|
| Nepal | Kaligandaki Valley, Kosi Basin, Mechi Basin | 16.08 |
| Bhutan | Whole | 7.60 |
| India | Sikkim, Arunachal Pradesh, Assam, Meghalaya, Nagaland, Mizoram, Manipur, Tripura | 52.03 |
| China | ZhongDian, DeQin, GongShan, Weixi, FuGong | 6.26 |
| Myanmar | Chin and Kachin states | 17.90 |

The region lies between two most populated nations exacting massive demand for input resources to support their impressive economic transformation. Fragmentation of ecosystems is more likely than not as economic development surpasses environmental concerns in the tradeoff conflict. It has inherited multiple biogeographic origins being at the intersection of Indo-Malayan Realm, Palearctic Realm and the Sino-Japanese Region. It also marks the frontier of collision between the monsoonal and mountain systems associated with intense thunderstorms and lightning. The EH which is a part of the HKH region is also steeped in metaphors and held in reverence as the "Water-tower for the 21st century", "The Third Pole", the largest cryospheric region outside the Poles, as 'hotspots of biodiversity', and warrant protection in order to maintain ecosystem integrity and adaptability (Figure 1).

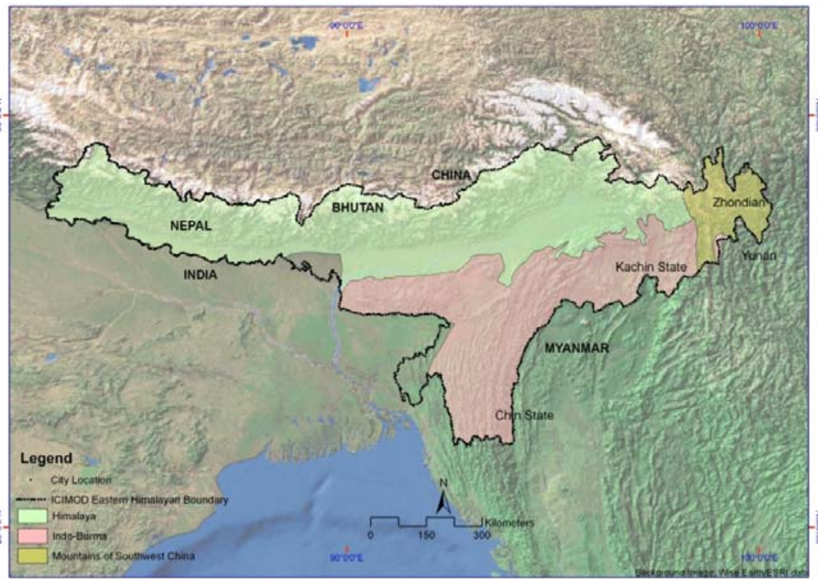

Figure 1: The Eastern Himalayan region map showing the three biodiversity global hotspots.

The eastern Himalayan region has been in the spotlight as a part of 'crisis Ecoregions' (Hoekstra et al. 2005); 'Biodiversity Hotspots' (Myers *et al.* 2000; Mittermeier *et al.* 2004); 'Endemic Bird Areas' (Stattersfield *et al.* 1998); 'Mega Diversity Countries' (Mittermeier *et al.* 1997) and 'Global 200 Ecoregions' (Olson and Dinerstein 2002). There are 99 protected areas covering 15% area of the EH (Table 2). The EH region has 25 ecoregions from a total of 60 in the HKH region. The Indo-Burma Hotspot alone is home to 7000 endemic plants and possesses 1.9% of the global endemic vertebrates (Myers *et al.* 2000). More than 7000 species of plants, 175 species of mammals, and over 500 species of birds have been recorded in the Eastern Himalayas alone (WWF and ICIMOD 2001).

Table 2: Protected area (PA) number and coverage within the extent of Eastern Himalaya (EH) boundary

| Country | Total area of the country ($km^2$) | Area within EH ($km^2$) | Number of PAs in EH | PA area coverage within EH ($km^2$) | PA area coverage with respect to area within EH (%) |
|---|---|---|---|---|---|
| Bhutan | 46500 | 39862.4 | 9 | 11195.0 | 28.1 |
| China | 9596960 | 32863.8 | 9 | 11917.9 | 36.3 |
| India | 2387590 | 272707.1 | 67 | 28379.2 | 10.4 |
| Myanmar | 676577 | 93854.9 | 3 | 8378.7 | 8.9 |
| Nepal | 147181 | 84338.6 | 11 | 19510.0 | 23.1 |
| Total | 12854808 | 523626.8 | 99 | 79380.9 | 15.2 |

**Climate Change: Variability and Extremes**

The IPCC AR4 on the global assessment of climate change has concluded that changes in the atmosphere, the oceans and glaciers and ice caps show unequivocally that the world is warming (IPCC 2007). These changes have been accompanied by changes in precipitation as well, including an increase in precipitation in the higher latitudes and a decline in the lower latitudes. These changes have also been accompanied by an increase in the frequency and intensity of extreme precipitation events. Floods and droughts are increasing in frequency and intensity and this trend is likely to continue into the future.

The existing knowledge of the climatic characteristics of EH regions is limited by both paucity of observations and insufficient theoretical attention given to the complex interaction of spatial scales in weather and climate phenomena in mountains. In order to determine the degree and rate of climatic trends, there is a need for long-term data sets which are lacking for most of the EH region.

Despite the limitations, a growing number of studies on the past climate and model-based projections have been reported in recent times albeit at various spatio-temporal scales, some of which cover the EH in parts or as a whole. Further work has been carried out by ICIMOD to consolidate past information and incorporate latest updates. A synthetic review and reassessment of climate trends and change projections to the end of this century is carried out to realign focus on the EH region in terms of observed climatic trends and place-based scenarios of future climate (Shrestha and Devkota 2008). The findings have confirmed earlier studies that temperature will continue to rise and rainfall patterns will be more variable projecting both localized increases and decreases. The figures for EH do not present drastic deviation from the IPCC outcomes for the South Asian region and the projected warming by the end of the century relative to the baseline is in the range of 2.5-5.3 $^{o}$C. Nonetheless, it reinforces the scientific basis to contend that EH is undergoing a warming trend.

Table 3: Regional Mean Temperature Trends for the period 1970-2000 (°C per year)

| | Annual | DJF | MAM | JJA | SON |
|---|---|---|---|---|---|
| Level 1 (<1 km) | **0.01** | **0.03** | 0.00 | **-0.01** | 0.02 |
| Level 2 (1 km- 4km) | **0.02** | **0.03** | 0.02 | **-0.01** | **0.02** |
| Level 3 (> 4 km) | **0.04** | **0.06** | **0.04** | 0.02 | **0.03** |

***Source: Shrestha and Devkota (2008)***

Annual mean temperature is increasing at a rate of 0.01$^{o}$C/yr (0.01-0.12$^{o}$Cyr$^{-1}$) or higher (Table 3). The warming trend has been greatest during the post-monsoon season and at higher elevations. Increases in temperature during the period (1977-2000) have been spatially variable indicating biophysical influence of land surface on the surrounding atmospheric conditions. In general, there is a south-west to north-east trending diagonal zone of relatively less or no warming for annual and seasonal trends. This zone encompasses the Yunnan province of China, Part of the Kanchin State of Myanmar, north-eastern states of India. Eastern Nepal and eastern Tibet record relatively higher warming trends. The worming in the winter is much higher and more widespread. Additionally, a significant positive trend with altitude has been observed throughout the region. High altitude areas have been exposed to comparatively greater warming effects than those in the lowlands and adjacent plains. The analysis suggests following major points:

1. The eastern Himalaya is experiencing widespread warming. The warming is generally higher than 0.01 $^{o}$C/yr
2. Using usual seasonal dichotomies, the highest rates of warming is occurring in the winter season and lowest or even cooling trends are observed in the summer season.
3. There is a progressively more warming with elevation, with the areas >4000 m experiencing the highest warming rates

The results suggest that the seasonal temperature variability is increasing and the altitudinal lapse rate of temperature is decreasing. Unlike, temperature precipitation does not show any consistent spatial trends. Annual precipitation changes are quite variable, decreasing at one site and increasing at a site nearby.

**Sensitivity of the Biodiversity Resources and Services to Climate Change**

Human societies derive many essential goods from natural ecosystems that constitute important and familiar parts of the economy such as food, fresh water, timber, fuelwood, fiber, non-timber products, biochemical, genetic materials, etc. Clearly, human economy depends upon the services performed "for free" by ecosystems. Natural ecosystems also perform fundamental life-support services without which human civilizations would cease to thrive. Many of the human activities that modify or destroy natural ecosystems may cause deterioration of ecological services whose value, in the long term, dwarfs the short-term economic benefits society gains from those activities. Fortunately, the functioning of many ecosystems could be restored if appropriate actions were taken in time. Climate change, including variability and extremes continue to impact on the mountain ecosystems sometimes beneficially, but frequently with adverse effects on the structure and functions of the ecosystems.

The Millennium Ecosystem Assessment (MEA) has many things in common with the climate assessments compiled by the IPCC. The two assessments share the aim to provide policy-relevant information in their respective subjects of investigation i.e. ecosystems and climate respectively, for the benefit of humankind. The main difference is that the IPCC focuses on a specific driver (i.e., climate change) whereas the MEA focuses on a specific system involved in the causal path (i.e., ecosystems). The concept of ‘‘ecosystem services’’ (MEA, 2005) forms a useful link between the functioning of ecosystems and their role for society, including the dynamics of change over space and time. Impacts of climate change on ecosystem structure, functioning and services have been observed (Parmesan and Yohe 2003; IPCC 2007), which in turn affect human society mainly by increasing human vulnerability. The following portion of the paper will mainly deal with the sensitivity of mountain biodiversity in the region.

***Climate change sensitivity of biodiversity and potential impacts***

The EH region intersects three global biodiversity hotspots with 38.9% of the Himalayan, 7.7% of the Indo-Burma and 12.6% of the Mountains of Southwest China. 25 ecoregions have been identified within the extent of EH boundary of which 12 are spread across the Himalayan hotpots, 8 in the Indo-Burma and 5 in the mountains of South West China (Chettri *et al.* 2008a). Presently, there are 17 protected area complexes, 41 candidate priority areas of high biodiversity importance, 175 key biodiversity areas and five landscape complexes (Terai Arc Landscape, the Bhutan Biological Conservation Complex, the Kangchenjunga-Singhalila Complex, the Kaziranga-Karbi Anlong Landscape and the North Bank Landscape), which are of high conservation significance (CEPF 2005) (Figure 2).

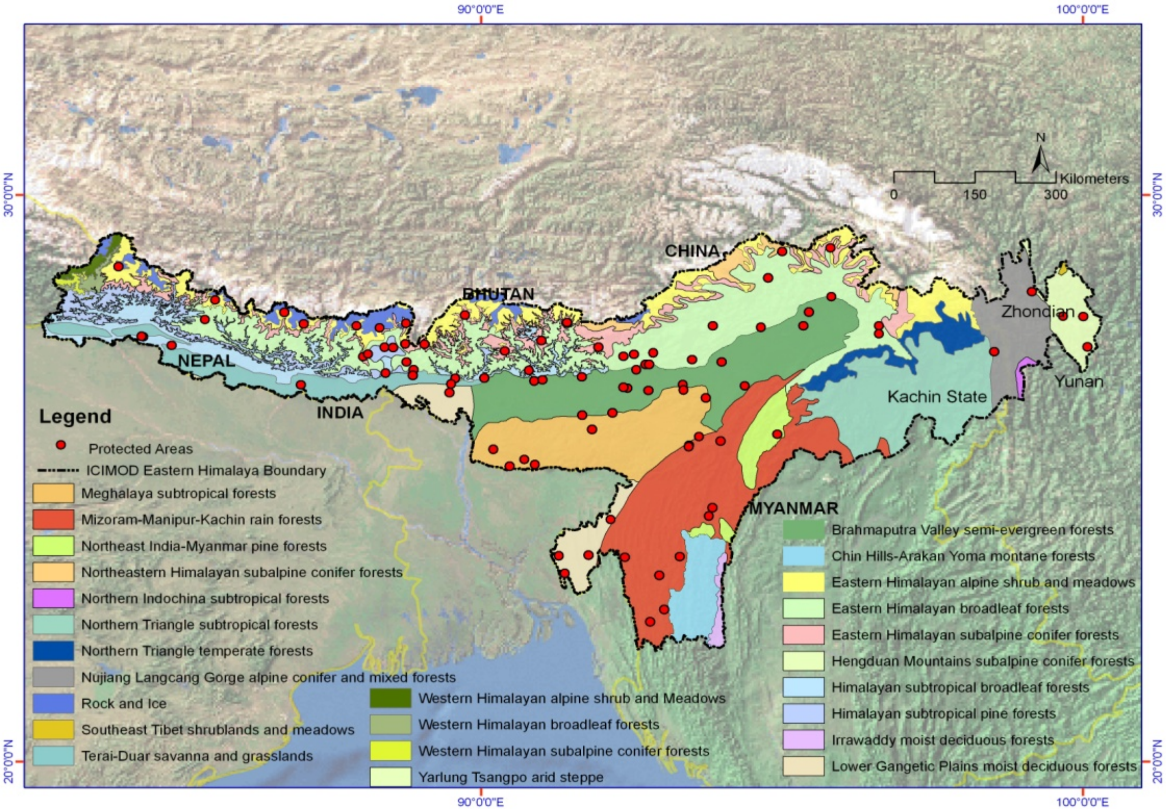


Figure 2: The EH region showing 25 ecoregions and protected area distribution.

The EH with diverse climatic condition and complex topography comprises of different types of forest and vegetations. The vegetation types in the EH can broadly be categorized into: (a) Tropical, (b) Sub-tropical, (c) Warm temperate, (d) Cool temperate, (e) Sub-alpine and (f) Alpine types, which can be further classified into layers based on other bioclimatic attributes (Chettri *et al.* 2008b). A recent review revealed that the EH is home to a remarkable number of globally significant mammals (45 species); birds (50 species); reptiles (16 species); amphibians (12 species); invertebrates (2 species) and plants (36 species), and majority of these species (about 144 species) are found particularly in the northeastern states of India (CEPF 2005). Besides supporting one of the world's richest alpine floras, about one-third of the total flora is endemic to the region (WWF and ICIMOD 2001; Dhar 2002). Details on species significance, distribution, endemism and other measures of conservation status are replete in documentations elsewhere, and require no further mention here.

Climate change has contributed to substantial species range contractions and extinctions in the past and the future projections can influence the species persistence leading to disproportionate distribution of species along the ecological zones (Wilson *et al.* 2007). In view of the prevailing trend, the consequences of biodiversity loss from climate change are likely to be greatest on the poor and marginalized people who depend almost exclusively on the natural resources. Grabherr *et al.* (1994) estimated that a $0.5^0$C rise in temperature per 100 m elevation could lead to a theoretical shift in altitudinal vegetation belts at the rate of 8-10 m per decade. This altitudinal shift in the EH is expected to be around 80m-200m per decade given the current trend in the region estimated at around $0.04^0$C-$0.1^0$C/yr with greater shifts at the higher altitudes since the rate of warming increases with altitude. However, such likelihoods are premised on the speculations (tenuous optimism) that species will adapt or shift in concert with the rate of climate change. Apart from animals and some seasonal, annual and biannual plant species, the scope to keep pace with the projected climate change is very limited. Unfortunately, there is still no straightforward explanation as to how the ecosystems and range may shift; notwithstanding the mechanistic hypothesis has almost assumed factual dimension. The multiplicity in eco-physiography along the altitudinal ascent and the facultative asymmetry in the species survival strategies would mean that the extant communities within a bioclimatic precinct could be quite different in a future with climate change.

The EH harbors numerous critical habitats and species within protected area systems; one example is that of the greater one-horned rhinoceros. Amongst the ecoregions, EH broadleaf forests, Brahmaputra Valley semi evergreen forests and Himalayan subtropical pine forests have the highest conservation values due to the presence of higher number of mammals, birds and plant richness (WWF and ICIMOD 2001). Alluvial grasslands of the tropical forests support high density of tigers. The Brahmaputra and Ganges rivers fend for the endangered Gangetic dolphin (*Platanista gangetica*). Herptiles residing in the moist forests and ephemeral freshwater habitats are also vulnerable to the impacts of climate change. A list of sensitive ecoregions have been identified in close consultation with stakeholders in the region taking on board the significance of composite impacts observed from multiple stressors including climate change, and the vulnerable biodiversity entities they are associated with (Table 4).

Table 4. Critical ecosystems in the EH with respect to climate change, as revealed during the consultation processes in the Eastern Himalayas

| SN | Critical habitat | Change indicator | Example of observed changes | Vulnerable entities |
|---|---|---|---|---|
| 1 | Alpine/Sub-alpine ecosystems nestled between the treeline in 4000m to the snowline at 5500m | • Changes in ecotones<br>• Desertification<br>• declining snowfall, glaciations events<br>• Changes in species composition<br>• Growth in unpalatable species decreasing productivity of alpine grasslands | Transformation of earlier *Quercus-Betula* forest into the 'Krummholz-type' of vegetation comprising of species of *Rhododendron, Salix, Syringia* | Ungulate species, Himalayan pica, high value medicinal plants, botanically fascinating species ( bhootkesh, Rhododendron etc.), curious species (Succulents, Ephedra), Alpine scrub flora |
| 2 | Cool-moist forests | • Changes in ecotones<br>• lossof habitat<br>• Blockage of | Decline in population of species of Mantesia, Ilex and | Habitat specialists such as red panda, blood pheasant, microflora and |

| | | | | |
|---|---|---|---|---|
| | | migration routes | insectivorous plants | associated fauna |
| 3 | Cloud forests of temperate elevations where moisture tend to condense and remain in the air | • Less precipitation and cloud formation during warmer growing season<br>• Loss of endemics /specific flora and fauna<br>• Upward range shift<br>• Desertification of soil, affecting the water retention capacity of forests | - | Endemic epiphytes and Lichens, Wildlife depended on cloud forest vegetation (Diversity of insects) |
| 4 | Area with intensive agriculture | • Reduced agro-biodiversity (monoculture)<br>• Low employment/gradual loss of traditional knowledge.<br>• Degradation of soil quality<br>• Potential increase of GHG emissions. | Loss of traditional variety, such as upland variety of rice, indigeneous bean, cucurbits and citrus variety<br>Pest increase in citrus specis | Crops, cereals and vegetables |
| 5 | Freshwater wetlands | • Loss of wetlands due to sedimentation, eutrophication, drying, drainage<br>• Successional shift to terrestrial ecosystems<br>• Increased salinity in aquifers | Decrease in population of Sus salvanius; Beels and associated biodiversity are changing | Large mammals such as crocodiles, river dolphins, wild-buffaloes, Wetland plant species, migratory avian species |
| 6 | Riparian habitats | • Damage or destruction of | Loss of pioneer species such as | Ibis bill (has nesting habitats in riparian |

| | | | | |
|---|---|---|---|---|
| | nurtured by silt deposited by overflowing river | riparian habitats by floods/GLOFs/ river bank erosion.<br>• Degradation due to increased /little deposition of sediments<br>• Reduced stream flow<br>• Disrupted successional stage | *Saccharum spontaneum* and other tree species leading to the change in species composition of the alluvial grasslands | zones), Market-value tree species found in riparian zone as sisso, simal |
| 7 | Ephemeral stream habitat | • Loss of ephemeral stream habitats.<br>• Increased salinity<br>• Riverine system impacted | Riverine island ecosystem such as Majuli in Assam is being threatened | Ephemeral stream species, especially herpetofauna |

Source: Chettri *et al.* (2008b)

**Knowledge Gaps and Research Needs**

The climate change adaptation in biodiversity conservation and sustainable use needs to grow out of clear understanding of the important habitats and species and the nature of their resiliency to climatic stresses. Some important research needs to advance understanding of climate change and its possible impact on biodiversity and to inform mitigation and adaptation works in the EH region are:

1. The need to strengthen and review policies to make them more sensitive to the interaction in processes and the linkages between consequences of biodiversity and climate change.
2. The EH region still does not have a comprehensive database of species and ecosystems and proper documentation of indigenous knowledge and practices on adaptation to climate change, including variability and extremes.
3. Extensive and in-depth assessment in the movement of alien, invasive species, critical landscape linkages to flagship species, PAs coverage and effectiveness, adaptability of the biodiversity entities, fire management regime, and impact on agricultural productivity are other important areas requiring urgent attention. Emphasis should be on riparian habitats, least explored ecosystems, habitats of threatened species, floral and faunal hotspots.
4. Comprehensive survey and inventory of distribution range of plants and animals, biodiversity within PAs, population trends of flagship/endemic or threatened species, status of mid-sized mammal and other group of animals.

5. Capacity building to carry out the specific research in taxonomy, conservation biology and impact assessment.
6. Efforts of various conservation initiatives active in the EH must be coordinated and collective partnership must be developed between stakeholders so that the entire EH region is able to cope with the present and future impacts from climate change.
7. Assess ecosystem structure, its functioning, productivity and delivery of ecosystem goods and services.
8. Study the interaction between climate change and landuse change to assess their combined impact on biodiversity, atmospheric $CO_2$ concentration, species composition and carbon dynamics under different ecosystems.
9. Economic valuation of ecosystem services from conservation areas.
10. Socioeconomic study on land tenure systems, food security, resources use rights, decision making process, governance that characterize community resiliency to climate change.

**Adaptation Strategies**

So far, biodiversity in the natural ecosystems have been adapting naturally or autonomously without much adjustment from people and communities who benefit from their services. As the magnitude of climate change, and other global change stressors for that matter, increases with time, the need for planned adaptation becomes more acute. Traditionally, communities who depend on biodiversity resources have informal institutions and customary regulations in place to ensure that external perturbations do not exceed natural resilience beyond certain threshold. Going by the rate of changes taking place in the demographic, economic and sociopolitical landscapes of human society and their positive feedback to the climate system, the age-old approaches may need to be supplemented by formal adaptation measures to address the new threats to biodiversity.

Recently, there is a strong drive to transition from contemporary conservation approaches to a new paradigm of landscape-level interconnectivity between protected area systems that are defined around the protectionist focus on species and habitats. The concept raves about the shift from the mundane species-habitat dichotomy to a more inclusive perspective on expanding the biogrographic range so that natural adjustments to climate change can proceed without being restrictive. The benefit of translating the concept into action is yet to be realized. Whatever the conservation approach, communities in a protected area system must be regarded as medium of adaptation rather than being perceived as the reason for environmental degradation and biodiversity loss. Local participation in conservation effort should include decision-making prerogatives and a cooperative environment of shared ownership in the process involved.

Good practices in planned adaptation are premised on the availability of adequate information on the status of biodiversity, trends in environmental change including climate change, and its potential impacts on biodiversity, human resources, expertise, institutional capacity, political commitments and the financial resources. Without being inclusive, some adaptation options in the EH region are:

1. Institutional arrangement that is responsive to addressing climate change issues and sensitive to the societal and economic priorities at the national and local levels

2. Research and development in agroforestry and community forestry to enhance carbon sequestration, reduce soil erosion, improve water quality and livelihood options.
3. Operationalise trans-boundary landscape approach in biodiversity conservation and protected area management.
4. Establish climate-monitoring stations to facilitate generation of accurate, long-term climatological time-series and associated infrastructure for operational networking and data sharing
5. Identify and monitor climate sensitive organisms as indicators for early detection of climate change signals and facilitate proactive adaptation mediation.
6. Sustainable management of rangements and formalizing climate-conscious pastoralism not only to enhance productivity but also to protect the ecosystem, reduce $CO_2$ emission and increase storage above and below ground.

**Transects and Landscapes Approach**

There is a need for monitoring of change using climatic parameters, physical and biological conditions, and socio-cultural and livelihoods situations in the HKH for generating consistent representative data. The information generated then could be used for sustainable development and for responding to climate change. For generating consistent information ICIMOD has conceptualized to use important landscapes from east to west, and north-south transects in the HKH region. These landscapes and transects are planned to be representative of the HKH and concerted efforts from the global programmes and within the region in the medium- and long-term are expected to bridge the knowledge gap. A separate paper on the landscapes and transect in this conference from ICIMOD elaborates the details and benefits of these approaches.

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