Perspectives on Climate Change and the Himalayas

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Abstract

Though the impacts of these vagaries in climate would be felt all across the world, the immediate repercussions are likely to be local; and the Himalayas are especially vulnerable to these impacts. The region suffers from a severe paucity of information on status of climate change and its impacts. There is need for a sound understanding and real-time information on the nature, extent, and impacts of ecological change, such that scientific and appropriate conservation/adaptation planning and action could be undertaken, at the national and global level through area-specific research and micro-level studies involving local communities. The review paper explores some of the most pressing issues in the region pertaining to climate change, the status of research and initiatives by various stakeholders in the region and the gaps that still need to be addressed.

Key words

Climate change, Himalaya, climate injustice, glaciology, hydrology, ecosystem, biodiversity, disaster, livelihood, participative, adaptation

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Introduction

Climate Change at the 'Third Pole'

"Climate Change", a global phenomenon is one of the most widely deliberated issues in today's time and has come to be a major cause of concern worldwide for all levels of stakeholders right from the communities to climate experts and the policy shapers. It is also beginning to be recognized that though the impacts of these vagaries in climate would be felt all across the world, the immediate repercussions are likely to be local; and the Himalayas are especially vulnerable to these impacts. This becomes a grave issue of concern, for the Himalayas being the feeding source some of Asia's major rivers support not just the indigenous communities residing here but also millions of people living downstream. In essence, they support 'half the humanity' and thus any climate-induced threat would be putting billions of lives at risk. Outside the polar region, the Himalayas have the maximum concentration of glaciers and snow and is often referred to as the "Third Pole". Many are of the opinion that when it comes to the present degree of threats from climate change, the region may rank first.

Probably everyone has heard about the effects of climate change in the Himalayas, but how serious is it? To what extent does this affect the present and future populations? Are modern strategies providing effective solutions? The review paper seeks to provide answers to some of these pertinent questions. It explores some of the most pressing issues in the region pertaining to climate change, the status of research and initiatives by various stakeholders in the region and the gaps that still need to be addressed.

Glimpses of Change

From west to east, the Himalayas comprise three distinct bio-geographic regions with eco-cultural variations – the Western Himalayas, the Central Himalayas and the Eastern Himalayas; hence the impacts of climate change are felt differently in all these regions.

Most precipitation in the high-altitude Himalayas is received in the form of snow. Most water in the rain-deprived "cold deserts" of western Himalayas comes from the snowmelt, providing moisture to farms and pasturelands, feeding the streams that are the lifeline of the settlements. With increased ablation rates stream flows are reducing, seasonal variability is on the rise and the livelihoods of the communities in the high Himalayas are at stake. It's ironic as these people are amongst those who contribute the least to global warming and still have to bear the brunt. Many climate activists and advocates refer to this as "climate injustice".

Meantime, heavy rainfall, which was unknown in the high altitude desert, has become more frequent, causing flash floods, washing away homes, farmlands, trees and livestock. In August 2010 entire nation woke up to one such event that had changed lives of the Ladakhi communities in the blink of an eye.

Coping with the constraints

The Himalayas are characterized by a fragile ecosystem, a complex interplay of climatic and geomorphological processes, and limited natural resources. The severe climate makes working conditions extremely tough. There is paucity of basic services for healthcare, higher education, communication, power, and water due to high establishment and maintenance costs. The region gets completely cut-off from the rest of the world during the severe, snow-bound winters. The economy of the region is at a subsistence level almost entirely based on agriculture and animal rearing. Landholdings are small and much of the land is not arable. The local biodiversity, currently under increasing stress is also closely linked to the livelihoods of the communities. Although aware of the risks, the communities are unable to adapt themselves due to lack of scientific knowledge and appropriate training. Their low capacity and near total dependence on natural resources also constrains them from responding effectively to climate crisis. Fragmented research and limited extension have failed to build local capacity towards climate change response. Limited information flow and awareness shortage of human resources as a result of high migration; and limited economic development because of Border Area Syndrome further cripple their coping mechanism. The region suffers from paucity of information on status of climate change and its impacts in certain pockets. These call for a sound understanding and real-time information on the nature, extent, and impacts of ecological change, such that scientific and appropriate conservation/adaptation planning and action could be undertaken, at the national and global level through area-specific research and micro-level studies involving local communities.

Review of Research Studies

Glaciology

One of the most visible impacts of climate change in the Himalayan region is the variations in the glaciers. Himalayan glaciers are an indicator of the overall health of the Himalayas. However, the rugged terrain makes regular ground monitoring an arduous task. Remote sensing has been found to be capable of providing extent of glacial areas similar to ground-based methods (Philip and Ravindran 1998, Kulkarni 1991), and most studies on Himalayan glaciers have used GIS and remote sensing tools. Several studies have suggested that altitudinal distribution influences glacial mass balance, as glaciers located at higher

altitude ranges reflect fewer variations than those at lower altitudes (Kulkarni and Alex 2003, Kulkarni *et al.* 2004, Berthier *et al.* 2006, Kulkarni *et al.* 2009). Studies on glacier mass balance in the Himalayas have been limited with very few glaciers sampled to assess their response to climate change (Berthier *et al.* 2006*)*. Various studies have focused on the scale of glacial retreat for some prominent Himalayan glaciers (e.g. Chhota Shingri glacier of Himachal Pradesh, Gangotri, and Parbati Glacier of Uttarakhand). Snow, icemelt, precipitation modeling has been done in glaciers of Bhutan Himalayas (Mool, et al., 2001, Payer et al., 2003). Altitude wise snow cover monitoring and digital analysis of glacial retreat by using satellite imagery have been undertaken for technology potential study and study of impact of global warming in Beas and Baspa river basins. Application of SAR interferometry has also been explored in studying Himalayan glaciers. Effect of global warming on ablation pattern in the Himalayas, glacial mass balance studies (e.g. Siachen Glacier of Nubra valley), role of glaciers and snow cover and glaciers on river head water hydrology under monsoon regime (e.g. study in Din Gad catchment in Garhwal Himalaya) has been carried out as individual, isolated studies (Bhutiyani, 1999, Das et al., 2006, Dobhal et al, 2002, Kulkarni et al., 2005, Naithani et al., 2001, Rupa Kumar et al., 2006, Singh et al., 2007, Singh, 1998, Swaroop et al., 2001, Thayyen et al., 2005, Wagnon, et al., 2008). Study of the paraglacial fans in upper Bhagirathi valley in the Gharwal Himalaya has shown how the Gangotri Glacier has gradually retreated over a period of 200 years (Owen and Sharma, 1998). Studies have also been conducted to estimate rate of erosion in glacier melt stream, sediment yield and suspended sediment load (Haritashya et al., 2005). Preliminary study on Himalayan permafrost belt has shown permafrost disappearing in certain localized pockets, which could destabilize the rock mass increasing the sediment in the rivers (IIT-R, 2009).

Snow cover, snow line, snow ablation patterns, mass balance and discharge dynamics have been studied, focused on certain prominent glaciers of the region. Comprehensive study spread across the region is the need of the hour for better understanding of effects of climate change on the glaciers and permafrost zones of the Himalayan region.

Meteorology

Most meteorological research in India has been focused on studying monsoonal variation, origin and dynamics of monsoon system, impacts of El-nino on monsoon anomaly, flood hazards and weather forecasting techniques (Anon., 2002, Baros and Lang, 2003, Bhattacharya and Das, 2007, Das and Hunt, 2007, Kalsi, 2001, Rajeevan, 2001, Srinivasan *et al*., 2005). Mountain weather forecasting using meso-scale MM5 modelling system, better understanding of weather patterns and change in atmospheric composition (through SHARE-ASIA network of remote high altitude monitoring stations) has been initiated (Bonasoni, 2006, Das *et al*, 2006, Das, 2005). Specific studies have however been carried out on Monsoonal control on glacial discharge (e.g. for *Dokriani* glacier in Garhwal Himalaya) and variability of

monsoon using ice-core records (e.g. 295 year record from *Dasuopu* ice core in Central Himalayas) etc at small scale (Duan and Yao, 2004). Research suggests that the Himalayas are showing a different response to global warming than other parts of the globe (Yadav *et al.* 2004). Accelerated tree-ring growth in the Western Himalayan region during the last few decades has been attributed to the overall warming trend over the region; higher snowmelt in winter and early spring being responsible for increased moisture availability and enhanced tree-ring growth (Borgaonkar *et al.* 2008). Extensive studies (Yadav *et al.* 2006, Singh *et al.* 2009, Yadav 2009) have demonstrated direct correlation between tree-ring growth and precipitation trends in the Himalayas, enabling large-scale reconstruction of precipitation trends and climate variability. Ample research has taken place on temperature and precipitation trends in the Himalayas, showing that the region has been experiencing the effects of global climate change. Study in Alakananda catchment has shown decline in rainfall along with rise in temperature and if this trend continues, the region could face droughts in future (Kumar et al., 2008).

With most meteorological research in India focusing on monsoons that drives the agro-economy of the country, flood hazards and forecasting, Himalayan microclimates have not received adequate attention as it remains out of the monsoon regime. Currently, mountain weather forecasting over the Western Himalayas is carried out through a combination of various products viz., regional model outputs, global model products, *in situ* observations, and satellite observations by collaborative efforts between meteorological organizations such as NCMRWF, IMD and SASE. Although surface observatories and upper air stations have been set up in the western Himalayas, observations over the region are very sparse (Das *et al.*). Major historical trend analysis for Himalayan region along with the link between monsoon precipitation and glacial accumulation pattern are yet to be examined at a significant scale.

Hydrology

Hydrographic studies in India have mainly concentrated on water pollution and water access for major rivers. Majority of rivers in Himalayas are primarily snow and glacier melt dependent. Several studies have been conducted in the western Himalayan Rivers to estimate stream-flows in order to enable water resource planning and management in the region (Dey *et al.* 1992, Singh 1998, Singh *et al.* 1997, Singh and Jain 2002, Bhutiyani *et al.* 2008). Study on stream-flow pattern of Satluj River (Bhutiyani et al. 2008) show decreasing discharge during winter and monsoon in spite of rising temperatures and average monsoon precipitation indicating reduced contribution of glaciers to stream discharge. Study on stream-flow simulation has been carried out on the Satluj River using a watershed model (Singh and Quick 1993). Much concern have been expressed about the likely impacts of the increased variability in flow on hydropower generation in the region (Alam and Regmi 2004). Detailed individual studies have also been conducted on flow regimes and sediment yield in various rivers (e.g. *Chenab, Sutlej, Beas, Baspa* in the

Himalayas), impact studies focused on dams/reservoirs, changes in water availability due to global warming, sustainability of water resources in context of growing disaster frequency (e.g. in *Ganga* basin), vulnerability assessment of GLOFs, floods, drought and other aspects of climate change (Barnett, *et al.,* 2005, De Scally, 1994, Dey, 2005, Ferguson, 1985, Kulkarni *et al.,* 2005, Kumar *et al,* 2002, Mall *et al*., 2006, Mool *et al.,* 2001, Negi, 2002, Sarin, 2001, Sharma *et al*., 1991, Singh and Jain, 2002, Singh, 1998, Thayyen *et al.,* 2005).

Although a few studies on stream-flow estimation have been carried out on Himalayan rivers, more detailed study on all major river systems is needed to understand the effect of climate change on the summer as well as runoff. There is further scope for improvement of models, comprehensive assessment through application in other catchments in the Himalayas. Estimation of glacier melt runoff and sediment yield and their spatial and temporal variations are of vital importance for the management of water resources in the region. Large scale integrated study on major river basins are yet to be carried out for a comprehensive regional scale understanding of the impacts of climate change. Detailed hydrological analysis for climate change implications, coupled with snow-hydrology studies at larger dimension is required to comprehend the regional scenarios.

Ecology

The Himalayan region has a wide variety of ecosystems, ranging from grasslands and subtropical forests to high alpine meadows and has also been identified as a 'Biodiversity Hotspot' by Conservation International owing to the rich biodiversity and a high species endemism. Climate change has affected the biodiversity of the Himalayas as visible in change in vegetation composition, migration patterns of flora and fauna, infestation of invasive species. Study on vegetation and climate interrelationships (Chauhan *et al.* 2000) has shown that rangeland productivity would decrease by 40-90% with increase in temperatures of 2-3ºC combined with low precipitation in the near future. Biological indicators of climate change are being researched upon, as they are considered extremely useful for monitoring and detecting changes in the concerned environment. Research on shifting patterns of Himalayan pine in the western Himalayan region of Himachal Pradesh (Dubey *et al.* 2003*)* suggest that the rate of shifting is largely dependant on their sensitivity to climate. Early flowering in Rhododendrons and the Magnolias are established as vital indicators of climate change (Chatterjee), while community observations also point towards phenological changes such as early flowering in Chir species and early flushing of oak leaves. These phonological changes, such as early budding or flowering and the ripening of fruits could have adverse impact on pollinators, leading to changes in ecosystem productivity and species composition of the high altitude habitats (Thuiller et al.2008). Community interactions have also revealed that birds (Monal, Himalayan crow) are spotted in different locations than their earlier preferred sites in Central Himalayas, while

reducing population of particular bee species vital for pollination is a concern in western Himalayas; however, much needs to be explored.

Studies on upward shift of tree species in the western Himalayas due to global climate change need to be expanded to other geographic areas of the region in order to standardize species and site-specific results and the impact on all links of ecological chain needs to be studied across the Himalayas. Low productivity and abandonment of agricultural lands have emerged as serious threats to the dynamics of hill agro-ecosystems (Rana *et al*. 2010*).* Since the dynamics of plant bio-resources, including agriculture, is different in the hills from those in the plains, it demands more focused research. Most environmental research efforts have focused on individual species of flora and fauna. Ecosystem resilience to climate change and specific impacts on High Altitude mountain ecosystems at landscape level needs to be explored further.

Livelihood security

Livelihood options in most regions of the Himalayas are limited, while the impacts on livelihoods would be felt more severely in the mountains as compared to the plains. Agriculture and other economic activities rely heavily on glacial melt, and changes in water availability can have serious impacts on the lives and livelihoods of the millions of people living in the Indus basin (ICIMOD, 2010). There are varying degrees of vulnerability at the national, state, district, village and household level, which calls for multi-level initiatives and partnerships (Price et al. 2002). In Nepal Himalayas, where the main source of economy is agriculture and availability of food is a major concern, the agriculture sector is hard hit by the loss of fertile soil due to erosion, floods and landslides. As a consequence of climate change, 70% of the high altitude pastures are also facing imminent degradation and this is affecting the livelihoods of high altitude pastoralists (Chauhan *et al.* 2000). Net cereal production of Eastern Himalayas is projected to decline by 4-10% by the end of the century, under the most conservative climate change scenario (Lal 2005), whereas in Darjeeling, a study among the local farmers between Singalila National Park and Senchel Wildlife Sanctuary reveal that climate change has been a mixed blessing with farmers being able to grow new crops, although there has been associated rise in crop diseases etc. Farmers in Chamoli and Lahaul & Spiti in central and western Himalayas have also reported increase in pest attacks that damage roots and foliage of vegetable crops. Land-use change and associated stress and change in agro-biodiversity and cropping pattern have been inspected for isolated stretches (Santaram *et al.* 2003, 2007, Singh *et al.* 1997, Singh 2004, Kuniyal *et al.* 1997, 2003, Khoshoo 1993).

Focused integrated studies on Himalayas and on livelihood options and economic sustainability is required to understand the emerging state of affairs for the deprived communities in these mountains due to climate change. Studies focusing on the socio-economic aspects of climatic change are sparse and

have almost exclusively restricted their analysis to the impact of environmental modifications on agricultural production, whereas studies to understand the impacts of climate change on rangelands and the subsequent impact on the livelihoods of pastoral communities (ICIMOD 2009) has mostly been concentrated in the Central Himalayan region. Although substantial research has happened in India on understanding the impact of climate change on the nature and magnitude of yield of different crops (Mall et al. 2006), there is dearth of studies specific to each Himalayan sub-region. Economic assessment models on climate change impacts have been mostly based research on costs and economic consequences of the changed climate, in agriculture (Anon. 2003, Anon., 2007, Deressa *et al*, 2005, Dinar and Mendhelson, 1999, Kumar and Parikh, 1998, 2001, Mendhelson, 2000, Murugan *et al*., 2005, Saxena *et al*, 2005, Tyrchniewicz and Yusishen, 2000, Yano *et al*., 2007). Economic approaches as followed elsewhere in the world to study climate change impacts (e.g. Ricardian approach and other agricultural models and agro-biodiversity studies in Egypt, South Africa, Cameroon, Sri Lanka, Bangladesh, Bukina Faso, desert states of US, South Asia), needs to be undertaken in the Himalayas for quantitative assessment of the impacts (Anon. 1996, Anon. 2003, Darwin, 1999, Kumar, 2006, Mano and Nhemachena, 2006). Research aimed at understanding the impact of climate change and variability and the resulting socio-economic responses, should take into account farmers' awareness of weather fluctuations. Most of these studies are based on people's perception and have not much foundation in terms of hard-core empirical data elements. Studies that explore livelihood options and economic sustainability in the context of escalating impacts of climate change are the need of the hour for the region.

Disaster Management

Over the past three decades, climate change in the region has induced increasingly frequent environmental disasters, among them being droughts, flash floods, landslides, avalanches and Glacial Lake Outburst Floods (GLOFs), causing immense destruction to life and property (Shrestha 2004; WWF 2005). The rugged terrain, coupled with erratic precipitation, has left the communities vulnerable to water-related natural hazards (Pathak et al 2008). Studies on discharge data of four northwestern Himalayan Rivers viz. Beas, Chenab, Ravi and Satluj indicate increased incidence of 'high magnitude' flood events over the last three decades (ICIMOD 2007). There are more than 150 glacial lakes in the Koshi Basin and threat of GLOF looms large. Substantial research had been conducted on landslides and avalanches in the region particularly in the areas of vulnerability assessment and susceptibility mapping. Scientists have also suggested tree ring analysis to reconstruct avalanche events when historic records are unavailable, to aid in the identification of regions with recurring avalanche hazards. Studies (Ledug & Mahat, 2009) show that women are most vulnerable to the social impacts of these disasters; hence, integration of gender issues requires major focus in disaster management.

Very few studies have concentrated on drought and desertification in the region as research on disasters has primarily focused on rapid-onset disasters and not so much on slow-onset ones. Little work has been done in terms of assessing the vulnerability of the inhabitant communities to different natural hazards, indicating a need for a comprehensive mapping and in-depth understanding of the risk profiles of the local communities to ascertain future action. Studies on natural hazards have tended to focus more on better accessible regions in the Himalayan range. There is a lack of a general understanding about the physical dimensions and properties of GLOFs as well as their life cycle, which makes predicting a GLOF event difficult. Besides, there is a lack of proper early warning systems and mathematical models for predictions of such events. Regional Climate Models (RCMs) need to be downscaled. Most of existing models are either still in test phase or not suitable enough to be used in their current form. There is also a serious lack of trained professionals and institutional capacity for hazard mapping, vulnerability assessment, and disaster forecasting. Adaptation strategies must be flexible to address locally specific and changing circumstances. IUCN, IISD, SEI-US and Intercooperation have developed a project planning and management tool called CRiSTAL (Community-based Risk Screening Tool – Adaptation & Livelihoods) that seeks to help project planners and managers to integrate risk reduction and climate change adaptation into community-level projects (Anon., 2007). Adaptation of such tools can be considered abd their implications determined. Various other aspects of community response and capabilities have been inspected through adaptation research (Bhattacharya, 2007, Garg *et al*., 2007, Patwardhan and Ajit, 2007, Roy *et al*., 2005, Runnalls, 2007, Salick, 2007, Schröter *et al.,* 2004, Singh, 2006, Willems and Baumert, 2003, Yamin, 2007). Similar studies for high altitude Himalayas needs to be carried out in context of climate change.

Review of initiatives addressing climate change

Strategic advancements

'Climate change in the Himalayas' has grabbed attention of policy makers and the government both at the Central and the State level has undertaken a number of initiatives towards facilitating adaptation, mitigation and capacity building. As a party to the ***United Nations Convention to Combat Desertification (UNCCD),*** India has taken various initiatives either direct such as programmes to reduce desertification exemplified by the setting up National Afforestation and Eco-development Board (NAEB) for the regeneration of degraded forest areas and lands adjoining protected and ecologically fragile areas. ***Hill Area Development Programme (HADP)*** has been in operation since the inception of the Fifth Five-Year Plan and is being implemented for the integrated ecologically sustainable socio-economic development of hill areas, keeping in view the basic needs of the inhabitant people. The ***Desert***

Development Programme (DDP) has played a crucial role in the cold deserts improving the socio economic conditions of poor sections of the village community, through creation, widening and equitable distribution of natural resource base. The ***Watershed Development Programme (WDP)*** introduced in 1995 promoted low cost and locally accessed technologies and participatory approach but was not highly successful in income enhancement. Inception of the '*National Core Group for Landslide Mitigation*' constituted by the Ministry of Home Affairs in 2004 was an important step towards providing advise and guidance to the State Governments on landslide mitigation, monitoring landslide mitigation activities and to evolve early warning systems and protocols for landslide risk reduction. In 2008, India's first National Action Plan on Climate Change (NAPCC) outlining existing and future policies was released, inclusive of the '***National Mission for Sustaining the Himalayan Ecosystem***'. The ***Shimla Declaration on Sustainable Himalayan Development, 2009*** drafted in presence of Chief Ministers of Himalayan states, the Union Minister of State of Environment and Forests, and other senior dignitaries reaffirmed the commitment to adhere to the basic principles enshrined in the NAPCC. It recognized the seriousness of the threat posed by climate change to the Himalayan States and the importance of preserving the ecological and environmental sanctity of the Himalayas. A State Centre for Climate Change, Disaster Management and Snow and Glacier Studies is proposed in Himachal Pradesh for chalking out climate change mitigation and adaptation strategies and to enhance the state's preparedness for natural disasters.

Other concerted efforts

Recognizing various ongoing climate change phenomena and their impact, collaborative endeavours are underway in form of 'Climate Himalaya Initiative', UN Solution Exchange, Mountain Forum, Hindu Kush Karakoram Himalaya (HKKH) Partnership, Mountain Partnership towards Sustainable Mountain Development who work closely with volunteers and partners in running web based interactive platforms, vibrant leadership networks and keep close watch on various climate change adaptation and mitigation processes in the region. Regional initiatives undertaken in the recent past or are currently underway in the region include: EV-K2-CNR under SHARE-Asia programme (Stations at High Altitude for Research on the Environment) with participation from over 180 national and international institutes, BrahmaTwinn project for twinning European and Asian transboundary river basins (Danube and Brahmaputra) for comprehensive solutions to integrated water resource management, Indian Himalayas Climate Adaptation Programme (IHCAP) by SDC and Ministry of Environment & Forests, initiative on Himalayan High Altitude Wetlands by WWF.

Local and regional initiatives of various scale are being run by various institutions e.g. Central Himalayan Environment Association (CHEA) aiming to build responsive network of climate leaders, Janadesh, Snow Leopard Conservancy, The Mountain Institute (TMI) spreading conservation awareness. Capacity

building for disaster preparedness and climate adaptation are being carried out by Centre for Environment Education (CEE), All India Disaster Mitigation Institute (AIDMI), and others focusing on various beneficiary groups. Snow and avalanche, landslides and associated hazards are being studied by Snow and Avalanche Study Establishment (SASE), Wadia Institute of Himalayan Geology (WIHG). Initiatives on renewable energy research, application and promotion in the region are being spearheaded by Ministry of New and Renewable Energy (MNRE), and organisations like Avani, Ladakh Ecological Development Group (LEDeG), GERES India, Pragya, CRT Nepal. Good practices and efficient technologies for water resource management in the Himalayas are being researched/implemented by Indian Institute of Technology - Roorkee (IIT-R), Nepal Water for Health (NEWAH), TERI Water Resource Division, Himalayan Environmental Studies and Conservation Organisation (HESCO), Central Himalayan Rural Action Group (CHIRAG), Leh Nutrition Project (LNP), People's Association for Himalaya Area Research (PAHAR) and others. In the face of the climate-induced water crisis in the Himalayas, scientists are exploring innovative technologies for water management in the Himalayan region, with progress made on design for in-stream water storage. Notable research and conservation initiatives towards sensitive Himalayan ecosystems and their biodiversity are being coordinated by IUCN, GB Pant Institute of Himalayan Environment and Development (GBPIHED), Development Alternatives, High Altitude Plant Physiology Research Centre (HAPPRC), People's Science Institute (PSI), Leh Environment & Health Organisation (LEHO), Ashoka Trust for Research in Ecology and Environment (ATREE) among others. Research and Extension services on economic bio-resources in Himalayan region leading to value added plants, products and processes for economic and environmental benefit are being carried out by Institute of Himalayan Bio-Resource Technology (IHBT), CSK-HPKV, Sher-e-Kashmir University of Agricultural Sciences and Technology (SKUAST), GB Pant University of Agriculture & Technology (GBPUAT), Vivekananda Parvatiya Krishi Anusandhan Sansthan (VPKAS, an ICAR institute), Defence Institute of High Altitute Research (DIHAR). GBPIHED and ICIMOD have been playing the role of nodal agencies in coordinating the various efforts for addressing climate change impacts in the Himalayas.

Most initiatives being implemented in the Himalayas for climate change response are of ad-hoc nature and the people at the grassroots level the real stakeholders are not empowered and their knowledge and needs tend to get overshadowed in the planning process. Although aong with scientific and technical assessments, participatory methods, or civic science, are being integrated to assess and monitor climate and environmental changes based on local perceptions, practices. However, much of it is in pilot phase and need to be mainstreamed for effective results. The immense diversity within the region need to be recognized: diversity of climates and topo-climates, hydrology and ecology, and, above all, the human cultures and activities for designing appropriate initiatives. Given the multiplicity and trans-boundary nature of issues, information sharing and coordination of efforts are the major hurdles to be surmounted.

Recommendations

Apart from the increasing threat s and uncertainties in the region, there have been several opportunities offered by the climate change with certain species such as floriculture crops being grown in the area. To avail these opportunities, there has to a blend of scientific and traditional knowledge for framing adaptation strategies for the Himalayan communities. Furthermore, there needs to be very high synergy among initiatives for ecological security and food security of the rural communities. Local adaptation research through Farmer Expert Groups with a focus on crops, cropping patterns and irrigation methods should be facilitated. 'Research & Extension counters' focusing on local adaptation needs to be set up in the region. It must be ensured that the research done is people-focused and made accessible to the community.

Focused efforts are required for developing low-cost solutions for natural resource management. Periodic surveys to identify disaster prone stretches and preparedness for catastrophic events must be conducted. Research and extension for drought-resistant high value crops must be promoted. Disaster Management plans for village level, school level have piloted in certain pockets and consolidated efforts are required to ensure coverage of all Himalayan settlements. The floating and mobile population (pastoral nomads, migrant road and dam workers, tourists) need to be factored in during the planning process.

A comprehensive network of weather monitoring system is a regional priority. Forest department and local institutes need to utilise their existing infrastructure setting up these stations. Remote sensing along with ground truthing with community participation is required for creating a 'spectral library' of the area. Landscape restoration for the already degraded landscapes is deemed another priority. Capacity building of the communities is essential for facilitating monitoring biodiversity through local Biodiversity Management Committees (BMCs) as maintaining Biodiversity Registers alone are not enough to address the current requirements. Local knowledge of climate should be incorporated into any strategy meant to mitigate the impact of climate change. The battle with climate change would be only half-won without the cooperation of the people who are the true custodians of the mighty Himalayas.

References

- Anon.; 2000; Inventory of glaciers, glacial lakes and glacial lake outburst floods, monitoring and early Warning system in the Hindu Kush Himalayan Region, Bhutan; ICIMOD and UNEP.
- Anon.; 2002; Early Warning, Forecasting and Operational Flood Risk Monitoring in Asia (Bangladesh, China and India); UNEP- Division of Early Warning & Assessment, Technical Report of Project (GT/1010-00-04):

December, 2002

- Anon.; 2004; NATCOM 2004 - India's Initial National Communication to the United Nations Convention on Climate Change; Ministry of Environment and Forests, Government of India.
- Anon.; 2005; An Overview of Glaciers, Glacier Retreat, and Subsequent Impacts in Nepal, India and China; WWF Nepal Program, March, 2005; 70 p.
- Anon., 2010. Climate change impacts on the water resources of the Indus Basin: Capacity building, monitoring, and assessment for adaptation, ICIMOD
- Barros, Ana P. and Lang, Timothy J.; 2003; Monitoring the Monsoon in the Himalayas: Observations in Central Nepal, June 2001; Monthly Weather Review, American Meteorological Society; Volume 131, pp. 1408-1427.
- Bhattacharya, S.; 2007; Lessons Learnt for Vulnerability and Adaptation - Assessments from India's First National Communication; BASIC Project - Paper 7 - September 2007; 11 p.
- Bonasoni, P. and ABC-PYR teams; 2006; ABC-PYR: a new remote high mountain station in the Himalayas to study the atmospheric composition Change and climate; Sref-ID: 1607-7962/gra /EGU 06-A-08824; Geophysical Research Abstracts, Vol. 8, 08824, 2006.
- Das S., Singh, S.V., Rajagopa, E.N. and Gall, R.; 2006; Remote Sensing Technologies for Monitoring Climate Change Impacts on Glacier and Permafrost-Related Hazards; Mesoscale Modeling for Mountain Weather Forecasting Over the Himalayas: A Workshop Report; 2006; ECI Conference on Geohazards Lillehammer, Norway 13 p. Farrokh Nadim, Rudolf Pottler, Herbert Einstein, Herbert Klapperich, and Steven Kramer (Eds).
- Dey, D.; 2005; Watershed Conservation And Management Of Glacial Lake Outburst Flood; Combating Climate Change In Himalayan Environment; South Asian Forum for Environment (Indian Chapter) Kolkata, India, Report 500019002/2005.
- Dimri, A.P., Mohanty and Mandal, 2004. Simulation of Heavy Precipitation Associated with an Intense Western Disturbance over Western Himalayas. Natural Hazards. Vol. 31, No. 2, pp.499-519
- Dobhal, D. P., Thayyen, Renoj J. and Gergan, J. T.; Role of glaciers and snow cover on Headwater river hydrology in Monsoon regime – Micro-scale study Of Din Gad catchment, Garhwal Himalaya, India; Current Science, Vol. 92, No. 3, 10 Feb; pp. 376- 382.
- Dortcha, J.M., Owena, L.A., Hanebergb, W.C., Caffeec, M.W., Dietscha, C., and Kampd, U., 2008. Nature and timing of large landslides in the Himalaya and Transhimalaya of northern India
- Ganju and Dimri, 2004. Prevention and Mitigation of Avalanche Disasters in Western Himalayan Region. Natural Hazards. Vol. 31, No. 2, pp. 357-371
- Gardner, J.S., 2002. Natural Hazards Risk in the Kullu District, Himachal Pradesh, India. Mountain Geography. Geographical Review, Vol. 92, No. 2, pp. 282-306.
- Gosain, A.K., Rao, S., and Basuray, D., 2006. Climate change impact assessment on hydrology of Indian river basins. Current Science. Vol. 90, No. 3
- Grabs, W.E. and Hanisch, J., 1993. Objectives and Prevention methods for Glacier lake Outburst Floods (GLOFs). Snow and galcier hydrology (Proceedings of the Kathmandu Symposium, Nov., 1992).
- Hasnain, Syed I.; 1999; Runoff characteristics of a glacierized catchment, Garhwal Himalaya, India; Hydrological Sciences- Journal-des Sciences Hydrologiques, 44(6) December 1999 847 - 854 pp.
- Joshi, J. C., Ganju, A. and Sharma, V., 2010. A new approach to avalanche prediction over Indian WesternHimalaya. Current Science. Vol. 98, No. 1
- Kamp, U., Growley, B.J., Khattak, G.A. and Owen, L.A., 2008. GIS-based landslide susceptibility mapping for the 2005 Kashmir earthquake region. Geomorphology. Vol. 101, No. 4, pp. 631-642

- Laxton, S.C. and Smith, D.J., 2009. Dendrochronological reconstruction of snow avalanche activity in the Lahul Himalaya, Northern India. Natural Hazards. Vol. 49, No. 3, pp. 459-467
- Payer, T., Leber, D., Haeusler, H., Brauner, M. and Wangda, D.; 2003; Snow/ice melt precipitation runoff Modelling of glaciers in the Bhutan Himalaya; Geophysical Research Abstracts, Vol. 5, 10227; European Geophysical Society.
- Rao, S. V. N., Ramasastri K. S. and Singh R. N. P., 1996. A Simple Monthly Runoff Model for Snow Dominated Catchments in Western Himalayas. Nordic Hydrology. 27 (4), pp. 255–274.
- Rautela, P. and Lakhera, R.C., 2002. Landslide risk analysis between Giri and Tons Rivers in Himachal Himalaya (India). International Journal of Applied Earth Observation and Geoinformation. Vol. 2, No. 3-4, pp.153-160
- Sah, M.P. and Mazari, R.K., 1998. Anthropogenically accelerated mass movement, Kulu Valley, Himachal Pradesh, India. Geomorphology. Vol.26, No. 1-3, pp. 123-138
- Sah, M.P. and Mazari, R.K., 2007. An overview of the geoenvironmental status of the Kullu Valley, Himachal Pradesh, India. Journal of Mountain Science. Vol. 4, No. 1, pp. 003-023
- Sarin, M. M.; 2001; Biogeochemistry of Himalayan rivers as an Agent of climate change; Current Science, Vol. 81, No. 11, 10 December 2001; pp.1446-1450.
- Saxena, K.G., Maikhuri R.K., Rao K.S.; 2005; Changes in Agricultural Biodiversity: Implications for Sustainable Livelihood in the Himalaya; Article ID: 1672-6316 (2005) 01-0023-09; Journal of Mountain Science Vol 2 No 1 (2005); pp. 23-31.
- Shroder, J.F., 1998. Slope failure and denudation in the Western Himalaya. Geomorphology. Vol. 26, No. 1-3, pp. 81-105.
- Shrestha, A.B. and Eriksson, M., 2009. Climate Change in the Himalayas. ICIMOD.
- Singh, J. S.; 2006; Sustainable development of the Indian Himalayan region: Linking ecological and Economic concerns; Current Science, Vol. 90, No. 6, 25 March 2006; pp 784-788.
- Vedwan, N. and Rhoades Robert E.; 2001; Climate change in the Western Himalayas of India: A study of local perception and response; Climate Research; Vol. 19, 2001; pp. 109–111.
- Venkataraman, G., Rao, Y. S. and. Rao, K. S; 2001; Application of SAR Interferometry for Himalayan Glaciers; 8 p.
- Wagnon et al.; 2008; Four years of mass balance on Chhota Shigri glacier (Himachal Pradesh, India), a new benchmark glacier in The Western Himalayas; P. Wagnon, A. Linda, Y. Arnaud, R. Kumar, P. Sharma, C. Vincent, J. G. Pottakkal, E. Berthier, A. Ramanathan and P. Chevallier; Geophysical Research Abstracts, Vol. 10, EGU2008-A-04020, 2008.

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