# APPLICATION OF LANDSLIDE MINIMIZATION TECHNIQUE AT THE ROHINGYA REFUGEE CAMP IN COX'S BAZAR, BANGLADESH

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## ABSTRACT

The Kutupalong Rohingya Camp in Cox's Bazar, Bangladesh, is the largest refugee camp in the world, spreading over an area of approximately 3,500 hectares. Since 2017, Bangladesh has witnessed an influx of Forcibly Displaced Myanmar Nationals. According to the UNOCHA, as of October 2022, the Kutupalong Rohingya Camp has a population of more than one million refugees. The District of Cox's Bazar receives an average of 4,300 mm of precipitation annually, and historically, during the monsoon season, landslides occur in this region. Following the Rohingya refugee settlement in the area, numerous landslide events occurred in the Kutupalong Rohingya Camp, mainly between April and September. Specifically, during the monsoon of 2021, more than 300 landslide incidents were reported. Additionally, the extremely severe cyclonic storm Mocha, which made landfall on 14 May 2023, destroyed over 300 shelters and damaged another 3,900. In addition, the storm damaged 1,060 WASH facilities and eight health posts and care centers. This present study considers the impact of the changing global climate on the Kutupalong camp area. It also evaluates the use of construction and demolition wastes to build gabion retaining walls to reduce landslide occurrences. Preliminary findings indicate that the gabion wall has advantages over the concrete retaining wall in terms of construction time and labour requirements. The utilization of construction and demolition waste is an eco-friendly and sustainable solution to the problem.

***Keywords:*** *Landslides, Gabion retaining walls, Kutupalong Rohingya Camp, Construction and demolition waste, Climate change*

## 1. INTRODUCTION

The Kutupalong Refugee Camp (KRC) in Ukhia, Bangladesh, has been home to the Forcibly Displaced Myanmar Nationals (commonly known as Rohingyas) since 2017. As the largest refugee camp globally, it houses around one million Rohingyas (Kamal et al., 2022a). The camp is located in the district of Cox's Bazar and is divided into 23 sub-camps (Kamal et al., 2022b). The Rohingyas live in densely spaced temporary shelters in the foothills, slopes, and flat hilltops, with a population density of 42,000 people/km$^2$ (GoB-UNHCR, 2021). Since 2017, the Rohingya influx in the KRC has led to significant land cover changes in Ukhia, causing the destruction of 5100 ha of vegetated land, 1000 ha of water bodies, and 450 ha of barren land for camp expansion and transportation (Hasan et al., 2020). This has resulted in numerous landslide events, with the KRC being highly vulnerable to flooding and 17% to landslides.

Poor water sanitation and health (WASH) facilities within the camp are causing severe sanitation issues. The largest number of landslides occurred in Camp 18, mainly during the monsoon months from April to September, when precipitation is heavy, infiltrating hilltops and causing seepage (Zaman et al., 2020). In this region, landslides are primarily caused by rainwater, which makes soil and rock components heavier, with pores ranging from 10% to 35% of their total size on slopes (Walker & Shiels, 2013). Water travels through pore spaces, reducing the cohesiveness of the soil material and causing particles to slide downward along slopes due to easy-to-dissolve cementation compounds such as calcium carbonate. Higher hill ranges in the Kutupalong area include strong brown, friable, silty clay loams and silty clay, whereas lower hill ranges have unconsolidated sand and clay. The difference between the highest and lowest elevations is 41 meters. With just 5,731 tube wells present, the Rohingya camps' water levels have decreased because of an over-dependence on groundwater (UNDP, 2019). As a result, there are few freshwater options, especially in Teknaf. According to the UNDP, decreasing groundwater recharge and the destruction of watersheds are to blame for the drying up of irrigation wells. This paper explores the effects of climate change and anthropogenic activities on the landslide intensity in the KRC and evaluates the feasibility of constructing a sustainable form of gabion wall as a protective measure.

## 2. METHODOLOGY

This study is primarily based on a systematic review of relevant scholarly and non-scholarly articles available on landslides in Chittagong and climate change impacts. The research focused on the problems faced in the study areas due to natural disasters such as cyclones and intense precipitation. Juxtaposing different engineering solutions and coming up with one that is environmentally friendly and can help achieve the current SDGs.

### 2.1 Study Area

The KRC is the largest refugee camp in the world and hosts approximately one million Rohingyas (Kamal et al., 2022a). It is located at 21.21˚N latitude and 92.16˚E longitude and is 14.6 km$^2$ in area. The KRC is divided into 23 sub-camps, which are numbered for identification (Kamal et al., 2022b).

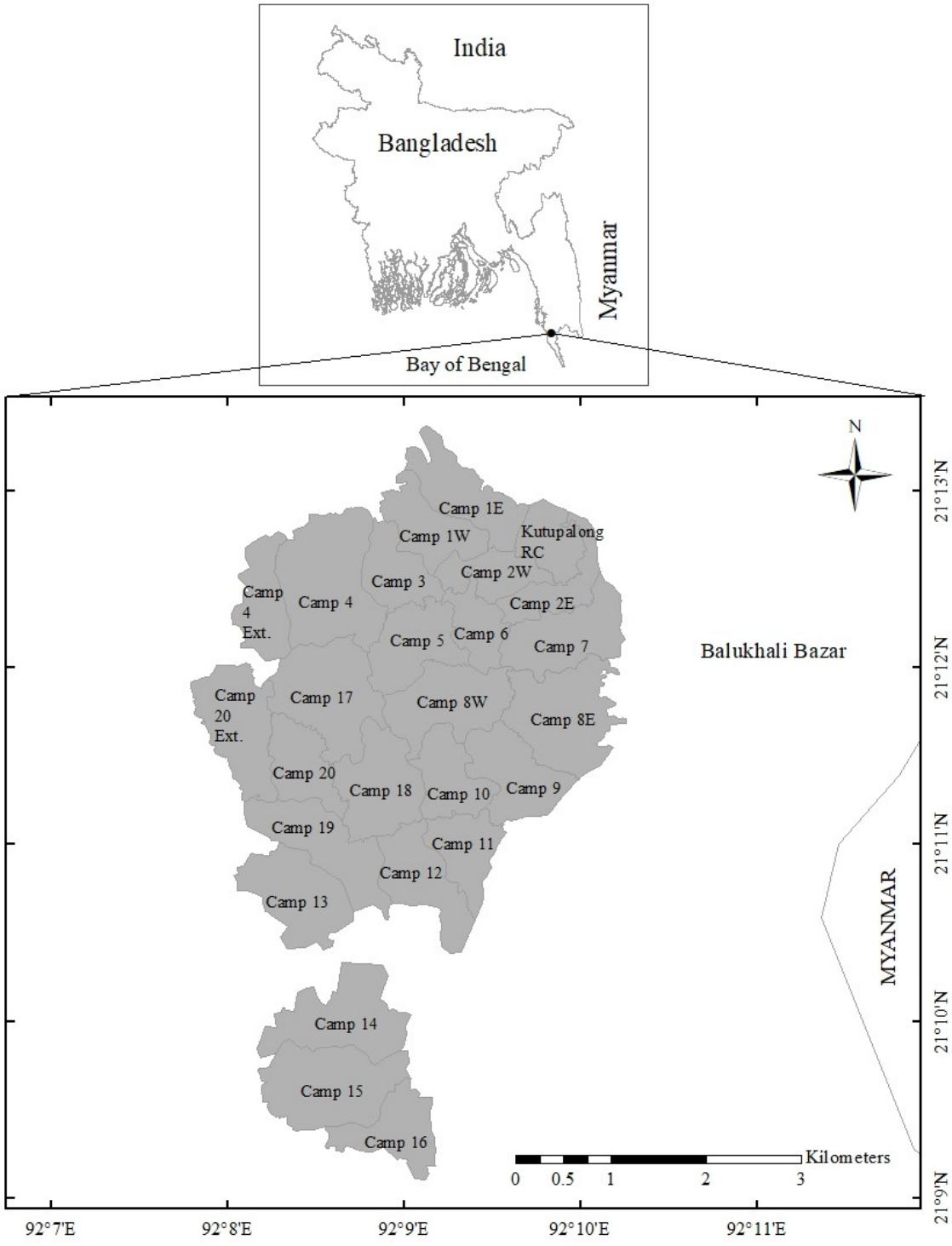


Figure 1: Study Area

The Rohingyas reside in camps located in the foothills, slopes, and flat hilltops that have densely spaced temporary shelters. The population density in the KRC is 42,000 people/km$^2$ (GoB-UNHCR, 2021). Since 2017, due to the influx of Rohingya people in the KRC, the land cover of large areas has experienced massive changes in Ukhia. The KRC is currently at capacity, and new arrivals have resulted in refugees begging for basic supplies and setting up temporary shelters along the streets. Currently, approximately 45% of the population lives in adequate shelters (UNHCR, 2017).

### 2.2 Geological Setting

The camp area of KRC is defined as a geographically tropical monsoon zone. The study area receives an annual average precipitation of 4000 mm, with the majority of the rainfall occurring in July (1029 mm) and the least rain occurring in January (2 mm). The average annual temperature in the area is 26.1°C, with the warmest month being May (32.2°C) and the coolest month being January (14.9°C; Bappa et al., 2022).

The region consists of two main types of soil. The higher hill ranges occupy a narrow belt; the most common soils are strong brown, friable, silty clay loams and silty clay, which grade into broken shale rock at 0.6096 to 1.2192 meters. The lower hill ranges consist of unconsolidated sand and clay. The soil in this range is deep red, friable, and clay loam to clay. Research revealed that the highest elevation from the mean sea level is 41 m, and the lowest is 2 m (Quader et al., 2020). In addition, due to excessive reliance on groundwater, the groundwater levels in the area surrounding the KRC have decreased by 5 to 9 m. Approximately 5,731 tube wells were installed to provide sufficient water to the refugees for daily use. Few freshwater alternatives exist in the impacted areas, especially in Teknaf. Due to the loss of watersheds and a significant decrease in groundwater recharge, irrigation wells are gradually drying up (UNDP, 2019). The residual soils have a bulk density of 1.49–1.97 g/cm$^3$, a liquid limit of 25–48%, a plasticity index of 5–16%, and an undrained shear strength of 23–46 kPa. The silty sandstones have a bulk density of 1.44–1.94 g/cm$^3$, an internal friction angle of 34°–40°, and a cohesion of 0.5–13 kPa (Kamal et al., 2022).

## 3. CLIMATE CHANGE AND LANDSLIDE IN KRC

The Chittagong Hill District (CHD) is a particularly vulnerable area, prone to landslide hazards caused by the impacts of climate change and global warming (Khan et al., 2012). Anthropogenic activities such as forest land conversion to urban areas have been identified as the primary source of landslides in the CHD. Note that large-scale landslide events were not documented in the KRC prior to the Rohingya camp setup (Ahmed, 2021). This, however, has changed as a result of the Rohingya refugee crisis and the establishment of the camp in 2017. Due to increased anthropogenic activity brought on by the sudden influx of refugees, the KRC is experiencing environmental problems (Grey, 2017).

In the Kutupalong region, landslides occur mostly during the monsoon season. In 2021, five to six days of incessant intense rain caused more than 300 landslides in the KRC (IOM, 2022; Ahmed et al., 2020). The coastal land is experiencing changes (for example, saltwater intrusion) due to rising sea levels brought on by global warming. The tidal effect impacts the pore water pressure of the soil on the slope materials (Pritchard et al., 2013). The KRC's sand-silt-rich lithology is experiencing seepage due to increased infiltration of rainwater brought on by increased frequency and intensity of rainfall events triggered by changing global climate (Kamal et al., 2022b; Grey, 2017).

Climate change and human activities are expected to make landslides and other hydrometeorological risks worse in the area (Gariano and Guzzetti, 2016). Consequently, to mitigate the vulnerabilities caused by landslides, it is imperative to classify calamitous landslide incidents in terms of their triggering factors and extent (Alam and Ray-Bennett, 2021). Landslides happened on the steep slope and were limited to a small area of the slope that led to the valley. It looked like the collapses were a mix of slump and mudflow types (Quader et al., 2020).

Flood events occurring over slopes, such as overland flow, sheet flow, return flow, and groundwater ridging, are possibly interrelated with soil erosion and landslides (Recare, 2018). The recent rainfall in August has resulted in significant inundation and a detrimental impact on the KRC situated in Cox's Bazar District. As of August 8th, 2023, precipitation has persisted in Cox's Bazar, resulting in an impact on a population of 300,000 individuals residing in 60 unions throughout three districts (Raeed, 2023).

## 4. WASH RELATED PROBLEMS

Safe and sufficient water, sanitation, and hygiene (WASH) facilities are critical for the overall well-being and health of people. During catastrophes or natural disasters, WASH concerns can be magnified as facilities may incur damage. Waterborne diseases are caused by poor sanitation, unsafe drinking water and hygiene practices, and unplanned drinking water tube wells placed near pit latrines in KRC, which threaten the quality of drinking water. This puts Rohingyas in danger of waterborne epidemics. (Kallen, 2022).

In May 2023, Extremely Severe Cyclonic Storm Mocha, a powerful and deadly tropical cyclone with an average wind speed of 115 km/h, affected Myanmar and parts of Bangladesh (UN Bangladesh, 2023). Over 2.37 lakh people migrated to 700 cyclone shelters in Cox's Bazar Sadar, Teknaf, Ukhyia, Ramu, Chakria, Pekua, Maheshkhali, and Kutubdia. Additionally, approximately 485 shelters in Ukhiya's Balukhali camp number 9 sustained damage, making it the most damaged. During the event, roughly 3,900 shelters were damaged, and nearly 300 were destroyed by the cyclone. Additionally, 1,060 WASH facilities were damaged, comprising nine water networks, 261 bathing facilities, and 751 latrines. Furthermore, four health posts and four primary health centres in Rohingya refugee camps suffered damage to infrastructure (ACAPS, 2023). The heavy rain and strong winds led to landslides in all 33 Rohingya refugee camps in Cox’s Bazar (ReliefWeb, 2023). The occurrence of intense precipitation and subsequent floods has the potential to cause detrimental effects on water supplies and sanitary infrastructure. This includes the flow of runoff and waste materials into nearby streams and lakes, contaminating the whole water supply (UNICEF).

## 5. LANDSLIDE MINIMIZATION TECHNIQUE

Based on the geological setting of the camp and its soil properties, constructing a gabion retaining wall is a feasible choice to minimize landslides. Slope instability can be effectively countered with gabion fascia. Double-weld mesh gabions as a retaining wall are a low-cost landslide mitigation solution. The gabion retaining walls stabilize slopes against debris fall by acting as a mass gravity structure (Tech, 2021). The retaining walls support the slopes by resisting lateral movement and pressure. Gabion retaining walls can be as high as 30 meters (Tech, 2021). Hamova et al. (2009) conducted a study on the effectiveness of gabion walls in stabilizing landslide terrain in Bulgaria. They found that gabion walls can be a useful mitigation technique when paired with geotextiles to provide water drainage capabilities and stop soil washout via the spaces in the wall. However, using boulders to build a retaining wall would not be financially practical because they do not naturally occur in the country. Chips made from well-burned bricks can be used in place of boulders. Reusing leftover concrete from construction and demolition projects (C&D waste) could be an effective solution to ensure sustainable development, provided that it is appropriately positioned inside the mesh weld (Peerdawood & Mawlood, 2010; Arunmozhi, 2022). Research shows that C&D waste is an untapped resource in Bangladesh (Nayeem et al., 2022). Figure 2 shows a cross-section of a possible design of a gabion wall.

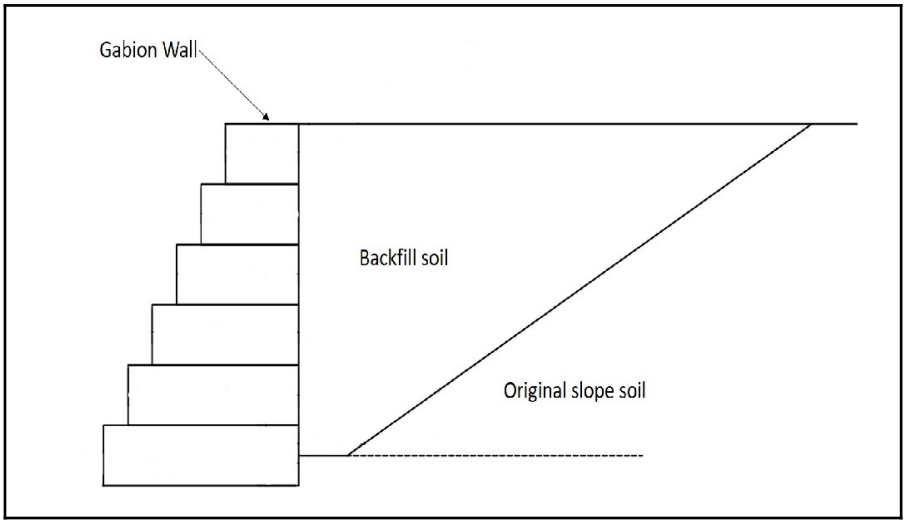


Figure 2: Gabion wall as a landslide minimization technique

## 6. RESULTS AND DISCUSSION

The KRC is situated in a natural disaster-prone area; the large refugee population makes the area more susceptible to natural calamities. Due to increased anthropogenic activity brought on by the sudden influx of Rohingyas, the area is experiencing a variety of environmental issues. According to research, there has been a 0.05% overall loss in the national forest area and a 1.67% loss in the forest region near Cox's Bazar (Fearon, 2021). More than 95% of the refugees also collect fuelwood from nearby forests (Fearon, 2021). In addition, the KRC is vulnerable to natural catastrophes, including floods, cyclones, and landslides, because of its geomorphological and climatic features. Moreover, due to the KRC's already unstable and unconsolidated soil being further degraded by the removal of tree roots, the likelihood of landslides increased (Fearon, 2021). The rapidly growing population, unplanned construction of shelters, and increased frequency and intensity of precipitation events resulted in the degradation of the area's WASH facilities. As such, it threatens both water quality and quantity. Over-extraction of groundwater may also increase salinity intrusion in this area. Various humanitarian organizations are attempting to deliver enough drinkable water to refugees; however, it has been challenging to maintain a consistent and safe supply of potable water. Because of the increased occurrence of landslides, sanitation amenities (for example, latrines and bathing spaces) are becoming insufficient. Thus, constructing a gabion retaining wall is an appropriate solution to minimize landslide occurrences in the KRC. Furthermore, using C&D waste as gabion fill is an eco-friendly and sustainable solution since it repurposes waste which would have ended up taking space in landfill sites which are already at capacity.

## 7. RECOMMENDATIONS

In landslide-prone areas, attention must be given to the sustainable construction of WASH infrastructure. Additionally, in times of humanitarian crisis, diarrhoea epidemics can be prevented and controlled with prompt action and effective WASH infrastructure and services. The construction of a gabion wall in the KRC is anticipated to mitigate the potential possibility of future landslip incidents. However, in areas where the construction of a gabion wall will not prevent landslides, it is suggested that other alternatives be used to stabilize the slopes. For example, soil stabilization, by keeping groundwater away from the landslide, (2) draining groundwater away from the landslide to lower the chance of a rise in groundwater level, (3) covering the landslide with an impermeable membrane, and (4) limiting surface irrigation. Adding weight or retaining structures to the front of the landslide or taking mass (weight) away from the front of the hill can also make it more stable. A good way to stabilize a hill is to plant trees. Some other ways to help modify slopes so they are less likely to be hit

by debris flows are to stop erosion and wildfires, which are known to make debris flows worse on steep slopes. (Geertsema & Highland, 2011)

## 8. CONCLUSIONS

Landslides are a major problem within the Chittagong Hill District, specifically the Kutupalong Rohingya camp. The main causes of such landslides are increased precipitation rates and deforestation due to the influences of climate change and anthropogenic activities. Both parameters tend to alter the pore water pressure within the soil, eliminating its cohesive properties. Most landslide occurrences take place during the monsoon season due to intense rainfall. The temporary shelters and WASH facilities are easily uprooted by strong winds, torrential rain, and, in some cases, destructive storm surges and flooding. A sustainable and eco-friendly solution to these problems could be constructing a gabion wall using construction and demolition waste as the gabion fill. It is a suitable slope stabilization technique for areas with soft soil, and at the same time, it reduces the rate of waste generation and landfilling. Construction and demolition waste is an untapped resource in the context of Bangladesh, leaving room for exploration in the future.

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