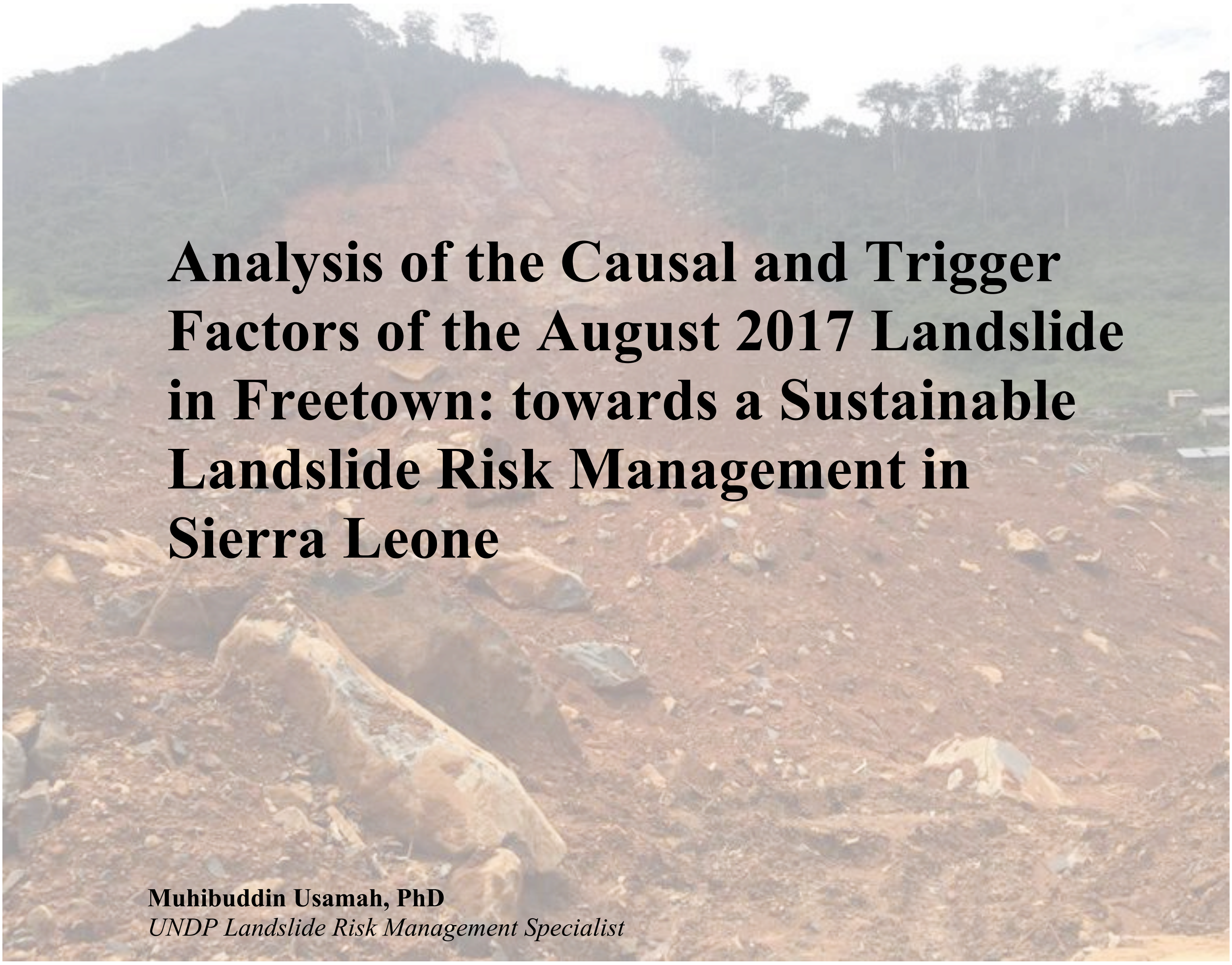

Analysis of the Causal and Trigger Factors of the August 2017 Landslide in Freetown: towards a Sustainable Landslide Risk Management in Sierra Leone

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Landslide in Regent (author).

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1. Introduction

The first ever national hazard assessment of Sierra Leone, which was developed in 2004 has indicated the vulnerability of the country to the impacts of flooding and landslide, among other climatic disasters (ONS 2004). Nonetheless, although notable number of small disasters has been recorded in Sierra Leone (see Chapter 4, Hazard Assessment in Freetown), almost none of them had impactful effects that brought national and international attention. Thus, the recent landslide incidence has been a wake up call for Sierra Leone on how vulnerable the populations are to the risk of landslide and other associated disasters caused by the climatic and hydro-meteorological disasters.

On the positive side, the recent landslide[1] disaster has been used as an opportunity by many government agencies and development actors to review the vulnerability of Freetown to the similar disasters in the future. More importantly, the government, UN agencies and other development actors are actively looking at the medium and long term strategy of landslide vulnerability reduction through Inter Agency Working Group on Development of Recovery Action Plan after the recent landslide.

This document is drafted to revealing the triggers and the root causes of the recent landslide incidence, integrating both technical and social analysis. The document includes an analysis of the geological factors that led to occurrences of landslides, modification of natural slopes and landuse pattern through deforestation or extension of agriculture or other livelihood activities or landuse changes. The document also analyzes the terrain and morphological features, including gradient of slope and stability of soil and rocks, as per how those indicators contribute as triggering factors of landslides. Further, an analysis of man-made activities is also included as the contributing social factors, which reflect (a) the community's low risk perception on landslide and other hydro-meteorological disasters in Freetown and (b) the lack of policy pertaining landuse or other aspects that exacerbate the vulnerability of Freetown populations to landslide and various hydro-meteorological disasters.

The document is concluded with some recommendations for a more planned vulnerability reduction for an effective landslide risk management. The recommendations cover various aspects from policy development and advocacy, public awareness, capacity building to implementation of landslide risk management in Freetown and other landslide risk areas in Sierra Leone.

A more detail recommendation for landslide risk management is presented in another document, which complement the recommendations provided in this document.

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[1] For simplicity, the notions of the 'recent landslide disaster' and/or 'recent landslide' refer to combination of various types of landslides (elaborated more in Section 7.1) and flash flood that occurred in four different areas in Freetown.

2. Methodology

This chapter outlines the adopted methodology in order to achieve the above-stated objective. The analysis of the triggers and the root causes of the recent landslide is mainly based on desktop studies (i.e. documentary analysis), combined with semi-structure interviews as well as field visit to the landslide areas. GIS-based mapping was also conducted to analyze environmental related aspects of Freetown, including landuse, topography, hydrological network, population and housing density.

2.1. Documentary analysis

A broad range of documents and policies are used throughout the whole process of the assessment.

To gain information on the environmental context, exploration of existing documents, technical reports and policies are analyzed. Existing national laws, regulations and guidelines related to hazard and risk management are studied, which include existing methodologies and various reports on hazard, vulnerability and risk assessment in the country.

Since the disaster has called upon the international attention,[2] various situational reports are available from various agencies. These reports provide information on how government and various international aid agencies responded to the disasters. In addition, they also provide information on a further need assessment after the disasters. The World Bank's Damage and Loss Assessment has been heavily analyzed and further studied. It is an important document that provides ground-truth information on the recent landslide.

In addition, existing technical documents on geology, slope and other environmental reports and analysis on Freetown are also explored. They are triangulated with the analysis of the existing maps, e.g. soil, slope and geology of Freetown. All the government documents were available in English hence translation is not needed.

Various scientific information and landslide-related studies from different countries are also explored, studied, compared and used in the assessment. Special attention was given to various landslide mapping techniques, which could be used as an adopted recommendations for a more detail mapping in Freetown and in the country, in the future.

[2] On 17th August 2017, IFRC issued a Flash appeal Sierra Leone: Mudslides - Emergency Appeal n° MDRSL007.

Some of the key documents are listed in Table 1. A bibliography consisting list of documents that are used as references throughout the whole process of this analysis are also provided.

Table 2-1. List of related key documents to be used in the documentary analysis. [3]

Document type	Document name, authors	Year
Government reports, including legislation and policies	National Hazard Assessment Profile, Office of the National Security (ONS)	2004
	Environmental Assessment and Evaluation of Natural Disaster Risk and Mitigation in Freetown, Freetown City Council, Urban Planning Project 2011-2014	2014
	National progress report on the implementation of the Hyogo Framework for Action (2009-2011), Disaster Management Department, ONS	2011
Landslide technical reports and Situational Reports (SitRep)	Rapid Damage and Loss Assessment of the Sugarloaf Landslide and Floods in the Western Area, Sierra Leone, draft report and presentation by the World Bank	2017
	Responses to the Freetown landslide, ONS, August 2017 (presentation by the ONS)	2017
	Sierra Leone: Mudslides - Emergency Appeal n° MDRSL007, IFRC	2017
	Sierra Leone: Flash Update 15 August 2017, UN Office for the Coordination of Humanitarian Affairs (OCHA West & Central Africa).	2017
	Sierra Leone: Landslide and Floods Situation Update no.5, 22 August 2017, UN Office for the Coordination of Humanitarian Affairs (OCHA) and UN Country Team in Sierra Leone.	2017
	Sierra Leone: Landslide and Floods Situation Update no.8, 31 August 2017, UN Office for the Coordination of Humanitarian Affairs and UN Country Team in Sierra Leone.	2017
Case Studies in landslide mapping and landslide risk management (complete references are presented as bibliography).	Landslide Types and Processes, United States Geological Survey (USGS)	2004
	Implementation of landslide disaster risk reduction policy in Uganda	2017
	Landslide characterization using a multidisciplinary approach	2017
	Landslide process and impacts: A proposed classification method	2013
	Rapid Assessment: Flash flood and landslide disasters in Uttaradit, Thailand, Asian Disaster Preparedness Center (ADPC)	2006
	Multi-Scale Landslide Risk Assessment in Cuba, International Institute for Geo-Information Science and Earth Observation, ITC, The Netherlands.	2008

[3] Not an exhaustive list. The complete list of documents used is presented in a bibliography.

2.2. Semi-structure interviews

Interviews were conducted with selected and relevant officials whose duties and responsibilities are related to disaster risk management. Interviewed officials vary from government sectors as well as international organizations based in Freetown.

Among the three major forms of interviewing: structured, unstructured and semi-structured (Dunn 2005), semi-structured interviews are employed in this assessment process for its flexibility in allowing an exploration of disaster-related experiences by various stakeholders in the country, based on a set of open-ended questions. The form of the semi-structured interviews come with some degree of pre-determined order but flexibility is ensured.

The list of interviewed organizations is presented below:

1. United Nations Development Programme
2. Food and Agricultural Organizations of the United Nations
3. Environmental Protection Agency (EPA)
4. Office of National Security
5. Ministry of Land, Country Planning and the Environment (MLCPE)
6. INTEGEMS (Integrated Geo-Information and Environmental Management Services)
7. Sierra Leone Institute of Geoscientists

In addition, the following meetings were attended:

1. Environmental Technical Working Group Meeting, managed by the MLCPE and EPA
2. Inter Agency Recovery and Risk Management Action Plan
3. Monthly Technical Working Group Meeting of the Sierra Leone Institute of Geoscientists.

2.3. Fieldwork to the landslide affected areas

Two field visits were organized to the landslide affected areas to validate the desktop exercise conducted at the EPA. The propose of the fieldwork is also to conduct ground truth on the geology, soil and other environmental indicators that are used to analyze the root causes and triggers of the recent landslide.

The field visits were conducted twice on the 21st and 26th September 2017. The site selection was organized fully by the EPA based on the accessibility to the area. A representative of the EPA accompanied the UNDP team to the field consisting of Landslide Specialist, Urban Risk Reduction Specialist and two persons from Communication Section of UNDP.

The first field visit was focused in Regent and also included visits to two holding centers, one of which is a temporary shelter managed by the ONS, WFP and UNICEF. The second field visit, organized on the 26th September, was focused on the eastern side of Regent, Malama / Kamayama, Juba/ Kaningo and Lumley.

2.4. Spatial Mapping

A GIS-based mapping / spatial analysis is conducted with the assistance of EPA. The purpose of the exercise is for the analysis of the landslide causal factors that are required to further analyze the different environmental parameters.

The spatial analysis is conducted based on the available data at EPA. The parameters used to analyze and produce spatial map are listed below:

1. Contour mapping
2. Production of Digital Elevation Model
3. Hydrological Network
4. Landuse map
5. Topography map
6. Flood Extent Susceptibility (riverine, flash flood and sea flooding)
7. Housing density
8. Population density
9. Delineation of green areas of Freetown.

The scope of the spatial mapping is extended to urban and rural part of Freetown and the set of spatial maps are included in another set of documents.

3. Overviews on Landslide

The term 'landslide' describes a wide variety of processes that result in the downward and outward movement of slope-forming materials including rock, soil, artificial fill, or a combination of these. These materials may move by falling, toppling, sliding, spreading or flowing (USGS 2008). A graphic illustration of a landslide, with the commonly accepted terminology describing its features is presented in Figure 3.1.

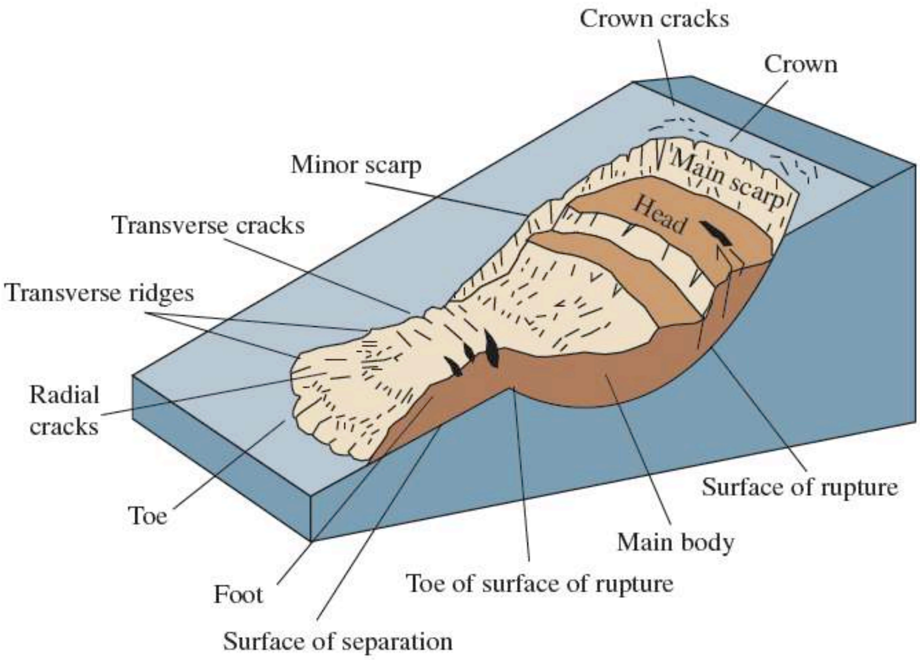


Figure 3-1. An idealized slump-earth flow showing commonly used nomenclature for labeling the parts of a landslide (USGS, 2004)

3.1. Landslide Classification

The landslides are generally classified or differentiated based on the types of material involved and the mode of movement. A more detail classification can be conducted based on the additional variables, such as the rate of movement and the content of water, air or ice in the landslide material (Varnes 1978, USGS 2008). This requires more data and usually is not used as part of the rapid assessment.

The most used classification of landslide is the one that was proposed by Varnes, 1978. The classification consists of a comprehensive categorization of landslide process that includes falling, topping, siding, spreading and flowing; all of which constitute conditions of causal effects and slope characteristics (see Figure 3.2).

TYPE OF MOVEMENT		TYPE OF MATERIAL		
		BEDROCK	ENGINEERING SOILS	
			Predominantly coarse	Predominantly fine
FALLS		Rock fall	Debris fall	Earth fall
TOPPLES		Rock topple	Debris topple	Earth topple
SLIDES	ROTATIONAL	Rock slide	Debris slide	Earth slide
	TRANSLATIONAL			
LATERAL SPREADS		Rock spread	Debris spread	Earth spread
FLOWS		Rock flow (deep creep)	Debris flow (soil creep)	Earth flow
COMPLEX		Combination of two or more principal types of movement		

Figure 3-2. Types of landslide (Varnes 1978)

The classification above shows how landslides or mass transport processes are categorized into six movement-based types: (1) falls (2) topples, (3) translational slides, (4) rotational kinds, (5) spreads, and (6) flows. Further, the prefix "rock" is added to the process names and established the material-based types: (1) rock fall (2) rock topple, (3) rock slide, (4) rock slump, (5) rock spread, and (6) rock flow or deep creep. Although the spreads, topples, and falls could be observed in modern sub-aerial environments, the deposits of these three processes in the ancient rock record would not have any distinguishing attributes. This is because deposits of spreads, topples, and falls would resemble debrites (i.e. deposits of debris flows). An illustrated comparison between various types of landslides is given in Figure 3-3.

A more detailed classification of landslides based on mechanical behavior and transport velocity can be seen in Shanmugam (2015).

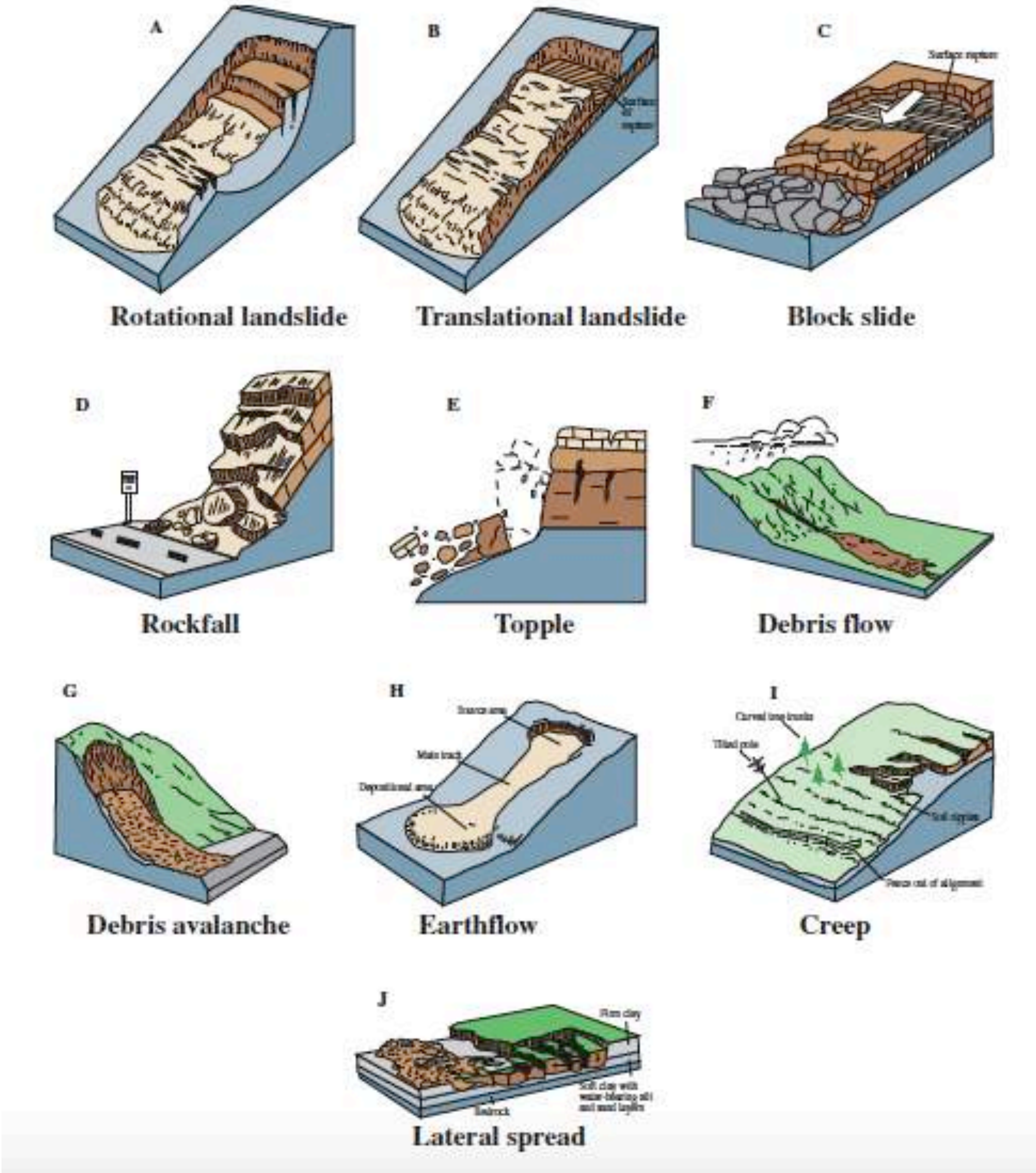


Figure 3-3. Illustrative images of major types of landslide movement (Varnes 1978)

The corresponding definition of the above classification is given in the table below.

Table 3-1. Definition of various types of landslide

Type of Movement	Definition
Falls	Abrupt movements of masses of geologic materials, such as rocks and boulders, that become detached from steep slopes or cliffs. Separation occurs along discontinuities such as fractures, joints, and bedding planes, and movement occurs by free-fall, bouncing, and rolling. Falls are strongly

	influenced by gravity, mechanical weathering, and the presence of interstitial water.
Topples	Toppling failures are distinguished by the forward rotation of a unit or units about some pivotal point, below or low in the unit, under the actions of gravity and forces exerted by adjacent units or by fluids in cracks
Flows	
Debris Flow	A form of rapid mass movement in which a combination of loose soil, rock, organic matter, air, and water mobilize as a slurry that flows downslope. Debris flows include <50% fines. Debris flows are commonly caused by intense surface-water flow, due to heavy precipitation or rapid snowmelt, that erodes and mobilizes loose soil or rock on steep slopes. Debris flows also commonly mobilize from other types of landslides that occur on steep slopes, are nearly saturated, and consist of a large proportion of silt- and sand-sized material. Debris-flow source areas are often associated with steep gullies, and debris-flow deposits are usually indicated by the presence of debris fans at the mouths of gullies. Fires that denude slopes of vegetation intensify the susceptibility of slopes to debris flows.
Debris Avalanche	A variety of very rapid to extremely rapid debris flow
Earthflow	Earthflows have a characteristic “hourglass” shape. The slope material liquefies and runs out, forming a bowl or depression at the head. The flow itself is elongate and usually occurs in fine-grained materials or clay-bearing rocks on moderate slopes and under saturated conditions. However, dry flows of granular material are also possible.
Mudflow	A mudflow is an earthflow consisting of material that is wet enough to flow rapidly and that contains at least 50 percent sand-, silt-, and clay-sized particles. In some instances, for example in many reports, mudflows and debris flows are commonly referred to as “***mudslides***.”
Creep	Creep is the imperceptibly slow, steady, downward movement of slope-forming soil or rock. Movement is caused by shear stress sufficient to produce permanent deformation, but too small to produce shear failure. Creep is indicated by curved tree trunks, bent fences or retaining walls, tilted poles or fences, and small soil ripples or ridges.
Lateral Spread	Distinctive type of landslide because they usually occur on very gentle slopes or flat terrain. The dominant mode of movement is lateral extension accompanied by shear or tensile fractures. The failure is caused by liquefaction, the process whereby saturated, loose, cohesion-less sediments (usually sands and silts) are transformed from a solid into a liquefied state. Failure is usually triggered by rapid ground motion, such as that experienced during an earthquake, but can also be artificially induced. When coherent material, either bedrock or soil, rests on materials that liquefy, the upper units may undergo fracturing and extension and may then subside, translate, rotate, disintegrate, or liquefy and flow. Lateral spreading in fine-grained materials on shallow slopes is usually progressive. The failure starts suddenly in a small area and spreads rapidly. Often the initial failure is a slump, but in some materials movement occurs for no apparent reason. Combination of two or more of the above types is known as a complex landslide.

3.2. Overview of the General Causes of Landslide

Although landslides are preliminarily associated with mountainous region, they can also occur in areas of generally low relief. The causes of such incidence may be caused by various geological and morphological causes, i.e. factors related to water and land interaction, especially in the areas where river actions are involved. The information from this section bring an introduction on the triggers and the root causes of landslide in August 2017 in Freetown.

The following factors as the physical causes / triggers of landslide (USGS 2008):

- Intense rainfall
- Rapid Snowmelt
- Prolonged intense precipitation
- Rapid drawdown (of floods and tides) or filling
- Earthquake
- Volcanic eruption
- Thawing
- Freeze-and-thaw weathering
- Shrink-and-swell weathering
- Flooding

In addition, the other causes are presented in table below.

Table 3-2. The three general causes of landslide (USGS 2008)

Geological Causes	Morphological Causes	Human Causes
▪ Weak or sensitive materials ▪ Weathered materials ▪ Sheared, jointed, or fissured materials ▪ Adversely oriented discontinuity (bedding, schistosity, fault, unconformity, contact, and so forth) ▪ Contrast in permeability and/or stiffness of materials	▪ Tectonic or volcanic uplift ▪ Glacial rebound ▪ Fluvial, wave, or glacial erosion of slope toe or lateral margins ▪ Subterranean erosion (solution, piping) ▪ Deposition loading slope or its crest ▪ Vegetation removal (by fire, drought) ▪ Thawing ▪ Freeze-and-thaw weathering ▪ Shrink-and-swell weathering	▪ Excavation of slope or its toe ▪ Loading of slope or its crest ▪ Drawdown (of reservoirs) ▪ Deforestation ▪ Irrigation ▪ Mining ▪ Artificial vibration ▪ Water leakage from utilities ▪ Other human activities.

In addition to natural factors (geology and geomorphology), the various human intervention is another factor that would be analyzed further, which exacerbates the incidences of landslide (see box 3.1). This will bring some debates and consequently, evidences need to be presented on how this August 2017 landslide disaster should not be seen as a mere natural cause.

Box 3-1. The debate on human interventions vs. un-natural-ness of disasters.

The impacts of natural hazards are inevitable and their occurrence have been increase in recent years (IPCC 2014). The increase is largely because of the consequence of growing vulnerability exacerbated by human activities (Huppert and Sparks 2006). On the other hand, the term "natural disaster" is often used to refer to a disaster, which involves an event originating in the environment. The term has led to connotations that the disaster is caused by nature or that these disasters are the natural (Kelman 2010). Therefore, human actions, behaviour, decisions, and values leading to vulnerabilities which cause disasters, with the potential implication that disasters are never "natural"
(O'Keefe, Westgate et al. 1976, Kelman 2010). Smith (2005) further summarizes that "it is generally accepted among environmental geographers that there is no such thing as a natural disaster¨.

From those arguments above, it can be stated that the existence of human input to all disasters has been generally accepted (Kelman 2010). Turcios (2001) asserts "natural disasters do not exist; they are socially constructed" and UNISDR (2002) notes that "Strictly speaking, there are no such things as natural disasters". A book on terminology on Disaster Risk Reduction by United Nations International Strategy for Disaster Risk Reduction does not include "natural disaster" (UNISDR 2009).

O'Keefe et al. (1976) in his paper ´taking naturalness out of disasters´ argued that ¨disasters are more a consequence of socio-economic than natural factors¨. Kelman (2010) further supported the argument by stating that ¨natural disasters do not exist because all disasters require human input¨ - a confirmation of the earlier argument by O'Keefe et al. (1976) that stated ¨disaster marks the interface between extreme physical phenomenon and a vulnerable human population¨. The conclusion is that those human decisions are the root causes of disasters, not the environmental phenomena and it is of paramount importance to recognize the human element in disasters (O'Keefe et al., 1976, Kelman 2010).

The key aspect of this discussion is the modification of triggering factors by human activities and their resultant interferences with nature. It was also supported by some findings showing that the causes of more than 20% of landslides are human interventions (Zezere, Ferreira et al. 1999, Alimohammad, Najafi et al. 2013). With regard to civilization and urbanization expansion, human activities in reforming and modifying the environment will increase the risk of landslide due to the excavation on slope body or overloading / disturbance of slope balance and slope sliding, to mention some of the triggers (Alimohammad, Najafi et al. 2013).

4. General Overview of Natural Hazard Risk of Freetown

The combined hazard analysis in Sierra Leone conducted by the Freetown City Council (FCC 2014) and historical analysis available from the international disasters data base (EM-DAT)[4] show that Sierra Leone is vulnerable to flooding (coastal and urban flooding), landslide, storm and wildfire. Between 1990 – 2014, it was recorded that landslide accounts for 42.7% of the reported geophysical / geo-hazard mortalities, higher than floods, storm and fire. Between the period, it was also recorded that 86.3% of the country's economic losses is caused by the combined hydro-meteorological disasters (Figure 4.1).

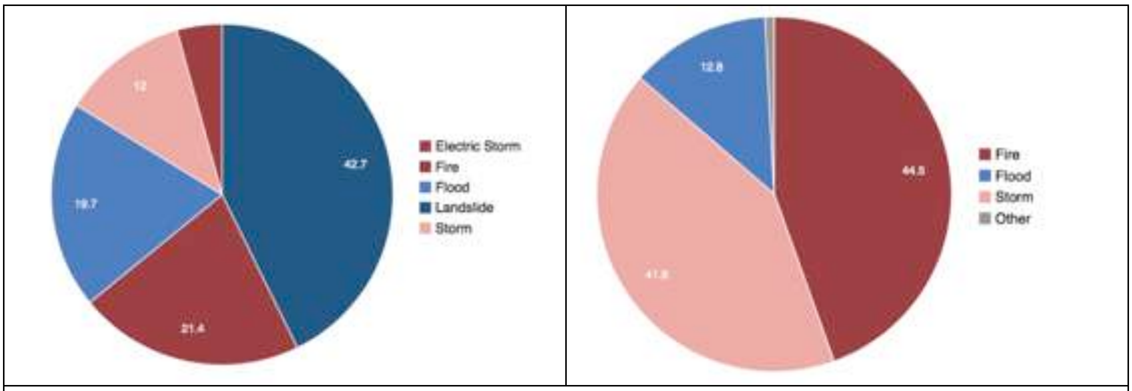


Figure 4-1. Nationally reported losses on mortality (left) and economic losses in Sierra Leone caused by disasters (Source: EM-DAT)

A comprehensive environmental assessment was conducted by the Freetown Citi Council (FCC 2014) detailing the risk of flooding other hydro-meteorological disasters, which are presented in this section.

4.1. Flooding

Flooding incidence in Freetown occurs regularly and causes frequent damage and casualties. The slums along the coastline in Freetown, some of the poorest neighborhood, experience flooding more than once a year and there have been some regular damages on the dwelling houses for their poor construction (FCC 2014).

Flooding in Freetown is generally caused by two factors, which define the types of flooding.

- Urban flooding; caused by the (not necessarily) heavy and prolonged rainfall that pour into the urban areas with poor drainage system.

[4] EM-DAT is the International Disaster Database, managed by the Université catholique de Louvain Brussels – Belgium. Country-wise data set is available at www.emdat.be. Particular data on Sierra Leone, is also available on Prevention Web http://www.preventionweb.net/countries/sle/data/.

- Inland stream flood, which is caused by the uncontrolled development, resulting in narrowing the stream channels blocking the natural course of water way. This type of flooding, which is also associated with urban flooding, is man-made, which is elaborated further in the Chapter 7.
- Coastal flooding; caused by the storm and high tide. The areas at risk of this type of flooding are the settlements along the coast like, notably around Kroo bay, the majority of which are of informal settlements. Notable historical coastal flooding is presented in the table below.

Table 4-1. Recorded historical coastal flooding and its impacts in Freetown (FCC 2014)

Dates of flooding	Social impact	Health impact & other effects
07/7/2012	Damage to shelters and property	Casualties
26/9/2006	Loss of income, property damaged	Casualties
10/08/2006	Property damaged, services disrupted	Changes in mosquito abundance
21/09/2005	Persons injured	Casualties, persons injured
16/07/2004	Damages to shelters, loss of livestock	
7/07/2002	Property damaged, services disrupted	Contamination of water with faecal matter and rodent urine
05/07/2002	Property damaged, services disrupted	Contamination of water with faecal matter and rodent urine
29/07/2002	Property damaged, services disrupted	Contamination of water with faecal matter and rodent urine
23/06/2001	Property damaged, services disrupted	Contamination of water with faecal matter and rodent urine

The areas at risk of flooding have been mapped by the Freetown City Council, which are listed below:

1. Areas prone to coastal flooding.
    - Kroo Bay and White Man's Bay environs;
    - Susan's Bay;
    - Madina and Mafenbe, back of RSLAF Headquarters;
    - Mabella;
    - Congo Town;
    - Kanikay (back of cement factory and Race Course Cemetery and environs)

2. Areas prone to Inland flooding
    - Lumley/ Babadorie/Amadu Lane areas;
    - Wilkinson Road–Cockerill–Indian Temple;
    - Congo River (Tengbeh Town to Congo Bridge);
    - Main Motor Road Brookfield–King Harman Road Junction, and Bright Street–King Harman Road Junction;
    - Hill Cot Road bridge and immediate vicinity;
    - Samba Gutter, Ministry of Works compound on to Joaque Bridge
    - Pultney Street–Siaka Stevens Street junction;

- Eastern Police–Annie Walsh roundabout;
- Mountain Cut–Kissy Road Junction;
- Africanus Road on to former Shell Company, Kissy;
- Ashobi Corner–Blackhall Road;
- Banana Water, Oloshoro;
- Pademba Road–Mends Street–Dundas Street junction;
- Fire force–Circular Road–Macauley Street junction;
- Berry Street (Model)–Circular Road junction.

The areas prone to various flooding are visualized in Figure 4-2.

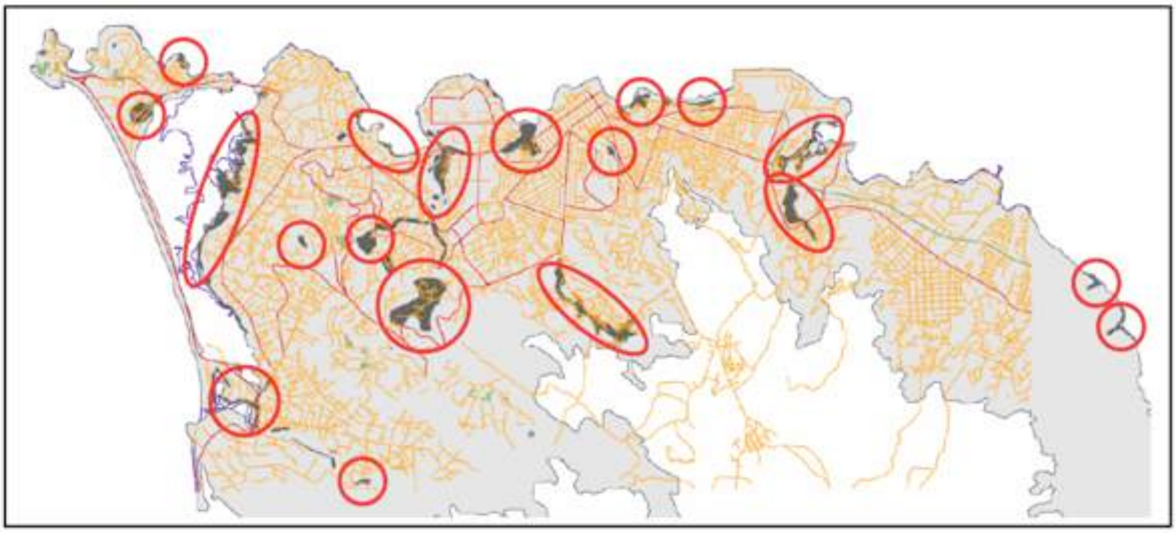


Figure 4-2. Areas prone to flooding in Freetown (FCC 2014)

4.2. Landslide

Landslide risk in Freetown has been defined as a cause of mixed of natural and human activities. The environmental report of the Freetown city council details natural factors and other causes of the landslide due to human activities (FCC 2014):

- Natural causes:
  1. Groundwater (pore water) pressure destabilizing the slope.
  2. Loss or absence of vertical vegetative structure, soil nutrients, and soil structure, e.g. after a wildfire (fire in forests etc. lasting for 3–4 days).
  3. Erosion of the toe of a slope by rivers or ocean waves.
  4. Weakening of a slope through saturation by heavy rains.

- Human activities:
  1. Deforestation, cultivation, mining, and construction, which destabilize the

already-fragile slopes.
2. Vibrations from machinery or traffic.
3. Blasting.
4. Earthwork which alters the shape of a slope, or which imposes new loads on an existing slope.
5. In shallow soils, the removal of deep-rooted vegetation that binds soil to bedrock.
6. Construction, agricultural, or forestry activities (logging) which change the amount of water which infiltrates the soil.

The areas prone to various of types of landslide have also been identified as follows:

- Areas prone to landslide.
  - Charlotte
  - Moyiba
  - Tengbeh Town
  - Congo Town
  - Dworzark
  - New England Ville
  - Ashobi Corner.
  - Slopes alongside House of Parliament, Tower Hill
  - Kissy Bypass
  - Juba Barracks
  - Denuded hillside, steep cut and dangerous slopes, e.g. Moyiba;
  - Bare hillsides or hillsides sparsely covered with soil or loose fine particles that rainfall carries downhill in surface run-off;
  - Slips where the soil (topsoil and subsoil) on slopes becomes over saturated and unstable resulting in slides on hillsides;
  - Slum areas where coast and stream banks experience periodic flooding (e.g. Kroo Bay and the other bays along the coastline)

- Areas prone to mudslide and rock fall.
  - Moyiba quarry
  - Hill Cot Road
  - Portee/Rokupa Wharf
  - Ashobi Corner, off Blackhall Road
  - Kanikay (back of cement factory)
  - Moa Wharf (back of PCMH)
  - Yandama Farm (Back of Benz Garage)
  - Falcon Bridge
  - Omolay Bush (New England Ville)
  - Congo Town, back of Ephraim Robinson School
  - Granville Brook,
  - Back of Racecourse Cemetery

- Kissy (back of Independence School)
- New England Vil

As part of the Rapid Damage and Loss Assessment of the Sugarloaf Landslide and Floods of the Western Area of Sierra Leone, historical landslides of Freetown has been mapped and mostly the incidences occurred in the southwest of Freetown with the slope class of medium-high. The areas that were affected by landslide in the past have been mapped by the British geological Survey and are shown in Figure 4-3.

A more comprehensive analysis of the landslide causes, incorporating geology, slope and other man-made factors is presented in Chapter 7.

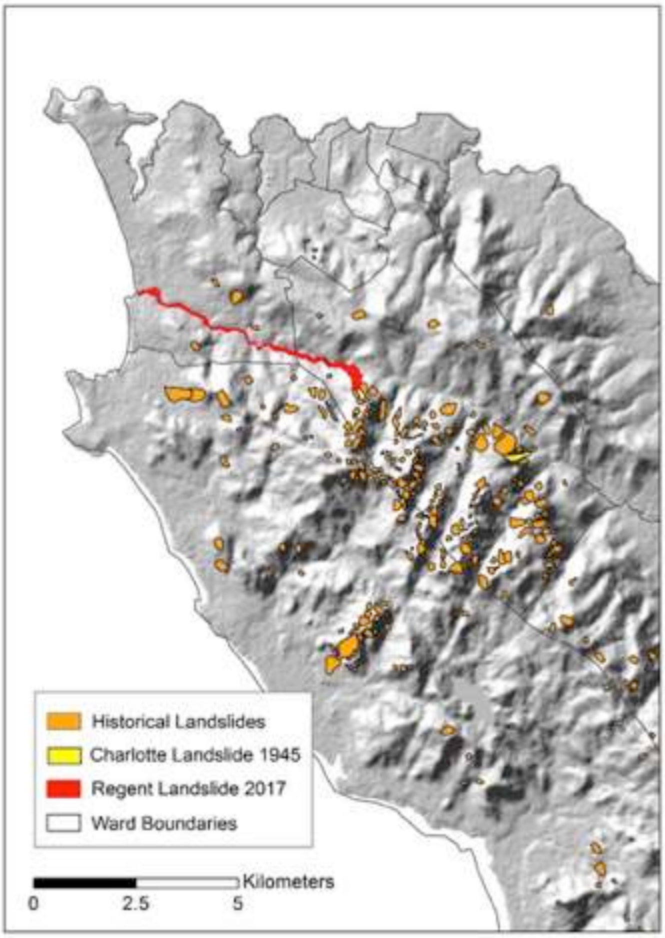


Figure 4-3. Historical landslide of landslide in Freetown (yellow and orange polygons) vs. the location of the recent landslide. Source: Rapid Damage and Loss Assessment (World Bank 2017).

4.3. Seismic and Tsunami Risk

According to the Ministry of Mineral Resources, Geological Surveys Department at New England in Freetown, Sierra Leone is located far away from major earthquake zones and is regarded as lying in a quiet zone with regard to seismic activity. Consequently, there is no record of earthquake or related activity for the past fifty years in Sierra Leone at the Geological Surveys Department in Sierra Leone (FCC 2014).

An assessment by the Freetown City Council reported that based on the geological map of Sierra Leone (scale 1: 50,000) from the Geological Surveys Department, there is only one fault line between Aberdeen and Hastings located at the Orugu. River alongside the Freetown Waterloo. Based on this fact, very minor soil instability activity may occur along the Orugu River fault line. However, lineaments are also included in one of the available geological maps (see Section 7.3.2).

In regards to tsunami risk, the main trigger of the tsunami may be provoked from the volcanic activity from the Cape Verde Islands, located about 1300 km north-west of Freetown. It was roughly calculated that a tsunami wave could take 1.5 to 2.4 hours to land at Freetown. It was also predicted that the tsunami wave of 10 meters would hit Freetown seriously (FCC 2014).

5. Geology and Geomorphology of Freetown[5]

5.1. Overview of Geology of Freetown

The geological characteristic, including description of the lithological units exposed in Freetown, were described from Jalloh, Sasaki et al. (2012).

About 75% of the country is underlain by rocks of Precambrian age, with a coastal strip of about 50 km in width comprising marine and estuarine sediments of Tertiary and Quaternary to recent age. The geology of Sierra Leone consists of 6 major structural units (Figure 5-1).

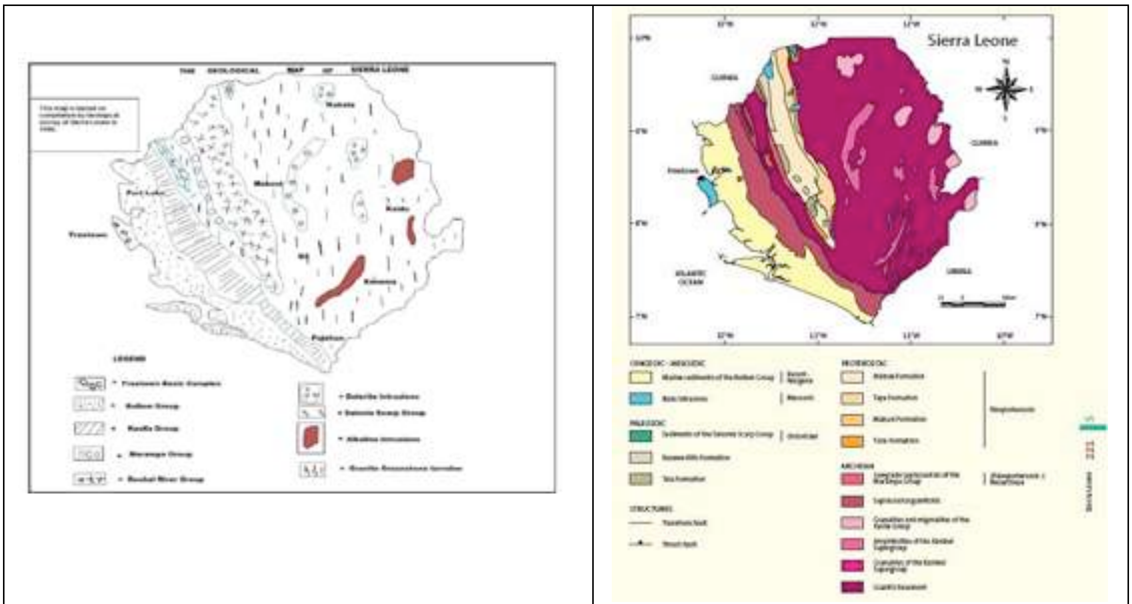


Figure 5-1. Geological map of Sierra Leone and its associated stratigraphy[6] (Dixey 1925, Jalloh, Sasaki et al. 2012).

These geological units are briefly described below:

a) The Granite-Greenstone Terrain. It represents parts of an ancient continental nuclei located on the edge of the West African Craton. Regional reconnaissance mapping indicates up crustal rocks and basic and ultrabasic

[5] The information provided in this chapter may contain technical information with some specific geological terminologies. This chapter aims at providing geological information and geomorphological processes that brings an introduction on the linkages of geological conditions and the incidences of landslide, to be presented in Chapter 7.

[6] Stratigraphy is a branch of geology that seeks to understand the geometric relationships between different rock layers (called strata). It provides information on rock formation of certain areas and its formation in relation to geological time scale.

intrusions. The infra crustal gneisses and granitoids were formed and reworked during two major orogenic events, an older Leonean event (2950-3200 Ma) and a younger Liberian event (2700 Ma).

b) The Kasila Group
The Kasila group is a high grade metamorphic belt with rocks trending in the NNW direction. It comprises a high grade series of granulites, consisting of garnet, hypersthene and hornblende gneisses, quartzites and associated migmatites.

c) The Marampa Group
This group is subdivided in to two layers; a lower, Matoto formation consisting of basic pillow lavas, serpentinites and andesites; and an upper, Roktolon formation consisting of psamites, pelites and banded iron formations.

d) The Rockel River Group, comprises of Precambrian to Cambrian sedimentary and volcanic assemblages deposited uncomformably on a basement complex.

e) The Saionia Scarp Group
This group forms a small ingression into Sierra Leone in the northwest of the country, and is composed of horizontally bedded arkoses, grits and shales with intruded dolerite sills.

f) Basic and Alkaline Intrusions
Dolerite intrusions are common as dykes trending mainly E-W within the basement complex, and as extensive sills above the Rockel River Group.

g) The Freetown igneous complex is a basic layered complex that forms an intrusive body on the coast. It is composed of gabbro, norite, troctolite and anorthosite. Platinum occurs in the gravels of the streams that drain the complex.

As seen in Figure 5-1, Freetown consists of specific igneous rocks with minerals that have been eroded or weathered by frequent rainfall and high humidity. The linkage between the weathering process and the types of geology that forms Freetown and their relation to the recent landslide events are presented in Chapter 7.

5.2. Overview of Geomorphology of Freetown[7]

[7] The information provided in this section is excerpted from a technical report on Hydrogeology of Sierra Leone, prepared by Hydro Nova for the Sierra Leone Water Company on behalf of the Ministry of Water Resources of Sierra Leone.

About two-thirds of Sierra Leone comprise of a series of highly-dissected plains and plateau out of which rise a number of mountain ranges and massifs. The plains and plateau are aged erosion surfaces with generally accordant summits. Much of the landscape is outlined by numerous narrow, dendritic stream valleys which have been deposited by alluvial and colluvium material to form seasonally flooded swaps. In general, the geomorphology of Sierra Leone consists of the following geomorphological classes:

1. Coastal terraces, consist of estuarine swamps, alluvial plains, and beach ridges
2. Interior plains, which consist of undulating plains, bolilands.
3. Plateau, including undulating high-lying plains, rolling plains and hills
4. Highlands, including hills on basic and ultrabasic rocks and hills on acid rocks.

Freetown municipality is located in a hilly region at the foot of mountains. The rivers and creeks that originate at the mountains and hills flow through the heart of the city into the Atlantic Ocean and the Sierra Leone River Estuary. Most of the urban developments have occurred and still occurring on the lower parts of the hills near the coast.

Freetown is surrounded by different types of coast: the western coastal fringe is characterized by long sandy beaches consisting mostly of steep slope and facing directly on to the Atlantic Ocean. The central northern coast area is rocky with a series of small bays. The small embayment along the northern shores are shallow with muddy shores and rocky headlands once covered by mangrove. The southeastern coastal zone is relatively straight with mudflats and mangrove vegetation for much of its length. These coastal zones are the main outfalls for the city's drainage system.

The peninsula hills south of Freetown rise steeply to heights of between 1,000 and 1,500 m above mean sea level and continue southwards as a once-protected forest highland and are now threatened by encroachment of uncontrolled urban developments. These developments have caused significant increase in storm water runoff and erosion resulting in pronounced changes in natural channels. Furthermore, the cutting down of forests on the hillsides is causing soil erosion and increased landslides and flooding in the City. A map showing the spatial slope distribution, depicting geomorphological units of Freetown is presented in Annexes (see specifically topographic map, digital elevation model).

5.3. Soil Characteristics of Freetown

Land Resources Survey Project (1980) conducted by FAO and UNDP classifies Sierra Leone earth surface into four broad categories i.e. coastal plain, interior plains, plateau, and mountainous regions (UNDP & FAO 1980). The survey revealed that there is a strong correlation between the geomorphological units of Freetown and the soil characteristics.

In this classification, the Freetown peninsula has coastal plain formation near west periphery and mountainous formation in the southeast portion. Coastal plain area is formed with yellow-brown sandy soil. Uplifted coastal terraces are formed with shallow soils over laterite sheet. Mountainous portion has dissected hills formed on early Mesozoic gabbro. Shallow soil layer is formed over it with pockets of deeper loams to clays.

Figure 5-2 shows distribution of soil formation in coastal plain (code 3, 4 and 8) and mountainous regions (code 39).

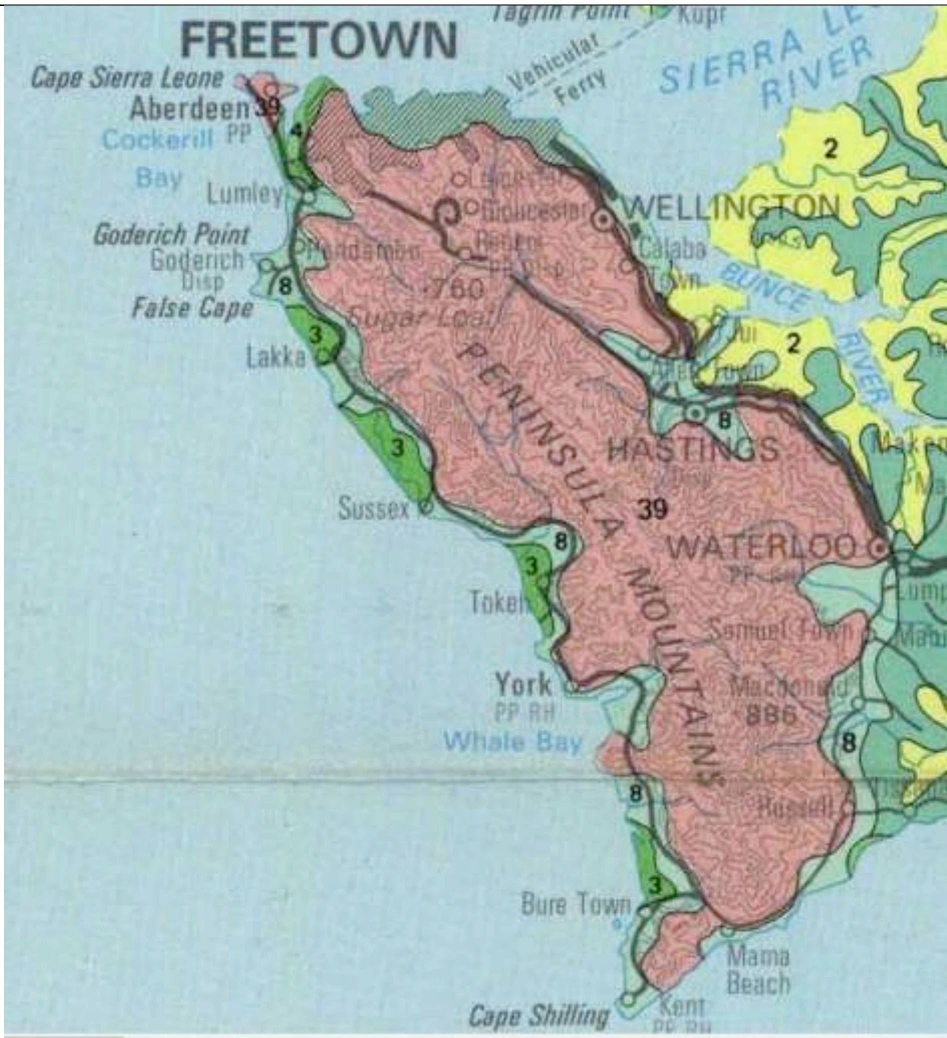


Figure 5-2. Soil formation type in Freetown (UNDP & FAO 1980).

6. Landslide Incidence in August 2017 in Freetown

Three days of heavy rains triggered flash flood and a massive landslide in and around the capital Freetown on 14th August 2017. The most severe disaster occurred in Regent and Lumley districts with a massive 6 kilometers of mudslide submerging and wiping out over 300 houses along the banks of the Juba river (Figure 6-1). Flash floods also affected at least four other communities in other parts of Freetown (OCHA 2017). At least 500 bodies have been recovered. However, several hundreds are still missing, An estimated 5,900 or more people are believed to have lost their homes or have been directly impacted (OCHA and UNCT a 2017). On 17 August, the IFRC launched an Emergency Appeal for CHF 4,637,689 to assist 4,800 people for 10 months (IFRC 2017).

Figure 6-1. The satellite image showing the extent of the landslide (bottom) and the locations of the four affected areas (Source: World Bank (2017))

As of 31th August 2017, the total number of confirmed deaths is slightly above 500 and the number of missing persons at 810. With 616 households (93 percent) verified, the results show that a total of 5,951 people reported being affected by the mudslide and floods, of which 969 are children under the age of five and 393 are pregnant and nursing women (OCHA and UNCT b 2017). At least 338 houses were completely destroyed in the four affected areas and 258 houses were partially damaged (Figure 6.2).

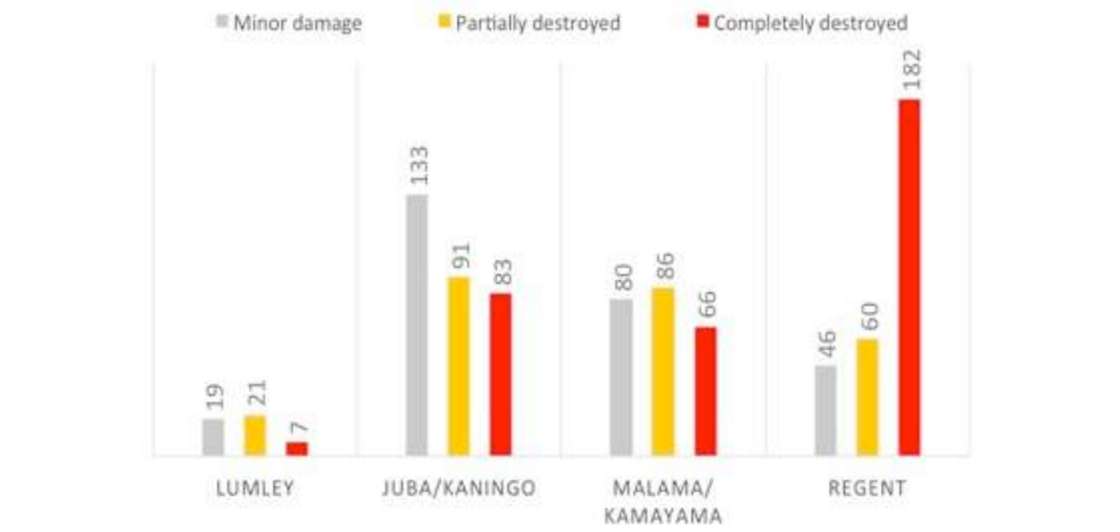


Figure 6-2. The cumulative number of impacted houses in four different locations (World Bank 2017)

The Rapid Damage and Loss Assessment conducted by the World Bank concluded that the combined multi-sectorial total loss and damage of the recent landslide is approximately US$ 30.6 Millions (Figure 6-3).

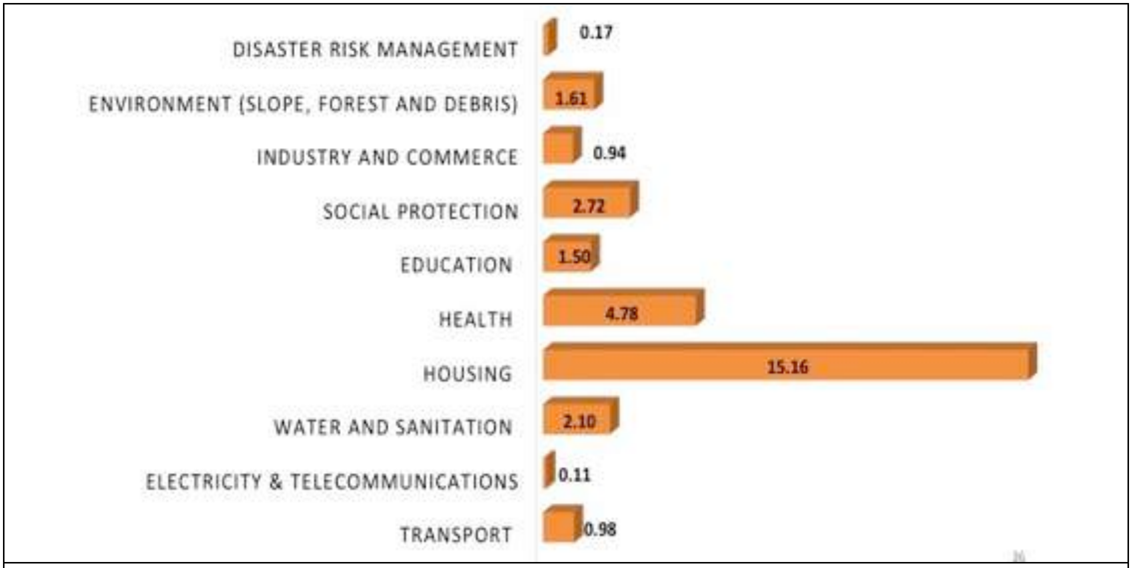


Figure 6-3. Sectorial damage and loss (in USD) of the recent landslide (World Bank 2017)

7. Analysis of the triggering factors and the root causes of the August 2017 Landslide

7.1. Types of Landslide

The landslide types that occurred in August 2017 can be identified based on the types of materials involved, the type of movement and the slope gradient. From the field visits conducted in Regent, Kamayama and Lumley, it was observed that different materials are observed in different areas; and there is a direct correlation between those materials, the slope gradient and the types of movement.

In Regent, situated in the upper part of the landslide-affected areas, which is the epicenter of the landslide (Sillah and Williams 2017), boulders of rocks various size of 1-5 meters, mixed with debris and finer particles were observed. [8]

Boulders of various sizes were deposited in the lower part of the slope that forms planar platform joining the stream networks. This phenomenon is classified as **rock fall** (figure 7-1) because of gravity and possible lineation (elaborated more in the next section). Some parts of the movement also form 'block slide' and further fragmented into smaller sizes that were deposited with the finer particles at the lower part of the slope.

The mechanism of this rock fall is abrupt, which detach from steep slopes. The falling material due to geological factor explained in the next section, stroke the lower slope at angles less than the angle of fall, causing bouncing. Hence, the falling mass broke on impact and began rolling on steeper slopes, and continued until the terrain flattens. It is observed that the boulders of rocks are visible in Malama and Kamayama and this is confirmed by the Damage and Loss Assessment conducted by the World Bank (World Bank 2017).

In the lower gradient, where the slope is plainer, rock fragments are hardly visible. Finer particles consisting of sand-sized and finer particles (Wenworth Classification), combined with soil formed by weathered rocks are widely observed.

[8] Based on Wenworth Classification.

Figure 7-1. The illustrative mechanism of rock fall (Varnes 1978) and the phenomenon of rock fall at the epicenter of the landslide in Regent. Note the sliding plane at the upper part of the hill, which is elaborated more in the 'lineament' section.

This rock fall also form rapid mass movement with other combined materials of smaller rock fragments, finer materials, soil, and water that flows downslope, which formed the **debris flows**.

The flashflood that flew from Regent to Lumley, triggered by the heavy rainfall (see Section rainfall below) was pushed by earth materials (composed of sand-sized or finer particles) that contain at least 50 percent sand, silt and clay-sized particles. These materials, combined with debris flows transported from the upper part of the slope form a type of landslide, which is called **mudslides.**

Figure 7-2. Illustrative mechanism of 'flow' (Varnes 1978) and the debris flow mixed with fragments of rocks observed in Regent.

Figure 7-3. General depositional materials consisting of sand to clay sized in the lower part of the slope (from Lumley to Kaningo, left) and the mark of the mudslide deposit (red line) in a one-story house in Kaningo.

For simplicity, all types of movement observed during the 2017 landslide, is referred to 'landslide'. The importance of identification of those different types of types of landslide is needed when and will be useful in designing specific structural mitigation measures for different types of landslide.

7.2. Triggering Factor / Physical Cause

7.2.1. Intense Rainfall

Among the key factors listed as the physical causes of landslide outlined in Section 3.2, the identified triggering factor of the August 2017 landslide was the intense rainfall.

Freetown is a city squeezing itself into the small space between the mountains and the sea, in a country with the highest annual rainfall in Africa. In August - the height of the rainy season – normally an average of 539.9 mm falls on Sierra Leone's capital (BBC 2017).

Every year, intense rains fall throughout Sierra Leone. In a dataset of annual precipitation by rainfall, Sierra Leone falls at number 12 globally. The Food and Agricultural Organization of the United Nations (FAO) estimated that the tiny West African countries received over 2,500 mm of rain from 2013 to 2017 (FAO 2017). Between 1st July – 14th August 2017 1,040 mm of rain fell on Sierra Leone; three times more than average over this period (World Bank 2017).

Generally, landslides are triggered by gravity, but weather can accelerate and intensify the movement. When heavy rainfall falls after a dry period, the ground can become saturated with water. This region of Sierra Leone saw more rainfall than what is typically seen during this time of year, meaning the ground was likely oversaturated. As the ground oversaturates, the ground becomes waterlogged and loses friction. When the ground eventually gives way, mudslides can rapidly speed up and pick up heavy boulders and rocks capable of causing intense damage, like what was seen in the recent landslide.

This is also strongly related to the geological formation of the landslide area, which consists of fractured and weathered Gabbro. Many of the Freetown formation, especially along the landslide line is composed of Gabbro complex, which after the heavy weathering processes allow the water to generate more cracks and thus trigger the frictions of the rock. The extreme peak of the rainfall during the landslide incidence has been accumulated by relatively frequent rainfall during the rainy season as well as the decrease of the slope stability caused by weathering and erosion.

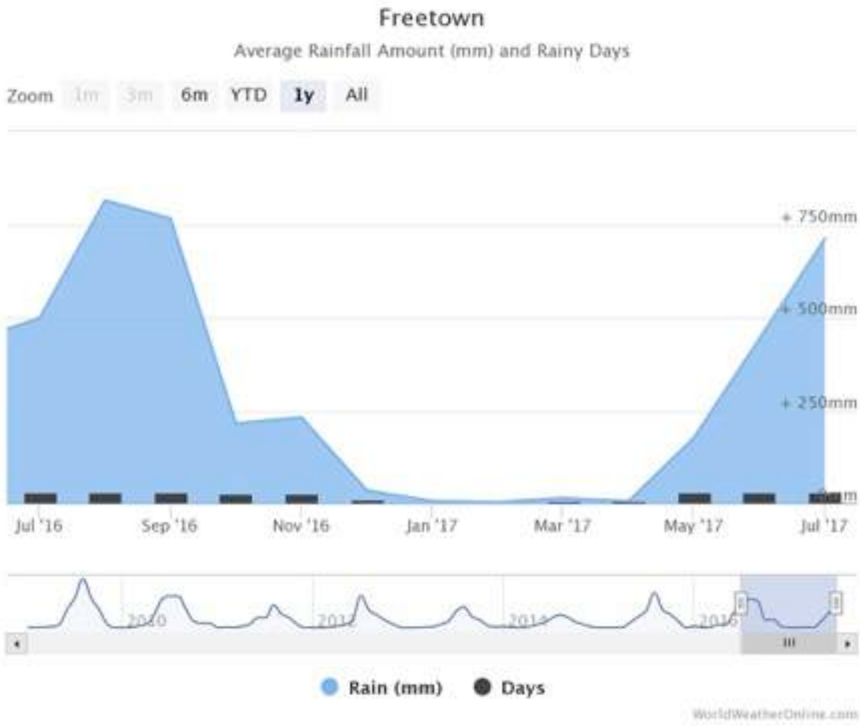


Figure 7-4. Average monthly rainfall in Freetown from July 2016 – July 2017, which is in average 1/3 of the rainfall in August 2017 (World Weather Online 2017).

7.3. Natural Causes

7.3.1. Geology, geomorphology and slope failures

The observed main cause of the recent landslide is due to slope destabilization, linked to environmental factors, namely the geomorphology, geology of sub-surface formations, soil type, the rate of weathering, rainfall intensity, land use change and the slope gradient.

The Sierra Leone Institute of Geoscientists published a short observation on the geomorphology and geological of the landslide affected areas. The geomorphology of the area comprises of undulating mountain ranges with tight narrow valleys dissecting the surrounding hills (Figure 7-5). The epicenter of the landslide is steep, with slope gradient of $>60^0$ (Sillah and Williams 2017).

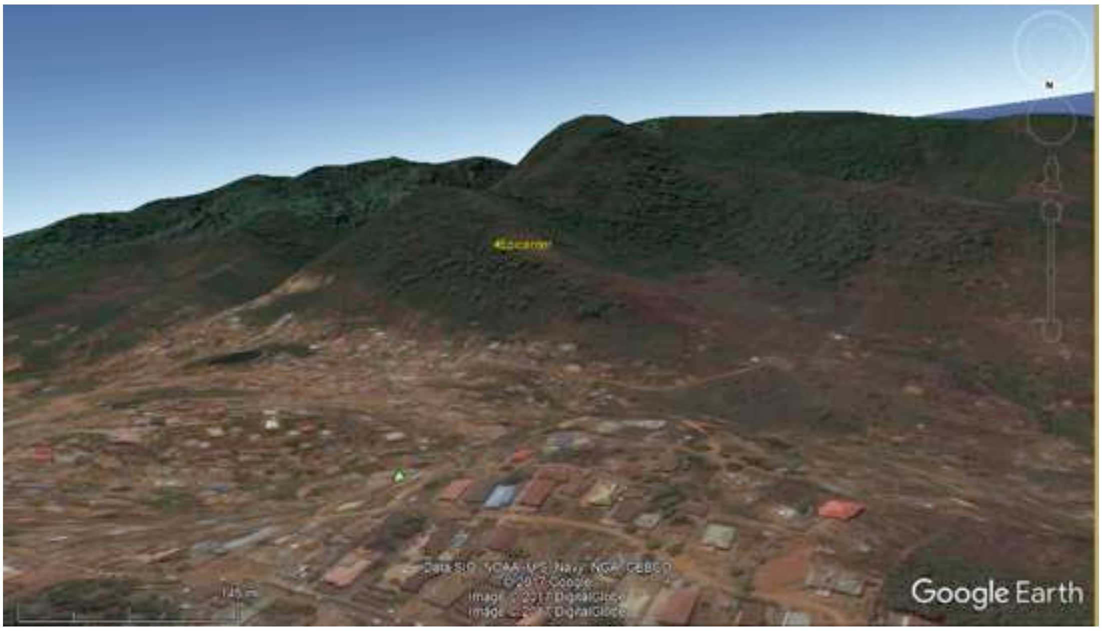


Figure 7-5. The undulating mountain ranges of the affected areas showing the epicenter's steep slope gradient and the on-going denudation process. Photo Credit: (Sillah and Williams 2017).

The geomorphology of the landslide area appears to be denuded due to forest logging (based on interview with communities) and other human activities, such as settlement. Figure 7-5 shows the denudation process and on-going process of land use and land cover transformation from forest into built-up areas.

The slope 'instability' due to slope gradient, weathering, erosion and geology of subsurface formation has shown few scars or gully erosions around the main landslide body in Regent. Figure 7-6 shows three scars / gully erosions that may trigger another landslides in the future, especially that one may be connected over time to the landslide's main scarp of the August 2017 landslide (left side). Although scientific evidences are not available, these scars may be also associated by lineament.

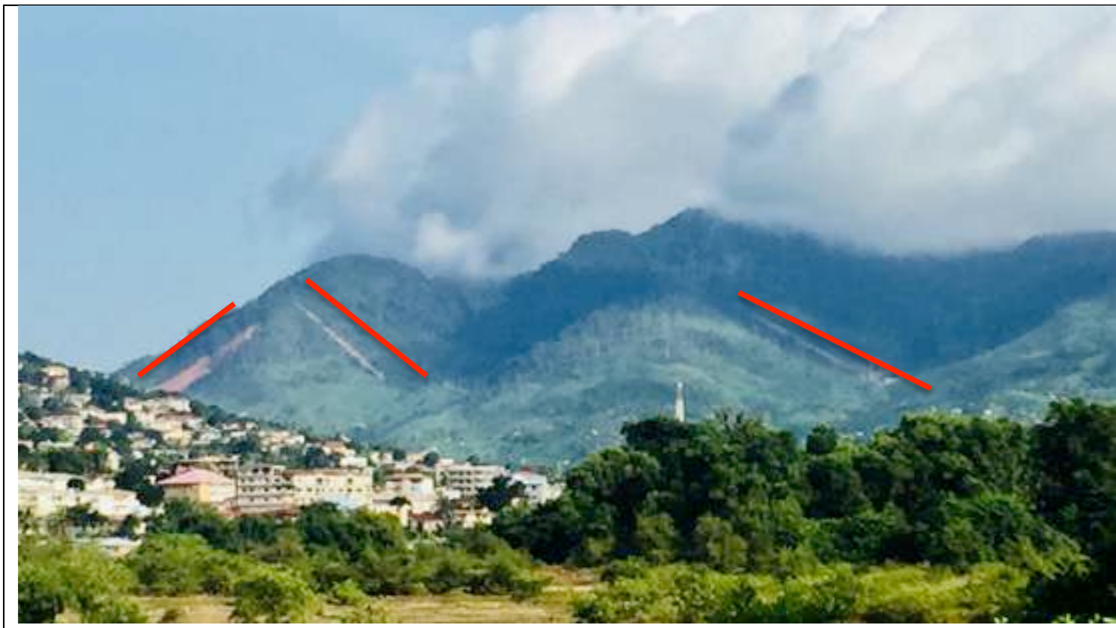


Figure 7-6. The observed scars / gully erosions around Regent (below the red line). One scar (left side) could be connected to the landslide's main scarp of the recent landslide, which can form a bigger landslide body. Photo taken from Lumley Beach, credit: Jnananjan Panda (UNDP, 2017).

7.3.2. Lineament

A lineament is a linear feature in a landscape, which is an expression of an underlying geological structure such as a fault. The lineament reflects the geological structure such as faults or fractures (Bates and Jackson 1980).

The geological map of Freetown shows few lineaments near the landslide's main scarp / head (Figure 7-7).

The lineaments may be one of the geological-related causes of the rock fall on the upper part of the slope. Lineaments that form landslide planar are observed at the landslide's main scarp / head in Regent (figure 7-8). At least 3 unconnected seasonal springs were observed flowing over the rock surface that forms the stratum of the weathered loose soil. These springs followed the sliding planar, which may be caused by lineament.

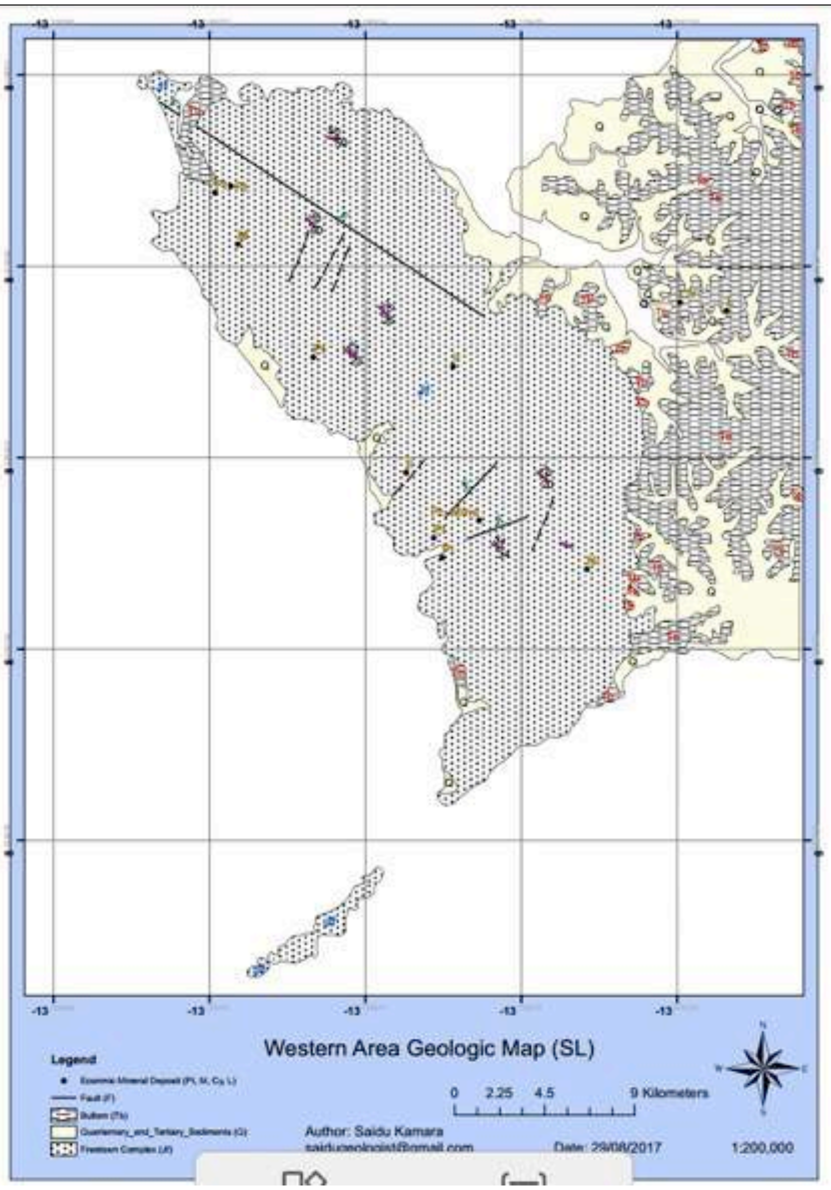


Figure 7-7. Lineaments as shown in the geological map of Freetown, which is near the landslide's epicenter, adopted from (Keyser and Mansaray 2004).

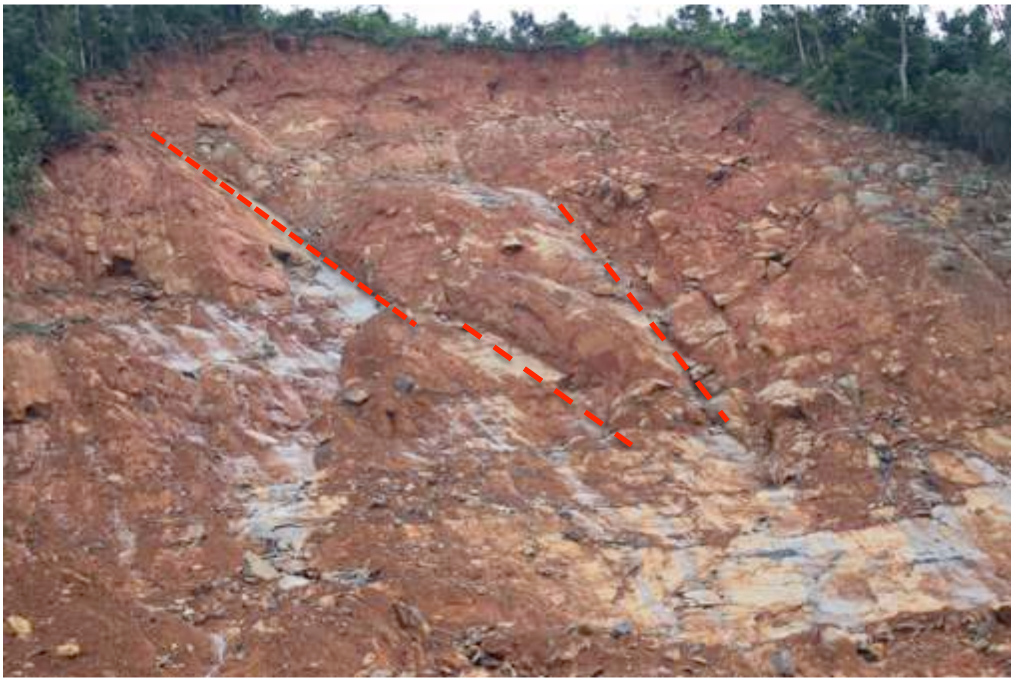


Figure 7-8. Fractured observed on the landslide main scarp (red line), which may be caused by lineament that further formed sliding plane. Photo Credit: Sillah and Williams (2017)

7.3.3. Weathering on the geological formation

The protoliths (lithology) of the affected areas are mostly of highly fractured of intrusive basic rocks that have been heavily weathered (Figure 7-9).

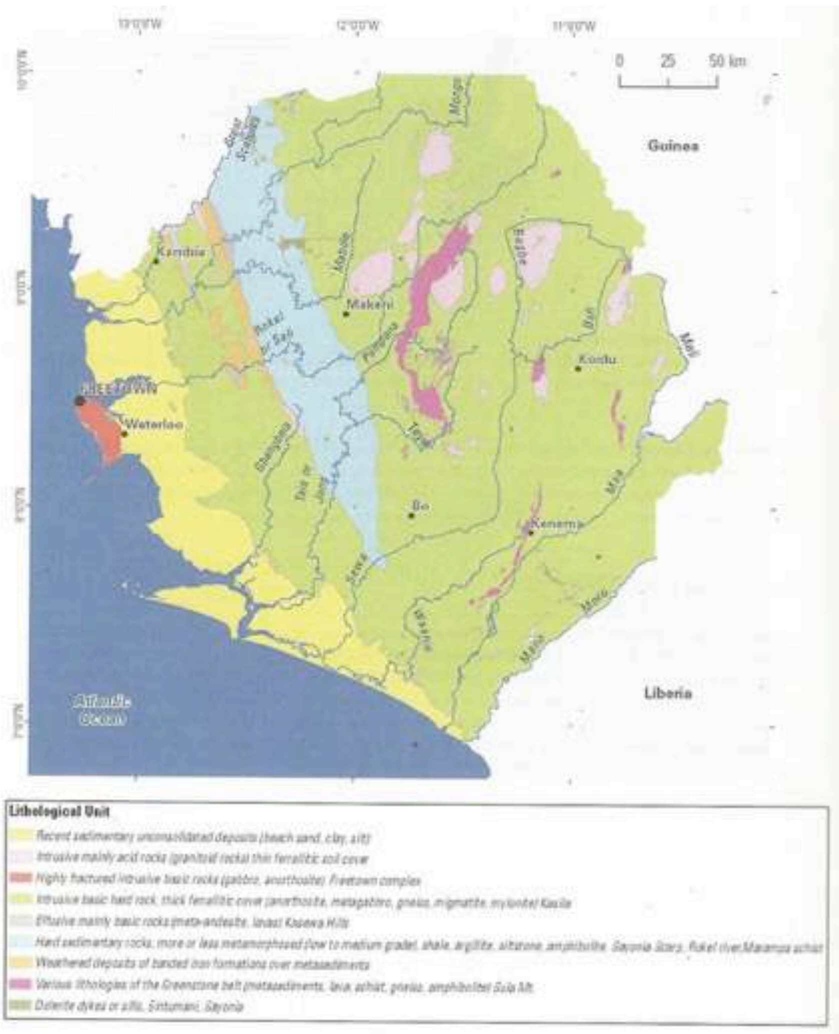


Figure 7-9. Lithological unit of Freetown composed of highly fractured intrusive basic rock (gabbro / anorthosite) (FCC 2014).

The Weathering profile is relatively thick (looking at the concave point of the breakage) at the top of the ridge. At the body of the landslide, the weathered oxidized material is loose while the underlying bedrock appears to have undergone differential weathering processes (Sillah and Williams 2017). Field observation on the lower part of the slope shows evidence of the heavy weathering of the base rock forming soil with thickness of around 50-60 cm (Figure 7-10).

The soil strength is a factor that may have not been considered by the affected populations when building the houses in supposedly not to be built-up areas.

Figure 7-10. The exposed weather materials at the top of the formation and at the lower part of the slope (upper foto, credit: Sillah and Williams, 2017).

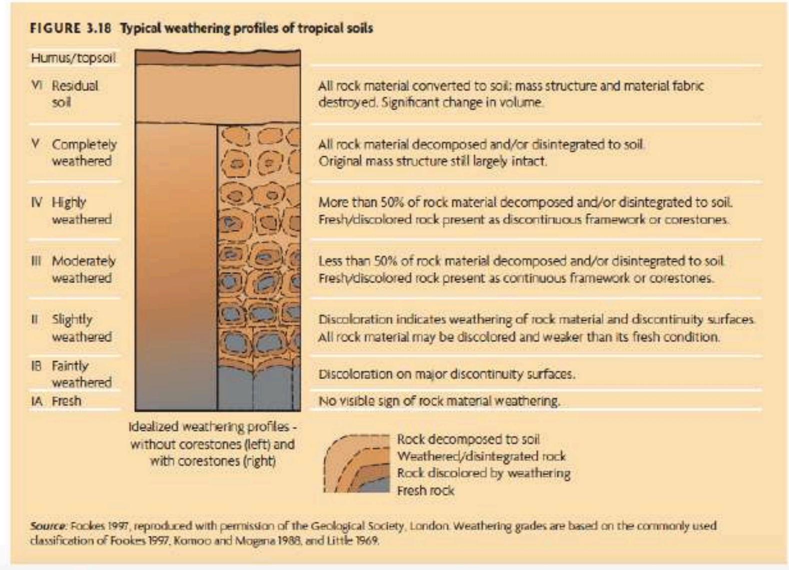


Figure 7-11. The Idealized weathering profiles on crystalline igneous and metamorphic bedrock, shown with and without residual rock cores. Source: British Geological Society, 1990 in (Thomas 1998).

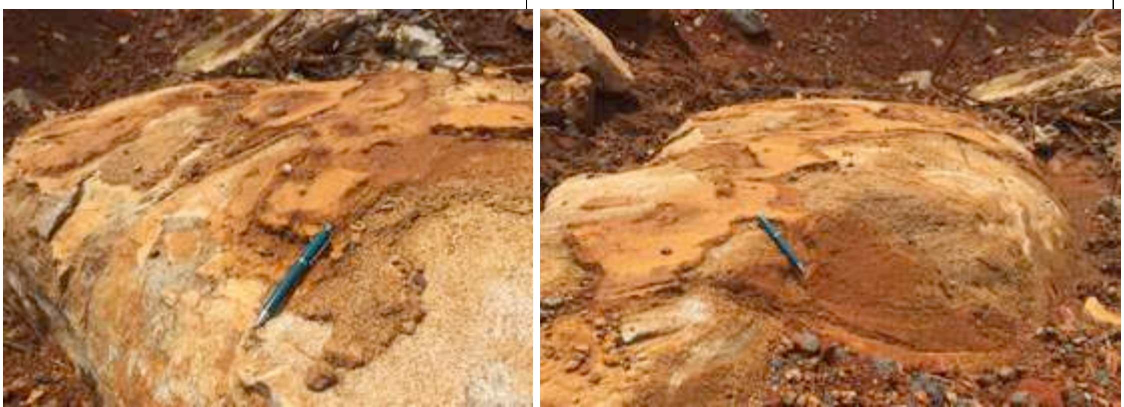


Figure 7-12. Exfoliation / onion-skin weathering on the host rock (Gabbro), photographed in Regent (left) and Malama (right).

With the top soil has been weathered and relatively thick at the crown crack of the landslide as well as the other areas of the lower parts of the slope (Figure 7-10), water infiltration with more than usual quantity may have destabilized the slope and thus triggered landslides in the lower part; in addition to forced strength causing rock falls at the upper part of the slope. Hence two forces have contributed to the landslide (a) gravity and lineament from the upper part of the slope and (b) slope destabilization at the lower part of the slope due to the erosion, weathering and various human activities triggering landuse change.

According to the weathering profile, more than 50% of the rock materials have been decomposed and disintegrated to soil (based on classification guidelines on Figure 7-11). The exposed rock surface has areas with clear exfoliation (Onion Skin weathering, Figure 7-12).

7.4. The un-natural-ness cause of the landslide

This section presents the human causes, which are together with the natural causes, contribute to the slope instability and the intense rainfall that trigger the recent landslide. The factors discussed in this section are explored from the debate that is presented in the Box 2-1 on how un-natural-ness of disasters are (hence the avoidance of using the term 'natural disaster'). It aims at bringing evidences about the human contribution of disaster and the importance of social aspect of disaster management. Debates and opinions after the recent landslide covered by various media have revealed how this recent landslide was a man-made tragedy that could have been prevented. [9, 10, 11]

This section thus presents various social aspects of the disasters, which are contributed by anthropogenic activities for various reasons. The general vulnerability factor of over population is briefly discussed in this section, in addition to some evidences on how human intervention has caused landuse change that has been altering the land cover characteristics around Freetown. The section further discusses the weak law enforcement allowing the population to reside in hazard-prone areas that are supposed to be buffer or green zone.

7.4.1. Landuse Change

Although in Sierra Leone, the availability of updated land-cover data is still limited, various studies in the country, using the available data, have shown how Freetown, the capital of Sierra Leone has experienced vast land-cover changes over the past three decades (Forkuor and Cofie 2011, Gbanie 2014, Mansaray, Huang et al. 2016). Rapid growth of population and urbanization has altered the natural land cover characteristics in Freetown. Between 2003 and 2011, a significant extent of forest, mangrove and agricultural lands has been reduced to accommodate the urbanization and human activities. As a result, built-up and bare land areas have been increased tremendously (Gbanie 2014). Figure 7-13 illustrates the changes occurred in land use of western urban area including the City of Freetown between 2003 and 2011.

During the 8 years, significant increases have been observed in built up area by 59.5%, bare land by 15.8% and water body by 20.6%, whereas significant reductions in forest regrowth (-7.6%), old growth forest (-8.6%), mangroves (-38.2%) and

[9] http://www.news24.com/Africa/News/sierra-leone-mudslide-was-a-man-made-tragedy-that-could-have-been-prevented-20170906.
[10] http://allafrica.com/stories/201708210030.html.
[11] http://af.reuters.com/article/africaTech/idAFKCN1AY0LI-OZATP

agriculture (-32.5%) were observed (Gbanie 2014). Sand mining along the coastline has caused infiltration of brackish water into swamps and, thereby, increase in area covered by water.

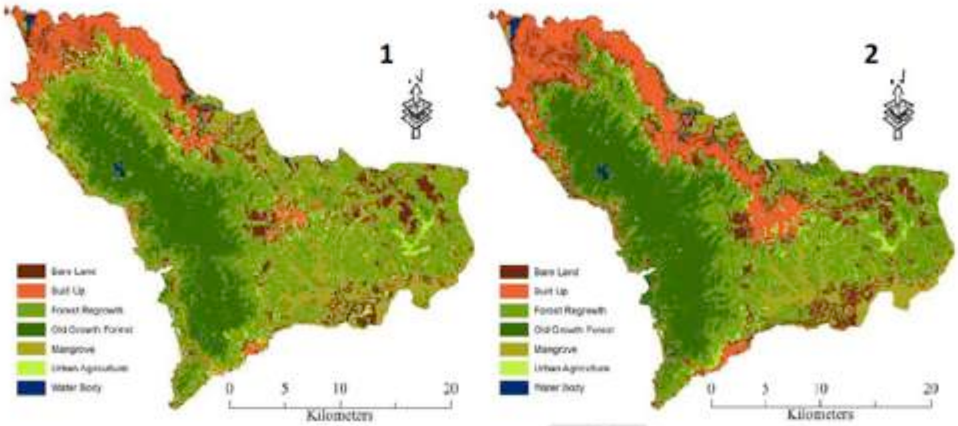


Figure 7-13. Comparison of Landuse change in 2003 and 2011 (Gbanie 2014)

The bar-diagram in Figure 7-14 illustrates the changes in proportion of different types of land cover occurred between 2003 and 2011.

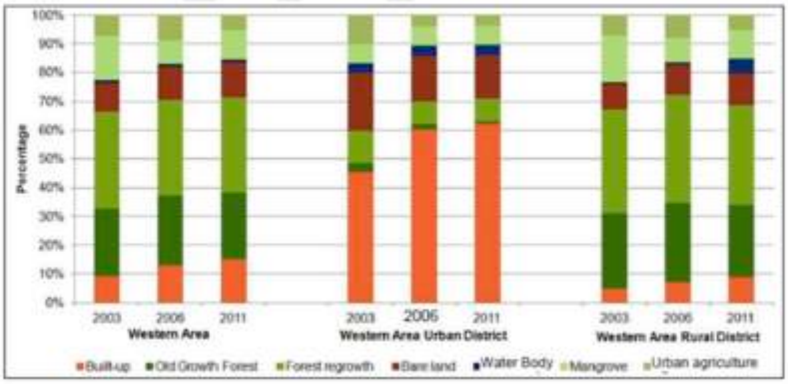


Figure 7-14. Graphical comparison between the land use changes in Western Area (Gbanie 2014)

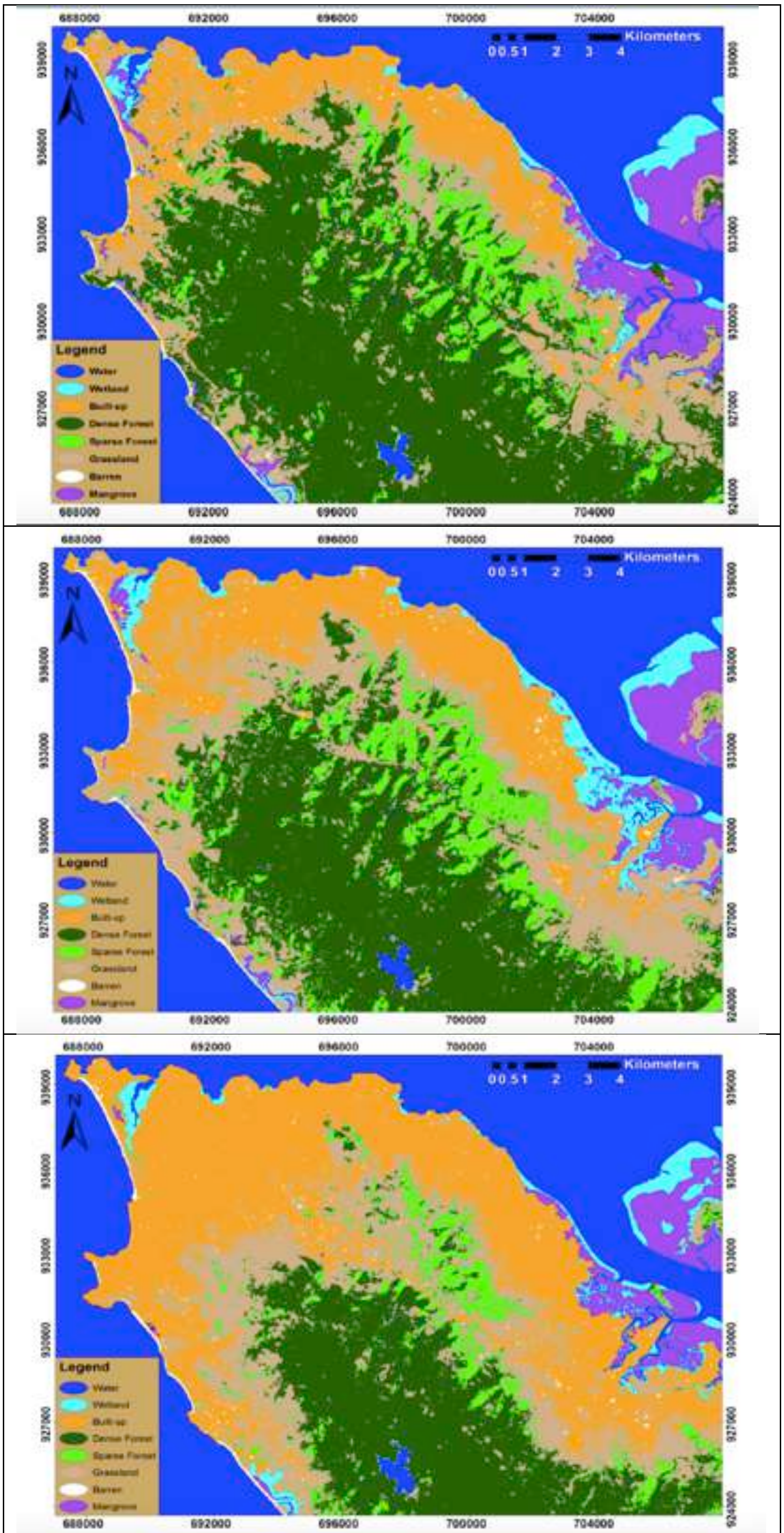


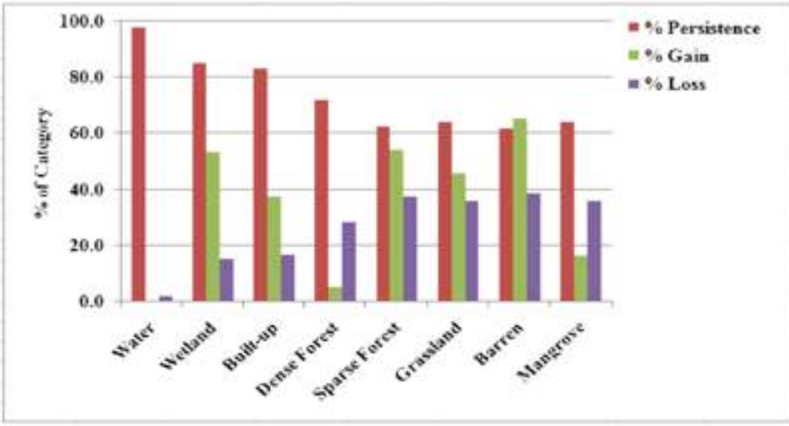
Figure 7-15. Land cover changes of Freetown from 1986, 2001 and 2015 (Mansaray, Huang et al. 2016)

Further, a study conducted in 2016 provided an up-to-date land-cover data for Freetown. Multi-temporal Landsat data at 1986, 2001, and 2015 were utilized to analyze the land cover changes over the last 20 years (Figure 7-15). The land-cover changes were mapped via post-classification change detection (Mansaray, Huang et al. 2016).

The study demonstrated the changes of land cover and landuse using eight land-cover classes or categories as follows:

1. Water (WT) includes rivers, ponds, lakes, sea, continental shelf or coastal waters
2. Wetland (WL) includes streams, swamps, and intertidal coastal and estuarine areas
3. Built-up (BT) includes residential, industrial, tarmac and other impervious surfaces
4. Dense forest (DF) includes evergreen forest, mostly of tall, hard wood or deciduous trees
5. Sparse forest (SF) includes degraded forest with reduced tree height, canopy and density
6. Grassland (GL) includes areas mostly of grass, shrubs, scattered trees, and annual crops
7. Barren (BN) includes bare earth, rocks, excavated surfaces, and sandy beaches
8. Mangrove (MG) includes coastal and riverine forests, mostly of the Rhizophora species

From the comparison of the multi-temporal data depicted in Figure 7-16, it shows that the land categories of built-up and barren have constantly increased, whereas the land categories of dense forest and mangrove have constantly been on the decline. This can be ascribed to the heavy pressure of humans on dense forest and mangroves. Dense forest has been on constant degradation to sparse forest, grassland, and to a lesser extent, built-up.



	Time points and area (km²)			Category interval change (%)		
Land-cover	1986	2001	2015	1986–2001	2001–2015	1986–2015
Water	105.8	104.2	106.5	−1.5	2.2	0.7
Wetland	6.9	12.5	6.0	81.2	−52.0	−13.0
Built-up	33.2	44.0	88.4	32.5	101.0	166.3
Dense forest	113.2	85.6	58.9	−24.4	−31.2	−48.0
Sparse forest	18.2	24.7	13.8	35.7	−44.1	−24.2
Grassland	53.1	62.7	60.0	17.6	−4.3	12.6
Barren	1.3	2.2	2.6	69.2	18.2	100.0
Mangrove	17.8	13.6	13.3	−23.6	−2.2	−25.3
Total	349.5	349.5	349.5			

Figure 7-16. Tabulated figures and statistics of land use change in Freetown depicting the increase of built areas by 166 % (Mansaray, Huang et al. 2016).

7.4.2. Population Growth

The root cause of the change of landuse and other factors that contribute to the loss of forest areas as the buffer zone is the rapid population growth in Freetown. The Freetown population has increased significantly over the past three decades (Statistics Sierra Leone 2016).

The population growth recorded from 2004 to 2015 is almost proportional to that recorded between 1985 and 2004. Tremendous migration into Freetown started during the civil war (1991–2002), and became more intense thereafter. As the political and business capital of the nation, Freetown's population continues to soar as more people move into the city, apparently in search of greener pastures (FCC 2014, Mansaray, Huang et al. 2016). Figure 7-17 shows the population growth profile of Freetown since 1963.

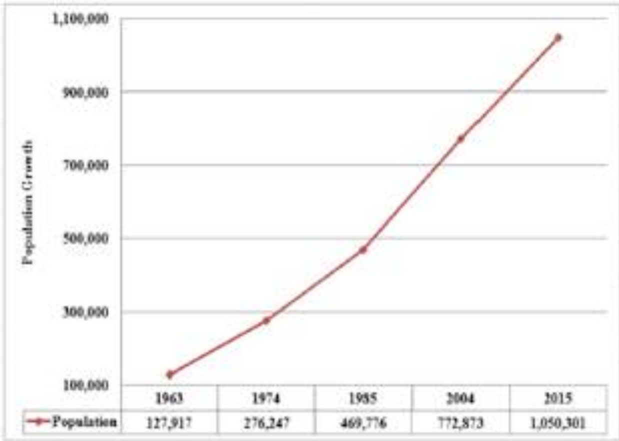


Figure 7-17. The trend of population growth of Freetown, compiled from various Sierra Leone Statistics reports (Mansaray, Huang et al. 2016).

The rapid population growth of Freetown as seen in Figure above definitely has implications for the land-cover changes in the city (see Section Landuse Change above). Residential land-use is apt to increase with increasing population. The major economic activities of most migrants in Freetown are small-scale farming, logging, quarrying, sand mining, and artisanal fishing. These activities, being intensified by the soaring population, have combined with the urban sprawl to trigger marked environmental degradation in Freetown (Mansaray, Huang et al. 2016).

Consequently, since the end of the civil war in 2002, it has been observed that the settlement areas have been doubled from 26.1 to 52.3 km2 (FCC 2014).

7.4.3. Deforestation

Deforestation means clearance or clearing or the removal of a forest or stand of trees where the land is thereafter converted to a non-forest use. It refers to the destruction of forests by people, include conversion of forestland to farms, ranches, urban use or built-up areas. [12]. Deforestation has become the order of the day with people grabbing any available land for housing, since land is very limited and hard to access, especially for the poor and middle-income groups (Forkuor and Cofie 2011, FCC 2014).

The Western Area Peninsula was declared a forest reserve in 1916 in order to retain the forest. The Western Area Peninsula Forest Reserve forms the only remnant of moist closed forest remaining in western Sierra Leone and probably the westernmost in the Upper Guinean Forest block. Deforestation in the Western Area has been exacerbated by ineffective policies and lack of law enforcement. Consequently, with the uncontrolled human settlement along the forested areas has been growing. The unplanned housing development has thus caused the forest boundary to be pushed

[12] Cambridge English Dictionary.

south by 5 km (FCC 2014). In addition, in the last four decades, there has been a lost of 60% of forest in the northern Freetown (Figure 7-18).

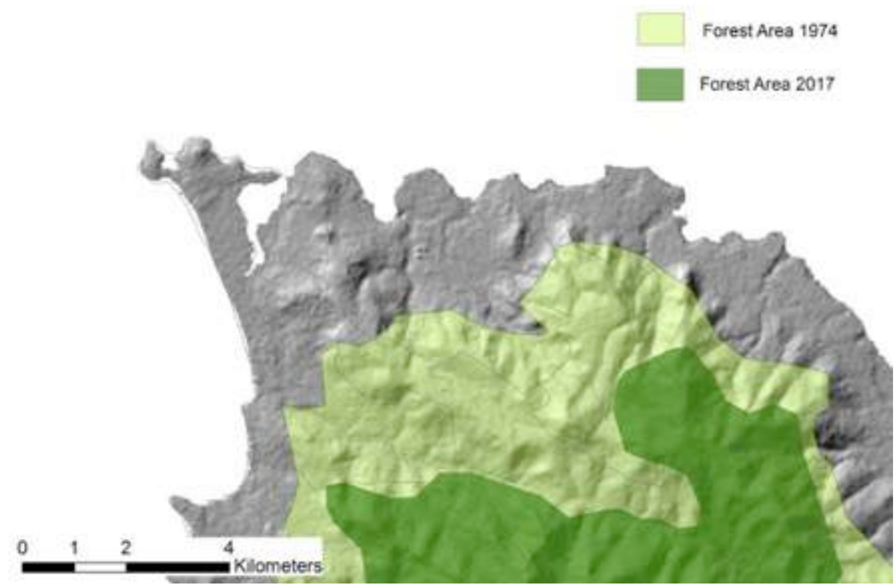


Figure 7-18. Comparison of forest area in 1974 and 2017 (World Bank 2017).

Section 7.4.1 has demonstrated the increased of the built-up areas, in which human influences are the principal driving forces of land-cover change in Freetown. An increase in population means more areas will be required for residential land-uses; and this is observed to be growing nowadays (Figure 7-19).

Figure 7-19. The growth of settlements around Regent showing the on-going process of land-use change from forest and grassland to built-up areas.

In other words, urbanization, agricultural expansion and other human activities have caused degradation of forests, resulting in degradation of buffer zone. The lack of proper urban planning, urban land use regulation and advocacy increases the risk of landslide and other related disasters. This is worsened by the lack of environmental

and disaster risk awareness of the local communities.
In other words, urbanization, agricultural expansion and other human activities have caused degradation of forests, resulting in degradation of buffer zone. The lack of proper urban planning, urban land use regulation and advocacy increases the risk of landslide and other related disasters. This is worsened by the lack of environmental and disaster risk awareness of the local communities.

7.4.4. The growth of Informal settlements

Sierra Leone is facing an urbanisation rate of 2.9 per cent, and 75.6 per cent of its urban population is currently living in informal settlements. Rapid urban development and a rising population have led to significant changes in Freetown over the last decades. The city of Freetown has seen a significant growth rate of about 3.07 per cent since 1985. Internal displacement during the civil war (1991-2002) and migration in search of employment to the city contributed to this population growth. Today, its population of over one million residents make it the most populous and densely settled city in Sierra Leone (ONS 2004, IIED 2017).

Rapid urbanization has led to the creation of pockets of informal, unplanned settlements. These are underpinned by a number of factors, notably the local economy, which is dominated by small-scale and informal businesses (mainly petty trade), and a growing demand for proximal living to business centers and markets, coupled with unaffordable land and housing in formalized areas (FCC 2014, IIED 2017).

The topography of Freetown, a peninsula constrained between the sea and the hills, limits the spatial expansion of the city, forcing low-income groups to settle mostly on marginal lands. The city has developed in three geographic areas: coastal settlements along rocky beaches of the Atlantic Ocean; sprawling inland settlements along the Sierra Leone River estuary; and hillside settlements on the steep hills of the city, which are rapidly encroaching onto vital forestland. In these settlements, flooding, various types of landslide as well as building collapses are common phenomena, which result in significant economic and other losses, such as the destruction of property and infrastructure, and can include injuries, diseases and fatalities. The incidence of epidemics, especially of waterborne diseases, is significantly high (FCC 2014, Mansaray, Huang et al. 2016, IIED 2017).

T he informal settlements that were closely observed were the ones that reside along the river bank, or within 1-15 meter strip of the river. The sizes and the structures of the houses of the informal settlements vary, depending on the length of the occupation and the capital they have to invest in the houses. Some of the houses are built of bamboo, duplex as well as brick (Figure 7-20).

Although there are no official numbers of the destroyed houses comparing formal and informal settlements, the remnants of the houses observed along the river banks were located very close proximity to the river. Although seasonal flooding is experienced by the informal settlers, the lack of risk knowledge on the occurrence of flash floods triggered by the intense rainfall could cause serious destruction to their settlements in the future. The colony of the uncontrolled growth of such settlements is growing and removing them from the high-risk areas would be more complicated since some have established their livelihood along the river bank itself.

Figure 7-20. Informal settlements along the river bank in Freetown City (A,B) and the old point bar in Kamalama (C). Note how the informal settlements have also formed a colony or neighborhood (Freetown Center, D).

In short, the growth and sprawl of informal settlements and the continuous lure of rural-urban migration have led to a range of risks, both episodic and ‘everyday’. These risks are more concentrated in the pockets of informal settlements and are becoming progressively embedded in the way of life of its residents, with adverse effects. In the long run, removal of such informal settlements would give a permanent solution for vulnerability reduction. However, without strong law enforcement, the growing vulnerability would be anticipated and more loss, damages and casualties could be expected.

Figure 7-21. The growing colony of informal settlements in Freetown and one of the examples of their attached established livelihood.

7.5. Weak Disaster Management Aspect

Aside from the natural causes and human dimensions that contribute to the incidence of landslide, some aspects pertaining to disaster management need to be highlighted, which reflect the un-preparedness state of the whole system including the communities living in hazard-prone areas in Freetown.

7.5.1. The Non-existence of a Landslide Hazard Zonation

The first risk assessment for Sierra Leone was conducted in 2004 through a document that details the hazard profile of Sierra Leone (ONS 2004). The natural hazard analysis includes three types of hazards:

1. Meteorological Hazards, which include drought, tropical storms, thunder and lightning.
2. Hydrological Hazards, which include flooding.
3. Geological Hazards, which include coastal erosion, upland erosion,

Although the section of geological hazards heavily discusses the landslide in details in Freetown, however it does not discuss about the landslide hazard zonation.

A more recent report on environmental impact assessment of Freetown details the areas at risk of landslide and flooding in Freetown. A spatial map was produced showing the areas at risk to landslide and flooding; however detail zonation of landslide types do not (yet) exist.

A current ONS-World Bank Multi-City Hazard and Risk Assessment includes Freetown as one of the project areas. The project outcome will be published in November 2017 and it would be crucial to see how detail the landslide assessment is done, which could be used to inform public and to be used as a tool for decision making process.

7.5.2. Lack of legislation pertaining to Landslide Risk Management

The growing settlements, either registered/ formal or informal, on the high-risk areas in a way demonstrates the weak enforcement of landuse planning that is based on disaster risk assessment.

The National Land Policy of Sierra Leone recognizes the complexity in increasing demand for land after the conflict and in managing the then-anticipated growth of informal settlement. Section 3.2. Page 16 of the National Land Policy states (GoSL 2015):

> "There is an increasing demand for land, following the upsurge of new settlement related to expansive migration during and after the war. The incidence of confrontations over land in Freetown and of illegal settlements has indeed become alarming, since violent land conflicts are not uncommon. As a result, the capacity of the land management system to deliver secure land rights in general, (for urban residential purposes and small entrepreneurs especially in Freetown and Bo) has been stretched tremendously.
>
> Thus, land rights especially in the Western Area have become unclear owing to the legacy of civil unrest, increased informal land occupations, encroachment on public lands, increasing land grabs, suspect land transactions, and the deterioration of paper records and the land registration process."

Further, Section 3.5. of the National Land Policy states:

> "the revision of Sierra Leone's land legislation is an on-going process. …..The work of Law Reform Commission is being carried out in-tandem with the formulation of a new Land Policy" (GoSL 2015)

In the Land Policy, the closest measure that touches upon the policy pertaining to land use planning and disaster risk is Section 8.1 on Land Use Planning Principles:

> "….It is recognized that land use planning is essential to the efficient and sustainable utilization and management of land and land based resources with a view to benefiting all Sierra Leoneans. Along with the planning emphasis on social stability, housing security, rural development, environmental protection and sustainable social and economic development, land use planning should be cognizant of the needs of vulnerable and marginalized people..."

Further, under Policy Statement, it states:

i. *The Government will conduct regulated spatial planning, and monitor and enforce compliance with those spatial plans*, including balanced and sustainable territorial development, in a way that promotes the objectives of this policy. In this regard, spatial planning will reconcile and harmonize different objectives of the use of land and land based natural resources.

ii. *National, regional and local spatial and structure plans* will be developed and coordinated, and appropriate risk assessments for spatial planning will be required.

The basic for establishing legislation pertaining to landslide risk management is there yet requires further plan of implementation and enforcement.

7.5.3. Community's Low Risk perception

The areas affected in fact are not new settlements. Field visits revealed that some of the houses in such settlement has been established for more than 30 year. In addition, there are also informal houses built along the river in the last 10, 5 and more recent years. The affected communities interviewed randomly at the holding center managed by WFP and UNICEF, revealed that they would come back to their old houses and rebuild them with their own resources. This is despite the fact that they would continue to live with constant risk of flooding and landslide. The zero or low risk perception is the major reason why the communities are willing to live in such high-risk areas.

New settlers residing along the river also revealed that the accessibility to water is one of the reasons why they decided to reside there at the first place, in addition to its proximate location in the city center. In fact, the impacts of the recent flood do not change their perception towards risk. The community members organized themselves in cleaning up the sediments brought by the flashflood and use the materials for construction and embankment to their settlements along the river. Positively, this shows community's coping strategy to the impending risk (Figure 7-22).

Figure 7-22. The growing construction of houses on the river bank as the result of low risk perception (top) and the use of river sediments for embankments and construction (bottom).

7.5.4. Non existence of early warning system or contingency plan

The initiatives of establishing community-based early warning system has not been established in the affected areas, or the areas identified as risk-prone areas listed in Section 4.1 and 4.2 above.

The foundation for establishing community-based early warning system is there at the community level, indicated by the existence of active community-based or religious based groups. It is observed that around the affected areas, religious facilities (i.e. mosques and churches) are available and there are active religious activities where local communities regularly participate.

The current initiative of UNDP Sierra Leone[13] in installing automated weather stations in various parts of the country is something that can be linked to the

[13] http://www.sl.undp.org/content/sierraleone/en/home/presscenter/pressreleases/2016/07/15/automatic-weather-stations-to-reduce-climate-change-effects-.html

community-based initiatives. The initiative of linking scientific information and community-based early warning system and subsequently, development of contingency plan will help at-risk communities in reducing the impacts of disasters.

8. Conclusion and Recommendations

The rather unexpected incidence of the August 2017 landslide in Freetown has revealed various dimensions of vulnerability faced by the stakeholders (i.e. institutional vulnerability) and many populations in Freetown. The disaster also triggered a lot of debates and opinions that that kind of disaster is man-made, which could have been prevented. Many, however, also thought that it was purely natural.

This report has thus revealed the causal and trigger factors the August 2017 landslide in Freetown, based on field observation, experts consultations and historical environmental-related assessment. This report also reveals the evolution of disasters, built up by small-scaled but frequent disasters in various parts of Freetown. To conclude, the trigger and causal factors of the recent landslide can be summarized as follows:

1. Physical cause, which was triggered by the intense rainfall. The 1500 mm rainfall recorded during the incidence is three times than the average recorded rainfall from July 2016-July 2017, which is way above rainfall average in Sierra Leone.

2. Natural causes; which are associated with gravity movement favored by typical geological and geo-morphological conditions prevailing the area. The weathered lithology, which is of Gabbro complex, exacerbated by the possible lineament causing linear cracks forming the sliding form in the upper part of the slope in Regent is one of the causes of the slope instability which triggered the landslide.
   The morphology / steep slope of the epicenter of the landslide is another cause that supported the gravity mechanism of the landslide.
   The heavily weathered surface soil is also one of the most important factors in the process. The surface soil layer provides an effective transport mechanism for water depending on the degree to which mass and particles are aggregated. The slope instability was thus caused by the stress of the mass from the upper part, due to geological processes described above. The stress from the lower part of the slope was caused due to the change of the landuse, which weakened the soil stability. The growing of the settlements along the river has caused the slope destabilization due to loss of strength of the soil layer. This, combined with the downward movement due to gravitational force described above, trigger the recent landslide.

3. Other social factors caused by human intervention in the high-risk areas were also identified as another human cause of the disaster. The rapid population growth has pushed the Freetown population to massively change forested areas to become settlements. The weak law enforcement on clearing the high-risk areas free from settlement in a way encouraged the growth of informal settlements.

4. Regulation pertaining to disaster management is another aspect that is observed to contribute to the overall causes of the landslide. Institutional reform is needed and various sensitization program on landslide and flashflood risk management need to be implemented to cover the gaps that were revealed by the recent landslide.

Although a more comprehensive recommendation for landslide risk management is provided in a separate document, the following recommendations are some of the key actions that could summarize the needs for an effective landslide risk management in Sierra Leone generally and specifically in Freetown:

1. Conducting a detail landslide hazard zonation for Freetown and other parts of the country.

   It is essential to identify, evaluate and delineate landslide hazard prone areas for proper strategic planning and mitigation. To delineate landslide susceptibility slopes over large areas, landslide hazard zonation (LHZ) technique can be applied.

   For landslide hazard assessment, it is generally assumed that the conditions that led to the past landslides in the area if reoccurred elsewhere in the given area, may again result in landslides. The first step of conducting LHZ is a systematic landslide inventory. Thus, data on location, type of landslide, dimension and material involved in the past landslide need to be recorded in an inventory of historical disaster, through field surveying and the GPS data point. However, landslides on inaccessible areas like gorges, high cliffs and in the dense vegetated areas were identified on through remote sensing. Many other techniques or methodologies on LHZ exist and can be adopted according to the data availability in the country.

   There is an an-going initiative of Sierra Leone Multi-Hazards Study, which includes Freetown Landslide Inventory Sourcing. This should be taken further and a more detail assessment aiming at having a landslide hazard zonation in the country should be conducted. With a proper landslide hazard zonation, proper sustainable planning could be exercised and could be manifested, for example through building regulation that informs 'what' could be 'built 'where' and 'how'.

2. Revision of policy on landuse planning in high vulnerable areas to the impacts of landslide.

   The existing National Landuse Policy of Sierra Leone lists down challenges on setting-up and implementing a sustainable land use plan, especially to the areas prone to landslides and flashflood. The ideal situation would clear the settlements along the identified areas at risk to landslide and flashflood, resulted from the landslide hazard zonation.

The upcoming strategy of the recovery program should not only consider the rehabilitation of multi-sectorial loss and damages, including livelihood restoration, but also revisiting the existing landuse plan and suggesting the revision that could prevent the growth of future vulnerability. Adoption of national policy on building / settlement regulation needs to be enforced seriously to prevent future settlements on the vulnerable areas. For example, the Philippines' legislation through the Presidential Decree No. 1067, known as the Water Code of the Philippines, specifies: [14]

> "Article 51. The banks or rivers and streams and the shores of the seas and lakes throughout their entire length and within a zone of three (3) meters in urban areas, twenty (20) meters in agricultural areas and forty (40) meters in forest areas, along their margins, are subject to the easement of public use in the interest of recreation, navigation… and salvage. No person shall be allowed to stay in this zone longer than what is necessary for recreation, navigation, fishing or salvage or to build structures of any kind"

3. Development of relocation policy guidelines for communities living in high-risk areas.

As it has been proved by other disasters, the recent landslide disaster has been used as an opportunity to dig deeper into the root causes of the vulnerability to landslide and other hydro-meteorological disasters. Residing in the high-risk areas, notably on the riverbanks and the areas not suitable for settlement is one the root causes of the recent landslide. Additionally, the same practice, mostly triggered by the informal settlement's pattern of land occupation in hazard prone areas or buffer zone could potentially grow more risk from future disasters.
The Government of Sierra Leone had taken an initiative of relocating the affected communities living along the high-risk areas. Although a land has been allocated for this purpose, relocation's is a complex exercise and its consequences can be disastrous than the initial event itself (Oliver-Smith 1991). However, if properly managed, resettlement programs following disasters can present significant opportunities for risk reduction and development. In the often-hectic context of reconstruction following a disaster, there is usually little time for meaningful stakeholder consultation or appropriate planning. Instead, decision-making tends to be reactive and top–down (Badri, Asgary et al. 2006).

Following the landslide disaster, an Environmental Risk Assessment Working Group was established, coordinated by the Environmental protection Agency (EPA) and the Ministry of Lands, Country Planning and the Environment (MLCPE). One of the agenda is developing relocation guidelines for resettlement of population residing in disaster prone areas around Freetown,

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[14] http://pcij.org/wp-content/uploads/2015/01/Joint-DENR-DILG-DND-DPWH-DOST-Adoption-of-Hazard-Zone-Classification.pdf.

Sierra Leone. UNDP is involved in this process and has drafted the above-mentioned proposed resettlement guidelines. The proposed guidelines highlight the importance of considering the following dimensions and attributes of the resettlement process: physical, legal, economic, social, psychological, cultural, environmental, political, administrative, and territorial.

The draft guideline is another deliverable of this assignment, and is attached with this report.

4. Setting up a reliable early warning system (EWS).

   One of the flaws observed in the recent landslide is the inexistence of the EWS among the communities living in high-risk areas. EWS is not only about warning people, but also involving complex analysis of the science and society, which makes it more people-centered. An effective people-centered EWS comprises four inter-related elements, spanning knowledge of hazards and vulnerabilities through to preparedness and capacity to respond: [15]

   - Risk Knowledge. Risk assessment and mapping will help to set priorities among early warning system needs and to guide preparations for response and disaster prevention activities. Risk assessment could be based on historic experience and human, social, economic and environmental vulnerabilities.
   - Warning Service. A sound scientific basis for predicting potentially catastrophic events is required. Constant monitoring of possible disaster precursors is necessary to generate accurate warnings on time. Approaches that address many hazards and involve various monitoring agencies are most effective.
   - Communication and Dissemination. Clear understandable warnings must reach those at risk. Regional, national and community level communication channels must be identified in advance and one authoritative voice established.
   - Response Capability. It is essential that communities understand their risks; they must respect the warning service and should know how to react. Building up a prepared community requires the participation of formal and informal education sectors, addressing the broader concept of risk and vulnerability.

   It is important to highlight that a weakness or failure in any one of these elements could result in failure of the whole system. The recommended people-centered EWS should have strong inter-linkages between all elements in the chain, from the design to the implementation level.

[15] A more through information can be referred to *A checklist of Development of Early Warning System:* http://www.unisdr.org/files/608_10340.pdf

In the context of Sierra Leone, support to Meteorological Department and other technical institutions would be helpful in data management and climate modeling. This, coupled with installation of certain physical infrastructure pertaining to EWS and community-based EWS, would certainly raise another level in the overall community preparedness level.

5. Development of emergency response mechanism at community level.

   The recent disaster revealed the low response capacity of the communities towards responding to disasters. It then suggests the importance of setting up a community emergency response mechanism. This response mechanism should be part of a broader disaster management plan at the community level, which is linked to municipality or other local government disaster contingency plan. It should include training of medical first responders, urban search and rescue teams, development of evacuation systems, and so on.

   This further reveals the importance and urgency of having a local (government)-level disaster management plan, which encompasses a comprehensive contingency plan, response mechanism, management of evacuation / emergency camp for displaced people by disasters, and so on.

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