Disaster Oriented Tourism Planning: Risk Management and Vulnerability Assessment by Using Geographic Information System

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Abstract:
Disaster-oriented tourism planning is a critical aspect of sustainable tourism development, aiming to minimize the negative impacts of disasters on tourism destinations while ensuring the safety of tourists and local communities. This article presents a comprehensive study on disaster-oriented tourism planning, focusing on risk management and vulnerability assessment using the most modern technology, Geographic Information Systems (GIS). The research explores the intricate relationship between tourism and disasters, highlighting the vulnerability of tourism destinations to various hazards such as natural disasters. It enhances the need for a proper scientific planning and preparedness to mitigate the future risks and ensure the solution of the tourism sector. The study explores a GIS-based approach to assess the vulnerability of tourism destinations to different hazards. GIS is utilized to collect, analyze, and visualize spatial data related to hazard occurrence, infrastructure, demographics, and tourism assets. By integrating these data layers, the research identifies areas of high vulnerability and assesses the potential impacts of disasters on tourism infrastructure, economic activities, and community well-being. Furthermore, the research examines various risk management strategies and their application in disaster-oriented tourism planning. East Sikkim is taken as a study area as the hilly Terrin of India are most disaster-prone, and MC -SDSS was used in GIS software for a better understanding. The findings of this research provide valuable insights for all tourism stakeholders in developing effective disaster management plans. By integrating risk management and vulnerability assessment into tourism planning processes, destinations can enhance their resilience to disasters, minimize economic losses, and ensure the safety of tourists and local communities.

Keywords: Disaster-oriented tourism planning, risk management, Geographic Information Systems (GIS), hazard mapping.

Introduction

Tourism encompasses a range of social, environmental and financial activities undertaken by individuals traveling within own country or internationally. Motivations for travel vary, including leisure, recreation, education, and visiting friends and relatives. This diverse range of activities, coupled with the services provided and the engagement of numerous segments, creates enchanting experiences for the tourists. While tourism is a significant part of modern life, it is rarely the primary concern. When planning trips, tourists weigh several key factors. These include the destination's attractions (Mutinda & Mayaka, 2012), budget considerations (Gunn, 1981) ,location and accessibility (Yan, 2021) , availability of suitable accommodation (Liyanapathirana, et al., 2023), seasonality (Dalir, 2024), and, crucially, safety (Aalami & Kattan, 2021) . A perceived lack of safety, regardless of the reason, can deter tourists from visiting a destination. Even a location with significant tourism potential and infrastructure will struggle to attract visitors if it is considered unsafe (Musavengane, Siakwah, & Leonard, 2020) . Indeed, research suggests that safety is a primary consideration for travellers when planning their trips (Singleton & Wang, 2014). Security is another vital factor that can influence a tourist's decision to visit a particular destination (Boakye, 2012). Therefore, safety and security act as either deterrents or motivators. A safe and secure destination, even with limited attractions or moderate infrastructure, may still attract visitors. Conversely, a destination perceived as unsafe and insecure will likely be avoided, regardless of its other offerings.

High-quality tourism services are intrinsically linked to safety and security (Kachniewska, 2006). A destination's ability to project an image of safety and security is paramount to its success, perhaps more so than in any other economic sector. Safety encompasses the consequences of natural disasters or hazardous phenomena such as storms, tsunamis, wildfires, floods, landslides, and earthquakes. Security, on the other hand, refers to threats stemming from human actions, including political instability, economic hardship, and acts of terrorism. A destination's overall security profile considers local security issues, health hazards, the safety of the natural environment, crime rates, and other relevant factors. These perceived risks can deter travel to a specific location, hindering tourism growth. Research has explored recreational travellers' perceptions of destinations that have recently experienced safety concerns, including how these concerns influence travel and leisure choices regarding destination and activity selection. Tourists are generally risk-averse, and perceived risk significantly influences travel behaviour. Kozak et al. (Kozak, Crotts, & Law , 2007) investigated the impact of perceived risk on international tourists, focusing on how risk perception affects the willingness to travel abroad and whether perceptions of high-risk destinations vary as per Hofstede's uncertainty avoidance index (Zou, 2023). Their findings indicated that most tourists were inclined to alter their plans for travel to high-risk areas, demonstrating a heightened sensitivity to any perceived danger at their intended destination. Tourist flow to a destination is thus directly related to the perceived risk. Transparency regarding potential risks and implemented mitigation strategies can positively influence tourist arrivals, as tourists feel more confident when they believe that potential threats are being addressed.

Generally, the risk associated with a tourist destination can be defined as the probability of various natural calamities or disasters under specific conditions (Faulkner , 2013). Risk is often understood as the statistical combination of hazard and exposure (Chen, et al., 2015).

Risk assessment aims to pinpoint the most dangerous elements and the likelihood of severe harm. Risk evaluation should be conducted against pre-established exposure limits, determined through testing under appropriate conditions. Risk management is a decision-making process focused on identifying the optimal strategies to reduce risk. it involves understanding and addressing disasters, taking proactive steps to minimize losses of life, property, and environmental damage. Sound operational, maintenance, and design practices are essential but do not replace the need for dedicated disaster management planning; they are integral components of a comprehensive safety management process. A fundamental principle of risk management is the shared responsibility of all sectors to proactively mitigate potential hazards. This involves strict adherence to established safety protocols and full compliance with all applicable regulations. Within any given project or facility, on-site disaster management planning is an integral function of project management. This localized planning must be coordinated with broader, off-site disaster management strategies developed and implemented by governmental level. When a disaster strikes, regardless of its origin (natural or anthropogenic), a rapid and accurate assessment of the situation is paramount. The immediate priority is to determine the scale and nature of the event. If the situation meets the criteria for a disaster, a formal emergency declaration must be issued without delay. The on-site rescue team leader plays a critical role in this initial phase, responsible for conducting the initial assessment of the hazard or disaster and promptly communicating this information to management. The scope of the emergency declaration, whether encompassing the entire facility or a specific area, will depend on the nature and extent of the catastrophe.

Sikkim, a mountainous state in Northeast India and very rich in tourism products, faces a range of risks and disasters, primarily natural in origin. Landslides are a common occurrence, particularly during the monsoon season, resulting in significant loss of life and property each year. Beyond landslides, the state's challenging terrain makes it susceptible to various other hazards, including earthquakes, cloudbursts, floods, forest fires, and avalanches. This vulnerability to natural disasters necessitates careful planning for both prevention and risk mitigation. The rugged topography of the Himalayas and the northeastern region contributes significantly to the prevalence of landslides. Furthermore, this difficult terrain complicates rescue and relief efforts, increasing the potential for damage to life and property.

Sikkim possesses significant tourism potential, offering captivating destinations for visitors. However, the state's tourism sector is characterized by seasonality and vulnerability to various disasters, posing risks to tourists. This susceptibility results in fluctuating tourist inflows, impacting revenue generation and investment, which in turn hinders infrastructure development. Furthermore, it contributes to overtourism, as visitor concentration is limited to a select few destinations. Consequently, the potential for pro-poor tourism and regional development through tourism is hampered by inadequate risk management and a lack of disaster-oriented planning. This article explores the feasibility of implementing scientific tourism planning, leveraging contemporary technologies such as Geographic Information Systems (GIS) (Malakar & Roy, 2024) . The aim is to enhance resilience through improved disaster planning and mapping, incorporating appropriate forecasting capabilities to better inform and protect tourists.

Study Area

Sikkim, a Northeastern Indian state bordering Tibet, Nepal, and Bhutan, holds significant strategic importance for India (Khan, 2024). Beyond its strategic value, Sikkim is a biodiversity hotspot. However, anthropogenic climate change poses a significant threat to this ecologically rich and inherently vulnerable region. Recognizing this vulnerability, the Indian government has prioritized disaster management strategies to facilitate environment and disaster related issues in most of the Himalayan states . This plan aimed to promote climate change adaptation through the application of effective and ecologically sustainable technologies. To operationalize this national plan, state-level action plans were developed to address the specific needs of individual states. Geographically, Sikkim is situated within the Lesser, Central, and Tethys Himalayas.

Its temperate climate fosters rich biodiversity, supporting a wide array of flora and fauna. As per 2011 census, Sikkim's population is 75 million, with approximately 75% residing in rural areas (Sharma, 2016). Despite its rich biodiversity, the state's environmental vulnerability is evident, particularly in the face of ongoing climate change. Analysis of long-term meteorological data reveals a rising average temperature trend of 0.2-0.3°C per decade, coupled with fluctuating monsoon patterns. The increasingly erratic rainfall patterns in Sikkim, with short, intense bursts and extended dry periods, are creating a dangerous combination for the state. The heightened risk of landslides and flash floods, along with the potential for water shortages, demands immediate action. A state-level climate change adaptation plan is urgently needed to address these pressing challenges. Such a plan provides a framework for translating intent into concrete action. To fully appreciate the rationale behind developing this strategic plan, it is crucial to assess the state's key areas of concern within the context of a changing climate.

Natural disasters impede developmental progress. The understanding that disasters can significantly hinder development outcomes in affected areas, often pushing communities into poverty and deprivation, is now widely accepted. Moreover, disaster-stricken regions become more susceptible to future hazards, creating a cycle of vulnerability. Therefore, mitigating the negative impacts of disasters is crucial for ensuring the resilience of development gains. One of the most effective strategies for achieving this resilience is conducting a comprehensive Hazard, Vulnerability, and Capacity Assessment (HVCA). This assessment is often considered the foundation of any disaster mitigation and management effort, as it operates on the principle that effective mitigation requires identifying all potential risks to which a region is exposed. Given that disaster risk is a function of hazard, vulnerability, and the coping capacity of a system, the HVCA can be viewed as a scientific tool for reducing vulnerability.

Methodology and Dataset

A mix methodology is used for obtaining accurate result. Firstly, Multi – Hazard Risk and Vulnerability Assessment was done by analysisng spatial data. Later , individual elements were analysied to achieve the objective. Landslide-inducing factors using a MC-SDSS (Othman, Naim, & Noraini, 2012) . This analysis, performed within a GIS environment, aimed to delineate landslide-prone zones. Data layers for these parameters were sourced from publicly available platforms such as the "USGS, NASA NATMO". Other data such as location of places of interests were coined through Google Earth. This process culminated in the creation of a GIS-based digital map illustrating Sikkim's landslide Zone map.

3.1. Model Creation

Criteria Selection: The criteria factors such as Landslide (L_d), Earthquake (E_K), Flood (F), Elevation (El), Slope (S) and Forest fire (F_f) were selected . Places of Interests were incorporated for the purpose of validation. The criteria are major hazards as well as factor related to hazards of Sikkim. Therefore, in this study of hazards zonation modelling (HZ_M) is given as:

$$D_{ZM} = f\int_{i=1-10}^{w_i} (L_d, E_k, F, El, S, F_f) \qquad (1)$$

3.2. Assigning of Weights to the Factors:

A crucial step in Multi-Criteria Spatial Decision Support Systems (MC-SDSS) is the assignment of relative importance weights to the various criteria. Several established techniques exist within a GIS context for this purpose, including Pair-wise Comparison, Ranking, and Trade-off Analysis (Malczewski, GIS and multicriteria decision analysis, 1999). This study employed the Pair-wise Comparison method, leveraging the researcher's pre-existing understanding of the relative importance of each criterion within the specific study area.

In pair-wise comparison method, a criteria versus criteria matrix (shown in Table 3.1) was created to compare each pair of criteria and assign relative ratings using the scale of pair-wise comparison (SAATY, 2002). Table 3.2 shows the pair-wise comparison of the different criteria used in this research. Next, this matrix was normalised by the sum of the column to create another matrix. From the normalized matrix, the row sums were calculated and subsequently divided by the total number of criteria to derive the Relative Criterion Weights (Table 3.3). These weights sum to 1, representing the complete distribution of importance across all criteria.

Several decision rules are available for implementing MC-SDSS models, including Simple Additive Weighting (SAW), Value/Utility Function, Analytical Hierarchy Process (AHP), Ideal Point, and Concordance methods (Malczewski, Spatial multicriteria decision analysis, 2019) . This research utilizes the SAW method due to its demonstrated effectiveness in addressing the majority of single-objective decision problems (Malczewski, GIS and multicriteria decision analysis) . SAW, also known as the weighted least squares method, operates on the principle of weighted averages. The decision-maker directly assigns weights reflecting the relative importance of each attribute. A composite score for each alternative is then calculated by multiplying each attribute's assigned weight by the corresponding scaled value of the alternative for that attribute, and then summing these products.

$$S = \sum_{j} w_j \times x_{ij} \quad (2)$$

Where,

S	total score
w_j	normalized weight of the j^{th} criterion
x_{ij}	score of the i^{th} alternative with respect to the j^{th} criterion

For the simple additive method to work, $\sum w_j = 1$.

In this research, individual categories of each criterion are classified into four classes and given a score ranging from 1 to 4.

$$S_t = \int W_1 S_{ct1} + W_2 S_{ct2} + \ldots + W_n S_{ctn} \quad (3)$$

Where,

S_t	Total Score
W^n	weight of the n^{th} criterion
n^{th} criterion and S_{ctn}	score of the n^{th} criterion

The weights and scores of each criterion are displayed in Table 3.4

MC-SDSS model, as detailed above, was implemented using ArcGIS 10.2 software. The resulting outputs and their interpretation are presented in the subsequent results section. After inspecting all tables, it can be concluded that Landslide is the most dangerous hazards for tourism. Existing and potential tourist spots were positioned against the final digital map for a better understanding.

In the next stage, tourist spots were inserted into the software to find out their vulnerability. Road network data was also incorporated to assess their vulnerability too. The outcome showed that most places of interest in Sikkim are absolutely landslide-prone. The researcher also carried out similar research on East Sikkim district taking as a study area for better demonstration purposes. All layers were explained against the places of interest as a composite map could face a data overlap issue which does not happen when the same is placed in a digital platform.

Table 3.1: Critera verses Critera Matrix

Criteria (C)	**F_f**	**E_k**	**F**	**El**	**S**	**L_d**
L_d	1	2	3	4	5	6
E_K	1.5	1	2	3	4	5
F	0.33	1.5	1	2	3	4
El	0.25	0.33	1.5	1	2	3
S	0.20	0.25	0.33	1.5	1	2
F_f	0.16	0.20	0.25	0.33	1.5	1.5
Column Sum($_c$)	3.44	1.28	8.08	11.83	16.5	21.5

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Table3.2: Pair-wise comparison of Criterion

Intensity of Importance	Definition
01	Relevant
02	Medium relevant
03	Medium to Better relevant
04	Strongly relevant
05	Strongly to very relevant
06	Strongly to very very strongly relevant

Table 3.3: Relative Criterion Weights

C	Ld	E_k	F	El	S	F_f	Row Sum ($_r$)	Relative Criterion Weight (RCW = $_R$/6)
L_d	.407	.468	.427	.368	.33	.287	2.287	.57950 (.581)
E_K	.205	.232	.284	.278	.257	.237	1.493	.148666669 (.148)
F	.137	.115	.143	.183	.191	.17	.933	.1403 (.143)
El	.101	.079	.069	.094	.130	.145	.524	.10250 (.103)
S	.081	.059	.049	.045	.065	.097	.392	.06633333 (.066)
F_f	.069	.047	.033	.032	.031	.046	.290	.04450 (.045)
Total (å$_c$)	1.00	1.00	1.00	1.00	1.00	1.00	1	1.086 = 1

Table 3.4: Weitage Scale

Criterion	RCW	Measuring Scale	Score/Points
L_d	0.381	Low 1 2 3 High 4	0.381 0.759 1.140 1.520
E_K	0.249	Low 1 2 3 High 4	0.148 0.498 0.747 0.996
F	0.161	Low 1 2 3 High 4	0.143 0.322 0.483 0.644
El	0.103	Low 1 2 3 High 4	0.103 0.206 0.309 0.412
S	0.065	Low 1 2 3 High 4	0.066 0.130 0.195 0.260

		Low	1	0.045
	0.044		2	0.087
F_f			3	0.132
				0.176
		High	4	

Result and Discussion

4.1 Sikkim's Multi-Hazard Risk and Vulnerability Assessment

Sikkim, a state in northeastern India, is particularly susceptible to a range of hazards. With over 75% of its population residing in rural areas (2011 census), Sikkim presents significant opportunities for development projects. However, the state's environmental fragility and vulnerability to multiple hazards necessitate careful consideration of risk. To inform decision-making at all levels regarding vulnerability reduction, a Multi-Hazard Risk Exposure Assessment was conducted for Sikkim. This assessment serves as a crucial document aimed at enhancing community preparedness.

The state is vulnerable to the following hazards:

- Landslides
- Earthquakes
- Fire hazards
- Floods/flash floods
- Storm hazards

To achieve its objectives, the assessment developed composite risk maps at the district, sub-district, and panchayat levels. These maps identified hazards and linked them to their geological and hydrological origins. Subsequently, the maps were scaled using appropriate tools. This information informed the development of a risk assessment system incorporating a risk grading scheme to support emergency response and management decision-making. This scheme categorized hazards into five levels:

Low Risk: The hazard is unlikely to occur in the specific area compared to other identified risks.

Low to Moderate Risk: The likelihood of occurrence is lower but still higher than a "low risk" hazard.

Medium Risk: The hazard falls within the mid-range of severity and frequency. Adequate preparedness measures are warranted.

Medium to High Risk: These hazards require prompt attention to develop appropriate mitigation strategies.

High Risk: These hazards pose the most significant threat and demand immediate action to mitigate potential impacts.

The vulnerability assessment aimed to empower decision-makers at all levels to make informed resource allocation decisions for preparedness and emergency management, ultimately contributing to a more resilient Sikkim.

Analysis of historical data revealed that landslides pose the highest threat to the state, occurring annually, particularly during the monsoon season (Fig. 01). Forest fires also represent a significant annual threat. Earthquakes have historically impacted the region at regular intervals. Flooding, while a concern, has had a comparatively limited impact due to the terrain, with much of Sikkim, excluding East Sikkim district, situated at high altitudes.

These hazards – earthquakes, forest fires, floods, and landslides – negatively impact Sikkim's tourism resources, often leading to extended disruptions. Earthquake tremors and frequent landslides affect the "number of tourism days," causing disruptions such as traffic congestion, water supply crises, and access challenges to tourist sites. The seasonal nature of Sikkim's tourism is further exacerbated by the occurrence of these multiple disasters, negatively impacting both tourists and tourism stakeholders and investors.

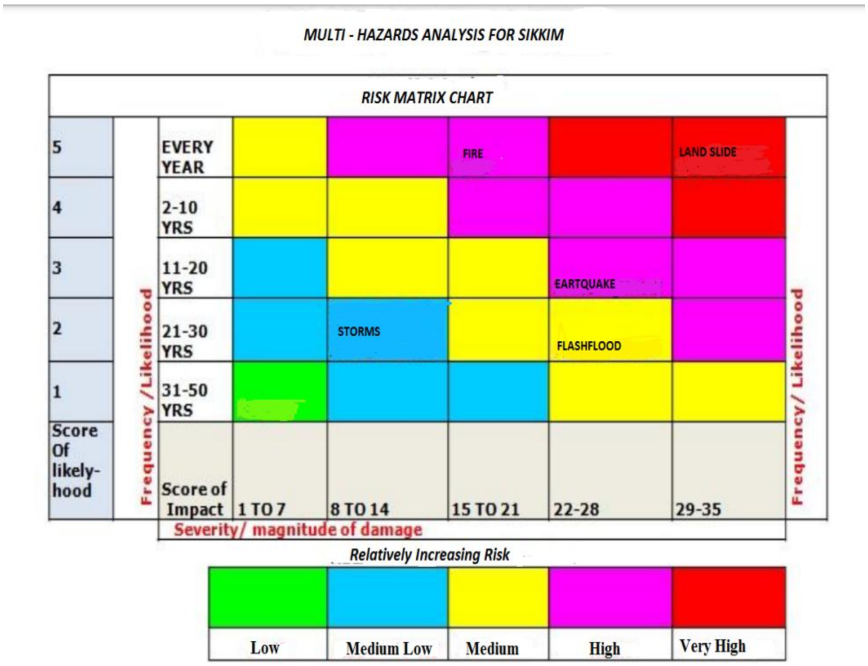

Fig: 01: Multi-hazards Analysis for Sikkim

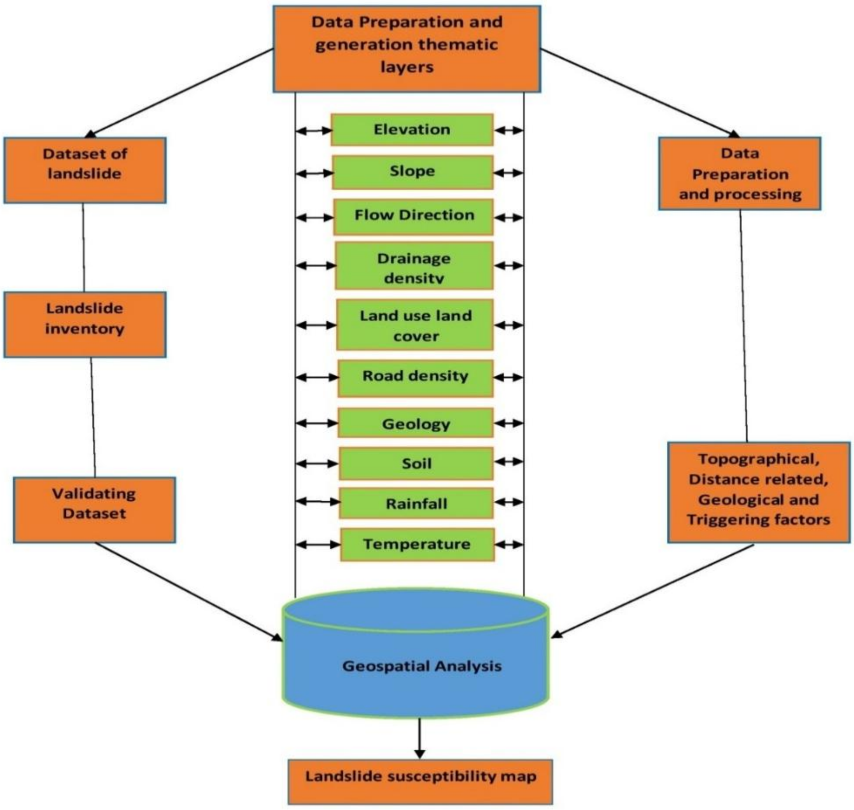

Fig 02: Landslide Susceptibility Model Flow Chart

A primary impediment to tourism in Sikkim is the frequent occurrence of landslides. Accessibility is a crucial factor in tourism development. Destinations with compromised road access face significant challenges. While air travel may bring tourists to a main hub, further travel to various points of interest becomes impossible when landslides obstruct roadways. Furthermore, essential supplies, including commodities, water, and electricity, are often disrupted by these sudden landslides, bringing daily life to a standstill and negatively impacting the tourist experience. Tourists' expectations are often unmet due to the unavailability of essential services and restricted access to attractions. Given that most visitors plan trips of a fixed duration, they may be forced to depart without fully experiencing the destination.

Landslide-induced Road closures isolate destinations, hindering new tourist arrivals and diminishing the already limited "number of tourism days" due to the region's challenging weather conditions.

Gangtok, the capital city, is accessible by road from Siliguri (the nearest plains area) via National Highway 31, a journey of approximately 175 kilometers and four hours. Darjeeling, a popular tourist destination in West Bengal, is about 126 kilometers away by road. The distance between Kalimpong and Gangtok is roughly 107 kilometers, and the nearest airport is about 153 kilometers away. Pelling, another prominent hill station, is 160 kilometers from the nearest airport (Bagdogra) and 131 kilometers from Gangtok. Sikkim's total road network spans 2308.52 kilometers (Road Network, Govt. of Sikkim).

Spatial analysis of all contributing factors using geospatial tools enabled the creation of a "landslide susceptibility map for Sikkim" (Figure 03), delineating "different landslide zones ranging from low to high susceptibility." The resulting map clearly indicates that a significant portion of the state falls within the high landslide susceptibility zone, highlighting the inherent vulnerability of these areas. In the final stage of the analysis, tourist locations were plotted on the landslide susceptibility map (Figure 4) to complete the analytical framework. This visualization reveals that the majority of Sikkim's tourist destinations are located in areas of high landslide vulnerability, emphasizing the need for careful management and mitigation strategies.

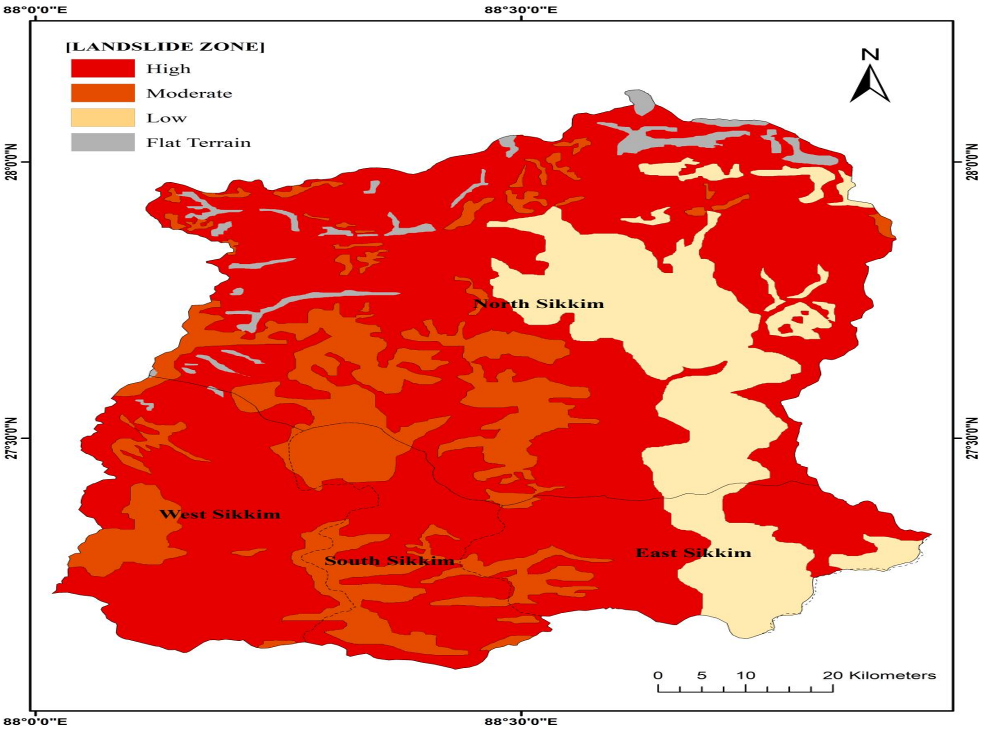

Fig 03: Landslide Susceptibility Map of Sikkim

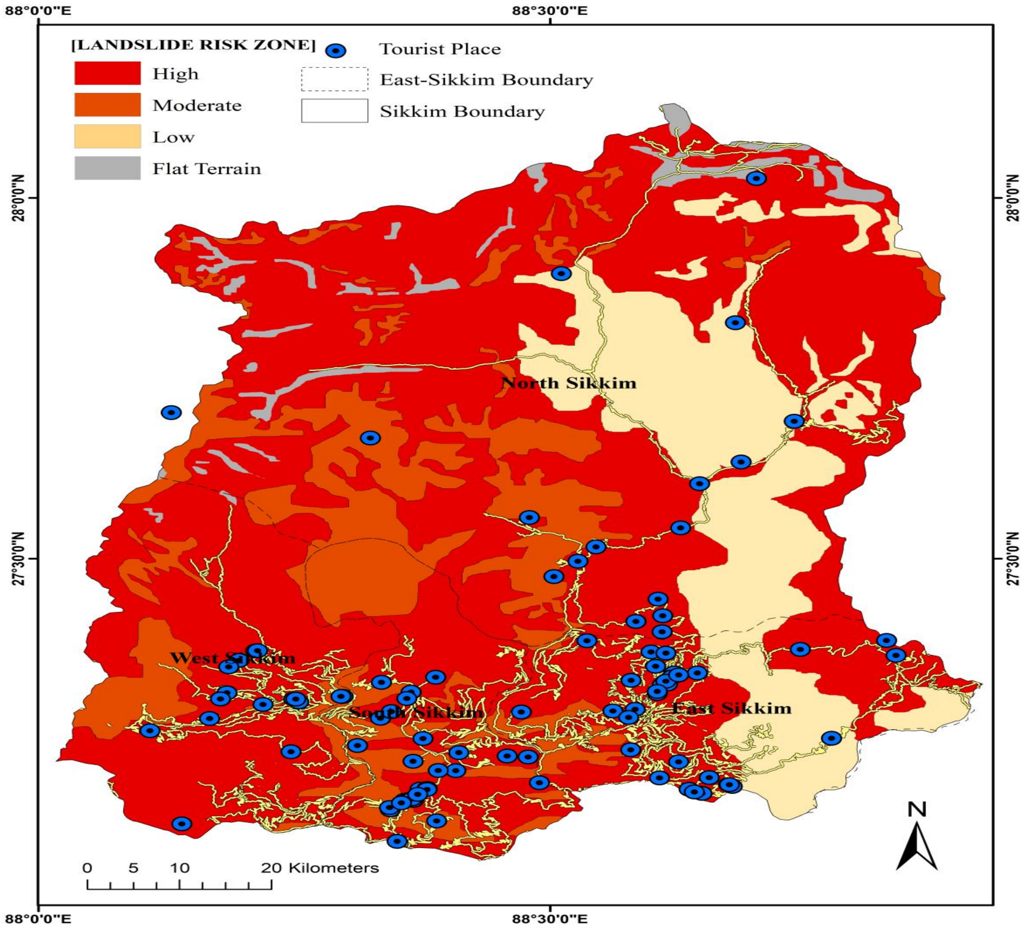

Fig 4: Places of Interests and Approachable roads on LSM

As demonstrated, Geographic Information Systems (GIS), with their advanced tools, are effective in achieving desired results. While Sikkim, India's second smallest state, boasts alluring natural attractions that draw tourists, its susceptibility to natural disasters creates a significant vulnerability. The majority of tourist activity is focused within the three districts covering Eastern, Western and Southern part, leaving the only one part which is Northern District largely inaccessible because of its harsh climate. The state experiences a range of natural disasters, including floods, forest fires, earthquakes, and landslides. Multi-hazard analysis reveals that landslides are the most significant and persistent challenge, posing a major obstacle for tourists, tourism service providers, and the tourism industry as a whole. A Landslide Susceptibility Map (LSM) for Sikkim was generated, and prominent and emerging tourist locations were plotted against the LSM to determine their specific vulnerability levels. Road networks leading to these locations were also included in the map to assess risk factors. This comprehensive model, residing on a digital platform, allows for case-by-case monitoring and future modifications. Planning authorities and government agencies can utilize this tool to develop effective disaster management plans and implement emergency evacuations during disaster events. Furthermore, it enables the dissemination of timely information to tourists. This conceptual model has the potential for broader application in any state or country to enhance tourism safety and resilience.

Conclusion

This study has demonstrated the critical role of GIS in disaster-oriented tourism planning, specifically within the context of Sikkim's unique challenges. By integrating multi-hazard analysis, vulnerability assessments, and spatial data, a comprehensive framework has been developed to enhance the resilience of the tourism sector. The creation of a Landslide Susceptibility Map, coupled with the identification of vulnerable tourist locations and road networks, provides a valuable tool for stakeholders. This data provides a foundation for planning authorities and government bodies to formulate specific disaster management strategies, execute efficient emergency response protocols, and proactively communicate potential hazards to tourists. Furthermore, the digital platform on which this model resides allows for continuous monitoring, updates, and adaptation to evolving conditions. Critically, this research highlights the importance of moving beyond reactive disaster management to proactive risk mitigation and preparedness. By understanding the spatial distribution of risk and vulnerability, Sikkim can strengthen its tourism sector, ensuring both the safety of visitors and the long-term sustainability of this vital economic activity. The adaptable nature of this model also suggests its applicability to other regions facing similar challenges, offering a pathway towards building more resilient tourism destinations globally. Ultimately, this research contributes to a broader understanding of how technology and spatial analysis can be leveraged to minimize the impact of disasters on tourism and promote sustainable development.

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