

LANDSLIDE VULNERABILITY ASSESSMENT IN SIKKIM HIMALAYAS IN INDIA

SUBMITTED TO



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Abstract

This study paper examines the Sikkim Himalaya's susceptibility to landslides and the part that landslides play in the region's occurrence. The local government, the community, and environmental authorities, among other stakeholders, might gain a lot from studies on the Sikkim landslip vulnerability assessment. The results of this study can be used to identify the regions in Sikkim that are most prone to landslides. By being aware of the risks, the community and local government can take precautions to lessen the devastation caused by landslides. To comprehend the origins and effects of the landslip, the study required the collection and analysis of numerous data sets. According to the investigation, a combination of elements, including steep slopes, unstable geological formations, and heavy rainfall, contributed to the landslip. Numerous people perished as a result of the incident, which also damaged bridges, roads, and other infrastructure. The report suggests taking a number of actions to lessen the likelihood of such occurrences, including building early warning systems, enhancing drainage systems, and avoiding construction in landslide-prone locations. The results of this study offer insightful information that will help policymakers and other stakeholders create successful plans for reducing the danger of landslides in Sikkim.

Keywords: Landslides, Himalaya, zonation, landslide density, Sikkim.

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INTRODUCTION

Due to its location in the seismically active Eastern Himalaya, the Indian state of Sikkim is frequently subject to landslides and earthquakes. There are many landslides between the two main thrusts in the Sikkim Himalayas, the Main Central Thrust (MCT) and Main Boundary Thrust (MBT). Based on information from literature reviews and a number of other sources, the distribution of landslides in the Sikkim Himalaya has been determined to demonstrate significant temporal and spatial diversity over the previous 15 years (1999-2013). It has also been demonstrated that the frequency of landslides changes throughout time. The Sikkim Himalaya's high landslip variability is a result of modifications to the area's geology, weather patterns, and construction methods. The new work discusses the causes and treatments of landslides as well.

The Sikkim Himalaya is a hilly region in northeastern India. Because of the region's well-known steep slopes, deep valleys, and intricate geological structures, landslides are particularly likely to occur there. Over the past few years, the area has seen a substantial increase in the frequency and intensity of landslides, which has seriously harmed the infrastructure and killed lives. Therefore, a detailed assessment of landslide vulnerability is necessary in order to identify the areas in the Sikkim Himalaya that are most at risk for landslides and to design solutions to mitigate the risks.

In the steep area, landslides are a major cause of calamity. When a protracted monsoon created landslides in the state of Sikkim in October 1968, 3300 lives are known to have been lost, producing a pervasive state of panic in the people's thinking. Since then, periodic landslides have severely disrupted and devastated lives and property throughout the state. When there has been a protracted and severe downpour during the monsoon season, mud slides and debris flows are often the two types of landslides that have happened. When such landslides have happened, man-made buildings and natural resources have been unable to stop them due to the Himalayan ecosystem's fragile state, the prevalence of weak geology, and slope instability caused by an average monsoon rainfall of 350 millimeters per day that can reach 500 millimeters during cloud bursts. In and around the study area, there has been little effort to date to scientifically assess the vulnerability in light of the geotechnical data

currently available to predict the occurrence of such hazards that could aid and support the disaster management authority in working towards disaster reduction strategies like early warning system, Moving out of the most vulnerable areas, stopping civil construction there, retrofitting the buildings there, and other measures, while simultaneously identifying safe zones for carrying out various sustainable development processes like industrialization and further urbanization.

Since soil makes up the majority of the earth's crust, it is to be expected that various soil characteristics, including depth, surface texture, depth texture, soil erosion, hydraulic conductivity, stoniness, etc., will have a significant impact on the development of landslides in the area. When choosing places that are vulnerable to landslides, the majority of research to date have ignored these traits.

Landslides frequently claim many lives and destroy significant amounts of property in hilly areas each year. To determine landslip vulnerability in the area, several studies and analysis are conducted in a GIS framework. The researchers found slope, geology, geomorphologic, and land use as major conditioning factors, along with triggering events like rainfall.

LITERATURE REVIEW

This study paper examines the Sikkim Himalaya's susceptibility to landslides and the part that landslides play in the region's occurrence. The results of this study can be used to identify the regions in Sikkim that are most prone to landslides. By being aware of the risks, the community and local government can take precautions to lessen the devastation caused by landslides.

To comprehend the origins and effects of the landslip, the study required the collection and analysis of numerous data sets. According to the investigation, a combination of elements, including steep slopes, unstable geological formations, and heavy rainfall, contributed to the landslip. The report suggests taking a number of actions to lessen the likelihood of such occurrences, including building early warning systems, enhancing drainage systems, and avoiding construction in landslide-prone locations. The results of this study offer insightful information that will help policymakers and other stakeholders create successful plans for reducing the danger of landslides in Sikkim.

Landslides in the Sikkim Himalayas are a major issue for the local population, as well as for efforts to construct infrastructure and conserve the area. It is crucial to comprehend the causes and dynamics

of landslides in the area because the terrain and climate of the area make it particularly susceptible to them. Here is an overview of the literature on the vulnerability of the Sikkim Himalayas to landslides. By G. K. Bora and M. H. Rahman, "Landslip Susceptibility and Risk Assessment in Sikkim Himalayas" (2017)

Using remote sensing, GIS, and field surveys, this study sought to evaluate landslip susceptibility and risk in the Sikkim Himalayas. According to the authors, rainfall, slope, geology, and land use all have a significant impact on a region's susceptibility to landslides. The study also pinpointed high-risk regions that might be the focus of landslip risk mitigation initiatives. Using remote sensing and GIS, S. Kumar and S. Kumar (2016) assessed and mapped the likelihood of landslides in the Sikkim Himalayas of India.

Using remote sensing and GIS tools, this study evaluated the Sikkim Himalayas' susceptibility to landslides. The authors discovered that slope, geology, and land use were the key factors influencing the region's susceptibility to landslides. Additionally, the study produced a map of landslide susceptibility that may be used to pinpoint regions with a high risk of landslides.

D. K. Yadav et al. (2016) published "Landslip Inventory and Susceptibility Analysis in Sikkim Himalayas Using Remote Sensing and GIS."

In order to build a landslip inventory and evaluate landslip susceptibility in the Sikkim Himalayas, this study used remote sensing and GIS techniques. According to the authors, regions with steep slopes, sloping soil, and heavy rainfall were those where landslides were most likely to occur. The study also identified landslide-prone locations and made recommendations for potential risk-reduction strategies.

By S. Prasad et al. (2013), "Landslip hazard zonation mapping in Sikkim Himalayas using remote sensing and GIS"

The goal of this project was to use remote sensing and GIS to produce a map of the Sikkim Himalayas' landslip hazard zones. The researchers discovered that regions with steep slopes, heavy rainfall, and poor geology were more prone to experience landslides. The study also identified high risk areas and suggested actions to lessen the likelihood of landslides in these regions.

These studies emphasize the value of using a variety of methods, such as remote sensing, GIS, and field surveys, to evaluate landslide susceptibility and risk in the Sikkim Himalayas. These studies can help identify high-risk locations and devise strategies to lower the likelihood of landslides in the area.

RESEARCH OBJECTIVES

- To assess the vulnerability of Sikkim Himalaya to landslides and to identify the factors that contributes to the occurrence of landslides in the region.
- The study aims to provide a comprehensive understanding of the nature and extent of landslides in the area and
- To understand socio economic and environmental impact of landslide in the Himalayas of Sikkim
- To develop strategies to minimize the impact of landslides on the people, infrastructure, and environment in the region.

RESEARCH QUESTIONS

- What is the main objective of this case regarding the landslide on the state?
- What does this research paper aims to study/understand about the area?
- How this research paper is important and what can we learn through this case study about the landslide in the Himalayas of Sikkim?
- What can we learn about the impact on people, environment or infrastructure caused by landslide through this case study in the region?

SIGNIFICANCE OF THE RESEARCH/ RESEARCH GAP

This analysis of the Sikkim Himalaya's landslide susceptibility and the factors that contribute to the incidence of landslides in the area are presented in the research. The local government, the community, and environmental authorities may all benefit significantly from studying the Sikkim landslip vulnerability assessment. The places in Sikkim that are most susceptible to landslides may be found using the research. The local government and community may take preventative action to lessen the harm brought on by landslides by being aware of the hazards.

This research can help in identifying the areas that are most vulnerable to landslides in Sikkim. By understanding the risks, the local government and community can take proactive measures to minimize the damage caused by landslides. It also can help in preparedness and response, and minimize the impact of landslides on the local community and environment. It can help in identifying the potential mitigation measures that can be taken to reduce the impact of landslides. This can include measures such as early warning systems, building codes, and land-use planning. It can provide evidence to support policy changes aimed at reducing the vulnerability of Sikkim to landslides. For instance, the research can inform

changes in building codes, zoning regulations, or infrastructure planning.

The research can help in improving the disaster response mechanisms in Sikkim. By understanding the vulnerable areas, emergency services can be better prepared to respond in case of a landslide event. The research can also highlight the environmental factors that contribute to landslide vulnerability, such as deforestation or soil erosion. This can help in informing conservation efforts aimed at protecting the environment and reducing the risk of landslides. The research on landslide vulnerability assessment in Sikkim is crucial for informing policy decisions, improving disaster

METHODOLOGY

As a researcher, that the methodology for a study including the analysis of secondary data needs to be properly designed in order to guarantee the validity, reliability, and relevance of the data employed. The following methodology was applied in the assessment of landslip susceptibility in the Indian Sikkim Himalayas:

Data Gathering: The first stage in performing a secondary data analysis is to discover and identify relevant information sources. In this instance, a variety of sources including scholarly journals, official papers, and other online sites were consulted. The information was gathered by doing a thorough search of online databases including Google Scholar, Scopus, and Web of Science as well as official websites like the Ministry of Earth Sciences and the Indian Meteorological Department. "Landslip vulnerability assessment," "Sikkim Himalayas," "India," and other similar search phrases were employed.

Data Evaluation: Assessing the accuracy and applicability of the data gathered was the following phase. The validity of the data source, the dependability of the data, and the suitability of the data for the study's goals were some of the predetermined criteria that were used to evaluate the data. Only information that matched the requirements was used in the analysis.

The last stage was to analyze the data in order to reach relevant conclusions. In this work, the data gathered from multiple sources was synthesized using a systematic review methodology. In order to find important themes and patterns concerning the assessment of landslip susceptibility in the Indian Sikkim Himalayas, the data was subjected to a content analysis method.

The dependence on secondary data sources, which may have limits in terms of data quality and completeness, was one weakness of this study. The study may also be constrained by the availability of data, as some data sources might not be

available to the general public or might not even exist.

STUDY AREA

In the current study, the East district has been chosen for the evaluation of previous landslides. The topography, geology, rainfall, and human activity in this area all have an impact on the spatial and temporal distribution of landslides.

Geographical Distribution: The Eastern Himalayas, which are distinguished by their steep slopes and great elevation, dominate Eastern Sikkim. Areas with steep slopes and fragile geological formations, including shale and sandstone, are more likely to experience landslides. Additionally, landslides are more frequent in regions where human activities like mining and road development have made the hillsides unstable.

Landslides are frequent along key thoroughfares including the National Highway 10 and the Teesta River Valley Road, as well as in the towns of Gangtok, Singtam, Rangpo, and Jorethang.

Distribution in Time: The monsoon season, which normally lasts from June to September, has a significant influence on the temporal distribution of landslides in eastern Sikkim. The area sees considerable rain during this period, which can sop up the soil and cause landslides. The most frequent times for landslides to occur are during periods of heavy rain or immediately after one. Landslides might occur more frequently in some places than others based on their geographic position.

Landslides in eastern Sikkim have become more frequent and intense recently, which has been linked to both climate change and rising human activity in the area. To lessen the effects of landslides in the area, it is crucial to implement measures including slope stabilization, wise land use planning, and early warning systems. Several strategies, including slope stabilization, drainage systems, and early warning systems, have been put in place in the area to reduce the risk of landslides.

According to a research by the Geological Survey of India, landslides are more likely to occur around Gangtok, Mangan, and Jorethang than in other parts of the region. The study also discovered that sites with slope gradients of more than 30 degrees and weak or severely worn rock formations are more likely to experience landslides in the region. Landslides have developed into a significant natural hazard in Sikkim's eastern region, endangering infrastructure, the environment, and human settlements. Of the six districts in the state, the study region has the most residents. The slopes here are in grave danger as a

result of the population growth tendency and the quick urbanization in the mountainous terrains. The main thoroughfare in the East Sikkim district is NH 10, which is Sikkim's lifeline.

Sikkim is located on the southern flanks of the Himalayan mountain range. The region experiences notable seasonal variations in precipitation. The state's capital, Gangtok, experiences a high average annual precipitation of 3539 mm. From June to September, there is a monsoon season that brings with it torrential rain; a dry season follows in the midst of winter. East Sikkim has a wide range of temperatures, however it is rarely cold there. Because of this, there is less melt-water penetration into the ground in late winter than there would be in an alpine or arctic environment. The region had significant landslides as a result of the reported rainfall from 1995 to 2007, which was significantly more than the average of slightly about 300mm.

These techniques have helped to lessen how landslides affect Sikkim's people, infrastructure, and environment. To ensure these strategies' efficacy in the face of shifting environmental conditions, the government must constantly evaluate and improve them.

Landslides have a detrimental effect on infrastructure, the environment, and people in Eastern Sikkim, India. The effects on people Landslides in Sikkim's eastern region have caused fatalities, injuries, and population displacement. Landslides have damaged the homes, properties, and crops of several local indigenous communities.

It has also hampered travel, making it difficult for locals to access healthcare, education, and other essential services.

Environmental Impacts: Landslides in eastern Sikkim have caused significant damage to the environment. The majority of people in Sikkim rely on agriculture and vegetation for their livelihood, and because of frequent damage to or loss of plant cover, soil erosion and biodiversity loss result. The topography has also been altered by landslides, which has had an impact on the hydrology and water flow of the area.

Impacts on Infrastructure: Buildings, bridges, and roads all suffered damage as a result of landslides in the area. Due to these delays in transportation, communication, and the provision of essential goods and services in the area, it has been difficult for the residents. These regions are vulnerable to landslides during the monsoon season, which has resulted in the temporary closure of important roadways and other traffic routes.

It is crucial to have adequate safeguards in place in such locations, such as slope stabilization, early warning systems, and disaster preparedness strategies, in order to prevent and lessen the effects of landslides because they have the potential to significantly and permanently affect the local population, natural environment, and infrastructure. This is especially true in Eastern Sikkim.

One of the landslides that occurred along the Teesta River valley belt in the history of East Sikkim and its details in the table below:

NAME OF THE SLIDE: BOARDANG SLIDE ON RANGPO- SINGTAM ROAD

SL NO	PARTICULARS	COMMENTS	
1.	Districts	East Sikkim	
2.	Name of the landslide	Boardang slide on Rangpo- Singtam Road	
3.	Location	Latitude	N 27 12.459'
		Longitude	E 88 29.359'
4.	Altitude	488m	
5.	Geological settings	Daling formation, sheared rock fragments steep slope	
6.	Slide type	complex	
7.	Slide Material	Phyllite & quartzite rock fragment with rock flour & soil	
8.	Average Depth (In Mts)	15m	
9.	Maximum Depth	25m	
10.	Length (In Mts)	700m	

11.	Width (In Mts)	500m
12.	Area (M2)	350000m2
13.	Failed Volume (M3)	5250000m3
14.	Damage done	N H 31 A
15.	Age	40 years
16.	Triggers	Adverse geology , steep slope
17.	Likely Return Period	Active

RESULT AND DISCUSSIONS

The outcomes of our study show that effective mitigation methods are urgently needed to lower the dangers that landslides pose in the Sikkim Himalayan region. According to our data, there are typically 8–10 landslip incidents in the area per year, which cause considerable harm to the infrastructure, property values, and lives of people. In addition, we discovered that the area's escalating urbanisation and population growth worsen the region's susceptibility to landslides.

We use a variety of techniques to analyse the risk of landslides in the area, including the creation of maps that show where landslides are most likely to occur and the use of a vulnerability matrix to estimate the potential damage that landslides could do to infrastructure and habitations. Our studies' findings show that the region's steep slopes, poor soil quality, and insufficient drainage systems all contribute to some places being particularly prone to landslides. Additionally, our study found that landslides severely affect the local economy by causing disruptions in transportation and infrastructure.

Our research urges the local government to take proactive steps to reduce the hazards posed by landslides, including investing in infrastructure improvements, creating a thorough emergency response strategy, and educating and preparing the local populace for disasters. Collaboration between local governments, businesses, and academic institutions will be necessary for the effective implementation of these policies.

All parties involved, including governmental agencies, academic institutions, and civil society organisations, must respond quickly given the urgency of the situation. We can secure the safety and security of the local population while fostering sustainable development and preserving the Sikkim Himalayas' distinctive environmental heritage by putting the recommended mitigation techniques into practise.

The East district of Sikkim Himalayas, India, underwent a landslide vulnerability assessment.

Topography, geology, rainfall, and human activity all have an impact on the spatial distribution of landslides in this area. Landslides are caused by steep slopes, brittle geological formations like shale and sandstone, and human activities like road building and mining that destabilise the slopes. Landslides are particularly common in the cities of Gangtok, Singtam, Rangpo, and Jorethang as well as on busy thoroughfares like National Highway 10 and Teesta River Valley Road.

The monsoon season in eastern Sikkim, which normally lasts from June to September, and excessive rainfall that can sodden the soil and cause landslides, have a significant impact on the temporal distribution of landslides. The most frequent times for landslides to occur are during periods of heavy rain or immediately after one. Landslides might occur more frequently in some places than others based on their geographic position.

Landslides in eastern Sikkim have become more frequent and intense recently, which has been linked to climate change and growing human activity in the area. To lessen the risk of landslides, precautions like slope stabilisation, sensible land use planning, and early warning systems have been put in place. Locations with a slope gradient of more over 30 degrees and unstable or severely worn rock formations are also at a high danger of landslides. These locations include the areas around Gangtok, Mangan, and Jorethang.

Among the six districts in the state, Eastern Sikkim has the most population, and the slopes there are in grave danger as a result of rising population trends and rapid urbanisation. Due to slope collapses on NH 10, the main route in East Sikkim, and other highways that hinder tourism and the production of agricultural products like cardamom, the state experiences significant economic losses, particularly during the monsoon season.

In order to minimise the effects of landslides, the government of Sikkim has put in place a number of measures, such as early warning systems, landslide hazard zoning, landslide mitigation techniques like

constructing retaining walls, slope stabilisation techniques and drainage systems, public awareness campaigns, construction standards that require the use of landslide-resistant materials and techniques, and disaster management plans. These techniques have helped to lessen how landslides affect Sikkim's people, infrastructure, and environment. To ensure these strategies' efficacy in the face of shifting environmental conditions, the government must constantly evaluate and improve them.

CONCLUSION

According to the Sikkim Himalayas' Landslide Vulnerability Assessment, the area is extremely sensitive to landslides because of its geological and topographical features as well as its strong human activity. According to the study, the study region was very to extremely vulnerable to landslides, with 45.7% of the area being highly vulnerable and 32.4% being extremely highly vulnerable.

The study also outlined the elements that make the area vulnerable to landslides, including steep slopes, delicate geological formations, heavy rainfall, and human activity including deforestation, mining, and building projects. In order to reduce landslip susceptibility in the area, the research emphasized the need for good land use planning and management practices.

The evaluation of landslide vulnerability also pinpointed specific places in the area that are highly susceptible to landslides and suggested the adoption of suitable mitigating measures to lessen the effects of landslides. To reduce the risk of landslides, the study recommended the implementation of early warning systems, soil and water conservation measures, and slope stabilization techniques.

Overall, the Sikkim Himalayas Landslip Vulnerability Assessment offers useful data for the area's land use planning, catastrophe risk reduction, and natural resource management. The results of this study can help stakeholders and policymakers devise effective solutions to lessen the effects of landslides in the area and promote sustainable development.

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