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**UNIVERSITY OF GHANA**

**DEPARTMENT OF GEOGRAPHY AND RESOURCE  
DEVELOPMENT**



**UNDERSTANDING MASS WASTING IN METROPOLITAN  
ACCRA**

**BY**

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**THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF  
GHANA, LEGON IN PARTIAL FULFILLMENT OF THE  
REQUIREMENT FOR THE AWARD OF MPhil GEOGRAPHY  
DEGREE**



**SEPTEMBER 2020**

**DECLARATION**

I, Abigail Ama Kum Arhinful, declare that this research and its entire content is a representation of my own work. All secondary resources have been duly acknowledged and I remain answerable to every question pertaining to this work. No part of this work has been submitted for the award of a degree in any other institution.

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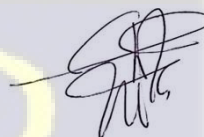
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**DEDICATION**

To my lovely family, God bless you for the support.



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I want to first thank God almighty for life and protection. To my supervisors Dr. John Kusimi and Prof. Martin Oteng-Ababio, I say a very big thank you for your unflinching support throughout this study. Their criticisms and directives ensured the success of this research. I will like to acknowledge Dr. G.A.B Yiran for his support and clarifications on the GIS aspect of this work. God bless you all.



## ABSTRACT

Metropolitan areas are one the fast-growing urban metropolis in Sub-Saharan Africa with respect to both demographic densification and expansion of the built-up environment. The sprawling nature of Metropolitan Accra has also resulted in various human activities such as settlement, stone quarrying, and sand mining. The resultant effect is the exhibition of signs of mass wasting in the metropolitan area for some years now. Mass wasting refers to the 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. The study employed a mixed-method approach to ascertain the triggers of mass wasting in Metropolitan Accra. Specifically, the study assessed the vulnerability levels, residents' perceived risk to mass wasting and presented some recommendations for policy considerations. A total of 130 respondents were used for the study: 124 household survey and 4 in-depth interviewees. The results further showed that the main trigger for mass wasting as perceived by respondents in the study communities were anthropogenic factors with environmental impacts making majority of responds in relation to mass wasting. The results again revealed that respondents at the summit of hills perceived themselves to be less exposed to mass wasting than those along the slope and base of the hill thus respondents along the slope and base of the slope are perceived to be at greater risk of mass wasting events. The findings again revealed that, majority of the communities at the northern part of Ga South were less prone to mass wasting compared to those of the southern part, exposed to high risk of mass wasting. Weija-Gbawe had some patches of areas very low to mass wasting with the interior part accounting for some major high-risk zones. The study suggested some recommendations for policy considerations to help manage the event.

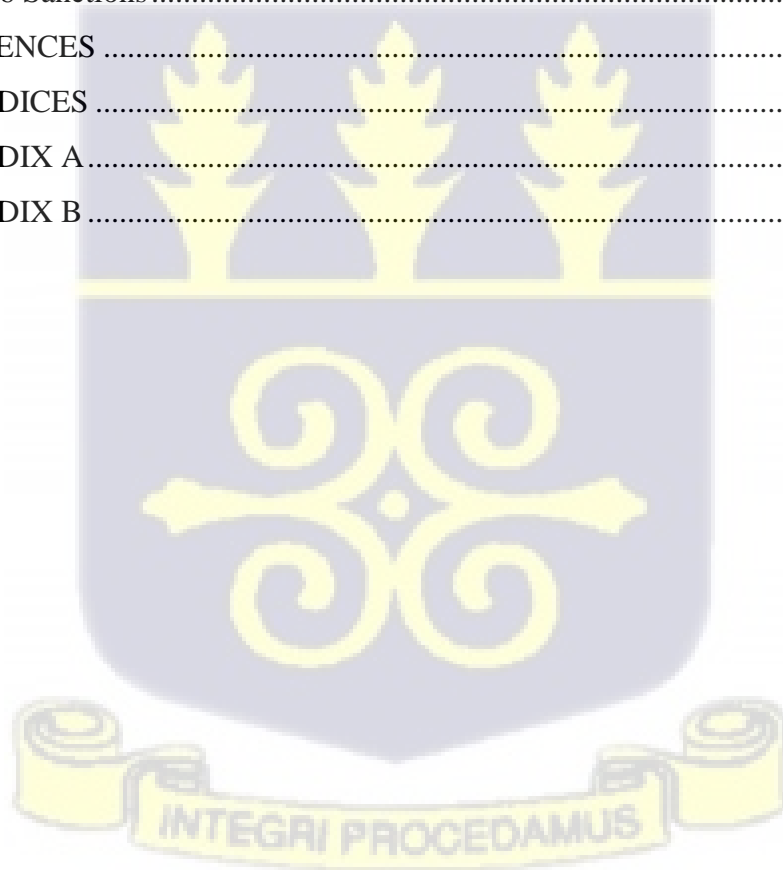
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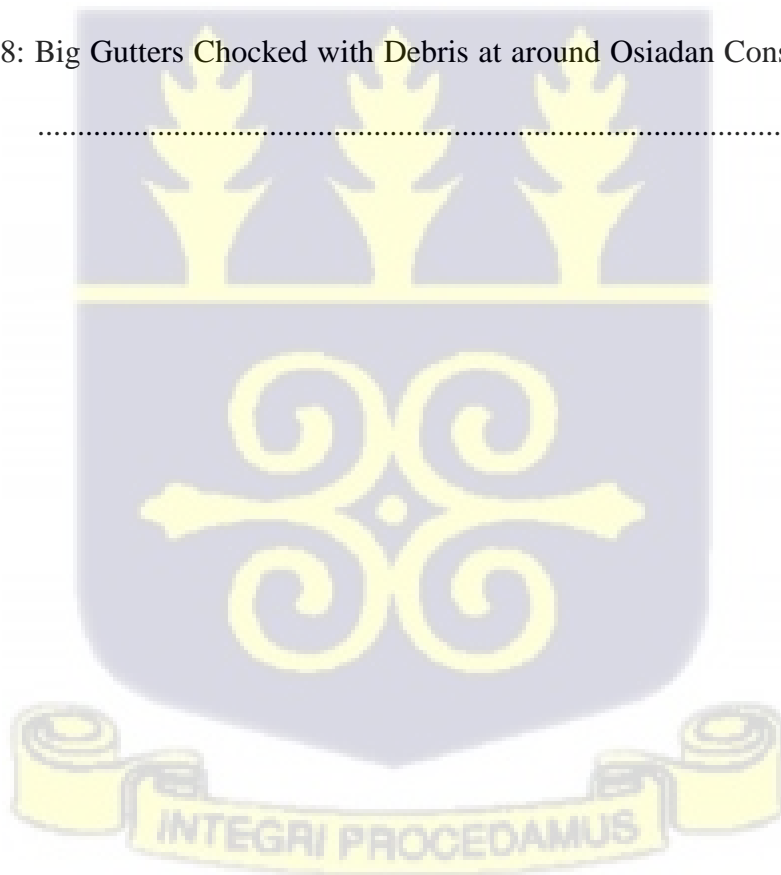
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## CHAPTER ONE

### BACKGROUND OF STUDY

#### 1.0 Introduction

The topic of urban settlements and their exposure to damage caused by environmental hazards, in the past decades, has become a major research subject in both the social sciences and the natural sciences. Its transdisciplinary relevance comes from the fact that in many past scenarios catastrophic events were linked to multiple interrelated factors (Simon, 2019). A wide range of urban hazards such as floods, earthquakes, volcanic eruption and mass wasting pose a potential threat to the security of people living in cities and municipal areas. Over the last decades, the study of mass wasting processes on slopes has become a major topic of research as they are eradicating the successes of development (Gruber, Huggel & Pike, 2009). They occur naturally in all parts of the world and are part of the normal adjustments of slopes to changing conditions (Rodriguez, Fournier, Chamot-Rooke and Huchon, 2012). Mass wasting “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” (USGS, 2016). Mass wasting is a general term covering all natural processes by which large masses of earth material are moved by gravity from one place to another. The term landslide will be restricted to rapid movements in which soil or unconsolidated earth material moves as one or several units on a single or many slip planes while the term mass movement and mass wasting will be used synonymously.

Mass wasting, among the various geologic hazards, are considered as one of the most serious geologic hazards and the third most crucial natural disaster, which threaten and

influence the natural and socio-economic conditions of many countries and the world at large (Abdallah, 2007; Igwe and Una, 2019; Schuster and Highland, 2007; Tofani, Segoni, Agostini, Catani, and Casagli, 2013). It is responsible for significant loss of life and injury to people and their livestock as well as damage to infrastructure, agricultural lands and housing (Perera, Jayawardana, Jayasinghe, Bandara and Alahakoon, 2018). Between 1990 and 2006 landslides caused more than 100,000 fatalities worldwide (Oven, 2005). Like other natural disasters where restoration can occur, mass wasting usually create permanently unstable sites that often are suitable only for designation as un-developable open space (Burke, Sattler and Terich, 2003). In cases where reconstruction is possible, solutions are often complex, expensive, and unfortunately, rarely work.

Mass wasting is termed differently depending on factors such as material composition and speed of movement (Rodriguez et al., 2012). Stetler (2014) stated that, the rates of mass wasting processes vary from imperceptible motion to rapid translation of large volumes of materials buttressing van Westen, Alkema, Damen, Kerle, and Kingma (2011) three (3) major classifications for mass wasting. As stated by van Westen et al., mass wasting can be classified according to rate of movement (rapid or slow), type of movement (fall, sliding or flowing) and types of material involved (rock, debris or soil). Hazards associated with these processes are, in large part, directly a function of the speed of the process.

The occurrence of mass movements depends largely on driving and resistant forces (Balsubramanian, 2011). Every mass standing on a slope possesses these forces. The standing mass has the driving force due to its weight. The slope and substratum have

the resisting force (Kusky, 2008). Slope stability depends on the equilibrium between the driving and restoring forces that act on potentially unstable soil mass. The driving forces acting on slope material, including gravity, result in a shear stress that must be counteracted by the available shear strength (van Beek, Cammeraat, Andreu, Mickovski and Dorren, 2008). In summary, when the driving forces (example: shear stress) overcome resisting forces (example: shear strength) the slope will fail thus causing mass wasting. Also, the steeper the slope's angle, the greater the component of force acting parallel to the slope and the greater the chances of mass wasting. The steepest angle that a slope can maintain without collapsing is its angle of repose. It is at this angle that the shear strength of the slope's material exactly counterbalances the force of gravity (Monroe and Wicander, 2006).

Sahin (2004) described triggers of mass wasting as an external provocation such as water, earthquake and volcanic eruption that causes a near-immediate reaction in the form of a mass wasting by rapidly increasing the stresses or by reducing the strength of slope material. Weak materials such as weathered materials on slope (Geological causes), morphological causes by vegetation removal (by drought or forest fire) and tectonic uplifts as well as human disturbances like excavation of slope, loading of slopes (placing earth fills at the top of a slope) and artificial vibrations from explosions are some examples of other triggers of mass wasting (Highland and Bobrowsky, 2008). Mass movements often are triggered by other natural hazards. For example, mass wasting and flooding are closely related because both may occur due to heavy precipitation, runoff, and ground saturation (Mahmood, Qureshi, Tariq, Atique and Iqbal, 2015; Sahin, 2004). Debris flow usually occurs in small, steep channels and are often mistaken for floods. Mass wasting and lateral spreads often result from seismic

activity (Mahmood et al., 2015). Consequently, the simultaneous or sequential occurrence of different hazards may produce cumulative effects that differ significantly from those expected from a single event. This is of critical importance in defining factors related to the occurrence of a given type of mass movement (Saha, Gupta and Arora, 2002).

The incidence of mass wasting and seismicity of East Africa has been attributed to the existence of the East African rift valley system. In West Africa, incidence of mass wasting is relatively low compared to the East with incidences occurring in Cameroun and the Benue state in Nigeria (Midzi et al., 1991 as cited in Adu-Boahen, Dadson, and Yike, 2020). In Ghana however, mass wasting activities date as far back as the 1930s. The first incident of a mass wasting occurred on June 15, 1933 on a section of the Akwapim-Togo range in the Volta region (Bokpe, 2015). In 1968, a mass wasting event released about 1,500 cubic meters of rock, soil and vegetation near Jamasi in the Sekyere District blocking the main Kumasi-Mampong truck road for a total of ten days. The Kasoa-Weija portions of the roads was blocked owing to mass wasting, resulting in a significant traffic jam for hours. The Accra-Aburi road in 2019 experienced some form of debris flow after a heavy down pour made it impossible for usage (Atarigiya, 2016). These records in the country have served as a wakeup call for researchers and hence this study. It is therefore important that proper attention be directed to evaluating the full range of potential mass wasting hazards for the purposes of risk assessment.

### **1.1 Problem Statement**

The Greater Accra Metropolitan Area (GAMA) is one of Sub-Saharan Africa's fastest-growing urban conurbations in terms of both demographic densification and built-up

area (Møller-Jensen, Agergaard, Andreasen, Oteng-Ababio, and Yankson, 2020). According to G. S. S. (2014), the municipalities have an intercensal growth rate of about 3.1%. Factors such as immigration and natural population growth contributes to its growth and expansion. This has rendered areas that were previously neglected and considered unsafe (earthquake and flood prone areas, steep slopes) to be gradually taken over putting the populace in harm's way (Simon, 2019). The sprawling nature of Metropolitan Accra has also resulted in various human activities such as settlement, stone quarrying, sand mining (plate B) and the likes (Adu-Boahen et al., 2020). This has resulted in the cutting of the slope basement, increasing the steepness of the slope and the possibility of mass wasting in the area. The springing up of buildings on and around the hill has also increased the amount of pressure exerted on the slope and the removal of the vegetation cover has rendered the area susceptible and vulnerable to the incidence of mass wasting (Adu-Boahen et al., 2020; Alexander, 2005). Activities from sand winning and stone quarrying have left the hills with gaping holes that can collapse at any point in time (plate B) (News Ghana, 2015b). Seismic activities also occurs in Accra (Amponsah, 2004). Amponsah (2002) observed that the Weija hills area is close to the boundary between the Greater Accra region and the Central region, a point where fault lines intersect. (Adu-Boahen et al., 2020) avers that, these fault systems are an extension of the Romanche fracture zone, which extends from Brazil to Africa across the equatorial Atlantic region.





**Plate 1.1: Evidence of Sand Winning around Michigani**

Source: Author's Field Data, 2020



**Plate 1. 2: Picture of Deep Gully in the Ga south Municipality**

Source: Google earth

Notwithstanding the increased volume in academic literature on different aspects of mass wasting science such as; triggers of mass wasting (Adu-Boahen et al., 2020; Bradley et al., 2019; Nelson, 2013; Saemundsson, Petursson, & Decaulne, 2003), perception related to mass wasting (Adu-Boahen et al., 2020; Calvello, Papa, Pratschke, & Crescenzo, 2016; Chiu & Eidsvig, 2017; Setiawan & Hizbaron, 2014); mass wasting studies using GIS and Remote Sensing (Cao et al., 2019; Nugroho, 2012; Pacheco and Suárez, 2014; Saha, Gupta and Arora, 2002; Sharma, 2008) mass wasting hazard mapping, risk assessment and management (Castro, 2013; Dahal and Dahal, 2017; LaPorte, 2018; Lee and Pradhan, 2007; Oven, 2005; Parkesh, 2012; UNISDR, 2016) and impacts and effects of mass wasting (Geertsema, Highland, & Vaugeouis, 2009; Gracheva & Urushadze, 2011; Kennedy, Petley, Williams, & Murray, 2015; Selby, 2012), demonstrates a significant gap in this field of research and requires further investigations such as;

- a. Additional research needed to ascertain the areas more prone or not mass wasting in Ghana.
- b. More published academic articles on mass wasting in Ghana.
- c. Some studies of mass wasting study topics in isolation especially researches on hazard mapping, perception of people on mass wasting and causes and impacts of mass wasting

This study deals with delineating the triggers of mass wasting in Metropolitan Accra, presenting an analysis of mass wasting based on vulnerability levels, risk perception in terms of experience, preparedness, causes and impacts, providing a more holistic idea of the occurrences of the hazard in the area.

## 1.2 Research Questions

- a. What are the principal causes of mass wasting in the study area?
- b. Where are the zones with the greatest mass wasting vulnerability?
- c. What are the impacts of mass wasting in the study area?
- d. How safe are the respondents in the Ga South and Weija-Gbawe Municipalities?
- e. What are some of the strategies that can be adopted to manage mass wasting?

## 1.3 Research Objective

The main objective of this study is to determine the triggers of mass wasting in Metropolitan Accra.

Specifically, the study seeks to:

- a. Assess the vulnerability levels of residents in the study area.
- b. Determine the causes and effects of mass wasting in the study area.
- c. Gauge residents' perception towards the risk from mass wasting.
- d. Provide recommendations for policy considerations on mass wasting.

## 1.4 Significance of Study

The findings of this study first will add to the knowledge of the causes and impacts of mass wasting along the Accra-Kasoa road. This will greatly benefit researchers especially those in disaster prevention and geomorphology by serving as a referral material. It will also help in the promotion of mitigation measures.

Additionally, the findings of this study will also aid in the sensitization of stakeholders for improved management measures and proper urbanization measures as this will help in resource allocation. It will assist stakeholders in identifying and delineating unstable

hazard prone areas, so that environmental regeneration programmes can be initiated, adopting suitable mitigation measures. It will also go a long way to help planners to choose favourable locations in the municipalities in when it comes to siting developments, townships, dams, roads and others and restrict new developments in hazard prone areas. further, the study will help the government in quick decision making for rescue and relief operations and provide researchers information on mass wasting.

### **1.5 Thesis Structure**

The study is arranged in six chapters. The first chapter will introduce the study, the problem statement, research questions and objectives and conclude with the significance of the study.

The second chapter reviews related literature on specific themes including mass wasting as a geological hazard, mass movement impact and human vulnerability, remote sensing and GIS in hazard mapping. The chapter will wrap up with a review on disaster management and vulnerability framework and adopt the Crunch “pressure and release” framework from (Blaikie, Cannon, Davis and Wisner, 2003)for this study.

Further, the third chapter will be dedicated to the Study Area and Methodology of the study. Specifically, the chapter will focus on the data collection methods, sampling technique, sampling size, data sources and the study area.

The fourth chapter analyses and discusses the vulnerability levels of respondents on mass wasting while chapter five looks at residents’ perceived risks of mass wasting.

Chapter six discusses some recommendations for policy discussions and the final chapter presents the summary of key findings, conclusion and recommendations.

### **1.6 Chapter Summary**

This chapter presents the general introduction of the problem statement with some research questions and the objectives of the study. It also states the significance of the study and the arrangement of the study. The next chapter is dedicated to the review of related literature, theoretical and conceptual frameworks of the study.



## CHAPTER TWO

### LITERATURE REVIEW

#### 2.0 Introduction

The chapter presents literature vital to the understanding of mass wasting, a challenge facing most urban communities. The central theme of the chapter is the discussion of the classification, causes of mass wasting, its impacts and human vulnerability. The chapter again looks at the use of the Remote Sensing (RS) and Geographic Information System (GIS) techniques in mass wasting hazard assessment.

#### 2.1 General Overview of Mass Wasting

Mass wasting according to Meinhold, Arslan, Lehnert, and Stampfli (2011) is a general term describing the down slope movement of sediment and rock under the pull of gravity without a transporting medium. It is a natural hazard that could result in severe damages and are difficult to control. It happens when the gravitational force acting on a mountain overcomes the resistive forces of that mountain which works to keep rocks and soil in their places. These resistive forces, including the cohesive strength and internal friction between materials, are referred to as the mountain slope's shear strength. Any factor that weakens the shear strength of the mountain slope could lead to mass wasting. Mass wasting generates significant financial losses as well as numerous fatalities and injuries. The majority of the losses occur in settlements built on gently sloping hillsides (Bogaard, 2001). Too often, their occurrence in places prone to other natural disasters, such as earthquakes, floods, or volcanic eruptions, obscures their full impact, resulting in unreported losses. Rapid, short-lived events, a slow-moving slide mass, or imperceptibly slow-moving soil creep are all examples of mass waste. They represent substantial short- and long-term direct and/or indirect risks. The damage

of structures that sustain transportation, parks and recreational places, residential and commercial buildings, sewage, and dam supplies are the most evident direct repercussions.

The formation of instability in the slope system is required for the operation of mass movement processes. The gravitational force is the most common source of stress (Rudolf-Miklau, Bäk, Schmid, and Skolaut, 2011). The steepness of slopes, the lithological quality of slope materials, and the amount of water in the material are all elements that influence mass motions. The angle of friction and cohesiveness are the two most significant characteristics in mass movement. The gravitational force's magnitude is proportional to the slope's angle and the weight of slope sediments and rock. The equation below models this relationship.

$$F = W \sin \phi \dots\dots\dots (1)$$

Where  $F$  is gravitational force,  $W$  is the weight of the material occurring at some point on the slope, and  $\phi$  is the angle of the slope.

The relationship between the stresses exerted to the materials that make up the slope and their intrinsic strength determines the slope's stability. When stresses surpass internal strength, mass movement occurs (Rudolf-Miklau et al., 2011). Frictional resistance, which is determined by the size, shape, and arrangement of the particles, provides intrinsic strength to slopes made of loose materials like sand and gravel (van Beek et al., 2008). Particle cohesion, which is governed by the availability of moisture in the soil, is obtained by slopes made up of silt and clay particles. Rock slopes generally have the greatest internal strength due to the crystalline structures (van Beek et al., 2008).

## 2.2 Classification of Mass Wasting

There are various classifications of mass movements dating back from the olden days till this present era (Abdallah, 2007, van Beek et al., 2008). The classification of mass wasting mostly relies on the motion and mechanism of it happening, but a more complex combination of processes of mass movements prevail in reality. Kusky (2008) argued that too much complex a classification would be ineffective. Hence three principal types of movement will be discussed – slide, fall and flow, and are classified depending on type of movement, type of material being displaced, moisture content, type of strain and failure and rate of movement (Abdallah, 2007; Nelson, 2018).

### 2.2.1 Slides

Slides can be subdivided into translational slides, which have predominantly planar shear surfaces, and rotational slides in which the shear plane is concave-up (Lucia, 2014). Translational movement is common in cliff forming units, particularly where there are interbedded competent and incompetent rocks. It is increased by the presence of marls, and invariably marly or argillaceous limestones. Rotational movement commonly occurs in relatively unconsolidated poorly cemented sandstones, weathered basalts and the surficial cover. The rotational movement may result in the upper part of the slumped mass being back-tilted towards the failure surface (Malamund, 2014).

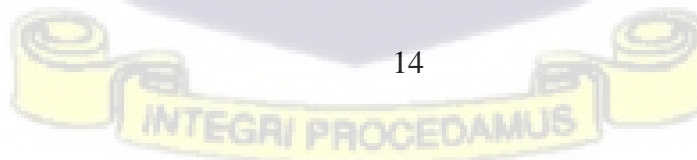
There have been a number of slide occurrences around the study area and parts of Ghana. Slides account for the highest number of occurrences in the country (Table 2.1; Table 2.2; figure 2.1 a, b, c, d).

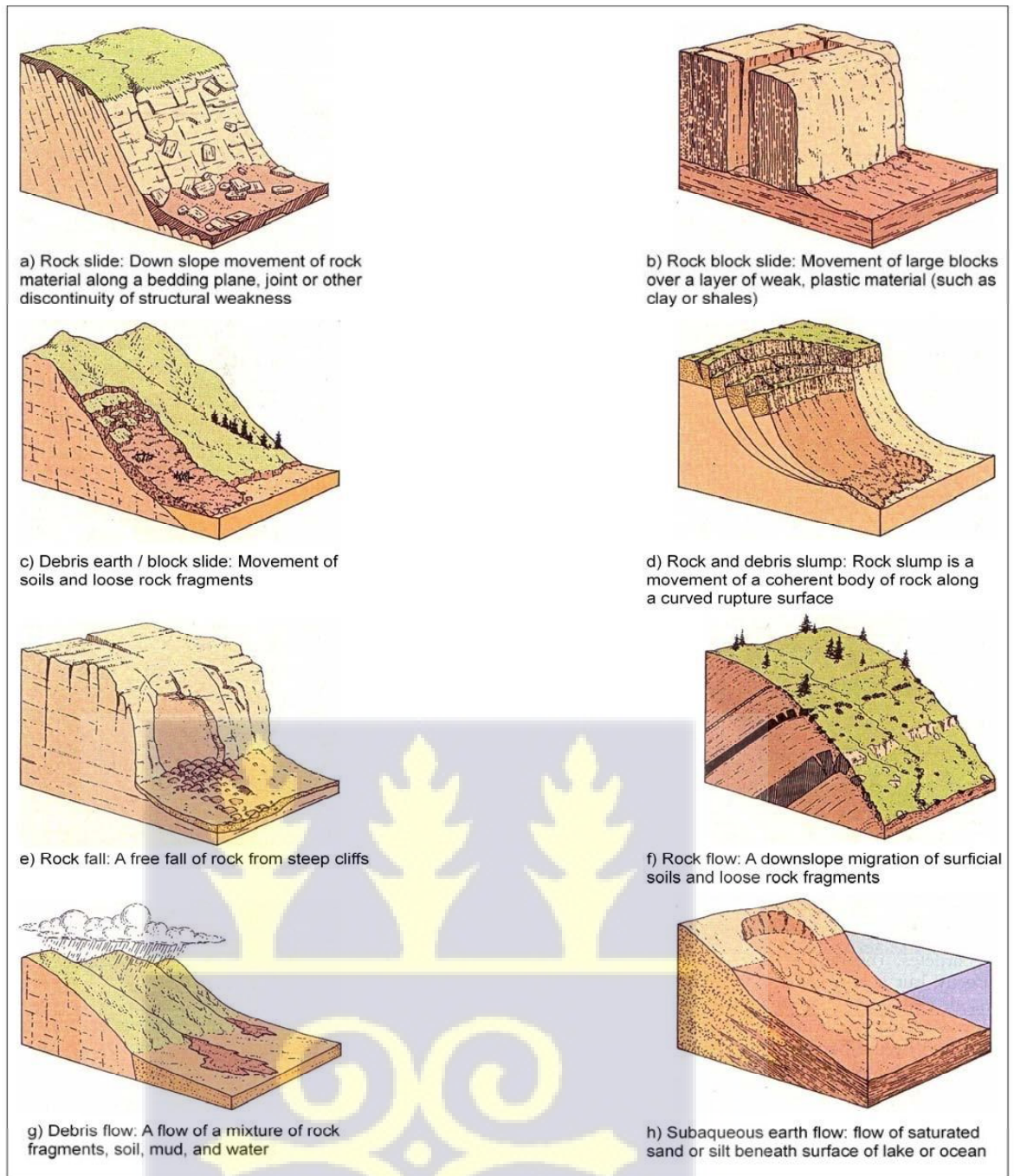


**Table 2.1: Classification of mass wasting**

Types of movement		Materials in motion	Moisture content	Nature of movement	Rate of movement	
Slide	Translational	Rock slide	Unfractured rock mass	Low	Shallow slide approximately parallel to ground surface of coherent rock mass along single fracture	Very slow to extremely rapid
		Rock block slide	Fractured rock mass		Shallow slide approximately parallel to ground surface of fractured rock	Moderate
		Debris/earth slide	Rock or soil debris	Low to moderate	Shallow slide of largely deformed masses of soil	Very slow to rapid
		Debris/earth block slide			Shallow slide of largely undeformed masses of soil	Slow
	Rotational	Rock slump	Rock	Low	Rotational movement along concave failure plane	Extremely slow to moderate
		Debris/earth slump	Rock or soil debris	Moderate		Slow
fall	Rock fall	Detached rock Joints blocks	Low	Fall of individual blocks from vertical faces	Extremely rapid	
	Debris/earth fall	Detached cohesive units of soil		Toppling of cohesive units of soil from near-vertical faces such as river banks	Very rapid	
Flow	Rock flow		Rock (especially readily deformable types such as shales and clays)	Low	Slow plastic deformation of rock, or soil	Very slow to extremely slow
	Debris flow		Mixture of fine and coarse debris (20-80% of particles coarser than sand-size)	High	Flow usually focused into pre-existing drainage lines	Very rapid
	Earth flow	Slow	>80% sand-size	Low	Confined elongated flow	Slow
		Rapid	Soil containing sensitive clay	Very high	Rapid collapse and lateral spreading of soil following disturbance, often by an initial slide	Very rapid

Source: Adopted from Abdallah, 2007





**Figure 2.1: Diagram showing the types of mass wasting**

Source: Abdallah, 2007



**Table 2.2: Occurrences of mass wasting events in Ghana**

Year	Region	Type of mass movement	Corresponding number of mass wasting event		
			Slides	Falls	Flows
1933	Akwapim-Togo ranges	Mass wasting	1		
1959	Saltpond bypass	Mass wasting			
1960	Cape Coast by pass	Mass wasting			
1960	Cape Coast by pass	Mass wasting			
1961	Cape Coast by pass	Mass wasting			
1961	Kumasi- Obuasi road mile 18	Mass wasting			
1961	Kumasi-Obuasi road mile 21	Mass wasting			
1961	Kumasi- Obuasi road mile 22	Mass wasting			
1962	Sekondi college face	Mass wasting			
Not known	Sekondi residency face	Mass wasting			
1962	Agona Akim road mile 7	Mass wasting			
1962	Agona Akim road mile 10	Mass wasting			
1962	Agona Akim road mile 9	Mass wasting			
1962	Agona Akim road mile 13	Mass wasting			
1963	Mpataba Elubu road mile 17	Mass wasting			
1963	Mpataba Elubu road mile 23	Mass wasting			
Not known	Kumasi Accra road mile 5	Mass wasting			
Not known	Kumasi Accra road mile 6.5	Mass wasting			
Not known	Kumasi Accra road mile 3.5 behind AGIP petrol dump	Mass wasting			
Not known	Kumasi-Mampong road mile 23	Mass wasting			
Not known	Accra coast at the back of Ussher Fort	Mass wasting			
Not known	Accra coast near Black Star Square	Mass wasting			
1969	Voltaian Scarp (near Jamasi)	Mass wasting	1		
1972	Kam	Mass wasting	1		
March, 2005	Kam	Mass wasting	1		
June, 2010	Peduase-Water Works Road	Mass wasting	1		
October, 2010	Adukrom-Yensi	Mass wasting	1		
October, 2012	Wassa Essikuma & Wassa Nkran	Mass wasting	1		
June, 2013	Kasoa-Weija Highway	Mudslide	1		
October, 2018	Peduase-Ayi Mensah Road	Rock fall		1	
October–November, 2019	Peduase-Ayi Mensah Stretch	Mass wasting Rock fall	2	1	
June, 2019	Kasoa– Accra Highway	Mudslide	2		

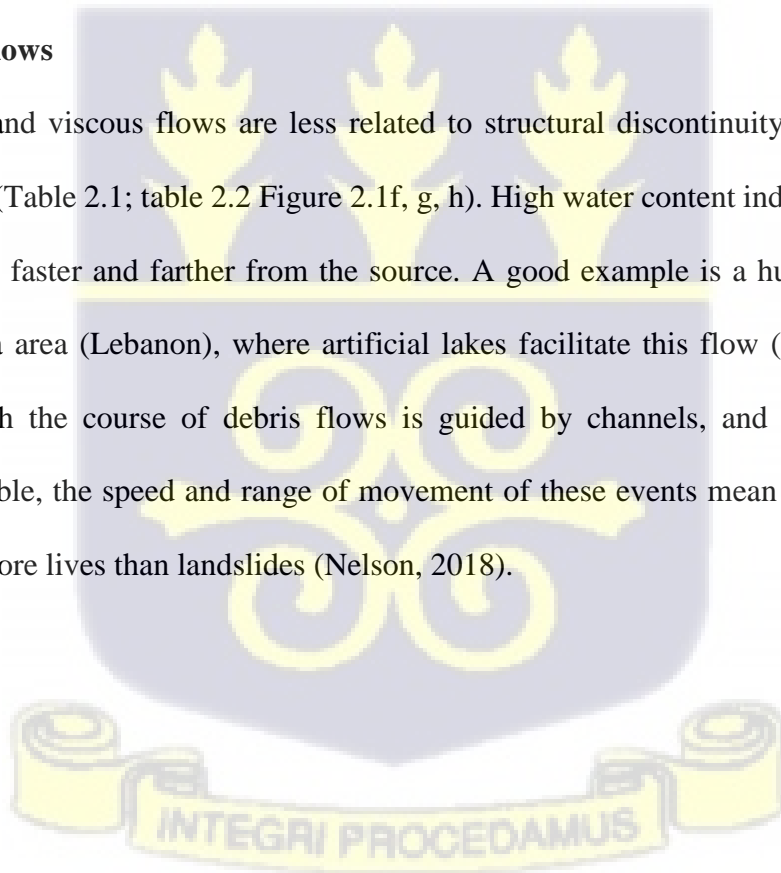
Source: Ayetey, (1991); GhanaWeb, (2019); News Ghana, (2015a)

### 2.2.2. Falls

Falls occur when masses of rock or other material detach from a steep slope or cliff and descend by free fall, rolling or bouncing (Abdallah, 2007). Falls are generally less frequent than slides in the study area and in the country as a whole (Table 2.1; Table 2.2; Figure 2.1e, Figure 2.2). Falls generally occur quite suddenly with very high velocities. Large rock falls originating from a considerable height above the ground spread their debris over an extensive area unless the dispersal of material is confined by topography. This is very treacherous in mountainous area (Bathurst et al., 2003; Carere and Ratto, 2001; Fard, 2001). The highest rock fall hazard exists when joints and bedding planes are inclined at a steep angle, as is the case of the highly folded sedimentary rocks that are common in alpine mountain belts.

### 2.2.3. Flows

Debris and viscous flows are less related to structural discontinuity (joints, bedding planes) (Table 2.1; table 2.2 Figure 2.1f, g, h). High water content induces the material to move faster and farther from the source. A good example is a huge earth flow in Aaqoura area (Lebanon), where artificial lakes facilitate this flow (Abdallah, 2007). Although the course of debris flows is guided by channels, and to that extent is predictable, the speed and range of movement of these events mean that they tend to claim more lives than landslides (Nelson, 2018).





**Figure 2. 2: Evidence of rock falls at Michigani, Tuba Junction**  
Source: Google Earth

### **2.3 Factors causing mass wasting**

The study of mass wasting involves an understanding of the factors that affect their occurrence. Many factors are responsible for mass wasting which can occur as a result of sudden or gradual changes on a slope including the types and properties of underlying bedrock, soils and surficial deposits, angle and direction of slope, type of vegetation, amount and distribution of rainfall, type of construction, placement of cuts and fills, and the presence of ancient mass wasting deposits. Again, certain management activities including clearing of forests and road construction are commonly perceived as potential mass wasting initiators. Some of these factors are explained below.

#### **2.3.1 Climate and Water**

Climate influences the amount and state of water in the form of snow or water. It also influences the type and amount of vegetation (James, Harden, and Clague, 2013). This

means that it “regulates” the addition or expulsion of water to increase or decrease the rate of slope failure and also the growth of vegetation which retards the power of erosion and mass wasting on a slope. Slope saturation by water is a primary cause of mass wasting. Saturation can occur in the form of intense rainfall, snowmelt, changes in ground-water levels, and surface water level variations along coastlines, earth dams, and in the banks of lakes, reservoirs, canals, and rivers (Guzzetti, Peruccacci, Rossi, and Stark, 2005; James et al., 2013). A study by Oven (2005) and Alexander (2005) revealed that, the predominant trigger of mass wasting activity was highly intensified and prolonged rainfall, with earthquakes and volcanoes being the far less frequent triggers.

Highland and Bobrowsky (2008) also stated that mass wasting and flooding are closely allied because both are related to precipitation, runoff, and the saturation of ground by water. Mass wasting can cause flooding by forming mass wasting dams that block valleys and stream channels, allowing large amounts of water to back up. This causes backwater flooding and, if the dam fails, subsequent downstream flooding. Alam (2020) also concluded that heavy rainfalls are the main cause of mass wasting in Rangamati and Chittagong which are communities in Southeast Bangladesh. According to Alcantara-Ayala and Moreno (2016), rainfall was documented as the main trigger of mass wasting in recent decades but the respondents also considered earthquake since seismic activity is common on a regional level. Igwe and Una (2019) added in their studies at Nanka, Nigeria that mass wasting in the area is mainly during the rainy season, and are triggered by water infiltration in slopes with high gradient, where poorly consolidated sands overlies less permeable silty clay units in the Nanka Formation. The

increase in pore water pressure due to soil saturation leads to the reduction of the shear strength and loss of apparent cohesion.

Sahin (2004) studied the relationship between the amount of rainfall and frequency of mass wasting events and also established that increase in the number of mass wasting coincided with the period of increased rainfall. Guzzetti et al. (2005) reported that the degrees of severity of Himalayan mass wasting are increasing due to heavy or prolonged rainfalls, earthquakes, or both. It was reported that the majority of the mass wasting occurred when daily rainfall was higher than 200 mm.

### **2.3.2 Geology and Soil**

Geological characteristics are one of the most crucial controlling factors of mass wasting, since each geological unit have different susceptibility rates. Weak rocks like sedimentary rocks will weather quickly than hard rocks like igneous and metamorphic rocks (Ameer et al., 2008).

Abdallah (2007) articulated that, mass wasting is quite important in areas where clayey rocks (clay-stones, marls, shales, muds, flysch) or morainic materials outcrop. Thus, higher soil clay percentage generally increases mass wasting susceptibility. This is because the presence of clay minerals between soil mineral particles can cause mutual repulsion force which causes friction between mass wasting causing particles especially when saturated with water. Yalcin (2007) in a study established that mass wasting mostly occurs on clay soils. The author further added that, higher clay fraction is more susceptible for landslides due to its extreme expansion potential. Guzzetti et al. (2005) further stated that, increase in soil moisture (especially soils with high clay contents)

due to rainfall reduces the cohesion of the soil particles. The excess moisture present in soils exerts pore water pressure making steep slopes vulnerable to landslides, under adverse climatic conditions.

### 2.3.3 Topography

The steeper the slope, the more likely it is to fail and the easier it is to upset equilibrium. Most mass movement occur along slopes that are 20° or 25° steep (Cardinali et al., 2002; Carrara et al., 2003). In addition, slope aspect is strongly affected by the microclimate and vegetation cover, thus influencing soil development and mass movement intensity. ‘Slope aspect defines the direction of slopes and reveals potential effects of prevailing winds, other weather conditions and incident solar radiation. The orientations by virtue of the local conditions receive more quantity or intense rainfall, the soil gets saturated more quickly, depending moreover on infiltration capacity, controlled by slope angle, soil type (permeability and porosity) and vegetation cover’ (Psomiadis et al., 2020 pg 10). High roughness slopes are more prone to mass wasting because gradient changes favour rainfall infiltration into the soil (Fard, 2001).

### 2.3.4 Vegetation

‘Vegetation and slope stability are interrelated by the ability of the plant life growing on slopes to both promote and hinder the stability of the slope. The relationship is a complex combination of the type of soil, the rainfall regime, the plant species present, the slope aspect, and the steepness of the slope’ (Food and Agriculture Organisation of the United Nations, 2007). Vegetation limits the movement of the debris present along slopes in two folds, that is, hydrological (capacity of infiltration into the soils, soil moisture, groundwater level and others), and mechanical (root length) (van Beek et al.,

2008). Through reinforcement, roots mechanically reinforce a soil transfer of shear stresses in the soil to tensile resistance in the roots, soil moisture modification via transpiration and interception. The foliage limit build-up of soil stress, destabilizing the influence from turning moments exerted on a slope as a result of strong winds blowing downslope through tress (wind throwing). Lastly, through buttressing and arching, anchored stems can act as buttress piles along a slope counteracting shear stresses (Bornsworth, 2015; Nelson, 2018; van Beek et al., 2008). The major effect of transpiration is the reduction of soil pore water pressures which counteracts the loss of strength which occurs through wetting, this is most readily seen as a loss of moisture around trees (van Beek et al., 2008). Greenwood, Norris, and Wint (2004) however argued that, it is not easy to rely on tree and shrub roots to remove water from slopes and consequently help ensure slope stability but it can be assumed that the chance of slope failure following saturation by storm event or periods of extended rainfall will be lessened as a result of transpiration.

Alternatively, vegetation can increase the hazard by overloading the slope with weight and by weakening the regolith strength through movement of the roots, for example during strong wind storms (Popescu, 2002; Reinhold, Medicus, Wolfgang and Zangerl, 2009). Another observed effect is that the vegetation cover indeed stabilizes the slope through root reinforcement; however, if the slope fails, the root weight could actually increase the size of the mass wasting (Papathoma-Koehle and Glade, 2013).

### **2.3.5 Human activities**

As the population on earth continues to increase, more land is colonized. Therefore, previously rejected areas are being occupied. Land-use activities affect the intensity of

mass movement significantly (Pullanikkatil, Palamuleni and Ruhiiga, 2016). Clearance of forest or erecting terraces for agriculture, tillage of the top soil, rock fragment removal from top soil, abandonment and regeneration of land, uncontrolled burning, and overgrazing are among the main human activities on landscapes (Kerényi, 2010; Siddhartho, 2013). These activities are constantly reshaping the contours of the land (topography) and thus altering the natural slope. In some instances, they can be considered as the primary cause of mass movements. As an example, unregulated mining operations have turned stable terrain (limestone) into mass wasting-prone terrain (Deniz et al., 2018). Residential development not only adds weight to the slope but may also lubricate fractures due to garden watering, and the seepage of water from swimming pools and sewage effluent systems (Goldewijk, Beusen, Drecht and Vos, 2011). In addition, vibration of trucks, machinery, blasting, fluctuating groundwater level (well drilling and over-pumping), and loss of root binding can constitute important transitory stresses that may lead to failure (Goldewijk et al., 2011).

### **2.3.6. Seismic Activities**

In places where minor and significant morphotectonic processes (uplift, subsidence, faulting, jointing, and earthquakes) occur, mass movements are common (Ahulu et al., 2018). Aside from the immediate effects of material collapse that is already precariously stable, earthquakes can exacerbate other types of instability by lowering rock shear resistance. In literature, some examples of strong relationships between seismic occurrences and mass movements have been described. In 551 A.D., a large earthquake that struck Lebanon depicts massive slides at Chekka, which is responsible for forming the city's current coastal structure, mass wasting induced by the Kashmir

earthquake in October 2005 (Mahmood et al., 2015), earthquake-driven Peru valley mass wasting in 2018 (Bradley et al, 2019), and many others.

Ghana is situated on the south-eastern edge of the West African Craton, far from any active plate borders (Amponsah, Leydecker and Muff, 2012). Since 1615, when an earthquake was discovered near Elmina on the Cape Coast, it has been prone to devastating earthquakes. (Ahulu et al., 2018). Earthquakes in Ghana are concentrated in the south (Figure 2.2), where a network of seismic recording stations has been established. Most of the epicenters south of Weija, according to Amponsah (2004) are owing to the existence of an ancient thrust zone that has been reactivated. Recent mass wasting activities in these locations, as well as seismic events, provides reason to be concerned. The majority of earthquakes in Ghana occur in the western area of Accra, near the intersection of two major fault systems, the Coastal boundary fault and the Akwapim fault zone, according to the report.

#### *2.3.6.1 Seismotectonics in Ghana*

Ghana lies between two major fault lines: Akwapim Fault and the Coastal Boundary fault.

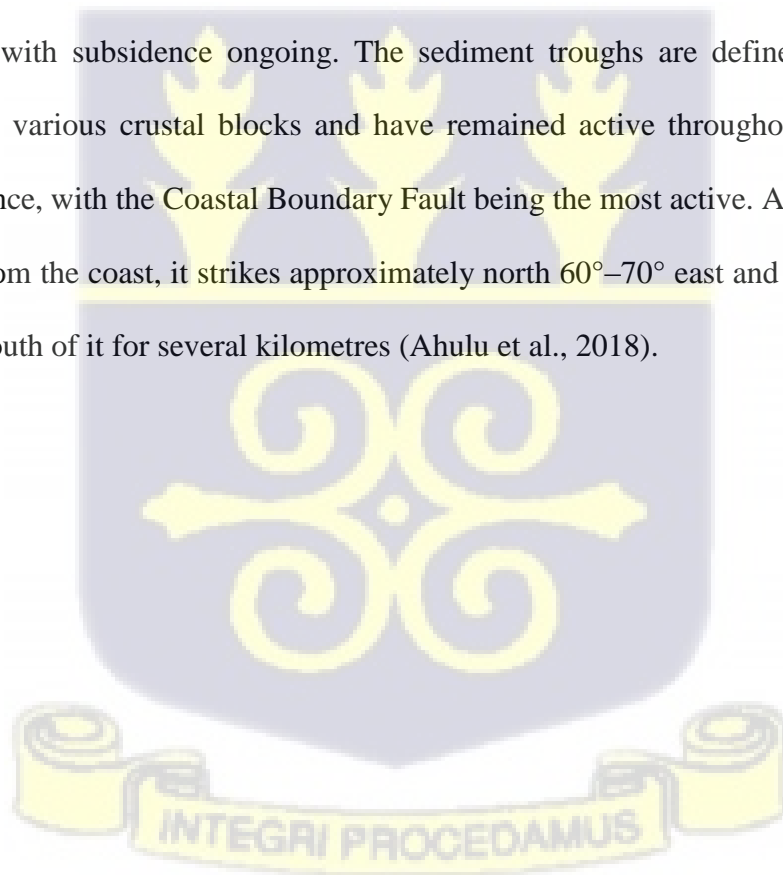
##### *2.3.6.1.1 Akwapim Fault*

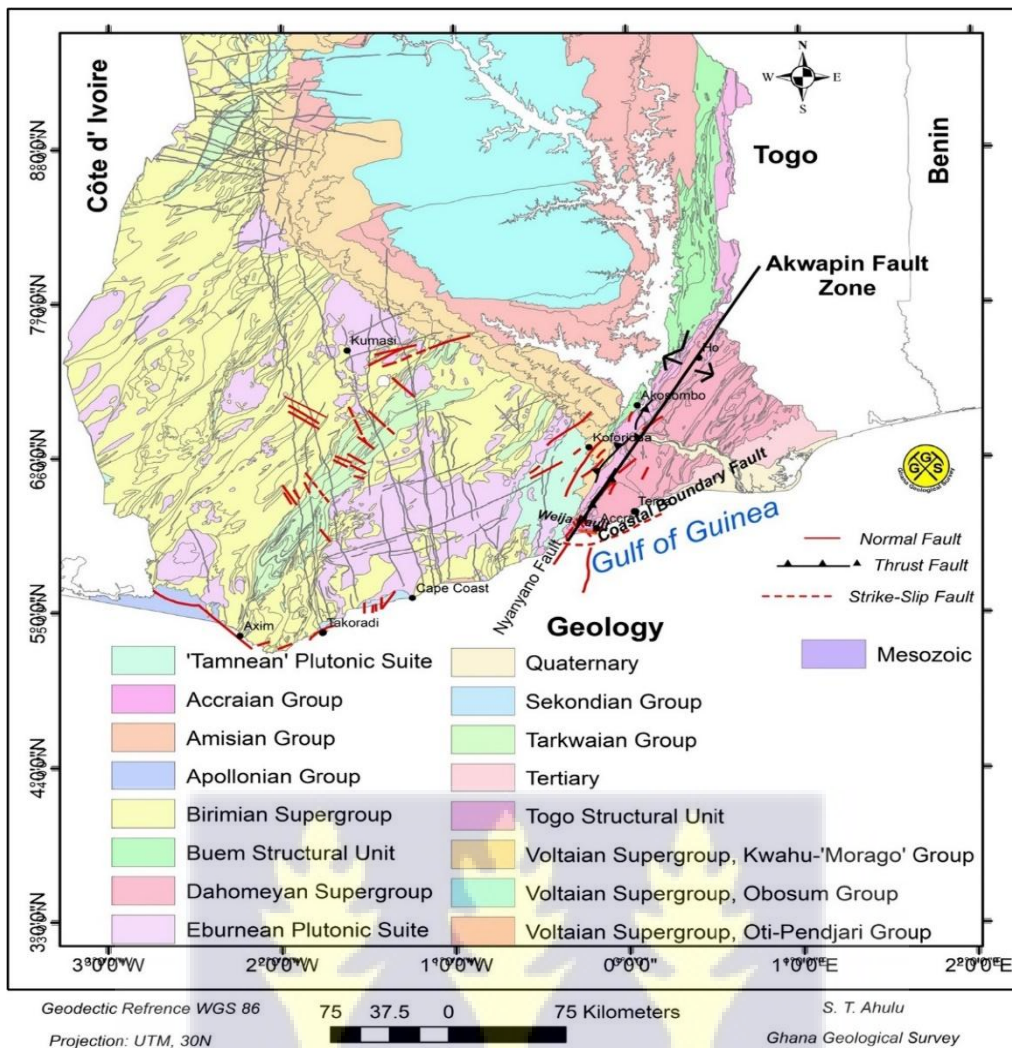
The Coastal Boundary Fault Zone and the Akwapim Fault Zone are the two major active fault zones in Ghana where the majority of recent earthquakes or tremors have occurred (Fig. 2.2). The Akwapim fault, which runs northeast from Accra, is part of the Akwapim fault zone, which has seen more recent faulting along an ancient line of thrust boundaries between the Birimian at the west end of the Togo Series and the Dahomeyan

at the east end of the Togo Series. A range of medium-grade metamorphic rock units make up the Dahomeyan (GSD and BGR, 2009). The Akwapim fault zone runs northeast through Kpong, Ho, and into Togo and Benin (Fig. 2.2). Recent large-scale mapping in the southern part of the Akwapim fault zone (Muff and Efa, 2006, quoted by Ahulu et al., 2018) demonstrates that the Akwapim–Togo Belt was subjected to a block tectonic style of deformation at a later period, and that several local-scale normal faults have evolved recently (Fig. 2.3)

#### *2.3.6.1.2 Coastal Boundary fault*

During the Atlantic Ocean's opening, the West African continental margin formed (Amponsah, 2004). The early era of opening was linked to basic magmatism. From the Jurassic to the present, flanking sedimentary troughs developed around the continental border, with subsidence ongoing. The sediment troughs are defined by faults that separate various crustal blocks and have remained active throughout the history of subsidence, with the Coastal Boundary Fault being the most active. At a distance of 3–5 km from the coast, it strikes approximately north 60°–70° east and down throws the block south of it for several kilometres (Ahulu et al., 2018).





**Figure 2. 3: Tectonic setting of the southern portion of Ghana**

Source: Ahulu et al., 2018

The Coastal Boundary Fault runs along the northern edge of a basin filled with Upper Jurassic to recent deposits. The Coastal Boundary Fault, according to Amponsah (2004), forms the northern edge of the Keta Basin and supports the claim that the flaw might be active during the entire deposition process. The fault curves to the west of Accra, striking east-west, and intersects with the Nyanyanu fault in the Akwapim fault zone. Earthquakes have occurred in the past and are still expected to occur around the intersection of the Akwapim fault zone and the Coastal Boundary fault zone, according to a recent study of geological and instrumental recordings (Amponsah, 2004; Kutu et

al., 2013). There are a number of other faults in the acute angle between these two major faults, the most important of which is the Weija fault striking West North West (Fig. 2.2). Numerous active faults have been mapped during the course of foundation investigation studies in and around Accra. The area within the acute intersection has high seismicity. Plate tectonic forces, according to (Amponsah, 2002), are responsible for tectonic activity in West Africa and proposed that the African plate's northward movement over the Earth's ellipsoid-shaped surface creates extensional stresses, which are still present today. These extensional forces were thought to be contributing to seismic activity in the West Africa zone, and as a result, some faults within the zone could become active.

#### **2.4 Mass Wasting in Ghana**

Ghana is not noted to be a frequent serious victim of mass movement. It is, however, noteworthy that Ghana has not been without mass wasting (Atarigiya, 2016). Mass wasting are generally of small scale although they affect highways and some opencast mines. Major mass wasting have occurred along the entire length of the receding Voltarian scarp. Modes of mass wasting have been studied in different geological and climatic-vegetational zones of the country (Atarigiya, 2016). It has become obvious that Ghana's slope instability problem may be divided into two categories: slope instability that can be controlled via good design and slope instability that cannot be controlled or corrected and should therefore be avoided. Mass wasting occurs in many parts of the country, especially in the central and southern parts (Sambou, 2019). Table 2.2 (pg 17) shows the number of occurrences in the country.

## 2.5 Impacts of Mass wasting

The motivation behind mass movement studies is the prevention and mitigation of disasters and reduction of risk. Most mass wasting events are small and their killing potential is limited. However, large mass wasting events may be very catastrophic. Delayed consequences to mass wasting may also tragically contribute to the death toll (Vittorio de Blasio, 2011). The negative consequences of mass movements however are not limited to loss of life, but include the destruction of houses and infrastructure, loss of productivity in the area affected, unpredictable changes in the local watercourse, and reduction of arable or habitable land (Department of Geological and Geophysical Surveys, 2019). In 1786, a local river in the province of Sichuan in China was dammed for 10 days as a result of a mass wasting event caused by a strong earthquake. As many as 100,000 people were drowned when the dam failed inundating 1,400 km area downstream. In 2005, a major landslide killed about 10 people and destroyed dozens of houses in the town of La Conchita, California (Plate C). The event happened at the end of a 15 – day rainfall. At Abancacy, Peru, a mass wasting event occurred on January 27, 2019 that killed at least 15 people and injured 34 when it destroyed part of a hotel during a wedding celebration (Plate D). Also, on December 4, 2019, heavy rains precipitated the deadly series of Burundi with mass wasting following later that night into the next day, affecting over 500 people in Nyempudu, Gikomero and Rukombe of the North-western province of Cibitoke bordering Rwanda and Bubanza as well as the North-western province of Cankuzo. This event killed at least 26 people, leaving 10 missing and injuring 10 others. Much property damage occurred as well. Table 2.3 reports some of the deadliest mass wasting on the Accra-Kasoa highway. In 2013 and 2019, heavy rains in Ghana caused mudslides where silt and muddy pools of water covered most parts of the road few kilometres from the Kasoa tollbooth making it

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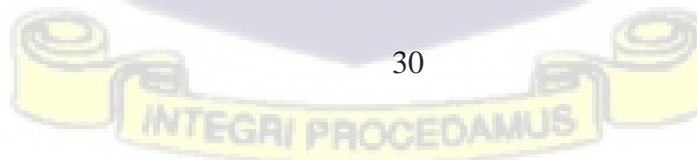
extremely difficult for drivers to use the road. In the absence of proper drainage in the settlements, running water and mud from the hills create deep gullies and ends up on the road (ABC News, 2019; Acquah, 2019). Sand from these hills also ends up in the Weija dam, swelling up its volume which floods other low-lying communities such as Denchira, Salami Kope, Ghanant farms, Gape Kope, Daniel Kope, Torgah Kope, Kwame Zolo Kope, Sackeyman, Ayigbe Kope, etc around the dam (Boakye, 2015).



**Table 2. 3: Some of the Deadliest Mass Movements**

Location	Country	Date	Number of people Killed	Mass Movement Type and Notes
Italy	Austria	1916	10,000	Mass wasting
Gansu Province	China	December 16, 1920	180,000	675 loess flows affected an area of 50, 000km <sup>2</sup>
China		1920	200,000	Earthquake triggered mass wasting
Japan		1945	1,200	Flood triggered mass wasting
USSR		1949	12,000-20,000	Earthquake triggered mass wasting
Yungay (Nevado Huascarán)	Peru	May 31, 1970	18,000	Rock avalanche mixed with ice and water, caused by earthquake along the path of the glacier
Armero (Nevado del Ruiz)	Columbia	November 13, 1985	25,000	Lahars formed by eruptions of ice-capped Nevado del Ruiz volcano
Khait	Tajikistan	1949	12,000	Rock avalanche detached by strong quake
Austria		1954	200	Mass wasting
Huaraz	Peru	December, 1941	4,000-6,000	Debris flow caused by morain dam break impounding glacial lake (GLOF); more events in 1962 and 1970
Kelud Volcano	Indonesia	1919	5,160	Drainage of the Crater lake
Yungay (Nevado Huascarán)	Peru	January 10, 1962	4,000-5,000	Rock avalanche mixed with ice and water, caused by earthquake
Colima	Honduras	September 20, 1973	2,800	Rock avalanche mixed with ice and water, caused by earthquake, and debris flow
Ranrahirca (Nevado Huascarán)	Peru	January 10, 1962	4,000	
Longarone (Belluno)	Italy	October 9, 1963	2,000	Rock avalanche onto artificial water reservoir, killing due to water splash
Bihar, Bengal	India	October 1, 1968	1,000	The region is prone to large quakes
Villa Tina (Medellin)	Columbia	September 27, 1987	217	Small and shallow slide in lateritic residual soils
Ecuador		1987	1,000	Earthquake related mass wasting
El Salvador		2001	585	Earth quake induced mass wasting
La Conchita	California (USA)	January 10, 2005	10	Debris flow mobilized previous mass wasting deposits due to intense rainfall
Philippines		2006	1126	Rain triggered Avalanche killing lots of people
Taiwan		2009	600	Typhoon Marakot triggered avalanche
Gansu	China	2010	1287	Rain triggered mudflow
Northern India		2013	5700	Heavy rain triggered mass wasting
Sierra Leone		2017	>1140	Mudflows

Source: Adapted from Malamund, 2014; Nelson, 2018; Vittorio de Blasio, 2011





**Plate 2.1: Mass wasting at La Conchita, California**

Source: USGS, 2016



**Plate 2.2: Mass wasting at Peru at a Hotel Causing the Walls of the Hotel to Collapse during a Wedding Ceremony.**

Source: USGS, 2016

“Mass movements are destructive agents. They change and modify the landscape – they disturb it. Destruction and disturbance is costly for built environment, it is costly for natural resources and yet it is essential for ecosystem cycling in the natural environment” (Geertsema, Highland, & Vaugeouis, 2009 p. 589).

## 2.6 Vulnerability to mass wasting

The term vulnerability as has been applied in many fields today has spanned a very long period of time. Weichselgartner (2001) regarded vulnerability as a fuzzy and stated that the term has no common conceptualization. UNISDR (2016 pg. 1) defined that vulnerability “is the conditions determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards”. Proag (2014 pg. 370) added that it is “the degree to which a system, or part of a system, may react adversely during the occurrence of a hazardous event. Thus, people become “vulnerable” if access to resources either at household, or at an individual level is the most critical factor in achieving a secure livelihood or recovering effectively from a disaster”.

To understand the concept of vulnerability, Weichselgartner (2001) identified 3 distinct themes within vulnerability discourse. The first theme examines vulnerability in the context of pre-existing conditions. These conditions refer to human occupancy of zones or regions termed as hazardous such as earthquake, flood prone areas and seismic zones. In the context, of this study identifying persons living in mass wasting prone areas, what the author failed to add were determining residents’ knowledge and their perception of risk and exposure with regards to the hazard in question as well as the levels of vulnerability of the area. The second group focuses on the coping responses including societal resistance to hazards. Finally, vulnerability is considered hazard place specific which combines the earlier two themes. This third theme was noted as geographically oriented. Vulnerability in this regard is considered as a bio-physical risk and social response that is examined at a specific area or geographical region. Various theoretical perspectives have also been advanced to explain the causes of vulnerability.

From a social vulnerability viewpoint, Watts and Bohle (1993) noted 3 processes that define vulnerability. They include economic capabilities (entitlement), empowerment (political/social power) and the political economy (historical/structural) (cited in) (Weichselgartner, 2001). Another model popularly referred to as the pressure and release model or the disaster crunch model was proposed by Blaikie et al. (1994). This model integrates much more elements under a cause and effect relationship between the elements that constitute vulnerability. According to Blaikie et al. (1994), the model includes in it “unsafe conditions that expose one to social vulnerability when in contact with any type of hazard”. The model also highlights “dynamic pressures” as another element. Much focus is oriented to this element as it explains the underlying driving forces that make a system vulnerable.

## **2.7 Risk Knowledge and Perception of Mass wasting**

People’s feelings according to Lowenstein et al., (2001) and Slovic et al., (2002) about what is good or bad in terms of causes and consequences of risks shape their beliefs about risk. Slovic (2000) further added that how people perceive and respond to risk is a function of their knowledge, experience, values, attitudes and feelings about the seriousness and acceptability of risks. When it comes to developing systems, procedures, and policies to safeguard local populations, risk perceptions are crucial. It is a series of psychological processes that occur when engaging with and/or comprehending a natural or built-environment hazard (Chauvin et al., 2007). It also demonstrates how communities, governments, and people perceive, judge, evaluate, and rank risk. Direct observation (that is, being present at a mass wasting) or knowledge gathered from other people, media, or social networks may be the source of these processes (for example, to read about an earthquake). Individuals or groups differ in

their perception of psychological, cultural and social factors (Calvello et al., 2015). That is to say, people take risk-related decisions from a range of alternatives based on local knowledge, past experience, experiments, opportunities and existing coping mechanisms. While outsiders might label two households as equally vulnerable – because they live in apparent similar conditions – the two households might still perceive risk differently and, as a consequence, prefer different risk reduction measures. The degree of perceived risk varies greatly among households and depends on class, gender, location, and other particular conditions shaped by economic, social and political processes (Heijmans, 2001).

Reality is constructed from perception in order to give the world more meaning and to respond to that meaning. When people have more disaster experience, that experience impacts their perceptions more, and when there is a lack of experience or the crisis is thought remote, judgments are more likely to be based on information gained through the media, as well as their own intuition (Alcantara-Ayala and Moreno, 2016) and immediate social networks.

Decision makers need to understand how people think about and respond to risks (Chauvin et al., 2007). This understanding helps improve risk communication among lay people. Not only technological, engineering and scientific aspects of risks have to be considered, but also the public concerns about the acceptable level of these risks needs to be evaluated. Public risk perceptions can fundamentally compel or constrain political, economic and social action to address particular risks (Leiserowitz, 2006).

A study by Chaturvedi and Varun (2015) on the public perceptions of mass wasting risk in the Himalayan Mandi Town revealed that since catastrophic mass wasting are rare events, most of the people of the town were risk averse. They did not show prevention behaviour, and they were not well prepared for an adverse event. Again, most of the respondents were of the belief that they lived in a safe place. This reiterated a previous study by Winter & Bromhead (2012) that indicated that most of the respondents showed low level of concern with mass wasting, indicating that though they know mass wasting is a problem, they are not especially worried about it. Further, they indicated that the most frequent source of information for mass wasting was the media followed by official and geotechnical reports then their personal experience. Qasim et al. (2018) added a little twist to it by studying the socio-economic determinants of mass wasting risk perception in the Muree hills of Pakistan. Age, income, educational levels, location and experiences were listed as variables that affect mass wasting risk. The results revealed that out of the five, three of them including past experiences, location and educational level were found to have positive effects on mass wasting risk perception. The findings also revealed that past experience is a good predictor for risk perceptions of natural hazards but a similar computation by Setiawan and Hizbaron (2014) revealed that there is no correlation at all between these variables and mass wasting experience but on the other hand these, these variables have a relationship with the respondents perception of mass wasting.

Some studies have found a weak or insignificant link between risk perception and disaster preparedness (Lindell and Whitney, 2000; Siegrist and Gutscher, 2006), while others have found a link between higher levels of perceived risk and increased preparedness behavior (Martin, Martin, and Kent, 2009; McNeil, Dunlop, Heath, and

Morrison, 2013; Miceli, Sotgiu, and Settanni, 2008; Paul and Bhuiyan, 2010). The perceived threat severity was favorably connected with disaster preparedness, according to McNeil et al. (2013), however the relationship between perceived threat likelihood and disaster preparedness was not as strong.

## **2.8 Mitigation and Coping Strategies**

Hazards have always been a part of life, and residents of hazard-prone locations have developed techniques to deal with extreme events based on their own capacities, skills, talents, knowledge, and technologies. These adaption tactics, which they learned from their forefathers and their own experiences, have become part of their traditions and culture (Heijmans, 2001; Weichselgartner, 2001). When disasters hit, people have always been prepared to cope and have not relied heavily on outside help and assistance, such as from the government. These strategies can be considered as mitigation and coping strategies.

Coping strategies refer to the application of indigenous knowledge in the face of hazards (Setiawan and Hizbaron, 2014). Mitigation and coping strategies are put in place to reduce the impacts and risks of hazards through proactive measures taken before an emergency or disaster occurs. According to Westen and Kigma (2011), fair knowledge on mitigation coping strategies is important to ascertain the type of disaster risk reduction programme that should be undertaken.

A research by Chaturvedi and Varun (2015) on the public perceptions of mass wasting risk in the Himalayan Mandi Town revealed that to reduce mass wasting risk, majority of the responded vouched for planting of trees followed by building stronger

foundations for their buildings. Osuret et al. (2016) agreed with the results but further added that from his findings terracing was a better coping strategy for reducing the risk and effects of mass wasting. They added that majority of the respondents relied on the support of government to help them cope. The research grouped coping strategies into economic, technological and social. Economic coping strategies included strengthening financial institutions; social coping strategies included night patrols and meetings to assist people affected by mass wasting while technological strategies looked at improving public facilities such as roads and water channels.

## **2.9 Remote Sensing and Geographic Information Systems in Hazard Mapping**

Mass wasting hazard mapping is a fundamental tool for disaster management activities in fragile mountainous terrains (Dahal and Dahal, 2017). The basis for hazard maps is a comprehensive assessment of geological and hydro(geo)logical framework conditions, slope instabilities, relevant triggering mechanisms, properties of displacement processes, potential risks and the vulnerability of endangered areas (objects) (Rudolf-Miklau et al., 2011).

Extraction of significant spatial information related to mass wasting occurrence is an integral part of hazard assessment. RS data married with GIS have proven to be competent tools for generating and processing spatial information. The advancement in earth Observation (EO) techniques facilitate effective mass wasting detection, mapping, monitoring and hazard analysis ( Tofani, Segoni, Agostini, Catani, and Casagli, 2013).

Aerial photographs are widely used for mass wasting detection and mapping using RS (Pardeshi, Autade, and Pardeshi, 2013). For accurate mass wasting detection and mapping, good quality aerial photographs are needed but they cannot be used in continuous mass wasting monitoring since it does not provide repetitive coverage of the same area (Sharma, 2008). In assessing the risk of mass waste, the Digital Elevation Model (DEM) is critical. Slope angle, slope aspect, curvature, lineaments, drainage, ridges, and other theme data layers can be retrieved with good resolution from DEM. Thematic data layers, computation of different indices, weight assignment, data integration, and the development of mass wasting susceptibility and hazard maps are all common uses of GIS in mass wasting hazard assessment. Several GIS-based mass wasting susceptibility zonation approaches exist, including the Artificial Neural Network (ANN), Decision Tree model, Weighted Overlay, and physically based mass wasting hazard models. (Abdallah, 2007; Pullanikkatil, Palamuleni, and Ruhiiga, 2016).

Pareta and Pareta (2012) used GIS and remote sensing techniques for mass wasting susceptibility mapping together with the weighted overlay method (WOM) to map the Giri river watershed of Yamuna basin. The study made use of data layers such as land use, vegetation cover, geology, slope gradient, aspect, drainage density and terrain height. The study concluded that, coupled with remote sensing, GIS is an excellent tool to display the spatial distribution of mass wasting along with their attributes. Rodeano et al., (2017) in their studies which also used WOM for mass wasting susceptibility analysis agreed with this and further stated that RS and GIS for hazard mapping helps planners in general planning assessment purposes. The study used the probabilistic method to obtain the weights of soil, geomorphology, distance to river, distance to lineaments, land use and lithology. Othman et al., (2012) in their research further added

multi-criteria decision making together with GIS is a powerful tool, which can be applied to predict and map mass wasting hazard zones.

### **2.10 Observation as a Method of Data Collection**

Observation is a method gathers data by watching behaviour, events, or noting physical characteristics in their natural setting without questioning or otherwise communicating with them (Centre for Disease Control And Prevention, 2018). This method is adopted by researchers to attempt to understand behaviour, societies and phenomenon by getting to know the persons and events involved, their symbols, beliefs and emotions. The technique qualifies as a scientific method of data collection when it is specially designed to answer a research question and it is systematically planned and executed with proper controls (Centre for Disease Control And Prevention, 2018). The versatility of the method makes it an indispensable primary source of data and a supplement to other methods. Observation can be structured or unstructured. Structured observation is where data is collected using specific variables and according to a pre-defined schedule while unstructured observation is a free and open manner method of data collection such that there will be no pre-determined variables or objectives (Whittle, Giazitzoglu, Wright, and Casey, 2019). According to Dudoviskiy (2014), some advantages of this method include high flexibility in terms of application, direct access to research phenomena and the generation of a permanent record for future referrals. Data can be collected in real-time while the phenomenon occurs or in suspended time by recording an event and later analysis via videos, field notes and photographs (Whittle et al., 2019).

## **2.11 Theoretical and Conceptual Framework**

The theoretical and conceptual framework of a study explains the path of a research (Dickson et al., 2018). It must be noted that, the overall aim of this is to make research findings more meaningful, acceptable to the theoretical constructs in the research field and ensures generalizability. In addition, it assist in stimulating research while ensuring the extension of knowledge by providing both direction and impetus to the research inquiry. The frameworks further enhance empiricism and rigor of a research. It is thus no exaggeration for Imenda (2014) to say that both the theoretical and conceptual frameworks give life to a research.

### **2.11.1 Theoretical Framework: The Disaster Crunch Model**

Dickson et al. (2018) accentuate that theoretical frameworks are the specific theories about aspects of human endeavour that can be useful to the study of events. The theoretical framework consists of theoretical principles, constructs, concepts, and tenants of a theory (Grant and Osanloo, 2014). Imenda (2014) acceded to the fact that theoretical framework assist researchers in situating and contextualizing formal theories into their studies as a guide. This positions their studies in scholarly and academic fashion. Moreover, the theoretical framework serves as the focus for the research and it is linked to the research problem under study. Therefore, it guides a researcher's choice of research design and data analysis plan.

There are lots of disaster models which include the Traditional or Disaster Management Continuum, the Kimberly, the Expand-contract and the Crunch model. The study adopts the disaster crunch model as the theoretical framework to explain its findings.

The Disaster Crunch Model states that, a disaster happens only when a hazard meets a

vulnerability (Hai and Smyth, 2012). People can be said to be vulnerable when they are unable to adequately anticipate, withstand and recover from a hazard. The model has two main dimensions: hazards and vulnerability, both of which influence the disaster risk (Fussel, 2007). The level of disaster risk therefore depends on the magnitude of the hazard and degree of vulnerability of the people. As explained above, a disaster will not happen if there is only hazard without a vulnerable community and vice versa. The Crunch model has been viewed as a framework of understanding and analysing the causes of disasters (Heijmans, 2001). The behaviour and trends of a hazard can be understood through examining its force, any warning signs, forewarning, speed of onset, frequency, time of occurrence and duration. Climate, or weather related hazards, should also be considered and analysed in the context of a changing climate, as the frequency, intensity and seasonality of climate related hazards, such as typhoons, floods and droughts may be affected (Dickson et al., 2018). Three layers of social processes that cause vulnerability are; root causes, dynamic pressures and unsafe conditions. The root causes (example: lack of government policy on land use planning) lead to dynamic pressures (example: no community organisation for collective efforts to reduce mass wasting) that explain how the unsafe conditions (example: poor housing conditions, dangerous location) have arisen and persisted (Heijmans, 2001).

According to Wisner et al, (2003), the crunch model (Figure 2.4) adopts a cause and effect perspective because of its focus on the causes and impact of disaster. The model is also known to analyse vulnerabilities and coping capacities of disaster affected communities. According to the crunch model (Figure. 2.4), the progression of vulnerability of a community is revealed. Furthermore, the underlying causes that fail to satisfy the demands of the people are identified (Asghar et al., 2006). This model

goes further to estimate the dynamic pressures and unsafe conditions (Figure 2.4). The model is important as it can help practitioners to understand and react to people's vulnerability to disasters (Hai and Smyth 2012). It therefore explains the relationship between natural hazards and vulnerabilities of communities, making the model applicable in this study. Hai and Smyth (2012) assert that the crunch model helps practitioners to understand and react to disaster vulnerabilities facing people. (Blaikie et al., 2003) notes that pressure can be released on those communities vulnerable to risk by decreasing or eliminating the various root causes, dynamic forces, and/or unsafe conditions available. It is for these reasons that the model was adopted for this study. However, the disaster crunch model has also not been spared from criticism of scholars and practitioners. Turner II et al. (2003) have argued that the crunch model lacks the feedback in the system. Cutter et al. (2008) noted that the model tracks the progression of vulnerability from the root causes, through to dynamic pressures, and to unsafe conditions, but fails to adequately address the coupled human–environment system associated with the proximity hazards.

### **2.11.2 Conceptual framework**

A conceptual framework is a framework that the researcher believes best explains the natural course of the subject under investigation (Camp, 2001). It is linked to the researcher's conceptions, empirical study, and essential theories for advancing and systemizing his or her expertise. It is the researcher's description of how the research question will be investigated. The framework allows the researcher to more readily specify and clarify topics inside the study's problem (Imenda, 2014). A conceptual framework is the simplest way through which a researcher presents the asserted remedies to the problem defined (Dickson et al., 2018). It accentuates the reasons why

a research topic is worth studying, the assumptions of a researcher, the scholars researcher agrees with and disagrees with and how the research approach is conceptually grounded (Camp, 2001). Asghar et al. (2006) opined that conceptual frameworks can be 'graphical or in a narrative form showing the key variables or constructs to be studied and the presumed relationships between them.

The study adopted the Crunch model from Wisner et al. (2003) (Figure 2.4) and is based on the idea that an explanation of disasters requires us to trace the connections that link the impact of a hazard on people with a series of social factors and processes that generate vulnerability. The explanation of vulnerability has three sets of links that connect the disaster to processes that are located at decreasing levels of specificity from the people impacted upon by a disaster. The root causes lead to dynamic pressures that explain how the unsafe conditions have arisen and persisted. Root causes are connected with the function (or dysfunction) of the state, and ultimately the nature of the control exercised by the police and military, and with good governance, the rule of law and the capabilities of the administration as seen in the example given in figure 2.4. Root causes reflect the exercise and distribution of power in a society. People who are economically marginal (such as urban squatters) or who live in environmentally 'marginal' environments (isolated, arid or semi-arid, flood prone coastal or forest ecosystems; steep, flood prone urban locations) tend also to be of marginal importance to those who hold economic and political power. This creates three often mutually reinforcing sources of vulnerability (Blaikie et al., 2003). Firstly, people's behaviours are likely to generate increased levels of vulnerability if they only have access to insecure and unrewarding livelihoods and resources. Second, government initiatives aimed at hazard reduction are likely to be low on the priority list. Third, those who are economically

and politically marginal are more likely to lose faith in their own self-defence mechanisms and in their own local expertise. Even if they still believe in their own abilities, their economic and political marginality, as well as limited or uncertain access to resources, may have caused the 'raw materials' or labor time required to vanish.

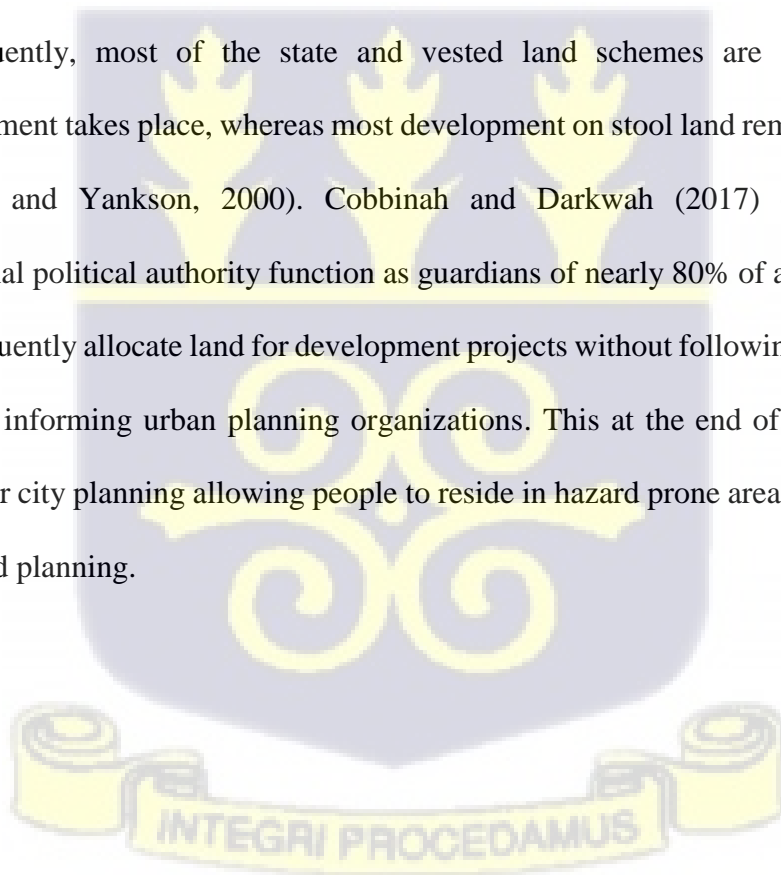
Negligence on the part of government as well as municipal assemblies have led to the selling of inhabitable lands in the municipalities to people for habitation by the landowners and custodians. None enforcement of government policies and sanctions have given people the audacity to purchase properties in reserved areas due to their hazard-prone state putting the lives of innocent ones at risk. Efforts from the government as well as the municipal assemblies will educate people more on mass wasting event in the Ga South and Weija-Gbawe Municipalities.

Land tenure issue of land tenure system in Ghana also leaves much to worry about. Lands in Ghana can be owned by the state or customary. State land is land compulsorily acquired by government through the invocation of the appropriate legislation. These lands are vested in the president on behalf of, and in trust for, the people of Ghana. This land is managed by the Lands Commission whose role is to: acquire and manage public lands; advise government on land use; advise the government, district assemblies and traditional authorities on land development and coordination; and maintain a register of all land titles (Gough and Yankson, 2000). In contrast, chiefs, or family heads, are still the custodians of customarily held land. However, they have to seek the consent and concurrence of the Lands Commission before disposing of or developing any portion of their land. The 1969 constitution removed the right to freehold tenure, but land may

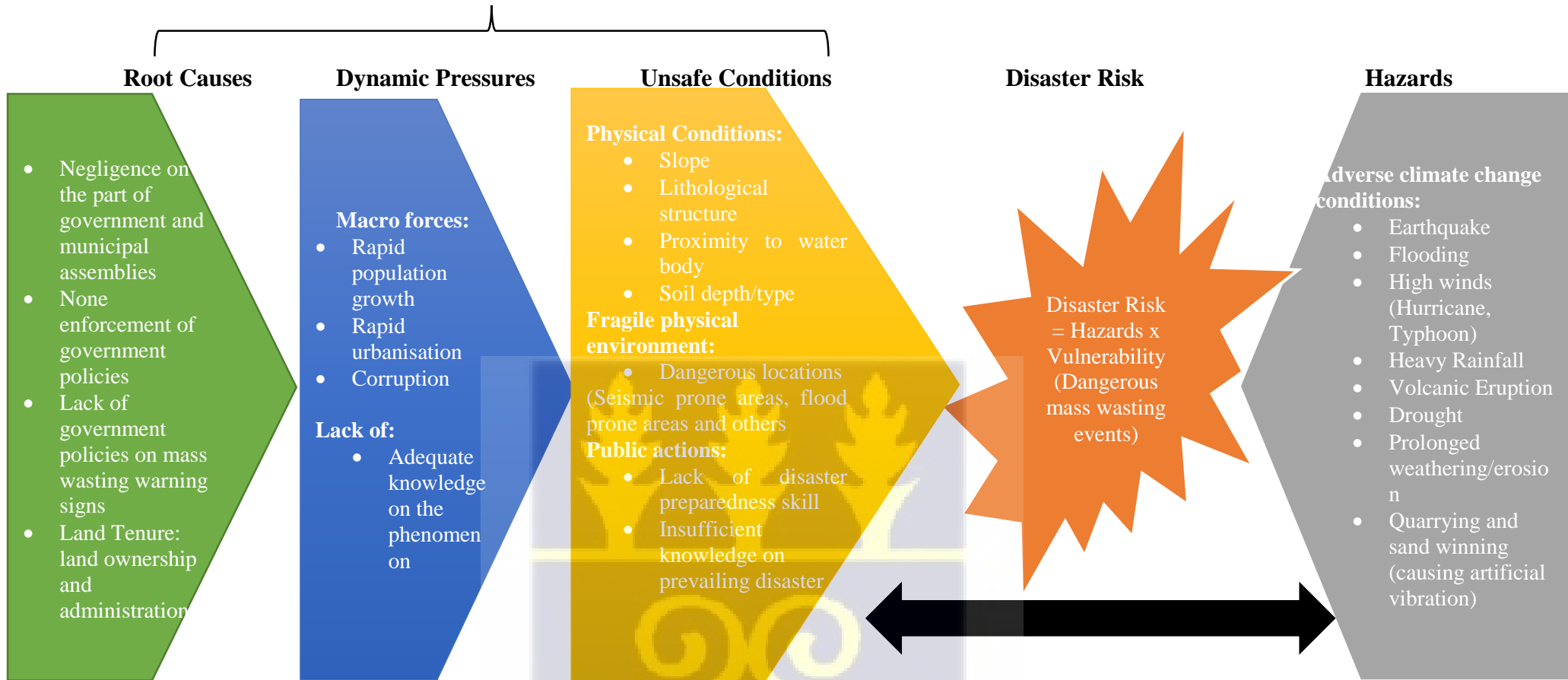
be sold and held as leasehold. The sale of stool land is managed by the chiefs and elders or family heads (Gough and Yankson, 2000).

The Town and Country Planning Department (TCPD) is also involved in land management, as it is in charge of setting goals and criteria for land use and development, as well as developing plans to guide growth and development. The TCPD, on the other hand, lacks the requisite resources to produce all of the needed planning scheme layouts. As a result, land is being sold at a much faster rate than the blueprints can be produced. As a result, leaders use surveyors who aren't always prepared to draft blueprints.

As a result, the layouts are frequently unprepared and lack suitable public places. Consequently, most of the state and vested land schemes are approved before development takes place, whereas most development on stool land remains unapproved (Gough and Yankson, 2000). Cobbinah and Darkwah (2017) emphasized that traditional political authority function as guardians of nearly 80% of all land in Ghana, and frequently allocate land for development projects without following urban planning rules or informing urban planning organizations. This at the end of the day leads to improper city planning allowing people to reside in hazard prone areas as development preceded planning.



## The Progression of Vulnerability



**Figure 2. 4: Modified Disaster Crunch Model**

Source: Adopted from Wisner et al., 2003

Dynamic pressures as already mentioned are processes and activities that 'translate' the effects of root causes both temporally and spatially into unsafe conditions. These are more contemporary or immediate, conjunctural manifestations of general underlying economic, social and political patterns (Blaikie et al., 2003). Dynamic pressures channel the root causes into particular forms of unsafe conditions that then have to be considered in relation to the different types of hazards facing people. These dynamic pressures especially for this study includes rapid population growth and rapid urbanisation. These forces people into dangerous location for housing, work to make ends meet, steepening of land to make room for constructional works and others that make them susceptible to disasters and in this case dangerous mass wasting events.

To add to, even as the study area is already experience an influx of people, their knowledge on the phenomenon will determine their preparation towards managing or curbing the event. The negligence on the part of government and the municipalities to educate them on the possible effect of the event to their lives and properties will leave the inhabitants very much prone to mass wasting. In essence, the level of understanding of the inhabitants on the event will determine the action and the method put in place to manage the harmful effects of mass wasting.

Unsafe conditions, on the other hand, are the exact ways in which a population's vulnerability manifests itself in time and place in response to a threat. People living in dangerous environments (for example, on lands with very shallow soils and soils that encourage water logging, with very fragile rock structures, and on very steep slopes), being unable to purchase safe constructions, and the lack of efficient state protection are all examples (for instance in terms of effective building codes). Such people may not necessarily have prior knowledge of existing disasters or events in the area and have

no skill for recovery hence are very vulnerable to the various hazards as stated in figure 6 which may make them vulnerable to dangerous mass wasting events. The black arrow is linking the box with “adverse climatic conditions” to that of “unsafe conditions” because climatic conditions feed into unsafe conditions and can equally lead to mass wasting hazard as well.

Extreme climatic conditions are capable of causing mass wasting events. Alternate seasonal variations also adds on to the likelihood of causing more mass wasting. The alternate warm (drought) and cold conditions (snow and extreme precipitation) renders the land unstable and vulnerable to mass wasting in the least provocation.

## **2.12 Chapter Summary**

This chapter provided relevant literature upon which the whole research is positioned. It helped explain mass wasting and its dynamics. It further explained the importance of GIS and Remote sensing and hazard mapping.

Again, the chapter focused on the conceptual framework for the study. The study adopted the disaster Crunch model, described it and showed its relevance to the study. The next chapter looked at the methodology adopted for the study and some form of insight into the study area.



## CHAPTER THREE

### STUDY AREA AND RESEARCH METHODOLOGY

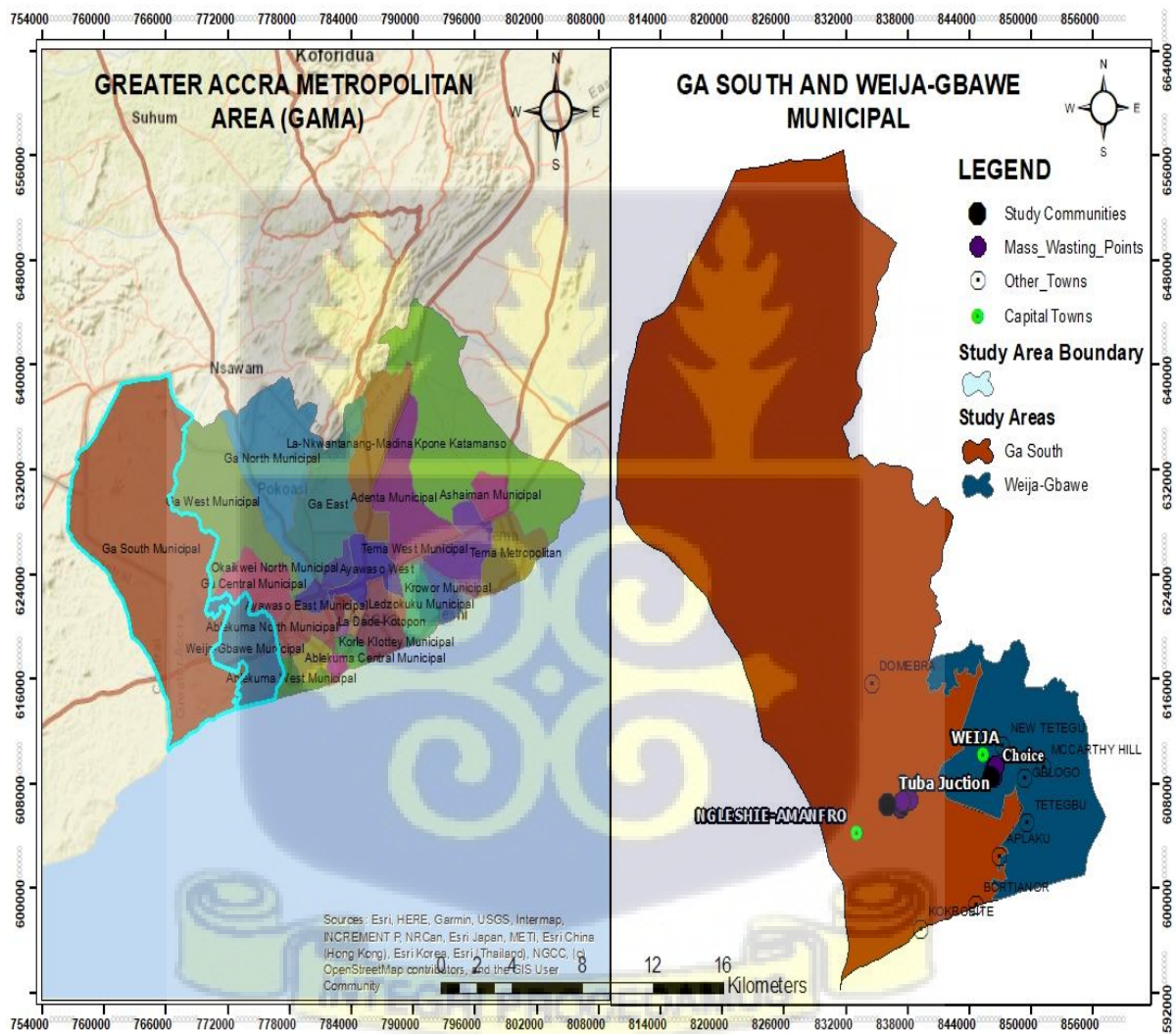
#### 3.0 Introduction

The chapter is devoted to presenting a detailed literature on the study area and the methodology that guided this study. Some features of the study area mentioned location and size, geology and soil, climate and relief and drainage, economic activities as well as population and settlement. The chapter also provided detail information on the methodology that guided the study. The methodology dwelt on issues of the philosophical background that underpins the study, while providing details on the research strategy, design, sampling technique, sample size and data analysis. In addition, the chapter provided a methodology on how the hazard maps were produced.

#### 3.1 Study Area

Introduced in the late 1980s, the concept of Greater Accra Metropolitan Assembly (GAMA), referred to the existing Accra Metropolitan Area (AMA), Tema Metropolitan Area (TMA) and the large, then essentially semi-urban area administratively called Ga Rural (Owusu, 2015; Yankson and Bertrand, 2012) as cited in (Møller-Jensen et al., 2020). “GAMA evolved as a key response to the challenges of the growth and sprawl of the area, and within the context of Ghana’s decentralization programmes, it has undergone continuous fragmentation into smaller local government areas (municipality districts)” (Møller-Jensen *et al.*, 2020 pg 6). What used to be Ga Rural was split into four Municipalities (Ga West, Ga East, Ga South, and Ga Central) in 2012, and in 2018 these were split further to add Ga North. In 2017, Ga South was split into Weija-Gbawe and Ga South districts (Ga South Municipal Assembly, 2018). AMA and TMA have also undergone further decentralization into sub-metropolitan districts. Important to

note, though, is that GAMA is not a legal unit. The power for urban planning has been decentralized to the corresponding municipal districts and not countered by any formal GAMA wise planning authority. Thus, the notion of GAMA should not be treated as a governance entity that coordinates city growth and the growing demand for services but as a catch phrase for the functional region undergoing urbanization (Møller-Jensen *et al.*, 2020). The study concentrated on communities in the Ga South and Weija-Gbawe Districts (Figure 3.1). The overall selection of the communities represents different histories of mass wasting occurrences. Apart from the fact these communities are located on seismically prone areas, they are also heavily encroached by humans.



**Figure 3.1: Map of Ga South and Weija-Gbawe Municipal Areas**  
Source: Author, 2020

### 3.1.1 Location and Size

Ga South Municipal Assembly is one of the Two Hundred and Fifty-Four (254) Metropolitan, Municipal and District Assemblies (MMDAs) in Ghana and among the twenty-Six (26) MMDAs in the Greater Accra Region. It has Ngleshie Amanfro as its capital. The assembly was carved from Ga South Municipal Assembly (Weija) in November 2017. Domeabra and Obom are currently the two (2) Zonal councils, which operates below the structure of the Assembly.

The Ga South Municipality is located in the South Western part of Greater Accra. It lies within latitudes  $5^{\circ}47'30''\text{N}$  and  $5^{\circ}27'30''\text{N}$  and longitudes  $0^{\circ}31'30''\text{W}$  and  $0^{\circ}16'30''\text{W}$ . The Municipality shares boundaries with Upper West Akim District to the North, Weija-Gbawe Municipal Assembly to the East, Gomoa East to the South-West, Awutu-Senya East to the West, Awutu-Senya West to the North West and the Gulf of Guinea to the South (figure 3.1). It occupies a land area of approximately 385.23 sq. km with a potential population density of 769.6pha, with about 70 settlements with population above 3000. The municipality has hundreds of satellite communities and hamlets.

Weija-Gbawe Municipal Assembly on the other hand, was carved from the then Ga West Municipal Assembly in November 2007 with the capital at Weija. The Weija-Gbawe Municipality is located in the South Western part of Accra. It lies within altitudes  $5^{\circ}47'30''\text{N}$  and  $5^{\circ}27'30''\text{N}$  and longitudes  $0^{\circ}31'30''\text{W}$  and  $0^{\circ}16'30''\text{W}$ . The Municipality shares boundaries with Ga South to the West, Ga Central Municipal Assembly to the East, and Ablekuma North Assembly to the Southeast. It occupies a land area of approximately 502.31 sq. km with about 120 settlements.

### 3.2 Geology and soil

The land area is underlain by shallow rocky soils and is extensively developed on the steep slopes of the Weija hills as well as basic gneiss inselbergs. The slopes are mostly formed over the clay soils of the Dahomeyan gneiss with alluvial areas surrounding the low lying coastal lagoons.

The geology of Weija according to Muff and Efa (2006) consist of the marine, lagoonal or fluvial sediments which are known to be prone to slope failure during earthquake due to liquefaction. These sediments are considered to be from the unconsolidated and poorly consolidated rocks, sediments and superficial deposits from the quaternary age. Tuba also has deeply weathered granitoid-pegmatite complex with bedrock that is very poorly exposed with most outcrops consisting of coarse-grained microcline pegmatites with graphic texture. Leucocratic, equigranular, medium to dark-coloured granitoid appears to be the host of the pegmatites. Weathered rocks here forms a layer of coarse-grained sand that consists of subangular quartz and feldspar grains. The weathered rocks possess good excavability for sanitary pits. The sand layer has good potential for shallow groundwater but it is unprotected from contamination. It has a good bearing capacity and slope stability of fresh rock. Drilling data indicates that, top soil has a 1 m depth and regolith has depth of up to 50 meters. Disintegrated rock provides good construction sand. The main type of soil in this area is the coastal savannah ochrosols. The coastal sands are pale yellow in colour and without humus or organic matter. These soils are suitable for coconut and shallots cultivation. On the Aplaku and Bortianor hills, the soils are mainly pale and sandy with bushy quartzite occurring to the surface in most places. These soils are rich in sand stone and lime stone that are good source of material for the construction industry.

The red earth is developed in old and thoroughly weathered parent materials. They are typically loamy in texture near the surface becoming more clay below. The red soils are porous and well drained, support road development, and provide ample moisture storage at depth for deep rooting plants. Nutrients supplies are concentrated in the humus topsoil.

### **3.2.1 Relief and drainage**

The land area consists of gentle slopes interspersed with plains in most parts and generally undulating at less than 76m above sea level. The Akwapim Range and the Weija hills rise steeply above the western edge. The crest of the Akwapim range lies generally at 300m southwards. This line of hills continues through to the Weija hills with the highest point reaching 192m near Weija.

There are two main rivers namely, the Densu and Ponpon river, which drain the Municipality. The largest is the Densu that drains down from the Eastern Region through the western portion of the Municipality to Bortianor where it enters the sea. It is the source of water supply for over half of the entire population of Accra Metropolis in the Greater Accra Region. Other Water bodies are mostly tributaries of the Adeiso, Doblo, Ntafafa and the Ponpon rivers. There is a potential of aquaculture in the Municipality and if well planned it would reduce unemployment rates in the Municipality.

### **3.2.2 Climate**

The rainfall pattern is bi-modal with an annual mean varying between 760mm on the coast to about 1120mm in the extreme north. The Municipality experienced more dry

seasons than wet seasons. The annual average temperature ranges between 26°C in August and 28°C in February and March, the hottest months with a relative humidity of about 75%. Average duration figures are about 94% and 69% at 6:00 and 15:00 respectively.

### **3.2.3 Economic activities**

The Municipalities are projected to have an economically active population. The structure of the local economy is gradually shifting away from agriculture and fishery to service and commerce with about over 57% of the economical active population engaged in the service and sales occupation. There is however, a great potential for the agriculture and fishery sector due to availability of land and the coast. There are large scale quarrying activities in the north-eastern part of the Municipality for export and construction works in the Greater Accra and Eastern Regions. What about sand mining. Write on things that have a bearing on your work

The informal sector is the largest employer in the Municipality, followed by the private formal sector. The proportion of the females working in the private informal sector is quite higher than of their male counterparts. However, the proportion of males employed in the public sector is higher than the females.

### **3.2.4 Population and Settlement**

Weija-Gbawe Municipality has its population to be 233,000 according to the (Andoh, 2018) but the population of Ga South Municipality as projected in the 2018-2021 Revised Medium Term Development Plan is 295,552 representing 7.3% of the Greater Accra regional population which stands at 4,010,054 (Ga South Municipal Assembly,

2018). For the purpose of planning, the projected population for the Municipality is estimated to be around 358,893 at the end of the 2021 plan period with an annual growth rate of 4.5%. The intercensal growth rate of both Municipalities however stands at 4.1%, which is quite higher than that of Greater Accra Region (3.1%) and Ghana 2.7% as a whole. This could be attributed to high migration into the Municipality especially those within the middle and higher class. The population increase the Municipality is experiencing can be attributed to its proximity to Accra, the capital city and Kasoa.

The Ga South Municipality is largely peri-urban and serves as a dormitory town with about 80 identified settlements. Out of this number there are about 15 urban towns with populations between 5000 and 80,000 and hundreds of satellite communities and hamlets most of which are located at the outside of the Municipality especially the northern part from Nsuobri to Kofi Kwei electoral areas. However, about 72% of the total population live in the urban area of the Municipality. The southern part of the Municipality which is about one-third (1/3) of the Municipality is urbanizing at a rapid rate due to its proximity to the Accra Metropolitan area, improved transportation network and serves as a centre between urban Accra and Kasoa area.

Most of the services and infrastructure relating to education, health, banking, security, market and others are located within this area. Majority of the settlements in the southern municipality are unplanned (nucleated) high density residential areas transiting to commerce and light industries along the Bortianor-Kasoa Highway. The Municipality is growing towards the central and northeastern direction with new buildings and needs to be planned for to avoid urban sprawl as identified in the

southern. Concrete structures happen to be the most used construction materials in the municipality especially in the southern part.

There are rural and agro-based settlements towards the centre and periphery of the Municipality. Most of the arable lands in these areas are rapidly turned to residential and estate developments leading to rural – urban migration and change in occupation from farming to construction (mason, carpentry and others). Unauthorized developments characterize most part of the peri-urban municipality mainly due to non-existent development plans and building byelaws for the development of these areas.

### **3.3 Research Methodology**

#### **3.3.1 Introduction**

The methodology for an academic research is very essential and crucial. A research methodology represents the concepts of development of the process to generate theory that is procedural framework within which the research is conducted (Mohajan, 2017). Cohen et al., (2002) agreed by saying that, research methodology is the procedure that describes, explains and predicts outcomes. It helps put the research on the right path by defining the principles and ground rules governing a particular research.

#### **3.3.2 Philosophical Underpinning and Research Strategy**

A research philosophy refers to the belief of what constitute reality and how research should collect information or data about this reality (Blaikie, 2000). The procedure and general ideas of how the world is visualized by a researcher is accentuated by the philosophical viewpoint. It is this perception about the world that guides a research through its designs and strategies for enquiry into the problem investigated. In a

research, a philosophical account takes two broader methodologies; epistemological viewpoint denoting a subjective gathering of information from the world where interpretation to the happening in the environment or reality is based on the understanding of situations around them and it is normally associated with qualitative studies. According to Bryman (2012) the emphasis is on extracting meaning of the social world through an in-depth understanding of the participants perceived meaning of the social world, their interpretations and behaviours. This inductively leads to the generation of grounded theory. Qualitative strategy is considered more advantageous as it is capable of constructing social reality and cultural meaning as it anchored on interactive process and event. Ontological viewpoint on the other hand is the opposite of the former. Here, data gathering is objective, where reality is what people perceive to exist rather than making out of the situations existing in the environment. This method is normally associated with quantitative studies. According to Cohen et al., (2007 p. 8) “this approach is characterized by procedure and methods which are design to discover general laws which are nomothetic”. Scotland (2010) opined that, knowledge generated is valued neutral according to the positivist paradigm since their methodology is valued neutral. According to Mikkelsen (2005); Teye (2012), quantitative methods is more appropriate for making predictions and generalizations. Castro et al., (2010) added that, the approach can also be considered for model specification including the establishment of the nature of correlations between different variables. However, the method has been criticized inefficient measuring social and cultural relations such as behaviour and perceptions. In response to the shortcoming of these two research approaches, scholars in recent times have tended to combine both approaches in a single research, an approach called the mixed methods approach Teye

(2012) agreeing to Creswell (2009) line of argument of the pragmatics which this study adopted.

Creswell (2009) stated that pragmatism as a worldview arises out of actions, situations, and consequences rather than antecedent conditions - as in post positivism. There is a concern with applications-what works-and solutions to problems. Pragmatism is not committed to any one system of philosophy and reality. It aligns to mixed methods research in that inquirers draw liberally from both quantitative and qualitative assumptions when they engage in their research. Pragmatism has been acknowledged to be the philosophical underpinning for mixed method research (Creswell, 2009). Pragmatics do not see the world as an absolute entity, but they believe that the world is composed of social, natural, historical and cultural aspects. The approach therefore gives a more extensive platform to researchers to make the choice of methods, techniques and procedures that best fit for investigating a specific problem thus making it possible for investigators to explore all aspects of a problem for a more holistic understanding (Morgan, 2007; Creswell, 2009). It is important to use different approaches because they will enhance better understanding of the research questions than using either approach exclusively (Creswell and Plano Clark, 2010).

This study seeks to ascertain the triggering factors of mass wasting by considering an interplay between natural and human activities on the environment. To the pragmatist researcher, both interpretivist and positivist approaches are feasible for a study. The interpretivist philosophy assisted in understanding better the drivers of mass wasting in the study area. This was done through in-depth interviews with some stakeholders in the study area. As a way of complementing the interpretivist approach and also to

ensure objectivity, the study however employed a positivist quantitative approach via administering questionnaires to residents in the study area. Thus, complementing the strength and weakness in each approach to obviating the challenges in using a single approach where some important information could have been missed.

Pragmatic worldview will be best as it allows for the use of mixed method techniques, as others will limit the holistic understanding of the problem under investigation. Also, since social reality is multifaceted, mixed methods designs therefore will provide an effective means of explaining the complexity of human behaviour (Teye, 2012).

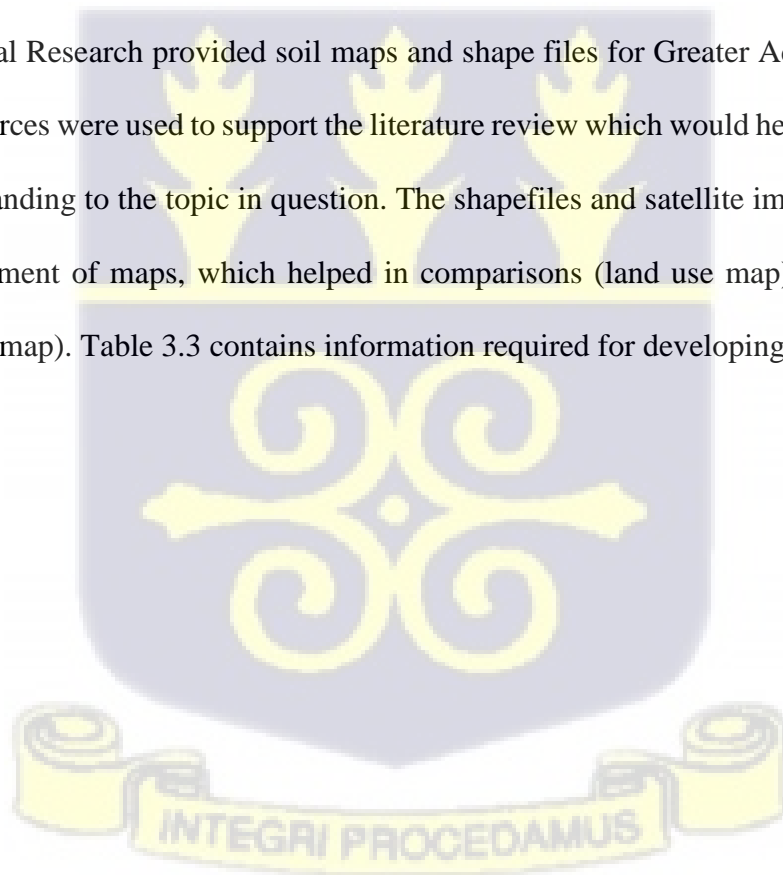
### **3.3.3 Research Design**

The research adopted a case study design, which sought to give an exhaustive and intensive analysis of the study area. This was considered to be the most ideal and apt because of the place and hazard specific nature of the research which concurs with Calgaro and Lloyd (2008) where they commented that when observing the place specific nature of vulnerability, case study design has the ability to analyse complex place based phenomena. Additionally, case study is most appropriate when the researcher's concern is about understanding what is happening in a specific context and is confident of gaining the co-operation of the people around whom the study is to be conducted (Robson, 1993 as cited in Adu-Boahen et al., 2020). The design assisted in gathering in-depth information of the condition under study, which will later aid in decision and policy making on monitoring, delaying and mitigating mass wasting effects.

### 3.3.4 Data Sources

The study made use of two main data sources; primary and secondary data sources. Primary data sources were derived from expert interviews, questionnaires, observations and pictures.

Secondary data was from published journals, publications, articles, books, newspaper reviews, reports, satellite images that were derived from earth explorer of the United State Geological Survey (USGS) website and the internet. Climate data was derived from the Ghana Meteorological Agency. The Ga South Municipal Assembly provided the new boundary shape files for the Ga South and Weija-Gbawe Districts. Digital Elevation Model (DEM), geological and Topographic maps were supplied by Ghana Geological Survey Department. The Soil Department of the Centre for Scientific and Industrial Research provided soil maps and shape files for Greater Accra Region. The data sources were used to support the literature review which would help in giving more understanding to the topic in question. The shapefiles and satellite images aided in the development of maps, which helped in comparisons (land use map) and projections (hazard map). Table 3.3 contains information required for developing the hazard map



**Table 3. 1: Summary of Environmental Data Needed for Hazard Mapping**

<b>Group</b>	<b>Data Layer and Types</b>	<b>Relevance for Mass wasting/ Mass wasting Susceptibility and Hazard Assessment</b>
<b>Digital Elevation Data</b>	Slope aspect	Might reflect differences in soil moisture and vegetation
	Slope profile, curvature	Indicators for slope hydrology
	Elevation	Important in relation to rainfall and exposure
<b>Geology</b>	Rock types	Lithological information
	Faults	Distance from active faults or width of fault zones
<b>Soils</b>	Soil types	Engineering soils with genetic or geotechnical properties
	Geotechnical properties	Grainsize (Particle size distribution),
	Stream networks	Buffer zones around streams
<b>Land use</b>	Land use maps	Type of land use/ land cover
	Roads	Buffer around roads in sloping areas with road cuts

Source: Adapted from Caribbean Handbook on Risk Information Management (CHARIM), 2014

Secondary data again made it possible for confirming or disagreeing with already established knowledge and hence augmenting or filling in the gaps in existing literature.

### **3.4 Target Population**

Households in Ga South and Weija-Gbawe Municipal were considered as target population for the purpose of this work. Specifically, the study area lies between Tuba junction and Broadcasting which is along the Cape Coast-Accra highway and beyond the Kasoa Toll booth, which is opposite the Densu River where Osiadan Construction Limited is located, in the Ga South Municipality. The selected areas for analysis comprised settlements at the foot of the hill that stretches from Tuba junction close to the tollbooth on the Kasoa-Accra highway to an area indicated as Broadcasting stretches from Michigani to broadcasting which is the top of the hill. In the Weija-Gabwe Municipality, Choice was selected with communities beneath through to residents

around Triple Hill Hotel which is on the hill. Apart from the fact these settlements are both located on seismically active areas and are heavily encroached by humans, the overall selection of settlements represents different histories of mass wasting occurrences. The target population constitutes 4751 individuals (GSS, 2014). This comprises of two communities; Choice and Tubakrom with 4,198 and 553 households respectively (GSS, 2014). These settlements were selected due to various happenings of mass wasting in the community. Several warnings have been issued by news items concerning these communities (ABC News, 2019; Andoh, 2018; Bokpe, 2015; Peacefmonline.com, 2015). They also were areas suggested by the municipal assemblies. Again, these settlements fall on the fault lines of Ghana making them earthquake prone zones making them more prone to mass wasting.

### 3.4.1 Sample Size Determination

A sample as defined by Bryman (2012) refers to a section of an entire population that mirrors the attitudes and attributes, opinions or characteristics that one wishes to investigate or study. It shows the procedure, which the researcher uses in gathering people, places, or items to study. This is necessary because the entire population cannot be investigated. The total number of households in the selected communities will comprise the sampling frame that will be used. To be able to sample out the required number of households that will be engaged in this study, the (Krejcie and Morgan, 1970) sampling size determination formula will be used. This is given as

$$S = \frac{X^2 NP(1-P)}{d^2(N-1) + X^2(1-P)} \dots \dots \dots (3)$$

Where;

S = The required sample size for the study.

**X** = The value of chi-square for one degree of freedom at a confidence interval of 5% = 1.96

**N** = The target population which is 4751 individuals.

**P** = The target population proportion which is assumed to be 0.50 since this will provide the maximum sample size.

**D** = Degree of accuracy or precision which is also expressed as 0.05

Therefore the sample is calculated as;

$$S = 1.96^2 \times 4751 \times 0.5(1-0.5) / 0.05^2 (4751-1) + 1.96^2 (1-0.5)$$

$$S = 3.8416 \times 4751 \times 0.5(0.5) / 0.0025(4750) + 3.8416 \times (0.5)$$

$$S = 4562.8604 / 11.875 + 1.9028$$

$$S = 4562.8604 / 13.7778$$

$$S = 331.1748 \approx 331$$

Therefore, 331 sampled respondents from the three communities will be needed for the study.

### 3.4.2 Sample Distribution

Proportionally, respondents for each community is calculated as follows

$$\text{Choice} = 4198/4751 \times 331 = 292.47 \approx 292 \text{ individuals}$$

$$\text{Tubakrom} = 553/4751 \times 331 = 38.52 \approx 39 \text{ individuals}$$

**Table 3. 2: Table Showing a Summary of Target Population and Sample Size**

Target Population (Community)	Sample Frame (Individuals)	Sample Size
Choice	4198	292
Tubakrom	553	39
Total	4751	331

### 3.4.3 Sampling Procedure

For each of the selected communities, the researcher employed non-probability sampling to select respondents for the questionnaire survey. Non-probability sampling is known to be much cost and time effective. Purposive sampling technique was used

to administer the questionnaire (Bryman, 2012; Cohen et al., 2007). The questionnaire was administered to respondents aged 18 years and above and those who have been in the community for at least a year and above hence the reason for the selection of this technique. This bracket was selected because they are old enough to recount the event that has been happening over the years. Respondents were selected from residents found on the Weija hills, those at the foot and those a little further away from the hill. This was done to ascertain the perception of safety of respondents at the various ends of the hills. Purposive sampling was again used to for the for the in-depth interviews.

#### **3.4.4 Data Collection Methods and Tools**

To answer Objective 1, quantitative data was used. This included remotely sensed images. Landsat images of 1991 (TM), 2003 (ETM+) and 2015 (ETM+) were used. The 1991 Thematic Mapper (TM) was captured by Landsat 4 sensor, while that of 2003 and 2015 Enhanced Thematic Mapper+ were captured by Landsat 7 sensor. The study area fell into scene by path 193 and row 56. Images were downloaded from earth explorer of the United State Geological Survey (USGS) website. The images were meticulously selected to avoid those inundated with cloud cover hence the reason for the dates chosen. In addition to this, field validation will be conducted to ensure accuracy of various training sites. Images from google earth were also taken for inventory mapping. Rainfall data of 27 years (1991-2017) from the climatic station at Weija was derived from the Ghana Meteorological Agency. The number of years was chosen to help see the trends of rainfall over the years. A geological map of 1:50000 from the Ghana Geological survey and DEM of 30m resolution from CERGIS at the Department of Geography and Resource Development were sourced. Again,

photographs were taken of the various events that were happening onsite to support the images that were downloaded online. Field notes were taken to back the images.

Both qualitative and quantitative techniques of data collection was be used to answer objective 2 and 3. The quantitative data was collected using a set of semi-structured questionnaire. The questionnaire survey gathered information about the risk knowledge and exposure, causes, the experiences of people with mass wasting, their preparedness in case of disaster, the impact of mass wasting on their environment as well as the participation of the local assemblies and the government. This method was used because questionnaires can provide valuable information to emergency management agencies for developing risk management procedures since they can reveal information on public knowledge, attitude, perception, experience and preparedness levels in relation to natural hazards (Bird, 2009). The questions included both open-ended and close-ended questions. The open-ended questions were for respondents to further explain their views or opinions. According to Bryman (2012) open-ended questions reveal unfamiliar responses which might not be anticipated by the researcher. The close-ended questions also provided multiple of answers from which the respondents' chose the one that best describes them. Closed-ended questions according to Bryman (2012), limit the extent of variability in the recording of answers. The questionnaires however, was categorized into sections based on the objectives of the study.

Qualitative data was in the form of in-depth interviews and personal observations, to capture respondent's perceptions, understanding and experiences with mass wasting its related hazard. Face-to-face interviews was used to acquire information from stakeholders like the municipal assemblies and the assemblymen from the study area.

Interviews were conducted with the Heads of Physical Planning and Development planning from the Ga south Municipal Assembly, the Disaster Control Officer from National Disaster Management Organisation (NADMO) in the Weija-Gbawe Municipal Assembly and the assembly members from Tuba, and Weija. The information above was stored on voice recorders, by taking of field notes and pictures. Based on the responses from the respondents, some policy recommendations were profiled aiding to answer objective 4 of the study.

Concerning the questionnaires administered, though the sample size per the calculation was 331, the study could not reach this number. This was because part of the questionnaires were being administered during the COVID-19 pandemic. This made some respondents unresponsive. Going on to administer the questionnaire during the pandemic also puts the life of the researcher at risk since it was mostly difficult to determine who has the disease and who does not at the early stages. Secondly, even before the pandemic, some of the respondents were not responsive as most of them indicated that some media houses have been there to cover the problem but they have not received help from the government or even the municipal assembly so they were not willing to barge or comply though they were emphatically told that it was for research purposes. This slowed down the whole process of data collection. In all, one hundred and fifty (150) questionnaires were administered but one hundred and thirty (130) questionnaires were brought back. Two (2) of them were rejected due to unwillingness of some respondents to continue and difficulties making contact with some respondents. In total, one hundred and twenty-eight (124) questionnaires and interview guides were used for this study (thirty-three (33) from Tubakrom and ninety-one (91) from Choice and four (4) interview guides were also administered to the

Senior Disaster Control Officer (NADMO), Municipal Heads of Development Planning and Physical Planning Departments of Ga South Municipal) Assembly, Tuba Assemblyman).

### **3.4.5 Data Analysis**

Data analysis varied among the objectives and several combinations of analysis were done for each objective. The Statistical Package for Social Sciences (SPSS) software was used to analyse the questionnaires. The instruments were coded and entered into the SPSS. Analysis tools such as descriptive statistics, cross tabulation and chi-square test were used to analyse the data in relation to objectives 2 to 3. The output data were mainly tables and charts. The interviews on the other hand were transcribed and field notes were typed. The transcribed data and the typed field notes and pictures were afterwards coded and organized into themes for analysis. Photographs were taken to provide physical evidence of impacts of the hazard, some coping strategies being adopted by residents to manage the risk of mass wasting and to show some of the types of mass wasting occurring in the area. To respond to Objective 1 that sought to develop a mass wasting hazard map for the study area, ArcGIS 10.4.1 and ENVI 5.0 were used. A mass wasting inventory map was first developed. A mass wasting inventory map according to Highland and Bobrowsky (2008) are inventories that identify areas that appear to have failed by mass wasting processes. The inventory map was created using satellite images from Google earth and they were verified on the field. Nineteen (19) mass wasting areas were identified in all for both municipalities and their points were taken. The type of mass wasting was named using what was seen on the satellite image and what is happening on the field. Some environmental data were also needed to

develop the hazard map. Table 3.3 shows the information that was used for the development of the hazard map (Pg 63).

#### *3.4.5.1 Hazard Map Production*

Items from Table 3.3 (pg 63) were put together to get the hazard map. From the table, data layers needed were DEM, soil, geology and land use. A Digital Elevation Model (DEM) of 30m resolution was used for the study. Using the DEM, slope gradient, aspect and curvature were derived using ArcMap using aspect, curvature and slope spatial tool in ArcGIS.

#### *3.4.5.2 Slope Gradient*

The slope was processed in degrees with slope values ranging from 0° to 81°. The slope values were then subdivided into the following five classes: 0° to 15° (gentle slopes), 16° to 33° (moderate slopes), 34° to 50° (moderate steep slopes), 51° to 65° (steep slopes) and 66° to 81° (very steep slopes). Ranks were then given accordingly.

#### *3.4.5.3 Aspect*

The aspect map on the other hand has been divided into 10 classes, representing angular sectors of 22.5° wide, namely, North (0-22.5), North East (22.5-67.5), East (67.5-112.5), South East (112.5-157.5), South (157.5-202.5), South West (202.5-247.5), West (247.5-292.5), North West (292.5-337.5), North (337.5-360) and flats (-1). This is automatically given by ArcGIS. In the reclassified map for the multi-criteria analysis, the raster map was divided into nine classes namely North, North West, West, South West, South, South East, East, North East and Flats.

#### 3.4.5.4 Curvature

In the curvature map, the positive curvature values indicate that the surface is convex at those cells and negative values show that the surface is concave at those cells. A flat surface has a value of zero. The more negative the value the higher the probability of mass wasting occurrence and the more positive the value the lower the probability (Ladas et al., 2007; Lee, Choi, and Min, 2004). The curvature map was divided into 10 classes from -35 to 23 but was reclassified into three concave (all the negative values), flat (zero) and convex (all the positive based on the analogy above).

#### 3.4.5.5 Soil

The soil shape file was obtained from the Remote Sensing and GIS Laboratory. The shape file of the study area was overlaid on the map and clipped using the clipping tool in ArcMap to capture that of the study area. The soil material used for the study area included Acrisols, Fluvisols, Leptols, Lixisols, Luvisols, Plinthosols and Solonetz. Soils with poor drainage and severely weathered soils are more prone to mass wasting than well-drained soils based on this, the map was reclassified into three; Acrisols, Leptosols and Luvisols.

#### 3.4.5.6 Geology

The geology of the study area was also acquired from the Remote Sensing and GIS Laboratory. That of the study area was clipped out using the clipping tool in ArcGIS. A geology map of the study area was then developed. They included alluvial, coastal sand, garnet, granite, lower Birimian, mixed (Quartzite and sandstone), Togo range, Volta alluvium, Voltaian, Voltaian sandstone. Heavily weathered, easily erodible and poor bearing rocks are more susceptible to mass wasting than hard, resistant rocks

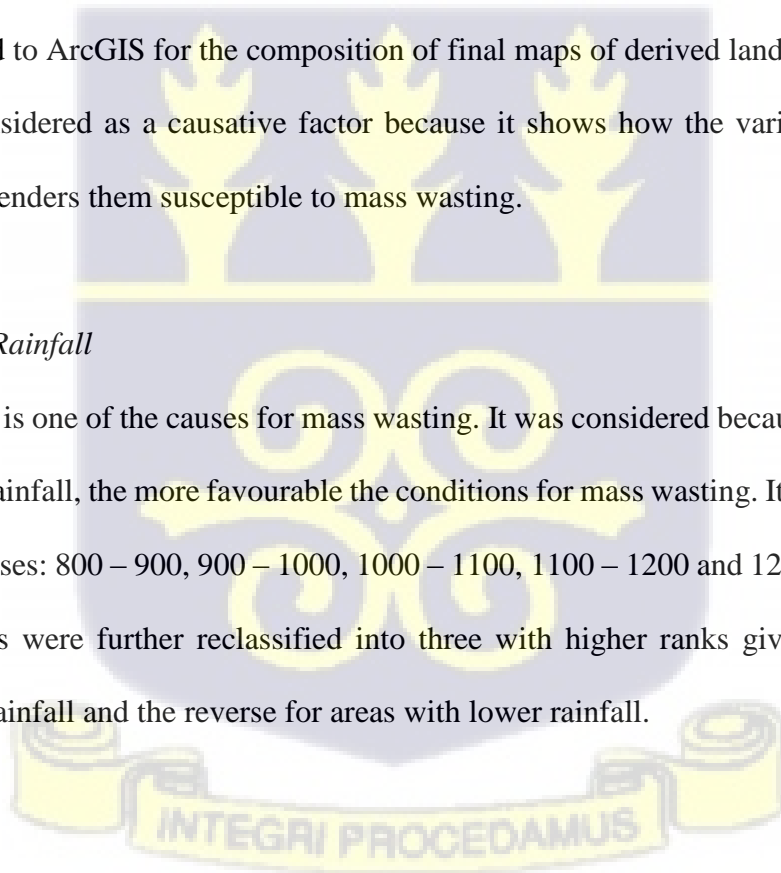
with good bearing capacity. Ranks were allocated to the various geology types based on this reason and reclassification was done.

#### *3.4.5.7 Land Use*

Landsat image of 2020 (ETM+) was used. The Landsat images were classified using the following band combinations and assigned false colour composite; 4 (red), 3 (green) and 2 (blue). The image was classified under supervised classification with reference to Google Earth image of the study area and training areas of sites taken in the field using a global positioning system (GPS). Supervised classification was used because it is suitable for quantitative analysis of remotely sensed images (Pullanikkatil et al., 2016). Four land cover types (built-up, bare land, water and vegetation) were classified using the maximum likelihood classifier module in ENVI. The classified images were exported to ArcGIS for the composition of final maps of derived landscapes. Land use was considered as a causative factor because it shows how the various type of land usages renders them susceptible to mass wasting.

#### *3.4.5.8 Rainfall*

Rainfall is one of the causes for mass wasting. It was considered because the higher the rate of rainfall, the more favourable the conditions for mass wasting. It was divided into five classes: 800 – 900, 900 – 1000, 1000 – 1100, 1100 – 1200 and 1200 – 1300. These divisions were further reclassified into three with higher ranks given to areas with higher rainfall and the reverse for areas with lower rainfall.



#### 3.4.5.9 Distance Maps

Distance maps were created for faults lines, drainage and roads. The major thrust and fault lines of the study area were acquired from an Environmental and Engineering Geology Map of Greater Accra Metropolitan Area of scale 1:50,000. The map was georeferenced in WGS 1984 using ArcGIS. That of the study area was clipped out using the clipping tool in ArcGIS. A distance map of the study area was then developed using 100-meter interval buffer. Ten classes were created in all. According to Ladas *et al.* (2007), fault zones increase the potential of mass wasting by creating steep slopes and sheared zones of weakened and fractured rocks therefore increasing distance from these zones means a decrease in the frequency of mass wasting.

Location of the mass wasting from water bodies was considered as another causative factor. This was taken into account on the hypothesis that water bodies affect the stability of the slopes both by saturating and by undercutting them. It was assumed that as the distance from water bodies increase the hazard of mass wasting decreases. A 100-meter wide buffer was created with eight resultant classes.

Another factor related to the occurrence of mass wasting is the distance from road network. It was assumed that mass wasting susceptibility decreases with increasing distance from the main roads located on hilly and mountainous areas. This assumption is based on the general hypothesis that mass wasting is more frequent in areas closer to roads, due to inappropriate road sections and drainage from the road. Ten classes were created using the multiple ring buffer, a proximity tool from the ArcGIS. 15000-meter buffer with 100-meter intervals around the roads. All the distance maps were

reclassified into five; 100, 200,300,400,500 and >500. Ranks were given in decreasing order based on the distance from the feature.

The primary vector thematic map-layers (soil, rainfall, land use, geology and distance map) presented were converted into raster format for future analysis through a vector to raster conversion procedure using a pixel size of 30 x 30m. This cell size was selected in order to match the spatial resolution of the DEM.

The Analytical Hierarchy Process (AHP) was then applied for the creation of the final hazard map. This was done through an AHP extension developed by Oswald Marinoni under ESRI. Weights were given to the various factors based on the responses of the respondents on the extent to which they cause mass wasting. To get the weights for each thematic layer, the study constructed the pairwise comparison matrix required to calculate factor weights in Analytic Hierarchy Process (AHP). “The diagonal boxes of the matrix take a value of 1 while the boxes in the upper and lower halves are symmetrical with one another and the corresponding values are therefore reciprocal with each other. When the factor on the vertical axis is more important than the factor on the horizontal axis this value varies between 1 and 9. Contrary to the above the value varies between the reciprocals 1/2 and 1/9”(Ladas et al, 2007 p. 8).

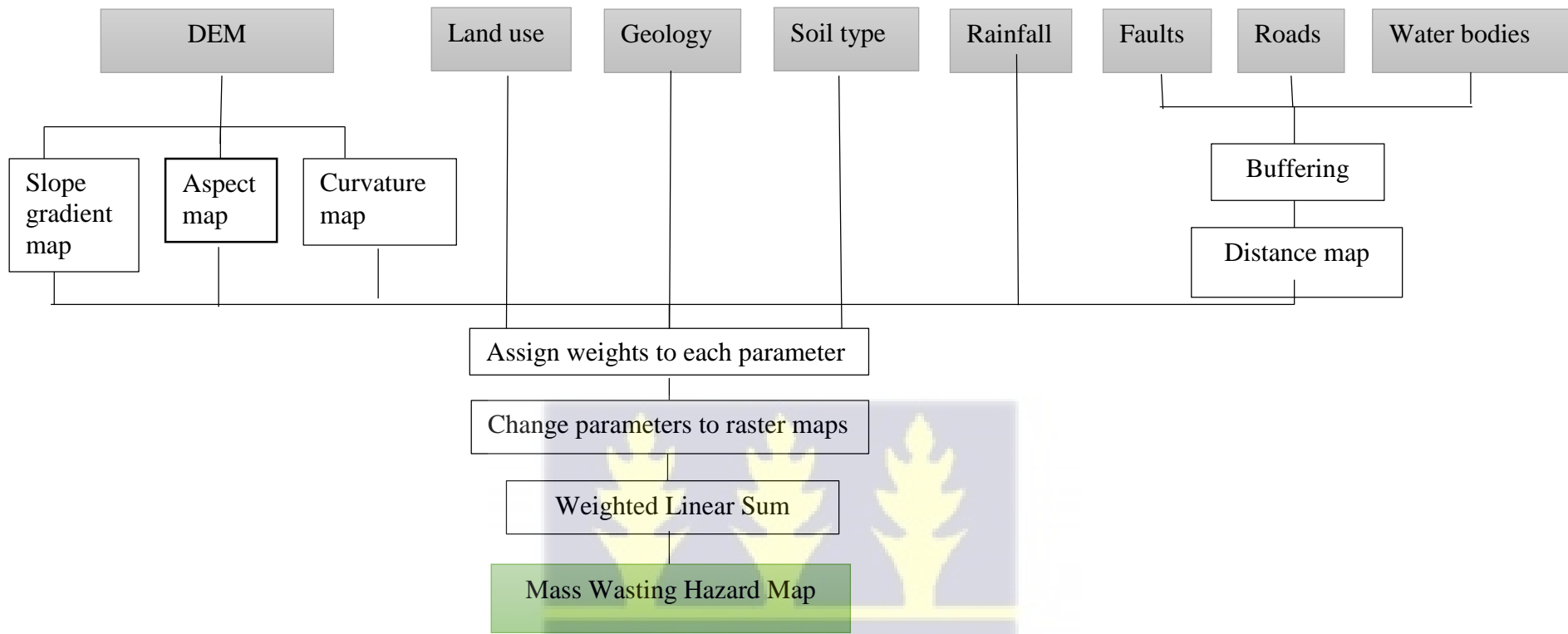
A basic requirement of weighting is that the sum of all weights equals 1. The consistency ratio (CR) was used to check the consistency used to build the matrix of pairwise score rating, which depends on the number of parameters and is automatically calculated by the software. The CR is representative of the probability that the matrix ratings were randomly generated. Saaty (1980) recommends that the CR must be less

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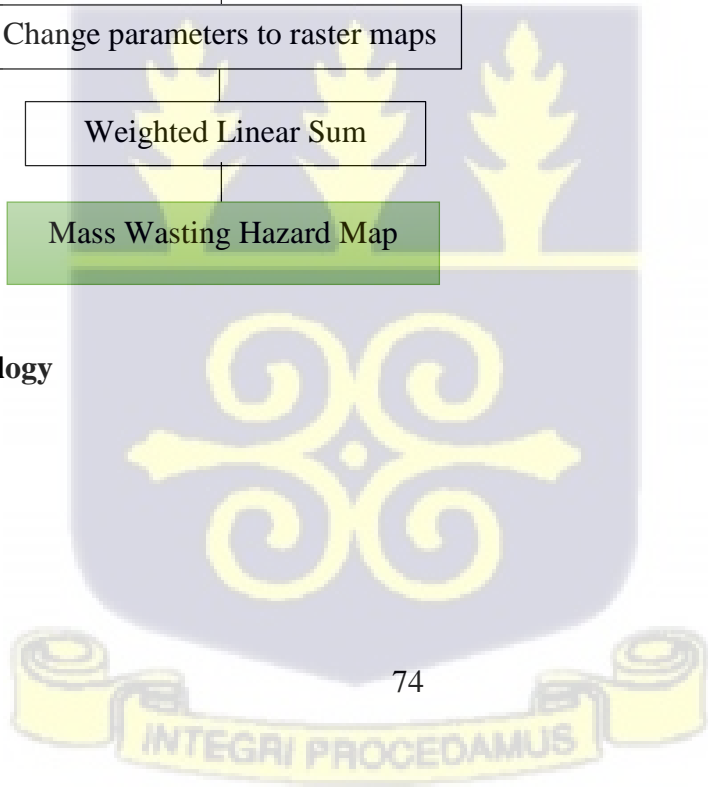
than 0.1 to accept the computed weights other than that the ratings should be re-evaluated. The CR is 0.06 indicating the degree of consistency of the comparison matrix is adequate. Ranks of 1-5 were then assigned to the various causative factors where higher rank indicate higher influence for the occurrence of mass wasting. The final map was automatically generated by GIS after the weights were imputed.

An area under the curve (AUC) curve approach, however, was used to analyse the prediction accuracy of the proposed models used in the development of the hazard maps.





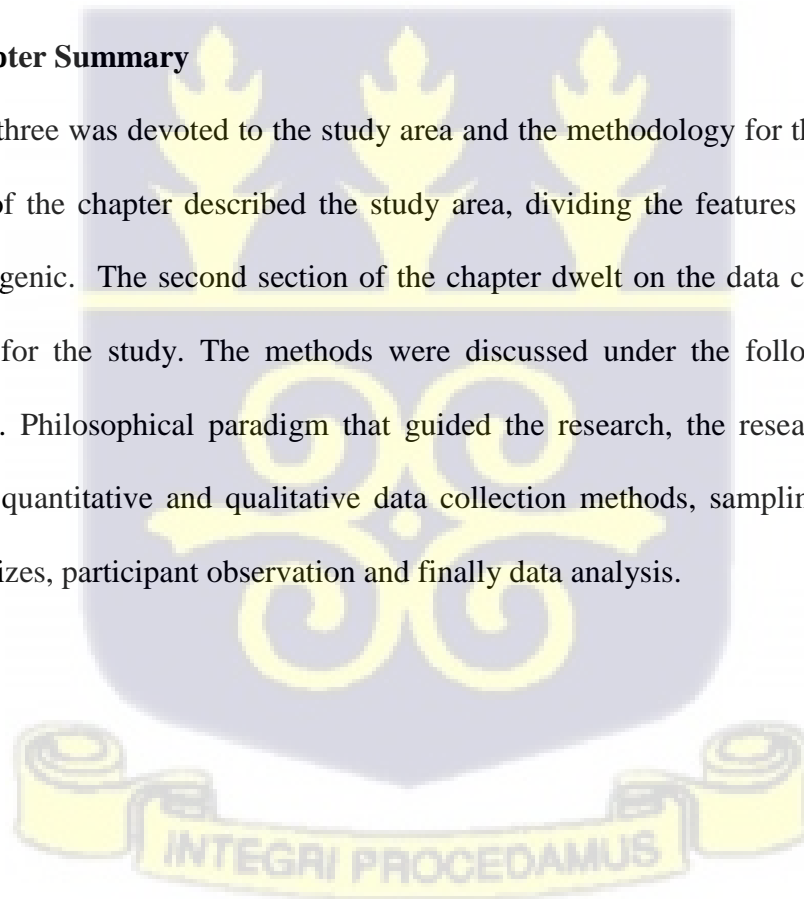
**Figure 3. 2: Flowchart of Methodology**  
 Source: Author, 2020



To obtain this, an ARCGIS extension called ArcSDM was downloaded from [www.sdmttoolbox.org](http://www.sdmttoolbox.org). ArcSDM was then added to ARCGIS by clicking add to Arc tool box, navigate to your storage folder and click on the ArcSDM toolbox to add to Arc tool box. Click on the plus sign to expand ArcSDM and click on calculate ROC curves and AUC values. Then, add the training points (Mass wasting points) and the mass wasting hazard map to the classification model, choose the storage location to save you graph and click ok. An AUC graph is automatically generated. Curves with values 0.9-1.0 are considered to be an excellent prediction, 0.8 - 0.9 equals very good prediction, 0.7-0.8 is considered as a good prediction, 0.6-0.7 is considered as satisfactory prediction while 0.5-0.6 is considered as unsatisfactory prediction.

### **3.5 Chapter Summary**

Chapter three was devoted to the study area and the methodology for the study. The first section of the chapter described the study area, dividing the features into physical and anthropogenic. The second section of the chapter dwelt on the data collection methods adopted for the study. The methods were discussed under the following themes and headings. Philosophical paradigm that guided the research, the research strategy, data sources, quantitative and qualitative data collection methods, sampling techniques and sample sizes, participant observation and finally data analysis.



## CHAPTER FOUR

### RESPONDENTS CHARACTERISTICS AND VULNERABILITY LEVELS

#### 4.0 Introduction

To determine the vulnerability levels of respondents on mass wasting, the characteristics of the population is of much importance. This chapter described the characteristics of respondents including age, gender, occupation, knowledge of mass wasting and others. These backgrounds are of immense importance as they place the views of respondents in a proper perspective to understand the context of discussions. The chapter also attempted to understand and appreciate respondents' knowledge on mass wasting, their source of mass wasting information and their experience with mass wasting. Also included are the various DEM derivatives, geological, land use, soils, rainfall, and other characteristics that together contribute to making the municipalities vulnerable to mass wasting, mass wasting inventory map as well as the potential mass wasting hazard map. The results are followed by a detailed discussion linked to the literature to place the issues within a broader context.

#### 4.1 The Background Characteristics of Respondents

The sex distribution for this study favoured the female respondents as confirmed in Table 4.1. The female population represented 56 percent of total respondents while the men accounted for only 44 percent. This is in agreement with the official records of the municipality, which shows a higher distribution of females than males (G. S. S., 2014). The higher number of female respondents was as a result of factors noticed across both communities under study. At the time of the study, most of the respondents who were available and cooperated were females. Also, they were the ones often met at home or in the shops. Meeting men at home was more difficult as they spent longer hours at their place of work. Besides, some of the men were so angry about the ongoing phenomenon in the

community so much so that they were not willing to talk about it anymore. Notwithstanding the factors listed above, the sex distribution has fairly represented the population.

The age distribution of the respondents has been placed in five ranges as shown in Table 4.1. The age group 20-30 years ranked first representing about 37 percent of total respondents followed closely by 31-40 age group constituting about 41 percent of respondents showing that respondents are highly youthful in nature between the ages of 20 to 40 years. This age group represents about 78 percent of the respondents. The age structure corresponds with the youthful distribution of the district's population (Ga South Municipal Assembly, 2018). Conversely, the relatively older respondents from the ages of 41 to 60 and above, representing about 22 percent, provided detailed insights into the historical development of the problem of mass wasting in the study area. A glance at the age distribution confirms the purview of respondents involved in this research giving it a fair representation to all community members. This nevertheless assisted in gathering a balanced account of the problems investigated across all age groups.

Results depicted in table 4.2 show that, majority of the respondents have had secondary (junior and senior high schools) education (50percent) whiles very few of them have had no form of formal education (11percent) (Table 4.1). A crosstab computation between respondents' level of education and gender showed that a higher proportion of females than males have had their education at the Junior High and Senior High School level. This results seem to be at variance with the official documents of the municipality which indicates that a higher proportion of males (92.6 percent) are literate than the females (83.6 percent) (G. S. S., 2014) (Table 4.2). It can also be deduced from the table that, a higher proportion of males than females completed their tertiary education (Table 4.2). The

implication is that more females are unable to continue their education to higher levels, perhaps due to marriage/child birth or other reasons (G. S. S., 2014). On the positive side, the table also shows that

**Table 4.1: Background Characteristics of Respondents**

Variable		Frequency	Percentage (%)
Sex	Male	54	43.5
	Female	70	56.4
	Total	124	100
Age (years)	20-30	46	37.1
	31-40	51	41.1
	41-50	17	14.7
	51-60	6	5.8
	61 and above	4	3.2
	Total	124	100
Level of education	No formal Education	14	11.3
	Basic	39	31.5
	Secondary	62	50.0
	Tertiary	9	7.3
	Total	124	100
Length of stay (years)	1 to 5	67	54.0
	6 to 10	36	29.0
	11 to 15	15	12.1
	16 to 20	6	4.8
	Total	124	100
Reason for stay	Closer to work/Came to work	71	57.3
	Family/Marriage	24	19.4
	Cheap Apartment	14	11.3
	Availability of land	15	12.1
	Total	124	100
Knowledge of mass wasting	Yes	124	100.0
	No	0	0
	Total	124	100

Source: Author's Field Data, 2020

**Table 4. 2: Respondents’ Level of Education**

Sex	Level of Education				Total
	No Formal Education	Basic	Secondary	Tertiary	
Male	5	16	28	5	54
Female	9	23	35	3	70
Total	14	39	63	8	124

Source: Author’s Field Data, 2020

The study also gathered information on the length of stay and reasons why respondents are living in their respective communities. From Table 4.1 a larger number have lived in the community for 1 to 5 years (about 54 percent) with the least length of stay being 16 to 20 years (about 5 percent). It can therefore be inferred from the results that, respondents have deeper understanding of the geomorphic processes taking place and are witness to the degrading landscape. A cross tabulation between the length and the reason of stay revealed that, majority of the respondents who have lived in the study communities from 1 to 10 were there because Table 4.1 further revealed that, majority of the respondents are living in the community because it closer to their work place or they just come to the community to work then return to their various homes (about 57 percent), others because of cheap apartments (about 19 percent), followed by land availability (about 11 percent) then marriage or family where people moved to join their parents or husbands in their residence (about 12 percent). This finding can be said to be a contribution to the rapid spatial expansion and residential development, with considerable migration of new settlers causing rapid urbanization and urban sprawl in the municipality. Table 4.3 showed that, respondents’ who have lived in these communities for 1 to 15 years are there particularly because their residence is closer to their place of work or they work in these communities. On the other hand, respondents who have lived there for over 15 years were there basically

because at the time, lands were readily available in that community at the time. A respondent commented,

*“I was fortunate enough to get my own land to build over here. Then, it was either you moved to the very outskirts at the north of Accra or towards the south which is our side. I preferred this end hence my reason for living here”.* (A 37 years old male trader from Choice).

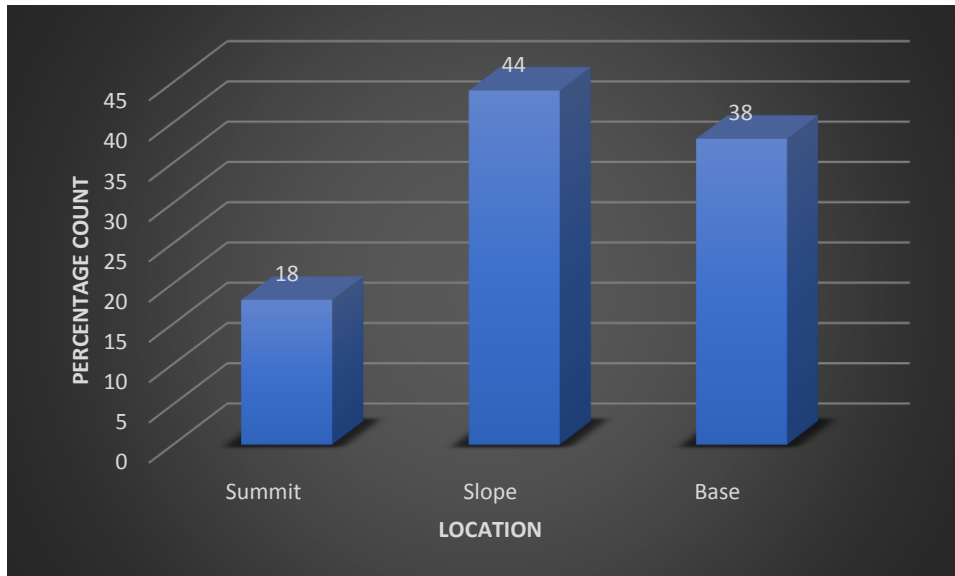
**Table 4. 3: Respondents’ Duration and Reason for Stay in the Communities**

Duration of Stay (Years)	Reason for Stay				Total
	Closer to work/Come to work	Family/Marriage	Cheap Apartment	Availability of Land	
<b>1 to 5</b>	44	16	4	3	67
<b>6 to 10</b>	19	5	6	6	36
<b>11 to 15</b>	7	2	4	2	15
<b>16 to 20</b>	1	1	0	4	6
<b>Total</b>	71	24	14	15	124

Source: Author’s Field Data, 2020

The study went further to analyse the location of respondents’ infrastructure on the basis of living on the slope, the basement or the summit of the hill. This is important as it will show the level of impact recorded by respondents living on each part of the hill. Figure 4.1 revealed that, 44 percent of the respondent were located on the slope, followed closely by residents at the base with 38 percent. It is believed that respondents at the base will suffer the greatest impact as infrastructure will be engulfed with floods and other related materials whenever there is an incidence of mass wasting. Respondents at the summit accounted for only 18 percent.



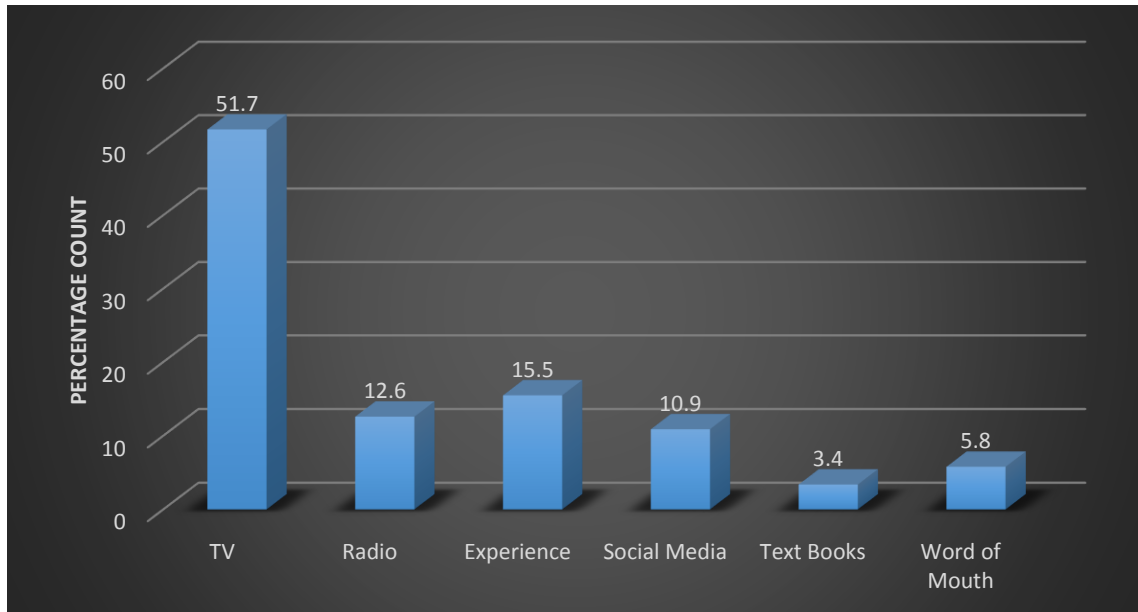


**Figure 4. 1: Location of Respondents' Infrastructure**

Source: Author's Field Data, 2020

Additionally, the study gathered information on the knowledge of respondents on mass wasting. Table 4.1 shows that all the respondents had a fair knowledge on mass wasting. The study again probed to know the medium through which respondents got to know about mass wasting. From figure 4.2, television is the most patronized source of information forming about 52 percent of the total responses. The respondents lamented that, warnings about an impending mass wasting disaster is only seen on television when an incident happens in Aburi or sometimes around Kasoa toll booth. Nothing about mass wasting is seen again until another incident occurs. Experience with mass wasting also came out as one of the mediums through which respondents got to know about mass wasting. From figure 4.3, about 20 percent and 36 percent of the respondents from Tuba Junction and Choice respectively have experienced mass wasting for themselves whiles about 12 and 20 percent respectively have suffered the impact of mass wasting. Out of this percentage,

about 19 percent of the respondent from the study both communities have experienced mass wasting and suffered the impact as well.

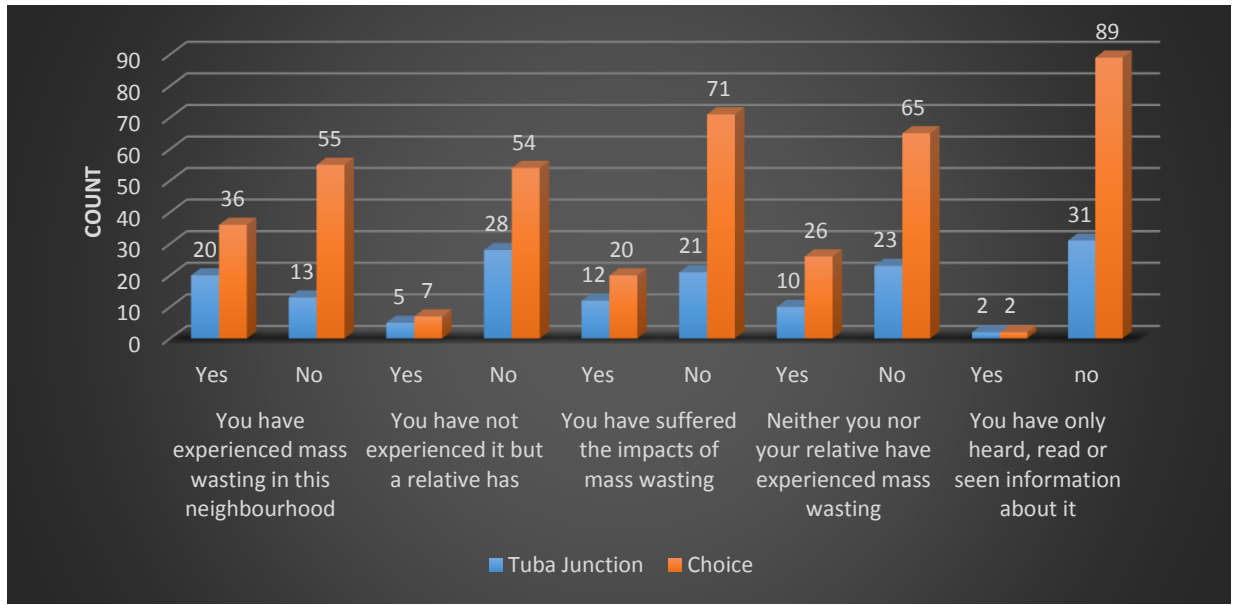


**Figure 4. 2: Source of Information on Mass wasting**

Source: Author's field Data, 2020

The category suffering from the two experiences were respondents who have lived in the study communities between 1 to 5 years. Word of mouth on the other hand formed 6 percent of the responses. The results of the study again revealed that, respondents who have lived from 1 to 5 years formed the majority of this category suggesting that though they might have been told about the incidences of mass wasting in the area they very much did not know of what exactly to expect or do to protect themselves thus resulting in their various experiences with mass wasting.

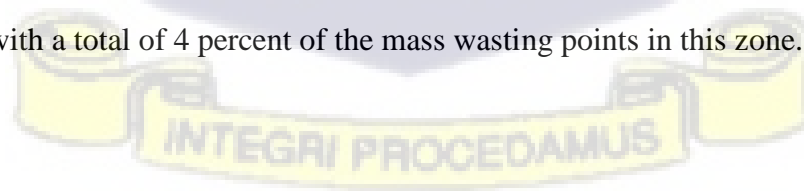




**Figure 4. 3: Respondents’ Best Experience with Mass Wasting**  
 Source: Author’s Field Data, 2020

#### 4.2 Potential Mass Wasting Hazard Map

The map was developed using weights generated from the responses of respondents on the various causative factors as well as some observation from the field (Table 4.15). The risk level was divided into four; very low, low, moderate and high risk. Table 4.16 reveals that, about 45 percent of the study area were at very low risk to mass wasting and these were mainly the northern part of Ga South and patches in the Weija-Gbawe municipal area (Figure 4. 11). However, about 32 percent of the mass wasting point picked were in this zone (Table 4.16). 28 and 20 percent account for low and moderate risk to mass wasting whiles about 53 percent accounting for the highest percent and 11 percent respectively fell at the low and moderate risk zone. Areas with high risk to mass wasting accounted for 7 percent with a total of 4 percent of the mass wasting points in this zone.



**Table 4. 4: Matrix of Factor Weight Evaluation**

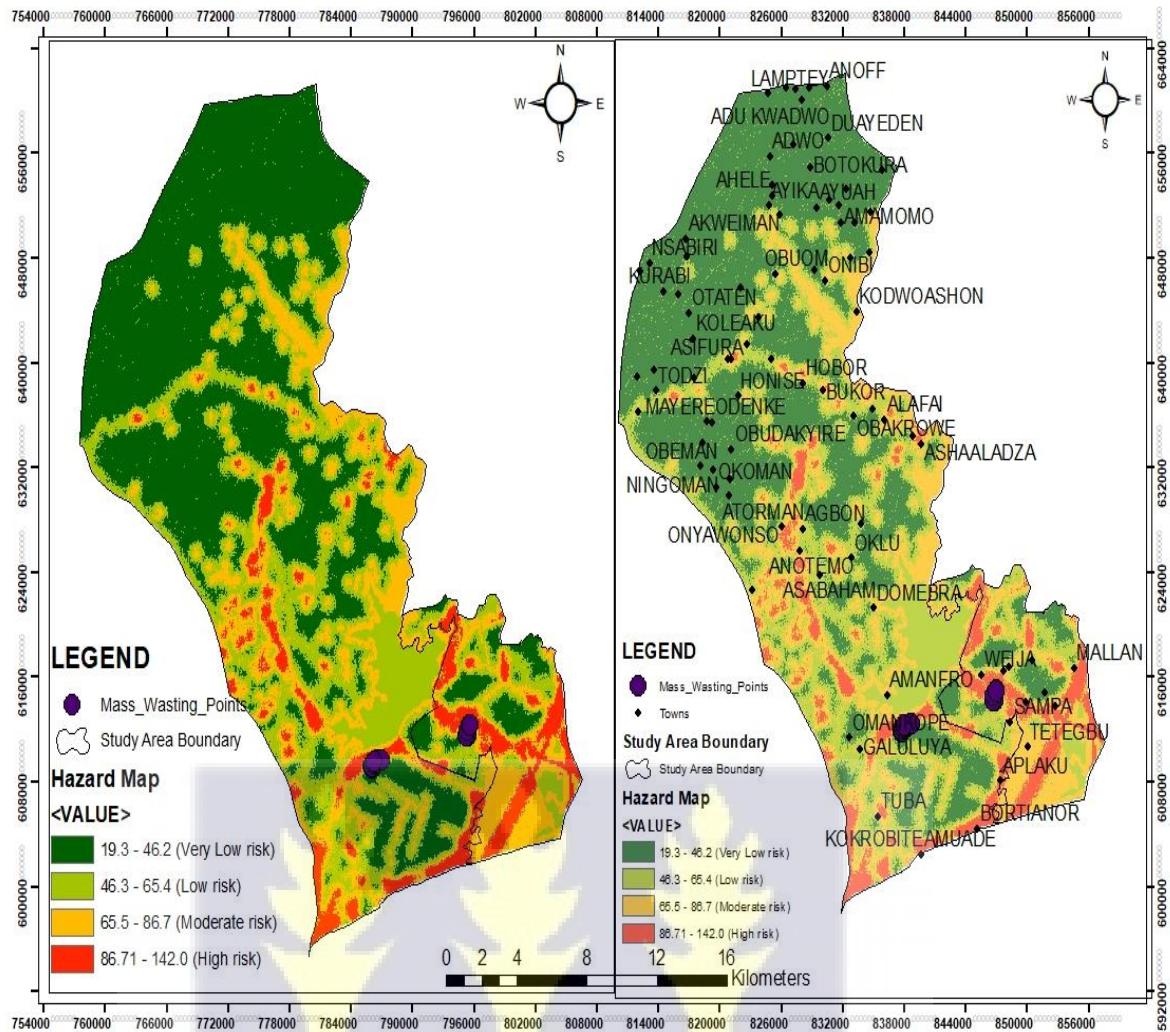
Data Layer	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	Weights
Rainfall (a)	1	3	2	3	2	1	2	2	4	4	0.5124
Geology (b)	1/3	1	3	4	3	4	3	3	5	3	0.5619
Land use (c)	1/2	1/3	1	3	3	4	3	2	4	3	0.4193
Soil (d)	1/3	1/2	1/3	1	2	2	2	1	4	3	0.2451
Distance to Water (e)	1/5	1/3	1/3	1/5	1	1	2	2	4	3	0.216
Distance to Fault (f)	1	1/4	1/4	1/2	1	1	4	3	3	4	0.2721
Distance to Road (g)	1/2	1/3	1/3	1/2	1/2	1/4	1	2	3	3	0.1653
Curvature (h)	1/2	1/3	1/2	1	1/2	1/3	1/2	1	2	2	0.1483
Aspect (i)	1/4	1/5	1/3	1/4	1/4	1/4	1/3	1/2	1	4	0.0969
Slope (j)	1/4	1/3	1/3	1/3	1/3	1/4	1/3	1/2	1/4	1	0.0803
Consistency Ratio (CR) = 0.7333											

Source: Author, 2020

**Table 4. 5: Number of Mass wasting Points in Each Class**

Class	Sections of Study Area Covered by Each Class	% Area Coverage by Sections of the Study	Total Area of Mass Wasting Points	% Area Coverage by Mass Wasting Points
Very Low	23,0757	45	5,400	32
Low	145,558	28	9,000	53
Moderate	105,873	20	1,800	11
High	36,664	7	900	4
Total	518,852	100	17100	100

Source: Author's Field Data, 2020



**Figure 4. 4: Mass Wasting Hazard Map**

Source: Author, 2020

Figure 4.11 reveals that towns around the Gulf of Guinea like Kokrobite, Bortianor as well as earthquake prone areas like Mendskrom and Oblogo were at high risk of mass wasting. Again, areas like Tetegu, Mallam, Tuba, Choice, and Weija are at moderate risk of mass wasting. Some of these areas again are areas prone to earthquakes and whiles others are also experiencing activities of undercutting by water bodies.

It again reveals that, most of the areas around the Northern part of the Weija Lake are located in the moderate risk zones. Amanfro and McCarthy Hills on the other hand were on the low risk zones. McCarthy Hill, though an earthquake prone area is a well laid out community. The community has water channels, with well laid out streets and drainage systems. It was realised that mass wasting caused by anthropogenic causes like sand winning and the likes will not be a factor for mass wasting events in the community but the main cause of mass wasting if there will be any, in the community is bound to be earthquakes. Lastly, Gbawe, New Tetegu and Akweiman were on very low risk mass wasting zones. Table 4.16 gives a list of most of the towns in the Ga South and Weija-Gbawe municipality and their level of risk



**Table 4. 6: Risk Level of Some Towns in the Ga South and Weija-Gbawe Municipality**

Towns	Risk Level Based on Pixel Class			
	Very Low	Low	Moderate	High
Asuba	✓			
Obuom		✓		
Adu Kadwo	✓			
Adwo	✓			
Agbon		✓		
Ahele		✓		
Akutuase		✓		
Akweiman	✓			
Alafai			✓	
Alafai No. 1	✓			
Alafai No. 2	✓			
Amamomo	✓			
Amanfro		✓		
Anoff	✓			
Anotemo			✓	
Asabaham		✓		
Ashaaladza				✓
Ashaliaman	✓			
Ashonamo	✓			
Asifura		✓		
Atorman	✓			
Ayika	✓			
Ayitekoto		✓		
Ayuah	✓			
Bebianihia	✓			
Besease		✓		
Botokuras	✓			
Bukor			✓	
Dantsera		✓		
Domebra		✓		
Domfaase		✓		
Duayeden	✓			
Fankyeneko	✓			
Galuluya		✓		
Gbawe	✓			
Gyatoman	✓			
Hobor		✓		
Honiakyem		✓		
Honise	✓			
Jaman		✓		
Katakaman	✓			
Kodwoashon			✓	
Kofi Dokor		✓		
Kofi Quaye	✓			
Koleaku	✓			
Kolokowhe		✓		
Konkon	✓			
Kudamakope		✓		
Kurabi	✓			
Kwamianum			✓	

Kwasi Nyarku	✓			
Kwesi Tenten	✓			
Kweke Panfo				✓
Lamptey	✓			
Maaphehia	✓			
Mallam			✓	
Mame Dede Nkwanta	✓			
Mayere	✓			
McCarthy Hill	✓			
Mendskrom				✓
New Tetegu		✓		
Ningoman	✓			
Nsabiri	✓			
Obakrowe		✓		
Obeman	✓			
Oblogo				✓
Obokwasi	✓			
Obudakyire	✓			
Odakwai	✓			
Odenke	✓			
Ofagyator		✓		
Oklu		✓		
Oklu Nkwanta		✓		
Okoman	✓			
Omankope	✓			
Onibi		✓		
Onyawonso			✓	
Otaten	✓			
Sampa			✓	
Sogbakukope	✓			
Tenbibian			✓	
Tetegu			✓	
Todzi	✓			
Tokusemitsigani		✓		
Twerebu	✓			
Weija			✓	
Aplaku				✓
Bortianor				✓
Tuba			✓	

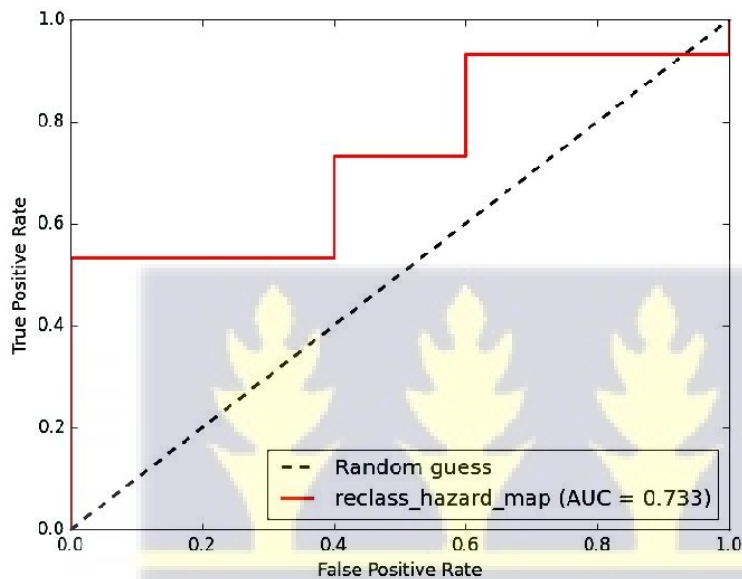
Source: Author, 2020

#### 4.2.1 Verification of the Mass Wasting Hazard Map

“For verification of mass wasting hazard calculation methods, two basic assumptions are needed. One is that mass wasting are related to spatial information such as topography, soil and forest cover, geology, the location of lineaments and land cover, and the other is that future mass wasting will be precipitated by a specific impact factor, such as rainfall

or an earthquake” (Lee *et al.*, 2004). This first assumption was satisfied by this study because the mass wasting is related to the spatial information and they were precipitated by one cause: rainfall in the study area.

Secondly, and area under the curve (AUC) was used to test for the success of the technique used in developing the map. AUC was equal to 73.3% (0.733) which considered good as it is close to 100% which is as considered as excellent.



**Figure 5.1: Success Rating Curve**

Source: Author, 2020

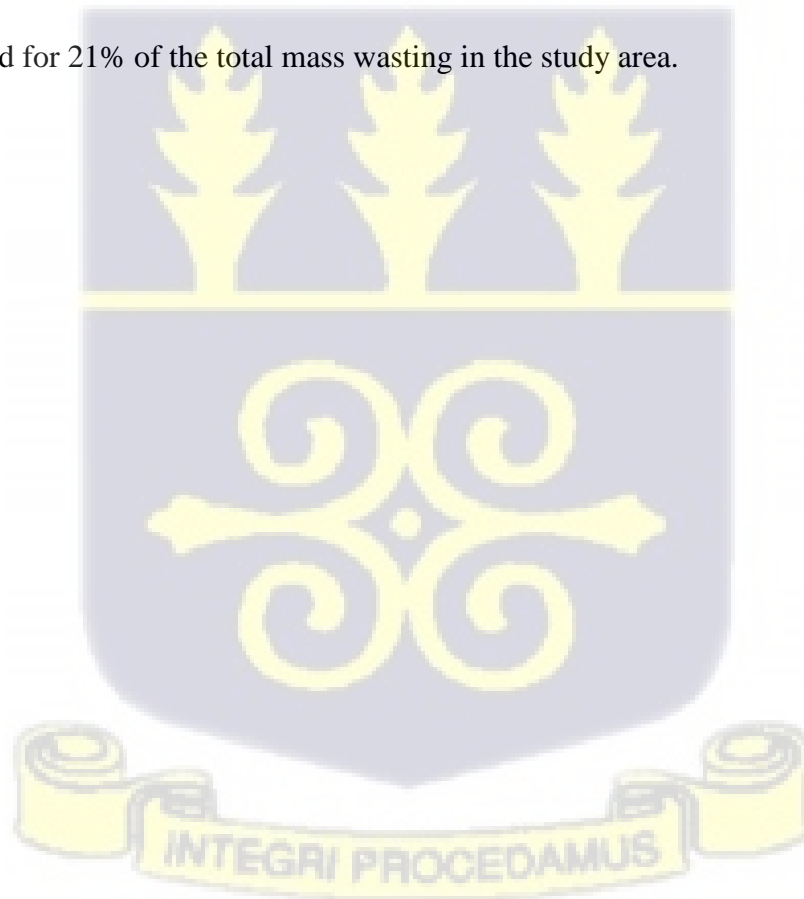
#### **4.3 The Vulnerability levels of Respondents through Vulnerability Mapping**

Vulnerable mapping highlights areas that are susceptible to a particular kind of hazard. They are used to direct attention to geographic areas where impacts on society are expected to be the greatest and that may therefore require adaptation interventions. This section of the chapter looks at DEM derivatives, geological, land use, soils, rainfall, proximity to

faults, distance from roads and distance to water bodies and characteristics of the municipalities that together contribute to mass wasting in the municipalities.

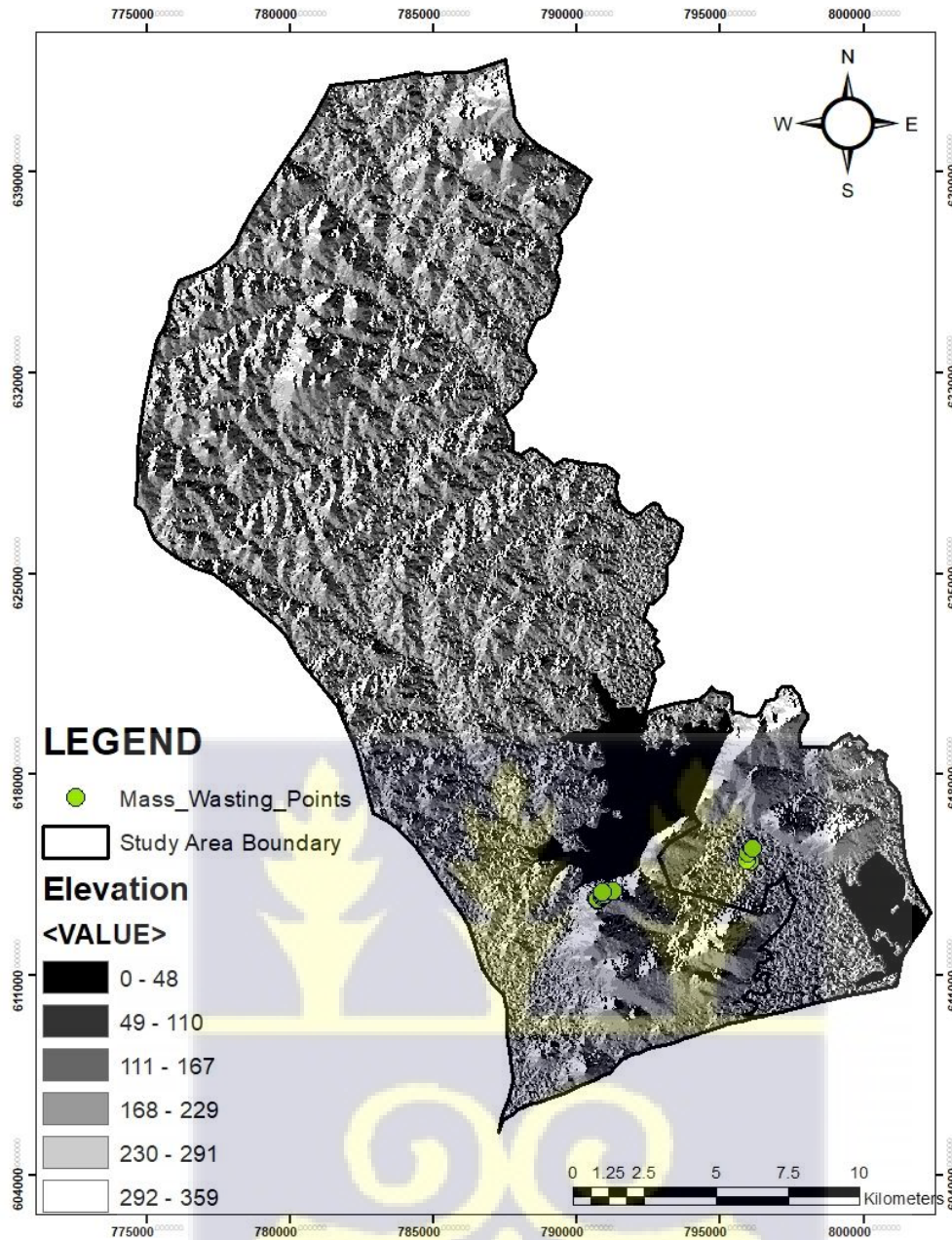
#### **4.3.1 Mass Wasting Inventory Map of the Municipalities**

Mass wasting inventories are essential so far as hazard mapping is concerned. A mass wasting inventory map was created for the study using google earth and field surveys to show the location of discernible failures based on mass wasting inventory (Table 4.4) (figure 4.4). The total pixel count for mass wasting points for the study areas was 17,100. From the table 4.4, majority of mass wasting occurred between 230°-359° accounting for 79 percent of the total mass wasting. These points were found on higher elevation indicating that steep slopes are more vulnerable to mass wasting. Angles 0° to 229° accounted for 21% of the total mass wasting in the study area.



**Table 4. 7: Mass wasting Points Identified**

Municipality	Area Name	Type of Mass wasting	Coordinates	Elevation (m)
Ga South	1	Debris slide, debris flow	5°32'54.42"N 0°22'17.64"W	57
Ga South	2	Debris flow	5°32'51.39"N 0°22'24.29"W	86
Ga South	3	Rock fall	5°32'44.95"N 0°22'31.70"W	101
Ga South	4	Debris flow	5°32'51.40"N 0°22'24.46"W	86
Ga South	5	Debris flow	5°32'50.51"N 0°22'31.56"W	55
Ga South	6	Debris flow	5°32'47.68"N 0°22'33.05"W	68
Weija-Gbawe	7	Debris flow, Rock fall	5°33'27.05"N 0°19'43.76"W	19
Ga South	8	Debris flow	5°32'42.11"N 0°22'32.38"W	107
Ga South	9	Debris flow	5°32'44.32"N 0°22'34.28"W	77
Weija-Gbawe	10	Debris flow	5°33'35.90"N 0°19'43.61"W	23
Weija-Gbawe	11	Debris flow	5°33'42.70"N 0°19'37.98"W	11
Weija-Gbawe	12	Debris flow	5°33'41.04"N 0°19'36.73"W	30
Weija-Gbawe	13	Debris flow and Rock fall	5°32'47.99"N 0°22'29.05"W	90
Ga South	14	Debris flow and rock fall	5°32'49.63"N 0°22'26.95"W	85
Ga South	15	Debris flow	5°32'50.54"N 0°22'26.56"W	77
Ga South	16	Debris flow	5°32'54.47"N 0°22'20.43"W	49
Ga South	17	Debris flow	5°32'55.29"N 0°22'20.43"W	40
Ga South	18	Debris flow	5°32'55.29"N 0°22'20.43"W	40
Ga South	19	Debris flow	5°32'53.10"N 0°22'27.31"W	53



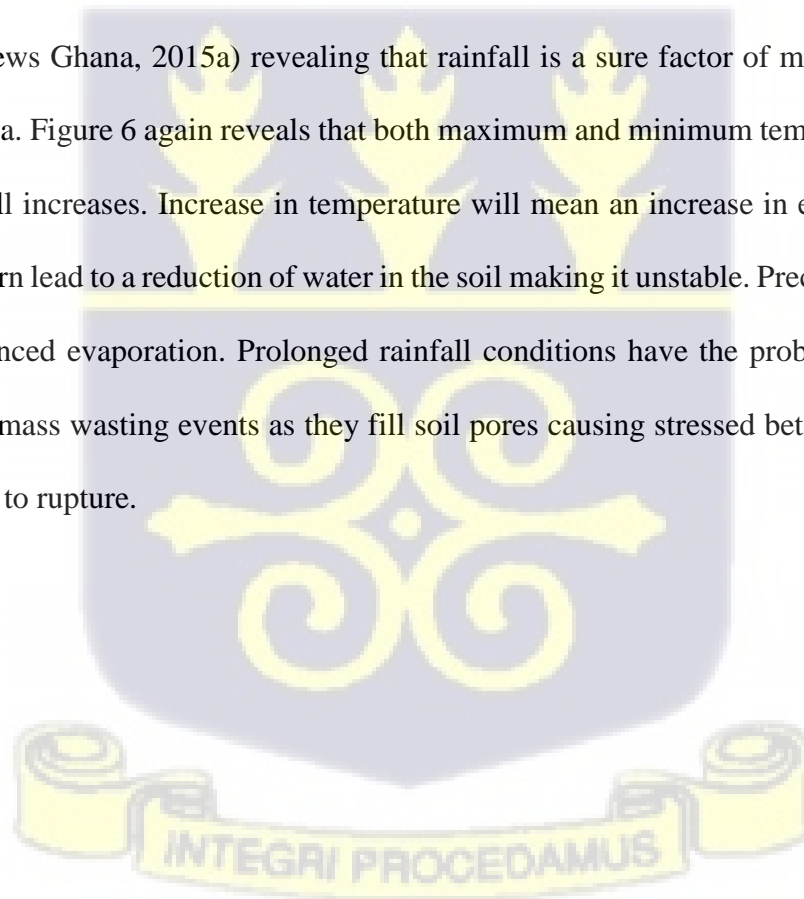
**Figure 4. 5: Mass Wasting Inventory Map**  
Source: Author's Field Data, 2020



#### **4.4 Relationship between Mass Wasting and the Causative factors.**

##### **4.4.1 Mass Wasting and Rainfall**

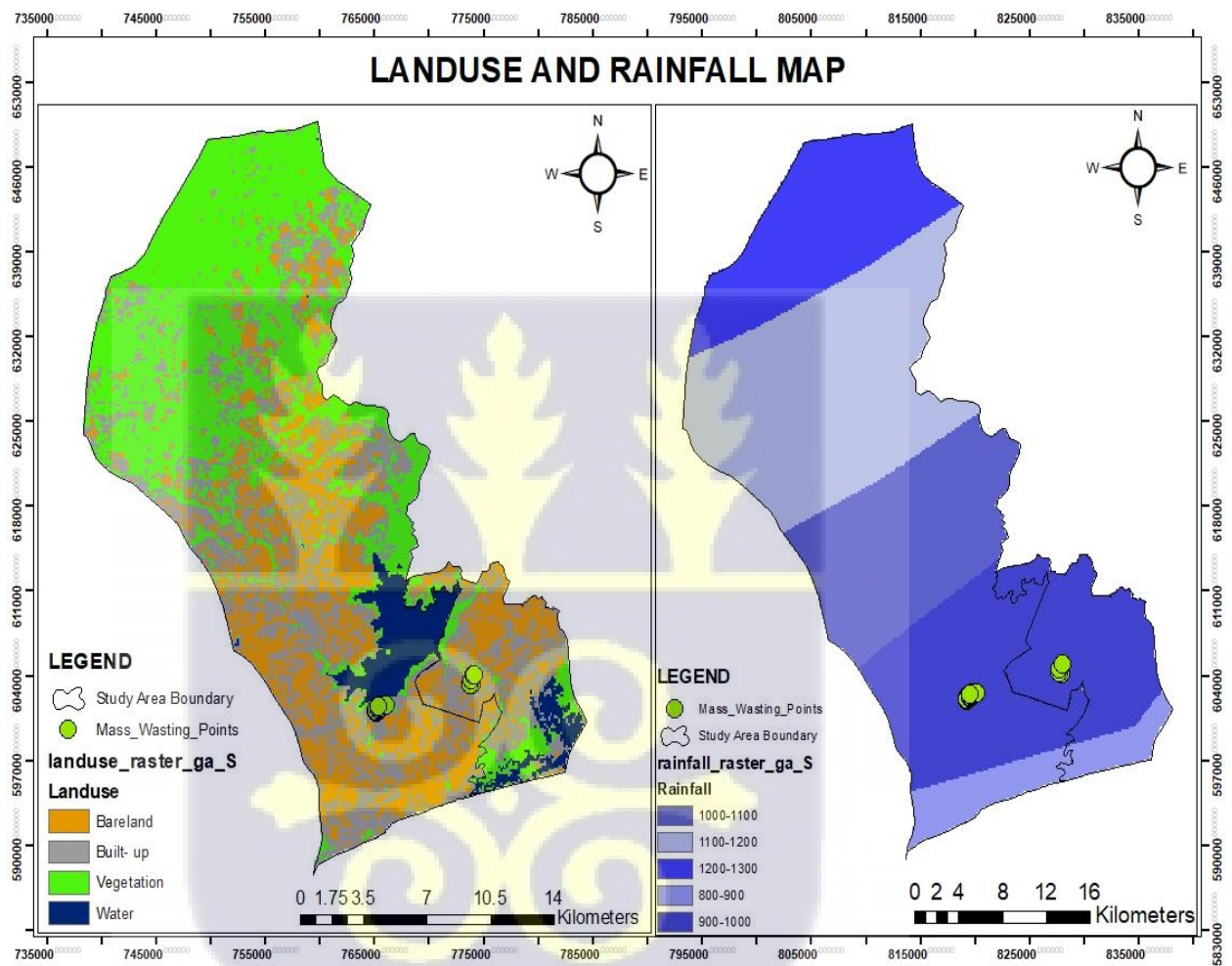
The study revealed that rainfall is one of the major causes of mass wasting in the study area. Higher rainfall implies higher risk of mass wasting due to an increase in shear stress. The distribution of mass wasting points were between areas receiving 900-1000mm of rainfall (Table 4.5) (Figure 4.5). It is expected that the regions with higher rainfall in the future will experience some form and more mass wasting activities. Rainfall data from the Ghana Meteorological Agency of the study area shows highest rainfall in June and the lowest in January (Figure 4.6) indicating that mass wasting events should be pronounced in June and less in January. This holds true as most of the records of mass wasting events in the area are normally recorded in June and others in October (Acquah, 2019; Bokpe, 2015; News Ghana, 2015a) revealing that rainfall is a sure factor of mass wasting in the study area. Figure 6 again reveals that both maximum and minimum temperature increases as rainfall increases. Increase in temperature will mean an increase in evaporation which will in turn lead to a reduction of water in the soil making it unstable. Precipitation balances the enhanced evaporation. Prolonged rainfall conditions have the probability of causing massive mass wasting events as they fill soil pores causing stressed between pores which will lead to rupture.



**Table 4. 8: Mass Wasting and Rainfall**

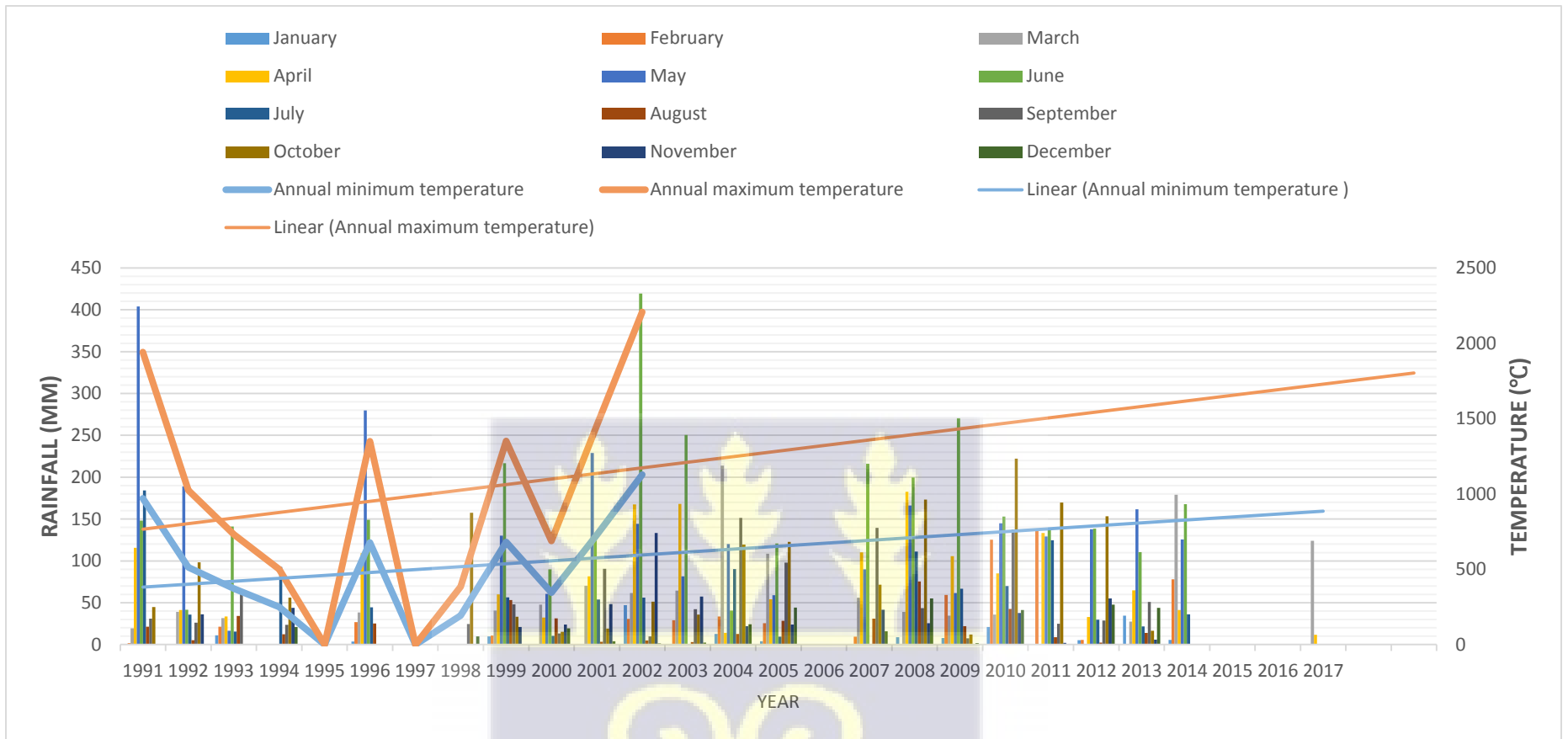
Data Layer (Causative factor)	Class	Pixel Count	%Pixel Count
Rainfall	800 – 900	0	0
	900 – 1000	17100	100
	1000 – 1100	0	0
	1100 – 1200	0	0
	1200 – 1300	0	0

Source: Author’s Field Data, 2020



**Figure 4. 6: Rainfall and Land Use Map**

Source: Author’s Field Data, 2020



**Figure 4. 7: Monthly Rainfall Chart from 1991 to 2017 with Temperature**

Source: Ghana Meteorological Agency

#### 4.4.2 Mass Wasting and Land Use

Land use has great influence on mass wasting. 79 percent of the mass wasting points were located in built-up areas (Table 4.6) (Figure 4.7). This corresponded with the actual happenings on ground. Events of mass wasting were located close to the residence of some respondents (either behind or beside them). Activities of man has also resulted to the happenings of mass wasting the study communities. The municipalities are experiencing great growth in their population causing areas that were forbidden to be inhabited. Again, construction works have precipitated in the steepening of the hills making the areas more vulnerable to mass wasting. Human activities again have resulted in deforestation in the area exposing the soil to the mercy of the climate. The soils exposure to climate causes stress resulting in slope failure. The type of climate will also help in determining the type of mass wasting as humid condition tends to have lots of slides and flows due to an increase in water saturation and dry conditions is bound to have lots of falls due to an increase in in temperature. Bare lands on the other hand accounted for about 21 percent of the total number of distribution of mass wasting points (Table 4.6) (Figure 4.7). Vegetation recorded no percentage of mass wasting points at all though it is known to have a strong influence on the stability of superficial deposits both hydrological (capacity of infiltration into the soil, soil moisture, groundwater level) and mechanical as the roots increase the shear strength of the soil depending on whether it is dense or not (van Beek *et al.*, 2008). Again, vegetation inhibit and serves as a blockage to erosion and other activities that will weaken the land making them prone to mass wasting. Roots binds the soils together making them stronger and less susceptible to mass wasting (Table 4.6) (Figure 4.7).

**Table 4. 9: Mass Wasting and Land Use**

Data Layer (Causative factor)	Class	Pixel Count	%Pixel Count
Land Use	Bare land	3600	21
	Built – up	13500	79
	Vegetation	0	0
	Water	0	0

Source: Author’s Field Data, 2020

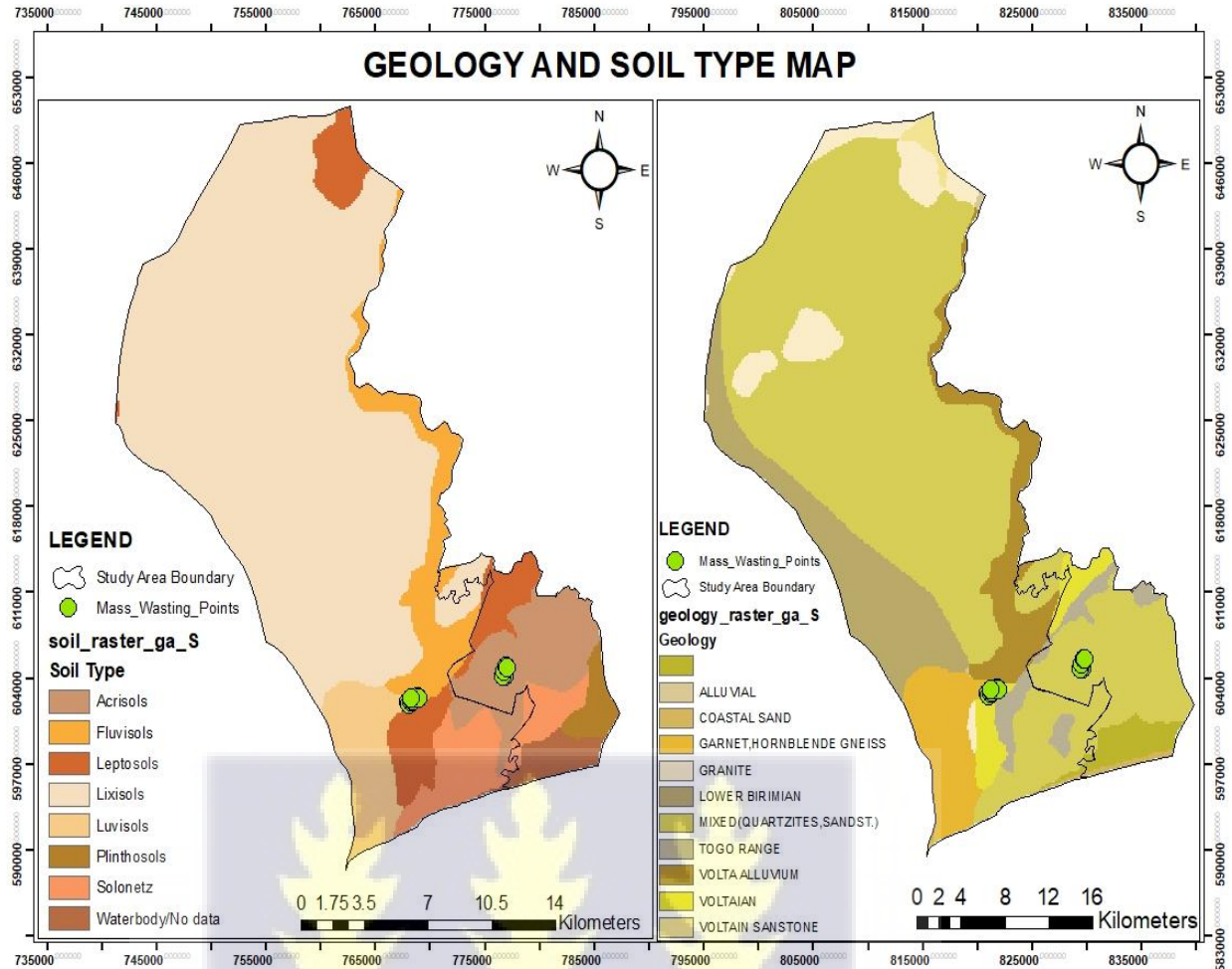
#### 4.4.3 Mass Wasting and Soil Type

Soils are also of much importance. Well drained soils have low probability of mass wasting occurrence than poorly drained soils. This is because poorly drained soils removes water from the soil very slowly leaving them saturated over long period of time thus increasing their probability to mass wasting. The study area was made up of three main soil types’ leptosols, Acrisols and luvisols (Table 4.7) (Figure 4.8). Luvisols are well drained soils yet severely, giving the soil a lose profile that makes them very much prone to slope failure. They formed the highest distribution of mass wasting points of 53 percent. Acrisols are poorly drained soils hence are more susceptible to mass wasting because of its inability to allow free flow of water. Acrisols formed about 26 percent of the total mass wasting points.

**Table 4. 10: Mass Wasting and Soil Type**

Data Layer (Causative factor)	Class	Pixel Count	%Pixel Count
Soil Type	Acrisols	4500	26
	Fluvisols	0	0
	Leptosols	3600	21
	Lixisols	0	0
	Luvisols	9000	53
	Plinthosols	0	0
	Solonetz	0	0
	Water Body	0	0

Source: Author’s Field Data, 2020



**Figure 4.8: Soil and Geology Map**

Source: Author's Field Data, 2020

#### 4.4.4 Mass Wasting and Geology

Hard resistant rocks like granite and Voltaian with good bearing capacity are less susceptible to mass wasting. Poor (coastal sand and Volta alluvium) to moderate (alluvial deposits) bearing rocks which are easily erodible and unconsolidated are more prone to mass wasting. Mass wasting points for the study area fell on Voltaian rocks (Ga South) with 74 percent and rocks with a mixture of quartzite and sandstone (Weija-Gbawe) with 26 percent of the total mass wasting points' coverage (Table 4.8) (Figure 4.8). Though Ga South is made up of rocks that have good bearing capacity, they were still experiencing

mass wasting. This is attributed to the fact that activities of humans such steeping of slope for construction, sand winning and the likes coupled with natural happenings have rendered the rock to be very weak making it succumb to mass wasting. Same can be said for Weija-Gbawe as quartzite is a known hard, chemically resistant rocks and sandstones on the other hand are largely made up of quartz which is also very hard and chemically resistant.

**Table 4. 11: Mass Wasting and Geology**

Data Layer (Causative factor)	Class	Pixel Count	%Pixel Count
Geology	Alluvial	0	0
	Coastal Sand	0	0
	Garnet/Hornblende Gneiss	0	0
	Granite	0	0
	Lower Birimian	0	0
	Mixed (Quartzite, Sandstone)	4500	26
	Togo Range	0	0
	Volta Alluvium	0	0
	Voltaian	12600	74
	Voltaian Sandstone	0	0

Source: Author's Field Data, 2020

#### 4.4.5 Mass Wasting and Proximity to Faults

Proximity to a faults and thrust seems to influence mass wasting. Fault zones are known to increase the potential of mass wasting by creating steep slopes and sheared zones of weakened and fractured rocks therefore increasing distance from these zones means a decrease in the frequency of mass wasting (Ladas *et al.*, 2007) hence the closer and area is

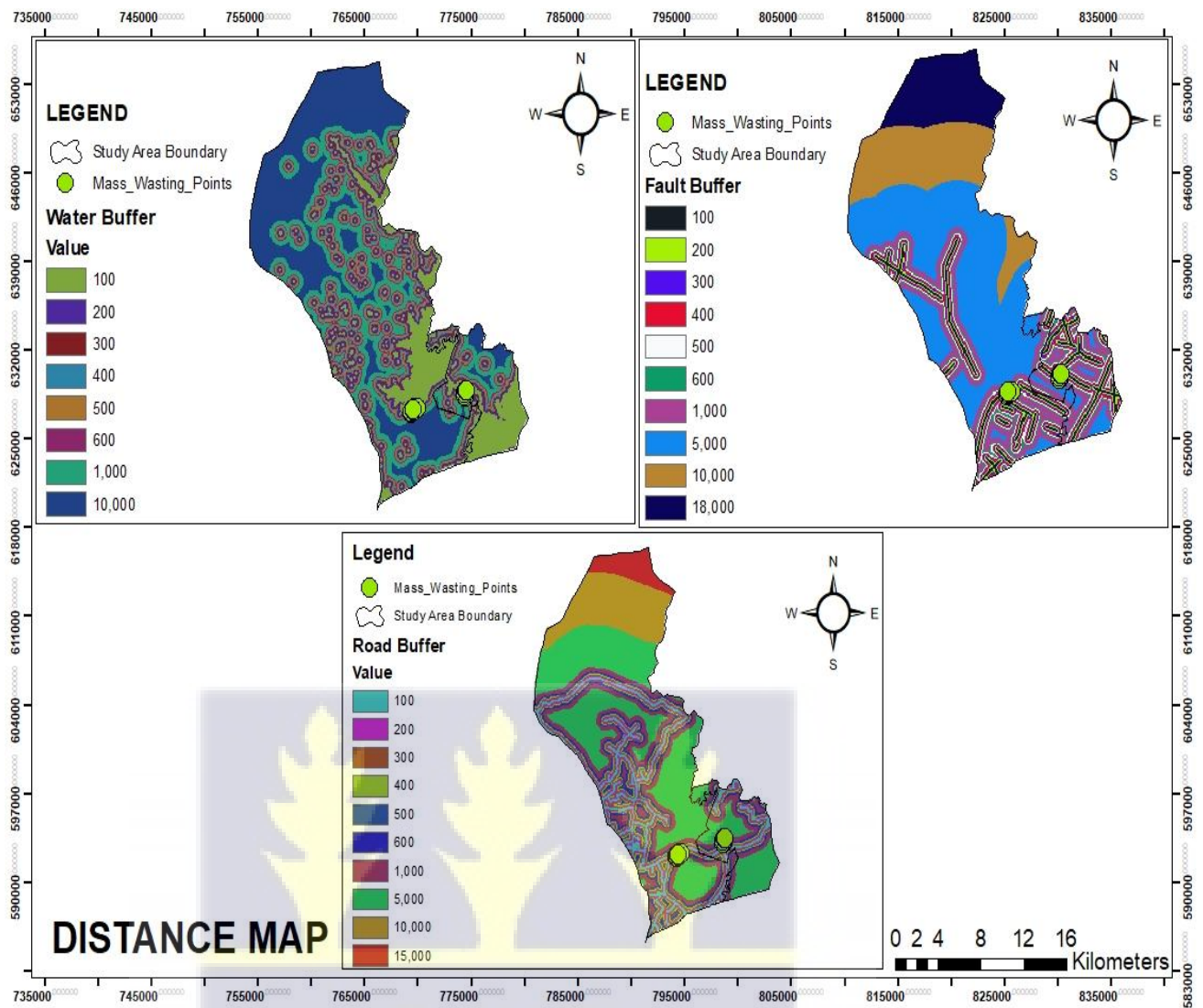
to a fault zone the more prone it is to mass wasting. Majority of the points were in the 1000 meters buffer zone. 500 meter buffer zone recorded the lowest. The study classified those beyond 500 meter as the area being less prone to mass wasting. On the whole, about 74 percent of the points fell outside the “danger zone” which make a greater majority of the population free from earthquake-induced mass wasting (Table 4.9) (Figure 4.9) but majority of the mass wasting points for Ga South were between 1000 – 5000 meter zones whereas that of Weija Gabwe was between 200 – 1000 meters. This inferably means that communities in Weija-Gbawe is more prone to earthquake-induced mass wasting than communities in Ga South.

Table 4. 12: Mass Wasting and Distance to Fault

Data Layer (Causative factor)	Class	Pixel Count	%Pixel Count
Distance from fault	100	0	0
	200	1800	11
	300	0	0
	400	0	0
	500	900	5
	600	0	0
	1000	11700	68
	5000	2700	16
	10000	0	0

Source: Author’s Field Data, 2020





**Figure 4. 9: Distance Maps**  
Source: Author’s Field Data, 2020

#### 4.4.6 Mass Wasting and Proximity to Water Bodies

Through saturation and undercutting, water bodies affect the stability of slopes increasing their susceptibility to mass wasting. Buffer zones beyond 500 meters again was considered as areas less prone to mass wasting. About 26 percent of the points picked fell beyond 500 meters which insinuates that larger population of the communities especially the ones close

to these water bodies in both municipalities are at risk of mass wasting (Table 4.10) (Figure 4.9). The distribution of mass wasting points fell between buffer zones of 200 to 500 meters accounting for about 74 percent of the total points. This suggests that, though slope undercutting by water bodies is a possibility, other external factors are accelerating the happenings of mass wasting in the study communities. This holds as human activities such as construction of buildings, sand winning among others were found at these study communities.

**Table 4. 13: Mass Wasting and Distance to Water Bodies**

Data Layer (Causative factor)	Class	Pixel Count	%Pixel Count
Distance from Water Bodies	100	0	0
	200	0	0
	300	2700	16
	400	6300	37
	500	3600	21
	600	3600	21
	1000	900	5
	10000	0	0

Source: Author’s Field Data, 2020

#### **4.4.7 Mass Wasting and Proximity to Roads**

Distance from roads is important consideration for mass hazard mapping. Roads without drainage at the banks sometimes crumble due to saturation. Again, vibrations created as a results of ploughing and as well as daily usage of roads by trucks and other types of vehicles especially on hills and steep mountains causes instability to the sides of the roads and are prone to slope failure at the long run. About 75 percent of the mass wasting points picked were closer to roads (Table 4.11) (Figure 4.9). As majority of the roads at the study

communities are untarred, daily usage of the roads by these vehicles as well as the action of climate and vibrations caused by these vehicles results in expansions and contractions which causes stress and will results in slope failure. Ga South and Weija-Gbawe is the home for the Accra-Kasoa highway which is used by all kinds of vehicles moving in and out of Accra. Vibrations from these vehicles can be a cause.

**Table 4. 14: Mass Wasting and Distance to roads**

Data Layer (Causative factor)	Class	Pixel Count	%Pixel Count
Distance from roads	100	0	0
	200	900	5
	300	6300	37
	400	2700	16
	500	2700	16
	600	900	5
	1000	1800	11
	5000	1800	11
	10000	0	0
	15000	0	0

Source: Author's Field Data, 2020

#### 4.4.8 Mass Wasting and Slope Gradient

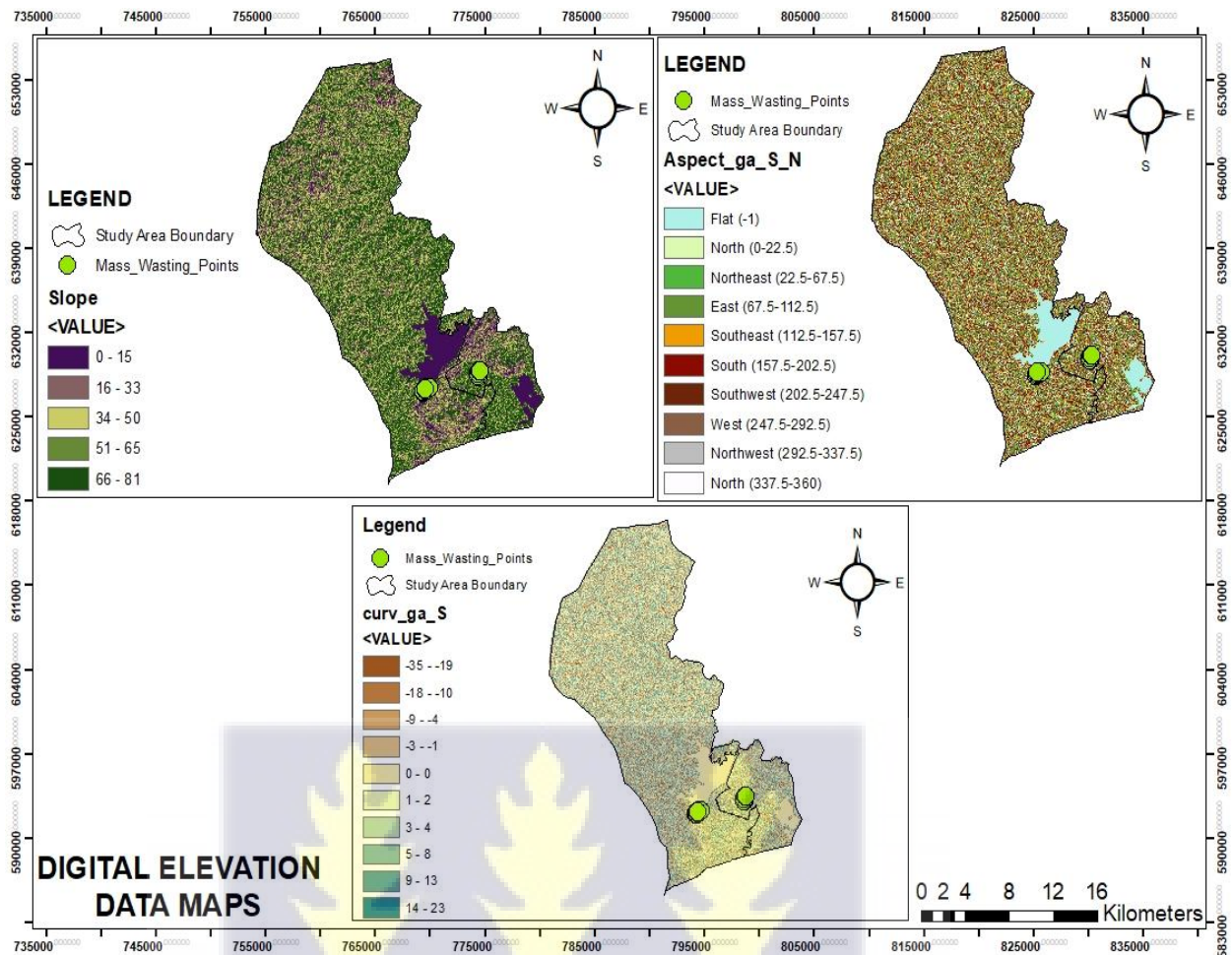
The gradient of a slope is very important so far as mass wasting is concerned. Slope gradient is one of the vital parameters as it regulates the subsurface flow velocity after rainfalls, the runoff rate and the soil water content thus as slope increases shear stress in unconsolidated soil cover generally increases as well increasing the land's susceptibility to mass wasting (Ladas et al., 2007). It is believed that steeper slopes are more susceptible to mass wasting. Also, increasing shear stress will mean an increase in slope gradient (Akgun

and Bulut, 2007; Dahal and Dahal, 2017; Huabin *et al.*, 2005; Ladas *et al.*, 2007). In the case of this study, a total of about 79 percent of the mass wasting points were on relatively gentle and moderate slopes while a total of about 21 percent were located on steep slopes (Table 4.12) (Figure 4.10). Gentle and moderate slopes are less prone to mass wasting unlike steep slopes. This insinuates that, an external force has contributed to this occurrence of mass wasting. The study communities is known for the activities sand winning causing the hills become weak and more vulnerable and this has contributed to this result. Also, especially for the communities in Ga South, these areas are not properly laid out and are without drainage systems (ABC News, 2019; Bokpe, 2015; News Ghana, 2015a). Again, moving water from rainfalls have created big trenches, further weakening the hills and accelerating mass wasting. This is in agreement with the conceptual framework of the study which states that vulnerability must meet hazard for disaster to occur. Vulnerability here refers to all the unsafe conditions (sand winning, lack of drains, slope and many others) in the area that causes mass wasting. Slope gradient may determine the type of mass wasting that occurs in a given area; creeps, slides or flows. Mass wasting inventory taken by the study revealed that majority of the process occurring were debris flow with a few rock falls.

**Table 4. 15: Mass Wasting and Slope Gradient**

Data Layer (Causative factor)	Class	Pixel Count	%Pixel Count
Slope (°)	0-15 (Gentle)	6300	37
	16-33 (Moderate)	7200	42
	34-50 (Moderate Steep)	0	0
	51-65 (Steep)	900	5
	66-81 (Very Steep)	2700	16

Source: Author's Field Data, 2020



**Figure 4. 10: Digital Elevation Maps**  
**Source: Author’s Field Data, 2020**

#### 4.4.9 Mass Wasting and Slope Aspect

Aspect is very important for any mass wasting hazard mapping. Aspect shows the direction of slope. The direction determines the amount of rainfall, shade, sunlight and others (Xie, Esaki, and Zhou, 2004) which make them susceptible or not to mass wasting. According to Zarfa (2015), the Weiija hills have steep western and gentler eastern slopes but the results from table 4.13 reveals that the western side of the hills (South West, North West and West) account for a sum of about 32 percent of the total mass wasting points while about the

eastern side (South East, North East and East) account for about 42 percent. The two municipalities; Ga South and Weija-Gbawe are located at the Southwestern part of Accra with the Weija hills rising steeply above the Weija edge. This indicates that, the slopes found in the municipalities are relatively steeper slopes. This suggests that, all things being equal, communities at the western are comparatively more prone to mass wasting than to mass wasting. Table 4.13 again reveals that, the eastern part slope (South east, north east and east) account for about 42 percent of the mass wasting points. This suggests the presence of external forces such as human activities accelerating the actions of natural processes in causing mass wasting. Shit, Bhunia, and Maiti (2016) added that, south-east and some pockets of south-west facing slopes are influential in creation of mass wasting due to availability of moisture during rainy season. Increase in moisture means an increase in stress in the soil particles of the slope making them more susceptible to mass wasting (Table 4.13) (Figure 4.10).

**Table 4. 16: Mass Wasting and Slope Aspects**

Data Layer (Causative factor)	Class	Pixel Count	%Pixel Count
Aspect	Flat (-1)	0	0
	North (0-22.5)	900	5
	North East (22.5-67.5)	1800	11
	East (67.5-112.5)	900	5
	South East (112.5-157.5)	4500	26
	South (157.5-202.5)	2700	16
	South West (202.5-247.5)	2700	16
	West (247.5-292.5)	900	5
	North West (292.5-337.5)	1800	11
	North (337.5-360)	900	5

Source: Author’s Field Data, 2020

#### 4.4.10 Mass Wasting and Curvature

Curvature values describes the morphology of topography. It plays a major role in influencing the distribution and potential of having different types of mass wasting in an

area (Zhang *et al.*, 2012). Potentially, concave slope can contain more water and retain it for a longer period than a convex slope hence concave slopes are potentially more prone to mass wasting than convex slopes. The distribution of mass wasting points on all the concave slope accounted for 27 percent whereas that of the convex side accounted for about 68 percent of the total mass wasting points. Concave slopes are gentle at the foot and steeper towards the top while convex slopes are steep at the foot and gentle toward the top (Table 4.14) (Figure 4.10).

**Table 4. 17: Mass Wasting and Curvature**

Data Layer (Causative factor)	Class	Pixel Count	%Pixel Count
Curvature	-35- -19 (Concave)	0	0
	-18- -10 (Concave)	1800	11
	-9- -4 (Concave)	900	5
	-3- -1 (Concave)	1800	11
	0 (Flat)	900	5
	1 – 2 (Convex)	7200	42
	3 – 4 (Convex)	3600	21
	5 – 8 (Convex)	0	0
	9 – 13 (Convex)	900	5
	14 - 23 (Convex)	0	0

Source: Author’s Field Data, 2020

The study realised that, though all these factors were considered, none of them work in isolation. For example, the responses of the respondents revealed that, rainfall was a major cause of mass wasting. Rainfall however reduces the resistance of the slope thereby making it unstable. Rainfall, howbeit, cannot stand alone in causing mass wasting. The aspect of the hill will again determine which part of the slope get more rain than the other whiles the

curvature will also determine which part accumulates water (concave) and which part allows water to flow easily (convex). More water will lead to less resistance hence causing slope instability. The parent material which is the geology will also determine the type of soil materials formed on the hill. If the rock had more of clay particles, it will mean less infiltration of water but more sand particles will mean more infiltration thus reducing mass wasting. Moreover, the land use pattern of the area will also induce or reduce the rate of mass wasting. In that, cutting of slopes for construction, farming, and settlement among other as it is happening in the study communities will reduce the resistance forces of the slope due to the additional weights added through these activities. Frequent seismic activities tend to leave rocks weak and causes cracks in them. Continuous seismic activities coupled with rainfall as well as modification the earth through anthropogenic activities via land use patterns can amount to incidences of rock falls and earth slumps.

#### **4.5 Chapter Summary**

The chapter looked at the various relationship between mass wasting and the various causative factors: soil, geology, DEM derivatives, and distances to fault, water bodies and roads. These were then combined to form the potential mass wasting hazard map which showed that areas around the coast along with majority of the areas in Weija-Gbawe were very much susceptible to mass wasting as well as areas around the southern part of the Weija Lake. Again, the northern part of both municipality were exhibiting lower levels of susceptibility to mass wasting. The study areas fell in the moderate risks zone. The next chapter will talk about the recommendations and conclusions of the study.

## CHAPTER FIVE

### RESIDENTS' PERCEPTIONS OF MASS WASTING

#### 5.0 Introduction

The beliefs of potential harm or the possibility of a loss is known as risk perception. It is a subjective judgement that people make about the characteristics and severity of a risk (Darker, 2013). This chapter shows how the respondents perceive, judge, evaluate and rank their level of risk. It also covers that causes, types and the impacts of mass wasting in the communities. The chapter further discusses the coping strategies adopted by in controlling the effects of mass wasting.

#### 5.1 Understanding Mass Wasting in the Ga South and Weija-Gbawe Municipality

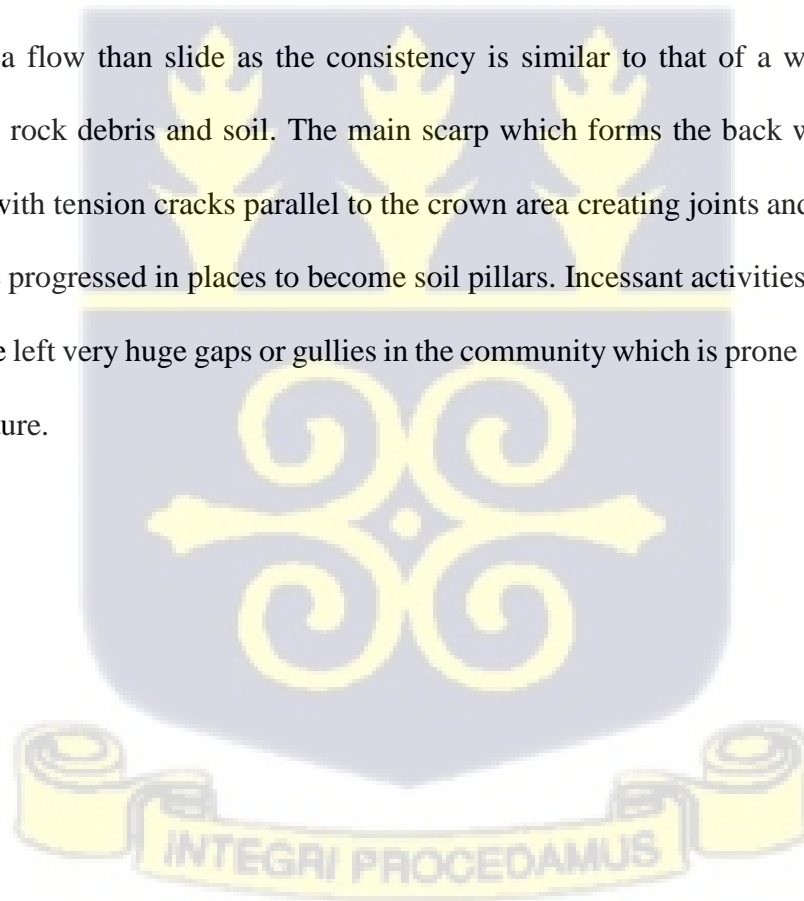
Understanding the pattern of mass wasting in the municipalities is of grave importance as this is an importance step to managing or curbing mass wasting. This has the capability to assist policy makers to better prepare strategies in managing mass wasting. This section deals with the respondents' perceived causes, types and impacts of mass wasting.

##### 5.1.1 Types of Mass Wasting

###### 5.1.1.1 Types of Mass Wasting at Tuba Junction

The common types of mass wasting occurring at Tuba Junction were debris slide, debris flow and rock fall. This conclusion was drawn based on the responses of the respondents and observations of the head scarps, flow tracks and debris deposits in the study communities. Respondents revealed that, the debris from the hill was deposited round the toll booth but now deposition occurs around Osiadan Construction Limited. The study

discovered that the causes of the movement type were due to human-induced (construction of building, sand winning activities), geomorphic (physical or chemical weathering) and climatic conditions (rainfall). Additionally, the style of movement is quite complex in that, the movement type appears to progress from slide to flow as it progress down the slope. The displaced material loses part of its debris to the buildings in the way as well as the scanty vegetation along its path. Lots of debris (sand, silt, clay, high frequency of rock fragments, waste materials and some small branches of trees) are seen deposited in the community. As you descend the hill to the base, loose sediment from the scarp and shear surface are seen accumulated in the gullies on the shear surface and are progressively confined into a single transport channel just at the western end of Osiadan Construction Limited down to the Kasoa-Accra highway (Plate G). At this point, the movement flow is more of a flow than slide as the consistency is similar to that of a wet cement; water-saturated rock debris and soil. The main scarp which forms the back wall of the slide is vertical with tension cracks parallel to the crown area creating joints and cracks in the soil that have progressed in places to become soil pillars. Incessant activities of this movement type have left very huge gaps or gullies in the community which is prone to deadly disasters in the future.





**Plate 5.1: Evidence of Debris Slide and Debris Flow at Tuba Junction (deposited debris from the flow and evidence of debris slide)**

Source: Author's field data, 2020; Acquah, 2019

Evidences of rock falls were also recorded at Tuba Junction. Detached rock masses from the hills were spotted at the bottom hills or away from their source region. Evidences were seen from google maps and they were also witnessed on the field as well (plate H). The respondents added that rock masses fall from the hills. Unlike the debris slide, an informal interview with the respondents revealed that, none of the bigger rock masses have neither rolled down the hills nor enter people's home. They are mostly found not too far from their source region. The smaller masses however were found along the slope down to Osiadan area. It was realized that, the initiation of a rock falls in the study community were from climatic (alternate hot and cold seasons), geomorphic (physical or chemical weathering) and human-induced (construction activities, sand winning) processes.



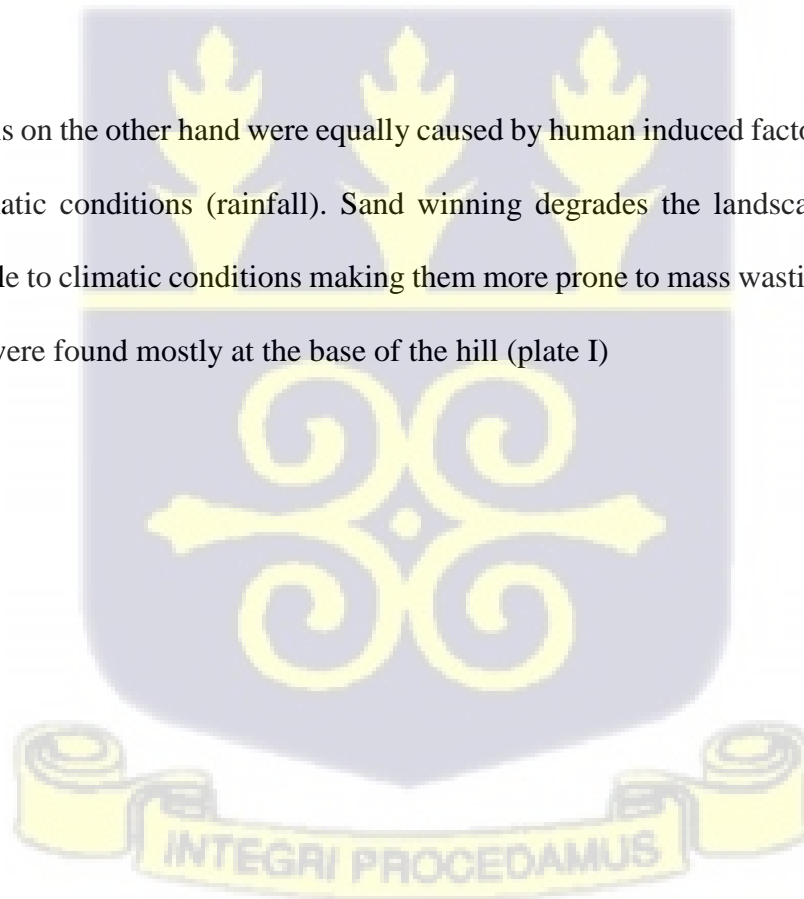
**Plate 5.2: Evidences of Rock falls at Tuba Junction**  
Source: Google Earth

INTEGRI PROCEDAMUS

*5.1.1.2 Types of Mass Wasting at Choice*

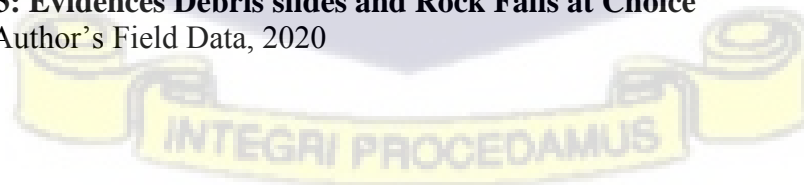
Mass Wasting types occurring at Choice were mainly debris flows and rock falls. The conclusion was drawn from observations, informal interviews with the respondents and the flow tracks in the study communities. Debris flows were prevalent at Choice. Respondents described it as “thick flood”. Causes of debris flows in the community were found to be human induced (sand winning) and climatic (rainfall). According to the respondents, they used to experience minimum flows with very minimum debris in the community but after the inception of sand winning, the flows thickened. The study realised that, this phenomenon is experienced mostly by respondents with their residents close to the foot of the hill and also respondents at the eastern side of the hill where sand winning has begun. Evidences of debris slides were also witnessed at the study community (plate I).

Rock falls on the other hand were equally caused by human induced factors (sand winning) and climatic conditions (rainfall). Sand winning degrades the landscapes leaving them vulnerable to climatic conditions making them more prone to mass wasting. Detached rock masses were found mostly at the base of the hill (plate I)





**Plate 5. 3: Evidences Debris slides and Rock Falls at Choice**  
Source: Author's Field Data, 2020

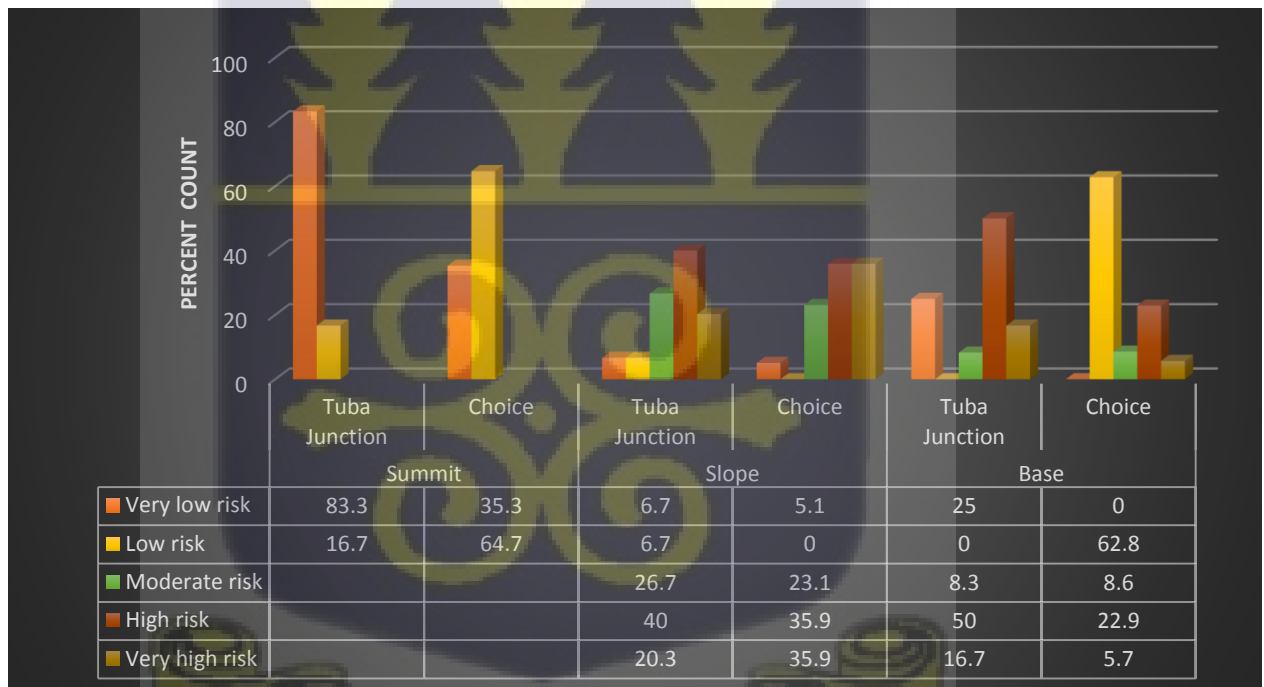


## 5.2 Proposed level of Exposure to Mass Wasting

Risk perception according to Setiawan and Hizbaron (2014) is “characterised as the intuitive judgement of individuals and groups of risks in the content of limited and uncertain information”. It is an important step to risk mitigation. Understanding these perceptions have the proclivity to assist planners, the government among others to prepare strategies in managing mass wasting hazard. This section tries to understand perceptions of respondents on their exposure to mass wasting based on location.

Regardless of the community, figure 5.1 revealed that, respondents on the hilltop considered themselves to be between low to very low risk of mass wasting. Respondents from both study communities believed that, they are far from the area being affected with mass wasting as it will take a while before they are affected. They further acknowledged that, there were chances of the event happening looking at the rate of human activities and land degradation in the area. Figure 5.7 again showed that, respondents on the slopes of the hill in both communities perceived themselves to be at high risk of mass wasting with rate between high to very risk accounting for about 60 percent and 72 percent for Tuba Junction and Choice respectively. The reason for the high percentage was because the respondents were mostly ones who have had an experience with mass wasting. At Tuba Junction, these respondents were those around Osiadan, Bonigas and parts of Michigani. For Choice, most of these respondents were around the area experiencing sand winning. Contrariwise, about 40 percent and 28 percent of the respondents from Tuba Junction and Choice respectively considered themselves to be at low risk. These were respondents found at the eastern side of the mountain where there is no activity of mass wasting at Choice and

some parts of Michigani at Tuba Junction. When asked about events of mass wasting for this category, they point towards areas around Bonigas, Osiadan and Michigani for the Tuba Junction and the respondents from Choice point the other side of the mountain. Interestingly, majority of the respondents (about 77 percent) at the base of the hill at Tuba Junction perceived themselves to be at high to very high risk of mass wasting while about 70 percent of the respondents perceived themselves to be at low to moderate risk of mass wasting. This is due to length of experience with mass wasting and the number of population experiencing mass wasting at the study communities. Tuba Junction have had longer experience and have undergone an extensive land degradation than Choice so obviously, experiences at Tuba will be different from that of Choice. Also at Choice, only a section of the hill is undergoing sand winning so the experiences from the respondents there were different from those at the other side of the hill.



**Figure 5. 2: Proposed Level of Exposure of Mass Wasting**

Source: Author's Field Data, 2020

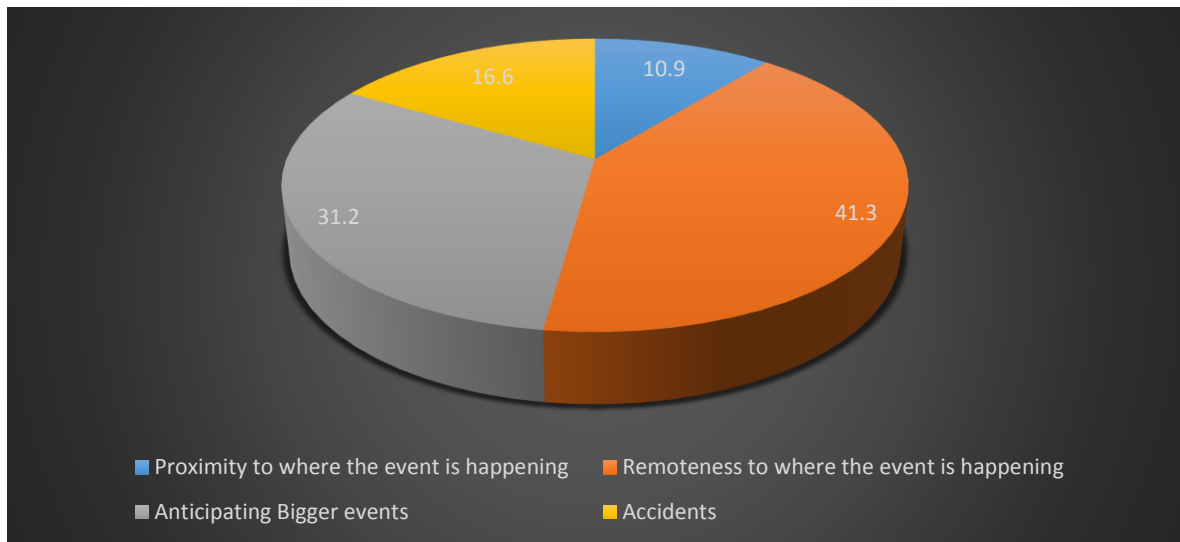
Based on respondents perceived exposure, about 95.2 percent and 88.2 percent from Tuba junction and Choice respectively regarded their community to be safe to with stand threats (Table 5.1). About 5.1 percent and 11.8 percent felt they were not safe as they acknowledged that though they might not be close to the section experiencing mass wasting, they are bound to experiencing it in the future. Nonetheless, respondents along the slope and at the base of the hill admitted that they were not safe to withstand any threats of mass wasting. The study revealed their responses were on a number of reasons.

**Table 5. 1: Perceived level of Safety in the Community**

Location	Community	Safe to Withstand Threats?	
		Yes (%)	No (%)
Summit	Tuba Junction	95.2	5.1
	Choice	88.2	11.8
Slope	Tuba Junction	46.7	53.3
	Choice	23.1	77.0
Base	Tuba Junction	25.0	75.0
	Choice	22.9	77.2

Source: Author’s Field Data, 2020

Figure 5.2 revealed that, the responses of the respondents were based on four reasons. These include proximity to where the event is happening, remoteness to where the event is happening, anticipating bigger events and accidents. The closer the location of the respondent to the area where mass wasting is occurring, the higher the chances of them falling victim to the events and its impacts. The farther they are from the area of event, the less chances of them falling to mass wasting.



**Figure 5. 3: Reasons for Perceived Level of Safety in the Community.**

Source: Author's Field Data, 2020

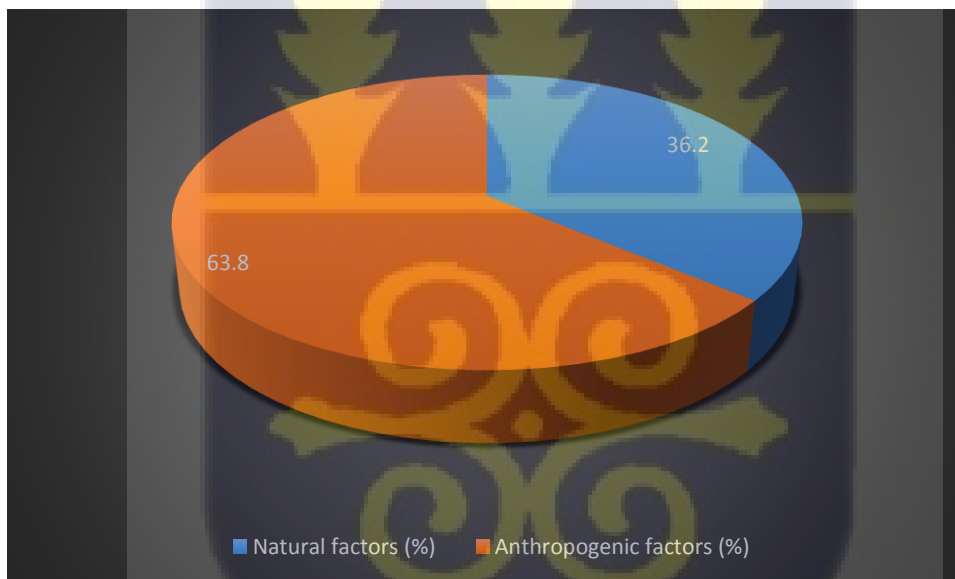
From figure 5.2 about 11 percent saw themselves to be closer to the area where mass wasting events occur hence, they felt unsafe in the community. About 31 percent and 17 percent felt unsafe because they are anticipating bigger events of mass wasting as well as incidences of accidents in the community which can lead to loss of properties, injuries and loss of lives. This tends to create deep sense of fear, stress and anxiety for fear of the unknown. This can even affect the mental and emotional health of respondents at the long run.

A respondent shared,

*“A huge boulder broke my wall and rolled into my compound. I was very glad that none of my family members were around that day. We have been in fear since that day because you don't know when another stone will come rolling down. Who knows what will happen”.* (A 51 years old female trader from Choice)

### 5.2.1 Perceived Causes of Mass Wasting

The respondents identified both physical and anthropogenic or human-induced causes of mass wasting in both municipalities. According to the respondents, anthropogenic factors accounting for about 64 percent, are largely responsible for mass wasting in the municipalities. The respondents believed that anthropogenic factors have served as a catalyst for mass wasting in the communities. Rapid urbanization in the Ga South and Weija-Gbawe Municipalities due to its proximity to the Accra Metropolitan Area, improved transportation network and as a center between urban Accra and Kasoa area have also contributed immensely to putting a lot of on the land. This result confirms the position of most geologists and geomorphologists that human activities are largely responsible for mass wasting, serving both as preparatory and triggering factors (Adu-Boahen et al., 2020; James et al., 2013). Physical Causes accounted for about 36 percent (figure 5.3).

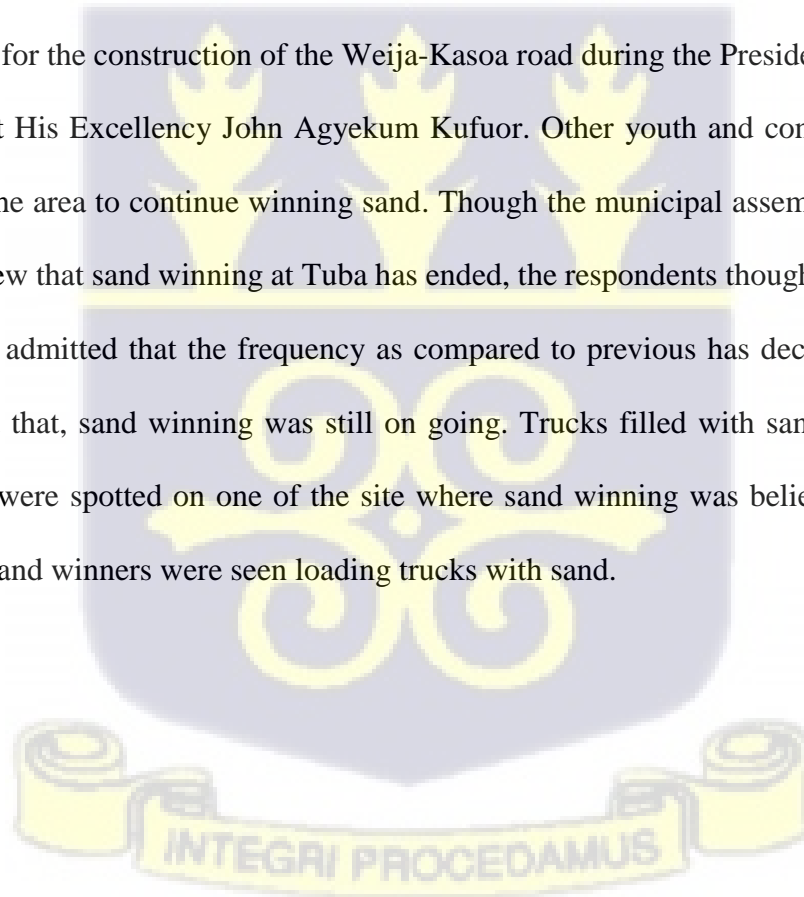


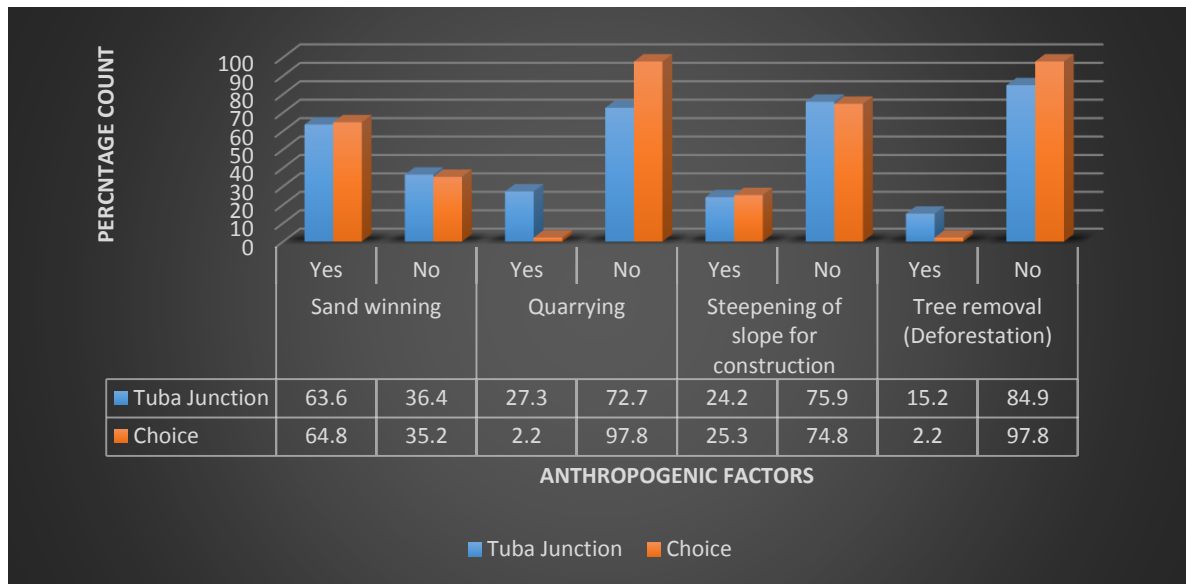
**Figure 5. 4: Causes of Mass Wasting**

Source: Author's Field Data, 2020

### 5.2.1.1 Anthropogenic Causes

The dependency of humans on land for food production and economic development is causing constant modification to the global landscape thereby putting a lots of pressure and stress on the land (Siddhartho, 2013). Anthropogenic factors are one of the pronounced and also the dimension that can be easily managed than the physical dimension. The results revealed varied perceptions of respondents on the causes of mass wasting with in the study communities. A large number of the respondents representing about 64 percent and 65 percent from Tuba and Choice respectively shared the view that sand winning is the highest anthropogenic cause of mass wasting (figure 5.4). An interview with the Head of Physical Planning of the Ga South municipality as well as responses from the respondents indicated that, sand was mined from the Weija hills at the Ga South Municipality close to Tuba Junction for the construction of the Weija-Kasoa road during the Presidency of the former President His Excellency John Agyekum Kufuor. Other youth and construction workers took to the area to continue winning sand. Though the municipal assembly officials were of the view that sand winning at Tuba has ended, the respondents thought otherwise. They however admitted that the frequency as compared to previous has decreased. The study observed that, sand winning was still on going. Trucks filled with sand as well as sand winners were spotted on one of the site where sand winning was believed to have been halted. Sand winners were seen loading trucks with sand.





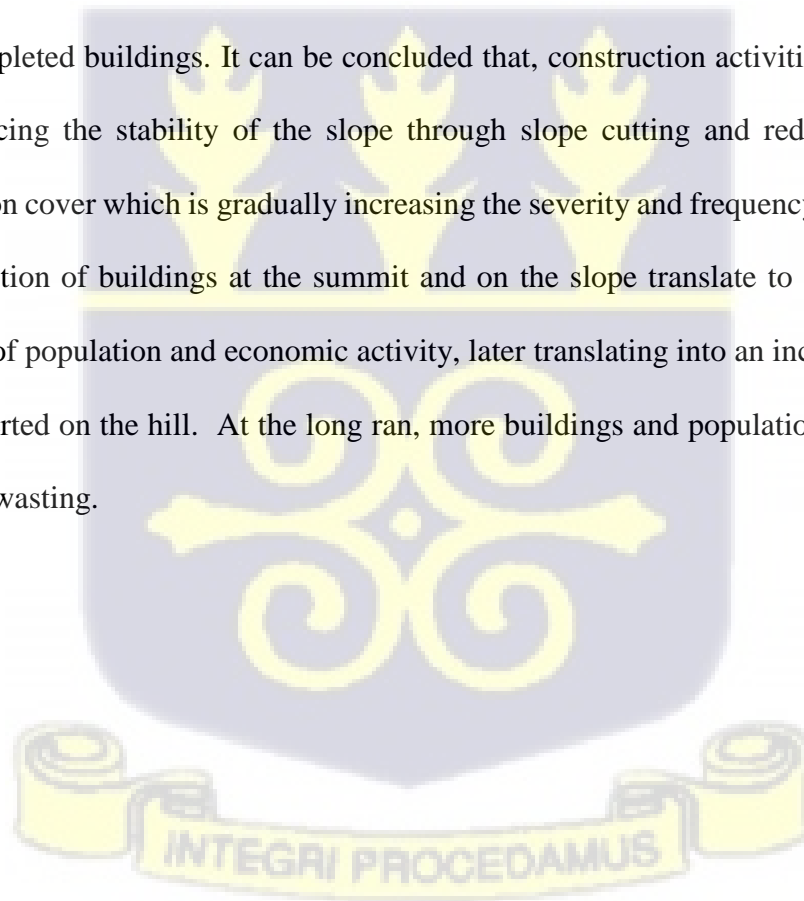
**Figure 5. 5: Anthropogenic Causes of Mass Wasting in the Study Communities**  
 Source: Author’s Field Data, 2020

Respondents at both study communities believed that the process of sand winning have accelerated mass wasting in the communities. They argue that, the sand can be exploited to satisfy human needs but this should be done using efficient and effective resource management to sustainable development. It was realized that in an event of an extreme natural activity such as extreme rainfall conditions, earth quakes the likes, a much greater event of mass wasting is bound to happen as the hills have been left exposed to natural activities.

A respondent at Tuba Junction recalled that,

*“Mass wasting events in this area began after mining of sand for the construction of the Weija-Kasoa highway. People took advantage of the situation and started mining sand indiscriminately. Though notices have been served to stop people from continuing winning from here, they still go ahead anyway. My only prayer is we should not have any major earthquake or rain in this area or else the nation will have a mass burial for all of us”* (A 42 years old male pastor at Tuba Junction).

Tuba Junction recorded the highest responses for Quarrying (about 27%) (Figure 5.4). Majority of the respondent from the community were of the view that, it used to be one of the major activities they struggled with aside sand winning. They were quick to add though that this is not the issue anymore as the activities of quarrying in the community has reduced. Construction of buildings on slopes on the other hand formed about 24 percent and 25 percent respectively in Tuba Junction and choice respectively. In Tuba Junction, lots of buildings were springing up in the community especially along the slope with a few at the summit of the slope (Plate E). It was realized that, communities at the summit of the hill were well laid out with roads and drainage facilities. Buildings found at the summit were more sophisticated than most of the buildings on the slope. Some of the buildings on the slope were still under construction while others were constructed with wood with very few completed buildings. It can be concluded that, construction activities to some extent, are reducing the stability of the slope through slope cutting and reducing the area of vegetation cover which is gradually increasing the severity and frequency of mass wasting. Construction of buildings at the summit and on the slope translate to an increase in the number of population and economic activity, later translating into an increase in the stress level exerted on the hill. At the long ran, more buildings and population might be at risk of mass wasting.



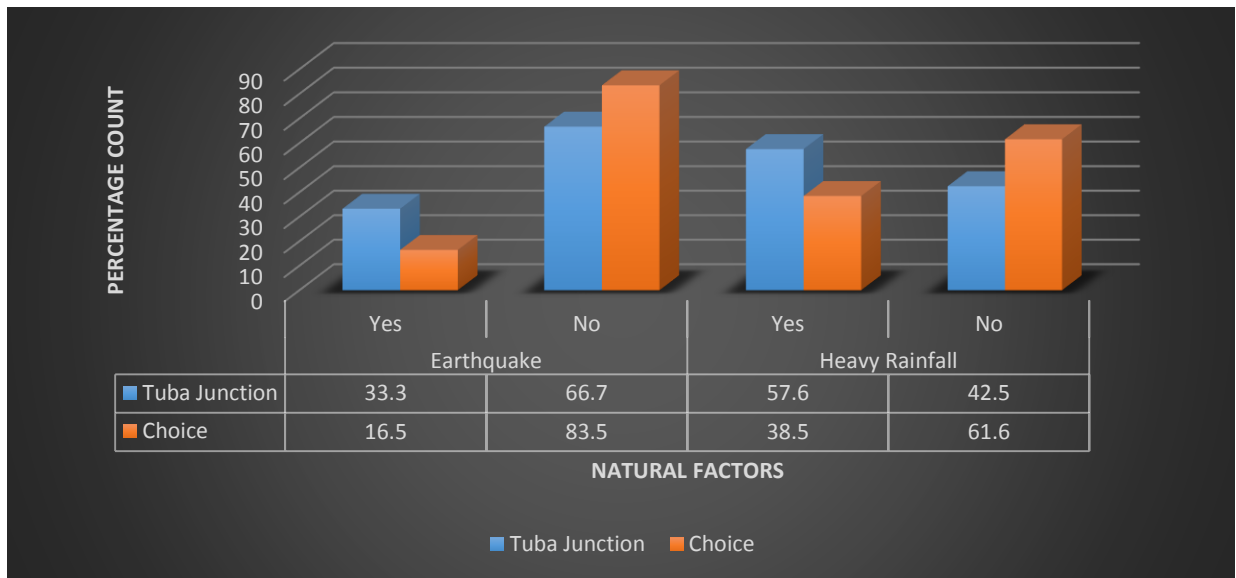


**Plate 5. 4: Some of the New Residential Apartments at Michigani (Tuba Junction)**

Source: Author's field data, 2020

#### *5.2.1.2 Natural Causes*

Natural causes are normally the preparatory factors for mass wasting as these gradually and noticeably or inconspicuously weakens the land such that a continuous activity of these physical factors or the presence of any external factor can cause slope failure (Nelson, 2013). It was inferred from the responses that, anthropogenic factors have served as catalyst for physical factors, increasing the pace at which mass wasting occur in the area. The respondents identified two natural causes of mass wasting namely rainfalls and earth quakes. Rainfall formed about 66 percent of the responses whereas earth quakes formed about 34 percent of the responses (figure 5.5).



**Figure 5. 6: Natural Causes of Mass Wasting in the Study Communities**

Source: Author’s Field Data, 2020

Rainfall was considered as the major triggering so far as natural factors are concerned accounting for about 58 percent and 39 percent for Tuba Junction and Choice respectively (Figure 5.5). It can be inferred that, any incidence of torrential rainfall in the study communities is recipe for disaster and majority of the residents were alarmed by this. Residents narrated how any heavy rainfall in the communities comes with some incidences of mass wasting. This result was in consonance with the findings of Adu-Boahen et al. (2020) in their study about mass wasting in the Weija Catchment area. According to the findings of the study, rainfall came out as a major natural cause of mass wasting in the area. Earthquake formed about 33 percent and 16 percent of the responses from Tuba Junction and Choice respectively (Figure 5.5). Respondents indicated that, though they experience earth quakes, they have not yet endured any mass wasting event caused by earth quakes yet. They however believe there is a possibility of it happening looking at the incessant experiences they had in the year 2020.

### 5.2.2 Impacts of Mass Wasting

As the population of humans expand and occupies more land surface, mass wasting processes are likely to affect humans. Impacts of mass wasting has been assessed based on environmental and socio-economic factors.

#### 5.2.2.1 Environmental Impacts of Mass Wasting

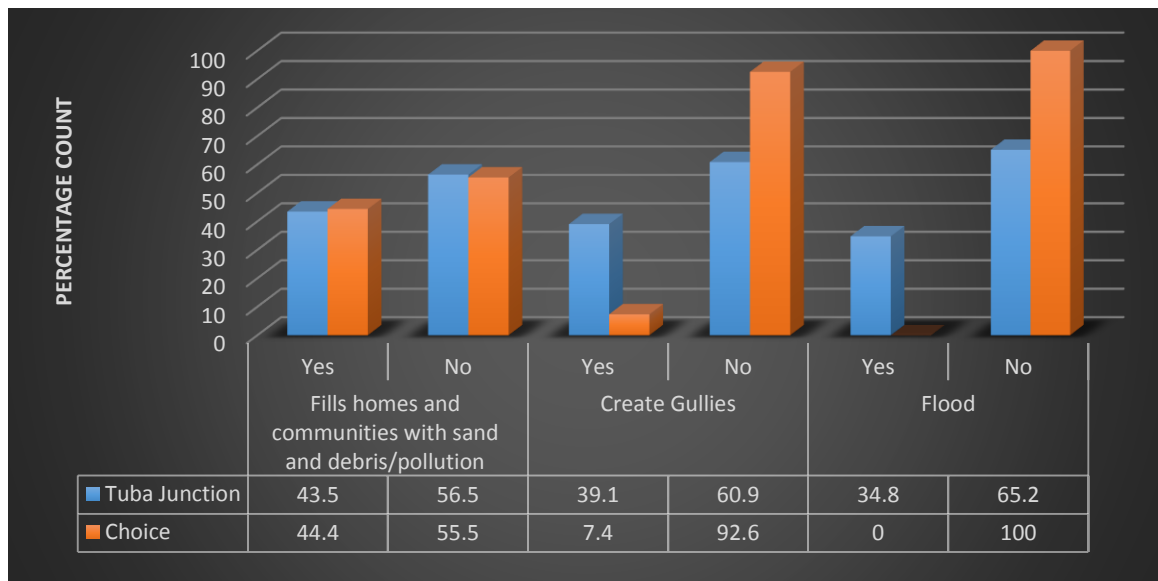
As already noted, mass wasting constitutes a serious problem in the Ga South and Weija-Gbawe Municipalities. However, the problem is more pervasive in one municipality than in others. This is as a result of the differences in the length of time in the inception of mass wasting in the study communities. Tuba junction have had relatively more experiences with mass wasting than Choice so obviously effect of mass wasting will be more pronounced in the former than that of the latter. The study revealed that about 39 and 7 percent of the respondents respectively articulated that, lands being destroyed through the creation of gullies as a major impact of mass wasting in the community (figure 5.6). The down flow movement of materials from the hill top through the process of abrasion have created large gullies making development in parts of community very difficult (Plate F). Even existing buildings continue to be under threats. At Tuba Junction, the study further realized serious incidents of erosion in the community. Gully initiation is the result of localized erosion by surface runoff and soil eluviation associated with rainfall events of high intensity (Egboka *et al.*, 2019). Erosion is frequently concentrated where the forest cover has been removed for agricultural, urbanization and construction purposes and also at sites of uneven compaction of surface soils through surficial changes and movements (Egboka *et al.*, 2019). The most serious and dangerous of all the gullies are the ones found behind Osiadan Construction Limited. These gullies are very deep and contain lots of loose soil making them very vulnerable to climate conditions which might lead to mass wasting (Plate B). A

respondent disclosed that the width of the gully has increased with time making it more dangerous as the years go by. Parts of the roads at Michigani and “Bonigas” have been rendered not plowable by gullies (Plate F) .



**Plate 5. 5: Some Gully Sites in the Community**

Source: Author’s Field Data, 2020



**Figure 5. 7: Environmental Impacts of Mass Wasting**

Source: Author’s Field Data, 2020

Figure 5.6 demonstrate that, about 44 percent of the respondents from both study communities acknowledged that mass wasting events leaves sand and debris in the communities. This phenomenon is more severe behind The Four square church down to Osiadan Company Limited at Tuba Junction. Respondents’ lamented that, part of the debris from the hill top are deposited in the area and this action is gradually increasing the level of the land. A respondents reported,

*“This part of the community used to down and flat. We were on a very low level ground but because of the sand from the hill have filled up this whole place” (A 32 years old female head dresser from Tuba Junction).*

Additionally, other respondents communicated that, some youths come to mine the sand that has been deposited in the area but even at that, the rate at which the ground level is increasing is alarming. Moreover, the residents added that, the force and the volume at which the debris come with have caused walls to break and cracks in their structures. It was added that, some of the debris sometimes overflow the walls. This findings concerted

with the results of Adu-Boahen et al. (2020) that stated that mass wasting can cause structural damages to properties. Again, they added that, some residents in the area add their waste (polybags, plastic bottles, human excreta as well as some other household waste) to the moving debris and these have added up in filling the community. They maintained that, this behavior sometimes leave the area with a stench (figure 5.6). The respondents further added that, this act is part of the main contribution to flooding in the community. The study realized that, another cause of floods in the community is mass wasting. Mass wasting and floods are closely related to intense rainfall, runoff and ground saturation hence mass wasting events can block channels and drainage inhibiting the free flow of water. This can cause backwater flooding on the area. This finding corresponds with that of Highland and Bobrowsky (2008) which stated that mass wasting and flooding are closely related as the occurrence of mass wasting can cause mass wasting dams that can subsequently cause flooding. The excerpts below highlight some concerns raised by some respondents:

*“The sand you see here were all brought from the hill top. We used to be on a low and flat level ground but as the rain falls; more and more sand fills this place. People also pour their rubbish into the sand when it reaches their side. This is also increasing the volume of sand filling the community. That is the reason why you see rubbish all around”* (A 50 years old male driver from Tuba Junction).

Another respondent added,

*“When we first settled here, the ground level was very low but sand started filling the community from the hilltop due to sand winning and deforestation. The sand here is sometimes mined and sold to the constructors by the youths if not for that I’m sure it would have been more than what you see here”* (A 62 years old female pensioner from Tuba Junction).

Whiles Tuba Junction suffered from filling of sand in their communities, floods and pollution from waste, Choice on the other hand suffered from sand filling their homes and pollution from dust as a result of sand winning. Respondents commented that, lots of dust are released into the atmosphere causing respiratory problems as they inhale the dust and dirtying their washed clothes in the process. The residents who suffer from these are the respondents right opposite the base of the mountain undergoing sand winning and residents with their homes just at the base of the mountain. Some respondents had this to say,

*“I live just opposite the area where sand is being mined. Anytime it rains, lots of sand is carried into my compound. It was not like that when we first moved here but since they started sand mining, we also began to experience these changes. Even the volume of water has changed. It used to be a small volume of water with a little sand because of the untarred road but now you can see that there is more sand in it. Also, now I have to go the hospital frequently because I cough a lot nowadays. Even my grandchildren are suffering because of the amount of dust it releases into the air”* (A 65 years old female pensioner from Choice).

A 36-year old also added,

*“My kids have been to the hospital about 4 times with respiratory issues since 2019. Because my residence is just next to where the sand is being mined, we experience the greatest impact. Also, I was the same attire for about 2 to 3 times a day because the amount of dust in the atmosphere is too much. It always dirtying our clothes”* (A 36 year old female trader from Choice).

#### 5.2.2.2 Socio-Economic Impacts of Mass Wasting

The study discovered the difficulty to use roads as a result of mass wasting (figure 5.7) for both study communities. At Tuba Junction, while some of the roads have been destroyed by deep gullies, others have been flooded making movement of the road difficult. The

phenomenon is more severe around Michigani from where debris reach Osiadan Construction Limited down to the Accra-Kasoa highway blocking a part of the road thereby hindering vehicular movement. This findings holds true the assertion of Perera et al. (2018) that an effects of mass wasting is blocking of roads thus making them inaccessible. Also, the result is in tandem with the reports of ABC News (2019) and Acquah (2019).

One of the respondents commented,

*“Nobody can use this road when it rains. The mud from the hills fills up this half of the road going to Accra, Madina and the others and this ends up causing a lot of traffic as all drivers are forced to use the other lane heading to Kasoa, Winneba and the others. It is an eyesore”* (A 44 years old male construction worker from Tuba Junction).

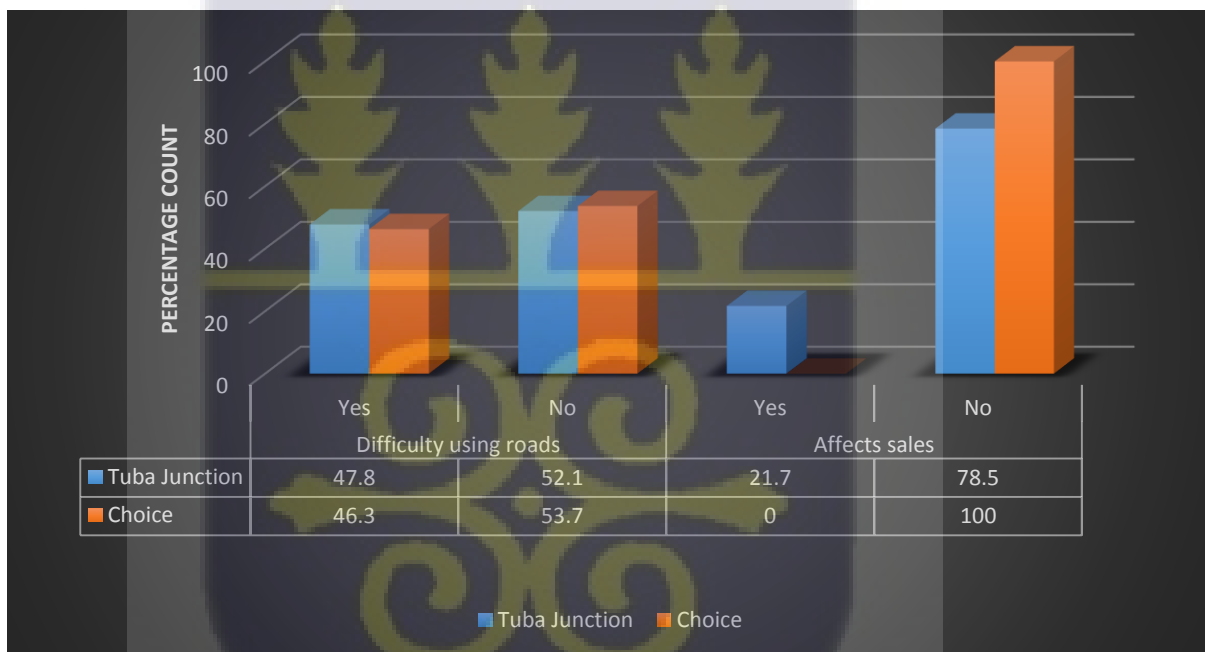
Some roads at Choice are untarred and plagued with erosion. This makes movement on the road especially during raining season quite difficult. Debris from the hill sometimes fill the road obstructing movement for both vehicles and pedestrians.

A respondent retorted,

*“Our roads are already untarred so you can imagine what we go through in this area. When it rains heavily, the mud sometimes comes down to fill the road making it difficult for both pedestrians and car owners to use the road. The drivers sometimes use alternative route for us to reach our destination. We sometimes have to descend at a point and walk if the driver is not ready to use the alternative”* (A 34 years old male mechanic from Choice).

Respondents added that, due to the inability of residents to access their shops due to the condition of the roads and mass wasting events, it affects their daily sales (figure 5.7). This response was peculiar to respondents at Tuba Junction. During mass wasting events, shop

owners around the Kasoa-Weija Highway are lose their daily sales they are forced to sometimes close their shops. Respondents around the Kasoa tollbooth complained about flooding during the rainfall seasons and mass wasting season. They have to focus on saving both their wares and their shops. Further, due of mass wasting, some drivers would often have to make extensive detours in order to reach their destination thereby increasing their time of travel but not sales. As some of the drivers could have made twice the income they made on a trip. Others use the situation to their advantage by charging huge amounts for “dropping” as passengers would not have any option than to board them. The study revealed that, fuel consumption increases during these times as lots of cars are caught in traffic increasing fuel carbon emissions, also the average travelling fuel consumption and delays to road users.



**Figure 5. 8: Socio-economic Impacts of Mass Wasting**

Source: Author’s Field Data, 2020

### 5.2.3 Mitigation and Coping Strategies

The study went further to know the various strategies that have been or are being put in place to by respondents to protect themselves against mass wasting hazards. Surprisingly, though majority of respondents knew about mass wasting hazards, their occurrence and the looming danger in their various communities, about 76 percent of the respondents have taken no step to protect themselves in the case of a disaster (Table 5.2) though most of these respondents admitted to knowing that they are prone to danger. The study found out that, majority of the respondents have not particularly taken a step to protecting themselves because they view that as the responsibility of the local government thus till that aid comes, they probably are not going to do anything at all to protect themselves. The study realised that majority of the respondents in this group kept blaming the government for what they were experiencing now. As a result, they expected the government to fix the situation and for that reason they have not done much themselves. The study has a dual stand on this because though the government is supposed to put in measures to protect the citizens of the community, respondents are also supposed to put in efforts to keep themselves and their properties safe, at least till the time help finally comes. This revelation is in consonance with the study of Chaturvedi and Varun (2015) and Winter and Bromhead (2012) which revealed that though majority of respondents knew about the problems of mass wasting in their communities, they were not especially worried about it hence they had done nothing to protect themselves.



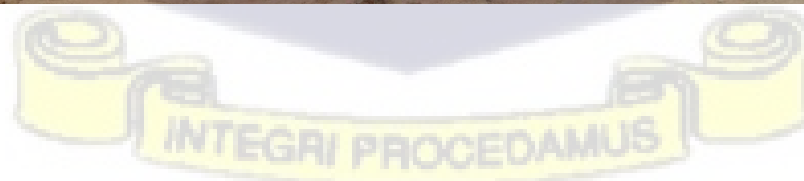
**Table 5. 2: Measures Undertaken by Respondents to Cope with Mass Wasting**

Location	Community	Protection of important documents and personal belongings		Identification of safe exit routes		Relocate		Done Nothing	
		Yes (%)	No (%)	Yes (%)	No (%)	Yes (%)	No (%)	Yes (%)	No (%)
Summit	Tuba Junction	0	100	0	100	0	100	100	0
	Choice	0	100	0	100	23.5	76.5	76.5	23.5
Slope	Tuba Junction	0	100	6.7	93.3	0	100	86.7	13.3
	Choice	17.9	82.1	7.7	92.3	7.7	92.3	61.5	38.5
Base	Tuba Junction	25	75	8.3	91.7	0	100	83.3	16.7
	Choice	0	100	0	100	0	100	97.1	2.9

Source: Author’s Field Data, 2020

About 17.9 percent of respondents along the slope of the hill and 25 percent from the base of the mountain at Tuba Junction were putting in measures to protect themselves and their properties (residence, shops among others). To do this, a number of options were sighted at the study communities. At Tuba Junction, retaining walls were dominant (Plate J) while Choice had sand bars and elevation of shops using cement blocks (Plate K). There two major types of retaining walls used at Tuba Junction; concrete retaining walls and retaining walls made out of blocks as seen in plate J. These are mostly found among residents around Kasoa Toll Booth close to The Foursquare Church. According to them, it is this retaining walls that are protection the toll booth from mass wasting. It was discovered that the debris that moved down the slope was trapped by these walls helping to reduce mass wasting events around the toll booth. This is also one of the major reasons why that part of the community has been filled with lots of sand. It was also realised that the walls were being buried by the debris from the hills. The respondents revealed that the church had to build a

second wall as the first one was being submerged by the debris. It can be concluded that the second wall will also be covered up in no time.





**Plate 5. 6: Retaining Walls at Tuba Junction**

Source: Author's Field Data, 2020



**Plate 5. 7: Sand bars and building elevation at Choice**  
Source: Author's Field Data, 2020

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A respondent commented,

*“I erected this sand bar in front of my house to redirect the flow of mud and water from entering my house. This has been my source of help but as you can see it is almost covered up by debris.”* (A 65 years old female trader from Choice)

Some respondents along the slope and at the base of the hill of Tuba Junction and others along the slope at Choice have identified safe exit routes in cases of disaster. Respondents from Tuba Junction have identified another relatively longer route leading to Kasoa old barrier through Kokrobite. Other respondents have plans of relocating in the future to other areas they saw to be safer as compared to their current location though upon interrogation had no specific place in mind or when they actually intend to move. These were mainly respondents from Choice. One of the respondents said,

*“All of us living in this community know the place is not safe. I will say we were going through a natural process till these Chinese started winning the sand. Things have changed around here. I will certainly move when I get money to a safer community. I do not really know where yet but I will definitely move.”* (A 36 years old male trader from Choice)

#### **5.2.4 Proposed Ways to Mitigate Mass Wasting in the Communities**

Preventing mass wasting involves correct design of infrastructure such as roads, houses, schools, railroads, and other related land uses. There is difficulty with the option of prevention as most of this infrastructure was developed before proper prevention techniques could be introduced (Adu-Boahen *et al.*, 2020). Respondents gave various ways through which they perceived mass wasting in the study communities could be remedied. These remedies are shown in figure 5.8 to some respondents, an integrated approach to

curbing the situation was more sustainable. This integrated approach comprises both soft and hard measures (Adu-Boahen *et al.*, 2020). While some were of the opinion that mass wasting can be remedied, others thought otherwise. About 17 percent of the respondents were of the view that nothing can be done to remedy mass wasting in the study communities (figure 5.8). These respondents lamented that they have lost hope in the government and the system. Additionally, about 40 percent of the respondents suggested that the only way out is to end sand winning and stone quarrying as these practices have greatly altered the landscape. This response was a concern to both study communities as they both revealed that the inception of sand winning in the communities led to the commencement of mass wasting due to the unsustainable ways that was used in mining. They require that the act be abolished so as to help curb the event of mass wasting in the community.

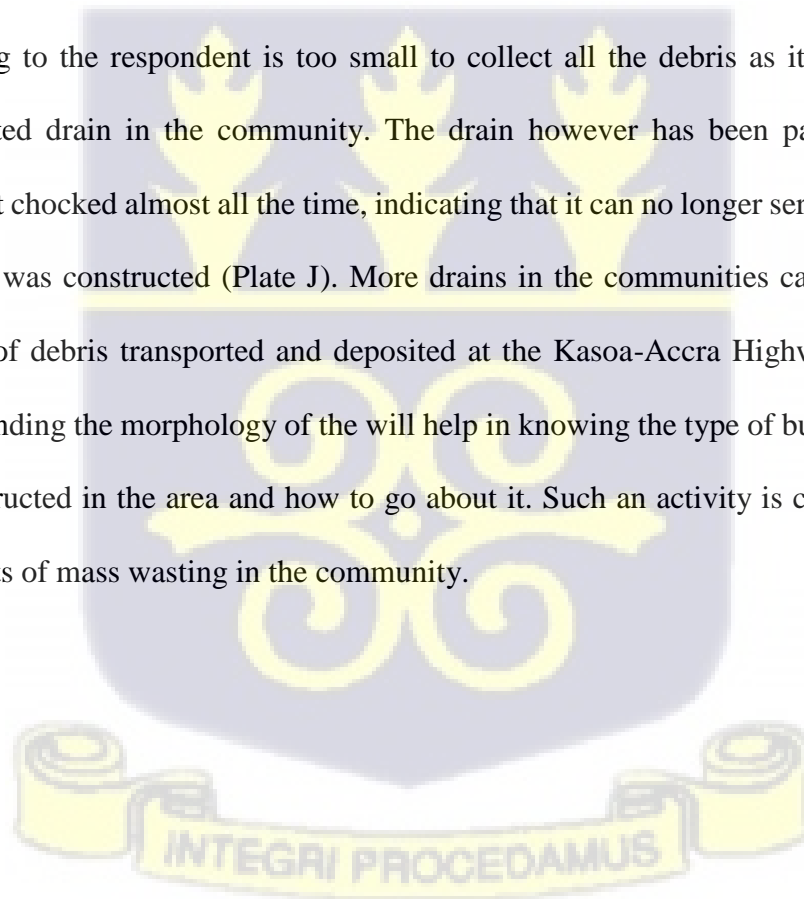


**Figure 5. 9: Perceived Measures to Manage Mass Wasting**

Source: Author's Field Data, 2020

About 12 percent of respondents further added that, tree planting and the construction of retaining will be appropriate in controlling mass wasting. The presence of vegetation has

the ability to protect and prevent excessive erosion as bare lands tend to have more gullies and erosional processes than areas with vegetation. This confirms Adu-Boahen et al.'s (2020) assertion that mass wasting liaises with other factors to cause mass wasting. Retaining walls on the other side are meant to hold the soil on the slope without it eroding, keeping it from collapsing. Respondents believe that encouraging tree planting and the construction of retaining walls on the hill will help check mass wasting. Community planning formed about 11 percent of the responses. Community planning for this study includes construction of drainage systems and following good building practices. Both study communities have no well-engineered drainage systems. Tuba Junction has one big drain in front of Osiadan Construction Limited which was constructed by the municipal assembly to purposely collect and assist in the flow of debris from the hill. This drain according to the respondent is too small to collect all the debris as it is the only well-constructed drain in the community. The drain however has been packed with debris leaving it choked almost all the time, indicating that it can no longer serve the purpose for which it was constructed (Plate J). More drains in the communities can help reduce the amount of debris transported and deposited at the Kasoa-Accra Highway. Furthermore, understanding the morphology of the will help in knowing the type of building that should be constructed in the area and how to go about it. Such an activity is crucial in reducing the events of mass wasting in the community.





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**Plate 5. 8: Big Gutters Chocked with Debris at around Osiadan Construction Limited**  
Source: Author's Field Data, 2020

### **5.3 Chapter Summary**

The study discussed the respondents' perceived causes, types and impacts of mass wasting. The chapter again looked at the mitigation and coping strategies adopted by respondents to cope with their current situation. The study realized that majority of the respondents, on their own, have done nothing to protect themselves against mass wasting as that is seen as the responsibility of the municipal assembly. The few numbers who had, adopted measures like construction of sand bars and retaining walls. The next chapter discusses the conclusions and recommendations of the study.

## CHAPTER SIX

### SUMMARY OF KEY FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

#### 6.0 Introduction

This final chapter summarizes the main findings of the study. It also draws some of the important conclusions and makes recommendations for policy consideration.

#### 6.1 Summary of Key Findings

This study has highlighted some salient issues surrounding the triggers of mass wasting in Metropolitan Accra. Below are the main findings vis-a-vis the objectives of the study.

##### 6.1.1 Vulnerability levels of Residents

The study first used both descriptive statistics and cross tabulation to analyse the demographics of the respondents. The study identified that all the respondents had knowledge about mass wasting. Again, the study identified that more than half of the respondents were either there to work or the respondents were living in the study communities because it is closer to their work place. It was realized that majority of them had lived there between 1 to 15 years. Additionally, the study found out that television was the main source of information for mass wasting alongside their own personal experiences with mass wasting.

To know the vulnerability levels of the respondents, the study used DEM derivatives, geological, land use, soils, rainfall, proximity to faults, distance from roads and distance to water bodies, and an inventory map containing 20 mass wasting points was used to develop

hazard map for the municipalities. The potential mass wasting hazard map showed that areas around the coast along with majority of the areas in Weija-Gbawe as well as areas around the southern part of the Weija Lake were very much susceptible to mass wasting. Again, the northern part of both municipality were exhibiting lower levels of susceptibility to mass wasting. The study areas fell in the moderate risks zone.

### **6.1.2 Residents' Perceived Risk to Mass Wasting**

The perceived causes of mass wasting according to the respondents were both anthropogenic and natural causes but the most perceived pronounced cause is anthropogenic factors. The study revealed, though there were signs of natural processes causing mass wasting in the study area, it was exacerbated by the frequent anthropogenic factors occurring in the municipality. The main anthropogenic cause is sand winning whiles that of natural causes was rainfalls. Debris slide, debris flow and rock falls were the types of mass wasting occurring at Tuba Junction whiles Choice experiences mainly debris flow and rock falls. Mass wasting is having devastating environmental and socioeconomic impacts on residents of the study communities. Moreover, out the environmental impacts, Choice experiences only deposition of sand in the communities and homes as well as gully creation whiles Tuba Junction experiences all two including flooding as a result of mass wasting. With socio-economic impacts, mass wasting at Tuba Junction makes it difficult to use roads and affect sales whiles that of Choice makes it difficult to use roads in the community. Again, the study realized that the impacts of mass wasting is causing lots fear, stress and anxiety to respondents of the community as the event is making them feel unsafe to withstand any threat future mass wasting event. Thus, the residents at the summit of the

hill of both study communities perceived themselves to low risk of mass wasting. Respondents along the slope and the base of the hill perceived themselves to be between moderate to very high risk of mass wasting. The study recognized that, mass wasting at Tuba Junction was more pronounced and risky than that of Choice due to the number of years of land degradation.

Lastly, the hazard map showed that, communities at the north part of the Ga South municipal is less prone to mass wasting while most of the southern part is at high of disastrous mass wasting events. Weija-Gbawe municipal on the other hand showed a higher risk of mass wasting with some small patches of areas with very low risk of mass wasting.

### **6.1.3 Mitigation Practices to Mass Wasting**

The study found a revelation that though the respondents knew about mass wasting and its impacts, majority of them have done nothing to protect themselves against the impact due to unwillingness as they saw that as the responsibility of the government. Others have found ways to protect themselves and their documents, have found safe exit routes and others plan on relocating to other communities in the future. Concerning mitigation strategies, the main perceived action was to stop sand winning and quarrying the community as that was perceived as the main anthropogenic cause of mass wasting.

### **6.2 Conclusion**

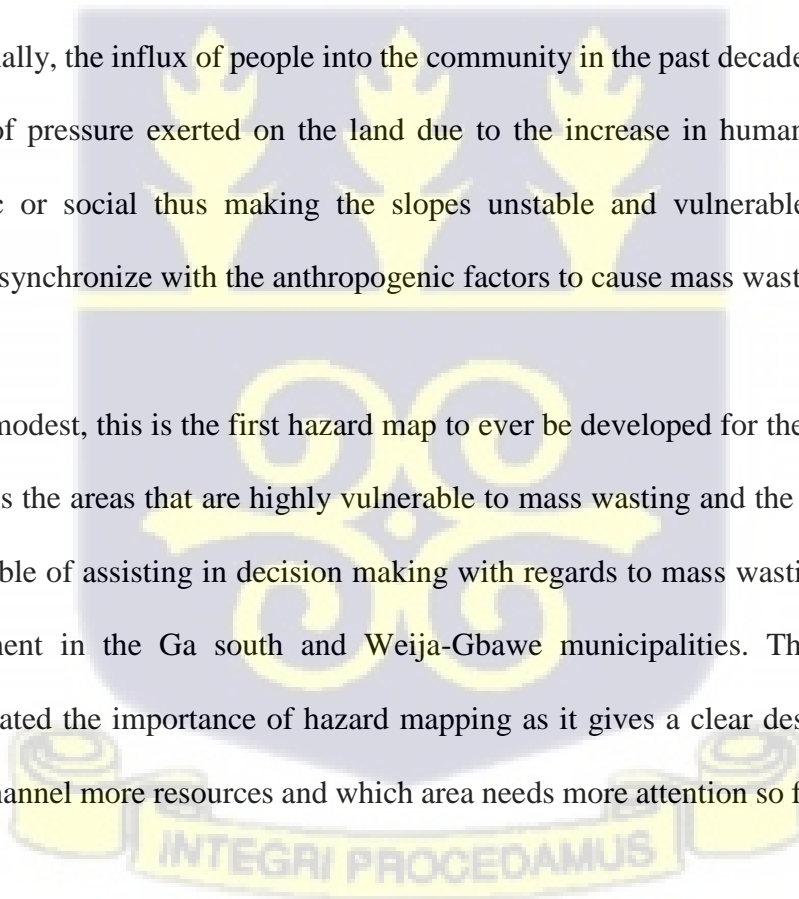
Based on the discussions of the findings, the following conclusions were drawn from the study. Mass wasting is a big challenge in Ga South and the Weija-Gbawe municipalities

which is causing very devastating effects. Respondents at the summit of the hill perceive themselves to be safe from mass wasting because they saw themselves to be far from the areas where mass wasting events were occurring. Respondents along the slope and the base were the ones at the mercy of the event. This has caused lots of stress and anxiety for respondents and lots of environmental as well as socio-economic impacts in the community.

Also, the absence of drainage facilities in the community is adding salt to injury as abrasive processes occur even as debris are being carried away. This creates new gullies and further widens old ones, increasing the vulnerability of the slopes.

Additionally, the influx of people into the community in the past decade has increased the amount of pressure exerted on the land due to the increase in human activity whether economic or social thus making the slopes unstable and vulnerable. Natural factors however synchronize with the anthropogenic factors to cause mass wasting.

Though modest, this is the first hazard map to ever be developed for the municipalities. It underlines the areas that are highly vulnerable to mass wasting and the areas that are not. It is capable of assisting in decision making with regards to mass wasting mitigation and management in the Ga south and Weija-Gbawe municipalities. The study has also demonstrated the importance of hazard mapping as it gives a clear description of which area to channel more resources and which area needs more attention so far as management



and mitigation is concerned. It is also going to help in further studies with regards to mass wasting hazard mapping in other communities.

### **6.3 Recommendations for Policy Consideration**

On the basis of the findings, the following recommendations are proposed for policy consideration:

#### **6.3.1 Construction of Drainage Systems**

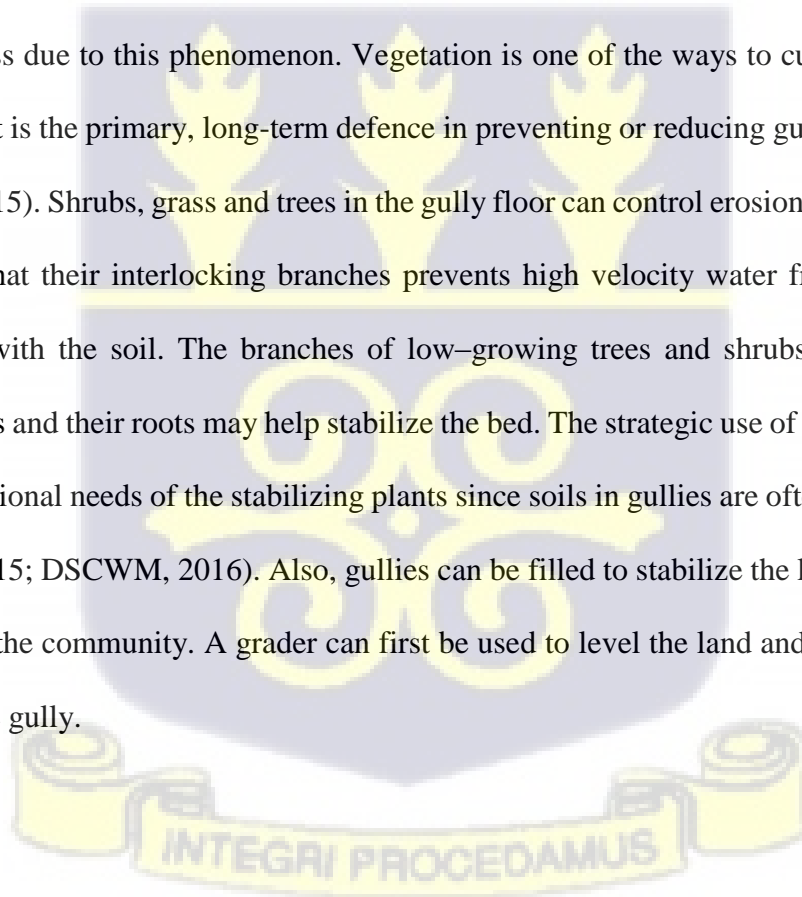
Drainage management is often a crucial remedial measure due to the important role played by pore-water pressure in reducing shear strength (DSCWM, 2016). Both study communities lacked proper drainage systems. A large drain was constructed at Tuba Junction to help curb mass wasting activities in the community by collecting the sediments from the hill. The drain could not serve its purpose as it is the only proper drain in the community, putting it at the receiving end of all the sediments and run-offs from the community. The absence of drainage systems in the communities have resulted in the formation of deep gullies weakening the hills and making them more susceptible to mass wasting. The study recommends the construction of drainage systems as this will prevent erosion and reduce infiltration thereby averting slope instability. It is noteworthy that, adequate surface drainage maintenance could the occurrence of landslides.

#### **6.3.2 Strengthening Slope Stability through Engineering Techniques**

Deep gullies, surface erosion, huge cracks, hollows as well as hanging rock and earth masses found at the study communities can be remedied using engineering techniques. All

hanging rocks and earth masses should be knocked down to avoid the risk to life and property from falling rock and earth masses. Huge cracks and hollows found at Tuba Junction can either be sealed or knocked down as well to prevent water from entering into the earth mass, which results in greater risk of mass wasting. Retaining walls can be used to hold the earth materials in place creating stable surfaces, preventing mass wasting at the long run.

In Tuba Junction, deep gullies as well as surface erosion were found. These were formed by an increase in surface run-off due to the absence of proper drainage facilities. The presence of deep gullies and surface erosion has limited the options for occupation and development in the community. There were parts of the community where vehicles could not access due to this phenomenon. Vegetation is one of the ways to curb the creation of gullies. It is the primary, long-term defence in preventing or reducing gully erosion (Carey et al., 2015). Shrubs, grass and trees in the gully floor can control erosion if they are closely spaced that their interlocking branches prevent high velocity water from having direct contact with the soil. The branches of low-growing trees and shrubs can reduce flow velocities and their roots may help stabilize the bed. The strategic use of fertilizer can meet the nutritional needs of the stabilizing plants since soils in gullies are often infertile (Carey et al., 2015; DSCWM, 2016). Also, gullies can be filled to stabilize the land especially the roads in the community. A grader can first be used to level the land and a bulldozer used to fill the gully.



### **6.3.3 Public Education and Sensitization**

The results of the study revealed that, though respondents knew about mass wasting and its effects, measures had not been put in place to protect both themselves and their properties. It was deduced that, majority of the respondents had no idea of the practices to put in place in order to protect themselves and their properties as others thought it was the responsibility of the government to see to it that they are protected. It is suggested that issue of public sensitization by the local government should be intensified. An intensive educational campaign should be embarked on focusing on teaching respondents best practices to put in place to protect themselves as well as their properties by both the National Disaster Management Organization and the local government. The study again showed that television is the most used medium for accessing information thus the television can also be used as a medium to educate members of the communities. Though not mentioned in the study, a door-to-door approach can also be used.

### **6.3.4 Re-Evaluation**

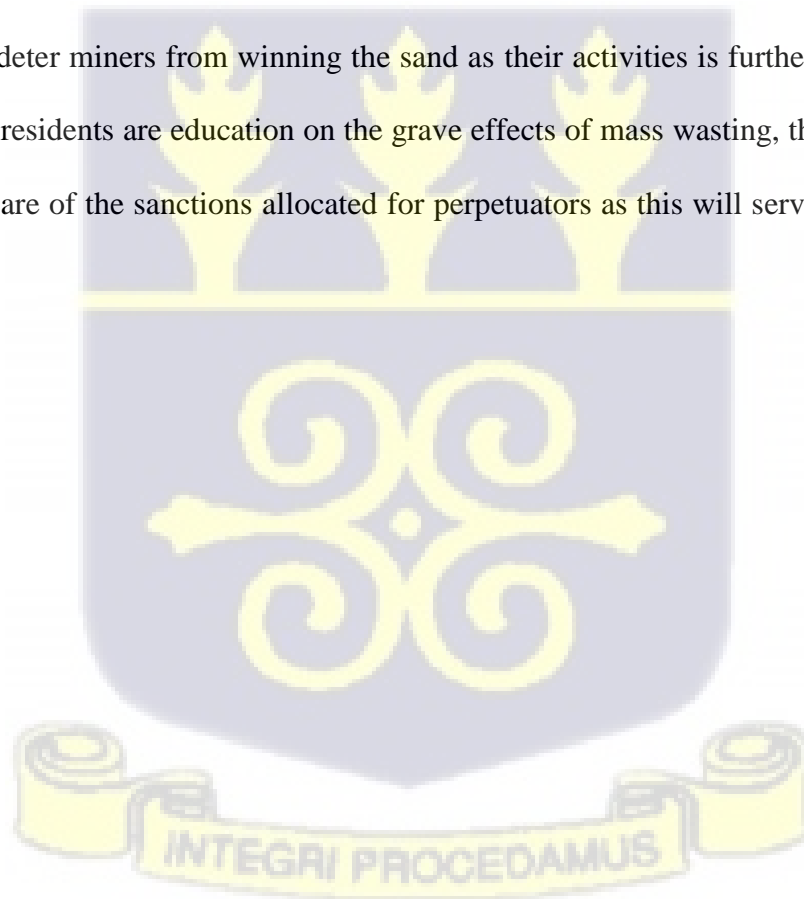
The study suggests a re-evaluation of the already existing plan of the two municipalities. This new plan should factor the inhabitants of the Weija Hills and all other areas that were designated as inhabitable but have currently been habited due to a breakdown in political systems or land tenure systems. This plan should include mitigation and refortification methods that will help residents already occupying susceptible areas. A building policy should be put together for such people to help protect both their lives and properties. In cases where the area is more broken and susceptible, relocation should be suggested.

### **6.3.5 Community-based Approach to Mass Wasting Mitigation**

During the field research, it was noted that residents were not involved in programs aimed at reducing their vulnerability to disasters. It therefore suggests that, it is most effective when the community is involved regularly in programs for reducing vulnerability to disasters like mass wasting. This helps them as direct beneficiaries to assess in detail their own physical, social and economic risks and again helps them to deal with it in a more personal, direct and effective way (ADPC, 2004).

### **6.3.6 Sanctions**

The field studies again revealed that sand winning was still ongoing though the local assemblies mentioned that it has been ceased. Grave sanctions should therefore be put in place to deter miners from winning the sand as their activities is further deteriorating the land. As residents are education on the grave effects of mass wasting, they should also be made aware of the sanctions allocated for perpetrators as this will serve as a deterrent to many.



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**APPENDICES**

**APPENDIX A**



**UNIVERSITY OF GHANA**

**DEPARTMENT OF GEOGRAPHY AND RESOURCE DEVELOPMENT**

**HOUSEHOLD SURVEY QUESTIONNAIRE**

My name is Abigail Ama Kum Arhinful, a second year MPhil student from the Department of Geography and Resource Development embarking on a study entitled “**Understanding Mass Wasting in Metropolitan Accra**”. Mass wasting is the process whereby part of the earth is detached from its source due to natural or human factors such as rain, earthquakes, steepening of slopes for construction and many others. This study seeks to know your knowledge of the phenomenon, the occurrences of the phenomenon, your preparedness against its dangers and many others. Your cooperation is humbly requested and your privacy is assured. Your responses provided to these questions will be treated strictly as confidential and used solely for academic purposes. No direct references will be made to the respondents in the writing of the final reports.

Thank you.

Community/Area:..... Questionnaire number:.....

Location (on/near/far from hill): .....



*Please tick ✓ the alphabet to indicate your response and where necessary, write your response in the space provided.*

**SECTION A**  
**DEMOGRAPHICS**

1. Gender
  - a. Male
  - b. Female
  - c. Others.....
2. Age: .....
3. Level of education
  - a. None (No formal education)
  - b. Primary
  - c. Junior High School/  
Middle school
  - d. Senior High School/Vocational/Technical Institute
  - e. Tertiary Education
  - f. Others (Please specify).....
4. Occupation
  - a. Trade
  - b. Artisan
  - c. Professional/Technical/Managerial
  - d. Transportation
  - e. Unemployed
  - f. Others (please state).....
5. How long have you been in this community?  
.....
6. Why do you live in this neighborhood?
  - a. Closer to place of work
  - b. Family/Marriage
  - c. Cheap apartment
  - d. Availability of land
  - e. Prestige
  - f. others.....

**PART II**

**Risk knowledge and exposure**

7. Have you heard of mass wasting?
  - a. Yes
  - b. No
8. How did you hear of it?
  - a. TV
  - b. Radio
  - c. Social media
  - d. Newsletter
  - e. Short course
  - f. Experience
  - g. Word of mouth
9. What do you think are some of the causes of mass wasting? (tick as many as you can)
  - a. Sand winning
  - b. Quarrying
  - c. Steepening of slope for construction
  - d. Earthquakes
  - e. Heavy rainfall
  - f. Tree removal (deforestation)

10. What are some of the strategies you think could be adopted in controlling effects of mass wasting?

.....  
.....

11. Has the community been faced with this event before? (If No, skip to 14 & 15 )

- a. Yes      b. No

12. If yes, can you describe it?

.....  
.....  
.....

13. What are/were the effects/impacts?

.....  
.....  
.....  
.....

14. If No, are they signs of it?

.....  
.....  
.....

15. Based on the location of your residence, what is your perception of exposure to mass wasting risk

- a. Very low risk      b. Low risk      c. Moderate risk      d. High risk      e. Very high risk

16. Do you think you are safe in this community to withstand any threat?

- a. Yes      b. No

17. Why do you say so?

.....  
.....  
.....  
.....



**PART III**

**Experience**

18. From the following sentences which one best indicates your experience with mass wasting, please?
- You have experienced mass wasting in this community
  - You have not personally experienced mass wasting, but a relative or close friend has
  - You have suffered the impacts of mass wasting
  - You have never suffered from the impact of mass wasting, neither has a relative nor a close friend
  - You have only heard, read or seen information related to mass wasting on the news

**PART III**

**Preparedness in case of disaster**

19. How often have you seen or heard about the following in case of an event (Frequency of information concerning mass wasting preventive measures)	Reponses (never, very few times, sometimes, frequently)
Information on emergency routes	
Best practices for protecting belongings during an event	
Location of shelters (places/houses to run to for safety)	
The presence of a warning system in case of event	
Regions/Areas at risk that need to be evacuated	
Ways people need to organise and participate in community activities	

The importance of having a radio with batteries	
Preparation of food and water supplies	
People responsible of providing an alert in case of emergency	

20. Which of the following recommendations have you undertaken to cope with mass wasting hazards (tick as many as you can)

- a. Protecting important documents or personal belongings
- b. Knowing the location of shelters
- c. Identification of safe exit routes
- d. Ensuring a provision of water and food supplies
- e. Relocate
- f. Done nothing
- g. Others (please state).....

21. How prepared are you in case a disaster strikes?

- a. Definitely prepared
- b. Probably prepared
- c. probably not prepared
- d. Definitely not prepared

<b>22. How necessary are these actions for the safety of inhabitants of risk areas?</b>	<b>Responses (very necessary, necessary, moderately necessary, slightly necessary, unnecessary)</b>
Implementation of a warning system for communities at risk	
Promotion of programmes for community preparedness	
Provision of health programmes for people affected by disasters	

Inclusion people in programmes for communicating mass wasting risk	
Provision of information on the best practices for protecting belongings during an emergency	
Promotion of evacuation drills in areas at risk	
Relocation of people who live in areas at risk	
Mass wasting instrumentation and monitoring	
Prohibiting construction of dwellings in areas at risk	
Establishment of shelters	

**PART IV**

**Participation of the Local assembly and the government**

23. Do you receive any form of capacity building from the local government to help make the community resilient to mass wasting events?

- a. Yes    b. No

24. If yes, what are they doing?

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**APPENDIX B**

**INTERVIEW GUIDE FOR ASSEMBLY MEN AND MUNICIPAL HEADS.**

Name of official:

Position:

Name of Assembly:

1. Do you know about mass wasting?
2. Are there occurrences or prone areas in this municipality?
3. What are some of the types happening in the municipality?
4. Which areas of the municipality?
5. What causes these events (both physical and anthropological)?
6. What are the measures being put in place to prevent catastrophic mass wasting events?
7. In case an event happens, how fast can you salvage the situation?
8. Do people have permits to build on the slopes/hills? What are you doing about that?
9. How are best are you sensitizing the members of the area?
10. Are these areas safe for building since they are earthquake prone areas?
11. Any policy on Mass Wasting?
12. Are there any efforts to get this done? (Is the government or the municipality doing something about that?)
13. Do you make use of any early warning systems?  
(Early warning system is an integrated system of hazard monitoring, forecasting and prediction, disaster risk assessment and communication and preparedness activities, systems and processes that enables individuals, communities, governments, businesses and others to take timely action to reduce disaster risk in advance of hazardous events)
14. Are these scientific or locally improvised?
15. Are these working or not?
16. Do you engage community members in any form of environmental sensitization?  
(Education on best practices, building locations, livelihood strategies)