ASSESSING THE SOCIO-ECONOMIC AND ECOLOGICAL IMPACTS OF GRAVEL MINING IN THE SAVELUGU-NANTON DISTRICT OF THE NORTHERN REGION OF GHANA

A Thesis Submitted to the Department of Agroforestry, Faculty of Renewable Natural Resources, Kwame Nkrumah University of Science and Technology, in partial fulfilment of the requirements for the Degree of

MASTER OF SCIENCE

IN

AGROFORESTRY

BY

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APRIL, 2013

DECLARATION

I hereby declare that this submission is my own work towards the MSc. and that, to the best of my knowledge, it contains neither material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

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ABSTRACT

Gravel mining (GM) plays an important role in the development of socioeconomic infrastructure of communities and constitutes an essential component of materials in the construction of roads, hospitals, schools and housing. Currently, gravel is widely used throughout northern region and it is regarded by many as the fastest developing region in West Africa. However, in the Savelugu-Nanton District, the emergence of GM activities constitutes a major threat to the socio-economic activities of people in the area. The gravel mining also has considerable effect on the air and water. It causes loss of biodiversity, soil pollution and land degradation, reduction of essential nutrients and organic matter of the soil. This study was undertaken to assess the socio-economic and ecological impacts of GM on the people of the Savelugu-Nanton District of the Northern Region of Ghana. Specific objectives were to: examine people's perception of impacts of gravel mining on their socio-economic activities, assess the impact (in terms of duration after gravel pit abandonment) on above-ground vegetative biomass (trees, shrubs grasses and litter) and assess major soil physicochemical property changes of abandoned gravel mines. Through the administration of structured questionnaires and field observations, information was gathered on respondents' perception of GM impact whiles soil and vegetation samples were collected and analysed in a laboratory. Data from gravel mines abandoned for 1-5, 6-10 and more than ten years and data from an un-mined site as standard reference were compared. Respondents' perceived GM to have resulted in the significant reduction of farmlands, and led to poor relationship between residents and gravel miners, caused significant land degradation and promoted the widespread incidence of diseases such as malaria, dysentery and typhoid fever amongst others. Total above-ground biomass (i.e. surface litter+ low growing flora + tree biomass) recorded in the control plot (32.8 t/ha) was found to be significantly higher ($p < 0.05$) than the abandoned mines which recorded total above-ground biomass of 17.7 t/ha, 18.1 t/ha and 18.6 t/ha dry matter for the 1-5, 6-10 and above ten years respectively. While available potassium (K) and percentage organic carbon (%OC) differed significantly ($p < 0.05$) between abandoned and un-mined sites, percentage nitrogen (% N), phosphorus (P), Cation Exchange Capacity (CEC) and pH did not differ significantly ($p > 0.05$). Correlation between the major soil chemical parameters (%OC, N, P, and K) were positive while that of physical parameters (% sand, % clay and % silt) were negative. The study recommends effective collaboration among key stakeholders in GM sector such as Environmental Protection Agency (EPA), Minerals Commission, Forestry Services Commission, Ministry of Food and Agriculture (MOFA) and District Assemblies in order to regulate the activity for controlled GM and improved availability of productive agricultural lands in the area; residents of communities should be made to benefit directly from gravel pits opened in their areas as this could enhance their commitments towards reclamation of abandoned gravel pits; tree planting and Agroforestry practices to increase the slow rate of natural succession by ameliorating unfavourable soil condition and providing a build-up of soil organic matter and higher above ground biomass; the reduction of negative activities such as perennial bushfires, over-cultivation of lands, over-grazing to reduce nutrient depletion rates and finally compliance with the statutory laws including L.I. 1652 of EPA Act 490 is required in order to regulate the conduct of gravel mining on sustainable basis to reduce its negative effects on the environment.

ACKNOWLEDGEMENTS

This project would not have been completed without the help, support, and contribution of many people and institutions. I am indebted to everyone and want to extend my special thanks and acknowledgements. First, I would like to thank my supervisor, Dr. Evans Dawoe for his selfless effort and the professional guidance he provided in making this thesis a success. I deeply appreciate his time, patience, and support throughout the preparation of this work.

I would also like to thank the people in the Agroforestry Department, both staff and students who in one way or the other provided me with support, encouragement, and guidance as well as friendship.

My most sincere thanks go to EPA staff both at Head office and the Northern Regional office for moral and financial support they have offered me during the course. I also wish to express similar gratitude to Mr. Abukari Baba, Planning Officer of Savelugu-Nanton District Assembly for providing me with the district information. Mention must also be made of Mr. Wahab of Accra Poly and Ahmed Dangkpema (a teacher) for their assistance and guidance during analysis of the thesis.

My appreciation is also extended to all participants who in one way or the other shared their experiences with me to accomplish this research. To all of them, I say thank you. I really appreciate your time and effort. A word of gratitude goes to Mr. M. Hardi Kofi, M. Awal Musah, and A. Muktadir Musah who assisted me in the data gathering process.

In addition, I would want to acknowledge the contributions of my family members and friends who contributed in diverse ways towards the successful completion of this course. I cannot forget the contributions of my wife, Abdulai Sa-ada and children (Aqeeda Tungteya, Halid Tiyumba and Nadia Nasara), I thank you and appreciate all that you did especially, for moral support and taking care of home as I spent time at Kumasi to finish the course.

The greatest of all thanks and appreciations finally goes to Allah the almighty, for granting me life, good health and knowledge throughout my study.

DEDICATION

I dedicate this thesis to my parents Imam Musah Adam (Soglimam), Imoro Azara Amiliya and my Guardians Mr. Ibrahim Adam and Mr. Muhammed Hardi (Assemblyman) and to everyone who contributed directly or indirectly in successful writing of this thesis. May Allah the almighty richly bless you all.

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LISTS I OF ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of Variance
ANSAB	Asia Network for Sustainable Agriculture and Bio-resources
AGTB	Above-Ground Tree Biomass
AK	Available Potassium
AP	Available phosphorus
BD	Bulk Density
CEC	Cation Exchange Capacity
CO_2	Carbon dioxide
CSIR	Council for Scientific and Industrial Research
DBH	Diameter at Breast Height
DMTDP	District Medium Term Development Plan
EAPs	Environmental Action Plans
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency
FAO	Food and Agriculture Organization
FGD	Focus Group Discussion
GHG	Green House Gas
GM	Gravel Mining
Ha	Hectare
IMF	International Monitory Fund
IPCC	Inter-Governmental Panel on Climate Change
K	Available potassium
Kg	Kilograms

KNUST	Kwame Nkrumah University of Science and Technology
MOFA	Ministry of Food and Agriculture
N	Nitrogen
%N	Percentage Nitrogen
OC	Organic Carbon
%OC	Percentage organic Carbon
OM	Organic Matter
OWRRI	Oregon Water Resources Research Institute
PNDCL	Provisional National Defence Council Law
SARI	Savannah Agricultural Research Institute
SEA	Strategic Environmental Assessment
SOM	Soil Organic Matter
TOC	Total Organic Carbon.
UNCED	United Nations Conference on the Environment and Development
UNCCC	United Nations Conference on Climate Change
USA	United States of America

CHAPTER ONE

1.0 GENERAL INTRODUCTION

1.1 Background to the study

Mining of natural aggregates, including gravel mining, represents the main source of construction aggregates used throughout the world, with examples from Australia (Erskine and Green, 2000), France, (Petit et al., 1996), Italy (Surian and Rinaldi, 2003), the USA (Kondolf, 1994) and Britain (Sear and Archer, 1998). However, mining operations, whether small- or large-scale, are inherently disruptive to the environment (Makweba and Ndonde, 1996).

Mining of aggregates frequently generates land use conflicts in populated areas due to its negative externalities including loss of vegetation, noise, dust, truck traffic, pollution and visually unpleasant landscapes. It also represents a conflict with competing land uses such as farming, especially in areas where high-value farmland is scarce and where post-mining restoration may be infeasible (Willis and Garrod, 1999). According to Ross, (2001) social and environmental activists have pointed out that, there are potential linkages between mineral resources exploitation and conflict and consequential underdevelopment.

In the past when population densities were low in most parts of the country, demand for gravel for construction purposes was not extensive and farmers could afford the luxury of moving to readily available fallow lands even if farmlands were degraded or destroyed through gravel mining. In such cases, household refuse and other unwanted materials were used to restore abandoned pits. However, with increased population growth which results in decreased farm land availability, gravel mining which further reduces farm lands appears to be a grave concern for people in the Savelugu-Nanton District.

According to the District Medium Term Development Plan (DMTDP, 2010), gravel mining is widespread in Savelugu-Nanton District and this to a large extent contributes to land degradation and desertification. The practice often leaves behind bare soils and large expanse of gullies which usually collect water during rainy seasons. Water collected in these gravel pits result not only in health related problems for neighbourhood communities, but also causes negative impacts on the environment (Heath et al., 1993; Veiga and Beinhoff, 1997; Warhurst, 1999).

1.2 Problem statement

A significant number of sub-Saharan countries are bedevilled with problems of environmental degradation, which results in serious food crisis and widespread malnutrition (EPA, 1996). In Ghana, majority of farmers are small scale farmers mainly because, they have smaller farmlands. This may be partly due to increased population growth which results in land fragmentation or increased gravel mining activities taking farmers' productive lands, all leading to food crisis and insecurity.

It is reported that Savelugu-Nanton District is the fastest growing district after the Tamale metropolis in the Northern Region (DMTDP, 2010). This has led to an increase in demand for gravel for housing and other infrastructural needs in the district. Because of desperation for the gravel, contractors usually would use all means to acquire land including prime agricultural lands to the detriment of farmers who constitute about 90% of the population in the district. These lands are mostly occupied by highly productive drought resistant trees of economic value which serve as important means of livelihood especially for women. Notable among these trees are Pakia biglobosa (Dawadawa), Adansonia digitata (baobab) and Viterallaria paradoxum (sheanut tree). Unfortunately, contractors involved in the gravel mining activities engage in destruction of the economic trees which apart from denying farmers of their productive land can also affect the natural balance of the environment (Makweba and Ndonde, 1996). It can also serve as a potential threat of conflicts between farmers and gravel miners in the area (Heath et al., 1993).

Furthermore, gravel mining has considerable effect on the air and water, loss of biodiversity, soil pollution and land degradation (Pandey and Kumar, 1996). It also results in reduction of essential nutrients and organic matter of the soil, reduces biological activity and decreases productivity of the soil.

Though gravel mining has become an important economic and developmental activity in the Savelugu-Nanton District, its effects on the average household farmland cannot be under-estimated. Farmers who may have lost their farmlands to gravel mining would want to come back to the abandoned gravel mines if they could still support any reasonable agricultural production. There is therefore little or no known study of the fertility or nutrient status of the abandoned gravel mines. There is also scarce or no known study of the possible impact of gravel mining on the socio-economic activities of people in the district. This study therefore seeks to investigate the effects of gravel mining on soil physicochemical properties as well as its impact on soil major nutrients availability in different mine sites in terms of duration after pit abandonment in the district.

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1.3 Rationale for the study

Gravel mining has considerable effect on land, air and water. Primarily, it causes loss of biodiversity, soil pollution and land degradation (Pandey and Kumar, 1996). It also results to clearing of vegetation, reduces essential nutrients and organic matter of the soil, reduces biological activity and decreases productivity of the soil (Pandey and Kumar, 1996). Mining activities directly or indirectly affect both the living things and non-livings things through the physical and chemical modification of the soil environment (Ratcliffe, 1974).

In recent times, gravel mining activities have been carried out on good farmlands in the Savelugu-Nanton District especially along the major roads and are usually used for construction works in the district. Though the activity has become an important economic activity in the district, there is little or no known study of its possible impact on the socio-economic and physicochemical properties of soil in the district, and how this would affect farming activities.

Also in the district, it is usually perceived that except some few community leaders such as the chief and some of his elders, majority of other community members are usually not consulted in respect of the lands (usually farmlands) that are released for gravel mining activities. Such perceptions have been lingering over decades now and little or no studies have really been conducted to confirm or disprove these assertion hence the need for this study to assess the peoples' perception on the impacts of gravel mining on communities in the district (DMTDP, 2010). The study also seeks to investigate the effects of gravel mining on soil physicochemical properties as well as its impact on soil major nutrients availability in different mine sites in terms of duration after pit abandonment in the Savelugu-Nanton district.

The outcome of the study will therefore provide useful and sustainable ways of conducting gravel mining such that people lives and environment will not be jeopardized. This is to provide a source of data on social, economic and ecological impact of gravel mining in Savelugu-Nanton district. Appropriate recommendations would also be suggested on reclamation of gravel mining pits based on the results obtained. This will not only ensure sustainable mining of gravel in the district, but as well improve agriculture and reduce poverty in the district. Also, it will help improve EPA's data base as well as assist in its awareness creation programmes not only in the Savelugu-Nanton District but, the Northern Region and the country at large.

1.4 Objectives of the Study

1.4.1 General Objective

The general objective of the study is to assess the socio-economic and ecological impacts of gravel mining in Savelugu-Nanton district of Northern Region of Ghana.

1.4.2 Specific Objective

The specific objectives were to:

- Examine people's perception of impacts of gravel mining on their socio-economic activities;
- Assess the impact of gravel mining (duration after gravel pit abandonment) on above ground vegetation biomass; and
- Assess major soil physicochemical property changes of abandoned gravel mines.

1.5 Hypotheses (Null Hypotheses, H0)

1. There is no significant relationship in the views of respondents from the various communities on the impact of gravel mining on residents;
2. Gravel mining activities have no significant impacts on above ground biomass in the Savelugu-Nanton District and
3. Gravel mining activities have no significant impacts on soil physicochemical properties in the Savelugu-Nanton.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

This chapter reviews literature relevant to the study. It focuses on general mining as a land use with particular reference to gravel mining, policy issues related to gravel mining in Ghana, impacts of gravel mining and land use conflicts, impacts of gravel mining on the physical and chemical properties of soils, effects of trees on soil chemical properties, effects of vegetation removal on soil physical and chemical properties, gravel mining on above ground biomass and Potentials for rehabilitating abandoned mined sites among others.

2.2 Mining as a land use

2.2.1 What is land use?

Land-use can be referred to as the management of land to meet human needs. This embraces rural land use such as agriculture, forestry, and aquaculture as well as all forms of urban and industrial use. It also involves the application of human controls, in a relatively systematic manner, to the key elements within an ecosystem in order to derive benefit from it (Evans, 2010).

2.2.2 What is mining?

Mining is the extraction of valuable minerals or other geological materials from the earth, from an ore body, vein or (coal) seam (Wikipedia, the free encyclopedia). The term also includes the removal of soil. Materials recovered by mining include base metals, precious metals, iron, uranium, coal, diamonds, limestone, oil shale, rock salt and potash. Mining in a wider sense comprises extraction of any non-renewable resource (e.g., petroleum, natural gas, soil or even water) (Langer, 1988). Mining of stone and metal has been done since pre-historic times. Modern and organized mining processes involve prospecting for ore bodies, analysis of the profit potential of a proposed mine, extraction of the desired materials and finally reclamation of the land to prepare it for other uses once the mine is closed (Langer, 1988).

2.2.3 Types of mining

Mining can be grouped into several types depending on the purpose and extent of mining. This may include stone mining, sand mining, gravel mining, base metal mining and precious metal mining which include gold, iron, uranium, coal, diamonds, limestone, oil shale, rock, salt and potash mining (Langer, 1988). He also classified mining into surface mining (usually associated with gravel, sand and sometimes mineral), deep mining (mostly associated with pure mineral), in-stream mining (mostly for sand, petroleum etc.) and upland mining (mostly gravel, stone etc.) depending on their locations.

2.2.4 Supply of and demand for sand and gravel

Transport and deposition of eroded bedrock and superficial materials create sand and gravel deposits. Gravel is usually considered to be particles ranging from 0.48 cm-7.62 cm in diameter which thus exclude crushed stone. Potential mining sites are typically chosen based on the natural supply of gravel material, intended use of the product; quality of the product needed, land ownership, and land use (Langer 1988).

Demand for gravel relates to the increasing need for construction materials, which accounts for approximately 96% of the total amount of mined gravel. Of the sand and gravel used in construction, approximately 43% is used for residential and non-residential buildings. Almost 91,000 kg of aggregate material (sand, gravel, and crushed stone combined) are needed to construct a 6-room house, and approximately 14 million kg of aggregate are needed to construct a school or hospital. Although these values are rough approximations, they give some indication of the volume of material used in building construction (Langer 1988).

In Ghana, similar situation exist although no quantifiable data is available. In the Savelugu-Nanton District, due to increasing population growth, demand for gravel for housing construction is high and this has resulted in increased cost of gravel per tipper trip (DMTDP, 2010).

2.2.5 Gravel mining

Gravel mining can be referred to as to the removal or obtaining a supply of gravel for industrial uses, such as road construction material, housing material, filling materials and landscaping. Gravel extraction often occurs at multiple times and at multiple sites either along a given stream or from an open land resulting in impacts that are likely to be both chronic and cumulative. When the rate of gravel extraction exceeds the rate of natural deposition over an extended time period, a net "mining" occurs due to the cumulative loss of gravel (Oregon Water Resources Research Institute [OWRRI], 1995). Gravel is an essential component of construction materials in almost all construction projects, including buildings, roads, bridges, and airports.

In the northern regions of Ghana, gravel mining occurs mainly on the lands. These lands are usually either agriculturally cultivated lands or fallow lands. During the gravel mining activities, top soils and other vegetative materials including trees are usually destroyed. According to Nelson and Sommers (1996), gravel extraction can significantly alter the physical, chemical, and biological characteristics of mined sources. Mining of gravel and other aggregates usually on upland often result not only in generating land use conflicts in populated areas due to its negative externalities including noise, dust, truck traffic, pollution and visually unpleasant landscapes, but also represents a conflict with competing land uses such as farming, especially in areas where high-value farmland is scarce and where post-mining restoration may be infeasible (Willis and Garrod, 1999). Social and environmental activists point out that there, are potential linkages between mineral resources exploitation and conflict and consequential underdevelopment Ross (2001).

2.2.6 Legal framework and Guidelines for Gravel Mining Activities in Ghana.

In Ghana in recent decades, land degradation and environmental burden from the extraction of natural resources including gravel mining activity has been significant (IMF, 2004). The nature of mining in general and gravel mining in particular creates a potential negative impact on the environment both during the mining operations and years after the mine is closed. This impact has led to most of the world's nations adopting regulations to moderate the negative effects of mining operations.

Various environmental regulations, laws and guidelines exist in Ghana for the management and control of the environment by mining companies. (Anon, 1994). Unfortunately, none of these specifically relate to gravel mining activities possibly due to the fact that, the negative environmental impact of gravel mining activities is relatively small compared with large scale mining activities like gold and bauxite mining and therefore not easily discernible (Mireku-Gyimah and Tsidzi, 1996).

Under the mineral and mining law of 1996 (PNDCL 153), all mining companies are expected to submit for approval an Environmental Action Plan (EAP) to address any negative impact that would arise from the activity. However, as already stated, decision makers and implementers of mining regulations and laws have for long mistakenly exempted gravel mining not by the law but by the operation and in the exercise of their duties. Consequently, little environmental Impact Assessment has been carried out in respect of gravel mining and if there was any, it was a pre-requisite for particular or a specific engineering work. It must therefore be re-emphasized that minerals and mining law (PNDCL 153) 1996 forms the basis for the environmental regulation. The guiding principles used in the preparation of these guidelines were as follows:

- Planning, design and management can minimize environmental impacts.
- Balance is required between environmental protection and the need for mining to contribute to Ghana's socio-economic growth.

- To be able to achieve a good balance, the following need to be considered in the planning and management of the resources; pre-empting of the impacts, containment of the impacts, compensation for and or replacement of resources and progressive reclamation of disturbed land.

2.2.7 Impacts of Mining and Landuse Conflicts

2.2.7.1 Gravel mining and conflicts in mining communities

Castro and Nielsen (2001) explain that, conflicts resulting from natural resource exploitation are typically "severe and debilitating, resulting in violence, resource degradation, and the uprooting of communities", and if not addressed, "can threaten to unravel the entire fabric of society". "each party wants to pursue its own interests to the full, and in doing so ends up contradicting, compromising, or even defeating the interest of the other" (Ochieng-Odhiambo,2000).

Gravel mining activities can be extremely environmentally destructive as top soils and important economic trees are destroyed. Over the course of many years, gravel mining can cause irreversible damage to surrounding landscapes since most of the scattered gravel mined sites are not closed and therefore left at the mercy of nature. For example, trees on large tracts of land are often removed to gain access to underlying gravel, and a vast quantity of often- productive topsoil, through continuous exposure to weathering agents, erode sand collects in nearby water bodies. However, in the Savelugu-Nanton District, it is usually perceived that except some few community leaders such as the chief and some of his elders, majority of other community members are usually not consulted in respect of the lands (usually farmlands) that are released for gravel mining activities. Such perceptions have been lingering over decades now and little or no studies have really been conducted to confirm or disprove these assertion hence the need for this study to assess the peoples' perception on the impacts of gravel mining on communities in the Savelugu-Nanton district (DMTDP, 2010).

2.2.7.2 Impact of Mining on Communities

Mining generally has both positive and negative impacts on local communities. Companies engaged in gravel mining may contribute to the development of key socioeconomic infrastructure such as roads, hospitals, schools and housing. While revenues accruing from mining activities contribute positively to the economy of the community, gravel mining activities serve as a major source of employment for local people, and trigger the establishment of a wide range of small businesses such as catering, transport and cleaning services. In Canada, for example, mining activities provide highly paid jobs to more than 340,000 Canadians in 150 communities (Hilson, 2000), while in Zambia, mining activities employs about 15% of the country's work force (MBendi, 1999).

According to Weigand (1991), removal of large woody debris from the source during gravel extraction activities negatively affects the plant community. Large woody debris is important in protecting and enhancing recovering vegetation in streamside areas (Franklin et al., 1995: OWRRI, 1995). Some other adverse impacts of gravel mining may include, inter alia, the following:

- Loss of ability to hunt, and gather,
- Loss of freedom of movement,
- Relocation of settlements,
- Fundamental disrespect for traditions.
- Land use disputes between community members and mining companies, individuals and other industries.

2.2.7.3 Mines and land use conflicts

Most gravel mines are situated within rural areas - mainly in locations of previously un-cleared forest, or where people make use of land for agricultural and subsistence purposes. Though the industry typically supports the view that with good technology and management, there should be no reason for preventing the opening of any mine, it is important to clarify that even in the most advanced of economies, soil or land will always remain the medium that satisfies primary human need for food and shelter (Verheye, 1997). Conflicts inevitably result between communities and mines simply because both place different socio-economic values on land (Verheye, 1997).

The most significant issue often overlooked by mine management is the cultural impacts mine operations have on the indigenous people. As Epps and Brett (2000) explain, indigenous people are commonly amongst the poorest segments of the population, and often engage in local economic activities such as small-scale agriculture, forestry and fisheries. Because these groups typically reside in small and simple communities, they are particularly vulnerable to the negative impacts of development, making it critical that important cultural resources are best managed. In their attempt to minimize conflicts and disaffection in communities where they operate, mining companies in the past have tried to provide both financial compensation and social support in exchange for land. However, because of strong ties to the environment usually dating back thousands of years, monetary compensation rarely makes up for land loss. For groups such as the Iroquois and Huron Indians, which have resided in certain parts of North America for over 20,000 years, and the Aborigines of Australia, who are arguably the first humans to occupy Oceania, it is unrealistic to assume that any sum of money could compensate entirely for the disruptions in lifestyle caused by local mining activity. It is therefore not surprising that, relationships between mine management and groups like these are typically fragile, and because mines are long-term projects, often, when a failed commitment results, conflict ensues (Epps and Brett, 2000).

2.3 Impact of Gravel Mining on Physical and Chemical Properties of Soils

2.3.1 Soil physical properties

Trees and biomass from trees have the ability to maintain or improve soil physical properties. Higher availability of soil water can be maintained under trees because of interception and redistribution of rain water within the system, reduced evaporation and increased infiltration (Breman and Kessler, 1995; Wallace, 1996). Torquebiau and Kwesiga (1996) showed that two-year fallows with *Sesbania sesban* decreased soil bulk density and resistance to penetration and increased water infiltration on alfisols in Eastern Zambia. Kang *et al*, (1997) however reported that, four years of fallow with diverse wood species (*Senna siamea*, *Luecaena leucocephala*, etc.) did not improve bulk density and infiltration rates in degraded alfisols in South Eastern Nigeria. They suggested that a longer fallow is needed to amend soil physical conditions of highly degraded alfisols. When tree cover is removed because of mining activities like gravel mining, these physical properties are adversely affected (Adewole and Adesina, 2011). Mining has considerable adverse effect on the air and water, resulting in loss of biodiversity and soil pollution leading to land degradation (Pandey and Kumar, 1996). Mining also results to clearing of vegetation, reduces essential nutrients and organic matter of the soil, as well as biological activity and productivity of the soil (Pandey and Kumar, 1996). Mineral exploration directly or indirectly affects both the living and non-living organisms through the physical and chemical modification of the soil environment (Ratcliffe, 1974). Crops such as maize, sorghum, cowpea, cassava and yam are major crops cultivated by farmers in the surrounding villages on the soils that have been inadvertently altered as a result of gravel mining. Nitrogen is one of the major soil nutrients for good growth and yield of crops. All these, therefore may cause low productivity of crops in the areas affected by gravel mining (Pandey and Kumar, 1996).

2.3.1.1 Soil Bulk Density

Bulk density (BD) is defined as the mass per unit volume of dry soils. This volume includes both solids and pores. There are several practical methods of determining BD. All the methods involve obtaining a known volume of soil, drying it to remove the water and weighing the dry mass. Soils with high proportion of pore space to solids have lower bulk densities than those that are more compact and have fewer pores. Any factors that influence soil pore space will affect BD.

Gravel mining increases the soil bulk density of abandoned sites since it involves stripping of topsoil (Soil Organic Matter) from the land. The activity exposes the soil air pores thereby subjecting it to increased peculation through the soil pores and low nutrient retention capacity of the major soil elements such as nitrogen phosphorus and potassium among others. Fined textured surface soils such as silt, loams, clays and clay loams generally have lower bulk densities than sandy loams. The organic matter content in sandy soils are low, the solid particles less likely to be aggregated together. The BDs are therefore commonly higher than the fine textured soils (Campbell et al., 1977).

The BD of clay, clay loam and silt loam surface soils normally range from 1.00mg\cm^3 to as high a 1.55mg\cm^3 depending on their conditions, the system of land management employed on a given soil also influence its BD. Increased BD is indicative of reduced infiltration of rain water and restricted root growth. Excessive use of farm machinery and over-grazing of land usually leads to reduced infiltration and hence increased BDs in soils (Campbell et al., 1977).

2.3.1.2 The Soil Texture

Soil texture is defined as the relative proportion of different soil separates in a soil. The texture of soil determines the nutrient-supplying ability of a soil, as well as the ability of the soil to hold and conduct air necessary for plant growth. He also described that, the texture of a soil is not easily modified for instance on large agricultural, forestry and wild-land areas. Therefore, soil texture is not changed by cultural management although processes such as weathering, erosion, illuviation and deposition over very long period of time can alter the texture of various soil horizons (Brady, 1990).

There are three (3) broad classes of soil texture and these are sandy, loamy (silt) and clayey soils each with sub divisions. Sandy soils comprise of at least 70% sand and 15%clay of the material by weight (Brady, 1990). Loamy soils are defined as soils with a mixture of sand, silt and clay particles that exhibit the properties of these separates in about equal proportion. Their specific textural classes are moderately course sandy loam and fine sandy loam; medium, very fine sandy loam, loam, silt loam and silt and moderately fine; sandy clay loam, silt clay loam and clay loam. Clay soils are dominated by clay separates and are fine textured. Specific classes are sandy clayey, silty-clay and clay (Lal, 1987).

There are two general methods of determining soil textural class. These are the feel method, which is common field method of determining the textural class of soil by its feel. The second method is the laboratory particle size analysis or mechanical analysis. It is therefore expected that continued gravel mining at a particular location over a longer period may alter the soil structure of the concerned (Lal, 1987).

2.3.2 Effects of Trees on Soil Chemical properties

Trees play significant roles in maintaining soil chemical properties. Arthur (1999) found that, *Leucaena leucocephala* planted in fallows is as effective as a natural bush fallow in maintaining soil pH, exchangeable Ca, and Mg, and Effective Cation Exchange Capacity

(ECEC) on an Oxic Kandiustalf in Nigeria. He observed that Exchangeable Ca, Mg, and Na increased in Haplic Acrisol. There were also increases in the soil contents of exchangeable Mg, K, Na in the Dystic Regosol after seven years of establishing a *Leucaena-Casia* plantation on Haplic Acrisol and Dystic Regosol in Ghana. Also For both depths, 0-15cm and 15 - 30cm of the two soil series, there were increases in base saturation.

Results from Nveawiah-Yoho (2000) in a seven-year of *Leucaena-Cassia* plantation on Acrisol in Ghana showed that; soil pH and organic carbon at two depths of 0-15cm and 15-30cm were higher. Base saturation also increased in the soil series.

2.3.3 Nitrogen fixation

According Young (1997), leguminous trees fix nitrogen into the soil and a well-nodulated legume can add 50-200kg/ha/yr to the soil (Donahue et al., 1983). As a result of gravel mining activities, most of the leguminous trees in some parts of Guinea Savannah of South-western Nigeria are destroyed together with the top soil; as such nitrogen together with other essential nutrients in the soil are destroyed alongside hence low nitrogen in the soil (Adewole and Adesina, 2011).

2.3.4 Effects of vegetation removal on soil physical and chemical properties

Removal of vegetation from a forest ecosystem might result in 1) soil compaction from movement of logs and heavy machines over the sites, 2) decreased aeration due to compaction (Kimmins, 1987) and 3) loss of nutrients through leaching (McColl and

Powers, 1984). The effects of nutrient removal on ecosystem will depend on the type and frequency of vegetation removal, intensity of vegetation removal and type of species removed (McColl and Powers, 1984 and Nwoboshi 1984). They also estimated that, nitrogen losses through removal of stem wood and bark were 50kg\ha and phosphorus losses were 10-30 kg\ha. These he anticipates could be multiplied by two to three folds when conventional above ground tree harvesting techniques were replaced by more intensive harvesting system. Similarly, Nwoboshi (1984) estimated that intensive removal of a 15-year-old teak plantation in Nigeria resulted in loss of more than 50-60% of total nutrient taken up from the soil during rotation.

Tropical forest soils are thought to be more vulnerable to nutrient loss through harvesting or vegetation removal as compared with temperate soils, in part because greater proportions of nutrients are immobilized in standing biomass and because storage is low in the forest floor (Chava *et al*., 1989, and Michelsen *et al*., 1993). Tropical sites are poorly buffered against fertility loss due to absence of forest floor and its associated nutrient pool (McColl and Powers 1984). Therefore proportionally more nutrients may be removed from a site through harvesting in the tropics than in the temperate zone (Chava *et al* 1989, and Michelsen *et al*,. 1993).

2.3.5 Environmental Degradation

Smallholder farming systems exert a very high pressure on the environment under the existing high population density. The situation is aggravated when gravel mining activities increase due to increase in demand for gravel for housing and road construction activities. This often puts severe burden on the natural resources and has often resulted in serious environmental degradation (EPA, 1996). The destruction of the vegetation through felling of trees and removal of top soil is the starting point of degradation.

It is generally held by people in most districts of Northern Region that productive agricultural lands are lost to gravel mining due to increase in demand for housing and roads resulting from rapid growing population. This results in shortage of land and as such, there is pressure on few lands for cultivation, thereby exacerbating the problems of soil degradation.

Estimates indicate that about 25% of cropland in the USA will lose 2.5cm³ of soil every 30 years as a result of soil degradation (Napier and Forster, 1982). According to Pimentel *et al.*, (1976), when there is loss of top soil as a result of soil degradation, it takes more than 30 years for restoration to take place. This is due to the fact that restoring the topsoil is very difficult; trying to reclaim the land once the topsoil has been lost. Few or no quantitative estimates are available of the rates of soil loss in low-income countries like Ghana. Nevertheless, these rates are likely to be much greater in such countries than in the USA (Anderson and Thampapillai, 1990). This is because in many low income countries like Ghana, the existing policies do not appears to encourage soil conservation.

It has been estimated that nitrogen and phosphorus losses from erosion on arable land were equivalent to three times the level of total fertilizer application in Zimbabwe in 1984/85. When this was expressed in financial terms, the estimated cost from erosion, depending on its levels, varied from US$20-50/ha on arable lands and US$10-80/ha on grazing lands (Stocking, 1986). Thus, erosion appears to have a high hidden cost for the Zimbabwean economy and it is undermining its resource base for the future. Even though there is no quantitative data available as of now; gravel mining would have a more severe negative implication on soil fertility than erosion. In addition, environmentally sound traditional agricultural practices attuned to low population densities have not been able to adjust rapidly enough to the decreasing land per person ratios, resulting in practices that are environmentally damaging (FAO, 1986). For any abandoned and un-reclaimed mining sites, and other degraded lands, there are usually many technologies that can be introduced to restore or rehabilitate the lost resources including the trees and soil fertility. To prevent unsustainable extraction of gravel and hence minimize gravel mining and loss of vegetation and soil fertility, Francis and Hilderbrand, (1989) suggested that technologies must be compatible with the environment and such environmentally sound technologies according to them, are found in agroforestry systems.

2.4 Tree biomass and above-ground vegetation biomass assessment

Forest ecosystem plays very important role in the global carbon cycle. It stores about 80% of all above-ground and 40% of all below-ground terrestrial organic carbon (IPCC, 2001). During productive seasons, carbon dioxide (CO_2) from the atmosphere is taken up by vegetation and stored as plant biomass (Losi *et al*., 2003; Phat *et al*., 2004). For this reason, the UNCCC and its Kyoto Protocol recognized the role of forests in carbon sequestration (IPCC, 2001). When the vegetation decomposes, they release carbon back to the atmosphere. Disturbances in the forest due to natural and human influences lead to more carbon being released into the atmosphere than the amount used by vegetation during photosynthesis (Brown, 1994). Sustainable management strategies are, therefore, necessary to make the forest a carbon sink rather than source.

According to FAO (2004), biomass is defined as "organic material both above and below-ground, and both living and dead, e.g., trees, crops, grasses, tree litter, roots etc." Above-ground biomass consists of all living biomass above the soil including stem, stump, branches, bark, seeds, and foliage. Below-ground biomass consists of all living roots excluding fine roots (less than 2mm in diameter). In forest biomass studies, two biomass units are used, fresh weight (Araujo, *et al*., 1999) and dry weight (Aboal *et al*., 2005; Montagu et al, 2005). In respect of carbon sequestration determination, the dry weight is more relevant because 50% of it is carbon (Losi *et al*., 2003; Montagu et al., 2005). Many biomass assessment studies conducted are focused on above-ground forest biomass (Aboal *et al*., 2005; Laclau, 2003; Losi *et al*., 2003) because it accounts for the majority of the total accumulated biomass in the forest ecosystem. This study also focuses on the assessment of above-ground dry biomass.

Biomass assessment is important for many purposes (Zhang *et al*., 2006). It is aimed at two major objectives: (1) for resource use and (2) for environmental management.

According to Kauffman et al (1995), biomass stock is vulnerable to losses when natural land use systems are converted to agricultural and pasture lands. In environmental management, biomass quantification is important to assess the productivity and sustainability of the terrestrial ecosystem. Biomass is also an important indicator in carbon sequestration. Consequently, the amount of carbon sequestered can be inferred from the biomass change since 50% of the forest dry biomass is carbon (Losi *et al*., 2003). The Kyoto protocol requires transparent reporting of forest removal and accumulation (biomass change). This implies the use of precise procedures to quantify forest biomass and its uncertainty.

Lu (2006) mentioned three approaches to biomass assessment. These are field measurements, remote sensing, and GIS-based approach. The field measurement which this study is employing is considered to be the most accurate (Lu, 2006) although it is proved to be very costly and time consuming. In the case of remote sensing, ground data is needed to develop the biomass predictive model. This means, it is always necessary to do small scale field measurement of biomass for predictive modelling or validation purposes. Typically, the procedure is to randomly select sample trees, measure tree variables (such as DBH or tree height) and measure sample tree biomass, then develop biomass equation using these measurements. The developed biomass equation is used to estimate the tree-based biomass. Two methods are available in measuring sample tree biomass: (1) destructive and (2) non-destructive. The destructive method is done by felling the sample tree and then weighing it. Direct weighing can only be done for small trees, but for larger trees, partitioning is necessary so that the partitions can fit into the weighing scale. In other cases, volume of the stem is measured. Sub-samples are collected, and its fresh weight, dry weight, and volume are measured. The dry weight of the tree (biomass) is calculated based from the ratio of fresh weight (or volume) to the dry weight. This procedure requires considerable amount of labour and cost, and the use of ratio is biased (Cochran, 1963).The non-destructive method does not require the trees to be felled. Measurements can be done by climbing the tree and measuring its various parts and computing the total volume. Tree density which can be found from literature is used to convert the measured volume into biomass estimate (Aboal *et al*., 2005). This approach takes even more time and cost to perform.

Another approach is by taking two photographs of the tree at orthogonal angles. Then the scale of the photograph is calculated so that the volume of each tree components (stem, branch, foliage) can be calculated. Density of the different tree components is calculated and used to convert the volumes into biomass (Montes *et al,* 2000). However, the calculated biomass from these procedures cannot be validated unless the sample tree is felled and weighed. Once sample tree variables and biomass data are obtained, and the biomass equation is developed by regression analysis, it is then applied to each tree in the sample plots to obtain the plot biomass. Landscape biomass is estimated depending whether sampling technique or remote sensing method is used.

2.4.1 Tree Biomass Determination in the Tropics using Field Measurement

Traditionally, tree biomass is estimated by destructively harvesting and weighing all portions of the tree (Newbould, 1967; Anderson and Ingram 1989). This approach is very laborious, time consuming and economically prohibitive. However, allometric equations based on diameter at breast height (DBH), total tree height (H) and wood specific density (ρ) has been developed by Chave *et al* (2005) on the basis of climate and forest stand types. Chave *et al* (2005) recommends the use of allometric formula below to estimate above ground biomass (AGTB) for dry forest stand;

$$AGTB = 0.112 \times (\rho D^2 H)^{0.916}$$

where: AGTB = above ground tree biomass in (kg); ρ = wood specific gravity (g /cm^3); D = tree diameter at breast height (cm); and H = tree height (m).The sum of the individual weights (kg) of a sampling plot is usually calculated and the value divided by the area of a sampling plot (m^2) to attain the biomass stock density in kg/m^2 and converted to t $ha^{-1}$by multiplying the value by 10.

Baker *et al*., (2004) have shown that ignoring variations in wood density results in poor overall prediction of the stand Above Ground Biomass (AGB). Wood-specific gravity is therefore an important variable in the regression model. The use of tree height as a predictive variable also improves the quality of the allometric equation which enables AGTB to be easily estimated, provided that diameter, total height, and wood specific gravity of a tree are available, irrespective of the tree species and of the location of the stand.

2.4.2 Effects of Gravel mining on above -ground Biomass (AGB).

Carbon dioxide (CO_2) is most abundant greenhouse gas and a primary agent of global warming. It constitutes 72% of the total anthropogenic greenhouse gases, causing between 9-26% of the greenhouse effect (IPCC, 2007). It also reported that, the amount of carbon dioxide in the atmosphere has increased from 280 ppm in the pre-industrial era (1750) to 379 ppm in 2005, and is increasing by 1.5 ppm per year. The dramatic rise of CO_2 concentration is attributed largely to human activities. Over the last 20 years, majority of the emission has been attributed to burning of fossil fuel, while 10-30% is attributed to land use change including gravel mining and deforestation (IPCC, 2001). Increase in CO_2 concentration, along with other greenhouse gases (GHG), raised concerns over global warming and climate changes. IPCC (2001) report concluded that climate has changed over the past century.

According to the Savelugu-Nanton District Medium Term Development Plan, MTDP (2010), gravel mining activities cause significant depletion of vegetation and deforestation of economic trees in the district. Aldhous (1993) reports that, tropical deforestation proceeds at a rate of 154000km^2 /yr with approximately 0.32 Gt C/ yr being lost to the atmosphere from lands in Africa. Much of this loss results from slash-and-burn agriculture and gravel mining. Land use changes, especially gravel mining may rapidly diminish soil quality, as ecologically sensitive components of the tropical forest ecosystem are removed leading to reduced litter inputs for instance. As a result, there may be severe deterioration in soil quality which could lead to a permanent degradation of land productivity (Nardi *et al*., 1996; Islam et al., 1999). Assessment of soil properties upon conversion of natural forests for varying purposes is of utmost importance to detect early changes in soil quality.

2.5 Potential of trees for rehabilitating mined sites

The rehabilitation of a drastically disturbed terrestrial system, such as lands mined for coal and minerals, requires site-specific knowledge to ensure the reclamation strategies chosen will be sustainable (Bradshow and Chadwick, 1980). In Central Europe, a large proportion of post-mining landscapes are reclaimed to forest. From an ecological point of view, reclamation is a process of restoring the whole ecosystem (Bradshow and Hüttle, 2001). According to Rodrigue *et al* (2002), a complete assessment of the reclamation processes should take into consideration many ecological factors. Therefore it is important to determine the soil development rate including the depth of organic horizons, nutrient accumulation rates, and balance of elements.

2.5.1 Forestation and tree planting

Natural regeneration of secondary forests on degraded tropical lands is often a slow and uncertain process, impeded by a combination of factors including human and livestock pressure, recurrent fires and unfavourable microclimatic conditions, soil infertility, and exhaustion of soil seed bank among others (Golley, 1993). On mined sites, these obstacles to natural regeneration are generally more acute than other degraded landscapes due to the removal of topsoil (resulting in the elimination of soil seed bank and rootstock) and soil profile disturbance (including compaction). Recent research in a number of tropical countries has shown that tree planting on such degraded sites can dramatically increase the otherwise slow rate of natural forest succession by ameliorating unfavourable soil condition and providing a habitat for seed dispersing wildlife that can lead to a progressive enrichment of floristic diversity (Mathur and Soni, 1983; Brown and Lugo, 1994; Fimbel and Fimbel, 1996).

2.5.2 Agroforestry, a tool for reclaiming abandoned gravel pits.

Agroforestry in general is a collective name for land use systems and technologies where woody perennials (trees, shrubs, palms, bamboos etc.) are deliberately used on the same land management units as agricultural crops and/ or animals, in some form of spatial arrangement or temporal sequence. In agroforestry systems, there are both ecological and economical interactions between the different components (Lundgren and Raintree, 1982).Reclamation agroforestry as a type of agroforestry can be used to restore gravel pits after abandonment since the technology involves planting of trees (including at least some nitrogen fixing species) on degraded land with the objective of checking erosion and restoring soil organic matter and fertility status. Substantial time is however needed to build-up the enlarged plant-litter-soil nutrient cycle (Kellman, 1979 cited in Kessler and Wiersum, 1995), a period during which exploitation of the vegetation should be very low with necessary protection from mining activities.

In moist savannahs of Benin, studies by Aihou *et al.*, (1999) revealed that alley cropping systems with *Leucaena leucocephala* and *Gliricidia sepium* (both N_2-fixing) and Senna siamea (non N_2-fixing) restored crop productivity on a degraded site characterized by Rhodic Ferralisols and Rhodic soils. From the farmer's perspective, agroforestry can be a way to reduce further deforestation or land clearing and increase crop yields and the diversity of products grown. Agroforestry, being one of several approaches for improving land use, is also frequently cited as an answer to shortages of fuel wood, cash income, animal fodder and building materials in sub-Saharan Africa (Rocheleau *et al*., 1988). Thus, agroforestry appears to have an enormous potential for alleviating many of the several agricultural problems that beset much of Africa including soil degradation, decreasing crop yields resulting from increasing scarcity of farmlands, soil erosion resulting from extensive cutting of trees and growing shortage of wood for fuel and timber and shortage of fodder. Agroforestry helps maintain or improve soil fertility in several ways. Deep-rooted trees act as nutrient “pumps” moving nutrient from deeper soil layers to the surface through litter fall. In some systems where trees are harvested and removed from the site, the nutrients stored in the tree are essentially lost and ways of their replacement must be made known to the farmer (Young, 1989).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Location of the Study Area

The study was conducted in the Savelugu-Nanton District in the Northern Region of Ghana (Figure 3.1). The district is one of the twenty three (23) administrative districts of the Northern Region. It was established by PNDC Law 207 under the Legislative Instrument of 1988 and carved out of the then Western Dagomba District Council, which included Tolon-Kumbungu and Tamale Metropolitan Assembly. It has total population of ninety one thousand, four hundred and fifteen (91, 415) people based on the 2000 population and housing census (DMTDP, 2010). With a growth rate of 3%, the projected population stands at one- hundred and nineteen thousand seven hundred and forty-seven (119,747) people as at 2009 with nearly 80% living in the rural areas while 20% are in the urban areas (DMTDP, 2010).

The predominant ethnic group is the Dagomba people who constitute more than 90% of the entire population. According to the 2000 population and housing census report, the male population is 49.7% and that of the female population stands at 50.3%. Thus, the district is a female dominant population. There are 149 communities in the District and the communities are administratively demarcated into one urban/town council (Savelugu, the district capital) and five Area councils, namely, Nanton, Diare, Pong-Tamale, Moglaa and Tampion.The 143 other communities could basically be described as rural.

3.2 Household Characteristics

Households are predominantly male-headed. The proportion of female-headed households was 3.1 % as at year 2000. In 2004, it rose to about 3.6 percent and subsequently to about 5.5 percent in 2005. The average household size is 8.7 with the smallest household comprising one member and the largest household having 47 members (DMTDP, 2010).

3.3 Environmental Situation

The district is located in an area of the country with un-favourable natural environmental conditions. There is little tree-cover and it suffers harsh dry harmattan winds, which leads to many bush-fires set up by farmers clearing their lands and hunters searching for game(DMTDP, 2010). The greatest threat however is the rate at which the tree vegetation is being destroyed by bushfires, charcoal burning and gravel miningactivities. Farming along river courses has also caused vast silting of the few drainage systems which therefore dry up quickly in the dry season and flood easily in the wet season (DMTDP, 2010).

3.4 Economic Activities

The economy of the Savelugu-Nanton District is based on agriculture. The sector engages about 97 % of the labour force, majority of who produce staple crops at subsistence level. Cash crop production is minimal and includes sheanut, soya beans, cotton and cashew. Agro-processing is generally done by traditional methods and on very small-scale basis (DMTDP 2010). There are, however, efforts by external support agencies to upgrade technologies, especially for women in the processing of sheanut, groundnuts, rice, cotton ginnery, and soap-making. Migrant fishermen also carry out some small-scale fishing on the White Volta at Nabogu and Kukuobilla dams.

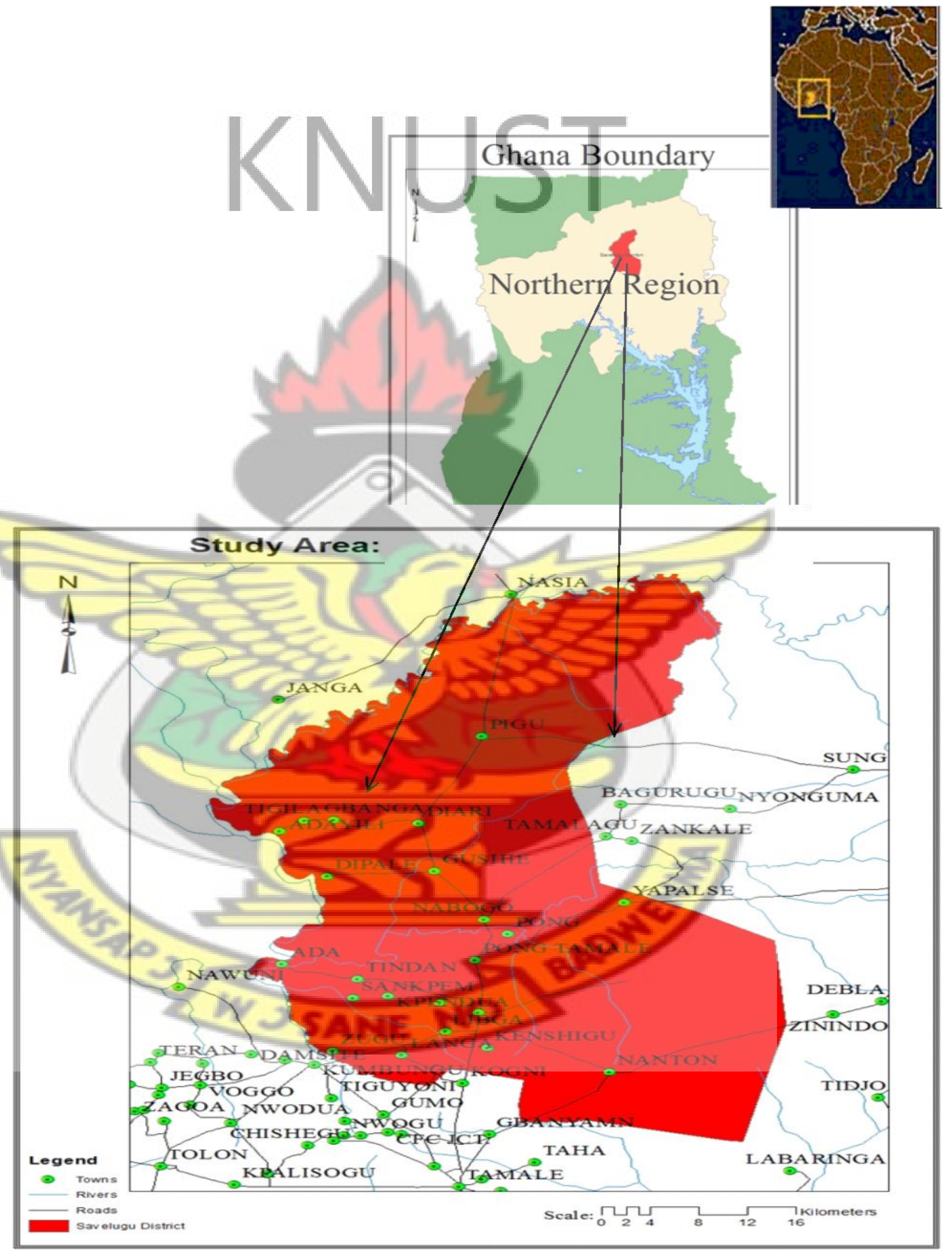

Figure 3.1: A map showing communities in the Savelugu-Nanton District within the national and regional contexts

3.5 Climate and Vegetation

The Savelugu-Nanton District falls within the Guinea Savannah zone. Annual rainfall ranges from 600-1000mm with unimodal distribution. Monthly temperature averages 34˚C and ranges between 16˚C and 42˚C annually. The lower temperatures are experienced from December to late February, during which the North-East Trade winds (Harmattan) greatly influence the district. The generally high temperatures as well as the low humidity brought about by the dry harmattan winds favour high rates of evapo - transpiration, leading to water deficiencies in the dry season (DMTDP, 2010).

3.6 Geology and Soil

The Middle and Upper Voltaian sedimentary formation characterize the geology of the district. The middle Voltaian covers the northern part of the district and comprises of sandstone, shale and siltstone. The Upper Voltaian covers the southern part of the district and consists of shale and mudstone. Underground water potential is generally determined by this underlying rock formation, which has varying water potential for underground water compared to the upper Voltaian formation. Consequently, borehole drilling is expected to have a higher success rate in the northern rather than the southern section (DMTDP, 2010).

3.7 Relief and Drainage

The Savelugu-Nanton District is generally flat with gentle undulating low relief. The altitude ranges between 122 to 244 metres above sea level with the southern part being slightly hilly and sloping gently towards the North. The main drainage system in the

District is made up of White Volta and its tributaries. The effect of the drainage system is felt mostly in the northern part of the district covering the areas between Nabogu and Kukuobilla. These areas are prone to periodic flooding during the wet season, thus making them suitable for rice cultivation. One of the tributaries of the White Volta, Kuldalnali stretches to constitute a natural boundary between the District and Tolon - Kumbungu district (DMTDP, 2010).

3.8 Agriculture

3.8.1 Primary Production

According to the District Medium Term Development Plan (DMTDP, 2010), Savelugu-Nanton District Assembly (SNDA) is predominantly agricultural with about 97% of the district's economically active population (18-54 years) involved in farming. The major food crops include maize, rice, yam, groundnut, cowpea & soya beans. The district has the potential to increase food crops output if modernized agriculture is effectively practiced. However, the sector encounters problems such as low soil fertility and small farm size per head which usually are as a result of factors such as gravel mining, high cost of farm inputs, post-harvest losses and reliance on rain fed agriculture. Agriculture is mainly dependent on rainfall which is erratic. Thus there is great seasonal unemployment.

Most trees found in the area are drought resistant and hardly shed their leaves completely during the long dry season. Most of the trees are of economic value and contribute to sustaining the livelihoods of the people especially women. Notable among these are shea trees, (the nuts which are used for making shea-butter) and "dawadawa" that provides seeds used for condimental purpose. The sparsely populated north of the district has denser vegetation mostly with secondary forest while the more populous south on the other hand, is depleted due to human activities such as farming, bush burning, sand and gravel mining and tree felling among others (DMTDP, 2010).

3.8.2 Livestock and Poultry

Livestock rearing is not a popular agricultural activity in the district. Despite the presence of the Pong-Tamale Veterinary College, farmers' involvement in activities to provide proper animal health care services have been lukewarm. Animal rearing perhaps is considered a hobby rather than a business. This attitude and the lack of needed infrastructure render the livestock and poultry sector a poor source of income for the people. However, almost all households keep a few animals/birds such as goats, sheep and fowls purely for domestic consumption (DMTDP, 2010).

3.9 Data Collection (Socio-economic)

3.9.1 Reconnaissance Survey and Selection of Research Communities

The sample frame of this study consists of communities close to major abandoned gravel mining sites in the Savelugu-Nanton district. In view of the vast nature of the area, a three-day reconnaissance survey was carried out in the area. In all, forty six (46) communities were visited based on the presence of abandoned gravel mines close to them. Most of these abandoned mines were small in sizes (50-100 m^2). Out of this, nine (9) communities were purposively selected for the study on the basis of their proximity to abandoned mining sites and fall within the range of 400m^2 and above. The reconnaissance survey helped in determining the gravel mining sites in respect of their age groups. Mining sites within the age groups 1-5,6-10, and above 10 years after abandonment were identified and selected as treatment. The sites were located in the following communities: Kanshegu, Savelugu, Bunglung, Pong-Tamale, Pong, Sankpem, Yiworgu, Kpendua and Nanton.

3.9.2 Data Collection techniques/instruments

A blend of quantitative and qualitative data collection techniques namely face-to-face interviews, focus group discussions and direct observations were employed. The instruments used in the process were structured questionnaires and semi-structured questionnaires (Appendix 15).

- Face-to-face interviews

Face-to-face interview involved the administration of questionnaires to obtain information from household heads, farmers and women as respondents in the study communities in the study area. The questionnaire was pre-tested in two communities before actual administration was done in the field.

- Focus Group Discussion

Two Focus Group Discussions (FGDs) were held in Yiworgu and Sankpem communities in the district. The purpose of this was to validate some of the pertinent responses given during the questionnaire administration. Also, it was to gather unbiased and balanced views from all segments of the adult population with regards to current realities in the localities. It also provided the opportunity to directly observe the group process and actions.

- Direct Observation

Direct observation was used throughout the questionnaire administration. The researcher observed the situation on the ground as he went about the collection of the data.

3.9.3 Determination of Sample Size

The sample size for the study was determined using the formula $n = N/1+N(\alpha)^2$ (Israel 1992), where n = the required sample size, N = sample frame or the population size and α= confidence level or the deserved level of precision. With the sample frame of 927 (total population of communities close to abandoned gravel mines), and 90 percent confidence level (0.10). The sample size was estimated as ninety (90) using the formula: $n = 927/1+927(0.10)^2$

3.9.4 Selection of respondents

Respondents were selected purposively based on the respondent's status in the household. Household heads were first targeted followed by the house wives in the event that the household head was absent and finally down to the youth (above 18 years of age).Thus one respondent was obtained from each household. These respondents (household heads, house wives and youth) were usually those whose farms were located close to gravel mining sites. A total of ten (10) respondents were obtained from each of the communities. Most of the questions raised were meant to elaborate and/or clarify the interviewee's understanding of a point or to direct the interviewee to a new topic relevant to the aim.

3.9.5 Analysis of Socio-economic Data

Statistical tools used in the analysis were SPSS and Excel. Whiles descriptive analysis was used to describe the socio-demographic characteristics (mainly in the form of bar charts and pie charts for the purpose of visual expression) chi-square analysis was carried out to assess the significance of residents' perception of the impact of GM in the district. The chi-square test was also used to determine homogeneity of respondents from different gravel mining communities (Table 4.1) and to assess the significance of the impacts of GM on peoples' livelihoods.

3.9.6 Data Collection (Ecological Studies, Soil and Vegetation Sampling and analysis)

3.9.6.1 Soil Sampling Procedure

Nine sampling sites were identified based on the availability of mined sites and required duration after abandonment. The sites were grouped into 1-5, 6-10, and above 10 years after sites were abandoned. A fallow / un-mined land was included as a standard reference (control). Each age group together with the reference site was replicated three (3) times giving a total of twelve (12) sites. On each of the sites, an experimental plot measuring 20 m x 20 m was established.

For the purposes of soil sampling, a sub-plot measuring 5 m x 20 m was established on each experimental plot. Soil samples were subsequently collected along an X-shaped transects on each of the sub-plots by auguring at 2 depths: 0-15cm and 15-30cm. For each sub-plot, samples were composited (pooled together and mixed thoroughly) and one sub-sample taken per plot for nutrient analyses in duplicates. All analyses were carried out at the laboratory of the Savannah Agricultural Research Institute (SARI) of CSIR at Nyankpala, Tamale, Northern Region.

3.9.6.2 Chemical Analysis of Soil Samples

Soil pH was determined in water and 0.1 M KCl solution at 1:2.5 soil/solution ratio. Organic carbon content was found by the modified $K_2Cr_2O_7$ digestion of Walkley-Black method (Nelson and Sommers, 1996). The Cation Exchange Capacity (CEC) was determined by adding the 1 M KCl extractable acidity to cations (Ca^2+, Mg^2+, Na+, K+) exchanged by neutral 1 M NH_4C2H3O2 (pH_7) as described in Thomas (1982). The K was measured with flame photometer and the CEC was obtained by summation of exchangeable cations and exchange acidity. The nitrogen (N) content was found by digestion method involving complete oxidation of organic matter (Nelson and Sommers, 1996).

3.9.7 Vegetation Sampling and Analysis

3.9.7.1 Tree Biomass Determination

On each of the 20m x 20m experimental plots, total number of trees was counted and data obtained on the trunk diameter at breast height DBH (cm), total tree height, H (m) and wood-specific gravity ρ (g/cm^3) was used in the allometric equation developed by Chave *et al*., (2005) to estimate above ground tree biomass (AGTB). This approach is particularly recommended because the tree destruction method is not environmentally friendly and therefore not permissible. Thus AGTB = 0.112 X $(\rho D^2 H)^{0.916}$ (Chave *et al*., 2005),

Where AGTB = Above Ground Tree Biomass (kg); ρ = wood specific gravity (g\cm^3); D= Tree Diameter at Breast Height (cm) and H= Tree Height (m). Total number of trees on each plot was counted and identified and the sum of the individual weights (kg) of a sampling plot was then estimated and the value divided by the area of a sampling plot (thus 20m x 20m= 400m^2) to attain the biomass stock density in kg/m^2 and converted to t ha^{-1} by multiplying the value by 10.

3.9.7.2 Estimation of Low-growing Flora Biomass (BLGF)

Sampling of low-growing flora was done from five 1m x 1m quadrats randomly established on each 20m x 20m plot. All plants (DBH < 2.5cm) including herbaceous species, creepers, climbers and seedlings within each quadrat were cut to base. Harvested fresh samples were weighed to 0.5g precision, sub-sampled and oven-dried at 105^{o}C. The amount of dry biomass per unit area from each sample plot was extrapolated on a per hectare basis for each treatment (age after pit abandonment) using the relation below:

$$BLGF = \frac{Wfield}{A} \times \frac{Wsub - sample,\ dry}{Wsub - sample,\ wet} \times \frac{1}{10000}$$

Where,

BLGF = Biomass of Low Growing Flora (t ha^{-1});

Wfield= Weight of the fresh field sample of low growing flora sampled within an area of size A (g);

A= Size of the Area in which low growing flora were collected;

Wsub-sample, dry = Weight of oven dry sub-sample of low growing flora; and

Wsub-sample, wet = Weight of fresh sub-sample of low growing flora.

3.9.7.3 Estimation of Above-ground Litter Biomass (AGLB)

Sampling of above ground litter was done through the same method as the low-growing flora. Five 1m x 1mquadrats were laid and litter in each quadrat was collected and processed for laboratory analysis as described for the low growing flora above. All litter collected from each quadrat was weighed to 0.5g precision, sub-sampled and oven-dried at 105^{o}C.The amount of dry biomass per unit area from each sample plot was extrapolated on a per hectare basis for each treatment (age after pit abandonment) using the relation below:

$$AGLB = \frac{Wfield}{A} \times \frac{Wsub - sample,\ dry}{Wsub - sample,\ wet} \times \frac{1}{10000}$$

Where,

AGLB = Above Ground Litter Biomass (t ha^{-1});

Wfield = Weight of the fresh field sample of above ground litter sampled within an area of size A (g);

A= Size of the Area in which litter, were collected;

Wsub-sample, dry = Weight of oven dry sub-sample of above-ground litter; and

Wsub-sample, wet = Weight of fresh sub-sample of above-ground litter.

3.9.8 Data Analysis

Statistical tools used in the analysis were SPSS and Excel. Whiles descriptive analysis was used to describe the socio-demographic characteristics (mainly in the form of bar charts and pie charts for the purpose of visual expression) chi-square analysis was carried out to assess the significance of residents' perception of the impact of gravel mining in the district. The chi-square test was also used to determine homogeneity of respondents from different gravel mining communities (Table 4.1) and to assess the significance of the impacts of GM on peoples' livelihoods.

Data on soil physicochemical properties and biomass from the different age groups were tested to ensure that they were normally distributed before being subjected to Analysis of variance (ANOVA). Analysis of variance was used to test for the significant effect (duration after pit abandonment) on above-ground biomass and soil physic-chemical properties. Where differences were significant, their means were contrasted with LSD tests at $p < 0.05$. All analyses were done using Minitab Probability version 16.

CHAPTER FOUR

4.0 RESULTS

4.1 Introduction

This chapter presents the results of socio-economic and ecological impacts of gravel mining in the Savelugu-Nanton District of the Northern Region of Ghana. The chapter is divided into the following sections: the socio-demographic characteristics of respondents, evidence of peoples' engagement in gravel mining, crops/livestock cultivated/reared in the district, gravel mining contribution to the scarcity of agricultural land, diseases perceived to be related to gravel mining, general impacts of gravel mining and the suggestions towards resolving gravel mining problems in the district. The rest include biomass estimation in different gravel mining areas and effects of Gravel Mining (GM) on soil physicochemical properties etc.

4.1.1 Socio-Demographic Characteristics of Respondents

4.1.1.1 Age Distribution of Respondents

Figure 4.1 shows the age distribution of respondents for the study. Out of the total respondents 7.8 % were aged between 20-30 years, 55.6 % between 31-40 years and 24.4 % between 41-50 years. Whereas the 51-60 age groups were 7.8 % of the respondents, 60 years and above age group constituted 4.4 %. However, there were statistical similarities ($p > 0.05$) in relation to ages of respondents in the research communities (Table 4.1).

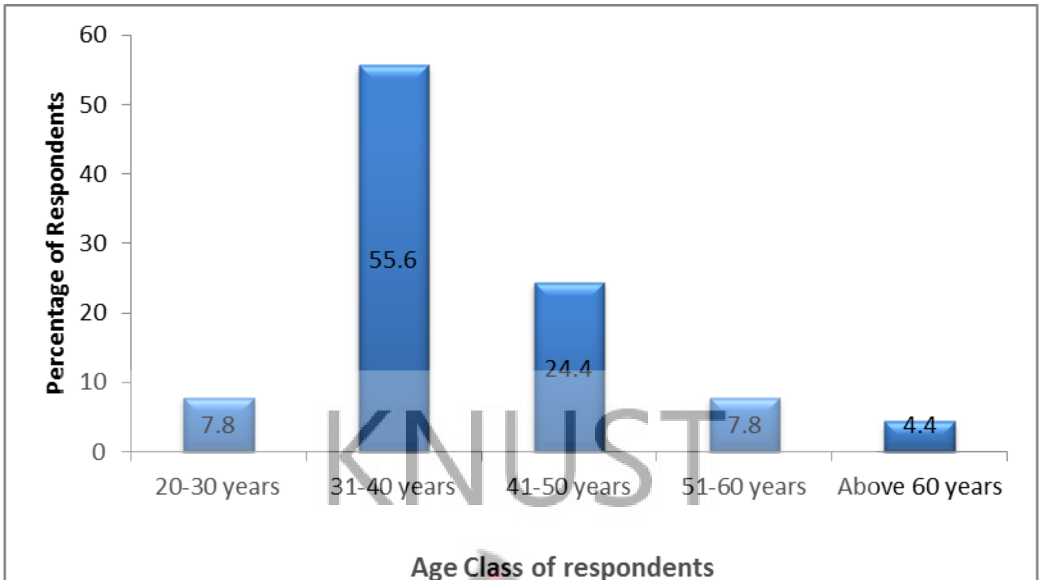

Figure 4.1: Age Distribution of Respondents

4.1.1.2 Sex Distributions of Respondents

Figure 4.2 shows the sex distribution of respondents. Majority of the respondents (83.3 %) were males with the remaining 16.7 % being females. Statistical similarities were observed ($p > 0.05$) in relation to sex distribution of respondents in the research communities (Table 4.1).

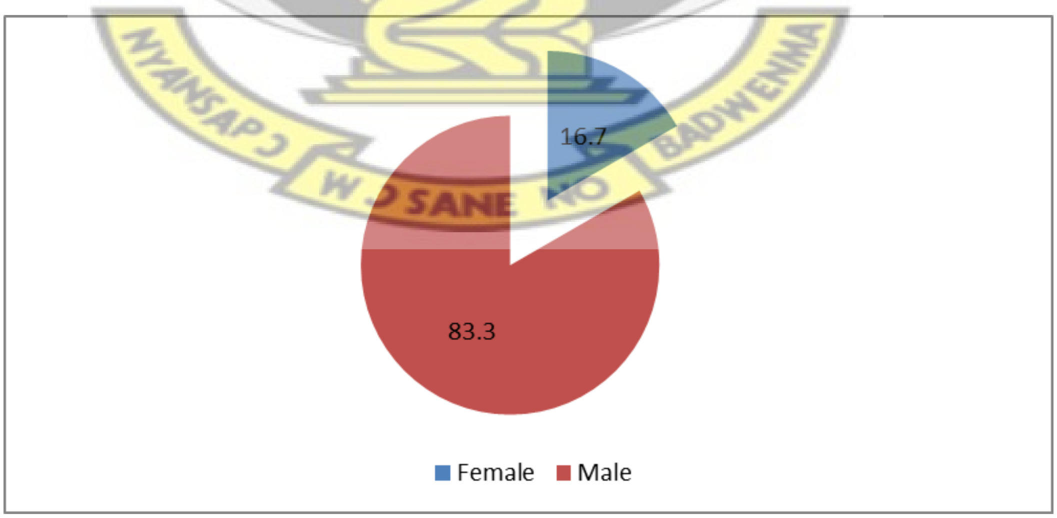

Figure 4.2: Sex Distribution of Respondents

4.1.1.3 Principal occupation of respondents

As shown in Figure 4.3, majority of the respondents (70 %) were engaged in farming as their main occupation. Their second most important occupation was livestock rearing (20 %). Only 3.3 % of the respondents were engaged in trading and the remaining 6.7% of them were engaged in other occupations such as fishing, rice and shea-butter processing as well as hunting. There were also statistical similarities ($p > 0.05$) in relation respondents' occupations in the research communities (Table 4.1).

Figure 4.3: Principal Occupations of Respondents
*Farming represents Crop production

Table 4.1: Chi-square analysis of differences in selected personal and demographic characteristics of respondents

Household charactersitics	Communities									χ^2 (df)	P values	Sig. levels
	Kan (%) n=10	Sav (%) n=10	Bun (%) n=10	Pan (%) n=10	Kad (%) n=10	San (%) n=10	Yiwo (%) n=10	Kpen (%) n=10	Nan (%) n=10			
Gender												
F	4.5	6.1	13.3	9.3	3.2	3.4	2.3	2.8	1.1	4.7		NS
M	7.7	14.5	9.8	8.2	4.1	2.3	3.3	3.6	0.5	(1)	0.064	
Age group												
20-30	3.4	1.8	3.4	0.6	1.2	2.3	4.6	1.9	1.1			
31-40	1.6	0.6	3.9	0.5	2.8	1.2	2.9	2.2	4.1	6.3		
41-50	4.4	4.2	2.5	5.3	2.7	0.1	1.1	0.8	0.5	(4)	0.057	NS
51-60	1.8	3.3	2.7	1.3	2.4	0.7	0.6	3.6	1.2			
Above 60	0.2	2.8	2.7	3.3	1.3	6.5	2.2	0.8	0.9			
Occupation												
Farming (crops)	0.9	0.3	3.9	4.0	4.0	4.1	3.8	3.4	0.2			
Livestock rearing	4.3	8.1	2.5	1.9	2.2	0.2	1.2	3.1	1.4	5.8		
Trading	0.8	11.8	0.1	0.4	0.5	0.6	0.8	1.2	9.2	(3)	0.072	NS
Others	2.1	4.5	3.1	1.4	4.1	2.9	1.3	1.6	4.1			
Educational level												
Primary	5.7	2.2	3.1	2.1	2.9	3.9	2.6	3.6	1.6			
JHS	2.2	0.8	1.4	2.0	3.9	2.8	3.9	3.0	1.6	3.8	0.13	NS
SHS	2.1	4.3	3.0	5.4	3.5	1.2	2.2	1.7	0.6	(3)		
Technical/vocational	5.3	4.4	3.8	3.4	2.3	1.6	3.0	1.8	1.1			

*** Kan= kanshegu, Sav=Savelugu, Bun=Bunglung, pon=Pong, Kad=Kadua, San=Sankpem, Yiwo=Yiworgu, Kpen=Kpendua and n=nanton**

The Chi-square analysis was conducted to test the significance of respondents' perception of the effects of Gravel Mining (GM) in the District (Table 4.1).The similarities observed means that any similarities in their perceptions is not due to the fact that there are more educated or older or more males or more females in some communities compared to others. It simply means that their perceptions as recorded are actually due to "felt impact" or "felt need" resulting from the effects of GM in the communities.

Table 4.2 **Percentage of responses of respondents' perception of the effects of Gravel Mining (GM) in the District**

Respondents perceptions	% of Responses For	% of Responses Against	% Total
• **GM reduces availability of trees on mined sites**	94.4	5.6	100
• **GM causes reduced farmlands**	73.2	26.8	100
• **GM mars relationship b/n miners and residents**	76.7	23.3	100
• **GM creates conditions for disease outbreaks**	73.3	26.7	100
• **GM causes low yields in mined sites**	73.2	26.8	100

4.1.2 Perception of Respondents on Gravel Mining in the District

Out of the 90 respondents interviewed, 83.3 % had observed GM activities in the district (Table 4.2). A significant proportion (94.4 %) observed lack or presence of few trees and vegetation at the various abandoned gravel mines. The respondents were predominantly farmers who cultivate food crops (mainly maize, rice, yams, groundnuts and soya bean).

Whiles 23.3 % of respondents claimed there was friendly relationship between gravel miners and residents, 76.7 % said the relationship was poor and bad due to miners' influence on chiefs to give their lands out for gravel mining. Focus group discussions revealed that community members perceived gravel miners to be destroying farmlands and this often resulted in misunderstandings and other confrontations between them. Opinions expressed by 73.3 % of respondents revealed that GM could be the possible cause of diseases such as dysentery, typhoid and malaria because gravel pits are usually used as waste dumping grounds close to the communities. In a similar vein, 73.2 % of respondents believed that gravel mining causes low crop yields in gravel mined sites. Responses in respect of residents' perception of GM were significant as it results in un-cordial relationship between gravel miners and residents of communities, loss of trees on abandoned gravel mines, reduction of crop yields, as well as creating conditions for land degradation and diseases among others (Table 4.3).

Table 4.3 Chi-square analysis of significance of respondents' perception of the effects of Gravel Mining (GM) in the District.

Respondents perceptions	χ^2	P-value	Sig. level
• **GM reduces availability of trees on mined sites**	6.1	0.014	S
• **GM causes reduced farmlands**	60.9	0.015	S
• **GM mars relationship b/n miners and residents**	51.5	0.002	S
• **GM creates conditions for disease outbreaks**	16.6	0.01	S
• **GM causes low yields in mined sites**	4.4	0.02	S

S represents significant

The results of the chi-square analysis of the significance of respondents' perception of effects of gravel mining in the Savelugu-Nanton District are shown in Table 4.3. Respondents were generally of the perception that, gravel mining leads to a significant reduction in the availability of trees on mined sites (χ^2= 6.1; p value = 0.014) and causes reduced farm sizes (χ^2 = 60.9; p value = 0.015). It is therefore generally perceived that gravel mining has significant adverse effects on the inhabitants of the Savelugu-Nanton District.

4.2 Biomass Estimation in Different Gravel Mining Areas

4.2.1 Biomass in Different Age groups after Gravel Pit Abandonment for Similar Physiognomic Classes

The mean biomass stocks in different age groups after gravel pit abandonment in similar physiognomic classes are shown in Table 4.4. Analysis of variance (ANOVA) showed that, mean values for litter biomass ($F_{3,\ 12}$ = 112; P= 0.001), LGF ($F_{3,\ 12}$ = 4.83; P= 0.033) and tree biomass ($F_{3,\ 12}$ = 4.32; P= 0.044) differed significantly between the un-mined and mined sites. However, there were no significant differences (p > 0.05) between the abandoned mines. The un-mined (control) site had significantly higher mean values compared with abandoned gravel mines (Table 4.4).Whereas mean surface litter biomass were 3.86, 0.16, 0.26 and 1.33 t/h for the control and plots abandoned for 1-5, 6-10 and above 10 years respectively, the mean values for Low Growing Flora (LGF), were 3.99, 1.42, 2.42 and 2.47t/h respectively for the mentioned age groups. Similarly, whiles mean tree biomass for the control plot was 22.9t/h that of 1-5, 6-10 and above 10 years sites were 16.1, 15.5 and 14.8 t/h respectively after pit abandonment. Total aboveground biomass (AGB) also ranged from 17.7t/h (1-5 years' site) to 32.8 t/h (control plot).

4.2.2 Biomass in physiognomic classes of gravel mining (GM) sites

The mean biomass stock in the different age group and physiognomic classes of abandoned gravel mines of the study areas are also shown in Table 4.4. Among all the physiognomic groups and across all the different age groups, the woody biomass (trees and shrubs) produced the highest biomass stock which was more than half or 79.5% of the total biomass of vegetation in the gravel mining areas. The next reservoir of biomass was the Low Growing Flora (LGF) which was 14.1 % of the total biomass. The above ground litter followed with 6.4 % of the total biomass.

Table 4.4 Mean biomass (±SE) in the different age group and physiognomic classes after gravel pit abandonment in Savelugu - Nanton District

Physiognomic Class	Control	1-5 years	6-10 years	Above10 years	Total Biomass (%)
Surface litter (t/ha)	3.9a (0.44)	0.2b (0.10)	0.3b (0.10)	1.3b (0.10)	**6.4**
LGF (t/ha)	6.0a (0.37)	1.4b (1.41)	2.4b (1.79)	2.5b (2.14)	**14.1**
Tree biomass (t/ha)	22.9a(1.35)	16.1b (0.47)	15.5b (5.82)	14.8b (1.85)	**79.5**
Total AGB (t/ha)	**32.8a**	**17.7b**	**18.1b**	**18.6b**	**100**

Mean values in the same row for the different age groups followed by a common letter are not significantly different ($p > 0.05$) as determined by Least Significant Differences (LSD. Values in parenthesis are standard errors of means.

4.3 Physicochemical properties of gravel mining sites in Savelugu-Nanton District.

4.3.1 Particle size distribution (%) and bulk Density (g / cm^3) changes.

Mean values (±SE) for particle size distribution and bulk density on the different gravel mining sites for the (0-30cm) depth are given in Table 4.5. Across the different ages, mean sand % ranged from 41.6 % to 52.6 % for the control and sites abandoned for between 6-10 years respectively. Also, whiles mean clay % ranged from 19.8 % for control, to 31.6 % for sites above 10 years that of the mean silt % ranged from 28.9 % to 38.6 %, for mined sites abandoned for above 10 years and the control plot respectively. For bulk densities, mean value for control plot was 2.3 g / cm^3, whiles those of the mined sites were 1.8 g / cm^3, 2.1 g / cm^{3}and 2.9 g / cm^{3}for 1-5, 6-10 and above 10 years' sites respectively after pit abandonment.

Table 4.5 Particle size distribution (%)and bulk density (g / cm^3) changes in un-mined and mined sites in the Savelugu-Nanton District

Land cover	Sand (%)	Clay (%)	Silt (%)	BD (g\cm^3)	Soil type
Control	41.6a (12.42)	19.8a (12.17)	38.6a (2.02)	2.3a (0.82)	Loam
1-5 years	46.7a (5.00)	21.8a (6.56)	31.4a (6.56)	1.8a (1.84)	Loam
6-10 years	52.6a (19.35)	13.72a (7.55)	33.7a (13.87)	2.1a (1.84)	Sandy Loam
Above10 years	51.3a (17.27)	31.6a (16.07)	28.9a (14.63)	2.9a (1.81)	Clay Loam

Mean values in the same column for the different age groups followed by a common letter are not significantly different (p> 0.05) as determined by LSD. Values in parenthesis are standard errors of means

Analysis of variance (ANOVA) showed that % sand ($F_{3, 12}$ = 0.35; P = 7.9), % clay ($F_{3, 12}$ = 1.3; P = 0.34), % silt ($F_{3, 12}$ = 0.45; P = 7.73) and bulk density ($F_{3, 12}$ = 0.45; P = 7.3) did not differ significantly between the different age groups. Using the USDA soil triangle, soil texture could be classified as loam for 1-5 years and control sites, sandy loam for 6-10 years' sites, and clayey loam for sites above 10 years' after pit abandonment.

4.3.2 Change in Soil Chemical Properties at (0-30 cm depth).

Mean values (±SE) for soil chemical properties on the different gravel mining sites for the (0-30cm) depth are given in Table 4.6. Across the different plot ages, mean (N %) was 0.04 % for control plot and 0.02 %, 0.02 %, and 0.04 % for sites abandoned for1-5, 6-10 and above 10 years. There were no differences ($F_{3, 12}$ =1.30; P = 0.34) between the different sites. Similarly, whiles mean values of phosphorus was 6.3 mg\kg for the control plot that of mined sites were 3.8 mg\kg, 4.4 mg\kg and 4.3 mg\kg for 1-5, 6-10 and above 10 years respectively. For potassium, the mean values ranged from 56.5 mg\kg to 144.9 mg\kg for plots abandoned for between 1-5 years and control plot respectively, whiles mean CEC values ranged from 10.4 Cmol+mg\kg to 18.6 Cmol+mg\kg for control and plots abandoned for between 1-5 years respectively. Percentage Organic Carbon (OC %) followed a similar pattern and mean values recorded were3.9 %, 0.4 %, 0.27 % and 0.5 % for the control, 1-5, 6-10, and above 10 years 'sites respectively. Mean pH for the control and different age groups (1-5, 6-10 and above 10 years' sites) were also 5.93, 5.37, 5.8 and 4.8 respectively.

Analysis of variance (ANOVA) revealed that percentage N, P, pH and CEC did not differ significantly ($p > 0.05$) between the different age groups (Table 4.5). On the other hand, mean values for % OC ($F_{3,\ 12}$ = 16.1; P= 0.001) and potassium (K) ($F_{3,\ 12}$ = 6.97; P= 0.013) differed significantly between mined and un-mined sites (Table 4.6). However, no significant differences were observed ($p > 0.05$) between the age groups after pit abandonment. Details of one ANOVA table are in appendices 11-15

Table 4.6 Means (±SE) for soil chemical properties in 0-30 cm depth of GM sites.

Land cover	Nitrogen (%)	Phosphorus (mg\kg)	Potassium (mg\kg)	CEC (Cmol+mg\kg)	OC (%)	P^H (1:2.5)
Control	0.037a (0.01)	6.53a (2.73)	144.9b (33.42)	18.61a (4.05)	3.85b (1.37)	5.93a (0.56)
1-5 years	0.022a (0.028)	3.83a (0.39)	56.46a (3.67)	10.37a (0.8)	0.39a (0.51)	5.37a (0.52)
6-10 years	0.017a (0.006)	4.37a (1.39)	132.44a (26.64)	15.43a (5.21)	0.27a (0.09)	5.81a (0.60)
Above 10 years	0.037a (0.009)	4.3a (1.1)	137.24a (32.85)	10.7a (1.58)	0.52a (0.11)	4.84a (0.44)

Mean values in the same column for the different age groups followed by a common letter are not significantly different ($p < 0.05$) as determined LSD. Values in parenthesis are standard errors of means.

4.4 Trends of nutrients in gravel mining sites after pit abandonment

Regression equations and graphs relating concentrations of N %, P, K, CEC, OC %, and pH to duration after pit abandonment are shown in Figures 4.4 - 4.9. Regression coefficients (R^2) ranged from 0.45 to 0.96 for K and N % respectively. This means that N

%(R^2= 0.96), P (R^2=0.81)and OC %(R^2 = 0.95) are highly predictive. Also, whiles pH (R^2 = 0.65)is moderately predictive that of CEC (R^2 = 0.44) and K (R^2 = 0.45) are less predictive due to low R^2 values.

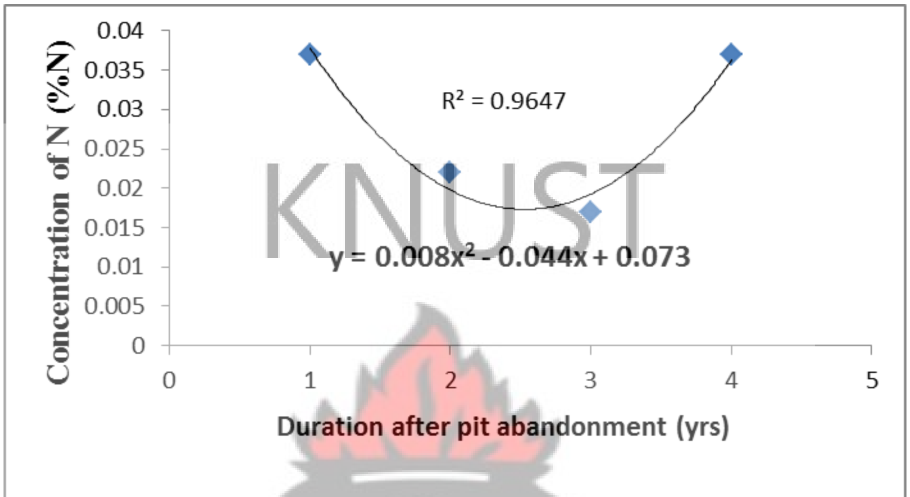

Figure 4.4: Percentage N in abandoned gravel mines

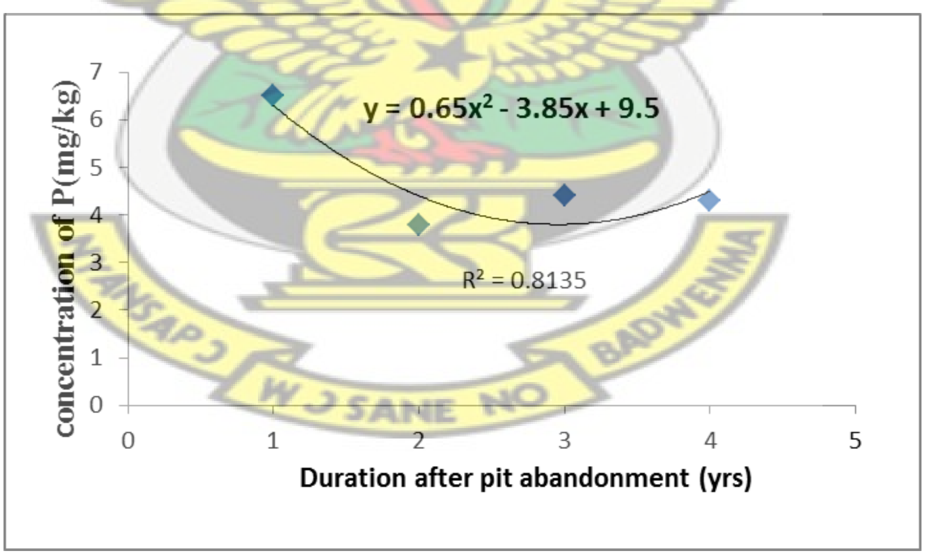

Figure 4.5: Available P in abandoned gravel mines

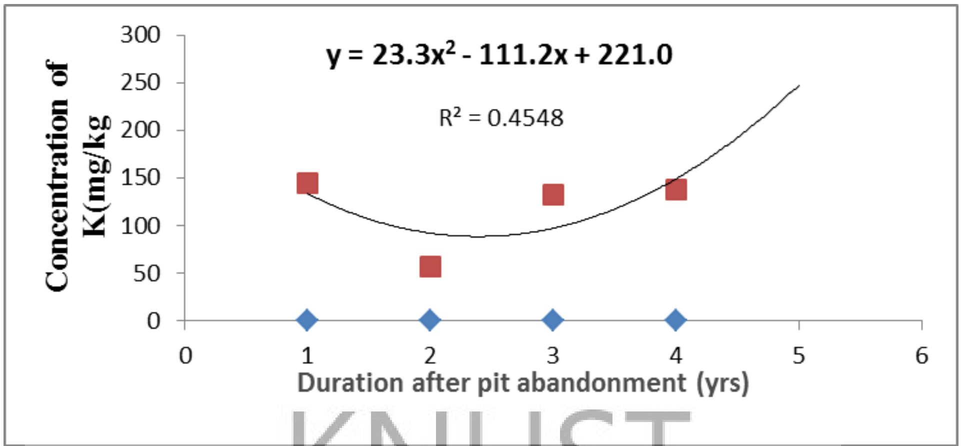

Figure 4.6: Available K in abandoned gravel mines

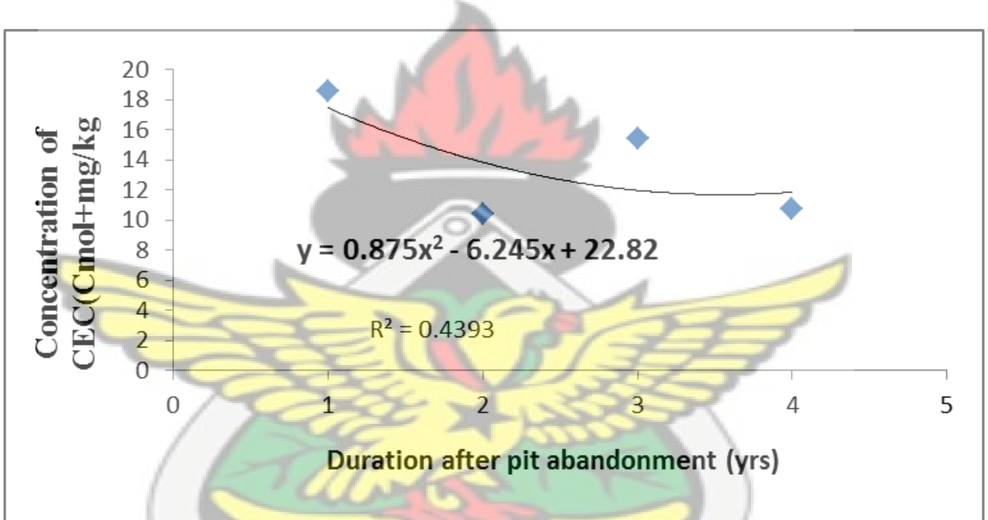

Figure 4.7: Level of CEC in abandoned gravel mines

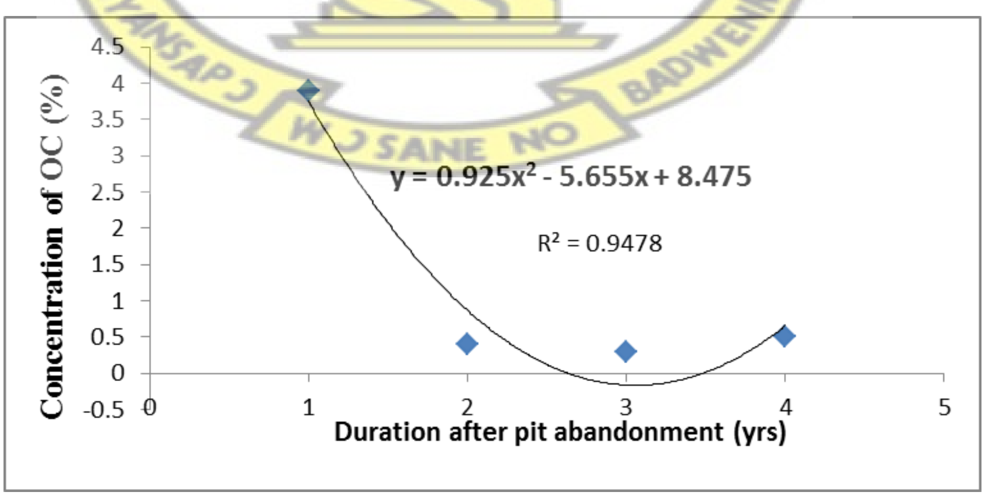

Figure 4.8: Percentage OC in abandoned gravel mines

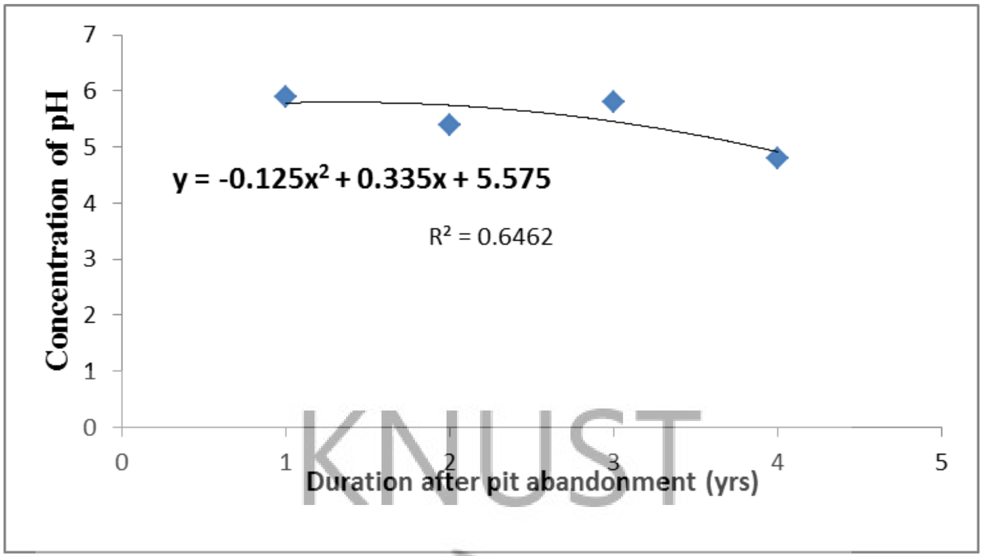

Figure 4.9: Level of pH in abandoned gravel mines

4.5 Correlations between various physicochemical parameters in mined and un-mined gravel mining sites.

Correlation amongst major soil parameters is shown in Table 4.7. Positive correlations were observed amongst % OC, % N, P and K. However, these correlations were weak and non-significant. On the other hand, whiles correlation between CEC, pH and P was strong, significant and positive, that between% sand, % clay and % silt and the various chemical parameters were found to be positive, weak or negative.

Table 4.7 Correlations between various physicochemical parameters in mined and un-mined sites

Soil properties	pH	% C	% N	P	K	CEC	BD	% Sand	% Clay
% C	0.266								
% N	-0.145	**0.522**							
P	0.653*	**0.383**	0.195						
K	0.222	**0.408**	0.337	0.485					
CEC	0.733**	0.451	0.061	0.696*	0.393				
BD	-0.147	0.190	0.678*	0.065	0.224	0.100			
% Sand	-0.155	-0.418	-0.297	-0.307	-0.239	-0.154	-0.510		
%Clay	-0.754*	0.088	0.310	-0.339	-0.016	-0.309	0.371	-0.147	
% Silt	0.587*	0.296	0.013	0.533	0.469	0.443	-0.029	-.587*	-0.445

*****Represents significant correlations ($p < 0.05$) as determined by Pearson correlation.

** Represents significant correlation ($p < 0.01$)

CHAPTER FIVE

5.0 DISCUSSIONS

5.1 Introduction

This chapter discusses the findings of socio-economic and ecological impacts of gravel mining in the Savelugu-Nanton District of the Northern Region of Ghana. The chapter is presented in three sections: Section one discusses the socio-economic and demographic characteristics of respondents (age distribution, sex distributions, principal occupation etc.),perception of respondents of the impact of gravel mining in the district (views on availability of trees in gravel mining sites, views on crops cultivated, views on whether gravel mining contributes to land degradation and scarcity of agricultural lands, relationship between gravel miners and residents, views on whether gravel mining causes diseases, views of impact of gravel mining on residents etc.). Section two focuses on biomass estimation in respect of the different age groups after gravel pit abandonment whiles finally, section three discuses soil physicochemical properties of these age groups and how they are correlated to each other in the Savelugu-Nanton District.

5.1.1 Socio-demographic characteristics of the respondents.

5.1.1.1 Age Distribution of the Respondents

Results in Figure 4.1 clearly showed that, respondents in respect of the data collection for the study were basically youthful. This information gathered could help to identify the category of dominant age group among the respondents consulted for data collection.

5.1.1.2 Sex Distributions of Respondents

Majority of the respondents (83.3 %) were males with the remaining 16.8 % being females. The result is that most households are headed by men and are therefore central to the decision making on matters relating to gravel mining. Therefore, when it comes to solving the problems of gravel mining their contributions could play an active role (Figure 4.2).

5.1.1.3 Principal occupation of Respondents

In the study area, majority of respondents (70 %) were farmers cultivating mostly maize, rice, groundnuts, soyabeans with livestock being 20 % and other occupations such as fishing, hunting, shea-butter and rice processing constituting 3.3 % (Figure 4.3). There was however no recorded respondents engaged in GM activities. It can be inferred from this that gravel mining activities do not provide jobs for residents but rather interferes with their agricultural lands. Also, the gravel miners are non-natives who come from adjoining communities and this could account for the existing bad relationship between residents of communities and the gravel miners. In agreement with this assertion, Verheye (1997) reported that, land remains the medium that satisfies primary human need for food and shelter and that, conflicts inevitably result between communities and miners because, both place fundamentally different socio-economic values on land.

5.1.2 Perception of Respondents on Impact of Gravel Mining in the District

5.1.2.1 Views on availability of trees on gravel mining sites.

Few (usually economic trees such as *Pakia biglobosa*, *Adansonia digitata*, *Viterallaria paradoxum* etc.) or no trees were present on abandoned mining sites as compared to un-mined sites. This could simply be deduced that GM may have contributed to these low numbers of trees as most of the trees are removed before the gravel is mined. This can negatively affect the socio-economic activities of women whose livelihood activities largely depend on these trees. The Savelugu-Nanton District Assembly Medium Term Development Plan, (MTDP, 2010), emphasized that the presence of economic trees generally offer some employment in the form of nuts and seeds picking which serve as important means of livelihood especially for women folk. Notable among these are *Pakia biglobosa* (Dawadawa), *Adansonia digitata* (baobab) and *Viterallaria paradoxum* (shea-nut tree) among others. In view of this, traditional leaders, youth groups, relevant government institutions and other civil society groups should collaborate effectively as a matter of urgency in dialogue to curtail the destruction rate of these economic trees in order to forestall loss of employment these trees offer to people in the district.

5.1.2.2 Gravel Mining Contributing to Scarcity and reduced Agricultural Lands

Gravel mining activities in SND usually involve stripping off surface of soils and leaving behind deep gullies of little or no value for any productive agricultural activity. This leads to losses in vegetation and soil nutrients as well as reduction in farm sizes. In agreement with this, Nardi *et al*., (1996) reported that, in the Tamil Nadu Region of India, over 70% of farmers agreed that, severe deterioration in soil quality may lead to a permanent degradation of land productivity. Similarly, in Nepal, Islam *et al*., (1999) found that, over 64 % of respondents were of the opinion that, deterioration of soil through loss of vegetation may lead to permanent degradation of productive lands.

Environmental Protection Agency EPA, (1996) through its annual review reports on Ghana has confirmed that the destruction of the vegetation through removal of trees and top soil is the starting point of degradation. Oregon Water Resources Research Institute, OWRRI, (1995), in its findings reported that, when the rate of gravel extraction exceeds the rate of natural deposition over an extended time period, a net mining occurs due to the cumulative loss of gravel. Findings of Willis and Garrod, (1999) which are in consonance with this result report that, aggregate mining in populated areas in USA results in negative externalities including loss of vegetation, visually unpleasant landscapes, and this represents a conflict with competing land uses such as farming, especially in areas where high-value farmland is scarce and where post-mining restoration may be infeasible. Thus, these appear to be a general consensus not only among farmers but that of all land users.

5.1.2.3 Respondents' views on some of the diseases influenced by GM in The district

In the study area, majority of respondents (73.3 %) principally attribute the prevalence of some diseases such as dysentery, typhoid and malaria to activities of GM. They observed over the years that, abandoned gravel mines are used as refuse damping grounds which collect water during the rainy seasons. These therefore serve as breeding grounds for vectors and/or parasites responsible for transmission of the mentioned diseases. In agreement with this finding, Heath et al., (1993), Veiga and Beinhoff, (1997) and Warhurst, (1999) have variously reported that, water collected in gravel pits result in health related problems for neighbourhood communities. Similarly, in Geita District of

Tanzania, Kitula (2004) found that, mining including gravel mining cause diseases especially malaria, bilharzias and other waterborne diseases.

5.1.2.4 Perception of residents about GM Impacts on Communities in SND.

Respondents within the study area normally assess the negative impacts of GM by loss of trees, low yields of crops after harvest and lack of vegetation on soils. Another important impact is scarcity or reduction in farmlands. Top soil is perceived to be good for agricultural production and when they are removed during gravel mining without being returned back, the soil nutrients is also lost and this can reduce agricultural productivity. However, though gravel mining may have some benefits its negative impacts on communities in SND is as well recognisable. Environmental Protection Agency EPA, (1996) through its annual review reports on Ghana, agrees with this finding that the destruction of the vegetation through removal of trees and top soil by means such as gravel mining is the starting point of degradation.

5.1.2.5 Suggestions towards resolving gravel mining problems in the district

Respondents offered several suggestions that they thought could address problems posed by gravel mining in the district (Table 5.1). These include refilling of gravel pits with topsoil, meting out punishment to offenders of the crime, allowing gravel pits to reinstate itself (natural fallowing and succession), tree planting as well as relocating gravel miners to distant areas. Studies in Doon valley of India have made similar recommendations; planting of trees on degraded sites including abandoned gravel mining sites can dramatically increase the otherwise slow rate of natural forest succession by ameliorating unfavourable soil condition and providing a habitat for seed dispersing wildlife that can lead to a progressive enrichment of floristic diversity (Mathur and Soni, 1983).

Table 5.1 Suggestions of respondents towards resolving gravel mining problems in the District

Suggested solutions to GM problems	Frequency	Percentage
Punishments	14	15.6
Reclamation/refilling	22	24.4
Fallowing	14	15.6
Tree planting/afforestation	36	40.0
Relocation of gravel mines to distant sites	4	4.4
Total	**90**	**100**

5.2 Above Ground Plant Biomass in Gravel Mining Areas.

5.2.1 Biomass in Different Age groups after Gravel Pit Abandonment for Same Physiognomic Classes

In respect of ground litter biomass, low growing flora (LGF), and tree biomass, the study observed a significant difference ($p < 0.05$) between un-mined and mined sites after pit abandonment (Table 4.4).The significantly higher mean above-ground biomass (AGB) values in the control plots could be attributed to the fact that they represent ecologically stable ecosystems with greater potential for carbon storage and that except for the gravel mining activities, all the land cover classes would have been agricultural lands.

Similarly, the higher AGB in control plots may be attributed to low level of environmental consciousness on the part of mining contractors or compliance of the Environmental Regulation (L.I. 1652) which restricts destruction of vegetation especially the economic tree species such as *Pakia biglobosa* (dawadawa), *Viterallaria paradoxum* (sheanut) and *Adansonia digitata* (baobab). Frequent annual ritual of bush fires may have also accounted for these differences. This is because, it is traditionally believed (not confirmed by research) that when sheanut trees are partially burnt during the dry season, it facilitates or enhances fruiting of the trees. This burning can result in reduction of the total biomass not only in the gravel mining sites but the adjoining areas. Other factors that may have accounted for this are; low rainfall regime in the area, soil erosion and tree felling among others.

5.2.2 Biomass in physiognomic classes of GM sites in the District

The woody plants (trees and shrubs) produced far more than half of the total biomass of the ecosystem (79.5 % of the total biomass) (Table 4.4). Other studies in West Africa(Bramryd, 1979: Longman and Jenik, 1987: Amanor, 1994) confirm that, large proportion of biomass in most tropical ecosystem are held in trees followed by low growing flora and then surface litter. Longman and Jenik 1989 and Dale *et al* (1991) have further explained that once the woody or tree vegetation is removed, it means that the nutrient bank of the land is removed, and that the land is stripped of its major biomass. Therefore human destruction or change of woody vegetation system especially for the gravel mining purposes or harvesting for fuel wood could significantly diminish the store of biomass of the land which subsequently could accelerate the loss of soil major nutrients.

5.3 Particle size distribution (%) and bulk Density (g\cm^3) changes.

5.3.1 Sand, Clay and Silt.

No significant differences were observed between un-mined and abandoned gravel mining sites in respect of the soil physical properties (mainly % sand, clay and silt) (Table 4.5). Soil type and colour were particularly similar between mined and un-mined sites. These similarities could mean that, it takes a very long time for soil physical properties to change following gravel mining. Other studies in transitional zone of Ghana (Brady, 1990) confirm that, the texture of a soil is not easily modified for instance on large agricultural, forestry and wild-land areas. He stressed that soil texture is not changed by cultural management although process such as weathering, erosion, illuviation and deposition over very long period of time can alter the texture of various soil horizons.

Textural classes for control site and the different age groups after gravel pit abandonment were determined using the USDA soil triangle. The soil texture were classified as loam for the control and 1-5 year' sites, sandy loam for 6-10 years' site and clayey loam for the above 10 years' sites (Table 4.5). Texture is an intrinsic soil property, but removal of vegetation cover as a result of gravel mining could have contributed to the variations in particle size distribution in the different land cover areas. This could be due to removal of soil particles through accelerated erosion during uncontrolled activities of the gravel mining as well as sloppiness of abandoned mines.

5.3.2 Soil Bulk Density (SBD)

Soil bulk densities did not differ significantly (p> 0.05) between un-mined and abandoned gravel mining sites (Table 4.5). Bulk densities were generally high on all the sites which partly may be as a result of loss of SOM in the study sites. It probably could be as a result of over cultivation (continuous farming), over-grazing, large scale use of farm machinery and annual ritual bushfires that may have occurred over the past years in the area. Studies in Ibadan Nigeria (Lal *et al*., 1997) confirm that, continuous use of machinery during cultivation seasons increased bulk densities (BDs). Similarly, in the Central Zagrous Mountains in Iran, Hajabbasi *et al*., (1997) carried out a study and found that, deforestation and subsequent tillage practices resulted in nearly a 20% increase in bulk density and a 50% decrease in SOM for a soil depth of 0-30 cm over 20 years.

5.4 Soil Chemical Properties of Gravel Mining Sites

5.4.1 Percentage Nitrogen (%N)

The soil nitrogen content (% N) in the study sites was generally low. No significant differences ($p > 0.05$) were found between un-mined and abandoned gravel mining sites (Table 4.6). Low level of awareness and compliance to the Environmental Regulation (L.I 1652) could be responsible for low N level in abandoned gravel pits. The mandate of the L.I stipulates that gravel miners are supposed to obtain an environmental clearance from EPA and District Assemblies before opening up a mine. Guidelines are usually provided to regulate how mines should be opened and closed. Because this process is not followed, gravels miners do not comply with the appropriate guidelines resulting in haphazard gravel mining. Also, low N levels observed in the control plots may be attributed to the general loss or low level of organic matter (OM) in the soil through annual bushfires, overgrazing and tree cutting. Soils with high content of OM are likely to have equally high N content. Accumulation of organic matter as a result of development of vegetation on the gravel mining sites with time can bring about increases in N level in the mined sites. In agreement with this, Wang et al, (2009) carried out a research in China and found that, there is a positive relationship between total nitrogen and total soil organic matter. SOM content also prevents soil erosion and nitrogen losses due to sedimentation.

The generally low % N in all the study plots including un-mined sites may be due to over cultivation, erosion, over-grazing and high rate of tree felling common in the district. These negative tendencies destroy soil structure and decrease infiltration rate, increase runoff, and leads to loss of large amount of nitrogen from soil surface through leaching. In agreement with this assertion, Adewole and Adesina, (2011) reported that, in some parts of Guinea Savannah of South-Western Nigeria, most of the leguminous trees are destroyed together with the top soil; as such nitrogen together with other essential nutrients in the soil are destroyed alongside hence low nitrogen in the soil.

5.4.2 Available Phosphorus

Available phosphorus (P) was not significantly different ($p > 0.05$) between un-mined and the various GM sites (Table 4.6). This could be due to the fact that soils in the area may be inherently low in P content. The generally low P content in the sites could be due to low SOM as result of over-cultivation, bushfires, other than gravel mining as well other forms of land degradation. The inherently low P content of the parent material cannot be ruled out. Top soil and vegetative cover is usually removed alongside organic matter and as such, phosphorus in the soil could be removed as a result. This is confirmed by Adewole and Adesina, (2011) who reported that, in some parts of Guinea Savannah of south-western Nigeria, most of the leguminous trees are destroyed together with the top soil; as such major essential nutrients are destroyed alongside hence low phosphorus in the soil.

5.4.3 Available Potassium

Highest (144.9 mg/kg) available K was recorded in un-mined sites compared with the various age groups of abandoned gravel mines which had significantly low available K (Table 4.6). Figure 5.2 shows the trend of available K in respect of age group after gravel pits abandonment. This low available K in abandoned gravel mines could be attributed to loss of vegetation in the mining sites which are still fresh and would require probably longer time for the development of organic matter to occur as a panacea for increases in soil essential nutrients including potassium. On the other hand, the significantly higher available potassium (K) in un-mined sites could be due to enhanced weathering of minerals containing potassium which is probably due to high SOM as a result of increased vegetation development at those sites. Also, high available K in soil surface of un-mined sites maybe due to the high ability of plants to absorb potassium from the underlying layers of soil and releasing it by the plant residues to the surface layer. In agreement with the results, Kayser and Isselstein (2005) reported that, continued nutrient export without potassium (K) supply will lead to depletion in the soil that, depending on K storage, may take from 3 to10 years.

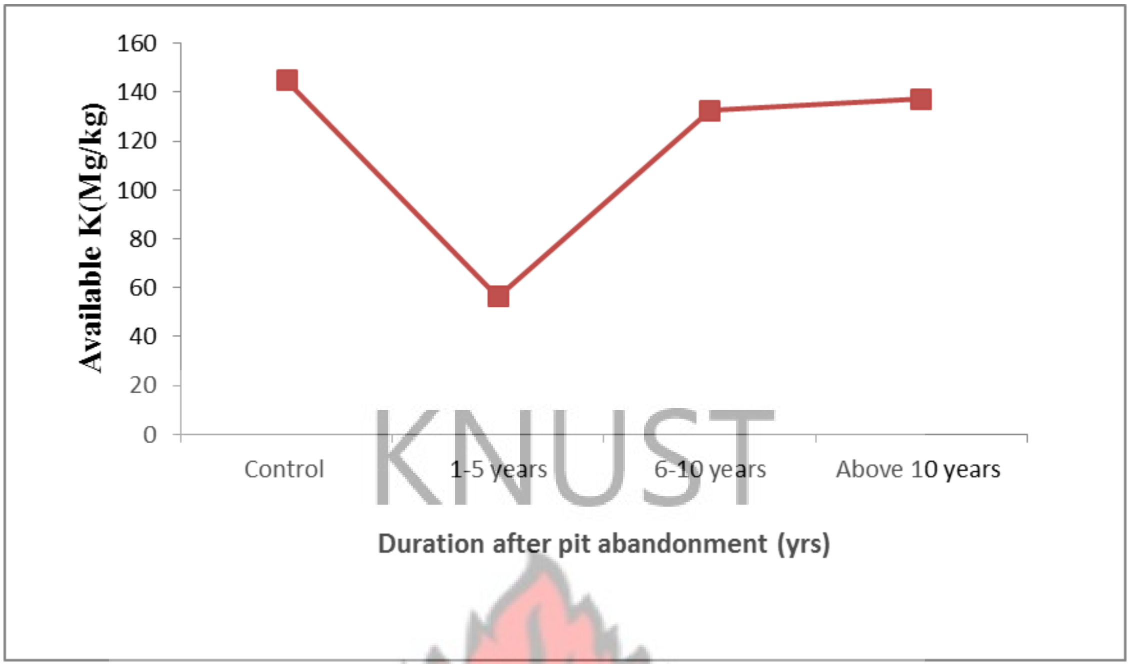

Figure 5.1: Level of available K in various age groups after gravel pits abandonment.

5.4.4 Cation Exchange Capacity (CEC)

Analysis of variance (ANOVA) showed no significant difference in CEC ($p > 0.05$) between the un-mined and abandoned gravel mining sites (Table 4.6). This may be attributed to heightened awareness of gravel miners to replace top soil after gravel extraction. Contractors who in recent times are engaged in gravel mining fill back the stock pile of top soils after extraction. The survey conducted confirmed that it is usually the foreign contractors who comply with the back filling and that have improved soil organic matter but not in significant quantities. Another reason could be that there was accumulation of organic matter as a result of development of vegetation on the abandoned gravel mines with time which result in maintenance of CEC at those levels.

On the other hand, it can be argued that, the un-mined sites may have been subjected to over cultivation, bushfires, over-grazing and other forms of anthropogenic activities (land use change) which may have resulted in the occurrence of non-significant differences between un-mined and abandoned gravel mines after pit abandonment. Studies in the Mediterranean mountain (Sanchez-Maranon et al., 2002) confirms that, land use change from pasture to other land uses including cultivation reduced CEC by 50%.

5.4.5 Percentage Organic Carbon (%OC)

Analysis of variance (ANOVA) showed that, % OC differed significantly between un-mined and mined sites (Table 4.6). This significant difference could be due to the higher vegetative cover on un-mined sites which resulted in high soil organic matter (SOM) decomposition from litter fall. On the other hand, the low % OC in the abandoned gravel mines could be attributed to breakdown of organic carbon due to exposure after vegetation removal by gravel mining. This explanation is in agreement with reports in Southern Brazil (Rio Grande do Sul) that, removal of vegetation decreases the amount of carbon by the following processes: (i) accelerated mineralization, (ii) leaching and translocation as dissolved or particulate organic Carbon and (iii) accelerated erosion. Similarly, Li *et al*., (2007) reported that land-use change from alphine pasture-land to other land uses including gravel mining decreased amount of carbon through accelerated mineralization, leaching and translocation as dissolved or particulate organic carbon and accelerated erosion.

5.4.6 The Soil pH

The soil pH showed no significant differences between abandoned gravel mines and that of un-mined sites. However, there were generally low soil pH levels (4.84 – 5.93) on all study sites (Table 4.6). This could be attributed to erosion as a result of over cultivation, annual ritual of bushfires, regular tree felling as well as over grazing which are common in the district. Leaching of basic cations due to rains and high levels of water collected by the gravel pits could also be the cause of these low pH values. This finding is supported by Hassan and Majumder, (1990) who reported that, in forest soils of Bangladesh India, pre-weathered parent materials and the intense leaching of basic cations during the monsoons are all the likely contributing factors to the naturally very acid pH levels in these soils.

5.5 Correlations between various physicochemical parameters in gravel mining sites.

Positively weak correlations were recorded (% OC, % N, P and K) in both the abandoned and un-mined sites (Table 4.7). Acidic or slightly alkaline nature of the soil could have influenced the low levels of these soil parameters. Positive correlation between parameters means that an increase in the value of one will lead to a corresponding increase in the other whiles negative correlation means that an increase in mean value of one will lead to a decrease in the other. The positive % C correlation with N, P and K suggest that to increase the levels of N, P and K requires that management practices to reclaim mined sites should aim at using materials (tree planting and increase vegetative cover etc.) with high organic carbon content (% C).

Similarly, the non-significant correlations (both positively and negatively) between % C and other soil physical parameters (sand %, silt % clay % and BD) in both un-mined and abandoned mining sites may be due to textural similarities of the soil and the fact that there was moderate content of clay. In agreement with this, Jones, (1973) reported that, in

Savanna soils; SOM content was not significant and negatively related with clay content when a soil contains clay contents higher than 35%. In this study, in most of the samples clay contents recorded was lower than 35%compared to sand and silt hence positive and insignificant correlation. The potential of the developing mine soils to meet plant nutrient requirements depends on the percentage of elements in forms available for plants. In the organic horizons, these forms depend directly on the decomposition rate and mineralization of organic matter developed in situ. Marcin, (2010) in his research findings reports that, in Krakow Poland, mineral horizons largely depend on weathering rate of minerals in the substrate.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

This study examined the respondents' perceptions of the impact of gravel mining on their socio-economic activities and assessed the impacts of gravel mining on plant biomass. It also assessed changes in soil physicochemical properties in abandoned gravel mining sites. From the results of the study, the following conclusions can be drawn:

i. Perception shared among local communities in the district is that gravel mining has contributed to the prevalence of some diseases, loss and/or reduction of farmlands, poor relationship between residents and gravel miners and low agricultural productivity among others. These effects have therefore been found to have significant impacts on the residents of the communities. This may be attributed to scarcity of agriculturally productive lands currently being experienced in the district and that, farmers and other land users could have limited land for use in the future if this un-controlled gravel mining is not curtailed in the district.

ii. Gravel mining has led to a significant reduction in above-ground plant biomass exposing the land to degradation processes. However, irrespective of duration after gravel pit abandonment (after mining has stopped), above-ground plant biomass was similar on all the abandoned mines. This could be due to slow rate of plant biomass regeneration which is predominantly grasses with sparse trees and shrubs. It could also be due to occurrence of annual bushfires, overgrazing and tree felling for fuel wood needs. Across the landscape and among the physiognomic classes of both un-mined and abandoned gravel mines, woody biomass (trees and shrubs) produced a

79.5 % of the total representing the highest reservoir of biomass in the study sites. The next reservoir of biomass recorded was Low Growing Flora (LGF) which produced 14.1 % total biomass with the above ground litter recording 6.4 % of the total biomass.

iii. Gravel mining resulted in a significant decline in the concentration of organic carbon and available potassium while soil pH, % N, CEC and available P did not change. This could be due to loss of OM as a result of loss of vegetative cover in abandoned gravel pits. Soil physical parameters such as sand, silt, clay and BD were similar on all the mined and un-mined sites. This may be due to textural similarities of the soil and the fact that there was moderate content of clay. Also, Organic carbon (% OC) correlated positively with major soil nutrients (N, P and K) and this suggests that in order to increase levels of N, P and K, management practices such as tree planting and increased vegetative cover can reclaim mined sites with high organic carbon content (% OC).

6.2 Recommendations and Policy Implication

To address the impacts of gravel mining activities the following under-listed recommendations are suggested:

i. Residents of communities should be made to benefit directly from gravel pits opened in their areas through participation of the mining activities and selection of sites for the mining. This could improve their economic livelihoods and also enhance their commitments towards reclamation of abandoned gravel pits which can as well reduce the unhealthy relationship that exist between them and gravel miners.

ii. Also, opening of pits should be done at distances from communities and closure ensured on timely basis as this can help reduce the prevalence rate of gravel mining related diseases in the communities.

iii. All relevant stakeholders in the gravel mining sector including Environmental Protection Agency (EPA), Minerals Commission, District Assemblies, chiefs and land owners among others should strengthen collaboration among themselves for effective enforcement and compliance of the gravel mining regulation. The law recommends that opening and closure of gravel pits should be inspected by EPA and if the land size exceeds 5 acres, it has to go through a minor assessment before clearance is offered and if larger than 10 hectares, a full scale EIA is required. Scale of extraction with specifications in terms of depth of mining is all included in the mining guidelines outlined in permit schedules.

iv. EPA should be given signatory status in the award of, and the disbursement of contract funds at the district levels. This will ensure that gravel miners adhere to reclamation bonds and guidelines. Failure to adhere to these guidelines will therefore deny the mining contractors the rights to access the funds. It can also help EPA to regulate opening and closure of gravel mines.

v. Agroforestry practices and tree planting in degraded gravel mining sites should be encouraged as this has proven to dramatically increase the otherwise slow rate of natural forest succession by ameliorating unfavourable soil condition and providing a build-up of soil organic matter and higher above ground biomass.

vi. Generally, gravel mining alone may not have caused the low levels of soil physicochemical properties in the study sites; it may be as a result of a combination of other factors. Negative activities such as perennial annual bushfires, over-cultivation of lands, over-grazing, tree felling for charcoal and other fuel wood requirement may have also contributed to the low levels of soil major nutrients. This therefore calls for collaboration between all stakeholders to enforce local level byelaws in order to regulate people's activities in respect of utilisation of environmental resources. Sustained education is required to reduce biomass loss in mining sites. Sanctions and penalties should also be included in the byelaws such that offenders of the laws will be punished accordingly. EPA, Forestry Services Division, MOFA and District Assemblies can play leading roles in the facilitation process. This will help develop pragmatic byelaws towards regulating gravel mining activities more effectively in order to improve availability of productive agricultural lands in the area.

6.3 Limitations of the Study

Although the research generally achieved its aims and objectives, there were some limitations in the following ways:

i. The research was conducted in Savelugu-Nanton District, one district out of twenty districts in the region. Though findings obtained are valid, they may not be representative of the entire Northern Region in particular and entire nation at large.

ii. The questionnaire administration was conducted during the harvesting season and this discouraged respondents interest and motivation in joining focus group discussions that followed. The discussions could have been richer and results more representative.

iii. The study did not assess impacts of gravel mining on soil microbial biomass in the district which would have enhanced the findings.

6.4 Recommendations for Future Research

The following recommendations for research are suggested:

i. Similar studies should be extended to six more districts in the northern region. Results obtained from these would then be more representative as far as the Northern Region is concerned. This would also give a broader picture of the problem to ensure that a more holistic approach is adopted.

ii. A further study is needed to assess the impacts of gravel mining on soil microbial biomass in the district since the study did not cover that area.

iii. Further research would also be required to assess gravel mining impacts on below-ground biomass in the district.

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APPENDICES

Appendix 1: One-way ANOVA: Litter biomass versus Treatment

Source	DF	SS	MS	F	P
Treatment	3	26.6268.875112.980.001			
Error	8	0.6280.786			
Total	11	27.254			

Appendix 2: One-way ANOVA: Low growing flora versus Treatment

Source	DF	SS	MS	F	P
Treatment	3	35.99	12.00	4.830.033	
Error	8	19.852.48			
Total	11	55.84			

Appendix 3: One-way ANOVA: Tree biomass versus Treatment

Source	DF	SS	MS	F	P
Treatment	3	127.2542.424.32		0.044	
Error	8	78.57	9.82		
Total	11	205.82			

Appendix 4: One-way ANOVA: Total AGB versus Treatment

Source	DF	S	MS	F	P
treatment	3	482.66160.89193.00.001			
Error	8	0.001	0.001		
Total	1	482.67			

Appendix 5: One-way ANOVA: Sand versus Treatment

Source	DF	SS	MS	F	P
Treatment	3	226	75	0.35	0.787
Error	8	1704	213		
Total	11	1930			

Appendix 6: One-way ANOVA: Clay versus Treatment

Source	DF	SS	MS	F	P
Treatment	3	493	164	1.30	0.340
Error	8	1013	127		
Total	11	1506			

Appendix 7: One-way ANOVA: Silt versus Treatment

Source	DF	SS	MS	F	P
Treatment	3	153	51	0.45	0.724
Error	8	907	113		
Total	11	1060			

Appendix8: One-way ANOVA: BD versus Treatment

Source	DF	SS	MS	F	P
Treatment	3	2.27	0.76	0.45	0.725
Error	8	13.49	1.69		
Total	11	15.76			

Appendix 9: One-way ANOVA: N versus Treatment

Source	DF	SS	MS	F	P
Treatment	3	0.001006	0.000335	1.30	0.339
Error	8	0.002061	0.000258		
Total	11	0.003067			

Appendix 10: One-way ANOVA: P versus Treatment

Source	DF	SS	MS	F	P
Treatment	3	13.00	4.33	1.61	0.262
Error	8	21.53	2.69		
Total	11	34.53			

Appendix 11: One-way ANOVA: K versus Treatment

Source	DF	SS	MS	F	P
Treatment	3	15263	5088	6.97	0.013
Error	8	5838	730		
Total	11	21100			

Appendix 12: One-way ANOVA: CEC versus Treatment

Source	DF	SS	MS	F	P
Treatment	3	142.2	47.4	4.03	0.051
Error	8	94.1	11.8		
Total	11	236.3			

Appendix 13: One-way ANOVA: OC versus Treatment

Source	DF	SS	MS	F	P
Treatment	3	26.93	8.98	16.11	0.001
Error	8	4.34	0.54		
Total	11	31.27			

Appendix 14:One-way ANOVA: pH versus Treatment

Source	DF	SS	MS	F	P
Treatment	3	2.206	0.735	3.35	0.076
Error	8	1.758	0.220		
Total	11	3.963			

Appendix 15: Questionnaire

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY
FACULTY OF RENEWABLE NATURAL RESOURCES
DEPARTMENT OF AGROFORESTRY

Ecological and Socio-economic impacts of gravel mining in the Savelugu-Nanton District of Northern Region, Ghana
Questionnaire/Interview Schedule

Questionnaire No………….. **Date:………**

The researcher is a final year student of the above university who is offering a post graduate programme in Agroforestry of the faculty of Renewable Natural resources,Kwame Nkrumah University of Science and Technology. He is conducting a study on the topic: **Eological and Socio-economic impacts of gravel mining in the Savelugu-Nanton District of Northern Region, Ghana**. This study is solely meant for academic purpose only, and any information obtained would be treated with all the confidentiality that it deserves.

Instructions:

SECTION A

PERSONAL DETAILS/HOUSEHOLD CHARACTERISTICS OF RESPONDENTS

(1) Name of respondent (Optional)…………………………………………….

Age

(i) 20-30 [ ] (ii) 31-40 [ ](iii) 41-50 [ ]

(iv) 51-60 [ ] (v) > 60 years [ ]

(2) Sex

(i) Male [ ] (ii) Female [ ]

(3) Marital status

(i)Married [ ], (ii) Single [ ], (iii)Divorced [ ], (iv)Widowed [ ].

(v) Other, specify……………………………………………………………………………...

(4) Educational background of respondents

(i)Primary [ ] (vi) Junior High School [ ]

(ii) Senior High School [ ] (vii) MSLC [ ]

(iii) Higher National Diploma [ ] (viii) Diploma [ ]

(iv) University Degree [ ]

(v).Commercial/technical/Vocational [ ]

(ix) Certificate "A (Teacher training) [ ]

(5) Number of children …………………….

(6) Ethnicity Migrant […..]; Indigene […..]

(7) Principal occupation

……………………………………………………………………………………………

SECTION 'B'

PERCEPTIONS AND THE SOCIO-ECONOMIC IMPACTS OF GRAVEL MINING ON LOCAL COMMUNITIES IN THE DISTRICT

(8) What are the major income generating /economic activities in the district in order of importance?

(i) Livestock production (ii) Cultivation of food crops (iii) Petty trading (iv) Fishing

(v) Shea butter extraction (vii) Rice processing (vii) Hunting (viii) others specify

(9) Is there any evidence of people in the community engaging in gravel mining in this community?

(i) Yes (ii) No

(10) Was the gravel mining site once used for farming activities?

(i) Yes (ii) No

(11) If yes, what was the average yield per hectare?

……………………………………………………………………………………………..

(12) Which crops were being cultivated?

…………………………………………………………………………………………….

(13) What was the average yield per hectare per crop?

…………………………………………………………………………………………….

(14) What are your current average yields per hectare?

………………………………………………………………………………………………..

(15) It can be observed that trees are mostly not found on the gravel mining sites, is it that they have been destroyed through the gravel mining?

(i) Yes (ii) No

(16) If yes, what tree species were found there?

………………………………………………………………………………………………
..

(17). Do you consider gravel mining a widespread economic activity in the district?

(i)Yes (ii) No

(18) Can gravel mining create a reliable and alternative job opportunity for inhabitants in the district?

(i) Yes (ii) No

(19) Have you ever paid a visit to the site of gravel mining in the community /district?

(i) Yes (ii) No

(20) If yes, how can you describe the methods used in the gravel mining activity in terms of its impacts on the soil/environment?

(i) Very good (ii) Good (iii) Very bad iv) Bad (v) Not certain.

(21) Methods used by gravel miners are responsible for the degradation of land in the area.

(i) Strongly agree (ii) Agree (iii) Strongly disagree iv) Disagree (v) Not certain.

(22) The activities of gravel miners is contributing to the scarcity of agricultural lands

(i) Strongly agree (ii) agree (iii) strongly disagree (iv) disagree (v) not certain.

(23) What is the current relationship between those mining gravel and the residents in the area?

(i) Very cordial (ii) Cordial (iii) Very bad (iv) Bad (v) Not certain.

(24) Give reasons to support your answer in (23) above…………………………………………

(25) Have there been any conflicts between miners and community members in the past?

(i) Yes (ii) No

(26) If yes, what was the cause of the conflict? …………………………………………………..

(27) As a result of water collecting in gravel pits in the rainy season, do you have occurrence of diseases in the area?

(i) Yes (ii) No

(28) If yes, what are the common diseases?

(i) Malaria (ii) Dysentery (iii) Typhoid (iv) Bilharzias (v) Airborne (vi) STD/HIV (vii) Worms

(29) Do you have the following other impacts of gravel mining common in the area in order of severity?

(i) Deforestation (ii) Diseases (iii) Reduced farm size (iv) Lost of farmland (v) others, mention ……………………………………….

(30) Are farmers able to put abandoned mine sites into agricultural use after some time?

(i) Yes ii) No

(31) If yes, after how many years of abandonment are such lands put back into agricultural use?

……………………………………………………………………………………………………..

(32) Can soil fertility improvement methods to increase farmers` yields or support their socioeconomic status be possible if the indiscriminate gravel mining continue to exist?

(i) Yes (ii) No.

(33) What do you think can be done generally to solve problems of the harmful effects of the phenomenon and to improve upon it……

THANK YOU FOR YOUR ATTENTION