Article

Regional Cooperation to Preserve the Himalayan System

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Abstract

The Himalaya is a unique ecological system and millions of people depend on its rivers for water, food and energy. It has distinctive biodiversity with a variety of high altitude vascular plants, grasslands, birds, etc. The Himalaya is under stress due to natural hazards such as earthquakes, landslides, floods, glacial lake outburst floods, climate change impacts such as the retreat of glaciers, and changes in precipitation patterns. Besides, anthropogenic activities related to infrastructure development, urbanisation, tourism, etc., also affect the Himalayan system. Defence-related activities by China, Pakistan and India have placed additional pressure on the Himalayan ecology. The geological, cryospheric, hydrological and atmospheric processes and their interaction need to be modeled for the preservation of the Himalayan ecosystem. The formation of the Himalayan Science Council (HSC) is a positive step but it needs to set up monitoring systems for observing/measuring geological, hydrological, cryospheric, atmospheric and biological phenomena. Collaboration between research institutes of the Himalayan nations is a critical necessity.

The Himalayan system supports humans and other biota to live and provide their water, food, and energy requirements. These mountains have spectacular landscapes and are a heritage to mankind. They have a profound influence on social, economic, cultural, and demographic aspects of India, Nepal, Bhutan, Pakistan, Tibetan plateau and the rest of China, Bangladesh as well as countries around the Bay of Bengal. According

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to World Population Review data (Figure-1), the population of China and India in 2022 was 1.43 billion and 1.42 billion, respectively.

Figure 1: Population of the Countries around the Himalayas in 2022

China	:	1,425, 887,000
India	:	1,417, 173,000
Pakistan	:	235, 824,000
Afghanistan	:	41,128,000
Nepal	:	30, 547,000
Bhutan	:	782,000
Bangladesh	:	171,186,000

Source: World Population Review[1]

The Himalaya, including the Tibetan Plateau, is known as the third pole and has the largest concentration of snow and ice outside the two polar-regions. It is the source of major river systems in Asia (Indus, Ganga, Brahmaputra, Irrawaddy, Salween, Mekong, Yangtze, and the Huang He), and the floodplains of these rivers provide food to almost 40 percent of the world's population. The Himalayan rivers draining into the Arabian Sea and the Bay of Bengal deposit a large mass of sediments and have formed 'the Indus Fan' and the 'the Bengal Fan' respectively that influence the ecosystem of the region. The dynamic system of snow, ice and glaciers influences weather (wind circulation, monsoon, storm tracks), river flows, irrigation, sediment load, power generation, etc. It holds large reserves of trapped carbon in permafrost and wetlands.

The Himalaya is warming much faster than the rest of the Indian subcontinent and can induce increased melting of snow and ice as well as the release of methane from permafrost. Being young mountains, they are fragile and hazard-prone, especially to earthquakes, landslides, etc. The Himalayan grasslands having unique biodiversity are under threat.

Our knowledge about the composition and structure of the Himalaya has advanced significantly in the last few decades, especially related to its role in modulating global climate and the Asian Monsoon. However, there are still several scientific challenges that must be overcome. Snow and ice play a very important role in influencing earth system processes through their interaction with the atmosphere, ocean, biosphere, and geosphere. These processes need to be modelled for forecasting weather, climate and hazards in the Himalayan region. The other challenge is to improve our understanding of complex dynamic processes within the crust, mantle and core and their linkages with geological and geophysical observations and earth processes operating at the land surface. These processes vary greatly from local, regional to global scale in space and from a few seconds to millions of years in time. The knowledge about these processes is critical in the context of food, water, mineral and energy resources, natural hazards, weather, and environment.

The social system, i.e., governance, infrastructure, and the human system of the Himalayan countries and their neighbours have a profound influence on climate, conservation of biodiversity and sustaining life systems of the Himalayan terrain. Anthropogenic activities and climate change have affected the Himalayan environment significantly and are likely to affect human security in the Himalayan nations and their neighboring countries. The magnitude of these challenges and geographical spread is such that no single institute or even a country can do justice to provide insight into the scientific knowledge needed to preserve the Himalayan system.

The formation of the Himalayan Science Council (HSC) under the Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation (BIMSTEC) has facilitated the study of earth processes of the Himalayan system. In this article, the evolution of the various hazards, its snow and ice, hydrosphere processes and the ongoing transformation of Himalaya has been discussed. The need for regional engagements in preserving the Himalayan system has been highlighted and a future course of action has been proposed.

Evolution of Himalaya and its Impact

The evolution of the Indian sub-continent and the Himalayas have been linked to the fragmentation and dispersal of the Gondwanaland Super-Continent, initiated about ~133 million years ago (Ma).[2] The Indian plate separated from Antarctica during the early Cretaceous and moved at a relatively faster speed of 18-20 cm per year.[3] The Indian plate collided with the Eurasian plate and in place of the Tethys Sea, Himalaya Mountains gradually rose and continues to rise. The Himalaya had attained its current elevation by 10-5 Ma.[4]

The rise of Himalaya and the evolution of the South Asian Monsoon (SAM) are strongly coupled. The modeling studies suggested that the role of the Himalaya as an orographic barrier is more important for SAM circulation than the elevation and the extent of the Tibetan Plateau.[5] The analysis of cores from the Laxmi basin provided evidence that the SAM intensification took place between c.3.2-2.8 Ma and the modern strength of SAM was attained by circa 1 Ma.[6] This period coincides with the Mid-Pliocene, the period of global warmth having CO_2 level (400 ppmv) like the present day. The high-resolution millennial scale records generated through deep drilling of 1.1 km in the Laxmi basin, the Arabian Sea under the International Ocean drilling Program, under the joint leadership of USA and India, have provided insight into climatic transitions and the nature of the crust of the Laxmi Basin and the evolution of Himalaya.[7]

The continued northward movement of the Indian plate and its under-thrusting beneath Eurasian plates resulted in accumulation of strain energy. GPS measurements have provided evidence of strain accumulation in the region.[8] This energy is periodically released during large and great earthquakes. It has been observed that during the past 200 years, less than 50 percent of the Himalayan arc has ruptured during great earthquakes.[9] One view is that there is very low potential for the occurrence of an earthquake of Magnitude (M) 9 in Himalaya. Such an earthquake will require a rupture length of about 1000 km and a width of 200 km. Such length and width are not available in Himalaya as it is segmented by transverse ridges running across it. However, large earthquakes in the unbroken segments (Uttarakhand, Himachal Pradesh) along the Himalayan belt cannot be ruled out. But it is not known when the accumulated strain energy will be released through great or large earthquakes. So, it is also imperative that concentrated efforts be made to make all public buildings, including schools and colleges earthquake resistant.

The risk from earthquakes in the region is real and can affect large populations (Figure 2). Since the prediction of earthquake in the near future is not a possibility, our efforts should be towards developing a coordinated programme, in association with neighboring countries, to understand earthquake processes. This will help scientists to assess long-term earthquake rates, facilitate probabilistic forecasting, and understand the structure and composition of the Himalayan lithosphere.[10]

Figure 2: Major Earthquakes in the Himalayan region 1992-2022

Year	Area	Magnitude
2016	India's Northeast	6.7
2015	Nepal	7.9
2005	India and Pakistan	7.6
2001	India (Bhuj)	7.9
1993	India (Latur)	6.2
2004	Sumatra (leading to Tsunami)	9.3

Source: List compiled by the author

Snow and Glacier Dynamics

The Himalaya, also known as the Third Pole, has the largest cryospheric surface outside the poles. Snow and ice or cryosphere, play a very important role in influencing earth system processes through its interaction with the atmosphere, biosphere, and geosphere. It is necessary to understand these processes and their impact on the Himalaya and environs. This region is least understood due to the paucity of observations, remoteness, challenging field conditions and limited time.

Glaciers cover 33,000 sq km area in Indian Himalaya. The first inventory of the Indian Himalayan glaciers was based on the satellite data of 1987 and was prepared at the Space Applications Centre, Indian Space Research Organisation (ISRO)[11], followed by the Geological Survey of India, which was based on aerial photos of 1962-63.[12] One of the important outcomes was the finding that most glaciers are fragmented in nature because of the ice recession during the last five decades. It is necessary that such inventories are produced at least every decade to understand the nature of change in glacier characteristics by all countries. The current availability of high-resolution radar images, high-resolution stereo data and hyper-spectral data can dramatically improve our knowledge about the characteristics of glaciers.

Though the information on aerial coverage of all glaciers is available, the information on the thickness of glaciers is sketchy. Hence there is a large uncertainty about the assessment of glacier-stored water. Ground Penetrating Radar (GPR) has been used to estimate thickness in few glaciers and observed they vary substantially.[13] Many researchers have developed models/methods to relate various glacier parameters to the volume of glaciers, however, these estimates have large uncertainties. Digital elevation models prepared using interferometric and photogrammetric techniques for obtaining high accuracy (< 1 m), along with unmanned aerial vehicle (UAV) based GPR data, should provide reasonable estimates of the thickness of glaciers.

Remote sensing, because of its multi-temporal capability, is an ideal tool to measure changes in glacial extent. Most glaciers have been retreating, however, there is a large variation in rates, from 1-60 m per year and appears to be complex. The reason for variability is attributed to micro and macro climatology, geomorphology (thickness, length, slope, altitude, debris cover), orography, nature of underlying substrate and nature of precipitation.[14] The glaciers in the Western Himalayas are retreating slowly, while those in the monsoon-dominated Eastern and Central Himalayas are retreating at faster rates.[15] The overall loss in glacier area in the Indian Himalaya is 16-17 percent from 1960 onwards.[16] A similar loss in glacier area has also been observed in the Chinese Himalayas.[17] In the Karakoram Himalayas, more than 50 percent glaciers are either advancing or stable[18], while the Siachen Glacier is retreating at the rate of 0.51 m per year.[19] The role of the nature of precipitation and underlying substrate needs to be investigated to explain variability in the advance and retreat of glaciers. Information on these two aspects is very sketchy. Other areas which need our attention include nature and characteristics of fragmentation. A geodetic network having accurate ground control points needs to be set up so that remote sensing data can be effectively used for monitoring glaciers.

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The impact of global warming and climate change may affect the nature of precipitation. Based on CMPI5 modelling, it has been estimated that 10.6 and 27 percent of glaciers may disappear under low and high-emission scenarios.[20] Since the extent of glaciers is directly related to changes in climate, it is important to concentrate on the climate of the Holocene period to understand the background of natural variability underlying anthropogenic climate change. Holocene climate variations have been larger and more frequent than is commonly believed.

Mass balance is one of the key factors in assessing the health of glaciers. It also affords to model future changes in the glacial expanse and resultant runoff.[21] However, its estimation in the field is very challenging due to the harsh and rugged terrain of the Himalaya. Hence such measurements are carried for very few glaciers and periodically. Mass balance studies over 110 years were carried out for a few glaciers in the Baspa basin[22] and both positive and negative mass balance in glaciers was observed. In another study, it was found that there is no accumulation in the Bara Shigri glacier in the Chandra basin. It is fed by avalanches and subsidiary glaciers.[23]

Attempts have been made to compute mass balance using Accumulation Area Ratio (AAR) method, which primarily uses remote sensing data. Chaturvedi and co-workers[24] have shown that the Karakoram ranges have a positive mass balance, while the mass loss in Western Himalaya is much lower compared to the Central and Eastern Himalaya. The

Figure 3: List of Glacial Lakes in India

Basin Name	Glacial Lakes	Water Bodies	Total
Brahmaputra	294	1099	1393
Ganga	178	105	283
Indus	31	321	352
Total	503	1525	2028

Source: Central Water Commission[28]

Figure 4: Glacial Lakes and Water Bodies in the Himalayan region
(having water spread area more than 10 Ha)

Country	Glacial Lakes	Water Bodies	Total
India	60	448	508
Bhutan	77	124	201
Nepal	57	45	102
China	309	904	1213
Myanmar		4	4

Source: Central Water Commission[29]

use of the Gravity Recovery and Climate Experiment (GRACE) data has shown mass loss of about 5 billion tons of ice annually.[25] During the last two decades, increasing imbalance in the mass budget has been observed. These studies also proved necessity for at least decadal monitoring of all glaciers in Himalaya (Figure 3 and 4).

Many moraine-dammed lakes are formed due to the retreat of glaciers and are among the major hazards in Himalaya. According to the survey carried out by the International Centre for Integrated Mountain Development (ICIMOD), there are 20,200 such lakes in the Himalaya and they can cause Glacial Lake Outburst Floods (GLOF). The increase in the number of these lakes between 1990-2015 is about 14 percent, leading to the increasing threat of GLOF.[26] The risk of flooding due to GLOF is likely to increase in the future. A model for the formation of such glacial lakes and their expansion has been developed.[27] An international network is required to monitor such lakes and to develop an early warning system.

The Tibetan Plateau is a large storehouse of ice and a vast expanse of permafrost (~ 1.6 M sq km). The release of methane gas from permafrost is a real possibility and can further enhance global warming. The permafrost on the Tibetan plateau has been shrinking and development of infrastructure can accelerate the disintegration. It has been reported that the lower altitudinal limit of permafrost has risen by 50-100 m along the Qinghai-Kang Highway compared to 15-16 m in twenty years.[30] The other aspect is the deposition of black carbon on ice and its impact on melting. Xu and co-workers (2009)[31] analysed five ice cores for black carbon from Himalaya and Tibetan Plateau. They have found a high concentration of black carbon during the 1950-60s and low concentration during the1970s-1980s and attributed their occurrence to the European emission source. The increase in black-carbon levels in the 1990s has been linked to a rapid industrial growth in the region. China has launched an 'International Third Pole Environment Project' to address many of these issues.

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Future studies should focus on mass balance and hydrological balance to differentiate climatic and non-climatic factors influencing the Himalayan glaciers. The setting up of the 'Himansh' Research station at the Sutri Dhaka glacier in the Chandra basin by the ESSO-National Centre for Polar and Ocean Research (NCPOR), Goa, has facilitated continuous measurements for energy balance, hydrology, and mass balance studies in the last eight years. This data set is ideal for modeling these glaciers. There is a need to set up many such stations in the Himalayas to understand the interactions between atmosphere, hydrosphere, and cryosphere.

The Himalayan Rivers

Three mighty rivers, the Indus, the Ganga, and the Brahmaputra, originate from the glaciers in the Himalaya and flow through China, India, and Pakistan. The Indus basin, which is mainly dependent on snow and glacier melt, supports most of the food production in Pakistan and about 25 percent in India.[32] Hence, the information about the health of the glaciers and the variability of snow cover is vital for understanding changes in snow and glacial melt runoffs.

The changing water cycle is a major issue and our understanding of it is limited. The information on snow cover variability is important as it feeds rivers during the summer months. Also, it has a very high albedo and is thus an important component of the Earth's radiation budget and modulating climate. The snow cover has been monitored since the advent of the satellite era in 1960. The volume of snow is computed using satellite-based snow cover and representative snowfall data. Algorithms have been developed for estimating snow depth using passive microwave radiometer.[33]

The rivers originating in Himalaya depend on snowfall-specific accumulation occurring in February-March and the post-monsoon season, and winter snowfall and monsoon rainfall in the western and central region, respectively; while rainfall and snowfall season are close to each other in the eastern region.[34] The average volume of snow in the Indus, Ganga and the Brahmaputra basins have been estimated to be about 54.5, 9.3 and 14.5 billion cubic meters, respectively.[35] Hence the water flow in the Indus basin greatly depends on the amount of snow.

In the Indus catchment, the glacier melt water makes a large proportion of the hydrological budget, and a loss of glacier mass will ultimately lead to decreasing water supply. In monsoon-fed Ganga and Brahmaputra basins, the contribution of glacial melt is comparatively small and the decrease in water supply is limited. Hence, it is expected that current changes in glaciers and snow cover will affect North-West India and Pakistan more severely compared to the Gangetic plains. Due to such a recession, the sustainable and steady supply of water to the rivers in the Indus basin is doubtful, especially the summer water flow. Such a scenario will affect population in these regions as well as biodiversity. Therefore, reliable estimates of snowmelt contributions in the glaciated Himalaya River basins are crucial for forecasting regional water availability.

Very few studies have been carried out to map changes in snow cover and there are no reliable estimates of any discernible trend in the snow cover. However, the study carried out in Bhutan showed a decreasing trend at the rate of 3 percent during 2002-2010.[36] All major rivers in Bhutan depend on snowmelt for discharge. In another study, the temporal variation of snow albedo in Arunachal Pradesh showed decreasing trend in the percentage area of dry snow and wet snow and the increasing trend for firn and ice during 2003-13.[37] It was also observed the pattern of snowmelt is different in basins which are relatively low altitude than that of high altitude.[38] Therefore, changes in snow cover due to climate change can influence the distribution and availability of water in the downstream region.

The North West Himalaya has experienced the highest rate of warming, about 2.2 degree C, especially in the winter season.[39] It has been observed that the duration of winter has been decreasing and consequently, the amount of winter snowfall may have decreased. Systematic studies of snow cover variability are essential. We also know that the high albedo from surfaces covered by snow and ice in the Himalaya region has a cooling effect over the mountains but a warming effect over the Persian Gulf and Arabian Peninsula.[40] Any long-term change in snow cover will affect not only the Himalaya but also the Middle East Asia.

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The frequency of heavy precipitation has increased, which is consistent with warming and increase in atmospheric water vapour. Five major flood events occurred in the Himalayan region during the last 10 years and caused economic loss of billions of rupees, migration of millions of people and casualty of thousands of human lives. The recent floods in the Rishi Ganga due to rockslide/avalanche caused excessive damage and loss of lives. A rising trend of precipitation has been observed during the last few decades and will continue in the 21st Century.[41] The Gangetic plains, Assam and Bangladesh are affected by floods every year. The reduction of forest cover is one of the reasons for flooding in Bihar. It has been suggested to build an international network to monitor risks from floods, especially from glacial lakes to provide an early warning – such as a tsunami warning system.[42] There is a need to improve observations in the Himalaya and enhance the efforts in modelling and developing a warning system.

The increase in the frequency of heavy and very heavy rainfall and the decrease in low and moderate events are likely to affect shallow ground water tables.[43] The shallow groundwater supports terrestrial ecosystems by sustaining base flow in rivers and root zones in the absence of rain.[44] The Gravity Recovery and Climate Experiment (GRACE) has been mapping Earth's gravity field with an accuracy of a few microGal (10-8/s2). The GRACE data, along with hydrological models, have been used to understand variability in groundwater storage. The changes in groundwater resources have been reported in north India[45] and the variability has been linked to precipitation patterns.[46] Routine monitoring of the regional ground water table needs to be initiated. Groundwater modeling is necessary to understand changing climate, terrain, and the sea level in the Sutlej basin, and this will also provide insight into processes and the regional pattern of water table.

All Himalayan States have built large and small dams for hydropower generation for meeting the energy requirements of not only mountain people but also those of the plains. According to ICIMOD, there are about 550 hydropower projects either built or under construction or planned. The inclusion of hydropower within the international "Clean Development Mechanism" and its subsidisation as "carbon offsets" have encouraged States to opt for hydropower generation where possible. However, large hydropower projects cause hydrological and ecological damage and ultimately affect people. It may be useful if micro and mini hydropower generation are planned to support local communities.

Cooperation in sharing water resources as well as in scientific data collection on international rivers has a positive impact on the socio-economic conditions of communities. The Indus Treaty has been functional for decades and is a good example of cooperation. The likely changes in water supply in future, however, may lead to political tensions. One of the major challenges is the sharing of data related to water resources. It is necessary to draft a policy to share data among scientists of all countries, though sensitive data need not be shared. It may be necessary that the management of the water resources also addresses social and economic issues in addition to ecological aspects. This, however, will be possible only if the diplomatic relations among the countries are stable, secure and cooperative.

Most of the past studies on the Himalaya have been short-term and inadequate campaigns. Questions related to patterns and trends in physical, geological, hydrological, and chemical processes are yet to be addressed. It is necessary to augment systematic, continuous, automated, and long-term observations of various atmospheric, hydrological, geological, and geophysical parameters in the Himalaya, followed by modeling.

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Transformation of Himalaya

The population in the Himalayan states has been increasing and it has led to the additional requirement of resources as well as infrastructure. The Himalayan environment is being affected due to the pressure of infrastructure development (construction of roads, railways, tunnels, airfields, etc.), tourism, urbanisation, pollution, deforestation, armed conflicts as well as climate change. These activities led to increased frequency of landslides, floods, degradation of forests, wildfires, loss of biodiversity, etc. This degradation of the environment has been affecting human security and society.

There is pressure on the Himalayan forest due to urbanisation, infrastructure development and agriculture-related activities. The encroachment in forest for agricultural purposes is more intense as 1500 people depend on each sq km of agricultural land in mountains compared to about 500 people in the plains.[47] The forest cover in Nepal has reduced by 33 to 25 percent, while Bhutan has maintained its forest cover at around 64 percent between 1995 and 2003.[48] However, in India, forest cover has increased from about 9-81 percent to 11-79 percent between 1995 and 2021 in Himalayan states.[49] Most of the forest areas are susceptible to forest fire and incidences of forest fire are increasing. The loss of forest cover has increased incidences of landslides, and soil erosion, especially in Nepal. The habitat loss has also degraded biodiversity. An optimum forest cover is vital for preserving biodiversity.

Landslides, though they affect limited areas, also cause environmental and economic loss. The occurrence of landslides does not get sufficient attention as the individual events affect remote localities and human losses are limited. However, the collective loss of human lives from all landslides is quite substantial and hence needs to be addressed.

Tourism is one of the major industries, especially in Nepal and Bhutan. Tourism is growing on both sides of the Himalaya. Tourists' impact on Mount Everest, Gangotri and many other places has led to litter and soot pollution on ice and glaciers. The hydropower generation and dam building, though essential for energy security of communities, has affected the ecology.

The border conflicts between Pakistan, India, and China have enhanced the pressures. Many infrastructure development works have been undertaken to support defence requirements. The solution is to build observational systems, data standards and exchange, and a prediction system. Networking of required services for human communities is crucial to improve the quality of life in this terrain. The environmental issues are considered secondary to state security and developmental needs by all governments. In India, various grass-root movements and judicial interventions have been able to limit destruction up to a certain extent. The Himalaya is witnessing how political decisions and anthropogenic activities interplay with the environment, climate change and natural hazards. It requires an interdisciplinary approach and mechanism to understand the Himalayan environment, its role in the earth system vis-à-vis international politics. It is, hence, necessary to launch collaborative projects involving research institutions, public and private industries and financial institutions, policy makers and communities of the Himalayan states to improve and preserve the Himalayan environment, manage the waters, and ensure livelihood of people.

> **There is a need to convert the knowledge about the Himalayan system into products and services for weather, climate, and hazards for the entire region.**

Regional Engagements So Far

There is a need to generate knowledge about the Himalaya to conserve and protect its environment and provide resilience from natural hazards. It will not be possible for a single country to provide insight into these challenging issues. International partnership is required to improve understanding of the earth system processes and develop numerical weather prediction models to meet national and regional needs. There is a need to convert the knowledge about the Himalayan system into products and services for weather, climate, and hazards for the entire region. ICIMOD has provided knowledge about the Himalaya but not sufficient for addressing current challenges. The issue of indigenous people inhabiting the hazardous terrain must be addressed as a priority. The solution is to build observational systems, data standards and exchange, prediction system, networking of required services for human communities is crucial to improve the quality of life in this terrain. A knowledge-based society will help to sustain people as well as the Himalayan environment.

There are many cooperative mechanisms that exist between countries of the Himalaya and are as follows.

i) South Asian Association for Regional Cooperation (SAARC) can be an ideal mechanism but currently, it is not functional.

ii) Bangladesh, Bhutan, India, Nepal (BBIN) addresses issues related to water resources management, connectivity of power, transport, and infrastructure among these countries. It has limited objectives and not all issues are related to the Himalaya.

iii) The Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation (BIMSTEC), though it leaves out China and Pakistan, addresses issues related to "Environment and Disaster management."

iv) India and China have cooperated in green focused confidence-building measures. However, the data-sharing arrangements for the Brahmaputra River broke down after the Doklam crisis.

v) The Ministry of Earth Sciences, Govt. of India, did have a Memorandum of Understanding (MoU) with the Chinese Earth Administration, but no joint studies have been undertaken.

The idea of forming the Himalayan Science Council (HSC) was first mooted in 2013 to address all environmental issues common to all Himalayan nations as well as neighbouring states. However, it did not find sufficient support within the country at that time. The HSC, it has been proposed, will address all issues, scientific, social, cultural, and demographic, related to the Himalaya.[50] The science-based solutions to preserve Himalayan environment are required by policymakers to develop sustainable solutions.[51]

The first meeting of the BIMSTEC National Security Chiefs held in Delhi in March 2017 decided to develop a concept paper on HSC and prepare a Plan of Action. The Expert Group met in December 2019 in Goa and recommended that HSC be established to promote scientific cooperation, and establish HSC Secretariat to coordinate activities. It also agreed that a proposal for creating a financial mechanism for the Secretariat be placed before the BIMSTEC Permanent Working Committee for approval. These efforts need to be strengthened and joint studies should be initiated. HSC should strive to involve China and Pakistan in these efforts.

The Way Forward

The Himalaya is ecologically important and provides livelihood for many people across several nations. The aspirations of the Himalayan people for social and economic development must be addressed. At the same time, the degradation of the Himalaya due to development activities must be minimised. There is a need to generate improved knowledge about the Himalayan system. The following steps need to be taken:

i) Regional Study of Snow and Glaciers: Augment systematic, continuous, automated, long-term observations of solar radiation, atmospheric (air temperature, pressure, humidity, wind), hydrological (snowfall, meltwater), geological (ice cores), and geophysical parameters to understand patterns and trends of earth system processes in the Himalaya. Second, location of these stations can be decided after consultations. Focused studies on the regional inventory of glaciers, ice dynamics, mass balance and evolution of the cryosphere to understand the fate of glaciers, the driving forces, and modelling of GLOFs are necessary.

ii) Regional Studies on River Basins: Regional projections on the impact of climate change on precipitation during 2030s, 2050s, and 2100 need to be undertaken. There is also a need to develop reliable estimates of snowmelt contributions to river basins for forecasting regional water availability.

iii) Himalayan Early Warning System: An early warning system for landslides, avalanches and GLOFs through understanding hazards generation of processes for landslides, avalanches and GLOF is a necessity. A coordinated programme to understand earthquake processes by setting up seismic stations and geological/ geophysical measurements among research institutes of the countries of this region is required to understand the structure and composition of lithosphere, and to facilitate probabilistic forecasting.

iv) Himalayan Research Institutes: A network of research institutes of Himalayan countries needs to be created to carry out collaborative projects in the fields of snow and ice, hydrology, hazards, and social science for addressing societal issues of the Himalayan System and to develop strategies to provide resilience to large populations. Capacity building in all fields (as mentioned in i, ii and iii) in the neighbouring countries needs to be taken up by this group.

v) Himalayan Indigenous People's Council: It's necessary to protect the culture and history of the indigenous people. A council of indigenous people needs to be formed.

vi) Development Policies and Governance System for Himalaya: A mechanism for development of policies, based on the scientific knowledge generated by the studies and scientific collaboration, has to be defined by the Himalayan Science Council. A governance system based on these policies should be evolved.

India has launched a National Mission on Sustaining the Himalayan Ecosystem under the National Action Plan on Climate Change; however, it deals only with the Indian Himalaya. It was envisaged to create a database across disciplines, climate projections, etc., under this mission. However, there has been limited success. It is of utmost importance that India sets up a separate research fund to study various aspects of the Himalayan environment.

The Himalaya should be treated as a unique, single ecological system. The degradation of the system affects large populations living not only in the mountains but also in the plains. The participation of all Himalayan states, along with their research institutes, and young researchers is critical to sustain the Himalayan system. At the same time, people of the Himalayan countries should be made aware of the potential risks as well as ecological and geological importance of the Himalaya. The Himalayan Science Council should facilitate the regulatory process by providing scientific information about geological, hydrological, cryospheric and ecological aspects on a sustained basis. Greater knowledge of the Himalayan system will enable all the concerned countries to develop policy and regulatory mechanisms for the preservation of the Himalayan system.

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