GEOSPATIAL ANALYSIS OF QUARRY ACTIVITIES IN MPAPE DISTRICT, ABUJA NIGERIA

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DECLARATION

I hereby declare that the work in this thesis titled "**GeospatialAnalysisof Quarry Activitiesin Mpape District, Abuja Nigeria**"was carried out by me in the Department of Geomatics under the supervisions of Prof. L. M. Ojigi and Dr. T. Adewuyi. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this work has been presented for another degree at any institution.

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Name of StudentSignature Date

CERTIFICATION

This thesis titled "**GeospatialAnalysisof Quarry Activitiesin Mpape District, Abuja Nigeria"**meets the regulations governing the award of Master's Degree in Geomatics in Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This project is dedicated to Almighty God for His continuous guidance and protection during the period of my study in this institution.

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ABSTRACT

Quarryinghas diversifying effects on the environment and human activities as most of these quarry are located within residential areas especially around Mpape community of Bwari Area Council, FCT, Abuja and environs. Their operations are obviously not been carried out with world best practices. The study is aimed at carrying out spatio-temporal analysis of quarrying sites within Mpape District Abuja, Nigeria.The study employed remote sensing and GIS techniques to analysis the spatial locations and geometric characteristics of the quarries. Conventional surveying technique with the use of GNSS receivers in differential mode was used to obtain data of the sites. IKONOS and Landsat 2005 and 2015 imageries were also used. In addition, spot heightens were acquired using TCX converter v20.30 and were densified with ASTERDEM (30m resolution void-free). ArcGIS v10.1 Desktop and ENVI v5.1 environments were used to processed and analyzed data. Three abandonedquarries (Julius Berger, Crush rock and Dantata) and six are active (Arab Contractors, Pongyum, Leenford, Perfect stone, Exsamine 1 and 2) were used. The study established that there are losses of vegetation around all the quarries. The LULC map revealed the increase in the sizes and numbers of quarry sites from six in 2005 to nine in 2015. The study discovered the increment in the rocky areas at the rate of 106.54$Km^2.yr^{-1}$, which indicated the immense outcrops of rocks in Mpape. The depth profiles of the derelict ponds showed that pond 1, 2 and 3 that are within Julius Berger quarry site have the highest depths with values of 25m, 20, and 15m, followed by the pond within Crush rock quarry with a depth of 16m, and the pond in Dantata quarry site has the least with a depth of 6m. The buffer analysis carried out at 100m and 150m distances revealed that settlements are already engulfing the three quarry sites located at the core center of Mpape. This study recommended for stakeholders in the Ministry of Environment, Ministry of Solid

Minerals,FCDA and environmental protection agencies to urge quarrying companies to restore abandoned derelict ponds into socio-economic use.

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ABBREVIATIONS

ASTER:Advanced Spaceborne Thermal Emission and Reflection Radiometer

CD:Change Detection

CCRS: Canadian Centre for Remote Sensing

CRISP: Centre for Remote Imaging, Sensing and Processing

DN: Digital Number

DOS: Dark Object Subtraction

DPV: Dark Pixel Value

EMR: Electromagnetic Radiation

ENVI: Environmental Visualization

ERDAS: Earth Resources and Data Analysis System

ESAI: Environmental Sensitivity Areas Index

ETM+: Enhanced Thematic Mapper Plus

FAO: Food and Agricultural Organization

FCC: False Color Composite

GDEM: Global Digital Elevation Model

GIS: Geographical Information System

GLCF: Global Land Cover Facility

GPS: Global Positioning System

HMM: Histogram Minimum Method

IFOV: Instantaneous Field of View

LANDSAT: Land Satellite

LGA: Local Government Area

LIS: Land Information System

LST: Land Surface Temperature

LULC: Land Use and Land Cover

MODIS: Moderate Resolution Imaging Spectroradiometer

MSAVI: Modified Soil Adjusted Vegetation Index

MSS: Multispectral Scanner

MWIR: Mid-wave Infrared

NASA: National Aeronautics and Space Administration

NDVI: Normalized Difference Vegetation Index

NIR: Near Infrared

NOAA AVHRR: National Oceanic and Atmospheric Administration Advanced Very High Resolution Radiometer

OLI and TIRS: Operational Land Imager and Thermal Infrared Sensor

RMSE: Root Mean Square Error

RS: Remote Sensing

RVI: Ratio Vegetation Index

SAVI: Soil Adjusted Vegetation Index

SRTM: Shuttle Radar Topographic Mission

SPOT: Satellite Pour l'Observation de la Terre

SWIR: Short wave Infrared

TM: Thematic Mapper

TOA: Top of Atmosphere

TVI: Transformed Vegetation Index

UNCCD: United Nation Committee to Combat Desertification

UNCOD: United Nations Convention on Desertification

USGS: United States Geological Survey

WRS: World Reference System

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Quarrying is the process of obtaining quarry resources, usually rocks, found on or below the land surface. The difference between mining and quarrying is that quarrying extracts nonmetallic rocks and aggregates while mining excavates the site for metallic mineral deposits. Some of the stones extracted are sandstone, limestone, perlite, marble, ironstone, slate, granite, rock salt and phosphate rock (Nartey *et al*., 2012). Quarry is a large artificial hole in the ground where stone, sand, etc. is dug for use as building material (Cambridge dictionary, 2016). Also, it can be defined as the process of removing rock, sand, gravel or other minerals from the ground in order to use them to produce materials for construction or other uses. Thus, a quarry is any place on the surface of the earth where minerals are extracted but quarries are also known by other names around the world: "surface mine", "pit", "open pit" or "opencast mine"(Quarrying explained, 2017). Quarries are places where materials are extracted from the surface of the earth. They usually refer to operations where the material is to be used in construction, although construction materials are occasionally extracted from underground, and may sometimes be referred to as underground quarries (Introduction to quarries, 2016).

Stone quarrying is the multistage process by which rock is extracted from the ground and crushed to produce aggregate, which is then screened into the sizes required for immediate use, or for further processing, such as coating with bitumen to make bituminous macadam (bitmac) or asphalt (Diaz, 2015).The process begins with a detailed three-dimensional survey of the quarry face. This allows the explosives engineer to design the blast and to plot

where the shot holes should be carried out safely and efficiently. The survey will show if there are any bulges or hollows in the face. A bulge will need more explosive than normal to ensure that it is completely fragmented and not left in place in the face. Hollow areas require less explosive than normal. The placement of explosives is professionally planned to ensure that the required fragmentation of the rock is achieved with the minimum environmental impact (North Stone, 2016).

Crushing can be done in three or four stages, primary (first stage), secondary (second stage), tertiary (third stage) and, in some quarries, a quaternary (fourth stage). Crushed rock, or product, is transported along the process line on conveyor belts or down chutes.Primary crushing is usually by a jaw crusher consisting of a heavy metal plate, which moves backwards and forwards against a fixed plate. Secondary, tertiary and quaternary crushers are generally gyratory, or cone, crushers. These operate on the principle of a steel mantle mounted on an eccentric bearing and vertical shaft assembly.Each stage of crushing produces progressively smaller sized stones. In order to produce a usable end-product, the crushed rock has to be screened into various size categories. Crushed and screened rock is called aggregate. Screening is carried out at various stages in the crushing process (Diaz, 2015).

Interestingly, quarrying provides income to local councils through taxation. Good communications are needed for transporting the products of quarrying. As a result, many remote rural areas benefit from improved access (Bitesize**,** 2016a). In considering the importance of quarry product, domestic uses of the state like building stones, sand, pebble, slabs, etc., are also products of immense value conclusively, the whole activity including marketing and distribution provides various job opportunities and economic aids. Besides,

quarry products are one of the most important non-metallic minerals and are indispensable commodities of roads, houses, and other engineering constructions as well as other domestic appliances (Sreenivasa and Reddy, 2014).

However, extraction of raw materials from their natural habitats by mining, drilling, harvesting and those that relate to large-scale water resources development projects, construction, agriculture, energy, industry and development projects, considerably affect the natural environment (Fedra *et al*., 2005). Again, creating the pits or quarries requires the removal of virtually all natural vegetation, top soil and subsoil to reach the aggregate underneath. Not only does this lead to a loss of existing animal wildlife, it also leads to a huge loss of biodiversity as plants and aquatic habitats are destroyed. Moreover, adjacent eco-systems are affected by noise, dust, pollution and contaminated water (TEA, 2008).Also, a working quarry needs methods of transportation and this means that large amounts of machinery and heavy traffic will be brought into the area, causing an increase in local noise, pollution and erosion (YPTE, 2016). Despite the benefits, quarrying also has negative impacts. The blasting needed in extracting the rock contributes greatly to noise pollution. The dust from the rock blasting is a major form of pollution. Roads frequently used by trucks to and fro the quarry industry may be expensive to maintain as they will require regular maintenance. The huge lorries may also block the roads, making it difficult for access by other users. Quarrying interferes with human settlement and wildlife habitat areas, leading to their displacement. Quarrying also leads to death, where workers are buried by the rocks(North Stone, 2016).

The Federal Capital Territory (FCT) of Nigeria was established in 1976 but physical development only began in 1980, and it has been characterized as one of the fastest

growing cities in West Africa. The territory has experienced rapid land use and land cover (LULC)changes, urban spatial expansion and transportation infrastructure expansion over the last 30 years and is the major focus of urban spatial analysis in this study (Mahmoud *et al.*, 2016) following (FCDA, 2001), (Aliyu and Bashiru, 2015). Again, a significant feature of Abuja is its stony and hilly terrain where stones of varying sizes can be explored to meet the demand of building materials. Therefore, an ample of mining companies explored these hilly sites for the search of granite stones (different sizes – stone dust, chippings, hardcore etc.) for construction of various infrastructures for economic purposes using heavy machinery for excavation and blasting, which in turn destroys and changes the nature, pattern and cover of the landscape of the vicinity(Akor and Achakpa, 2011).

The management of quarries can be encouraged to be more sustainable during and after quarrying. The quarrying company is expected to restore or improve the quarry site after they have extracted the rock. Measures can be put in place to enable this to happen in a more sustainable way.Quarry restoration can take place. Areas that have already been quarried can be restored while works go in other areas of the quarry (Bitesize,2016b**).**Environmental Management Strategy provides the framework forenvironmental management during the construction and operation of quarry toensure compliance with the projects development consent conditions and other legalrequirements. The Strategy builds on environmental management controls that are based on environmental impact assessment (Holcim, 2013).

Environmental assessment is a procedure that ensures that the environmental implications of decisions are taken into account before the decisions are made. Environmental assessment can be undertaken for individual projects, such as a dam, motorway, airport or

factory (European Commission, 2016). Environmental Impact Assessment (EIA) is the process by which the anticipated effects on the environment of a proposed development or project are measured. If the likely effects are unacceptable, design measures or other relevant mitigation measures can be taken to reduce or avoid those effects (EPA, 2016).

Spatio-temporal analysis usually investigates quantitatively the spatial and temporal changes in land-cover. Spatio-temporal analysis of land use and land cover changes have been widely carried out using multi-temporal Remote Sensing (RS), due to its high spatial and temporal coverage (Jat *et al*., 2008 as quoted in Ashraf *et al*., 2015).Spatio-temporal assessment of the quarry site using remote sensing technique over a period will give a clue over the rate at which the solid rock is crop out to meet the demands of the increasing population (Adeoye, 2012).Spatio-temporal change detection analysis includes the integration of GIS and remote sensing methods and the output in GIS platform. The advantage of using GIS is the ability to incorporate different source data into change detection applications (Lo and Shipman, 1990 as quoted by Ravindra and Mundhe, 2013). Development for the economic growth of any area. Detection of changes in the environment involves use of at least two period data sets. The changes in land use / land cover due to natural and human activities can be observed using current and archived remotely sensed data (Jenson, 1986, Luong, 1993 as quoted by Babu *et al*., 2014).

Geospatial technologies are invaluable for the monitoring and assessment of land management sustainability due to the very nature of land management sustainability. Geospatial technologies are those information technologies that handle geo-referenced data (i.e. data with information on their absolute locations on the Earth's surface). Remote sensing entails the acquisition of information about the Earth's surface without actually

being in physical or intimate contact with it, affording spatial, spectral and temporal information that cannot be obtained from ground data. It provides systematically collected, digital, spatially explicit and continuous data on the Earth's surface across the globe, both in the visible range of the electromagnetic spectrum and beyond (e.g. thermal infrared or microwave). Satellite imagery and aerial photography are available for periods as early as the 1970s and 1930s respectively, offering insights about historic land conditions and change that may be difficult to obtain in the absence of long-term field monitoring projects. Remote sensing is an invaluable tool for data acquisition for integration into a Geographic Information System (GIS). GIS are information systems that facilitate the capture, storage, manipulation, analysis, management and presentation of geo-referenced data. GIS can integrate remotely sensed and geo-referenced field data from any discipline. Global Positioning Systems (GPS) are another form of geospatial technology (Beunemann, 2009).

1.2 Statement of Research Problem

Akor and Achakpa (2011) quoted that "environmental justice presupposes that citizens have the right of nature and the right to live in dignity within the environment. The environment and its natural base of Abuja and some urban communities inNigeria, is seen as a commodity and therefore commercialized, leading to its destruction. The case of development is inadvertently creating destruction of landscape and natural architecture of Abuja and environs. The resulting effect being that the environment is not able to support residents' livelihoods and daily experiences. Extensive environmental monitoring work across these urban communities has been done by the non-governmental organization known as Women Environmental Programme (WEP) in the past three years within the city of Abuja". Also, Akor and Achakpa (2011) quoted that their research is supported by

documented evidence on the scope of mining and extractive activities in the communities of Chika, Kuje, Mpape, Karmo and Gwagwalada.

Recently, the Nigerian senate committee on environment have threatened to shut down five stone mining companies operational at Mpape, a suburb of Abuja, for non-compliance with environmental safety laws. These companies have been blasting and crushing rocks in Mpape for over 30 years, but none of them have an environmental impact assessment certificate or a plan on how to remedy the environment after mining. Neither did any of the them have a corporate social responsibility project in the community to reclaim, restore and re-use the degraded sites for nature conservation and recreational purposes(Omosanya and Ajibade, 2011).

ThisDay (2010) reported the dispute between the then Chairman of the Senate Committee on Environment and Ecologyand some construction companies in Abuja, is one of many examples of the poor application of Environmental Impact Assessment (EIA) in Nigeria. On a visit to the quarry sites of Julius Berger, Setraco, Arab Contractors, HongyumMining Industrial Company in the Federal Capital Territory that week, The Chairman gave the companies two weeks to obtain their EIAs or have the sites shut down. She cited complaints from residents as her reason for the intervention".

Therefore, it is evident that quarrying activities are executed heavily by quarrying companies on the aforestated communities within the FCT. As quarrying is a continuous operation to meet the demand of construction, thus, it entails a constant scour of materials in all the nooks and crannies of the sites. These sites expand in depth and space (size) as exploration continues, leading to environmental changes in ecosystem and landform. This

has also led to the abandoning of quarrying, thereby transforming into stagnant pool with several years of continuous excavation. Reduction in fauna and flora in these affected communities is another effects of these expansions.

From the aforesaid, it is obvious that quarrying is predominant inMpape community of the FCT. Also, as the operation continues, there is every tendency in the expansion of these sites in size and depth. It has environmental, economic and health implications on the surrounding habitats and inhabitants. Consequently, there is need to characterize them for subsequent planning for restoration. Therefore, this study seeks to address the following questions:

i. What is the distribution of the quarry sites and what are their geometrical characteristics within the study area?
ii. What is the land use and land cover (LULC) change rates due to quarrying for the period of 2005 – 2015?
iii. How close are the sites to residential areas, and are there evidences of quarry-induced structural deformations in the study area?
iv. What is the effect on vegetation, water and land surface in the area?

1.3 Aim and Objectives

1.3.1 Aim

The aim of this study is to carry out geospatial analysis of quarrying activities in Mpape District, Bwari Area Council of Abuja, Nigeria.

1.3.2 Objectives

The objectives to adopt in accomplishing the above aim are to:

i. Map and establish the spatial distribution of quarry sites and determine the geometrical characteristics of the quarry sites.
ii. Determine a land use and land cover change rate in the area.
iii. Establish the proximity of the various active quarry sites to residential areas.
iv. Determine the effects of quarrying activities on vegetation, water and land surfaces.

1.4 Justification of the Study

Akor and Achakpa (2011) reported that Abuja'srapid growth over the years is largely due to ensuing urbanization in the city following the relocation of the federal capital from Lagos, and to the economic opportunities that the city seems to offer. This has put enormous pressure on the city's infrastructure, particularly housing, as well as other services. Many government establishments, embassies, international agencies and several corporate conglomerates are headquartered in Abuja. The city has seen the development of major constructions of structures and infrastructures to meet up with the demands of accommodation for office, residential and recreational spaces.

It has been observed that quarrying activities are on the rise in their number, space and depthwithin urban settlements in Abuja. This study is embarked upon in Abuja because of the significance of the city in the country with its characteristic stone-richen hilly terrain, which serve as habitats to fauna and flora. The hilly terrain also serves as a beautification to the city. Focusing on the urban sprawl and unprecedented population growth of city, quarrying will continuously expose earth top soil leading to rise in dust, noise generation emanating from blasting and crushing of stones by heavy machines. Therefore, this study seeks to carry out spatio-temporal analysis of quarrying sites in part of Abuja, Nigeria.

This research should enable stake holders in the ministry of environment, Federal Capital Development Authority (FCDA) and environmental protection agencies to realize the spread of these quarry companies; their expansion in size; there nearness to residential areas and the modification of the land cover of these sites overtime. Also, the outputs of this research (maps, charts, reports) will serve as tools to aid visual communication and understanding among these stakeholders.

1.5Scope of the Study

It will be intriguing to analyze all the quarrying sites in Abuja, but it is also challenging because of the spatial extent, availability of high satellite image and time of the study. Therefore, this study looked into quarry sites within Mpape districts. The study covered nine quarry sites within Mpape communities where the quarrying companies are located. The spatial analyses worked with both raster and vector models to achieve the set objectives. This study worked in the premise of physical and geometric indicators that can be derived quantitatively from remotely sensed imagery and field observations. These are the physical and ecological indicators (vegetation and water). Thus, indices such as Normalized Difference Vegetation Index (NDVI) and Normalized Difference Water Index (NDWI) were derived to target these indicators. The analysis of the quarrying sites was based on the nature of the land cover; impact on vegetation cover; presence of stagnant water at the site, depth and sizes of the quarries, and the proximity of the sites to settlements.

The remotely sensed data that was used is IKONOS imagery of 2005 and 2015. The study intended to use satellite imagery at an interval of three (3) years interval. Unfortunately, the availability of high resolution image at three (3) years interval bedeviled the intention of

the research. Also, Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) on-board Landsat 8 of 2015 and Enhanced Thematic Mapper Plus (ETM+) sensor on-board Landsat 7 of 2002 were acquired because of its multiband nature, so as to derive necessary indices. It is important to note that the study acquired Landsat 7 of 2002, because there is a huge void of Landsat data from 2003 to 2012. In addition, ground-surveying techniques was intended to be used for acquiring the geometrical characteristics of the quarry sites, unfortunately, access was not granted due to bureaucratic bottleneck. However, the depth of only Julius Berger quarry was measured using ground-surveying method.

1.6The Study Area

1.6.1 Geographicallocation

Approximately 10minutes' drive from the city center sits Mpape (Jimoh, 2017). It is one of the districts in Bwari area council of the Federal Capital Territory (FCT). Mpape is one of the numerous communities in the suburbs of Abuja, not too far from the choice places where the who's who live like Maitama. It lies on the foot hills and on the top of the famous Mpape Rocks that are easily sighted from the neighbouring Maitama District. Comparatively, it could be likened to what Maroko is to Victoria Island in Lagos (Okeke, 2016).

Geographically, Mpape lies between latitude 9.175699° and 9.113010° north of the equator and longitude 7.463892° and 7.524349°east of the Greenwich Meridian. Itoccupies a land area of 44.325 Ha.Figure 1.1 is showing the location of FCT Abuja while Figure 1.2does show Bwari Area Council. An inset map portraying the study area is shown in Figure 1.3 and 1.4.

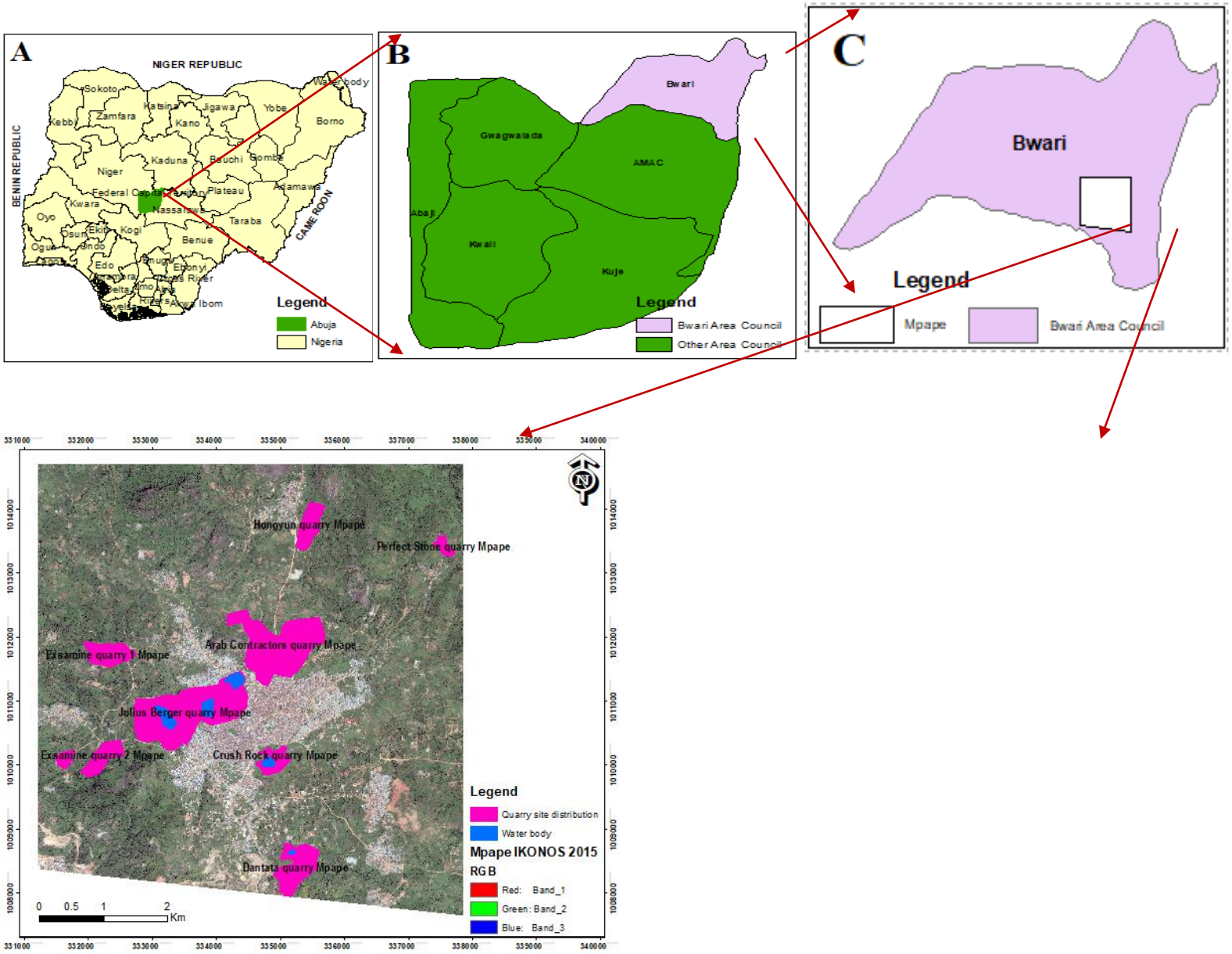

A
NIGER REPUBLIC
BENIN REPUBLIC
CAMEROON
Sokoto
Zamfara
Kebbi
Katsina
Jigawa
Yobe
Borno
Kano
Kaduna
Bauchi
Gombe
Niger
Federal Capital Territory
Plateau
Adamawa
Kwara
Nassarawa
Taraba
Oyo
Osun
Ekiti
Kogi
Ogun
Ondo
Benue
Edo
Enugu
Ebonyi
Rivers
Delta
Cross River
Akwa Ibom
Legend
Abuja
Nigeria
B
Bwari
Gwagwalada
AMAC
Abaji
Kwali
Kuje
Legend
Bwari Area Council
Other Area Council
C
Bwari
Legend
Mpape
Bwari Area Council
Hongyun quarry Mpape
Perfect Stone quarry Mpape
Arab Contractors quarry Mpape
Examine quarry 1 Mpape
Julius Berger quarry Mpape
Examine quarry 2 Mpape
Crush Rock quarry Mpape
Dantata quarry Mpape
0 0.5 1 2
Km
Legend
Quarry site distribution
Water body
Mpape IKONOS 2015
RGB
Red: Band_1
Green: Band_2
Blue: Band_3

Figure 1.1: An inset map of the study area. **Source:** Modified after (AGIS,2016).

1.6.2 Climate and weather

Mpape, being one of the districts in Abuja shares the same climate and weather with the FCT at large. Abuja experiences a hot and humid rainy season, from April to October; a dry season, from October to April; and a brief windy season in between known as the harmattan season, when the dry and dusty West African trade wind blows through the city, coupled with intense cold. Sometimes the dust storms severely limit visibility and can even block the sun for several days, comparable to a heavy fog (World travel, 2016).

Also, daytime temperatures reach 28-30 degrees and night time lows range around 22-23 degrees. In the dry season, daytime temperatures can rise to 40 degrees and night time temperatures can drop to 12 degrees, resulting in chilly evenings. Even the chilliest nights can be followed by daytime temperatures well above 30 degrees.The high altitudes and rolling terrain of the FCT act as moderating influence on the weather of the territory. The annual total rainfall is in the region of 1100 mm to 1600 mm (Abuja city, 2016b).

In a nutshell, the annual weather facts are given below:

i. The months of June, July, August and September have nice weather with a good average temperature.
ii. On average, the temperatures are always high. Most rainfall (rainy season) is seen in May, June, July, August, September and October.
iii. Abuja has dry periods in January, February, November and December.
iv. On average, the warmest month is March. On average, the coolest month is December. September is the wettest month.
v. This month should be avoided if one does not like too much rain. January is the driest month (World weather and climate information, 2016).

1.6.3 Geology and relief

Similarly, Mpape has the same geology and relief with the FCT. Abuja is almost predominantly underlain by high grade metamorphism and igneous rocks of Precambrian age generally trending, these rocks consist of gneiss, migmatites, granites and schist belt outcrops along the eastern margin of the area (Oyawoye, 1972; McCurry, 1976) as quoted by (Abam and Ngah, 2013). The belt broadens southwards and attains a maximum development to the southeastern section of the area where the topography is rugged and their relief is high. In general, the rocks are highly sheared. The lowest elevation in the FCT is found in the extreme southwest where the flood plain of the river Guraja is at an elevation of about 10m above sea level from there, the land rises irregularly eastward, northwards and north westwards. The highest part of the territory is in the northeast where there are many peaks over 760m above sea level. Hills occurs either as clusters or form long ranges (Martins Library, 2016).

1.6.4 Population and culture

Mpape is the largest slum settlementsAbuja (Jimoh, 2017) and densely populated (John-Mensah and Adeniyi, 2016). With the rural-urban migration reportedly on the rise in Nigeria, the village has grown into an informal settlement with a population tethering over 1.1 million inhabitants without the commensurate infrastructure (Jimoh, 2017).

The swelling population is opening the community into phases and neighbourhoods. With Mpape Phase II adding to Unguwar Rimi, Unguwar Usuma, Masafa Road, Berger Yard, and Gwari Village areas, the community boasts of an age-long intertwined relationship. While Gwari Village, Unguwar Rimi, Masafa Road and Unguwar Usuma could pass for a

slum due to its unplanned housing and open drainages within residences, the Berger Quarry Area is said to be reserved for the rich (Mensah and Adeniyi, 2016).

Mpape population grew in geometrical progression following the demolition of some settlements in Abuja like Karmo, Durumi, Gwarimpa village, Kado village, Apo and various other settlements along airport road, by the former Minister of the FCT, Mallam Nasiru El-Rufai. Originally inhabited by the Gbagis, Mpape can be described as a melting point of cultures, attracting people from all tribes in Nigeria such as Nupe, Ebira, Igbo, Yoruba, Hausa etc. (Jimoh, 2017).

1.6.5 Socio-economic activities

Despite its squalid environmental condition, its population keeps growing by the day. The reason being that rent here is comparatively cheap and its near to the city centre where most workers go to, only that the traffic situation has become a night mare to Mpape dwellers, only that the situation has become a night mare to Mpape dwellers. The population has provided ready market for some smart businesspersons who are smiling to the banks. In such human community, crime is inevitable, but interestingly, Mpape is not known for major violent crimes. Petty crimes though remain rampant (Okeke, 2016).

The rocky nature of Mpape makes it suitable for quarry business which thrives here(Okeke, 2016).Mpape has been home to a number of mining sites owned by major construction companies benefiting from government contracts for road and other projects in Abuja and beyond. Little wonder many districts derive their names from that of the closest company, thus names such as Berger Quarry Road I, Berger Quarry Road II, and Arab Road, are used to describe areas. This explains the large movement of heavy trucks in and out of Mpape at

regular intervals (Jimoh, 2017).It is obvious to say that Mpape is a time bomb waiting to explode someday, especially if cognizance is not taken, the safety concerns associated with explosions from quarry sites on a daily basis. Health concerns from the filth and quarry dusts. The people of Mpape are endangered (Okeke, 2016).

1.6.6 Landuse and land cover

Mpape is highly noted for its hilly and rocky topography(Jimoh, 2017).Most parts of the area is swampy during the rains and dusty at dry seasons (Okeke, 2016). It is mainly comprised of built-up areas because of its teeming population. The unbuilt- up areas comprise farmlands and vegetation. The land use comprises residential, industrial and educational (primary and secondary schools) (Solomon, 2017).

CHAPTER TWO

LITERATURE REVIEW AND THEORETICAL FRAMEWORK

2.1 Introduction

This chapter includes two sections. The first section looks into the concept and theories that constitute this study. It includes perception of land degradation, concept of quarrying, remotely sensed data used, spatio-temporal analysis (change detection). The second section entails the review of related studies by various authors and the gap deduced from their works.

This section explains the importantly related concept and theory that serve as elements of this study.

2.2 Perception of Land Degradation

Land degradation occurs in all kinds of landscapes over the world, but is a particular problem in parts of Africa and South Africa. Its consequences can be devastating for people and wildlife. It is often closely linked with other environmental and social problems such as climate change and poverty and its remedy is tied up with them (Veld and Flora, 2010).

Land degradation: under the UNCCD "land degradation" means reduction or loss, in arid, semi-arid and dry sub-humid areas, of the biological or economic productivity and complexity of rain-fed cropland, irrigated cropland, or range, pasture, forest and woodlands resulting from land uses or from a process or combination of processes, including processes arising from human activities and habitation patterns, such as: soil erosion caused by wind

and/or water; deterioration of the physical, chemical and biological or economic properties of soil; and long-term loss of natural vegetation (UNCCD, 2012).

Land degradation can be defined as a composite term; it has no single readily-identifiable feature, but instead describes how one or more of the land resources (soil, water, vegetation, rocks, air, climate, relief) has changed for the worse. Land degradation generally signifies the temporary or permanent decline in the productive capacity of the land (UN/FAO definition). Another definition describes it as, "the aggregate diminution of the productive potential of the land, including its major uses (rain-fed, arable, irrigated, rangeland, forest), its farming systems (e.g. smallholdersubsistence) and its value as an economic resource." This link between degradation (which is often caused by land use practices) and its effect on land use is central to nearly all published definitions of land degradation (Anon, n.d).

Land degradation can be defined as a long term loss of ecosystem functions over time, as perceived by the land users. The relationship between land degradation and land use is clear, as land use implicitly includes the way farmers and pastoralists use and manage the land, which can inherently change it for the better and / or the worse. Land use is the single most important driver of land degradation as it focuses on interventions on the land which directly affect its status and impacts on goods and services (Nachtergaele and Petri, 2013).

2.2.1 Causes of land degradation

Although degradation processes do occur without interference by man, these are broadly at a rate which is in balance with the rate of natural rehabilitation. So, for example, water erosion under natural forest corresponds with the subsoil formation rate. Accelerated land degradation is most commonly caused as a result of human intervention in the environment.

The effects of this intervention are determined by the natural landscape (Anon, n.d). Some of the causes of land degradation are explained below:

i. Deforestation: The removal of trees and other vegetation (for firewood, commercial logging or to clear land for farming and settlements).

ii. Overgrazing: Allowing farm animals to eat all the covering vegetation until the soil is exposed and the plants cannot regenerate themselves.

iii. Poor Land Management: This can be inappropriate farming methods for the type of land/soil; farming that is too intensive (forcing the land to produce food crops year after year without letting it 'rest' to build up the nutrients again; using chemical or no fertilizers rather than natural fertilizers such as animal dung or organic matter).

iv. Fires: This includes bush and veld fires, caused by people, which strip the soil of the plant material that prevents soil erosion.

v. Pollution: This is caused by dumping scrap metal, plastics and packaging and building rubble.

vi. Mining: This damages the soil and the underlying structure of the land. Chemicals used or mined themselves pollute soil and water courses.

vii. Neglect: Failing to look after local plants, trees and biodiversity. Neglect means that the soil will not be naturally fertilized and protected, so it cannot in turn nurture other life (Veld and Flora, 2013).

2.2.2 Indicators of land degradation

An indicator is a parameter (or value derived from parameters) which provides information about a phenomenon. Indicators should not be confused with raw data from which they are derived. Indicators are quantified information which helps to explain how things are

changing over time and space for decision making. An environmental indicator is a parameter which provides information about the situation or trends in the state of environment, in the human activities that affect or are affected by the environment or about relationships among such variables. Land degradation indicators are a sub-set of environmental indicators focusing on a particular trend in state of the environment and associated human activities (DESIRE, 2016).

Land degradation is, however, difficult to grasp in its totality. The "productive capacity of land" cannot be assessed simply by any single measure. Therefore, we have to use indicators of land degradation. Indicators are variables which may show that land degradation has taken place – they are not necessarily the actual degradation itself (Anon, n.d). The indicators are categorized as: physical and ecological; economic; and social indicators. They are explained below (Agricultural University of Athens, 2008):

2.2.2.1 Physical and ecological indicators

a) Climate: Air temperature, Rainfall, Aridity index, Potential evapotranspiration, Rainfall, seasonality, Rainfall erosivity
b) Water: Water quality, Water quantity, Groundwater exploitation, Water consumption/water demands.
c) Soils: Drainage, Parent material, Rock fragments, Slope aspect, Slope gradient, Soil depth, Soil texture, Soil water storage capacity, Exposure of rock outcrops, Organic matter surface horizon, Degree of soil erosion, Electrical conductivity.
d) Vegetation: Major land use, Vegetation cover type, Plant cover, Deforested area,
e) Water runoff: Drainage density, Flooding frequency, Impervious surface area
f) Fire: Fire frequency, Fire risk, Burned area.

2.2.2.2 Economic indicators

a) Agriculture:Farm ownership, Farm size, Land fragmentation, Net farm income, Parallel employment.
b) Cultivation: Tillage operations, Tillage depth, Tillage direction, Mechanization index
c) Husbandry: Grazing control, Grazing intensity
d) Land Management: Fire protection, Sustainable farming, Reclamation of affected areas, Reclamation of mining areas, Soil erosion control measures, Soil water conservation measures, Terracing.
e) Land Use: Land abandonment, Land use intensity, Land use type, Period of existing land use, % urban area, Rate of change of urban area.
f) Water Use: Aquifer over exploitation, Irrigation percentage of arable land, Runoff water storage, Water consumption by sector, Water scarcity.
g) Tourism: Tourism intensity, Tourism change.

2.2.2.3 Social

Human poverty index, Old age index, Population density, Population growth rate, Population distribution.

2.3 Concept of Quarrying

It can be recollected that one of the players of land degradation is human beings, and this constitute one of the causes of land degradation in the form of mining. This damages the sub-soil and exposes the top layer of the soil through constant excavation for the search of mineral resources.

Mining can be defined as the extraction of valuable minerals, liquids and gases from the earth which are present as orebodies, veins, seams or liquids. Mining is required to obtain

any non-renewable resource that cannot be grown or created artificially in a factory or laboratory (iMINCO, 2016). On the other hand, quarrying can be defined as a process of obtaining quarry resources, usually rocks, found on or below the land surface.The difference between mining and quarrying is that quarrying extracts nonmetallic rocks and aggregates while mining excavates the site for metallic mineral de-posits. Some of the stones extracted are sandstone, lime-stone, perlite, marble, ironstone, slate, granite, rock salt and phosphate rock (Nartey *et al*., 2012).They usually refer to operations where the material is to be used in construction, although construction materials are occasionally extracted from underground, and may sometimes be referred to as underground quarries (University of Leicester, 2016). Thus, for clarification quarrying is a form of mining if it is being carried in an open-pit and to search for nonmetallic minerals.

Therefore, a mine can be defined as a place where mechanical disturbance of the ground or any excavation is made to explore for or to produce coal, mineral bearing substances, placer minerals, rock, limestone, earth, clay, sand or gravel(Mines Act, 2017).



Plate I: A typical example of a quarrying site.

2.3.1 Methods of quarrying

The method used to quarry stone depends on the stone's composition, hardness, structure, cleavage, and other physical properties. The characteristics and placement of rock mass deposits is also an important consideration. For stone that is deposited in relatively accessible beds, hand tools such as drills, hammers, and wedges are employed. The demand for crushed rock such as limestone has actually led to the development of new kinds of quarrying techniques. The techniques are explained below (Hem, 2012; Dambov *et al*., 2013; QuarryScapes, n.d):

i. Explosives

The use of explosives capable of blasting away larger portions of hillside is a common method of quarrying today. The stone then gets split with the use of wedges or by the plug-and-feather method, or crushed by a heavy steel ball weighing several tons. Holes are drilled deep enough into the rock that it will break. The drilled holes are partially filled with explosives, which are then detonated.Sometimes the holes are drilled along the outside of the rock block to be removed. Wedges, used in combination with explosives, are driven into a block of rock to split it into more manageable-sized pieces. Most quarries separate larger masses of rock first and then later divide the rock mass into smaller blocks of desired sizes. Sometimes the rock is stratified and then holes must be drilled at a right angle to the plane of separation. If a rock mass has no rift or stratification or the natural plane of

separation is too far apart, then holes are drilled into the quarry face and wedges are driven into the rock to separate it. To prevent the stone from shattering, lighter gunpowder is preferred to fracture dimension-stone. In the production of crushed-stone, more powerful dynamite and explosives are used (Hem, 2012; Dambov *et al*., 2013).

ii. Compressed air

A new technique to emerge in granite quarries is the use of compressed air to separate layers of rock in conjunction with a small charge of dynamite. For example, granite has no natural rift so a hole is drilled down to the depth where the layer is to be split, creating a cavity in which a small amount of powder is exploded to produce a crack that runs parallel to the rock surface. A compressed air pipe is sealed into the opening to introduce increased pressure. Water under pressure may also be used with small amounts of gunpowder to achieve the same results (Dambov *et al*., 2013; QuarryScapes, n.d).

iii. Channeling

Another method of quarrying called channeling or broaching involves cutting long, narrow channels into the rock to free up the sides of large stone blocks. In this process special machines called channelers are used. Formerly steam-driven, these self-propelling machines today are powered by diesel or gasoline engines. They cut the stone with a cutting edge that traverses back and forth along the seam of the rock bed until a deep cut is made. The cut is deep enough to allow wedges to be inserted down into the rock until it is split. The cut in the stone is used to guide the fracture in the rock. The use of channeling is extensive in soft rock quarries such as those containing limestone, marble, and sandstone (Hem, 2012).

iv. Mining

Sometimes the stone bed to be quarried is too thin and removing the overburden on top is too expensive. In such situations the quarry is treated like a mine and the methods used to extract desired blocks of stone are similar to methods used in mining. For example, horizontal rock beds are cut near the top or the bottom of the bed. The face of the quarry is divided into blocks by saw cuts, channels, or rows of drilled holes. The blocks are then separated through wedging or blasting. As stoping moves forward, some of the rock is left behind as pillars to provide roof support. This approach is particularly common in European slate quarries where rock beds tend to dip down from a horizontal position. Similar to mining, the rock is worked by stopes that follow along the inclination of the rock bed (QuarryScapes, n.d and Dambov *et al*., 2013). From the aformentioned, the methods of quarrying involve applying explosives to the quarry; immersing of compressed air into the quarry; cutting long, narrow channels into the rock to free up the sides of large stone blocks; lastly, the stones are extracted in the form of a mine.

2.3.2 Stages of quarrying

A quarry usually goes through the following stages before reaching the production stage (Hem, 2012):

i. Prospecting and exploration: Firstly, the following properties of the rock are studied in the prospecting programs: physical & mineralogical properties, color and appearance, uniformity, strength, flaws, cracks, etc.

ii. Development**:** Secondly, along with the removal of overburden, development stage also involves developing the processing and other construction facility near the quarry. The main role of the processing facility is to cut and polish the rock. Large

amount of wastes is generated in processing, so it is required to plan for some storage or dump space for the cuttings.

iii. Production: Thus, the stones or materials in a quarry are excavated with any of the methods explained in section 2.3.1.

2.3.3 Steps in the operations of an ideal quarry

The steps involved in operating an ideal quarry are explained below (University of Tennessee, 2008; North Stone, 2016; Vulcan, 2016).

i. Finding, preparing and designing a site

Before operating a quarry, many preparations must be made. First, Geologists must find a place where there is a large supply of rocks beneath the earth's surface. A quarry is frequently located near a community where products are needed because if it is not, it will cost customers too much to haul the crushed stone, which is very heavy, over long distances. This step can be grouped under the prospecting and exploration stage.

ii. Obtaining permits

After finding a good place to put a quarry, Geologists carryout geotechnical survey the land, and develop a design that will make the quarry safe and efficient. Then, a variety of operating permits from local, state and federal governments will be sought. For instance, to obtain the environmental permits, it is necessary to provide a plan that shows it can and will obey all environmental rules of the state and federal governments. Once the proper permits are obtained, equipment is purchased, roads are built to the facility and we begin building the processing plant.

iii. Being a good neighbor

It is very important that operators of quarries should be good neighbors in the communities where we build quarries. For example, at many sites buffer zones are created around the quarry so noise is kept to a minimum. The entrance to the quarry should be landscaped so that it blends with the surrounding area. Special water systems are install so that the water being used in processing can be recycled, and many other features are put in place to protect the health and safety of employees and neighbors.

iv. Being good environmental stewards

Great care is also taken to protect the environment and the animals that live on quarry lands. A quarry site might be as big as 600 or more acres, but, only a small part of that land is actually used for the quarry and processing plant. Wildlife habitats are established in the buffer zones to attract and protect animals that might live around within quarries. At some locations parks, nature trails and ball fields in buffer zones are built. Quarries are supposed to be full of so many interesting things that they are often seen as huge outdoor classrooms where students can come to see what is done and learn about earth science and nature. Once where to put a quarry is decided, the site for quarrying is prepared.

The above two (iii and iv) steps are usually undertaken in environmental impact assessment (EIA). This entails recognizing the likely environmental hazard that the quarry is going to cause to the inhabitants and the ecosystem.

v. Preparing the site

In order to get to the rock beneath the surface of the earth, the land to be mined must be cleared. Once the land prepared, mining rock begins. At many sites, the material that is

removed is used to begin construction of berms and other buffer areas, or donated for landscaping or construction projects in the community. This step can be grouped under the development stage.

vi. Getting rocks out of the Earth

Drilling and blasting is a very important part of how rocks are moved out of the earth. The process on how much rock is to be broken is designed, the type of rock that will be worked on and the size pieces to be broken. Experts are hired to help with drilling and blasting because they know exactly how to work with explosives to make sure this part of the process is handled safely, efficiently and as quietly as possible.

First, holes are drilled in the earth and explosives are placed inside. The explosives are detonated to provide the smallest release of energy for the most efficient blast. The entire blasting process occurs in just a few seconds. Larger quarries may blast once a day and smaller quarries may blast once or twice a week. Blasting is monitored with a special machine to record sound and vibrations so that the community around our quarry remains protected and safe. The blasts that occur when the explosives are set off free the stone from the quarry wall. The big pieces are removed by pit loaders and dumped into large haul trucks. This step can be grouped under the production stage.

vii. Loading rocks and hauling rocks from the pit

The area that begins to form out of the earth when blast is applied and takes away a big piece of rock becomes the quarry or pit. Very large haul trucks are used to load and move

the rocks out of the pit and to the processing plant where they are crushed and divided into different sizes. Trucks move back and forth between the pit and the processing plant. Now that the rocks have been moved out of the ground and moved over to the processing plant, big rocks are broken into little rocks.

viii. Breaking rocks

When trucks deliver the big pieces of rock to the processing plant, the rocks are put into a primary crusher that will break them into smaller pieces. The primary crusher can crush between 300 and 2,000 tons per hour. Depending on what the rocks are to be made, they may be put through different kinds and smaller sizes of crushers one or two more times. As the rocks pass through the crushers, they are moved around the processing plant on conveyor belts.

ix. Separating rocks into different sizes

After crushing, comes screening. As the rocks are broken down to smaller sizes, screens are used to separate them into piles that are the same size. Some screens are larger and they allow the bigger rocks to pass through. The smaller screens let only the small rocks through. Rocks may be crushed and screened many times before they are put in a stockpile with other rocks the same size.

x. Moving rocks around the processing plant

For rocks to get from one place to another at our plant, they travel on long, continuously moving conveyor belts. The conveyors help move rocks in an economical way, saving money and time.

xi. Taking care of employees and neighbors

During the entire quarrying process, the health and safety of employees and neighbors are protected. Mining rocks and moving rocks around a processing plant can create fine particles of dust. Dust is controlled by using water sprays on the rocks as they are processed, and by using spraying equipment to wet quarry roads. To protect the environment, water that is recycled in a closed loop water system that collects rainwater and water that we use during processing. Water is stored in a recycling pond where the sediment is allowed to accumulate. If water is to be discharged recycling pond, the water is tested to make sure that it is safe and that it meets environmental water quality regulations.

xii. Storing rocks

Stockpiles are huge piles of rock, sand, gravel and other materials, and are huge. Some of the stockpiles are as much as 30 feet high and 800 feet around. They are so big that they have to be kept outside. Because they are exposed to the weather, they have to be carefully maintained so heavy rain doesn't wash them away. Efforts must be made so that other materials get mixed in with them. Bulldozers and front end loaders are used to keep the stockpiles in place. When customers come to the facility for a load of crushed stone, they go to the stockpile. Shipping loaders are used to fill their trucks with the rocks and other aggregates from the stockpile.

xiii. Weighing rocks and trucks

The rocks are sold in ton. Before customers are billed for the material they want to buy, the weight of each load must be determined. When trucks come to the facility, they are weighed before loading. Once they are loaded they are weighed again. Then, the weight of the empty truck is subtracted from the weight of the full truck. Weighing is also important

because it helps to ensure that the trucks leaving the quarry are not too heavy for the roads they will travel on. Each state has laws that say how much weight a truck can legally carry. If a truck weighs too much, some of the material is taken-off it and then it is weighed again before it leaves the quarry.

xiv. Delivering rocks to where they are needed

Finally, the materials have to be moved over greater distances. If materials need to be moved a long way, use of boats, trains or barges are used to move them(University of Tennessee, 2008; North Stone, 2016; Vulcan, 2016). Unfortunately, these practices of operating an ideal quarry are not practiced in Abuja, Nigeria.

2.3.4 Environmental impacts of quarrying

Some of the environmental disturbancecreated by quarrying is caused directlyby engineering activities during aggregateextraction and processing. The most obviousengineering impact of quarrying is a changein geomorphology and conversion of landuse, with the associated change in visualscene (Uglow, 1999). This major impact may be accompaniedby loss of habitat, noise, dust, vibrations,chemical spills, erosion, sedimentation, andderelictionof the mined site. Some of theimpacts are short-lived and most are easy topredict and easy to observe. Most engineeringimpacts can be controlled, mitigated, keptat tolerable levels, and restricted to the immediatevicinity of the aggregate operation byemploying responsible operational practicesthat use available engineering techniques andtechnology (Langer, 2001).

Quarrying is necessary to provide much of the materials used intraditional hard flooring, such as granite, limestone, marble,sandstone, slate and even just clay to make ceramic tiles. However,like many other man-made activities, quarrying causes a significantimpact on the environment. In particular, it is often necessary to blastrocks with explosives in order to extract material for processing butthis method of extraction gives rise to including noise pollution, airpollution, damage to biodiversity and habitat destruction (Cohen, 2016).

Quarrying can generate a number of on-site and off-site environmental effects through the blasting, excavation, crushing, screening, stockpiling andtransport of aggregate.The degree and nature of effects caused by quarrying varies according to the type of quarry, the scale of operation, methods used to excavateaggregate, the geology of the area, the receiving environment and the surrounding land uses. The effects of quarries also vary by their nature (rockor sand) and whether they are in short- or long-term use, in continuous use or used irregularly or seasonally.Gravels and sand are normally sourced from river beds (both current and old) and from beaches. Excavation typically involves machinery, withoutthe need for blasting. Crushing of gravel is usually limited to larger gravels while screening is used to separate out smaller sizes for specific uses.Aggregate products requiring further refinement can often involve additional washing, crushing and screening processes (Quality planning, 2016b):

Effects are either on site, on neighbouring properties or completely off site, such as the transportation of aggregate. The environmental effects ofquarrying primarily include (Uglow, 1999; Langer, 2001; Cohen, 2016):

i. Noise pollution

The primary source of noise from extraction of aggregate and dimension stone is from earth-moving equipment, processing equipment, and blasting. The truck traffic that often accompanies aggregate mining can be a significant noise source. The impacts of noise are highly dependent on the sound source, the topography, land use, ground cover of the surrounding site, and climatic conditions. The beat, rhythm, pitch of noise, and distance from the noise source affect the impact of the noise on the receiver.

ii. Dust pollution

Dust is one of the most visible,invasive, and potentially irritating impactsassociated with quarrying, and its visibilityoften raises concerns that arenot directly proportional to its impacton human health and the environment. Dust mayoccur as fugitive dust from excavation,from haul roads, and from blasting, or canbe from point sources, such as drilling,crushing and screening.Site conditions that affect the impact ofdust generated during extraction of aggregateand dimension stone include rockproperties, moisture, ambient air quality,air currents and prevailing winds, the sizeof the operation, proximity to populationcenters, and other nearby sources of dust.Dust concentrations, deposition rates, andpotential impacts tend to decrease rapidlyaway from the source.

iii. Damage to biodiversity

One of the biggest negative impacts of quarrying on the environment is the damage to biodiversity.

Biodiversity essentially refers to the range of living species, including fish, insects, invertebrates, reptiles,birds, mammals, plants, fungi and even micro-organisms.

Biodiversity conservation is important as allspecies are interlinked, even if this is not immediately visible or even known, and our survival depends onthis fine balance that exists within nature.Quarrying carries the potential of destroying habitats and the species they support. Even if the habitatsare not directly removed by excavation, they can be indirectly affected and damaged by environmentalimpacts – such as changes to ground water or surface water that causes some habitats to dry out orothers to become flooded. Even noise pollution can have a significant impact on some species and affecttheir successful reproduction. Nevertheless, with careful planning and management, it is possible tominimize the effect on biodiversity and in fact, quarries can also provide a good opportunity to create newhabitats or to restore existing ones**.**

iv. Water table and water course alteration

Quarrying activities can lower the water table and result in water wells running dry, however, in the Indian quarries, operations were not found to go deep enough to affect ground water aquifers. Likewise, an alteration of drainage courses and water patterns through quarrying can lead to flooding of land during the rains.

v. Ground vibration

Ground vibration from explosions in small-scale artisanal quarries can be a disturbance to nearby residential properties. This can also cause land subsidence. Other impacts of quarrying are disturbance of land and vegetation; disturbance of river beds or coastal marine areas; disruption of habitats for birds, freshwater and wildlife species; traffic; visual effects; impact on cultural and historic heritage valuesthe discharge of contaminants into air, water, land and the coastal marine area.

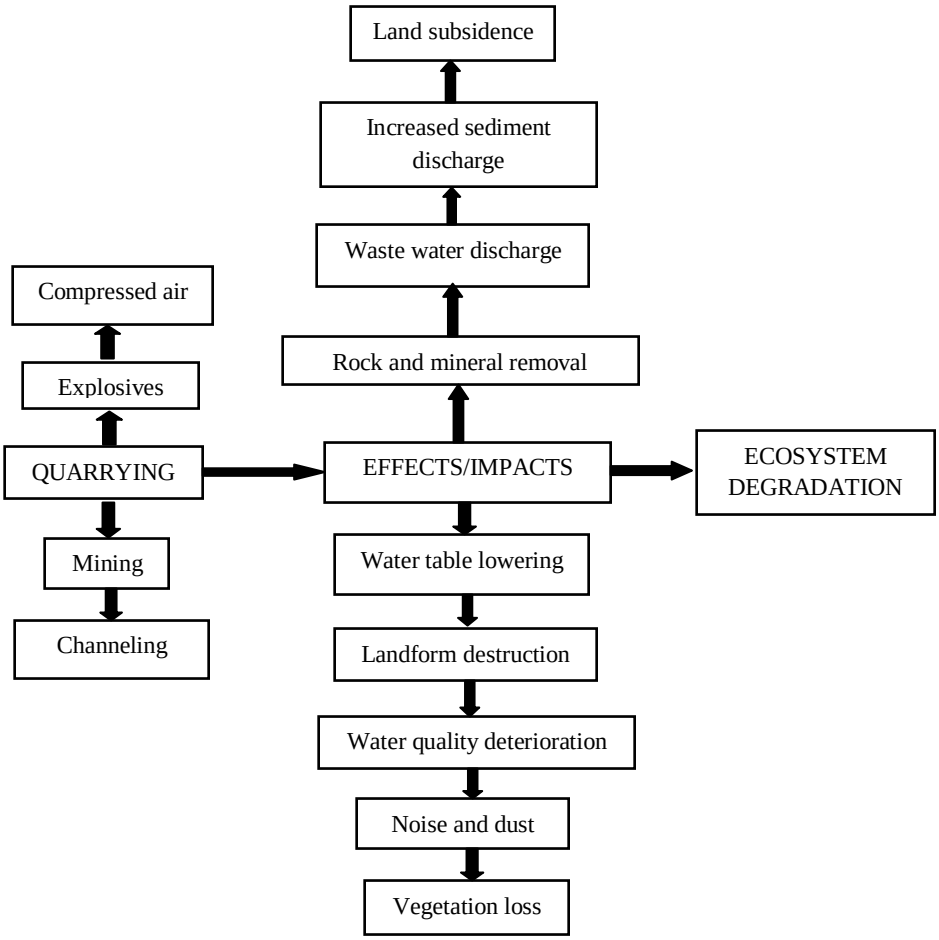

Land subsidence
Increased sediment discharge
Waste water discharge
Compressed air
Rock and mineral removal
Explosives
QUARRYING
EFFECTS/IMPACTS
ECOSYSTEM DEGRADATION
Mining
Water table lowering
Channeling
Landform destruction
Water quality deterioration
Noise and dust
Vegetation loss

Figure 2.1: An overview of quarrying methods and impacts on ecosystem (source:modified after Langer, 2011).

2.3.5 Possible solutions to the problems of quarrying

The following are the possible solutions to quarrying problems (Cheergalsal, 2016).

i. Landscaping could be used during quarrying to diminish the visual scar, and also once quarrying has been completed, to try to return the area to nature as best as possible.
ii. The quarry could be restricted in size, so that it does not engulf the surrounding area.
iii. Lines of trees can be used to reduce noise pollution and try to improve the look of the area. Also, Topographic barriers or vegetated areas can shield or absorb noise.
iv. Trains could be used instead of lorries, which would cut down the traffic and damage to roads.

2.3.6 Positive benefits of quarrying

The positive benefits of quarrying should be considered alongside any adverse effects.

Positive effects include (Quality planning, 2016b):

i. Quarry provides direct and indirect employment opportunities.
ii. It serves as a diversification of the local economy and support of ancillary services such as engineering, mechanic and construction businesses.
iii. It reduced social and economic costs of having aggregate resources closer to demand.
iv. It creates opportunity for the end use of quarries, for example, recreational or habitat opportunities.

v. It contributes to the economic and social development of an area through the provision of raw materials to maintain and enhance community facilities, services and infrastructure such as water treatment plants, hospitals, schools, airports, new roads, bridges, motorways and new buildings.

vi. Quarry enhances flood protection through the removal of excess aggregate from riverbed.

vii. It create habitats for birds where gravel extraction is well managed.

2.4 Satellite Imagery Applications in Quarry Monitoring

Remote sensing can be broadly defined as the collection and interpretation of information aboutan object, area, or event without being in physical contact with the object. Aircraft and satellitesare the common platforms for remote sensing of the earth and its natural resources (Sanderson, n. d). Remote sensing is the science (and to some extent, art) of acquiringinformation about the Earth's surface without actually being in contactwith it. This is done by sensing and recording reflected or emitted energyand processing, analyzing, and applying that information (CCRS, 2007).

The availability of remotely sensed data is increasing with the development of remote sensing techniques and satellites. Exhaustive overview of remote sensing tools is available today, including information on resolution, spectral bands, revisit capacity, swath, price levels, catalogues access and websites. The most common and cost effective remote sensing data used are high resolution (HR) and in particular Landsat TM (Lindert, 2000). The remotely sensed data do not correspond directly with the information needed and must be interpreted to derive soil and vegetation parameters. For example, reflection data need to be converted to properties relevant for the soil erosion process, requiring detailed fieldwork

to establish relations to be used for the conversion. On the other hand, the advantages of remote sensing are that large areas can be covered at relatively low cost, with a high temporal frequency (Lindert, 2000).

Spatio-temporal analysis usually investigates quantitatively the spatial and temporal changes in land-cover. Spatio-temporal analysis of land use and land cover changes has widely been performed using multi-temporal remote sensing (RS), due to its high spatial and temporal coverage (Jat *et al*., 2008) as quoted in (Ashraf *et al*., 2015).Spatio-temporal assessment of the quarry site using remote sensing technique over a period of time will give a clue over the rate at which the solid rock is crop out to meet the demands of the increasing population (Adeoye, 2012).

Detection of changes in the landuse / land cover involves use of at least two period data sets.The changes in land use /land cover due to natural and human activities can beobserved using current and archived remotely senseddata (Babu *et al*., 2014). A critical prerequisite for application of change detection by remote sensing is the identification of suitable pairs of images representing the same region. The analyst must assure that: the two images are registered (that they match exactly when superimposed); they were acquired during the same season, especially if use to track changes in vegetation; and there are no significant atmospheric effects. In brief, the two images must be compatible in every respect-- scale, geometry, resolution – otherwise the change detection algorithm will interpret incidental differences in image characteristics as changes on the landscape (Parece and Campbell, 2013).

Macleod and Congalton (1998) list four aspects of change detection, which are important when monitoring natural resources:

i. Detecting the changes that have occurred.
ii. Identifying the nature of the change.
iii. Measuring the area extent of the change.
iv. Assessing the spatial pattern of the change.

2.4.1 The Normalized Difference Vegetation Index (NDVI)

The Normalized Difference Vegetation Index (NDVI) is a numerical indicator that uses the visible and near-infrared bands of the electromagnetic spectrum, and is adopted to analyze remote sensing measurements and assess whether the target being observed contains live green vegetation or not (FSNAU, 2016). Generally, healthy vegetation will absorb most of the visible light that falls on it, and reflects a large portion of the near-infrared light. Unhealthy or sparse vegetation reflectsmore visible light and less near-infrared light. Bare soils on the other hand reflectmoderately in both the red and infrared portion of the electromagnetic spectrum (Rouse *et al.*, 1993).

This ratio yields a measure of the photosynthetic capacity and produces values in the range of -1.0 to 1.0, where vegetated areas will have values greater than zero and negative values indicate non-vegetated surface features such as water, snow or clouds.

Mathematically,

$$\text{NDVI} = \frac{NIR-RED}{NIR+RED} \quad (2.1)$$

Where: NIR is the near infrared band and red is the red band.

2.4.2 The Normalized Difference Water Index (NDWI)

The Normalized Difference Water Index (NDWI) is a satellite-derived index from the Near-Infrared (NIR) and Short Wave Infrared (SWIR) channels. The SWIR reflectance reflects changes in both the vegetation water content and the spongy mesophyll structure in vegetation canopies, while the NIR reflectance is affected by leaf internal structure and leaf dry matter content but not by water content (Product fact sheet, 2011).

The Normalized Difference Water Index (NDWI) is a new method that has been developed to delineate open water features and enhance their presence in remotely-sensed digital imagery. The NDWI makes use of reflected near-infrared radiation and visible green light to enhance the presence of such features while eliminating the presence of soil and terrestrial vegetation features (McFeeters, 1996).

$$\text{NDWI} = \frac{RED - SWIR}{RED + SWIR} \quad (2.2)$$

$$\text{NDWI} = \frac{GREEN - NIR}{GREEN + NIR} \quad (2.3)$$

Where: RED is the red band, NIR is the near infrared band and GREEN is the green band.

It ranges from -1 to +1, -1 to represent no water content while +1 represent presence of water content.

Equation 2.2 is used to monitor changes in water content of leaves, using near-infrared (NIR) and short-wave infrared (SWIR) wavelengths (Gao, 1996). Equation 2.3 is used to monitor changes related to water content in water bodies, using green and NIR wavelengths (McFeeters, 1996).

2.5 Review of Related Works

This section explains evaluation of various related works by different researchers and was done so as to identify what has been done previously and gaps to be filled by this study. Here, the research problem (thesis i.e. the claim or argument), data type, objectives (factsthe work was intended to accomplish), method (used in achieving the objective), results (what happens when the method was applied) and conclusion were stated (Kothari, 2004).

2.5.1 Related studies in other parts of the world

Eshiwani (2014) understudied the effects of quarrying activities on the environment in Nairobi county: a case study of Embakasi district. The objectives of the study sought to: examine the effects of quarrying on the natural environment; establish the effects of quarrying activities on the quarry workers and the area residents; establish if the law governing quarrying activities are adhered to by concern parties. Questionnaires and interview were used as tools of data collection. The information collected was analyzed using SPSS for cross tabulation and to generate frequencies and statistical graphs for the interpretation of data. Through Chi square test, it was established that there was a relationship between the quarrying activity and the health of both the quarry workers and area residents. The findings showed that regardless of the important role that quarrying activities played in the economic growth; it resulted into negative effects to the environment such as land degradation. Also, the quarries produce a lot of noise, dust and there has been a huge loss of vegetation. Most of the quarries have been abandoned and they have been used as dumping sites by other construction sites and nearby households.

Again, Mwangi (2014) carried out an assessment of environmental impacts of quarrying activities in Ndarugo area, Kiambu county Kenya. The objectives were to: evaluate the

legal frameworks and policies governing quarrying activities; assess the bio-physical and socio-economic effects of quarrying activities in the area; examine the state of the abandoned quarries and what use they are put to; identify and explain mitigation measures that should be adopted to manage andcontrol the negative environmental impacts of quarrying activities. The data was collected using questionnaires and was usedin computation of statistics such as frequencies, totals, percentages, tabulations and cross tabulations.Secondary sources and observation provided data on bio-physical characteristics of the site aswell as the quarrying process. The study concluded that some of the quarry sites have been abandoned and the activequarry sites have numerous negative environmental impacts both bio-physical and socio-economicwhich affect both the people living in close proximity to the mining sites and theworkers who work in the sites. The study also concluded that both the abandoned and active quarry sites have hugely contributed to the degradation ofthe environment as well as posing numerous risks associated with open pits.

Tagore *et al*. (2012) mapped degraded lands in Bhopal India using remote sensing and GIS techniques. The datasets used are the Indian Remote Sensing (RS) satellite (IRS P-6) LISS III sensor and SRTM for slope derivation. Also, ancillary data were used for land use and land cover and soil characteristics. Based on length and degree of slope fromSRTM, land use /cover and soil characteristics asrevealed by IRS-LISS-III data and other related ancillary data. The study concluded that three soil erosion categoriesnamely sheet erosion, gullied, and stony wastewas found in the study area. The sheet erosion occupied 58365 hectaresfollowed by gullied 1519 hectares. The stonywaste is encountered in 923 hectares. Theextent and geographical distribution of degradedlands like sheet erosion, gullied and

stony wasteareas can be used as an input for future planningreclamation conservation program.

Also, Sreenivasa and Reddy (2014) investigated socio-economic and environmental perception of inhabitants of a quarry area - a case study of Bidadi, Bangalore rural district, Karnataka. The objectives were to: investigate the impacts of quarry on the physical and human environment; assess the pollution and other impacts on the surrounding environment; make comparative study of social and economic status of the workers and non-worker inhabitants; identify different problems faced by inhabitants and their environmental perception; study the attitudes of both beneficiaries and non-beneficiaries of the quarrying activity; and highlight certain impacts on livestock health and productivity of crops. A total number of 25 sites were surveyed. The study used questionnaires to collect primary data and had three major parts namely; demographic; economic; and environmental aspects.etc. They concluded that many positive impacts were realized from a long-term quarry unit. In this context, provision of job opportunities, business, transport and communication, laborer etc. are the major ones.However, negative impact also prevails in this environment like health hazards, crop loss (both in productivity and health) reduction in livestock population etc., resulting in higher reduction in economic status of certain household.

Mohamed and Mohamed (2013) studied quarry blasts assessment and their environmentalimpacts on the nearby oil pipelines, southeast of Helwan City Egypt. Data was collected by using five seismographs at different times and distances to record the vibrations of blast from the quarry site. Thewave forms are analyzed by picking the first breaks and determiningthe travel time-distance (T–D) curves and depth modelsusing

SeisRefa software package, which is acomplete seismic refraction processing and modeling software.It is based on its processing on the delay time and ray tracingmethods.According to the first arrival P-waves, the wave forms areanalyzed. The deduced time-distance curves and the corresponding2-D depth model at each profile are obtained in orderto interpret the subsurface features. Also, by applying the MASW technique, they obtained the dispersioncurves (phase velocity versus frequencies). The shear wavevelocity profiles are obtained through an inversion process forthe dispersion curve of the Raleigh-type surface waves on amulti-channel record. It was concluded that from the shallow seismic survey for the P-waves and multi-channel Analysis of Surface Waves(MASW), it is obvious that, the closest area of thetwo pipelines of SUMED company near the National CementQuarry is not affected by shallow structures, caves or low velocity layers. Also, the safe distance to avoid any environmental effects is 650m, following the deduced Peak Particle Velocity (PPV) and scaled distance (SD) relationship.

Interestingly, Nartey *et al.* (2012) evaluated the effects of quarry activities on some selected communities in the Lower Manya Krobo District, Eastern region of Ghana. Data collection was done by primary and secondary methods. The primary data involved data collected by dust level (particulate matter) measurement, PM_{10} in the study area. The secondary data involved data collected from health records in the hospitals most patronized by the people. Social survey was also conducted by questionnaire administration in the communities sampled. The work concluded that common health cases recorded were acute respiratory tract infection, ear and eye infections, cough and pneumonia. Also, thedevastating effects of limestone mining include the loweringof water tables, creation n of labour bottlenecks forpeasant agriculture, encroachment onto agricultural land, destruction of buildings due to

cracks, pollution of rivers, loss of biodiversity, destruction of crops and unclean rain water harvested from roofs.

Fadhil (2009) executed land degradation detection using Geo-information technology for some sites in Iraq. In his work, the objectives were to assess land degradation severity and calculate land degradation risk in the ecologically vulnerable area in upper Mesopotamian plain of Iraq using Geo-information technology; to develop a new index for monitoring, assessing, and mapping the Iraq sand dunes accumulations, and assess the sand dunes expansion rate and then differentiate regional trends in land degradation. The datasets used are two Landsat TM and ETM+ imageries. ERMapper 7.1, Erdas Imagine 9.2, ArcView 3.3, and ArcGIS 9.1 environments to process, manage, and analysis the raster and thematic datasets.The Normalized Differential Water Index "NDWI", Tasseled Cap Transformation Wetness "TCW", and a new index proposed in this study that is the Normalized Differential Sand Dune Index "NDSDI".The results showed a clear deterioration in vegetative cover (2,620.4 km^2), an increase of sand dune accumulations (1,018.8 km^2), and a decrease in soil/vegetation wetness (1,720.4 km^2), accounting for 12.9, 5.0, and 8.5 percent, respectively, of the total study area.In addition, a decrease in the water bodies area was detected (228.1 km^2). Sand dunes accumulations had increased in the total study area, with an annual increasing expansion rate of (10.2 $km^2 year^{-1}$) during the ten years covered by the study. The land degradation risk in the study area has increased by 111% during the study period. The study concluded that most of the counties in the study area are exposed to a serious risk of land degradation and drought water bodies.

Gao and Liu (2009) determined land degradation causes in Tongyu county, Northwest China via land cover change detection. The degraded lands were mapped from satellite

images: two full-scene Landsat TM/Enhanced TM plus (ETM+) images recorded on 18 September 1992 and 22 June 2002, respectively. The land covers inside the study area were mapped into barren, degraded land, productive (healthy) farmland, fallow (harvested) farmland, grassland, woodland, settled areas, wetland, and water using maximum likelihood method of classification in ERDAS imagine environment. These land cover maps revealed that the area subject to land degradation in the form of soil salinization, waterlogging and desertification increased from 2400 km^2 to 4214 km^2, in sharp contrast to most severely degraded land that decreased by 122.5 km^2. Newly degraded land stems from productive farmland (263 km^2), harvested farmland (551 km^2), and grassland (468 km^2). Therefore, the worsened degradation situation is attributed to excessive reclamation of grassland for farming, over cultivation, overgrazing, and deforestation.

Jessica (2002) carried land degradation detection, mapping and monitoring in the Lake Naivasha basin, Kenya. Multi-source and multi-temporal data, namely: Landsat TM, ASTER and ERS-2 SAR data were used. Ancillary data such as topographic maps, geological map, soil map and DEM were used. The materials used to analyze these datasets are ILWIS v3.0, ERDAS Imagine v8.4, hand penetrometer, field spectroscope, mylar, digital camera, Garmin 12 XL GPS receiver. Analysis of the datasets was done to reveal different degradation classes. It was concluded that there are usually more than two degradation classes found per mapping unit and visualization becomes a constraint. Constraints to which generalizing spatial data forfeits the purpose of developing methods for an improved detection and mapping of land degradation useful for micro-scale planning.

Furthermore, Mustafa *et al*. (undated) mapped degraded lands from multi-date remotely senseddata using decision tree based classification (DTC). IRS-P6 LISS3 satellite data of three dates namely, 1st February, 8th May and 23rd October 2009 (path: 097, row: 052) were used for the study. The remote sensing processing software used was ENVI v4.7 and three remote sensing derived indices were used such as Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI) and Soil BrightnessIndex (SBI) for identifying vegetation, waterlogged area and salt affected land respectively.Results revealed that about 41.24% of area is non-agricultural land in which four categories of degradation could be identified i.e. degraded hill(4.05%), degraded forest (3.46%), wetland (6.26%) and ravinous land (3.26%). The remaining (58.76%) is agricultural land out of which 75.08% is normal land and (24.92%) suffers from two types of degradation viz., chemical (salinity) and physical deterioration(waterlogged).

2.5.2 Relatedstudies in Nigeria

Afeni and Adeogun (2015) assessed communities – company relation in limestone mining region of southwest Nigeria: The Ewekoro socio-economic view. Data were collected through the use of well-structured pre-tested questionnaires and oral interview in order to assess the socio economic impact of quarrying and processing of limestone on the inhabitants of the community and the workers. It also shows that the benefits derived by the host community like employment, good roads, schools and hospitals are insignificant when compared with the negative effects of the exploitation on the community which includes reduction in crop production, negligence of education by students, overcrowding and high competition for little-available social amenities.

Ujoh *et al*. (2014) executed Multi-temporal change detection at a limestone miningand cement production facility in central Nigeria. Materials used are multi-temporal satellite imageries, namely: Landsat (1976,1986, 1996) and Nigeriasat-1 (2006) were used as datasets. They were analyzed using ILWIS Academia 3.3 and SPSS Version 15. Land use and land cover (LULC) change detection;land surface temperature (LST) extraction; and normalized differentials of vegetation index (NDVI) estimation werecarried out. The study concluded that there is rapid decline in density and quality of vegetation cover within thestudy area.

Abbas and Fasona (2012) applied remote sensing and geographical information technique as a veritable tool for assessing land degradation. The study used Landsat TM image of 1986 and Nigeriasat-1 image of 2008 to assess the degraded lands for the respective years in a section of Niger Delta, Nigeria. GIS software was used for the processing and analysis of the datasets. Land cover classification was carried out to categorize the study area into classes. The results show the different types of land degradation, the area coverage of the degraded lands for the years and how the people of the study area were affected.

More so, Omosanya and Ajibade (2011) evaluated the impact of quarrying on the inhabitants of Otere Village, southwestern Nigeria. In their work, detailed geological mapping was carried into order to grasp the orientation of major tectonic forces whilst interviews were conducted to understand the sufferings of the inhabitants. Rosette diagram was plotted for the orientation of joints in the area.The suffering of the inhabitants of the Otere village as a result of the quarrying activity is immense. The study concluded that the activities by the operator of the quarry in Otere village has adversely affected the villagers,

their health standard have been compromised, their abode endangered, and their means of livelihood (farming) jeopardized.

Lameed and Ayodele (2010) examined the effect of quarrying activity on biodiversity: Case studyof Ogbere site, Ogun state Nigeria. The materials used for the research work are recording sheet, compass,binocular, pencils, zoom lens .35 Camera, Global Positioning System (GPS), 300m tape rule, areas map, structuredquestionnaire and a field assistant.The methods used for fauna survey are both direct and indirect by line-transect, while analysis of Mueller-Dombois and Ellenberg was adopted for vegetation. The research was carried out at both dry and wet seasons in 2008. Unexploited area that was subjected to assessment isestimated to about 450,000km^2. The line transect method was used for the study. The area was subdividedinto four transects, with a kilometer interval in-between eachtransect and parallel to one another. TheDirect method required actual sighting and recording of the speciesinto data sheet along the predetermined transects, while indirectmethod is the recording of the significant signs along the sametransect lines. Also, questionnaires were administered to provide adequateinformation on the socio-economic status of the species utilizationby the inhabitants at the surrounding villages. The study concluded that he activity of quarrying is acomplete removal of the vegetation, which serve as theabode and niches for the wild animals. Only few serial orsuccessional species that are more adaptable will takeadvantage of transitory and unstable situations.

2.5.3 Gapsidentified from reviewed literature

The authors adopted different methods of data collection and use of data; and research methods and analyses. The reviewed studies can be analyzed under the following:

i. Methods of data collection and use of data

Some of researchers used primary data collection method using questionnaires and oral interviews as tools for data collection. The reviewed works that fall under this category are: Afeni and Adeogun (2015); Eshiwani (2014); Mwangi (2014); Sreenivasa and Reddy (2014); Nartey *et al.*, (2012); and Lameed and Ayodele (2010).

In addition, others used secondary data collection method using remote sensing satellites sensors for data collection. The quantities derived from the remotely sensed data were analyzed using appropriate software to find answers. The reviewed works that fall under this category are: Ujoh *et al.*, (2014); Abbas and Fasona (2012); Tagore *et al.*, (2012); Jessica (2012) and Mustafa *et al.*, (undated).

Also, some used both primary and secondary methods of data collection methods using Global Positioning System (GPS) and remote sensing satellites sensors. The reviewed work that fall under this category is Fadhil (2009). Lastly, the third category is those that used geological technique to ascertain the problems are Mohamed and Mohamed (2015); Omosanya and Ajibade (2011) and Lameed and Ayodele (2010).

ii. Methods of analysis and presentation

Those that used questionnaires analyzed the data using statistical approach for analysis. They are Afeni and Adeogun (2015); Eshiwani (2014); Mwangi (2014); Nartey *et al.*, (2012); Sreenivasa and Reddy (2014).

In the same vein, those used satellite remotely sensed data analyzed the data by deriving land use and land cover maps and suitable indices such as Normalized Difference Vegetation Index (NDVI) and Normalized Differential Sand Dune Index (NDSDI) using software such as ArcGIS, ERDAS Imagine and ILWIS. The authors are Ujoh *et al*.,(2014); Abbas and Fasona (2012); Tagore *et al.*, (2012); Jessica (2012), Mustafa *et al.*, (undated) and Fadhil (2009). Lastly, those that used geological technique analyzed the data using line transect method. They are Mohamed and Mohamed (2015) and Omosanya and Ajibade (2011); and Lameed and Ayodele (2010).

However, this study will not only apply Normalized Difference Vegetation Index (NDVI), but also Normalized Difference Water Index (NDWI) for the target indicators derived from remotely sensed satellite data. This is because remotely sensed data offer a synoptic view, temporality (revisit capacity), multi-spectral observation, high level of automation, quick method of data collection, wealth of information, and ease of measurement.

From the above, none of the review studies, both in Nigeria and other parts of the world, investigated quarry depth, proximity of the sites to residential areas, and evidences of quarry-induced structural deformations. Therefore, this study will employ standard mapping tool such as Differential Global Positioning System (DGPS) to carry out quarry depth and quarry-induced structural deformations. The rationale for incorporating conventional mapping technique for this investigation is because it is in-situ; offers high accuracy; it is highly updated; and has a complete coverage.

CHAPTER THREE

MATERIALS AND METHOD

3.1 Introduction

This chapter discusses the methodology employed for processing and analyzing the datasets for this study, and is explained in two parts: namely, materials and method for processing and analyzing datasets.

3.1.1 Reconnaissance survey

This was done in two stages: namely field and office reconnaissance. The study area was reconnoitered for knowledge and primary information acquisition in order to fathom likely challenges that could impede data acquisition. This was done by physically visiting the eight (8) quarry sites and collected their attributes data in order to verify their spatial location on the images. In addition, an office reconnaissance was carried out to search for all available data that were relevant to this research.

3.2 Materials

This includes software, hardware and datasets employed for this study.

3.2.1 Software and hardware

Geographical information system (GIS) and remote sensing software were used to process, analyze and integrate the spatial data to achieve the aim of this research. The software and hardware used are listed.

a) Software used

i. ArcGIS v10.1 Desktop
ii. ENVI v5.1
iii. TCX converter v20.30

iv. Google Earth v7.1.2 2041

v. SAS planet. Unicode (an image downloading software)

b) Hardware used

i. Hi-Target Differential GNSS Receiver, ii. Digital camera,iii. HP Laptop computer

3.2.2 Datasets and source

The datasets used for this study are both raster and vector models, namely: field observation data, satellite imagery and shapefiles. These are shown in the Table 3.1:

Table 3.1: List of datasets used and their sources.

S/n	Data type	Data name	Data date	Source	Scale/Resolution	Purpose	Description
1.	Primary	Quarry length, breadth and depth	Existing	Field observation		Determining of geometrical characteristics of quarry sites for spatial analysis	An X, Y, Z data obtained using Hi-Target GNSS receiver.
2.	Secondary	IKONOS	2015	Purchased from Vendor	4m	Land cover mapping and spatial analysis	3-band multispectral image: NIR, red and green
3.	Secondary	IKONOS	2005	Purchased from Vendor	4m	Land cover mapping and spatial analysis	3-band multispectral image: NIR, red and green
4.	Secondary	Landsat 8: OLI and TIRS	2015	USGS	30m except band 8 (panchromatic) with 15m.	Derivation of NDVI and NDWI	11 bands multispectral image acquired by OLI and TIRS
5.	Secondary	Landsat 7: ETM+	2002	USGS	30m except band 8 (panchromatic) with 15m.	Derivation of NDVI and NDWI	8 bands multispectral image acquired by ETM+
6.	Secondary	ASTER Digital Elevation Model (DEM) V2	2015	IPDAAC	30m in both horizontal and vertical directions.	Terrain modelling and depth analysis	A raster Digital Elevation Model (DEM) with global coverage.
7.	Secondary	TCX elevation points	2015	Generated with TCX converter	Random interval	Terrain modelling and depth analysis	Elevation points collected from Google Earth.
8.	Secondary	Bing image	2015	SAS Planet. Unicode	0.59m	Ancillary data for land cover mapping.	Quick look multispectral image displayed over red, green and blue color gun.
9.	Secondary	Administrative map		http://www.gadm.com		Study area boundary demarcation.	A map of political boundaries of Nigeria, its states and LGAs in vector format.

3.2.2.1 Satelliteimagery

Two IKONOS imagery of 2005 and 2015 were acquired for this study and their characteristics are shown in Table 3.2. Also, two cloud-freeLandsat sensors; Enhanced Thematic (ETM+) sensor on-board Landsat 7 of 2002 and Operational Land Imager and Thermal Infrared Sensor (OLI and TIRS) on-board Landsat 8 of 2015 wereused. The satellite scenes have the same climatic conditions with closely matching acquisition dates. This is to ensure that diurnal sun angle effect is minimized in the results. In addition, an Advanced Spaceborne Thermal Emission and Reflection Radiometer Digital Elevation Model (ASTERDEM) of the study area was acquired for surface analysis, and its characteristics is shown in Table 3.1.The satellite scenes came georeferenced and co-registered to World Geodetic System (WGS 84) datum and into UTM zone 32 projection Northern hemisphere. The characteristics of the Landsat data are shown in Tables 3.3 and 3.4 respectively.

Table 3.2: Characteristics of IKONOS sensor used in the study.

Satellite	**IKONOS**
Ground Resolution (m)	4m×4m except 4 = 0.82m×0.82m
Quantization level	11 bit (256 levels)
Repeat coverage	3 days
Altitude	681 Km
Swath with	11.3 Km
Spectral bands (µm)	5 bands 1 = 0.45 -0.52 (blue) 2 = 0.52 – 0.60 (green) 3 = 0.63 – 0.69 (red) 4 = 0.76 – 0.9 (NIR) 5 = 0.45 – 0.90 (Panchromatic)

Source:Digitalglobe, (2015).

Table 3.3: Landsat datasets used in the study.

Scene	Path/Row	Cloud Cover	Year		Sensor	Processing Status	Source
			2002	2015			
1	190/54	0%	30/12/2002		ETM+	Orthorectified	USGS
2	190/54	0%		10/12/2015	OLI & TIRS	Orthorectified	USGS

Source: (USGS, 2015 and GLCF, 2015).

Table 3.4: Characteristics of Landsat 7 and 8 sensors used in the study.

Satellite	Landsat 7	Landsat 8
Sensor	ETM+	OLI & TIRS
Ground Resolution (m)	30m×30m except 8 =15m×15m and band 6 = 60m×60m	30m×30m except band 8 = 15m×15m; band 10 and 11 = 120m×120m
Inclination	98.2°	98.2°
Quantization level	8 bit (256 levels)	16 bit (65536 level)
Orbital type	Sun-synchronous	Sun-synchronous
Repeat coverage	16 days (233 orbits)	16 days (233 orbits)
Altitude	705 Km	705 Km
Swath with	185 Km	170×185 Km
Spectral bands (µm)	8 bands 1 = 0.45 -0.515 (blue) 2 = 0.525 – 0.605 (green) 3 = 0.63 – 0.69 (red) 4 = 0.75 – 0.90 (NIR) 5 = 1.55 – 1.75 (Mid IR) 6 = 10.40 – 12.5 (TIR) 7 = 2.08 – 2.35 (Mid IR) 8 = 0.52 – 0.9 (Panchromatic)	11 bands 1 = 0.433 - 0.453 (Deep blue) 2 = 0.450 - 0.515 (Blue) 3 = 0.525 – 0.6 (Green) 4 = 0.630 - 0.680 (Red) 5 = 0.845 - 0.885 (NIR) 6 = 1.560 - 1.660 (SWIR) 7 = 2.100 - 2.300 (SWIR) 8 = 0.500 - 0.680 (panchromatic) 9 = 1.360 - 1.390 (Cirrus) 10 = 10.3 – 11.3 (TIR) 11 = 11.5 – 12.5 (TIR)

Source:USGS (2015) and GLCF (2015).

3.2.2.2 Ancillarydata

Before undertaking any visual image interpretation task, the image analyst should consider several factors. This involves collecting any relevant collateral sources of information (e.g., maps, field reports, other images) to exploring and identifying the data for possibleattributes that will allow discrimination between the classes (Lillesand *et al.*, 2004).This was used to remedy many of the weaknesses of remote sensing in terms of proper identification of features. For this study, a high spatial resolution Bing image of the study area was downloaded using SAS Planet image downloader. In addition, an administrative shapefile of the study area was used for boundary demarcation. Their characteristics are shown in Table 3.1.



Plate II: A Bing satellite image covering the study area (source:SAS Planet. Unicode, 2004).

3.3 Method

This section explains the various steps used in the processing and analysis of the acquired datasets to execute this study.

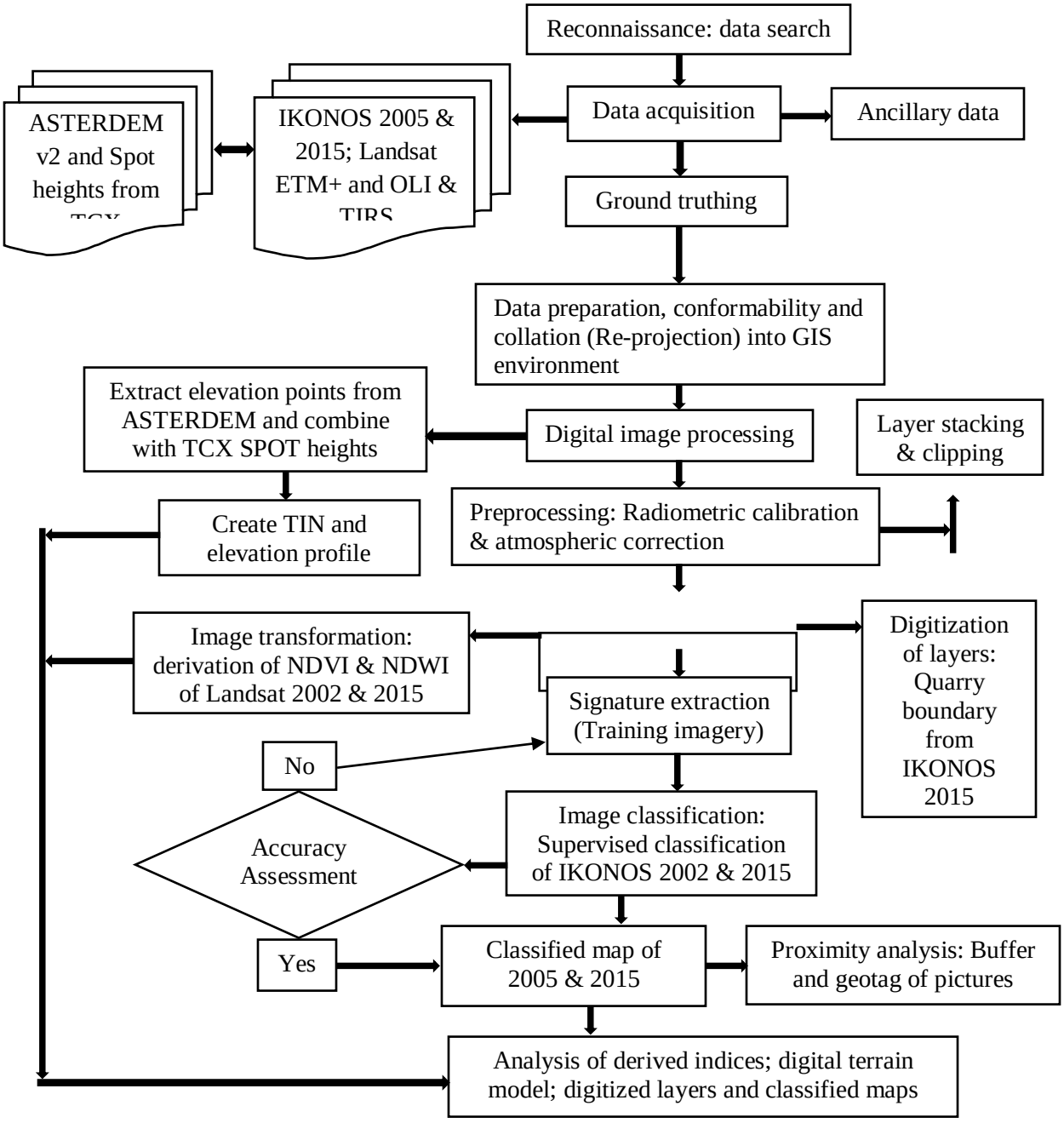


Figure 3.1: Flow diagram showing the steps used in the study.

3.3.1 Data acquisition

In this study, two IKONOS remotely sensed image of Mpape were obtained from a vendor, while the Landsat satellite images were downloaded at the United States Geological Survey (USGS) websites via global visualization (Glovis) platform. In addition, the ASTERDEM, which was developed jointly bythe U.S. National Aeronautics and Space Administration (NASA) and Japan'sMinistry of Economy, Trade, and Industry (METI), was downloaded at the Land Product Distribution Analysis Archive Center (LP DAAC) website. The quarry depths were collected through field data acquisition using Hi-Target Global Positioning System (GPS) receivers.The characteristics of the data is shownin Tables3.2, 3.3 and 3.4 respectively.

3.3.1.1 Fieldworkfor ground Survey method of geometric data acquisition

The quarry depths and other geometrical characteristics of the quarries were acquired using a dual frequency Hi- Target GNSS receivers in a differential mode. Differential system of GPS observation (Base and Rover) was applied for the survey. The base receiver was setup on a known FCT control (FCT 11P) and an in-situ check was done on another FCT control (FCT 12P), all of which are within Mpape. The coordinates for the controls are shown in Table 3.5. All necessary GPS settings were done to obtain and transmit on RTK mode. The rover was switched on, setup and initialized to link up and obtain corrections from the base. Then, the rover was used to acquire all the boundary points and depths of the quarries under study.

Table 3.5: The coordinates of control points used for data acquisition.

S/n	Point ID	Northing (m)	Easting (m)	Height (m)
1	FCT 11P	1009590.472	332336.159	808.310
2	FCT 12P	1008308.734	333743.992	735.707

3.3.2 Data preparation

The acquired data were unzipped and checked carefully to verify the completeness/coverages, consistency, coordinate and projection system of the data. The IKONOS image came already layer-stacked to three multispectral bands and resampled to 0.46 meters spatial resolution.The Landsat ETM+ and Landsat OLI and TIRS came in individual files of variable spatial resolutions Also, the ASTERDEM came as 30 metersresolution. All remotely sensed imagery were projected from geographical coordinate system (GCS) to projected coordinate system (PCS): UTM zone 32N. This is because they were going to be used to create two-dimensional maps in map view for analysis in a GIS environment. In general, the data were prepared in a format suitable for import into GIS environment.

3.3.3 Ground truthing and fieldwork

Here, the information revealed by the remotely sensed data were verified by examining the ground for patterns. It is used for cross – checking of the accuracy of remotely sensed images based on data actually measured in the field.Also, this enable the analyst to be able

to identify land use or land cover suitable for the study area and compare it to what is shown on the image.

3.3.4 Digital image processing

The Landsat ETM+ and Landsat OLI and TIRS remotely sensed data were corrected for radiometric and atmospheric errors in this study. This is necessary when carrying out multitemporal analysis of images (especially NDVI). In general, gain and offset equations for the conversion of remotely sensed images from digital number (DN) to radiance and surface reflectance are shown in equations 3.1 to 3.5.

i. Conversion of Digital Number (DN) to radiance (for TM and ETM+)

$$L_\lambda = \text{Gain} \times DN + \text{Bias} \quad (3.1a)$$

$$L_\lambda = \frac{(LMAX) - LMIN\lambda)}{(Qcalmax - Qcalmin)} (Q_{CAL} - Q_{CALMIN}) + L_{MIN\lambda} \quad (3.1b)$$

Where:

L_λ= Spectral radiance at the sensor's aperture

G = Detector gain of responsivity ($W \cdot m^{-1} \cdot ster^{-1} \cdot \mu m^{-1}$).Equivalent to the gradient (rise/run) from $L_{MIN\lambda}$to $L_{MAX\lambda}$

B = Detector bias or background response. Equivalent to $L_{MIN\lambda}$

Q_{CAL} = Qunantized calibrated pixel value (DN)

Qcal = Minimum quantized pixel value (DN=0 forLPGS products, and DN=1 for NLAPS products).

Q_{calmin} = Maximum quantized pixel value (corresponding to $L_{MAX\lambda}$) inDN=255

Q_{calmax} = Spectral radiance at sensor aperture ($W. m^{-1}. ster^{-1}. \mu m^{-1}$)

[ster = steradian (three dimensional angle from a point on Earth's surface to the sensor)]

$L_{MIN\lambda}$ = Spectral radiance that is scale to *Qcal min*(W. m^{-1}. $ster^{-1}$. μm^{-1})

$L_{MAX\lambda}$= Spectral radiance that is scaled to *Qcal max* (W. m^{-1}. $ster^{-1}$. μm^{-1}).

These values are contained in the product metadata (MTL.file) supplied by the image provider[(Irish, 2008), (Chander and Markham, 2003), (Lathrop, 2004), (Yale, 2013b)].

ii. Conversion of radiance to Top of Atmosphere (TOA) reflectance (for TM and ETM+)

$$\rho\lambda = \frac{(\lambda \times L_{\lambda} \times d^2)}{(ESUN_{\lambda} \times COS_{SZ})} \quad (3.2)$$

Where:

$\rho\lambda$= unitless TOA or planetary reflectance

$L\lambda$= spectral radiance at the sensor's aperture

d = Earth-Sun distance in astronomical units from nautical handbook or interpolated values from Julian day calendar and day of the year (DOY) in excel file.

$ESUN_{\lambda}$= mean solar exoatmospheric spectral irradiance. To be found in Landsat 5 handbook.

COS_{SZ}= solar zenith angle in degrees. ($_{SZ} = 90^{o} - \Theta_{SE}$), where SE = sun elevation[(Irish, 2008), (Chander and Markham, 2003), (Lathrop, 2004), (Yale, 2013b)].

iii. Conversion of DN to Radiance (for OLI and TIRS)

OLI and TIRS band data can be converted to TOA spectral radiance using the radiance rescaling factors provided in the metadata file.

$$L_{\lambda} = M_L \times Q_{cal} + A_L \quad (3.3)$$

Where:

L_{λ}= Spectral radiance at the sensor's aperture (W. m^{-1}. $ster^{-1}$. μm^{-1})

M_{L} = Band-specific multiplicative rescaling factor from the metadata (RADIANCE_MULT_BAND_x, where x is the band number)

A_L = Band-specific additive rescaling factor from the metadata (RADIANCE_MULT_BAND_x, where x is the band number)

Q_{cal} = Quantized and calibrated standard product pixel values (DN) (USGS, 2013).

iv. Conversion to TOA Reflectance (for OLI and TIRS)

OLI band data can also be converted to TOA planetary reflectance using reflectance rescaling coefficients provided in the product metadata file (MTL file). The following equation is used to convert DN values to TOA reflectance for OLI data as follows:

$$\rho\lambda' = M_\rho \times Q_{cal} + A_\rho \qquad (3.4)$$

TOA reflectance with a correction for the sun angle is then:

$$\rho\lambda = \frac{\rho\lambda'}{\cos(\theta_{SZ})} = \frac{\rho\lambda'}{\sin(\theta_{SE})} \qquad (3.5)$$

Where:

ρλ' = TOA planetary reflectance, without correction for solar angle. Note that ρλ' does not contain a correction for the sun angle.

Mρ =Band-specific multiplicative rescaling factor from the metadata (REFLECTANCE_MULT_BAND_x, where x is the band number)

Aρ = Band-specific additive rescaling factor from the metadata (REFLECTANCE_ADD_BAND_x, where x is the band number)

Qcal = Quantized and calibrated standard product pixel values (DN) (USGS, 2013).

TOA reflectance with a correction for the sun angle is then:

$$\rho\lambda = \frac{\rho\lambda'}{\cos(\theta_{SZ})} = \frac{\rho\lambda'}{\sin(\theta_{SE})} \qquad (3.6)$$

Where:

$\rho\lambda$ = TOA planetary reflectance

θ_{SE} = Local sun elevation angle. The scene center sun elevation angle in degrees is provided in the metadata (SUN_ELEVATION).

θ_{SZ} = Local solar zenith angle; $\theta_{SZ} = 90° - \theta_{SE}$(USGS, 2013).

However, the radiometric calibration was not computed using the above expressions, rather, it was carried out in ENVI 5.1 software since the expressions had been modelled into the software. In ENVI 5.1, the method used was Fast Line-of-sight Atmospheric Analysis of Spectral Hypercubes (FLAASH) module and is shown in Figure 3.3. The Landsat images were first converted to at-sensor radiance, then totop-of-atmosphere reflectance (0 to 1.0) using the information available in the metadata file of each sensor. For the IKONOS image, a dark object subtraction (DOS) was carried out for atmospheric correction and is shown in Figure 3.4. The corrections were necessary when carrying out comparison of multi-temporal images (e.g. indices) and multi-sensor data. These corrections ensured uniformity of output across the face of the image and across time. Also, it eliminates noise due to Earth – sun distance (or Earth – sun geometry); atmospheric scattering and absorption; band width (the spectrum at which radiation is received); and sun illumination at the time of acquisition.

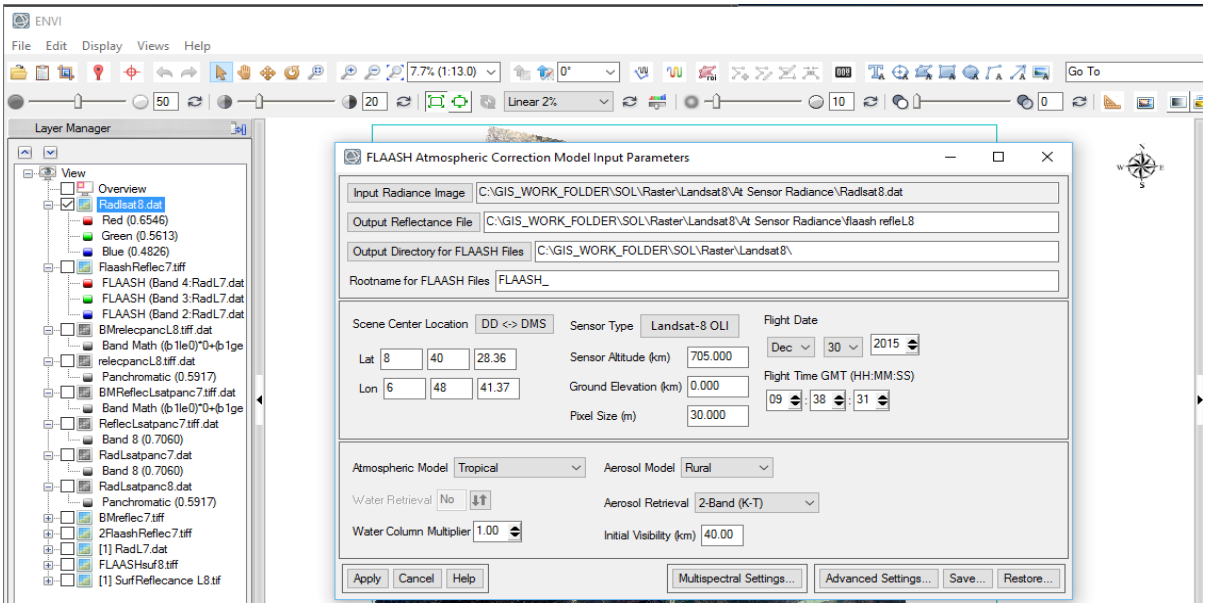


Figure 3.2:A Screen shot of TOA reflectance conversion of Landsat 8 using FLAASH tool in ENVI 5.1.

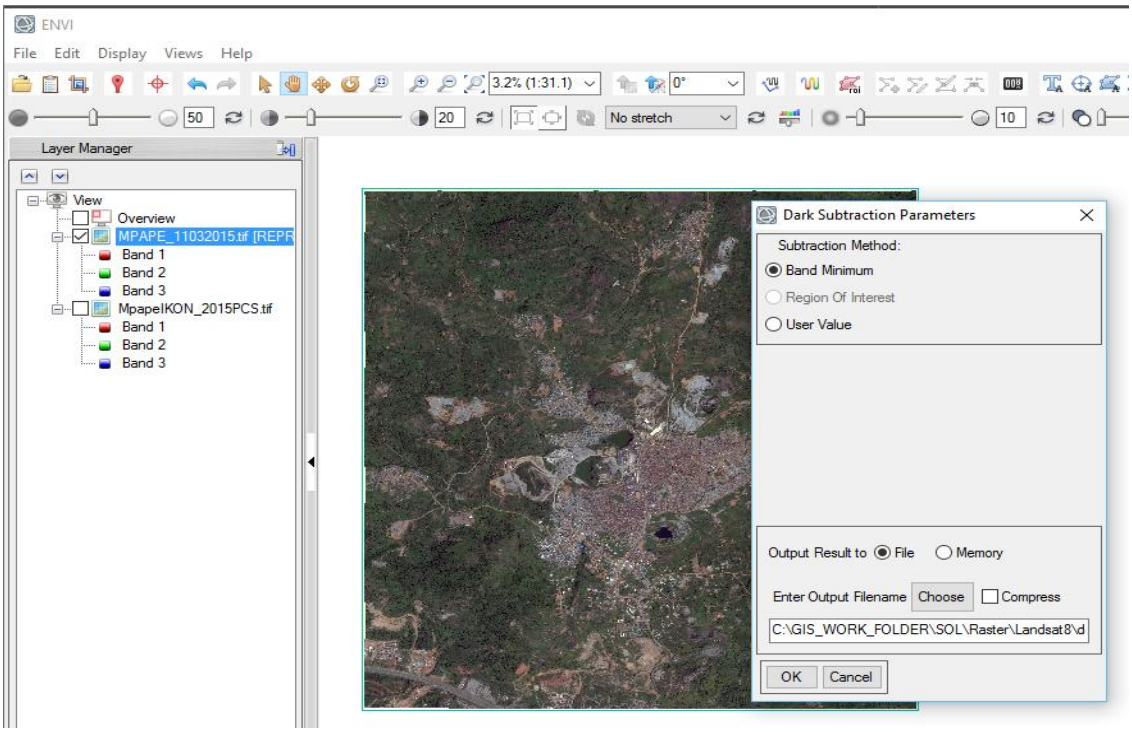


Figure 3.3:A screen shotof the Dark Object Subtraction (DOS) of IKONOS 2015 in ENVI 5.1.

3.3.5 Layerstacking and clipping

The radiometrically corrected individual bands (which were in grey scale – black and white) of Landsat 7 and 8 were layerstacked to display them in different renditions. For Landsat 8 image, only six bands (2, 3, 4, 5, 6, 7) were layerstacked, namely: blue, green, red, NIR, SWIR 1 and SWIR 2 respectively. In the same vein, for landsat 7 image, six bands (1, 2, 3, 4, 5, 7) were layerstacked, namely: blue, green, red, NIR, MIR 1 and MIR 2 respectively. The uniformity in the number of bands in both images was to consistency, which is a requirement in remote sensing change detection. After this, the layerstacked images were clipped (or subsetted) to focus on the area of interest (Mpape). Also, the IKONOS and ASTERDEM image data were also clipped to the extent of the study area. This operation also enables larger files of image data to be reduced to free up computer disk space. The layerstacking and clipping was achieved using a shapefile of Mpape extent and was in the ArcGIS 10.1 environment. The display is shown in Figure 3.5.

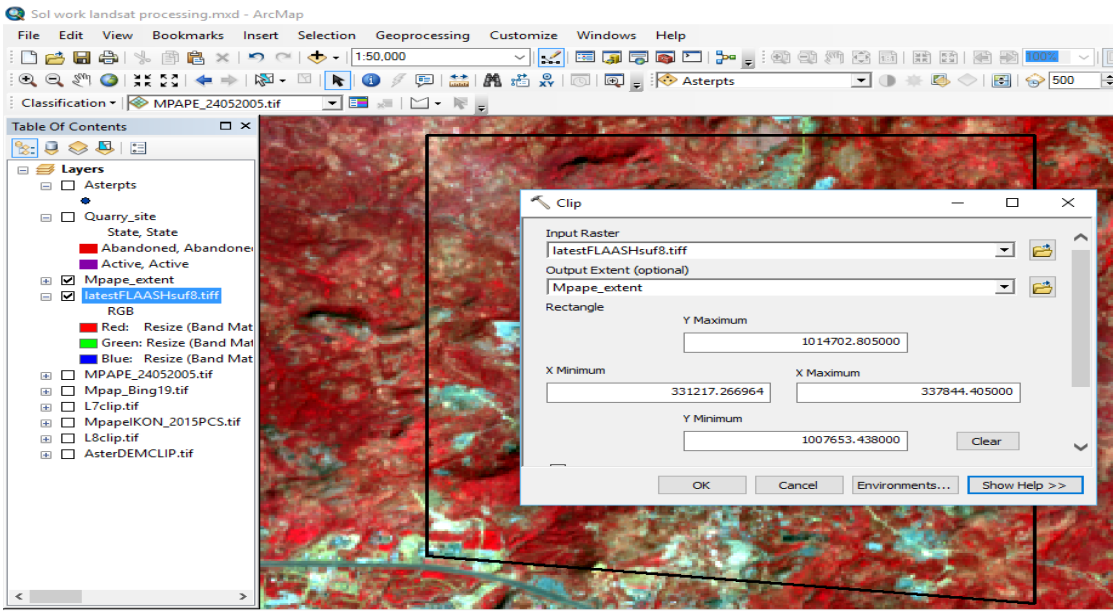


Figure 3.4: A subset of layerstackedLandsat 8Image 2015 of Mpape with FCC (5, 4, 3) color rendition.

3.3.6 Image Enhancement

Particularly, the IKONOS images were enhanced to improve the clarity of the features in the image. For the purpose of digitizing the layers and classification, there was need for images to be sharpen. Thus, a high pass filter (3 by 3-moving convolution). This enhances and sharpens the edges and boundaries between features represented in the raster. A filter tool in spatial analyst toolset was used in ArcGIS software.

3.3.7 Extraction of elevation points from ASTERDEM

Elevation points from the clipped ASTERDEM was extracted to create a smooth triangulated irregular network TIN for the creation of 3D model of the study area, and. A total of 46666 points were extracted and were converted to excel format. In ArcGIS 10.1 environment, raster to point tool in the conversion toolset was used to extract the points. The minimum elevation is 532m and the maximum elevation is 814m respectively. Similarly, spot heights were collected from Goole Earth using TCX software and the spot heights were randomly collected, but closely at each quarry site for proper representation of the surface condition of each quarry site. The generated TCX spot heights from Google image were combined with the extracted DEM points for densification of the area. Then, the combined points were again converted to a resampled raster of 15 meters resolution for creation of a smooth TIN surface. This is a 2-dimensional representation of 3-dimensional data, which will assist in the analysis of the depth in each quarry site within the study area. Topo to raster tool in 3D analyst toolset in ArcGIS v10.1 environment was used. The extracted points and TCX points are shown in Figure 3.6.

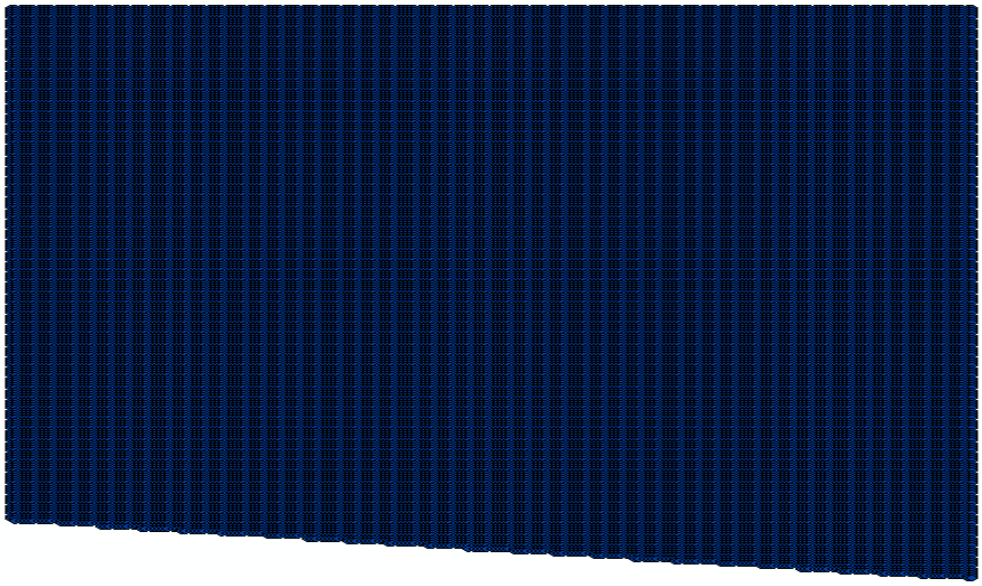


Figure: 3.5:A Screenshot of the 30m resolution extracted ASTERDEM elevationpoints in ArcGIS 10.1 environment.

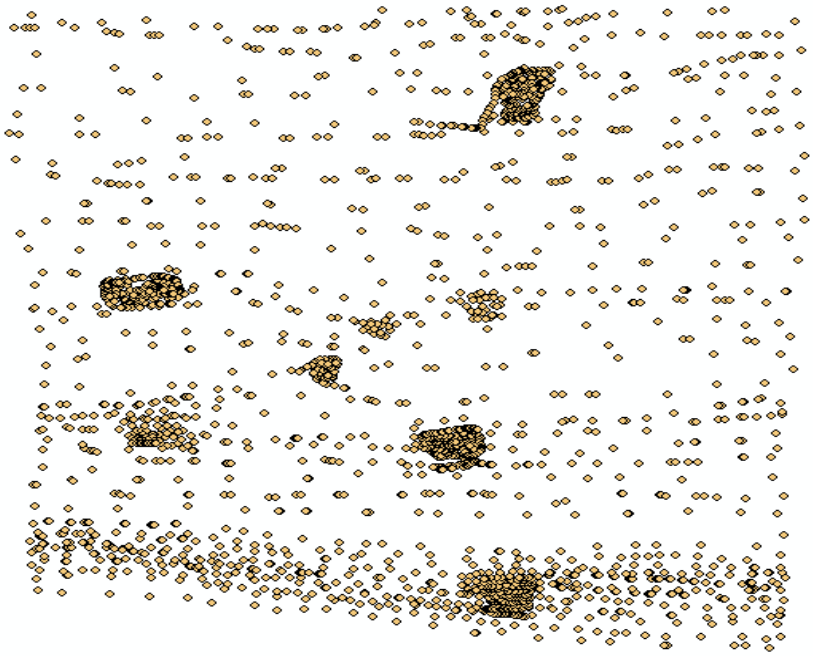


Figure 3.6: A screenshot of generated TCX heights from Google.

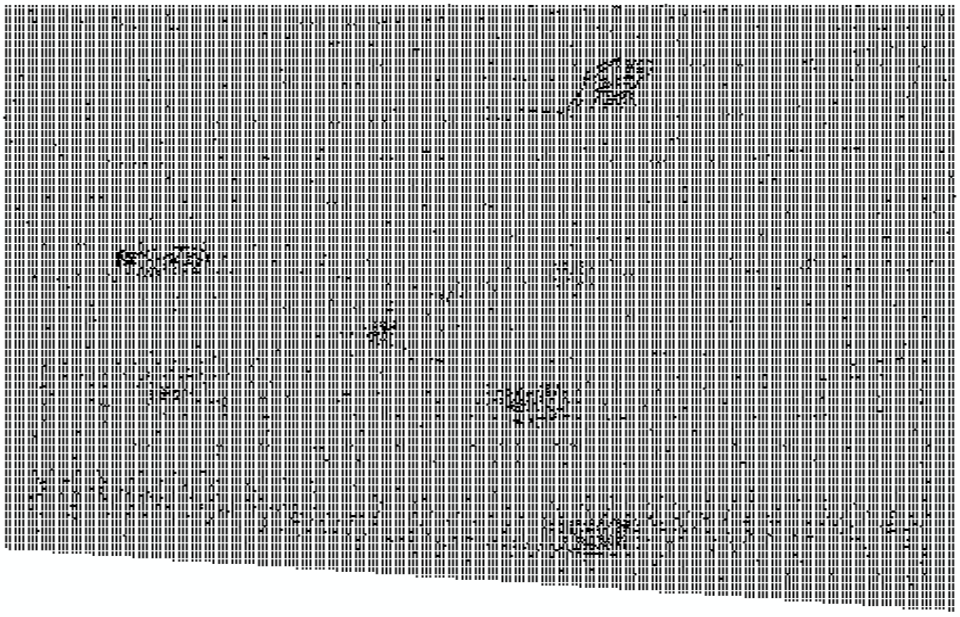


Figure 3.7: A screenshot of merged extracted ASTERDEM and TCX elevation points.

Table 3.6: A table showing the statistics of elevation points.

S/n	Statistics	a	b	c
1	Count	46666	2158	48824
2	Minimum	532	538	532
3	Maximum	814	793	812
4	Mean	661.16	668.40	29.54
5	Standard deviation	39.39	33.53	137.56

.

3.3.8 Digitization of layers

For the mapping of the distribution of the quarry sites within Mpape, a vector model was adopted. Shapefiles were created for settlement, quarry site, roads, water body and open space (non built-up area) were created. A polyline feature type was used for creating a road layer while polygon feature type was used for others. An on-screen digitizing method was

adopted. The quarry sites were digitized as active and abandoned polygons. This works simply by tracing each feature of interest in the IKONOS 2015 image and was achieved in the ArcGIS 10.1 environment. The created layers are shown in Figure 3.9.

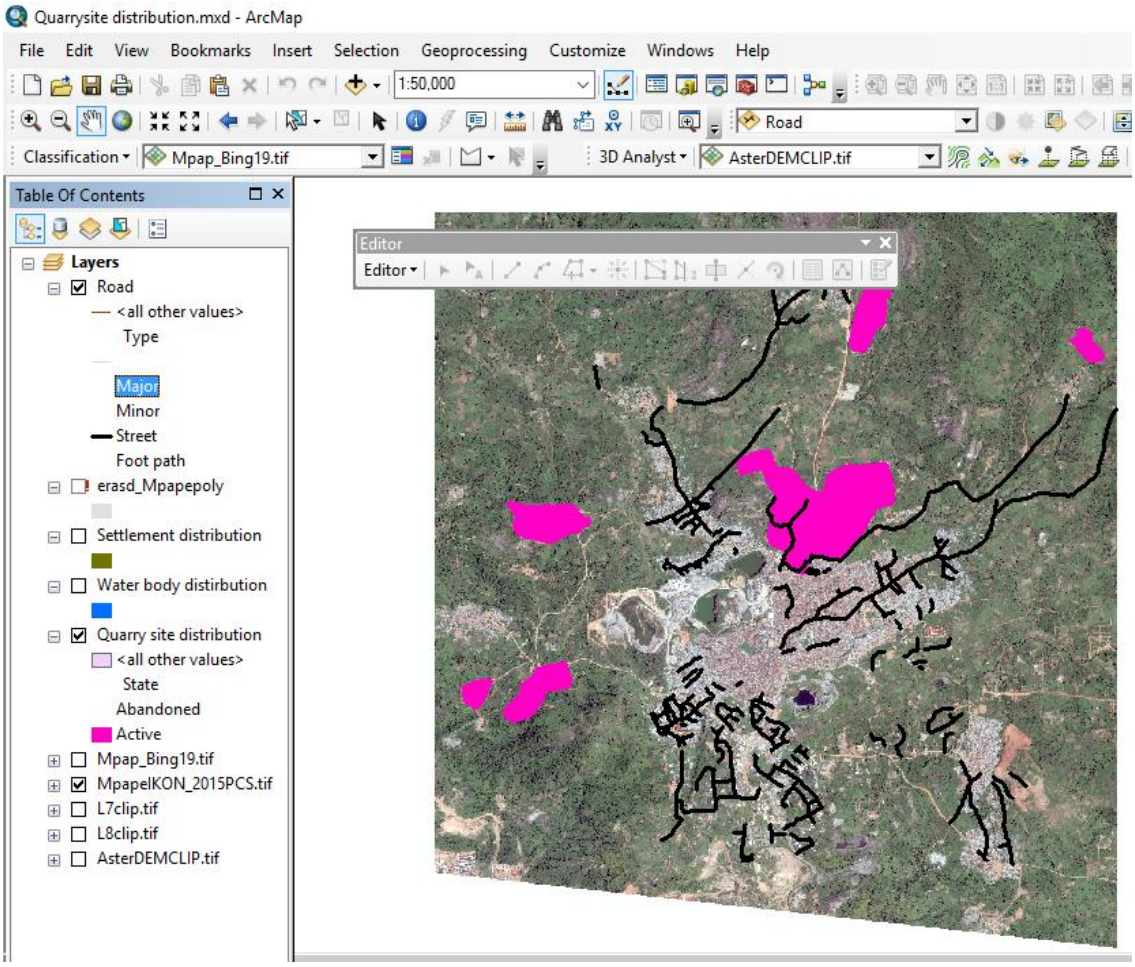


Figure 3.8: A screenshot of some digitized layers (quarries and roads) in the IKONOS image of 2015 in ArcGIS 10.1 environment.

3.3.9Image transformation (indices derivation)

For the purpose of delineating effects of the quarry sites on vegetation and water within Mpape, an NDVI and NDWI were created. The NDVI projects the vegetation content in an

area and suppresses non-vegetated areas. In addition, the NDWI highlights water contents in an area and suppresses features that are not water.

Mathematically, given by Equations 3.6 (Rouse *et al*, 1993) and 3.7 (McFeeters, 1996).

Normalized Difference Vegetation Index

$$\text{NDWI} = \frac{\text{NIR} - \text{RED}}{\text{NIR} + \text{RED}} \quad (3.7)$$

Where NIR = near infrared band (which is band 4 for Landsat 7 and band 5 for Landsat 8). Red band is band 3 for Landsat 7 and band 4 for Landsat 8 respectively.

Normalized Difference Water Index

$$\text{NDWI} = \frac{\text{NIR} - \text{GREEN}}{\text{NIR} + \text{GREEN}} \quad (3.8)$$

Where Green = band 2 for Landsat 7 and band 3 for Landsat 8. NIR = band 4 for Landsat 7 and band 5 for Landsat 8 respectively.

The above equations were entered into ERDAS imagine v9.2 and spatial modeler tool was used to calculate the various indices. The spatial modeler is equivalent to the raster calculator tool in the ArcGIS and ENVI software. In the computation, instead of using the layerstacked 7 bands each for Landsat 7 and Landsat 8, the individual radiometrically

corrected bands in the equation were used for the computation. Figure 3.10 shows the execution of the indices derivation in ERDAS imagine environment.

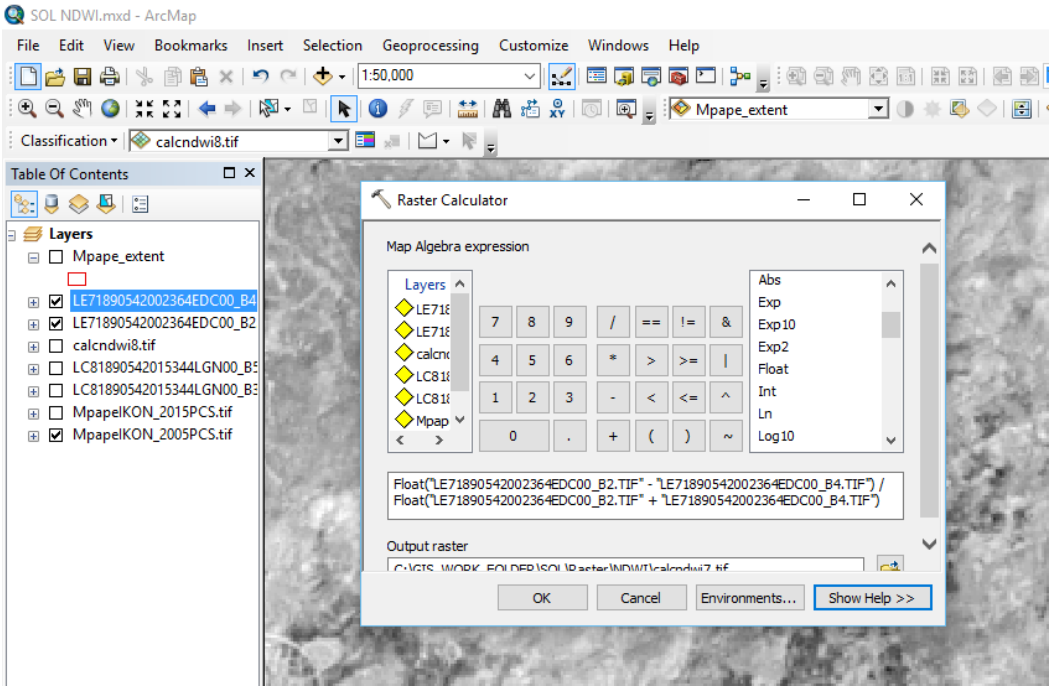


Figure 3.9:A screenshot of NDWI derivation of Landsat 7 of 2015 using raster calculator of ArcGIS v10.1.

3.3.10 Signature extraction (Training Samples)

The procedure for collecting training samples from imagery is analyst dependent i.e. the analyst must be acquainted with features within the image with the use of ancillary data and adoption of visual analysis. In this study, training samples were collected from the IKONOS images of 2005 and 2015, displaying each in a false color composite (FCC) color rendition. Also, the Bing image was also scrutinized in order to identify the various land cover conditions available in the imagery. This was like a comparison approach between the IKONOS images and the Bing image. Elements of visual interpretation such as tone,

shape, size, pattern, texture, shadow, and association were also used to distinguish between individual classes.

The training samples were collected using image classification toolbar in ArcGIS 10.1. Based on the objectives of the research, six land covers were chosen, and color and number codes were assigned to each. The description of the land covers is displayed in Table 3.7. Then, a draw polygon tool in the image classification toolbar was used to collect samples by digitizing (on-screen) each land cover of interest as shown in figure 3.11. Numerous samples (say 15) were collected for each land cover for precision to attain a high level of accuracy and suitable color was chosen for each class in the training sample manager. This would later be reduced to five classes after the image must have been classified. The collected training samples were saved and stored in a default format (.gsg).

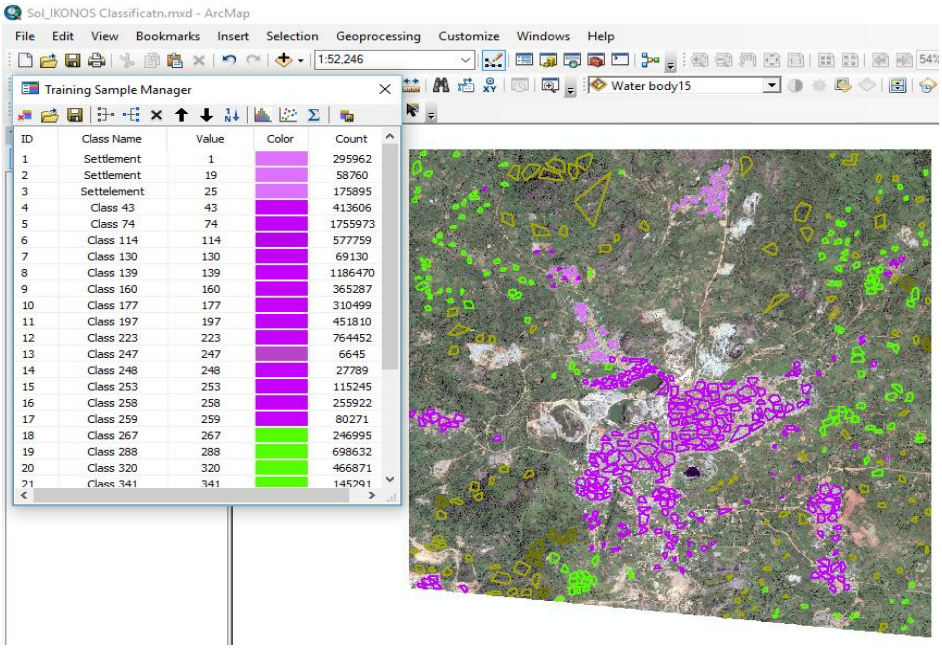


Figure 3.10: A Screenshot of generated training samples of IKONOS 2015 image in ArcGIS v10.1.

Table 3.7:A Description of the Land Cover Chosen for the IKONOS Images.

	Training sample	Code	Color Assign	Description
1	Quarry site	4	Purple	Land consisting of rocky, stony materials and where mining activities are evident.
2	Settlement	1	Electron gold	Commercial, industrial, residential, government facilities and settlements.
3	Water body	6	Blue	Land surface occupied by pond and waterlogged area.
4	Vegetation	3	Dark Green Green	Land covered with trees; land/plants for grazing: grass-covered used for grazing livestock.
5	Farmland	2	Light Green	Land occupied or related to agriculture or farming activities.
6	Rocky surface	5	Black	Land consisting of rocky and stony materials.

Source: Modified after Anderson (2008).

3.3.11 Image classification

The objective of image classification is to match the spectral classes in the data to the information classes of interest. The ideais to categorize all pixels of same digital number, radiance or reflectance response into one class. Rarely is there a simple one-to-one match between these two types of classes. Rather, unique spectral classes may appear which do not necessarily correspond to any information class of particular use or interest to the

analyst. In addition, it can be very difficult to classify a settlement class or cover as both residential and industrial. This is because they are both built-up areas; they have the same spatial context (proximity) and share the same spectral characteristics.

The six chosen land covers are settlement, quarry site, water body, vegetation, rocky surface and farmland. Both settlement and quarry site are both built-up areas, also, the quarry sites have spatial context with the settlements. Therefore, they have the same spectral characteristics and making it difficult to distinguish them. The bone of contention here is how to classify the images using the conventional image classification methods (supervised or unsupervised). Therefore, the study adopted an integration of qualitative and quantitative approaches. The quantitative approach (a raster model) is the conventional image classification, which collects numerical spectral values from each pixel. The qualitative approach (vector model) is the digitizing of classes of interest. The whole idea is to combine both quantitative and qualitative approaches to yield an optimum result, since the aim of image classification is creating a thematic information of area of interest.

For this study, a supervised classification was carried out on each IKONOS images using the maximum likelihood classification as a parametric decision rule. It is based on the probability that a pixel belongs to a particular class. The basic algorithm assumes that the probabilities are equal for all classes and that the input bands have normal distribution.

3.3.12 Procedure for qualitative and quantitative approach of image classification

Step 1: The IKONOS images were classified into three classes, namely vegetation, settlement and farmland using supervised (maximum likelihood) classification. Then, they

were converted into a vector data type (vectorized) using raster to polygon tool in ArcMap 10.1.

Step 2: The conflicting classes (quarry sites, rocky surface and water body) were carefullydigitized using the editor tool in editor toolbar.

Step 3: Each shapefile for quarry site, rocky surface, and water body were erased from the vectorized classified map using erase tool in overlay toolset in analysis toolbox. In the attribute table of each shapefile, a new field was created and named GRIDCODE. It was populated with number four (4) for quarry site, five (5) for rocky surface and six (6) for water body.

Step 4: The result of the step 3 (erased dataset) and the vectorized classified image were merged using merge tool in general toolset in data management toolbox.

Step 5: The result from step 4 (merged shapefiles) was then dissolved using dissolve tool in general toolset in data management toolbox to create six unique values for the six land covers. This also enabled the computation of area for each class.

3.3.13 Land use and land cover change rate

A quantitative rate of change was carried out by the subtraction of the area distribution of each land cover class of previous year from recent year. Some of the statistics are highlighted below (Mmom and Fred-Nwagu, 2013):

i. Area of change: This is the difference in area (in Km^2) between two years of study i.e. $A_2 - A_1$. (3.8)

   a. Where A_1= previous year and A_2= recent year.

$$\% \text{ change} = \frac{\text{Area of each class}}{\text{Total area}} \quad (3.9)$$

ii. Rate of change $= \frac{(A_2 - A_1)}{A_1} \times 100$ (3.10)

Where A_2 = Recent year area of land use land cover in square kilometers.

A_1 = Previous year area of land use land cover in square kilometers.

iii. Area percentage occupied by each quarry:

$$\text{Area \%} = \frac{\text{area of each quarry}}{\text{Sum of areas of all quarries}} \times 100\% \quad (3.11)$$

iv. Area percentage occupied by all quarry sites:

$$\text{Area \%} = \frac{\text{Sum of areas of all quarries}}{\text{Total area of Mpape}} \times 100\% \quad (3.12)$$

$$= \frac{318.04}{4432.53} \times 100 = 7.175134742 = 7.175\%$$

3.3.14 Derivation of quarry depth using transect analysis

In this section, in order to determine the depth of derelict pond in each quarry, the TIN surface generated from the combination of elevation points from both ASTERDEM and TCX was used to generate the depth of each derelict pond formed as a result of intensive quarry operations. Series of horizontal and vertical lines were drawn across each derelict pond and different colors were assigned to each. The tool used in drawing these lines is "interpolate line" available in 3D analyst toolbar. After drawing each line, "profile graph" tool in 3D analyst toolbar was used to plot the depth profile of each drawn horizontal and vertical lines. The horizontal and vertical lines were drawn to ensure that the depth values were correctly interpolated from the TIN surface. A profile graphs was plotted for each

line. The horizontal axis of the graph indicates the horizontal distance (in meter) drawn on the surface, while the vertical axis indicates the depth values from the TN surface. This operation is shown in Figure 3.12.

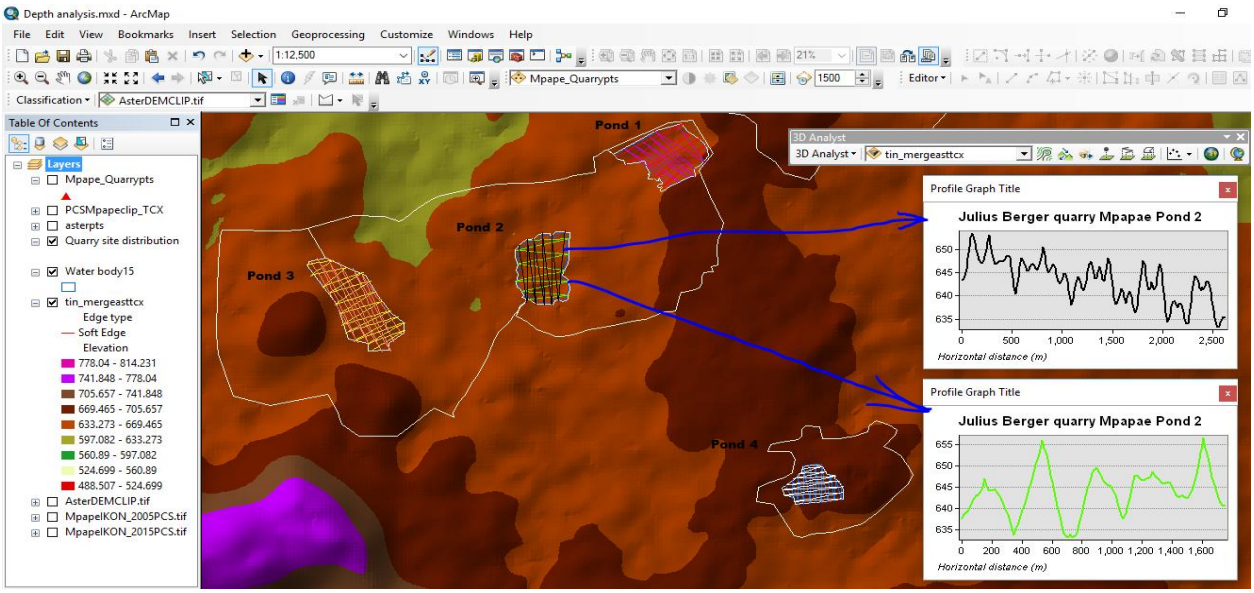


Figure 3.11: A screenshot of the transect analysis of quarry depth Profile from TIN surface.

3.3.15Proximity analysis technique

Proximity analysis was carried out to determine the nearness of both the active and abandoned quarry sites to residential treas. The digitized quarry sites and IKONOS image of 2015 was used for this analysis. The buffer tool in analysis toolbox in ArcGIS was used for the analysis. A buffer distance of 100m and 150m was carried out for the quarry sites and was overlaid on IKONOS image of 2015 as shown in Figure 3.13.In addition, photographs of settlements nearer to both active and abandoned quarry sites were acquired in the site at distances of 100m and 150m respectively. The photographs were geotagged to locations on the ground and were plotted on the IKONOS image of 2015. This was done to

show evidence of encroachment of settlement to quarry sites and impact of active quarry sites to residential areas.

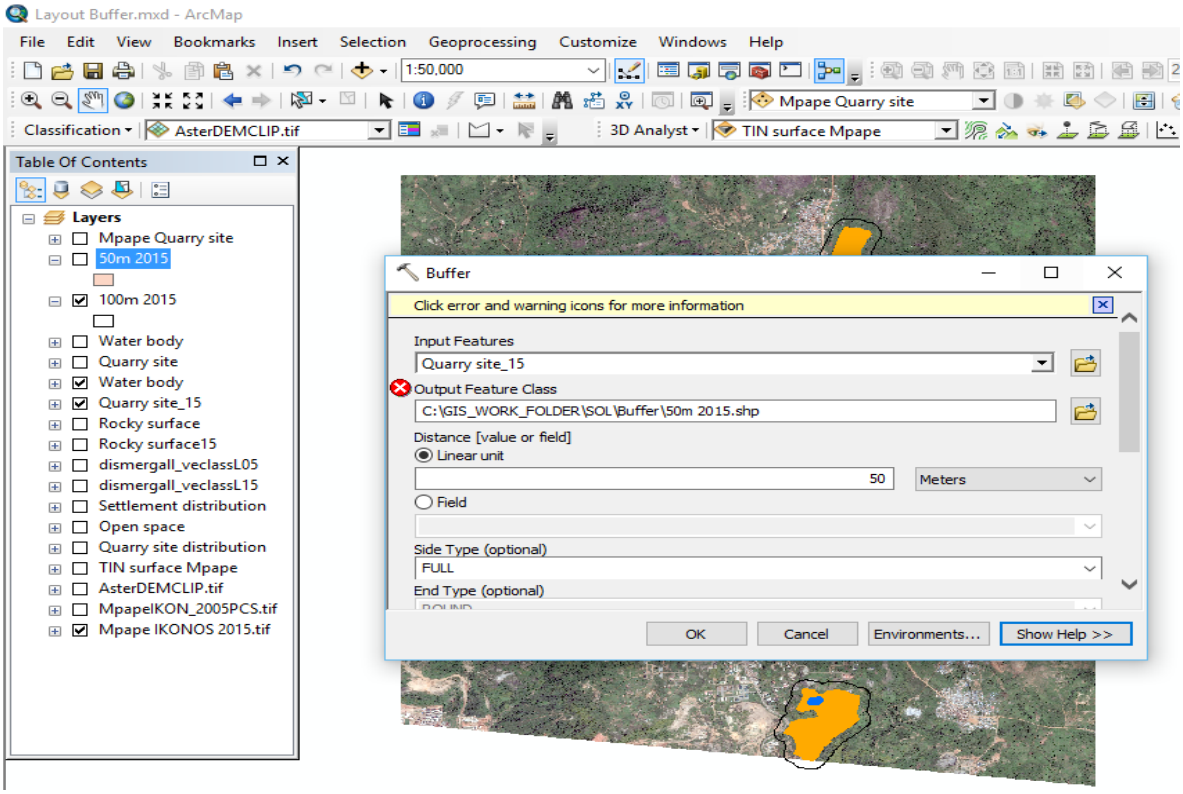


Figure 3.12: A screenshot of 50m buffer of quarry sites in 2015.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter displays the results of the analysis carried out in this study. They are presented in the form of maps, graphs, charts and statistical tables. This include results of the spatial distribution of quarry sites in the area; impact of quarrying on vegetation, water and land surfaces; quarry depth and land use and land cover change rate in the area; and proximity of the various quarry sites to residential areas.

4.2 Geometrical Characteristics of Quarry Sites

The spatial distribution and geometrical characteristics of the quarry sites were established using two methods, field survey and remote sensing. For the field survey, a dual frequencyGPS receiver was used to acquire the coordinates of the boundary points of the quarries. The field data was downloaded from the equipment, list of coordinates and area computation sheets are attached as Appendix 1, 2 and 3. Table 4.1 shows the characteristics of the quarries as captured using field survey.

Table 4.1: The area of quarry site within Mpape district from field survey.

S/n	Quarry Name	Area (Ha)	Status
1	Arab Contractors	88.801	Active
2	Crush Rock	14.910	Abandoned
3	Dantata	33.958	Abandoned
4	Exsamine 1	21.896	Active
5	Exsamine 2	17.452	Active
6	Hongyum	17.530	Active
7	Julius Berger	113.967	Abandoned
8	Leenford	5.043	Active
9	Perfect Stone	4.483	Active

The Remote Sensing (RS) method was achieved by digitizing the quarry sites on the IKONOS image 2015, thus, their length, breadth, area and spatial coordinates was also computed and is shown in Table 4.2.

Table 4.2: The geometrical characteristics of quarries within Mpape district.

S/n	Quarry Name	Area (Ha)	Status	Number of derelict pond	Length (m)	Breadth (m)	Spatial location	
							Easting	Northing
1	Julius Berger	105.780	Abandoned	3	1,830.39	624.89	333619.651	1010890.816
2	Arab Contractors	92.169	Active	-	1,366.64	840.10	335162.355	1011654.773
3	Crush Rock	13.095	Abandoned	1	559.68	427.39	334890.580	1010042.628
4	Dantata	33.39	Abandoned	1	873.73	570.87	335380.749	1008468.893
5	Hongyum	18.379	Active	-	785.95	288.46	335430.264	1013760.543
6	Exsamine 1	21.524	Active	-	828.49	361.97	332228.363	1011837.533
7	Exsamine 2	17.591	Active	-	787.51	427.94	332327.283	1010225.097
8	Perfect Stone	5.679	Active	-	370.20	154.89	337561.226	1013432.702
9	Leenford	5.581	Active	-	346.00	256.20	331615.395	1010094.692

In Table 4.2, Julius Berger is largest with an area of 105.780Ha second largest is Arab Conractors with an area of 92.169Ha, followed by Dantata, Exsamine 1, Hongyum, Exsamine 2, Exsamine 2, Crush Rock, Perfect Stone and Leenford respectively. In addition, Julius Berger quarry contains three (3) derelict ponds, Crush Rock has one (1) and Dantata has one (1). All these quarry sites are abandoned.

Table 4.1 and 4.2 has revealed that the computed area gotten from the field survey differ from the digitized from the image. Thus, the field survey is the accepted area and is used for the study.

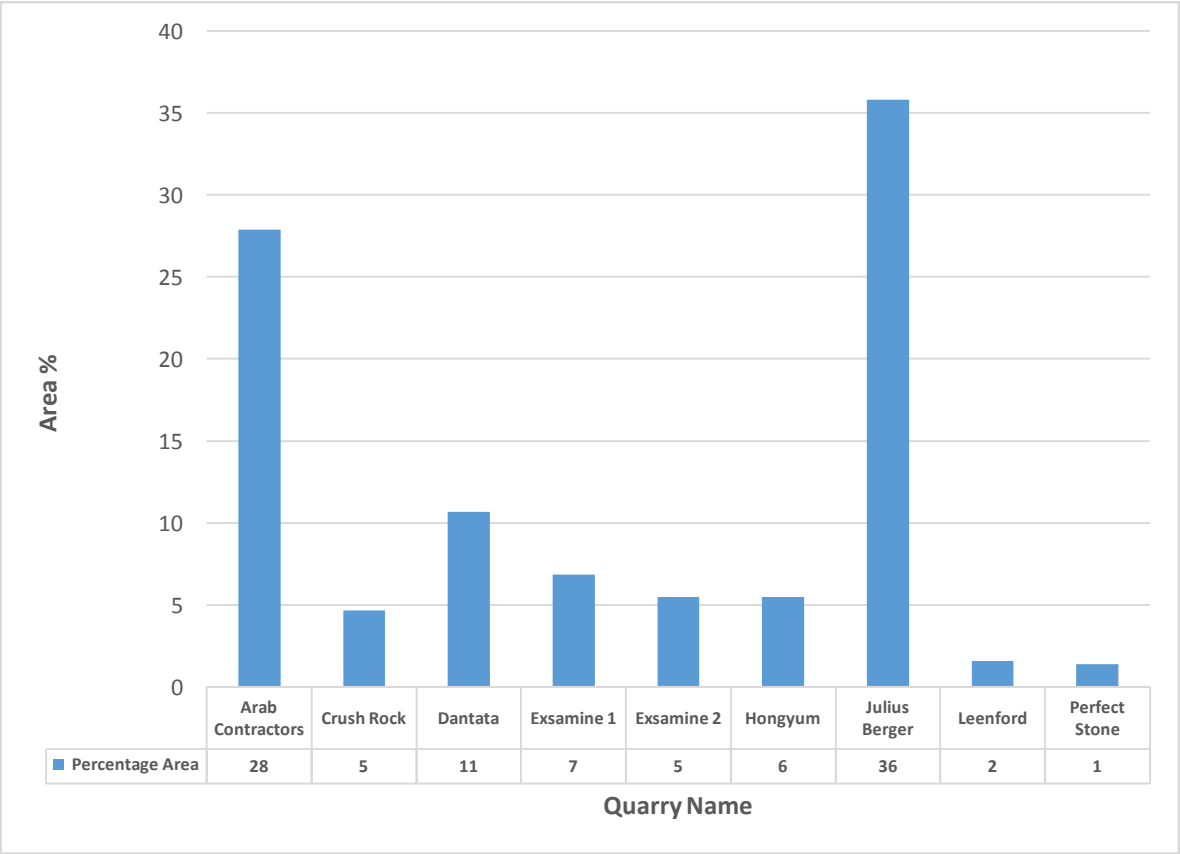


Figure 4.1: A bar chart of area percentage of each quarry in Mpape.

The area percentage occupied by all the quarries is shown in Figure 4.1. In the chart, Julius Berger and Arab Contractors have the highest value, follow by Dantata, Exsamine 1, Hongyum, Exsamine 2, Crush Rock, Leenford and Perfect Stone quarries.In addition, the area percentage occupied by all the quarries is 7.175%.

4.2.1 Spatial distribution of quarries

A map of the quarry sites (active and abandoned) together with settlements, roads, and water body is displayed in Figure 4.1 and Figure 4.2 shows the quarry sites overlaid on IKONOS 2015 image.

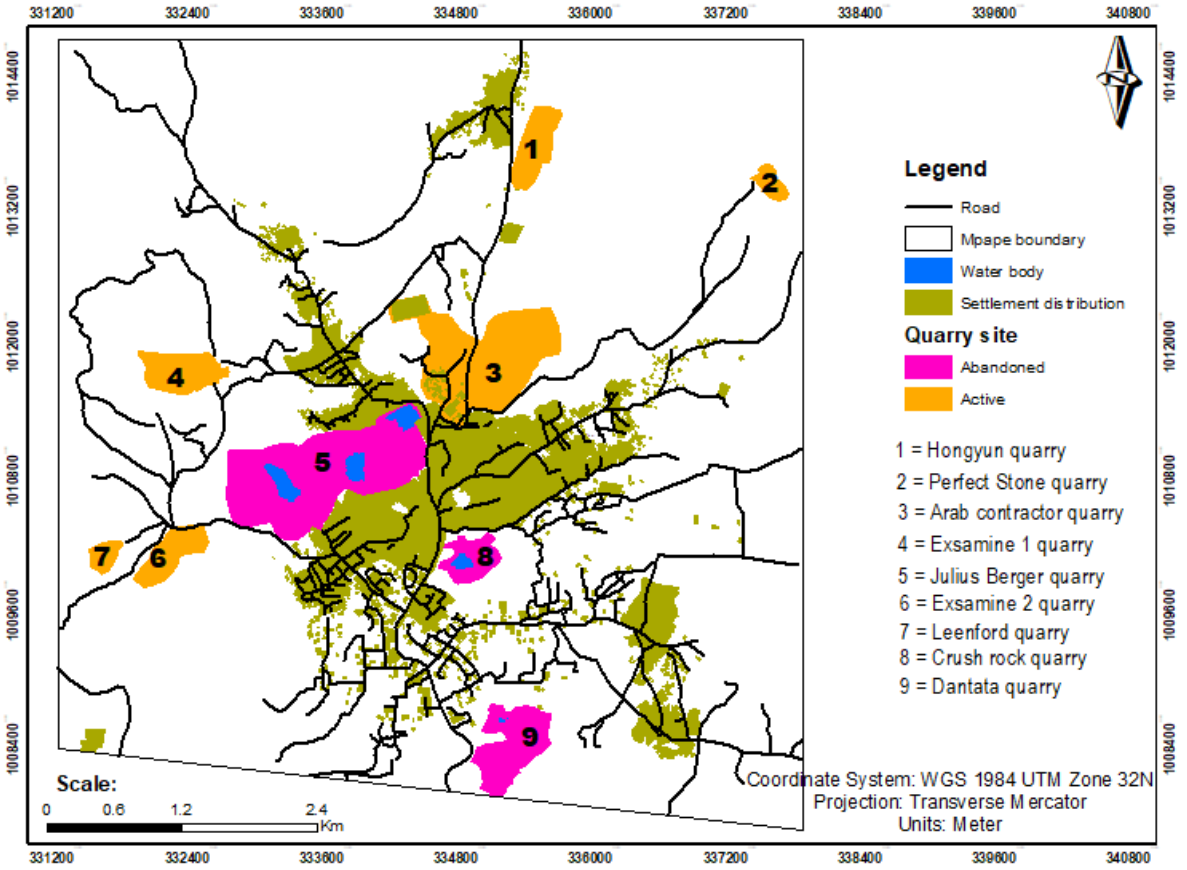


Figure 4.2: Quarry distribution showing quarry sites, settlements, roads and open-space.

In Figure 4.2, it shows the map of quarry sites comprising settlements, roads, water body and open-space. It can be seen that the active quarry sites are in golden color, while the abandoned quarry sites are shown in pink. Also, settlements are displayed green color; all the roads are in black; and water body that are ponds within the quarry sites are in blue color.

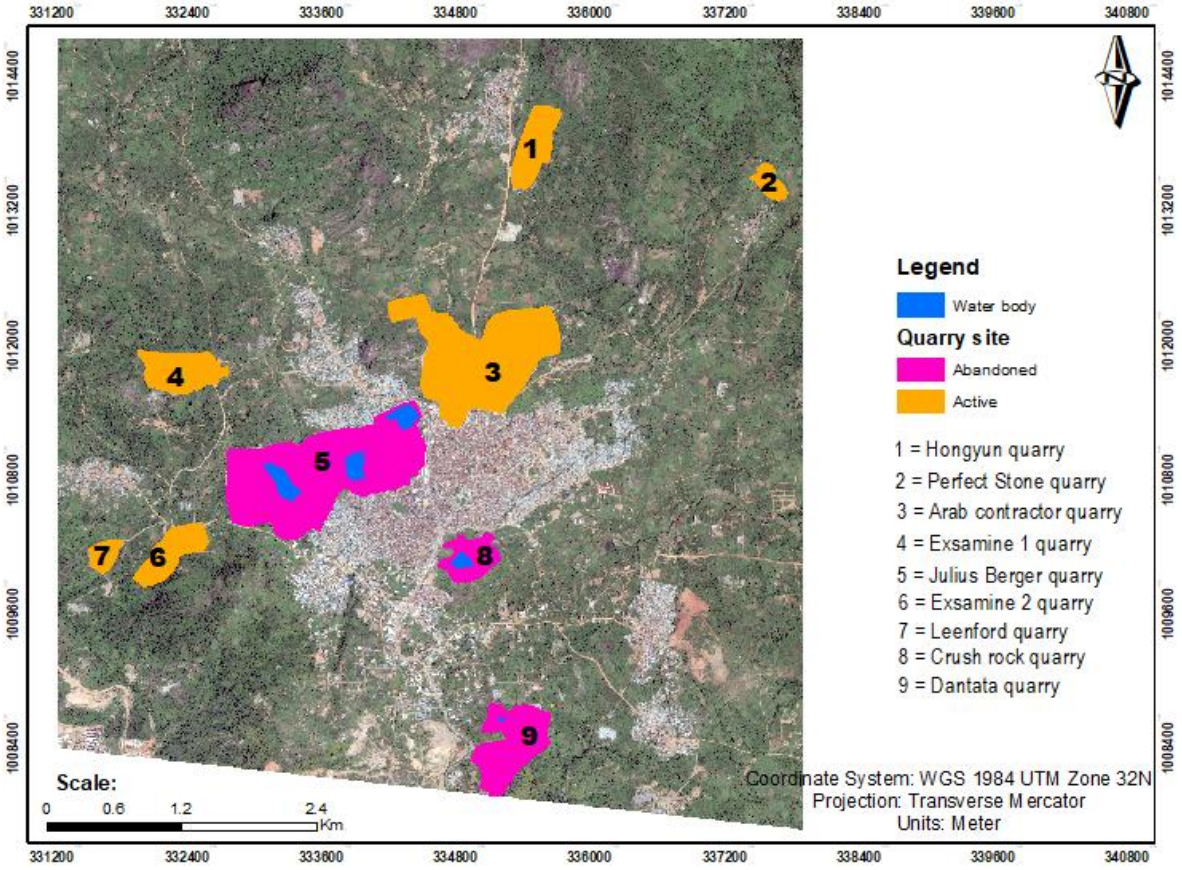


Figure 4.3: An image map of quarry distribution overlaid on IKONOS image of 2015.

Figure 4.3 shows the quarry sites in an image map, the active quarries are in golden color while abandoned quarries are in pink color. The active quarries are Chinese quarry, Exsamine quarry 1, Exsamine quarry 2, Arab contractors quarry, Perfect Stone quarry and Leenford quarry. The abandoned quarry sites are Julius Berger, Crush rock and Dantata quarries. The three largest quarries are situated at the core of Mpape, two are abandoned quarries (Julius Berger and Crush rock) and the third is active (Arab contractors). The third abandoned quarry (Dantata) is located in the lower part of Mpape. Also, Exsamine quarry 1 and 2, Chinese, Perfect Stone and Leenford quarries are located remotely from the core of

the settlement. Julius Berger quarry has three (3) derelict ponds within it due to its abandoned state; Dantata quarry has one derelict pond within it; and Crush rock contains one derelict pond.

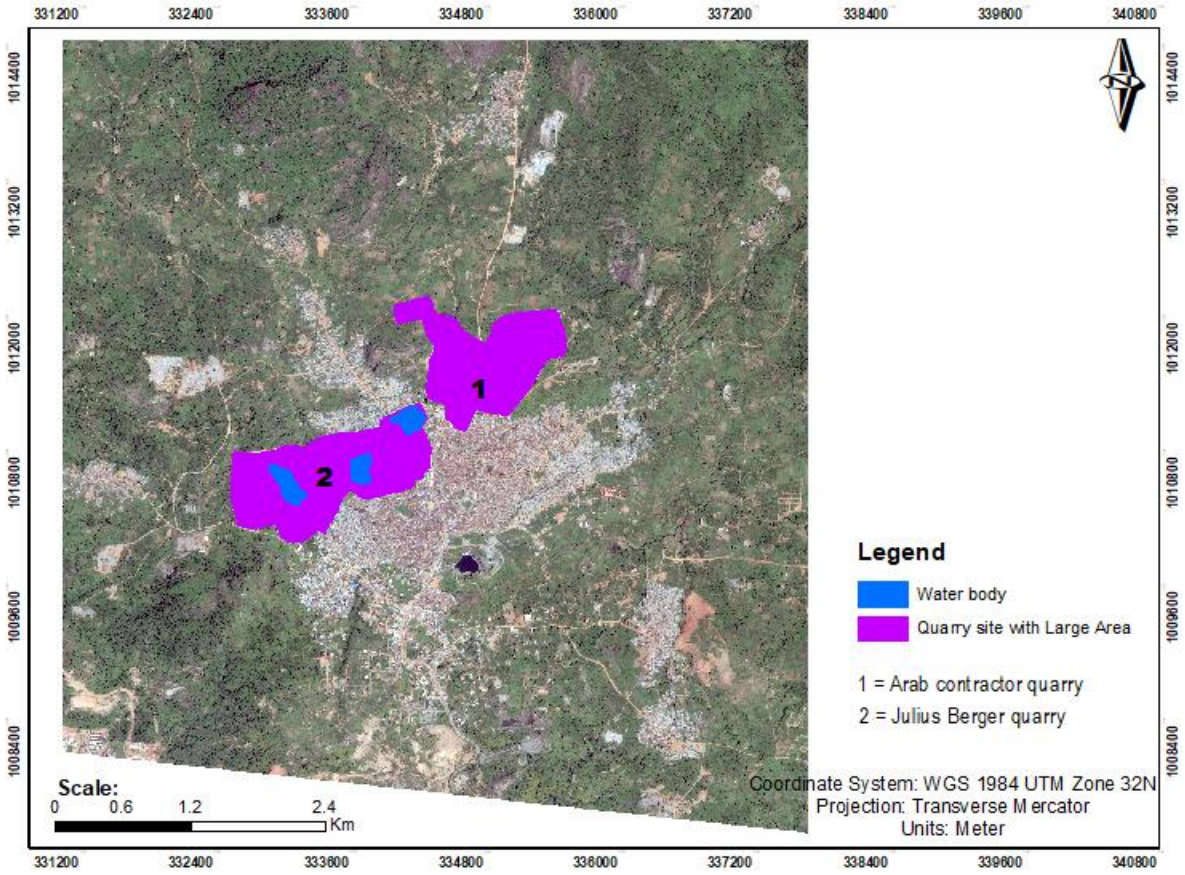


Figure 4.4: An image map of quarries with large area overlaid on IKONOS image of 2015.

In Figure 4.4, Julius Berger and Arab contractor are the largest quarries with areas of 113.967Ha and 88.801Ha. Also, these quarries are the ones situated in the core of Mpape.

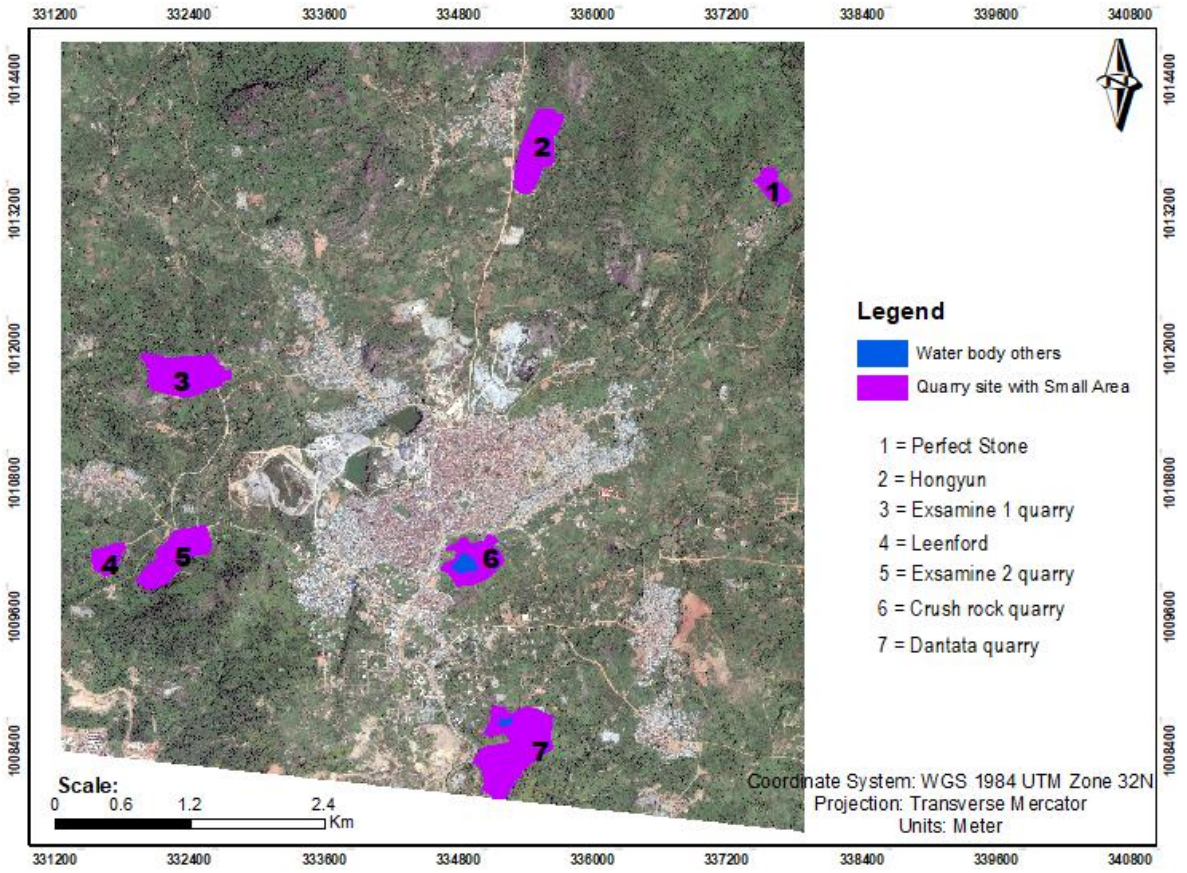


Figure 4.5: An image map of quarries with small area overlaid on IKONOS image of 2015.

In Figure 4.5, there are seven quarries with small area, namely: Perfect Stone with an area of 4.483Ha; Hongyun with an area of 17.530Ha; Exsamine with an area of 21.896Ha; followed by Exsamine 2, Crush rock and Dantata quarries with areas of 17.452Ha, 14.910Ha and 33.958Ha respectively.

The image map of quarries with three ponds and single pond are shown in Figure 4.6 and 4.7 respectively. The quarries are shown in purple color.

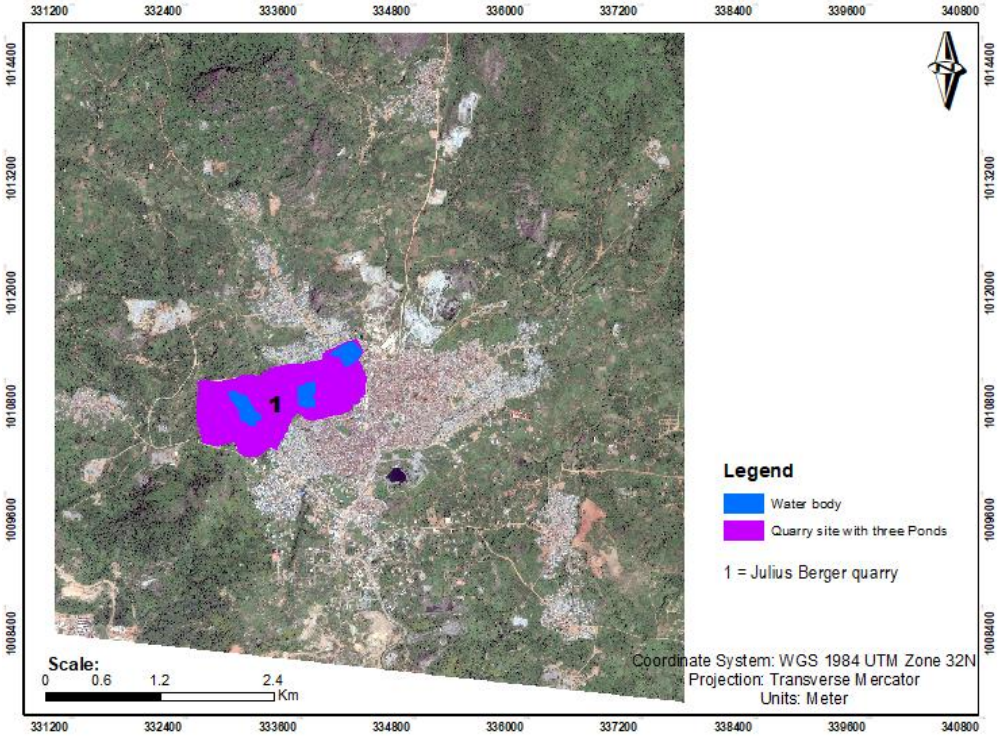


Figure 4.6: An image map of quarry with three ponds overlaid on IKONOS image of 2015.

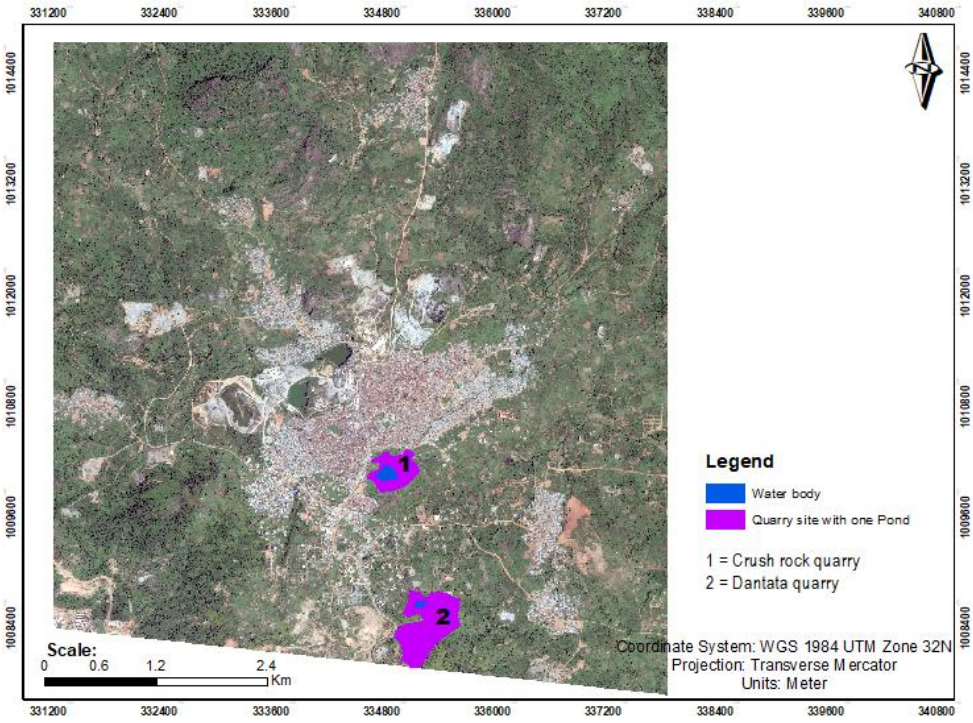


Figure 4.7: An image map of quarry with one pond overlaid on IKONOS Image of 2015.

4.2.2 Quarry depth derivation

The terrain representation of Mpape by a TIN surface and a 3D model are shown in Figure 4.8 and 4.9.

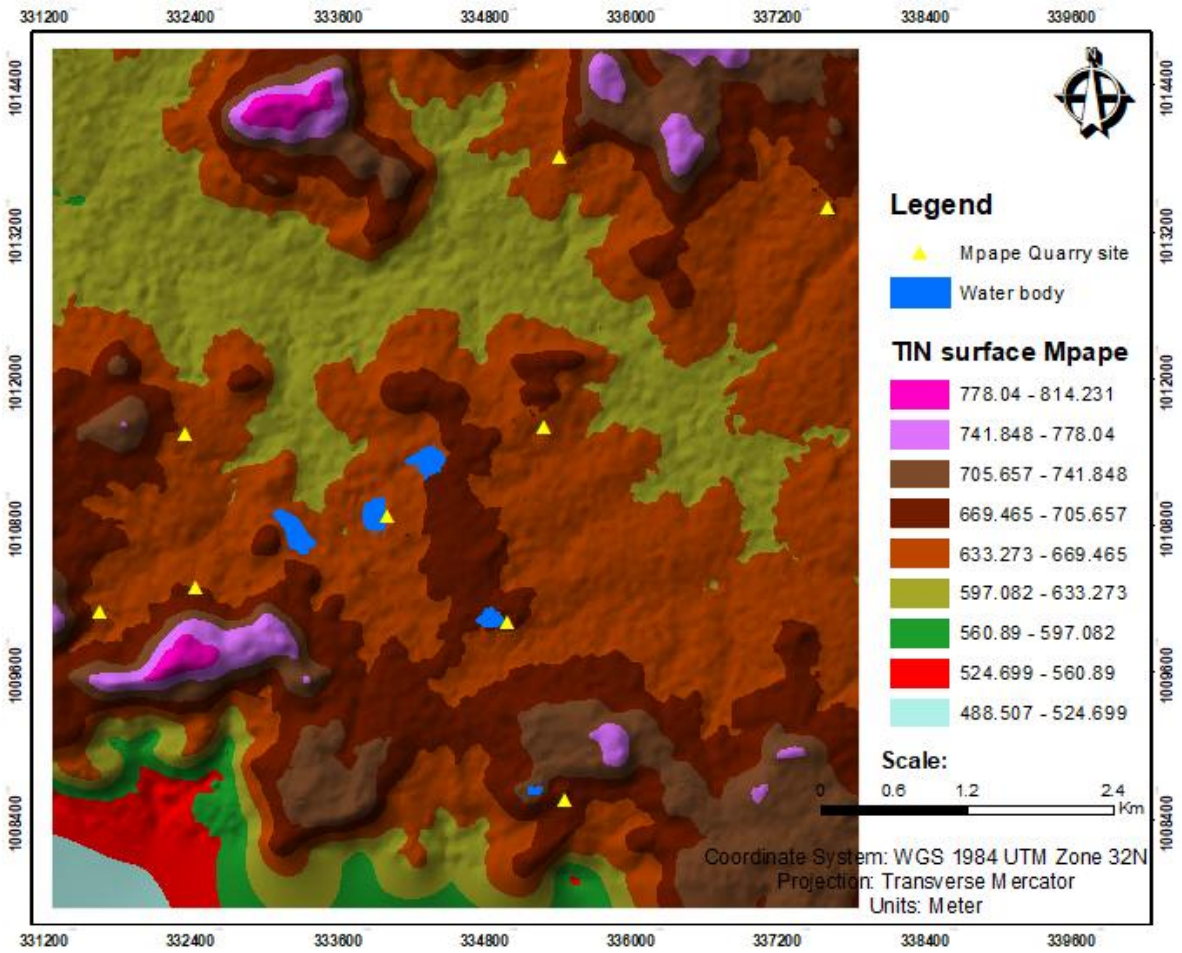


Figure 4.8: The terrain representation of Mpape by a TIN surfacewith an overlay of quarry site and water body.

In Figure 4.8, areas of highest elevation are shown in pink color, and are between 778.04m to 814.231m; while areas of lowest elevation are shown in light blue colors, and are between 488.507m to 524.699m. The elevation points where quarry sites are shown in orange and brown colors, their elevation values are 633.273m to 669.465m and 633.273m to 705.657m. This signifies that quarry operations are being carried out on grounds with

high elevations. In addition, it can be seen that the derelict ponds (water body) are formed on elevated areas within the quarry sites. This is contrary to the formation of water body in areas of low elevation. This could be due to blasting of rocks, therefore, creating astronomical holes within the region. The surface map shows that areas of highest elevation are in both the upper and lower region of Mpape. The high elevation in the upper region also signifies the concentration of rocky surface. The settlements were developed on high elevation ground with values of 633.273m to 669.465m and 633.273m to 705.657m. This could make the settlement not to be prone to flooding since it is on a high ground.

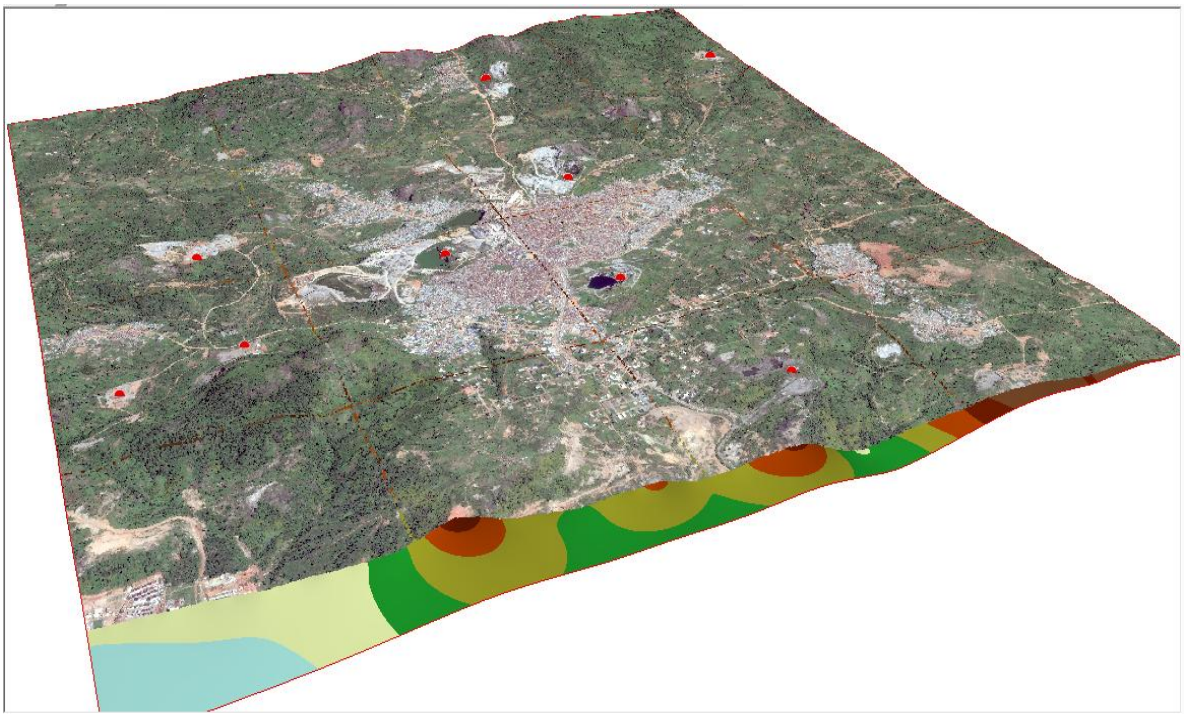


Figure 4.9: A Gridless 3D Model of Mpape with an Overlay of IKONOS Image of 2015 on TIN Surface in ArcScene.

In Figure 4.9, the IKONOS image of 2015 and quarry (points) locations were overlaid on the TIN surface in ArcScene with a vertical exaggeration of one (1). This 3D model corroborates the TIN surface in Figure 4.8, showing the areas of highest elevation and rocky surface to be in both the upper and lower region of Mpape.

The results for quarry depth derivation using the transect analysis technique are shown in Figures 4.10, 4.11, 4.12, 4.13, 4.14 and 4.15 respectively.

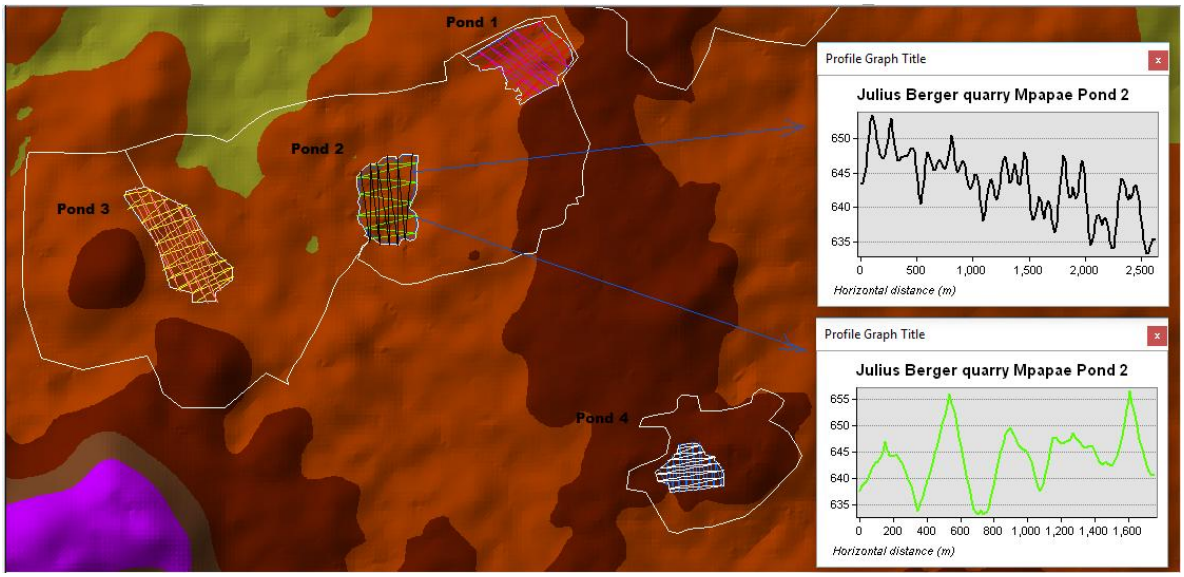


Figure 4.10: Theresult oftransect analysis of depth profile of ponds withinJulius Berger quarry site on a TIN surface.

In Figure 4.10, from the two horizontal (in green color) and vertical (black color) lines drawn over pond 2 within Julius Berger quarry site, the depth profile showed that the lowest point is 635m and the highest is 655m. Therefore, the depth of pond 2 within Julius Berger quarry site was interpolated to be 25m. Similarly, the depth profiles of other ponds are shown in Figures 4.11, 4.12, 4.13, 4.14 and 4.15.

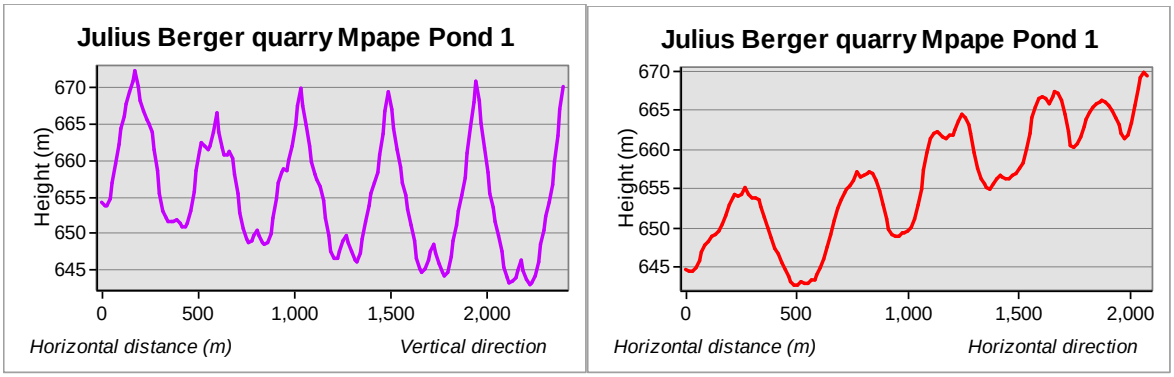


Figure 4.11: The depth profile of pond1 within Julius Berger quarry site.

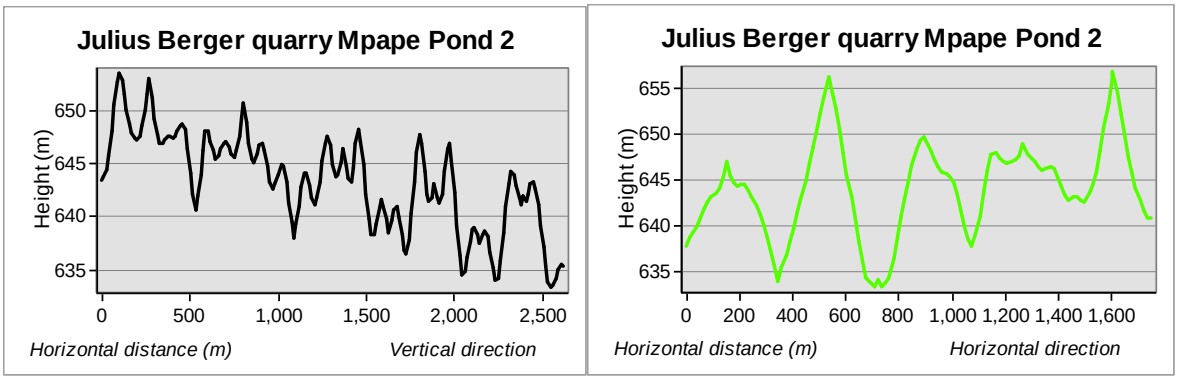


Figure 4.12: The depth profile of pond 2 within Julius Berger quarry site.

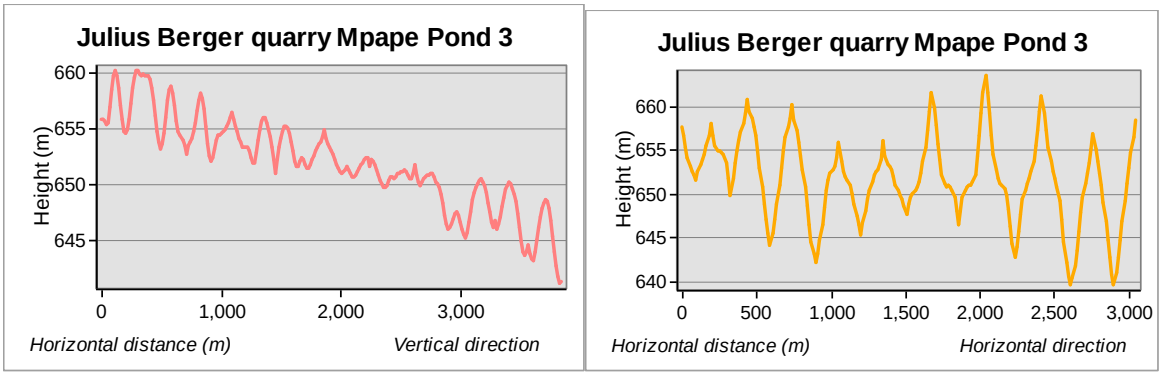


Figure 4.13: The depth profile of pond 3 within Julius Berger quarry site.

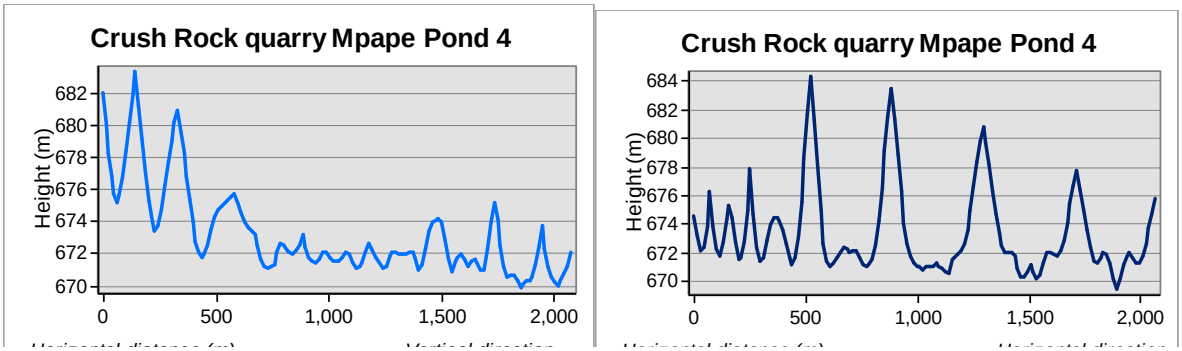


Figure 4.14: The depth profile of pond 4 within Crush Rock quarry site.

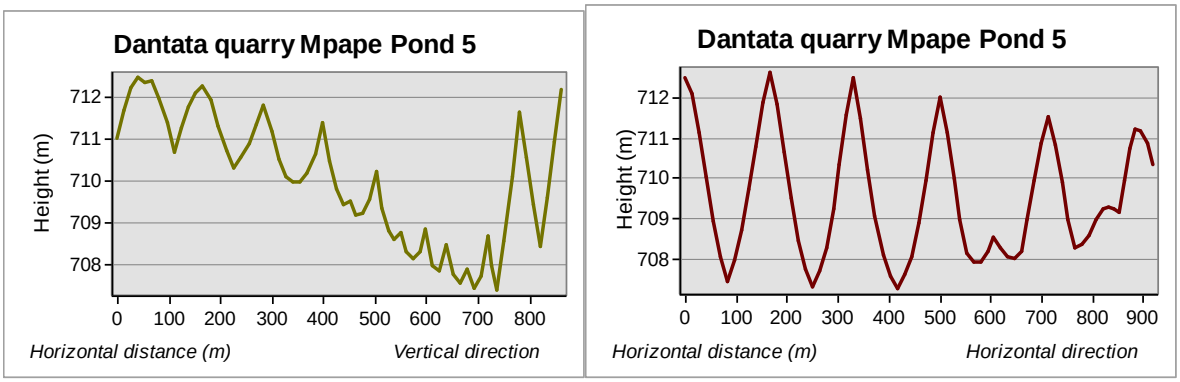


Figure 4.15: The depth profile of pond 5 within Dantata quarry site.

In the Figure 4.11 to 4.15, the derelict ponds in Julius Berger quarry site have the highest depth values. Pond 1 has a depth of 25m, pond 2 has 20m and pond 3 has 15m depths respectively. Pond 4 in Crush rock quarry site has a depth of 14m, and pond 5 has a depth of 6m. With the depth values of pond 1, 2 and 3 in Julius Berger quarry site, it is an indication why the quarry has been abandoned. A chart showing the depths is shown in Figure 4.16.

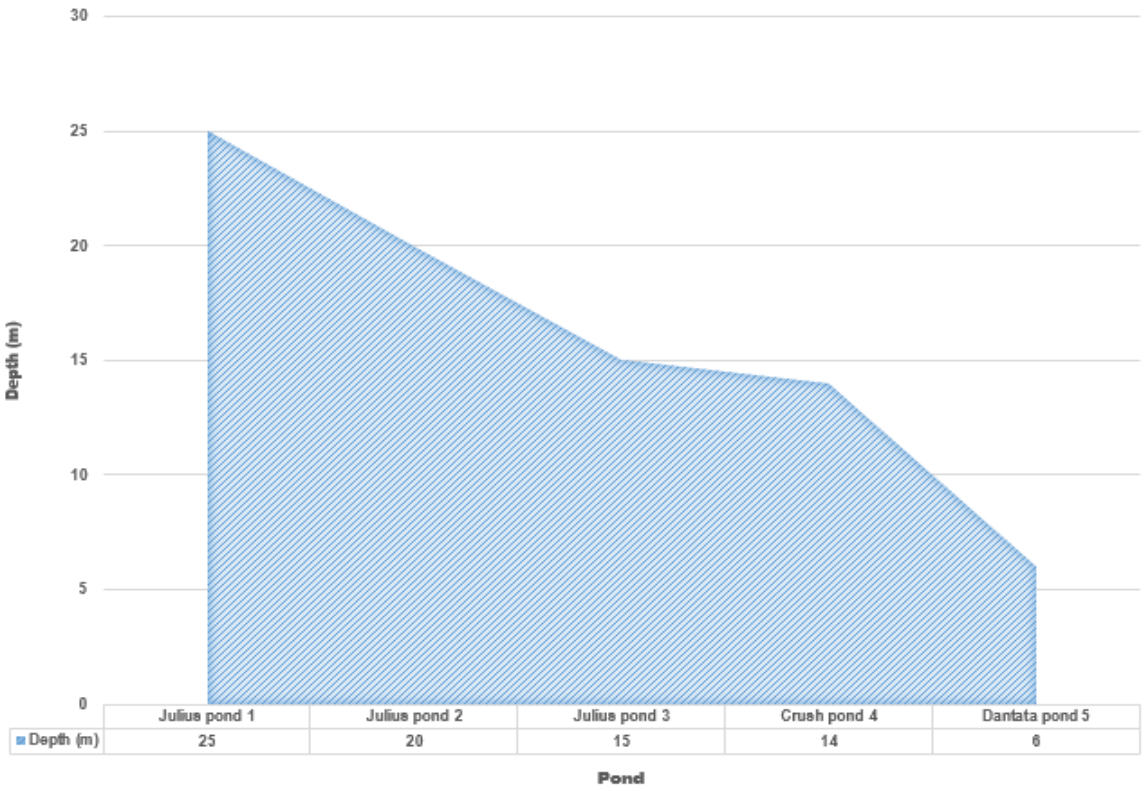


Figure 4.16: The Chart Showing the Various Depths of the Quarry Sites.

Interestingly, the three ponds within the Julius Berger quarry were measured by ground survey technique using a Hi-Target Differential GNSS receiver. The data collected contains spatial coordinate (E, N and H) of the ponds with heights and depths, it is shown in Table 4.3.

Table 4.3: A table showing spatial location with their depths of derelict ponds within Julius Berger quarry.

Easting	Northing	Height(m)	Depth(m)
333211.805	1010756.695	674	11
334302.365	1011356.453	660	19

4.3 Land Use and Land Cover Change RateandQuarry Depth

Following the processing of IKONOS images of 2005 and 2015, the thematic maps produced are shown in Figure 4.17 and 4.18.

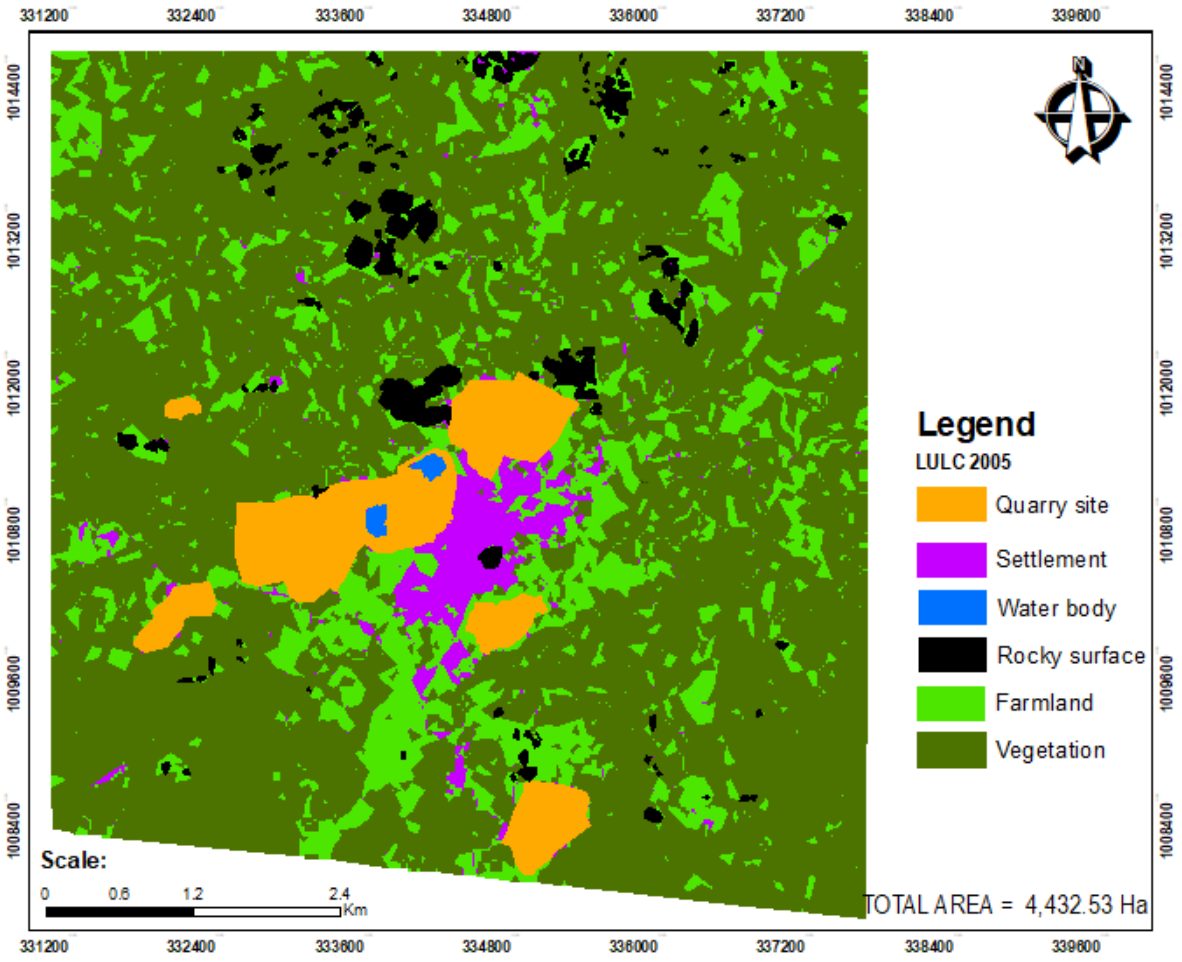


Figure 4.17: Thematic map of Mpape districtin Abuja derived from IKONOS imagery of 2005.

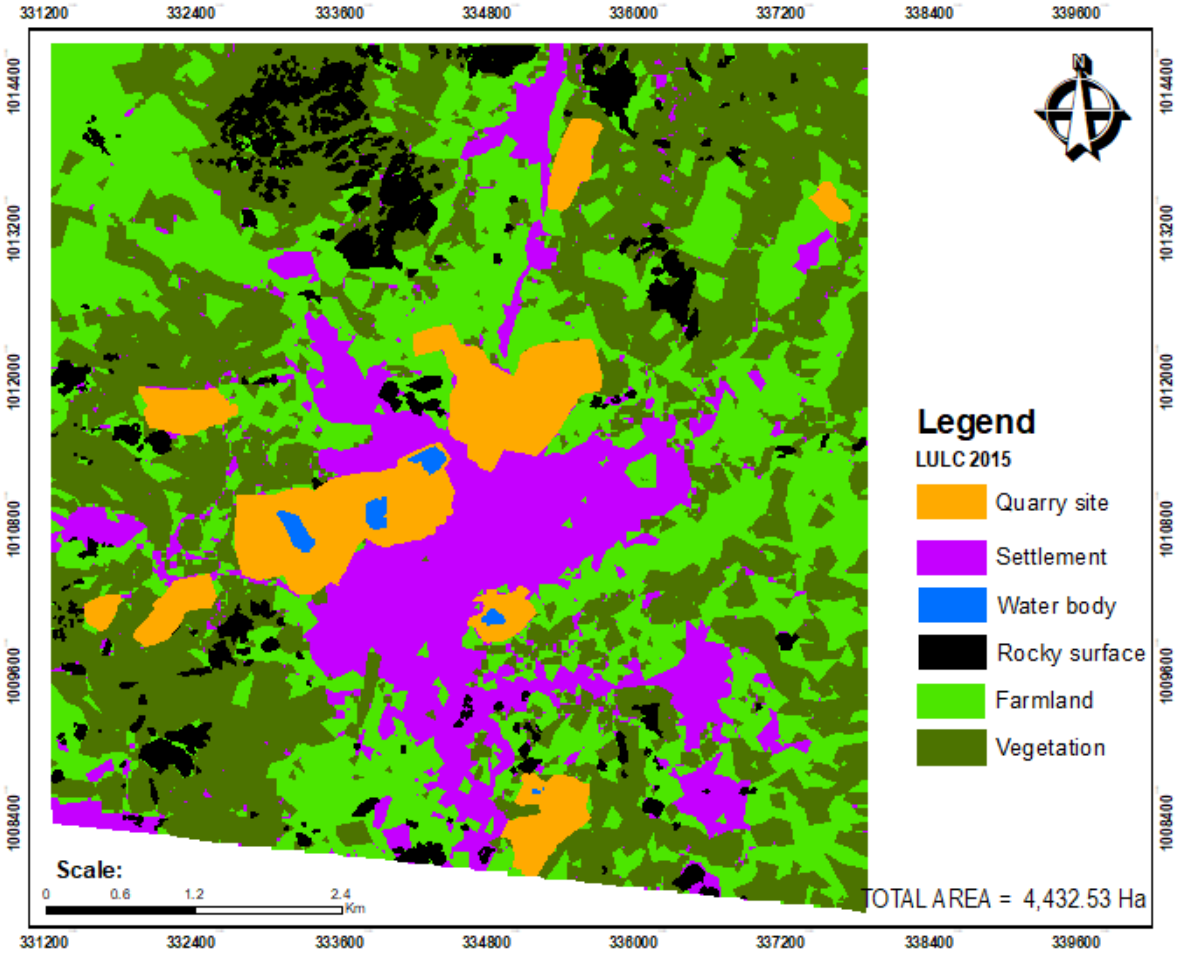


Figure 4.18: Thematic map of Mpape district in Abuja derived from IKONOS imagery of 2015.

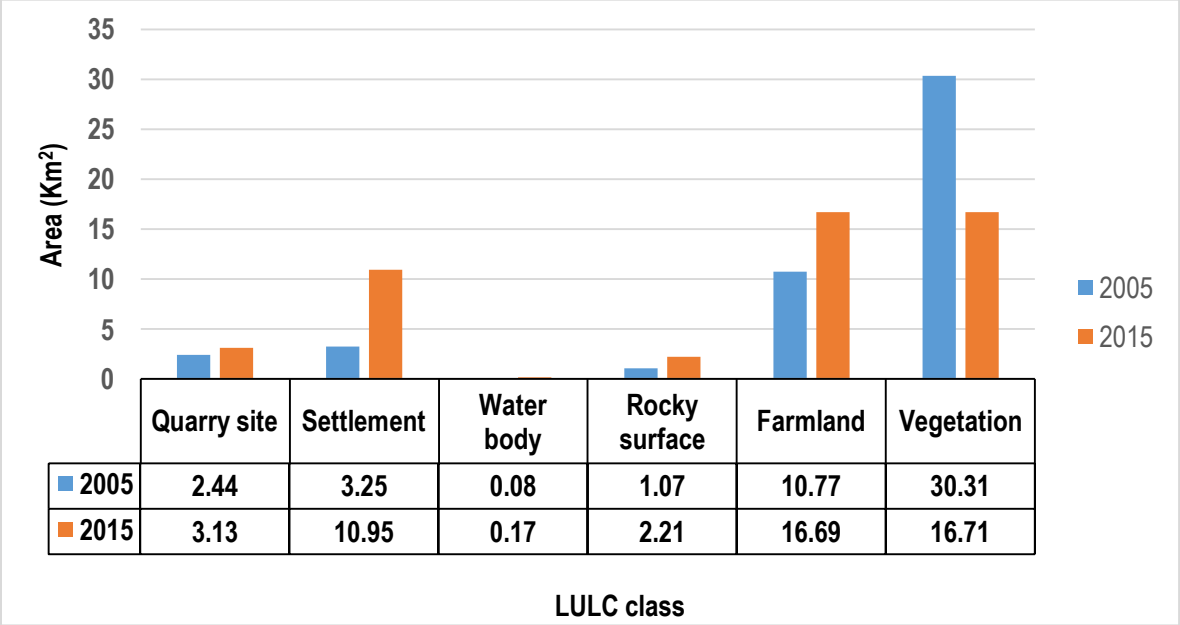
In Figure 4.17 and 4.18, quarry sites are rendered in golden color; blue for water body; purple for settlement, black for rocky surface; light green for farmland and dark green for vegetation. The thematic maps closely represent the processed IKONOS images of 2005 and 2015 respectively. In Figure 4.17 (i.e. 2005 thematic map), it can be seen that the settlements are clustered and are concentrated in the center of the Mpape and are contiguous to three quarry sites, namely: Arab contractors, Julius Berger and Crush rock quarry. The other quarry sites are remote the core center settlement and no settlement is

contiguous to them. Also, the rocky surfaces are sparse and majorly at upper part of Mpape. Farmland and vegetation occupy the chunk of space in Mpape.

In the 2015 thematic map, there is an urban sprawl in the settlements, as it is clustered and widely spread around Mpape. The settlements are almost engulfing the Julius Berger quarry site and can be found closely around other remote quarry sites. In addition, between 2005 and 2015, there tend to be an increase in the number and size of quarry sites from six to nine. There is a clustering of rocky surface towards the upper and lower region of Mpape. Farmland and vegetation fill up the remaining space in both maps.

4.3.1 Quarry land use and land cover change rate

The land use and land cover distribution and their rate of change of 2005 and 2015 thematic maps are shown Figure 4.18 and tables 4.4 and 4.5.



	Quarry site	Settlement	Water body	Rocky surface	Farmland	Vegetation
2005	2.44	3.25	0.08	1.07	10.77	30.31
2015	3.13	10.95	0.17	2.21	16.69	16.71

Figure 4.19: The land use and land cover distribution of 2005 and 2015 thematic maps.

Table 4.4: The change in area of land use and land cover between 2005 and 2015.

LULC CLASS	2005 - 2015	
	AREA (Km^2)	AREA (%)
Quarry site	0.69	1.19
Settlement	7.70	15.18
Water body	0.09	0.17
Rocky surface	1.14	2.20
Farmland	5.92	11
Vegetation	-13.60	-29.74

Table 4.5: The rate of change of land use and land cover between 2005 and 2015.

LULC CLASS	2005 - 2015	
	ANNUAL RATE ($Km^2. yr^{-1}$)	AREA (%)
Quarry site	28.28	23.38l
Settlement	236.92	223.89
Water body	112.5	7.62
Rocky surface	106.54	98.65
Farmland	54.97	48.95
Vegetation	-44.87	-47.02

In Figure 4.19, it is evident that there an increase in area of quarry sites from 2.44 Km^2 to 3.13Km^2. The settlement increased in area from 3.25$Km^2$to 10.95Km^2. This indicted an urban sprawl in Mpape in spate of ten years from 2005 to 2015. There are also increases in water body and rocky surface. The increase in water body (derelict ponds) in the quarry sites indicated heavy quarry activities that must have occurred between 2005 and 2015. The increase in rocky surface is also an indication of the increase in sizes and number of more quarry sites, especially towards the upper region of Mpape. This is a sign that more quarry activities will be seen in the future, as more rocky areas will be explored further. Similarly,

there is an increase in farmland from 10.77$Km^2$to 16.69$Km^2$from 2005 to 2015. There tend to be a decrease in vegetation from 30.31Km^2 to 16.71Km^2 between 2005 and 2015. In general, the increase in settlement, rocky surface, quarry sites and farmland led to the decrease in the area of vegetation.

In Table 4.5, it can be seen that the settlement has the highest annual rate of change of 236.92Km^2. yr^{-1}; followed by rocky surface with 106.54Km^2. yr^{-1}; 112.5 Km^2. $yr^{-}1$ for water body; 54.97 Km^2. yr^{-1} for farmland; 28.28 Km^2. yr^{-1} for quarry site; and -44.87 decrease in rate of change of vegetation.

4.4 Proximity of Quarry Sites to Residential Areas

The proximity analysis to determine the nearness of quarry sites to residential areas is shown in Figure 4.20. The result showed a 100m and 150m buffer of nine (9) quarry sites that are present in the 2015 image. At 100m and 150m, the settlement in the core of Mpape are engulfing the already abandoned Julius Berger quarry. In addition, the settlements are also engulfing the active Arab contractors quarry which is contiguous to the Julius Berger quarry. Crush rock and Hongyum quarries are also been encroached at 100m and 150m buffer. Other remote quarries such as Dantata, Exsamine 1, Exsamine 2, Perfect Stone and Leenford quarry sites do not have settlements contiguous to them at 100m and 150m buffer.

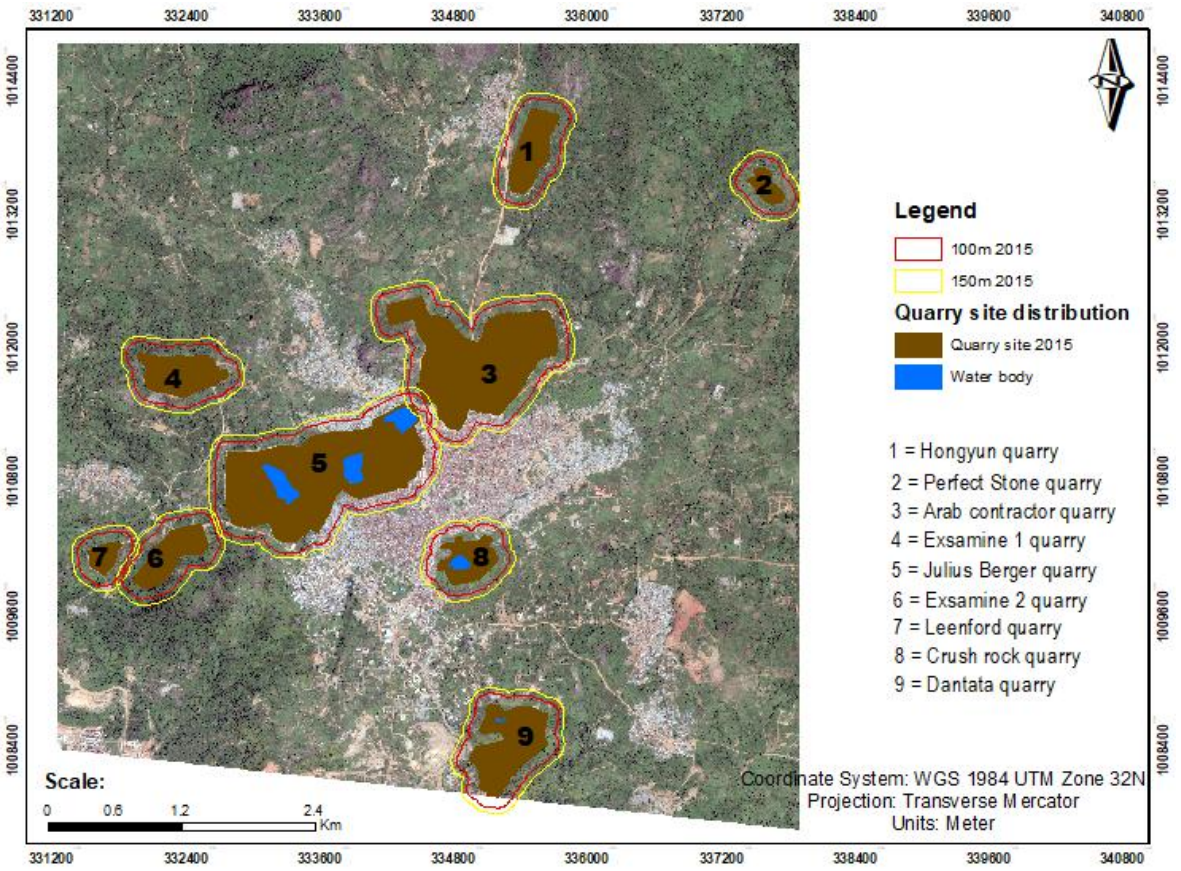


Figure 4.20: A 100m and 150m buffer of quarry site overlaid on IKONOS image of 2015.

In addition, the displayed geotagged photographs of Julius Berger, Arab Contractors, Crush rock, and Hongyum quarries on the IKONOS image of 2015 is shown in Figure 4.21, 4.22, 4.23, 4.24 and 4.25 respectively. The photograph of Julius Berger quarry showed abandoned state of the quarry and evidences of residential encroachment to it at 150m. The photograph of the active Arab contactor quarry showed the encroachment of settlement to it at 150m.

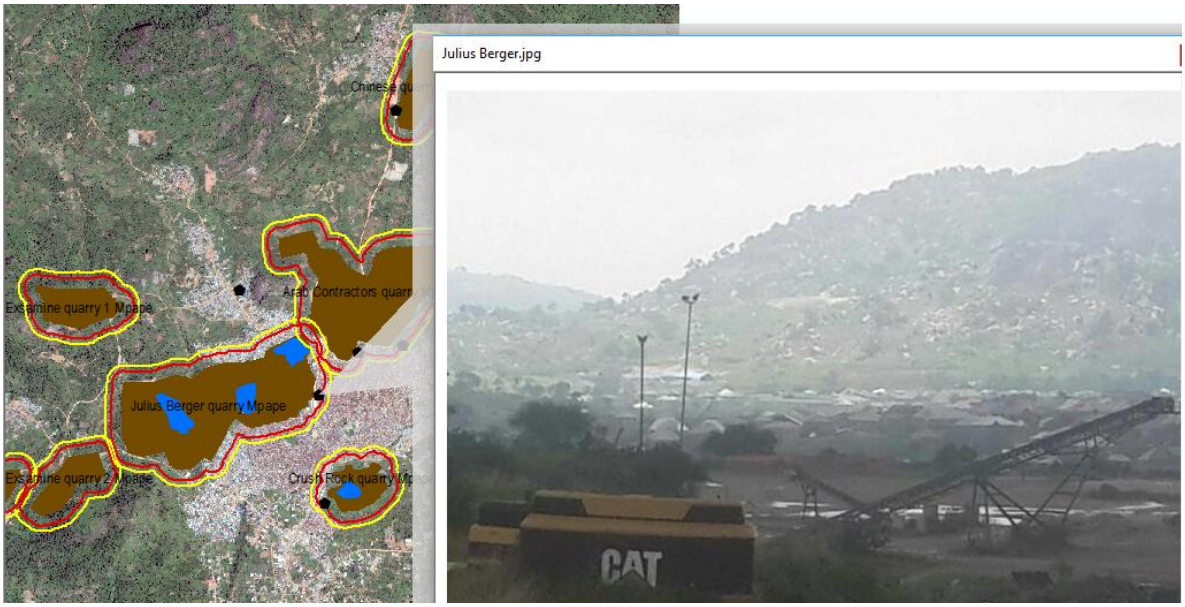


Figure 4.21: A Geotagged Photo of Julius Berger Quarry at 100m Buffer Distance.



Figure 4.22: A geotagged photo of Julius Berger Quarry at 150m buffer distance.



Figure 4.23: A geotagged photo of Arab Contractor quarry at 100m buffer distance.

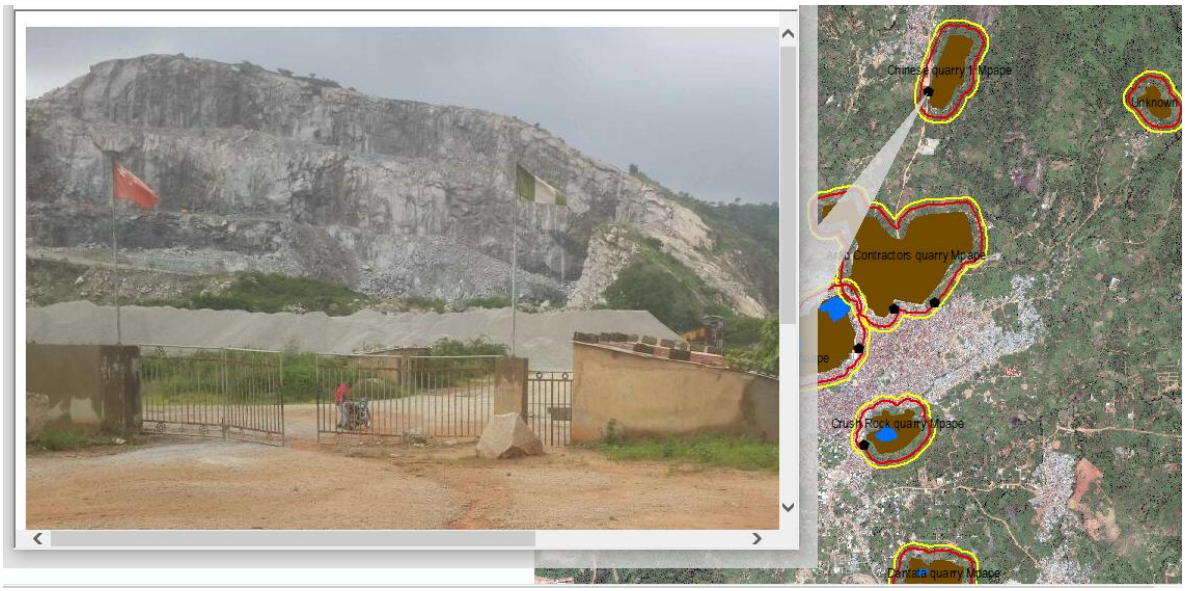


Figure 4.24: A geotagged photo of Hongyumquarry at 100m buffer distance.



Figure 4.25: A geotagged photo ofArab Contractor quarry at 100m buffer distance.

4.5 Impact of Quarrying On Vegetation, Water and Land Surfaces

Below is the outputs of the radiometric corrections carried out on the Landsat 7 ETM+ and Landsat 8 OLI and TIRS, especially, for the derivation of indices such as NDVI and NDWI. The histograms of the images before (in DN) and after (radiance and surface reflectance) the conversion is shown in Figure 4.26 and 4.27.

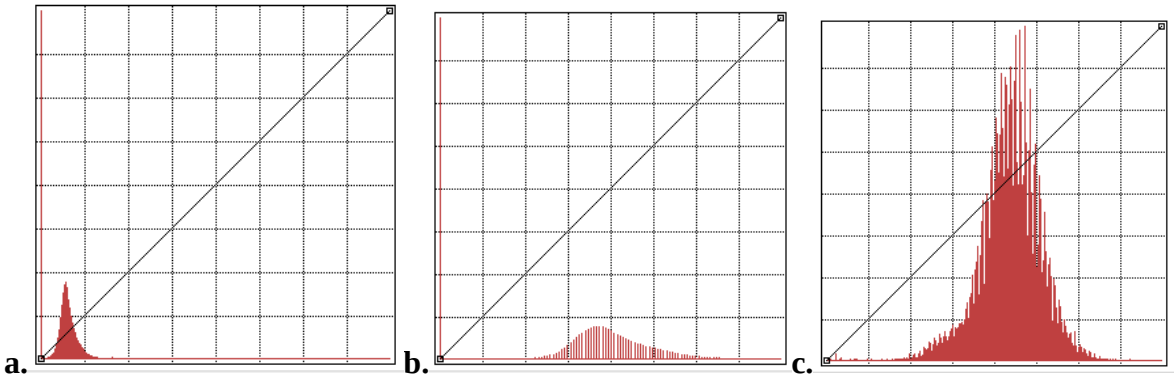


Figure 4.26: The histograms of radiometric corrections of Landsat 7 ETM+ from: **(a)** DN to **(b)**radiance and to **(c)** surface reflectance.

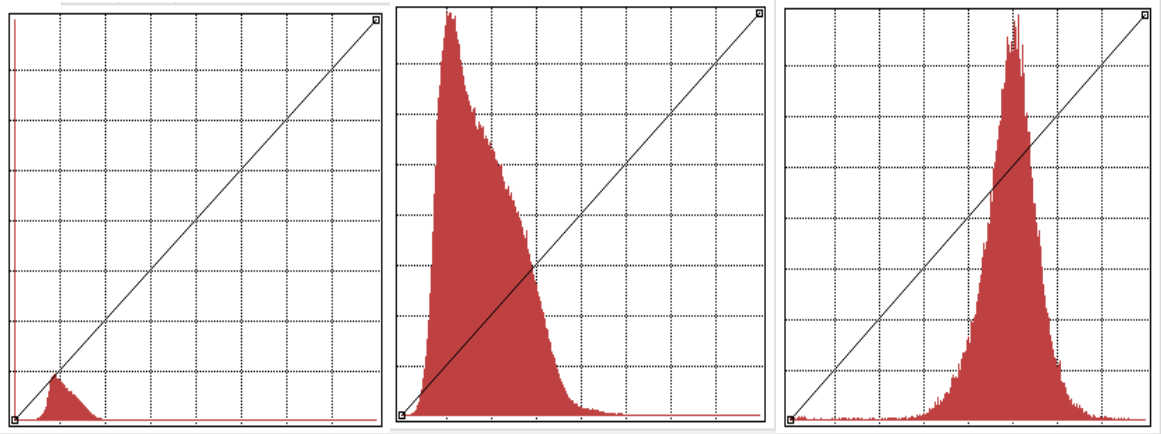


Figure 4.27: The histograms of radiometric corrections of Landsat 8 OLI and TIRS from: **(a)** DN to **(b)**radiance and to **(c)** surface reflectance.

The effect of the radiometric corrections in Figure 4.26 and 4.27 is that areas that are highly vegetated will have a corresponding high NDVI values, instead of low and NDVI values. The failure to correct the images would make the derived NDVI to be an incorrect representation of reality.

Therefore, the results of normalized difference vegetation index (NDVI) for 2002 and 2015; and normalized difference water index (NDWI) for 2002 and 2015 are shown in Figure 4.28, 4.29, 4.30 and 4.31 respectively.

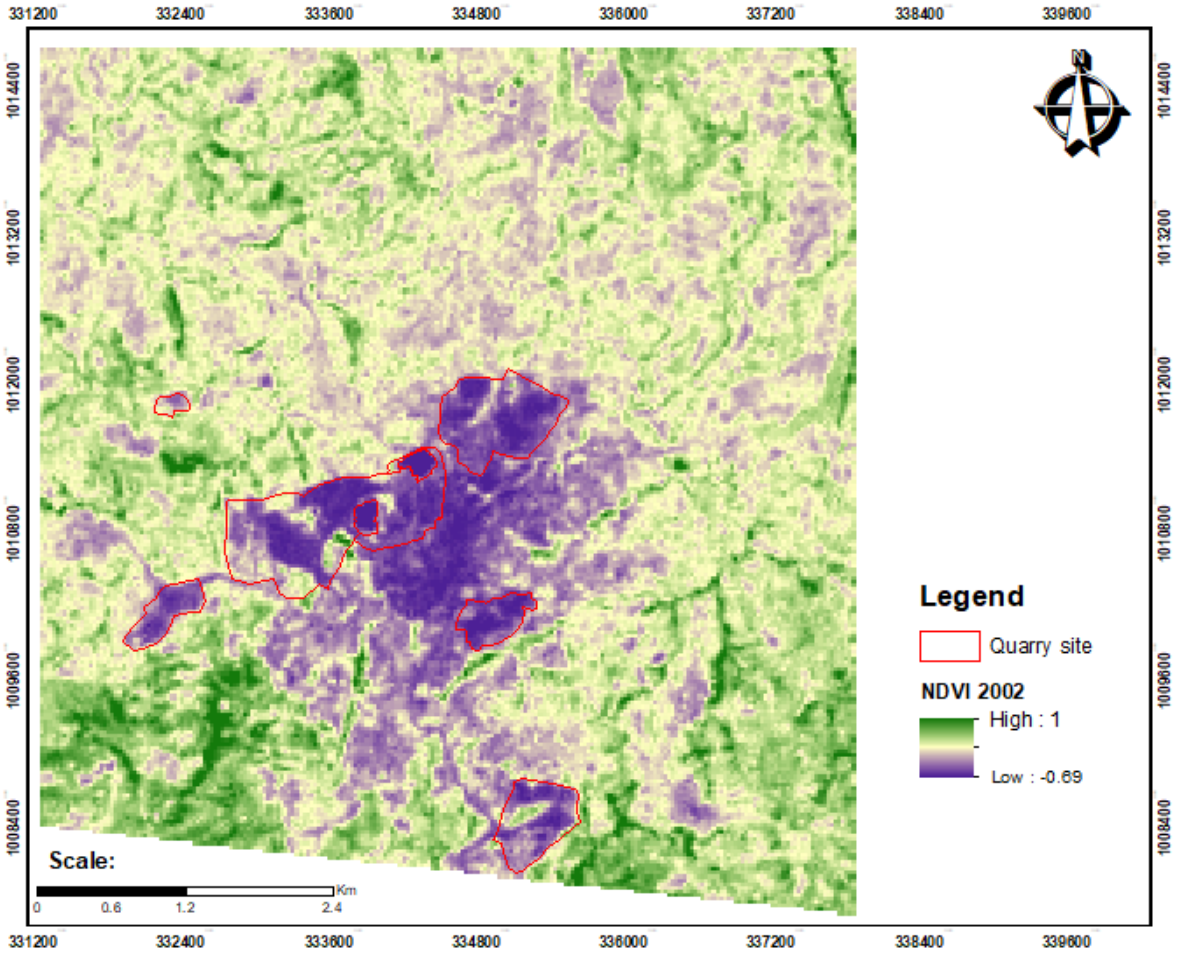


Figure 4.28: The Derived Normalized Difference Vegetation Index (NDVI) map of Landsat 7 of 2002.

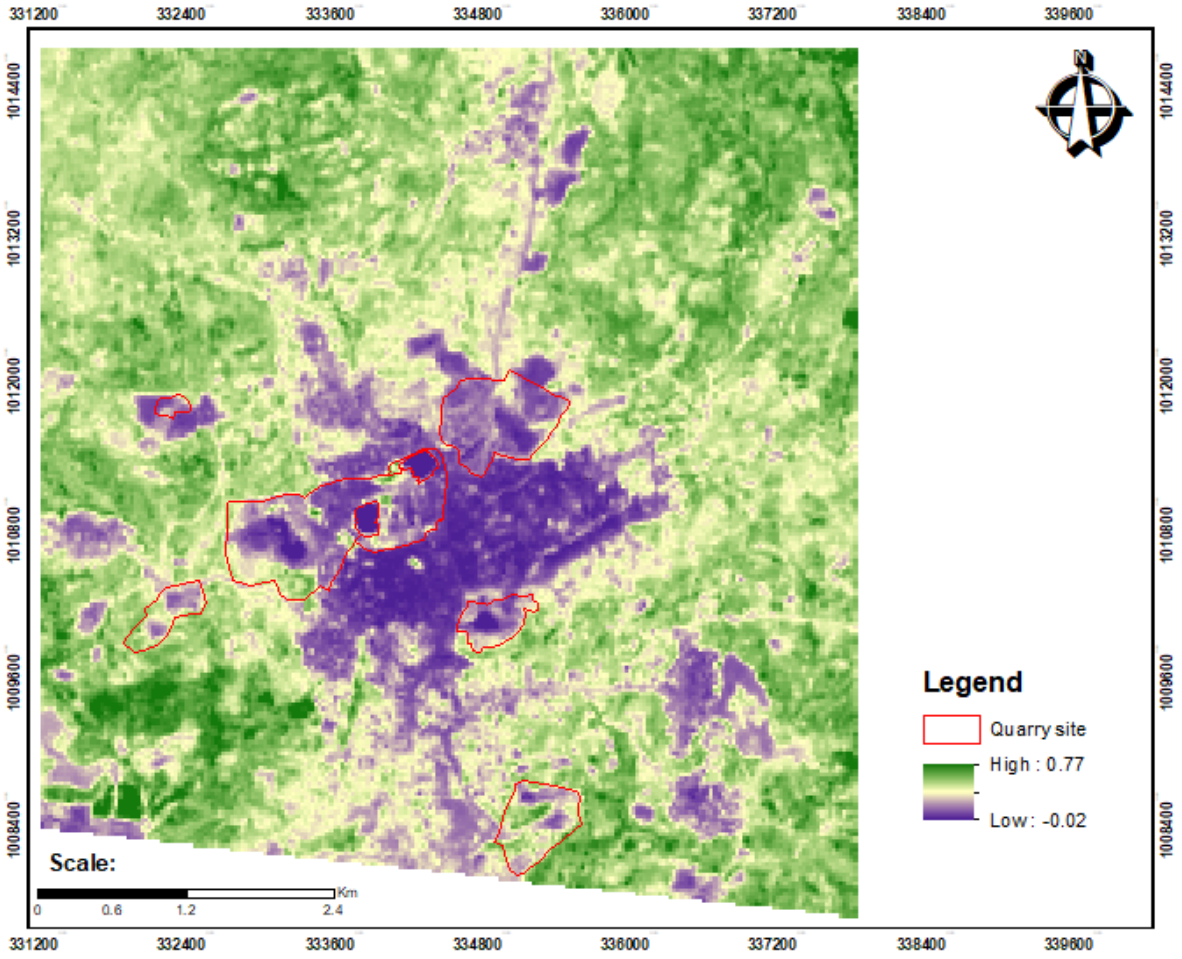


Figure 4.29: The Derived Normalized Difference Vegetation Index (NDVI) map of Landsat 8of 2015.

In Figure 4.28, the NDVI values range from -0.69 to +1 with a color ramp of purple to green. The dark green color indicates areas of high greenness, while the dark purple represent areas without greenness. The light colors (green and purple) in between the color ramp represent areas of little greenness and surface with little greenness. In Figure 4.29, the NDVI values range from -0.02 to 0.77 with a color ramp of purple to green.

In Figure 4.28 and 4.29, the quarry sites were overlaid on them to show the nature of vegetation around each quarry site. It can be seen that there are losses of vegetation around

the quarry sites in both 2002 and 2015 NDVI images. In addition, the NDVI matches the land use and land cover map and it indicated that there are losses of vegetation around settlements. The highly vegetated areas in the NDVI images correspond to farmland and vegetation classes. The NDVI images of 2002 and 2015 have low values of 0.09 at settlement; values of 0.08 at quarry sites and rocky surfaces, while water body has negative values. Farmland and vegetated areas have high NDVI values of 0.3 to 0.5 and 0.53 to 0.8 respectively.

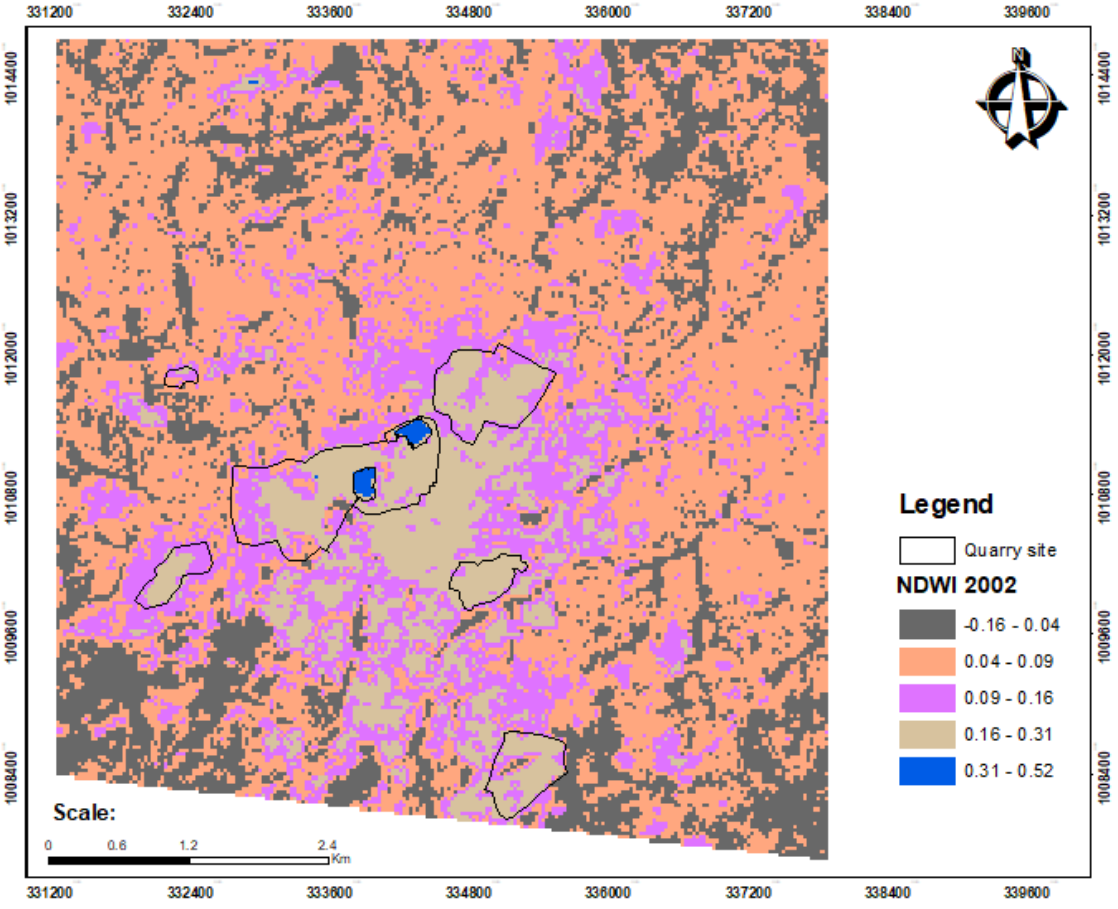


Figure 4.30: The Derived Normalized Difference Water Index (NDWI) map of Landsat 7 of 2002.

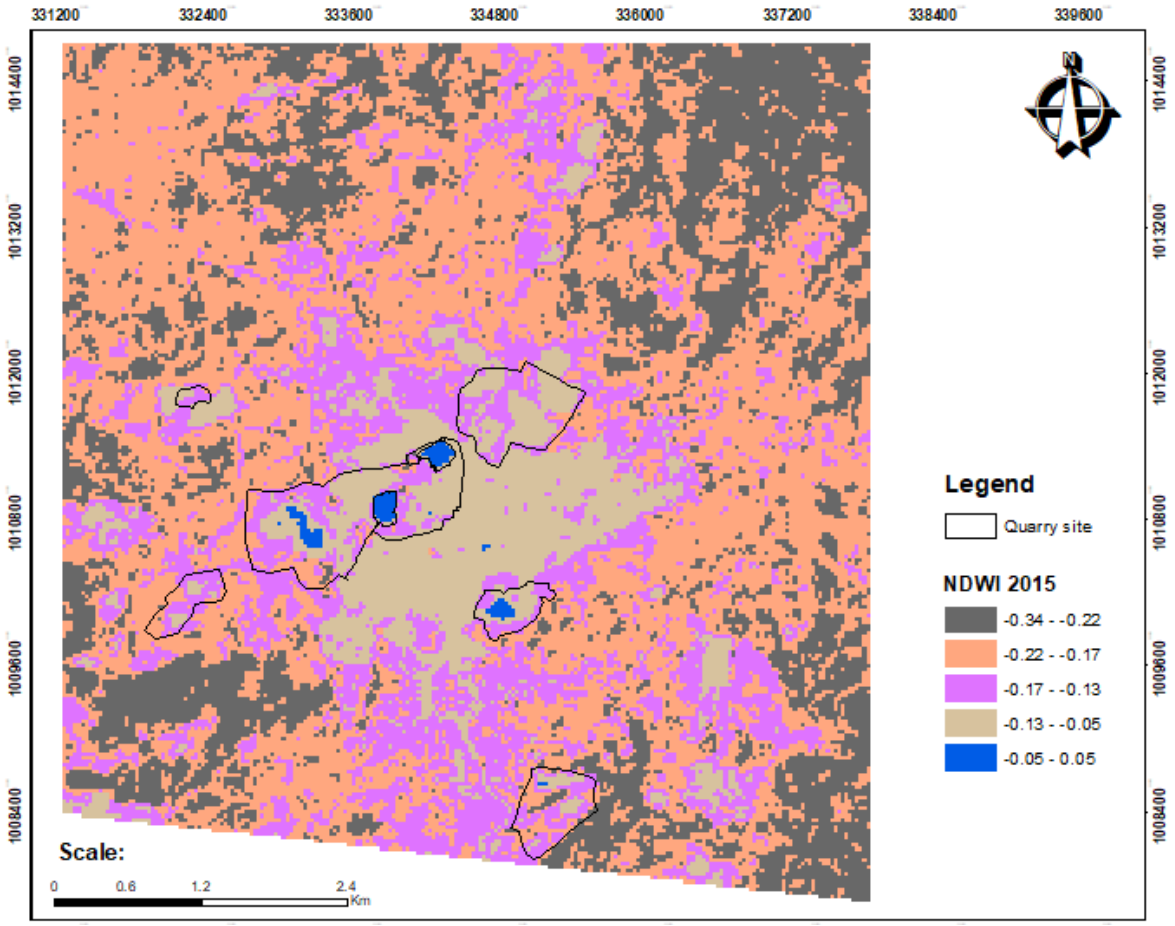


Figure 4.31: The Derived Normalized Difference Water Index (NDWI) map of Landsat 8 of 2002.

Ideally, NDWI values range from -1 to +1, with +1 corresponding to areas with water content, while -1 corresponds to areas with no water content. In Figure 4.30, NDWI values of Landsat 7 range from -0.34 to 0.52 and were classified into to five classes with different colors. Areas with water content range from 0.31 to 0.52 are shown in blue color and indicated water bodies. Interestingly, it is situated around Julius Berger quarry and corresponds to the derelict pond formed as a result of rigorous mining activity in the Julius Berger quarry site.

In Figure 4.31, the values range from -0.34 to +0.05 and were also classified into five classes. The areas with water content correspond to class with values of -0.05 to +0.05 and are indicated by blue colors. It can be seen that the derelict ponds increased from two in Julius Berger quarry site to three; one in Crush rock quarry site and another in Dantata quarry site.

In general, it is evident (in Figure 4.28, 4.29, 4.30 and 4.31) that there are rarely water body and vegetation around the vicinity of settlement in both images. This could be the continuous operation of quarry activities such as frequent blasting of rocks, vibration of machines, spread of dusts by machine and heavy duty vehicles transvering the roads during stones conveyance. In addition, there is no sign of flowing water body (stream, river etc.) within the study area as portrayed by both NDWI images of 2002 and 2015. In addition, the derelict ponds are situated only at the abandoned quarry sites, namely: Julius Berger, Crush rock quarry and Dantata quarry sites respectively.

4.6 Discussion of Results

With regard to the analyses carried out, the results evinced that the three abandoned quarry sites: namely, Julius Berger, Dantata and Crush Rock contained derelict ponds as at 2015. Similarly, as at 2002, there were only two derelict ponds in the Julius Berger quarry and others (Crush Rock and Dantata) had none. This fact was established by derivation of NDWI in Figure 2.30 and 2.31. The presence of these ponds could be one of the reasons for the abandonment of the quarry sites. Interestingly, the active quarry sites contain no derelict ponds.

More so, Julius Berger quarry is the largest with an area of 1,057,807.31m^2, followed by Arab Contractors with an area of 921,693.95m^2, followed by Dantata, Exsamine 1, Hongyum, Exsamine 2, Exsamine 2, Crush Rock, Perfect Stone and Leenford with areas of 333,992.05m^2, 215,243.82m^2, 183,796.85m^2, 175,918.56m^2, 130,955.31m^2, 56,792.23m^2, and 55,812.16m^2as shown in Table 4.2respectively.

As regards to the distribution of the quarry sites, only six quarry sites were in the 2005 and they are Julius Berger, Arab Contractors, Crush Rock, Dantata, and Exsamine 1 and 2 quarry stes. In 2015, there are nine quarry sites with the addition of three quarry sites, namely: Hongyum, Perfect Stone and Leedford quarry sites. More so, Julius Berger, Arab Contractors and Crush Rock quarry sites are situated in core of the study area, while Dantata quarry site is located in the extreme southern part of Mpape. Also, Hongyum and Perfect Stone quarries are located in the extreme northern part of Mpape, while Exsamine 1 and 2, and Leedford quarries are located in eastern part of the study area. This was established by the mapping of the distribution of the quarry sites as shown in Figure 4.2. In addition, of all the quarry sites, two abandoned quarry sites (Julius Berger and Crush Rock) are located in the core of the study area, while only one active quarry site (Arab Contractors) is located in the core of the study area.

Furthermore, the result of the depths of the derelict ponds within the quarry sites showed that the three ponds within the abandoned Julius Berger quarry site are the deepest with values of 25m. 20m and 15m respectively. Also, the pond within Crush Rock is 14m and the one in Dantata quarry is 6m as shown in the chart in Figure 4.16. Although, he study intended to ascertain this objective by the use of ground survey method using a Hi – Target

GNSS receiver. Access was not granted to the quarry sites due to bureaucratic bottleneck. However, the depths of the ponds within Julius Berger quarry was surreptitiously measured using the Hi-Target GNSS receiver. The values obtained for the three ponds are 19m, 16m and 11m respectively as shown in Table 4.3. These values are close to the depths determined by the transect analysis method and this served as a corroboration.

In the derived land use and land cover maps of 2005 and 2015 in Figure 4.17 and 4.18, these results indicated that the study area is endowed with rocks and are mostly situated in the northern part of the study area. In the 2005 land use and land cover map, the rocky areas increased from 1.07$Km^2$to 2.21Km^2as shown in Figure 4.19. The result of the generated Triangular irregular Network (TIN) from the ASTERDEM confirmed that the rocky areas have high elevation values as shown in Figure 4.8 and it happens to be where quarrying activities are occurring. With the increment in the rocky areas at the rate of 106.54Km^2. yr^{-1} as shown in Table 4.5, this is an indication that there will be more rigorous activities of quarrying in the study area. Importantly, the land use and land cover map showed the increase of settlements from 3.25m in 2005 to 10.95m in 2015 at a rate of 236.92Km^2. yr^{-1} as shown in Figure 4.19 and Table 4.5. This urban sprawl is predominantly in the city center of the study area. The implication of the spread in settlement is that the Julius Berger, Arab Contractors and Crush Rocks quarry sites are being engulfed by these settlements. This can also be corroborated by the result of the 100m and 150m buffer analyses in Figure 4.20, together with the result of the geotagged photo of Julius Berger and Arab Contractors as shown in Figures 4.21, 4.22, 4.23, 4.24and 4.25.

In addition, vegetation cover diminished from 30.31$Km^2$to 16.71Km^2 at a rate of -44.87Km^2. yr^{-1} as shown in Figure 4.19 and Table 4.5. This indicates that the vegetation cover was converted to settlement and farmland. Farmland increased from 10.77$Km^2$to 16.69Km^2. interestingly, the NDVI of 2002 and 2015, and NDWI of 2002 and 2015 results in Figure 4.28, 4.29, 4.30 and 4.31 show that there is no vegetation and water within the settlement in the core of the study area.

This is also the same view withEshiwani (2014), Abbas and Fasona (2012), Fadhil (2009)and Mwangi (2014)thatrevealed that quarrying activitiesresulted to degradation of the environment and huge loss of vegetation. In addition, as regards to the results of the NSWI, it was found that there are three derelict ponds within the Julius Berger quarry and one each in Dantata and Crush rock quarries. Therefore, it is certain that quarrying can results to the creation of derelict ponds. Similar finding has also been observed by Mustafa *et al*., (n.d).In the same vein, the NDVI analysis, it revealed that there was loss of vegetation around the quarry sites. Ujoh *et al.* (2014) corroborated this finding through the NDVI analysis. Lameed and Ayodele (2010)also concluded with the same findings as shown in this study.

CHAPTER FIVE

SUMMARY,CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter entails the conclusions arrived in this study and recommendations based on the findings of this study.

5.2 Summary of Findings

The findings obtained from the processing of all acquired datasets are encapsulated in accordance with the order of the stated objectives.

i. The study showed nine quarry sites in total. Three are abandoned and six are active. Three of them are located in the core center of Mpape. Out of the three, two are abandoned, namely: Julius Berger and Crush rock quarries. The third one (Arab contractors) is active. The other six are Dantata (abandoned), Chinese (active), Exsamine 1 and 2 (active), and two unknowns (active) quarries are located remotely from Mpape.

ii. It was found out from the derived NDVI images that there are losses of vegetation around all the quarries. There are also loss of vegetation around the settlement. Though, the Landsat 7 and 8 images during autumn (i.e. month of December), this was to ensure that the study area is exaggerated with the presence of vegetation. In

addition, the derivation of NDWI revealed that water bodies could be located at the abandoned quarry sites. As at 2002, only two derelict ponds were present in the Julius Berger quarry. In the 2015 NDWI, the water bodies increased to three. Also, Crush rock contain water body and Dantata quarry has a small extent of water body.

iii. The LULC map revealed the increase in the sizes and numbers of quarry sites from six in the year 2005 to nine in the year 2015. Also, there was an urban sprawl in settlement and an increase in rocky surface and farmland. The decrease was in vegetation. In the depth analysis, it was found out that the rocky surface have the highest elevation and are located in the upper and lower region of Mpape. The quarry sites and settlement are located on a high elevation ground. Importantly, it revealed that the derelict ponds were formed as a result of rigorous quarry activities, since there is no tributaries connecting each of the derelict ponds.

iv. The depth profiles of the derelict ponds showed that pond 1, 2 and 3 that are within Julius Berger quarry site have the highest depths, followed by the pond within Crush rock quarry, and the pond in Dantata quarry site has the least.

v. The buffer analysis carried out at 100m and 150m distances revealed that settlements are already engulfing the three quarry sites located at the core center of Mpape. Also, Chinese quarry site has been encroached, while the other six do not have settlement contiguous to them at 100m and 150m buffer distances.

5.3Conclusions

The study has mapped and analyzed spatio-temporal variability of quarry site in Mpape district inBwari area of the FCT. The results from the study were compared to results from earlier works where applicable.In this study, the distribution of quarry sites within Mpape

district of Abuja has been investigated through fieldwork and mapped using high-resolution IKONOS satellite image. A total of nine quarrying sites were identified within the study area. Three quarry sites are abandoned, namely: Julius Berger, Crush rock and Dantata quarries. The remaining six are active, namely: Arab contractors, Hongyum, Exsamne 1 and 2, Perfect Stone and Leenford quarry sites. Julius Berger quarry site is the largest and contains three derelict ponds; Crush rock and Dantata quarry have contain one each. Also, Julius Berger, Arab contractor and Crush rock quarry sites are located in the core center of Mpape, while others are dispersed across the study area.

On the impact of quarrying on water, vegetation and land surface, the results derived from the NDVI images showed that there are losses of vegetation around all the quarrying sites and the settlements, despite the fact that the Landsat images were acquired in autumn (i.e. month of December). Inaddition, the derivation of NDWI revealed that water bodies could be located at theabandoned quarry sites. As at 2002, only two water bodies were present in the JuliusBerger quarry. In the 2015 NDWI, the water bodies increased to three. Both Crushrock and Dantata quarries containwater body each. There tend to be a decrease in vegetation from 30.31Km^2 to 16.71Km^2 between 2005 and 2015. In general, the increase in settlement, rocky surface, quarry sites and farmland led to the decrease in the area of vegetation.

The study revealed that there was an increase in the sizes and numbers of quarry sites from six in the year 2005 (area of 2.44Km^2) to nine in the year 2015 (area of 3.13Km^2). The settlement increased in area from 3.25$Km^2$to 10.95Km^2 with an annual rate of change of 236.92Km^2. yr^{-1}. This indicted an urban sprawl in Mpape in spate of ten years from 2005 to

2015. The increase in water body (derelict ponds) in the quarry sites indicated heavy quarry activities that must have occurred between 2005 and 2015. The increase in rocky surface is also an indication of the increase in sizes and number of more quarry sites, especially towards the upper region of Mpape. This is a sign that more quarry activities will be seen in the future, as more rocky areas will be explored further. Similarly, there is an increase in farmland from 10.77$Km^2$to 16.69$Km^2$from 2005 to 2015.

On the depths of the derelict ponds formed as a result of rigorous quarrying, the three ponds within the abandoned Julius Berger quarry have the highest depths of 25m, 20m and 15m respectively. The ponds in the abandoned Crush rock has a depth of 14m and the pond in abandoned Dantata quarry has the least depth of 6m. Furthermore, the study has shown that the settlements in the core center of Mpape have already encroached Julius Berger, Crush rock and the active Arab contractors quarries at distances of 100m and 150m.

Therefore, this study has investigated the spatial distribution, nearness to settlements and depth of quarry sites within Mpape District of Abuja using IKONOS and Landsat multi-temporal satellite images, and image processing software to map the quarry sites.

5.4Recommendations

The following recommendations were made according to the findings of this study.

i. There is need for stakeholders in the Ministry of Environment, Federal Capital Development Authority (FCDA) and environmental protection agencies to urge quarrying companies to convert abandoned derelict ponds into socio-economic use.
ii. Policies should be implemented for residential areas to keep off quarrying sites with a minimum distance of 150m to 200m as compared to other standards in countries

like India and Bangladesh. Also, authorities that are responsible for environmental protection should always embark upon environmental impact assessment of the quarrying sites in Mpape to unravel the level of destruction being made to the ecosystem.

iii. The quarrying companies should be task to plant grasses around the quarrying vicinity as this aid in trapping rising dust due to blasting of quarries and frequent movement of heavy duty vehicles, and on the other hand, it helps to mitigate air pollution.

iv. Regulations on quarrying in Mpape should be formulated and if already available, should be implemented fully. Also, this study should be viewed as a resource to stakeholders wanting to conduct environmental impact assessment in quarrying.

5.5 Contributions to Knowledge

The following are the contributions deduced from the study:

i. This study has for the first time determined the geometric characteristics (length, breadth, area and depths) of some quarry sites in Mpape district of Bwari area council of Abuja.

ii. The study established the existence of active and abandoned quarry sites in Abuja. In addition, it established three derelict ponds in Julius Berger quarry site and one each in Crush rock and Dantata quarry sites by transect analysis technique using 3D analyst toolbar in ArcGIS v10.1 together with a TIN surface that was. This was achieved by the integrating extracted elevation points from ASTERDEM and the derived spot heights from the utilization of Google Earth and TCX software.

iii. Most importantly, the research has established the combination of qualitative and quantitative techniques of classifying land use and land covers within the study area, especially when a land use or land cover of interest conflicts with another. This was necessary when two or more land use and land covers share similar spectral characteristics (digital or brightness number, radiance or reflectance). Other researchers on previous studies classified LULC using the conventional method of classification (supervised and unsupervised). The integration of the qualitative and quantitative methods is tantamount in appearance and quality to the object-based image classification.

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APPENDIX 1: AREA COMPUTATION OF THE QURRY SITES

Area Computation of Julius Berger Quarry

Cadastral Zone : F14

Location: Mpape Abuja

	From	Northing (m)	Easting (m)	Brg (d m s)	Dist (m)	To
PB 38	1011477.750	334383.579	152 47 03	156.200	PB 39	
	PB 39	1011338.843	334455.016	215 13 04	082.584	PB 40
	PB 40	1011271.375	334407.391	157 13 03	215.230	PB 41
	PB 41	1011072.937	334490.735	189 14 46	172.903	PB 42
	PB 42	1010902.280	334462.954	212 16 33	089.186	PB 43

PB 43	1010826.874	334415.329	314 59 47	011.225	PB 44
PB 44	1010834.811	334407.391	237 59 42	074.882	PB 45
PB 45	1010795.124	334343.891	191 18 34	060.711	PB 46
PB 46	1010735.592	334331.985	255 42 35	434.121	PB 47
PB 47	1010628.436	333911.297	293 11 54	181.351	PB 48
PB 48	1010699.873	333744.609	208 13 44	427.927	PB 49
PB 49	1010322.841	333542.202	293 57 44	78.176	PB 50
PB 50	1010354.591	333470.764	228 00 46	160.182	PB 51
PB 51	1010247.435	333351.702	302 00 19	299.530	PB 52
PB 52	1010406.185	333097.701	259 35 33	197.722	PB 53
PB 53	1010370.467	332903.232	284 49 34	139.585	PB 54
PB 54	1010406.185	332768.294	356 43 09	624.118	PB 55
PB 55	1011029.280	332732.575	085 59 32	624.623	PB 56
PB 56	1011072.937	333355.670	74 29 35	712.534	PB 57
PB 57	1011263.437	334042.266	346 45 34	069.311	PB 58
PB 58	1011330.906	334026.391	068 11 55	384.703	PB 59
PB 59	1011473.781	334383.579	000 00 00	003.969	PB 38

Area : 1139666.841 meter square113.967 hectares

APPENDIX 1 Continues

Area Computation of Crush Rock Quarry

Cadastral Zone: F14

Location: Mpape

From	Northing (m)	Easting (m)	Brg (d m s)	Dist (m)	To
PB 75	1010297.375	335028.436	116 58 50	081.646	PB 76
PB 76	1010260.333	335101.196	216 40 28	077.523	PB 77
PB 77	1010198.156	335054.894	138 11 58	150.842	PB 78
PB 78	1010085.708	335155.436	223 07 32	257.385	PB 79
PB 79	1009897.854	334979.488	259 03 20	243.885	PB 80
PB 80	1009851.551	334740.039	328 40 18	142.483	PB 81
PB 81	1009973.260	334665.956	279 51 56	061.767	PB 82

PB 82	1009983.843	334605.102	008 07 46	056.127	PB 83
PB 83	1010039.406	334613.039	064 58 59	131.390	PB 84
PB 84	1010094.969	334732.102	358 05 27	079.419	PB 85
PB 85	1010174.344	334729.456	273 37 57	083.512	PB 86
PB 86	1010179.635	334646.112	024 13 36	029.014	PB 87
PB 87	1010206.094	334658.018	074 37 26	109.763	PB 88
PB 88	1010235.198	334763.852	000 00 00	034.396	PB 89
PB 89	1010269.594	334763.852	086 33 58	066.265	PB 90
PB 90	1010273.563	334829.998	168 22 01	045.923	PB 91
PB 91	1010228.583	334839.258	079 59 31	159.861	PB 92
PB 92	1010256.365	334996.686	036 34 24	051.065	PB 93
PB 93	1010297.375	335027.113	090 00 00	001.323	PB 75

Area: 149099.336 meter square 14.910 hectares

Area Computation of Dantata Quarry

Cadastral Zone: F14

Location: Mpape Abuja

From	Northing (m)	Easting (m)	Brg (d m s)	Dist (m)	To
PB 94	1008688.044	335592.529	188 07 49	187.089	PB 95
PB 95	1008502.835	335566.070	162 38 44	088.705	PB 96
PB 96	1008418.168	335592.529	230 21 21	360.786	PB 97
PB 97	1008187.980	335314.716	156 48 06	020.149	PB 98
PB 98	1008169.460	335322.653	232 07 30	090.502	PB 99

APPENDIX 1 Continues

PB 99	1008113.897	335251.215	180 00 00	042.334	PB 100
PB 100	1008071.563	335251.215	230 11 41	041.329	PB 101
PB 101	1008045.105	335219.465	212 09 08	109.379	PB 102
PB 102	1007952.501	335161.257	275 26 25	111.628	PB 103
PB 103	1007963.084	335050.132	000 00 00	031.750	PB 104
PB 104	1007994.834	335050.132	291 48 04	085.490	PB 105
PB 105	1008026.584	334970.756	021 48 06	056.993	PB 106
PB 106	1008079.501	334991.923	347 16 32	168.172	PB 107
PB 107	1008243.543	334954.881	288 26 08	075.301	PB 108
PB 108	1008267.356	334883.444	022 00 41	134.131	PB 109

PB 109	1008391.710	334933.715	078 03 21	281.256	PB 110
PB 110	1008449.918	335208.882	339 13 41	082.064	PB 111
PB 111	1008526.648	335179.778	273 55 06	193.599	PB 112
PB 112	1008539.877	334986.632	024 18 16	179.995	PB 113
PB 113	1008703.919	335060.715	331 23 22	033.152	PB 114
PB 114	1008733.023	335044.840	038 17 25	064.049	PB 115
PB 115	1008783.294	335084.528	105 15 18	090.501	PB 116
PB 116	1008759.482	335171.840	127 14 05	083.081	PB 117
PB 117	1008709.211	335237.986	059 51 31	094.845	PB 118
PB 118	1008756.836	335320.007	091 18 07	116.447	PB 119
PB 119	1008754.190	335436.424	110 26 59	166.604	PB 120
PB 120	1008695.981	335592.529	180 00 00	007.937	PB 94

Area: 339578.570 meter square 33.958 hectares

Area Computation of Hongyun

Cadastral Zone: F14

Location: Mpape Abuja

From	Northing (m)	Easting (m)	Brg (d m s)	Dist (m)	To
PB 1	1014108.507	335458.517	106 55 39	254.441	PB 2
PB 2	1014034.424	335701.934	206 53 46	163.765	PB 3
PB 3	1013888.374	335627.851	189 27 44	283.255	PB 4
PB 4	1013608.973	335581.284	250 27 49	069.625	PB 5

APPENDIX 1 Continues

PB 5	1013585.690	335515.667	180 00 00	080.000	PB 6
PB 6	1013505.690	335515.667	223 10 42	197.973	PB 7
PB 7	1013361.323	335380.200	289 33 18	124.104	PB 8
PB 8	1013402.862	335263.254	002 21 11	193.309	PB 9
PB 9	1013596.008	335271.191	020 14 44	542.863	PB 10
PB 10	1014105.332	335459.046	350 32 26	003.219	PB 1

Area: 175302.069 meter square 17.530 hectares

Area Computation of Exsamine Quarry 1

Cadastral Zone: F14

Location: Mpape Abuja

From	Northing (m)	Easting (m)	Brg (d m s)	Dist (m)	To
PB 60	332549.814	1011905.582	308 50 04	126.580	PB 61
PB 61	332629.189	1011806.981	004 06 07	020.956	PB 62
PB 62	332650.091	1011808.480	274 05 09	037.136	PB 63
PB 63	332652.737	1011771.438	008 17 52	064.172	PB 64
PB 64	332716.237	1011780.699	278 25 39	072.218	PB 65
PB 65	332726.821	1011709.261	202 37 12	085.990	PB 66
PB 66	332647.446	1011676.188	257 54 17	037.883	PB 67
PB 67	332639.508	1011639.146	200 47 49	294.345	PB 68
PB 68	332364.341	1011534.636	168 54 08	350.514	PB 69
PB 69	332020.382	1011602.104	108 26 06	133.871	PB 70
PB 70	331978.048	1011729.105	065 46 17	058.027	PB 71
PB 71	332001.861	1011782.021	117 49 26	161.554	PB 72
PB 72	331926.455	1011924.897	356 09 25	382.920	PB 73
PB 73	332308.514	1011899.232	002 14 54	238.308	PB 74
PB 74	332546.639	1011908.581	316 37 59	004.367	PB 60

Area: 218955.157 meter square 21.896 hectares

APPENDIX 1 Continues

Area Computation of Exsamine 2 Quarry

Cadastral Zone: F14

Location: Mpape Abuja

From	Northing (m)	Easting (m)	Brg (d m s)	Dist (m)	To
PB 121	1010396.153	332495.574	162 28 27	197.693	PB 122
PB 122	1010207.637	332555.106	205 38 29	091.714	PB 123
PB 123	1010124.955	332515.418	264 48 20	219.181	PB 124
PB 124	1010105.111	332297.137	211 25 47	279.071	PB 125
PB 125	1009866.985	332151.615	253 44 23	165.365	PB 126
PB 126	1009820.683	331992.865	299 55 54	125.938	PB 127

PB 127	1009883.522	331883.724	037 31 42	287.754	PB 128
PB 128	1010111.726	332059.011	349 59 31	057.093	PB 129
PB 129	1010167.950	332049.089	042 47 51	243.396	PB 130
PB 130	1010346.544	332214.454	079 45 22	278.953	PB 131
PB 131	1010396.153	332488.960	090 00 00	006.614	PB 121

Area: 174519.538 meter square 17.452 hectares

Area Computation of Perfect Stone Quarry

Cadastral Zone: F14

Location: Mpape

From	Northing (m)	Easting (m)	Brg (d m s)	Dist (m)	To
PB 11	1013465.039	337382.571	065 51 15	084.086	PB 12
PB 12	1013499.435	337459.300	004 34 27	066.357	PB 13
PB 13	1013565.581	337464.592	084 17 20	106.361	PB 14
PB 14	1013576.165	337570.425	164 24 26	118.118	PB 15
PB 15	1013462.394	337602.175	142 07 30	181.004	PB 16
PB 16	1013319.518	337713.301	234 27 45	091.042	PB 17
PB 17	1013266.601	337639.217	307 25 38	326.512	PB 18
PB 18	1013465.039	337379.925	090 00 00	002.646	PB 11

Area: 44834.572 meter square 4.483 hectares

APPENDIX 1 Continues

Area Computation of Leenford Quarry

Cadastral Zone: F14

Location: Mpape, Abuja

From	Northing (m)	Easting (m)	Brg (d m s)	Dist (m)	To
PB 132	1010227.481	331770.615	160 20 48	39.333	PB 133
PB 133	1010190.439	331783.844	232 25 55	43.395	PB 134
PB 134	1010163.981	331749.448	189 27 43	64.376	PB 135
PB 135	1010100.481	331738.865	213 28 35	196.666	PB 136
PB 136	1009936.439	331630.385	302 16 32	59.458	PB 137
PB 137	1009968.189	331580.114	292 37 11	68.792	PB 138

PB 138	1009994.647	331516.614	349 02 45	167.086	PB 139
PB 139	1010158.689	331484.864	075 20 08	292.638	PB 140
PB 140	1010232.773	331767.969	153 26 06	05.917	PB 132

Area: 50431.387 meter square 5.043 hectares

APPENDIX II: LIST OF COORDINATES

Point ID	Northing (m)	Easting (m)	Height (m)	Description
1	1014108.507	335458.517	677.245	Hongyon Quarry
2	1014034.424	335701.934	678.982	Hongyon Quarry
3	1013888.374	335627.851	690.254	Hongyon Quarry
4	1013608.973	335581.284	701.001	Hongyon Quarry
5	1013585.69	335515.667	705.221	Hongyon Quarry
6	1013505.69	335515.667	709.712	Hongyon Quarry

7	1013361.323	335380.2	702.331	Hongyon Quarry
8	1013402.862	335263.254	698.425	Hongyon Quarry
9	1013596.008	335271.191	688.221	Hongyon Quarry
10	1014105.332	335459.046	678.212	Hongyon Quarry
11	1013465.039	337382.571	667.252	Perfect Stone Quarry
12	1013499.435	337459.3	678.122	Perfect Stone Quarry
13	1013565.581	337464.592	679.221	Perfect Stone Quarry
14	1013576.165	337570.425	702.342	Perfect Stone Quarry
15	1013462.394	337602.175	701.234	Perfect Stone Quarry
16	1013319.518	337713.301	699.232	Perfect Stone Quarry
17	1013266.601	337639.217	698.213	Perfect Stone Quarry
18	1013465.039	337379.925	697.231	Perfect Stone Quarry
19	1012233.6	334383.248	721.243	Arab Quarry
20	1012182.006	334184.81	723.342	Arab Quarry
21	1012357.161	334162.32	726.614	Arab Quarry
22	1012424.629	334475.852	726.987	Arab Quarry
23	1012265.879	334539.352	729.332	Arab Quarry
24	1012218.254	334717.947	727.452	Arab Quarry
25	1012019.816	334975.916	721.323	Arab Quarry
26	1012242.067	335098.947	719.112	Arab Quarry
27	1012309.006	335601.657	720,314	Arab Quarry
28	1012309.536	335602.98	718.112	Arab Quarry
29	1011908.162	335673.094	717.324	Arab Quarry
30	1011848.63	335498.469	715.223	Arab Quarry
31	1011380.317	335169.062	717.145	Arab Quarry

APPENDIX II Continues

Point ID	Northing (m)	Easting (m)	Height (m)	Description
32	1011435.88	334887.28	716.323	Arab Quarry
33	1011237.442	334799.968	720.432	Arab Quarry
34	1011348.567	334613.436	722.654	Arab Quarry
35	1011447.786	334609.467	724.567	Arab Quarry
36	1011531.13	334462.623	728.321	Arab Quarry

37	1011943.881	334522.155	722.434	Arab Quarry
38	1011477.75	334383.579	732.143	Julius Berger Quarry
39	1011338.843	334455.016	738.345	Julius Berger Quarry
40	1011271.375	334407.391	738.123	Julius Berger Quarry
41	1011072.937	334490.735	737.412	Julius Berger Quarry
42	1010902.28	334462.954	735.146	Julius Berger Quarry
43	1010826.874	334415.329	737.881	Julius Berger Quarry
44	1010834.811	334407.391	740.321	Julius Berger Quarry
45	1010795.124	334343.891	739.112	Julius Berger Quarry
46	1010735.592	334331.985	738.675	Julius Berger Quarry
47	1010628.436	333911.297	737.994	Julius Berger Quarry
48	1010699.873	333744.609	737.021	Julius Berger Quarry
49	1010322.841	333542.202	736.412	Julius Berger Quarry
50	1010354.591	333470.764	736.002	Julius Berger Quarry
51	1010247.435	333351.702	735.924	Julius Berger Quarry
52	1010406.185	333097.701	736.012	Julius Berger Quarry
53	1010370.467	332903.232	733.234	Julius Berger Quarry
54	1010406.185	332768.294	731.547	Julius Berger Quarry
55	1011029.28	332732.575	730.233	Julius Berger Quarry
56	1011072.937	333355.67	731.153	Julius Berger Quarry
57	1011263.437	334042.266	731.224	Julius Berger Quarry
58	1011330.906	334026.391	730.123	Julius Berger Quarry
59	1011473.781	334383.579	731.021	Julius Berger Quarry
60	332549.814	1011905.582	742.356	Exsamine Quarry 2
61	332629.189	1011806.981	744.543	Exsamine Quarry 3
62	332650.091	1011808.48	742.322	Exsamine Quarry 4
63	332652.737	1011771.438	743.765	Exsamine Quarry 5

APPENDIX II Continues

Point ID	Northing (m)	Easting (m)	Height (m)	Description
64	332716.237	1011780.699	747.185	Exsamine Quarry 6
65	332726.821	1011709.261	748.324	Exsamine Quarry 7
66	332647.446	1011676.188	747.543	Exsamine Quarry 8
67	332639.508	1011639.146	749.025	Exsamine Quarry 9
68	332364.341	1011534.636	750.143	Exsamine Quarry 10

69	332020.382	1011602.104	751.654	Exsamine Quarry 11
70	331978.048	1011729.105	749.332	Exsamine Quarry 12
71	332001.861	1011782.021	747.854	Exsamine Quarry 13
72	331926.455	1011924.897	746.854	Exsamine Quarry 14
73	332308.514	1011899.232	745.234	Exsamine Quarry 15
74	332546.639	1011908.581	744.229	Exsamine Quarry 16
75	1010297.375	335028.436	726,712	Crush Rock Quarry
76	1010260.333	335101.196	728.343	Crush Rock Quarry
77	1010198.156	335054.894	726.456	Crush Rock Quarry
78	1010085.708	335155.436	729.456	Crush Rock Quarry
79	1009897.854	334979.488	728.564	Crush Rock Quarry
80	1009851.551	334740.039	729.865	Crush Rock Quarry
81	1009973.26	334665.956	730.321	Crush Rock Quarry
82	1009983.843	334605.102	732.877	Crush Rock Quarry
83	1010039.406	334613.039	733.543	Crush Rock Quarry
84	1010094.969	334732.102	735.123	Crush Rock Quarry
85	1010174.344	334729.456	736,234	Crush Rock Quarry
86	1010179.635	334646.112	734.332	Crush Rock Quarry
87	1010206.094	334658.018	733.124	Crush Rock Quarry
88	1010235.198	334763.852	732,821	Crush Rock Quarry
89	1010269.594	334763.852	733,102	Crush Rock Quarry
90	1010273.563	334829.998	732.123	Crush Rock Quarry
91	1010228.583	334839.258	732.021	Crush Rock Quarry
92	1010256.365	334996.686	731.221	Crush Rock Quarry
93	1010297.375	335027.113	730.321	Crush Rock Quarry
94	1008688.044	335592.529	678.532	Dantata Quarry
95	1008502.835	335566.07	699.021	Dantata Quarry

APPENDIX II Continues

Point ID	Northing (m)	Easting (m)	Height (m)	Description
96	1008418.168	335592.529	700.123	Dantata Quarry
97	1008187.98	335314.716	689.123	Dantata Quarry
98	1008169.46	335322.653	687.312	Dantata Quarry
99	1008113.897	335251.215	686.234	Dantata Quarry
100	1008071.563	335251.215	687.323	Dantata Quarry
101	1008045.105	335219.465	688.453	Dantata Quarry

102	1007952.501	335161.257	689.021	Dantata Quarry
103	1007963.084	335050.132	688.543	Dantata Quarry
104	1007994.834	335050.132	686.324	Dantata Quarry
105	1008026.584	334970.756	682.342	Dantata Quarry
106	1008079.501	334991.923	683.023	Dantata Quarry
107	1008243.543	334954.881	683.423	Dantata Quarry
108	1008267.356	334883.444	685.765	Dantata Quarry
109	1008391.71	334933.715	687.992	Dantata Quarry
110	1008449.918	335208.882	684.654	Dantata Quarry
111	1008526.648	335179.778	682.875	Dantata Quarry
112	1008539.877	334986.632	681.021	Dantata Quarry
113	1008703.919	335060.715	682.765	Dantata Quarry
114	1008733.023	335044.84	680.332	Dantata Quarry
115	1008783.294	335084.528	681.231	Dantata Quarry
116	1008759.482	335171.84	679.232	Dantata Quarry
117	1008709.211	335237.986	678.221	Dantata Quarry
118	1008756.836	335320.007	679.432	Dantata Quarry
119	1008754.19	335436.424	678.354	Dantata Quarry
120	1008695.981	335592.529	680.245	Dantata Quarry
121	1008688.044	335592.529	683.567	Dantata Quarry
121	1010396.153	332495.574	652.245	Exsamine 2
122	1010207.637	332555.106	656.453	Exsamine 3
123	1010124.955	332515.418	655.321	Exsamine 4
124	1010105.111	332297.137	653.987	Exsamine 5
125	1009866.985	332151.615	652.123	Exsamine 6
126	1009820.683	331992.865	652.657	Exsamine 7

APPENDIX II Continues

Point ID	Northing (m)	Easting (m)	Height (m)	Description
127	1009883.522	331883.724	651.578	Exsamine 8
128	1010111.726	332059.011	650.345	Exsamine 9
129	1010167.95	332049.089	652.876	Exsamine 10
130	1010346.544	332214.454	654.012	Exsamine 11
131	1010396.153	332488.96	653.874	Exsamine 12
132	1010227.481	331770.615	632.145	Leenford Quarry

133	1010190.439	331783.844	636.228	Leenford Quarry
134	1010163.981	331749.448	638.321	Leenford Quarry
135	1010100.481	331738.865	636.456	Leenford Quarry
136	1009936.439	331630.385	631.332	Leenford Quarry
137	1009968.189	331580.114	629.425	Leenford Quarry
138	1009994.647	331516.614	629.221	Leenford Quarry
139	1010158.689	331484.864	626.432	Leenford Quarry
140	1010232.773	331767.969	630.234	Leenford Quarry