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

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Abstract

Mountains are not only remarkably diverse, they are also important globally as centres of biological diversity. The greatest value of mountains is probably as sources of all the world's major rivers, and those of the Himalayas are no less important in terms of providing ecosystem services that have thus far sustained huge human populations and rich biodiversity. The survival of these ecosystems and wildlife is now threatened by human activities such as timber harvesting, intensive grazing by livestock, agricultural expansion in to forest lands, and, above all, climate change. This paper presents findings from the Eastern Himalayas that have reconfirmed earlier studies that suggested that temperatures will continue to rise and rainfall patterns will become more variable, projecting both localised increases and decreases. The magnitude of climate change is predicted to be greater for the Eastern Himalayan region than projected by the International Panel on Climate Change (IPCC) for the Asian region. As a result, the altitudinal shift in vegetation belts is expected to be around 80-200 m per decade and is even expected to increase over time in high-altitude ecosystems as the rate of warming increases with altitude. Anecdotal evidence from various consultations revealed that there are many vulnerable entities ranging from species to ecosystems that need immediate attention. At present, there is limited and imprecise knowledge and scientific evidence about how climate change affects biodiversity and human wellbeing, and to address this limitation consistent data generation is a prerequisite. Should the present trend continue, the impact will be severe, considering the economic, sociopolitical, and technological shortcomings of the region. Local people need to increase their adaptive capacities. The International Centre for Integrated Mountain Development (ICIMOD) has devised landscape and transect approaches to bridge the gap in the medium and long term.

Introduction

Climate and natural ecosystems are intrinsically coupled and the stability of this coupled system provides an important ecosystem service. Chapter 13 of Agenda 21 of the Rio Declaration gave official, explicit recognition to the fact that mountains and uplands are an important component of the global environment. Chapter 13 sets the scene by describing the role of mountains within the global ecosystem and expressing serious concern about the general decline in their environmental quality. Beyond their common characteristics of high relative relief and steep slopes, mountains are remarkably diverse (Ives et al. 2004) and are important on a global level as centres of biological diversity.

The Himalayas are recognised for their ecosystem services to the Asian region (as well as to the world at large) for maintaining slope stability, regulating hydrological integrity, and sustaining high levels of biodiversity and enhancing human wellbeing. Mountains, due to their exclusive and inimitable biodiversity, have recently been receiving priority in the context of biodiversity conservation in global agendas. The Hindu Kush-Himalayan (HKH) region has a dynamic landscape with rich and remarkable biodiversity (Pei 1995; Guangwei 2002; Chettri et al. 2008a). Stretched over an area of more than four million square kilometres, the HKH region is endowed with a rich variety of genepools, species, and ecosystems (Myers et al. 2000), and numerous critical eco-regions of global importance (Olson et al. 2001; Olson and Dinerstein 2002).

The survival of mountain ecosystems and their biodiversity are now threatened by various drivers of change such as timber harvesting, intensive grazing of livestock, and agricultural expansion on to forest lands, and, above all, climate change. Problems associated with modernisation like greenhouse gas (GHG) emissions, air pollution, land use conversion, fragmentation, deforestation, and land degradation have already crept into the HKH region. The landscapes and communities in the HKH region are being affected concomitantly by rapid environmental and socioeconomic changes. Identification and understanding of key ecological and socioeconomic parameters of mountain ecosystems, including their sensitivity and vulnerability to climate change, have become crucial for formulating plans and policies for environmental management and sustainable development of mountain regions as well as areas downstream. The welfare of approximately 1.3 billion people downstream is inextricably linked to the state of natural resources in the HKH region (Schild 2008).

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

The Eastern Himalayas

The Eastern Himalayas are the focus of this paper because of their global significance in terms of ecosystem diversity and biodiversity, and considering their importance in geopolitical, demographic, and socioeconomic terms. The Eastern Himalayan (hereafter EH) region falls between 82.70°E–100.31°E latitude and 21.95°N–29.45°N longitude and covers an area of 524,190 sq km, extending from Eastern Nepal to Yunnan in China. The country-wise area percentages are given in Table 1. The region is physiographically diverse and ecologically rich in natural and crop-related biodiversity. It is also significant from geopolitical, environmental, cultural, and ethnic perspectives, and in terms of ecosystems and tectonic orogeny.

Table 1: **Percentage share of the Eastern Himalayan region by country**

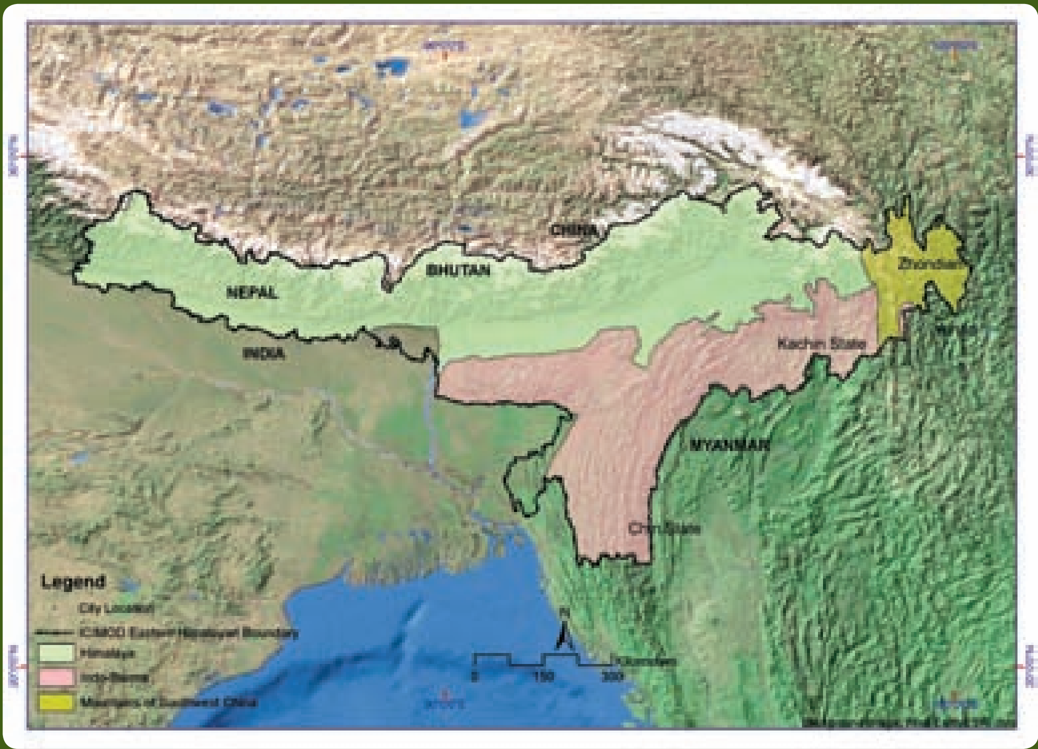
Country	Areas	% of EH area
Nepal	Kali Gandaki Valley, Kosi Basin, Mechi Basin	16.08
Bhutan	Whole	7.60
India	Sikkim, Arunachal Pradesh, Assam, Meghalaya, Nagaland, Mizoram, Manipur, Tripura	52.03
China	ZhongDian, DeQin, GongShan, Weixi, FuGong	6.26
Myanmar	Chin and Kachin states	17.90

Source: This study

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

The Eastern Himalayan region has been in the spotlight as a part of the 'Crisis of Eco-regions' (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 Eco-regions' (Olson and Dinerstein 2002). There are 99 protected areas covering 15% of the total area of the EH (Table 2). The EH region has 25 eco-regions out of a total of 60 in the HKH region as a whole. The Indo-Burma Hotspot alone is home to 7,000 endemic plants and possesses 1.9% of the global endemic vertebrates (Myers et al. 2000). More than 7,000 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).

Figure 1: **Map of the Eastern Himalayan region showing the three global biodiversity hotspots**



Source: developed using information from Mittermeier et al. 2004

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

Country	Total area of the country (km²)	Area within the EH (km²)	Number of PAs in the EH	PA area coverage within the EH (km²)	PA area coverage with respect to area within the EH (%)
Bhutan	46,500	39,862.4	9	11,195.0	28.1
China	9,596,960	32,863.8	9	11,917.9	36.3
India	2,387,590	272,707.1	67	28,379.2	10.4
Myanmar	676,577	93,854.9	3	8,378.7	8.9
Nepal	147,181	84,338.6	11	19,510.0	23.1
Total	**12,854,808**	**523,626.8**	**99**	**79,380.9**	**15.2**

Source: Chettri et al. 2008a and IUCN, WCMC, UNEP 2005

Climate change: variability and extremes

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

The existing knowledge of climatic characteristics in the EH region is limited by both paucity of observation and insufficient theoretical attention to the complex interaction of spatial scales in weather and climate phenomena in the mountains. In order to determine the degree and rate of climatic trends, long-term data sets are needed, and these are not available for most of the EH region.

Despite the limitations, studies of the climate in the past and projections based on climate models have increased in recent times, albeit on various spatio-temporal scales, some of which cover the EH in part or as a whole. Work has also been carried out by ICIMOD to consolidate past information and incorporate the latest updates. A synthetic review and reassessment of projected climate trends and change towards the end of this century were carried out to realign focus on the EH region in terms of observed climatic trends and location-based scenarios of future climate situations (Shrestha and Devkota 2008). The findings have confirmed suggestions by earlier studies that temperatures will continue to rise and rainfall patterns will be more variable, projecting both localised increases and decreases. The figures for the EH do not present a drastic deviation from the IPCC outcomes for the South Asian region. Nonetheless, they reinforce the scientific basis of the contention that the EH is undergoing a warming trend.

Table 3: **Regional mean temperature trends for the period 1977-2000 (°C per year)**

Regions	Seasonal	Annual			
	Winter (Dec-Feb)	Pre-monsoon (Mar-May)	Monsoon (Jun-Sep)	Post-monsoon (Oct-Nov)	
Trans-Himalayas	0.12	0.01	0.11	0.10	0.09
Himalayas	0.09	0.05	0.06	0.08	0.06
Middle Mountains	0.06	0.05	0.06	0.09	0.08
Siwalik	0.02	0.01	0.02	0.08	0.04
Terai	0.01	0.00	0.01	0.07	0.04

Source: Shrestha and Devkota 2008

Annual mean temperature is increasing at a rate of 0.04°C/yr (0.01-0.12°Cyr-1) or higher (Table 3). The warming trend has been greatest during the post-monsoon season and at high elevations. Increases in temperature during the period (1977-2000) have been spatially variable indicating the biophysical influence of land surface on the surrounding atmospheric conditions. In general, there is a southwest to northeast 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, northeastern states of India. Eastern Nepal and eastern Tibet record relatively higher warming trends than the lowland areas. The warming in winter is greater than the normal scenario 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 the following major points.

1. The Eastern Himalayas are experiencing widespread warming. The warming is generally greater than 0.01°C/yr
2. Using usual seasonal dichotomies, the highest rates of warming are occurring in the winter season and the lowest, or even cooling, trends are observed in the summer season.
3. There is progressively more warming with elevation, with the areas >4000 m experiencing the greatest warming rates

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

Sensitivity of 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; viz., food, fresh water, timber, fuelwood, fibre, non-timber forest products, biochemicals, and genetic materials. Clearly, the human economy depends upon the services given 'for free' by the ecosystem. Natural ecosystems also perform fundamental life-support services without which human civilizations would cease to thrive. Many human activities that modify or destroy natural ecosystems may cause deterioration in ecological services whose value, in the long term, dwarfs the short-term economic benefits society gains from such activities. Fortunately, the functioning of many ecosystems can be restored if appropriate and timely action is taken. Climate change, including variability and extremes, continues to impact mountain ecosystems; sometimes beneficially, but frequently with adverse effects on the structure and functions of these ecosystems.

The Millennium Ecosystem Assessment (MEA) has many things in common with the climate assessments compiled by the IPCC. The two assessments have a common aim of providing policy-relevant information in their respective areas of investigation, i.e., ecosystems and climate, respectively, for the benefit of humanity. 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) provides a useful link between the functioning of ecosystems and their role in 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); and these in turn affect human society – mainly by increasing human vulnerability. The following section of this paper will cover mainly the degree of sensitivity of mountain biodiversity to climate change in the region.

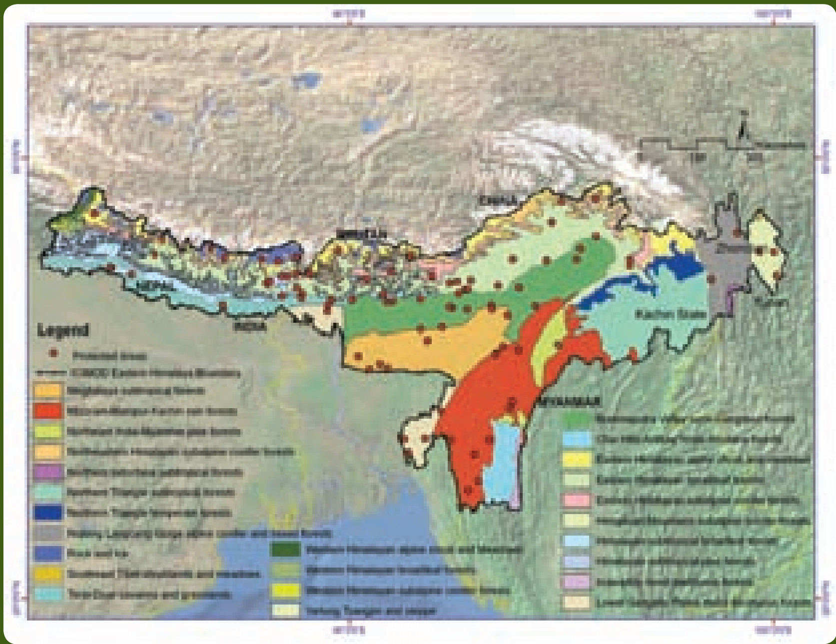
Sensitivity of biodiversity to climate change and potential impacts

The EH region intersects three global biodiversity hotspots: 38.9% of the Himalayan, 7.7% of the Indo-Burmese, and 12.6% of the mountains of Southwest China. Twenty-five eco-regions have been identified within the EH boundary, 12 of which are spread across the Himalayan hotspots, eight in the Indo-Burmese, and five in the mountains of South West China (Chettri et al. 2008a). Presently, there are 17 protected area complexes, 41 are candidate priority areas of great importance to biodiversity conservation, 175 are key biodiversity areas, and five are 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 important in terms of conservation (CEPF 2005) (Figure 2).

The EH with diverse climates and a complex topography is comprised of different types of forests and vegetation. The vegetation types in the EH can be categorised broadly into: (a) tropical, (b) sub-tropical, (c) warm temperate, (d) cool temperate, (e) sub-alpine, and (f) alpine types; and these 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 the majority of these species (about 144 species) are found in the northeastern states of India particularly (CEPF 2005). Besides supporting one of the world's richest alpine flora banks, about one third of the total flora are endemic to the region (WWF and ICIMOD 2001; Dhar 2002). Details about the significance of species and their distribution, endemism, and their conservation status have been documented comprehensively and need not be repeated here.

Climate change has contributed to substantial contractions in species' range and extinctions in the past, and projections for the future indicate that it could influence species' persistence and lead to disproportionate distribution of species throughout ecological zones (Wilson et al. 2007). In view of the prevailing trend, the consequences of biodiversity loss as a result of climate change are likely to be greatest on the poor and marginalised people who depend almost exclusively on natural

Figure 2: **The EH region showing 25 eco-regions and protected area distribution**



Source: Developed using data from WWF 2006

resources for their sustenance. Grabherr et al. (1994) estimated that a 0.5°C rise in temperature per 100 m elevation could lead to a theoretical shift in altitudinal vegetation belts at a rate of 8-10 m per decade. This altitudinal shift in the EH is expected to be around 80-200 m per decade given the current rises in temperature in the region, which are estimated at around 0.04°C-0.1°C/yr in high-altitude ecosystems where the rate of warming increases. Such a possibility, however, is based on the speculation (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 for keeping pace with the projected climate change is very limited. Unfortunately, there is still no straightforward explanation about how ecosystems and range may shift; notwithstanding that the mechanistic hypothesis has almost assumed a factual dimension. The multiplicity in eco-physiography along the altitudinal ascent and the facultative asymmetry in species' survival strategies would mean that communities extant within a bioclimatic precinct could be quite different in the future as a result of climate change.

The EH harbours numerous critical habitats and species within protected area systems: one example is that of the greater one-horned rhinoceros. Amongst the eco-regions, the EH broadleaf forests, Brahmaputra Valley semi-evergreen forests, and Himalayan subtropical pine forests have the highest conservation values because of the presence of greater than average numbers of mammals, birds, and plants (WWF and ICIMOD 2001). Alluvial grasslands of the tropical forests support a high density of tigers. The Brahmaputra and Ganges rivers are home to 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 eco-regions has been drawn up in close consultation with stakeholders in the region, taking on board the significance of composite impacts observed from multiple stress factors— including climate change—and the vulnerable entities of biodiversity associated with them (Table 4).

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

Critical habitat	Change indicator	Example of observed changes	Vulnerable entities
Alpine/sub-alpine ecosystems nestled between the treeline from 4,000m to the snowline at 5,500m	• Changes in ecotones • Desertification • Declining snowfall, glaciation events • Changes in species' composition • Growth in unpalatable species, decreasing productivity of alpine grasslands	Transformation of earlier Quercus-Betula forest into the 'Krummholz-type' of vegetation comprised 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
Cool-moist forests	• Changes in ecotones • Loss of habitat • Blockage of migration routes	Decline in population of species of mantesia, ilex, and insectivorous plants	Habitat specialists such as red panda, blood pheasant, microflora, and associated fauna
Cloud forests of temperate elevations where moisture tends to condense and remain in the air	• Less precipitation and cloud formation during the warm growing season (summer) • Loss of endemics/ specific flora and fauna • Upward range shift • Desertification of soil, affecting the capacity of forests to retain water	-	Endemic epiphytes and lichens, wildlife dependant on cloud forest vegetation (diversity of insects)

Table 4 cont…

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Critical habitat	Change indicator	Example of observed changes	Vulnerable entities
Area with intensive agriculture	• Reduced agro-biodiversity (monoculture) • Low employment/ gradual loss of traditional knowledge. • Degradation of soil quality • Potential increase in GHG emissions	Loss of traditional variety, such as upland varieties of rice, indigenous beans, cucurbit, and citrus varieties, pest increases in citrus species	Crops, cereals, and vegetables
Freshwater wetlands	• Loss of wetlands due to sedimentation, eutrophication, drying, drainage • Successional shift to terrestrial ecosystems • 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
Riparian habitats nurtured by silt deposited by overflowing rivers	• Damage or destruction of riparian habitats by floods/glacial lake outburst floods (GLOFs)/river bank erosion • Degradation due to increased/little deposition of sediment • Reduced streamflow • Disrupted successional stage	Loss of pioneer species such as *Saccharum spontaneum* and other tree species leading to a change in species' composition in alluvial grasslands	Ibis bill (has nesting habitats in riparian zones), market-value tree species found in riparian zone such as sisso, simal
Ephemeral stream habitat	• Loss of ephemeral stream habitats • Increased salinity • Riverine system impacted	Riverine island ecosystems, such as that of Majuli in Assam, are being threatened	Ephemeral stream species, especially herpetofauna

Source: Chettri et al. (2008b)

Knowledge gaps and research needs

Adaptations to climate change for the conservation of biodiversity and its sustainable use need to come from a clear understanding of the important habitats and species and the nature of their resiliency to climatic stress. The following is a list of the important research work needed to advance understanding of climate change and its possible impacts on biodiversity and to assist work on mitigation and adaptation in the EH region.

- Policies should be reviewed and strengthened to make them more sensitive to the interaction in processes and the linkages between the consequences of climate change to biodiversity.
- The EH region needs a comprehensive database of species and ecosystems and proper documentation of indigenous knowledge and practices on adaptation to climate change, including variability and extremes.
- Extensive and in-depth assessment of the movements of alien, invasive species and critical landscape linkages to flagship species, PA coverage and effectiveness, adaptability of biodiversity entities, fire management regimes, and impacts on agricultural productivity are other important areas requiring urgent attention. Emphasis should be placed on riparian habitats, least explored ecosystems, habitats of threatened species, and floral and faunal hotspots.
- A comprehensive survey and inventory of the distribution range of plants and animals, biodiversity within PAs, population trends of flagship/endemic or threatened species, and status of mid-sized mammals and other groups of animals should be carried out.
- Capacity building is needed to carry out specific research in taxonomy, conservation biology, and impact assessments.
- Efforts of various conservation initiatives active in the EH must be coordinated and collective partnerships developed between stakeholders so that the entire EH region is able to cope with the present and future impacts of climate change.
- An assessment should be carried out of ecosystem structures, functioning, and productivity and delivery of ecosystem goods and services.
- A study should be carried out on the interaction between climate change and land use change to assess their combined impact on biodiversity, atmospheric $CO2$ concentration, species' composition, and carbon dynamics in different ecosystems.
- Economic valuation should be made of ecosystem services from conservation areas.
- Socioeconomic studies of land-tenure systems, food security, rights to use of resources, decision-making processes, and governance that characterise community resiliency to climate change should be carried out.

Adaptation strategies

So far, biodiversity entities in natural ecosystems have been adapting naturally or autonomously without much adjustment on the part of those who benefit from their services. As the magnitude of climate change and other factors of global change increases with time, the need for planned adaptation will become acute. Traditionally, communities that depend on biodiversity resources have informal institutions and customary regulations in place to ensure that external perturbations do not exceed natural resilience. Going by the rate of changes taking place in the demographic, economic, and sociopolitical landscapes, and their positive feedback to the climate system, traditional approaches may have to be supplemented by formal adaptation measures to address the new threats to biodiversity.

Recently, there has been a concerted move towards transition from contemporary conservation approaches to a new paradigm of landscape-level interconnectivity between protected area systems defined around the protectionist focus on species and habitats. The concept raves about the shift from the mundane species-habitat dichotomy to an inclusive perspective on expanding the biogeographic 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 realised. Whatever the conservation approach, communities in a protected area system must be regarded as a medium of adaptation, rather than being perceived as the reason for environmental degradation and biodiversity loss. Local participation in conservation efforts 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 about the status of biodiversity; trends in environmental change, including climate change and its potential impacts on biodiversity; and the status of human resources, expertise, institutional capacity, political commitment, and financial resources. Some of the adaptation options in the EH region include the following.

- An institutional arrangement responsive to addressing the climate-change issues and sensitive to the societal and economic priorities at national and local levels
- Research and development in agroforestry and community forestry to enhance carbon sequestration, reduce soil erosion, improve water quality, and increase livelihood options
- Operationalisation of the transboundary landscape approach to biodiversity conservation and protected area management
- Establishment of stations to monitor the climate and facilitate generation of accurate, long-term climatological time series and associated infrastructure for networking and sharing data
- Identifying and monitoring climate-sensitive organisms as indicators for early detection of climate-change signals and facilitating mediation for proactive adaptation
- Sustainable management of rangelands and formalisation of climate-conscious pastoralism not only to enhance productivity but also to protect the ecosystem, reduce CO2 emissions, and increase storage above and below ground

The transect and landscape approach

Change needs to be monitored in the Hindu Kush-Himalayas (HKH) through use of climatic parameters, physical and biological conditions, and sociocultural and livelihood situations to generate consistent, representative data: the information thus generated could be used for sustainable development and to respond to climate change. In order to generate consistent information, ICIMOD has conceptualised the use of important landscapes from east to west and transects from north to south in the HKH region. The planned landscapes and transects are representative of the HKH and concerted efforts from global programmes and other programmes within the region are expected to bridge the knowledge gap in the medium and long term. A separate paper from ICIMOD (to be delivered at this conference) on the landscapes and transects describes the details and benefits of these approaches.

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