

Exploring Rainfall-induced Landslide Risk Reduction Strategies in Low-income Informal Settlements of Chattogram

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Abstract

Geo-physical vulnerability: rainfall-induced landslide has become a pressing topic for the Port City Chattogram, Bangladesh. Numerous hills and hillocks are scattered all over the urban terrain of Chattogram. Communities living in informal settlements along hill slopes and foothills recurrently observe devastating landslides, with loss of lives and properties, triggered by heavy rainfall during the monsoon season. Due to rapid urbanization, and industrialization, rural-to-urban enterprising migration took place, leaving the hearth and home, in search of opportunities. Study shows that due to unaffordable housing, approximately 30 percent of the total urban population live in informal settlements with underprivileged access to basic living standards. Ineffective hill management and weak implementation policies by the national and local authority levels have created loopholes for informal foothill settlement growth. The research aims, first, to understand the driving forces of landslide disasters through historical and contextual analysis, based on both qualitative methods. The next phase will focus on analyzing regional issues related to landslides and informal settlement developments to explore future strategies rather than retrofitting current adversities. The final phase aims to explore comprehensive design and planning strategies for landslide risk reduction applicable in any particular area to ensure the foothill settlers' immediate safety.

Keywords: Landslide; Vulnerability; Informal Settlements; Risk-reduction; Strategy.

1 Introduction

1.1 Background

Flooding, tropical cyclones, tidal surge, river erosion, and drought have been historically prevalent in Bangladesh. However, the current trend of spontaneous urbanization in the hills and hillocks, as well as the impact of landslides on urban terrain populations, indicates a rapid increase in the risk of landslide disasters in Bangladesh (Ahmed, 2015; Chisty, 2014). Natural disasters, largely caused by climate change, are linked to the developing Port City Chattogram and have a significant negative impact on the inhabitants of the slums, which are more often described as informal settlements. In Chattogram's steep regions, the geophysical vulnerability of landslides is becoming an increasingly common and devastating natural event. There are five slope movement types that are referred to as "landslides": falls, topples, slides, spreads, and flows. Rainfall-induced landslides during monsoons typically occur in all climatically unfavorable situations, causing billions in monetary damages as well as hundreds of fatalities and injuries annually. For example, between 2000 and 2018, a number of catastrophic landslides in the Chittagong Hill Tracts (CHT) killed over 725 people. Landslides frequently result in long-term socio-economic disruption, population displacement, and other detrimental environmental repercussions. Landslide disasters have been categorized as an emerging national threat due to a number of factors; the increased frequency of extreme precipitation events, flat-land population pressure, rapid urbanization, hill cutting, deforestation, and a lack of cultural understanding (Alam, 2020; Ahmed, 2017). The growth of informal foothill communities has been triggered by loopholes enabled by ineffective hill management and retrofitting current adverse situations rather than implementing actual solutions and effective policy at the national and municipal levels. Considering these facts, this research will explore the possible contextual planning measures, and structural and non-structural landslide risk reduction strategies, and analyze the possible root causes and effects of landslide vulnerability to mitigate the informal foothill settlers' potential suffering.

1.2 Research Objective & Methodology

The purpose of this research is to contribute to the exploration of a design strategy that can reduce landslide vulnerability, and thus risk to informal settlers. The rainfall-induced landslide adversity in low-income informal settlements, caused by unplanned growth of urbanization and inadequate application of policy and planning, has reduced the natural retention capacity. This has transformed the benefits of the natural landscape, which has lost its significance, into a threat. Thus, by evaluating landslide causes and effects, risk, potential outcomes, constructability, environmental implications, and contextual feasibility, the research will suggest a suitable mitigation approach based on the port city Chattogram. The core objectives are as follows:

- a) Tracing landslide vulnerabilities through historical and contextual analysis.
- b) Uprooting regional issues for anonymous informal settlement developments to address landslide adversity.
- c) Exploring comprehensive future design and planning strategies for landslide risk reduction rather than retrofitting current adversity.

According to Fig: 1.1, the research will be based on qualitative methods which comprise primary and secondary data analysis; literature reviews; historical and contextual analysis; review of scientific literature; publications by the Government and non-government organizations; and news articles about landslides in Bangladesh, specifically in the Chattogram metropolitan context. The ultimate goal of this research is to rationalize this information to analyze the landslide vulnerability to explore required mitigation and risk reduction measures for selected informal foothill settlements through a strategic framework.

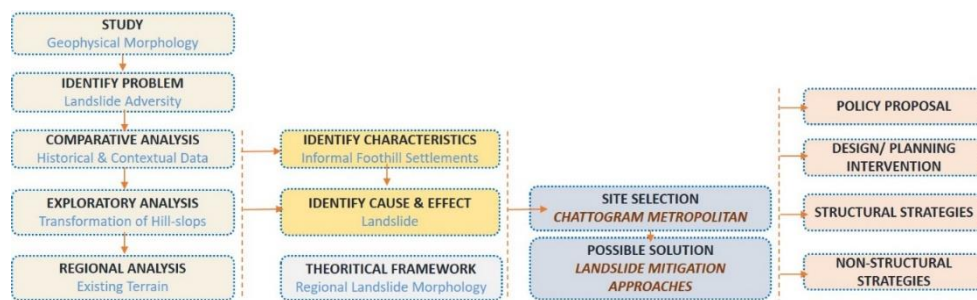


Fig: 1.1 Research Methodology

1.3 Scopes & Limitations

Since 1997, only cyclones have resulted in more fatalities than landslides in Bangladesh. The government has implemented a number of mitigation measures and numerous disaster management committees have been established at the national and municipal levels, yet none of them are qualified to reduce the informal settlers' landslide susceptibility. Potential mitigation strategies would benefit from consideration of the local situation. According to the study, there is still room for developing innovative mitigation strategies that would lower the danger of landslides without threatening eviction or reducing low-income communities' sources of income.

Inadequate data on landslide issues at various administrative levels in Bangladesh is one of the study's weaknesses. The number of fatalities and the value of the property loss are poorly reported while Government studies on institutional landslide mitigation strategies remain confidential. Another restriction is the informal settlers' unwillingness to cooperate. Locals were reluctant to respond to inquiries individually because of ongoing disputes involving land tenure and eviction between informal settlers and the government.

2 Research Context

2.1 Problem Statement

Landslides are common in the hilly areas of Bangladesh, particularly its south-eastern region, Chattogram, and the CHT (Karim and Haider, 1991). South-east Bangladesh, primarily Chattogram, has a long history of instability and though landslides occur every rainy season, there are relatively few written records of these incidents (Karim and Haider, 1991). Major devastating landslides have been recorded in this region, as seen in the metropolitan zone on June 11, 2007, and August 18, 2008. Approximately 140 individuals lost their lives in the major landslide incidents that hit Chattogram City in 2007 and 2008, and a sizable amount of property was destroyed. Between 2000 and 2009, there were at least eleven landslide incidents, with rainfall being the primary cause.

2.2 Cause & Effect

In sloped areas, there are many factors that can cause landslips: geological, morphological, and human-induced. They are usually triggered by natural phenomena such as heavy rainfall, earthquake, erosion, loss or absence of vertical vegetation, or changes in temperature (induced by climate or seasonal change). Landslides have become much worse due to human intervention, with resource exploitation being the primary cause. In the CHT region

deforestation and infrastructure construction are two of the main catalysts. Thus, during extreme rainfall, the frequency of erosion and landslides is exacerbated.

Landslides can be catastrophic and fatal, causing land and community displacement, loss of life and property, degradation of soil, and loss of biodiversity. Two major landslides, one in Chattogram and another in Bandarban, occurred in August 1999, respectively claiming 17 lives. This left Aziz Nagar, Bandarban, inaccessible due to rugged hilly terrain. More recently, during the 2021 monsoon season, more than 12,000 Rohingya refugees were affected, as the landslide in their Cox's Bazar camp destroyed more than 2700 shelters (UNHCR 2021). These are some of the more significant examples of the effects of landslides in Chattogram on record.

2.3 Informal Settlement

Residential areas known as "informal settlements" do not meet local government's required standards to be considered traditional (formal) townships. They are almost always illegal and situated on property that has not been designated for residential use. They exist because urbanization outpaces government provision of housing, infrastructure, and land. Informal settlements tend to be characterized by:

- Insufficient infrastructure environment that is inappropriate.
- Remarkably high and unregulated population densities.
- Homes that are unsuitable, and limited access to career prospects, healthcare, and educational facilities.
- Ineffectiveness of the government and management.
- Substantial risk with regard to health, fire, and crime.

Bangladesh is rapidly urbanizing while being an agrarian society. This is fueled by rural poor who are encouraged by the perceived likelihood of finding pay in the industrial sector and driven by the scarcity of jobs in rural areas. Many new arrivals are forced to live in informal settlements because they cannot afford decent accommodation. Particularly, beginning in 1990, rural residents from across the country began moving to the hilly region as there is an abundance of land and natural resources, making it easier for the migrant population to find work and a place to live (Rahman, 2012). Due to their lack of knowledge about living on hills and the hill ecosystem, these people from the flat plains unknowingly invite increased landslide risk from unsustainable land use, vegetation, disturbing natural drainage of a hill, etc. About 30 percent of the population of Chattogram City resides in informal settlements, where living conditions are deplorable and residents are the most negatively impacted by the quality of and access to local amenities. Many new arrivals are forced to live in informal settlements because they cannot afford adequate accommodation.

2.4 Risk of Landslides in Chattogram City

When a landslide or rock fall occurs, the movement of the materials is determined by the slope and caused by slope instability. This is frequently seen in Chattogram and the surrounding areas of Bangladesh. These slope instabilities are brought on by a number of geological, morphological, and human-induced changes. Tertiary hills include the Chittagong Hills. These hills feature weak soils and a fragile geological structure, both of which increase the risk of landslides. Areas with weak population density and hillside settlements are more risk prone. Landslides have become more dangerous in recent decades, while much of the city's growth has been caused by hill-chopping for irrational urban development. In the city and adjacent urban centers, 15 landslides have killed close to 400 people since 1997. For instance, the June 2007 landslide tragedy caused by heavy rains claimed 128 lives and injured 2,072 families across five settlements that did not have permits (Khan 2008). Following these terrible events, awareness grew among local and national groups about the threat and gravity of the ostensibly ignored natural hazard. Landslides were listed as a natural catastrophe on a national scale by the Ministry of Food and Catastrophe Management. Later landslide incidents resulted in a higher death toll. In 2010, SAARC hosted a workshop in Bhutan with the theme "Landslide Risk Management in South Asia." A paper by Mahmood and Khan (2010) on that workshop used the 2007 landslide as a case study. In order to create a landslide-prone zoning map, they conducted a GPS (Global Positioning System) survey, which was ultimately approved by the disaster management committee. According to Fig: 1.2 & 1.3, here, this research has classified Chattogram City into three zones based on landslide vulnerability.

2.4.1 High-Risk Areas:

High-risk areas include the Lebu Bagan area near Chattogram Cantonment in Hathhazari Thana; hills under APBN-2 in Baizid Bostami thana; Kushumbagh residential area located near the Chattogram Metropolitan Police Line; Batali Hill; and Motijharna located at Lalkhan Bazar near Tiger Pass. The majority of people living here are poor laborers/workers who reside in slums on the foothills. Despite landslides frequently occurring in Kushumbagh, many residences and businesses have been built at the foothill. In Motijharna and Batali Hill, there are large populations of lower-class people; The majority of them work in factories for meager wages.

2.4.2 Moderate Risk Areas:

Moderate-risk areas cover the majority of Foy's Lake and Khulshi Hill. Behind the slopes of Foy's Lake, a number of home developments are under construction, which involves a significant hill-cutting operation.

However, few people live there, and certain areas still lack any housing. On the north and south faces of Khulshi Hill, there is an upscale residential neighborhood. In this region, indiscriminate hill-cutting is frequent.

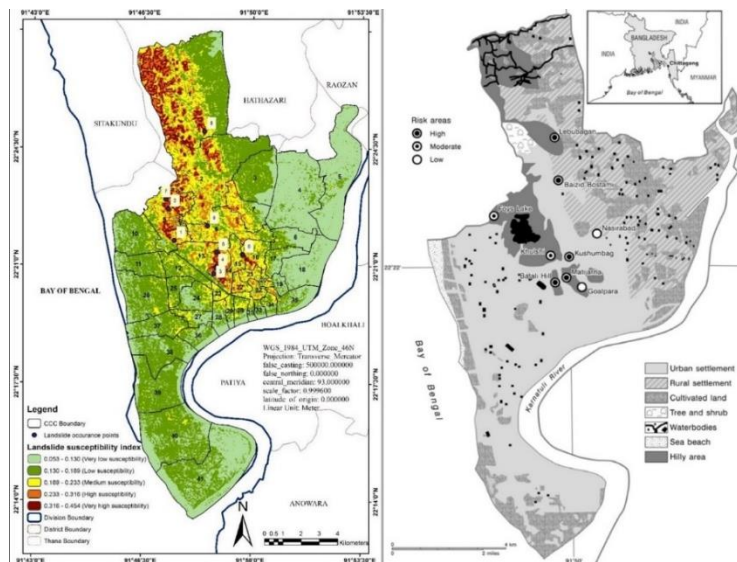


Fig: 1.2 Landslide Susceptibility Index of CCC Area Fig: 1.3 Landslide Vulnerability of Chattogram City

2.4.3 Low-Risk Vulnerable Areas:

Low Vulnerability Areas include the Goal Para slum, which is close to the Tiger Pass and the Chattogram Stadium, and the Nasirabad neighborhood, an affluent area of Chattogram City. The majority of the projects there are complete. Since hills surround Nasirabad, the residents constructed concrete retaining walls to protect their homes which makes this area of Chittagong City less exposed than other steep areas. Goal Para, on the other hand, is a slum and home to impoverished residents who cannot afford this type of protection. Fortunately, the hills in this area are not overtly steep, so the risk is low.

3 Institutional Influences Initiating Landslide Risk

Landslide disasters in these regions are mainly caused by the susceptibility of socially disadvantaged communities residing on developed hills. These individuals, often facing poverty and marginalization have migrated from areas, including those affected by climate change. Due to limitations, they settle in hillside or foothill areas. Exploitative practices are prevalent, where influential figures offer housing to the population and charge them rent. Unauthorized groups known as "land grabbers" further exacerbate the situation by clearing hills for construction by leveraging connections with authorities. This allows them to conduct their activities without any oversight. The urbanized hill settlements heavily rely on jobs in the neighboring cities, such as retail and garment industry work, rickshaws and taxi operations, and everyday labor. They primarily rely on these activities for their subsistence. They can quickly get where they want to go on foot and have access to nearly all metropolitan amenities within a 1-kilometer radius. Despite being aware of the dangers posed by landslides, they opt to remain silent owing to external pressures from the wealthy and powerful elite. They constantly worry about being forcibly evicted and lack the information and understanding necessary to negotiate the steep terrain (Ahmed, 2021).

4 Recommended Strategies

4.1 Planning Measures

When it comes to planning for landslides there are measures and strategies that combine reactive approaches which aim to reduce the associated risks. The following is a detailed overview of the planning measures and strategies: (a)Risk Assessment and Mapping, (b) Land Use Planning and Zoning, (c) Building Codes and Standards, (d) Vegetation Management, (e) Slope Stabilization Measures, (f) Drainage Infrastructure, (g) Emergency Response Plans, (h) Landslide Monitoring and Research. Disasters may be unavoidable, but we can strive to reduce the losses by taking certain measures.

4.1.1 Future Projection-Based Solutions

To predict future landslides, both dynamic and static factors should be considered; through historical analysis and future climate variables future projections and solutions can be determined (Tyagi et al., 2023).

4.1.2 Community Awareness and Preparedness

Organizations of people, individuals, and government should take prepared action and swiftly respond to the situation with disaster management plans, training, and maintenance with precise support and long-term solutions (Wesnawa, 2021).

4.1.3 Disaster Preparedness in Schools

We can learn how to be ready for environmental threats at school. It is where we first learn in depth about natural hazards and their causes. More texts can be added by educational institutions to help students learn about and prepare for natural disasters like landslides. This will raise awareness among the young people in our nation.

4.1.4 Disaster Preparedness by Faith-Based Organizations

Faith-based religious institutions that can significantly help to reduce the landslide issue and help to prepare for it are mosques, temples, pagodas, and churches. Most people heed the advice of their respective religious leaders who they take seriously. Religious leaders may speak about catastrophe preparedness on certain important days. If there is a chance of a landslide or other natural danger, faith-based organizations can make an announcement beforehand.

4.2 Structural Risk Reduction Measures

Building physical structures to stabilize slopes and prevent landslides is a common component of structural mitigation strategies for landslides. Examples of structural landslide mitigation strategies include:

4.2.1. Retaining walls: Gravity retaining walls are built at the bottom of slopes to prevent soil from sliding downhill. They can be made of concrete, stone, or other materials, and are intended to withstand the weight of the earth behind them (Singh et al., 2020). However, constructing retaining walls is expensive and requires considerable space. This means that not all dangerous hillside slopes can have retaining walls constructed.

4.2.2. Soil nails are long steel rods drilled into slopes for reinforcement and landslide prevention. To provide maximum stability they are typically installed at an angle and spaced several feet apart (Bhandari et al., 2019).

4.2.3. Gabion walls: Gabion walls are structures made from wire mesh cages filled with rocks or other materials. By absorbing the weight of the soil behind them they can be used to stabilize slopes and prevent landslides (Jain et al., 2018).

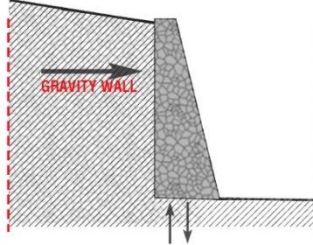


Fig: 1.4 Retaining wall



Fig: 1.5 Soil nails technique



Fig: 1.6 Gabion wall

4.2.4. Grouting: Grouting involves injecting a mixture of cement and water into the soil for stabilization and landslide prevention. It can be used to fill voids in the soil and improve its stability (Huang et al., 2018).

4.2.5. Rock bolting: Rock bolting involves drilling holes into rocks and inserting steel rods to reinforce them and prevent landslides. It is commonly used in areas with steep slopes and loose soil (Liu et al., 2019).

4.2.6. Drainage: Different drainage methods, like surface drains and sub-drainage, along with the effect of vegetation on water movement, can help prevent water from entering unstable areas. Surface drains remove water from low points, while sub-drainage uses various types of drains to manage groundwater. Plants help by absorbing excess water from the ground. Using these methods maintains soil stability and reduces the risk of landslides caused by water. Among these, using plants is both effective and environmentally friendly.

4.2.7. Slope stabilization through vegetation: By using bioengineering techniques or by putting vegetation on slopes, landslide danger can be reduced. The stabilization and binding of the soil is aided by plant roots.

4.3 Non-Structural Risk Reduction Measures

Non-structural landslide mitigation solutions seek to reduce the danger of landslides by altering the natural and artificial factors that contribute to their occurrence. Examples of non-structural landslide mitigation strategies include the following:

4.3.1 Land use planning: Land use planning consists of recognizing landslide-prone areas and prohibiting construction there. Additionally, it can include relocating residents of landslide-prone locations.

4.3.2 Early warning systems: Prior to anticipated landslides, early warning systems can alert people, giving them time to evacuate and take other safety measures. These systems could include weather monitoring equipment, communication networks, and sensors to detect soil movement.

4.3.4 Community-Based Landslide Risk Reduction:

Urban landslide catastrophe risk is rising in Chattogram City, and new methods for developing and implementing on-the-ground landslide risk reduction strategies are urgently needed. Managing tragedies in Small Steps, also known as community-based landslide risk reduction, offers policymakers, project managers, and

practitioners' useful advice on how to cooperate with the most vulnerable urban areas to lessen landslide tragedies.

4.4 Policy Measures

Besides all planning, it is vital to have effective management of landslides through a policy-level framework to regulate other aspects of mitigation and risk reduction systematically.

4.4.1 Firm Building Codes and Ethical Construction Practices

Significant attention needs to be paid to the structural design of the buildings, which will reduce future risks. Besides buildings being resistant to the ill effects of landslides, conventional methods to prevent landslides, like sponge cities, flood warning mechanisms, and green roofs need to be a significant part of the construction codes (Aysha et al. 2022).

4.4.2 Risk Reduction Measures

For each area, different land-use methods need to be adopted to promote identified best practices and ideal scales for the topography and watershed boundaries (Dolidon et al. 2009).

4.4.3 Role of Stakeholders

Here, active and firm participation of all key stakeholders involved are essential for the utmost constructive outcome to resist landslides in order to build back better; key stakeholders include the Government, Non-Government Organizations (NGOs), inter-governmental organizations, local community, institutional bodies, and the general public (Ahmed, 2021). If addressed at the proper institutional and spatial scales, landslide risk can be decreased.

5 Conclusion

Implementing Rainfall-induced Landslide Risk Reduction Strategies in low-income informal settlements of Chattogram is vital to safeguard the lives and properties of vulnerable communities. A holistic approach can be achieved by combining proactive measures like slope stabilization, drainage improvement, and early warning systems, with community education and engagement. However, sustained commitment from local authorities, collaboration with residents, and allocation of resources are imperative for the success and long-term effectiveness of these strategies. The efforts undertaken in these settlements serve as a crucial step towards enhancing resilience and minimizing the devastating impacts of landslides triggered by heavy rainfall.

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