UNIVERSITY OF EDUCATION, WINNEBA

ASSESSING THE IMPACTS OF QUARRYING ON THE GEOLOGICAL STRUCTURE OF WEIJA HILLS IN GA SOUTH MUNICIPALITY

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DECLARATION

Student's Declaration

I, Esther Yamoaba Bonful, declare that this thesis, with the exception of quotations and references contained in published works that have all been identified and duly acknowledged, is entirely my original work, and it has not been submitted, either in part or whole, for another degree elsewhere.

Signature: ………………………...

Date: ………………………………

Supervisor's Declaration

I hereby declare that the preparation and presentation of this work was supervised in accordance with the guidelines for supervision of theses as laid down by the University of Education, Winneba.

Prof. Isaac Boateng (Supervisor)

Signature: ………………………...

Date: ………………………………

DEDICATION

I dedicate this research project to my beloved husband, Mr Stephen K. Ntiri, and my children Nana Kwadwo, Nyameye and Aseda. Thank you for your understanding and for standing by me during this study. May God Almighty bless you abundantly.

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LIST OF ABBREVIATIONS

ASTM	– American Society for Testing and Materials
ATI	– Acute Respiratory Tract Infection
AQB	– Air Quality Bureau
CPR	– Common – Pool Resources
CSIRO	– Commonwealth Scientific and Industrial Research Organisation
DEM	- Digital Elevation Method
EIA	– Environmental Impact Assessment
EPA	– Environment Protection Agency
ETM	– Enhanced Thematic Mapper
FAO	– Food and Agricultural Organisation
FD	– Finite Difference
FE	– Finite Element
GCP	– Global Construction perspectives
GDP	– Gross Domestic Product
GIS	– Geographic Information Systems
GNP	– Gross National Product
GSD	– Geological Survey Department
LEM	– Limit Equilibrium Method
LI	– Legislative Instrument
MEA	– Millennium Ecosystems Assessment
MLC	– Maximum Likelihood Classification
NMED	– New Mexico Environmental Department
NRD	– Natural Resources Department
OLI-TIR	– Operational Land Imager – Thermal Infrared Sensor

SESs	– Socio – Ecological Systems
SLA	– Sustainable Livelihood Approach
TM	– Thematic Mapper
UNCSD	– United Nations Commission for Sustainable Development
UNEP	– United Nations Environment Programme
UNCED	– United Nations Conference on Environment and Development
USGS	– United State Geological Survey
WCED	– World Commission on Environment and Development

ABSTRACT

Quarrying has become an important socio-economic activity in many societies as it provides a number of services for human well-being. This notwithstanding, the unique environmental characteristic of every proposed site for quarry activity should be taken into consideration. The Weija Hills at the Ga South Municipality falls within the earthquake zone of Accra, yet quarrying activities are carried out at various sections of the hills causing series of environmental problems. The study assessed the impact of quarrying on the geological structure of the Weija Hills. The study employed the mixed method approach following the exploratory sequential research design. The study found out that, the local geology of the Weija Hills is still stable. However, there are serious environmental problems such as erosion taking place and large quantities of weathered and eroded sediments are carried down slope any time it rained. This leads to flooding and blocking of the Mallam-Kasoa Highway annually. The study also found that, institutional control and involvement in dealing with the problem had not been very effective. If the condition remains unchanged, there could be an imminent landslide at the Weija Hills in the near future. Therefore, the study recommended that; first, the quarrying activity should be stopped on the Weija Hills and secondly all government institutions; the Minerals Commission, Mines Department of the Environmental Protection Agency, NADMO and the Municipal Assembly should collaborate and reclaim the land at the quarried sites as early as possible.

CHAPTER ONE

INTRODUCTION

1.0 Background

Quarrying is a form of land use where non-metallic resources such as rocks and aggregates (sand, gravel and stone) are extracted from the land and have become an important activity for many communities (Sayara, Hamdan, & Basheer-salimia, 2016). Nartey, Nanor & Klake (2012) also explains quarrying as the process of obtaining quarry resources, usually rocks, found on or below the land surface. It is usually done by an open-cast method using rock drills, the explosion of dynamite and use of other methods (Ming'atel & Mohamed, 2016). Rock is an important part of the environmental components that have important functions for human life, in supporting economic development as it provides livelihoods for thousands of people and source of revenue for local governments. Rocks as a natural resource occur in a variety of natural settings and are usually utilized by local communities for developmental activities in the field of construction which has caused an increase in quarry activities in recent times. Some of the stones extracted are sandstone, limestone, perlite, slate, granite, rock salt and coal. The rocks are crushed into various sizes and used for different purposes in human life worldwide. Nartey, Nanor & Klake (2012) group quarry into two methods; the first is dimension stone where blocks or sheet of stone such as marble are extracted in different shapes and sizes for different purposes. On the other hand, is the crushed-stone industry where granite, limestone, sandstone, or basaltic rocks are crushed for use as concrete aggregate or road stone. The method used during quarrying depends on the desired size and shape of the stone and its physical characteristics.

Rocks are found on land, in mountains or hills, oceans and sometimes rivers and have become very important materials for our society due to its plentiful uses such as the construction of buildings, bridges and other infrastructure all over the world. The demand for gravels and stones is growing around the world, particularly in the developing countries where the rapid economic development has led to increase in demand for housing and other infrastructure causing strong growth of the construction industry. For instance, in the United States alone, the global trade value of stone, sand and gravel imports for the year 2010 was estimated to be $40.3 billion with China, Singapore, Italy, Germany and the Netherlands being the highest importers, respectively (United Nations Commodity Trade, 2010). Also, the global value of construction industry is expected to reach 12 trillion United States Dollars per annum in 2020 or about 13 per cent of global GDP (Global Construction Perspectives, 2012), confirming the rate of world demand for quarry materials. According to the United States Geological survey‘s mineral commodity summaries (2019), in 2018, the estimated value of total nonfuel mineral production in the United States alone was $82.2 billion. Of this total, $25.3 billion was construction aggregates production (construction sand and gravel and crushed stone) especially those used in infrastructure, oil and gas drilling operations, and residential construction.

In Palestine, quarry resources have contributed immensely to the economy. Stone and marble industries are a successful business, Sayara, Hamdan, & Basheer-salimia (2016) reported that, more than three hundred (300) quarries and thousand (1000) factories and workshops exit in Palestine which contribute about 4.5% and 5.5% of GNP and GDP respectively, Sayara et al (2016). Africa has significant mining and quarries in the Republic of South Africa, Nigeria, Kenya and Ghana just to mention few. As a readily available construction material, gravels and stones are the foremost construction raw material that prevails in most African societies because of the availability of rock resources within and around some communities and it provides employment for thousands of people all over Africa. Therefore, quarrying has significantly contributed to the incomes of the stone workers, quarry owners and the communities in which these activities are carried out.

Notwithstanding the remarkable economic importance of quarrying worldwide, within the last decade, environmental concerns have gained prominence throughout the world because this human activity causes a significant impact on the receiving environment in several ways. Concerns about the impact of quarrying are hardly new. According to the British Geological Survey (NERC 2017), complaints about quarrying activities were voiced as far back as the 1890s and several international conventions have been established by the global community to deal with the emerging environmental issues. Yet, in many countries today, extraction is carried out without proper planning, unscientifically and unsustainably due to inadequate modern technology leading to negative impacts on both the environment and humans (Nartey et al 2012). The extraction process normally depends on heavy machines such as bulldozers and explosives to extract material for processing resulting in noise pollution, air pollution, and damage to biodiversity and habitat destruction which affect the human environment of a particular area (Okafor, 2006).

Landscape structure and composition of every place changes continuously over time and space as a result of both natural and man-made activities. Such changes may affect the stability of individual elements in the landscape and spatial structure of the landscape (Xiao, Zhao, Sun, Zhang (1990). According to Banez, Ajaon, Bilolo and Dailyn (2010), forces shape the earth‘s surface, and there is a great force of human invented industries that can alter gradually the different landforms. Thus, all over the world, almost all landforms and landscapes have been altered or undergone remarkable changes and the cause whether natural or human, differ from one place to another (Otoo, 2017; Farina, 2006). Quarrying is one human activity which extracts rocks from where they exit naturally and by so doing causes changes in the landscape.

Furthermore, the operations in stone quarrying, whether small or large-scale, are inherently disruptive to the environment, producing enormous quantities of waste that can have damaging impacts for decades and that the environmental deterioration caused by quarrying occurs mainly as a result of inappropriate and wasteful working practices and rehabilitation measures. Quarrying on farms and fallow agricultural land is becoming common and this is having noticeable impacts on the soil structure, vegetation and local wildlife in the rural areas. The magnitude of the situation beyond the affected communities and the region at large is enormous and poses a threat not only to the environment but also to food security (Salifu, 2016); since some farmlands have now been leased to mine contractors. Consequently, it has been argued that because of this globalizing extent and the magnitude of its impacts, sand and gravel harvesting should be considered as an aspect of global environmental change (Sonak, Pangam, Sonak and Mayekar (2006) that need immediate attention and corrective measures (Muendo, 2015).

Even though quarrying has such negative effects on the environment, the activity keeps expanding due to increase in demand for sand, gravels and stones for construction and another purpose as communities grow because the construction at present requires less wood and more concrete, which sprout a demand for low-cost construction materials. The worst part of the situation is the fact that quarrying activities are widespread, highly unregulated, uncontrolled and is being carried out at an alarming rate. Quarrying is regulated by law in many places but is still often done illegally (Aromolaran, 2012).

The population of Ghana is growing very fast. According to the Ghana Statistical Services, Ghana's population as of 2010 stood at 25 million but it is now around 29 million based on the United Nations estimates as of April 2018. Population growth coupled with rapid urbanisation has led to increased demand for sand in Ghana as a result of increasing building construction projects and other infrastructural developments in many towns and cities of Ghana as it is the case globally and more especially in the capital city, Accra. Stones, gravels and sand are non- substitutable raw materials in industrial construction worldwide which is used in everyday infrastructural development (Osei, 2016). There is a relationship between urbanisation and environmental degradation and changes in landform (Reynard, Pica & Coratza 2017). Quarry workers clear the vegetation prior to extraction to make access roads into the quarrying areas. Pits also require large open lands to be cleared to allow miners to extract quality aggregates. Continuous removal of vegetation exposes the land and increases soil erosion (formation of gullies), trigger micro-climate variation and also expose buried rocks to the atmosphere to weather (Mngeni, Cecilia, Mpundu, & Vincent, 2016).

In other instances, urbanisation has led to the modification of some relief features. Artificial landforms are thus created, hills are flattened while in some cases, a hill is formed of various waste materials. Man has been able to transformed hill and plateau tops for settlement. There are often infillings designed to eliminate slopes and to facilitate mobility. Quarrying can possibly cause different calamities such as landslides and floods, land degradation, loss of biodiversity, destruction of the landscape and weakening the stability of rocks in the area due to the excavation.

What makes quarrying activities more disturbing is that the extraction of such natural resources in most cities in Ghana and for that matter Accra has over the years been a complex issue because there is inequality when it comes to implementation of the laws governing such activities. This situation had pitched owners of these resources against the exploiters of the resources and the government. The government agencies saddled with the responsibility of implementing development control have shown ineffectiveness and this has resulted in intensive uncontrolled stone quarrying in Accra. Metropolitan, Municipals and district assemblies are supposed to influence the use of livelihood assets, livelihood activities and their outcomes. They do this by enacting by-laws and creating livelihood strategies for people in need. The strategies used by these local authorities usually produce positive or negative livelihood outcomes but when it comes to stone and gravel quarry, most of these institutions appear to have no interest in the operations in our cities as most quarry companies do not adhere to the set environmental legislation.

1.1 Statement of the Problem

Although many studies have examined effects of quarrying on the environment, agriculture and health of people who live close to quarry sites, little emphasis has been given to how quarrying and removal of the quarrying dust affect the geological structure (landscape and rock stability) of an area. The Ga South Municipal area exist within the Accra region, which is experiencing rapid urbanisation but not considering seismic hazard in land use planning. The uncontrolled use of land for building and other anthropogenic activities has made it possible to develop sites that are vulnerable to earthquake hazard (Ahulu, Danuor & Aseidu, 2017). Work done by Bacon and Quaah (1981) indicates that most of the earthquakes in Ghana occur in the western part of Accra at the junction of the two major fault systems namely, the Coastal boundary fault and Akwapim fault zone where the study is situated. The area within the acute intersection has high seismicity. The Weija hills lies between the Dahomeyide Orogen thrust and the Akwapimian (or Togo Formation) block. The narrow middle or internal meta-sedimentary unit referred to as the Akwapimian (or Togo Formation) block and the rocks of the granulite Dahomeyide terrane block to the east within the Coastal belt of Ghana are all separated by clear lithotectonic fault boundaries which possess a challenge to social, economic and natural environment of the area under study. Three major seismic activities occurred in 1862, 1906 and 1939. The effects of these earthquakes were highly felt in the Accra (Amponsah, 2004). According to Bacon and Quaah (1981), most of the epicentres are located south of Weija suggesting that there is little activity north-eastward along the Akwapim range and westward along the Coastal boundary fault. This they allege to be due to the existence of an old thrust zone, which has been reactivated. Communities within this zone include McCarthy Hill, Gbawe, Weija, Bortianor and Nyanyano according to the Ghana Geological Survey Authority. The geological structure of the Weija Hills is characterised by the Upper Precambrian age type of rocks which consist of quartz-schist unit mainly of serictic quartz schist and quartzite units. The land area is underlain by shallow rocky soils and is extensively developed on the steep slopes as well as basic gneiss inselbergs. On the Akwapim range, the soils are mainly pale and sandy with brushy quartzite occurring to the surface in most places.

These soils are rich in sandstone and limestone that are a good source of material for the construction industry. This account for the reasons why heavy quarrying is going on in the area since such rocks are not very compact like igneous rocks and are easily broken down into quarry dust. The activities of quarrying and failure to reclaim most quarry sites in most parts of the study areas have created serious erosional effects associated with gullies and unconformity in the areas. Also variation of rock types, depths and weathering of rocks due to the aftermath of quarrying activities determine the level of seismic risk within the Greater Accra Region where the area lies (Amponsah et. al, 2009). Experts have warned that Weija hills in Accra on the Accra-Kasoa road is a disaster looming. Again, in March 2018, a senior seismologist with the Geological Survey Authority (GSA), Mr Nicholas Opoku, told the Daily Graphic that forces were acting on the earth in parts of the fault lines, especially in the Weija area, resulting in putting more stress on the rocks (Daily Graphic, 28/03/2018) leading to minor shocks. Fairly industrialised and densely populated, the Weija Hills area is a high risk to the impacts related to seismic activity and natural disasters (Amponsah et al., 2009). In recent times, the area has been experiencing mudslides especially during the rainy seasons which blocks one side of the Mallam-Kasoa highway causing huge traffic. This event can be attributed to the quarrying activities taking place on the hill. Also, there is expansion in built-up as a result of quarrying activities. Most of these buildings are not earthquake resistant and some of them may be located along fault lines. This could increase the rate of fatalities should a potential heavy hazard occur in the area.

Researchers have studied about other areas relating to seismic activities within the Weija area. These include studies by Ahulu, Danuor and Asiedu (2017) on the probabilistic seismic hazard assessment of Southern part of Ghana and that of Gyekye (2011) who studied geomorphic assessment of floods within the urban environment of Gbawe-Mallam. Little or less knowledge is known about the extent to which quarrying activities and its resultant building developments are increasing the stressed of the Weija hills, and what happens to the slope as part of it is being exploited every day. The risk in this area is very high considering the geological and tectonic settings as well as the fault system which is associated with earthquakes while there is also massive infrastructural development and high population concentration without proper planning due to urbanisation. It is therefore not out of place to research in this area to find out the extent to which quarrying activities on Weija Hills in Ga South Municipality is compounding the rick factors to have impact on the geological structure of the hills.

1.2 Research aim and objectives

This study aims to assess the impacts of quarrying activities on the geological structure of Weija Hills in Ga South Municipal and how these changes impact on the local environment. To achieve the above aim, the following objectives will be perused:

- To examine the impact of quarrying activities on the geological structure of the Weija Hills in Ga South Municipality.
- To assess the changes that have occurred in the local environment which can be attributed to quarrying activities.
- To evaluate the effects of quarrying activities on the slope stability of the local geology.

1.3 Research Questions

The research would be based on the following questions:

- In what ways has quarrying activities impacted the geological structure of Weija hills in Ga South?
- What changes have occurred in the local environment which can be attributed to quarrying activities?

- What are the effects of quarrying activities on slope stability of the local geology of Weija hills?

1.4 Purpose of the Study

People‘s lives are closely tied to the physical environment within which they live. The purpose of the study is to create awareness on the negative impacts quarrying activities have on the landscape and the geological structure of the Weija Hills in Ga South Municipality.

1.5 Significance of the Study

It is hoped that the results of this study will add to knowledge and form the basis for further research in the area of study. Again, the recommendations made based on the findings will serve as guidance for decision-makers who are specifically involved in the review of quarry operations to make a more informed decision in formulating and implementing sustainable development policies in terms of regulating quarrying activities.

1.6 Structure of the study

To assess the impacts of quarrying activities on the Weija Hills in Ga South, Chapter one provides a background of this study. Chapter two of this study reviews literature on concepts and definitions, processes and methods used in quarrying, institutions and laws available to control quarrying activities. Chapter three presents the strategies, methods and techniques that will be used in the collection and analysis of data on the field of study. Chapter four presents the presentation of findings while chapter five looks at the analysis and discussion of the findings and results, conclusions and recommendations.

1.7 Summary

This chapter gives an introduction to the study. The chapter touched on the background to the study from a global perspective, Africa and in Ghana and describe the problem that, in recent times, the Weija hills in the Ga South Municipality has been experiencing mudslides especially during the rainy seasons which poses serious threats to the geology of the study area. Against this background, the general objective of the study is to assess how quarrying alters the geological structure of the Weija hills. The general objective is further subdivided into specific objectives which helped in the formulation of the research questions that guided the study.

CHAPTER TWO

REVIEW OF RELATED LITERATURE AND THEORETICAL FRAMEWORK

2.0 Introduction

This chapter reviews other Scholars‘ works which are relevant to this study and the theoretical framework for this research.

2.1 Review of Related Literature

Quarrying for gravels and sand has become one important economic activity which provides industrial raw materials and livelihood for many people but it is also poses danger to the environment. This has become a global concern and many scholars have written about it. In this chapter, the researcher looks at what some of these scholars have said about quarrying in general under the following headings:

- The meaning of quarrying.
- Types and methods of quarrying
- Drivers of quarrying activities
- Impacts of quarrying on the geological structure and the local environment
- Institutional framework and laws that regulate quarrying in Ghana
- Measures put in place by some countries to control quarrying

2.2 The Meaning of Quarrying

According to the UK Institute of Quarrying (2019), the term 'quarrying' is derived from the Latin word; 'quadraria' which described a place where natural stone is extracted to produce building stone and further explains quarrying as the process of removing rock, sand, gravel or other minerals from the ground to use them to produce materials for construction or other uses. Eshiwani (2007) defines quarrying as a type of open-pit mine from which rock material and sand are extracted. Quarrying is the process of extracting, removing and disposing of quarry resources found on or underneath the surface of private or public land. It serves as a source of livelihood to the sand and gravel industry (Nduka, 2003). Thus, a quarry is a place where rocks, sand, or minerals are extracted from the surface of the Earth. Quarries are also known by other names around the world: 'surface mine', ‗pit', 'and open pit ‗or ‗opencast mine'. In literature and some parts of the world, mining is used interchangeably with quarrying (UK Institute of Quarrying, 2019).

For this study, quarrying refers to an activity in an area that is dug out from a piece of land or the side of a mountain in order to obtain sand, stone or gravels by digging, drilling, or using explosives for constructional materials. It is associated with the word excavation. Quarries principally produce sand and gravel and crushed rock for construction and these materials are usually described as aggregates. In developed countries where very large quarries are common, quarries may have their processing plants such as ready-mixed-concrete plants. In many developing countries including Ghana, there are both large and small scale quarries.

2.3 Forms and Methods of Quarrying

There are two principal branches of the quarrying industry namely Dimension-stone and Crushed-stone (Sayara et al 2016). Unweathered carbonate rocks provide crushed stone and dimension stone resources. The term ―crushed stone" refers to the product resulting from the crushing of rocks such that substantially all faces are created by the crushing operation (ASTM, 2000). Sand, gravel or crushed rock excavated from a quarry is called aggregate. Aggregate is used in construction to create stable foundations for things like roads and railroad tracks. They are also used to make concrete and asphalt. The term ―dimension stone" on the other hand is generally applied to masses of stone, either naturally occurring or prepared for use in the form of blocks of specified shapes and sizes that may or may not have one or more mechanically dressed surface (Bowles, 1939: ASTM, 1998). That is, dimension stones are large, precisely cut stones excavated from a quarry. Dimension stones are used for constructing buildings and monuments, or for decorating the outside of buildings. Clover & Bannett (1994) group the stone industry based on the uses for which the stone is intended: (1) dimension stone; for building purposes, paving blocks, curb stones, switchboards, blackboards, and monumental use; (2) crushed stone; for concrete aggregate, road metal, ballast, and riprap; (3) manufacturing stone; for Portland cement, lime, refractories, and various chemical and metallurgical uses. Granitic rocks, limestone, marbles, slates, sandstones, and other types are used. Selection of a quarry site will depend on the need for a particular kind of stone and on the use for which it is intended.

In the US, Line drilling and sawing are more modern techniques for quarrying dimension-stone. Line drilling (also called slot drilling) consists of drilling a series of overlapping holes using a drill that is mounted on a quarry bar or frame that aligns the holes and holds the drill in position. Sometimes, a variety of explosive techniques are also used to quarry dimension stone, but explosives generally are used in very small amounts, if at all, to avoid fracturing the stone block (US Geological Survey, 2001).

On the other hand, crushed stones are relatively small pieces of rock that are suitable for crushing into gravel-sized particles. According to the US Geological Survey Department, to produce crushed stone, the rock is first drilled and blasted. Blasting commonly breaks the rock into pieces suitable for crushing. When the blasted material is dry, it can be extracted by using conventional earth-moving equipment, such as bulldozers, front loaders, track hoes, and scraper graders (US Geological

Survey, 2001). On the other hand, Eshiwani (2007) whose study was on the effects of quarrying activities on the environment in Nairobi County indicated that the most common and simple method of quarrying is the use of hand tools such as a pickaxe, shovel, hammer and wheelbarrow. It is commonly used in easily accessible beds such as loose rocks in river beds, and soft rocks such as limestone in mountains that can be easily broken down. This method is popular in small scale quarries. However, she confirms that sometimes it becomes necessary to blast rocks with explosives in order to extract material for processing (Eshiwani, 2007).

In Ghana, two main forms of the quarry are done, namely, the open pit and the deep pit. Methods used in quarrying mainly depending on the location of rocks to be quarried and the size of quarry. Method used include excavation, wedging, drilling and blasting. Digging or Excavating is when stones buried in the earth or under loose overburden are excavated with pickaxes, crowbars, chisels, hammers. Wedging: This method is mainly used for sedimentary rocks, which are comparatively soft, such as sandstone, limestone, marble, slate, and laterite. In this method, first of all naturally occurring cracks or fissures are located in the rocks, to be excavated. The steel wedges or points are then driven with the help of a hammer into the fissures or cracks till stones are detached. The split out blocks of stone can be converted into marketable forms and supplied to users. Blasting: In this method, the explosives are used to convert rocks into small pieces of stones. This method is used when stone to be excavated is of very hard variety and it has no cracks or fissures. Moreover, if the stone is to be excavated on a very large scale, blasting method will have to be adopted. No definite size blocks can be excavated by this method. After blasting, the excavated stone is sorted out in different sizes and categories. Explosives such as blasting powder, blasting cotton, dynamite and cordite are used. Drilling: Drilling involves the creation of deep holes in the overburden rock deposits. With the use of a driller and chisels, deep and larger openings or holes are created to pave way for the blasting and subsequent exploitation of the rock products. The process of extracting the stone demands both horizontal and vertical drilling holes concurrently.

2.4 Drivers of Quarrying

Drivers here refer to the reasons behind quarrying activities irrespective of the location and negative impacts it can bring. The materials produced by quarrying are essential to our everyday lives. Quarry materials play a very significant role in every economy due to its numerous uses providing the construction materials to build roads and buildings delivering vital minerals to agriculture. For instance, crushed carbonate rock has numerous agriculture and industrial uses. Agricultural uses include fertilizers and insecticides. Industrial uses include the manufacture of cement, pharmaceuticals, processed food, glass, plastics, floor coverings, paper, rubber, leather, synthetic fabrics, glue, ink, crayons, shoe polish, cosmetics, chewing gum, toothpaste, and antacids. In 1999 alone according to Tepordei (1999), over one billion tons of crushed limestone, dolomite, and marble valued at over $5.5 billion were produced from about 2,200 quarries operating in 48 states including Texas, Florida, Illinois, Ohio, Missouri, Pennsylvania, Tennessee, Kentucky, Indiana, and Alabama. Dolley (1999) added that, in recent times, stone is considered by many to be the premier building material and is experiencing a resurgence in use for commercial and residential construction. For example, dimension stone has a large number of uses ranging from rustic walls and roughly-shaped paving stones to highly polished floor tile, countertops, and building facades (Dolley, 1999).

Quarrying is a very important activity in the building industry because it produces the materials that are needed for the construction of buildings and roads. The quarrying industries provide both direct and indirect employment to a large number of people. Direct employment includes contractors, stone crackers, drivers, loaders and other related industries such as block building and construction of drainage materials (Eshiwani, 2007). Others may include transport and catering services and many more. In some communities, it is the only source of income for many youths, both males and females as was the case of the Ga South Municipality. According to Bewiadzi et al (2017), in Daglama of the Volta Region, many unemployed junior and senior high school graduates who have not been able to continue with their education engage in stone quarrying to sustain their livelihood. Also, Quarrying provides regular source of income since there is ready market for quarried products as compared to agriculture. Data gathered from the field indicated that weekly, workers in the quarry industry could earn between GH¢ 300.00 and GH¢ 600.00 (Bewiadzi et al, 2018). Thus, the stone business could be very rewarding. The families of those that are employed directly or indirectly by the quarrying operations are also dependent on the employees‘ salaries and wages for their livelihood. This is a tangible economic benefit. The number of dependents can simply be calculated by multiplying the total number of employees by the average family size.

2.5 Impact of Quarrying on the Geological Structure and the Environment

The idea of impact here refers to changes in the initial geological and environmental parameters due to quarrying activity. The parameters, which govern the "quality of the environment", may involve several components: chemical composition or level and colour of water, soils, the biological diversity; geology (size and shape) and aesthetic qualities, just to mention few (UK Institute of Quarrying, 2019). Surface landforms are influenced by various forces, such as natural processes and human activities, over long-term periods. Some of the natural driving forces include erosion, weathering, volcanoes and earthquakes. Many human activities degrade the ecosystem, including deforestation, agricultural practices, urbanization, tourism, military activities, water exploitation and mining including quarrying (Drew, 1999). Some of the geological and environmental disturbance created by quarrying is caused directly by engineering activities during aggregate extraction and processing (US Geological Survey, 2001; Grosic, Gazibara, Arbanas, & Arbanas 2013). The most obvious engineering impact of quarrying is a change in the geomorphology and conversion of land use. For instance, agricultural land could be turned into built-up and such land may not be productive again with the associated change as well as its visual scene after quarrying activities. This major impact may be accompanied by loss of habitat, noise, dust, vibrations, chemical spills, erosion, and sedimentation, changes in the landscape and desertion of the mined site without any reclamation. Some of the impacts are short-lived and mostly easy to predict and easy to observe. Most of these impacts can be controlled, mitigated, kept at tolerable levels, and restricted to the immediate vicinity of the aggregate if responsible operational practices, techniques and technologies are employed (US Geological Survey, 2001) while others become long term impacts and very expensive to be managed or corrected. Some of the impacts are discussed below;

2.5.1 Impacts on the geological structure

Geological structure in this study refers to the topography and the underlying rock profile of a landform and all other visible features of an area of land in terms of its aesthetic appeal, size or shape. Quarrying is one human activity that can cause changes to all the attributes of a landform. In most cases, the quarried rock is subjected to external forces which tend to change its position or its shape, create cracks or fractures in them. According to the US Geological Survey report (2001), the extent of the geomorphic impact of quarrying on the geology largely depends on the size of the quarry, the number of quarries, the location of the quarry and more importantly, the methods used, especially concerning the overall landscape and the local landforms. Considering the location, for instance, the U S Geological Survey (2001) describes limestone, dolomite, and marble (the carbonate rocks) as the principal quarry rocks. Karst areas constitute about 10 per cent of the land surface of the world, Drew (1999), and this raises a widespread concern for the effects that human activities such as quarrying have upon the karst environment.

Quarrying rocks for use as crushed and dimension stones can be accomplished with no significant impacts to the environment if done carefully and within the limits set by nature. However, if proper precautions are not taken, many human activities including extraction rocks can result in irreversible damages to the environment (U S Geological Survey, 2001). The issue therefore associated with quarrying has to do with the extent, rate of quarrying rocks and technology being used. Considering the location, quarries can be located: first, on flat ground, the second is along or into the side of a valley, and the third is usually on the side of a hill. In most situations, quarries excavated into the flat ground have a relatively small impact on geomorphology. Quarries on valley sides can extend laterally along the valley side causing large geomorphic impacts, or they can work back into the valley wall, where the impact is less but quarries on hills generally have a large geomorphic impact (Gunn & Bailey, 1993).

The geology of Ga South Municipality is made up of quartzite, quartz-schist with subordinate phyllite that are quarried for constructional materials. Considering this location, the study area forms part of Accra classified as a geohazard zone of Ghana due to an existing fault line as shown by *figure 1 below.*

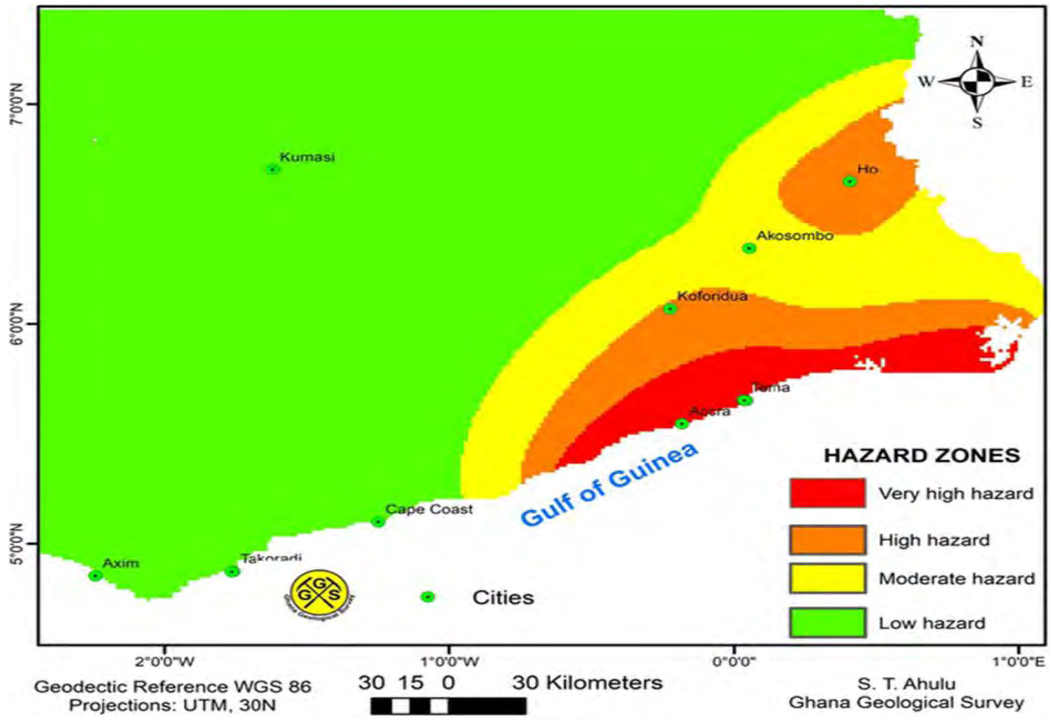

Figure 1: The Seismic hazard zones for southern Ghana

Source: Ahulu et al, (2017)

The geology possibly present zones of weakness in the rocks, which are due to steeply dipping faults (Opoku Nicholas, 2016). Therefore, in such case, an acceptable standard should be adopted according to the particular conditions of the area. The most important parameter to be considered should be the natural environmental conditions before an activity such as quarrying is done. These conditions could include geology, seismicity and another damaging geological phenomenon (groundwater, landslides and loosened bedrock) and topography (Hodgson, 2011). This has been emphasized by Abramson, Lee, Sharma & Boyce (2002) that, natural slopes that have been stable for many years can suddenly fail because of changes in topography, seismicity, groundwater flows, loss of strength, stress changes and weathering. Much of the concerns of this work is inspired by the adverse geological impacts of previous human activities that have occurred in other places. Recently in October 2019, there were two mudslides on the Aburi road near Peduase Lodge, Ghana which environmental experts attributed to slope instability caused by human factors such as built-up which has put much stress on the mountain. Hence, quarrying for sand and gravels on the Weija Hills become worrisome for fear of future implications.

Quarrying has an associated visual impact. A study conducted by Ako et al in Luku, Nigeria revealed that landscape destruction is one of the significant effects of mining in the area. The original landscape has been destroyed and altered as a result of excavated pits and trenches, leaving behind unpleasant sights which as well render the land unsuitable for any productive purpose (Ako et al, 2014). Aigbedion, (2005) in his work on Environmental pollution in the Niger delta, confirmed with Ako et al that one common negative effect of quarrying minerals from the earth‘s surface is the destruction of its natural landscape, creating open space in the ground and generating heaps of rock wastes that cannot be easily disposed of. Aigbedion added that these phenomena are amply demonstrated in several parts of Nigeria, where commercial mining and quarrying had occurred in the past or is currently taking place.

Quarrying is also associated with the development of cracks in rock mass as a result of blasting and drilling through the rocks. The cracks are enlarged through erosion. This further promotes both mechanical and chemical weathering of the exposed rocks. Viles (2012) states that weathering is linked complexly to the erosion and evolution of rock slopes and influences both the strength of rock slopes and the stresses that act upon them. This is supported Balasubramanian (2014) that, weathering destabilizes the surface materials and encourage the removal of part of the landforms by erosion. Abramson et al., (2002) add that severe weathering could induce landslides but emphasized that the rate of weathering depends on the climatic factors, drainage characteristics and the nature of residual soils, the Quarrying activities may also render slopes of the quarried area unstable leading to landslides, rockfall, soil creep and more.

2.5.2 Slope Stability

The stability of a slope or landform refers to the ability of the slope to resist failure caused by the force of gravity and shear stress of the slope. Kliche (1999) define slope stability as the resistance of the inclined surface to failure by sliding or collapsing. This depends on the shear strength of the slope or landform. Shear strength consists of the forces holding the material on the slope and could include friction, and the cohesion forces that hold the rock or soil together. Some of the things that increase the strength or resistance to failure include the type of rock, vegetation cover, soils and more (Nelson, 2013). For instance, vegetation makes slopes stable through mechanical cohesion and removal of water through evapotranspiration. Plant roots provide a strong interlocking network to hold unconsolidated materials together and prevent flow (Noroozi & Hajiannia, 2015). On the other hand, a section of a slope generally fails when the driving forces in the slope overcome its ability to resist these forces. Typical driving forces include the weight of soil and rock materials, groundwater pressures, earthquake forces and the weight of buildings. Therefore, slope failures are caused by the processes that increase the shear stress or decrease the shear strength of the soil or rock mass (Abramson et al., 2002). Some of these processes include removal of support through erosion and human activities such as excavations, overloading through natural causes such as weight of soil, amount of running water, human activities including construction of buildings and other overloads at the crest; transitory effects such as earthquakes and the removal of underlying materials that provide support through weathering and underground erosion (Abramson et al., 2002).

A quantity known as Factor of Safety (FoS) is used to evaluate how stable or unstable a slope is. FoS is simply the ratio of resisting forces (sheer strength) to driving forces (sheer stress). A slope is stable when the FoS is equal to 1.0 (Priest & Brown, 1983) as shown in *tables 1 and 2*. When resisting forces exceed driving forces, the ratio is higher than 1. An FoS of 1 means that a slope or structure will fail exactly when it reaches the maximum resistive force, and cannot support any additional stress. Slope or structures with FoS < 1 are not viable; basically, 1 is the minimum. The higher the ratio, the higher the stability of a slope. Instability occurs when FoS becomes less than1. This happens when resistive forces decrease, and driving forces increase or both occur simultaneously (Mazzoccola & Hudson, 1996; Nelson 2013).

One consequence of quarrying which is common in literature is slope failure. Girard and McHugh (2000) stated that slope stability accidents are very common when it comes to mining includes quarrying. This is because, for example, in an open-pit method of quarrying, an excavation is made into the earth for the extraction of valuable rocks. This excavation is cut in slopes and quarrying also involves taking part in rock masses creating lines of weakness in rocks (Agyei, Osei, & Adoko 2018; Grosic et al., 2013). Additionally, Mngeni (2016) found that, in the Mngazi quarrying site in South Africa, landslide occur due to excavation. Quarrying involves the removal of vegetation and soil to access rocks to be quarried. According to Noroozi and Hajiannia (2015), the removal of vegetation allows infiltration of water and decreases cohesion in soils and increases weight and pore water pressure in granular media. Also, as soil and rock get buried deeper in the earth, the grains can rearrange themselves to form a more compact structure, but the pore water is constrained to occupy the same space. This can increase the fluid pressure to a point where the water ends up supporting the weight of the overlying rock mass. When this occurs, friction is reduced, and thus the shear strength holding the material on the slope is also reduced, resulting in slope failure (Nelson, 2013).

According to Grosic et al (2013), the stability of slopes is controlled by geological elements such as faults, discontinuities, alteration of different geological units. Among these major factors, some of minor scale geological elements, such as joint and fissure orientations, may influence slope stability, commonly on a local scale. For instance, Grosic et al had done a study on a landslide that occurred at the Torine open pit quarry which is situated about 9 km southwest of the Našice city in the Slavonia region in the eastern part of the Republic of Croatia on November 2012 (Grosic et al., 2013). The study indicated that the area was characterised by faults and the failure had resulted from cracks and massive weathering. Again, Moloi and Zvarivadza (2016) while investigating slope failures and Rockall control at a South African Coal Mine that occurred in 2015, find out that, slope failure at Nchanga open pit located in Chingola, Zambia resulted in the loss of 10 people‘s lives in 2001. In Algeria, there had been a great landslide on the 8th of September, 2008 in a quarry at the North East (Fredj et al., 2017). The study added that there were cracking about 250m upstream of the platform that was observed during the field survey in February 2013, suggesting the beginning of a new potential slip caused by vibrations generated by the rock blasting, fire and explosives.

2.5.2.1 Slope stability Analysis

Slope stability analysis involves identifying the failure mechanism and the factor of safety for the mechanism. This knowledge helps specialists to identify critical failures that should be eliminated or mitigated. It can be used to proactively improve designs or situations at costs far less than would be needed should a failure occur. There is, therefore, no universal factor of safety value that can be described as adequate or appropriate for all slope situations. For a type of structure or slope situation being analysed, engineers select an appropriate factor of safety threshold after careful consideration of the following:

- The reliability of input data such as material properties and loadings.
- The accuracy of the approach used to calculate the factor of safety, and
- The consequences or impact of failure.

Acceptance criteria allow stakeholders (including regulators, engineers, land owners and the general public) to define the acceptable level of slope performance, which is captured in a factor of safety or probability of failure. In this study, only the factor of safety is considered in evaluating the slope stability of quarried sites at Weija Hills due to the scarcity of data. Typical values of acceptable factors of safety as discussed in the paragraphs above are described in Tables 1 and 2.

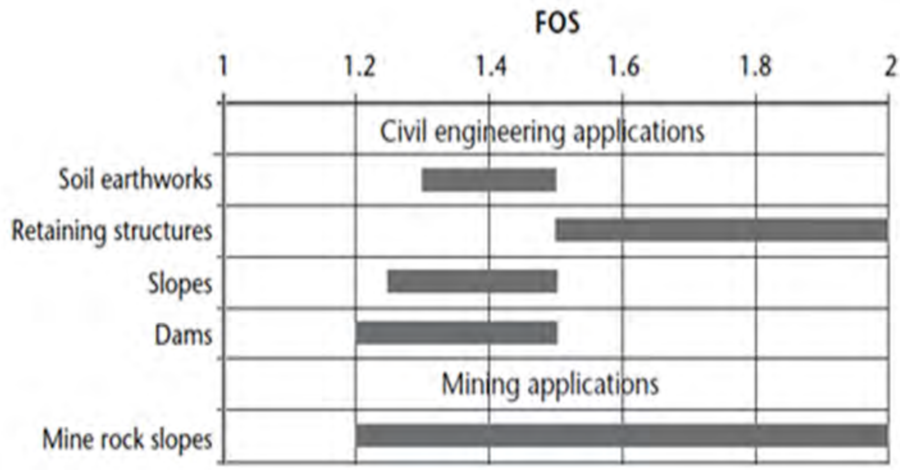

Table 1: Acceptable factor of safety ranges for a variety of slopes encountered in engineering practice. (Guidelines for Open Pit Design)

Source: Priest &Brown (1983)

		Acceptable Values		
Consequence of failure	Examples	Mean FoS	Minimum P(FoS<1.0)	Maximum P(FoS<1.5)
Not Serious	Individual benches; small (<50m) temporary slopes, not adjacent to haulage roads	1.3	10%	20%
Moderately serious	Any slope of a permanent or semi-permanent nature	1.6	1%	10%
Very Serious	Medium-sized (50-100m) and high slopes (<150m) carrying major haulage roads or underlying permanent mine installations	20	0.30%	5%

Table 2: Acceptable factors of safety for a variety of based on the consequence of failure. (Guidelines for Open Pit Design)

Source: Adapted from Priest & Brown (1983)

There are various methods for calculating the factors of safety of slopes. These include empirical methods and charts, analytical equations, limit equilibrium methods (also known as methods of slices), and numerical methods (Alejano, Bastante, Alonso & Gómez-Márquez, 2001; Cevikbilen, 2018). Empirical and analytical methods can be easily done manually (by hand), while limit equilibrium and numerical methods require the use of computers. Limit equilibrium methods (LEM) are the most commonly used approaches because they are relatively simple, compute fast and can accommodate a broad range of slope geometries and types. Numerical approaches are the most sophisticated of all the methods for slope stability analysis. They, however, require the most useful skill and computing resources.

Limit equilibrium analysis makes several simplifying assumptions to make the calculation of factor of safety possible for slopes. These include the following:

- Assumptions on the shapes and locations of failure surfaces.
- Assumption that sliding mass move as rigid blocks, with movement occurring only along the failure surface.
- Assumption that when a slope fails it does so along its entire length at the same time, and
- Various assumptions on the forces acting between the slices into which a sloping mass is divided, to make the solution of the equilibrium equations possible.

There are several different methods of slices, based on the assumptions used in the methods' formulations. Chakraborty & Goswami (2016) mentioned some of these methods: Fellenius method, Simplified Janbu method, Bishop's method, Generalized Janbu method, Morgenstern - Price's and Spencer method of slices.

Some of the properties that serve as input data for slope stability analysis include; geology conditions of the area, site topography, geotechnical properties such as soil, groundwater and seismicity (Alejano et al., 2001; Abramson et al., 2002). In using the limit equilibrium (LEM) for stability analysis and design for a limestone quarry in NW- Spain, Alejano et al., found out that, LEMs have shown to be accurate enough to adequately obtain safety factors and correctly design the slope. According to Karray (2018), approaches commonly used to assess the seismic stability of slopes range from the relatively simple pseudo-static method to more complicated nonlinear numerical methods, examples include finite element (FE) and finite difference (FD). The pseudo-static method, in particular, is widely used in practice as it is inexpensive and substantially less time consuming compared to the much more rigorous numerical methods.

2.5.3 Impact on Pollution on the Environment

Unfortunately, quarrying involves several activities that generate significant amounts of noise. The excavation of the mineral itself involves considerable noise, particularly if blasting methods are used. According to the US National Academy of Sciences, one of the most frequent complaints the public makes to the crushed stone industry situated near population centres is about blasting noise (National Academy of Sciences, 1980). When a blast is ignited, some energy will escape into the atmosphere causing a disturbance in the air. Following this, the use of powered machinery to transport the materials as well as possibly processing plants to crush and grade the minerals, all contribute even more noise to the environment. Such extraction of raw materials from their natural habitats by mining, drilling and harvesting affect the natural environment considerably. For example, in the work of Okafor (2006) on Rural Development and the Environmental Degradation versus Protection, one of the findings was that quarrying activities in Nigeria have caused a significant impact on the environment, the blasting rocks with explosives, in order to extract material for processing, gives rise to noise pollution, air pollution, damage to biodiversity and habitat destruction which affect the human environment of a particular area (Okafor, 2006). This is confirmed by UNESCO that, in Nigeria, the greatest pollution effect comes from large scale exploitation of petroleum, limestone and rocks used in the construction works (UNESCO-MAB, 1995).

Dust is also one of the most visible, invasive, and potentially irritating impacts associated with quarrying (Howard and Cameron, 1998). Dust may occur from excavation, from haul roads, and blasting, or can be from drilling, crushing and screening (Langer, 2001). Also, Eshiwani (2007) asserted that dust particulates from quarries that result from the disintegration of rocks can cause air pollution when it remains in the atmosphere for long. The particulates may cause interference with human respiratory functions, it is susceptible to persons with respiratory disease, young and elderly and to vegetation, and it may lead to a reduction in plant growth by physical blockage of light when deposited on the leaf surfaces.

Air pollution is also one of the environmental impacts observed by Ako et al in Luku, Nigeria where sediments from mines running off into river and wetlands are a significant source of water pollution (Ako et al 2014). In New Mexico, Blodgett (2004) carried out the Environmental Impacts of Aggregate and Stone Mining. The results of his study showed that the primary environmental impacts from aggregate and stone mining in New Mexico are degraded air quality with its associated health effects, resulting from airborne emissions from both the stack and the disturbed areas at these mines and groundwater usage. Surface and groundwater quality impacts from such mines were relatively non-threatening in New Mexico due to the semi-arid climate and lack of perennial streams because the economics of construction materials depends heavily on the proximity of the mine to the point of use, the highest concentrations of aggregate and stone mines were found in urban areas where most home and office construction and general highway construction occurs.

Overall, quarrying can result in relatively local impacts such as increased runoff and reduced water quality. Dust discharged from quarries settles not only on land, plants and trees but also on surface waters used for drinking and other domestic chores by the community. A study that won the Ghana Quarry Life Award in 2016 was titled ‗impacts of quarrying activity on water resource and effects on biodiversity; Odonata assessment.' This study which was done in Beposo- Shama District in the Western

Region, used dragonfly and Damselfly species diversity as a tool in assessing changes in water quality and determining the effects of quarry operations on the quality of water resources. According to the team, dust from quarries can change the chemistry of water resources by dissolving them and this has effects on the flies.

2.5.4 Impact on Biodiversity in the Environment

One of the biggest negative impacts of quarrying on the environment is the damage to biodiversity (Anand, 2006). Biodiversity essentially refers to the range of living species, including fish, insects, invertebrates, reptiles, birds, mammals, plants, fungi and even microorganisms. Biodiversity conservation is important as all species are interlinked, even if this is not immediately visible or even known, and our survival depends on this fine balance that exists within nature (Anand, 2006). Miners also dispose of waste on open areas and riverbeds causing land pollution. Some types of quarries do not produce large amounts of permanent waste, such as sand and gravel quarries, whereas others will produce significant amounts of waste material such as clay and silt (Wang, 2007). However, there is still potential for damage to the environment, particularly with water contamination.

In Palestine, Sayara et al (2016) assessed the impact of air pollution from quarrying and stone cutting industries on agriculture and plant biodiversity by first measuring the particulate matters (dust) as well as using a social survey. The significant-high concentration of dust, as well as total suspended solids, were presented in three examined sites located at the northern region of West- Bank in Palestine. The study revealed that there was an occurrence of a high amount of air pollution and dust in the examined areas which had a notable negative impact on plant biodiversity, habitat destruction, and plant survival. Hence, a wide range of plants was affected or even extinct, and olive was the most affected. The study, therefore, recommended that green belt surroundings should be developed at quarries using pollutant-tolerant trees (usually with broad leaves) to restrict spreading of quarrying dust through intercepting, filtering and absorbing pollutants (Sayara et al 2016).

Quarrying also discharges dust that settles on land, plants and trees. Dust and noise pollution from tipper trucks ferrying sand and gravel are a cause of concern to villagers as the trucks move even at night, disturbing sleep, (Madyise, 2013). Dust from quarry sites is a major source of air pollution, although the severity will depend on factors like the local microclimate conditions, the concentration of dust particles in the ambient air, the size of the dust particles and their chemistry, for example, studies have shown that limestone quarries produce highly alkaline dust, whereas coal mines produce acidic dust. The air pollution is not only a nuisance in terms of deposition on surfaces and possible effects on health, in particular for those with respiratory problems but dust can also have physical effects on the surrounding plants, such as blocking and damaging their internal structures and abrasion of leaves and cuticles, (Guach, 2001). Lameed and Ayodele (2010) asserted that nature, has provided wildlife and biodiversity with a certain form of habitat and not as adaptable as a man to the surrounding. Thus the expansion of human population and the unfolding of human‘s horizon to exploit resources for economic and other purposes tend to displace such indigenous resources and can even put some species into extinction.

A study conducted by Musah (2009) assessed the sociological and ecological impacts of sand and gravel mining and he noticed that commercial sand and gravel extraction to supply aggregate to the construction industry in the Northern Region of Ghana particularly the East Gonja District (EGD) and the Gunnarsholt area of Southern Iceland, had been on the increase in recent years. This has to a large extent contributed to land degradation and desertification through the destruction of economically important trees, mostly indigenous in nature leading to unemployment among the women folk. This practice leaves behind bare soil and a large expanse of gullies which can collect water during rainy seasons. Other common impacts shown in the results obtained from his work were loss of farm or grazing lands, destruction of landscape, and generation of conflicts, loss of biodiversity and dust pollution (Musah, 2009).

2.5.5 Impact on Health in the Environment

Quarrying makes remarkable contributions towards economic development in that in some communities, quarrying is the major source of livelihood and income for the people. This fact notwithstanding, it has an adverse impact on the health of quarry workers and people who live around quarry sites. In India, quarrying has affected many of the people working in the mining industry. According to Azad and Ashish (2006) cited in Eshiwani (2007), stone quarrying and crushing have been known as a highly hazardous work, whereby workers are affected by many debilitating occupational health hazards and diseases. The study indicated that the most common exposure is from silica dust, which causes Silicosis among the exposed workers. Unfortunately, Silicosis according to them is a disabling, non-reversible and sometimes fatal lung disease caused by overexposure to silica. The study further explains the Silicosis condition that overexposure to dust that contains microscopic particles of crystalline silica can cause scar tissue to form in the lungs, which reduces the lungs' ability to extract oxygen from the air and the inhalation of crystalline silica particles has been associated with other diseases, such as bronchitis and tuberculosis.

On March 16th 2020, one Rebecca Kwei reported in the daily graphic with the caption: ‗help! Young people dying from silicosis.'' According to Dr Jane Afriyie-Mensah, a Respiratory consultant of the Department of Medicine, Korle Bu Teaching

Hospital who explained the medical condition in the report, within six months, six young men have been diagnosed with silicosis of which five have died within the six months. She further explained that the disease is the progressive destruction of the lungs leaving them predominantly scarred and rendering its victims the inability to perform any physical action to the extent that they have to depend on relatives to use the bathroom. In the advance stage, silicosis patients have to depend on supplementary oxygen which is costly and many of them cannot afford. According to the report, those at risk of this disease are those in the mining industry such as ‗galamsey' operators, stone quarrying and crushers, quartz miners, sand miners and more who usually get exposed to the organic dust, silica. This report confirms the study of Azad and Ashish (2006) above as stated in Eshiwani (2007).

Both reports indicated that there was no cure for the disease but it's preventable. It recommends employers and workers to work together to reduce exposures to silica dust by using proper protective gear such as helmets, safety belts, face-masks, safety shoes. Other health hazards Azad and Ashish found were associated with heavy manual labour, minor or major injuries and accidents at the workplace, and long working hours. Lack of basic sanitation facilities, drinking water, and shelter add to the aggravation of the bad working conditions (Azad and Ashish, 2006).

In Africa, some studies done on impacts of quarrying have confirmed that quarrying activities negatively impact on the health of both workers and residents near quarry sites. Eshiwani (2007) in her work on the effects of quarrying activities on the environment in Nairobi County: a case study of Embakasi district established that quarrying activity in Kenya has affected the environment by leaving scares on the surface which are not easy to rehabilitate, this has rendered part of the area uneconomical. Also, the study found out that the people living in the surrounding area are affected by water-borne diseases such as malaria, which result due to the presence of the quarries in the area. Eshiwani established that some companies did not provide their workers with the proper protective gear that they need to use so as to protect themselves as they carry out their duties. This seam to confirm the findings of Azad and Ashish though on different locations. Most workers, therefore, suffer in silence. Also, many people die yearly from acute respiratory problems in developing countries, for the most part being aggravated by environmental pollution emanating from quarrying, sandblasting and emission of dangerous chemicals (Ming' ate and Mohamed, 2016).

Also in Ghana, a study was conducted by Nartey et al (2012) in the Lower Manya Krobo District of the Eastern Region of Ghana which assessed the environmental effects of limestone quarrying on some selected communities in the study area by measuring Particulate Matter (inhalable particles) from three monitoring stations every three months, from January to October and a fourth site located far from the quarries was used for comparative purpose. Data were also collected from three health facilities mostly patronized by the indigenes in the study area in addition to a social survey. The findings of this study indicated that; there were a noticeable increase in dust-related diseases since the quarries started operating in the study area. Acute Respiratory Tract Infection (ATI) such as chest pain and asthma were on the increase, the cough was slightly on the increase with pneumonia, colds, ear and eye infections, as well as water related sicknesses like malaria infection, also rose significantly from 2005 when the quarries were established. The latter was attributed to flooding of lands (quarry pits) leading to stagnant waters which serve as breeding grounds for mosquitoes (Nartey et al, 2012). In East Gonja District, abandoned mine pits served as sources of breeding grounds for the spread of diseases (Salifu, 2016).

According to the Millennium Ecosystems Assessment (2005) and human well-being, over the past 50 years, humans have changed the ecosystems more rapidly and extensively than in any comparable period in human history, largely to meet rapidly growing demands for food, freshwater, timber, wood and fibre, and fuel. And that, although this transformation of the planet has contributed to substantial net gains in human well-being and economic development, not all regions and groups of people have benefited from this process, thus many have been harmed (Millennium Ecosystems Assessment 2005). The assessment further found that approximately 60% of the ecosystem services examined during the Millennium Ecosystem Assessment are being degraded or used unsustainably. For instance, in Kenya, Ming'ate and Mohamed (2016) found out when they assessed the impact of stone quarrying on the environment and livelihoods in communities that, most of the land which was formally used for agriculture and animal grazing as well as the vegetation of the study area have been degraded due to stone quarrying.

Nartey et al (2012) also established in their study that quarrying activities have an impact on buildings around quarry sites. Several buildings were observed to have developed different degrees of cracks with some near collapse. These cracks were due to strong vibrations coming from rock blasting. Another study was carried out in Kayole, Kanya on how quarrying activities affect adjacent residential buildings of Kayole quarry sites. The study aimed to investigate and relate the blasting of rocks at the quarries to the development of defects in these buildings near quarry sites. The study confirmed that some buildings had developed cracks and that, the cracks were more pronounced in houses near the quarries than those that were far from quarries (Kibicho, 1998). Also, heavy-duty trucks often destroy roads leading to mining sites in communities. Pools of water collected by manholes created in the raining season force their way through parts of the roads eroding them and making them unmotorable (Tagoe, 2005). Continuous removal of vegetation exposes the land and increases soil erosion (formation of gullies). Clearing of vegetative cover as a result of sand mining can trigger micro-climate variation Mngeni et al, (2016) and also expose buried rocks to the atmosphere and the rocks begin to weather.

Quarrying on farms and fallow agricultural land is becoming common and this is having noticeable impacts on the soil structure, vegetation and local wildlife in the rural areas. The gravity of the situation beyond the affected communities and the region at large is enormous and poses a threat not only to the environment but also to food security Salifu, (2016) since some farmlands have now been leased to mine contractors.

2.6 Institutional and Operational Framework for Quarrying

While quarries can cause significant impact on the environment, with the right planning and management, many of the negative effects can be minimized or controlled in most cases Lameed & Ayodele (2010). Unfortunately, in some countries especially developing countries, environmental concerns are not made a priority in government programmes. Hence as stated by Warhurst (1999), most international firms locate their production activities where they can easily externalize the environmental damage cost of their production, that is, developing countries where environmental regulation are either limited or poorly enforced. The most controversial problems of mineral development in developing countries have to do with their relation to the developed countries as providers of capital and technology. Operations of quarrying and crushing stones are a hazard to the environment as well as to human beings. To minimise the hazard, it requires strong will and continuous monitoring of the quarry as well as the workers. Oyaigheviven, (1998) indicated that the reason why there have been many environmental problems associated with resource extraction as in the case of quarrying, is that most quarrying activities lack environmental considerations in the planning and building of major projects.

In Ghana, the institutions and operational frameworks that regulate issues on resource usage, management and protecting the environment including quarrying is defined by the following laws: The Minerals and Mining Law PNDCL 153, now Act 703 (2006), Small Scale Mining Law PNDCL 218, Sand Winning and Stone Quarrying Bye-Laws and Environmental Assessment Regulations Law LI 1652. According to the law, every mineral in its natural state in, under or upon any land in Ghana, rivers, streams, water-courses throughout Ghana, the exclusive economic zone and any area covered by territorial waters or continental shelf is the property of the Republic of Ghana and is vested in the government for and on behalf of the people of Ghana. Therefore, the following institutions; the Minerals Commission, the Mines Department, the Environmental Protection Agency and the District Assemblies are tasked with the enforcement and monitoring of the laws government minerals in any part of the country through the different roles they play.

2.6.1 Role of the minerals commission regarding quarrying

Sand and rocks are considered as minerals. They, therefore, come under the Minerals and Mining Law (PNDCL 153) of 1986. The Minerals Commission is a government agency established under Article 269 of the 1992 Constitution and the Minerals Commission Act 1993 (Act 450). The Minerals Commission as the main promotional and regulatory body for the minerals sector in Ghana is responsible for the regulation and management of the utilization of the mineral resources of Ghana and the coordination and implementation of policies relating to mining. It also ensures compliance with Ghana's Mining and Mineral Laws and Regulation through effective monitoring. Passage of Act 703 makes the Mines Department an Inspectorate Division of the Minerals Commission to improve efficiency (Section 101 & 102).

The Commission is required by law to carry out the following functions:

- The commission is responsible for granting mineral permits to prospective mineral exploiters. They do this by investigating the background, process applications for mineral rights and recommend their grant or otherwise to the Minister;
- Review agreements relating to minerals; Collect, collate and analyse data on the operations of mining companies for the decision making and for dissemination;
- Organize and attend workshops/ seminars/ conferences, as well as issue publications to promote mineral sector activities;
- Liaise with other governmental agencies, notably the Geological Survey Department (GSD) and the Environmental Protection Agency (EPA) to monitor and ensure the adherence of mining companies to the terms and requirements of the mineral rights granted to them.

The Minerals and Mining Law (PNDCL 153) of 1986 applies to all prospective quarrying contractors. Contractors need to obtain license or mineral right from the Minerals Commission before they can operate anywhere within a town. This law has been made to control indiscriminate mineral extraction to minimise environmental problems such as land degradation, pollution of all kinds as well as flooding which eventually impact negatively on the socio-economic life of the communities within which such activities are carried out. Besides the mineral Commission, Environmental

Protection Agency and the District Assemblies also have their roles to play before such activity of mining could take place.

2.6.2 Role of the mines department

Generally, the Mines Department exists to ensure compliance with Ghana‘s mining and mineral Laws and Regulations through effective monitoring and the provision of other needed sector services. The Mines Department was established with the following specific duties;

- Compliance and enforcement of occupational health and safety regulations for the mining sector;
- Inspection of areas of mineral operations to ascertain whether any nuisance is created in the area by the mineral operation;
- Issuance of operating permits for reconnaissance, exploration and mining;
- Enforcement of licensing and leasing provision of Mineral titles;
- Technical inspection, control and enforcement of technical regulations for mining.
- Inspection of distribution, storage and handling of explosives; enforcement of the Explosives Regulations both within and outside the Mining Sector.

Anyone who wishes to operate in minerals take the right to that concession through the Mines Department. Without their license, no one can undertake any activity such as mining, quarrying and even sand winning. The Mines Department as an inspectorate and monitoring body of the Minerals Commission, issue to people who want to undertake quarry and sand winning activities.

2.6.3 Role of the environmental protection agency regarding quarrying

The functions of the Agency are;

- They are mandated by the Government to issue environmental permits to the quarrying companies and to also ensure that they comply with the necessary environmental guidelines governing the exploitation of minerals in a more sustainable manner. The companies are mandated by law to submit Environmental Impact Assessment (EIA) reports to the Environmental Protection Agency (EPA), stating the potentially negative effects of their operations on the environment and mapping out strategies for mitigating the stated effects.
- They issue pollution abatement notices for controlling the volume, types, constituents and effects of waste discharges, emissions, deposits or any other sources of pollutants and of substances which are hazardous or potentially dangerous to the quality of the environment or a segment of the environment that could result from quarrying;
- The issue a notice in the form of directives, procedures or warnings to any other person or body for the purpose of controlling the volume, intensity and quality of noise in the environment and to prescribe standards and guidelines relating to the pollution of air, water, land and any other forms of environmental pollution including the discharge of waste and the control of toxic substances;
- They ensure compliance with the laid down environmental impact assessment procedures in the planning and execution of development projects, including compliance with respect to quarrying.

- They act in liaison and co-operation with government agencies, District Assemblies and any other bodies and institutions to control pollution and generally protect the environment
- They initiate and pursue formal and non-formal education programmes for the creation of public awareness of the environment and its importance to the economic and social life of the country.
- They promote effective planning in the management of the environment;

In accordance with the above-listed measures, quarrying contractors or companies are required to register with EPA for an Environmental Permit. The EPA conducted an Environmental Impact Assessment (EIA) of the quarry site before such permit is granted. During the assessment, the unique natural environmental characteristics or conditions of the area are considered. This is to ensure that, the extraction activities will be conducted with minimal adverse effects on the environment and eventually socioeconomic life. Some of the natural environmental conditions that could be considered include geology, seismicity, and another damaging geological phenomenon (groundwater, landslides and topography (Hodgson, 2011). For instance, an EIA of quarry sites on the Weija Hills will have to consider the fact that the area is an earthquake zone and the extent of human settlement in the area before granting a permit for quarrying activities to take place in the area.

2.6.4 Role of the District Assembly

Under the Local Government Act (Act 462) section 51, the District Assemblies are made the managers of the environment within their jurisdiction. The Environmental Management Sub-committee is in charge of Sand Winning and Stone Quarrying and thus, each assembly is to have its bye-laws to this effect. This act grants the District

Assemblies the sole responsibility to manage the environment by making sure that all prospective contractors and the traditional authorities conform to sustainable environmental practices stated in the bye-laws for sand winning and stone quarrying in the district or municipality. Unfortunately, most district and municipal assemblies including the Ga South Municipal Assembly do not have their bye-laws to regulate quarrying activities. They use the general environmental laws of Ghana but it is important to note as mentioned earlier that, all environments are not the same.

The institutional framework of Ghana also involves traditional authorities as custodians of lands in Ghana. They are usually engaged by the districts/municipal assemblies when it comes to land use. Laws on land use are not adequately applied in most Ghanaian communities. Although the land may be owned by a particular stool or individual who has purchased or lease the land, the issues of land uses could be determined by an environmental expert. Unfortunately, in many instances, people are allowed to go ahead and use the land for whatever they wish, leading to conflicts in the communities due to environmental problems that may occur as a result of particular land use.

As part of the requirement for applicants to acquire a licence, a person who wishes to engage in quarrying provides a reclamation measure and abandonment proposal. Yet, old quarry sites in several parts of Ghana are left unclaimed. Pits and holes dug during quarrying collect water and become breeding sites for insects. In some countries, such sites have rather been turned into other use and tourists‘ attractions which generate revenue for the local governments. For instance, a study conducted by Baczyńska, Lorenc & Kaźmierczak (2017) which sought to assess ‗Landscape Attractiveness of Abandoned Quarries‘ indicated that, old limestone quarry located on Portland Island which had an area of about 20,000 m^2 and from the east is adjacent to the English

Channel, is now a major tourist attraction because it is close to the ocean. Additionally, some of it is characterised by almost vertical walls, which are eagerly used for climbing and it is partly legally protected. Also, former serpentines quarry located on the slope of Mount Słupicka (335 m above sea level), covering about 2500 m^2 is protected as an ecological area, a good state of preservation.

With all these institutional arrangements in place, some quarry contractors operate without a permit, there are issues with the environment; pollution, the use of explosives near settlements which sometimes leads to loss of lives. Either the laws are inadequate or the institutions are weak in enforcing the mining laws. There are flexibility and inefficiencies in enforcing the laws. Those involved in quarry activity take advantage of the weakness in the system and ignore the necessary protocols. For quarrying to be allowed on the faulted Weija Hills suggest there is an institutional failure. This statement is supported by Ata-Era (2015) that, the laws regulating mining in developing countries are weak and so add to the externalization of the environmental cost of mining. Again, the findings of Salifu (2016) on the implications of sand mining on livelihoods and environment in the Brong Ahafo Region of Ghana implied that most of the institutions that are supposed to regulate the use of natural resources and protect the environment have no interest in the operations of sand miners. They also have limited knowledge about the actual effects of the activities of sand mining in the communities. Consequently, most of the local authorities either lack regulations governing sand mining or are not enforcing the regulations even when they existed. In recent times, there has been reports that about eighty-five percent of sand winners in the country are operating illegally. The question here is whether the Mineral Commission has adequate staff, logistics and the cooperation of the other relevant regulatory bodies to discharge their duties. There should be proper coordination among the various regulatory bodies such as the Minerals Commission, Environmental Protection Agency (EPA), District Assemblies, Security Agencies and Traditional Authorities.

For what the institutional frameworks put in place to work effectively to curb the current environmental problems, there is the need for coordination among the institutions put in place by the government to regulate quarrying activities including the Mines Department of the Minerals Commission, Environmental Protection Agency and Municipal and District and traditional leaders. Some contractors deal with the traditional leaders or landowners directly in acquiring land for quarrying without going through the proper procedure in acquiring a permit. The various institutions especially the Mineral Commission and the EPA can perform their mandate better if provided with the necessary staff and logistics.

2.7 Measures put in Place by some Countries

According to Blodgett, (2004) in his report for Rural Conservation Alliance that tried to identify the environmental impacts of aggregate and stone mining in New Mexico, states that in New Mexico, aggregate and stone mining is regulated by the New Mexico Environment Department (NMED) which issues air quality and water quality permits for mines and their associated crushing plants. Every aggregate and stone mines are required to obtain this air quality permits from NMED that specify the amount of particulate matter or other pollutants a given mine or mill is allowed to emit. It does not end there, Blodgett further indicated in his report that, the Air Quality Bureau (AQB) in NMED maintains 34 monitoring sites across the state for ambient air quality (Blodgett, 2004). Such regulations check air pollution which otherwise would have engulfed mining areas in the state.

In Barbados, the Natural Resources Department (NRD), while responsible for encouraging the sustainable exploitation of natural resources for the benefit of the country, is also cognizant of the fact that mining activities will have significant impacts on ecosystems through the loss of agricultural land, rerouting of watercourses, and removal of topsoil among other things. As such the department works with other agencies, such as the Environmental Protection Department to ensure the minimization of risks to ecosystems. The NRD encourages operators to use methods such as wetting, tree cover, berms, and netting to reduce potential negative impacts of their operations on persons residing in close proximity to a particular quarry. Also, operators typically carry out regular safety drills and post warnings in various locations on site (Barbados Ministry of the Environment, Water Resources and Drainage, 2009).

Some African countries have also put in place measures to reduce the impact of quarrying. For instance, in Senegal, uncontrolled expansion of quarrying has led to coastal erosion, a reduction in the area of available farmland and skin and lung problems for the quarry workers and people who live nearby. Therefore, the situation has forced the government to stop issuing more permits to the people who want to engage in the quarrying activities in the affected areas within the country (Irin Africa, 2003) as cited by Eshiwani (2007) and in many African countries, for instance, South Africa, it is required of a person or company to have an approved environmental management programme or environmental management plan before permit is given for quarrying and miningg activities Also in Kenya, there are several pieces of legislation that governs the quarrying industry according to Eshiwani (2007). For example, the Occupational Safety and Health Act, 2007 and Environmental Management Co-ordination Act 1990 gives guidelines that are to be used in the mining industry such as the level of noise, the vibrations and protective clothing for the workers in the different workplace although a study conducted by Eshiwani (2007) in Embakasi area, Nairobi County revealed that, the relevant provisions of the Acts are not fully observed by mining operators. The study, therefore, recommended to the Kenyan government to ensure that the laws governing the quarrying and mining industries are observed through enhanced surveillance (Eshiwani, 2007). Also in 2013, the government of Togo shut down 90% of the illegal sand quarries, justifying the closures through new environmental protections.

2.8 Theoretical Approach and Conceptual Framework

Landscapes are said to evolve. They are indicators of the complex negotiations between nature and cultures, over time and humans are the dominant evolutionary force reshaping the biosphere (Alexandra, 2012). Landscapes found at various places change constantly from both natural and anthropogenic drivers. Land use and land cover changes by humans have been identified as a primary effect of human activities on natural systems (Petrosillo Aretano, & Zurlini 2005). Thus, the human society represents the driving forces of the biosphere and ecological system changes. Hence, Steffen et al (2004) have this to say; ―the Earth‘s environment has been transformed profoundly owing not only to the great forces of nature but rather largely to the numbers and activities of people." The theoretical underpinning for this study is the Millennium Ecosystem Assessment and Human well-being, one of the frameworks of the Socio-Ecological Systems Theory (SESs). Assessment was carried out between 2001 and 2005 to assess the consequences of ecosystem change for human well-being and to establish the scientific basis for actions needed to enhance the conservation and sustainable use of ecosystems and their contributions to human well-being.

Ecosystem services are the benefits people derive directly or indirectly from ecosystems. These services ranges from provisioning services such as food, clean water, forest products through the regulating services; climate regulation, food regulation, disease regulation and water purification), Supporting services (nutrient cycling, soil formation and primary production) and finally Cultural services (aesthetic, spiritual, educational and recreation). These together provides livelihood, health, security, recreation and education for the people. The knowledge of these aspects should improve natural system management and their capacity to support human and natural capital without destroying any part of the system. Meadows (2008) defines a system as ―a set of things such as people, cells, molecules, and others which are interconnected in such a way that they produce their pattern of behaviour over time." This basic description of a system suggests that through the dynamic interactions between interconnected parts, systemic properties emerge that cause system to produce and maintain their patterns of behaviour over time. Thus, if one cell within the system is destroyed, it affects other cells due to their interconnectivity. According to Gundersen el at (2011), ‗The Earth is a system in which atmosphere, oceans, land, and life are all connected' and as human beings and nature co-exist in any given environment, there is constant interaction and dependencies between humans and their environment.

Human well-being is assumed to have multiple constituents, including the basic material for a good life, such as secure adequate livelihoods, enough food at all times, shelter, clothing, and access to goods; health, including feeling well and having a healthy physical environment, such as clean air and access to clean water; good social relations, including social cohesion, mutual respect, and the ability to help others and provide for children; security, including secure access to natural and other resources, personal safety, and security from natural and human-made disasters; and freedom of choice and action, including the opportunity to achieve what individual values doing and being. Freedom of choice and action is influenced by other constituents of well-being (as well as by other factors, notably education) and is also a precondition for achieving other components of well-being, particularly with respect to equity and fairness. However, during the past few decades, improvements in human well-being is achieved at escalating costs due to the decline or degradation of more than 60% of the ecosystem across the globe. This decline or degradation in ecosystem may increase the risks of nonlinear or abrupt changes, and may lead to further marginalization of some groups of people.

Changes in any of the services affect human well-being in many ways. The MEA examines how the growing demand for ecosystem services has brought about increasingly serious degradation in the capacity of the ecosystem to provide a list of services to address human well-being. The assessment is done by asking and answering the following questions: How have ecosystem and their services changed? What has caused these changes? How have these changes affected human well-being? How might ecosystem change in the future and what are the implication for human well-being. What options exist to enhance conservation and contribute to human well-being? But how do changes occur in the ecosystem services? Petrosillo et al (2005) stress that human beings are the driving forces causing changes to the human environment (biosphere or ecological systems) thereby causing changes in the services it provides. It is relevant to consider the human sources of ecological change by understanding the driving forces that motivate human actions. Thus, there are several examples of how human choices and the consequent environmental effects influence each other.

For instance, rocks are resource units that have become very important to the socio-economic life of most communities. Quarrying rocks into stones, gravels and sand provides construction materials and also serve as a major source of livelihood for many people worldwide. In recent time, the demand for quarrying materials of all sizes is on the increase. These are the direct drivers of change. According to the Millenniums Ecosystem Assessment (2005), the indirect driving forces that motivate such human activity such as quarrying everywhere include demographics, economic and socio-cultural factors. Considering the direct driving forces, increase global demand for services; livelihoods and social amenities such as education, recreation, housing stock, health, road construction and other infrastructural development to meet human needs and make life more comfortable (well-being) has a corresponding demand for quarried resources. Coupled with indirect drivers such as population growth, urbanisation, life style and more leads unsustainable, unscientific and over-exploitation of quarry materials at the detriment of the environment in general (Tagoe, 2005), causing rapid changes in the ecosystem.

For this reason, it becomes relevant that societies improve natural system‗s management by regulating the use of environmental resources to reduce human dependence on the environment for the benefit of all its members now and future generations. Ostrom (1990) was much concerned about governing environmental resources. In her book ‗Governing the Commons' describes how Common-Pool Resources (CPR) and public goods such as water, fisheries, land, sand and rocks and others are governed through effective institutional arrangements by humans themselves as they use the resources to meet their needs. Ostrom and her colleagues describe Common-pool resources as systems that generate finite quantities of resource units and that one person's use subtracts from the quantity of resource units that will be available to others who are also beneficiaries of that resource (Ostrom, Gardner, and Walker, 1994). Therefore, the individuals jointly using such CPR agree on and establishes the rules and strategies to improve resource sustainability (Ostrom et al, 1994).

The MEA (2005) suggest the need for countries to make deliberate attempt to integrate environmental issues in national policies at all levels and strategies to manage resource usage so as to ensure its sustainability and wellbeing of all. Institutional arrangements are essentially the ―rules" influencing human behaviour and actions which include both formal and informal rules. Formal institutional arrangements are codified in constitutions, statutes, regulations, plans and policies (Smajgl, Vella & Greiner 2003). The formal institutional framework includes written or documented laws/rules regarding land use, property rights and specific resource management put in place to control resource usage while the informal includes customs, norms and taboos, Boateng (2006) which are manifest in societal expectations of resource access and use (Smajgl et al, 2003). Therefore, both formal and informal institutional arrangements are necessary to ensure that man uses the scarce resources in a more sustainable manner.

At the international level, never in the history of mankind has attention been accorded to the relationship between environment and development (Agyemang, Mcdonald & Carver 2007; UNCED, 1992; WCED, 1987; World Bank, 2001) cited in (Boon et al., 2008). Several conferences on the environment have been held where heads of countries present pledged to protect the environment having realise that, the environment holds fundamental but finite resources for economic and social development (WCED, 1987; UNEP, 2002). Nations have realised the relevance of analysing the impact of human activities on the environment and sustainable development/ human well-being. For instance, the United Nation's Millennium Development Goals and Sustainable Development made emphasis on the environment. International bodies such as the United Nations Environment Programme (UNEP) comes out with programmes to achieve such goals which serve as guidelines for countries and increased awareness on the need to protect the environment and use local resources sustainably. Some countries have adopted specific laws, policies, and administrative arrangements MEA (2005) and have put in place institutions and operational frameworks to govern natural resources use while in other instances, either there are no institutional arrangements regarding resource use or the institutions exist but there are weaknesses in the implementation and enforcement of the rules which makes resource management ineffective. Until such challenges are dealt with, various concepts such as the MDGs and SD: Sustainable Ecosystem management and human well-being will not be fully achieved.

Ghana's national development planning process from one government regime to another over the years seem to put a lot of emphasis on economic growth, with little attention for the integration of environmental concerns in the core of the country's development agenda (Boon, Ahenkan & Domfeh, 2008); and thus, decoupling environmental pressures from economic growth and development plan and programmes is a fundamental challenge of SD in Ghana and most developing countries especially those that still largely depend on primary production to sustain their economy (Boon, Ahenkan & Domfeh 2008). Environmental policies in Ghana include; The National Environmental Policy (NEP) which provides framework for the implementation of the National Environmental Action Plan (NEAP). The ultimate aim of this policy is to ensure sound management of the environmental and thus, avoid the over exploitation of natural resources. The policy states that: ―*The State shall take* *appropriate measures needed to protect and safeguard the national environment for posterity; and shall seek co-operation with other states and bodies for purposes of protecting the wider international environment for mankind''* (Boon et al., 2008). To decentralize such programmes, the District Environmental Plan (DEP) and several others all aiming at ensuring sustainable resource use have been formulated but how many districts in Ghana have a functioning DEP?

The District assemblies, Environmental Protection Agency and the Mines Inspectorate Division are some of the existing regulatory bodies charged with the implementation of environmental policies. However, the poor state of Ghana's environment; deforestation, land degradation, soil erosion, flooding, pollution just to mention few, is an indication that the existing laws and policies are inadequate or we've not done well with enforcing them. There is therefore the need for these agencies to collaborate and have an integrated policy that will strengthen the regulatory frameworks. Also, different institutional approaches are needed in different contexts due to variations in cultures, values and societal norms (Boateng, 2006). District assemblies must therefore collaborate with traditional authorities to govern resource use and its management.

It is a common perception in Ghana that, informal institutions are more effective especially in the rural areas while formal institutions are more applicable in the urban areas. In most cities, though institutions are available whether formal or informal, they are not enforced satisfactorily, perhaps as a result of urbanisation and institutional weakness. ―*Among the gravest hindrances to developing sustainable systems has to do with our institutions. That is, how to break the institutional gridlock that binds how we manage landscape, water, biodiversity and our industries and communities*," (CSIRO, 2003) as stated in (Samjgl et al, 2003). There is a situation where there are so many institutional arrangements and policies to help manage the ecosystem and other environmental resources which has created artificial congestion or blockage, yet nothing seem to be working. No or little progress is being made despite the presence of numerous programmes.

In the rural areas, the rules governing environmental resource such as the forest, water bodies and others seems to be working better because, once the traditional authorities or priest declares certain areas as sacred (‗no-go areas'), everyone comply with this rule because it is attached to spirituality. As members of the community observed such taboos, they indirectly preserve the ecosystem. Usually, local and indigenous knowledge evolves in specific contexts, and good care should be taken so as to not de-contextualize its application. Conventional ―best-practices" methods focusing on content may not be appropriate to deal with local or indigenous knowledge (MEA, 2005).

Accessibility to natural resources plays a critical role in the livelihood conditions of people. This is so because the formal sectors in developing countries have very little potential in terms of job creation. Thus the informal sector has become an alternative for achieving livelihood needs. Meanwhile, the indirect drivers such as population growth and its associated high demand for natural resources have put severe stress on the available resources with dreadful consequences on the sustainability of the ecosystem. In Ghana, quarrying has become an important socio-economic activity which strive in many parts of the country. It serves as source of raw materials for the construction industry. Ghana as a developing country, there has been an increased demand for infrastructural developments in all parts of the country. Quarry provide materials for the construction of schools, health facilities and roads to connect the food growing areas to the towns and cities.

Quarrying also employs quiet a number of the local populace such as contractors, drivers, crushers, loaders just to mention a few and indirectly food vender, transport services and more. The income received is used to provide basic needs of the family such as food, clean water, clothing, health, education and recreation for their well-being. Another intrinsic provision of quarrying is that, it leads to the development and expansion of settlements as constructional materials become readily available.

Since everyone in the world depends completely on the same Earth‘s ecosystems and the services they provide, and to ensure that people feel safe where ever they are, this study uses the MEA to assess how quarrying activities has caused changes in the geological structure of the Weija Hills in the Ga South Municipality. The extent of impact on the geological structure of quarried sites may depend on the physical characteristics of the area and methods used in the quarrying. The effects on the environment may include loss of vegetation cover, erosion, flooding and pollution of air and water bodies which negatively influence human wellbeing. As discussed earlier in this chapter, the Weija Hills lies within the earthquake zone of southern part of Ghana. As much provisions are taken from the environment, its quality and quantity does not remain the same. Meanwhile, well-being includes a healthy physical environment and must ensure personal safety of the community members and safety from both natural and human-made disasters. As changes occur on the Weija Hills as a result of quarrying activities, the slope of the landform may also be rendered unstable as masses of rocks and soils get detached from each other.

In view of the objectives of this study, the conceptual framework shows how quarrying as a socio-economic activity is driven by the desire of people to meet their human needs but end up causing changes in some environmental components such as the geological structure and stability of landforms which are supposed to support human life. The framework begins at **A,** a major ecosystem service, is driven by the factors in **B** which are causing changes in the ecosystem services. **C** represent the changes that take place as a result of quarrying activities. Meanwhile, the framework suggests that, with the appropriate management arrangements and the enforcement of the regulations shown at **D,** there will be improvement in the use and management of ecosystem services and human well-being. At the end of the conceptual framework, **E** shows the expectation that, there will be an improvement in natural system management with a corresponding positive effect on human well-being. The conceptual framework is shown in *figure 2* below.

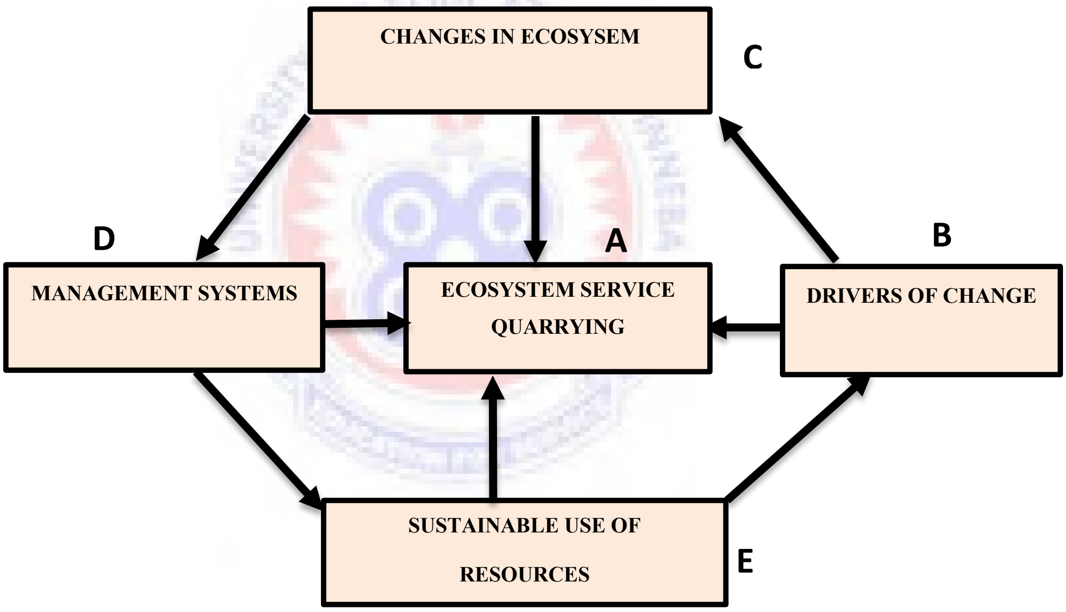

Figure 2: Conceptual framework

Source: Adapted from MEA 2003 and 2005

2.9 Summary of the Chapter

This chapter was divided into two sections. The first section discussed literature relating to the study to ascertain information about similar studies that have been done in other parts of the world relating to the research questions. The second section focused on the key features of the Millennium Ecosystem Assessment from which the conceptual framework of the study was drawn.

CHAPTER THREE

RESEARCH METHODOLOGY

3.0 Introduction

This chapter focuses on the research methodology used for the study. It involves the research approach and design, data collection processes and methods used for data analysis.

3.1 Study Area

The study area for the research was the Weija Hills in the Ga South Municipal Assembly of the Greater Accra region of Ghana. The study area lies within the coordinates 5 30 15 N to 5 33 10 N and 0 20 55 and 0 23 20 . The study area lies opposite to the Weija Lake near the Kasoa toll booth along the right-hand side of Mallam - Kasoa highway towards Broadcasting junction near Hazelway International School (New Bortianor) and along the Kasoa by-pass (New road) at Tuba. Settlements with the study area include; Bortianor Hills, Tuba, Machigani, NetLynk Estates and Broadcasting which are all within the larger New Bortianor Township. The Ga South Municipal Assembly with its new capital Ngleshie Amanfro in the Greater Accra region is one of the existing Assemblies affected by other districts carved out of it by the Local Government Act, 2016 (Act, 936) with a Legislative Instrument (2316). The Assembly was officially re-inaugurated to assume administrative responsibilities on 15th March, 2018 (GSMA, 2018).

The Ga South Municipality Assembly is located in the South-Western part of Greater Accra. The municipality lies within latitudes 5°47'30"N and 5°27'30"N and longitudes 0°31'30"W and 0°16'30"W. The Municipality shares boundaries with Upper West Akim District to the north, Weija-Gbawe Municipality to the east, Gomoa East

District to the south-west, Awutu-Senya East Municipality to the west, Awutu-Senya West District to the north-west and the Gulf of Guinea to the south. It occupies a land area of approximately 385.23 sqkm. The Municipality covers part of the Akwapim range with the soils there, rich in sandstone and limestone that are a good source of material for the construction industry. The land area consists of gentle slopes interspersed with plains in most parts and generally undulating at less than 76m above sea level (GSMA, 2018). These formations are underlain by poorly consolidated to unconsolidated sediments due to a series of folds and faults. Rainfall within the municipality is bi-modal with an annual average temperature ranging between 25.1 C in August and 28.4 C in February and March (GSS, 2014; GSMA, 2018). The Municipality consists of three main vegetation types, namely the Moist Semi-delicious forest, Mangrove swamp and Coastal Shrub and Grassland with the Coastal Savannah Ochrosols being the main type of soil. There are two main rivers namely, the Densu and Ponpon rivers, which drain the Municipality (GSMA, 2018).

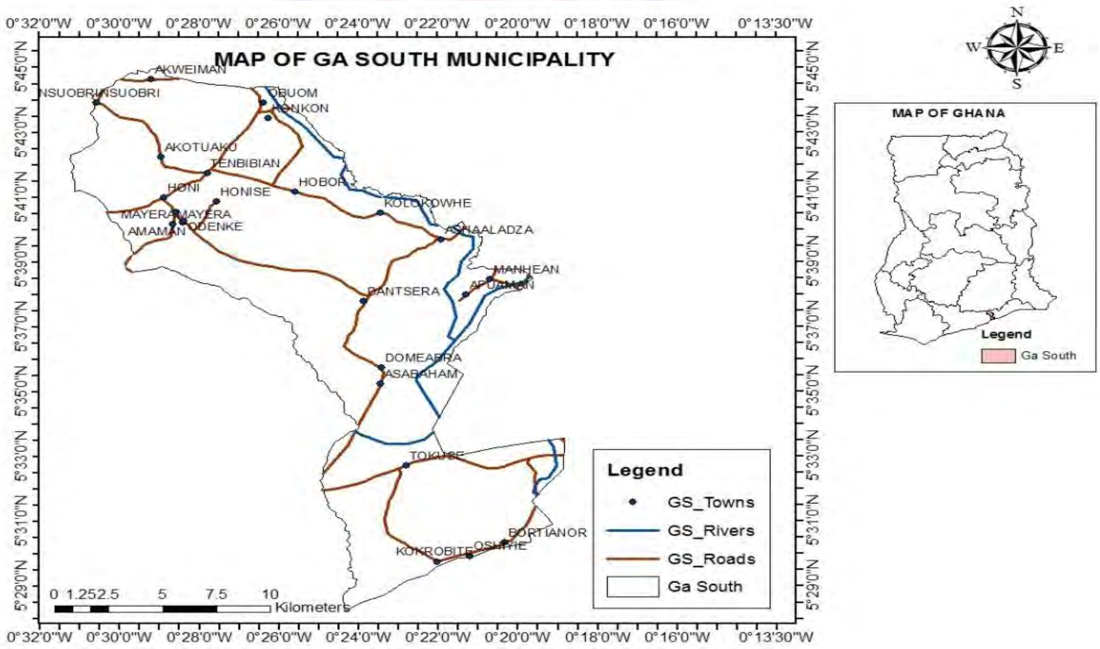

Figure 3: Map of the study area

Source: Author‘s Construct

3.2 Research Approach and Design

The study adopted the mixed-method approach but quantitatively bias to assess the effects of quarrying activities on the geology and environment of the Weija Hills. The approach involved the integration of elements of both qualitative and quantitative methods. The combination of qualitative and quantitative approaches provides deeper insight and understanding of a research problem than either approach can fully solve (Creswell, 2014). For instance, the qualitative approach seeks to understand social reality in its terms, as it provides a rich description of phenomena in natural settings Gubrium & Holstein (1997) while a quantitative study facilitates easy and reliable comparison of variables (mean, statistical analysis, maps). The exploratory sequential study design was adopted for this study. This study design affords the researcher the opportunity to start with qualitative data, to explore a phenomenon to see how it occurs, and then builds or connects the initial qualitative results to the quantitative components (Creswell, Plano Clark, Gutmann & Hanson, 2003). As the linkage is made, it allows data to be visually brought together to draw out new insights beyond the information gained from the separate quantitative and qualitative results (Fetters, Curry, and Creswell 2013). Quarrying activities occur at several parts of the country, but the Weija Hills in the Ga South Municipality was specifically chosen because the area is described by seismologists as within the geo-hazard zone of the Greater Accra region with quarrying activities on going within the area. Table 3 shows summary of the methods used.

Table 3: Methodology for objectives

Objectives	Methodology
• Examine how quarrying activities affect the geological structure of the Weija Hills in Ga South Municipality.	Digital Elevation Model and Field observation.
• Assess the changes that are occurring in the local environment which can be attributed to quarrying activities.	GIS, remote sensing and field observation
• Evaluate whether quarrying activities will cause instability of the local geology.	Field observation and Limit Equilibrium Method (SLIDES).

3.3 Data Collection Processes

Both primary and secondary sources of data were adopted for the study. The primary data were collected directly from field observation during which much data were gathered including photographs. Several visits were made to quarry sites at different seasons with the idea of getting different information brought by each season. This provided the opportunity to observe, understand, assess and explore the nature and extent of the impact of quarrying activities to avoid being speculative. Based on the preliminary observation, three quarry sites referred to in the study as A, B & C were selected for the study. Site A in this study was located opposite to the Densu River along the Mallam-Kasoa highway to Broadcasting junction. Site B was located at the side of the hill that faces the Tuba road, near NetLynk Estate while Site C was located at Bortianor extent of the Weija Hills. After assessing the information gathered from the various sites, the researcher concluded that site A was the most affected by quarrying activities among the three sites chosen for the study. To that effect, Site A became the area of interest in assessing the impact on the geological structure and it was also modelled for the slope stability analysis. The figure below shows an aerial photograph of quarried Sites A taken by drone not to scale.

Figure 4: Quarried sites A on the Weija Hills.

Source: Golder Associates, 2017

The secondary data, on the other hand, included review of related literature. Also, the Digital Elevation Model (DEM) was used for elevation change between 2007 and 2014. This was due to the fact that, the current data available was 2014. Geographic Information System (GIS) and remote sensing were used to determine changes in land use and land cover that have occurred in the study area over the years and finally, the Limit Equilibrium Method (LEM) was used to assess the slope stability of the Weija Hills.

There are various ways of analyzing the change in elevation of a place. These include using already existing DEMs from the United State Geological Survey (USGS) data depository or using the Training Center XML (TCX) convertor to convert elevation points from the Google earth. The elevation for 2007 was acquired from Google earth pro software as elevation points while DEM for 2014 was easily acquired from the USGS website. These points were interpolated using the Inverse Weighting distance interpolation in ArcMap version 10.8. In determining the elevation change in ArcMap

10.8, the raster calculator in the spatial analyst tool was used. The expression ―New elevation‟ minus ―Old elevation,‟ (New elevation) – (Old elevation) was used to arrive at the final change in elevation of the study area.

For land use and land cover changes, a 30 metres/pixel multi-temporal satellite imagery dataset by the LANDSAT 5 and LANDSAT 8 satellite was used. The satellite imagery was derived from the United States Geological Survey data depository. The data acquired include satellite imagery for 1991, 2003 and 2020 respectively. All images were acquired in January, this was because satellite usually captures clear and cloud-free images of the earth surface in January. This also accounted for the uneven year‟s intervals. This data was used to produce the land use/land cover maps of the study area.

Table 4: Specification of satellite images

Landsat Image Specification			
Sensor	Spatial Resolution	Band Combination	Acquisition Date
Landsat 5 TM	30m	7, 4 & 2	10-01-1991
Landsat 7 ETM+	30m	7, 4 & 2	12-01-2003
Landsat 8 OLI-TIRS	30m	7, 6 & 2	02-01-2020

Source: USGS, 2013

3.4 Image Pre-processing

The satellite images acquired from the USGS data depository were pre-processed for better image enhancement. The image enhancement involved creating a natural-like composite through layer stacking of the bands 7, 4 and 2 for both the Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) images. This combination provides a "natural-like" rendition, while also penetrating atmospheric particles and smoke (USGS, 2013). In this stacked image, healthy vegetation looks bright green and can saturate in seasons of heavy growth, grasslands appear green, pink areas represent barren soil, oranges and browns represent sparsely vegetated areas. The light-green spots inside the built-up area indicate grassy land cover - parks. Olive-green to bright-green hues/ shades normally indicate forested areas with the coniferous forest being darker green than deciduous. Sands, soils and minerals are highlighted in a multitude of colours. This band combination provides striking imagery for rocky regions. It is useful for geological, agricultural and wetland studies. However, if there were any fires in this image, they would appear red. Urban areas appear in varying shades of magenta. Since urban area and croplands have responded almost in same spectral reflectance, band 4 could not be able to separate these areas. Band 2 provides increased penetration of water bodies and also capable of differentiating soil and rock surfaces from vegetation and for detecting cultural features, (USGS, 2013).

The image enhancement for the Landsat 8 Operational Land Imager-Thermal Infrared Sensor (OLI-TIRS) image was created using the false colour for visualizing urban environment (band 7, 6 and 2). This combination also provides a purple-like image showing areas of built-up. In this band croplands and grasslands shows higher reflectance (brighter tone) than the forest. This combination also has separated croplands from bare croplands. Since standing crops (vegetation) has higher reflectance in the near IR region, they appeared as brighter tone and due to the presence of moisture content in the bare croplands, they appeared as darker tone. In the band 4, barren lands, urban areas and highways appeared as dark tone. Band 4 is useful for crop identification and emphasizes soil-crop and land-water contrast. Besides, healthy vegetation in this band combination appears in shades of reds, browns, oranges, and yellows. Soils may be in greens and browns, urban features are white, cyan, and grey, bright blue areas represent recently clear-cut areas and reddish areas show new vegetation growth, probably sparse grassland.

3.5 Image classification

Supervised classification was used in this study to cluster pixels in the satellite dataset into classes corresponding to the user-defined signature classes. This classification type required selecting sample signature areas for use as the basis for classification. Of the most common supervised classification techniques, Maximum Likelihood Classifier (MLC) for the parametric rule was applied. Having, prior knowledge of the area, knowledge of reflectance properties of ground material was considered for a better and effective classification of the images taking into account the assumption of abnormality.

The land use land cover classes applied in this study were adopted from the FAO land use land cover classification scheme widely applied in African Countries (FAO, 2016). For the sake of simplicity, the researcher modified the descriptions of some of the land use land cover classes considering the land use/land cover of the study area. Therefore, three major land use/land cover nomenclatures: built-up, vegetation and bare areas, were used to produce the final land use/land cover map of the study area as presented in Table 5.

Table 5: FAO Classification Scheme

No	Land use/Land cover	Description based on FAO land cover classes
1	Urban/Built-up/Artificial Surfaces	Areas that have an artificial cover as a result of human activities such as construction (cities, towns, transportation), extraction (open mines and quarries) or waste disposal.
2	Forest	It is referring to land with a tree canopy cover of more than 10% and the area of more 0.5 ha.
3	Bare areas	This class describes areas that do not have an artificial cover as a result of human activities. These areas include areas with less than 4% vegetative cover such as bare rock areas.

Source: Adapted from FAO, 2016

3.6 Slope Stability Analysis

The Limit Equilibrium Method (LEM) was used for slope stability analysis. A 3D slope model in the Rocscience slope stability programmer –Slide 3 was developed to determine the factor of safety. Slide 3, a software developed by a Canadian company, Rocscience, which was used to perform the slope stability analysis is based on the Limit Equilibrium Method and does three-dimensional analysis, which is most relevant to the geometry and conditions at Weija Hills. The LEM for slope stability analysis was carried out through the analysis of available information namely topography, geology, geotechnical properties, groundwater and seismicity. Material layers were assigned their geotechnical properties alongside that of groundwater surface (water table). Seismic considerations were based on pseudo-static analysis.

Limit equilibrium analysis makes several simplifying assumptions to make the calculation of factor of safety possible for slopes. The Slide3 analysis in this study was based on the assumptions of Bishop (1955) and Janbu (1954) for the evaluation of the acceptability of calculated factors of safety based on acceptable criteria for high consequence failures (since the study area is well populated and having many residences and close to major roads) followed to arrive at the stability.

3.7 Data Processing and Analysis

According to Creswell (2014), data analysis is a process which involves drawing conclusions and explanation to findings of a study. The results of the study were presented and analysed using various approaches and techniques. For change detection for the satellites images for the years 1991, 2003 and 2020, a post-classification comparison technique was applied in change detection analysis via the use of overlay operations of classified images to detect the changes that would have occurred in each cover type over the study period. It is a comparative analysis of independently produced classifications of different dates via a simple mathematical combination pixel by pixel (Sallaba, 2009). The outcome was a matrix of change classes that shows the change from class to class in a cross-tabulation. The thematic change analysis was carried out using Erdas Imagine 2015 and ArcGIS 10.5. The pseudo-static method of seismic analysis and factor of safety of slopes were modelled and analysed using Slide 3. Finally, the analysed data were presented through graphical illustrations. These were in the form of tables, graphs, maps depending on how easily any of them could be employed and understood.

3.8 Summary of the Chapter

This chapter focused on the methodology of the study. It adopted a mixed method approach following the exploratory sequential design. Both primary and secondary data were collected from relevant sources. The results of the study were presented and analysed using various approaches and techniques.

CHAPTER FOUR

IMPACT OF QUARRYING ACTIVITIES ON THE GEOLOGIC STRUCTURE OF THE WEIJA HILLS

4.0 Introduction

This chapter presents the findings of data collected from the field at Weija Hills as provided by observation, remote sensing and GIS as well as LEM. These findings are presented from both primary and secondary sources in relation to the research objectives of the study which involve the impacts on the geological structure of the Weija Hills, changes to the local environment due to quarrying and the slope stability of the local geology of the Weija Hills resulting from quarrying.

4.1 Impact of Quarrying on Geological Structure

According to the U.S Geological Survey (2001), the extent of geomorphic effects of quarrying on the geology of an area largely depends on the size of the quarry, the methods used and the location of the quarry, especially with respect to the overall landscape and the local landforms. Regarding the Weija Hills, the study used three quarrying sites (A, B &C) that were relatively large and were located at various portions of the hills. Main quarrying activity identified was crushing of rocks and sand mining for constructional aggregates, thus sand, gravels and stones. **Site A** was the largest among the three quarries. The site had been abandoned for about five years now, hence, the site showed evidence of massive weathering and erosion. **Site B** was the second largest site. This site was also not operational, there were no equipment or workers on site but the effects of the quarrying activities especially the changes that have occurred on the landscape were physically evident. One could observe that it was operational recently since the rocks showed fresh cut surfaces. Only **Site C** was operational at the time of the study.

The study observed that, operators used the excavation and crushing methods. This involved the use of an excavator and wheel loader. The study did not witness the use of explosives to blast the hard rocks. However, it was observed that, blasting had taken place at Site A to break rocks into smaller sizes previously, rocks here were quartzite. For Site B and C, the excavator due to its digging power, was able to dig rocks from the earth without blasting. Also, because the rocks were not deep but close to the earth, the excavator was able to lift heavy boulders, dig trenches and move piles of debris in large scale. The wheel loader on the other hand, is a type of tractor which had a bucket with teeth and it was use to scoop, dig and remove gravel and soil then to load the tipper trucks with the materials. Quarry sites are shown in *figure 5* below,

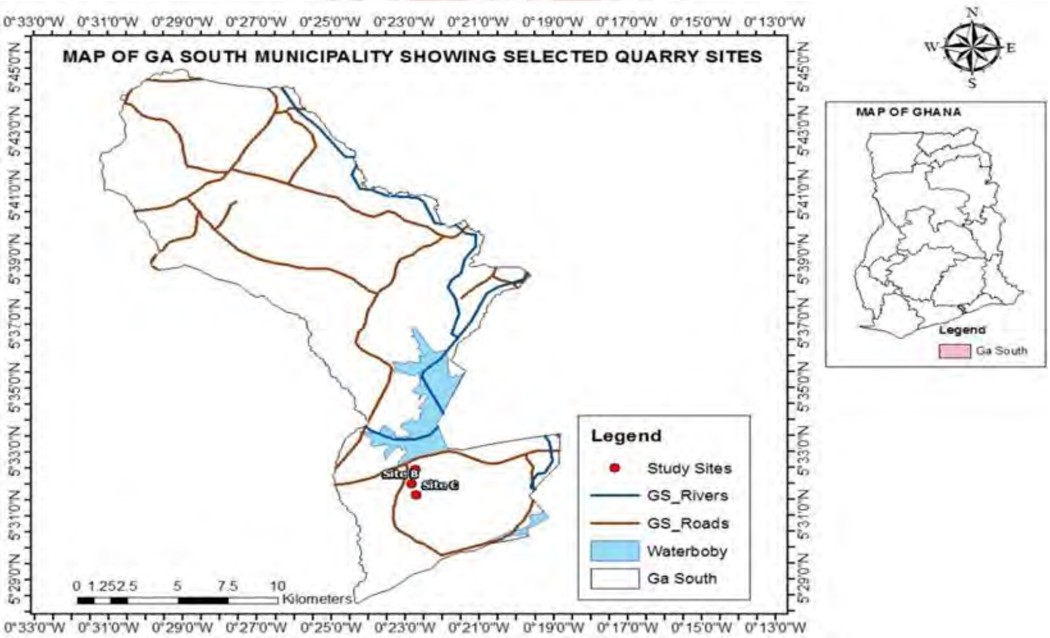

Figure 5: showing quarry sites

Source: Author‘s construct, 2020 (ArcGIS 10.5)

The sandstone was fine grained and had a red ferruginous cement. It is generally very friable and easy to quarry and to carve. They had been metamorphosed into phyllite, and quartz-schist which were deeply weathered and altered by erosion.

Figure 6: Showing quarrying materials at Site B

Source: Field data, 2020

An observation was made on the quantity and volume of quarried materials (sand, gravels and stones) that were being evacuated from the hills. The observation was made from 10am to 4pm for five days. It was observed that two types of tipper trucks: double axel (20 cubic metres) and single axel (10 cubic metres) were loaded with constructional materials from Site C which was operational. For the first day of observation, 11 of the double axel and 5 single axel of tipper trucks were loaded, a total of 270 cubic metres. Day two saw 13 double axel and seven single axels (330 M^3). Day three witnessed 9 double axel and 5 single axels (230 M^3), day four; 14 and 4 (320 M^3) whilst day five had 11 and 5. So for a period of five days, the total volume of quarried materials (sand, gravels and stones) evacuated from quarried Site C stoods at 1,420 cubic metres. The average volume per a day was $284m^3$.

4.1.1 Development of Cracks in Rocks

The study found out that, some rock masses of abandoned quarried sites had developed cracks in them as shown by *figure 7* since the rocks had been exposed and worked on by climatic elements. The cracks on the quarry floor had been widened and deepened by erosion as shown by *figure 8.*

Figure 7: Showing cracks in rocks after being exposed by quarrying at Site A

Source: Field data, 2020

Figure 8: Showing cracks on quarried floor widened by erosion at Site A

Source: Field data, 2020

4.1.2 Change in Topography or Landscape of the Hills

The study found out that, quarrying activities had made various portions of the hills flat leading to expansion in building development and settlement. Also, as the side of the hill was cut off, the original slope had been altered into steep slopes as *shown in figure 9 below.* The topsoil and underlying bedrock had been removed.

Figure 9: Showing portions of the hills that has been become steep due to quarrying and lowered portions prepared for development at Site B

Source: Field data, 2020

Also, the landscape had been destroyed at the excavated portions of the hills. The aesthetic beauty of the hills had also been lost as shown in *figure 10* below.

Figure 10: Showing the destruction of the aesthetic beauty of the Weija Hills at Sites B&A respectfully

Source: Field data, 2020

4.1.3 Change in Elevation

Another important impact of quarrying on the geological structure discovered by the study was a change in elevation of Weija Hills. The study found out that, elevation of the area had shrunk over the years due to erosion. This was caused by absence of vegetation cover and anthropogenic factors such as quarrying. The study showed that the western part of the elevation had been eroded in 2014.

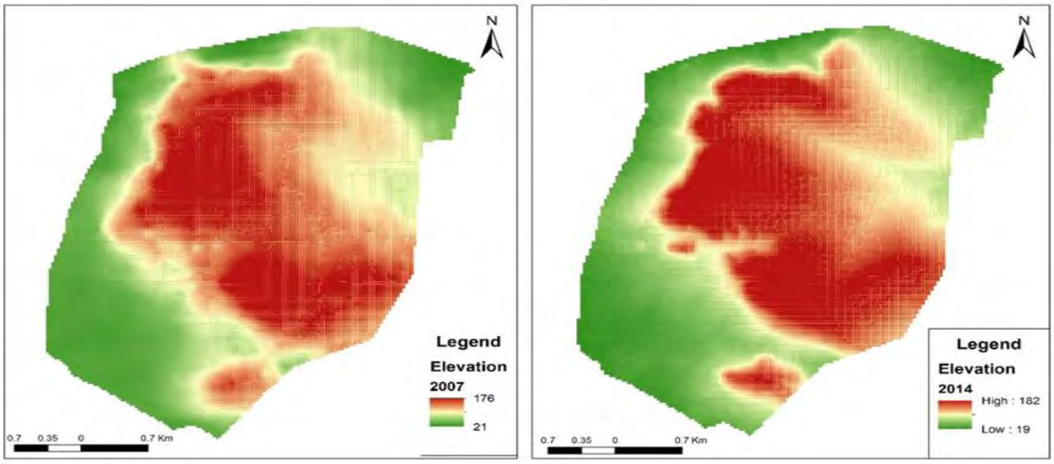

Figure 11: Showing change in elevation

Source: Field data, 2020

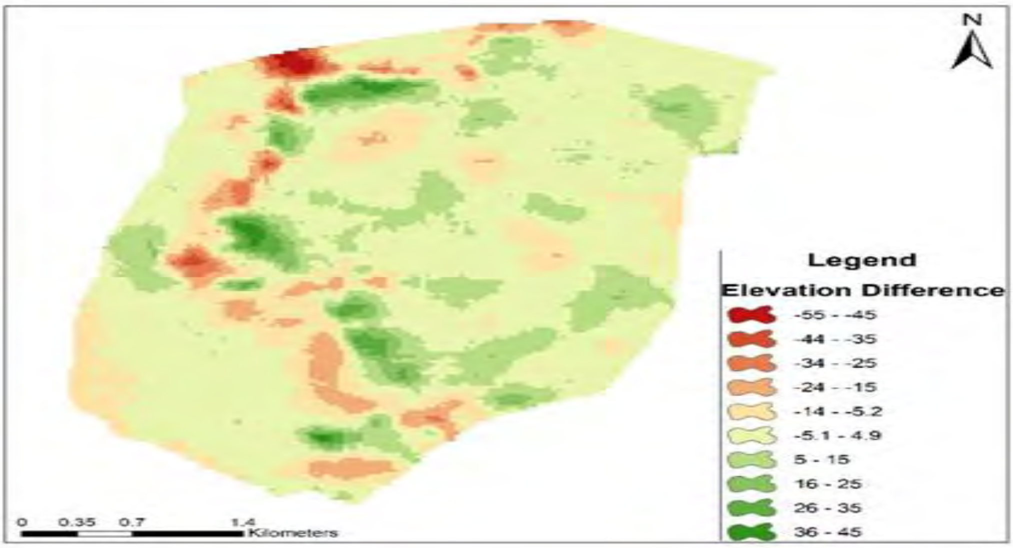

Figure 12: Showing elevation difference

Source: Field data, 2020

Figure 12 above shows the difference in elevation from 2007 and 2014. The figure revealed areas of erosion and deposition. The deep red signifies erosion while deep green portrays deposition. The study revealed that over the period, from 2007 to 2014, there had been about -55m loss of height in study area. Areas around the apex of the hills with light green to deep green portrays areas of deposition.

4.2 Extent of Change to Local Environment

This section addresses the land use and cover distribution of the study area to analyse the changes that had occurred over the period under study.

4.2.1 Land cover distribution and change

The land cover distribution of the Weija Hills is shown in *figure 13* below for the years 1991, 2003 and 2020 which were being reviewed for this study. The land cover distribution was grouped into three classes namely; Built up areas, Bare land and light vegetation.

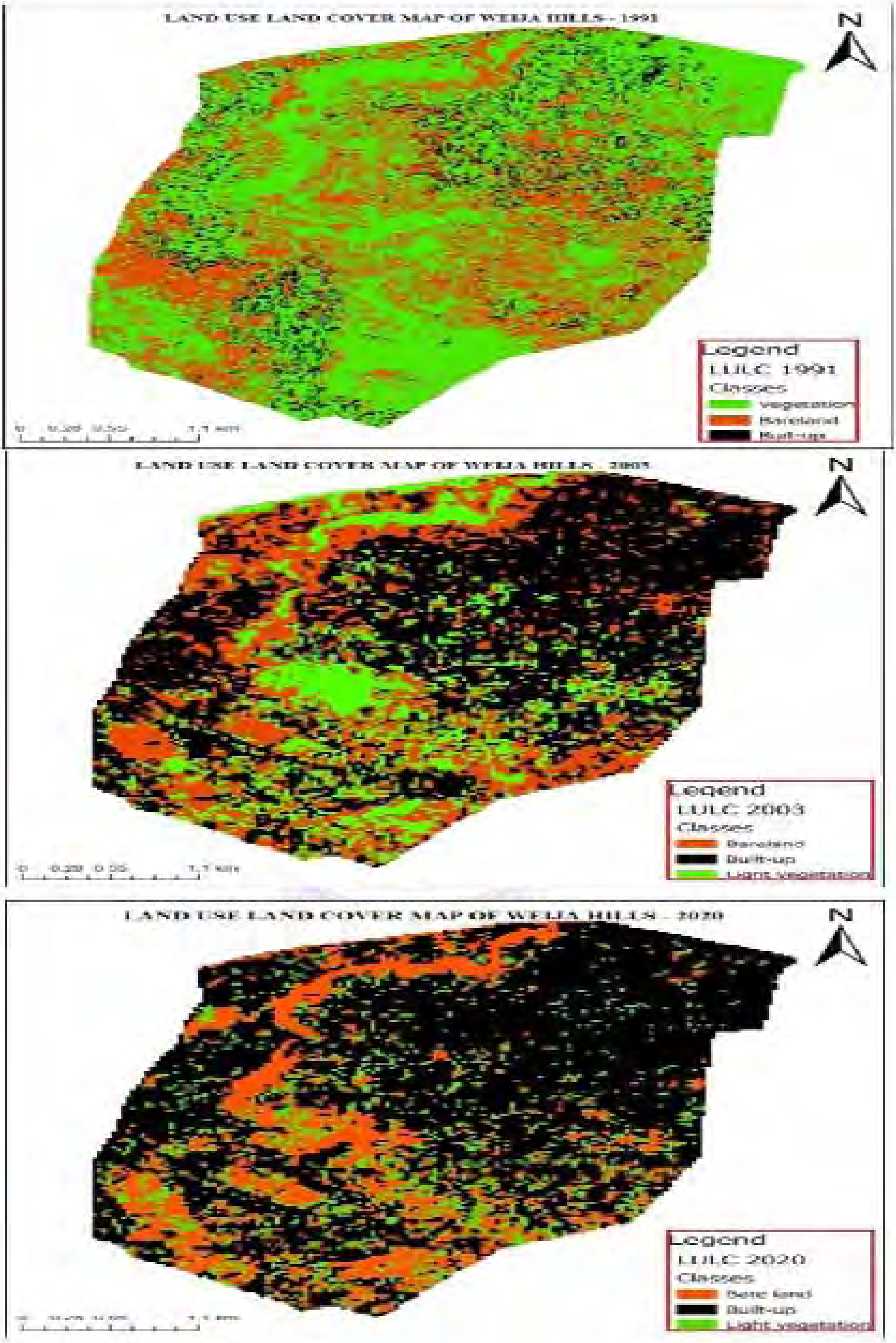

Figure 13: Land Use Land Cover Maps of Weija Hills for 1991, 2003 and 2020

Source: Author's Construct from Landsat Images of 1991, 2003 and 2020

The land use land cover distribution for the years 1991, 2003 and 2020 for the study followed different patterns in terms of the domineering features for the various years. The direction of flow of change for the various land use land cover types was consistent from one year to another either increasing or decreasing. The land use land cover distribution, according to the study in 1991 revealed that, Light vegetation was the domineering feature type of 9.913081 square kilometres (61.3%), followed by bare land and built-up areas that recorded 5.090561 square kilometres (31.4%) and 1.173698 square kilometres (7.3%) respectively. The land use land cover classes in 1991 showed a vast land covered by vegetation with built-up being the least feature type. This can be attributed to the reason that the area was used as a farm land by the Nkrumah government in the 1960s. Thus, the land became a state land from that period forward. There were few bare lands in the area and some people had settled there. Later, when the lands were abandoned and not used any longer for the intended purpose for which the state had taken them, the lands were returned to the chiefs and they sold them to the public.

In the year 2003, the land use land cover distribution saw built up become the domineering feature type increasing by 598.02% within a 12-year period of 1991 to 2003. Built-up areas covered 8.1927 square kilometres (50.7%) of the entire area. Bare land areas within the same period of 1991 to 2003 marginally diminished by 4.74%, covering an area of 4.8492 square kilometres (30%). Vegetation within the same period hugely decreased by 68.61% as it covered an area of 3.1113square kilometres (19.3%) in 2003. These changes to the land cover in 2003 could be ascribed to the handing over of the state land to the indigenes in the early 2000. This led to the selling of the land in plots to the public who also transformed the area into buildings. This explains the drastic decrease of the vegetative cover in the area. In

2020, the land use land cover feature type of built-up areas continued to be the domineering feature type further increasing by 28.38% within the 17-year period of 2003 to 2020. Built-up areas covered a land area of 10.5174 square kilometres (65.1%) in 2020. In all, within the 29-year period (1991 to 2020), built-up areas increased significantly by 796.09%. Bare land areas further decreased within the 17-year period by 25.87% covering an area of 3.5946 square kilometres (22.3%) in the year 2020. Light vegetation, also further decreased by 34.39% while it covered a land area of 2.0412 square kilometres (12.6%) in the year 2020. Thus, bare land and light vegetation suffered major losses to their coverage between the years 1991 to 2020, a 29-year period. Bare land areas and light vegetation decreased significantly by 29.39% and 79.41% respectively. The figure below illustrates the net change in the various land use land cover feature types between the years 1991 to 2020.

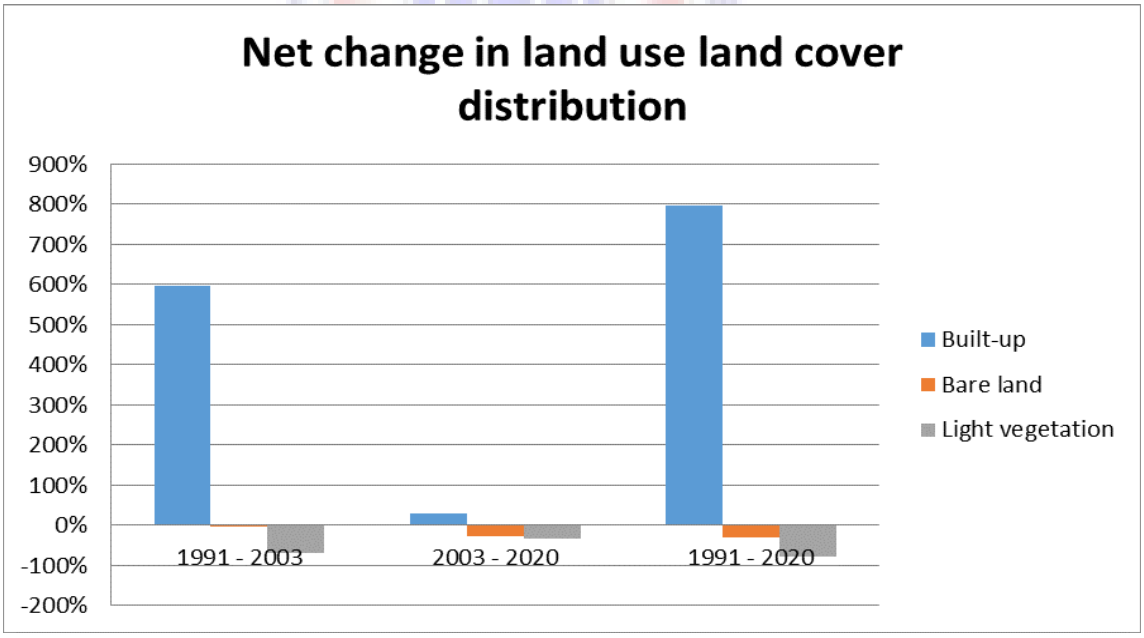

Figure 14: Net change in land use land cover distribution

Source: Author‘s Construct from Landsat Images 1991, 2003 and 2020

The study revealed a general decrease in both bare land areas and light vegetation over the 29 years between the years 1991 and 2020 as shown in figure 14 above. A concurrent increase in built-up areas in the opposite direction to bare land areas and light vegetation with an overall increase of 796.09%. The various changes to the land use land cover types in terms of land coverage were also addressed. In general, the land use land cover type of built-up areas expanded in term of land area by 43.4% from 1991 to 2003 and a further gain of 14.4% between the years 2003 to 2020, that is, 17 years.

Table 6: Land cover change percentage distribution

Land cover type	**1991**	**2003**	**2020**	**Percentage change (%)**		
	km²	**km²**	**km²**	**1991-2003**	**2003-2020**	**1991-2020**
Built-up	1.173698 (7.3%)	8.1927 (50.7%)	10.5174 (65.1%)	43.4	14.4	57.8
Bare land	5.090561 (31.4%)	4.8492 (30%)	3.5946 (22.3%)	-1.4	-7.7	-9.1
Light vegetation	9.913081 (61.3%)	3.1113 (19.3%)	2.0412 (12.6%)	-42	-6.7	-48.7
Total	**16.2 (100%)**	**16.2 (100%)**	**16.2 (100%)**			

Source: Author‘s Construct from Landsat Images 1991, 2003 and 2020.

With reference to bare land areas, the feature type experienced a flow in direction opposite to that of built-up areas. Bare land areas recorded a marginal decrease in terms of land area losing 1.4% of its area to built-up in the year 2003. Another loss of area to built-up by bare land areas in 2020 accounted for a further decrease of 7.7% of the area covered by bare land in 2003. Finally, light vegetation covering 61.3% of the total land area of the Weija Hills experienced decline in its area losing potential resources to built-up area. Light vegetation lost a substantial land area of 42% of its original 61.3% to built-up areas in 2003 and subsequently losing an extra 6.7% to built-up in 2020. Within the 29- year period of 1991 to 2020, bare land areas and light vegetation lost a total of 9.1% and 48.7% respectively of their original land areas as at 1991. Built-up areas within the same time period gained an additional land area of 57.8% to its original area of 7.3% in 1991. This result could be attributed to the continuous development of the area as individuals put up private homes alongside estate developers (Table 6).

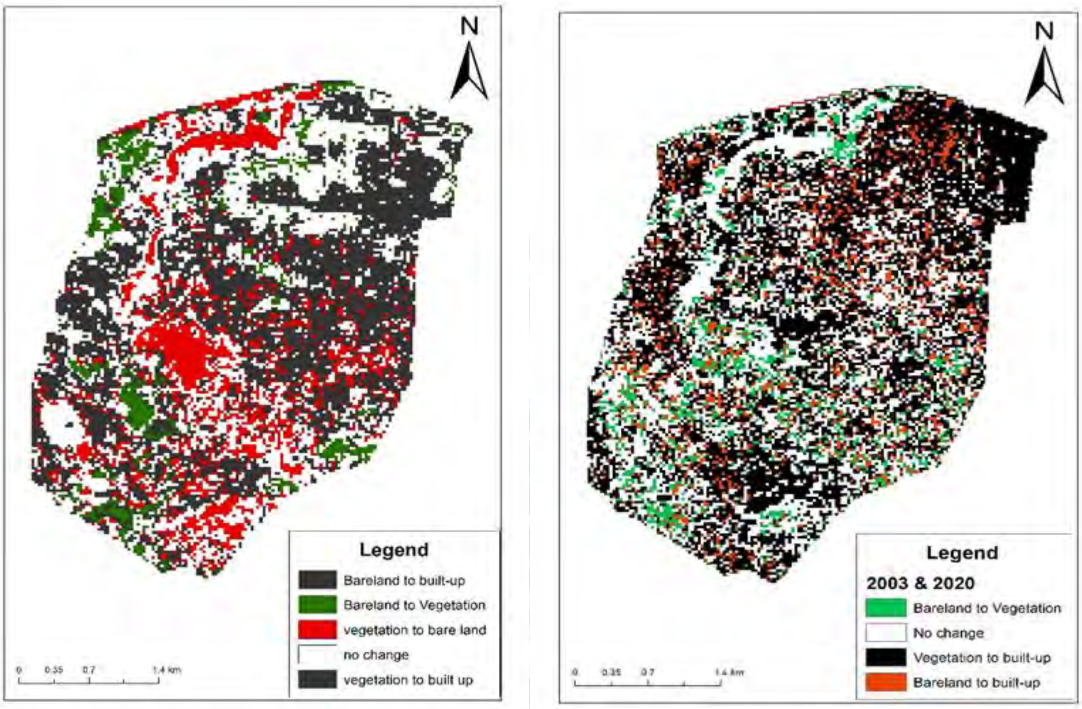

Figure 15: Showing an overlay analysis of vegetation distribution and change

Source: Author‘s Construct from Landsat Images 1991, 2003 and 2020.

Satellite images taken from Google Earth for the years; 1990, 2010 and 2020 also showed a drastic change in land use land cover over a period of thirty years as shown below in *figure 16.* In 1990, the Weija Hills was covered with vegetation and had few bare areas. By the year 2010, the hills had lost its vegetation cover to development, that is, built-up. By 2020, the few green areas had also been developed. The study found out that, this development had been made possible because, the hill was quarried and made plain for settlement.

Figure 16: Land Use Land Cover Maps of Weija Hills for 1990, 2010 and 2020

Source: Image Landsat/ Copernicus on Google Earth

4.2.2 Changes to local environment attributed to quarrying activities

The section reveals the various environmental changes at the Weija Hills due to quarrying activities in the area. The study observed the combination of erosion, loss of vegetative cover, deteriorating roads and loss of agricultural lands, disaster potential, open pits and dust were the major environmental effects of quarrying on the study area. The clearing of vegetation for quarrying activities around the Weija Hills had made the local environment bare causing various forms of water erosion. Anytime it rained heavily, the Kasoa to Mallam side of the highway (Site A) of the study area was always blocked by the eroded materials which flooded the road making vehicular movement virtually impossible unless the Authority (the Municipal assembly or Ghana Highways) came to clear the road of the sediments. Also, a portion of the recently constructed Tuba road has deteriorated because sediments from quarried Site B fills the drains and blocks it, as a result, rain water floods the road which has destroyed it within a short time. Again, the eroded parts of the hills had developed gullies and this could also be said of all the untarred roads which developed very rough rocky surfaces after downpours.

Figure 17: Examples of environmental effects on the Weija Hills and environs

Source: Field data, 2020

4.3 Stability of Local Geology

This section provides results of what had happened to the hill (geomorphic impact) as parts of the rocks were being taken. Slope instability can be inherent; such as weakness in the composition or structure of rock or soil, variables such as heavy rain, snow melt and changes in ground water level; transient such as seismic or volcanic activity or due to new environmental conditions such as those imposed by construction activity. This section studies the means by which any change in slope caused by any of the factors listed above could cause slope instability using only Site A.

Figure 18: Site A of the Weija Hills Used for slope stability analysis. (The image is not drawn to scale.)

Source: Golder Associates, 2017

4.3.1 Hydrogeological condition

The slopes of Weija Hills were assumed to be pressurised by a water table approximately 3m below ground surface. This is a conservative assumption developed based on the field observations of the site, and the commonly accepted understanding of prevailing groundwater typical of such settings.

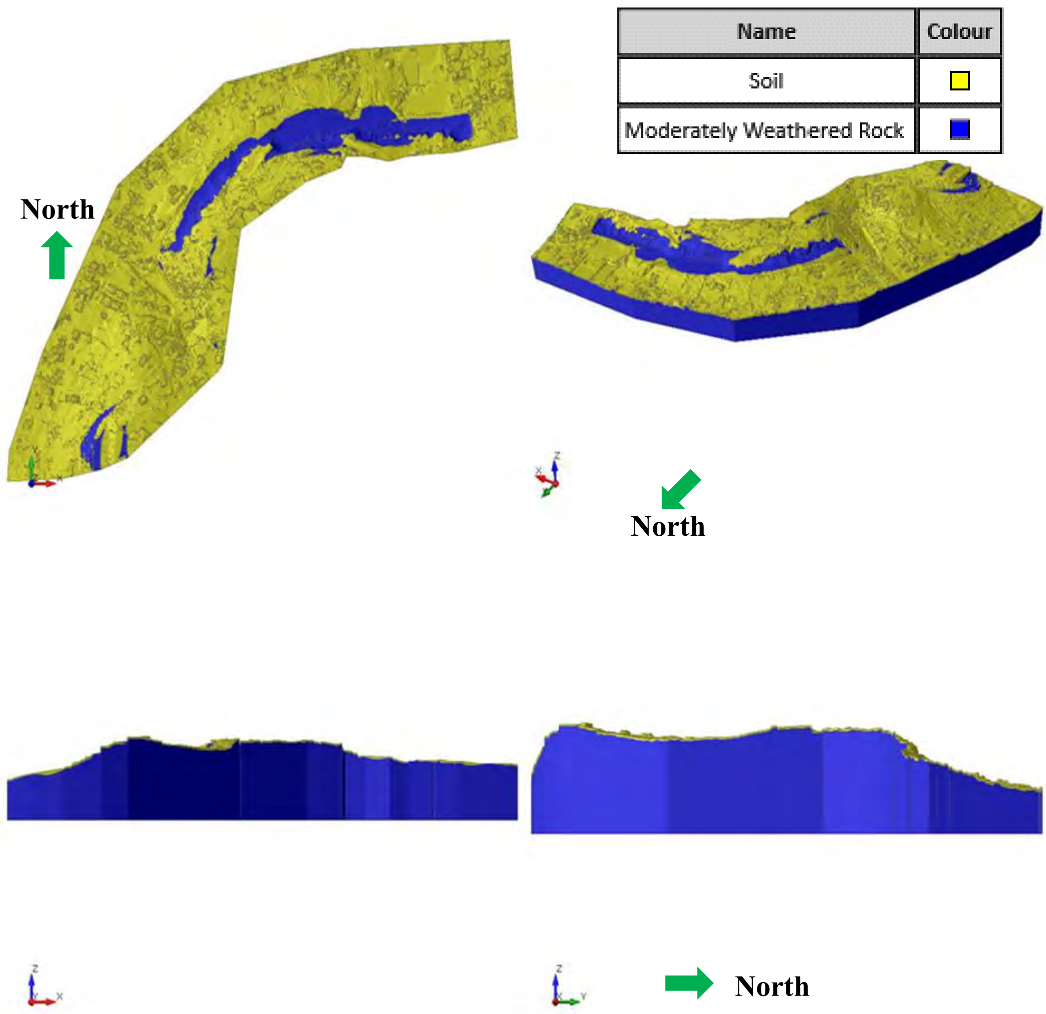

Figure 19: Images showing the plan, perspective and side views of the 3D slope model of quarry site A. In each of the views, North is parallel to the y-axis.

Source: Author‘s Construct, 2020

The modelling showed that the exposed walls created from quarry activities did not show any evidence of groundwater or seepage, that is, the faces were dry. The walls of deep erosion channels at the site were also dry. These indicated a water table that was at least the height of an exposed face below the ground. Typical of the tropical environment, the water table was situated within the highly weathered zone of rock materials or at the top of the moderately weathered zone. Observation of the exposed quarry faces indicated that the depth of the highly weathered zone did not exceed 5m. The materials extracted from the quarries seem to have ranged from moderately weathered to slightly weathered rocks. The fact that the extracted materials were used for construction indicated that the rocks were competent (and of high strength) even when weathered. This is consistent with the understanding of the formation of the mountain, a zone of competent rock that weathered much more slowly than surrounding rock and thus became a mountain.

4.3.2 Geotechnical properties

Geotechnical strength parameters used in the analysis were estimated from the ranges for weathered quartzite. The Weija Hills are made up of quartzite-based rock. Such rocks were formed under high temperatures and pressures, which made them strong with minimal pores. Quartzite rocks in the Accra area are bedded (show parallel sets of thinly spaced joints). They weather slowly and therefore project as mountain ridges with thin and barren soil cover. Quartzite are very competent, and resistant to weathering. Quartzite are commonly quarried for construction aggregate material. The study found from the Ghana Geological Survey Department drilling data, the topsoil was 1m deep, and the weathered profile extends to depths of 50m. In the current modelling, topsoil was conservatively assumed to be 3m in thickness. The moderately weathered profile was modelled in *figure 20* below.

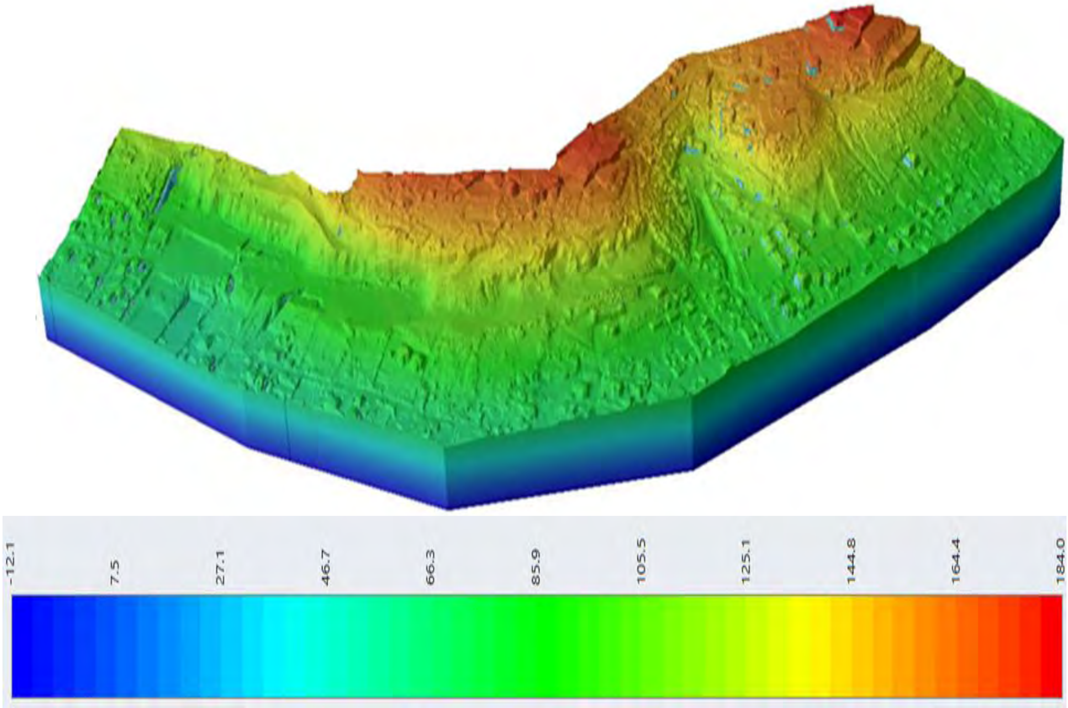

Figure 20: Contouring of the model site showing the elevations of the site.

Source: Author's Construct

4.3.3 Surface water effect on slope stability

The results showed the effect of surface water on slope stability. When surface water flows fast (which is typical of steep slopes), it could combine with vegetation loss to erode slopes. Significant erosion from this combination was evident in several areas of the Weija Hills where quarrying had been carried out. With time, erosion could cause small localized failures. If unchecked, this erosion could lead to larger slope failures.

Table 7: Factor of safety of slope stability

Scenario	Factor of Safety		Acceptance Criteria
	Bishop	**Janbu**	
Base Case	1.88	1.83	1.6 or 2.0
Seismic Stability	1.82	1.78	1.0 – 1.2

Source: Bishop, (1955) and Janbu (1954)

The study showed that, Site A of the Weija Hills though seriously eroded, it was still stable. A smaller portion showed less stability which does not mean it is unstable. A pseudo-static overall factor of safety of 1.88 was obtained for the critical cross-section, which is higher than the acceptable threshold of 1.6 according to Bishop (1955) and (Janbu, 1954). From *table 7* above, the acceptable criterion for permanent slopes with moderately serious failure consequences is 1.6, while the criterion for very serious consequence failures is 2.0.

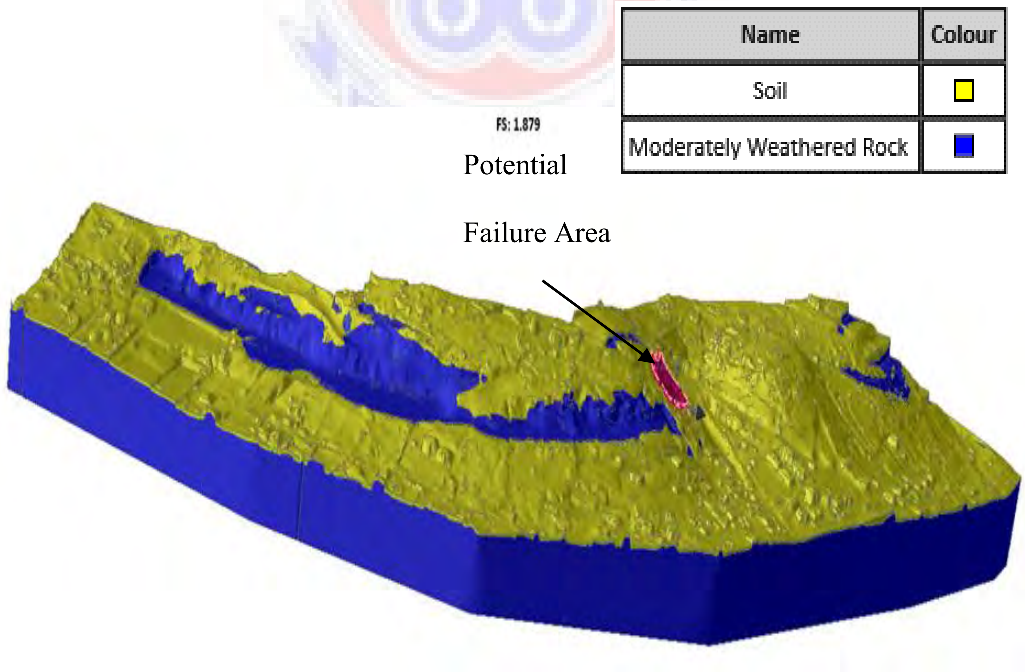

Figure 21: Critical failure mechanism and location. The purple coloured patch on the image shows the potential failure area.

Source: Author‘s Construct

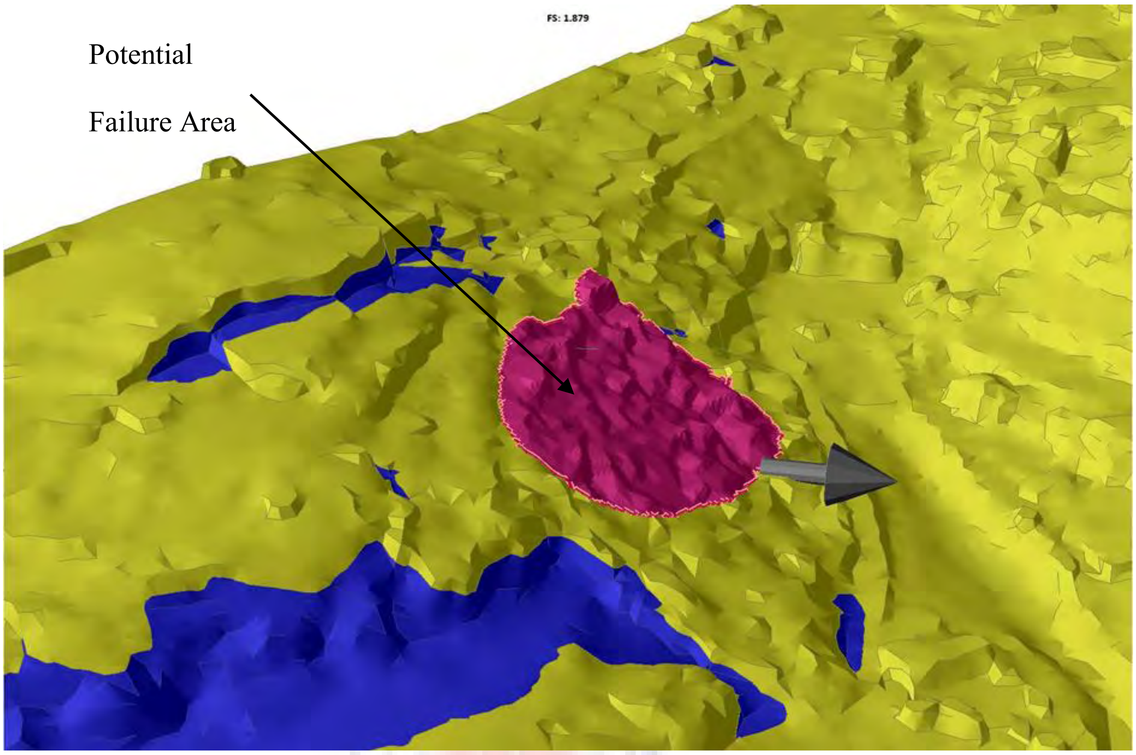

Figure 22: Close up of critical failure mechanism

Source: Author's Construct

4.3.4 Seismic considerations

The study also, as a result of the underlying condition of the area as an earthquake zone studied the seismic conditions of the area with reference to its slope stability. Earthquakes could cause slopes to fail. For the analysis of the Weija Hills slopes, the potential impact of earthquakes was considered through the pseudo-static method of seismic analysis. The zone of the critical failure is shown in red below (fig. 23).

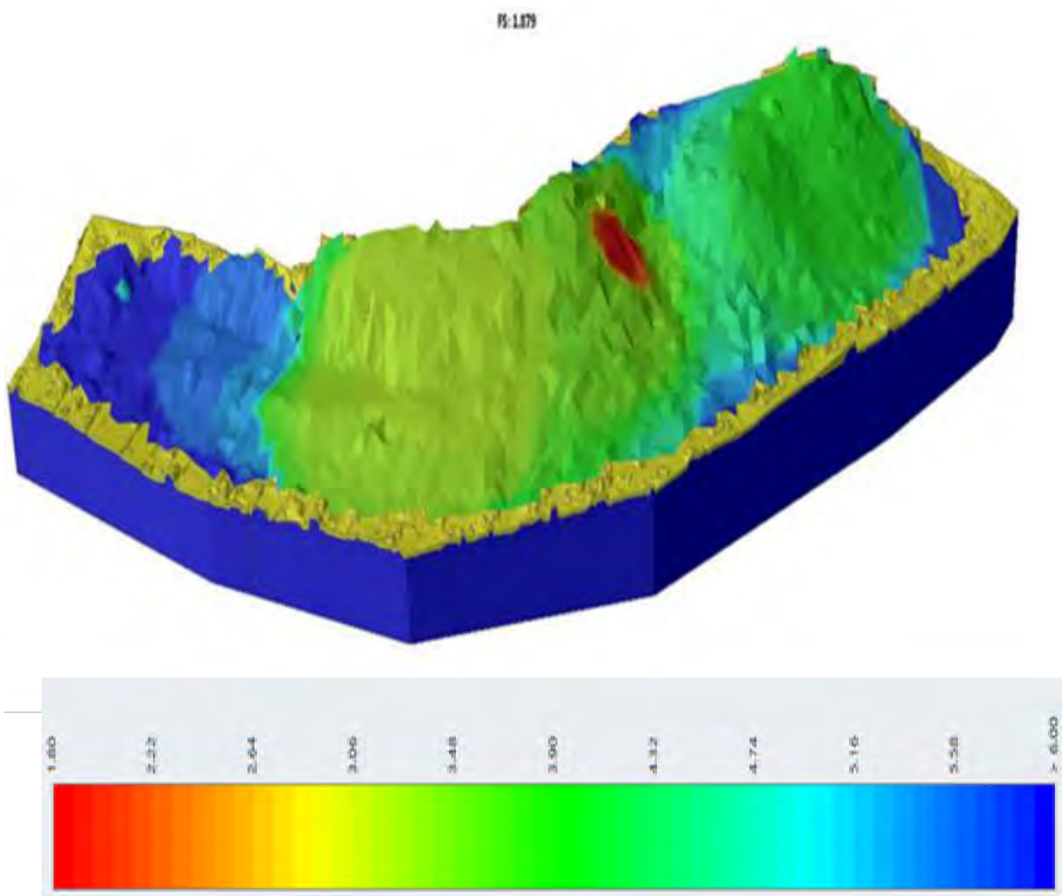

Figure 23: Safety map of the modelled area

Source: Author‘s Construct

The pseudo-static method of seismic analysis uses blocks of materials which were assumed to experience additional forces due to horizontal accelerations induced by earthquake shaking. A value of half the Peak Ground Acceleration (PGA) from the seismic map of Africa for western Accra area was used for the pseudo-static slope stability analysis. This translated into a horizontal acceleration of 0.026. This is standard practice for pseudo-static stability analysis. Typically, computed pseudo-static factors of safety between 1.0 and 1.2 are considered as acceptable for natural, cut, and fill slopes (Bray & Travasarou 2011). The seismic map of Southern Ghana is shown in figure 24.

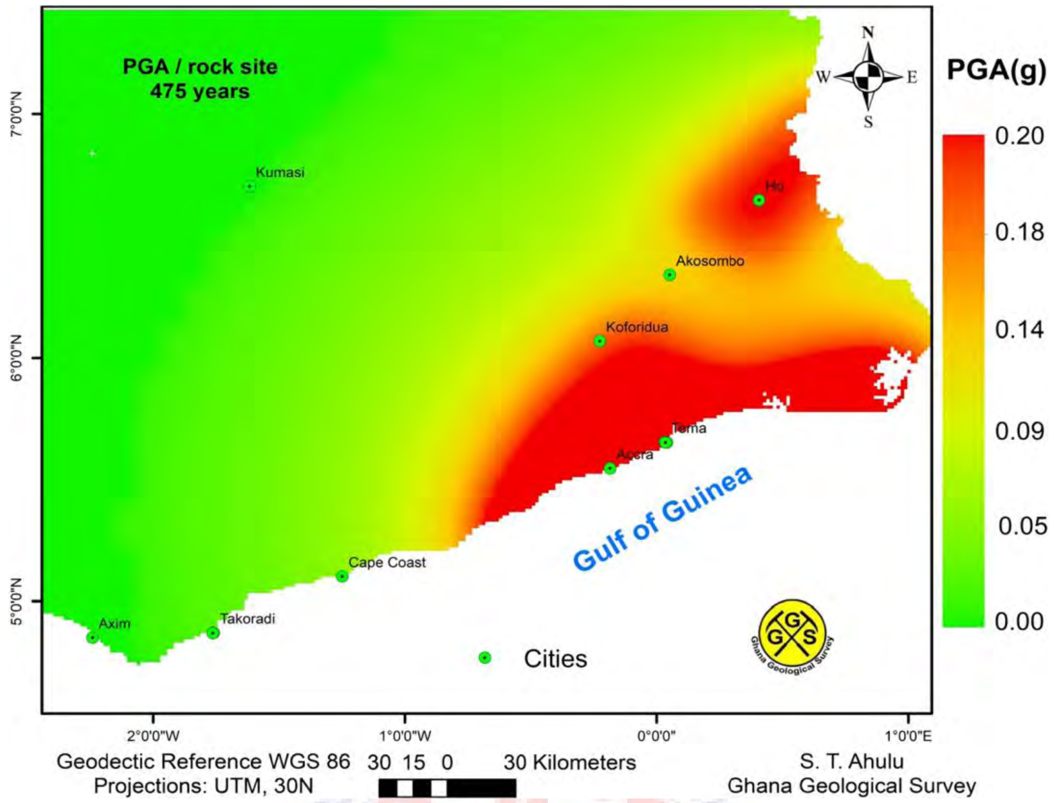

Figure 24: The Seismic hazard zones for southern Ghana

Source: Ghana Geological Survey

4.4 Summary of the chapter

This chapter presented the findings of the study based on the research questions. It linked the data collected through literature and field observation after which conclusions were made concerning the effects of quarrying activities on the Weija Hills.

CHAPTER FIVE

DISCUSSION

5.0 Introduction

This chapter discusses the results or findings of the research in relation to previous studies.

5.1 The type and Method of Quarrying used at Weija Hills

The study used three quarrying sites at the Weija Hills. The activities involved the extraction of rocks for aggregates (constructional materials-sand and gravels). The main methods used in the extraction of rocks were excavating and crushing of rocks. The initial process employed in quarrying was the process of excavation. This was done following the discovery of a suitable mother or burden rock, which was deemed exploitable by the quarries. This process was employed when the rock to be quarried were lying buried in the earth or under loose overburden rock. The activity becomes necessary to expose the overburden rock and made the exploitation of the rock product possible. And this was done by the excavator. After this, then crushing of the rocks was done. Crushing involved the breaking down or the disintegration of rock products into desired sizes and aggregates which was dependent on the type of rocks. This finding was in line with the findings of Ata-Era (2015) that, excavating and crushing were quarry methods used by several quarrying companies in Wenchi. This finding also shows that, not all quarries use the blasting methods to break down rocks. Although blasting is very common in many quarrying fields, it did not always apply as in the case of the study area.

5.2 Impact of Quarrying on the Geological Structure

The quantity of quarried materials being evacuated from the hills was averagely 284m^3 per a day which is very dangerous for a fragile slope such as the Weija Hills. This observation was for only Site C which was the only site in operation among the three sites used in the study. In a year (365days), the hills lose as much as 103,660 cubic metres of constructional materials. This figure would increase as demand also increases. There were other operational sites that were not considered in this study due to limited time and distance. Taking into account that the rate of regeneration is slower and cannot compensate for the quantity taken, this definitely would have an impact on the geology and slope as well as elevation of the Weija Hills.

Also, the study found out that, the features of the Weija Hills have been degraded. This is in line with the assertion made by Power & Power (2013) that, because mineral extraction tends to be land intensive, it imposes a disruptive footprint on the natural landscape and contributes to significant environmental degradation. The study found changes in some initial geological parameters on the Weija Hills due to quarrying activities. For instance, there had been a change in the slope of quarried sides of the Weija Hills. The slopes have become steeper which accelerate the speed of rain water and thereby carrying lots of sediments (weathered and eroded materials) downslope. The rate of soil erosion was observed to increase with slope due to high velocity and erosivity of the runoff. Other portions of the hill have been made flat to pave way for building development. This, with time have reduced the size of the hills.

The study also observed that the exposed rocks had been weathered and some had developed lines of weakness or cracks in them. To get access to the rocks, the vegetation covering rocks were removed. The removal of protective vegetation and the top soils increased the surface area of rocks and exposed them to the agents of weathering such as rain fall and temperature. The rocks get heated by daily temperatures during the day due to the absence of vegetation cover causing rocks to expand and contract, increasing the stress on the lines of weakness and causing them to break down (physical weathering). The study also found that, lines of weakness developed on quarried floor were gradually being enlarged. Also, exposure of rocks to rain water will increase the rate of chemical weathering by altering certain minerals in the rocks. This chemical process can further weaken rocks, making them more susceptible to other forces. For example, some Saprolite and phyllite were identified at the quarried sites. This meant that the original bedrock had been completely weathered, the rocks contained soil-like materials.

Once weathering had damaged the rocks and broken them down, it had become easy for the forces of erosion to take over, hence, most rocks had been eroded. The major underlying factors affecting the rate and severity of soil erosion were precipitation, topography, soil characteristics, and vegetation/land cover changes. This has resulted into rain water carrying large quantities of eroded materials to the main road annually. The other dominant cause of soil erosion in the area are the spatial and temporal changes in land use/cover types and conversions resulting from anthropogenic activities. This finding is consistent with Grosic et al (2013) who found out that, the Torine open pit quarry was characterised by faults and the failure had resulted from cracks and massive weathering. Also according to Mngeni et al (2016) that, clearing of vegetative cover as a result of sand mining can trigger micro-climate variation and also expose buried rocks to the atmosphere and the rocks begin to weather.

Again, the study observed that, there were thin layers of top soil at Sites A & B. The soils had been lost to quarrying. This would further affect the soil profile of the area. Rocks covered by vegetation or soils may weather slowly as compared to those without any covering. The aesthetic qualities had also been compromised. Such destruction of land because of quarrying therefore changes the land surface. Quarrying pits can significantly change the topography and stability of the landscape. A study conducted by Ako et al (2014) in Luku, Nigeria confirmed that, landscape destruction is one of the significant effects of mining in the area. The original landscape had been destroyed and altered as a result of excavated pits and trenches, leaving behind unpleasant sights. This is to say that, the extraction of geological materials from the Earth, is inextricably tied to geomorphology and that, activities associated with extracting substances from near the surface create planed landforms and landscapes. The US Geological Survey (2001) report supported the above findings that, quarrying has an associated visual impact and usually a change in geomorphology. The survey further explained that, the extent of the geomorphic impact of quarrying on the geology largely depends on the size of the quarry, the number of quarries, and the location of the quarry, especially with respect to the overall landscape and the local landforms. This study found out that quarries at the Weija Hills were wide spread and had led to changes geological structure of the hill. The work of Gunn and Bailey (1993) stated that quarries on hills generally have a large geomorphic impact.

Another important finding discovered by this study was a change in elevation of the Weija Hills. The study found out that, there had been an elevation loss of -55m between 2007 and 2014 as a result of massive erosion. Soil protection is very significant controlling factor in erosion. This change could be as a result of anthropogenic factors such as quarrying for constructional materials and land use land cover changes. Quarrying makes soil and rock particles lose because the removal of vegetation destroys the binding of soils to bedrock by tree roots. As a result, these unconsolidated materials are being gradually worn away by rainwater. As rainwater passes across land or rocks, it carries these grains of soil and other forms of rock particles away. Several years of such occurrences reduce the size of hills and mountains, and it cuts through the ground to create large gullies such as in the case of the study area. Change in the elevation of the Weija Hills can also be connected to the rate of urbanisation that had led to an increase in the demand of land for building development. The study found that, there had been massive expansion in the area which encouraged further flattening of portions of the hill for building constructions. This finding is supported by Reynard et al (2017) that, urbanization is a vector of relief transformation and that artificial landforms are sometimes created by fillings to eliminate slopes and to facilitate mobility. They added that, even though landforms provide goods and services to cities, they sometimes lead to hazards due to poorly controlled urban expansion. This is confirmed by Li, Qian & Wu (2014) that, China's mountain flattening program carried out to build new cities, created several hydrological and geomorphological impacts such as landslides, subsidence and soil erosion. Therefore, continuous cutting off portions of the Weija Hills may in the near future have a greater geomorphological impact on the hills.

5.3 Environmental Effects

This section discusses the effects of quarrying on the environment as the extent on land cover, land use and other related effect on the environment.

5.3.1 Land cover distribution and change

The land cover distribution and change of the Weija Hills were assessed in this study for the years 1991, 2003 and 2020. The land cover was apportioned into three classes namely; vegetation, bare land and built-up. The analysis of the land cover area of the Weija Hills in 1991 revealed a vast land covered by vegetation with few built-up. This was because the area was used for agricultural activities (state farms) from the 1960s to the 2000s but the land was later returned to the Bortianor stool. From hence, the lands were sold to estate developers as well as individuals. At this same time, quarrying activities had been started at various portions of the field leading to bare land and subsequently, to built-up. Bare lands should have had a corresponding increase with vegetation loss but that was not the case at the Weija Hills. This is because, all bare lands were immediately development for housing and other infrastructure. Meanwhile, quarrying activities were extended to other places on the hills over the years including sites. By 2020, built-up in the area had increased than any other land cover class. Some of the bare lands were also being prepared for buildings development. This type of LULC changes typically contributed to the widespread and highest quantities of soil erosion.

Quarrying activities had lowered the land and made it suitable for building. This had changed the greater part of the study area from light vegetation to built -up. As mentioned already, the rate of development on the hills had been drastic within a span of twenty-nine years. This might be attributed to the fact that Ga South Municipality is one of the fastest-growing areas of Greater Accra region due to general population growth in the city leading to expansion (Ga South Municipal Assembly report, 2018). Since lands in the city of Accra were expensive, most people turned their attention to the western part where lands were readily available at a relatively cheaper cost. This growth has led to a corresponding infrastructural development and various livelihood strategies such that, an area which should have remain a buffer zone due to its geological weakness had to be developed. This is an indication that there is significant impact of population and its development activities on LU/LC change. This expansion also means an increased load on the hill, adding to the stress of the hill.

Also, the quarries provide constructional materials for most buildings in the study area. This ready market also motivates quarry contractors to increase production without thinking about the negative effects it could bring to the hills. This finding is in consistent with Musah (2009) in Nigeria, Tagoe (2005) and Salifu (2016) in Ghana that, several farmlands have been converted to quarrying sites where commercial sand and gravel extraction were done to supply aggregate to the construction industry. Ata-Era (2015) also supported the view that, continuous quarrying had reduced farmland in Wenchi since the activity had proved to be a fast income generation venture. Consequently, a lot of trees and vegetation cover had also been cleared in various places to make way for sand mining activities. Salifu (2016) and Musah (2009) added that the conversion of farmlands to quarrying sites had to a large extent contributed to the loss of fertile soils, land degradation and desertification through the destruction of economically important trees, mostly indigenous in nature. This view confirms the views of Aromolaran (2012) who stated that, in the Ogun State of Nigeria, the activities of sand mining had led to the loss of vegetation and forest cover.

5.3.2 Open Pits

Open pits were one of the effects of quarrying activities identified by the study at the local environment of the Weija Hills. As mentioned above, the method used in quarrying in the study area is the open-pit method. As a result, some pits were left behind which collected water during the raining season and serve as breeding grounds for mosquitoes and other insects. This finding is supported by Ata- Era (2015), Salifu (2016) in Ghana and Mngeni et al (2016) in South Africa that, quarrying leaves behind open pits, bare soil and a large expanse of gullies which collects water during rainy seasons.

5.3.3 Dust

The issue of dust was also identified to be associated with quarrying activities in the study area. Most of the roads leading to quarry sites were untarred. It was observed that, due to the hilly nature of the area plus the load, truck drivers often drove with a speed which blew a lot of dust into the atmosphere. Dust also occurred from the excavation and crushing of quarry materials. Quarry dust settles on land, leaves of trees and plants. This finding is in line with the views of Howard and Cameron (1998), Langer (2001) and Eshiwani (2007) that, dust is one of the most visible, invasive, and potentially irritating impacts associated with quarrying usually produced from roads, blasting, drilling, crushing and screening. Also, Madyise (2013) asserted that dust particulates from quarries that result from the disintegration of rocks can cause air pollution when it remains in the atmosphere for long.

A study carried out by Nartey et al (2012) in the Lower Manya Krobo District of the Eastern Region of Ghana which assessed the environmental effects of limestone quarrying on some selected communities in the study area by measuring Particulate Matter (inhalable particles) from three monitoring stations every three months indicated that, there were noticeable increases in dust-related diseases since the quarries started operating in the study area. This finding confirms the view that, quarrying activities generate dust and it is dangerous to human health.

5.3.4 Deterioration of the road

The study found out that most roads leading to quarry sites were in a very bad state. All the roads were untarred and had very rough rocky surfaces. The roads easily wear off as a result of the volume of constructional materials the truck is carrying. Tagoe (2005) confirms this finding that, heavy-duty trucks often destroy roads leading to mining sites in communities. Pools of water collected by manholes created in the raining season force their way through parts of the roads eroding them and making them unmotorable.

5. 4 Slope Stability of Weija Hills

Using the available data such as the type of rocks, observation of quarries, assumption of surface and groundwater levels and other factors, the study discovered that, the slope of the local geology of the Weija Hills is stable. A relatively small portion of Site A showed less stability with 1.88 as its factor of safety. This is within the acceptable range of 1.6 for areas with moderate failure consequence (Priest & Brown, 1983) provided in chapter two. That is for a moderate impact should there be any failure. Also according to Janbu (1954) and Bishop (1955), a serious failure consequence area, for instance highly populated or area with activity should have a greater factor of safety; 2.0 or more since in case of failure, the impact would be much greater. This finding is supported by Mazzoccola & Hudson (1996); Nelson (2013) that, in a normal circumstance, the minimum factor of safety of a stable slope could have is 1.0. Hence, the higher the ratio, the higher the stability of a slope. Considering the location of the Weija Hills, it is a high consequence area because it is very close to a major high way, and also highly populated area. Therefore, a much greater factor of safety is needed to ensure its continued stability and prevent any future slope failures.

5.5 Imminent Slope Failure

The findings above revealed enormity risk factors in the study area; the quantity of materials being evacuated from the hills, the gradient of the slope of the Weija Hills had been made steeper and the occurrence of serious erosion as a result of quarrying and anthropogenic activities, exposes the hills to great risk if things remain the same. Erosion had produced large gullies and resultant unconformities on the Weija Hills especially at quarried Sites which had been abandoned for some years now without any reclamation. Also as stated above, the absence of vegetation increases infiltration of water which in turn reduces cohesion of rocks and soils upslope. This could cause the movement of larger masses of rocks or soils that are detached to move downslope. Again, the study found out that, apart from those factors listed above, the level of development (built-up) on the Weija Hills may also increase weight at the crest of the hills causing more stress to the hills.

The Ghana Geological Survey Authority also confirmed that slope instability on the Weija Hills may be triggered by the distribution of weight along the slope. Load on the top of the slope may have a great influence on stability. Likewise, cutting the slope at its base diminishes the defence of the lower layers underneath and this may promote sliding conditions. It must be noted here that, the main forces responsible for mass movement is gravity and sheer stresses. Gravity is the force that pulls everything on the Earth‘s surface in a direction toward the centre of the Earth. On a steeper slope, the tangential component of gravity increases, and the perpendicular component of gravity decreases (Nelson, 2013). Sheer stress in rock mass may increase due to additional loads at the top of the slope and increase in water pressure in cracks at the top of the slope, increase in soil weight due to increased water content, excavation at the bottom of the slope and seismic effects. Also, continuous quarrying and construction in the study area could disturb the isotactic stability of the geological arrangement of rock particles. When this happens, it gives room to high possibility of slope failure. Already existing fault lines may also be expanded, this will lead to slope failure.

The issues raised above corroborate with LaMoreaux and Newton (1986) that, the removal of vegetation allows increased infiltration and that deprives the soil of its root material. Also, intense rainfall can contribute to slope instability as soils are largely non-cohesive upon saturation. Steep terrain and intense development are considered to be the major causes of the failures. Erosion, and pore-water pressure build-up at shallow depths are the most common ways through which rainwater affects the slope stability. These together increase the shear stress of slopes and can lead to instability. Girard and McHugh (2000) have mentioned that, slope stability accidents are very common in the U.S when it comes to mining which includes quarrying. Mngeni et al., (2016) confirmed that, quarrying on hills are usually associated with landform instability which are as a result of the removal of protective vegetation and the steep nature of the slopes. Their study added that, in Mngazi quarrying site in South Africa, landslide occurred due to excavation. Grosic et al., (2013) also shared this view in their study which sought to find the cause of slope failure in Torine open pit quarry, Croatia. That study confirmed that, the massive landslide experienced in November 2012 was as a result of cracks in the rocks that had resulted from quarrying.

Given these findings discussed above, this study concludes that, since the sheer stress of the Weija Hills is becoming greater, there could be an imminent slope failure shortly if measures are not taken to minimise erosion and other stress factors of the hills.

5.6 Summary of findings in relation to the conceptual framework

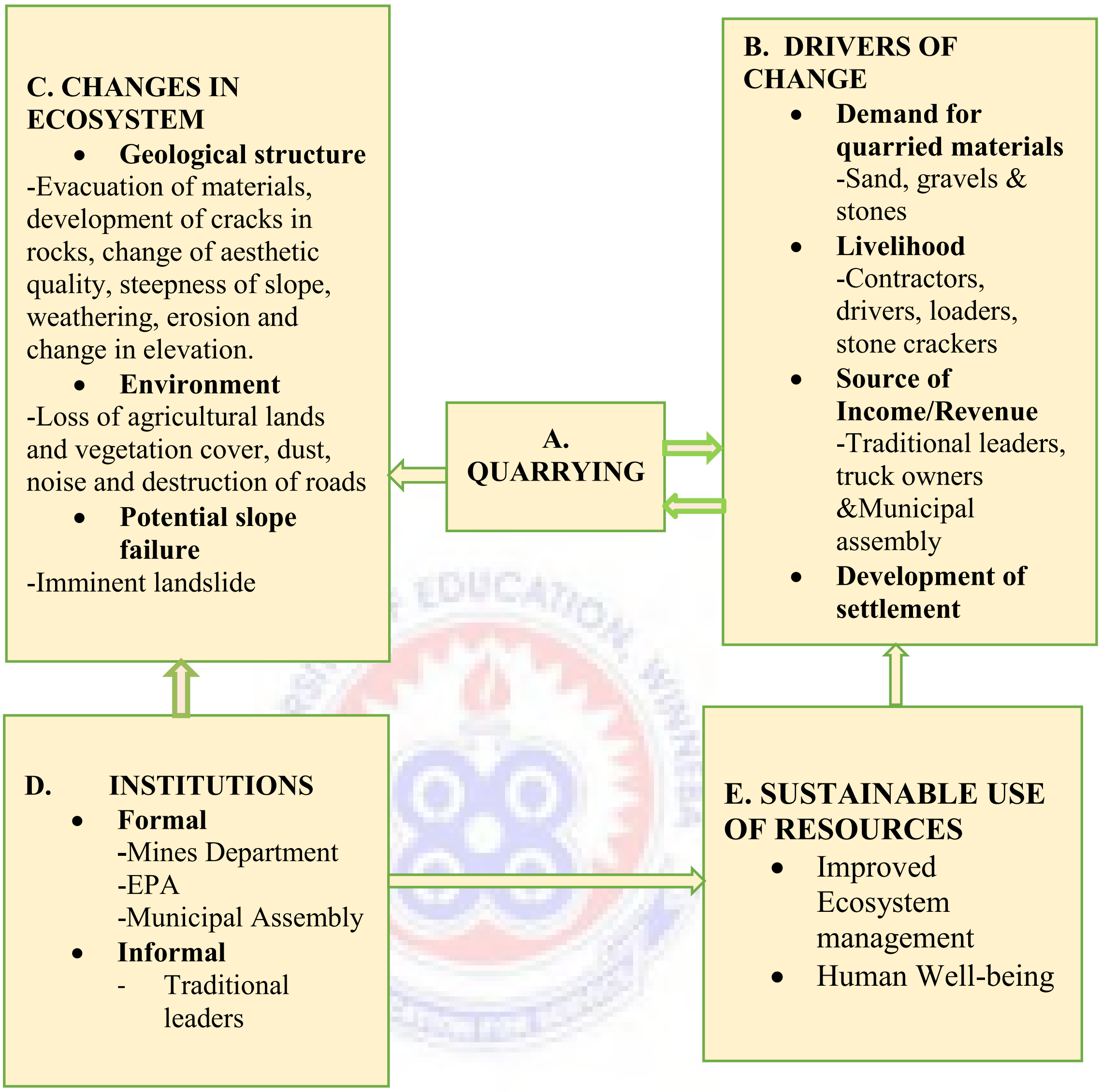

Figure 25: Framework on the impact of quarrying activities on the geological structure of the Weija Hills at GA South Municipality

Source: Adapted from MEA 2003 and 2005

Relating the empirical evidence to the conceptual framework, the findings of the study shows that, indeed human beings have a great interaction with their environment. The Weija Hills forms part of the ecosystem and provided habitat for plants, animals and humans and natural resources such as rocks, water bodies and minerals. It also provided a number of services: it provides food through farming, wood for energy and more. The hills again regulated the Weija lake, purifies the air and its vegetation help control soil erosion as well as supported soil formation and plant nutrient. Culturally, the aesthetic quality of the Weija Hills provided a scene environment for the people who lived around it just to mention few. With time, quarrying activities on the Weija Hills had become an alternative livelihood to farming. This was driven by the benefits which it provided to all stakeholders involved in the activity. Quarrying served as a livelihood for the contractors, trucks, and wheel loaders and excavators drivers and provides a quick source of income compared to farming to the operators, the traditional leaders as well as the truck owners to enable them to meet their needs and also support their families. It is an important source of revenue for the Ga South Municipal Assembly through the collection of tolls, permits, processing and reclamation fees and provided a wide variety of materials for the construction industry. Also, quarrying activities paved the way for the expansion of settlement and population growth in the municipality.

These direct drivers are driven by the indirect drivers which includes population increase and its resultant demand for more infrastructure, housing; there is advancement in technology has provided the equipment and machinery to make quarrying easier and faster. Again, many Ghanaians are shifting away from that lifestyle where the extended family members could all live in one household. In recent times, every individual wants to own a house. This increases demand for more lands and housing. In order to keep themselves in business to meet their needs, the actors in the quarrying business failed to realize how their activity is endangering their own lives and that of others. Human well-being includes being safe from both natural and human induced disasters.

As people satisfy their needs through quarrying, they leave behind trade-offs which causes change in the geology and general environment of quarried sites. For instance, as so much materials are evacuated from the Weija Hills, the size of the hills does not remain the same, the slope as well as elevation have been degraded, changing this part of the ecosystem completely. Other changes that had occurred were; development of cracks in rocks, weathering, serious erosion, floods and loss of agricultural land and vegetation cover to built –up. As the factors that kept of the slope of the hill stable (vegetation, type of rock and soil materials) were being lost to quarrying activities and its effects, the ability of the slope of the hills to resist any eventual failure was also reducing and there could be an imminent landslide all things being equal. Hence, the safety of the inhabitants of the Weija Hills is at stake and the ecosystem would not be able to continue providing services for its dependants. Old quarry pits were found to collect water during the raining season which breed mosquitoes that causes malaria. This affects the health of people around.

To ensure continual provisions of ecosystem services and to reduce the negative impact on the environment and human wellbeing, there is the need for sustainable use and management of resources. Institutions and laws have already been put in place to regulate and control the effects of quarrying activities irrespective of the size or location. Institutions mandated to ensure effective adherence of the environmental laws regarding quarrying include the Mines Department, the EPA and the district/municipal assemblies. However, there are lapses and inefficiencies on the part of law enforcers to control the activities on the hills. As a result, those involved in quarry activity take advantage of the weaknesses in the system to flout the laid down rules. The traditional leaders who are usually the custodian of resources, also support the institutions to management and control the use of ecosystem services. The effective management strategies will lead to sustainable use of resources and ensure human well-being.

In conclusion, benefits cannot be a justifiable reason for quarrying activities to continue on the Weija Hills because the geological and the environmental impact induced by this human cause, cannot be underestimated. The earlier the activity is stopped on the hills and the land reclaimed, the less stressed the hill would be and people who live around would also be safe.

CHAPTER SIX

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

6.0 Introduction

This study examined the diverse ways by which quarrying activities were impacting the geological structure of the Weija Hills in Ga South Municipality. It also assessed the changes that were occurring in the local environment which could be attributed to quarry activities. And finally, the study evaluated the effect of quarrying activities on slope stability of the local geology. Following the analysis and discussion of the results from the field in the preceding chapter, this chapter summarizes the major findings from this research and presents the conclusions drawn. The challenges identified in the research serve as a basis for recommendations to be made in this research.

6.1 Summary of Key Findings

This section discussed the key findings of this research.

- The study found out that, quarrying activities had become one major activity at the Weija Hills because quarrying provided employment for a number of people, materials evacuated also provided building materials for constructional purposes. This had made the slope at some portions of the hills flat (gentle) for easy building development, thereby expanding settlements around the hills. Having too many structures on the fragile hills increased to the stress on the hills and thus, poses danger to settlers.
- Another important discovery made by the research was that, quarrying activities at Weija Hills had brought about negative effects on the hills in the following ways: it had led to the development of cracks in the rocks, it had

destroyed the landscape and its aesthetic beauty, increased the steepness of the slope and hasten the rate of weathering and erosion. These together had impacted the geological structure of the hills.

- Quarrying activities had also led to changes on the environment of the Weija Hills. It bought about changes in land use and land cover. It was established from the study that; the Weija Hills were covered with vegetation including farms until after the 2000s where quarrying activities started on the Weija Hills. Fertile soils for farming were lost and vegetation was turned into bare lands and subsequently, into built-up. Within a space of twenty-nine years, light vegetation had reduced from 9.913081kmsq (61.3%) in 1991 to 2.0412kmsq in 2020, bare land also decreased from 5.090561 (31.4%) in 1991 to 3.5946kmsq in 2020 while built-up rather saw an increase from 1.173698 (7.3%) in 1991 to 10.5174kmsq (796.06%) in 2020.
- Other environmental changes that had occurred as a result of quarrying activity included land degradation in the form of open pits and development of large gullies on the hills leading to unconformity of the land, dust and noise pollution and fast deterioration of roads due to constant flooding. Also, massive erosion which was accompanied by downward movement of sediments blocking the main Mallam-Kasoa side of the Highway near the Kasoa toll booth annually. This had resulted in vehicular traffic to the extent that, sometimes, the road users were directed by the police to use one lane of the opposite side of the road. This had emanated from abandoned quarrying sites.
- The study found out that, the local geology of the study area was still stable with a factor of safety of 1.88. However, the study found that, a slope was

much stable if the factor of safety was equal or greater than 2. It could therefore be concluded that, quarrying reduced the factor of safety in localized areas. Therefore, quarrying has impacted the geological structure of the Weija Hills but not to the point of immediate instability. However, quarrying had encouraged severe erosion which may lead to instability with time. So in the long term, there would be instability from quarrying if measures were not taken to minimize erosion and other risk factors.

6.2 Conclusion

Based on the objectives and key findings of this research, the following conclusions are made.

- Quarrying which is an activity that deals directly with the landscape has led to development and enlargement of cracks in rocks, increased in the rates of physical and chemical weathering and erosion at some portions of the Weija Hills leading to unconformity of the geology. Also, there has been evacuation of large quantities of constructional materials from the hills leading to slope and elevation change, and thus, would have a long term impact on the geological structure of the study area.
- The following changes that have occurred in the local environment of the Weija Hill: removal of vegetation cover leading to serious erosion and loss of fertile topsoil, generation of dust leading to environmental pollution and downward movement of eroded sediments causing floods annually on the Weija hills within the last twenty-seven years, could be attributed to quarrying activities taking place at various portions of the hills.
- Quarrying activities have caused a relatively small portion of the local geology of Weija Hills to be unstable. Having in mind that the Weija Hills is a seismic

zone through available literature, if the activities is allowed to continue, the shear stress of the hills would increase and hence, there could be slope failure in the near future.

6.3 Recommendations

Several issues have been brought to light by this research. This section of the report further recommends certain measures to minimize the potential effects of quarrying and to enhance a more sustainable approach in mitigating the effects that have already been created.

- **Reclamation of abandoned quarried sites**

  The study recommends that abandoned quarried sites especially Site A should be reclaimed by the use of modern but less expensive methods. The environmental effects associated with quarrying such as erosion, creation of large gullies and open pits causes danger to both humans and the future of the environment. This research, therefore, call for the need to implement best environmental practices through the reclamation of the large dugout pits and erosion gullies. The abandoned pits must be covered with soil. The reclamation of the large pits could be a way of putting the unproductive large pits into productive use in the future. Erosion, on the other hand, could be controlled by maintaining protective cover on soil through afforestation and reforestation programmes. Restoration of the vegetation cover of the area will help reduce erosion by absorbing some of the energy of rainwater causing the erosion and downward movement of sediments. Also creating a barrier to an agent of erosion (water in this case) through the following: large surface drainage channels needs to be constructed and desilted regularly, the landscape should be modified to control runoff amounts and rates.

- **Slope Stability**

Based on the slope stability analyses done for the study, the following actions are recommended;

- Further research is required to better identify specific risk areas if any.

- There should be strong collaboration among the regulatory bodies; Mines department, EPA and the Municipal assembly to ensure that processes are duly followed especially environmental impact analysis before permits are given to quarry operators and contractors.
- There must also be effective public education by NADMO for people building on the Weija Hills to build earthquake resistant structures. If possible, those living at critical zones of the hills should be evacuated.
- The Ministry of Environment, Science, Innovative and Technology should adopt best environmental practices which will go a long way to minimize the potentially impact of quarrying on the environment.

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