# Climate Change Scenario and Vulnerability in Mountain Ecosystem: Focusing on India

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**ABSTRACT**

***Climate change is one of the main environmental challenges facing the world today. India is facing several problems. Climate change is associated with various adverse impacts on agriculture, water resources, forest and biodiversity, health, coastal management and increase in temperature. A majority of population depends on agriculture directly or indirectly. Climate change would represent additional stress on the ecological and socioeconomic systems that are already facing tremendous pressure due to rapid industrialization, urbanization and economic development. This paper analyzes the impact of climate change and its various aspects in the Indian mountain ecosystem context.***

***Keywords: Climate change, Impact, India, Risk, Vulnerability***

## 1. INTRODUCTION

The most important crisis, facing humanity across the globe, is climate change1 and its impact on the immediate human environment and natural ecosystems. Globally, the impacts of climate change include among others, rising temperatures, shifts in rainfall pattern, melting of glaciers and sea ice, sea level rise and an increased intensity and frequency of extreme weather events. The Fourth Assessment Report, IPCC (2007), has pointed out that historic emission of greenhouse gases in the atmosphere has already committed the Earth to some level of climate change. Over the last century atmospheric concentration of carbon dioxide increased from a pre-industrial value of 278 parts per million to 379 parts per million (ppm) in 2005 and globally average temperature has risen by 0.74 degree Celsius. The report also gives a detailed projection for the twenty-first century, which shows that the Earth will witness a continual and accelerating trend in global warming and best estimates indicate that the planet could become warmer by 3 degree Celsius by 2100 if enough measures to reduce concentration of GHGs is not timely implemented.

## 2. INDIAN HIMALAYAN ECOSYSTEM

The Himalayan ranges are the youngest and loftiest among the mountain systems of the world. They represent a highly complex and diversified system both in terms of biological and physical attributes. The region has a discrete geographic and ecological entity. It produces a distinctive

climate of its own and influences the climate of much of Asia. However, the variations in topographical features along three dimensional frame work (i.e., latitudinal: South-North; longitudinal: East-West; altitudinal: Low-High) cause diversity in climate and habitat conditions within the region. The Himalayan ecosystem is fragile and diverse. It includes over 51 million people who practice hill agriculture and remains vulnerable. The Himalayas house one of the largest resources of snow and ice and its glaciers which form a source of fresh water for the perennial rivers such as the Indus, the Ganga, and the Brahmaputra. Glacial melt may impact their long-term lean season flows, with adverse impacts on the economy in terms of water availability and hydropower generation. Recession of Himalayan glaciers will pose a major danger to the country. Currently available data gathered by multiples of institutions without a coordinated effort do not indicate systematic trends of recession of Himalayan glaciers. The Himalayan landscape systems are unique. These systems, with their steep slopes and sharp gradients, are heterogeneous and exhibit sharp and most often systemic changes in climatic variables over very short distances. These features consequently result into enhanced changes in hydrological processes, with accelerated direct runoff and erosion. Major rivers of the region have their origin from these mountains and are the source of water for a large proportion of the human population within and outside the mountain region. Many of the world's crops originate in mountains, a crucial resource that should be conserved for sustaining modern agriculture. Natural wealth in the region, including geological assets, forms an important part of the Himalayan eco-system. All this has contributed to a whole range of diversity in indigenous human habitations, cultures and knowledge systems. The Indian Himalayan Region with geographical coverage of over 5.3. lakh Km2 comprises of the vast mountain range extending over 2500 km in length between the Indus and the Brahmaputra river systems and raising from low-lying plains to over 8000 m above sea level, it is around 300 Km at its widest part with an average width of 80 Km. As the world's highest mountain chain, the Himalaya is characterized by a complex geologic structure, snow-capped peaks, large valley glaciers, deep river gorges and rich vegetation. More than 41.5% of its geographical area is under forests representing one-third of the total forest cover in India and nearly half (47%) of the "very good" forest cover category of the country. These forests generate a plethora of goods and services. However, a complex interplay of climatic and geological processes, destructive patterns of resource use and economic marginalization have led to the situation of heavy resource degradation and associated environmental consequences on the highly diverse and fragile Himalayan eco-system. The Indian Himalayan Region is a range that spans ten states of India namely, Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Sikkim, Arunachal Pradesh, Meghalaya, Nagaland, Manipur, Mizoram and Tripura as well as the hill regions of two states - Assam and West Bengal. The Indian Himalayan Region physiographically, starting from the foothills of south (Siwaliks), this mountain range extends up to Tibetan plateau on the north (Trans-Himalaya). Three major geographical

entities, the Himadri (greater Himalaya), Himanchal (lesser Himalaya) and the Siwaliks (outer Himalaya) extending almost uninterrupted throughout its length, are separated by major geological fault lines. Mighty but older streams like the Indus, Sutlej, Kali, Kosi and Brahmaputra have cut through steep gorges to escape into the Great Plains and have established their antecedence.

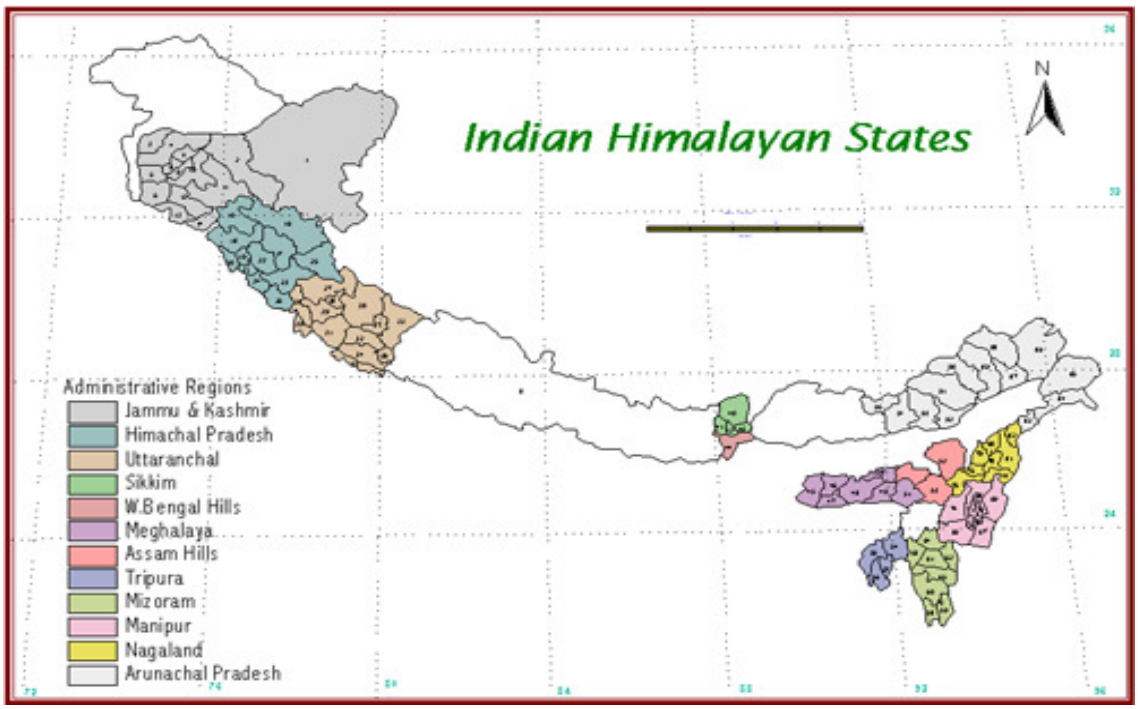


**Figure 1: Location Map of Indian Himalayan Ecosystem in India, with State Boundary**

***Source: gbpihedenvis.nic.in***

## 3. CLIMATE CHANGE IMPACTS AND RISK

The climatic changes described above will have serious implications for a number of sectors and resources, including agriculture, water availability and quality, and ecosystems like coastal zones. They will also have an influence on the frequency and magnitude of natural disasters. Very minor changes to temperature can have major impacts on systems on which human livelihoods depend, including changes to water availability and crop productivity, the loss of land due to sea level rise and the spread of disease. The lives and livelihoods of many different communities will be at risk. Rural areas are highly vulnerable to climate change, since people there depend heavily on natural resources such as local water supplies and agricultural land. In fact, about 70 % of the population in developing countries lives in rural areas, where agriculture is their main source of livelihood (IPCC 2007).

**Figure 2: Climate Change Impact Assessment of different sectors with associated Risk**

| | | |
|---|---|---|
| **Health** | ❖ Increased mobility and mortality<br>❖ Increased burden of health<br>❖ Thermal stress<br>❖ Resulting in discomfort<br>❖ Psychosocial stress and illness | ❖ Availability of fresh water<br>❖ Availability of Sanitation facilities<br>❖ Vector borne diseases<br>❖ Thermal stress |
| **Water Resource** | ❖ Stress on water shortage<br>❖ Reduced supply of drinking water<br>❖ Increased mobility and morbidity<br>❖ Reduce availability of water resource for industrial and food purposes<br>❖ Reduced potential of hydro electric power generation | ❖ Availability of Fresh water<br>❖ Reduced quality of availability water resource<br>❖ Reduced stream flow<br>❖ Depletion in ground water<br>❖ Flood and Drought |
| **Biodiversity** | ❖ Loss of ecosystem services<br>❖ Loss of livelihood for people dependent on forestry<br>❖ Decline ambient air and water quality leading to health<br>❖ Extinction of species | ❖ Long dry spells<br>❖ Intensity of land use<br>❖ Fragmentation of habitats<br>❖ Species invasion<br>❖ Desertification<br>❖ Land degradation |
| **Agriculture** | ❖ Increased risk of desertification<br>❖ Land degradation<br>❖ Decline in crop yields<br>❖ Decline in crop production<br>❖ Decline in availability of food<br>❖ Increased incidence of malnutrition | ❖ Temperature stress<br>❖ Erratic precipitation<br>❖ Reduce soil moisture<br>❖ Flood and Drought<br>❖ Invasion of parasitic species<br>❖ Diseases |
| **Forest** | ❖ Increased intensity of forest fire<br>❖ Exacerbating problem of carbon emission<br>❖ Destruction of habitat<br>❖ Decline of major species<br>❖ Impact on indigenous flora and fauna | ❖ Temperature stress<br>❖ Precipitation increase<br>❖ Loss productivity<br>❖ Reduce soil moisture<br>❖ Health of forest<br>❖ Occurrence of pest and diseases |

***Source: Based on IPCC Assessment Report***

## 4. VULNERABILITY ASSESSMENT OF CLIMATE CHANGE ON MOUNTAIN ECOSYSTEM

The climate change in the Himalayan region is visible and its early impacts are realized by the local communities too. The increase in frequency and intensity of extreme weather events and natural hazards in mountain regions is noticeable. These changes might result in multiple impacts on livelihoods water availability and the food security of the mountain community as well as downstream. Nearly 80% of the people living in the mountain region rely on natural resources for their livelihood, making them vulnerable to variability in climate, cropping pattern shifts, uncertain crop productivity, reduced water availability and shifts in tree line. The Indian Himalaya Region is affected by anthropogenic activities including developmental activities, habitat loss, poaching and fragmentation. Mountain landscapes are associated with widespread poverty and socio-economic vulnerabilities. They are also quite vulnerable to potential impacts of climate change - which can in turn have implications for the development in the region.

**Table 1: People's Perception on Climate Change in Indian Mountain Ecosystem**

| Kind of Change | Evidence |
|---|---|
| Warming | Decline in snow fall period, depth and persistence, decline in apple yield, success of cabbage/pea/tomato cultivation in high elevations in recent years, shortening of maturity period of winter crop, increased pest infestation. |
| Decline in rainfall during March-May | Large scale mortality, abandonment of panicum miliaaceum in rainfed area, declining yield of Amaranths. |
| High rainfall during August/September instead of normal peak in July/August | Damage to rainy season crop when they are close to maturity, increased frequency and severity of landslides and flash flood |
| Winter precipitation in January/February instead of December/January and decline in intensity of snow fall | Delayed sowing of winter crop, decline in barley and wheat yields |
| Increase in instance of cloud burst | Heavy losses of life and property |

***Source: ENVIS Bulletin, Vol 11(2)***

The Himalayan region, one of the most dynamic and complex mountain ranges, has a profound effect on the climate of the Indian subcontinent. It prevents frigid, dry Arctic winds from blowing

south into the subcontinent, which keeps South Asia much warmer than corresponding temperate regions in the other continents. It also forms a barrier for the monsoon winds, keeping them from travelling northwards, and causing heavy rainfall in the Terai region. But now Himalayas are vulnerable to global climate change and increasing human activities. In addition to the already existing threats and pressures on mountain ecosystem, climate change can be an additional burden to bear by the mountain ecosystems, species and peoples. Mountain people have lived with and survived great hazards for thousands of years, but current rates of climate change are among the most rapid known and they are superimposed on severe and, equally uncertain socioeconomic pressures. Mountain regions are seeing the greatest impacts on livelihoods and ecosystems with reduced ice and snow cover affecting **biodiversity and water resources**. A range of issues and policy areas are identified, from the regional to local community levels, through which these problems might be addressed. They involve land use, water management, disaster management, energy consumption, and human health. It is argued that community-led adaptive strategies and capacities, as well as substantial efforts to reverse the human drivers of climate change, are needed. Uncertainties about the rate and magnitude of climate change and potential impacts prevail, but there is no question that it is gradually and powerfully changing the ecological and socioeconomic landscape in the Himalayan region.

Ecologically sensitive mountainous areas, like the Himalaya, are prone to adverse impacts of global climate changes on account of both natural causes and anthropogenic emissions in other parts of the world as well as those arising out of unplanned developmental activities in the region. Himalayan Ecosystem resources are critical on the face of **natural disturbances**, anthropogenic activities and climate change. It has important implications for formulation of management strategies and sustenance of dependent human societies. Some of the significant consequences arising out of the global warming on the Himalayan region could relate to a) variability in the volumetric flow of water in the rivers, b) loss in biodiversity, c) unsustainable changes in ecology, d) glacier recession, e) deforestation and degradation, f) conditions for impending natural disasters and g) dislocation of traditional societies dependent vulnerably on the Himalayan ecosystem. Ganges, Brahmaputra, Yamuna, and other major river systems originate in the Himalayas. Any changes in the Himalayan glacier dynamics and melting are expected to severely affect about 1.3 billions of people.

The **Himalayan glaciers** are the second largest body of ice in the world, covering 17% (3 million hectares) of the mountain area and are the source of water for the numerous rivers that flow across the Indo-Gangetic plains. Unfortunately, the Himalayan glaciers are retreating faster than any other glaciers. The image shows the approximate recession of the Gangotri glacier- one of the largest glaciers in the Himalayans. From 1780 to 2001 this glacier retreated almost 2 km. Compared to

other glaciers around the world, there is a lack of information on the impact of global warming on the Himalayan glaciers. Described as "a blind spot, a big scientific question mark" scientists are working to correct this gap. Millions of the peoples living in Himalayan region are relying on the glacial melt waters from the Himalayan glaciers. A decline in glacier mass balance can mean less water available for rivers. It is a worry that the receding glacier trend could lead to the Ganga, Indus, Brahmaputra and other rivers in northern India becoming seasonal rivers (IPCC 2007). If these major rivers are dry during the summer months. It will affect the water supply for irrigation.

The presence of highly complex river basin systems indicates the importance of glaciated mountains, which account for most of the glacial melt water. Both glacial melt water and monsoonal precipitation provide a significant component of **water resources** for different parts of the country. While snow and glacier melt are the major factors in the western and central Himalayan region, rainfall patterns in the eastern part of India are responsible for the changing water regime. Impact of deglaciation on the water resources of the Himalayan region and change in local water discharges can respond to future climate scenarios. This may results in increased water availability in some river basins and decreased water supplies in other regions in the coming decades. The glacial fed rivers of Uttarakhand are an important resource for the Ganga basin with many rivers contributing to the irrigation potential of some of India's most densely populated states like Uttar Pradesh, Bihar, Delhi, Haryana etc.

A warmer climate, with its increased climate variability, will increase the risk of floods. As there are a number of climatic and non-climatic drivers influencing flood impacts, the realization of risks depends on several factors. **Floods** include river floods, flash floods, urban floods and sewer floods, and can be caused by intense and/or long-lasting precipitation, snowmelt, dam break, or reduced conveyance due to ice jams or landslides. Floods depend on precipitation intensity, volume, timing, antecedent conditions of rivers and their drainage basins (e.g., presence of snow and ice, soil character, wetness, urbanization, and existence of dikes, dams, or reservoirs). Human encroachment into flood plains and lack of flood response plans increase the damage potential.

The Indian Himalayan Region (IHR) harbours about 8000 species of flowering plants, i.e., nearly 50% of the total flowering plants of India. Of this, nearly 30% are endemic to the region. There are over 816 tree species, 675 edibles and nearly 1740 species of medicinal value in the Indian Himalayan Region. The Himalaya with its vast green cover acts as 'sink' for carbon dioxide. Annual carbon sequestration by the forests of western and north-eastern Himalaya is just one of the important ecosystem services being performed by the Himalayan forests. This service needs to be therefore further strengthened and exploited for global good. Further, vast area under permanent snow cover and glaciers (about 17% of Indian Himalayan Region), and about 30-40% under

seasonal snow cover, form a unique water reservoir. This feeds several important perennial rivers that provide water for drinking, irrigation, and hydropower. Indian Himalayan Region is home to nearly 4% of the country's population, and is provider for their livelihoods.

Indian Himalayan Region is highly vulnerable both due to geological reasons and on account of the stress caused by increased pressure of population, exploitation of natural resources and other related challenges. These effects may well be exacerbated due to impact of climate change. Climate change is likely to adversely impact the Himalayan eco-system through increased temperature, altered precipitation patterns, episodes of drought, and biotic influences. This would not only impact the very sustenance of the indigenous communities in uplands but also the life of downstream dwellers across the country and beyond. Change in climate could also cause **infectious diseases** transmitted by insects, i.e., vector borne diseases like malaria, yellow fever etc. The distribution of vector-borne diseases is restricted by climatic tolerance and any climatic change is expected to alter the edges of current geographical distribution. Mountain regions are predicted to encounter above-average climate changes caused by human activities; thus the implications for human health from the impacts of climate change need reviewing.

- **Seismic Vulnerability:** The Vulnerable are the Urban population and people in slip potential regions of the Himalayas
- **Modification of Glacial System and Reduction in Snowfall:** According to 4th assessment study of IPCC, Himalayan glaciers are melting at a faster pace since late seventies. A recent study concluded that almost 75 percent of Himalayan Glaciers are receding at a fastest rate.
- **Rainfall:** Indian Metrological Department observation show that events of extremes rainfall have increased by 50 percent during the past 50 years.
- **Agriculture** in around 70-80 percent of the region is rainfed. An increasingly erratic weather change in particularly time and space has given hardships to the farming community, impacting the productivity. The reducing agricultural diversity is adding to the vulnerability of the hill farming community.
- **Extreme events**: Extreme weather events leading to cloud burst are a phenomenon known in the Himalayan and have devastating consequences. Compilation of reported cloudburst.

**Figure 3: Climate Change Vulnerability: Major Point**

An important socioeconomic consequence of global warming the hydrological cycle is linked to potential changes in **runoff** extremes. Not only the mountain population but also the people in the plains downstream depend on unregulated river systems and thus are particularly vulnerable to

climate-driven hydrological change. Current difficulties in implementing water resource development projects will be compounded by uncertainties related to hydrologic responses to possible climate change. Among these, possible increases in sediment loading would perturb the functioning of power-generating infrastructure. Sensitivity of mountain hydrology to climate change is a key factor that needs to be considered when planning hydropower infrastructure. **Hydro power projects** have only added to the vulnerability of the local communities as they have rendered the rivers non-functional, affecting the environmental needs of living beings in its catchment or dependent on the rivers. Resources required for **tourism** are climate-dependent—that is, their availability may be affected in the short and long term by variability, extremes, and shifts in climatic means. These resources include the landscapes of natural and anthropogenically influenced ecosystems and climatic conditions that are suitable for specific activities. Impacts of climate change on tourism in mountain areas may be divided into two types: direct and indirect. The former would result from changes in the atmospheric resources necessary for specific activities (e.g., clean air, snow). Indirect changes may result from these changes and from wider-scale socioeconomic changes, for example, fuel prices and patterns of demand for specific activities or destinations. Various indirect impacts may also derive from changes in mountain landscapes—the "capital" of tourism (Krippendorf, 1984)—which might lead potential tourists to perceive them as less attractive, and consequently to seek out new locations. There also may be new competition from other tourist locations as climates change, particularly on seasonal timeframes, especially in relation to vacation periods.

## 5. CONCLUSION

The context of climate change, rapid development is sustainable development in the case of a low-income country. If they fail to develop rapidly, low-income countries will be unable to adapt to climate change with any degree of success. Future generations in these countries will have to pay a heavy price if the present generation fails to achieve rapid development. For low-income countries, sustainable development is the best form of adaptation.

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