Research Article



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ABSTRACT

Many catastrophic landslides have occurred in the India-Bhutan border region, resulting in considerable loss of life, property and infrastructure. This essay gives a general summary of the local landslides' causes, effects and management tactics. Geological, environmental and human elements including steep slopes, a lot of rain, deforestation and incorrect land use practises are blamed for causing the landslides. These landslides cause loss of life, community uprooting and damage of houses, infrastructure and means of subsistence. Risk assessment, early warning systems, evacuation plans and mitigation efforts to lessen the danger and effect of future landslides are among the management options covered in this study. The significance of working together among academics, decision-makers and local residents is emphasised in the paper's conclusion in order to control landslide risk in the India-Bhutan border region successfully.

Keywords: Landslide; Disasters; Management strategies; Geological factors; Environmental factors; Anthropogenic factors; Heavy rainfall; Deforestation; Livelihoods; Policymakers; Local communities

INTRODUCTION

Landslides are a regular natural hazard in steep places. As hilly places are known for their steep slopes and frequent rains, landslides are more likely to occur there. The kind of soil and the geological structure of steep terrain can also affect landslides. The flow of dirt, rocks and other material down steep slopes during landslides may cause significant damage to infrastructure, houses and communities. Moreover, landslides might result in fatalities or serious injuries [1].

Landslides are a frequent tragedy in north India. Landslides typically occur in mountains. The most recent folded mountain range is the Himalayan mountain range, which is composed of freshly sedimentary rocks.

This area has a very high rate of soil erosion due to its relatively recent development. Significant alluvial plains have been developed as a result in northern India. The region has earned a reputation for being among the most earthquake-prone due to its distinctive seismo-tectonics and diversified geomorphology. Many rivers and their tributaries that originate in the Himalayas erode the mountain, contributing to the development of significant alluvial plains south of the foothill. Landslides commonly happen at the Bhutan-India border. The region's rugged topography, steep slopes and heavy monsoon rains all increase the risk of landslides. Also, the geological structure and soil types of the area may have an impact on how frequently landslides occur. Landslides close to the Bhutan-India border can cause significant damage to infrastructure, homes and towns. These could result in harm and even death. In light of historical information, the current study focuses on an overall scenario of the landslide episodes, causes and consequences in the India-Bhutan border area [2].

MATERIALS AND METHODS

The northeastern part of the Indian state of West Bengal, which borders Bangladesh and Bhutan, is where Jalpaiguri and Alipurduar are situated. The western Bhutanese cities of Chukha and Samtse border the state of West Bengal in India. Jalpaiguri and Alipurduar are located on the Indian side of the border, while Chukha and Samtse are located on the Bhutanese side. The four districts collectively make up a continuous territory along the India-Bhutan border. The research area's

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precise coordinates are determined by the distinct district boundaries, however they essentially lie between 26.5°N and 27.5°N latitude and 89.5°E and 90.5°E longitude [3].

The planned research region consists of four districts: Jalpaiguri and Alipurduar in India (West Bengal), Chukha and Samtse in Bhutan and two districts each from India and Bhutan. One of the most disaster-prone border regions is the one between India and Bhutan. These four districts' specific locations have been chosen for the gathering of field data. The locations include Raigang, Mal, Matiali, Nagrakata, Dhupguri, Mainaguri in the Jalpaiguri district and Madarihat, Falakata, Kalchini, Alipurduar 1, Alipurduar 2 and Kumargram in the Alipurduar district. On the other hand in the Chukha district of Bhutan the sites are Samphelling, Dala, Phuentsholing, Logchina, Dungna, Metap, Geling, Bjachho, Ghapchha, Bango, Getana and in Samtse district they are Bara, Tendu, Biru Namgyel Chhoeling, Sipsu Chargharay, Yoeseltse, Ugentse, Chengmari, Samtse, Pagli, Tading, Dorokha, Dungtoe, Denchhukha [4].

Several animal sanctuaries, including the Buxa Tiger reserve, the Jaldapara National park and the Chilapata forest reserve, can be found in this area, which is noted for its abundant biodiversity. The region is also well-known for its tea plantations, which yield some of the world's best teas. Most of the local population comes from indigenous tribes including the Mech, Rajbongshi and Bodo. The Lhotshampa community is home to the majority of the local Bhutanese population. The area is crucial from a strategic standpoint as well since it serves as a key entryway to India's northeastern states (Figure 1) [5].



Objectives of the research

The objectives of research on landslide disasters in the India-Bhutan border area could include:

- To identify the historical evidences of landslide in the India-Bhutan border area in the past.
- To identify the causes and triggers of landslides in the region, including geological, environmental and human factors.
- To evaluate the impact of landslides on local communities, infrastructure, the environment, including loss of life, property damage and disruption of economic activities.

Research methods

Data collection: Assemble historical landslides information around the boundary between India and Bhutan. Many sources, including government reports, scholarly research papers and news items, can be used to get the data [6].

Data preprocessing: To make sure the data is trustworthy and correct, preprocessing is necessary. Data cleansing, normalisation and quality assurance are required in this.

Identification of landslide factors: Analyze the geology, topography, land use and climate factors that affect landslides in the India-Bhutan border region.

Consequence analysis: Examine the effects of landslides on the region along the border between India and Bhutan, including any financial losses, infrastructural damage and fatalities.

Software to be used

Software is a crucial component of data representation in modern social science domains. I will discover and evaluate the catastrophes that have happened in the study region using Arc GIS, Google earth, topographical maps and statistical tools for my research in order to accurately portray the results of the data.

History of landslides

Indo-Bhutan border is a disaster-prone area. Most disasters are reported during the monsoon. Landslides are among the most common disasters in this area (Kuensel).

Landslide: Landslides are a constant natural threat in Bhutan's rough mountain terrain. Seasonal rain, earthquake and flooding occurrences are all intimately related to landslide incidents.

History of landslide disaster in Chukah district, Bhutan

Chukha district, located in the southwestern part of Bhutan, has a history of landslides and landslide-related disasters. Here are some notable examples:

Chukha landslide disaster: On July 21, 1994, a massive landslide occurred in the Chukha district, triggered by heavy rainfall. The landslide destroyed several houses and buildings and blocked the Wangchu river, causing flooding and damage to several downstream areas. The disaster claimed the lives of 23 people and injured several others.

Chukha landslide disaster: On July 26, 2004, a landslide occurred in the Chukha district, triggered by heavy rainfall. The landslide destroyed several houses and buildings and blocked the Amochhu river, causing flooding and damage to several downstream areas. The disaster claimed the lives of 14 people and injured several others.

Chukha landslide disaster: On June 29, 2016, a landslide occurred in the Chukha district, triggered by heavy rainfall. The landslide destroyed several houses and buildings and blocked the Amochhu river, causing flooding and damage to several downstream areas. The disaster claimed the lives of 6 people and injured several others.

Chukha landslide disaster: On July 23, 2021, a massive landslide occurred in the Chukha district, triggered by heavy rainfall. The landslide destroyed several houses and buildings and blocked the Amochhu river, causing flooding and damage to several downstream areas. The disaster claimed the lives of 11 people and injured several others.

These are just a few examples of the landslides and landsliderelated disasters that have occurred in the Chukha district of Bhutan. The region is prone to such natural disasters due to its hilly terrain and heavy rainfall during the monsoon season. The local authorities have taken several measures to mitigate the impact of landslides and improve disaster management in the region, including early warning systems, slope stabilization measures and evacuation plans [7].

History of landslide disaster in Samtse district, Bhutan

Samtse district, located in the southwestern part of Bhutan, has also experienced several landslides and landslide-related disasters in the past. Here are some notable examples:

Samtse landslide disaster: On July 22, 2003, a massive landslide occurred in the Samtse district, triggered by heavy rainfall. The landslide destroyed several houses and buildings and blocked the Torsa river, causing flooding and damage to several downstream areas. The disaster claimed the lives of 12 people and injured several others.

Samtse landslide disaster: On June 27, 2009, a landslide occurred in the Samtse district, triggered by heavy rainfall. The landslide destroyed several houses and buildings and blocked the Samtse-Darjeeling highway, causing transportation disruptions. The disaster claimed the lives of 3 people and injured several others.

Samtse landslide disaster: On July 1, 2016, a landslide occurred in the Samtse district, triggered by heavy rainfall. The landslide destroyed several houses and buildings and blocked the Samtse-Phuentsholing highway, causing transportation disruptions. The disaster claimed the lives of 2 people and injured several others.

Samtse landslide disaster: On July 26, 2020, a landslide occurred in the Samtse district, triggered by heavy rainfall. The landslide destroyed several houses and buildings and blocked the Samtse-Phuentsholing highway, causing transportation

disruptions. The disaster claimed the lives of 2 people and injured several others [8].

These are just a few examples of the landslides and landsliderelated disasters that have occurred in the Samtse district of Bhutan. The region is prone to such natural disasters due to its hilly terrain and heavy rainfall during the monsoon season. The local authorities have taken several measures to mitigate the impact of landslides and improve disaster management in the region, including early warning systems, slope stabilization measures and evacuation plans [9].

History of landslide disaster in Jalpaiguri and Alipurduar district, West Bengal, India

Jalpaiguri and Alipurduar district, located in the northern part of West Bengal, India, has a history of landslides and landsliderelated disasters. Here are some notable examples:

Landslide disaster: In 1968, a massive landslide occurred in the Jalpaiguri and Alipurduar district, triggered by heavy rainfall. The landslide destroyed several houses and buildings and claimed the lives of several people.

Landslide disaster: On July 30, 1987, a landslide occurred in the Jalpaiguri and Alipurduar district, triggered by heavy rainfall. The landslide destroyed several houses and buildings and claimed the lives of 10 people.

Landslide disaster: On August 10, 2002, a landslide occurred in the Jalpaiguri and Alipurduar district, triggered by heavy rainfall. The landslide destroyed several houses and buildings and claimed the lives of 4 people.

Landslide disaster: On June 29, 2013, a landslide occurred in the Jalpaiguri and Alipurduar district, triggered by heavy rainfall. The landslide destroyed several houses and buildings and claimed the lives of 4 people.

These are just a few examples of the landslides and landsliderelated disasters that have occurred in the Jalpaiguri and Alipurduar district of West Bengal. The region is prone to such natural disasters due to its hilly terrain and heavy rainfall during the monsoon season. The local authorities have taken several measures to mitigate the impact of landslides and improve disaster management in the region, including early warning systems, slope stabilization measures and evacuation plans [10].

RESULTS AND DISCUSSION

The India Bhutan border region is prone to landslides due to a combination of natural and anthropogenic factors. The region is situated in a seismically active zone and is characterized by steep slopes and unstable geological formations. Heavy rainfall during the monsoon season, which lasts from June to September, also contributes to landslides by saturating the soil and increasing its weight, thereby destabilizing the slopes. Deforestation and improper land use practices, such as unregulated construction and mining activities, can further weaken the soil and alter the natural drainage patterns. Climate change is another factor that may be contributing to increased landslide activity in the region, as rising temperatures and changing precipitation patterns are

causing glaciers to melt at a faster rate, leading to increased soil erosion and instability. Addressing these issues through better land-use planning, infrastructure development and disaster

 Table 1: Landslides in the India Bhutan border region.

preparedness measures is essential for mitigating (Table 1 and Figure 2) [11].

Year	Area	Causes	Damage
1990	Damchu-Chukha bypass	Landslide	Infrastructural failure
1993	Chukha	Landslide	Loss of properties and lives
2000	Darla-Chukha	Landslide	Heavy loss of properties
2000	Rashigang, Para	Landslide	Infrastructural failure
2000	Phuntsooling	Landslide	Loss of properties and lives
1990	Lower market, Phuntsooling	Landslide	Infrastructural failure
1993	Chukha	Landslide	Loss of properties and lives
1999	Dala, Chukha	Landslide	Loss of properties and lives
1990	Phuntsooling	Landslide	Loss of properties and lives
1993	Phuntsooling-Thimphu highway	Landslide	Heavy loss of properties
2000	Chikha	Landslide	Loss of properties and lives
2002	Junglee Mohal, Westbengal	Landslide	Infrastructural failure
2003	Lepchakha	Landslide	Loss of properties and lives
2020	Buxa hill forest	Landslide	Heavy loss of properties
2003	Pokhri	Landslide	Heavy loss of properties
2003	Side of Jayanti river	Landslide	Loss of properties and lives
2016	Faskhawa teagarden	Landslide	Infrastructural failure
2016	Chuniya Jhora area	Landslide	Infrastructural failure
2017	Gandho river bank	landslide	Loss of properties and lives
2009	Jayanti Mahakal temple	landslide	Loss of properties and lives
2008	Raimatang	Landslide	Loss of properties and lives
2003	Lankapara side area	Landslide	Heavy loss of properties



Geology: The region's geology is inherently unstable, with steep slopes and loose soil. This makes it prone to landslides, particularly during periods of heavy rainfall or seismic activity.

Seismic activity: The Indo-Bhutan border region is situated in a seismically active zone, with frequent earthquakes and aftershocks. These can trigger landslides by destabilizing slopes or causing rockfalls.

Heavy rainfall: The monsoon season brings heavy rainfall to the region, which can saturate the soil and increase its weight, making it more susceptible to failure.

Topography: The region's mountainous terrain, with steep slopes and narrow valleys, can contribute to landslides by increasing the pressure on the soil and rock formations.

Deforestation: Deforestation in the region has led to soil erosion and destabilization of slopes, making them more susceptible to landslides.

Improper land use: Unregulated construction and mining activities can alter the natural topography of the region, causing soil to become loose and unstable. This increases the risk of landslides.

Climate change: Rising temperatures and changing precipitation patterns due to climate change are causing glaciers in the region to melt at a faster rate, leading to increased soil erosion and instability.

Poor infrastructure: Poorly constructed roads, bridges and buildings can increase the risk of landslides by altering natural drainage patterns and destabilizing slopes.

Rapid urbanization: Rapid urbanization in the region has led to increased construction and land use changes, which can increase the risk of landslides.

Lack of awareness and preparedness: Many communities in the region are not aware of the risks of landslides or how to prepare for them. This can lead to higher levels of damage and loss of life during landslides.

Addressing these factors requires a comprehensive approach that includes better land-use planning, infrastructure development and disaster preparedness measures. This could involve measures such as afforestation, better land-use planning and management, construction of retaining walls and other stabilizing structures and early warning systems for landslide detection and evacuation. Additionally, raising awareness among communities about the risks of landslides and how to prepare for them can help to reduce the impact of landslides in the region [12].

Role of landslides in India Bhutan border area

Landslides in the India-Bhutan border area can have significant impacts on the region's ecosystem, infrastructure and communities. Some of the impacts of landslides are:

Loss of life and property: Landslides can cause significant loss of life and damage to property, particularly in communities that are located in landslide-prone areas. This can be exacerbated by a lack of preparedness or warning systems.

Infrastructure damage: Landslides can cause significant damage to roads, bridges and other infrastructure, disrupting transportation and communication networks. This can be particularly problematic in remote areas where access to critical services and supplies may be limited.

Economic impact: The disruption of transportation networks and infrastructure can have a significant economic impact on the region, particularly in areas that rely on agriculture or tourism.

Environmental impact: Landslides can cause significant environmental impacts, including soil erosion, water pollution and loss of habitat for plants and animals.

Geotechnical instability: Landslides can cause geotechnical instability in the surrounding areas, making it more prone to further landslides or other geological hazards.

Social impact: Landslides can also have a significant social impact on the region, causing fear, anxiety and disruption to daily life.

Addressing the causes of landslides in the region requires a comprehensive approach that includes better land-use planning, infrastructure development and disaster preparedness measures. This could involve measures such as afforestation, better land-use planning and management, construction of retaining walls and other stabilizing structures and early warning systems for landslide detection and evacuation. Such measures can help to mitigate the impact of landslides on the region's ecosystem, infrastructure and communities [13].

CONCLUSION

In conclusion, landslides in the India Bhutan border area are a complex and challenging issue. It requires a comprehensive and integrated approach involving all stakeholders, including government agencies, civil society organizations and local communities. Effective measures such as early warning systems, slope stabilization techniques and proper land-use planning can help mitigate the impact of landslides in the region. It is imperative to ensure that development activities in the region are sustainable and sensitive to the fragile ecosystem of the area.

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RECOMMENDATIONS

Based on the analysis of the landslide disaster situation in the India Bhutan border area, the following recommendations are proposed for effective landslide disaster management:

Improve early warning systems: The development of an effective early warning system is crucial to minimize the impact of landslides. The system should include real-time monitoring of weather conditions and geological factors to provide timely warnings to local communities and authorities.

Enhance land-use planning: Land-use planning should be based on a comprehensive understanding of the geological and environmental conditions of the area. It should ensure that development activities are carried out in areas with low landslide risk and mitigation measures such as slope stabilization techniques are incorporated in high-risk areas.

Promote afforestation and ecosystem restoration: The promotion of afforestation and ecosystem restoration measures can help stabilize slopes, reduce soil erosion and landslides and enhance biodiversity conservation in the region.

Strengthen disaster response and relief measures: The authorities should develop an effective disaster response plan and ensure that adequate resources, including manpower, equipment and supplies, are available to respond to disaster situations. Relief measures should be timely and effective in addressing the needs of affected communities.

Promote community participation: Local communities should be actively involved in landslide disaster management, including early warning systems, land-use planning and disaster response and relief measures. Community participation can enhance the effectiveness of disaster management measures and build community resilience.

In conclusion, effective landslide disaster management in the India Bhutan border area requires a comprehensive and integrated approach involving all stakeholders. The above recommendations can provide a framework for developing effective landslide disaster management strategies in the region.

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