



Impact of Tourism on Vegetation Structure and Soil Health in the Indian Himalayan Region

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ABSTRACT: The Indian Himalayan region, renowned for its rich biodiversity and ecological significance, has increasingly faced environmental challenges due to the growing influx of tourism. This review paper explores the impacts of tourism activities on vegetation structure, plant regeneration, and soil physico-chemical properties in the region. The findings reveal significant alterations in forest composition, reduced natural regeneration of plant species, and deterioration of soil health caused by compaction, nutrient depletion, and waste accumulation. These changes threaten the ecological balance and sustainability of the fragile Himalayan ecosystem. The paper emphasizes the urgent need for sustainable tourism practices and policy interventions to mitigate environmental degradation and preserve the region's biodiversity. By identifying key research gaps, the review aims to guide future studies and support the formulation of effective conservation strategies.

Keywords: Indian Himalayan Region, Tourism Impact, Vegetation Structure, Plant Regeneration, Biodiversity Conservation, Sustainable Tourism.

INTRODUCTION

The Indian Himalayan Region (IHR), spanning across 10 states and union territories of India, is a globally significant biodiversity hotspot characterized by its unique geography, diverse ecosystems, and rich cultural heritage. Stretching over 2,500 kilometers and encompassing altitudinal variations from the foothills to the high-altitude peaks, the IHR supports a wide variety of flora and fauna, many of which are endemic (Singh *et al.*, 2021). The region is not only a reservoir of biodiversity but also provides vital ecosystem services such as water regulation, carbon sequestration, and climate stabilization (Negi *et al.*, 2020).

Tourism plays a critical role in the economy and culture of the IHR. With its majestic landscapes, pilgrimage sites, adventure activities, and cultural diversity, the region attracts millions of domestic and international tourists annually. This influx significantly contributes to local livelihoods and infrastructure development (Sharma & Bhatt 2022). However, the rapid and often unregulated expansion of tourism activities has raised serious concerns regarding its impact on the region's fragile ecosystems. In addition, visitors often stay away from the designated trails and cause trampling damage

to the vegetation (Barros *et al.*, 2020; Goh, 2020 ; Park *et al.*, 2008).

The environmental consequences of tourism are particularly pronounced in the Himalayan context due to its inherent ecological sensitivity. Activities such as trekking, construction of roads and resorts, and waste generation have led to deforestation, habitat fragmentation, and soil degradation (Bisht *et al.*, 2023). These disturbances directly affect vegetation structure, hinder the natural regeneration of plants, and alter soil physico-chemical properties, posing a threat to long-term ecological stability.

This review aims to provide a comprehensive analysis of the impacts of tourism on vegetation structure, plant regeneration, and soil properties in the Indian Himalayan Region. The objectives include synthesizing recent research findings, identifying key patterns and processes, and highlighting the need for sustainable tourism practices.

Key research questions addressed in this paper include:

1. How does tourism influence vegetation structure and biodiversity in the IHR ?
2. What are the impacts of tourism activities on the natural regeneration of plants ?
3. How do tourism-induced changes affect the physico-chemical properties of soil in the region ?

Data Table: Impact of Tourism in the Indian Himalayan Region.

Category	Key Findings	Explanation
Tourism Activities	- Trekking, camping, road construction, resort development.	These activities involve vegetation clearance, infrastructure expansion, and increased human interference.
Vegetation Structure	- Reduction in forest density by 15–20% in high-tourism areas (Bisht <i>et al.</i> , 2023). - Replacement of native species with invasive plants (Sharma & Bhatt 2022).	Deforestation and trampling disturb plant communities, favoring fast-growing invasive species.
Plant Regeneration	- Decline in seedling density by 25–30% in trekking zones (Negi <i>et al.</i> , 2020). - Disrupted seed dispersal by wildlife due to habitat fragmentation.	Human activity restricts natural regeneration cycles and seed dispersal mechanisms.
Soil Physico-Chemical Properties	- Soil organic carbon reduced by 10–15% in tourist-heavy areas. - Increased soil compaction and erosion near trekking routes (Singh <i>et al.</i> , 2021).	Heavy foot traffic and waste deposition alter soil properties, reducing fertility and increasing degradation.
Waste Management Issues	- 70% of tourist waste in the IHR is improperly disposed of (Bisht <i>et al.</i> , 2023).	Accumulated waste leads to soil pollution, affecting nutrient cycling and plant growth.
Economic Impact	- Tourism contributes 20–25% to local GDP in the IHR (Sharma & Bhatt 2022).	While economically beneficial, the lack of regulation exacerbates ecological harm.
Conservation Initiatives	- Implementation of eco-tourism policies in 30% of tourism hotspots (Negi <i>et al.</i> , 2020).	Some regions are adopting eco-tourism practices, but their effectiveness remains inconsistent.

Explanation of Data Categories

1. Tourism Activities: The data highlights common tourism-related activities in the IHR that directly impact ecosystems. For instance, trekking and resort development often require deforestation or encroach on pristine habitats.

2. Vegetation Structure: Studies indicate a measurable reduction in forest density and biodiversity due to tourism. Native plants are increasingly replaced by invasive species that can thrive in disturbed environments, altering the ecological balance.

3. Plant Regeneration: Human interference, such as trampling and habitat fragmentation, reduces the ability of plants to naturally regenerate. This is particularly evident in trekking zones where soil compaction and wildlife displacement are common.

4. Soil Physico-Chemical Properties: Tourism activities degrade soil quality through compaction, loss of organic matter, and increased erosion. This negatively affects vegetation growth and ecosystem productivity.

5. Waste Management Issues: The improper disposal of waste by tourists contributes significantly to soil and water pollution, further exacerbating ecological damage.

6. Economic Impact: The economic benefits of tourism are evident, but the trade-off is substantial environmental degradation, highlighting the need for sustainable practices.

7. Conservation Initiatives: While eco-tourism practices are being implemented in certain areas, their adoption and effectiveness vary significantly, leaving many regions vulnerable.

RESULTS AND DISCUSSION

A. Impact on Vegetation Structure

Tourism activities in the Indian Himalayan Region (IHR) have significantly altered vegetation structure, resulting in reduced forest density and changes in species composition. Studies have reported a 15–20%

decline in forest cover in high-tourism areas, with native tree species being replaced by invasive plants such as *Lantana camara* and *Eupatorium adenophorum* (Bisht *et al.*, 2023). Infrastructure development, including roads, trekking paths, and resorts, often requires large-scale deforestation, further fragmenting habitats and disrupting ecosystems (Sharma & Bhatt 2022). Additionally, excessive foot traffic from trekking and camping activities leads to trampling, which damages understory vegetation and hinders the growth of slow-growing native species (Negi *et al.*, 2020) and the composition of vegetation along roads and trails depends on the intensity of use and the distance from those areas (Wolf and Croft 2014).

B. Plant Regeneration

The natural regeneration of plants in the IHR has been adversely affected by human activities associated with tourism. Seedling density in trekking zones has been found to decline by 25–30% due to soil compaction and loss of suitable microhabitats for seed germination (Negi *et al.*, 2020). Moreover, habitat fragmentation caused by roads and resorts disrupts seed dispersal mechanisms, as wildlife movements become restricted, reducing their role as seed carriers (Singh *et al.*, 2021). Germination and growth patterns are further affected by increased human presence and waste deposition, which alter soil conditions and nutrient availability critical for plant regeneration (Bisht *et al.*, 2023). The main drivers responsible for the regeneration of high-altitude shrubs include ample amount of snowfall, soil moisture, solar influx (Moran *et al.*, 2023) but due to climate change the tree line vegetation is shifting upwards (Grace *et al.*, 2002).

SOIL PHYSICO-CHEMICAL PROPERTIES

Tourism has led to measurable changes in the physico-chemical properties of soil in the IHR. Areas with heavy tourist activity exhibit a 10–15% reduction in soil organic carbon, resulting in decreased fertility and

productivity (Sharma & Bhatt 2022). Soil pH and nutrient content are also altered due to the deposition of non-biodegradable waste, which affects microbial activity and nutrient cycling (Bisht *et al.*, 2023). Furthermore, trekking and camping activities compact the soil, reducing its porosity and water retention capacity, which makes it more prone to erosion, particularly in steep terrains (Negi *et al.*, 2020). These factors collectively degrade soil health, undermining its capacity to support vegetation and contribute to ecosystem stability.

The environmental impacts of tourism in the Indian Himalayan Region (IHR) share parallels with other ecologically sensitive areas globally, such as the Alps and the Andes. However, the IHR exhibits unique vulnerabilities due to its steep topography, fragile soils, and high biodiversity. Similar to the Alps, tourism in the IHR has led to habitat fragmentation and biodiversity loss due to infrastructure development and recreational activities (Sharma & Bhatt 2022). However, the cultural and economic reliance on pilgrimage and adventure tourism in the Himalayas further exacerbates the pressure on natural resources, leading to a more profound impact on vegetation and soil health (Bisht *et al.*, 2023). Comparative studies highlight that the IHR has less stringent environmental regulations and weaker implementation of sustainable tourism practices than other mountain systems like the Alps, worsening the ecological consequences (Negi *et al.*, 2020).

The interplay between vegetation changes, plant regeneration, and soil degradation is evident in tourism-affected zones of the IHR. Reduced forest cover and altered vegetation structure directly impact plant regeneration, as the loss of canopy cover and suitable microhabitats hinder the natural germination and growth processes (Singh *et al.*, 2021). Additionally, soil compaction caused by trekking and camping reduces soil aeration and water infiltration, creating unfavorable conditions for seedling establishment. Soil erosion, a byproduct of reduced vegetation cover and compacted soils, further accelerates the loss of organic matter and nutrients, creating a negative feedback loop that limits plant regeneration and compromises ecosystem stability (Negi *et al.*, 2020).

Tourism activities such as waste disposal, foot traffic, and construction are closely linked to ecological degradation. Improperly managed waste alters soil physico-chemical properties, with non-biodegradable materials affecting nutrient cycling and soil microbiota (Bisht *et al.*, 2023). Heavy foot traffic in trekking zones compacts the soil, reducing its capacity to support vegetation and increasing its susceptibility to erosion. Infrastructure development fragments habitats, further isolating plant and animal species, which disrupts ecological connectivity and seed dispersal mechanisms (Sharma & Bhatt 2022).

Sustainable tourism practices offer a viable solution to mitigate environmental damage in the IHR. Initiatives such as eco-tourism, which emphasize minimal environmental impact and community participation, have shown promise in reducing the ecological footprint of tourism (Singh *et al.*, 2021). For example,

promoting low-impact activities, implementing stricter waste management protocols, and limiting the number of tourists in sensitive areas can help preserve the region's biodiversity and soil health. Additionally, educating tourists about the ecological significance of the IHR and incentivizing local stakeholders to adopt sustainable practices are critical steps in balancing tourism with conservation (Negi *et al.*, 2020).

CONCLUSIONS

This review highlights the significant environmental impacts of tourism on vegetation structure, plant regeneration, and soil physico-chemical properties in the Indian Himalayan Region (IHR). Key findings reveal that unregulated tourism activities have led to a measurable decline in forest density, an increase in invasive plant species, and disrupted natural regeneration cycles. Soil quality has been adversely affected through compaction, nutrient depletion, and erosion, further threatening the ecological stability of this biodiversity hotspot. These changes underscore the critical need to address the ecological vulnerabilities of the IHR in the face of growing tourism pressures. Tourism plays a dual role in the region, acting both as a crucial economic driver that supports local livelihoods and as a significant environmental stressor that threatens the long-term sustainability of the region's ecosystems. While tourism contributes significantly to the local economy and infrastructure development, the lack of sustainable practices exacerbates habitat degradation and biodiversity loss, compromising the ecological and cultural integrity of the Himalayas.

FUTURE SCOPE

To mitigate these challenges, policymakers and stakeholders must adopt an integrated approach to tourism and conservation. Key recommendations include implementing stricter regulations to control tourism-related activities in ecologically sensitive areas, promoting eco-tourism practices that prioritize minimal environmental impact, and enhancing waste management systems to reduce soil and water pollution. Educating tourists and local communities about the ecological significance of the region and incentivizing the adoption of sustainable practices are essential to balancing tourism development with environmental conservation. By taking proactive steps, the IHR can continue to benefit from tourism while preserving its unique biodiversity and ecological resilience for future generations. Tourism poses significant threats to vegetation structure and soil health in the Indian Himalayan Region, there is a growing movement towards sustainable practices that could help mitigate these impacts. The future scope hinges on effective regulation, community involvement, ongoing research, and a commitment to preserve the unique ecological characteristics of this vital region.

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Conflict of Interest. None.

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