Himalayan Popular Lecture

Importance, Changes and Resilience Building in the Hindu Kush Himalaya

Eklabya Sharma
International Centre for Integrated Mountain Development
GPO Box 3226, Kathmandu Nepal

Organised by

G.B. Pant National Institute of Himalayan Environment & Sustainable Development
Kosi-Katarmal, Almora-263643, Uttarakhand
(12 July 2017)

Dr. Eklabya Sharma

Dr. Eklabya Sharma, Deputy Director General at the International Centre for Integrated Mountain Development (ICIMOD), is an ecologist with over 35 years of experience in developing, managing, and implementing programmes mainly on sustainable natural resource management.

Dr. Sharma has a PhD in ecology from Banaras Hindu University, India, where he started his career in 1985 as a postdoctoral fellow. Between 1989 and 2001, he established the GB Pant National Institute of Himalayan Environment and Sustainable Development in Sikkim, an autonomous regional research centre of the Ministry of Environment, Forest and Climate Change of the Government of India, as the founder Scientist In-Charge. In 1994, he spent some time at the University of Glasgow as a visiting scientist under the exchange programme between the Indian National Science Academy and the Royal Society of Great Britain. He joined ICIMOD in 2001 and has served as Programme Managers of Farming Systems; Natural Resources Management; Environmental Change and Ecosystem Services; and served six years as Director Programme Operations.

Dr. Sharma has received many national and international awards including the Young Scientist Award of the Indian National Science Academy in 1988; Eminent Scientist Award from the Ministry of Environment and Forests, Government of India in 1995; and Honorable Mention Paper Award from the Soil and Water Conservation Society, USA in 1999. He was elected Fellow of the National Institute of Ecology, New Delhi, India, in 1994; Fellow of the National Academy of Sciences, India, in 1999; and Fellow of the Indian National Science Academy, New Delhi, India in 2014. He has more than 200 publications to his credit, including 18 books, with the majority published in peer-reviewed international journals. He was the Chief Editor of the Journal of Hill Research published in Sikkim from 1992 to 1996 and was the Regional Editor for Asia of Mountain Research and Development between 2002 and 2010, and now serves on the international editorial board and one of the directors of this journal. He has supervised seven PhD theses on ecology, primarily dealing with natural resource management of the eastern Himalayas.

Dr. Sharma has expertise in research and development related to mountain ecology. He has made contributions to diverse fields of work, including mountain ecosystem studies and ecosystem management; participatory mountain development focusing on natural resource management and protected areas; appropriate technology development, demonstration and capacity building of mountain communities on farm productivity and sustainable natural resource management; biodiversity conservation (scientific and participatory monitoring); transboundary landscape conservation and development; biodiversity and ecotourism in mountain areas; mountain farming systems specializing in linkages such as agroforestry, forests and agriculture; and biogeochemical cycling in ecosystems with a special thrust on nitrogen fixation, phosphorus solubilization and biological maintenance of soil fertility; watershed management including land use and land cover change, hydro-ecological linkages and carbon dynamics; and climate change impact assessments and adaptations.

Himalayan Popular Lecture Series:

Admiring actions & opinions for sustainable development

The Himalaya is a world within itself with heterogeneous environment, diversity of landscapes, cultures, traditions, and climatic variability. Understanding of such a diverse system requires views, actions, opinions, experiences, and observations of a wide cross-section of the people who have lived and worked in/for Himalaya and are familiar with the grandeur, mythology, traditions, the inherent sanctity and fragility of this diverse challenging environment. This understanding requires knowledge of many other things beyond the wisdom of science and the logic. There are large number of outstanding scholars, practitioners, renowned specialists, grassroots-level workers, scientists, artists, activists, planners and community leaders in the Himalayan Region. Their competences and knowledge are to be utilized for the welfare of the region in the desired way. Considering this G.B. Pant National Institute of Himalayan Environment and Sustainable Development (GBPNIHESD) has initiated the 'Himalayan Popular Lecture Series' to advance general understanding on environment & development of the Himalayan region. The lecture series focuses to debate and discuss contemporary, pertinent, thought-provoking and inspirational issues that can play a key role in sustainable development of the region.

Introduction

Mountains provide more than 40% of global environmental goods and services. The ecosystem services arising from the Hindu Kush-Himalaya (HKH) in the form of water, biodiversity and niche products, hydroelectricity, timber, mineral resources, and recreation are enormous. This mountain region is enriched by a diversity of cultures, ethnic groups and traditional knowledge systems. Thus it is a paradox that, in spite of rich natural resources and cultures, poverty is widespread in the mountain region. Recently the HKH region has been facing many different types of changes driven by both internal and external forces including climate change. This article deals with mountain resources and services; the HKH region and its services; drivers of changes the region is facing and impacts; and how regional institution like ICIMOD and its partners are responding to these changes. The article also elaborates the progress on adaptation and evolving resilience building with solutions particularly focusing the HKH region.

Mountain resources and services

Mountains occupy 22% of the world's land surface area and 915 million people live in mountains with a further 14% living in their immediate vicinity (Meybeck et al. 2001; FAO 2015). Half of the humanity directly depends on mountain resources, particularly for water and biodiversity. The huge water storage capacity of mountains provides a lifeline for millions, in the form of snow, glaciers, permafrost, snow-packs, soil, or groundwater, wetlands, and rivers as well as through watershed functions increasing ground water recharge (Quyang 2009). This attribution often refers mountains as ''water towers'' specifically for contributions that they provide for densely populated downstream (Schild 2008; Molden and Sharma 2013). Ethnic diversity is higher in mountains than other regions of the world. Poverty and vulnerability remain with roughly 39% of mountain populations in developing countries who are also considered vulnerable to food insecurity (FAO 2015; ICIMOD 2017a).

Mountains comprise of the steep terrain with diverse climatic zones and fragmented landscapes; they are a storehouse of biological diversity in terms of both species diversity and endemism (IPCC 2007a, b; Korner 2009). Most of the 34 global biodiversity hotspots are in mountains, and they harbor quarter of global terrestrial biodiversity (ICIMOD 2009). Of the world's total acreage of land-based protected areas, about 28% is situated in mountains (Kollmair et al. 2005).

As mountain areas are repositories of biological and cultural diversity, they provide vital services with a tangible economic value – such as water, hydropower, tourism, minerals, medicinal plants, and fibres – to mountain communities and, even more important to downstream areas. About 13% of the world's population depends directly on mountain resources for their livelihoods and well-being, while an estimated 40% depend on them indirectly for water, hydroelectricity, timber, biodiversity, mineral resources, recreation, and flood management (Schild 2008; Schild and Sharma 2011; Molden and Sharma 2013; FAO 2015).

It is seen that the majority of mountains provide some of the last bastions of pristine, biodiverse 'islands' in a sea of transformed lowlands, providing a number of significant ecological functions extending beyond the mountains themselves benefiting entire river basins and countries (Hamilton 2002; Körner and Ohsawa 2005). Additionally, natural and semi-natural vegetation cover in mountains helps to stabilize headwaters, preventing flooding and maintaining steady year-round flows by facilitating the seepage of rainwater into underground aquifers.

Mountain areas are unique, characterized by limited accessibility and isolation, environmental fragility, social marginality, as well as rich and diverse natural resources. In addition to the vulnerabilities and fragilities, mountain areas are also resilient, a characteristic that helps people and communities survive and thrive in isolation. Such features are described as "mountain specificities" by many of those working in mountain regions and with mountain peoples (Jodha et al.1992). These features have biophysical and socio-economic dimensions, and most of them are directly or indirectly inter-linked. There has been general realization on the importance of mountain specificities and perspectives, but they are not usually mainstreamed in policy, planning and investments.

At the same time, the relevance of freshwater, biodiversity, traditional knowledge and identification with local values has brought mountains into focus and given them attention that these communities have never before experienced in modern times. Melting glaciers, intensification of floods and extended droughts are amongst the most visible and alarming signs of climate change. Compared to the situation during the 1992 "Rio Summit" - the United Nations Conference on Environment and Development in Rio de Janeiro, Brazil, mountain systems are now strategically seen as providers of ecosystem services, which are a prerequisite for food security and poverty reduction as well as a central argument for sustainable development especially given the effects of climate change. Small shifts in mountain climates can cause major problems in food security, especially in terms of water resources, potentially threatening the habitability of long-established communities (Schild and Sharma 2011).

Mountains have only recently begun to receive some attention, due in large part to the cascading impacts of climate change in mountain systems. Climate change and its impacts have raised a number of issues for which the relevance of mountains for providing global goods and services is realized. The enormous and often rapid economic growth in the vicinity of mountain regions; the dynamic development of

communication and transportation linking mountain regions with each other and with non-mountain regions; and the increasing globalization of international relations and exchange of goods and services have all influenced the evolution of mountain communities including the rapid expansion of urban centers in line with the world's urbanization trend. In fact, rapid urbanization, particularly through rural-to-urban migration, has led to increased marginalization for some of the most isolated mountain communities, often drawing out human and other resources which formed the resilient backbone of those locations (Schild and Sharma 2011; Molden 2015).

Hindu Kush Himalayan region and its services

The HKH region is characterized by rugged terrain with a harsh environment, and an extremely varied climate along the mountain chain extending 3500 km from Afghanistan to Myanmar.The HKH includes the Karakoram and Pamir ranges, as well as the Tibetan Plateau. These climatic and environmental conditions create challenges, but also a wide range of opportunities for livelihood options. Despite rich natural resources, they are home to some of the world's poorest peoples. The HKH region remains on the fringes of society - geographically, politically and economically marginalized. Language is a good indicator of ethnic diversity, and the endangerment and death of minority languages clearly indicates the threat to mountain cultures (Turin 2005).

Table 1: Geographical area, population, glacier coverage, major land-use, and protected area of countries within the HKH

Country	Total area within HKH[$]		Population in 2007	Glacier area[£]	Forest	Grassland, shrubland, and similar	Agricultural land[¥]	Protected area[€]	
	km^2	%	million	km^2	km^2		km^2	km^2	%
Afghanistan	391,560	61	28.48	2,677	2,179	235,935	94,577	2,461	<1
Bangladesh	15,543	11	1.33	-	4,920	7,912	2,723	632	4
Bhutan	39,837	100	0.71	680	28,739	3,994	2,897	12,681	32
China	2,395,105	26	29.48	29,529	228,699	1,388,496	688,294	1,522,172	64
India	404,701	13	72.36	12,296	140,097	137,806	99,886	62,417	15
Myanmar	323,646	49	11.01	24	143,588	112,488	63,747	23,967	7
Nepal	147,163	100	27.80	4,213	41,942	26,929	68,777	24,972	17
Pakistan	479,039	55	39.36	10,994	5,541	354,044	84,644	18,721	4
Total	**~4,190,000**		**210.53**	**57,736**	**595,705**	**2,267,600**	**1,105,546**	**1,668,023**	**40**

[$]approximate area; % total country area; [£] approximate area; [¥]includes irrigated and rainfed cropland and mosaic cropland/vegetation; [€] % of HKH area protected.

Sources: Bajracharya et al. (2010), Bajracharya and Shrestha (2011), Chettri et al. (2008), Singh et al. (2011), Globcover 2009 Version 2.3 from European Space Agency

The HKH range spans over 4.2 million km^2, including Bhutan and Nepal in their entirety and parts of six other countries, namely Afghanistan, Bangladesh, China, India, Burma, and Pakistan (Chettri et al. 2008; and Table 1) with widely varying geographical terrain, ecosystems, and a plethora of cultures. It is often referred to as the 'Third Pole' and the 'Water Tower of Asia', as it stores a large volume of water, particularly in the form of ice and snow, while regulating the flow of the ten major river systems in the region (Chettri et al. 2012; Figure 1).

The ethnic diversity and cultural wealth of the HKH region is enriched by the Hindu Kush valleys in Afghanistan; the high mountains of Nepal, India, and Pakistan; the Tibetan plateau of China; and the Three Parallel Rivers (consisting of the Irrawaddy, Salween and Yangtze gorges) in the far southwest Yunnan of China. Throughout human history, the region has often been a hotspot for political and military conflict, which continues today in locations such as Afghanistan and the Siachen Glacier. The Gangetic Plain, Indus Delta and Bangladesh floodplains are historically unique systems of global importance, which have produced food and been the backbone of cultural and economic development in the region for millennia. Recently, changes in the river systems and their basins have directly impacted the wellbeing of millions of people (Schild 2008).

The mountain cultures live with rich and remarkable biodiversity (Pei 1995; Brooks et al. 2006). The region, with its varied landscapes and soils, plus its variety of vegetation types and climatic conditions, is well known for its unique flora and fauna showing high endemism (Myerset al.2000). Elevation zones across the HKH extend from tropical (< 500 meters above sea level) to alpine ice-snow (> 6000 meters above sea level), 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; Guangwei 2002). Endowed with a rich variety of gene pools and species, it incorporates numerous ecosystems of global importance by holding parts of four 'Global Biodiversity Hotspots': the Himalayan, Indo-Burman, the Mountains of South-West China, and the

Mountains of Central Asia hotspots (Mittermeieret al. 2004). Approximately 39% of the HKH is managed under protected areas (Chettri et al. 2008; Table 1).

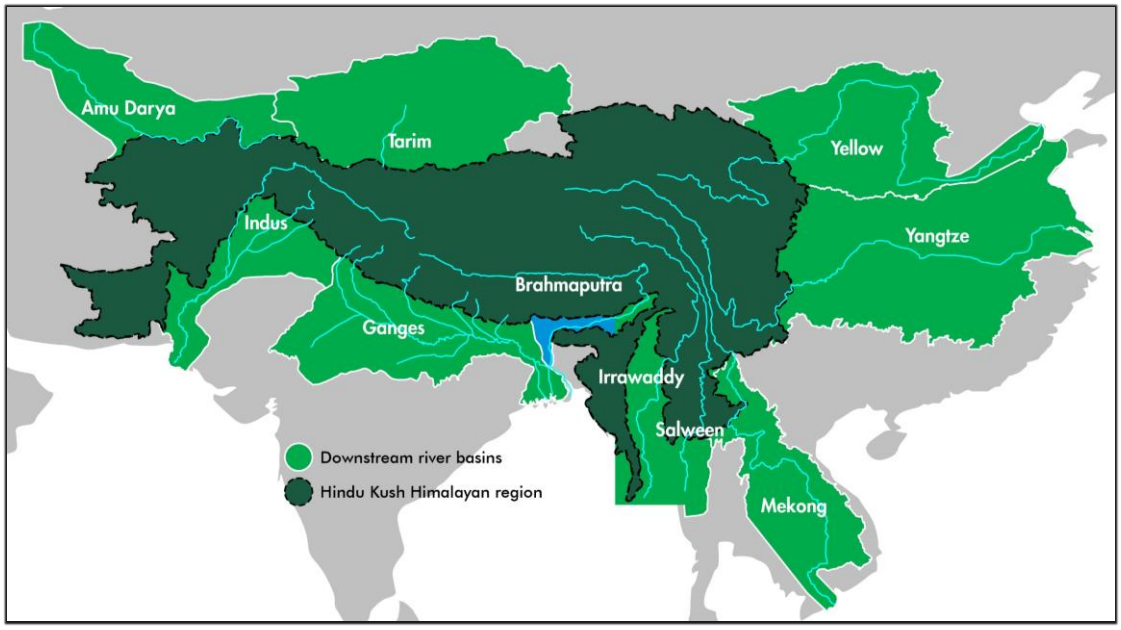

Figure 1: Map of Hindu Kush Himalaya showing mountain region (dark green) and downstream basin (light green).

The HKH region plays an important role in global atmospheric circulation, biodiversity, and the hydrological cycle, in addition to the unparalleled beauty of its landscape and provision of other ecosystem amenities. The uniqueness of the HKH is amply demonstrated by the fact that the world's tallest ten mountains are all located in the region. The HKH region is also home to many diverse ethnic communities speaking about 1000 different living languages and dialects, with enormous socioeconomic and cultural diversity (Turin 2005). These communities practice a variety of traditional livelihoods, including diverse farming approaches, which have exploited agricultural land and reaped harvests sustainably despite harsh environment. A recent analysis shows that 31% of the HKH population lived below the poverty line, compared to 26% as the national average of these countries, indicating that mountain peoples are poorer than those in non-mountain areas (Hunzai et al. 2011).

The growing awareness of the importance of the HKH region gives new significance to the development discussion of upstream-downstream relations. An important question is how services from mountains provided to those in the downstream areas who reap the rewards compensate upstream areas. That is, what are the policies and strategies, which make the services sustainable in the interest of regional development, factoring in mountain and non-mountain interests, and brining in more investments to the HKH region.

Drivers of change and impacts

Climate change, globalization, land use change and population dynamics such as migration are the main drivers of change in the HKH region. These drivers have changed the livelihoods of mountain people, increasing their economic and environmental vulnerabilities dramatically. Disasters such as floods related vulnerabilities of mountain and downstream population have immensely increased in recent past. The sources of these drivers are both internal and external to the HKH region. And they mutually reinforce the effects they have on human wellbeing, and natural resource availability and use. Because these changes impact entire river basins, their effect extends far beyond the HKH, eventually having global influences (ICIMOD 2007; Singh et al. 2011).

Intergovernmental Panel on Climate Change (IPCC) provided overwhelming evidence of the global relevance of human-caused climate change. The last two-assessment reports (IPCC 2007a, 2014) show that the warming of the global climate system is unequivocal. Climate change has thus emerged as a prominent force in global change; however, it is embedded in a matrix of drivers including globalization, population dynamicslikeout-migration, and local land-use changes. This presents challenges in the disaggregation of climate change impacts from other factors, augmenting the complexity involved in dealing with the experiences of changes on the ground. According to the IPCC (2007a), the HKH region is a 'data deficit region' in that it lacks consistent long-term data, which would help to identify changes and develop approaches to deal with them. The IPCC (2014) assessment report is still not representing the HKH region well. This results into a reason for strong call towards global, regional, and national attention to fill this data gap, in addition to drawing on local sources and traditional knowledge to combine with external

observations. During the past ten years, significant progress has been made to address the 'data gap' issue in the HKH region, especially in areas of rich biodiversity and snow and ice-dominated areas (Chettri et al. 2008; Sharma et al. 2010; Bajracharya and Shrestha 2011; Lutz et al. 2014; Shrestha et al. 2015).

The data that are available around the HKH show consistent trends in overall warming over the past 100 years (Du et al. 2004; IPCC 2007a), with indications that temperatures are rising at higher rates in higher altitude areas. Studies in Nepal, China and the Eastern Himalayas have shown that temperatures are rising at higher rates in high altitude areas than elsewhere (Shrestha and Devkota 2010). There is a distinct rise in temperature from the foothills to the trans-Himalayan region in Nepal (Table 2). With rising temperatures, the areas covered by permafrost and glaciers are decreasing in much of the region. Many of the Himalayan glaciers are receding at a rate faster than the world average while others are currently advancing with observed 'glacial surging' occurring locally in the Karakoram sub-range in Northern Pakistan also being linked to climate change. In many areas, a greater proportion of total precipitation appears to be falling as rain. As a result, snowmelt begins earlier and winters are shorter. This affects river regimes, ecosystem services including water supply and livelihoods, as well as causing or exacerbating natural hazards such as floods, droughts, and landslides (Xu et al. 2007; Sharma et al. 2009; Tse-ring et al. 2010; Singh et al. 2011).Lutz et al. (2014) projected that by 2050 there will not be any decrease on annual volumes of water, however glacier dependent Indus may start water shortage while the eastern region shall receive similar amounts of rainfall.

Table 2. Regional mean temperature trends of Nepal for the period 1977–2000 (°C per year)

	Seasonal				Annual
Regions	Winter	Pre-monsoon	Monsoon	Post-monsoon	Jan-Dec
	Dec-Feb	Mar-May	Jun-Sep	Oct-Nov	
Trans-Himalaya	0.12	0.01	0.11	0.10	0.09
Himalaya	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
All Nepal	0.06	0.03	0.051	0.08	0.06

Source: Update after Shrestha et al. (1999) and Xu et al. (2007)

Temperature in the HKH region is projected to be increasing by 1-2 °C in general and in some high altitude areas up to 4-5 °C by 2050 (Shrestha et al. 2014). The 1.5 °C world as agreed in Paris UNFCCC 2015 even if achieved then for the HKH region temperature rise is expected to be higher by 2-3 times. This means the mountains and especially the HKH region should receive different approaches and investment for adaptation and building resilience.

Mountains are also unique areas for detecting and assessing climate change (Nogués-Bravo et al. 2008). They are recognized as 'hotspots' of climate change largely due to the increasing rate of glacial ice loss driven by an increase in global mean air temperatures (Dyuergerov and Meier 2005; Kaltenborn et al. 2010; Lutz et al. 2014). But they also warrant special focus in the context of global change due to their extreme diversity. Rapid elevation changes over short distances translate into remarkably varied climatic conditions, vegetation, hydrology, ecology, and even socio-economic settings (Xu and Melick 2006; Shrestha et al. 2015). This, in turn, is reflected in the richness of mountain cultures, however not at the expense of recognizing the complexities of environment-society interactions. People and the environment influence each other in complex, often sustainable systems of coexistence Biodiversity often increases proportionately with cultural diversity in mountain areas (Turin 2005), and also creates the basis for varied livelihood options due to a broad base of natural resources. Nonetheless, mountain cultures and communities have been recognized as particularly vulnerable to the negative impacts of climate change.

Climate change affects all aspects of life, making rainfall less predictable, changing the character of the seasons, and increasing the likelihood and severity of some extreme events such as certain types of floods and droughts. Assessing the impacts of and vulnerability to climate change, and subsequently working out adaptation needs requires good quality information from multiple sectors and disciplines including climate, hydrology, agriculture, economics, livelihoods, and social sciences (Fischer et al. 2002; Schröter et al. 2005). Available analyses and projections show increasing magnitudes of change with elevation, both in mean shifts in temperature and in greater precipitation variations. Climate change is poised to alter the delicate balance in which HKH communities and their environments have frequently achieved over centuries with far-reaching consequences for the condition of biodiversity, ecosystems, livelihoods, development, sustainability and well being of the environments and communities in the region (Sharma et al. 2009; Singh et al. 2011; Tse-ring et al. 2010).

The land use and land cover changes in the HKH region are influenced by various factors. Land cover depicts distinctly the ecological zonation in the HKH. When examining biodiversity, the HKH region is facing tremendous change through species loss and extinction from habitat degradation and the fragmentation of landscape elements (Myers et al. 2000; Ives et al.1997; Pandit et al. 2007). Natural resource availability in the HKH region is declining, mainly due to lack of incentives for local communities to conserve biodiversity and water resources. This leads to development that is environmentally unfriendly, including loss of resources and services, which in turn, eventually hurts the communities. In recent decades, there has been significant development in biodiversity conservation policies and practices in the region from 'people exclusionary' and 'species focused' approaches to 'people-centered' and 'community based' approaches using an ecosystem/landscape-scale perspective that combines ecosystem management with local livelihoods, thereby reducing competition between uses (Sharma et al. 2010).

Human migration also characterizes the HKH region, both domestically and internationally, and across timescales such as seasonally, annually, and permanently. Rural-urban migration is one of the most widespread global demographic trends, which is also predominant in the HKH. Overall effects of global change have increased migration considerably, particularly among young people (Hoermann and Kollmair 2009). Migration has both negative and positive consequences in the development of the HKH region. On the one hand, it brings substantial remittances and reduces population-related pressures in isolated communities. On the other hand, because labor outmigration is predominantly male dominated, that leaves women and children behind to take on the burden of managing resources. This in turn drives more rural-urban migration in a vicious cycle. Migration is thus one of the major drivers of change in the region.

Responding to change

ICIMOD and its partners have embarked on many HKH-level studies to address the challenges related to the data gap both on physical and social aspects. Climate change has added another layer of complexity to the challenges. Managing protected areas with various important elements of biodiversity (Chettri et al. 2008), paradigm shifts in conservation policies and practices around the HKH (Sharma et al. 2010), and analyses of implementation of Convention on Biological Diversity by HKH countries (Desaiet al. 2011), amongst many other initiatives, have been prepared for promoting protection of ecosystem services and ecosystem-based livelihoods. Transboundary landscape management has begun in a number of locations for enhanced ecosystem services, with prominent examples including the 'Kailash Sacred Landscape' (China, Nepal, and India), 'Kangchenjunga Landscape' (Bhutan, China, Nepal, and India), Far Eastern Himalayan Landscape (China, India and Myanmar) and the Hindu Kush Karakoram Pamir Landscape (Afghanistan, China, Pakistan and Tajikstan) (Chettri et al. 2007; Zomer and Oli 2011;Joshi et al. 2013; Kotru et al. 2014; Wu et al. 2016; Chettri and Sharma 2016; ICIMOD 2017a).

The countries in the region have started realizing on the need for regional cooperation with good science and data support in combating challenges of climate change. For instance, ICIMOD has mapped the HKH's cryosphere. The total number of glaciers is 54,820 covering 60,411 km^2 area and having 6,101 km^3 of ice. Maximum snow cover extent is 760,000 km^2 which is 18.23% of the HKH's total area. Glacial lakes number 20,485 with 4,320 km^2 area and their distribution pattern has also been mapped. These data will serve as baselines for monitoring and responding to future changes (Bajracharya and Shrestha 2011; Gurung et al. 2011).

Furthermore, HKH countries have accepted the importance of climate change and the need for regional understanding and development of frameworks for national action. India and China have prepared national action plans for climate change. India has taken a step further where, amongst other approaches, the "National Mission for Sustaining the Himalayan Ecosystem", which aims to evolve management measures for sustaining and safeguarding Himalayan glaciers and mountain ecosystems (GoI 2008). The mission, among other statements, aims to: (i) improve the understanding of the cryosphere; (ii) establish an observational and monitoring network for the Himalayan environment; and (iii) promote community-based management through incentives to community organizations for protecting forested lands.

Similarly, countries like Bhutan, Bangladesh and Nepal have prepared 'National Adaptation Programs of Action' (NAPAs), while other HKH countries are still preparing them. In some countries, 'Local Adaptation Programs of Action' (LAPAs) are also being worked on. More recently, Nepal has started preparing the 'National Adaptation Plans (NAP)" while some other HKH countries are also considering to follow the NAP approaches. Research capacities are being built and developed for monitoring the cryosphere while glaciological studies, ecological studies, and human studies are being expanded to focus on the mountain region.

It is realized that local adaptation needs can be better framed, especially within the national and local contexts in which they operate. Consequently, those working on climate change topics in the HKH can ensure that modeling and top-down endeavors not only produce solid cutting-edge science, filling in the data gap and supporting the tools needed to understand changes, but are also useful for those who need the results most in order to deal with climate change. One example is the publication of 'The Himalayan Climate and Water Atlas' based on research in sub-basins in Indus, Koshi, upper and middle Brahmaputra, and Salween-Mekong (Shrestha et al. 2015). The research results are used to formulate key messages and policy recommendation for policy makers of the HKH region.

At the community level climate smart villages was tested in Kavre District of Nepal where simple, affordable and replicable technologies and approaches were tested with the women groups bringing substantial benefits to local communicates on adaptation strategies. This has also adopted the ICIMOD approach for developing resilient solutions considering climate, socio-economic and future resilience for application in the HKH region (ICIMOD 2017b)

Building resilience with solutions

The HKH region is a hotspot of climate change and communities in this region are vulnerable to the impacts of climate change (Macchi et al. 2014; Gerlitz et al. 2014; ICIMOD 2015). People in HKH are highly dependent on the natural resource base for their livelihoods, and tend to live a subsistence lifestyle, making the most of marginal lands in a challenging climate with limited resources and little opportunity to build up surplus resources as a buffer against extremes and disaster (Molden 2015). People are facingthe changes related to economic development, urbanization, rapid population growth, and migration, particularly outmigration of men. Climate change further compounds the already challenging problem of ensuring sufficient food, water, and energy to meet growing demand (Rasul2014). But people are adaptable, and adaptation in the HKH as elsewhere means a process both of adjusting to climate and other changes and exploiting the opportunities they present to achieve a positive transformation (ICIMOD 2015).

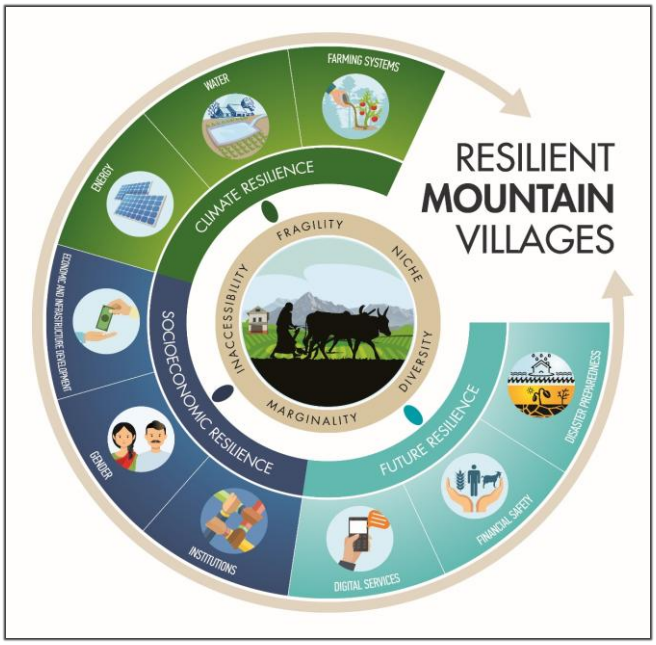

Figure 2: ICIMOD's Resilient Mountain Solution approach.

The mountain context, with its 'specificities' like inaccessibility, fragility, and marginality makes resilience building pre-requisite to achieving sustainable development goals (SDGs). There are many ways in which the mountain 'specificities' can hinder/constrain efforts on SDGs achievement. 'Inaccessibility' imposes restrictions on development interventions and aggravates the impacts of disasters by challenging timely post-disaster relief, recovery and rehabilitation efforts; the 'fragility' of mountain environment makes the ecosystem and communities dependent on them extra vulnerable to disaster-related disturbances, often resulting in irreversible loss of ecosystem services and functioning; and 'marginality' implies inadequate development governance and poverty alleviation efforts (ICIMOD 2017b; Mishra et al. 2017).

There has been some progress in adaptation research, demonstration of adaptive approaches, building adaptive capacities of communities and developing plans for action by countries. However, it is being realized that changes are so rapid that just adaptation approaches may not be sufficient for the mountain regions. Moving forward from adaptation to resilience building of the communities is becoming more relevant for the mountain regions.

It is realized that if the resilience and wellbeing of mountain systems are not maintained and built up, then it is likely to impact resilience capacities in the downstream populations as well. There are some examples such as clear links between snow and glaciers melt in the mountains and water availability in the plains; and land degradation and crop depredation leading to abandoning of mountain agriculture. It is essential for institutions and governments to realize this upstream-downstream linkage and frame the policies in this line. The HKH region especially transboundary ecosystem services must receive attention to such linkages otherwise there could be even greater challenge for resilience building in the region.

Sustainable and resilient mountain development efforts of ICIMOD build on resilience of mountain socio-ecological systems. Initiatives like setting up resilient mountain village, developing sustainable value chains, preparing participatory natural resource management plans, and optimizing ecosystem management, are a few examples in contributing to community level resilience building (ICIMOD 2017b).

ICIMOD while piloting the adaptation to climate change demonstrated various climate smart agriculture practices. In this process local communities quickly adopt climate smart village practices. However, we realized that adaptation measures are not adequate when mountain specificities and challenges are not considered holistically. Using the mountain specificities as basic context a "Resilient Mountain Solution (RMS)" approach has been developed (ICIMOD 2017a). RMS constitutes of climate resilience with farming systems, water and energy solutions; socio-economic resilience with solutions on infrastructure and income

generation, gender and institutions; and future resilience with solutions on digital services, financial safety and disaster preparedness (Figure 2). This approach is being tested across the HKH region by ICIMOD and its partners, and will be further promoted in coming years.

It is vital that we understand what factors can contribute to building resilience in different social-ecological contexts and draw priorities for research and action. Way forward on resilience building is to understand dynamic relationship and interaction between socio-economic and ecological systems; measure, monitor and evaluate 'resilience' of complex socio-ecological systems; develop regional approach to building resilience in areas of transboundary landscapes and river basins; and achieve policy uptake using experience of solutions which are simple, affordable and replicable for the mountain communities.

Conclusion

The mountains provide enormous good and services, however they have not received enough attention in global, regional and national policies for more investment in research and development. This paradigm has to change if impacts of climate change are to be reduced for people both in mountains and those living in downstream regions, and also in achieving sustainable development goals by 2030. The increasing awareness of the impacts of climate change on mountains, mountain ecosystems, and mountain communities, and the consequences these pose for the rest of the world, mountains need to be at the center of international debate on good science and policies. The HKH region is rich in natural resources and provides ecosystems services to 210 million people living in the mountains and 1.3 billion people in the downstream. The region is fragile, vulnerable and poverty has become a most critical issue. Good science for supporting decision-making and regional cooperation among the HKH countries are crucial to meet the challenges of changes recently faced by the HKH region. In addressing issues related to poverty, reducing physical and social vulnerabilities, and enhancing the ecosystem services, we realize that the resilience building with solutions acceptable to mountain communities are extremely crucial. There is a need for research, development and policies to implement adaptation more rigorously and move towards resilience building especially in the context of the HKH region.

References

Bajracharya SR, Shrestha B (eds) (2011) *The status of glaciers in the Hindu Kush-Himalayan region*. ICIMOD, Kathmandu, Nepal

Bajracharya SR,Maharjan SB, Shrestha F, Khattak GA, Wanqin G, Junfeng W, Shiyin L, Xiaojun Y (2010) *The status of glaciers in the Hindu Kush-Himalayas*. ICIMOD, Kathmandu, Nepal

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

Chettri N, Sharma E (2016) Reconciling the Mountain Biodiversity Conservation and Human Wellbeing: Drivers of Biodiversity Loss and New Approaches in the Hindu-Kush Himalayas. *Proceedings of the Indian National Science Academy*82: 53-73

Chettri N, Sharma E, Shakya B, Bajracharya B (2007) Developing forested conservation corridors in the Kangchenjunga landscape, Eastern Himalaya. *Mountain Research & Development* 27(3), 211-214

Chettri N, Shakya B, Thapa R, Sharma E (2008) Status of a protected area system in the Hindu Kush-Himalayas: An analysis of PA coverage. *International Journal of Biodiversity Science & Management* 4(3), 164–178.

Chettri N, Shrestha A, Zhaoli Y, Bajracharya B, Sharma E, Quyang H (2012)Real World Protection of the 'Third Pole and its People' Chapter 5, pp. 113-133. In Falk Huettmann (ed) *Protection of Third Poles*. Springer

Desai BH, Oli KP, Yongping Y, Chettri N, Sharma E (2011)*Implementation of the Convention on Biological Diversity: A Retrospective Analysis in the Hindu Kush-Himalayan Countries*. ICIMOD, Kathmandu, Nepal

Du MY, Kawashima S, Younemura S, Zhang XZ, Chen SB (2004) 'Mutual influence between human activities and climate change in the Tibetan plateau during recent years.' *Global Planetary Change* 41: 241–249

Dyurgerov MD, Meier MF (2005) Glaciers and changing earth system: a 2004 snapshot. INSTAAR, University of Colorado, Occasional Paper No. 58. Boulder: Institute of Arctic and Alpine Research, University of Colorado.

FAO (2015) *Mapping the vulnerability of mountain peoples to food insecurity*. Food and Agriculture Organization of the United Nations, Rome, Italy.

Fischer G, Shah M, van Velthuizen H (2002) *Climate change and agricultural vulnerability*. (International Institute for Applied Systems Analysis special report to the UN World Summit on Sustainable Development, Johannesburg 2002). Laxenburg, Austria: IIASA.

Gerlitz V, Banerjee S, Hoermann B, Hunzai K, Macchi M, Tuladhar S(2014) Poverty and vulnerability assessment: A survey instrument for the Hindu Kush Himalayas. ICIMOD, Kathmandu, Nepal

GoI (2008) *National Action Plan Climate Change. Prime Minister Council on Climate Change*. Government of India, pp. 48, New Delhi, India

Guangwei C (2002) *Biodiversity in the Eastern Himalayas: Conservation through dialogue*. ICIMOD, Kathmandu, Nepal

Gurung DR, Giriraj A, Aung KS, Shrestha B, Kulkarni AV (eds.) (2011)*Snow-Cover Mapping and Monitoring in the Hindu Kush-Himalayas.* ICIMOD, Kathmandu, Nepal

Hamilton LS (2002) Why Mountains Matter. World Conservation. Mountain High. *The IUCN Bulletin*, 1. Gland, Switzerland: IUCN, The World Conservation Union.

Hoermann B, Kollmair M (2009) *Labour migration and remittances in the Hindu Kush-Himalayan Region*. ICIMOD, Kathmandu, Nepal

Hunzai K, Gerlitz JY, Hoermann B (2011) *Understanding Mountain Poverty in the Hindu Kush-Himalayas: Regional Report for Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan*. ICIMOD, Kathmandu, Nepal

ICIMOD (2007) *Strategy on Partnerships for Sustainable Development of the Hindu Kush-Himalayas*. ICIMOD, Kathmandu, Nepal

ICIMOD (2009) *Mountain biodiversity and climate change*. ICIMOD, Kathmandu, Nepal

ICIMOD (2015) *Scientific framework for ICIMOD's regional programme on adaptation to change*, ICIMOD Working Paper 2015/1.ICIMOD, Kathmandu, Nepal

ICIMOD (2017a) *ICIMOD Strategy and Results Framework*. ICIMOD, Kathmandu, Nepal

ICIMOD (2017b) *ICIMOD's Medium-Term Action Plan IV (2018-2022)*.ICIMOD, Kathmandu, Nepal

IPCC (2007a) *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge and New York

IPCC (2007b) *Climate change 2007: The scientific basis, Working Group I contribution to the Intergovernmental Panel on Climate Change Fourth Assessment Report*. Cambridge University Press, Cambridge, UK

Ives JD, Messerli B, Spiess E (1997) Mountains of the world: A global priority. pp. 1-15. In B. Messerli & J. D. Ives (Eds.) *Mountains of the world: A global priority*. Parthenon, New York & London

Jodha NS, Banskota M, Partap T (eds.) (1992) *Sustainable mountain agriculture* (Vols. 1 – 2).IBH Publishing Company, New Delhi

Joshi S, Jasra WA, Ismail M, Shrestha R, Yi SL, Wu N (2013) Herders' Perceptions of and Responses to Climate Change in Northern Pakistan. https://link.springer.com/article/10.1007/s00267-013-0062-4

Kaltenborn BP, Nellemann C, Vistnes II (eds.) (2010)*High mountain glaciers and climate change – Challenges to human livelihoods and adaptation,* United Nations Environment Programme Report, GRID-Arendal, Norway

Kollmair M, Gurung GS, Hurni K and Maselli D (2005) Mountain: Special places to be protected? An analysis of worldwide nature conservation efforts in mountains.*International Journal of Biodiversity Science and Management* 1:181-189

Körner C (2004) Mountain biodiversity, its causes and function. *Ambio*, Special Issue 13:11–17

Körner C, Ohsawa M (2005) Mountain systems. pp. 681-716. In R. Hassan, R. Scholes, N. Ash (Eds.), *Ecosystems and human well-being: current state and trends. Millennium Ecosystem Assessment, Volume 1*. Island Press, Washington D.C.

Kotru R, Rawal RS, Mathur PK, Chettri N, Chaudhari SA, Uddin K, Murthy MSR, Singh S (2014) Effective Management of Trans boundary Landscapes-Geospatial Applications. ISPRS-*International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* 1:1309-1317

Lutz AF, Immerzeel WW, Shrestha AB, Bierkens MFP (2014) Consistent increase in High Asia's runoff due to increasing glacier melt and precipitation. *Nature Climate Change* 4(7): 587–592

Macchi M, Gurung AM, Hoermann B (2014) Community perceptions and responses to climate variability and change in the Himalayas. *Climate and Development* 1–12.

Meybeck M, Green P, Vörösmarty C (2001) A new typology for mountains and other relief classes: An application to global continental water resources and population distribution.*Mountain Research and Development* 21: 34-45

Mishra A, Rucha G, Maharjan A, Gurung J, Pathak G, Upraity AN (2017) Building ex ante resilience of disaster-exposed mountain communities: Drawing insights from Nepal earthquake recovery. *International Journal of Disaster Risk Reduction* 22: 167-178

Mittermeier RA, Robles Gil P, Hoffman M, Pilgrim J, Brooks T, Mittermeier CG, Lamoreux J, da Fonseca GAB (2004) *Hotspots revisited: Earth's biologically richest and most endangered terrestrial ecoregions*. CEMEX, Mexico

Molden D (2015) *Climate Plus Change: Actions for Adaptation and Transformation for the Hindu Kush-Himalayan Region*. G. B. Pant Memorial Lecture, GBPNIHESD, Koshi-Katarmal, Almora, India.

Molden D, Sharma E (2013) ICIMOD's Strategy for Delivering High-quality Research and Achieving Impact for Sustainable Mountain Development. *Mountain Research and Development*, Vol. 33 (2): 179-183.

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

Nogués-Bravo D, Araújo MB, Romdal T, Rahbek C (2008) Scale effects and human impact on the elevational species richness gradients. *Nature*, 453(8) 216-219.

Ouyang H (2009) The Himalayas – water storage under threat. *Sustainable Mountain Development* 56: 3-5

Pandit MK, Sodhi NS, Koh LP, Bhaskar A, Broo BW (2007) Unreported yet massive deforestation driving loss of endemic biodiversity in Indian Himalaya. *Biodiversity and Conservation* 16: 153–163

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

Rasul G (2014) Food, water, and energy security in South Asia: A nexus perspective from the Hindu Kush Himalayan region. *Environmental Science and Policy* 39: 35–48

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

Schild A, Sharma E (2011) Sustainable mountain development revisited. *Mountain Research and Development* 31: 237–241

Schröter D, Cramer W, Leemans, R, Prentice IC, Araújo MB, Arnell NW …… Zierl B (2005) Ecosystem service supply and human vulnerability to global change in Europe. *Science*, 310(5752): 1333-1337

Sharma E, Chettri N, Tse-ring K, Shrestha AB, Jing F, Mool P, Eriksson M (2009) *Climate Change Impacts and Vulnerability in the Eastern Himalayas*. ICIMOD, Kathmandu, Nepal

Sharma E, Chettri N, Oli K (2010) Mountain Biodiversity Conservation and Management: A Paradigm Shift in Policies and Practices in the Hindu Kush-Himalayas. *Ecological Research* 25: 909-923

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. ICIMOD, Kathmandu, Nepal

Shrestha AB, Wake CP, Mayewski PA, Dibb JE (1999) Maximum temperature trends in the Himalaya and its vicinity: Analysis based on temperature records from Nepal for the period 1971-94. *Journal of Climate* 12: 2775-2787

Shrestha AB, Agrawal NK, Alfthan B, Bajracharya SR, Merechal J, van Ort B (eds.) (2015) *The Himalayan Climate and Water Atlas: Impacts of Climate Change on Water Resources in Five of Asia's Major River Basins*. ICIMOD, GRID-Arendal and CICERO.

Shrestha MS, Kafle S, Gurung MB, Nibanupudi HK, Khadgi VR, Rajkarnikar G (2014) *Assessment of flood early warning systems from a gender perspective: Nepal study*, ICIMOD Working Paper 2014/4. ICIMOD, Kathmandu, Nepal

Singh SP, Bassignana-Khadka I, Karky BS, Sharma E (2011) *Climate change in the Hindu Kush-Himalayas: The state of current knowledge*. ICIMOD, Kathmandu, Nepal

Tse-ring K, Sharma E, Chettri N, Shrestha A (eds.) (2010)*Climate change vulnerability of mountain ecosystems in the eastern Himalayas - Synthesis report*. ICIMOD, Kathmandu, Nepal

Turin M (2005) Language Endangerment and Linguistic Rights in the Himalayas: A Case Study from Nepal. *Mountain Research and Development* 25(1): 4-9.

Wu N, Yi S, Joshi S, Bisht N (eds) (2016) *Yak on the Move: Transboundary Challenges and Opportunities for Yak Raising in a Changing Hindu Kush Himalayan Region*. ICIMOD, Kathmandu, Nepal

Xu J, Melick D (2006) Emancipating indigenous knowledge: can traditional cultures assist Himalayan sustainable development? *Sustainable Mountain Development in the Greater Himalayan Region* 50: 31-35

Xu J, Shrestha A, Vaidya R, Eriksson M, Hewitt K (2007)The melting Himalayas: Regional challenges and local impacts of climate change on mountain ecosystems and livelihoods. ICIMOD Technical Paper, Kathmandu, Nepal

Zomer R, Oli KP (2011) *Kailash Sacred Landscape Conservation Initiative – Feasibility Assessment Report*. ICIMOD, Kathmandu, Nepal

G.B. Pant National Institute of Himalayan Environment and Sustainable Development

G.B. Pant National Institute of Himalayan Environment & Sustainable Development (formerly known as G.B. Pant Institute of Himalayan Environment & Development) was established in 1988-89, as an autonomous Institute of the Ministry of Environment, Forest & Climate Change (MoEF&CC), Govt. of India. The Institute is identified as a focal agency to advance scientific knowledge, to evolve integrated management strategies, demonstrate their efficacy for conservation of natural resources, and to ensure environmentally sound development in the entire Indian Himalayan Region (IHR). The Institute attempts to maintain a balance of intricate linkages between socio-cultural, ecological, economic and physical systems that could lead to sustainability in the IHR. To achieve this, the Institute follows a multidisciplinary and holistic approach with due consideration of fragility of mountain ecosystems, indigenous knowledge communities and sustainable use of natural resources. A conscious effort is made to ensure participation of local inhabitants and other stakeholders through training, environmental education and awareness for long-term acceptance and success of various programmes.

Himalayan Popular Lectures organized so far…

1. **Shri S.S. Garbyal**, Director General & Special Secretary, MoEF&CC, Govt. of India, New Delhi (May 15, 2014)
2. **Prof. Tamo Mibang**, Vice Chancellor, Rajiv Gandhi University, Arunachal Pradesh (September 10, 2014)
3. **Shri K.C. Pradhan**, Former Chief Secretary, Govt. of Sikkim, Gangtok, Sikkim (September 10, 2014)
4. **Shri Vijay Jardhari**, Environmentalist, Beej Bachaon Andolan, Tehri (September 10, 2014)
5. **Shri B.S. Parsheera**, Former Secretary, Ministry of Home Affairs, Govt. of India (September 10, 2014)
6. **Prof. K.S. Valdiya**, Honorary Professor, JNCASR, Bangalore (October 28, 2014)
7. **Shri Chandi Prasad Bhatt**, Dasholi Gram Swaraj Mandal, Gopeshwar, Uttrakhand (April 22, 2015)
8. **Prof. P.K. Das**, Director, North Eastern Regional Institute of Science and Technology (September 10, 2015)
9. **Prof. U.S. Rawat**, Vice Chancellor, Sri Deb Suman University, Tehri Garhwal (September 10, 2015)
10. **Prof. K.K. Katoch**, Vice Chancellor, Ch. Sarvan Kumar HP Agri. Univ., Palampur, H.P. (September 10, 2015)
11. **Sh. Sonam Wangdii,** Former Chief Secretary, Govt. of Sikkim, Gangtok (September 10, 2015)
12. **Dr. Edwin Bernbaum**, Co-Chair, IUCN Group on CSVPA, USA (January 25, 2016)
13. **Mr. Omkar Singh**, PCCF & Principal Secretary, Govt. of Arunachal Pradesh (September 10, 2016)
14. **Dr. Bharat Jhunjhunwala**, Lachmoli, Bagwan, Srinagar (Garhwal), Uttarakhand (September 10, 2016)
15. **Dr. Sanjay Kumar**, Director, IHBT, Palampur, H.P. (September 10, 2016)
16. **Prof. S.G. Tashi**, Vice Chancellor, CFAI University, Sikkim (September 10, 2016)
17. **Ms Radha Bhatt**, Lakshmi Ashram, Post Kausani, Dist.Almora, Uttarakhand (March 8, 2017)
18. **Dr. D.K. Agrawal,** Former Member, National Green Tribunal, New Delhi – 110 070 (June 5,