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Research article

DIMA HASAO, ASSAM (INDIA) LANDSLIDES' 2022: A LESSON LEARNT

Santanu Baruah[1,2*], Chandan Dey[1,2], Nandita Dutta[3], Manoj Kumar Phukan[1]

[1] CSIR-North East Institute of Science & Techanology, Jorhat - 785006, Assam, India; manojphukan06@gmail.com (M.P.)

[2] Academy of Scientific and Innovative Research (AcSIR), Ghaziabad - 201002, India; s.chandandey@gmail.com;

[3] Assam State Disaster Management Authority (ASDMA), Guwahati - 781005, Assam, India; nanditadutta7@gmail.com

* Correspondence: santanub27@gmail.com

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Abstract: During the monsoon season of 2022, the Dima Hasao district of Assam faced a series of landslides across multiple locations, resulting in significant damage to property and newly developed communication infrastructure. These landslides were caused by a combination of natural and anthropogenic factors. The region being host to one of the world's wettest monsoon belts and under tremendous tectonic stress with sedimentary geological formation is highly susceptible to landslides. In addition to these natural factors, the construction of communication infrastructure and roadways may have contributed to destabilizing the slopes and increasing the risk of landslides. Excavation activities for the expansion of highways and the conversion of railway tracks to broad-gauge may have altered the natural slope dynamics, exacerbating the severity of the landslides. This paper explores the causes and consequences of the landslides from an environmental determinism and possibilism perspective. It argues for the optimization of the neo-determinism fine line by identifying remedial countermeasures to prevent or minimize the impact of future landslides in the area. Effective communication and collaboration among the government, non-governmental organizations, community leaders, and the public are essential for reducing the risk of natural disasters and promoting sustainable development in landslide-prone regions. The identified countermeasures have practical implications for disaster management and planning in similar regions globally.

Keywords: Dima Hasao Landslides; Resilience; Neo-Determinism; NE India; Community awareness.

1. Introduction

Landslides, a major natural hazard, are triggered by the movement of a mass of rock, debris, or earth down a slope (Cruden, 1991). Intense rainfall, cloudburst, earthquake, storm waves, rapid stream erosion or other such stimuli, which increase or decrease shear stress in slope-forming materials, are typically responsible for landslides (Yao, Tham, & Dai, 2008). Human activities, predominantly in the form of deforestation or slope excavation for constructing roads and buildings etc., have become important landslide triggers as development expand into unstable hillslope areas (Li, Wang, & Mao, 2020).

Assam, a north-eastern (NE) state of India, is prone to different kinds of natural hazards. Flood, landslides, earthquakes are the common examples of such calamities that the people of Assam have witnessed since long (Singh, 2005). The geological settings & tectonic environment of the state are very complex that may contribute to some of the natural disasters (Baruah et al., 2021; Mitchell, 1993). From the geotechnical point of view, the state of Assam, especially whole Northeast India falls in seismic zone-V (Kayal, 2008). Assam is located in the path of tropical cyclones that affect the Bay of Bengal region, leading to heavy rainfall and floods. The state is also situated in one of the world's wettest monsoon belts, which makes it susceptible to flooding and landslides during the monsoon season.

In this paper, we attempt to highlight the probable triggers for the landslides and identified a few necessary and important remedial countermeasures to avoid of minimize the impact of future landslides. The vulnerability of Assam to natural disasters underscores the importance of having a robust disaster management system in place. The authorities ought to necessary measures to prevent disasters, including developing early warning systems, implementing infrastructure development plans, and conducting regular risk assessments. The authorities must also work closely with communities to develop community-based disaster management strategies that take into account the unique needs and vulnerabilities of different groups, including indigenous communities.

The region being host to one of the world's wettest monsoon belts and under tremendous tectonic stress with sedimentary geological formation is highly susceptible to landslides and exhibit the traits of environmental determinism. And at the same time, widespread developmental activities involving extensive slope excavation and deforestation indicate possibilism action. The large-scale mass wasting disaster is a combined result of both these actions and a case for optimizing the neo-determinism fine line is suggested.

2. Incident

The monsoon season of 2022 brought unprecedented rainfall to the Northeast region of India, particularly in the state of Assam. Cyclone Asani further intensified the rainfall, leading to catastrophic floods and landslides. The unrelenting rain poured down in two major episodes in May and June, each lasting over a week and including frequent torrential sessions, resulting in significant damage to the infrastructure and people's livelihoods. The Dima Hasao district of Assam was among the hardest-hit areas. A series of landslides occurred at multiple locations, triggered by a phase of continuous rain with frequent torrential outpour, directly affected 12 villages. The landslides killed at least three people and displacing nearly 57,000 residents from the district, according to the Assam State Disaster Management Authority (TWC, 2022). The magnitude of the devastation caused by the landslides and flooding was immense, with over 200 homes destroyed and 10321.44 hectares of cultivated land swamped in flooding (TWC, 2022).

The photographs shown in Figure 1A, B, and C captured the scale of devastation, with entire villages submerged in water and massive landslides burying homes and farmlands. The government, along with various non-governmental organizations and disaster relief agencies, worked tirelessly to provide emergency aid and assistance to those affected by the disaster.

3. Aftermath and Causes

Dima Hasao is a spectacular hilly district under the Assam state of India and also known as the "Mini Switzerland of Northeast India". The district is famous for scenic beauty, heritage railway tracks, mountains, ancient monuments, clouds and rains. To rejoice the spectacle, a vista dome train to Haflong from Guwahati was also launched recently. By virtue of its geographical location, it is considered as the fulcrum between the Brahmaputra and Barak valleys. Jatinga, a small village located near Haflong, is a famous tourist attraction for the mysterious phenomenon of birds committing suicide during the end of monsoon. Several development projects have been implemented in the region and a few are still in the progress. However, the catastrophic landslides, which transpired suddenly, caused heavy damage to all the major development projects (Talukdar, 2022). These projects were supposed to benefit the people living in the region, but they were instead victims of the disaster. The district was cut off from the rest of the state for several days, with multiple segments of roads collapsed, railway tracks washed away, and a few important bridges drifted away (Talukdar, 2022). Many remote villages remained cut off completely as there were no means of contacting the people because of landslides coupled with electricity and internet outage. Most of the areas under the brunt were along slopes concomitant with anthropogenic activities and establishments, most of which are communication infrastructures. It is the worst such disaster according to the witnessing populace and a number of cause and reasons are speculated, ranging between different parcels and facets of natural and anthropogenic circumstances.

Tectonically, the umbrella effect of the complex geodynamic configuration of NE India (Dey et al., 2021) is also ubiquitous in the Dima Hasao district which host segments of the Kopili Fault, Dauki Fault and the Naga Thrust (Fig 2A). All the three lineaments are seismically very active and play an intrinsic role in characterizing the tectonic configuration of NE India. The region is part of the foreland basin of the Indo-Burma Subduction Zone. Consequently, the district is hit by at least 13 earthquakes since 1950 (ISC, 2022), with the magnitude (M_b) range of 3 to 6. (Fig. 2A). Geologically, the region comprises of tertiary and quaternary sedimentary rocks, mainly sandstone, belonging to Barail, Surma, Tipam and Dihing Group. The sedimentary formation of Dima Hasao region under the influence of tectonic manifestation coupled with high intensity of rain is extremely prone to mudflow and landslides.

With respect to the recent landslides, the region along the recently constructed/renovated communication network between Maibong and Ditokcherra of Dima Hasao was the worst affected (Fig. 2B). Several cases of landslides sweeping away highways were reported from this transect (Fig 1B).

Fig 1A: Specimen photographs capturing devastation caused by rain and landslides at the New Haflong railway station (Source: ASDMA).

Fig 1B: Specimen photographs of eroded section of highway along the Maibong and Ditokcherra stretch (Sources ASDMA).

Fig 1C: Specimen photographs of eroded section of railway line along the Maibong and Ditokcherra stretch (Sources: ASDMA).

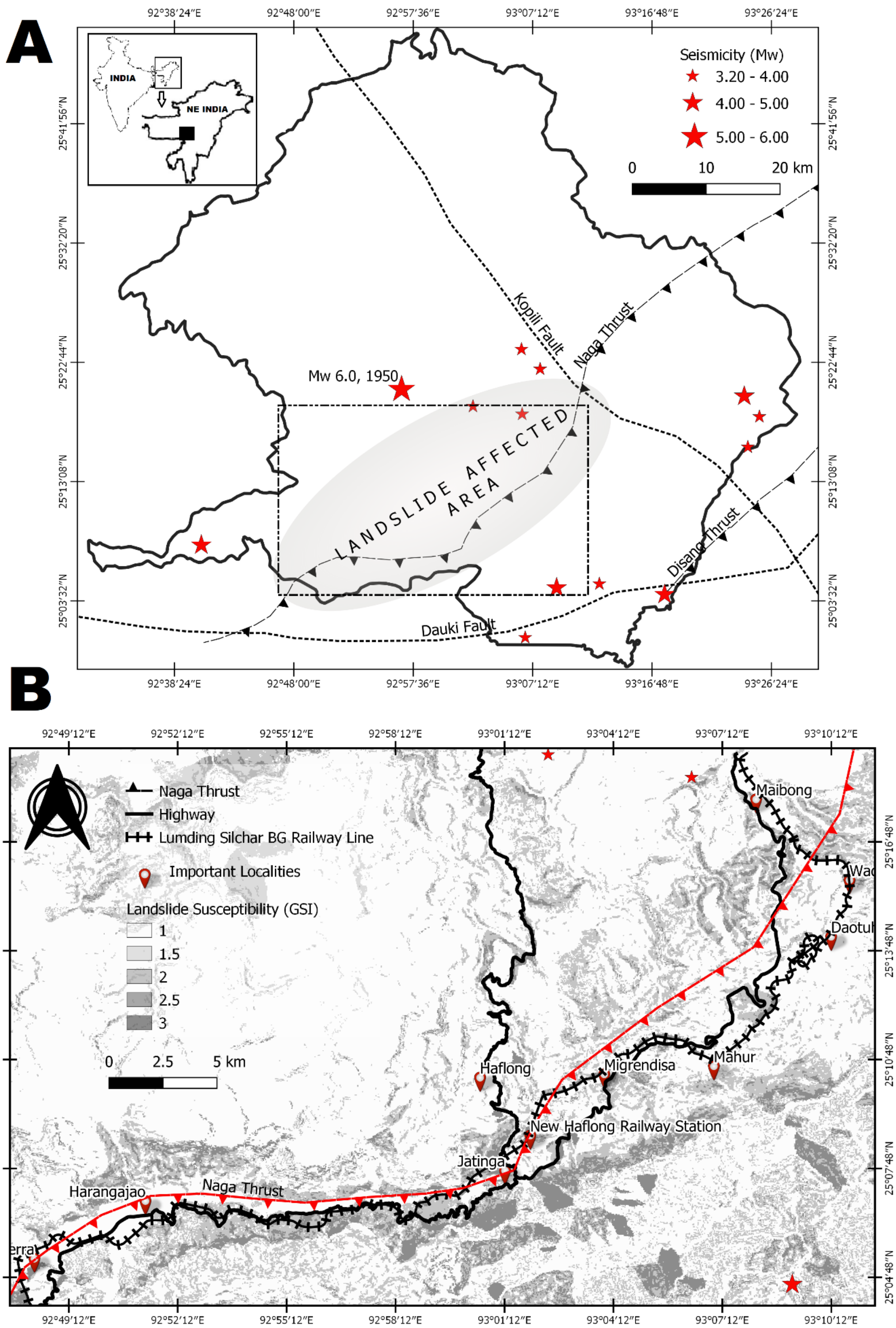

Fig 2: A. Map showing the Dima Hasao district of Assam along with the major tectonic features and seismicity (ISC, 2022). The oval shaded area is severely affected by the episode of landslides and the dotted rectangle represents the area shown in map B. Inset map in top left corner showing the study area from the perspective of India and NE India. **B.** Map showing the highway and railway communication network along with the Naga Thrust and locations of severe devastations. Landslide susceptibility (GSI) is also shown with 3 and 1 indicating extremely high and low susceptibility, respectively.

Subgrade foundation of railway track was washed away at multiple locations due to landslide (Fig 1C). At Daotuhaja, several meters of rails fastened to sleepers laid hanging on the air as the subgrade underneath was eroded (Fig 1C). The New Haflong Railway Station was dumped under debris and the nature of mud flow was so intense that a train was derailed (Fig 1A). Several road and railway tunnels along the transect were blocked by mud debris. The highway, part of east west corridor of India, and the railway, connecting important NE states of India, along the said stretch lie very close to the Naga Thrust. The Jatinga and the Mahur river, flowing near parallel with the Naga Thrust, was responsible for mudflow and floods along with the landslides. The communication network between Maibong and Ditokcherra, as shown in Fig 2B, occur along patches of high landslide susceptibility. About 15 km stretch of near parallel highway and railway line from Jatinga to Harangajao consistently run through high landslide susceptible zones. The same stretch also lies very close and follows the trend of the Naga Thrust. Besides, the railway line from Jatinga to Migrendisa and Harangajao to Bandarkhal run very close following the trend of the Naga Thrust. Therefore, it is observed that the pattern and distribution of severe landslide localities follow a close trend with respect to the Naga Thrust.

The Naga Thrust, characterized by the Indo-Burma Subduction Zone, is a major crustal dislocation zone and marked by very high rate of erosional activities (Gupta, 2006). The landslide and mass wasting potential is also evident from clustering of high landslide susceptibility zones (GSI, 2022) along the thrust. Both the railway and highway connectivity through the region was recently overhauled, with the two-lane highway receiving an expansion of four lane and the meter gauge railway track converted to broad-gauge.

4. Countermeasures

The causes of the series of landslides in the Dima Hasao district could be attributed to a combination of natural and anthropogenic factors. It is apparent that a combination of natural and human-induced factors have played a role in the series of landslides that have caused significant damage and disruption in the district. Studying both the natural and anthropogenic scenarios, the following countermeasures are identified for holistic application towards avoiding or minimizing the impact of future landslides:

I. Landslide Hazard Mapping and Zonation

Landslide hazard mapping and zonation can be a helpful tool to identify high-risk areas for landslides. The identification of these areas could help to inform land-use planning and disaster risk reduction measures. Landslides are more likely to occur on slopes greater than 30 degrees and in areas with high rainfall intensity (Dai, Lee, & Wang, 2003). Studies have shown that combining geospatial techniques with field-based observations and inculcation of neural network models can improve the accuracy of landslide hazard mapping (Aditian, Kubota, & Shinohara, 2018). The mapping process typically involve collection of different types of data, including topographic, geological, and rainfall data. The data should then be analyzed using various techniques, such as the Analytical Hierarchy Process (AHP), to identify and rank the different landslide hazard factors (Pourghasemi, Pradhan, & Gokceoglu, 2012). The landslide hazard maps can identify the areas that are most susceptible to landslides, helping local authorities and emergency responders to develop appropriate measures for disaster risk reduction. The maps produced can be used for land-use planning and decision-making by local authorities and developers. Moreover, updating and refining landslide hazard maps regularly is essential to account for changes in the landscape, such as new land-use practices or climate-induced changes, which may affect the stability of slopes (Huabin, Gangjun, Weiya, & Gonghui, 2005).

II. Slope Stabilization

Slope stabilization is a crucial countermeasure to reduce landslide risk. One way to stabilize slopes is by using vegetation. Plant roots can help to bind soil particles together, thus reducing the chances of soil erosion and landslides. A study conducted in the hills of Uttarakhand found that slope stabilization through soil-specific holistic vegetation can significantly reduce landslide risk (Vasistha, Rawat, & Soni, 2011). Engineering interventions towards slope stabilization include retaining walls, soil nailing, rock bolting, and shotcrete. For example, soil nailing involves the insertion of steel reinforcement bars into the ground, which are then grouted with concrete to create a stable slope. Similarly, rock bolting involves the use of steel bolts to anchor rocks to the ground, thereby reducing the chances of rockfall. These techniques have been successfully implemented in various landslide-prone regions around the world, including in India (Pradhan & Siddique, 2020). Controlled blasting can be used to remove loose soil and rocks from slopes, reducing the risk of landslides. However, it should be carried out under expert supervision to avoid any adverse effects on the slope stability.

III. Drainage System

Drainage systems play a crucial role in mitigating the risk of landslides as they help to control the excess water that can trigger slope failures. Surface water can saturate the soil, making it more prone to erosion and landslides. Therefore, proper drainage systems should be developed to remove surface water from slopes. In a study conducted in Nepal, it was found that poor drainage was a significant cause of landslides (Ghimire, 2011). In Dima Hasao, it is essential to develop a drainage system that can handle heavy rainfall and prevent the accumulation of water on steep slopes. The construction of surface drains, culverts, and catchment basins can help in the effective management of water on the slopes. In addition, it is crucial to ensure that the drainage systems are properly maintained and cleaned regularly to ensure their optimal functioning.

IV. Early Warning System

Early warning systems (EWS) play a crucial role in mitigating the damage caused by landslides by providing timely alerts to communities at risk. Research has shown that effective early warning systems can significantly reduce the impact of landslides and save lives (Guzzetti, Peruccacci, Rossi, & Stark, 2008). The early warning system for landslides is typically based on rainfall thresholds, which are established based on the geological and climatic conditions of a particular region. In Dima Hasao, the development of an effective early warning system is crucial due to the high susceptibility of the region to landslides. The system should incorporate the use of modern technologies such as sensors, remote sensing, and communication systems to provide timely alerts to the affected communities and authorities. The integration of indigenous knowledge and community participation in the development and implementation of the early warning system can also enhance its effectiveness and sustainability (Alessa et al., 2016).

V. Building Codes and Regulations

Building codes and regulations play a crucial role in reducing the risk of landslides in hilly regions like Dima Hasao. The codes and regulations ensure that buildings are designed and constructed in a manner that can withstand the forces of nature, including landslides. Proper building codes and regulations also prevent the construction of buildings in vulnerable areas, such as steep slopes and unstable terrains, which can increase the risk of landslides. A study conducted by the United Nations Development Programme suggests that enforcing building codes and regulations can significantly reduce the risk of landslides in hilly regions like Northeast India (ADRC 2015). In a study conducted in the Himalayas, it was found that the implementation of building codes and regulations reduced landslide risk significantly (Vaidya et al., 2019).

5. Community Awareness and Preparedness

Community awareness and preparedness play a crucial role in mitigating the impact of landslides. The community members living in landslide-prone areas should be informed about the risk of landslides and how to respond to such situations. This information can be disseminated through various channels such as community meetings, awareness campaigns, and the use of social media platforms. The community should also be educated on the importance of complying with building codes and regulations to ensure that their homes and infrastructure are constructed in a manner that reduces the risk of landslides. Moreover, community members can play a significant role in monitoring and reporting potential landslide hazards. They should be encouraged to report any signs of instability, such as cracks in the ground or tilting of trees, to the authorities. This early warning can allow authorities to take appropriate action before a landslide occurs. The success of community awareness and preparedness efforts depends on the involvement of various stakeholders, including the government, non-governmental organizations, and community leaders. These stakeholders should work together to design and implement effective programs that address the unique needs of each community. By working together, we can create a culture of safety and resilience that helps to reduce the impact of landslides on communities.

Besides, the unique topography and natural beauty of Dima Hasao have made it a preferred location for tourism in the recent days. Consequently, there is a rapid increase in population growth and urbanization which has put pressure on the environment. Existing regulations may not be enough, as inappropriate and non-contextual urban development are observed in the district, highlighting the need for better implementation of building codes and provisions. Inculcation of building codes and provisions are necessary to mitigate the impact of landslides. Building codes should be updated to include provisions that address the risks associated with landslides. For example, homes and infrastructure should be built on stable ground and reinforced to withstand potential landslides. The community should also be educated on the importance of complying with building codes and regulations to ensure that their homes and infrastructure are constructed in a manner that reduces the risk of landslides.

6. Conclusion

A variety of perspectives prevail which debates phenomena involving natural disasters, such as landslide, from the subjugator purview of nature and/or human. The concept of 'environmental determinism' upholds the influence of nature over human and its activities and treats human subordinate to nature, and the concept of 'environmental possibilism' regard human as a geographic agent who modifies the environment according to needs such that the nature eventually gets humanised and starts bearing the imprints of human endeavour (Lewthwaite, 1966). The 'neo-determinism' idea dwells between the determinism and possibilism concepts and dismisses the situation and condition for both absolute necessity and absolute freedom (Lewthwaite, 1966).

The Dima Hasao situation presents a classical scenario for optimizing the neo-determinism fine line for co-existence between determinism bearings produced by the tectonic and geographic dispensation and the possibilism approach to develop and tame the harsh topography of the region. The neo-determinism fine line can be attained by considering all the parameters influencing the determinism force of nature. All the counter measures identified in this paper attempts to address the core parameters towards adopting the neo-determinism approach.

The developmental initiatives are essential for progressive upliftment of a society. However, adequate measures should be adopted collectively to constrain the ill determinism bearings of the nature as a result of such actions. The Dima Hasao tragedy has taught a lesson and should be considered as a case study for evaluating the additional local parameters and devising site specific scientific and engineering solutions. There needs to be a complete safety and environmental review of all development projects for a region like NE which is seismically very active. It is essential that this disastrous course should be reversed without delay. Otherwise, similar disasters are bound to happen in the future.

Declarations

Availability of data and materials: The data used in this study can be directly accessible by sending a request to the Director, CSIR-North East Institute of Science and Technology, Jorhat-6, Assam, India at director@neist.res.in.

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References

Aditian, A., Kubota, T., & Shinohara, Y. (2018). Comparison of GIS-based landslide susceptibility models using frequency ratio, logistic regression, and artificial neural network in a tertiary region of Ambon, Indonesia. *Geomorphology*, *318*, 101–111.

Alessa, L., Kliskey, A., Gamble, J., Fidel, M., Beaujean, G., & Gosz, J. (2016). The role of Indigenous science and local knowledge in integrated observing systems: moving toward adaptive capacity indices and early warning systems. *Sustainability Science*, *11*, 91–102.

Baruah, S., Sharma, A., Dey, C., Saikia, S., Boruah, G. K., Eluyemi, A. A., … Sailo, S. (2021). Correlation between crustal anisotropy and seismogenic stress field beneath Shillong–Mikir Plateau and its vicinity in North East India. *Geomatics, Natural Hazards and Risk*, *12*(1), 2070–2086.

Center, A. D. R. (2015). Sendai framework for disaster risk reduction 2015–2030. *United Nations Office for Disaster Risk Reduction: Geneva, Switzerland*.

Cruden, D. M. (1991). A simple definition of a landslide. *Bulletin of the International Association of Engineering Geology-Bulletin de l'Association Internationale de Géologie de l'Ingénieur*, *43*(1), 27–29.

Dai, F. C., Lee, C. F., & Wang, S. J. (2003). Characterization of rainfall-induced landslides. *International Journal of Remote Sensing*, *24*(23), 4817–4834.

Dey, C., Baruah, S., Choudhury, B. K., Chetia, T., Saikia, S., Sharma, A., & Phukan, M. K. (2021). Living with Earthquakes: Educating masses through earthquake awareness: North East (NE) India perspective. *Annals of Geophysics*, *64*(3).

Ghimire, M. (2011). Landslide occurrence and its relation with terrain factors in the Siwalik Hills, Nepal: case study of susceptibility assessment in three basins. *Natural Hazards*, *56*(1), 299–320.

GSI. (2022). *National Landslide Susceptibility Mapping, Assam Susceptibility*.

Gupta, I. D. (2006). Delineation of probable seismic sources in India and neighbourhood by a comprehensive analysis of seismotectonic characteristics of the region. *Soil Dynamics and Earthquake Engineering*, *26*(8), 766–790.

Guzzetti, F., Peruccacci, S., Rossi, M., & Stark, C. P. (2008). The rainfall intensity–duration control of shallow landslides and debris flows: an update. *Landslides*, *5*, 3–17.

Huabin, W., Gangjun, L., Weiya, X., & Gonghui, W. (2005). GIS-based landslide hazard assessment: an overview. *Progress in Physical Geography*, *29*(4), 548–567.

ISC. (2022). International Seismological Centre 2022, On-line Bulletin. https://doi.org/https://doi.org/10.31905/D808B830

Kayal, J. R. (2008). *Microearthquake seismology and seismotectonics of South Asia*. Springer Science & Business Media.

Lewthwaite, G. R. (1966). Environmentalism and determinism: A search for clarification. *Annals of the Association of American Geographers*, *56*(1), 1–23.

Li, Y., Wang, X., & Mao, H. (2020). Influence of human activity on landslide susceptibility development in the Three Gorges area. *Natural Hazards*, *104*(3), 2115–2151.

Mitchell, A. H. G. (1993). Cretaceous–Cenozoic tectonic events in the western Myanmar (Burma)–Assam region. *Journal of the Geological Society*, *150*(6), 1089–1102.

Pourghasemi, H. R., Pradhan, B., & Gokceoglu, C. (2012). Application of fuzzy logic and analytical hierarchy process (AHP) to landslide susceptibility mapping at Haraz watershed, Iran. *Natural Hazards*, *63*, 965–996.

Pradhan, S. P., & Siddique, T. (2020). Stability assessment of landslide-prone road cut rock slopes in Himalayan terrain: a finite element method based approach. *Journal of Rock Mechanics and Geotechnical Engineering*, *12*(1), 59–73.

Singh, T. (2005). Impact of earthquake disasters on new urbanization pattern in north eastern region of India. *Journal of Environmental Systems*, *32*(1).

Talukdar, S. (2022). Dima Hasao Tragedy: Climate Change, Policy Faults and Govt Apathy to Blame. *Newsclick*. Retrieved from https://www.newsclick.in/dima-hasao-tragedy-climate-change-policy-fault-govt-apathy-blame

TWC. (2022). Northeast India Braces for Very Heavy to Extremely Heavy Rainfall from May 16-20; Assam, Meghalaya, Arunachal on Alert. *The Weather Channel*. Retrieved from https://weather.com/en-IN/india/news/news/2022-05-16-very-heavy-rains-to-seize-assam-meghalaya-arunachal-and-sikkim

Vaidya, R. A., Shrestha, M. S., Nasab, N., Gurung, D. R., Kozo, N., Pradhan, N. S., & Wasson, R. J. (2019). Disaster risk reduction and building resilience in the Hindu Kush Himalaya.

The Hindu Kush Himalaya Assessment: Mountains, Climate Change, Sustainability and People, 389–419.

Vasistha, H. B., Rawat, A., & Soni, P. (2011). Hazards mitigation through application of bio-engineering measures in landslide areas. *Disaster and Development*, *5*, 37–52.

Yao, X., Tham, L. G., & Dai, F. C. (2008). Landslide susceptibility mapping based on support vector machine: a case study on natural slopes of Hong Kong, China. *Geomorphology*, *101*(4), 572–582.