Conservation Science

Translating Knowledge into Actions

# Reconciling Mountain Biodiversity Conservation in a Changing Climate: A Hindu Kush-Himalayan Perspective

**Nakul Chettri***


## Summary

Mountains occupy 24% of the global land surface area and are home to 12% of the world's population. They have ecological, aesthetic, and socioeconomic significance, not only for those living in mountain areas, but also for people living beyond. The Hindu Kush-Himalayan region (HKH) expanding to over four million square kilometres is endowed with rich biodiversity, culture, and sources of varied goods and services that serve more than 200 million people living in the region and 1.3 billion people living in the river basins receive services from them. The countries sharing the HKH have set aside 39% of the biodiversity rich area for different systems of protection. However, in the recent years, the HKH is facing numerous drivers of environmental change including climate change. Various studies suggest that warming in the HKH has been much higher than the global average over the last 100 years and the HKH is already facing climate change threats at ecoregions, ecosystems and species levels. While climate change is a global problem requiring a global solution, the HKH countries have initiated various reconciling initiatives to link conservation with climate change for enhancing ecological and socio-economic resilience. However, there is serious paucity of expertise, capacity and data on climate change as well as biodiversity in the HKH bringing challenges in enhancing the resilience. Considering the significance of the HKH on local, regional, and global levels, it is imperative to close the gaps to meet the challenges arising from the consequences of climate change. International Centre for Integrated Mountain Development (ICIMOD), with its partners, has conceptualised a number of innovative conservation approaches with an objective to reconcile biodiversity conservation goals with climate change challenges. These conservation approaches have a huge potential for mutual benefits from the common good practices, resources and expertise and there is a need for more formal cooperative agreements between the various institutions and communities of the countries at the regional level for addressing regional issues of conservation in the changing climate.


**Keywords** Himalayas, Biodiversity, climate change, impacts, reconcile, conservation, data gaps


## Essay

### *Article history*

| | |
|---|---|
| Received | 09 October 2014 |
| Accepted | 02 December 2014 |
| Published Online | 03 February 2015 |
| Editor | Uttam Babu Shrestha |


*Corresponding author

Nakul Chettri
nakul.chettri@icimod.org

International Centre for Integrated Mountain Development (ICIMOD)
GPO Box 3226
Khumaltar, Lalitpur,
Nepal

Citation: Chettri N (2014) Reconciling Mountain Biodiversity Conservation in a Changing Climate: A Hindu Kush-Himalayan Perspective. Conservation Science 2, 17—27



Funding: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH and Austrian Development Agency (ADA)

## 1. Introduction

Mountains, including the major ranges such as the North American Cordillera, Appalachians, Caledonian Belt, Andes, Urals, Himalaya, Alps and the Tasman Belt are complex and fragile ecosystems that cover almost a quarter of the earth's land surface and host 12 percent of its people (GTOS 2008). Due to the extreme heterogeneity of environments (climates and soils), rapid elevational changes (altitudinal vegetation belts), and variable directional orientation (aspect), the mountains have diverse vegetation and varied microclimatic and ecological conditions (Sharma et al. 2010). As a consequence, mountains exhibit high biodiversity, often with sharp transitions (ecotones) in vegetation sequences, and equally rapid changes from vegetation and soil to snow and ice (Debarbieux and Price 2012). In addition, mountain ecosystems are often rich in endemics, because many species remain isolated at high elevations compared to lowland vegetation communities that can occupy climatic niches spread over wider latitudinal belts. Thus, they are the last bastions of wild nature "islands" in a sea of transformed lowlands and provide a number of very important ecological functions (Hamilton 2002). These functions contribute to half of the humanity for their wellbeing well beyond the immediate vicinity, benefiting entire river basins (Grêt-Regamey et al. 2012). In addition, natural and semi-natural vegetation cover on mountains helps to stabilize headwaters, preventing flooding, and maintain steady year-round flows by facilitating the seepage of rainwater into underwater aquifers. As a result, mountains have often been referred to as 'natural water towers' because they contain the headwaters of rivers, which are vital for maintaining human life in the densely populated areas downstream (Schild 2008). Most prehistoric hunters and gatherers preferred mountains because of the great plant and animal diversity within short distances, year round water, wood, shelter and conditions favorable for self defense (Chester et al. 2013).

The Hindu Kush-Himalayan region (HKH), is one of the most complex and dynamic regions in the world with rich and remarkable biodiversity (Pei 1995, Chettri et al. 2008a, Chettri et al. 2010). The HKH, with its varied landscapes and soil formation, and variety of vegetation types and climatic conditions, is well known for its rich biodiversity (Pei 1995, Chettri et al. 2008a). Numerous critical ecoregions of global importance can be found in this region (Olson and Dinerstein 2002). As a result, the HKH has been highlighted in many global conservation prioritization strategies (see Brooks et al. 2006). Endowed with a high level of endemism, richly diverse gene pools and species, and ecosystems of global importance, the region hosts parts of four Global Biodiversity Hotspots: the Himalayan, Indo-Burma, Mountains of Southwest China, and Mountains of Central Asia (Mittermeier et al. 2004). These 'Hotspots' are the cornerstone of conservation for the many endemic species that are confined to these areas.

In terms of species diversity, the region is equally rich in flora and fauna (Chettri et al. 2008b, Chettri et al. 2010, Chettri et al. 2011). It is a home to all four big cats of Asia: the snow leopard (*Uncia uncia*), tiger (*Panthera tigris*), common leopard (*Panthera pardus*), and clouded leopard (*Neofelis nebulosa*). Ungulates, a number of which are endemic, such as the Tibetan wild ass (*Equus kiang)*, wild yak (*Bos grunniens*), Chiru (*Pantholops hodgsoni*), and Tibetan gazelle (*Procapra picticaudata*) are of special significance (Chettri et al. 2011). In addition, cryospheric components of the HKH represents a unique source of freshwater for agricultural, industrial, and domestic use, and are an important economic component of tourism and hydro-electric power production and maintains water quality, regulates water flow (floods and droughts), and supports biodiversity (Trisal and Kumar 2008, Eriksson et al. 2009, Xu et al. 2009). These regions also play an important role in mitigating the impacts of climate change by acting as carbon sinks (ICIMOD 2009, Trisal and Kumar 2008).

However, this mountain ecosystem is facing overarching threats of species loss and extinction from various drivers such as habitat degradation and fragmentation of landscape elements (Myers et al. 2000, Pandit et al. 2007); Climate Change (Shrestha et al. 2012). The resources in the HKH are declining mainly due over exploitation of resources for economic growth. This lead to development that is environmentally unfriendly including loss of biodiversity which increasingly is destroying the development itself. Even the protected areas such as national parks, nature reserves and wildlife sanctuaries face tremendous pressures from external driving forces such as economic development and globalisation and communities living inside and outside for tgeir dependency in the resources (Sharma and Yonzon 2005). Considering the diverse nature of ecosystem, geo-political differences, difference in conservation and development priorities, the role of Inter-Governmental organisation like International Centre for Integrated Mountain Development (ICIMOD) has been realised to be important. ICIMOD, a regional knowledge development and learning centre is serving the eight regional member countries of the Hindu Kush Himalayas – Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan – and based in Kathmandu, Nepal. ICIMOD aims to assist mountain people to understand these changes, adapt to them, and make the most of new opportunities, while addressing upstream-downstream issues.. Overall, ICIMOD is working to develop an economically and environmentally sound mountain ecosystem to improve the living standards of mountain populations and to sustain vital ecosystem services for the billions of people living downstream – now, and for the future.This paper is an attempt to provide the overview of reconciling initiatives taken forward by ICI-

MOD on biodiversity conservation and climate change perspectives with some evolving regional conservation and climate change adaptation experiences.

## 2. Climate change and its impact

The HKH region is facing enormous pressures from an array of drivers and impacts from environmental change, including climate change (Erikson et al. 2009, Xu et al. 2009, Tse-ring et al. 2010). While the Fourth Assessment Report (4AR) of Intergovernmental Panel on Climate Change (IPCC) made a strong science-based rationale for the need for actions countering the potential ill effects of climate change globally (IPCC 2007), it also pointed out the lack of reliable data and data collection efforts in the HKH. It is evident that climate change in the HKH will affect all aspects of the climate, making rainfall less predictable, changing the character of seasons, and increase the risk to biodiversity (Xu et al. 2009, Chettri et al. 2010). The increasing risk for human livelihoods and well-being include increasing frequency and severity of extreme events such as cyclones, landslides and floods. Within the HKH, the impact of these changes is often aggravated by existing environmental and socio-economic problems, such as poverty, water scarcity or food deficiency (Mertz et al. 2009). These in turn contribute to a downward-spiralling cycle with adverse impacts on livelihoods driving people to desperate measures that decimate natural resources, further increasing the impacts of climate change. Observational evidence indicates that the impacts related to climate warming are well underway on the HKH, with indications of vegetation degradation (Arthur et al. 2007), the cumulative negative mass balance of glaciers (Yao et al. 2007), thickening of the active layer, and increases in permafrost temperature (Zhao et al. 2004) and increased threats to biodiversity and derived ecosystem goods and services (Chettri et al. 2010, Chettri et al. 2011).

**Table 1**: Temperature trends by elevation zone for the period 1977–2000 (°C/year)

| Elevation zone | Annual | DJF | MAM | JJA | SON |
|---|---|---|---|---|---|
| Level1 | 0.01 | 0.03 | 0.00 | -0.01 | 0.02 |
| Level 2 | 0.02 | 0.03 | 0.02 | -0.01 | 0.02 |
| Level 3 | 0.04 | 0.06 | 0.04 | 0.02 | 0.03 |

(Level 1- <1000 m, Level 2 - 1000m -4000m, Level 3 - >4000m; Source: Shrestha and Devkota 2010)

It was evident from the recent studies that despite various limitations on availability of data and low priority on research, the review work on the 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 Eastern Himalayas region in part or as a whole (Sharma et al. 2009, Tse-ring et al. 2010, Shrestha and Devkota 2010). These studies shows that the Eastern Himalayas is a) experiencing widespread warming and the warming is generally higher than 0.01°C/yr; b) the highest rates of warming are occurring in winter (DJF) and lowest or even cooling trends are observed in summer (JJA) and c) there is progressively more warming with elevation, with the areas >4000 m experiencing the highest warming rates (**Table 1**). Similarly, the studies also highlight the potential impacts and vulnerabilities of biological diversity due to climate change (Sharma et al 2009; Chettri et al. 2010; Tse-ring et al 2010). These studies revealed that among the 25 ecoregions, 17 protected area complexes, and 41 candidate priority areas in the Eastern Himalayas the ecoregions such as Eastern Himalayan broadleaved forests, Brahmaputra Valley semi-evergreen forests, and Himalayan subtropical pine forests have the greatest conservation values because of the number of mammals, birds, and plants found in them (WWF and ICIMOD 2001); and are vulnerable to climate change. Thus, considering the vulnerable biodiversity entities and the potential change indicators, seven ecosystems or habitats in the Eastern Himalayas have been identified as critical (**Table 2**). Some of the ecoregions located within the Eastern Himalayas harbour many threatened mammal species, some of which are greatly threatened or restricted endemic species with a narrow habitat range (Chettri et al. 2010). As a result, the low land areas of the Brahmaputra valley are more vulnerable than other areas in terms of biodiversity conservation (Sharma et al. 2009, Tse-ring et al 2010).

## 3. Changing paradigm in conservation policies and practices

In the HKH, the classical approach of biodiversity conservation started with emphasis on the flagship species conservation. The assumption was that if the flagship species, which usually occupied the top of the pyramid in the food web in an ecosystem, flourished, then the ecosystem was considered healthy. However, the approach changed significantly from species focused conservation to landscape level within last three decades due to the realisation that some of these flagship species needs wider habitat range and a healthy habitat with connectivity is vital for species survival (Sharma et al. 2010). Moreover, the region also withnessed changes in protected area governance practices with the evolving concept of landscape approach where local community were empowered in conservation and management decision making process (Phuntsho et al. 2012). As of 2007, there were 488 protected areas (IUCN category I-VI) within the HKH, covering more than 1.6 million km2, representing about 39% of the region's terrestrial area (Chettri et al 2008a). Interestingly, the proportion of terrestrial area covered by the protected areas in the HKH is much higher (39%) than in Central America (26%) (Chape et al. 2005). Such growth in the number and areas of protected areas is a significant achievement

**Table 2**: 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 ecosytems nestled between the tree line at 4,000m to the snowline at 5,500m | • Changes in ecotones<br>• Desertification<br>• Declining snowfall, glaciation events<br>• Changes in species' composion<br>• Growth in unpalatable species, decreasing productivity of alpine grasslands | Transformation of earlie *Quercus-Betula* forest into the 'Krummholz-type' of vegetation comprising of species of *Rhododendron, Salix, Syringia* | Ungulate species, Himalayan pika, high-value medicinal plants, botanically fascinating species ( bhootkesh and Rhododendron ), curious species (succulents, Ephedra), alpine scrub flora |
| 2 | Cool-moist forests | • Changes in ecotones<br>• Loss of habitat<br>• Blockage of migration routes | Decline in population of *Mantesia sp. Ilex sp.* and insectivorous plants | Habitat specialists such as red panda, blood pheasant, microflora and associated fauna |
| 3 | Cloud forests at temperate elevations where moisture tends to mix with other particles and remain in the air | • Less precipitation and cloud formation during warmer growing seaso<br>• Loss of endemics /specific flora and fauna<br>• Less precipitation and cloud formation during warmer growing seaso<br>• Upward range shift<br>• Desertification of soil, affecting the water- retention capacity of forests | | Endemic epiphytes and lichens, wildlife dependant on cloud forest vegetation (diversity of insects) |
| 4 | Area with intensive agriculture | • Reduced agro-biodiversity (monoculture)<br>• Low employment rate/gradual loss of traditional knowledge<br>• Degradation of soil qualit<br>• Potential increase of greenhouse gas (GHG) emissions. | Loss of traditional variety such as upland varieties of rice, indigenous beans, cucurbits, and citrus varieties<br>Pest increase in citrus species | 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 nurtured by silt deposited by overflowing river | • Damage or destruction of riparian habitats by floods/glacial lake outburst floods (GLOFs)/ riverbank erosion.<br>• Degradation due to increased / little deposition of sediments<br>• Reduced stream flow<br>• Disrupted successional stage | Loss of pioneer species such as *Saccharum spontaneum* and other tree species leading to the change in species' composition of the alluvial grasslands | Ibis bill (has nesting habitats in riparian zones), Market-value tree species found in riparian zone; e.g., sisso, simal |
| 7 | Ephemeral stream habitat | • Loss of ephemeral stream habitats.<br>• Increased salinity<br>• Riverine system impacted | Riverine island ecosystems, such as Majuli in Assam, are being threatened | Ephemeral stream species, especially herpetofauna |

(Source: Chettri et al. 2010)

on the part of the HKH countries towards fulfilling their global commitment to conservation. Interestingly, the analysis showed that the protected areas in the HKH have adopted a shift away from strictly managed protected area systems to community based, as also observed by Zimmerer et al. (2004).

## 4. Reconciliation of biodiversity conservation and climate change adaptation

Several recent initiatives in the region offer significant opportunities for advancing and piloting innovative and regionally appropriate conservation and adaptation approaches. In particular, the importance biodiversity conservation in protected areas, corridors and transboundary landscapes focussing on climate resilience by maintaining ecosystem integrity for enhancing flow of environmental goods and services have been the thrust for ICIMOD since last one decade. Here are some examples on the reconciling initiatives piloted by ICIMOD in the HKH.

### *4.1.Trans-Himalayan Transect Approach*

Climatic, environmental and other change processes across the HKH have of both regional and global concerns (Messerli, 2009). Nevertheless, the HKH is one of least scientifically studied or monitored areas in the world, and a "data-deficit" region (IPCC 2007). Basic hydro-meteorological data are lacking, sparse, or not readily available. This is true for other environmental data, e.g. biodiversity, landuse and landcover change, climate change impacts on various ecosystem goods and services, and carbon cycles. An improved understanding of these regional change processes is essential to provide the basis for informed decision making, risk and vulnerability mapping, adaptation and mitigation strategies, and effective biodiversity conservation and management. ICIMOD, being an intergovernmental regional centre, is working in the eight countries of the HKH and has been active in facilitating its regional member countries through various conservation and development approaches. The 'HKH Trans-Himalayan Transect', an approach to address the information gaps across the HKH, was rationalized, conceptualized and discussed among global and regional stakeholders in 2008 (Chettri et al. 2009). Four 'Transects' have been proposed considering biodiversity significance, critical ecoregions, critical habitats for flagship species with representation from west to east, dry to wet and the south to north latitudinal expanse of the HKH region (**Figure 1**). As indicated above, additionally, seven Transboundary Landscapes provide an initial opportunity for piloting of the concept and activities including a range of monitoring and the initiation of long-term environmental and socio-ecological research. The geographically defined virtual "Transects" allow for co-locating research, monitoring and sampling sites, in-depth studies, and action research across the region, and for both comparative research and synergistic efficiencies. ICIMOD envisaged playing a facilitating role amongst the regional, national and local partners, and the global research community and other stakeholders through participatory and consultative processes encouraging regional cooperation and national ownership. On an experimental basis ICIMOD has initiated a number of pilot programmes (**Box 1**).

### *4.2. Landscape/Ecosystem Approach in biodiversity conservation*

Landscape/Ecosystem approach in biodiversity conservation is an evolving concept (Worboys et al. 2010). The concept has emerged primarily out of recognition that strict protection through a network of protected areas (e.g. national parks, sanctuaries, wildlife reserves) is an essential but insufficient biodiversity conservation strategy (Naughton-Treves et al. 2005, Ervin 2011). These researchers and others argue that protected areas are essential as these are the places where biodiversity conservation is the primary objective; yet insufficient as

**Box 1**: The Kailash Sacred Landscape Conservation and Development Initiative (KSLCDI)

Piloting the concept, ICIMOD has been engaged in partnership with United Nations Environmental Programme (UNEP), German Agency for International Cooperation (GIZ), Department of International Development (DFID, United Kingdom and member countries in the Kailash Sacred Landscape. This transboundary landscape includes an area of the remote southwestern portion of the Tibetan Autonomous Region of China, and adjacent parts of northwestern Nepal, and northern India, and is comprised of a broad array of bioclimatic zones, rich natural and cultural resources, and a wide range of forest types. The initiative engages regional, national and local stakeholders in a consultative process for facilitation of transboundary, integrated approaches to sustainable development and conservation. Ecosystem management is promoted through the Regional Cooperation Framework development process, based upon a Conservation Strategy, supported by a Comprehensive Environmental Monitoring Plan, to address threats to the environmental and cultural integrity of this area, analyze change processes, and to develop a knowledge base upon which to build regional cooperation.

(Zomer et al. 2010)

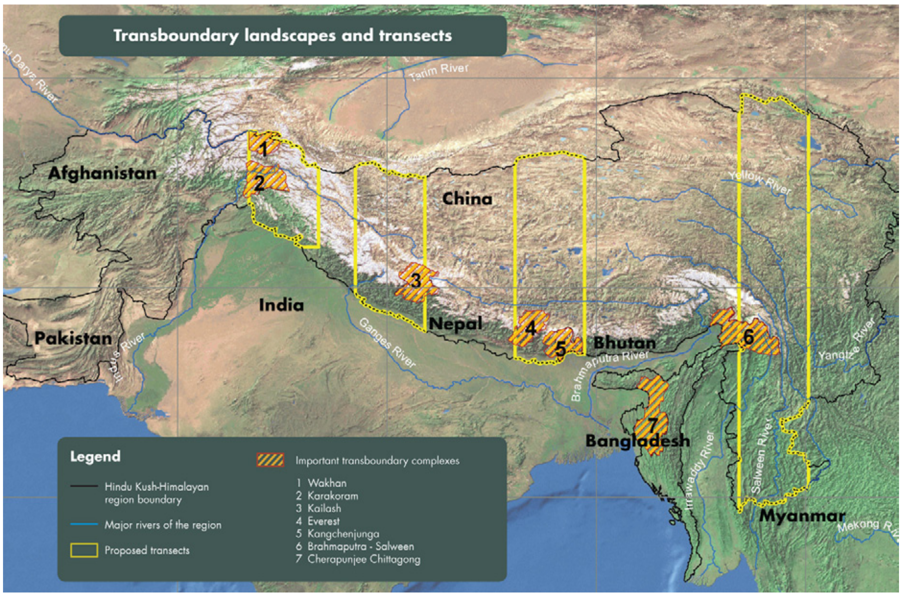


**Figure 1**: Map showing transboundary landscapes and transects in the HKH

they are too small to meet the ecological needs of viable population of wide ranging species in the changing climate and (Ibisch et al. 2010). Thus, more than preserving isolated patches of sustained wilderness in the form of protected areas, the focus is now widening on the necessity of maintaining landscape integrity, of viewing and conserving ecosystems as part of larger agro-ecological and socio-cultural landscapes to withstand the challenges posed by varied drivers of changes including climate change (Worboys et al. 2010).

Application of landscape or ecosystem approach, as advocated by the Convention on Biological Diversity (CBD), recognizes the need of increased regional cooperation, in part due to the biophysical nature of these mountainous areas, the extreme heterogeneity of the region, inter-linkages between biomes, habitats, and sectors, and the strong upstream - downstream linkages related to the provisioning of ecosystem services. Seven critical 'Transboundary Landscapes' have been identified by ICIMOD (**Figure 1**), highlighting the crucial role of improved cooperation amongst the countries of the region to enhanced the understanding the value of biodiversity and the potential impacts of environmental change on ecosystem goods and services. Among the seven identified landscapes, ICIMOD has been instrumental in facilitating regional cooperation among parts of Tibetan Autonomous region of Republica of China, parts of Uttarakhand state of northen India and western Nepal through its Kailash Sacred Landscape Conservation and Development Initiatives (KSLCDI) (Zomer et al. 2010, Zomer et al. 2014). Likewise, initiatives are underway with preparatory phases in Kangchenjunga Landscape considering parts of eastern Nepal, Sikkim and North Bengal of India and western Bhutan; far eastern landscape considering parts of Yunnan of China, northern Myanmar and parts of north eastern states of India etc. (see following link for more detail: http://www.icimod.org/?q=9121). In these initiatives, ICIMOD is promoting transboundary cooperation with integrated approach looking at socio-economic development perspectives, ecosystem management, resources governance and long term environmental and socio-ecological monitoring at a landscape level and piloted in a number of transboundary landscapes since late 1990s (See Sherpa et al. 2003, Sharma and Chettri 2005, Sharma et al. 2007, Zomer et al. 2010, Zomer et al. 2014).

### *4.3. Valuation and rewarding ecosystem service providers*

Humans benefit from biodiversity rich areas with the provision of ecological services such as climate regulation, soil formation, and nutrient cycling; and from the direct harvest of biodiversity for food, fuel, fibers, and pharmaceuticals. In the face of increasing human pressures on the environmental change, these benefits could act as powerful incentives to conserve nature (MA 2005), yet evaluating them has proved difficult because they are mostly not captured by conventional, market-based economic activity and analysis (Rasul et al. 2011). In the recent years, a new generation of conservation approaches with economic dimensions is rapidly emerging. They differ from traditional approaches in three critical and interrelated ways: a) they emphasize human-dominated landscapes; b) focus on ecosystem services, and c) utilize innovative finance mechanisms (Costanza et al. 2011). Such concerns have moved beyond the science community to the global stakeholder and policy makers with the

**Table 3**: Total value of selected ecosystem goods and services from the corridors area of east Nepal.

| Types and sources of value | Value US$ million | Percent |
|---|---|---|
| **Value of provisioning services** | | |
| 1 Timber and other wood | 19.4 | 15.68 |
| 2 Livelihood inputs (fodder, litter, agriculture appliances) | 72.5 | 58.61 |
| 3 Food products | 0.4 | 0.29 |
| 4 Medicinal plants | 5.2 | 4.17 |
| **Value of regulating services** | | |
| 5 Carbon sequestration | 23.0 | 18.58 |
| **Value of supporting services** | | |
| 6 Increase in crop income | 3.3 | 2.67 |
| Total value | 123.7 | 100.00 |

Source: Pant et al. 2011.

publication of the Millennium Assessment (MA, 2005). The analysis acknowledges that biodiversity plays a significant role in directly providing goods and services as well as regulating and modulating ecosystem properties that underpin the delivery of ecosystem services. To rationalise the conservation value of biodiversity and the derived goods and services in the landscapes, ICIMOD developed an assessment framework paper (Rasul et al. 2011) and also identify and even quantify the ecosystems goods and services provided by the protected areas, corridors and landscape, mainly provisional services, both marketed and not marketed values in the Kangchenjunga landscape (Pant et al. 2011). The study revealed that more than 80% of the populations living in or near the protected areas and corridors are directly depended on the ecosystems goods and services. The study also revealed that about 70% of the total household income is derived from the provisional goods and services from the forest ecosystems and each hector of land fetches more than 400US$ per annum. More interestingly, the selective ecosystem goods and services derived from the whole eastern Nepal corridors, which could be measures in economic terms was more than a billion dollar (**Table 3**). Similar studies have also been done in wetland ecosystems of Bhutan (ICIMOD and RSPN, 2014) and Nepal (ICIMOD and MoFSC, 2014) These results showcase that many of the ecosystem goods and services can be valued and the value of these resources are much higher than one can actually realise. The study was important in terms of reconciling conservation and climate change as it rationalises the need for enhancing ecological resilience through conservation intervention. Such studies have been replicated in other critical ecosystems in the HKH and the experimental works are in progress.

## 5. Recommendations and way forward

While acknowledging the significant diversity of biological resources in the HKH region and the existence of a fair understanding of the important drivers of change, it is recognised that concerted efforts are needed to monitor and research the impacts of climate change on biodiversity. During the course of ICIMOD's learning, four priority thematic areas were identified to strengthen the reconciling process.

### *5.1 Long-term monitoring of environmental and socio-ecological changes*

The importance and need for establishing long-term, consistent monitoring on climate change and its impact on biodiversity is clearly realised. Permanent plots and /or units need to be established on an altitudinal transect spanning the tropics to the alpine regions in order to monitor diverse ecosystems. An institutionalised monitoring system, however, requires standardisation of monitoring parameters. In this respect a consistent, uniform methodology and a network of collaborative efforts to collect and analyse data and information regularly is to be made a prerequisite. Realising the need for a facilitating institution at a regional level, ICIMOD has taken the role by developing Long Term Environmental and Socio-Ecological Monitoring Framework (Chettri et al. 2015). Academic and research institutions from the KSLCDI are beingengaged to establish and maintain the permanent research plots, carry out the regular monitoring, and generate and analyse the data. The involvement of communities for monitoring in the respective areas was seen to be critical in maintaining the plots, in participatory action research, and in carrying out observations and sharing perceptions.

### *5.2. Focused research on impacts, coping mechanisms and adaptation to climate change*

Documentation on impacts is, as yet, anecdotal for the most part – there is a need, therefore, to document impacts as well as coping mechanisms of communities to change systematically. The most promising indicators seem to be agro-biodiversity, followed by other forms of biodiversity (both flora and fauna). Documentation of changes in crops and their performance and coping mechanisms of communities, focusing on changes in cropping patterns, crop shifts, and cropping system management should be carried out on a priority basis. One important aspect requiring documentation and monitoring is the changes in nutritive value of crops as a result of the impacts of climate change. Systematic documentation and monitoring, however, will need a framework of institutional support and re-orientation of existing government research programmes and institutions in regard to adaptive research. Efforts are being made as mentioned in section 5.1. by developing the Framework (Chettri et al. 2015) and implementing in the field through the landscape programme.

### *5.3. Assessment of critical habitat linkages, protected area effectiveness, ecological and social vulnerabilities*

In addition to the functional responses of existing protected areas to climate change (which could provide critical information about responses of natural systems to change and hence provide benchmark parameters), new potential habitats and required corridors between the existing protected areas and habitats needs to be identify and sternthen (Worboys et al. 2010). Existing protected areas require constant monitoring to document changes in vegetation, identification, and census of indicative species (to monitor population dynamics as a function of changing climate impacts). The effectiveness of protected area management have to be central to all research and feed into evolving responsive management approaches and technologies (Watson et al. 2014). Findings and conclusions from the above should provide insight into adaptive responses and into resilience of natural systems; and these should become critical elements in evolving decision-support systems and hence require priority. Research on institutional frameworks and their effectiveness in governance and assessments of good practices with examples of community- led conservation have to be central to formulation of an effective and responsive governance system. Strong emphasis has to be placed on indigenous knowledge systems, particularly in regard to natural resource management approaches and institutional frameworks, drawing upon traditional practices of management and governance especially in regard to sacred landscapes.

### *5.4. Policy analysis on climate change, adaptation and coping mechanisms; and relevant adjustments to existing policies*

In order to support and strengthen community efforts to cope with change, an enabling policy environment is essential. Documentation and assessments indicate the need for policy dialogues focusing on areas identified. Policy dialogues would need to focus on areas where adjustments in existing policies are required, particularly in regard to economic benefits, governance frameworks, and local-level policy adjustments. A clear concern was the multiplicity of policy actors governing natural resource management and livelihood support and the need for convergence of different (often conflicting) policies under one forum for ease of implementation (Phuntsho et al. 2012). Dialogues need to focus on this required convergence before moving on to sectoral details. There is a critical role for scientific institutions in regard to policy formulation concerning natural resource management, livelihood support, and climate change. Policy makers require authentic data inputs and, more often than not, these are not available or not in a comprehensible form (Sharma et al. 2010). Scientific institutions need to fill this gap so that policy making can be based on scientific findings.

## 6. Acknowledgement

I express my sincere gratitude to the Director General of ICIMOD, Dr David Molden, for his inspiration and for providing the required facilities for the preparation of this paper. Dr Eklabya Sharma guided me right from the inception of this paper and I am indebted for his guidance and support. I am also thankful to many ICIMOD colleagues for their support and contributions.

## References

Arthur AD, Pech R, Jiebu J, Zhang Y, Hui L (2007) Grassland degradation on the Tibetan Plateau: The role of small mammals and methods of control. ACIAR Technical Reports No. 67, 35 pp.

Brooks TM, Mittermeier RA, da Fonseca GAB, Gerlach J, Hoffman M, Lamoreux JF, Mittermeier CG, Pilgrim JD, Rodrigues ASL (2006) Global biodiversity conservation priorities. Science 313, 58-61

Chape S, Harrison M, Spalding M, Lysenko I (2005) Measuring the extent and effectiveness of protected areas as an indicator for meeting global biodiversity targets. Philosophical Transactions of Royal Society B 360, 443-455

Chester CC, Hilty AA, Hamilton LS (2013) Mountain gloom and mountain glory revisited: A survey of conservation, connectivity, and climate change in mountain regions. Journal of Mountain Ecology 9, 1–34

Chettri N, Bubb P, Kotru R, Rawat GS, Murthy MSR, Wallrapp C, Pauli H, Shrestha AB, Mool PK, Chaudhary D, Chaudhary, RP, Mathur PK, Peili S, Ning W, Sharma E (2015). Long term environmental and socio-ecological monitoring in transboundary landscapes. International Centre for Integrated Mountain Development (ICIMOD), Kathmandu, Nepal.

Chettri N, Shrestha AB, Zhaoli Y, Bajracharya B, Sharma E, Hua O (2011). Real world protection for the 'third pole' and its people. In falk huettmann (ed). Protection of three poles. Springer, Japan. Pp 113-133. DOI 10.1007/978-4-431-54006-9_5

Chettri N, Shakya B, Sharma E (2008b) Biodiversity conservation in the Kangchenjunga landscape. International Centre for Integrated Mountain Development (ICIMOD), Kathmandu

Chettri N, Shakya B, Thapa R, Sharma E (2008a) Status of protected area system in the Hindu Kush Himalaya:

an analysis of PA coverage. International Journal of Biodiversity Science and Management 4(3),164–178

Chettri N, Sharma E, Shakya B, Thapa R, Bajracharya B, Uddin K, Oli KP, Choudhury D (2010) Biodiversity in the Eastern Himalayas: Status, trends and vulnerability to climate change. Climate change impact and vulnerability in the Eastern Himalayas – Technical Report 2. International Centre for Integrated Mountain Development (ICIMOD, Kathmandu

Chettri N, Sharma E, Thapa R (2009) Long-term monitoring using transect and landscape approaches within the Hindu Kush-Himalayas. In Sharma E (eds) Proceedings of the International Mountain Biodiversity Conference Kathmandu, 16–18 November 2008. International Centre for Integrated Mountain Development (ICIMOD), Kathmandu, Nepal.

Costanza R, Kubiszewski I, Ervin D, Bluffstone R, Boyd J, Brown D, Chang H, Dujon V, Granek E, Polasky S, Shandas V, Yeakle, A (2011) Valuing ecological systems and services. F1000 biology reports, 3.Debarbieux B, Price M F (2012) Mountain Regions: A Global Common Good? Mountain Research and Development, 32(S1), S7-S11

Eriksson E, Xu J, Shestha AB, Vaidya RA, Nepal S, Sandström K (2009) The changing Himalayas: Impact of climate change on water resources and livelihoods in the greater Himalayas. International Centre for Integrated Mountain Development (ICIMOD), Kathmandu

Ervin J (2011) Integrating protected areas into climate planning, Biodiversity, 12:1, 2-10

Grêt-Regamey A, Brunner SH, Kienast F (2012) Mountain Ecosystem Services: Who Cares? Mountain Research and Development, 32(S1), S23-S34. 2012

GTOS (2008) Why focus on mountain regions? URLhttp://www.fao.org/gtos/tems/mod_mou.jsp accessed on 03.09.2009.

Hamilton LS (2002) Why mountain matters? World Conservation: The IUCN Bulletin 1/2002.

Ibisch PL, Vega AE, Herrmann TM (2010) Interdependence of biodiversity and development under global change. Technical Series No. 54. Secretariat of the Convention on Biological Diversity, Montreal.

ICIMOD (2009) Potential carbon finance in the land use sector of the Hindu Kush Himalayas: A Preliminary Scoping Studies. International Centre for Integrated Mountain Development, Kathmandu, Nepal

ICIMOD, MoFSC (2014) An integrated assessment of natural and human disturbances effects on a wetland ecosystem: A retrospective from the Koshi Tappu wildlife reserve, Nepal. ICIMOD, Kathmandu, Nepal

ICIMOD, RSPN (2014) An integrated assessment of the effects of natural and human disturbances on a wetland ecosystem: A retrospective from Phobjikha Conservation Area, Bhutan. Kathmandu: ICIMOD

IPCC (2007) IPCC Summary for Policymakers: Climate Change 2007: Climate Change Impacts, Adaptation and Vulnerability. IPCC WGII Fourth Assessment Report

Liu X, Chen B (2000) Climatic warming in the Tibetan Plateau during recent decades. International Journal of Climatology 20, 1729–1742.

MA (2005) Ecosystems and Human Well-being: Synthesis. Millennium Ecosystem Assessment Report. Published for World Resources Institute, Island Press, Washington, DC

Mertz O, Padoch C, Fox J, Cramb RA, Leisz SJ, Lam NT, Vien TD (2009) Swidden Change in Southeast Asia: Understanding Causes and Consequences. Human Ecology 37, 259–264

Messerli B (2009) Biodiversity, Environmental Change and Regional Cooperation in the Hindu Kush-Himalayas. In Sharma E (eds) Proceedings of the International Mountain Biodiversity Conference Kathmandu, 16–18 November 2008. ICIMOD, Kathmandu, Nepal.

Mittermeier RA, Gils PR, Hoffman M, Pilgrim J, Brooks T, Mittermeier CG, Lamoreaux J, da Fonseca GAB (2004) Hotspots revisited: Earth's biologically richest and most endangered terrestrial ecoregions. Mexico City: CEMEX/ Agrupación Sierra Madre

Myers N, Mittermeier RA, Mittermeier CG, da Fonseca GAB, Kent J (2000) Biodiversity hotspots for conservation priorities. Nature 403, 853–858

Naughton-Treves L, Holland MB, Brandon K (2005) The role of protected areas in conserving Biodiversity and sustaining local livelihoods. Annual Review of Environment and Resources 30, 219–252

Olson DM, Dinerstein E (2002) The Global 200: Priority ecoregions for global conservation. Annals of Missouri Botanical Garden 89, 199-224

Pandit MK, Sodhi NS, Koh LP, Bhaskar A, Brook BW (2007) Unreported yet massive deforestation driving loss of endemic biodiversity in Indian

Himalaya. Biodiversity Conservation 16, 153-163

Pant KP, Rasul G, Chettri N, Rai KR, Sharma E (2011) Economic Valuation of Forest Biodiversity in Kanchenjunga Landscape with Special Reference to Nepal. Draft Analytical Report, ICIMOD, Kathmandu, Nepal.

Pei S (1995) Banking on biodiversity: report on the regional consultations on biodiversity assessment in the Hindu Kush Himalaya. ICIMOD, Kathmandu, Nepal.

Phuntsho K, Chettri N, Oli KP (2012) Mainstreaming community-based conservation in a transboundary mountain landscape –Lessons from Kangchenjunga. ICIMOD, Kathmandu, Nepal

Rasul G, Chettri N, Sharma E (2011) Framework for Valuing Ecosystem Services in the Himalayas. ICIMOD, Kathmandu, Nepal.

Schild A (2008) The case of the Hindu Kush-Himalayas: ICIMOD's position on climate change and mountain systems. Mountain Research and Development 28(3/4), 328-331

Sharma E, Chettri N (2005) ICIMOD's Transboundary Biodiversity Management Initiative in the Hindu Kush-Himalayas. Mountain Research and Development 25(3), 280-283

Sharma E, Chettri N, Gurung J, Shakya B (2007) Landscape approach in biodiversity conservation: A regional cooperation framework for implementation of the Convention on Biological Diversity in the Kangchenjunga Landscape. Kathmandu: ICIMOD

Sharma E, Chettri N, Oli KP (2010) Mountain biodiversity conservation and management: A paradigm shift in policies and practices in the Hindu Kush-Himalayas. Ecological Research 25, 909-923

Sharma E, Chettri N, Tse-ring K, Shrestha AB, Fang Jing, Mool P, Eriksson M (2009) Climate change impacts and vulnerability in the Eastern Himalayas. Kathmandu: ICIMOD

Sharma UR, Yonzon PB (2005) People and Protected Areas in South Asia. Resources Himalaya Foundation, Kathmandu and IUCN World Commission on Protected Areas, South Asia, Bangkok.

Sherpa LN, Peniston B, Lama W, Richard C (2003) Hands Around Everest: Transboundary Cooperation for Conservation and Sustainable Livelihoods. International Centre for Integrated Mountain Development, Kathmandu, Nepal

Shrestha AB, Devkota LP (2010) Climate change in the Eastern Himalayas: Observed trends and model projections; Climate change impact and vulnerability in the Eastern Himalayas – Technical Report 1. International Centre for Integrated Mountain Development (ICIMOD), Kathmandu

Shrestha UB, Gautam S, Bawa KS (2012) Widespread climate change in the Himalayas andassociated changes in local ecosystems. PLoS ONE 7(5), e36741.

Trisal C, Kumar R (2008) Integration of high altitude wetlands into river basin management in the Hindu Kush Himalayas: Capacity building need assessment for policy and technical support. New Delhi: Wetlands International-South Asia

Tse-ring K, Sharma E, Chettri N, Shrestha A (2010) Climate change vulnerability of mountain ecosystems in the Eastern Himalayas; Climate change impact and vulnerability in the Eastern Himalayas – Synthesis report. Kathmandu: ICIMOD.Watson J E, Dudley N, Segan D B, Hockings M (2014). The performance and potential of protected areas. Nature, 515(7525), 67-73.

Worboys GL, Francis W, Lockwood M (2010) Connectivity conservation management: a global guide. Earthscan, London, UK.

WWF, ICIMOD (2001) Ecoregion-based Conservation in the Eastern Himalaya: Identifying Important Areas for Biodiversity Conservation. WWF Nepal, Kathmandu.

Xu J, Grumbine ER, Shrestha A, Eriksson M, Yang X, Wang Y, Wilkes A (2009) The melting Himalayas: Cascading effects of climate change on water, biodiversity, and livelihoods. Conservation Biology 23(3), 520–530.

Yao T , Pu J , Lu A et al. (2007) Recent glacial retreat and its impact on hydrological processes on the Tibetan Plateau, China, and surrounding regions. Arctic, Antarctic, and Alpine Research 39(4), 642–650.

Zhao L, Ping CL, Yang DQ et al. (2004) Change of climate and seasonally frozen ground over the past 30 years in Qinghai-Tibetan Plateau, China. Global and Planetary Change 43, 19–31.

Zimmerer KS, Galt RE, Buck MV (2004) Globalization and Multi-spatial Trends in the Coverage of Protected-Area Conservation (1980–2000). Ambio 33(8), 520-529.

Zomer R, Sharma E, Oli KP, Chettri N. 2010. Linking biodiversity conservation and climate change perspectives in bio-culturally rich transboundary areas in the Kailash Sacred Landscape region of China, India, and Nepal. In Biodiversity and climate change: Achieving the 2020 targets, Abstracts of Posters Presented at the 14th Meeting of the SBSTTA of the CBD, May 2010, Nairobi, Kenya, CBD Technical Series No. 51, pp 142-144. Montreal: Secretariat of the CBD

Zomer RJ, Trabucco A, Metzger MJ, Wang M, Oli KP, Xu J (2014) Projected climate change impacts on spatial distribution of bioclimatic zones and ecoregions within the Kailash Sacred Landscape of China, India, Nepal. Climatic Change DOI 10.1007/s10584-014-1176-2

**Biography**

Dr Chettri joined ICIMOD in 2002 and worked in different capacities since then. He is responsible for facilitating stakeholders to formulate strategic plans for conservation and landscape management and for promoting regional cooperation in conservation through participatory conservation planning, policy analysis, and the development of a new policy framework at the landscape level in the Hindu Kush-Himalayas. Dr Chettri has an MSc (1995) and a PhD in Zoology (2000) from North Bengal University, India. Since January 2013, Dr Chettri is working as Sr Biodiversity Expert and leading a team of multidisciplinary professionals working on climate change science, the economic valuation of ecosystem services, biodiversity informatics, and the up-scaling and promotion of transboundary landscapes and trans-Himalayan transects in Kangchenjunga Landscape and Kailash Sacred Landscape. Before joining ICIMOD, Dr Chettri served as a Fellow at the Ashoka Trust for Research in Ecology and the Environment in its Eastern Himalayan Programme.