# Himalayan Biodiversity Hotspot: Impact of Climate Change and Adaptation Strategies

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## ABSTRACT

*The Himalayan biodiversity hotspot, renowned for its exceptional richness and endemic species, faces escalating threats from climate change and anthropogenic pressures. This region, warming at a rate significantly higher than the global average, is experiencing rapid environmental shifts including glacier retreat, altered hydrological regimes, and upward migration of vegetation boundaries that profoundly disrupt ecosystem structure and function. Climate change exacerbates phenological mismatches, increases forest fire incidence, and facilitates the spread of invasive species, thereby undermining native biodiversity and the ecological services vital to local communities. In addition to climatic stressors, overexploitation of biological resources, overgrazing, illegal wildlife trade, and habitat fragmentation further intensify biodiversity loss. To address these multifaceted challenges, the adoption of holistic adaptation strategies is critical. Proposed measures emphasize ecosystem-based approaches such as afforestation, watershed and soil conservation, and restoration of degraded landscapes alongside climate-resilient agricultural practices, sustainable land management, and diversification of livelihoods. Strengthening local capacities and integrating scientific and community knowledge are essential for enhancing resilience and safeguarding the ecological integrity of the Himalayan hotspot in the face of ongoing climate change.*

Keywords: Himalayan biodiversity hotspot, climate change impacts, ecosystem resilience

## ARTICLE

Climate change represents one of the most pressing global challenges of the present era, posing wide-ranging environmental, economic, social, and political threats. The impacts of climate change also need to be categorized according to various climatic elements viz., rainfall, temperature, CO2 concentration, etc. (Negi et al., 2012). It has direct and indirect impacts on species survival, and the long-term consequences of harsh climatic circumstances are affecting the morphology, physiology, and behavioural individualities of species, with considerable disruptions due to solar radiation, temperature extremes, and cold (Gegechkori, 2018). These changes in river flow regimes could trigger a range of social and environmental challenges, including reduced hydropower potential, threats

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to biodiversity, degradation of forest resources, disruption of agriculture-based livelihoods, and negative impacts on the overall well-being of mountain communities. Further, the invasion of exotic species has been triggered by changing climatic scenarios, resulting in expansions in climatically favourable environments (Bellard et al., 2012). Climate change is anticipated to produce more suitable regions for invasive alien species, facilitating their spread, which has already had detrimental implications for livelihoods, the economy, and biodiversity (Shrestha et al., 2018).

The Himalaya, renowned for its biodiversity, is home to numerous unique plant species. However, this biodiversity is threatened by various natural and human-induced threats, which are adversely affecting the status of biological resources. The major threats affecting the Himalayan ecosystems include the high dependence of local communities on natural resources, overgrazing, and the overexploitation / harvesting of plants for local and commercial purposes, as well as the emerging threats of illegal wildlife trade and wildlife crime. Further, the region is experiencing the worst impacts of environmental transformation i.e. climatic changes, habitat fragmentation and habitat destruction, emergence of invasive and alien species, which are throwing the native species under various threat categories depending on their habitat choice, restricted distribution, and commercial exploitation and use patterns. Apart from these, anthropogenic activities are playing a vital role in biodiversity loss (Mehta et al., 2020).

**Impacts of climate change in Himalayan biodiversity**

The Himalayan region is warming at a 3-times higher rate than the global average (Xu et al., 2009). The warming in the Himalayan region from 1982 to 2006 is approximately 0.06 °C per year (Shrestha et al., 2012), significantly higher than the global average of 0.85 °C from 1880 to 2012 (about 0.006 °C per year) (IPCC, 2013). This rapid warming poses a major threat to the region's threatened and endemic plant species. Many studies in Himalaya have reported that numerous plant species, including the Himalayan pine, have shifted upwards. Moreover, the treeline is reported to have moved 388 ± 80 m asl upslope in the IHR between 1970 and 2006 (Dahal et al., 2021).

A rise in forest fires is another significant effect of climate change. The drying of organic materials in forests has been hastened by increasing temperatures, resulting in a twofold increase in forest fires. Climate change-induced droughts are expected to increase tree pathogens' frequency, mainly due to their indirect effects on host physiology. It also alters different phenological events like germination, flowering, fruiting, and senescence in the life cycle of plants (Gaira and Dhar, 2020). All these changes in the phenological events of plants have interfered with pollination and seed dispersal due to a mismatch between the flowering time and the pollinator's visit. Medicinal and aromatic plants and their secondary metabolites are also observed to be affected by climate change (Das et al., 2016). Climate change has also been linked to shifts in species distribution. It is expected that IHR will lose the cooler climatic zones at mountain peaks, and there will be upward shifting of tree lines (Wani and Pant, 2021). As the climate warms, lower-altitude forests will migrate to higher-altitude woods (Verma, 2021). However, some plant species will be able to adapt and shift, while

others will be unable to do so and may face extinction. Alpine and endemic species are more prone to such extinctions, as these species are already growing at higher altitudes and have nowhere to shift (Verma, 2021). Numerous modelling studies have been conducted in the Himalayan region over the past decade to forecast how different species would respond to climate change.

**Observations of shift in species distribution in IHR**

A recent summary of treeline shifts worldwide found that 67% of studied alpine treelines had shifted upwards while 33% remained stable (based on 142 published studies), and 88.8% of the 143 undisturbed alpine treelines across the Northern Hemisphere had shifted upwards. In adjoining areas of the IHR near Langtang, Nepal, Abies spectabilis has shifted by 100-150m above treeline in response to warming. Similar studies have reported a shift of 2.6m yr in Abies spectabilis in Nepal and a shift of 14-19m per decade in Pinus wallichiana in IHR (Schickhoff et al., 2015). Betula utilis (Birch), on the other hand, is getting adversely affected by intensified pre-monsoon drought under the influence of global warming (Singh et al., 2018).

It was found that endemic plant species in the alpine region of the Sikkim Himalaya have shifted their elevational range margins by nearly 90%. Six species showed more than a 50% contraction compared to their historically recorded range extents (Rheum nobile Hook. f. & Thomson, Saussurea stella Maxim., Rhodiola bupleuroides Wallich ex Hook.f. & Thomson, Saussurea uniflora Wall., Saussurea leontodontoides (DC.), Ponerorchis chusua (D. Don) Soo.), while four species (Microgynaecium tibeticum Hook.f., Meconopsis simplicifolia Walp., Pedicularis trichoglossa Hook. f. and Lancea tibetica Hook. f. & Thomson) showed range expansion by more than 100% of their historical range border (Telwala et al. 2013). The distribution of the three treeline species (Abies spectabilis, Betula utilis, and Pinus wallichiana) in the Nepal Himalaya indicates that climatic shifts will likely influence future habitat suitability. The suitable habitat for the three treeline species is predicted to shift to higher elevations under future climatic conditions and may also experience an overall range expansion (Chettri et al., 2018). Schickhoff et al. 2016). About 90% of the endemic species in the Sikkim Himalayas have been displaced at the rate of 27 - 22 m/ decade. Many species, including Potentilla pamirica, found in the northwest Himalayas of eastern Ladakh, have moved upwards by about 150 m asl above the plant distribution limit (Chaudhary et al., 2023). It is predicted that under future climate scenarios, the habitat of Rhododendron species in the Sikkim region will shrink. The study indicates that the distributions of ten selected Cyananthus and Primula alpine species will shift upward in elevation and northward in latitude across various climate change scenarios (Kumar, 2012). Another study on eleven multi-purpose tree species in the mid-hill zone of the northwestern Himalayas (1999-2017) showed that phenological changes, particularly leaf emergence, advanced significantly from 1999 to 2006, with varying growth period extensions among species, impacting future ecosystem dynamics.

**Adaptation strategies**

The changing climatic scenario and rising temperature in the Himalayan biodiversity hotspot are significantly affecting the plant diversity of the

region. Adaptation strategies need to be adopted to mitigate the effects of climate change, which include strengthening local livelihoods through integrated approaches. Ecosystem-based solutions, including afforestation, watershed management, soil conservation, and restoration of degraded slopes to reduce landslides, floods, and erosion are major strategies to conserve and manage the ecosystem services. Climate-resilient agriculture should be promoted within the region with crop diversification, use of stress-tolerant varieties, improved irrigation, and sustainable land management.

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