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POTENTIAL IMPACTS OF CLIMATIC VARIABILITY ON INDIAN HIMALAYAN REGION

Kavita Tariyal and Dhanesh Mohan Bartwal
Department of Applied Sciences and Humanities, THDC Institute of Hydropower Engineering and Technology, Bhagirthipuram, Tehri Garhwal-249001, Uttarakhand, India
Corresponding author's E Mail: **kavitathdc16@gmail.com**

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Abstract: The Himalayan region represents enormous variability of climates, hydrological and ecological systems, plus a diversity of cultures and communities. It is an essentiality to the ecological security of the Indian landmass, through providing forest cover, feeding recurrent rivers that are the source of potable water, irrigation, and hydropower, conserving biodiversity, providing a rich foundation for high value agriculture, and spectacular landscapes for sustainable tourism. Increasing concentration of greenhouse gases in the troposphere and the consequential global warming is posing a great environmental threat to water and food security at universal level. Change in climate may affect exposures to air pollutants by affecting weather, anthropogenic emissions, and by changing the distribution and types of airborne allergens. This potential variability in climate will have a serious impact on several ecosystem services, such as cleaning water and removing carbon from the atmosphere. Various services of ecosystems viz. land and water resources, agriculture, biodiversity will experience a wide range of stresses together with pests and pathogens, invasive species, atmospheric pollution, acute events, wildfires and floods. Direct stresses posed due to climate change may get intensified through high temperatures, reduced water availability, and altered frequency of extreme events and severe storms. Climate change will potentially make a threat on the availability of, and access to, water resources. The Himalayan ecosystem is vulnerable to the impacts and consequences of a) changes on account of natural causes, b) climate change resulting from human-induced emissions and c) developmental paradigms of the modern society. Adaptation factors in the element of 'sustainability' into development initiatives and provides for additional measures and resources to safeguard environmental gains against climate impacts.

Keywords: Adaptation; Anthropogenic emissions; Climate impacts; Ecosystem services; Himalayan ecosystem; Sustainability; Water resources.

Postal Address: Assistant Professor, Department of Applied Sciences and Humanities, THDC Institute of Hydropower Engineering and Technology (A Constituent College of Uttarakhand Technical University), Bhagirthipuram, Tehri Garhwal-249001, Uttarakhand, India

INTRODUCTION

The Himalayas are considered as one of the major geo-ecological features of the planet. Not only is the Mount Everest, the highest mountain, found here, but also nine of the world's 14 tallest peaks. The progression of the monsoon rainfall pattern of the whole of Asia is attributable to the presence of Himalayan Mountains. The high mountain ranges tend to intercept cold winds from the north and trap moisture from the winds rising from oceans in the south. In this way they create a nautical climate in a continental location (Singh and Singh, 1992). The juvenile and growing mountains have an adolescent topography, which makes the slopes very vulnerable to erosion, causing heavy silt loads in rivers originating in the Himalayas. The amount of rainfall varies extensively in the Himalayan ranges. It is tremendously high in a few regions of the eastern Himalayas such as Meghalaya, where it reaches 11,600 mm annually, specifically in Mawsinram (Dhar and Nandargi, 2008); while in the north of the main Himalayan ranges there are huge rain shadow areas. The Himalayan glaciers are usually considered as the source for most of the major river systems of the Indian subcontinent. As the studies show, the glaciers have extensively been reported to be receding, even if the rate of this retreat is not yet utterly clear (Dyurgerov and Meier, 2005). A substantial area of the Himalayan region is under alpine meadows (locally called buggyals), known for precious medicinal plants and used for grazing sheep and goats. The alpine meadows are capable for soil carbon sequestration, particularly where peat lands develop. Climate change is one of the most important universal ecological challenges that are affecting all the natural ecosystems of the world. Mountain ecosystems are the most susceptible to the impact of climate change due to their fragile properties. Mountains have been documented as important ecosystems by the Convention on Biological Diversity (CBD). Mountain regions symbolize about one fourth of the Earth's terrestrial surface, provide ecosystem services to more than half of humanity and are in the nearby environs of approximately one fourth of the global population. Symbolized as Water Towers, Mountains are the source of a major portion of world's fresh water; repositories of nearly half of the world's biodiversity 'hot spots', destinations for leisure, areas of cultural diversity, knowledge and heritage. They provide food, energy, non-timber forest produce (NTFP) and timber. The number of people living in mountainous region is estimated to be 1.2 billion, with 90% of this population residing in developing and transition countries which are having poorest and food-insecure populations, one-third in China and two-thirds in Asia and the Pacific. Nearly 10 % of the world population is directly dependent on the mountain resources such as water, forests, agriculture and NTFP for their livelihood (Task Force Report on Mountain Ecosystems, 2006). The Himalaya and neighboring mountain ranges in the north-east region within Indian Territory, jointly known as Indian Himalaya Region (IHR), represent highly fragile and vulnerable Mountain Ecosystems in the country. The IHR, a land of heavenly environment, is renowned as one of the important global 'Biodiversity Hotspots'. The area encompasses a diverse range of ecosystems, wide-ranging environmental conditions and unique cultural landscape. This region is considered important for maintaining the regional climate, carbon sequestration and provides numerous Ecosystem services to mankind. Yet, the people residing here suffer from socio-economic marginality, inaccessibility, and lack of livelihood opportunities.

Environmental Problems in the Region

Few years ago, Chapter 13 of the Agenda 21 document accredited the significant role of global change issues in mountain regions by pointing out that mountain environments are essential to the survival of the global ecosystem and that many of them are experiencing swift degradation. This conventional opinion has become outdated which said that mountains are untouched ecosystems completely inaccessible from human impact and only marginally connected to economic, political and cultural centers of influence. This can be understood by taking an example of massive and widespread retreat of alpine glaciers which highlights the impact of global climate change at high elevations and the consequences for lowland agriculture, hydroelectric power, mitigation of natural hazards and eco-tourism. Likewise, greater physical, administrative and market integration of mountain and upland agriculture with mainstream systems has distorted local resource management strategies leading to resource use intensification and overexploitation. Many mountain systems are in jeopardy by the rising global scale of both systemic human impacts, which impact environments at global scale, and cumulative ones, which operate at local scale but are becoming globally persistent. These systems are moving along trajectories that couple high rates of environmental change in delicate ecosystems with economies that are strongly dependent on local environmental resources and restricted in terms of response capability. In future also, these impacts might be compounded by globalization processes that are likely to be equally important as drivers of change in mountain regions. The combined impact may drastically threaten the ability of mountain regions to provide critical goods and services, both to mountain inhabitants and to supply the extra-regional demands of other communities.

Impact on Glaciers

Glacial retreat is the product of climate change; truly reckoned as veritable thermometers of global warming. At higher altitudes of Himalayas, snowfall builds up year-after-year to form glaciers, the long-term reservoirs of water. Although the data which are available are not so much reliable, the higher Himalayas and the inner Asian ranges together have the largest glaciated areas outside the Polar Regions (Dyurgerov and Meier, 2005). According to a UNEP report a number of glaciers in Nepal and Bhutan are receding at the rate of 2-100 m per year. Gangotri, a well known glacier in Uttarakhand, the source of the Gangetic river system retreated during the last 30 years at a rate nearly three times higher than the preceding 200 years. The rate of glaciers thaw would boost further as glaciers become smaller. Glaciers in Nepal are thinning at rates between less than 5m and 20m per year (Fujita *et al.,* 2001). On the whole, Himalayan glaciers are melting more rapidly than the world average (Dyurgerov and Meier, 2005). However, according to some studies, there is extensive evidence of development or down slope redistribution of ice in Karakoram (Hewitt, 2005). Impacts are now visible to everyone. The rivers and adjacent ecosystems would be harshly affected by the rapid snow melting and subsequent phase of the absence of the snow melt water forever with the loss of glaciers. The rapid release of melt water and rainfall may merge to activate debris flows and flash flood in higher ranges, including the formation of potentially dangerous lakes. These lakes may breach suddenly, resulting in discharge of huge volume of water and debris which is called Glacial Lake Outburst Flow (GLOF). Many species of the alpine grasslands are able to start their growth with the supply of snow melt water, just before the beginning of monsoon in June-end (Singh and Singh, 1992). In this way, their growths and life cycles might be disrupted because of the lack of snow- melt water once glaciers are gone. Several organisms and ecosystem processes which entail flow of water are going to be affected once these snow reserves are gone. The species composition and structure and functioning of alpine meadows (buggyals), which are well recognized for their carbon sequestering property, are going to change both because of increased temperatures and loss of snow. Table 1 shows the magnitude of this process which is going to be more severe with every passing year.

Table 1. Recession of Himalayan Glaciers (Task Force Report on Mountain Ecosystems, 2006)

Name of Glacier	Period of Measuring	Period (years)	Recession (m)	Average rate (m/yr)
Milam	1849-1957	108	1350	12.50
Pindari	1845-1966	121	2840	23.40
Gangotri	1962-1991	29	580	20.00
Tipra bank	1960-1986	26	325	12.50
Dokriani	1962-1991 1991-2000	29 09	480 161.15	16.5 18.0
Chorabari	1962-2005	41	238	5.8
Shankulpa	1881-1957	76	518	6.8
Poting	1906-1957	51	262	5.13
Glacier no-3 Arwa	1932-1956	24	198	8.25
Bara Shigri	1956-1963	07	219	31.28
Chhota Shigri	1987-1989	03	54	18.5
Sonapani	1909-1961	52	899	17.2
Kolai	1912-1961	49	800	16.3
Zemu	1977-1984	07	193	27.5

A rapid increase in glacial melting is likely to amplify runoff and glacial lake outburst floods. Decline in the Cryosphere can also amend upstream hydrology, stream flow, primary productivity and mountain farming. Other consequences of reduced hydrological functions may comprise scarcity of drinking water, drop in agricultural and hydropower production (Shrestha *et al*. 2000). Hill aquifers have been providing water in the form of springs since the time immemorial which is responsible for sustaining domestic livestock and agricultural activity. Already access to safe drinkable water is limited in the Indian Himalayan Region. Under the changed precipitation conditions, leading to increased run-off and less infiltration; coupled with removal of forest cover, has already started showing signs of depleted hill aquifer regimes in the IHR. Climate change has been resulting into changes in the frequency and magnitude of extreme weather events (Tariyal *et al.,* 2013).

Impact of Climate Change on Crop and Livestock Productivity

Changing precipitation patterns along with increasing temperature would have direct impact on crop productivity. Much of the area would face aridity with the disappearance of glaciers and diminishing summer runoff. Climate change would negatively affect the quality of horticultural crops such as apple and apricots. There may be shifts in fruit belts but there exists very little scope for expansion. Phenology of flowering and fruiting of many plant species would be amended. Generally late snowfall is known to affect the processes of pollination in some way. Not only this, the relative immobilization of bees is enhanced due to low temperatures brought about by late snowfall. In the same way, rangelands and pastoral production systems are likely to get affected. Positive factors such as carbon dioxide fertilization effect and better water use efficiency would be challenged by negative feedback such as deficit of water and higher temperature fluctuation. Changing climatic scenario would affect the rangeland forage quality and quantity, suggesting an increased necessity for feed supplements for livestock. There would be an increased livestock production at higher altitudes because of increased temperature and heat stress. As livestock diseases are influenced by climate change, transmission of many wind borne diseases viz. Foot and Mouth Disease viruses may increase (Task Force Report on Mountain Ecosystems, 2006).

Effect on Forests and Biodiversity

Change in climate is likely to promote the frequency and intensity of forest fires in the mountains, exacerbating problem of carbon emissions, haze and habitat destruction. Same factors which apply on plants and crops in general will also largely apply to forests. A depletion of soil moisture may become a causative factor for declining of productivity of major species. There would also be a reduction in the productivity of moist deciduous forests. Global climate change has provoked serious concern over the potential negative impacts to the world's ecological systems and wildlife. Shifting in habitat due to climate change will have an impact on indigenous flora and fauna, and their ability for adaptation in changing climatic conditions. The hydrological changes to a species' habitat which are climate-induced are likely to become more and more prominent as the global mean temperature of the earth will rise; resulting in changes in salinity, water temperature, and increase in sun exposure in areas due to evaporation, melting ice, and various other interconnected implications.

Implication for Human Health

For proper understanding of the climatic variability impacts and climate change requires information and thorough research at multiple levels. The data in case of health observation in Indian Himalayan Region is not readily available which makes projections and observations complicated. Some of the widely accepted implications for human health are perceived as follows:

i) Increase in ambient temperature may cause thermal stress, which would result in discomfort, physiological stress, and ill health.

ii) There are already many problems associated with water quality which would further exacerbated by climate change. There would be a boost in the risk of water-borne diseases.

iii) Climate change will also induce infectious diseases viz. malaria, dengue, and schistosomiasis. These diseases are susceptible to temperature as well as to land-use changes.

Impact of Climate Change on Ecological and Sociological Aspects of Himalaya

Change in climate will noticeable impact the social life in mountains too. Potential ecological cascading effects include secondary extinctions triggered by losses of key species in the alpine ecosystems. The endemic-rich Himalayas are comprised of many plant species that may not respond successfully to projected rates and scale of climate change (Mutke and Barthlott, 2005; Salick *et al*. 2009). One of the obvious risks which is associated is species extinctions from mountains which is not high enough to offer escape routes in the case of upward shifts of taxa (Becker *et al.* 2007). Generally, the response of natural vegetation to predictable climate change will be complex; some species will decrease, some increase, and new ones may also appear (Chen *et al*. 2003; Williams *et al*. 2007). Invasions of weedy and exotic species from lower elevations are likely (McCarty, 2001). Climate change is predicted to severely affect the tourism industry in view of shorter duration winter snow and lower river discharge in summer. High temperatures are also likely to affect the tourist trend leading to crowding of smaller resorts having comfortable temperature levels, but its consequences on the environment are likely to be severe. The poorer sections of the society in the Indian Himalayan Region are less prepared to tackle the impacts of climate change as compared to richer sections. Malnutrition due to reduction in food quality and quantity is likely to increase in this region. Mountain areas and related communities are vulnerable to climate change. The mountain communities of this region largely depend on the diverse forest types and alpine meadows to provide for their personal needs and their livestock's sustenance (Sati, 2006). Fluctuations in the physical environment of the Himalayan glaciers are being reflected in the livelihood changes of the local communities. Effective human adaptation is needed here to combat the problems associated with climate change which include the establishment of adaptive capacity, knowledge and governance and the adaptation itself *i.e*. changes in behaviors and livelihood practices to meet new conditions (Smit and Pilifosova, 2001; Mirza, 2007).

Climate change and Adaptive Measures

The major risks associated with the changing climatic scenario at the rate and scale projected in the Greater Himalayas, however, cannot be eliminated by a natural process of gradual adaptation. People should also act now to reduce future negative consequences with adaptive measures. For example, Floods are known to be induced by precipitation, but riverbank retaining walls, bio-stabilization of slopes, and terracing fields can alleviate flood impacts to some extent. Various other damages such as landslides, rock-falls, and mudflows can also be reduced by these measures. Mountain citizens have evolved fine-tuned social systems to deal with natural hazards using customary ecological knowledge and traditions (Xu and Rana 2005; Byg and Salick, 2009). According to different studies done on the Tibetan Plateau there are various links between rural livelihoods, land use, human health, and climate change (Wilkes 2008; Xu *et al*., 2008). Even though information on the budding impacts of climate change is becoming increasingly available, there is very little done for the existing adaptive capacities of communities in the region and their vulnerabilities to predicted changes. The cascading effects of climate change on local people need to be identified, predicted, and filtered through many cultural contexts, but this has not been done yet (Wang *et al*. 2002).

Climate change and Remedial Measures

India is committed to follow the major principles as included in the National Environmental Policy, 2006 as a signatory to Kyoto Protocol. Just commit to these principles across the globe is not well enough for the mountain people, meanwhile these people themselves will have to get well adapted and duly equipped to deal with the ensuing penalty of climate change. There will be required a series of technological interventions backed by scientific research and socio-economic as seen by the researchers, policy makers the mountain people. In view of their multiple disadvantages and poverty, mountain communities will require a very upbeat and integrated package of assistance, particularly in capacity building. Other programmes which are well recommended in the mountain regions are given below:

a) Set up of Meteorological Stations across Indian Himalayan Region

A network of meteorological stations across Indian Himalayan Region is indispensable in view of sudden and intense catastrophic events in recent time, and initiate an integrated study on climatology through coordinated effort among various institutions, collect technical (forecasting, monitoring, mapping ,and training for professionals) political and financial support for the this objective. Various models are needed to be developed using composite data to predict the changes and compute their impact in the various ecosystems of this region for better management plans.

b) Deep and intensive monitoring of glacial retreat to get the reliable data

Glaciers in Himalayan regions are needed to be deeply and incessantly monitored for determining the trend of the impact global climate change and get reliable information to envisage factual things.

c) Mapping and monitoring Glacial Lake Outburst Flow (GLOF) and resulting flash floods

Remote sensing monitoring as well as ground truth information can be very important for the prediction of the natural hazards along the glacial rivers. This strategy would be very much helpful for intensifying the mountain hazard mitigation measures in the whole Himalayan regions, especially the vulnerable ones. There should be open discussions among the brains of national and regional levels on how to address flood risk and disaster preparedness in general, and flash-flood management in particular. National capabilities need to be strengthened to develop vigilance on the sensitive villages and communities.

d) Introduce better water conservation strategies and management practices

Water harvesting systems should be more improved and well acclimatized according to the need and capabilities of rural people. It has been recognized that the quantity of runoff depends on the conditions of weather. By allowing better management practices in terms of effective, advance and well equipped water conservation practices, there can be better long-term control of water for irrigation and power supplies.

e) Improved as well as Integrated Disease Inspection and Forecasting System

Mountain ecosystem has now become vulnerable and sensitive for various vector borne diseases due to remarkable change in the environment and climate especially on higher altitudes. Therefore, it is a burning need to kick off integrated disease surveillance and forecasting system for vector borne diseases across the Indian Himalayan Region.

f) Keeping the hopes alive by Bio-prospecting for future crops

Regional people and researchers should be motivated to conserve the local germplasm of the future crops of the mountain areas on farms. Nearly all native food crops cultivars promote important natural traits such as drought tolerance and disease resistance. Subsidiary crops, such as finger millet, barnyard millet, foxtail millet, buckwheat, chenopod, rice bean, horse gram, etc. are such type of resilient food crops. Applications of modern genetic engineering can be of huge help in budding super-crops with introduced traits of mountain crops.

CONCLUSION

The Indian Himalayan Region (IHR) is vulnerable to global warming and increasing human activities. Due to the uncertainty in science and research in the Himalayas, policies should be clear and easily adapted by local people. There is also indecision about the rates and proper direction of these changes, because so little is known about the dynamics of Himalayan climates and hydrological processes and their response to changing climatic conditions. Mountain people are under the great threat of various hazards such as flash floods, avalanches, and droughts for millennia. There is a strong need to build capacity to adapt and strengthen the social-ecological system in this changing climate scenario. The degradation of the environment and ecology of the Himalayan States and its huge impact on the lives and livelihoods of the people of the region and the country as a whole has become a vital need to focus attention on preserving and enhancing the Himalayan ecosystem. For combating climate change in time, it is urgent to use renewable energy sources at domestic level. Carbon sequestration by composting, rising of green legumes and uses of manure is an important activity in agricultural production systems. Efforts are needed from all levels of societies, institutions, NGOs and other youth forums. People must be sensible to use less combustive vehicles. The use of renewable energy sources like solar torch, solar batteries, solar water heating system must be recognized for energy saving and reducing GHG emission which are important for cooling the earth.

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