OPEN ACCESS
Quick Response Code:



Website: https://wgges.us



Creative Commons (CC BY-NC-SA 4.0):
This is an open access journal, and articles are distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International Public License, which allows others to remix, tweak, and build upon the work noncommercially, as long as appropriate credit is given and the new creations ae licensed under the identical terms.

Manuscript ID:
IJWGAFES-2026-030909

DOI: 10.5281/zenodo.24457108

DOI Link:
https://doi.org/10.5281/zenodo.24457108

Volume: 3
Issue: 9
September
Year: 2026
E-ISSN: 3066-1552

Submitted: *08 Aug 2026*
Revised: *15 Aug 2026*
Accepted: *16 Sept. 2026*
Published: *30 Sept. 2026*

[1]Associate Professor and Head, Department of Environmental Studies, Nar Bahadur Bhandari Government College, Tadong,Gangtok, Sikkim, India
[2]MSC Discipline of Geography, School of Sciences, Indira Gandhi National Open University (Study Centre 2401, Gangtok, Sikkim, India), Sikkim, India
Email: evsnbbgc2023@gmail.com

Address for correspondence:
Dr. Ajay Chhetri
Associate Professor and Head, Department of Environmental Studies, Nar Bahadur Bhandari Government College, Tadong,Gangtok, Sikkim, India
Email: evsnbbgc2023@gmail.com

How to cite this article:
Chhetri, A., & Shanker, S. (2026). Impact of Landslides on Sustainable Tourism in Gangtok: Challenges and Resilience Strategies. International Journal of World Geology, Geography, Agriculture, Forestry and Environment Sciences, 3(9), 47–57. https://doi.org/10.5281/zenodo.24457108

Impact of Landslides on Sustainable Tourism in Gangtok: Challenges and Resilience Strategies

Dr. Ajay Chhetri[1],Sushma Shanker[2]

Abstract

Mountain tourism serves as a primary economic engine across the Eastern Himalayas, yet rapid infrastructural expansion on geologically fragile slopes has intensified vulnerability to climate-induced geo-hazards. This study investigates the cascading socio-economic, infrastructural, and perceptual impacts of recurrent landslides on sustainable tourism development in Gangtok, Sikkim, and evaluates community-institutional resilience strategies. Adopting a convergent mixed-methods research design, primary data were collected via structured questionnaires (N = 200) administered to local residents (40.5%), tourists (22.0%), government officials/disaster experts (19.5%), and tourism stakeholders (18.0%), complemented by geospatial hazard zonation (Geological Survey of India/National Remote Sensing Centre, 2026) and field observations across high-risk corridors (Syari, Ranipool, and Chandmari). Descriptive metrics, weighted mean scores (WMS), and Pearson's chi-square contingency analyses with Cramér's V effect sizes were executed. Results demonstrate that 84.0% of respondents directly experienced landslides, driven primarily by intense monsoonal precipitation (39.0%), unscientific road cutting (33.5%), and unplanned urbanization (16.5%). Landslides frequently disrupt tourism operations (70.0% reporting frequent or very frequent disruption; WMS = 3.94, SD = 1.09), disproportionately crippling arterial transportation along National Highway 10 (51.5%) and hospitality operations (22.5%), while eroding visitor safety perceptions (83.5% agreement; WMS = 4.21, SD = 0.94) and inflicting significant economic losses on 54.0% of respondents (WMS = 3.36, SD = 0.80). Chi-square tests reveal statistically invariant risk awareness across stakeholder categories (χ^2 = 13.353, df = 12, p = .344, V = 0.149), age cohorts (χ^2 = 17.839, df = 16, p = .333, V = 0.149), and occupational groups (χ^2 = 9.446, df = 12, p = .664, V = 0.125), confirming a systemic, destination-wide vulnerability profile. Furthermore, 70.0% of respondents rated existing municipal risk-control measures as only partially effective (45.0%) or inadequate (25.0%), whereas 85.0% strongly endorsed sustainable tourism practices (WMS = 4.28, SD = 0.90), prioritizing real-time early warning systems (33.0%), strict construction regulation (21.0%), and engineered slope drainage (15.5%). The paper concludes by formulating an integrated five-pillar Resilience-Oriented Sustainable Tourism Framework (ROSTF) aligned with United Nations Sustainable Development Goals 8, 11, 12, and 13.

Keywords: *landslide susceptibility, sustainable mountain tourism, disaster resilience, Gangtok, Eastern Himalayas, NH-10 corridor, geo-hazard governance*

Impact of Landslides on Sustainable Tourism in Gangtok: Challenges and Resilience Strategies

Introduction

Mountain tourism has emerged as one of the fastest-growing segments of the global hospitality economy, particularly across the ecologically fragile landscapes of the Himalayan arc (Kumar, 2025; Nepal & Chipeniuk, 2005). Spanning multiple South Asian nations, the Himalayan mountain system attracts millions of domestic and international visitors annually through its dramatic topographic relief, biodiversity hotspots, sacred monastic heritage, and adventure recreation circuits (Apollo, 2021; Pradhan, 2022). In rugged upland states such as Sikkim, where steep gradients and climatic constraints severely restrict arable agricultural expansion, tourism functions as an indispensable pillar of regional economic development—generating direct and indirect employment across hospitality, transport, retail, and artisanal sectors while catalyzing public investment in road and civic infrastructure (Bhutia, 2024; Government of India, 2006; Palit et al., 2020).

However, the rapid commercialization of mountain destinations frequently generates severe ecological externalities when infrastructural growth outpaces environmental carrying capacity (Alam et al., 2022; Kumar, 2023). As a young, tectonically active fold-mountain belt formed by the ongoing collision of the Indian and Eurasian plates, the Eastern Himalayas exhibit deeply weathered lithology, active seismic faults, and steep valley slopes exposed to intense monsoonal precipitation (Dahal & Hasegawa, 2008; Havenith & Bourdeau, 2024; Zhang et al., 2025).

When these inherent geological vulnerabilities intersect with anthropogenic disturbances—such as unscientific hill-cutting, highway widening, deforestation, improper surface drainage, and high-density multistory construction—slope equilibrium is compromised, triggering recurrent landslides, debris flows, and rockfalls (Gupta & Ahmed, 2018; Kaur et al., 2019; National Disaster Management Authority [NDMA], 2020). Moreover, anthropogenic climate change has amplified monsoonal rainfall variability and cloudburst frequency across the Himalayas, accelerating the incidence and magnitude of slope failures (Dahal et al., 2024; Times of India, 2026; Yadav et al., 2024).

Gangtok (elevation ~1,650 m above mean sea level), the capital city of Sikkim, exemplifies the acute tension between tourism-driven urban expansion and geo-hazard vulnerability. Serving as the administrative center and primary logistical gateway to premier Eastern Himalayan circuits—including Tsomgo Lake, Nathula Pass, Rumtek Monastery, and North Sikkim's Yumthang Valley—Gangtok has experienced exponential growth in hotels, homestays, and vehicular traffic over the past two decades (Government of Sikkim, 2018; Sarkar, 2025; Suman, 2013). Despite state policy commitments toward ecotourism and environmental stewardship (Government of Sikkim, 2011; Sikkim Tourism, 2025), monsoon-triggered landslides routinely sever National Highway 10 (NH-10)—the sole arterial lifeline linking Gangtok to Siliguri and the Indian mainland—alongside intra-urban corridors such as Syari, Ranipool, and Chandmari (Bhasin et al., 2002; Sengupta & Nath, 2022). These slope failures obstruct visitor mobility, strand tourists, damage hospitality assets, erode destination safety perceptions, and destabilize the livelihoods of tourism-dependent households (Dahal et al., 2024; Sharma, 2022). Examining the nexus between landslide hazards and sustainable tourism in Gangtok is therefore critical for operationalizing disaster risk reduction (DRR) and advancing United Nations Sustainable Development Goals (SDGs) 8 (Decent Work and Economic Growth), 11 (Sustainable Cities and Communities), 12 (Responsible Consumption and Production), and 13 (Climate Action) (United Nations, 2015; United Nations World Tourism Organization [UNWTO], 2018).

Literature Review

1 Global and South Asian Perspectives on Geo-Hazards and Mountain Tourism

International scholarship increasingly conceptualizes sustainable mountain tourism through the lens of socio-ecological resilience, recognizing that economic viability in upland destinations cannot be decoupled from environmental stability and hazard governance (Bramwell & Lane, 2011; Sharpley, 2020; UNWTO, 2018). In their seminal investigation of the Nepal Himalayas, Dahal and Hasegawa (2008) established empirical rainfall thresholds governing landslide initiation, demonstrating that prolonged monsoonal precipitation elevates pore-water pressure, destabilizes colluvial slopes, and severs transport corridors vital to tourism-dependent economies. Similarly, Nyaupane et al. (2006) illustrated in the Annapurna region that climatic instability and perceived physical hazards directly erode destination competitiveness, as risk-averse travelers divert itineraries away from regions perceived as environmentally volatile.

Across the broader Hindu Kush Himalaya (HKH), the HI-AWARE initiative documented by Trivedi (2015) revealed that households reliant on tourism and subsistence agriculture suffer acute livelihood precarity when landslides disrupt road connectivity and supply chains. Broader econometric and policy analyses across South Asia corroborate that unregulated urban sprawl, deforestation, and deficient disaster governance exacerbate ecological degradation in mountain tourism hubs (Alam et al., 2022; Font & McCabe, 2017; UNEP & UNWTO, 2005). Consequently, global frameworks advocate embedding hazard zonation, early warning systems, and climate-resilient infrastructure directly into destination management plans (UN Environment Programme, 2019; World Bank, 2021).

2.2 Landslide Susceptibility and Tourism Pressures in the Indian Himalayan Region

Within the Indian Himalayan Region (IHR), the Landslide Hazard Zonation Atlas of India classifies large swaths of Sikkim, Uttarakhand, and Himachal Pradesh under high-to-very-high landslide susceptibility due to complex thrust tectonics, fragile phyllite-schist lithology, and intense orographic rainfall (NDMA, 2019). Remote sensing and Geographic Information System (GIS) assessments by Gupta and Ahmed (2018) and Kaur et al. (2019) demonstrate that anthropogenic slope modification—particularly road excavation, quarrying, and barren land conversion—acts as a primary catalyst amplifying natural landslide susceptibility across the Eastern Himalayas. Empirical case studies from Dharamshala in Himachal Pradesh (Government of Himachal Pradesh, 2019; Katoch et al., 2021; Siroha, 2023) and the Uttarakhand Himalayas (Bora et al., 2026) confirm that unbridled real estate expansion and weak enforcement of building bylaws intensify slope instability, resulting in recurrent highway blockades, seasonal occupancy collapses, and severe revenue losses for local hospitality enterprises (WWF India, 2023).

3 Regional Evidence from Sikkim and the Gangtok Urban Corridor

Site-specific geotechnical investigations in Gangtok trace the city's chronic slope instability to the interplay of steep terrain, deeply weathered micaceous schists and phyllites, heavy monsoonal downpours, and rapid urban densification (Bhasin et al., 2000, 2002). Bhasin et al. (2002) warned over two decades ago that unscientific excavation for multistory hotels and residential buildings without commensurate subsurface drainage or retaining structures was critically degrading slope safety factors across Gangtok. More recently, high-resolution GIS susceptibility modeling by Sengupta and Nath (2022) delineated multiple very-high-hazard zones intersecting Gangtok's municipal wards and transit arteries. Concurrently, tourism scholarship in Sikkim highlights mounting pressures on municipal carrying capacity, including solid waste accumulation, vehicular congestion, and infrastructural strain (Singh et al., 2020; Sustainable Tourism and Waste Management Challenges of Gangtok City in Sikkim, 2026; Towards the Development of Sustainable Tourism, 2019). Dahal et al. (2024) further confirmed that recurrent landslides in the Sikkim Himalaya inflict severe financial instability on transport operators and hospitality workers during monsoon months, underscoring the urgency of integrating disaster resilience into Sikkim's sustainable tourism governance (Naqvi et al., 2023; Sharma et al., 2021).

Research Gaps

A critical synthesis of existing international, national, and regional literature reveals four substantive gaps that limit evidence-based policy formulation in Gangtok:

1. **Disciplinary Siloing Between Geotechnical Hazard Mapping and Tourism Economics:** Prior investigations in Sikkim have predominantly examined either physical landslide susceptibility using GIS/geotechnical modeling (Bhasin et al., 2002; Kaur et al., 2019; Sengupta & Nath, 2022) or macroeconomic tourism growth and waste management (Palit et al., 2020; Singh et al., 2020), rarely integrating spatial hazard zonation with empirical socio-economic impact metrics.
2. **Absence of Multi-Stakeholder Perceptual Comparisons:** Limited empirical research has systematically compared risk awareness, safety perceptions, and economic vulnerability across distinct actor groups—specifically contrasting local residents, visiting tourists, private tourism operators, and municipal disaster officials within a unified analytical sample.
3. **Under-Exploration of Micro-Corridor Bottlenecks:** Existing regional assessments seldom link localized intra-urban slide corridors (such as Syari, Ranipool, and Chandmari) with broader arterial choke points (NH-10) to map how localized slope failures cascade into destination-wide service disruptions.
4. **Lack of Actionable, Stakeholder-Prioritized Resilience Frameworks:** While general recommendations for afforestation and zoning exist (NDMA, 2020), empirical evaluations of stakeholder satisfaction with current municipal controls and quantitative rankings of preferred resilience interventions remain scarce in the Gangtok context.

Rationale of the Study

The rationale for this investigation stems from both an urgent practical imperative and a theoretical need in Himalayan sustainability science. Practically, Gangtok serves as the economic nerve center of Sikkim's tourism industry, supporting thousands of livelihoods across hospitality, transportation, and allied enterprises (Bhutia, 2024; Sarkar, 2025). As climate change intensifies monsoonal extremes and urban construction encroaches onto marginal slopes, recurrent landslides threaten to undermine decades of state investment in eco-tourism branding and regional infrastructure (Sikkim Tourism, 2025; Times of India, 2026). Without empirically grounded resilience strategies, seasonal road closures and safety anxieties risk locking Gangtok into a cycle of recurrent disaster losses and economic precarity.

Theoretically and methodologically, bridging geospatial hazard data with multi-stakeholder econometric and perceptual analysis provides a replicable template for assessing destination vulnerability in fragile mountain ecosystems (Torres-Delgado & Saarinen, 2014; UNWTO, 2004). By quantifying how physical slope instability translates into sectoral disruptions, perceived travel risk, and livelihood losses—and by evaluating institutional efficacy alongside community support for sustainability—this study generates actionable policy insights for municipal planners, the Sikkim State Disaster Management Authority (SSDMA), and regional tourism boards.

Research Objectives and Hypotheses

Guided by the identified research gaps, this study addresses three primary objectives: (1) to evaluate the empirical impacts of landslides on local livelihoods, sectoral operations, and tourist safety experiences in Gangtok; (2) to examine demographic and occupational variations in landslide risk awareness, perceived monsoon arrival decline, and economic loss; and (3) to assess stakeholder evaluations of institutional risk governance and prioritize community-supported resilience strategies. Accordingly, four testable hypotheses were formulated:

Hypothesis 1 (H1): H01: There is no statistically significant association between respondent stakeholder category (local residents, tourists, tourism stakeholders, officials/experts) and landslide risk awareness levels in Gangtok. Ha1: Landslide risk awareness levels differ significantly across respondent stakeholder categories.

Hypothesis 2 (H2): H02: There is no statistically significant relationship between respondent age group and the perception that landslides reduce monsoon tourist arrivals. Ha2: Perceptions of landslide-induced tourism decline vary significantly across respondent age groups.

Hypothesis 3 (H3): H03: There is no statistically significant association between respondent occupation and the severity of economic losses experienced due to landslides. Ha3: Perceived severity of landslide-induced economic losses differs significantly across occupational groups.

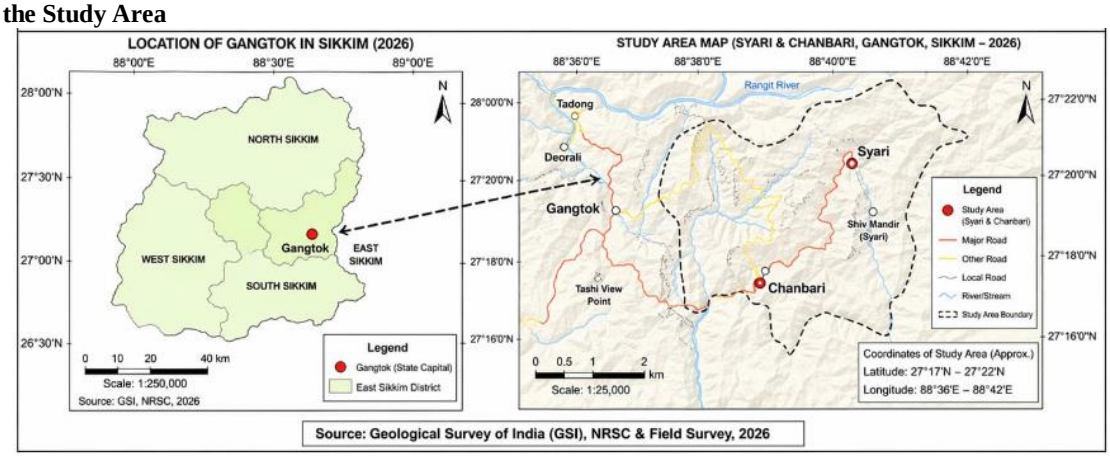
Hypothesis 4 (H4): H04: There is no statistically significant association between respondent landslide awareness level and support for sustainable, eco-friendly tourism practices. Ha4: Higher landslide risk awareness is significantly associated with stronger support for sustainable tourism practices.

Research Methodology

1 Study Area Profile

The empirical investigation was conducted in Gangtok (27°17'N–27°22'N latitude, 88°36'E–88°42'E longitude), the capital of Sikkim situated in the Eastern Himalayas at an elevation of approximately 1,650 m. Field surveys and physical slope inspections focused intensively on the active urban-transit corridors of Syari, Ranipool (27.291662°N, 88.596470°E), and Chandmari–Jawaharlal Nehru Road (27.337210°N, 88.621815°E), alongside the central tourism hub and the NH-10 transit axis. Geologically, the study area is underlain by sheared phyllites, schists, and quartzites of the Daling Group, characterized by steep topographic gradients, high drainage density within the Rani Khola/Rangeet watershed, and heavy monsoonal precipitation exceeding 3,000 mm annually (Bhasin et al., 2002; Sengupta & Nath, 2022).

Location of the Study Area



Landslide Hazard of study area

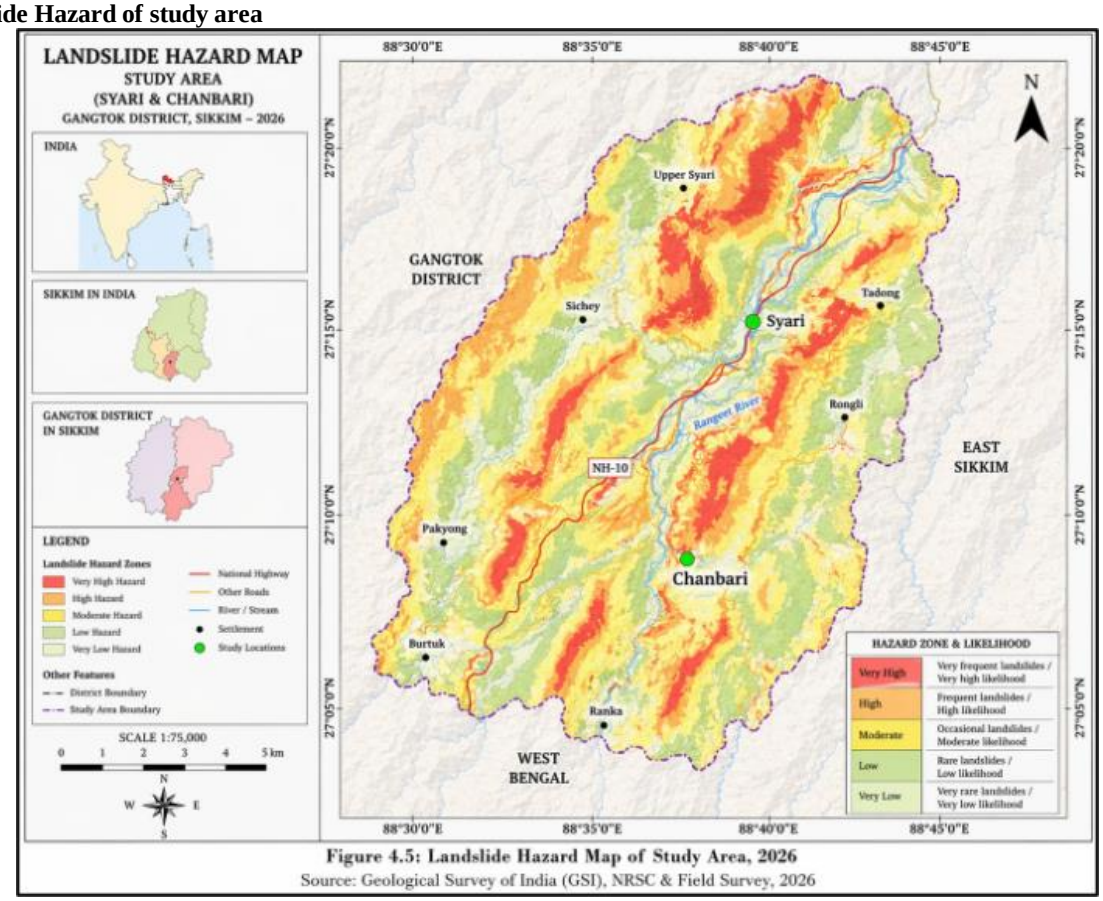


Figure 4.5: Landslide Hazard Map of Study Area, 2026
Source: Geological Survey of India (GSI), NRSC & Field Survey, 2026

2 Research Design and Sampling Strategy

A descriptive-analytical convergent mixed-methods design was employed to triangulate quantitative survey metrics with qualitative field observations and geospatial hazard mapping (Creswell & Creswell, 2018; Kothari, 2004). A total sample of N = 200 respondents was selected across Gangtok using a dual-stage sampling strategy (Kumar, 2019). First, stratified random sampling was applied to ensure proportional representation across three core grassroots cohorts: local residents (n = 81; 40.5%), domestic and international tourists (n = 44; 22.0%), and private tourism stakeholders including hoteliers, taxi operators, and travel agents (n = 36; 18.0%). Second, purposive expert sampling was used to recruit government officials and disaster management specialists (n = 39; 19.5%) possessing domain expertise in municipal planning and slope mitigation.

3 Data Collection Instruments and Geospatial Integration

Primary data were collected in April 2026 using a 15-item structured questionnaire divided into four thematic modules: (a) demographic and occupational profile; (b) direct landslide exposure, causal attribution, sectoral disruption, safety perception, and economic loss; (c) hazard awareness and monsoon arrival impacts; and (d) institutional performance evaluation and preferred resilience strategies. Likert-type items utilized 5-point ordinal scales (1 = Strongly Disagree/Never to 5 = Strongly Agree/Very Frequently) and a 4-point severity scale for economic loss (1 = Not at All to 4 = Yes, Significantly). Primary survey records were triangulated with geotagged field photography of active rock-debris slides in Ranipool and Syari, community road restoration assessments in Chandmari, and secondary spatial datasets from the Geological Survey of India (GSI), National Remote Sensing Centre (NRSC, 2026), NDMA (2019), and SSDMA. Informed consent was obtained from all participants prior to data collection, and respondent anonymity was strictly maintained.

4 Statistical and Spatial Analytical Procedures

Quantitative data were coded and analyzed using SPSS and Python statistical libraries. Univariate distributions were summarized via frequencies and percentages, supplemented by Weighted Mean Scores (WMS) and standard deviations (SD) to quantify central tendency and dispersion across ordinal perception scales. Bivariate hypotheses (H01–H04) were tested using Pearson's chi-square test of independence (χ^2) at $\alpha = .05$, accompanied by degrees of freedom (df), exact p-values, and Cramér's V effect size coefficients to evaluate association strength independent of sample size. To synthesize spatial vulnerability with stakeholder perceptions, a bivariate proportional topological cartogram was constructed integrating GSI/NRSC (2026) landslide hazard zonation with sectoral tourism exposure metrics.

Findings and Statistical Calculations

1 Socio-Demographic and Occupational Profile of Respondents

Table 1 summarizes the demographic and occupational composition of the 200 surveyed participants. Gender representation was balanced between male (49.0%) and female (48.0%) respondents, with 3.0% identifying as other. Economically active adults aged 21–30 years (38.5%) and 31–40 years (30.0%) comprised 68.5% of the sample. Occupationally, 67.0% of respondents were directly engaged in tourism-related work (36.5%) or local commercial business (30.5%), reflecting Gangtok's high structural dependence on the visitor economy.

Table 1

Socio-Demographic and Occupational Distribution of Survey Respondents in Gangtok

Demographic Variable	**Category / Sub-Group**	**Frequency (n)**	**Percentage (%)**
Respondent Category	Local Residents	81	40.5
	Tourists	44	22.0
	Government Officials / Experts	39	19.5
	Tourism Stakeholders	36	18.0
Gender	Male	98	49.0
	Female	96	48.0
	Other	6	3.0
Age Group	Below 20 years	20	10.0
	21–30 years	77	38.5
	31–40 years	60	30.0
	41–50 years	31	15.5
	Above 50 years	12	6.0
Occupation	Tourism-Related Work	73	36.5
	Business / Commerce	61	30.5
	Student	28	14.0
	Government Service	23	11.5
	Other	15	7.5
Total Sample	**All Categories Combined**	**200**	**100.0**

Note. N = 200. Stratified random sampling was applied for residents, tourists, and tourism stakeholders; purposive sampling was applied for government officials and disaster experts.

2 Empirical Impacts of Landslides on Tourism Operations, Infrastructure, and Livelihoods

As detailed in Table 2, an overwhelming majority of respondents (84.0%, n = 168) reported directly experiencing or witnessing landslides in Gangtok. Respondents attributed slope failures to a combination of hydrometeorological and anthropogenic triggers, led by heavy monsoonal rainfall (39.0%) and unscientific road cutting/construction (33.5%), followed by unplanned urbanization (16.5%), deforestation (6.5%), and climate change variability (4.5%). Tourism disruptions occur on a chronic basis: 70.0% of respondents reported that landslides disrupt tourism activities very frequently (38.5%) or frequently (31.5%), yielding a high Weighted Mean Score of 3.94 (SD = 1.09 on a 5-point scale).

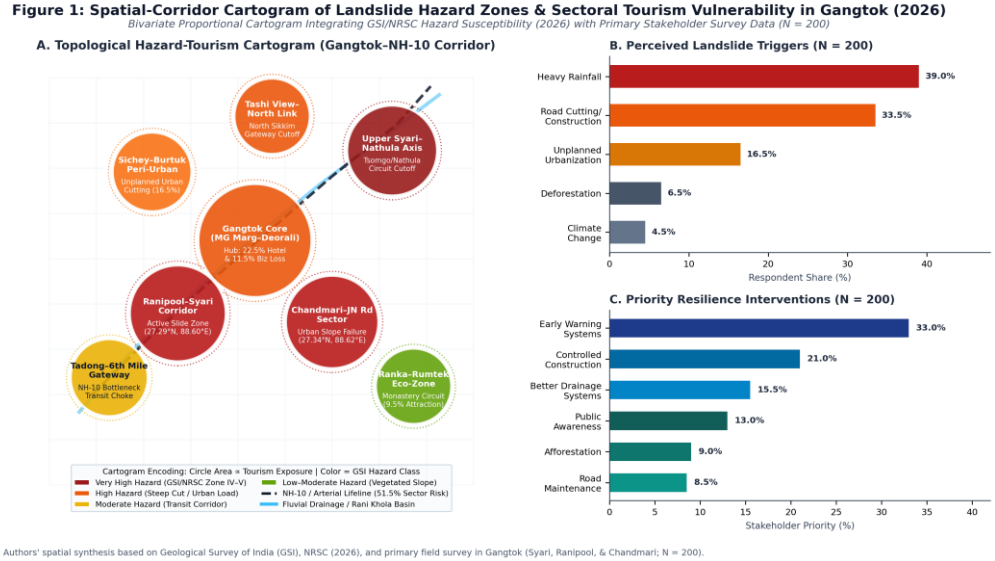
Sectorally, transportation infrastructure emerged as the primary vulnerability node, identified by 51.5% (n = 103) of participants as the sector most severely affected by slope failures, followed by hotels and accommodation (22.5%), local retail businesses (11.5%), tourist attractions (9.5%), and communication networks (5.0%). Furthermore, 83.5% of respondents strongly agreed (46.0%) or agreed (37.5%) that landslides compromise tourist safety and degrade the overall travel experience (WMS = 4.21, SD = 0.94). Economically, 84.5% of participants reported either significant (54.0%) or moderate (30.5%) financial losses attributable to landslide-induced cancellations, road blockades, and supply chain interruptions (WMS = 3.36, SD = 0.80 on a 4-point severity scale).

Table 2

Empirical Assessment of Landslide Triggers, Sectoral Disruptions, Safety Perceptions, and Economic Losses

Analytical Dimension	**Response Category**	**n**	**%**	**Descriptive Metric (WMS ± SD)**
Direct Landslide Exposure	Yes (Experienced / Witnessed)	168	84.0	Binary Exposure: 84.0% Yes
	No	32	16.0	
Primary Causal Trigger	Heavy Monsoonal Rainfall	78	39.0	Anthropogenic Share: 56.5%
	Road Cutting / Construction	67	33.5	(Road + Urban + Deforest.)
	Unplanned Urbanization	33	16.5	
	Deforestation	13	6.5	
	Climate Change Extremes	9	4.5	
Disruption Frequency (1–5)	Very Frequently (5) / Frequently (4)	140	70.0	WMS = 3.94 ± 1.09
	Occasionally (3)	41	20.5	(High Chronic Disruption)
	Rarely (2) / Never (1)	19	9.5	
Most Affected Sector	Transportation (NH-10 & Link Roads)	103	51.5	Modal Vulnerability: Transport
	Hotels and Accommodation	45	22.5	
	Local Businesses	23	11.5	
	Tourist Attractions	19	9.5	
	Communication Services	10	5.0	
Negative Impact on Safety & Experience (1–5)	Strongly Agree (5) / Agree (4)	167	83.5	WMS = 4.21 ± 0.94
	Neutral (3)	21	10.5	(Severe Safety Erosion)
	Disagree (2) / Strongly Disagree (1)	12	6.0	
Economic Loss Severity (1–4)	Yes, Significantly (4)	108	54.0	WMS = 3.36 ± 0.80
	Moderately (3)	61	30.5	(84.5% Moderate–Severe Loss)
	Slightly (2) / Not at All (1)	31	15.5	

Note. N = 200. WMS = Weighted Mean Score; SD = Standard Deviation. Disruption frequency and safety perception were measured on 5-point Likert scales (1–5); economic loss severity was measured on a 4-point ordinal scale (1 = Not at all to 4 = Yes, significantly).



Note. Figure 1 integrates geological hazard zonation (GSI/NRSC, 2026) with primary stakeholder exposure metrics (N = 200). In Panel A, proportional node area encodes tourism infrastructure density and transit dependency, while node color denotes physical landslide susceptibility along the NH-10 and intra-urban corridors (Syari, Ranipool, and Chandmari).

3 Institutional Governance, Mitigation Preferences, and Sustainability Support

Evaluation of existing institutional risk management revealed substantial governance deficits (Table 3). Only 17.5% (n = 35) of respondents affirmed that local authorities are taking adequate measures to control landslide risks, whereas 45.0% (n = 90) rated government interventions as only partially effective and 25.0% (n = 50) deemed them inadequate (with 12.5% unsure). Conversely, public endorsement of sustainable and eco-friendly tourism practices was exceptionally strong: 85.0% of respondents strongly agreed (49.0%) or agreed (36.0%) with adopting sustainability-oriented risk mitigation (WMS = 4.28, SD = 0.90). When asked to prioritize specific resilience interventions, stakeholders ranked real-time early warning systems first (33.0%), followed by strict enforcement of controlled construction activities (21.0%), engineered slope drainage systems (15.5%), public awareness programs (13.0%), slope afforestation (9.0%), and improved road maintenance (8.5%).

Table 3

Stakeholder Evaluation of Institutional Risk Governance, Priority Resilience Interventions, and Sustainability Support

Governance & Resilience Dimension	**Response / Intervention Option**	**Frequency (n)**	**Percentage (%)**
Adequacy of Authority Measures	Partially Adequate	90	45.0
	No (Inadequate)	50	25.0
	Yes (Adequate)	35	17.5
	Not Sure	25	12.5
Priority Resilience Interventions	Early Warning Systems (EWS)	66	33.0
	Controlled Construction Activities	42	21.0
	Better Subsurface & Surface Drainage Systems	31	15.5
	Public & Tourist Awareness Programs	26	13.0
	Slope Afforestation & Bio-Engineering	18	9.0
	Improved Road Maintenance	17	8.5
Support for Sustainable Tourism	Strongly Agree (5)	98	49.0
(WMS = 4.28 ± 0.90)	Agree (4)	72	36.0
	Neutral (3)	22	11.0
	Disagree (2) / Strongly Disagree (1)	8	4.0

Note. N = 200. Support for sustainable tourism was evaluated on a 5-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree).

7.4 Bivariate Cross-Tabulations and Chi-Square Hypothesis Testing

To test Hypotheses H01 through H04, cross-tabulations and Pearson's chi-square contingency analyses were conducted across key demographic and perceptual variables (Tables 4 and 5). For Hypothesis 1, awareness levels (Very

Aware or Aware) were high across all groups—local residents (76.5%, 62/81), government officials/experts (79.5%, 31/39), tourists (77.3%, 34/44), and tourism stakeholders (72.2%, 26/36)—yielding $\chi^2(12, N = 200) = 13.353$, $p = .344$, Cramér's V = 0.149. Because $p > .05$, H01 was retained, indicating uniformly high hazard recognition across stakeholder groups.

For Hypothesis 2, agreement that landslides reduce monsoon tourist arrivals was consistently strong across age cohorts, particularly among economically active respondents aged 21–30 (77.9%, 60/77) and 31–40 (83.3%, 50/60), resulting in $\chi^2(16, N = 200) = 17.839$, $p = .333$, Cramér's V = 0.149 (H02 retained). For Hypothesis 3, although workers in tourism-related jobs (89.0%, 65/73) and commercial business (86.9%, 53/61) reported high rates of significant or moderate economic losses, the contingency test across all occupational categories showed $\chi^2(12, N = 200) = 9.446$, $p = .664$, Cramér's V = 0.125 (H03 retained), reflecting broad spillover losses across Gangtok's economy. Similarly, for Hypothesis 4, strong support for sustainable tourism persisted across awareness tiers (87.9% among very aware respondents vs. 83.3% among aware respondents), yielding $\chi^2(16, N = 200) = 16.648$, $p = .409$, Cramér's V = 0.144 (H04 retained).

Table 4

Condensed Bivariate Cross-Tabulation Distributions Across Stakeholder Categories, Age Cohorts, and Occupations

Cross-Tabulated Variables	Sub-Group	High / Affirmative Tier	Moderate / Neutral Tier	Low / Negative Tier	Total (n)
Category × Hazard Awareness	Local Residents	62 (76.5%)	15 (18.5%)	4 (4.9%)	81
(Very Aware + Aware vs. Mod vs. Slight/Not)	Tourists	34 (77.3%)	6 (13.6%)	4 (9.1%)	44
	Tourism Stakeholders	26 (72.2%)	9 (25.0%)	1 (2.8%)	36
	Officials / Experts	31 (79.5%)	5 (12.8%)	3 (7.7%)	39
Age Group × Monsoon Arrival Decline	Below 20 years	14 (70.0%)	3 (15.0%)	3 (15.0%)	20
(SA + A vs. Neutral vs. D + SD)	21–30 years	60 (77.9%)	9 (11.7%)	8 (10.4%)	77
	31–40 years	50 (83.3%)	5 (8.3%)	5 (8.3%)	60
	41–50 years	26 (83.9%)	1 (3.2%)	4 (12.9%)	31
	Above 50 years	11 (91.7%)	0 (0.0%)	1 (8.3%)	12
Occupation × Economic Loss Severity	Tourism-Related Work	65 (89.0%)	7 (9.6%)	1 (1.4%)	73
(Sig + Mod vs. Slight vs. Not at All)	Business / Commerce	53 (86.9%)	6 (9.8%)	2 (3.3%)	61
	Student	20 (71.4%)	7 (25.0%)	1 (3.6%)	28
	Government Service	19 (82.6%)	3 (13.0%)	1 (4.3%)	23
	Other	12 (80.0%)	3 (20.0%)	0 (0.0%)	15

Note. N = 200. Full 5×5 and 5×4 contingency matrices were used to compute exact Pearson chi-square statistics reported in Table 5.

Table 5

Summary of Pearson's Chi-Square Contingency Tests and Effect Sizes for Study Hypotheses

Null Hypothesis	Variables Tested	Pearson χ^2	df	p-value	Cramér's V	Statistical Decision
H01	Respondent Category × Landslide Awareness	13.353	12	.344	0.149	Retain H01 (Invariant)
H02	Age Group × Perceived Monsoon Tourism Decline	17.839	16	.333	0.149	Retain H02 (Invariant)
H03	Occupation × Landslide Economic Loss	9.446	12	.664	0.125	Retain H03 (Invariant)

	Severity					
H04	Awareness Level × Support for Sustainable Tourism	16.648	16	.409	0.144	Retain H04 (Invariant)

Note. N = 200; significance threshold α = .05. Cramér's V values (0.125–0.149) indicate small effect sizes, confirming that risk awareness, perceived tourism decline, economic vulnerability, and sustainability endorsement are broadly shared across demographic and stakeholder strata.

Discussion and Analytical Synthesis

The empirical findings provide compelling evidence that landslides act as a systemic stressor undermining the ecological, infrastructural, and economic pillars of sustainable tourism in Gangtok. First, the causal attribution profile—in which 56.5% of respondents identified anthropogenic drivers (road cutting 33.5%, unplanned urbanization 16.5%, and deforestation 6.5%) alongside heavy monsoonal precipitation (39.0%)—corroborates geotechnical assessments across the Sikkim Himalaya (Bhasin et al., 2002; Dahal et al., 2024; Kaur et al., 2019). Field inspections conducted in April 2026 at Ranipool–Syari Road and Chandmari–Jawaharlal Nehru Road visually confirmed that vertical slope excavation without adequate toe-retaining walls or lined storm-water drains accelerates rock-debris failures in weathered phyllitic formations, mirroring patterns documented in Dharamshala and Uttarakhand (Bora et al., 2026; Katoch et al., 2021; Siroha, 2023).

Second, the topological cartogram (Figure 1) and sectoral impact rankings demonstrate an acute 'arterial bottleneck effect.' Because Gangtok's tourism circuit relies on a single primary highway artery (NH-10) and steep radial link roads connecting MG Marg, Deorali, Syari, and Chandmari to high-altitude attractions (Tsomgo Lake, Nathula, and North Sikkim), localized slope failures along NH-10 or Ranipool–Syari (51.5% sectoral impact) trigger immediate cascading losses across hotels (22.5%) and local retail enterprises (11.5%). This spatial vulnerability explains why 83.5% of participants reported diminished tourist safety and experience quality (WMS = 4.21), reinforcing international evidence that perceived environmental insecurity erodes destination image and suppresses repeat visitation (Apollo, 2021; Nyaupane et al., 2006).

Third, a critical analytical insight emerges from the retention of null hypotheses H01–H04 ($p > .05$, Cramér's V = 0.125–0.149). Rather than indicating an absence of landslide impact, statistical invariance across stakeholder categories, age cohorts, and occupations demonstrates that geo-hazard vulnerability in Gangtok is pervasive and destination-wide rather than confined to a single demographic niche. Tourists exhibit hazard awareness levels (77.3%) nearly identical to local residents (76.5%) and officials (79.5%), while non-tourism workers experience indirect economic spillovers comparable to direct hospitality operators (89.0% vs. 82.6% in government/allied services). Simultaneously, the stark mismatch between high public support for sustainable tourism (85.0%; WMS = 4.28) and low confidence in existing municipal hazard controls (only 17.5% rating them adequate) exposes a major institutional governance gap requiring urgent policy reform (Alam et al., 2022; World Bank, 2021).

Conclusion and Resilience Strategies

This study demonstrates that sustainable tourism development in Gangtok cannot be achieved in isolation from geo-hazard risk reduction and climate-adaptive urban governance. Recurrent monsoon-triggered landslides—amplified by unscientific road cutting and unplanned slope urbanization—sever arterial transportation along NH-10, compromise visitor safety perceptions, and inflict widespread economic losses across Gangtok's tourism-dependent community. While hazard awareness and demand for eco-friendly tourism are uniformly high across residents, visitors, and industry stakeholders, existing municipal mitigation measures remain largely reactive and insufficient.

To transition Gangtok toward a disaster-resilient and sustainable mountain tourism model aligned with SDGs 8, 11, 12, and 13, policymakers, the Sikkim State Disaster Management Authority (SSDMA), and the Department of Tourism and Civil Aviation should operationalize a five-pillar Resilience-Oriented Sustainable Tourism Framework (ROSTF):

1. **Real-Time Multi-Hazard Early Warning Systems (EWS):** Deploy automated rain-gauge telemetry, soil-moisture extensometers, and Doppler radar alerts along NH-10, Ranipool–Syari, and Chandmari, linked to SMS/mobile advisory dashboards for tour operators and incoming visitors (addressing the top stakeholder priority at 33.0%).
2. **Strict Land-Use Zoning and Carrying-Capacity Enforcement:** Mandate GIS-based micro-zonation clearance (Sengupta & Nath, 2022) prior to issuing hotel or commercial building permits, enforcing height restrictions, slope-gradient bans, and scientific cut-and-fill regulations (21.0% stakeholder priority).
3. **Engineered Subsurface Drainage and Bio-Engineering Stabilization:** Retrofit high-risk urban wards (Chandmari, Syari, Sichey) with lined cascading storm-water drains, subsurface horizontal weep-holes, anchored retaining walls, and deep-rooted native Himalayan vegetation to reduce pore-water pressure during peak monsoons (24.5% combined priority).
4. **Community-Led Disaster Preparedness and Co-Management:** Institutionalize ward-level disaster response committees integrating local indigenous slope knowledge, homestay associations, and taxi unions—building on successful community road-rehabilitation initiatives documented in Chandmari—to accelerate rapid debris clearance and emergency tourist evacuation.
5. **Seasonal Diversification and Tourism Risk Insurance:** Promote low-impact monsoon cultural, wellness, and conference tourism within safe urban zones while introducing parametric weather-indexed insurance schemes to buffer small hospitality enterprises and transport workers against highway closure losses.

Future longitudinal research should integrate multi-temporal Interferometric Synthetic Aperture Radar (InSAR) ground-deformation monitoring with panel econometric tracking of hotel occupancy and tourist arrival elasticity across multiple monsoon cycles in the Eastern Himalayas.

Acknowledgement
The authors would like to extend their heartfelt thanks to their research guides, academic mentors, colleagues, and institutional authorities for their valuable guidance, continuous encouragement, and constructive suggestions throughout the research process.
Special appreciation is extended to the local residents, tourism stakeholders, hotel owners, tour operators, tourists, and other respondents in Gangtok who shared their valuable experiences, opinions, and insights regarding the impact of landslides on tourism activities, local livelihoods, infrastructure, and environmental sustainability. Their cooperation and participation have been invaluable to this study.

Financial support and sponsorship
Nil.

Conflicts of interest
The authors declare no conflicts of interest with respect to the research, authorship, or publication of this article. Field observations, geospatial mapping, and primary stakeholder surveys were conducted across the Gangtok urban corridor (Syari, Ranipool, and Chandmari) in Sikkim, India, during 2026 in compliance with institutional ethical standards.

References

1. Alam, M. S., Paramati, S. R., Shahbaz, M., & Bhattacharya, M. (2022). The role of tourism and environmental sustainability in South Asia. Environmental Science and Pollution Research, 29(12), 16786–16799. https://doi.org/10.1007/s11356-021-16867-y
2. Apollo, M. (2021). Himalayan nature-based tourism: Challenges for sustainability. International Journal of Conservation Science, 12(3), 1021–1036.
3. Apollo University. (2022). Climate change and environmental challenges in Himalayan tourism regions. Apollo University Press.
4. Bhasin, R., Grimstad, E., Larsen, J. O., Dhawan, A. K., Singh, R., & Verma, S. K. (2000). Landslides and their mitigation in Gangtok, Sikkim. Journal of Nepal Geological Society, 22, 585–590. https://doi.org/10.3126/jngs.v22i0.32434
5. Bhasin, R., Grimstad, E., Larsen, J. O., Dhawan, A. K., Singh, R., Verma, S. K., & Venkatachalam, K. (2002). Landslide hazards and mitigation measures at Gangtok, Sikkim Himalaya. Engineering Geology, 64(1–2), 351–365. https://doi.org/10.1016/S0013-7952(01)00096-5
6. Bhutia, J. N. (2024). Understanding the concept of sustainable tourism and its application in Sikkim [Doctoral dissertation]. University of Calcutta.
7. Bora, P., Rawat, S., & Mehta, A. (2026). Building sustainable tourism in disaster affected regions: A case study of the Uttarakhand Himalayas. International Journal of Research and Review, 13(5), 218–230.
8. Bramwell, B., & Lane, B. (2011). Critical research on the governance of tourism and sustainability. Journal of Sustainable Tourism, 19(4–5), 411–421. https://doi.org/10.1080/09669582.2011.580586
9. Creswell, J. W., & Creswell, J. D. (2018). Research design: Qualitative, quantitative, and mixed methods approaches (5th ed.). SAGE Publications.
10. Dahal, D. R., & Hasegawa, S. (2008). Representative rainfall thresholds for landslides in the Nepal Himalaya. Geomorphology, 100(3–4), 429–443. https://doi.org/10.1016/j.geomorph.2008.01.014
11. Dahal, D. R., Khawas, V., Mishra, P. K., & Pradhan, A. (2024). Assessing causes and impacts of landslides in the Sikkim Himalaya, India. Disaster & Development, 13(2), 29–44.
12. Font, X., & McCabe, S. (2017). Sustainability and marketing in tourism: Its contexts, paradoxes, approaches, challenges and potential. Journal of Sustainable Tourism, 25(7), 869–883. https://doi.org/10.1080/09669582.2017.1301721
13. Government of Himachal Pradesh. (2019). Conducting a baseline study on existing impact of tourism in Himachal Pradesh. Department of Forest and Wildlife.
14. Government of India. (2006). Sikkim tourism master plan. Ministry of Tourism.
15. Government of Sikkim. (2011). Sikkim ecotourism policy. Department of Forest, Environment and Wildlife Management.
16. Government of Sikkim. (2018). Sikkim tourism policy 2018. Department of Tourism and Civil Aviation.
17. Gupta, R. P., & Ahmed, I. (2018). Landslide hazard and risk assessment in the Eastern Himalayas using remote sensing and GIS. Natural Hazards, 94(2), 743–766. https://doi.org/10.1007/s11069-018-3440-1
18. Havenith, H. B., & Bourdeau, C. (2024). Earthquake-induced hazards in mountain regions: A review of case histories from Central Asia. Natural Hazards and Earth System Sciences, 24(1), 45–63. https://doi.org/10.5194/nhess-24-45-2024
19. Katoch, A., Rajput, P., Dhiman, S., & Kumar, S. (2021). Landslide disasters impacting the tourism destinations in Himalayas: A study of smart city Dharamshala, Kangra, Himachal Pradesh. International Research Journal of Management Science & Technology, 12(8), 60–68.
20. Kaur, H., Rawat, G. S., & Sharma, R. (2019). Landslide susceptibility mapping in Sikkim Himalaya using GIS and remote sensing. Journal of Mountain Science, 16(2), 245–259. https://doi.org/10.1007/s11629-018-5016-2
21. Kothari, C. R. (2004). Research methodology: Methods and techniques (2nd ed.). New Age International Publishers.
22. Kumar, R. (2019). Research methodology: A step-by-step guide for beginners (5th ed.). SAGE Publications.
23. Kumar, R. (2025). Sustainable tourism in the Himalayas: Challenges and opportunities. International Journal of Social Science Research, 1(2), 1–10.
24. Kumar, V. (2023). Sustainable mountain tourism and regional development in the Indian Himalayas. Journal of Tourism Studies, 18(3), 55–70.

25. Miller, G., & Twining-Ward, L. (2005). Monitoring for a sustainable tourism transition: The challenge of developing and using indicators. CABI Publishing.
26. Naqvi, M. H., Ahmed, A., & Pervez, A. (2023). Implementing sustainable tourism practices in luxury resorts of Maldives: Sustainability principles and triple bottom line approach. arXiv. https://arxiv.org/abs/2311.18453
27. National Disaster Management Authority. (2019). Landslide hazard zonation atlas of India. Government of India.
28. National Disaster Management Authority. (2020). National landslide risk mitigation strategy. Government of India.
29. Nepal, S. K., & Chipeniuk, R. (2005). Mountain tourism: Toward a conceptual framework. Tourism Geographies, 7(3), 313–333. https://doi.org/10.1080/14616680500164849
30. Nyaupane, G. P., Morais, D. B., & Dowler, L. (2006). The role of community involvement and number/type of visitors on tourism impacts: A controlled comparison of Annapurna, Nepal and Northwest Yunnan, China. Tourism Management, 27(6), 1373–1385. https://doi.org/10.1016/j.tourman.2005.12.013
31. Palit, S., Patra, U., & Halder, S. (2020). Tourism and its impact on local economy: A study on part of Gangtok Municipal Corporation area, East Sikkim, India. PalArch's Journal of Archaeology of Egypt/Egyptology, 17(9), 7211–7224.
32. Pradhan, N. (2022). Eco-tourism and sustainable development: A case study of Sikkim. Journal of Mountain Development, 12(1), 22–36.
33. Sarkar, S. (2025). An exploratory study with reference to the Sikkim state, India. International Journal of Economics and Business Management, 5(3), 67–73.
34. Sengupta, A., & Nath, S. K. (2022). Landslide susceptibility mapping in Gangtok, Sikkim Himalaya. In P. K. Shit, H. R. Pourghasemi, P. P. Adhikary, G. S. Bhunia, & V. P. Sati (Eds.), Geospatial technology for environmental hazards (pp. 539–559). Springer. https://doi.org/10.1007/978-3-030-75197-5_24
35. Sharma, P. (2022). Tourist satisfaction towards existing infrastructure in Sikkim [Master's thesis]. SRM University.
36. Sharma, P., Dubey, R. S., & Gupta, A. (2021). Sustainable tourism development in Himalayan regions: Opportunities and challenges. International Journal of Geoheritage and Parks, 9(4), 509–520. https://doi.org/10.1016/j.ijgeop.2021.11.003
37. Sharpley, R. (2020). Tourism, sustainable development and the theoretical divide: 20 years on. Journal of Sustainable Tourism, 28(11), 1932–1946. https://doi.org/10.1080/09669582.2020.1779732
38. Sikkim Tourism. (2025). Swadesh Darshan 2.0 inception report. Government of Sikkim.
39. Singh, P., Thapa, R., & Tamang, D. (2020). Tourism development and environmental sustainability in Sikkim Himalaya. Journal of Tourism and Sustainability, 5(1), 33–47.
40. Siroha, A. (2023). Sustainable tourism and environmental pollution in the Indian Himalaya: Himachal Pradesh policy analysis (2019). ILI Law Review, Special Issue, 108–126.
41. Suman, P. (2013). A study on Gangtok and its surroundings. European Journal of Geography, 4(2), 45–58.
42. Torres-Delgado, A., & Saarinen, J. (2014). Using indicators to assess sustainable tourism development: A review. Tourism Geographies, 16(1), 31–47. https://doi.org/10.1080/14616688.2013.867530
43. Trivedi, S. (2015). A study of landslide affected areas of North and West Sikkim (HI-AWARE Working Paper). Himalayan Adaptation, Water and Resilience Research.
44. United Nations. (2015). Transforming our world: The 2030 agenda for sustainable development. United Nations General Assembly.
45. United Nations Environment Programme. (2019). Sustainable mountain tourism and climate resilience. UNEP.
46. United Nations Environment Programme, & United Nations World Tourism Organization. (2005). Making tourism more sustainable: A guide for policy makers. UNEP & UNWTO.
47. United Nations World Tourism Organization. (2004). Indicators of sustainable development for tourism destinations: A guidebook. UNWTO.
48. United Nations World Tourism Organization. (2018). Tourism and the Sustainable Development Goals – Journey to 2030. UNWTO.
49. World Bank. (2021). Resilient tourism and infrastructure development in South Asia. World Bank Group.
50. WWF India. (2023). Sustainable tourism in the Himalayas. World Wide Fund for Nature India.
51. Yadav, R., Lombardo, L., & Huser, R. (2024). Statistics of extremes for natural hazards: Landslides and earthquakes. Journal of Geophysical Research: Solid Earth, 129(4), e2023JB028123.
52. Zhang, Y., Chen, X., & Li, W. (2025). Geological complexity and increasing landslide susceptibility in mountain environments. Environmental Earth Sciences, 84(3), 1–16.