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13. Impacts of Climate Change in Indian Himalayan Region: an Overview

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Abstract:

Mountain regions provide diverse goods and services to human society. At the same time, mountain ecosystems are sensitive to rapid global warming. The fragile landscapes of the Himalayan region are highly susceptible to natural hazards, and there is ongoing concern about current and potential climate change impacts. A great deal of research work has been carried out on different aspects of Indian Himalayan Region (IHR) but the findings have yet to be correlated in the context of climate change. So, this article presents and overview of impacts of climate change in different aspect of Indian Himalayan Region based on literature review and anecdotal evidence.

***Keywords**: Climate change, Indian Himalayan Region (IHR), Biodiversity.*

13.1 Introduction:

The Himalayas is recognized for its ecosystem services to the Asian region as well as to the world at large for maintaining slope stability, regulating hydrological integrity, sustaining high levels of biodiversity and human wellbeing. Due to its high biological and sociocultural diversity, the region has been identified as one of 34 “biological hotspots” (Gautam et al., 2013). The fragile landscapes of the Himalayan region are highly susceptible to natural hazards, and there is ongoing concern about current and potential climate change impacts which may include abnormal floods, droughts and landslides (Barnett et al. 2005; Cruz et al. 2007), loss of biodiversity and threats to food security (Xu et al. 2009).

Mountains, due to their exclusive and inimitable biodiversity, are recently receiving priority for biodiversity conservation in global agendas. Mountains are among the most fragile environments and are most vulnerable to catastrophic events. If mountains become degraded, or fail to provide essential services, the costs may be severe. Therefore, Chapter 13 of the United Nations Agenda 21 specifically recognizes the value of mountain systems. Yet these recommendations are not sufficiently reflected in national, regional, and international policies and priorities (Pandey 2012).

Mountains are early indicators of climate change (Singh *et al*. 2010). As glaciers recede, and snowlines move upwards, river flows are likely to change, and alteration in water flow regime may lead to a plethora of social issues and affect hydropower generation, endanger biodiversity, forestry and agriculture-based livelihoods and overall wellbeing of the people. Temperature trends in Eastern and Western Himalayan regions substantially exceed the global mean trend of 0.85^0 C (between 1880 and 2012), with winter season temperature trends being generally higher than those of other seasons (Schick off et al., 2015).

The greatest average temperature increase, 0.07^0 C/year is observed in winter, whereas the least increase, 0.03^0 C/year in summer (Shrestha et al., 2012); and the warming rate increases with altitude, peaking between 4800 and 6200 m altitudes (Singh et al., 2011). Satellite imagery suggests almost 67% of the glaciers in the Himalaya have retreated. As glacier margins recede, and snowlines move upwards, river flow rates are likely to change. Furthermore, an alteration in water flow regime may lead to a plethora of social issues, endanger biological communities, impact forestry and agriculture-based livelihoods and affect the overall well-being of the people.

Recent studies showed that the Himalayan glaciers are reducing alarmingly. This is attributed to global warming. It is reported that the Northeast India of Eastern Himalayan Region warming over was around 0.2^0C/decade during 1971–2005 (Dash et al., 2007). Similarly, Shrestha et al., (2012) reported that the warming rate of Nepal Central Himalaya during 1977–2002 was also to be 0.6^0 C/decade.

Recently, Singh (2019), based on 32 yrs. observed data between 1980 and 2012 for a central Himalayan site Mukteshwar (an IMD station in Uttarakhand), showed that annual average maximum and minimum air temperature (observed at 2 m height) were significantly (P-value <.05) increasing (0.01 and 0.02^0C/ decade).

These studies indicate that the Himalayan region is probably warming at rates higher than the global average. The ongoing climatic changes are increasingly affecting this mountain system and various workers have voiced their concern on increasing warming (Archer and Fowler, 2004, Bhutiyani et al., 2007, Jhajharia and Singh, 2011) and decreasing rainfall trends over the region (Basistha et al., 2009, Bhutiyani et al., 2010).

Impacts on Socio-economic and health

Climate change can influence the socioeconomic setting in the Himalaya in a number of ways. The impacts of climate change on the socio-economic conditions of people living in the Himalaya can be observed in agriculture, livestock, forestry, tourism, fishery, as well as human health (Sharma et al., 2009).

This region is characterized by poverty, poor infrastructure (roads, electricity, water supply, education and health care services, communication, and irrigation), and other indicators of underdevelopment, making the Himalayan inhabitants more vulnerable to climate change because their capacity to adapt is quite low. Climate change has a powerful impact on human health directly (e.g., impacts of thermal stress, death/injury in floods and storms) and indirectly through changes in the ranges of disease vectors, water-borne pathogens, water quality, air quality, food availability and quality (McMichael *et al.* 2003), cardiovascular mortality and respiratory illnesses, transmission of infectious diseases and malnutrition from crop failures (Patz *et al.* 2005).

With a rise in surface temperature and changes in rainfall patterns, the distribution of vector mosquito species may change (Patz and Martens, 1996). Malaria mosquitoes have recently been observed at high altitudes in the region (Eriksson et al., 2008).

Huge quantities of municipal waste produced in the Himalayan Mountain towns are further compounding the problem of emission, sanitation and associated health hazards (Bhatta 2007). Another health hazard is posed due to burning of pine forests that give rise to smoke containing sulfur dioxide, benzo pyrene, carbon monoxide, nitrogen oxides, polycyclic hydrocarbons and albeitic acid. These gases alone or along-with carbon could be the responsible factors for lung injury with fibrosis (Rison et al., 2000). Aerosols have been shown to contribute to global warming (Guleria et al., 2001).

Impact on forest ecosystem:

The distribution, structure and ecology of forests across globe are controlled by mainly by the climate. Several studies on climate-vegetation have shown that certain climatic regimes are associated with particular types of plant communities (Whittaker 1975, Thornthwaite 1948). Even with global warming of 1 - 2 ºC, much less than the most recent projections of warming during this century (IPCC 2001a), most ecosystems and landscapes will be impacted through changes in species composition, productivity and biodiversity (Leemans & Eickhout 2004). Due to increase in temperatures, rapid deforestation, decreasing rainfall, habitat destruction and corridor fragmentation may lead to a great threat to extinction of wild flora and fauna. In the Indian Himalayan mountains early flowering of several members of Rosaceae (e.g., *Prunus*, *Pyrus* spp.) and rhododendrons has often been linked with global warming. Negi (1989) found that forest trees along an altitudinal gradient of 600 - 2200 m altitude in Kumaun Himalaya vary with respect to periodicity of phenolphases such as vegetative bud break, flowering, fruiting and leaf drop. These phenophases were found to be influenced by variations in temperature and rainfall changes over two consecutive years (1985-1987).

Due to the spread of invasive species such as *Lantana*, *Mimosa*, *Eupatorium* and *Parthenium* spp.) In the natural forests has also been linked with Climate change which will have a competitive impact on existing species.

The phenophases of plants such as vegetative bud break, flowering, fruiting and leaf drop were found to be influenced by variations in temperature and rainfall changes over the years. Early bud break in *Betula utilis* has been recorded in 2010 as compared to earlier years (Pandey, 2012).

The changes in phonological behavior of species may be a strong indicator of climate change since many species are highly sensitive even smallest change in the long prevailing climate of any ecosystem. Research on alpine vegetation suggests that many species are able to start their growth with the supply of snow-melt water well before the monsoon begins in June (Negi *et al.* 1991).

Growth and phenology of these species are already being disturbed because of reduced water from snowmelt. Changes in plant phenology act as important early warning of impending ecological change by altering the timing of activities that allow species to coexist.

Repeated incidences of forest fire are another prominent change that is linked with climate change. The frequency, size, intensity, seasonality, and type of fires depend on weather and climate in addition to forest structure and composition. In 2005-2006, a record 8,195 hectares of forest in Himachal Pradesh was lost to fire (Bhatta 2007).

In four districts of Uttarakhand (Almora, Chamoli, Tehri and Pauri Garhwal), in one of the most devastating forest fires of recent decades on 27 May, 1995 a total of 2115 km2 (between altitudes 600 m to 2650 m) was damaged severely (Semwal & Mehta 1996).

A comparison of air temperatures during the fire season for the two years 1994 (no fire event) and 1995 (large fire events) in Binsar Wildlife Sanctuary, Kumaun Himalaya showed that in 1995 the air temperature was higher (Sharma & Rikhari 1997).

It is expected that with the CC, scenario of the forests, both in terms of structure and functioning, is likely to change substantially. In the case of many dominant forest species of the region like sal (*Shorea robusta*), tilonj oak (*Quercus floribunda*) and kharsu oak (*Q. semecarpifolia*) seed maturation and seed germination coincide with monsoon rainfall. In wet conditions these species show vivipary. A rise in temperature and water stress may advance seed maturation, which might result in the breakdown of synchrony between monsoon rains and seed germination (Singh *et al*. 2010).

Impacts on Agriculture:

The challenge is intensified by agriculture's extreme vulnerability to climate change. Climate change's negative impacts are already being felt, in the form of increasing temperatures, weather variability, shifting agroecosystem boundaries, invasive crops and pests, and more frequent extreme weather events. Mountain agriculture is mostly rainfed (appx. 85 %), and driven by biomass energy of surrounding forests and confined to terraces carved out of hill slopes. The irrigation systems, have been severely affected with the rainfall becoming erratic. Some of the documented impacts on mountain agriculture that are linked with climate change in the Himalayan region are: (i) Reduced availability of water for irrigation; (ii) Extreme drought events and shifts in the rainfall regime resulting into failure of crop germination and fruit set; (iii) Invasion of weeds in the croplands and those are regularly weeded out by the farmers (e.g., *Lantana camara, Parthenium odoratum, Eupatorium hysterophorus* etc.); (iv) Increased frequency of insect-pest attacks; (v) Decline in crop yield (Negi & Palni 2010). These factors have highly led to loss in agridiversity and change in crops and cropping patterns. In the Himalayan mountains traditional agriculture has been a rich repository of agrobiodiversity and resilient to crop diseases. For example, in Uttarakhand over 40 different crops and hundreds of cultivars selected by farmers, comprising cereals, millets, pseudo-cereals, pulses and tuber crops are cultivated (Agnihotri & Palni 2007; Maikhuri *et al.* 1997). Another best example of rich agridiversity of the region is mixed cropping of 12 crops (*Baranaja*) (Ghosh & Dhyani 2004). These crops are adapted to the local environmental conditions and possess the inherent qualities to withstand the environmental risks and other natural hazards. This adaptability has ensured the food and nutritional security of the hill farmers from generations. However, the area under traditional crops has drastically declined (> 60 %) particularly during the last three decades and many of the crops are at the brink of extinction, such as *Glysine* spp., *Hibiscus sabdariffa, Panicum miliaceum, Perilla fruitescens, Setaria italica, Vigna* spp., to name a few (Maikhuri *et al.* 2001; Negi & Joshi 2002). Recent studies at the Indian

Agriculture Research Institute (IARI), New Delhi indicate the possible loss of 4 - 5 million tons in wheat production in future with every rise of 1 ºC temperature throughout the growth periods. Losses in other crops are still uncertain but they are expected to be relatively smaller, especially for kharif crops (Uprety & Reddy 2008). Deficit in food production in Kashmir region has reached 40 % in 2007 from 23 % in 1980 - 81 has been linked with climate change. (Ghosh & Dhyani, 2004).

Conclusion:

The greater Himalayan region "the roof of the world" – contains the most extensive and rugged high altitude areas on Earth, and the largest areas covered by glaciers and permafrost outside the polar regions. The region and its water resources play an important role in global atmospheric circulation, biodiversity, rainfed and irrigated agriculture, and hydropower, as well as in the production of commodities exported to markets worldwide. Climate change induced hazards such as floods, landslides, and droughts will impose significant stresses on the livelihoods of mountain people and downstream populations. As the Indian Himalayan Region is home to some of the most fragile ecosystems in the world, the poor and marginalized people living in this region face a pressing challenge of adapting to changing climate. The IHR is vulnerable to changing climate because of the population inhabited, its dependence on the ecosystem services and physiographic features. As agriculture is the main source of livelihood in the region, predicted warming and changes in precipitation patterns in the region will certainly affect the livelihood and economy. There is lack of expertise, observed data, policy, and collaboration, in the region which increases the level of uncertainty in drawing any conclusion with statistical confidence. So there is a urgent need to strengthen climate data collection in the Indian Himalayan region. Local climate data are scarce, assessment methods are usually not uniform and the instrumentation is not sufficiently standardized (Negi et al. 2012). The vulnerable mountain ecosystems are likely to face greater risk of climate change impacts than other ecosystems. Coordinated efforts are therefore required to develop effective strategies for adaptation and mitigation. The Global Forest Biodiversity Initiative (GFBI) is a new global research network focused on the use of "big data" to share information about biodiversity loss and climate change. This new network can supplement this information with massive ground-sourced inventory data, which will greatly enhance our understanding of forest dynamics in a global context (Liang et al. 2016). Linking these local efforts with international initiatives is likely to produce greater transparency and more effective global cooperation in responding to regional environmental threats in the Indian Himalayan Region.

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