Effect of Climate Change on the Himalayas*
An Overview

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The Himalayas being fragile landscapes, are highly susceptible to changing climatic conditions. Reduction in glacier volumes, snow cover areas, water availability, and biodiversity, along with changes in the patterns and intensity of rainfall is evident in the Himalayas. All these changes ultimately impact the Himalayan rural sector—both ecologically and economically. At the outset, locals of the region need to be educated about climate change, its impacts, and mitigation measures. Furthermore, forging collaboration of the Himalayan regions with the scientific community and policy-making bodies should be one of the main strategies for identifying and addressing climate change concerns in the region.

Climate change is the biggest challenge the world faces today [1]. It refers to a major, long-lasting change in climate and includes the change in precipitation, temperature, wind patterns, and various other effects occurring over several decades [2]. The Himalayas form the world’s largest mountain range, an orogenic belt comprising the Indo-Gangetic plain and the Tibetan block [3]. The ‘greater Himalaya’, the highest mountain range in the Himalayan belt, is considerably affected by changing climate. The climate of the Himalayan region is changing at an alarming rate, posing a serious threat to its unique biodiversity; for example, a 0.6°C warming per decade in Nepal (the greater Himalayas), as compared to the global average of 0.74°C over the last 100 years [4]. Climate change, along with other environmental stresses, has a severe impact on Himalayan biodiversity. Also, it has a profound effect on water availability. Reduction of snow, in turn, reducing the underground water storage capacity is ac-

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**Glacial Retreat**

The melting of glaciers due to global warming is the principal concern of climate change in the Himalayas; Himalayan glaciers are decreasing at a much higher rate than the average world. In the latter half of the 20th century, 82% of the glaciers in western China [6], and in the past forty years, 7% of the glaciers in the Tibetan plateau have retreated [7]. The retreating rate of Himalayan glaciers due to increased temperature and decreased precipitation is six times higher than the retreating rate of glaciers across the world. In an attempt to model the scenario, it has been predicted that 35% of the present glaciers are going to disappear with a 2°C increment in the temperature by 2050 [8]. This high retreating rate of Himalayan glaciers may destabilize the slopes, leading to landslides and floods wreaking havoc downstream [9].

The increased fluctuations in growth and depletion of mountain glaciers in response to changing precipitation and temperature is actually an important indicator of climate change [10]. Specifically, Kashmir Himalaya shows higher glacier loss (0.77±0.31 km² a⁻¹) compared to other Himalayan regions. Glaciers of Kashmir Himalayas have shown an increased recession of 29.32±12.09 km² (28.82%) from 1980 (101.73±16.79 km²) to 2018 (72.41±4.7 km²) [11]. The recession of 7.15±8.54 km² during 1980–1992, 8.56±0.11 km² during 1992–2000, 11.21±3.4 km² during 2000–2013 and 2.4±0.04 km² during 2013–2018 was observed (see Figure 1). Furthermore, the south-facing glaciers receded at a
higher rate ($\approx 38\%$) in comparison to the north-facing glaciers ($\approx 27\%$) [11]. The increased temperature with a declined solid precipitation in winter has resulted in an increased glacier melting rate leading to a decline in stream flows, which would affect the dependent sectors of the economy if continued in future [11].

### Glacial Lake Outburst and Floods

Accelerated by changing climatic conditions, the Himalayan mountain ecosystem is at risk of multiple hazards and natural disasters, with an increment in the severity of flash floods and landslides [12]. The climate change induced glacial melt leads to glacial lake formation at terminal moraine dams in Central and Eastern Himalayas. Dams break as they cannot hold more water, leading to large outbursts of debris and water [4]. These glacial lake outburst floods (GLOFs) can lead to devastating floods causing severe damage to lives, forests, farms, infrastructure, and property. 25 GLOFs have been reported in Nepal in the last 70 years.

**Figure 1.** Himalayan glacier (Kashmir Himalaya) retreating at a rapid rate [11].

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and in recent decades, the incidence of such events is on the rise [4]. In Hindu Kush Himalayas, 204 glacial lakes, which can burst at any time, are very dangerous, [12]. On the other side, in Central Asia, an increase in temperature will increase the probability of avalanches, landslides and mudflows that could severely affect the human settlements [4].

Climate change has increased glacier degradation, profoundly impacting downstream water resources. A rise in temperature changes the precipitation form—from snow to rain, reduces the snow cover by less accumulation of glaciers and increases the melting of snow caps [4]. Changes in precipitation type and amount, intensity, and distribution over space and time directly affect the total river runoff, causing catastrophic floods as we saw in Kashmir in 2014. Excessive ice melting in combination with liquid precipitation triggers debris flow and flash floods [2]. It has been estimated that in Asia, a quarter billion people in China and a half billion people in the Himalayan region, depending on the Himalayan glacial melt for their water supply, will be seriously affected by flash floods caused by climate change induced glacial melt [13].

**Agro Biodiversity and Productivity**

Changing climate has caused substantial species contraction and extinction, disturbing the species distribution along different ecological ranges [14]. Climate change also affects grasslands, the composition and distribution of plant communities, and animal productivity [15]. Rangelands are degraded by drier and warmer climates; for example, temperature rise has resulted in 40% dryland area in the Tibetan Plateau, which increases 3 to 5% per year [16, 17]. A shift of woody vegetation to alpine meadows and a rise in the tree line to higher altitudes has been widely reported. In the eastern Himalayas, the tree line rises 5 to 10 m per decade [18]. Changing climate may significantly impact the agricultural productivity of Kashmir Himalayas [19], and the cropping patterns of maize, rice, and apple.
Warming of the Himalayas and the climatic change affects the forest ecosystem and leads to alteration in species composition and vegetation type [5]. The forest vegetation of the Eastern Himalayas is decreasing significantly and is expected to be attacked by pests and forest fires due to an increase in warmth and climatic dryness [20]. Satellite-derived normalized difference vegetation index (NDVI) has also reported a decrease in average vegetation productivity of the Himalayan forests [21]. There is a decrease in the distribution pattern of *Pinus* spp., *Rhododendron* spp., and *Quercus* spp., with alterations in temperature and precipitation [22]. The timberline being more sensitive and vulnerable to changing climate, show decreased distribution due to the increased encroachment of shrubs and anthropogenic influences [5]. Additionally, agricultural productivity and food systems of the Himalayas are being stressed by changes in rainfall patterns, frequent occurrence of extreme weather events, water resource exhaustion and reduction of irrigation potential [23]. The overall situation in Himalayan agricultural biodiversity, as well as productivity, can be made economically and ecologically sound by the integration of various sectors of the Himalayan economy with local agricultural production systems and climate change adaptation mechanisms in the region.

**Rural Livelihoods**

A major proportion of the rural population, especially poor and landless people, earn their livelihood from agricultural hard labour, rural patterns of processing of livestock and agricultural products, preparation of agricultural tools and conventional handicraft objects, and collecting forest products such as medicinal plants. However, due to the reduction of forest resources, and thereby the reduction of overall biodiversity, employment opportunities have drastically decreased in this traditional sector [12]. The fast-changing climate, especially the decreased annual rainfall, the increment in high-intensity rainfall, landslides and flash floods, water sources depletion and declining irrigation potential, have diminished the regional biodiversity, reduced forest productivity
and livestock and disrupted the traditional food and agricultural setup [21]. But, in the Himalayas, agriculture remains the major economic activity. Hence, it will be one of the core elements of the climate change adaptation strategy henceforward [12].

Conclusion and Recommendations

The vulnerability of Himalayan communities has been escalated by climate change, which in turn has increased the rate of environmental degradation. Himalaya is undergoing fast and extensive changes in rainfall patterns leading to the prevalence and intensity of extreme weather events. There is a decline in the overall number of rainy days, rainfall amount, and the occurrence of high-intensity rainfall events followed by an increase in droughts. Meanwhile, there is also a growing decrease in livelihood opportunities in conventional agricultural sectors in the region, causing an acceleration in the outmigration of rural youth [24]. The development of sustainable livelihoods should be a priority for decreasing the vulnerability of Himalayan communities to climate change. Moreover, the overall productivity of the entire Himalayan crop and livestock system may be improved utilizing agro-climatic diversity from productive valleys to higher elevations for the diversification of agriculture, dairying, horticulture, forestry, and floriculture.

Suggested Reading

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