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IMPACT ON ENVIRONMENT AND ECO-SYSTEM DUE TO THE CLIMATE CHANGE ON THE MOUNTAIN RANGE HIMALAYAS

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ABSTRACT

Climate change and its effects are now being felt across many parts of the world and critical ecosystems and livelihoods are being affected through extreme weather events. Impacts on high mountain systems, including glacial retreat, could be among the most directly visible signals of global warming. Other obvious changes include a rise of 10-25 cm in global sea levels in the past century. One of the most important and visible indicators of climate change is the recession of glaciers in many parts of the world. On a time scale, recent glaciations occurred around 20,000 years ago as part of earth's paleoclimatic history. Although some scientists have suggested the recession of glaciers is a natural phenomenon, an increase in the rate of retreat has been observed in most glaciers around the world including the Himalayas in the latter half of the 20th Century.

The Himalayan region has the largest concentration of glaciers outside the polar caps. With glacier coverage of 33,000 sq km, the region is aptly called the "Water Tower of Asia", as it provides around 86,000,000 cubic metres of water annually. These Himalayan glaciers feed seven of Asia's great rivers, the Ganga, the Indus, the Brahmaputra, the Salween that passes through China and Myanmar, the Mekong, the Yangtze and the Huang Ho. They ensure a year-round water supply to about one billion people. Receding glaciers are visible signs of the impact of global climate change. We can see this in the Himalayan range of mountains stretching in an arc from Afghanistan in the West to Myanmar in the East. The youngest chain of mountain ranges is also home to some of the world's loftiest mountain peaks, which have been the cynosure of the adventurer for the centuries. The Himalayan ecosystems are one of the most fragile ecosystems in the world with a wide and diverse range of habitats and floral and faunal values.

KEYWORDS: Climate change, Glacial Retreat, Livelihoods, Melting Snow, Himalayas.

INTRODUCTION

Climate change and its effects are now being felt across many parts of the world and critical ecosystems and livelihoods are being affected through extreme weather events. Impacts on high mountain systems, including glacial retreat, could be among the most directly visible signals of global warming. Other obvious changes include a rise of 10-25 cm in global sea levels in the past century. One of the most important and visible indicators of climate change is the recession of glaciers in many parts of the world. On a time scale, recent glaciations occurred around 20,000 years ago as part of earth's paleoclimatic history. Although some scientists have suggested the recession of glaciers is a natural phenomenon, an increase in the rate of retreat has been observed in most glaciers around the world including the Himalayas in the latter half of the 20th Century.

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SEVERE THREAT

Receding glaciers are visible signs of the impact of global climate change. We can see this in the Himalayan range of mountains stretching in an arc from Afghanistan in the West to Myanmar in the East. The youngest chain of mountain ranges is also home to some of the world's loftiest mountain peaks, which have been the cynosure of the adventurer for the centuries. The Himalayan ecosystems are one of the most fragile ecosystems in the world with a wide and diverse range of habitats and floral and faunal values. However, the region's ecosystems are currently under severe threat due to the rapid expansionist approach of humans and related developmental activities. The changes in climate variability have led to a rapid retreat of mountain glacier systems, which is considered the life line of river basins and ecosystem. Scientific studies have shown that 67 percent of glaciers are retreating at startling rate in the Himalayas as a result of various factors including climate change. Such changes in average global surface temperatures can have serious consequences on the stability of the glacial systems.

CURRENT CONDITION

The Greater Himalayas, the regional monsoon is a function of distance from the main sources of moisture (the Bay of Bengal, Arabian, and Mediterranean seas), montane orographic influences, and global atmospheric circulation systems. Currently, however, rainfall measurements are taken primarily in valley bottoms, resulting in significant underestimates of precipitation amounts. Much subbasin variation is masked by current dependence on regional rainfall and temperature data that do not capture local variation.

The high Himalayan and Inner Asian ranges have 116,180 km^2 of glacial ice, the largest area outside polar regions. Throughout the Greater Himalayas, water melts from permanent snow and ice and from seasonal snow packs and is stored in high-elevation wetlands and lakes. Melting occurs mainly in high summer, but when this coincides with the monsoon, it may not be as critical for water supply as melting in the spring and autumn shoulder seasons. When the monsoon is weak, delayed, or fails to materialize, melted water from snow and ice limits or averts catastrophic drought.

The contribution of snow and glacial melt to the major rivers in the region ranges from <5 to >45% of average flows. Melting snow and ice contribute about 70% of summer flow in the main Ganges, Indus, Tarim, and Kabul Rivers during the shoulder seasons (i.e., before and after precipitation from the summer monsoon). The contribution of glacial melt to flows in the Inner Asian rivers is even greater. Indus River irrigation systems in Pakistan depend on snowmelt and glacial melt from the eastern Hindu Kush, Karakoram, and western Himalayas for about 50% of total runoff. In western China, about 12% of total discharge is glacial melt runoff, providing water for 25% of the total Chinese population in the dry season. Climate also determines biodiversity, and the Greater Himalayas have much higher biodiversity values than the global average. The eastern Himalayas have the highest plant diversity and richness. Changes in hydrology can influence biodiversity in a variety of ways; moisture availability governs physiology, metabolic and reproductive processes, phenology, tree-line positions, and the geographic distribution of freshwater and wetland habitats. In turn, these influences affect the ability of biological systems to support human needs.

WORK OF GLACIOLOGISTS AND CLIMATOLOGISTS

Past work by glaciologists and climatologists indicates that the accelerated rate of glacial melt in some of the important glaciers in the Himalayan region is expected to have serious consequences for the freshwater ecosystems of the Ganga basin with long-term impacts for biodiversity, people and livelihoods as well as regional food security. This will not only mean repercussions on the region's agricultural productivity and industrial activity but also on the Terai ecosystems and species like the Ganga River Dolphin.

There are no true estimates on the total number of glaciers in the Himalayas, inventories by various institutions including the Geological Survey of India suggest that there are well over 5000-6500 glaciers in the Indian part of the Himalayas. For example, in the State of Uttarakhand the four sub-basins of the Ganga, the Yamuna, the Bhagirathi and the Alaknanda together constitute nearly 900 glaciers. One of the most iconic of Indian glaciers is the majestic Gangotri glacier, which occurs in Uttarakshi is considered the second longest glaciers in the region. In recent times, the 30 km-long glacier has shown considerable recession.

Monitoring glacial retreat:-

Various methods are used in study glacial retreat patterns in different parts of the world. These methodologies help in monitoring glacier positions including changes in snout position, surface area, volume elevation and ice mass. Two commonly used methods are

Remote Sensing:-

Recent advances in satellite technology have enabled scientists to monitor changes in glacial retreat patterns using a combination of remote sensing satellite imageries. By superimposing past satellite maps on present maps, area of recession of individual glaciers is estimated with a fair degree of accuracy using techniques like image enhancement.

Mass Balance:-

The mass balance of a glacier is the direct link between climate and glacial retreat. The overall mass balance of a glacier is measured to calculate the volume of a glacial mass and glacial run off characteristics. For mass balance measurements, glacier size can range anywhere between 2-5 sq km to ensure accuracy of measurements. The mass balance of a glacier can be measured through a direct glaciological method where at a number of individual points the change in levels of surface area is measured between two dates. eg. Summer and winter. The difference in surface levels between these two dates multiplied by near surface density can then lead to an estimate of total net mass balance of the glaciers. Depending on the amount of melted snow and ice, mass balance can be either positive or negative (gain or loss of glacier volume).

OBSERVED AND PROJECTED CHANGES

Temperature and Precipitation:-

The Greater Himalayas as a whole is very sensitive to global climate change. Progressive increases in warming at high elevations are already occurring at approximately 3 times the global average. The Intergovernmental Panel on Climate Change (IPCC) has projected that average annual mean warming will be about 3 °C by the 2050s and about 5 °C in the 2080s over the Asian land mass, with temperatures on the Tibetan Plateau rising substantially more. Given that current discussions about dangerous climate change are centered around increases of 2–3 °C, these temperatures are potentially catastrophic for Greater Himalayan peoples and ecosystems.

During the last few decades, the Greater Himalayas have experienced increasing and decreasing precipitation trends. Monsoon patterns have shifted, but the picture remains ambiguous. The IPCC predicts that average annual precipitation will increase by 10–30% on the Tibetan Plateau as a whole by 2080, although rising evapotranspiration rates may dampen this effect.

Glacial Response:-

Glaciers, ice, and snow cover 17% of the Greater Himalayan region and are receding more rapidly than the world average. The rate of retreat has increased in recent years. If current warming continues, glaciers located on the Tibetan Plateau are likely to shrink from 500,000 km^2 (the 1995 baseline) to 100,000 km^2 or less by the year 2035. The predicted hydrological responses of 10 rivers in the Greater Himalayan region are given below in Table 1.

Table 1. Predicted hydrological responses of 10 rivers in the Greater Himalayan region to climate change.

River (basin area, km^2)	Glacial melt in river flow (%)	Signal of trends	Probable future
Tarim (1,152,448)	40.2	wetter in past half century; increasing river flow in some tributaries; 9 tributaries dried up	sharp drop in runoff in glacier retreated catchment, floods occur owing to extreme rainfall
Amu Darya (534,739)	10–20	increase in precipitation but drop in annual runoff	by 2100, probability of river runoff increase of 83–87% owing to mainly an increase in precipitation
Indus (1,081,718)	44.8	significant increase in rainfall (19%); increase in river flow between 14 and 90%	flow from glacial sub-basin peaks at about 150% of initial flow around 2060; 4% less annual mean flow
Ganges (1,016,124)	?9.1	slight increase in rainfall and heavy rain; decrease in rainy days per 100 years	flow from glacial sub-basin peaks at about 170% of initial flow around 2070; 18% less annual mean flow
Brahmaputra (651,335)	12.3	increase in runoff (low flow and high flow); nonsignificant change in precipitation but change in runoff at lower basin	annual flow in Lhasa River increases by 11.3% and monthly maximum flow increases by 45% in 2050s
Irrawaddy (413,710)	small	unknown	unknown
Salween (217,914)	?8.8	increase in river flow during monsoon	river-flow decrease over short term (2010–2039) and increase over long term (2070–2099)
Mekong (805,604)	?6.6	increase in precipitation during early monsoon; increase in runoff	rainfall and extreme floods increase
Yangtze (1,722,193)	18.5	increase in precipitation, extreme rainfall and frequent floods; no significant change in runoff	glacier areas in upper Yantze decrease by 11.6% and glacial discharge runoff increases 28.5% by 2050
Yellow (944,970)	?1.3	no significant change in precipitation, but significant decrease in runoff	rainfall and evapotranspiration increase; river flow decreases
	17.4 (average)		

Water Related Hazards:-

Water is not only a source of life, livelihoods, and prosperity but also a cause of death, devastation, and poverty. Water-related hazards and risks are omnipresent in the Greater Himalayas, and landslides, debris flows, and flash floods are projected to increase in frequency in the uplands (300–3000 m), with river and coastal floods likely increasing in the lowlands (<300 m). Significant fluctuations in snow and ice melt will likely result in periodic excessive (short to medium term) or insufficient (long term) water supplies.

Ecosystem Composition and Dynamics:-

It is highly likely that climate change will affect the composition and distribution of vegetation types throughout the Greater Himalayas, including alpine meadows and steppes, wetlands and peatlands, and forests. Alpine meadows are, for example, currently associated with >400-mm annual precipitation, whereas alpine steppe and desert vegetation types are found in areas with <400-mm annual precipitation. These vegetation types are fed by glacier and snowmelt and water discharge into wetlands. Although water availability is key, rangeland degradation on the Tibetan Plateau is also caused by overgrazing (rodents accelerate degradation by consuming both aerial biomass and the roots of plants) and climate warming is but one underlying cause. Himalayan grasslands affect regional atmosphere circulation and hydrology through the effects of reflection rates on overall albedo, surface energy, wind drag, evaporation, soil moisture, and precipitation patterns. Grasslands also play a role in regulating the streamflows of major rivers.

High-elevation wetlands exist in a transition zone between glaciers, permafrost, grasslands, rivers, and lakes, and can be affected by minute changes in hydrology. Shifts in Tibetan Plateau ecosystems due to climate change, however, are not projected to be subtle.

Today, alpine steppe and alpine desert cover 53.5% of the plateau; their combined area is projected to contract to 37.9%, a loss of 15.6%. These shifts have important implications for ecosystem cascading effects due to reduction in permafrost and increased desertification.

Effects on Ecosystems and Livelihoods:-

Basic research on ecological responses of high-elevation species to climatic variables is notably lacking in the Greater Himalayas, but it is generally expected that rapid responses by individual species to climate change may disrupt interactions. Potential ecological cascading effects include secondary extinctions triggered by losses of key species in the alpine ecosystems. The endemic-rich Himalayas include many plant species that may not respond successfully to projected rates and scale of climate change. One of the obvious risks is species extinctions from mountains not high enough to offer escape routes in the case of upward shifts of taxa. In general, the response of natural vegetation to projected climate change will be complex; some species will decrease, some increase, and new ones may also appear. Invasions of weedy and exotic species from lower elevations are likely.

Climate-change-induced risks at the rate and scale projected in the Greater Himalayas, however, cannot be eliminated by a natural process of gradual adaptation. People must act now to reduce future negative consequences. Floods, for example, are triggered by precipitation, but riverbank retaining walls, biostabilization of slopes, and terracing fields can mitigate flood impacts. Such measures can also reduce damage from landslides, rockfalls, and mudflows. Mountain people using traditional ecological knowledge and customs have evolved fine-tuned social systems to cope with natural hazards. Studies on the Tibetan Plateau show inextricable links between rural livelihoods, land use, human health, and climate change. Although information on the potential impacts of climate change is becoming increasingly available, there have been very few studies of the existing adaptive capacities of communities in the region and their vulnerabilities to predicted changes. The diversity of likely cascading effects of climate change on local peoples need to be identified, predicted, and filtered through many cultural contexts, but, so far, this has not occurred.

Downstream and Global Effects:-

It is very likely that changes in flow regimes will have significant impacts on water availability for downstream ecosystems and populations. Yet, quantitative projections of downstream effects of changing water flow regimes in Greater Himalayan rivers are rare. Although research on glaciers, snowpack, and permafrost has been completed in some areas, there are few baseline studies, particularly for areas above 4000 m asl. The full-scale downstream impact of reduced glacier, snow, and ice cover cannot yet be estimated precisely.

The Greater Himalayas play a key role in global atmospheric circulation. The Himalayan environmental changes have climatic effects, and those changes have consequences on precipitation and temperature patterns on a global scale. Glaciations and snow cover at low latitudes likely play an important role in Earth's radiation budget. In summer, the vast highlands in Asia heat up more than the Indian Ocean, leading to a pressure gradient and a flow of air and moisture from the ocean intensifying the Indian monsoon. This pressure gradient may be changing owing to loss of glacial and snow cover in the Greater Himalayas.

Loss of Greater Himalayan ice and snow will have still-unknown cascading effects on global sea-level rise. The IPCC's most conservative average sea-level rise estimate of 40 cm does not account for loss of terrestrial ice and snow; recent research projects a minimum average rise of 80 cm by 2100. These levels would lead to further global cascading effects, including submerged coastlines on the megadeltas of Asia, hundreds of millions of environmental migrants, and loss of agricultural lands due to rising coastal and riverine salinity levels.

The Greater Himalayas are also an important carbon sink. Studies estimate that the organic carbon content of soils subtending grasslands on the Qinghai–Tibetan Plateau composes about 2.5% of the global pool of soil carbon. In grassland ecosystems net productivity (the amount of carbon sequestered) is very small compared with the size of fluxes, so climate impacts affecting fluxes could possibly change the net flow of carbon, transforming grasslands from CO_2 sinks to CO_2 sources. In similar alpine ecosystems under the range of climate changes projected for Himalayan wetlands, researchers have reported a doubling of annual emissions.

CONCLUSION

On current evidence, as this review shows, we recognize uncertainty in this region on a Himalayan scale: physical manifestations of climate change will include broad, heretofore unknown temperature increases (with decreases in some places), shifts in ecosystems, and increased frequency and duration of extreme events. Certainly, there will be significant changes in volumes and timing of river flows and freshwater sources, but precise responses are unknown. To address data gaps, we recommend more widespread and long-term tracking of glacial ice volumes, monitoring of alpine flora and fauna, landscape and transboundary approaches to biodiversity conservation, open data exchange, and cooperation between all countries in the Greater Himalayas.

Given levels of scientific uncertainty, we highlight three critical scales of adaptation: local community, urban and rural, and regional and transboundary. For local adaptations, as in much of the less-developed world, rural people in the Greater Himalayas remain divorced from natural resource decision making. This complex topic is beyond the scope of this paper, but one thing is clear: if local peoples' successful adaptations to past environmental change are to be learned from, local and regional governments will need to reach out and collaborate more actively with villagers.

At the urban–rural scale, there are inherent differences between city and village dwellers over specific climate-change adaptations. Policies addressing centralized, downstream populations, urban infrastructure, and large-scale agricultural systems must be integrated with those for local peoples living montane livelihoods. Designing integrated land and water resource management at river-basin levels would help bridge this urban–rural divide. In both urban and rural areas, attention should focus on reducing overall water demand and modernizing irrigated agriculture. Urban demands should not trump the creation of low-cost community-scale adaptations.

At the regional-transboundary scale, current research makes clear that adaptations must be designed for the long term because some climate impacts are already likely irreversible over the next 1000 years even after emissions cease. Regional risk assessment and mapping across the Greater Himalayas would help decision makers select appropriate strategies. Nevertheless, we found no regional or transboundary authority addressing the complexities of climate change that we have discussed. This situation must change if climate-change adaptations and mitigations are to be successful. China and India play critical roles here because most of the Greater Himalayas are within the boundaries of these two nations.

As much as we would welcome the formation of a regional Greater Himalayan climate change authority, we recognize that top-down policy making has a decidedly mixed track record in this region. This status quo can no longer hold; political leaders must act. Whatever the scale or policy arena, the onus is on scientists to generate knowledge to reduce uncertainty.

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