IMPACTS OF ARTISANAL AND SMALL-SCALE MINING ON THE ENVIRONMENT IN PARTS OF NASARAWA STATE, NIGERIA

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PhD/SPS/2016/947

THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGER STATE, NIGERIA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF PhD DEGREE IN ENVIRONMENTAL MANAGEMENT

JULY, 2023

ABSTRACT

The impacts of artisanal and small-scale mining (ASM) on soil and surface water in parts of Nasarawa state was assessed. The study examined the impacts of ASM on social and *economic lives of miners, mine owners, community members and professionals in Awe, Keana and Obi Local Government Areas. Qualitative method; (fifteen (15) soil and water samples (wet and dry seasons) were analyzed using the Atomic Absorption Spectroscopy (AAS) method at LABCHEMNEC JANS LTD, Abuja an accredited laboratory by the National Institute of Science Laboratory Technologists), because water and soil affect human health, plant and the environment adversely if managed and quantitative method; (fieldwork (visits to sites, insitu observation and sampling), Key informants' interview, focus group discussions and questionnaire administration) were adopted. Findings revealed that baryte, copper, lead, salt, baryte with shoots of copper and charcoal, low grade iron and sandstone are mined in the study areas. Also, Land use and land cover study revealed alarming changes at rates of 41%, 38% and 34% for Awe, Obi and Keana respectively within the four epochs of 1986-2016, indicating that Awe is the most degraded due to ASM activities. Socioeconomic study revealed that environmental changes increased as the population and mining activity increase. Similarly, opinion of mine owners, workers, professionals and community members revealed that: the practice of backfilling of mining pit would have a strong positive impact on the mine's sites, Water de-sedimentation before discharge into rivers would have a strong positive impact on lifestyle and health of the humans, flora/fauna. Reclamation, reseeding and chemicals management will have strong positive impact on environmental management. Improving soil retention, water quality and air quality in the mining sites is a necessary adaptive measure with ornamental plants to reduce deforestation and major landscape change. Improved access to water through education of mine owners and workers on sustainable environmental and health practices. Furthermore, the study revealed that iron was highly concentrated and was above the Upper Continental Crust (UCCC) limit of 3.5. For Zinc, most sites recorded less than the UCCC of 71 but Abuni (ABU) and VNI with 730.7 and VN1 71.57 respectively were above the UCCC standard. For Copper (Cu) ADU, ABU, Keana Vein, and Vein 17 (VN17), and Vein 18 recorded values of 40.89, 58.63, 41.55, 50.76 and 32.42 respectively above the UCCC limit of 25. Lead (Pb) was absent in most of the sites, but locations like ADU, Sauni Sarki with 778.5, Sauni Sarki (SS), and and Vein 1 (VN1) with 778.5, 216.6 and 81.83 respectively were far above the UCCC standard of 20. Furthermore, for water quality, the study also established that, the temperature of water at the various mining sites were below the 40-degree Celsius permissible limit as prescribed by the Federal Ministry of Environment of Nigeria; with only AKSM recording the highest value of 37.9 degree Celsius in dry 25 degrees Celsius during the dry season. Lastly, the study showed that ADU, AKS, AKSM, AKWS and KNS had Total Dissolved Solids (TDS) values greater than the standard limit of 500mg/l, which can have serious health implications Obi local government area (LGA) with one site has the least pollution, while Keana with seven mine sites is next to Awe having thirteen mine sites due to the number of mine sites in the LGAs. An adoption of this research work by the Nigerian Geological Survey Agency (NGSA), Ministry of mines and steel development (MMSD), Non-government organizations (NGOs), National Environmental Standards Regulation and Enforcement Agency (NESREA) and Town Planning agency as an environmental management plan for miners, operators and workers will reduce the impact of ASM on the environment.*

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ABBREVATIONS

ASM	Artisanal and Small-Scale Mining
EA	Environmental assessment
EIA	Environmental Impact Assessment
SEA	Strategic Environmental Assessment
NGSA	Nigerian Geological Survey Agency
LULC	Land Use and Land Cover

PI	Pollution Index
Igeo-	Geoaccumulation Index
EF-	Erichment Factor
WGS 84-	World Geodetic System
UTM-	Universal Transverse Mercator & Datum
TIRS-	Thermal Infrared Sensor
OLI-	Operational Land Imagery
TM	Thematic Mapper
ETM+	Enhance Thematic Mapper Plus
SEA	Social Environmental Assessment
MIREMCO	Mineral Resources and Environmental Management Committee
NGSA	Nigeria Geological Survey Agency
NESREA	National Environmental Standards Regulatory and Eforcement Agency
FEPA	Federal Environmetal Protection Agency
FME	Federal Minstry Of Environment
MMSD	Ministry of Mines and Steel Development
LULC-	Land Use and Land Cover
https-	hypertext transfer protocolsecure
IDRISI Terrset-	Terrset Software
MSO	Microsft Word Office 2013
ME	Microsft Excel
ASM	Artisanal and Small-Scale Mining/Miner (S)
%	Percentage
MC	Metal Concentration
^{O}C	Organic Carbon
NTU	Nephelometric Turbidity Unit
TDS	Total Dissolved Solvent
OC	Degree Celcius
TSS	Total Suspended Solids
DO	Dissolved Oxygen
EMP	Environmental Management Plan

KG/L	Kilogram Per Liter
CSR	Cooperate Social Responsibility
GDP	Gross Domestic Product
ADU	Adudu
ABU	Abuni
KNV	Keana Vein
SS	Saunin Sarki
SQL	Structure Query Language
SHR	Sohon Rami
VEN17	Vein 17
WSV	Wuse Vein
AKS	Akiri Salt
AKSM	Akiri Salt Mine
AKWS	Akiri Warm Spring
VN2	Vein 2
V18E	Vein 18
VN1	Vein 1
KDK	Kuduku
OTM	Otome
KNS	Keana Salt

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Mineral mining is a major economic activity in many developing countries. Throughout the world, mining is carried out basically in resource endowed areas. Mining is an activity which has to pass through a lot of processes before the final product is arrived at. Mining activities have attracted a lot of attention in the world over as many people are involved and several economies are affected by various mining processes. Significant changes in global mining investment flows occurred in the 1990s as a result of the changes in national regulatory frameworks in over 90 countries of the world (Bridge, 2004; Dougherty, 2011). One of the numerous repercussions of these shifts has been an increase in investment flowing via South America and into Africa.

Mining is seen with two spectacles; a blessing or a curse. This assertion depends on how an area, group, community or country is positively or negatively impacted by these activities and processes of exploitation of the mineral resources (Kitula, 2006). The continent Africa is heavily endowed with abundance of mineral resources, for example, Africa has about 30 % of the world mineral reserves these ranges from deposits of gold (40 %), cobalt (60 %) and platinum (70 %) respectively. Africa produces an estimated 70 % of platinum, 30 % gold, 28 % palladium, and 16 % bauxite world over (Apam, 2014).

Artisanal and small-scale mining (ASM) in many developing nations, is becoming a substantial socioeconomic activity for most rural poor (Hilson, 2009). In effect, small-scale artisanal miners are largely subsistent miners. Artisanal miners are not formally hired by a mining firm; however, they work panning or mine for gold on their own for precious minerals like gold, barite, calcite, coal, granite, iron ore, kaolin, lead, limestone, mica, river alluvium, schists and tantalite using personal resources. Small-scale mining entrepreneurs are businesses or people who hire personnel to mine, but who mostly use hand tools (Banchirigah, 2008). Artisanal miners frequently engage in seasonal activities, such as farming during the season of rain and mining during the dry seasons. They do, however, regularly go to mining locations and labor all year.

The artisanal mining sector employs an approximated 13-20 million children, adult male and female from over 50 developing nations (Hilson, 2002). Siltation of water, soil degradation and erosion can occur in rivers found near mining sites as a result of the excavating of particles of soil and soil sluicing involved in the artisanal mining processes. Rivers are frequently diverted to get access to mineral-rich riverbeds. Mine excavation can also expose and spread dangerous pollutants such as lead that are present in the soil. Most activities related to artisanal mining take place in forest surroundings home to large number of biological diversities, therefore forest protection is also a major priority. Ford *et al.* (2010) reported that some mining activities are also said to operate within environmentally protected zones.

An environmental impact assessment (EIA) evaluates the environmental repercussions (both good and negative) of a plan, policy, program, or specific project (Pope and Morrison-Saunders, 2004). Environmental impact assessment (EIA) in this context refers to particular initiatives carried out by businesses, people and government as a strategic environmental assessment (SEA). It refers to policies, programs and plans proposed by agencies of the government (Fischer, 2010). Assessments of mining impact on the environment may be subjected to judicial evaluation which are controlled by procedural administrative regulations governing involvement of the public and decision-makers.

1.2 Statement of the Research Problem

The impacts of artisanal and small-scale mining observed in Awe, Keana and Obi Local Government Areas of Nasarawa State, Nigeria is that miners abandon mining sites once they have exploited the mines up to their capacity. Such abandoned sites constitute environmental hazards and lead to erosion, land degradation, and leaching of heavy metals into nearby waterways and farm lands.

The rate of extinction, exploitation, digging, clearing of the earth/land for human need in the quest to earn livelihood with no recourse to the impact of these activities on the environment is the reason for this research. Soil and water contamination due to ASM activities leading to loss of Agricultural land for farming cannot be over looked; the quality of food, health and lifestyle of any community depend on the quality of soil and water available and accessible to the people; this in-turn determine the economic activities practiced by the people. In Awe, Keana and Obi Local Government Areas of Nasarawa State, Nigeria; ASM activities are on the increase and are carried out without recourse to compliance with National Environmental Standards making these activities unsafe and unsustainable.

1.3 Research Questions

i. What are the types of mineral ores mined in the study area?
ii. What is the trend of land use and land cover (LULC) in the study area?
iii. What is the impact of Artisanal Small-Scale Mining on the environment of the study area?
iv. Are the mining activities in the study area in compliance with the National Environmental Standards?

1.4 Aim and Objectives of the Study

The aim of this study is to assess the Impact of Artisanal and Small-Scale Mining activities on the environment in parts of Nasarawa State, Nigeria. The specific objectives are to:

i. Examine the types of mineral ores in the environment of the study area,
ii. Analyze the trend in land use and land cover changes of the study area,
iii. Assess the environmental impacts of Artisanal Small-Scale Mining in the environment of the study area,
iv. Compare the environmental degradation outlook of the study area with the Federal Ministry of Environment Standards.

1.5 Justification for the Study

The industrial mining of minerals like the phosphate, kaolin, baryte, gypsum, talc, mica and feldspar as well as construction minerals such as granites, gemstones, sands, marbles; or metallic minerals such as dolomite, tantalite, columbite lead and zinc are among the minerals commonly mined by small-scale artisanal miners in Nigeria (MMSD, 2008). The mining of these minerals leads to land degradation, which is a regular occurrence in most unmanaged, unmonitored and uncontrolled small-scale mining operations. Landscapes are also significantly harmed by small-scale artisanal mining undertakings. Artisanal small-scale mining operations, in particular, are responsible for the loss of huge amounts of vegetation on the soil surface and extensive land deforestation as a migratory business (Mensah *et al.,* 2015). Lead is a recognized toxin that has no known good effects on the human body. It harms brain, liver, kidneys, the reproductive and central nervous system (Lovei and Levy, 2000).

Since the 2010 lead poisoning crisis in Zamfara, the health and environmental consequences of ASM in Nigeria have received a lot of attention. ASM presently contributes the most to worldwide emissions of anthropogenic mercury, accounting for 37 % of all emissions (Zielonka *et al.*, 2012). As a result, knowing the impact of mining and the changes it causes on the environment may aid in the development of sustainable management techniques and, as a result, the reduction of environmental problems in the affected regions (Korir, 2014). The justification of this study is arising from the need to obtain in-depth data of the minerals mined and the extent of their compliance to relevant laws and regulations as they impact the environment. In line with the above, the activities of ASM in parts of Nasarawa State was investigated with focus on land use and land cover changes over time while assessing the extent of water and soil contamination in relation to socio-economic impact. Evidence abound that much has not been studied and documented on thorough impact and associated health risks of artisanal and small-scale mining activities in Nasarawa State, Nigeria. This study and the results obtained filled that gap.

1.6 Scope and Limitations

The research was conducted within the scope of establishing the extent of degradation of land use and cover (LULC) due to Artisanal and Small-scale Mining activities and the limitation to this work is to compare the extent of soil and water contamination in mining sites of the (study area) environment in parts of Nasarawa state to the national standard for sustainable Artisanal and Small-scale mining practice. The study covered three local government areas for the extent of LULC degradation. The major areas are Awe, Obi and Keana as shown in (Figure 1.1), they were selected for extent of degradation of land use and cover due to Artisanal and Small-scale Mining activities and its implication on the environment of the study Areas.

The justification for the selection of these areas is that the areas are known for high deposit of different minerals which can be used for the socio-economic development of the area and the country at large. Soil and water samples were collected across the study area for laboratory analysis, also, Data from Landsat TM, Landsat ETM+ and OLI for 1986, 1996, 2006 and 2016 were utilized and the processing was purely remote sensing and GIS-based, integrated with Global Positioning System (GPS), topographic map data and detailed ground truthing of the study area. Other ancillary data employed were Google Earth images and ASTER GDEM data.

The limitation to this work borders on the time required to attend to respondents at their various level and in returning questionnaires. Due to limitation of funds, the number of water and soil samples was limited to 15 samples covering three different local governments in the study areas.

1.7 The Study Area

The study area is discussed under various sub-headings which are listed here.

1.7.1 Geographical location of the study area

Nasarawa State was established in October 1996 as a geographical entity (Binbol and Marcus, 2010). It is strategically located in Nigeria's middle belt area. The state is located along the Equator within latitudes 7° 45' and 9° 25' N and along Greenwich meridian on longitudes 7° 29' and 9° 37' E. Nasarawa state is bordered by the state of Kaduna on the north, the state of Plateau on the east, state of Taraba and Benue on the south, and on the west by the Federal Capital Territory and Kogi state. The entire land area of the state is 27,138.8 square kilometers, and has population density of around 67 people per kilometer square (Mamman *et al*., 2016). Nasarawa State is divided into 13 local government areas out of which three (3) Awe, Keana and Obi Local Government Areas of Nasarawa State, Nigeria was selected for study as shown in Figure 1.1.

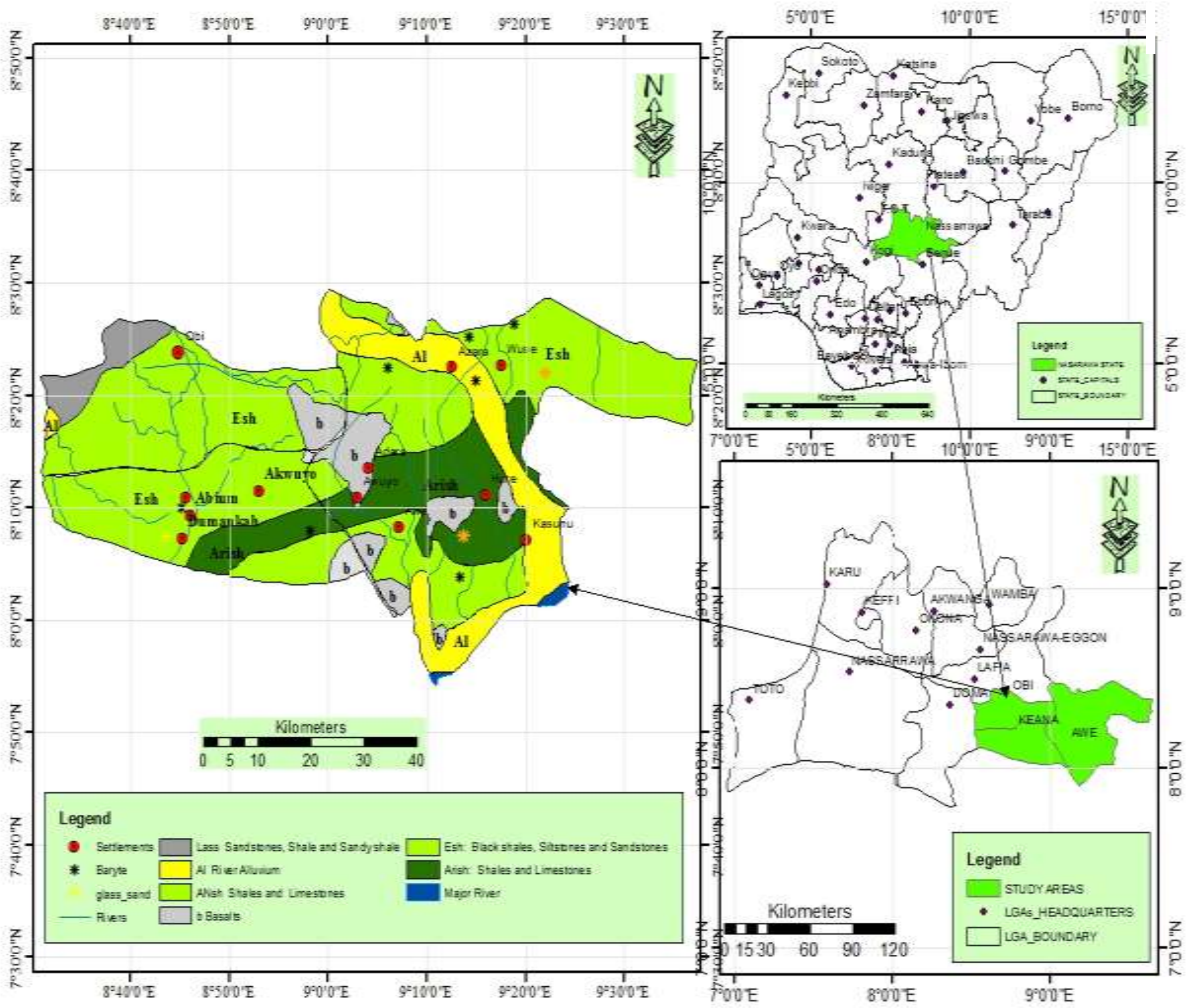


Fig. 1.1: T**he Study Area (Keana, Obi and Awe LGAs, Nasarawa State, Nigeria).** Source: Nigeria Geological Survey Agency (NGSA), 2023.

1.7.2 Physical settings

Nasarawa State's landscape is characterized by hills, dissected terrain, undulating plains, and lowlands (Binbol and Marcus, 2010). A walk from the south to the north of the state reveals that the southern Awe, Toto and Doma local government areas of the Nasarawa are surrounded in the south by the Benue River. Its troughs and valleys stretch over 30 kilometer inland, which comprises of flood plains of the Benue River that are normally lower than 250 meters in elevation. The floodplains extend farther along the inland of the river banks Guma, Ayani, Farin Ruwa, Dep and Mada. All of the rivers flow into Benue River.

1.7.3 Climate

Nasarawa State is characterized by sub-humid tropical climate (Binbol, 2007; Lyam, 2000). Lyam (2000) stated that the area is characterized by two distinctive rainfall seasons with the wet season beginning from April and lasting still the ends in October. The twelve-monthly rainfall in the area ranges from about 1100 to 2000mm with about 90 % rainfalls within the months of May to September. The wettest rainfall months are July and August. Binbol (2007) added that rainfall occurrence is mostly in form of frontal and conventional nature. The rainfalls usually come with thunderstorms and high intensity at the onset and toward the termination of the rainfall season (Lyam, 2000). Generally, temperatures are high in the state especially during the day, partly because of the state's location in sub-humid tropical climate (Binbol, 2007; Lyam, 2000). Binbol (2007) observed that temperature gradually increased between the months January and March before the start of rains around the month of May which ushers in noticeable temperature declines. Average monthly temperatures range between 26.8^0C and 27.9^0C (Binbol, 2007; Lyam, 2000), while the hottest months include April and March. The months that are coldest include December and January (Lyam 2000). Unlike the other elements, wind velocity in this region is relatively steady (Binbol, 2007).

1.7.4 Vegetation and soil

Nasarawa State is classified under the Southern Guinea Savanna Zone (Lyam 2000), with some characteristics of Northern Guinea Savanna (Aboki *et al.*, 2007). However, the vegetation is cleared for farming, firewood harvesting, saw-milling for cottage industries as well as domestic uses. The development and regrowth of vegetation are at different levels. Aboki *et al.* (2007) explain that the vegetation of the study area, which lies in the Guinea Savanna is derive from temperate deciduous woodland that existed centuries ago. They added that the vegetation is characterized with interspersions of thickets, grassland tree savannah, and fringing woodland or gallery forests along the valleys.

The dominant woody species in this area include *terminalia laxiflora, albizia zygia, ficus exasperate, ficus syncomorous, khaya senegalesis*, *tarmarindus indica* (tsamiya), *parkia biglobosa* (Doruwa), *vitellaria pradoxa “Kadanya” or* Shear butter), *vitex doniana* (dinya), *Annona sengalensis* (Aboki *et al.,* 2007). They listed the species of grasses that are found in the state as *penisetum, andropogan, monocymbium, ceressiformse, hyparrhernia, brancharia* and *aristida* among others. Lyam (2000) confirmed that the vegetation on the hilly parts compose mostly isolated trees and grasses.

The key units of soil in the study area are categorized into oxisols or tropical ferrigenous types of soils (Nyagba, 1995 cited in Lyam, 2000). The predominant soil parent materials in the area are derived from the cretaceous sandstone, siltstone, shale and ironstone of the Precambrian to Cambrian (Samaila and Ezeaku, 2007). According to Lyam, (2000), the hilly regions carry superficial skeletal type of soils and some part of the regions are heavily gulled. Since most people in the area are farmers, extensive clearing of land occurred for farming activities, thus exposing the land in the areas sheet erosions.

1.7.5 Relief and drainage

The Maloney Hill found in the state is a historic relief feature. All the rivers in the State are tributaries of other larger rivers (Ogah *et al.,* 2013). Water resources in the area include surface water (River Wuse in Awe and Akeana stream in Keana LGAs) and ground water. The surface water in the region is found in river channels, rivulets, streams and rivers. The presence of water on the surface however varies in space and time. The amount of water available for human exploitation is affected by climate and the geology of the area.

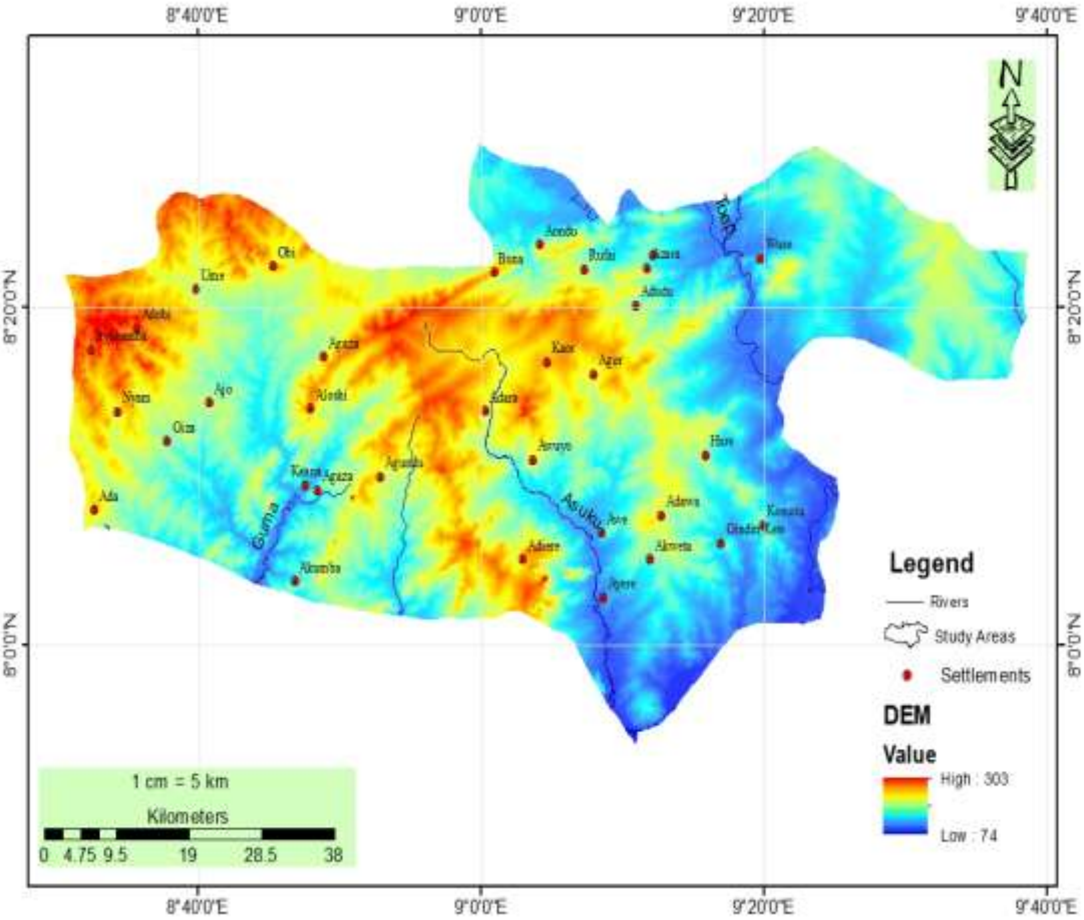


Figure 1.2 Relief Map of the Study Area

Source: Author's field work, 2023

The surface water in the area is usually seasonal. During the dry season, water becomes limited and can only be found in perennial streams and rivers. Surface water is further depleted in the dry season by high evaporation and seepage. The region is made up of basement complex rocks which are exposed to the surface and raised to meaningful heights thereby constituting the water-shed for most streams and rivers (Adamu, 2011). Water embedded in underground sources is also important for water supply in the area. Groundwater in the region also varies in time and space in terms of quantity and quality. This variation is attributed to the nature of rock, climate and other environmental factors.

These ground waters are usually tapped through wells and boreholes. (Samaila and Binbol, 2007).

1.7.6 Communication and transportation

The dominant Indigenous tribes in Nasarawa State include Alago, Tiv, Angaz, Akwala, Fulani, Hausa, Gbagyi and Yoruba (Dalat and Filaba, 2007). Traditional religions may be found all throughout the world. But the two most popular religious groups (Christians and Muslims) had a bigger influence on the general public (Lyam 2000). The social organization and culture reflect their traditional religious affiliations. While Hausa and English are widely spoken, Lyam (2000) explains that all ethnic groups in the area also have their own dialects or languages.

Transportation modes in the State includes head portage and road transport (Onosemuode 2007). The state is well connected to other parts of the country through trunk A Federal tarred road, for example Abuja-Keffi expressway, Keffi –Abuja-Lafia-Makurdi Road, Keffi-Akwanga-Jos Road, Keffi-Kaduna Road, keffi-Nasarawa-Toto Road etc. (Onosemuode, 2007 and Lyam, 2000). According to Lyam (2000), Road transportation is the most common mode of transportation in Nasarawa state, Motor vehicles and motor cycles are predominantly used and bicycles are also used by few. Movement of people and resources depends on these modes of transportation in the state. He added that Nasarawa State do not have airport, but the state serves the Abuja airport.

1.7.7 Geology

The Keana Formations and Late Albian - Cenomanian Awe (containing primarily of sandstones intercalated with bands of clays and shales) and Cenozoic volcanoes make up the research area, which is located in Nigeria's Middle Benue Trough (Patrick *et al.*, 2013). The bedding, cross bedding, graded bedding, huge bedding, mud cracks, lamination, joints and folds were all detected on the field. The principal structural tendencies are directed in the following directions: NE-SW, NW-SE, NNW-SSE and WNW-ESE.

The trough of the Benue is an intra-cratonic rift that stretches across the north of Niger Delta boundary to the Chad Basin's southern borders (Likkason, 2007). For convenience of charting, the valley is split geographically into the Upper, Middle and Lower Benue troughs; an area inhabited by about 600 m of fluviodeltaic and marine sediments compressed into folded non-orogenic shield environment. The research region at Abuni and its surrounds is a part of the Middle Trough of Benue, which is of special importance in this study (Awe Local Government Area of the State). The research region falls under south-eastern section of the State, encompassing roughly 36 km^2, and two of the six formations of sediments on the Middle Trough of the Benue.

The Keana Formation, Awgu Formation, Asu River Group, Awe Formation, Ezeaku Formation and finally the Lafia Formation are the six formations, with the Awe Formation and Keana Formation forming two of the exposed formations in the study area. The Awe and Keana Formation compose sandstones with intercalated of calcareous claystone and shale covered by laterite that results from the volcanic weathering of rocks that were emplaced within (Ene *et al*., 2012).

Falconer (1911) claimed that the Asu River Group happened to be the oldest marine sedimentary formations in the Middle Benue Trough of Nigeria, and it is known as the "Lower Shale." Tattam (1944) the lithological units characterized as the "Cross River Series,"—a term which referred "Asu River Group". The Keana Formation was assumed to be the northern equivalent of the "Muri Sandstones." The formation in the Lafia-Awe region was later dubbed the "Keana Sandstone" by Cratchley and Jones (1965). Simpson (1954) characterized a series the shale into hard dark grey to black flaggy calcareous shale, sandstone and siltstone within the streams of the south along the Okigwe-Afikpo road as the "Ezeaku Formation" in the literature. Shell-BP geologists were the first to notice the formation.

The structural organization and geometries of the sub-basins, that is, the Upper, Middle and Lower Benue regions are attributed to sinistral wrenching, which is dominated by tectonic processes, according to research on the structural geology of the area (Benkhelil, 1989). He had previously identified the Nigerian Benue Trough, an intra-cratonic rift structure, stretches from the north boundary of the Niger Delta to the south margins of the Lake Chad Basins. A thorough gravity survey carried out in 1979 by Ajayi and Ajakaiye (1986) in order to explore the regional structure of the Middle Benue, was to describe the depth, intrusions, folds and faults, which constitute the key regional structures of interest. In terms of economics, Offodile (1976) conducted a study on mineral resources of the Trough of Benue which identify zones with specific mineral resources. In the same way, (Akande *et al*., 1992) conducted another thorough investigation on the genesis of the Benue Trough's Lead-Zinc-Fluorite-Barite deposit. Offodile (1992) defined a water-bearing aquifer and described the Middle Benue Trough's water chemistry and quality as satisfactory. The goals of these studies were to look at the environmental effects of artisanal small-scale mining (ASM) in Abuni mining areas and its surrounding.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Regional Geology of Benue Trough

The Benue Trough has been extensively researched because of its remarkable geologic characteristics (Offodile, 1984; Obaje, 1994; Obaje *et al*., 2006). Offodile, 2014; Bata *et al*., 2018) all pointed that the Trough stretches 800 kilometers beginning at Niger Delta and ending at the south-west in the Lake Chad basins, trending NNE-SSW and varying in breadth from 130 to 250 kilometers (Patrick, Fadele and Adegoke, 2013). The saline ground waters in the Central Benue Troughs and Southern is commonly linked to tectonic components like mineralized intrusive veins, leading to conclusion that the seawaters are not restricted to any type of bedrock but have comparable properties to hydrochemicals. The Middle Benue Trough's Keana-Awe axis is Nigeria's largest baryte, copper and lead-zinc mining region (Bata *et al*., 2018).

Also, underlain the region is Cretaceous sedimentary rocks from the Ezeaku Formations, Awe, Asu River and Keana, according to the research. Molybdenum, copper, barium, cobalt, chromium, and nickel are severely enriched in the soil's trace elements of the Awe and Keana brine fields, while zinc and arsenic are the excessively concentrated metal pollution of surface sediments can have a direct impact on groundwater quality, with possible health effects (Christophoridis *et al*., 2009). This can lead to disorders including liver and thyroid damages (Meunier *et al*., 2005).

2.2 Conceptual Framework

The influence of mining on the wellbeing of the environment and human lives is depicted in the conceptual framework. This conclusion is based on a survey of the literature. On the ground, mining methods might be either underground (deep shaft) or surface. There are environmental and health consequences to any of these strategies. The environmental effect of mining operations is astounding (Akcil and Koldas, 2006). To begin with, mining activities necessitate the purchase of enormous swaths of land. Both deep and surface mining harm the land surface since the entire forest is destroyed. As a result, farmland and other agricultural land is being lost. Furthermore, spills of chemicals such as lead and other harmful compounds into neighboring streams pollute the water, harming aquatic life and damaging water bodies. Human health is also harmed by exposure to such substances. Gas and other types of vapour created by heavy machinery and equipment, as well as other substances, contribute to air pollution in the environment.

Several health consequences are linked to mining operations; (Zhao *et al*., 2012) point out that mining activities such as rock blasting cause air and noise pollution, which affects people in the surrounding regions. Respiratory infections in upper tract such as asthma, cancer, cough and cold can occur as a result of these factors. Acute conjunctivitis, malaria, diarrhea and accidents are also common in mining areas, all of which cause morbidity and mortality. As a result, mining firms often aim to establish health measures by offering health facilities such as hospitals, clinics and different types of health education. Regardless, the detrimental environmental and health consequences of mining activities are so severe that immediate action is required.

The cumulative environmental and health costs and harms of mining activities, according to the research examined, considerably surpass their economic and social advantages, the size of which cannot be calculated (Duker *et al.,* 2005). Due to the mining operations that come at a great cost in terms of health.

2.2.1 Artisanal and small-scale mining

Generally, artisanal and small-scale mining are mining activities done by individual, families, and cooperatives groups without any form of automation, usually done illegal (informal) markets. A common artisanal and small-scale mining (ASM) definition is yet to be established, even though numerous efforts. In certain countries, there are differences between 'artisanal mining,' which is entirely done manually and carried out on small-scale, and 'small-scale mining. The small-scale mining is more automated and carried out on a larger-scale compared to artisanal mining. The small-scale mining is differentiated from artisanal mining in several West African countries (Niger, Burkina Faso, Nigeria and Mali) due to the occurrence of fixed, permanent facilities constructed after proving the existing ore body. The phrases artisanal and small-scale mining are used interchangeably in this research.

It is feasible to put together the criteria utilized and stratify the mining business, and in particular, categorize the ASM operations, after revising the legislative dispositions controlling mining activities in different nations. This classification does not exclude the use of more than one criterion at the same time, nor does it imply that their use is contingent on the presence of particular references in the relevant mining legislation or the existence of a minor mining law. There are nations that have small mining programs that are not included in the country's mining legislation, and there are countries that have specific laws that handle small mining differently, like as Brazil's "Garimpo" or "Garimpogen" law. Following this explanation, the most commonly utilized criteria are:

i. The volume of production
ii. Number of persons per productive unit
iii. Amount of capital invested in the mining activity (intensity)
iv. Productivity of the manpower or labour
v. The size of mine claim
vi. Quantity of reserves
vii. Sales volume
viii. Continuity of mine operation
ix. Reliability of the mine operation

x. The mining cycle duration

Due to its various character, artisanal and small-scale mining (ASM) were described differently across the world (Maconachie and Hilson, 2011). The exploitation of minerals by impoverished people using rudimentary instruments such as diggers and shovels (spades) on a small scale is known as artisanal and small-scale mining. However, in recent years, the ASM sector has undergone steady expansion in several nations, resulting in the usage of complex technology.

Mining is the process of extracting mineral reserves from the earth's surface or under it (Nordstrom, 2011). The informal small-scale or artisanal small-scale miners and the official small-scale miners are the two most frequent mining industries in Nasarawa State. The latter contains untrained small-scale, informal, and often illegal miners who extract natural resources using primitive methods and procedures and who, in most cases, have little or no awareness of environmental problems (Aubynn, 2009). The study area's unregulated mining has exposed the environment to major risks such as the development and uncontrolled release of massive amounts of hazardous wastes, which have a negative impact on human health and the ecosystem (Hilson, 2008).

Semi-industrial, industrial small-scale and artisanal mining have similar and distinct issues. The ASM's most typical difficulties are depicted in Figure 2.1.

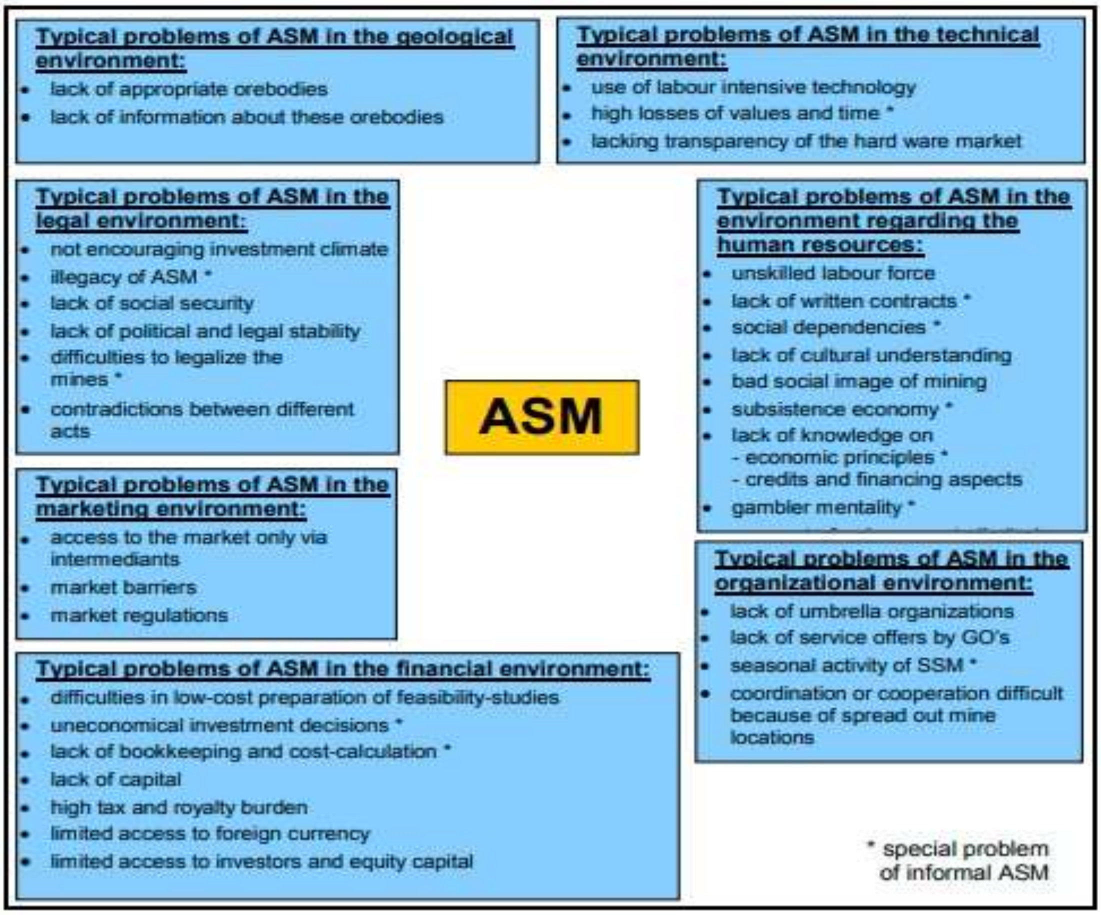


Figure 2.1: Typical Problems of Artisanal Small-Scale Mining (ASM)

Source: Author's field work, 2023

2.3 Assessment of Environmental Impacts

2.3.1 Purpose and definition of EIA

The Environmental Impact Assessment (EIA), a method, technique or tool used in the development of project and program decision-making (Ness *et al*., 2007). It's a systematic procedure for predicting the environmental repercussions of any project development. EIA guarantee the possible issues identified and addressed in the early design and planning of a project. Prior to reaching a final decision, an EIA is used to determine environmental implications, social as well as economic impacts of a planned development. The EIA as a process has been widely recognized and used in the international community (example, the UN 1992 Conference on sustained Development

Environments and the 1987 Brundtland Reports of World Commission on sustaining Development of the Environment) and European Communities (example, 1992 CEC) are key mechanisms for achieving sustainable development and protection of the environment (Jay *et al*., 2007).

Indeed, the Brundtland Commission's report emphasized the critical necessity of sustainable development and EIA to humanity's long-term well-being (Gibson, 1993). However, a specific principle (17) on EIA was unaccepted till the 1992 United Nations Conference on Development and Environment. This basically refers to EIAs' capacity to prevent, reduce, or negate negative substantial social, biophysical and other relevant consequences of development projects prior to their implementation, among other things. EIA as a result was a superb illustration of the principles of precautionary action for prevention of better compare treatment (Glasson, 1994).

2.3.2 EIA adoption by developing countries

The EIA is currently used in over 100 countries throughout the world (Wood, 2003). There are significant disparities between EIA systems in developed and developing nations, the same way a difference exists between EIA systems in developing and developed countries. Hence, many differences exist between the EIA situations in Eastern and Central Europe, where nations implement the Directive in Europe on the preparation of EIA for EU membership (Kolhoff *et al*., 2009). Southeast Asia and Latin America, where countries developed EIA systems with varying degree of effectiveness (Petts, 2009; Iwaro and Mwasha, 2010); and Africa, whereas many countries have no EIA system (Petts, 2009; Iwaro and Mwasha, 2010; Sandham and Pretorius, 2008).

For example, within Africa, the South African EIA system (Retief *et al.,* 2008) exhibits many of the characteristics of an urbane advanced nation EIA system, while EIA had become more relevant in countries like Ghana (Appiah-Opoku, 2001). In Somalia, though, EIA is not important. According to George (2000), there are variety of causes for differences in the scope, regulatory structure, and practical implementation of EIA in various developing nations. Administrative, social, resources, political, cultural structures on the characteristics and amount of economic growth are all factors to consider. In Nigeria, for example, there are several different types of EIA regulations (Ogunba, 2004). A good EIA system should evolve to include provisions for monitoring and auditing once decisions are made and implemented. According to Singh *et al*. (2008) follow-up assessments following development consent are needed to examine the accuracy of effect forecasts and guarantee improvements in project environmental design. In previous EIA studies, Lesirma (2016) mentioned another indicator: the granting of effective enforcement capabilities to EIA authorities. They connected the requirement for institutional frameworks, the agencies' ability to adequately implement legislation as well as conduct EIA evaluations.

Despite these differences, it is true that EIA in underdeveloped nations is generally considerably different from EIA in rich ones. The most notable distinction is that the earliest EIAs in developing nations were frequently requested on a project-by-project basis by development assistance organizations, rather than responding to widespread indigenous demands for stronger protections for the environment.

The introduction of the sustainable development agenda, according to Bhamra *et al*. (2015), was also a significant aspect in the creation of various Asian EIA systems. EIA was implemented later with less deeply ingrained in the process of developing poor and middle-income nations than in rich nations, according to Lee and George (2000). Notwithstanding that EIA standards in Colombia (1974) as well as the Philippines (1977) predated those of many affluent nations, the developing nations have just recently created official law underpinnings EIA development (Donnelly *et al.*, 1998).

Currently, there are several EIA examples among emerging nations, not all of which are the product of donor agency pressure (Biswas, 1992; Hildebrand and Cannon, 1993; Sadler, 1996; Briffett, 1999; Glasson *et al.*, 1999; Modak and Biswas, 1999; Lee and George, 2000). The countries where EIAs are developing include Chile (de la Maza, 2001), Brazil (Glasson and Salvador, 2000), Columbia, China, India (Banham and Brew, 1996; Egypt (Ahmad and Wood, 2002), Ghana (Appiah-Opoku, 2001), Ramanathan and Geetha, 1998; Selvam *et al.*, 1999), Indonesia (Boyle, 1998), Lesotho (Mokhehle and Diab, 2001), Lebanon (El-fadal, Zeinati, and Jamali 2000.), South Africa (Wood, 2002), Malaysia (Memon, 2000), Tanzania (Mwalyosi and Hughes, 1997), Swaziland, Sri Lanka, Thailand (Boyle, 1998), Zimbabwe (Adger and Chigume, 1992) as well as Turkey (Ahmad and Wood, 2002).

2.4 EIA Regulatory Framework in Nigeria

Adopting the Agenda 21, an environmental principles and practices blueprint that all countries must take into action was a policies actions of the United Nation Conference on Sustainable Development (UNCSD). This policy was a twenty-first century achievement of the UN which dubbed as the "Earth Summit" in 1992 Rio de Janeiro conference Brazil (Linner and Selin, 2013). The Declaration of the Rio on the Environment was a collection of environmental management principles which govern environmental behavior, and serve a crucial supporting tool of Agenda 21.

This was sign of their commitment to Declaration at the Rio conference which enables Federal Government of Nigeria to pass the 1992 Environmental Impact Assessment (EIA) Act No. 86. Project assessments in Nigeria were mostly restricted to feasibility studies and economic-cost-benefit analyses prior to the implementation of the EIA Act (Ameyan, 2008). The majority of these analyses ignored public opinion, social, environmental costs and consequences of developmental programs. In certain ways, the EIA Act is unusual. To begin with, it is Nigeria's first of its sort. Second, when projects or activities expected to have major effects on environment are planned, EIA is required. Third, unlike other environmental regulations, Environmental Impact Assessment is proactive. Its purpose is to avoid, lessen, or mitigate harmful consequences of activities and projects on the environment prior to their implementation. The EIA Act established the Federal Ministry of Environment an agency mandated to implement the EIA processes in all large developmental project, beginning with the stage of planning (Ogunba, 2004). The act guarantees potential environmental issues, as well as suitable mitigation measures to meet development's unavoidable repercussions, are identified and handled before the project execution and all through the period of the life cycle of project.

2.4.1 Application EIA implementation in Nigeria

The 1987 startling detection of hazardous waste deposited by an Italian business at Koko in the old Bendel State, the now Edo State, prompted Nigeria to adopt EIA (Adeh, 2010). The country came together unexpectedly to demand a workable law to defend and protect the environment from abuse and neglect. EIA is carried out in Nigeria in nine phases, according to Isah (2012), beginning with EIA processes, the EIA review processes. The EIA studies/report preparation involves public review, panel and in-house reviews, EIA mitigation, mediation and approval.

2.4.2 Procedures and requirement for EIA legislation

The Federal Environmental Protection Agency (FEPA), an agency initially charged with the responsibility of EIA implementation before it became the Ministry of Environment was the principal agency mandated by legislation (the 1992 Decree 86) of December, 1992. The agency was mandated EIA for all development projects in the public and private sectors (Ogunba, 2004). It contains thirteen principles and three aims. Prior to any authority or person deciding, beginning or approving a project undertaken, any action with probability of causing significant harm to the environment or have any environmental implications, such activity should be carefully considered.

In order to encourage deployment of proper processes in order to achieve the aforementioned aim. To stimulate the creation of reciprocal mechanisms for notice, information sharing, and consultative activities that are anticipated to have major trans-state (boundary) consequences on the environment. Prior to the introduction Decree 86 of the Nigeria Environmental Impact Assessment (EIA), examines the socioeconomic and environmental implications of key developmental projects was sparse, if not non-existent (Ameyan, 2008). The EIA recognition as a tool that improves preservation and management of the environment at national level began in the beginning of the 1980s. It was introduced by the 1981–1985 Fourth National Development Plan, fueled by increased environmental consciousness in many areas of the world.

This strategy, on the other hand, suggested the creation of environmental impact statements (EIS) for all feasibility studies (public and private) and required that an EIS contain strategies to mitigate a project's negative environmental consequences. A part on environmental protection and planning was made part of EIA in Nigerian development planning for the first time. Similarly, the application of EIA method for attaining sustainable development has been acknowledged in a number of national papers on the environment, construction, and agricultural policy (Hacking and Guthrie, 2008). Many academics have written about the need of EIA as a grassroots activist have pushed for restitution in Nigeria's natural resource zones, where mining may occur. In view projects which was submitted to complete EIA on Artisanal Small-Scale Mining in Nasarawa State, Nigeria, this chapter will analyze the EIA legislation and method further.

The method and regulations are similar in most nations throughout the world, but execution and enforcement differ depending on how seriously a country takes environmental issues. The Decree No. 58 of 1988 of Nigeria Federal Environmental Protection Agency (FEPA) is sometimes referred to as the EIA "forerunner" law (Isah, 2012). This is as a result of Section 5 of FEPA Decree No. 58 assigns the Agency the following duties i. preservation and management of the environment; ii. setting guidelines and standards for the environment and iii. enforcing and monitoring compliance with environmental standard set by the Agency. FEPA passed Decree No. 86, after which the Agency released a "Guideline for EIA Procedure" in August 1994. (FEPA 1995). In October 1994 and February 1995, the Agency held two workshops to evaluate the order and enhance awareness of it. Before starting with a project, the EIA Decree mandates proponent, whether it is private or the public sectors of the economy, get FEPA's permission. A project is defined as physical work in which the proponent seeks to construct, decommission, abandoned, modified, operated or otherwise carried out, or a physical action in which the proponents propose required conducting or otherwise carrying out, according to Section 63(1) of the decree (Ogunba, 2004).

2.4.3 Impacts of artisanal and small mining on the environment and health

Since the 2010 lead poisoning crisis in Zamfara, the health and environmental consequences of ASM in Nigeria have received a lot of attention. ASM presently contributes the most to worldwide emissions of anthropogenic mercury, accounting for 37 % of all emissions (Zielonka *et al.*, 2012). These emissions are also increasing at a rapid rate; between 2005 and 2013, ASM emissions of mercury doubled, resulting in total water and land emissions exceeding 800 tons annually. When air-emissions are considered, some estimates put the entire quantity at 1600 tons annually, however this might just reflect more precise reportage (UNEP, 2013). In many ASM regions, the highly harmful (even fatal) effects of mercury and lead poisoning aggravated by pervasive poverty or a general deficiency of access to healthcare. There are also negative effects on women and children, as well as harmful discharges into the atmosphere, soils and water. The cost of tackling health consequences is and will remain high — current lead poisoning therapy may cost sufferers up to $1500 per kid.

The March 2010 Medecins Sans Frontières (MSF) identified an outbreak of lead poisoning in Zamfara, Nigeria's northwestern state. Hundreds of people died as a result (UNEP/OCHA, 2010). The origins of the epidemic were traced back to artisanal aluminum ore processing in mining areas (Azubike, 2011). Food and drinking water, contaminated dust inhalation and oral absorption of particles by youngsters and breast-feeding newborns are particularly paths via which individuals were harmed. Lead is a recognized toxin that has no known good effects on the human body. It harms man's liver, central nervous system, kidneys, brain, and reproductive system (Lovei and Levy, 2000). Mercury may be found in the environment in biological, metallic and inorganic forms. Methyl mercury is the most prevalent organic form, which is created by tiny organisms in the soil and water. Irritability, lung damage, tremors, memory issues, nausea, skin rashes, poor eyesight, and other symptoms might result from elevated mercury levels in the kidneys, brain, and developing fetus (UNEP/OCHA, 2010).

Gold and diamond mining are popular among artisanal miners because of the relative simplicity of mining, processing, and transporting of these elements (MMSD, 2002; Werthmann, 2009; Eftimie *et al.*, 2012). Gold is extensively mined by ASM operators in Niger, Zamfara, Kaduna, and Osun states Nigeria, (Jaiye, 2013; Ayantobo *et al.*, 2014). The other minerals mined by artisanal miners in Nigeria include phosphate, kaolin, feldspar, gypsum, baryte, mica, talc all of which are industrial minerals; construction minerals like granite, marble; sand, gemstones, metallic and dolomite minerals like columbite; lead tantalite, gemstones, metallic and, zinc, minerals like lead, columbite, zinc and tantalite (MMSD, 2008).

2.4.4 Health impact of mining

Lead and mercury have health effects that are not instantaneously apparent and develop over a time period. According to scientific study reviews, mercury exposure causes neurologic and renal problems in ASM populations, as well as probable immunotoxin or autoimmune consequences (Gibb and Leary, 2014). Delayed development, mental retardation, seizures, vision and loss of hearing are the most prevalent impacts of mercury exposure with central neurological systems and cardiovascular diseases being the most sensitive. Additionally, nerve, kidney, muscle and liver damages as well as coordination, reproductive issues, lead poisoning has many of the same consequences. The health impacts of mercury and lead poisoning are particularly obvious in young children. Excessive exposure might put you in a coma or possibly kill you. Mercury exposure during pregnancy is associated with an increase in deformities and miscarriages in women (Human Rights Watch, 2011).

Despite the fact that they both come from artisanal mining, it's vital to think about lead and mercury exposure separately. The only cause of lead poisoning is concentrated lead in the soil where gemstones are extracted. Lead dust is emitted into the air while mined ores are mechanically crushed and processed. The use of dry milling throughout the processing step tends to exaggerate the amount of dust generated (Telmer and Stapper, 2012). Processing of lead was often carried out in home compounds in many regions by women using mortars and pestles, the same used meals preparation. When processing takes place away from the hamlet, miners frequently come to the house with clothing contaminated with lead. Children also go to the mining sites throughout the day to sell food exposed to poison with lead and mercury and they contribute to bringing back and cross-contaminating exposed unsold food. Apart from airborne lead transfer, the grinding and sluicing operation frequently takes place in water sources and poisoned water surface.

Mercury used in ASM to amalgamates and extract gold out of fine-grains of materials, notably in gold. The remaining mercury linked to the gold is eventually burnt off and released as vapor, which may easily be breathed by others in the area (WHO, 2013). This route is particularly dangerous, because more mercury is absorbed by breath than through eating or cutaneous contact. Some mercury runoff makes its way into streams, where anaerobic microbes convert it to methyl mercury. Phytoplankton absorbs the methyl mercury, which travels up the food-chains prior being consumed by downstream inhabitants through infected fish. The toxicity of methyl mercury is significantly greater than that of pure mercury.

2.4.5 Environmental and social impact of mining

Regardless of the size of the activity, mining has an influence on the environment (Azapagic, 2004). The level of the damage is primarily determined by the mining and processing procedures employed. Although regulated small-scale mining has certain negative environmental consequences, these may usually be mitigated by obtaining an environmental permit and having field officers examine the activities on a regular basis. Artisanal small-scale miners, on the other hand, whose operations are difficult to control because to their covert and clandestine character, are harmful to the environment.

(a) Impact on lithosphere

All effects on the lithosphere fall under the first group. Degradation of land is a regular occurrence in most unmanaged, non-monitored small-scale mining operations. Landscapes are also significantly harmed by small-scale mining. Small-scale artisanal mining was particularly responsible for loss of huge amounts of vegetation on surfaces and extensive deforestations as a migratory business (Mensah *et al*., 2015). Miners also frequently abandon pits and ditches without properly retrieving the treasures. As a result, landscape damaged with holes and bereft of cover plants are relatively frequent after periods of extensive prospecting. The facts are that the areas chosen as sites for exploration are primarily dependent on regional opinions exacerbates the situation.

Due to a lack of geologic and scientific tools for well-organized prospection, opinion of the community and knowledge of the public are typically the furthermost credible guiding sources existing, resulting in enormous areas of land left with dips and expose to unnecessarily agents of erosion. Several areas across the world have been severely impacted by artisanal small-scale mining. For example, gold output in Colombia's Choco area is increasing by 7.2 percent yearly, which resulted to deforestation rates of 1000 hectares per year (Lacerda *et al.*, 1998), owing to increased exploration activities. An estimated 100,000ha of land in Zimbabwe is removed yearly due to small-scale mining zones, exploration of heavy gold also contributes to extensive deforestations (Maponga and Anderson, 1995).

Additionally, due to mining operations and crowding, sanitations are sometimes poor, new deforestations can happen as a result of increased demand for fuel wood, and fertile soils are frequently polluted. As Traore (1994) describes, artisanal small-scale mining in the West African' Liptako-Gourma area - which encompasses Mali, Niger and Burkina Faso- has increased ever since 1984, and by the beginning of 1990s, up to 10000 individuals might be found in a single mining site. Widespread precious metal mining activities, for instance, left numerous moon-surface' terrains without flora in southwest Colombia and the Brazilian Amazon (Lacerda *et al.*, 1998). Large trenches have been left exposed as a result of the procedure, which renders the areas unfit for other use as countless dips are filled with waters, serving as grounds for breeding malaria-infected anopheles mosquitoes (Gilbert and Albert, 2016). Acidic mine drainages (on a microscale), cyanides contaminated (in some regions), siltation, dredging of river and modification as well as erosion are some other notable environmental repercussions of small-scale gold mining.

(b) Impact on soil quality

A vast region of land where mining is carried out has become polluted soils. Agricultural procedures in those mining vicinities may be particularly jammed. "Mining activities commonly change the neighboring environment by revealing previously undisturbed soil elements," (Singh and Singh, 2016) a European Union commissioned study. Exposed soils, tailings, fine debris and extracted mineral ores in heaped rock wastes can cause substantial loading of sediments in surface waterways and drainages. Furthermore, hazardous substance leaks as well as spills and the depositions of polluted dust that are windblown can cause soil contamination. In most mines, fugitive dust can result in issues of serious environmental concern. These dust's intrinsic toxicities are determining vicinity of the environmental receptors and the kind of ores the dust is extracted. Windblown dust with high quantities of arsenic, lead, and radionuclides is generally the most dangerous. However, when soils polluted by chemical residues and spills at mining areas are employed materials for filling, ornamental landscapes, or supplement soils, they may constitute a direct contact danger (Vaszita, 2014).

(c) Impact on hydrosphere

All effects on the hydrosphere are included in the second category. Such operations have a negative impact on the system of the drainages in most small-scale mining regions (Law and Turner, 2011). Solid mercury suspensions, which are often dumped into neighborhood bodies of waters when sluicing processes and amalgamations respectively, damage rivers and streams. As a result, such waterways get silted and discolored. During severe rains, improperly discarded tailings wash into streams and rivers, causing sedimentation issues and renders stream unsuitable for home and manufacturing uses. Removal of vegetation also promotes erosion of soil, which raises the turbidity of surface water runoffs. Draining of emollients and other lubricants into the streams, according to Tyulenev and Lesin (2014), creates issues such as de-oxygenation of waters, which pose hazard to lives of aquatic animal.

(d) Water pollution from mines

Body of water are necessary for the existence of life on planet. Unpolluted streams, rivers, lakes, and seas must be a requirement of sustainable development. The state of Nigeria's fresh water is causing increasing public concern. Fresh water is contaminated by mining effluent dumped into the environment, as well as seepage from tailings and waste rock impoundments. The large usage of water in ore processing has the same effect (Mudd, 2008). Human actions like mining are putting the water supplies on which we all rely in jeopardy. The "most common casualty" in mining has been dubbed water. The environmental impact of mining activities that were carried out with little regard for the environment is becoming more widely recognized. Minerals have come at a hefty price for us in our daily lives. Mining in its nature diverts, depletes and pollutes potential water resources or sources.

2.5 Availability of water in Africa

Water is widely considered as the most basic and necessary of all-natural resources, and it is apparent that without it, neither social and economic growth nor environmental variety can be sustained (Vorosmarty *et al.*, 2010). Almost every country today has serious and growing issues in meeting the quickly increasing demand for water, which is driven by rapidly growing populations (Biswas *et al.*, 1993; Gleick, 1998). Water resources are depleting due to pollution and resource depletion, while demand is rapidly increasing due to population increase, rapid industry, automation, and urbanization

(Ochieng *et al.,* 2010). This problem is particularly significant in the world's arid regions, where water shortages and the resulting increase in water pollution have hampered social and economic growth and are directly tied to poverty, hunger, and disease (Tiwari *et al.,* 2009).

Compared to the rest of the world, Africa's water resources are highly changeable, and water supplies are unequally distributed in terms of geographical breadth and duration (Pickering and Davis, 2012). Large swaths of the African continent have been ravaged by a succession of protracted and severe droughts, which are frequently "broken" or "relieved" by equally severe flood occurrences. There is also substantial, though untested, evidence that current global climate change patterns will exacerbate the problem. A substantial amount of the continent's water resources is made up of huge river basins or subterranean aquifers that are shared by numerous nations, in addition to climate fluctuation. The countries that share these water resources frequently have vastly different degrees of economic, social, and political development, as well as vastly differing water needs. The large inequalities in socioeconomic development and water requirements hamper the quest for equitable and long-term solutions to water supply issues (Hoekstra *et al*., 2012).

The population of practically every African country increased significantly over the past centuries, and this trend is anticipated to continue. Despite evident inequities across a range of social, economic, and political systems, this population rise has coincided with an equally rapid increase in water demand. Several African nations have already reached or past the point identified by Falkenmark and Molden (2008) as indicating significant water stress or deficit, where water shortage effectively hinders future growth. Many more African nations will reach and surpass the limits of their commercially useable, land-based water resources before 2025, based on current population projections and patterns of change in water consumption (Schuol *et al*., 2008). These grim figures highlight the critical need for long-term solutions to the challenge of securing safe and appropriate water supply for all African countries. All peoples have equal access to water, which is recognized as a fundamental right (Gleick, 1998). However, it is necessary that we create a shared understanding of the actual worth of water, as well as the critical need to reform or refocus our methods to water management and consumption on regional and continental dimensions, in tandem with this right of equitable access (Schuol *et al*., 2008).

While each country's water allocation and distribution priorities must be aligned closely with regional as well as national developmental goals, more emphasis must be placed on the rigorous effort made to ensure the limited water resources of the continent are utilized maximally for long-term benefits of the people of Africa (WHO, 2004).

However, achieving this aim will require prudent and cautious water resource management. The urgent need to guarantee that all segments of society have equal access to and utilization of available water resources is a critical priority. This is especially true when it comes to Africa's common river basins. If peace and prosperity are to be preserved and war avoided, each country's water resource management strategy should ideally be closely linked with those of its neighbors (Kramer, 2008).

2.5.1 Water pollution from mining

According to Schwarzenbach *et al.,* (2010), mining has four different types of effects on water qualities. Acidic mine drainages, sedimentation, acidic rock drainages, and erosion mineral pollution, and heavy metal contamination are among them:

2.5.1.1 *Acidic rock drainages (ARD)/ acidic mines drainage (AMD)*

Acidic Rock Drainages (ARD), a natural process in which sulphides in rock materials expose to water and air result to production of sulphuric acids (Akcil and Koldas, 2006). As reported by McCarthy (2011) Acidic Mine Drainages (AMD), essentially involving the same processes as the one on a much larger scale. Sulphuric acid is formed when huge amounts of sulphide mineral containing rocks are dug from open pit or expose from an underground mine and react with oxygen and water. Species of naturally occurring bacterium called Thiobacillus ferroxidans can kick, especially when the water reaches a specific degree of acidity. The speed up of acidification and oxidation processes can lead to leaching of trace metals from the waste materials. The acid, on the other hand, leaches from rocks as long as the rocks' sources are exposed to water and air, and awaiting the Sulphide has leached out, which take hundreds or thousands of years. Rainwater or surface drainage carries acid away from the mine site, depositing it in neighboring groundwater, streams, rivers and lakes. AMD wreaks havoc on the quality of the water, kills aquatic life, and renders water nearly useless.

Water acidification has an immediate negative impact on aquatic habitats (Gibson *et al.*, 2011). The conversion of all carbonate and bicarbonate into carbonic acid, which dissociates into carbon dioxide and water below pH 4.2, is a direct impact (Kelly *et al.*, 2011). This depletes the water's bicarbonate buffer system, which works as an acidity regulator. Second, because many photosynthetic organisms need bicarbonate as their inorganic carbon supply, when bicarbonate decomposes and becomes less accessible, their capacity to photosynthesize is restricted or killed entirely (Whitehead *et al.*, 2009). Third, in water bodies substantially damaged by acid influx, breakdown (and hence nutrient cycling) will be inhibited and eventually halt (Dupont *et al.*, 2010). Finally, acid waters can kill organisms by disrupting ionic balances, harming cell components, or breaking carbonate exoskeletons (Crain *et al.*, 2008)

Because of the many chemicals employed in the mining processes and the potentially harmful metals and compounds extracted from the earth with the ore, significant pollution of the region surrounding mines is a possibility (Rodriguez *et al.*, 2009). Because of the large volume of water produced by aqueous extraction, mine cooling, mine drainages as well as other activities in mines. The chemical elements have greater chances of contaminating surface and ground water. Geologists as well as hydrologists perform thorough measurements of soil and water in well-regulated mines to rule out any sort of water pollution caused by the mine's operations (Das, 2014). In contemporary American mining, the reduction or elimination of environmental degradation is enforced by state and federal legislation, which requires mine operators to satisfy criteria for safeguarding ground and surface water from pollution. The process is best accomplished by using non-toxic methods of extraction such as bio-leaching. If the project site gets polluted anyhow, mitigating procedures like acid mine drainage (AMD) must be used (Akcil and Koldas, 2006).

Groundwater pumping, ponds containment, diversion, sub-surface drainages and barrier systems are the five major technological applications use to manage and monitor the flow of water at mining areas (Gusek and Figueroa, 2009). When it comes to AMD, polluted water is usually piped to a treatment facility where the toxins are neutralized (Wills and Napier-Munn, 2015). "Water quality forecasts provided after incorporating the mitigation effects usually overestimated actual consequences to surface, groundwater, and seeps water," according to a 2006 study of environmental impacts statements (Brown, 2010). Because mining in the undergrounds is occasionally done below the water tables, water must be pumped out of the mines on a regular basis to avoid flooding. When mines are abandoned, pumping stops and the mines become flooded. The first step in dealing with this flooding is to inject water. In the majority of acid rock drainage issues.

Now, because of weathering of rocks, acid rock drainage occurs naturally in various settings. Huge-scale earth disturbances, such as those generated by mining and other large building projects, can worsen it since they usually occur inside rocks with a high concentration of sulfide minerals (Akcil and Koldas, 2006). In regions where the soil has been disturbed, acid rock drainage can develop (for example, building sites, subdivisions, and traffic corridors). In most regions, the liquid drains of coal stocks, washeries, handling facilities as well as garbage landfills is quite acidic. It is managed as acidic rock drainages (Chikkatur *et al*., 2009). Once the last large rise in the sea level occurs, disturbances of acidic soils containing sulfate produced in estuarine and coastal condition that may trigger similar chemical reactions and processes, offering a similar environmental issue.

Another environmental issue related to mining is dissolution and movement of heavy metals via ground water runoff, as shown at the Britannia Mines, where copper was formerly mine in the British Columbia’s Vancouver (Duruibe *et al*., 2007). The abandoned mining creeks in the region near Picher, Oklahoma is Superfund sites now managed by the Environmental Protection Agency, is likewise contaminated with heavy metals. Water resources from mines carrying heavy metals solutions including gold, lead, cadmium and mercury contaminated local groundwaters. Long-term dust storage and tailings cause further issues since they can easily be blown away by the wind action that happened in Skouriotissa copper mines close to Cyprus.

Mine installations cause substantial changes in animal habitats and lesser perturbation, like mine-wastages, pollution residuals on the environment that occur along the broader scales of the exploitation areas. Longtime after the mining activity is over, negative repercussions might be seen (Gryska, 2015). The destruction or radical alteration of the original site, as well as the release of manmade contaminants, can have a major impact on biodiversity. Habitat degradation is the primary cause of biodiversity loss. Direct poisoning from mine-extracted material or indirect poisoning through food and water can also cause this. This can kill plants, animals as well as bacteria or other microbes. Communities in the region disrupted by habitat alteration such as pH and temperature changes. Endangered species are particularly vulnerable because they require highly precise environmental conditions. Their habitat is threatened by destruction or minor change, putting them at risk of extinction. Non-chemical items like huge boulders from abandoned mine areas in the surrounding affects the landscape with little or no regard for natural habitats. These non-chemicals can harm habitats when there isn't enough terrestrial (Kaoud, 2015).

Rainfall, temperature, pH, salinization, and amount of metal are variables that affect communities around the acidic mining sites, and they can have a significant impact on communities over time (Gerhard *et al*., 2004). Solubility of metals affects bioavailability and quantity, may be affected by changes in pH or temperature, which has a direct influence on organisms. Furthermore, pollution endures overtime for as long as ninety years after the pyrite mine are closed. The pH of the water was still quite low, and the microorganism community was dominated by acidophil bacteria.

High zinc concentration in acidic water will have algae communities which are less diversified, and stress mine drainages reduce primary production (Das *et al*., 2009). Any alteration in the chemical composition has significant impacts on the population of the diatom. pH phytoplankton ensemble, and excessive metal concentrations reduce planktonic species abundance. However, certain species of diatom may develop in sediments with high level of metal concentrations. Cysts suffered rusting as well as thick coating in sediments near to the surface. Total algal biomass is minimal under severely contaminated environments, and the planktonic diatom population is absent (Hellawell, 2012). However, in the event of functional complementarity, phytoplankton and zooplankton mass may stay steady.

Population of water bugs and crustaceans are found in the areas around the mines which altered, due to low trophic predator-dominated and completeness in the ecology (Zhou *et al.*, 2008). But if sensitive live species are replaced with more tolerant organisms, the biodiversity of macro invertebrate can be conserved. When variety is diminished, stream pollution has little effect on the biomass abundance, implying that species tolerant that perform the same role taking the habitat of species sensible contaminated areas. The behavior of macro invertebrates may be affected by changes in pH as well as increased metal concentrations, demonstrating that direct toxicity is not the sole concern. pH, temperature, and chemical concentrations all have an impact on fish.

According to Kabata-Pendias (2010), the soil texture of the disturbed areas of land and water can be considerably altered, resulting in changes to plant communities. The majority of plant species have limited metals tolerance in the soil; however, species sensitivity varies. High pollutant concentrations have less of an impact on grass diversity and total area cover by shrubs and forbs (Bardgett, 2005). Waste-material from mines is rejected and traces left behind by mining activities. These are located around the mines, and sometimes rather sources far away from the mines. If their environment is polluted with heavy metals or metalloids at concentrations too high for their physiology, well-known plants cannot migrate from disturbances and they finally perish. Species of some kinds are more resistant to these high levels of metals concentrations and can survive them, while non-native species that cannot withstand high soil concentration will relocate to the mine's surrounding areas to fill the ecological niche.

Plants can be poisoned directly; for example, arsenic in the soil diminishes bryophyte variety. Ali and his colleagues (2009). Chemical pollution can cause soil acidification, which can lead to a reduction in the number of species. Contaminants can alter or disrupt microorganisms, altering availability of nutrient can result in vegetation loss in region. Some roots of trees skip the deeper layer of soil to escape the polluted zone, and as a result, they lose anchoring and may be uprooted by winds as their heights and shoots weights grow. Roots exploration are generally decreased in polluted regions when compare to unpolluted areas. Species of plant diversity is lower in environments that are reclaimed than in natural regions (Finnegan and Chen, 2012).

Cultivated crops near mines might be a hazard. Most crops can grow on marginally polluted locations, although yields are often lower than they would be under normal growing circumstances (Kabata-Pendias, 2010). Heavy metals are also accumulated by plants aerian organs, which might lead to consumption by human through vegetables and fruits. Long-term metal exposure may create health concerns if consumed on a regular basis. Because tobacco are inclines to collect zinc and cadmium in the leaves, cigarettes derived from tobacco grown on polluted locations may have negative consequences on the human population (Satarug, 2012).

Destruction of habitat is among the most devastating repercussions of mining operations (Azapagic, 2004). Larger natural habitats are destroyed in times mines development and exploitations, leading faunas to evacuate the areas. Animal species can be directly poisoned by products of mines as well as residuals. Due to bio-accumulation of mine products in plants or microscopic critters that horses, sheep, and goats consume, they are exposed to potentially harmful quantities of lead and copper in grass in specific locations (Gruiz *et al*., 2009). There are fewer species of ants in soil with high levels of copper such as those found around copper mines. Ants are sensitive to environmental perturbations because they dwell directly in the soil and act as an efficient environmental control. If fewer ants are seen, it's likely that other species in the surrounding area are also being harmed by the elevated copper levels. Because of their tiny size, microbes are highly sensitive to changes in the environment such as temperature, pH, as well as chemical concentration. The presence of arsenic and antimony in soils, for instance, reduces the overall number of microorganisms in the soil. Furthermore, similar to water, a modest change in soil pH can cause pollutants to remobilize, additionally have direct influence on species pH-sensitive (Zhengfu *et al*., 2010).

There are several occupational health risks as well. The majority of the miners have respiratory and skin ailments (Jarup, 2003). Asbestosis, silicosis, black lung disease, and other diseases affect miners who work in many types of mines. The overburden of covered in forest, which must be remove prior to opening the cast for commencement of mining. Despite the fact that mining-related deforestation is minimal in compared to high level of local endemism deforestation in total. This may result in the extinction of species. Large holes and earth surface fissures are created by sand and gravel mining. Mining can sometimes go so far that it contaminates underground wells, ground water, the water table and springs (Pickering and Davis, 2012).

2.5.2 Erosion and sedimentation

When building and maintaining roads, garbage impoundments, mineral development affects soil, open pits and rock (Riba *et al*., 2005). Erosion of the exposed ground, in the absence of proper preventative and control techniques, may move significant volumes of silt into streams, rivers, and lakes. At many mines, minimizing the disturbance of organic materials which comes up close to the streams or other aquatic habitats as major concern. Erosion heaps of waste rocks or runoff of water after heavy rains usually increased the sediment loading of surrounding bodies of water. Mining can also change the morphology of streams by breaking them, altering their slope or bank stability, and diverting stream flows. These disturbances have the ability to change the characteristics of stream sediments dramatically, reducing water quality (Julien, 2010).

Higher sediment concentrations enhance turbidity in natural environments, lowering the amount of light accessible for photosynthesis by aquatic plants (Bornette and Puijalon, 2011). Furthermore, higher silt loads in streams and seas can suffocate benthic animals, removing key food supplies for predators and reducing suitable habitat for fish to migrate and breed (Julien, 2010). Higher sediment loads can also reduce stream depth, increasing the danger of flooding during periods of strong stream flow (Delpla *et al*., 2009).

Siltation accumulation of fine solid particles along river beds or lakebed as a result to excessive loading of suspended solid in rivers (Oelofse, 2009). Mining activities, on the other hand, create vast amounts of dust and finely powdered rock, with much of it reduced to particle sizes of less than 0.2 mm. Though the materials discarded following the extraction of the mined commodity have tiny particle size and good physical qualities, they are not suitable for plant development or water retention. Because these materials are made of hard weathered materials, they may or may not contain fine clay or organic microbial activities (Azapagic, 2004). As a result, dump mines can be extremely unstable when blown by heavy winds, especially when such dumps are dry and battered by heavy rain water as wet materials. Rains as well as winds carrying small particles into surrounding waterways, resulting in a buildup of suspended solid materials and, in eventual siltation.

2.5.3 Heavy metal contamination

When metals like lead, silver, cadmium, cobalt, arsenic, copper, and zinc excavated from rocks or an underground mine come into contact with water sources. They pollute the environment with heavy metals (Alloway, 2013). Metals are leached from the rock surface and carried downstream by the water. Metals can become mobile in neutral pH environments; however acid mine drainage can worsen pH conditions that promote leaching. Minerals extracted (such as lead) spill, seep, or leach into nearby water bodies, polluting the environment. Lead, which is the most abundant mineral in the research region, may be extremely harmful to humans and wildlife.

(a) **Lead and its effect on human health**

Lead, abbreviated as Pb from the Latin word plumbum, is a corrosion-resistant, dense, ductile, and malleable blue-gray metal that is commonly found in the naturally occurring lead sulfide mineral ore Galena (Leteinturier *et al*., 2001). Lead is generated and found in a variety of rock types, sedimentary rocks, including ingenuous and metamorphic; sedimentary lead deposits can occur as veins, single grains, or replacement deposits in carbonate rocks like dolostone and limestone (Makumba, 2013)

Exposure pathways are the means through which people come into contact with lead, and these include soil, dust, water, and foodstuff; exposure routes, on the other hand, are the methods by which humans get contaminated by lead compounds, which include skin or eye contact, inhalation and ingestion (Nnorom *et al*., 2005). Because recent research has demonstrated that lead poisoning can develop at low dose environmental exposures that were previously assumed to be innocuous, the dosage and duration of exposure play an important role in the possible health implications of lead poisoning (Office of surface mining reclamation and enforcement, 2014). This shows that, despite the fact that lead's toxicity has been known since Classical Greece, the new revelation of its low-dose harmful effects indicates that there is still a lot we can learn about its impacts on human health. People can be exposed to lead either at work or in the environment, although mine employees are mostly exposed to lead by inhalation of particles and accidental consumption of the mineral ore. Populations residing in the vicinity of the mine site, on the other hand, may be exposed and polluted by ingestion of contaminated soils, inhalation of mine particles, and eating of contaminated foods (Caravanos *et al*., 2013).

At doses of 60 g/dl or higher, the consequences of lead poisoning in children become obvious; frequent clinical symptoms include stomach discomfort, clumsiness and joint pains, which are subsequently followed by headaches and behavioral abnormalities, which might be an indication of early encephalopathy or brain problem. Changes in awareness, stupor (near unconsciousness), and convulsions are all symptoms of encephalopathy (Plumlee and Suzette, 2011). Also, "a substantial number of children who recover from clinical encephalopathy [tend to] have severe cognitive and behavioral deficits," according to the study. Adults, on the other hand, are usually affected by lead poisoning, which affects their kidneys, blood pressure as well as peripheral and central nervous systems (Sansom, 2008). Adults accumulate lead mostly in their bones, which explains why their blood lead levels appear to be lower. However, severe headaches, increased intracranial pressure, stomach discomfort, hypertension, central nervous system dysfunction, anemia, joint pain, and renal dysfunction are all indications of lead poisoning. Blood lead levels of more than 10 g/dl should be considered dangerous, even if clinical symptoms do not appear until the level reaches 60 g/dl, as they do in babies (Tembo, 2006).

Health studies have found a link between increased levels of lead in human blood and bad health in those who are exposed to lead at work or who live near lead mining and smelting sources (Kamenov, 2008). However, lead's toxic effects on human health are now seen as a continuum, ranging from well-known high-dose effects like blindness, encephalopathy (brain disorder), convulsions, renal (kidney) failure, severe gastrointestinal distress, and death to previously unknown low-dose chronic effects like neurodevelopment, motor development, anemia, and kidney disease (United Nations Environment Program, 2011)

Low-dose lead exposures that were previously assumed to be safe have now been proven to be just as dangerous (Walsh, 2007) The phrase "subclinical toxin" is used to characterize the damaging effects of low doses of lead; nevertheless, it's worth noting that the word's underlying premise is that there is a continuum of toxicity that illustrates how lead's clinical effects are equally as destructive as its subclinical effects (World Health Organization, 2013). The above-mentioned high-dose clinical manifestations of lead poisoning, such as brain disorder and kidney failure are found in the upper echelon of the toxicity continuum, whereas low-dose subclinical manifestations, such as red blood cell enzyme impairment, fetal damage and neurological function changes are found in the lower echelon. As a result, it's vital to remember that low-dose lead poisoning is just as dangerous as high-dose poisoning, and that any amount of lead exposure should be regarded potentially dangerous.

Despite the fact that lead has an effect on both male and female reproductive systems, women appear to be the ones who are most affected. Men's reproductive systems are impacted by decreased sperm count and teratospermia, mostly as a result of occupational lead exposure, whereas women's reproductive systems are affected by a high incidence of stillbirths and newborn mortality, although both genders experience a decline in fertility (World Bank, 2003). Low dosages of lead poisoning in women can induce neurological impairment to the baby at concentrations as low as 15g/dl. This is due to the way the mother's lead-contaminated blood crosses the placenta unobstructed to her unborn child (Zambia Environmental Management Agency, 2011).

(b) Arsenic and its health effect

Arsenic is an element that occurs naturally in the earth's crust. In the studied locations, arsenic may be found in both deep bedrock and shallow glacial deposits (Villaescusa and Bollinger, 2008). Inorganic arsenic is commonly found in the environment. Arsenic, which is inorganic, dissolves quickly and penetrates both subterranean and surface waters. The presence of arsenic in the environment can be linked to one of three sources: residual arsenic from previous pesticide usage, smelter emission from gold ores such as arsenopyrites, or sulphur treatment plant emissions (Finnegan and Chen, 2012).

Franblau and Lillis (1989) described two cases of sub-chronic arsenic poisoning caused by occasional (once or twice a week) intake of polluted well water (9-10.9 mg/L). There were acute gastrointestinal symptoms, central and peripheral neuropathy, bone marrow suppression, liver toxicity, and minor mucous membrane and skin alterations. Based on a body weight of 65kg and arsenic intake of 238 to 475ml water per day, the predicted dosage was between 0.03-0.08mg/Kg/day. The consequences of short-term arsenic exposure (edema, upper respiratory symptoms or gastrointestinal) are different than those of long-term arsenic exposure (damages to the nervous system and skin disorders). Even after stopping the arsenic consumption, some of the subjects or humans developed symptoms such as peripheral neuropathy (USEPA, 1988).

Skin cancer is caused by continuous dermal exposure to arsenic, according to Mazumder (2008). In locations where chronic inorganic arsenic exposure is significant, the prevalence of skin cancer is quite high. The inorganic form of arsenic is classed as a class A human carcinogen by Beyersmann and Hartwig (2008). This classification is based on human data that offers sufficient proof. That instance, higher lung cancer mortality has been documented in a number of communities exposed to arsenic predominantly through the use of arsenic-contaminated water. In populations ingesting drinking water with high inorganic arsenic concentrations, higher mortality from several internal malignancies (lung, liver, bladder and kidney) as well as an increased risk of skin cancer have been documented (Celik *et al.*, 2008).

(c) Cadmium and its health effect

Cadmium, a soft, ductile metal is produced by the smelting of lead and zinc ores as a by-product (Bernard 2008). Another source of cadmium in the environment is volcanic eruption. Cadmium levels in the atmosphere are considered to be around 2ng/m3 in nature, although greater amounts have been discovered around zinc smelters. Cadmium in the research region might arise from zinc and other chalophilic metals mining and processing (Mainier *et al*., 2011). Since of their surface input to soil systems, anthropogenic sources of cadmium in the environment represent a severe concern because the metal is more accessible for plant and animal absorption. Cadmium is mostly derived as a by-product of processing zinc-bearing ores and refining lead and copper from sulphide ores.

Cadmium is largely utilized in the manufacturing of nickel-cadmium batteries, metallic alloys, metal plating, plastics, pigments and synthetics according to McManus (2012). Cadmium has been proven to be hazardous to humans through occupational inhalation and accidental intake of cadmium-contaminated food. Cadmium dust inhalation in some work situations has been linked to an elevated risk of lung cancer. Other signs and symptoms include upper respiratory tract irritation, a metallic taste in the mouth, coughing, and chest pains (Singh *et al.*, 2009). Consumption of high amounts of cadmium has been linked to renal and skeletal system toxicity, as well as an increased risk of cardiovascular disease and hypertension.

2.5.4 Measurable parameters in water management: physico-chemical indices

A complicated hydrological cycle connects all freshwater bodies to the seas, the atmosphere, and aquifers. Wetlands, icecaps, and biosphere water are all part of the continual flow of water on the globe. Evaporation and gravity drive the Earth's hydrological cycle, which ecosystems and human cultures rely on. Growing populations may put pressure on natural resources, affecting both water quality and the hydrological budget (Keith, 2004). Many anthropogenic contaminants' fate and transit are determined by physicochemical processes as well as hydrological cycles. Comprehensive monitoring regimes are becoming increasingly vital in order to limit the impact of human societies on natural waterways.

Water resource monitoring can assist policymakers evaluate water quality, identify impairments, and make land use decisions that will not only protect natural regions but also improve people's quality of life. The characteristics of the in-situ environment that can be monitored remotely by deployable sensors are described (Keith, 2004). pH, dissolved oxygen, total suspended particles, total dissolved solids, electrical conductivity, and true color are among the parameters examined in this study.

2.5.4.6. Acidity and Basicity of Aqueous (pH)

The pH of natural water may reveal a lot about a lot of biological as well as chemical processes are indirectly linked to a number of problems (Bellingham, 2004). The common logarithm of negative impact of the activities/concentrations of hydrogen ions is the pH, which measures the acidity or basicity of solution, usually denoted by $-\log[H^+] = pH$ the pH scale in natural waters ranges from 0 to 14. A 7 pH indicates neutrality, while less than 7 indicates acidity and higher than 7 indicates alkalinity or basicity of water devoid of dissolved gaseous particles and ions spontaneously as H2O H+ + OH. The amount of ions [H+] of hydrogen molecule is equal to the amount of ions [OH-] hydroxide. The actual number of water molecules that ionize is quite minimal. The concentration of [H+] in pure water at normal temperature is 1 x 10-7 moles per liter. The –log ($1 X 10^{-7}$) defines, a pH of 7 is considered neutral (Mendham, 2006).

The carbon dioxide exchange within the atmosphere controls the pH of unpolluted or clean waters (Chen and Lu, 2003). Carbon (IV) dioxide is readily soluble inside water and the CO_2 amount that dissolves inside water depends on the temperature and CO_2 concentration in the air. CO_2 will be transformed to H_2CO_3 when the gaseous CO_2 turns aqueous, making the water become acidic to around 6 pH. If there is presence of alkaline earth metals like sodium, carbonates and bicarbonates generated by CO_2 solubilization which interacts with sodium thereby increasing basicity and pushing the pH up above 7 (Bellingham, 2004). Lower pH readings indicate significant acidity, which can be induced by acid-forming chemicals deposition in precipitation. Because of the carbonate chemistry, a large organic content will tend to lower the pH. As microorganisms break down organic matter, CO2 is released as a byproduct, which dissolves and equilibrates with water to generate carbonic acid (H2CO3). Organic decomposition can also produce other organic acids as humic and fluvic acids (Chen and Lu, 2003).

Mineral acids produced by the hydrolysis of metal salts such as aluminum and iron might affect the acidity of natural waters in addition to organic acids and carbonate chemistry (De Anil, 2003). As the pH of the water lowers, most metals become more soluble. Acid rain, for example, is caused by sulphur in the atmosphere from coal combustion. As the rain falls on man-made structures and into bodies of water, acid rain will dissolve metals such as copper, lead, zinc, and cadmium (Mendham, 2006). The health of aquatic species will be harmed by excesses of dissolved metals in solution.

The concentration of hydroxide, which is indicated by a pH greater than 7, controls the alkalinity of natural waters. This is generally a measure of how many carbonates and bicarbonates are involved in shifting the equilibrium and creating [OH-]. Boron, phosphorous, nitrogen-containing substances, and potassium are all alkaline pH contributors. The presence of an industrial pollution, photosynthesis, or the respiration of algae feeding on a contamination can all cause pH changes. Most ecosystems are sensitive to pH fluctuations, and pH monitoring is now required by most developed nations' environmental legislation (Bellingham, 2004). The pH of aquatic ecosystems, livestock drinking water sources, recreational waters, industrial discharges, irrigation sources intakes, and storm water runoff are all commonly monitored (Schwarzenbach *et al*., 2003).

2.5.4.2 *Dissolved oxygen*

All types of aquatic life, including microbes that break down man-made pollution, require dissolved oxygen (DO) (Ugwu and Wakawa, 2012). Water is soluble in oxygen, and oxygen dissolved in water will equilibrate with oxygen in the atmosphere. As the temperature rises, oxygen becomes less soluble. At sea level, the DO of fresh water will range from 15 mg/l at 0 °C to 8 mg/l at 25 °C. Unpolluted fresh water concentrations will be close to 10 mg/l (Schwarzenbach *et al*., 2003). Biological activity will, in general, affect the concentration of dissolved oxygen. During the day, photosynthesis in some aquatic plants raises DO levels, but at night, it decreases.

Microorganisms will devour man-made contaminants or natural organic material in natural streams. As microbial activity rises, organisms will take oxygen from the water in order to speed up their digestive process. Because of this, the water around the sediment will be oxygen-depleted. The water will turn anaerobic as the oxygen is depleted. DO levels of less than 2mg/l will usually kill fish (Bellingham, 2004).

Membrane electrodes are commonly used as in situ DO sensors, whereas titrations are used in the laboratory. The biological oxygen demand (BOD) and the chemical oxygen demand (COD) are two more indirect laboratory methods for determining DO (COD). The BOD is the amount of oxygen necessary to biologically break down a pollutant, whereas the COD is the quantity of oxygen immediately consumed by an oxidizing chemical contamination Schwarzenbach *et al.* (2003).

2.5.4.3 *Electrical conductivity*

In natural waterways, electrical conductivity (EC) is a normalized measure of the water's capacity to carry electric current (Gorde and Jadhav, 2013). Dissolved salts like sodium chloride and potassium chloride have a big impact on this. Electrical conductivity is measured in Siemens per meter (S/m). The majority of freshwater sources will have a conductivity of 0.001 to 0.1 S/m. An oversupply of dissolved salts owing to inadequate irrigation management, minerals from rain water runoff, or other discharges might be the source of EC. The water quality metric "Total Dissolved Solids" (TDS) or salinity is also measured in EC. The salinity affects the health of various crops and freshwater aquatic animals at a concentration of roughly 0.3 S/m. The quantity of total dissolved solids (TDS) in natural waterways is measured by EC in the field. The presence of dissolved inorganic ions such as K+, Na+, Mg++, Ca++, Cl-, SO24-, HCO3-, and CO32- in an aqueous solution or soil matrix is referred to as salinity (Mendham, 2006). Salinity is measured in terms of electrical conductivity and is defined as the total concentration of soluble salts.

2.5.4.4 *Total suspended solids*

Total Suspended Solids (TSS), is a substance in water that influences its transparency or light scattering (Bin Omar and Bin MatJafri, 2009). Natural water has a range of 1 to 2000 NTU. Manual field methods for testing TSS include Secchi discs, which include lowering a metal disc into water with a calibration line. TSS is exactly proportional to the depth at which the disc vanishes. The backscatter of infrared light is measured using in situ electronic turbidity sensors to calculate the water's NTU. Fine clay or silt particles, plankton, organic substances, inorganic compounds, or other microbes are common components of TSS (Ugwu and Wakawa, 2012). TSS is defined as material that cannot pass through a 45m diameter filter in established laboratory testing. These suspended particles range in size from 10 nm to 0.1 mm. Changes in pH can affect both TSS and TDS levels. Some solutes will precipitate when the pH changes, and the solubility of suspended materials will be affected. Erosion, storm water runoff, industrial discharges, microbes, and eutrophication are all examples of man-made sources of TSS. Many fish species are vulnerable to long-term TSS exposure, and TSS monitoring is an essential criterion for determining water quality (Carr and Neary, 2008).

2.5.4.5. *Total dissolved solids (TDS)*

Inorganic salts (mostly sodium, calcium, potassium, bicarbonates, chlorides, magnesium, and sulfates) and minute quantities of organic matter are dissolved in water to form Total Dissolved Solids (TDS) (Bellingham, 2004). Natural sources, sewage, urban runoff, and industrial waste-water all contribute to TDS in drinking water. In some countries, salts used for road de-icing may also add to the TDS concentration of drinking water. Due to changes in mineral solubility, TDS concentrations in water vary significantly between geological locations. A high total dissolved solids content does not always indicate that the water is a health threat, but it may indicate that the water may have aesthetic or nuisance issues. These issues might be caused by discoloration, taste, or precipitation. In the case of trace metals, a higher total dissolved solid may indicate the presence of dangerous metals in the water. High amounts of TDS in drinking water, on the other hand, may be undesirable to consumers (Schwarzenbach *et al.*, 2003).

2.5.5 Impact on atmosphere

Activities are carried out in ambient air, the impact of small-scale mining on the environment is typically thought to be negligible. Nonetheless, gaseous pollutant release does occur because the particles created from mining sources lie in the respirative dusts ranging from those capable of causing disorders to dust-related from small-scale mine activities to generate dust that might be detrimental to the health of human (Zhengfu *et al.,* 2010).

2.5.6 Impact of mining on air quality

Emissions occur as airborne through the mining process, but specifically in the course of developments, constructions, explorations and processing operations (Li, 2009). In the course of mining operations, larger number of materials is mobilized and waste piles which contain minute number of particles are simply distributed by winds. According to Pacyna *et al.* (2010) the principal air pollution sources in mining operations includes particulate matters carried by the wind as a result of material transportation, blasting, excavations, wind erosion (usually common in mining open-pits), and dust fugitive from tailing facilities, haul highways, trash dumps and stockpiles. The level of the particles is elevated by emissions from exhaust of mobile vehicles (heavy equipment, cars and trucks). After pollutants enter the atmospheric environments, they undergo chemical and physical alterations prior getting to the receptors (Seinfeld and Pandis, 2016). These toxins have the potential to be hazardous to health of people as well as the environs. Large-scale mining, on the other hand, have potentially considerable contribution to air pollutions, particularly during the operating period. Equipment, materials generators and processes that produce hazardous pollutants of air like sulfur dioxide, particulate matters, carbon monoxide, heavy metals and nitrogen oxides are all used in ore extraction, processing, handling, and transportation.

2.5.7 Impact on wildlife

Wildlife is a wide phrase that refers to all non-domesticated plants and animals (or other species). Mining has an impact on the environment and related biota by removing plants and soils, releasing pollutants, displacing wildlife, and producing noise (Eisler and Wiemeyer, 2004).

2.5.7.1 *Habitat loss*

Existence of wildlife species in communities that are dependent on one another type of species can survive on these species, if it influences the conditions of the soil, land height, local temperature, as well as other ecological variables. Mining has an adverse effect on wildlife, both indirectly and directly (Krausman and Harris, 2011). The land surface disturbance, removal, and redistribution have the biggest impact. Some impacts are confined and limited to the mine site, while others have long-term, far-reaching implications. Extinction or migration of species in areas where mining waste is deposited or extracted has the most direct impact on wildlife (Goswami, 2013). These areas are where game birds, animals, and predators, as well as other nomadic wildlife species, leave. Burrowing rodents, a variety of reptiles, invertebrates and small mammals that are more immobile may be particularly vulnerable. When streams, marshes, lakes, and ponds are drained or filled, aquatic invertebrates- fishes as well as amphibians are affected severely. Food supplies for predators are reduce as a result of the loss of these species of terrestrial and aquatic origins. Many species of animal rely on vegetation that develops along natural drainage networks for survival. This plant provides food, nesting places, and predator protection. Damage to vegetation around the wetlands, reservoirs, ponds and marshes reduces the quantity of the species and the quality of habitat required for ducks, shorebirds, as well as a range of terrestrial animal species (Krausman and Harris, 2011).

Many animals’ species' habitat demands hinder them from adjusting to changes induced by land disturbance, according to Chakravarty *et al.* (2012). As a result of these changes, the amount of living space available is reduced. To varied degrees, animals accept human competition for space. Some animals are able to handle a great deal of stress. When a species' access to a critical habitat, such as a lake, pond, or important breeding area, is restricted, the species may go extinct. Surface mining has the potential to harm aquatic environments, with consequences felt several kilometres away from the mine. Surface mining, for example, is known to cause silt pollution of rivers and streams.

2.5.7.2. *Fragmentation of habitat*

Fragmentation occurs in the habitat when huge amounts of land are splitter into smaller units of the chuck making native species dispersion difficult or impossible from one patch to the next and cutting off migratory pathways (Lindenmayer and Fischer, 2013). Isolation can lead to localized species extinction or genetic implications like organism’s inbreeding. Larger species that requires large areas of forest may just perish due to fragmentation.

2.5.8 Impact on social values

The social consequences mining as a large-scale project are controversial as well as complex. Development of minerals can provide some degree of wealth, but it can also create major problems that drains the wealth (Petkova *et al.*, 2009). Mining operations may produce employment, roads, and schools in rural and underprivileged regions, as well as stimulate demand for products and services, but the benefits and expenses may be unevenly distributed. If communities perceive they are being treated unfairly or inadequately compensated, mining activities can provoke social tension and violent conflict. EIAs, according to (Bawole, 2013), might undervalue or even overlook the effects of mining developments on local communities. Communities are especially susceptible when their relationships to authorities and other sectors of the economy are shaky, or when mining's environmental repercussions (water, soil, and air pollution) have an influence on local people's sustenance and livelihood.

2.5.9 Displacement and resettlement of humans

“The relocation of established people is a primary cause of animosity and conflict linked with large-scale mining development,” Owen and Kemp (2015) write. Entire communities may be uprooted and forced to migrate, often to purpose-built towns where they do not wish to live. Along with their homes, communities may lose their land, and hence their livelihoods. Institutions and power dynamics in the community may be impacted as well. Frequently, displaced people are transferred to areas with minimal resources or left near mines. In these areas, they could be expose to pollutants and contaminations. Forcible resettlement could particularly harmful to indigenous tribes, who have strong cultural and spiritual ties to their ancestors' homelands and may struggle to live if these ties are broken."

2.5.10 Mining and migration

"One of the most significant repercussions of mining activity is the migration of people into a mine location," according to Landau and Segatti (2009), "especially in distant portions of developing nations where the mine represents the single most important economic activity." For example, the local population of the Grasberg mine in Indonesia grew from fewer than 1000 in 1973 to between 100,000 and 110,000 in 1999. Similarly, since 1990, the population of the squatter communities near Porgera, Papua New Guinea, has increased from 4000 to over 18,000 people.

This flood of newcomers can have a significant influence on the original residents, and conflicts over land and benefit distribution may occur. (These were among the elements that contributed to Grasberg's violent uprisings in the 1970s and 1990s.) "Sudden population growth may put a strain on land, water, and other resources, as well as create sanitation and waste disposal issues." The repercussions of migration may reach well beyond the mine's local neighborhood, according to Petkova *et al*. (2009). Improving infrastructure may also result in an influx of new residents. The 80-meter-wide, 890-kilometer-long transportation corridor built from the Atlantic Ocean to the Carajas mine in Brazil, for example, is projected to have produced a 300,000-square-kilometer area of effect."

2.5.11 Lost access to clean water

Water quality and quantity impacts are among the most controversial parts of mining operations, according to Bebbington and Williams (2008). Companies claim that by employing contemporary technology, they would be able to maintain ecologically beneficial mining methods. However, evidence of past mining activity's severe environmental repercussions has caused local and downstream residents to be concerned that fresh mining activity will have a detrimental influence on their water supply.

2.5.12 Mining and livelihood

When mining activities are not properly managed, the outcome is deteriorated soils, biodiversity, forest and water resources, which are vital to the livelihood of local people, according to (Hilson and Banchirigah 2009). When pollution is not controlled, expenses are passed to other economic sectors such as agriculture and fisheries. Mining operations in regions inhabited by historically discriminated against, excluded or marginalized groups exacerbate the problem. Proponents of mining operations must guarantee that the basic rights of persons and communities affected by the project are respected and not violated. These include the right to own and utilize land, the right to safe drinking water, and the right to a decent living. These rights can be codified in national law or conveyed through a variety of international human rights instruments and agreements. Under the legislation, all groups are equal, and the needs of the most vulnerable (disadvantaged and low-income groups) must be identified and safeguarded.

2.5.13 Mining and public health

Environmental impact studies usually undervalue the possible health impacts of mining activities (EIAs). Hazardous wastes and chemicals in the soil, water, and air can cause serious health problems. The World Health Organization (2013) defines health as "a condition of total mental, social and physical well-being, rather than merely the absence of disease or disability." Hazardous substances are a broad term that encompasses any chemical that has the potential to damage persons or the environment (Van Leeuwen and Vermeire, 2007).

Surface and ground water contamination with metals and elements due to microbiological pollution from sewage and garbage in campsites and mine worker residential areas. Sulfur dioxide, particulate matter, heavy metals such as lead, cadmium and mercury exposure, as well as hazardous element deposition from air emissions. Mining operations may have an immediate influence on the quality of life of local residents and their physical, emotional, social, and mental health. In makeshift mining communities and camps, food availability and safety are frequently threatened, increasing the risk of malnutrition. Increased prevalence of TB, asthma, chronic bronchitis, and gastrointestinal illnesses are some of the indirect consequences of mining on public health (Goswami, 2013).

2.5.14 Impact on cultural and aesthetic resources

As a result of mining operations, cultural resources may be harmed directly or indirectly. Construction and other mining activities may have immediate ramifications. Indirect consequences include soil degradation and increased access to current or future mining sites. Mining projects can harm natural landmarks, sacred landscapes and historical infrastructure, according to Goodland (2012) and Dudley (2008). Degradation or destruction of the resource as a result of topographic, soil movement or hydrological pattern changes, (removal, erosion, sedimentation); complete destruction of the resource as a result of surface disturbance or excavation; as a result of increasing access to previously inaccessible locations, there has been unlawful removal of artifacts or damage.

2.5.15 Climate change considerations

Every project that has the potential to change the global carbon budget should undergo an EIA that includes a carbon impact assessment (Giddens, 2009). Large-scale mining initiatives, on the other hand, have the ability to change global carbon in at least three ways:

2.5.15 .1 *Lost carbon dioxide ($CO_{2)}$ uptake*

Most of the large-scale mining operations have been suggested in tropical regions with densely wooded areas, which are crucial for the absorption of atmospheric carbon dioxide (CO2) as well as the maintenance of healthy balance between CO2 emission and CO2 uptake. Some mining operations call for the destruction of tropical forests for an extended period of time, if not permanently. Environmental impact assessments for mining projects must account for how any proposed disturbance of tropical forests may affect the carbon budget (Gisore and Matina, 2015). An examination of the possibility for the host country to lose financing from international consortiums that have been created or will be established to protect tropical forests should also be included in the EIA.

2.5.15.2 *Carbon dioxide ($CO_{2)}$ emitted by machines*

During the life of the mining project, the EIA should contain a quantitative estimate of CO2 emissions from machinery and vehicles that will be used. These calculations may be made using the rate of fuel consumption (usually diesel fuel) multiplied by a conversion factor that connects the amount of fuel consumed (often liters or gallons) to the amount of CO2 released (typically metric tons).

2.5.15.3 *Carbon dioxide (CO_2) emitted by the processing of ore into metal*

An example may be found in a study conducted by Australia's CSIRO Minerals, which employed the Life Cycle Assessment approach to estimate greenhouse gas emissions from copper and nickel production, including mining (Mudd, 2010). The Life Cycle of greenhouse gas emissions from copper and nickel production, according to this study, is roughly 3.3 kilograms (kg) of CO2 per kilogram of copper metal smelting. For nickel generated through pressure acid leaching, solvent extraction, and electrowinning, the LC is roughly 16.1 kg of CO2 per kilogram of metal. In the end, metal mining produces more than 1 kilogram of greenhouse gas for every kilogram of metal produced. This does not account for the carbon absorbed by removed forests.

2.6 The Legal, Policy and Institutional Framework Governing Artisanal Small-Scale Mining in Nigeria

It's vital to assess the responsibilities of various government organizations at the federal and state levels, as well as their separate legal and regulatory authorities, when contemplating how to handle chemicals used in artisanal small-scale mining, such as mercury and lead. While the Ministry of Mines and Steel Development is solely responsible for solid mineral extraction, several bodies have a role in regulating mining-related activities, including mercury use. The Federal Ministry of Environment and numerous state environmental bodies, for example, are responsible for concerns relating to the environmental effect of mining activities. Mining-related activities can also be regulated by state and municipal governments (including Emirates and Local Government Areas).

2.6.1 Overview of key institutions

The Federal Ministry of Mines and Steel Development (MMSD) and the Federal Ministry of Environment are in charge of enforcing the legislative framework that governs mining operations and their environmental consequences (FMENV). FMENV administers

Nigeria's general environmental protection legislation (the National Environmental Standards and Regulation Enforcement Agency (NESREA) Act), whereas MMSD administers the country's mining law (the 2007 Minerals and Mining Act) and its regulations (Mallo, 2012).

2.6.1.1 *Ministry of mines and steel development*

The MMSD was founded in 1985 with the goal of promoting the development of the country's solid mineral resources (Mallo, 2012). It is the primary player in the country's solid minerals industry in terms of information, policy, and regulatory control. Formulating policies, providing information and expertise to improve investment in the industry, regulating activities, and earning suitable income for the government are all part of its responsibilities. The Minerals and Mining Act of 2007 and the Minerals and Mining Regulations of 2011 are administered by the Ministry. It is divided into four main technical departments: (i) The Mining Cadastre Office, (ii) the Mines Environmental Compliance Department, (iii) the Mines Inspectorate Department, and (iv) the Artisanal and Small-Scale Mining Department are the four departments that make up the Mining Cadastre Office. These departments work together to oversee the issue of mining permits, inspections, and environmental monitoring in Nigeria.

2.6.1.2 *Federal ministry of environment*

Environmental protection must be monitored and enforced. Water quality, ozone protection, effluent restrictions, atmospheric protection, noise management, air quality, and the removal and control of hazardous chemicals are all areas where standards and rules are set. On topics connected to environmental preservation and natural resource conservation, collaborating Federal and State, Local statutory authorities and institutions for research and development.

2.6.2 Mining policy and regulatory laws

The legal framework of the MMSD is built on the Mining and Minerals Act of 2007 as well as 2011 Mining and Minerals Regulations. The Nigerian National Metals and Minerals Policy of 2008 and 2009 and Report of the Vision 2020 National Technical Working Group on Metals and Minerals Development. Also, the Road Map for the Metals and Solid Minerals Sector Development 2012 all provide advice on mining. Artisanal and small-scale mining are addressed in varied degrees by these legal and regulatory mechanisms. While they together grant MMSD broad jurisdiction to help small-scale artisanal miners in the actuality, and it aid ministry to limit small-scale artisanal miners. The available legal of mining cooperation are significantly less in numbers compared to the number of miners that are unregistered now to engage in mining operations, has been premised on artisanal miners.

2.6.2.1 *2007 and 2011 minerals and mining Act*

Nigeria approved the 2007 Mining and Minerals Act, which would be managed by five departments in the MMSD, in order to improve mining practices (the 2007 Mining and Minerals Act). The Act that abolished the Mining and Minerals Decree of 1999 mining laws gave the federal government ownership of all mineral resources and gave mining priority over other land use forms. The Office of Mining Cadastre was established by the Act to administer mineral mining titles while keep track of mining tenancies. The law also established a Department for Environmental Compliance as well as Inspectorate. The departments issues mining permit and environmental protection systems that benefits community base on requirements.

The MMSD Act gave the authority a grant to six different kinds of licenses, leases and permits as listed below. The permits or licenses often grant non-exclusive rights to land use whereas licenses grant exclusive rights to land use for a specific purpose. The leases grant exclusive rights of ownership for a wider range of uses (Minerals and Mining Act, 2007). Reconnaissance grants a non-exclusive "access right to territory that seek mineral resources explorations."

- **(i)** **Exploration licenses**—exclusive right to investigate mineral resources, including the rights to install plants and machinery as well as ability to perform sampling and selling bulk samples.
- **(ii)** **Mining leases**—exclusive rights to land uses, occupancies, and exploitation of minerals in the lease area, which is not to exceed 50 kilometers.
- **(iii)** **Small-scale mining leases**—the rights to extract mineral resources in areas ranging from 5 acres to 3 square-kilometers utilizing low-cost technologies or methods that do not need significant investment.
- (iv) **Permits for water uses—**grant the rights to the uses of water resources for quarrying, mining and other mineral exploration.
- (v) **Quarry leases—**grant rights for the collection and disposition of any mineral resources quarriable in an area not exceeding 5 square kilometers, including necessary excavation and building.

Under the Act, gold buyers must additionally apply for a mineral acquisition license. According to the Act, gold mineral acquired under the lease for Small-Scale Mining (including artisanal mined gold) are to be sold to Center licensed to Buy Minerals (2007 Mining and Minerals Act). Despite these facts, majority of the Acts are centered on large-scale mining and commercial mining activities. This does include mining in small-scale sectors that follows the footsteps of the mining Decree of the 1999. Artisanal mining is subject to the same laws as small-scale mining since it is designated in the subset of small-scale mining Act. Artisanal and small-scale miners can both apply for a small-scale mining lease (but must be first organize of cooperative or member of artisanal miners).

There are no particular leases for artisanal mining under the mineral mining Act. The specific parameters for a small-scale mining lease are outlined further down.

The finalized MMSD for the mineral resources mining regulations under the 2007 Act in May 2011. The mining laws includes a section that briefly explain artisanal small-scale mining activities. This section permits mineral miners to enable register as artisanal small-scale mining organizations and get the Ministry of Minerals and mines extension services such as help receiving funds and financial supports from Department of Solid Minerals. As noted previously, artisanal mining cooperative can apply for minerals' mining rights in form of a lease for small-scale mining activities.

2.7 Federal Environmental Regulatory Laws

The Federal Environmental Protection Agency of Nigeria was abolished in 1999, and the Federal Ministry of the Environment took its place (Federal Ministry of Environment and Environmental Protection Agency, 2012). The National Environmental Standards and Regulation Enforcement Agency Act as cited by (Okonkwo, 2018). The Act superseded FEPA from their primary statute environmental management and protection under Section 20 of the Constitution, was passed in 2007. NESREA is a Federal Ministry of the Environment (FMEnvt) parastatal responsible for conducting environmental impact assessments and enforcing international environmental treaties like the Basel Conventions and Minamata.

2.7.1 Environmental impact assessment decree

The Ministry of the Environment is required to do a pre-construction study of activities that raise environmental concerns under the Decree No. 86 of 1992 Environmental Impact Assessment (EIA 1992). Without an EIA, no activity that falls under the Decree's required list, such as mining in new regions larger than 250 hectares or ore processing (including gold concentrating), can be carried out (EIA, 1992). The Mines and Minerals Act and its rules augment the Decree by requiring all mining leases to undergo a pre-construction EIA. The Ministry of Mines and Environment as well as Department of Environmental Compliance under the MMSD examine all completed EIAs. EIAs are expected to include activity description as well as the possible impact on the environments, according to the Decree. The practical as well as the assessment options are most likely or prospective consequences on environment. Identification of activities and impacts as well as description of mitigation actions, as well as a statement of knowledge gaps (Federal Ministry of the Environment, 2012). Surface infrastructure plans (including water pollution control) groundwater, air pollution and surface water analyses are among the mining-specific criteria.

2.7.2 Prescriptive environmental regulation

Mining activities must conform to background environmental laws administered by NESREA on behalf of the Ministry of Environment in addition to the Minerals and Mining Act and the EIA regulation. The NESREA Act mandates the Ministry of Environment to enact laws aimed at safeguarding public health and welfare (Muhammed, 2012). In terms of mining, the FMENV issued laws in 2009 controlling Pollution Abatement in Coal, Ores, and Industrial Minerals Mining and Processing. The laws aim to reduce pollution from industrial minerals mining, coal, and ores processing, as well as set emission limits for certain pollutants (Muhammed, 2012). The rules, however, do not cover mercury usage in ASSM activities, and there are presently no laws or regulations in Nigeria that regulate mercury use in ASM.

2.7.3 State policies and environmental laws

The States of the Federation have power to establish environmental legislation which do not preempted or competing national legislation. Nigeria, on the other hand, have the constitutional clause that lists the "exclusive legislative rights" vests sole the National

Assembly with legislative authority including those of minerals and mines (Constitution of Nigeria). With a few exceptions, the Minerals and Mines Act of 2007 and federal rules would preempt most state ASM regulation. Environmental agencies and legislation exist in every Nigerian state (Makinde and Adeyoke 2007). These state agencies operate under the cooperative federalism concept, which means that states have concurrent control over most environmental issues. Regulations adopted by the Ministry of Mines and the Ministry of the Environment create a floor. The EIA process is frequently monitored and enforced by state authorities, who also issue permits, perform surveys, and participate in outreach.

2.8 Geographic Information System Application

Geographic information systems (GIS) have evolved into indispensable tools for spatial and statistical analysis of water resources in order to improve management (Abdelbaki *et al.,* 2017). GIS have been characterized by many as a very powerful tool when it comes to information technologies. GIS stands for Geographic Information System, and it is a system for managing, analyzing, and displaying geographic knowledge that is represented using a series of data sets (Awad *et al*., 2017). However, the University of Wisconsin-Madison describes GIS as: a system designed to capture, analyse, manipulate, manage, present and store all types of geographical referenced data. The capability of GIS lies in its ability to geo-referenced data. This technology is geographically reliant, which implies that part of the data is spatial.

Therefore, GIS can be used for several purposes especially problem solving and decision-making processes, not leaving behind its main feature of visualising data on a spatial environment. GIS analyzes geographical data to establish feature positions and linkages, where the most and least of certain features occur. The density of features in a particular region, what is going on inside an area of interest, activities around some feature, and changes in a specific area over time (A Saminu *et al*., 2013). Realising the power of GIS application in various fields, it has also been intensively used in mining field to produce mineral maps.

2.8.1 ArcGIS

ArcGIS is a collection of professional software in GIS (applications) for solving issues, achieving goals, increasing efficiency, making better decisions, and communicating, visualizing, and understanding an idea, a plan, a dispute, a problem, or the current state of a scenario (Awad *et al*., 2017; Hillier, 2011). ArcGIS can be utilized to create models that can be integrated for water distribution networks. In simple terms, the system contains six main procedures. Digital vector maps are created, followed by the establishment of a geo-database to hold network data. Then, to ensure proper network drawing, geometric networks must be built, followed by topological rules to assure precise spatial links. Finally, relationship classes are used to connect the data from the external model to the GIS database. ArcGIS uses basic tools for data visualization and data inquiry handled by the ArcMap platform.

One of the widely applied tools is the structured question language (SQL) attribute select tool. SQL is a standard computer language for accessing and managing databases. In ArcGIS, SQL is used to define subset of data in order to perform some operations. Furthermore, ArcGIS use thematic maps symbology are helpful in the way to visualize data associated with drawings, they are used to represent data with colours and symbols. Also, data can be labelled using the labelling tool. In WDN management the platform offers transfer attributes application or plugins. The application adjusts GIS layers to be used in hydraulic analysis models. This plugin copies attribute data from point features such as pipes to adjacent line layers (Ayad *et al.,* 2016).

2.8.2 Idrisi Terrset

Idrisi terrset is a software system that comprises tools for GIS analysis, image processing, vertical applications for land change analysis, surface analysis, earth trend modeler, ecosystem services, climate change adaptation modeler and more. The program comes with a wide range of image processing features, making it a great choice for land cover mapping applications using remotely sensed data, which is a key part of our research. The software also includes tools for image restoration, classification, transformation and enhancement as well as a number of machines learning tools, including maximum likelihood classification, artificial neural network classifiers, time series analysis and land change as used for analysis in this study (Rahnama, 2021)

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Types of Data and their Sources

This chapter discussed materials as well as the methodologies used to set up measurements for various parameters, as well as the data collection and analysis method employed, as well as the study strategy. To answer the research questions, the study gathered data from primary and secondary sources.

3.1.1 Materials

The primary data collection methods employed for this study/fieldwork include Photographs from the field, *in situ* observation, focus group discussions, GPS for picking geographic coordinates, questionnaire, water samples, soils and key informant interviews, for tests and analysis.

The secondary data were sourced from the Nigeria Geological Survey Agency (NGSA geological) map of the research region, as well as information from the National Bureau of Statistics (NBS), For the land use and land cover LULC trend maps of the researched regions, the geo-referencing characteristics in 1986, 1996, 2006, and 2016 were utilized, which included the universal Transverse Mercator (UTM) projections and datum WGS 84, zone 32 IDRISI Terrset. The location maps were created, displayed, and processed using ArcGIS 10.3.

3.1.2 Software components

The software used Idrisi Terrset and Aeronautical Reconnaissance Coverage Map 10.3:

3.1.2.1 *Idrisi terrset*

This is a software system that comprises tools for GIS analysis of vertical applications for land change analysis, image processing, surface analysis, earth trend modeler, ecosystem services, climate change and adaptation modeler and more for the study and display of spatial data. The program came with a wide range of features for image processing, making it a great superior application for mapping land cover using remotely censored acquired data, which is a key part of our research. The software also included tools for image restoration, enhancement, classification, and transformation, as well as a number of machine learning tools, including maximum likelihood classification, time series analysis, land change and artificial neural network classifiers, the majority of which were used in this study ((Rahnama, 2021)

3.1.2.2 *Aeronautical reconnaissance coverage (Arc) map 10.3*

The aeronautical reconnaissance coverage (Arc) map 10.3 was used to producing Local State and National government boundary map of the study area. This was used to extract the study area from each satellite scene and thereafter exported to Idrisi for further image analysis. Aeronautical Reconnaissance Coverage Geographic ESRI's Geographic Information System (ArcGIS) is a vector and raster-based software. It offers a scalable framework for Geographic Information System (GIS) implementation for users. ArcGIS collection tool of GIS software can be used to create a full GIS. Modules such as Arc-Catalogue, Arc-Map and geographical analysis were employed in the research (ESRI, 2015 and Awad *et al*., 2017)

3.2 Methods of Data Analysis

3.2.1 Examination of the various types of minerals in the environment of the study area.

Reconnaissance survey was undertaken to the study areas and rock samples were collected for preliminary investigation. Garmin handheld global positioning system (GPS) 76 was used to take coordinates of ASM points, physical collection of rock samples from twenty-one (21) ASM sites in the study locations. The GPS was used to get latitude and longitude, Physical observation, examination and discussions with various professionals (Geology experts, miners and mine owners) helped to determine the mineral mined in each site, the name of the site and the status of the pit, this screened out the mine site to fifteen (15) due to activeness of the sites. Comparing the minerals with the Mineral Map from the Nigeria Geological Survey Agency (NGSA) resulted in the outcome of the minerals mined in the various sites as shown in Table 4.1. As a sub-section, visual interpretations of the aspects of the artisanal mining locales are shown and the results obtained from Preliminary survey were used for further field investigation and laboratory analysis.

3.2.2 Analyze the extent of land use and land cover of the area under the study.

The research regions' vectors were imported into a GIS system to create geo-references utilizing geo-spatial techniques. Landsat satellite imageries of 1986, 1996, 2006, 2016 through the use of maximum classification of likelihood scheme with five (5) classes of land use and land cover (mining site, water body, farmland and vegetation as well as built-up areas). Data for the description of mining site and mineral type was gathered using surveys and key informant interviews. Other mining-related characteristics were found and mapped, degraded soils, including pits (for example, erosion), destruction of flora, and consequences of physical activities on streams (bodies of water), photographs of the characteristics and activities seen in the mining sites were obtained.

At the conclusion of the fieldwork, the data was entered into a Geographic Information System (GIS) environment to generate maps of mine host communities and soil and water sample collection points (including mine locations). The information gathered from these activities was examined using the descriptive research approach. Calculating area under cover in hectares, the various land use and land cover (LULC) types can be used for each research while comparing the findings. The data used for this study was acquired from time series photos from the landSat enhanced thematic mapper plus (ETM+) and

Thematic Mapper (TM) with Thermal Infrared Sensor (TIRS) as well as photographs from the operational land imager (OLI) in 2016.

The land use land cover (LULC) of the study areas and maps were created using this method. Landsat TM, ETM+, and OLI (30m) (Table 3.1), data are extremely valuable for land use and land cover categorization, and general mapping, because to their high spectral resolution. The data spans four decades, from 1986 to 1996, 2006 to 2016, to name a few. The raw satellite data came from the US Geological Survey and Earth Explorer archives. The LULC maps were created with the Universal Transverse Mercator (UTM) and the zone 32 datum WGS 84. Land cover information were compared to determine the changed percentage, trend, as well as rate of changes throughout the period of research. The first step was the creation of table that displayed the covered area in hectares and in percentage changes from each presiding year for each land cover category.

Table 3.1: Details of Satellite Data Used

S/N	Sensors	Path / Row	Sources	Year of Acquisition	Scale of resolution
1	LANDSAT TM	187/054	USGS	1986, 1996	30
2	ETM+	187/054	USGS	2006	30
3	OLI	187/054	USGS	2016	30
4	ASTER DEM	187054	USGS	2016	30

Source: USGS (United State Geological Survey) website

The level 1 categorization of Anderson *et al.* (1976) was accepted and changed into five classes: built up, vegetation, agricultural, sand bar, and aquatic body (Table 3.2). A supervised classification technique was employed to apply a per-pixel image classification approach for ground cover analysis, which is the act of utilizing samples of known identity to categorize unknown identity. Because it is one of the best classification methods for assigning pixels to the class with the highest chance to determine class ownership of a specific pixel, the maximum Likelihood Method was utilized.

Table 3.2: Classification and Description of the Scheme used for this Study

S/N	Class	Description
1	River and water bodies	Rivers, lakes, reservoirs, and streams as well as permanent open water, canals, ponds, low-lying regions, permanent and seasonal wetlands, swamps and marshy ground are examples of open water features.
2	Built-up	Homestead areas are included in the urban and rural built-up areas. Residential, commercial, mixed-use, and industrial sectors, as well as pavements, man-made structures, villages, towns, and the road network.
3	Mining Pits	Open dry sand, bare soils, excavation sites and open space.
4	Farmland	Fallow land, construction sites, earth and sand land in-fillings, open space, developed land, bare soils, the remaining land cover types and excavation sites.
5	Vegetation	Trees, mixed forest, parks, playgrounds, natural vegetation, gardens, grassland, crop fields vegetated lands and agricultural lands.

3.2.3 Assessment of the environmental impacts of artisanal and small-scale mining on the local environment of the area under study.

Water samples were taken from mine pits and waterways near Baryte panning sites. Six water samples from the river and the mining sites (200 meters apart), where process water from the sluicing area drains in Awe. One sample from farm land and one sample of water from the mine hole was taken in Obi but away from the farms. Water samples from up and down the streams in the Keana mining sites were also taken.

Soil samples were taken from active and abandoned mine sites at a depth of 30cm. The water and soil sample collection points in and around Adudu, Azara and Keana in the Awe, Obi and Keana LGAs, are displayed on the map in Figure 3.1. A mixed method approach was used (interviews and observation techniques) to collect data in the study areas on the implications of artisanal and small-scale mining operations.

This method was complemented with in-depth discussions on ASM management challenges. Interviews were conducted for community leaders from the mines' host villages. Following that, questionnaires and focus group talks were given to a random sample of mine employees (including farmers) who had lived in the mine host villages their whole lives. The opinion of artisanal miners, mining regulators, and other industry stakeholders were also sampled. Finally, the data was processed and the results were presented in an informative manner.

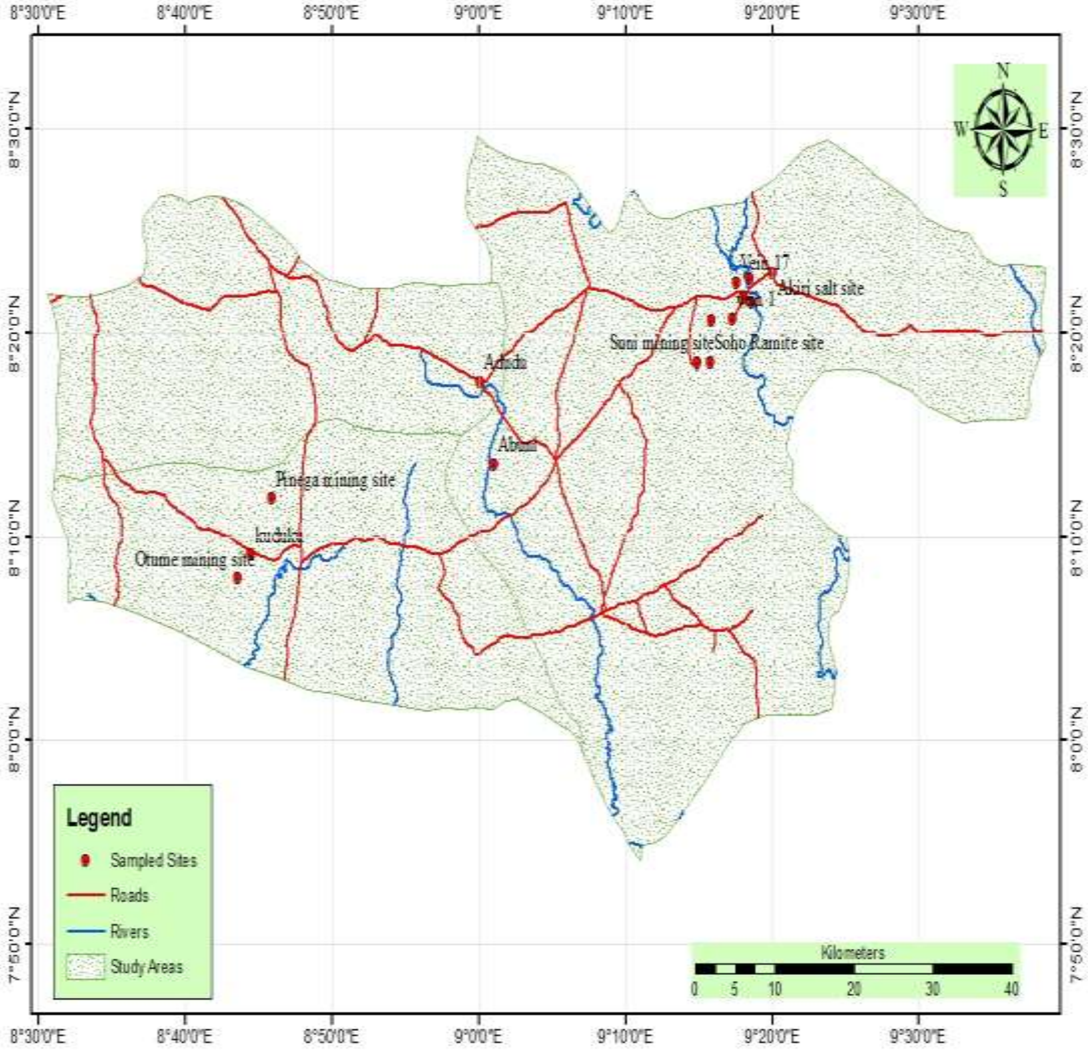


Figure 3.1:Sample Collection Points from the Study Areas (Awe, Keana and Obi LGAs)

Source: Author's fieldwork map, 2023.

3.2.4 Compare the environmental degradation outlook of the study area with the Federal ministry of environment standards.

To evaluate the presence and quantity of heavy metals, water and soil samples were collected and examined. Fifteen (16) soil samples were analyzed using an X-Ray Fluorescence (XRF) equipment, type Panalytical, at the LABCHEMNEC JANS LTD, Abuja, for physical and chemical parameters. The XRF process entails drying and pulverizing the sixteen soil samples, with around 10 grams of each sample being weighed.

The sample was then placed in the XRF machine's sample cup and examined with Millipal 4 software (Brouwer and Clemence, 2013).

3.2.4.1 *Electrical conductivity (EC) determination*

The electrical conductivity value was obtained by utilizing digital conductive meter lab tech model AVI 648. The conductivity probe was plugged into the unit prior to sampling, then, the calibration of the meter in terms of cell constant, standard solution, reference temperature and automatic temperature corrections was reset by the makers. The electrode was inserted into the samples and EC value (µS/cm) props up shortly after the insertion.

3.2.4.2 *pH determination*

The pH sample values were obtained using multi-parameter model DZS-700. The procedure involved calibration of the meter by inserting the meter probe or electrode into the buffer 7 solution. In order to avoid contamination, the electrode was be rinsed with the sample to be analyzed and agitated to allow for homogeneity before taking the readings at stabilized state.

3.2.4.3 *Nephelometric turbidity unit (NTU) determination*

Turbidity is the intensity of light scattered by the sample under prescribed conditions compared to the intensity of light scattered by the standard reference suspension under the same conditions. The turbidity of the samples was obtained using an electronic turbidity meter through Nephelometric method. The procedure involved calibrating the meter with a standard solution 400 NTU and replacing the standard solution with 0 NTU utilizing distilled water as reference adjusting the calibration knob after which the samples are inserted to read off their turbidity values.

3.2.4.4 *Chemical parameters*

Major ions in the samples include K^+, Na^+, Ca^{2+}, Mg^{2+}, Cl^-, CO_3^{2-}, HCO_3^-, SO_4^{2-} and NO_3^-

Similarly, fifteen (15) water samples for wet and dry seasons were collected from mine sites, discharged water from pits and streams in Awe, Keana and Obi respectively were analyzed at LABCHEMNEC JANS LTD, Abuja an accredited laboratory by the National Institute of Science Laboratory Technologists because at the time of sample dispatch, the National Geological Laboratory had closed for the year. The water samples were examined using the Atomic Absorption Spectroscopy (AAS) method to analyze the water quality. AAS entails converting samples into gaseous atoms in a hot flame in a system that includes a unique radiation source known as the hollow cathode and a method that uses a nebulizer to inject the sample into the hot flame. The AAS is very useful for identifying metallic elements because the exact wavelength associated with the atomic spectra lines allows for accurate analyte identification (Oladipo *et al.*, 2014). It's commonly utilized in single-element and multi-element analysis. To reduce contamination, seventeen 2-litre clean plastic and amber bottle containers were used; all of the sampling bottles were cleansed with distilled and sample point water.

The source of water, sampling location and date of water sample collection were tagged and labeled. As a preservative, the water samples were acidified with (0.5ml) concentrated nitric acid (HNO3). This was done since the water samples were not going to be examined right away and needed to be stabilized in order to retain the metallic ions in a single oxidized state and minimize precipitation, adsorption to the container walls, and microbial deterioration (Batley and Gardner, 1977). The containers were then placed in a cold box with ice pellets in order to preserve the samples before transporting them to the laboratory for examination. As, Pb, Co, Zn, Ni, Cr, Cu, Hg, V, Mn, Fe, and Cd are the heavy metals of interest in both soil and water samples because they affect human health, plant and the environment adversely if taken in large quantity.

The data from the laboratory analysis of the soil samples were processed, analyzed, and interpreted to determine the Contamination Factor (CF) and Index of geo-accumulation (Igeo). This is done using the equations CF = Cm/Bm where Cm is the measured concentration, Bm is the background concentration and Igeo = log2[Cm/(1.5xBm)] (Taylor and McLennan, 1995). The Geo-accumulation index assigned a numerical contamination level based on the quality of the medium (soil and water). Based on Igeo, Table 3.3 depicts various ranges of pollution.

Table 3.3: Index of Geo-accumulation Contamination Classes (Igeo)

S. No.	Range (categories)	Description
1	Igeo <0	Unpolluted
2	0<=Igeo<1	unpolluted to moderately polluted
3	1<=Igeo<2	moderately polluted
4	2<=Igeo<3	moderately to strongly polluted
5	3<=Igeo<4	strongly polluted
6	4<=Igeo<5	strongly to very strongly polluted
7	Igeo>=5	very strongly polluted.

Source: (Taylor and McLennan, 1995).

The Contamination Factor (CF) allowed researchers to characterize the contamination of soils and water bodies in the study regions and differentiate between metals emitted by human activities (such as mining) and those emitted by natural processes (such as weathering). The categories (CF pollution level in soils) are shown in Table 3.4.

Table 3.4: Categories and Meaning of Contamination Factors (CF)

S. No.	Range (Categories)	Description
1	Cf<1	low contamination factor
2	1≤Cf<3	moderate contamination factors
3	3≤Cf<6	considerable contamination factors
4	Cf≥6	very high contamination factor

Source (Taylor and McLennan, 1995)

The observed background concentrations of heavy metal in the earth's Upper Continental Crust, as gathered by (Taylor and McLennan, 1995), show element concentrations devoid of anthropogenic activity, were utilized as reference (background) materials for this investigation. Because there are no national soil quality recommendations or standards for heavy metal in soils in Nigeria, the comparisons in this study must be made using other known controls for heavy metal concentrations in soils as background (control) soils (Taylor and McLennan, 1995).

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Identification and Mapping of the Various Mineral in the Study Areas

In Obi local government area Adudu **one (1) mining site** was located where lead and zinc are mined; it is an active mining site where minerals are mined without personal protective kits for miners, material buyers, mine owners and laborers. Figure 4.1 reveal the mineral of Obi LGA showing the different types of minersls.

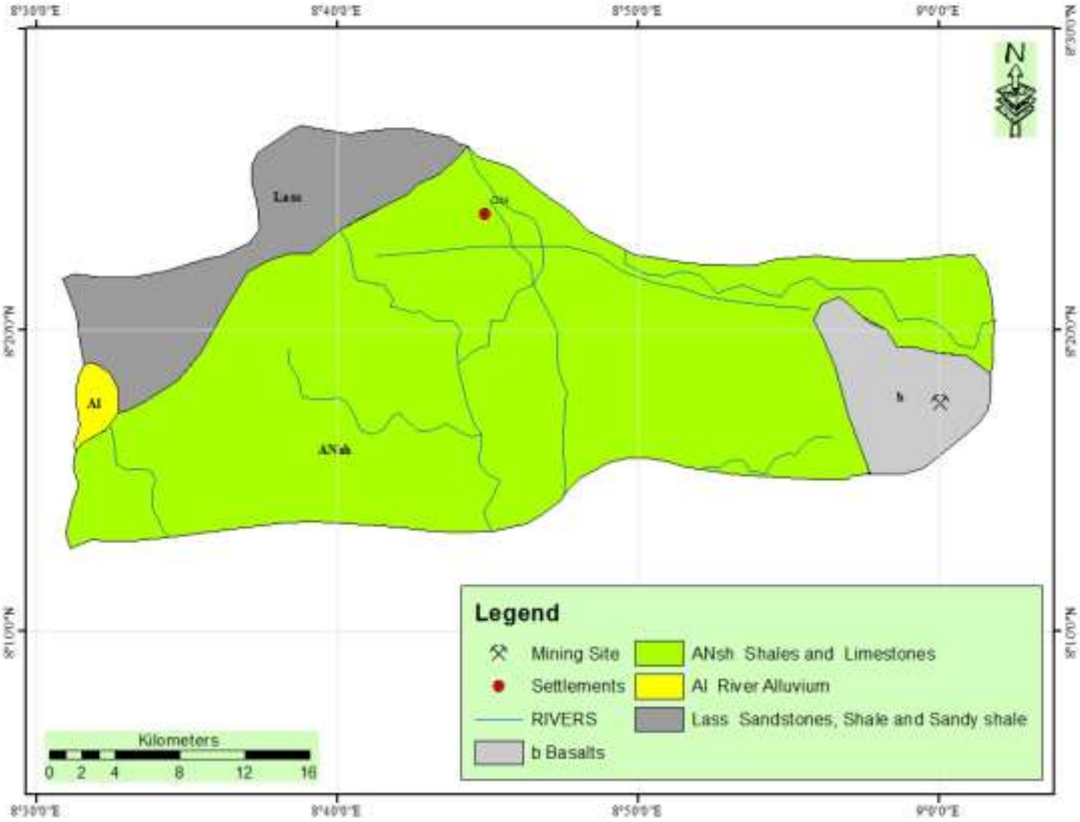


Figure 4.1 Mineral Distribution Map of Obi.

In Awe local government area, **thirteen (13) sites** were identified, three were abandoned and a warm spring was identified, ten (10) were active; Abuni (lead, zinc, chalcopyrite, iron oxide), Azara-sauni sarki (baryte), sohon rami (baryte), vein 17 (baryte and iron), wuse vein (baryte), Akiri salt (baryte with shoots of copper and charcoal), Akiri mine (salt), vein 1 (baryte and sandstone), Akiri spring (warm water) and Azara mine site (coppedr) while three (3) Vein 2 (low grade iron), Vein 18 extension (baryte) and Kanje (copper) were abandoned as at the time of the site visit. Figure 4.2 and 4.3 shows the mineral distribution map of Awe and Keana showing the different types of minerals in the areas.

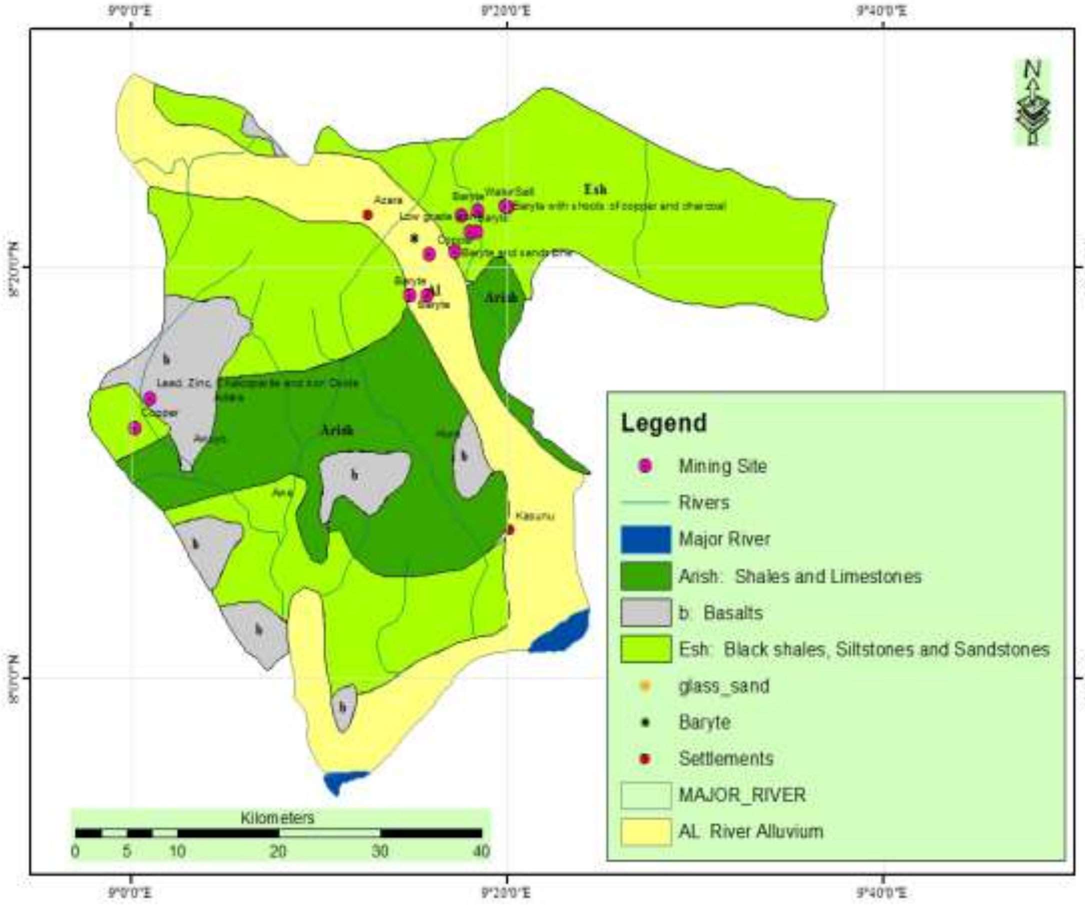


Figure 4.2: Mineral Ore Distribution Map of Awe.

In Keana local government area, **seven (7) mining** sites were identified of which three (3)-Otume and Otume 2 (baryte) and pfa’a (lead) sites were abandoned while four (4) are active in Kuduku (lead and baryte), Pinega (lead and zinc), Ribi (baryte) and Pinata (baryte)

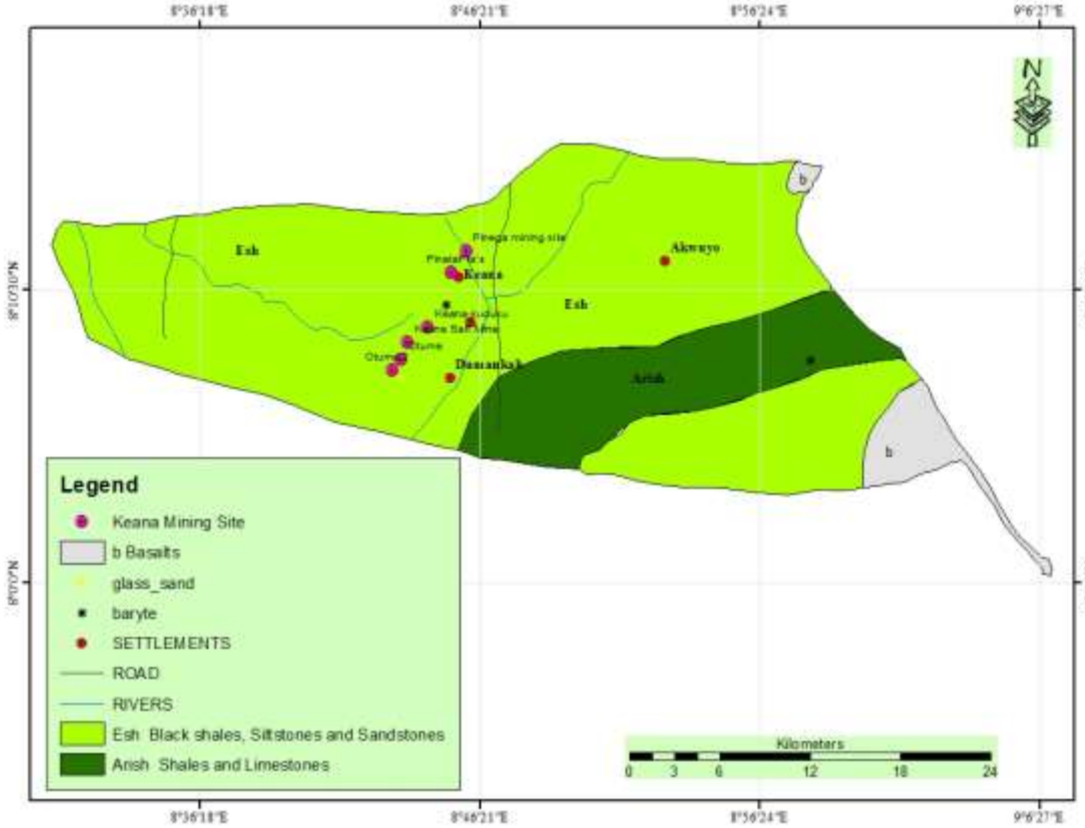


Figure 4.3: Mineral Distribution Map of Keana

Additionally, Table 4.1 shows the location of mining sites and the minerals mined across the study areas. The table shows the status of the various mining sites, the active once and those abandoned.

Table 4.1: Location of Mining Sites and the Minerals Mined

S/N	Name of site/LGA	Mineral mined	Lat	Long	Status
1	Obi-Adudu	Lead and Zinc	8.2935	9.000803	Active
2	Awe-Abuni	Lead, Zinc, Chalcoparite and iron Oxide	8.226178	9.017132	Active
3	Pfa'a	Lead	8.185428	8.755733	Abandoned
4	Saunin Sarki	Baryte	8.30948	9.247772	Active
5	Sohon Rami	Baryte	8.309475	9.262972	Active
6	Vein 17	Baryte and Iron	8.37419	9.292643	Active
7	Wuse vein	Baryte	8.378068	9.307833	Active
8	Akiri mine site	Baryte with shoots of copper and charcoal	8.382085	9.331723	Active
9	Akiri Salt Mine	Salt	8.38167	9.33416	Active
10	Vein 2	Low grade Iron	8.361423	9.30669	Abandoned
11	Vein 18 extension	Baryte	8.361103	9.300415	Abandoned
12	Vein 1	Baryte and sandstone	8.344937	9.287657	Active
13	Kanje	Copper	8.20268	9.003615	Abandoned
14	Akiri warm spring	Water	8.382085	9.331723	Active
15	Keana-kuduku	Lead and Baryte	8.15221	8.741418	Active
16	Azara copper mine site	Copper	8.343108	9.264667	Active
17	Otume	Baryte	8.132982	8.725642	Abandoned
18	Keana salt	Salt	8.143685	8.729372	Active
19	Pinega mining site	Lead and Zinc	8.197867	8.76462	Active
20	Pinata	Baryte	8.185428	8.755733	Active
21	Otume 2	Baryte	8.12695	8.720238	Abandoned

Figure 4.4 reveals the status of the mining site, it indicates that there are six (6) abandoned mining locations which are Kanje, Vein 18 extension, Pfa'a, vein 2, Otume and Otume 2 while other locations are active.

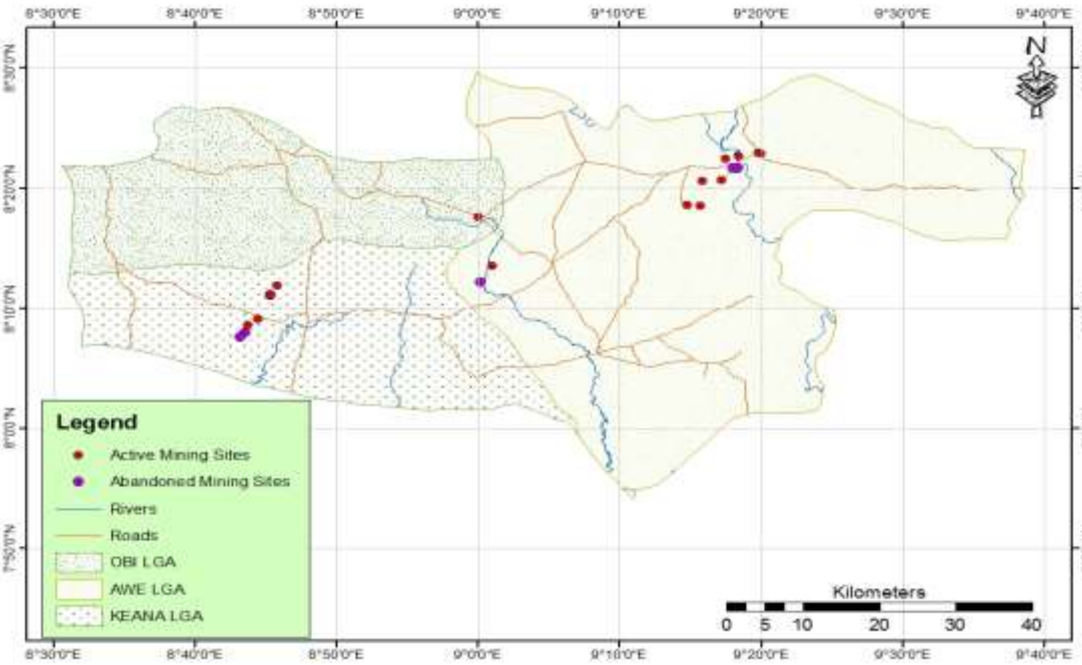


Figure 4.4: Mining Status of the Study Area.

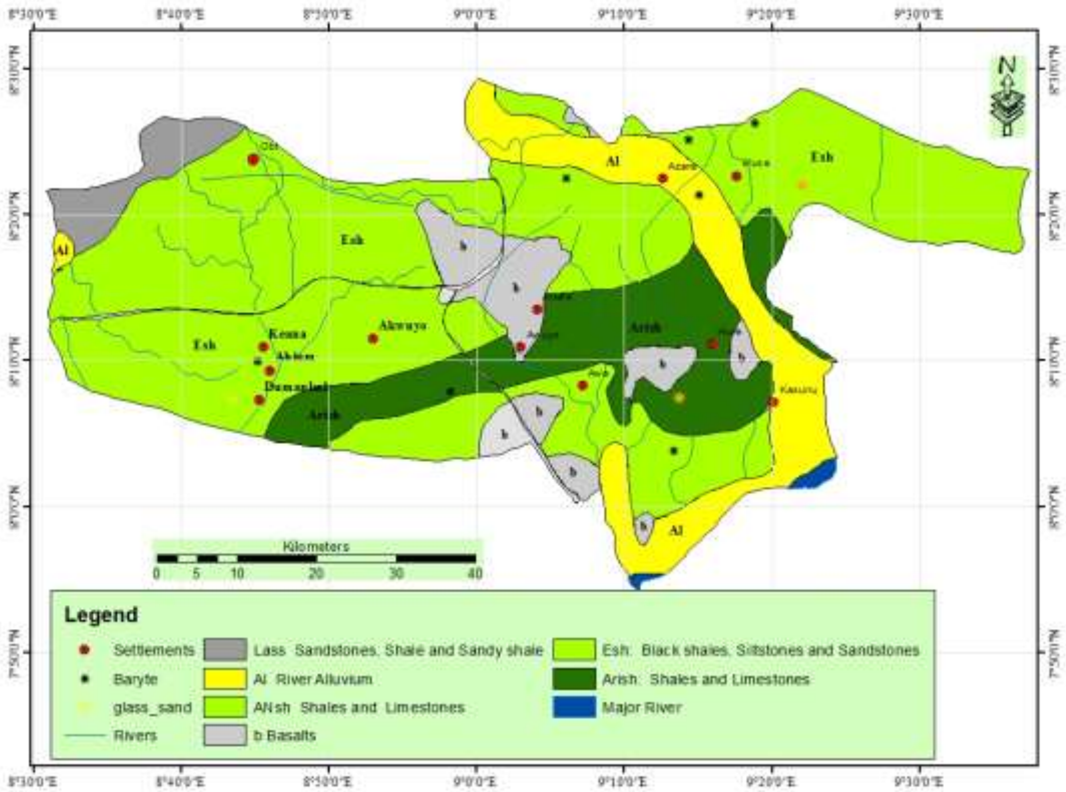


Figure 4.5: Geological Map of Obi, Awe and Keana

Furthermore, Figure 4.6 shows the mineral types across the mining sites. Findings shows that baryte, lead, zinc, chalcopyrite, iron oxide, iron, sandstone, barytes with shoots of copper and charcoal, copper and salt were the major minerals across the study locations. However, when compared with the geological map obtained from the Nigeria Geological Survey Agency (NGSA), it shows that more minerals have been identified but those found from the study are not on the map; this requires update.

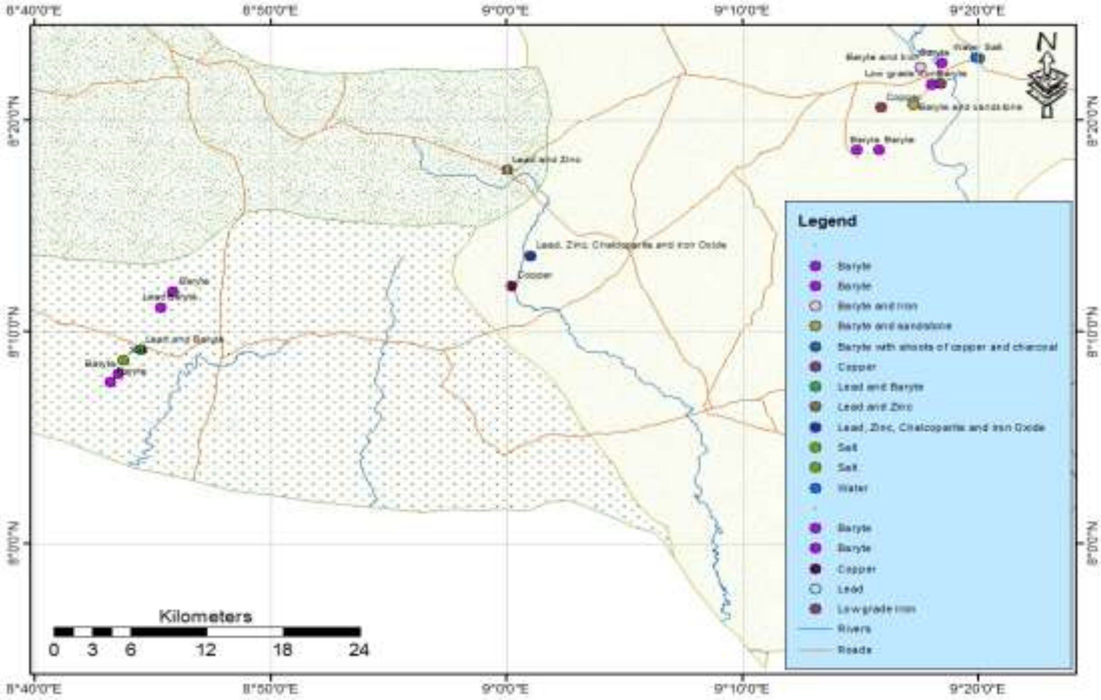


Figure 4.6: Mineral Map of the Study Areas

4.2 Land use and Land Cover Trend Analysis of the Area Studied

4.2.1 Classification and analysis of Awe land use and land cover

4.2.1.1 *LULC classification of Awe using 1986 satellite imagery*

The landuse and land cover map of the study area for 1986 (figure 4.7), showed that farmlands were the dominant features of land covering about 1445.425 kilometer square (57.95%) of the study area. This is spread across the area under study since the areas were more of rural settlements at the time the satellite image was captured. This was followed by vegetation cover, which occupied an area of 861.144kilometer square (34.53%), of the total land mass of the areas studied. Most of the vegetation cover can be found mainly in the northern eastern, central and towards the southern part of the areas studied. The built-up areas accounted for approximately 157.554kilometer square (6.32%) were typical across the area as well as the western and eastern bank of the rivers. The land use showed that in 1986 there were few settlements within the study areas. Also, mining pit covers roughly 5.2578kilometer square (0.21%), the mining company at that time was Nigeria Barite Mining and Processing Company, while water body covers 24.7887 square kilometer (0.99%). The total land area is approximately 106.78.68kilometer square.

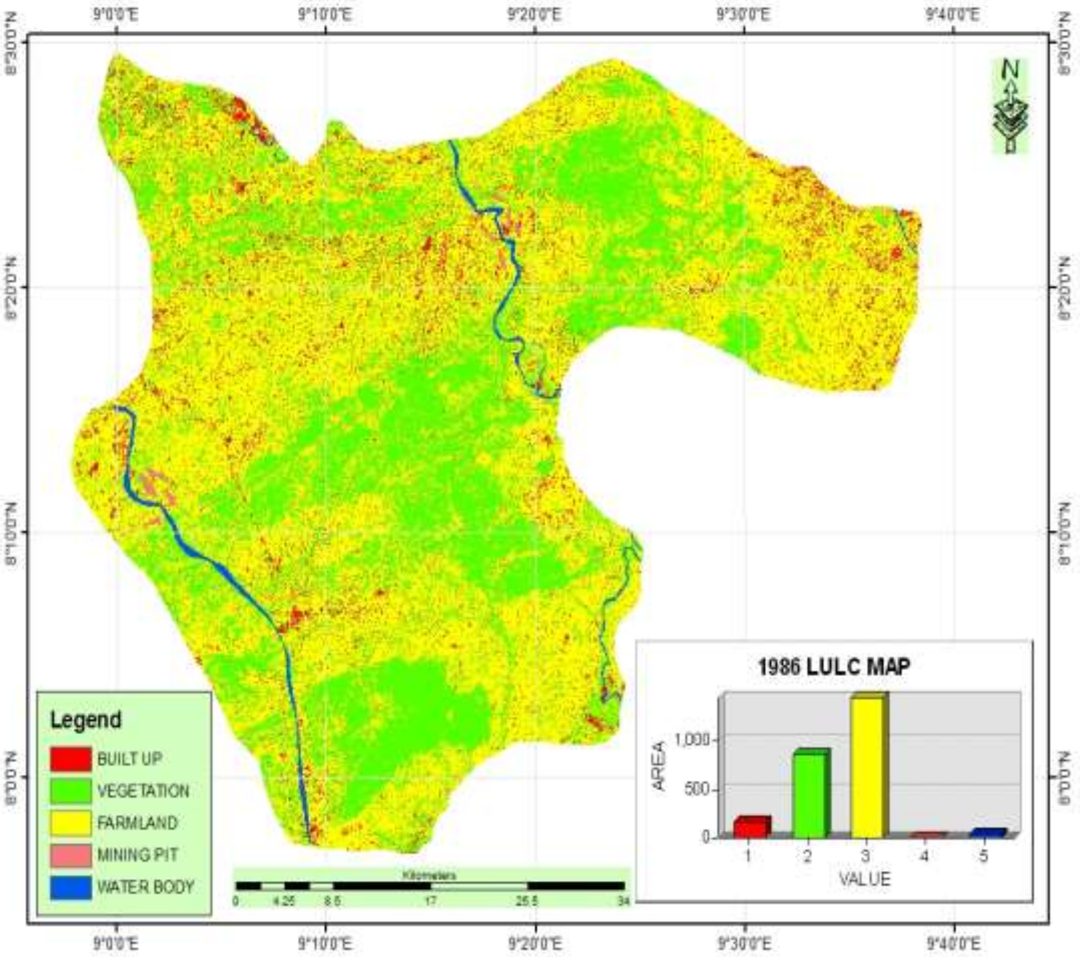


Figure 4.7: Land Use and Land Cover in Awe 1986

4.2.1.2 *Land Use and Land Cover of Awe in 1996*

The land use change map of Awe in 1998 (Figure 4.8) showed that farming continues to expand, reaching a total area of 1263.294 square kilometers (50.55 percent). Large part of farming land was scattered throughout the study area. Due to the fertile soil in the area, the bulk of the population were farmers, as evidenced by the huge share of farms. This was followed by vegetation which covers 826.9569kilometer square (33.09%), while built-up areas increased to 289.299 square kilometer (11.58%). This increase in population can be attributed to the fact that, this was when the state was created and there was influx of people to the area for business and job opportunities. Then mining pit area was 79.35 square kilometer (3.17%), the increase in mining pit was attributed to the influx of people to the area and availability of various minerals in the area, while water body was 40.314 square kilometer (1.61%) respectively.

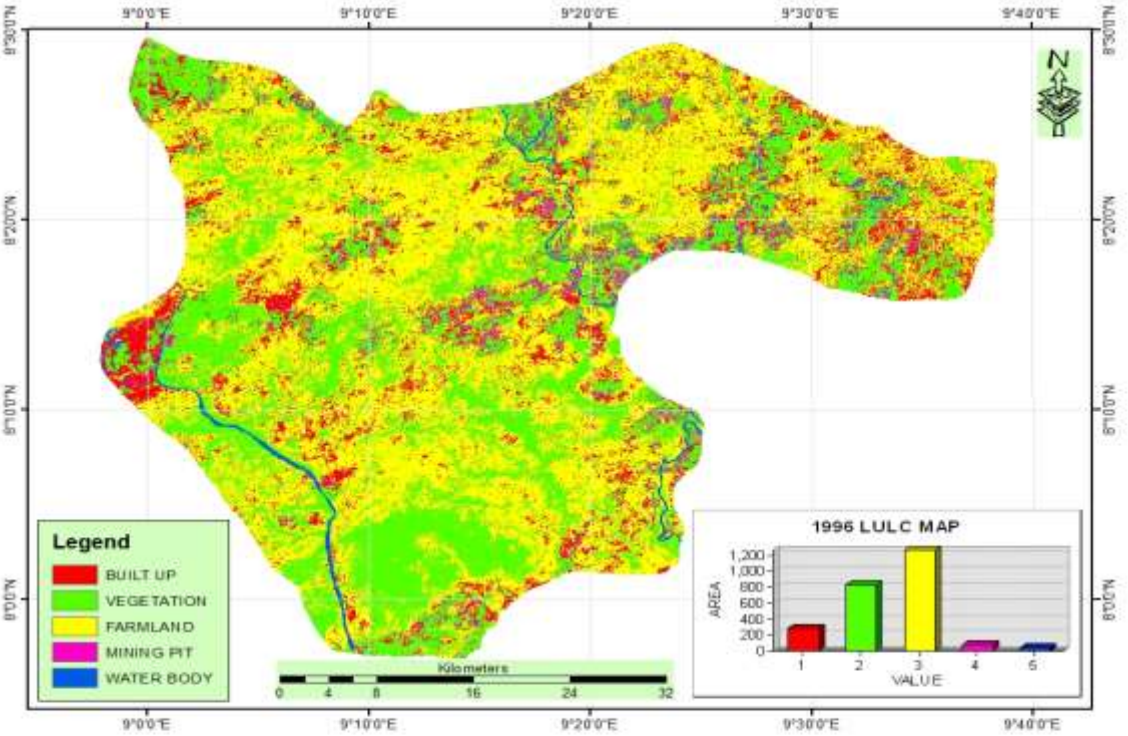


Figure 4.8 Land Use and Land Cover in Awe 1996

4.2.1.3 *Land Use and Land Cover of Awe in 2006*

The result in Figure 4.9 showed that 2006 LULC of the study region indicated that farmland had decreased dramatically over the last 10 years, from 1263.294 square kilometer (50.55 percent) in 1996 to approximately 954.0045 square kilometer (Km^2) in 2006. (37.23 percent). On the other side, area of vegetal cover grew from 826.9569 Km^2 (33.09%) to 1127.579 Km^2 (44.0%), indicated that farming operations were reduced and more vegetation was discovered. Furthermore, the built-up area grew as settlement spread to diverse parts of the study area. Built-up had increased from 289.299 (Km^2) (11.58%) in 1996 to approximately 413.4087 (Km^2) (16. 13%) an indication of increased population. The mining pit covers 79.35 square kilometer (3.17%) in 1996 and reduced to 34.191 (Km^2) (1. 33%) in 2006 while Water bodies reduced from 40.314 (Km^2) (1.61%) respectively in 1996 to 33.3045 (Km^2) (1.29%) in 2006.

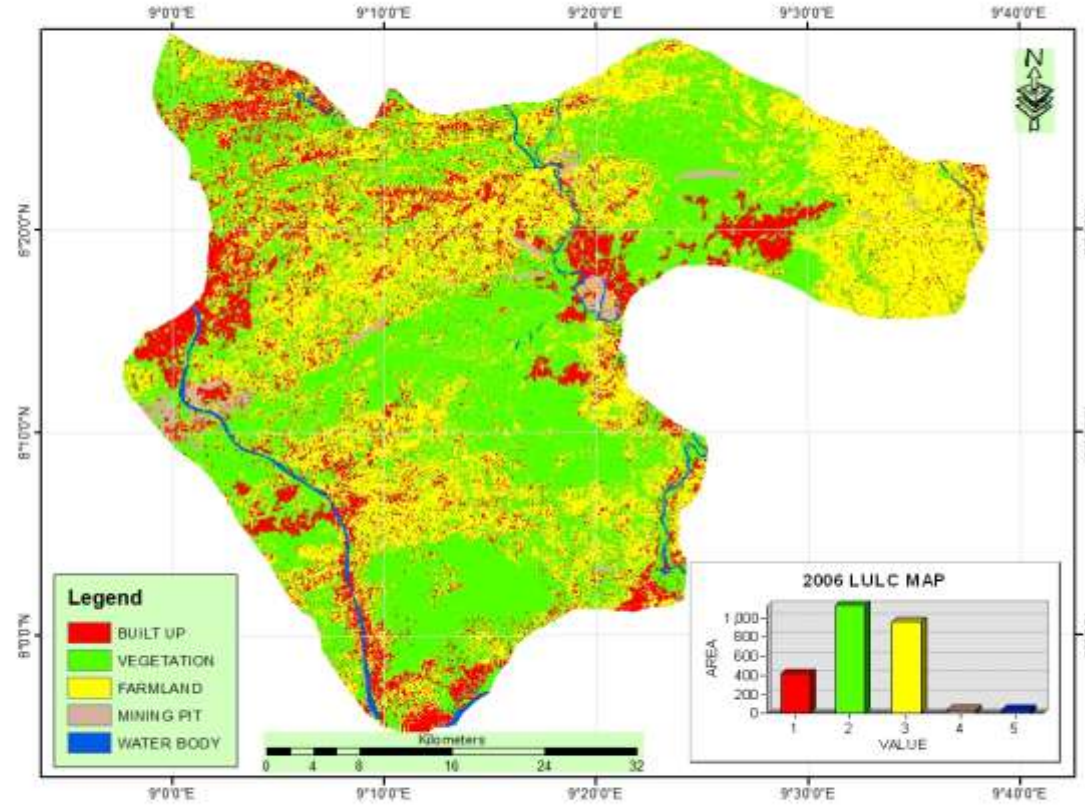


Figure 4.9 Land Use and Land Cover in Awe 2006

4.2.1.4 *Land use land cover change in Awe 2016*

Figure 4.10 showed the 2016 LULC map. Built-up areas and mining pits were on the rise, while other land use and cover types continue to decline as a result of human activities. According to the area covered by each of the LULC, vegetated land was the most prevalent land use and land cover type, accounting for 1055.744 Km2 (41.20 percent) in 2016. This was followed by the areas occupied by farmland which was about 751.8492Km2 (29.34%), while built-up area also increased from 413.4087 (Km^2) (16. 13%) in 2006 to 616.5117 Km^2 (24.06%) in 2018, an increase of 211. 2957 (Km^2) (8.25 %) which ultimately resulted in the conversion of other land use and land cover types to build-up due to influx of people. Also, the mining areas increased from 34.191 (Km^2) (1. 33%) in 2006 to 105.3369 Km^2 (4.11%). Finally, water bodies covered an area of 32.9949 Km^2 (1.29%) of the land mass of total study area.

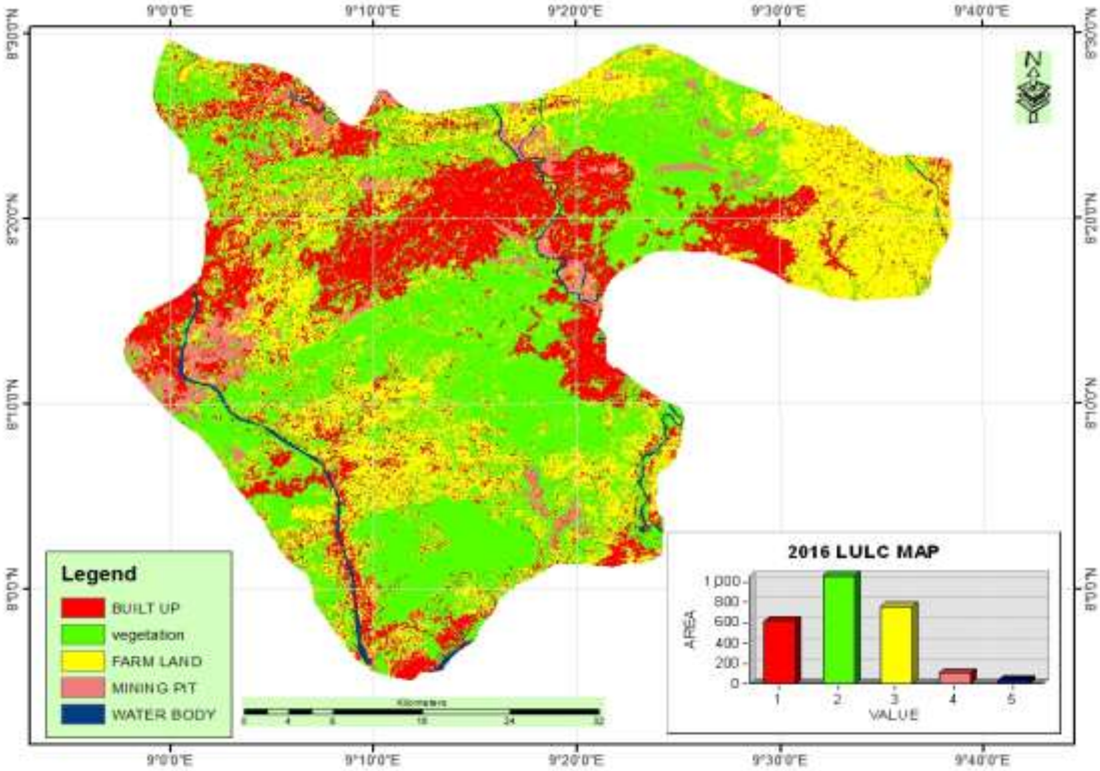


Figure 4.10: Land Use and Land Cover in Awe 2016

Similarly, Figure 4.10 showed that some part of the lands are degraded at the various mining site; at Awe specifically-Abuni and Azara mining areas of the Local Government Areas, other mining sites includes Saunin Sarki where baryte is mined, Sohon Rami (glass), Vein 17 (Baryte and iron), River Wuse site (baryte), Akiri mine (baryte with shoots of copper and charcoal, salt), Vein 2 (iron abandoned), Vein 18 extension (baryte abandoned), Vein 1 (mix of baryte and sand stone) while Kanji copper site was abandoned. This agrees with the work of (Atayi *et al.*, 2016) who carried out similar work on the impacts of large-scale mining on LULC changes.

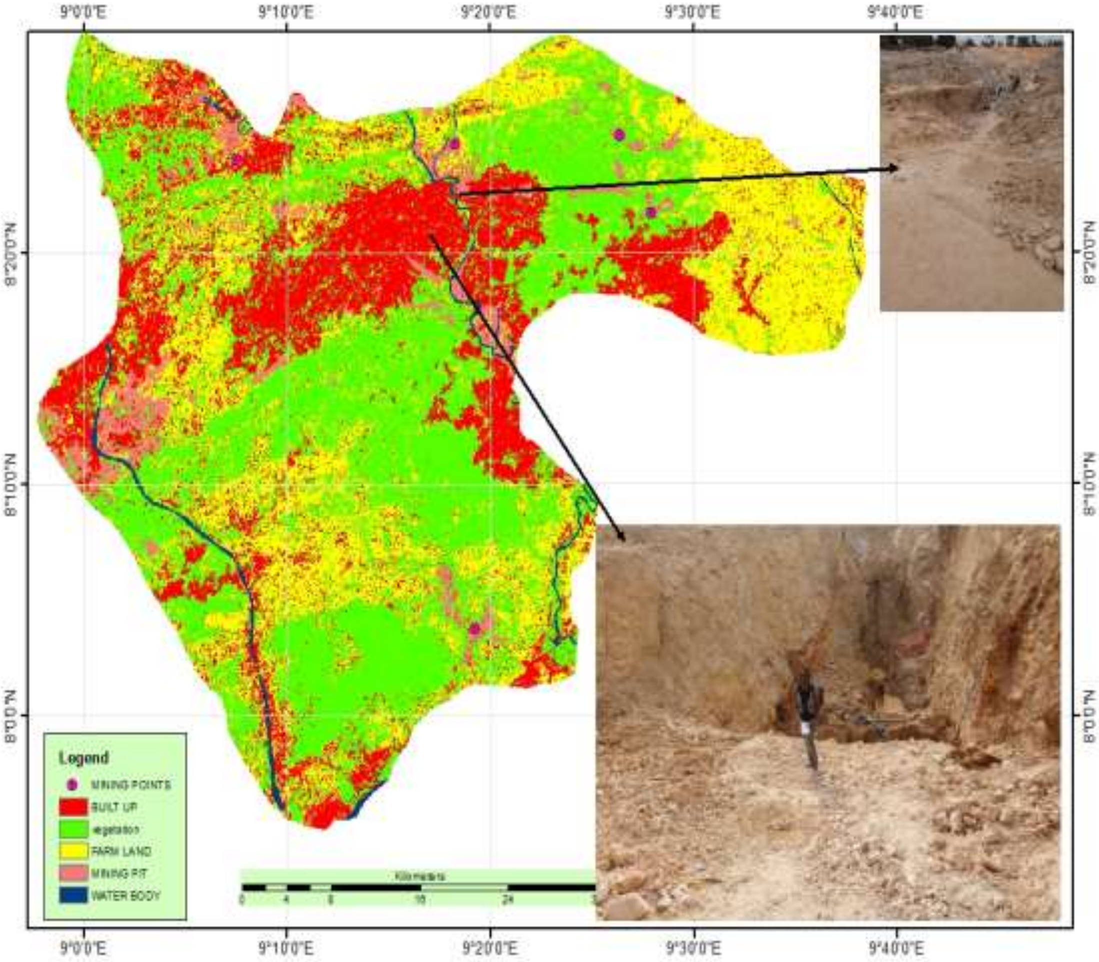


Figure 4.11: Geo-Tagged Image of Degraded Land

The result in table 4.2 showed the summary statistics of Awe from 1986 to 2016.

Table 4.2: Land Use and Land Cover Distribution in Awe (1986, 1996, 2006 and 2016)

LULC	**1986**		**1996**		**2006**		**2016**	
Land Cover Category	Area (Sqkm)	Area covered (%)	Area (Sqkm)	Area covered (%)	Area (Sqkm)	Area covered (%)	Area (Sqkm)	Area covered (%)
Build-up	157.554	6.32	371.6793	14.50	413.4087	16.13	616.5117	24.06
Vegetation	861.1443	34.53	1136.942	44.36	1127.579	44.00	1055.744	41.20
Farmland	1445.425	57.95	1002.483	39.12	954.0045	37.23	751.8492	29.34
Mining pit	5.2578	0.21	18.1557	0.71	34.191	1.33	105.3369	4.11
Water body	24.7887	0.99	33.282	1.23	33.3045	1.23	32.9949	1.29
Total	2562.4629	100	2562.4629	100	2562.4629	100	2562.4629	100

Additionally, figure 4.12 shows the mean land use and land cover distribution for Awe while and figure 4.13 shows the mean percentage distribution of the various land use and land cover of Awe.

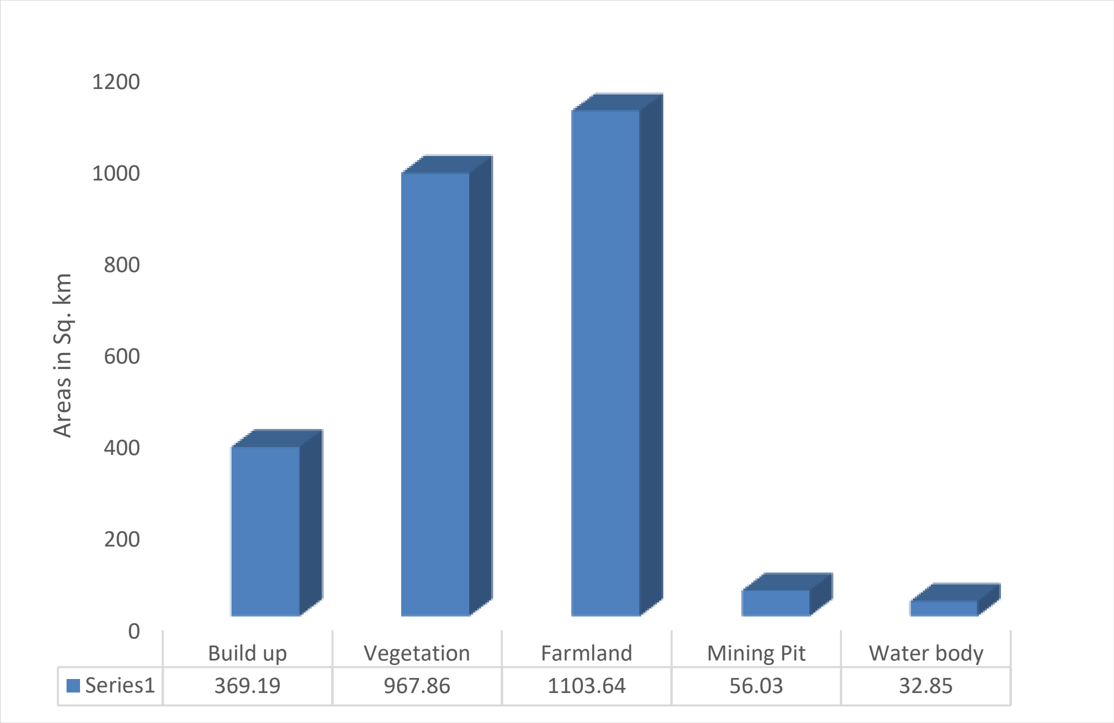


Figure 4.12: Mean Land Use and Cover Distribution for Awe

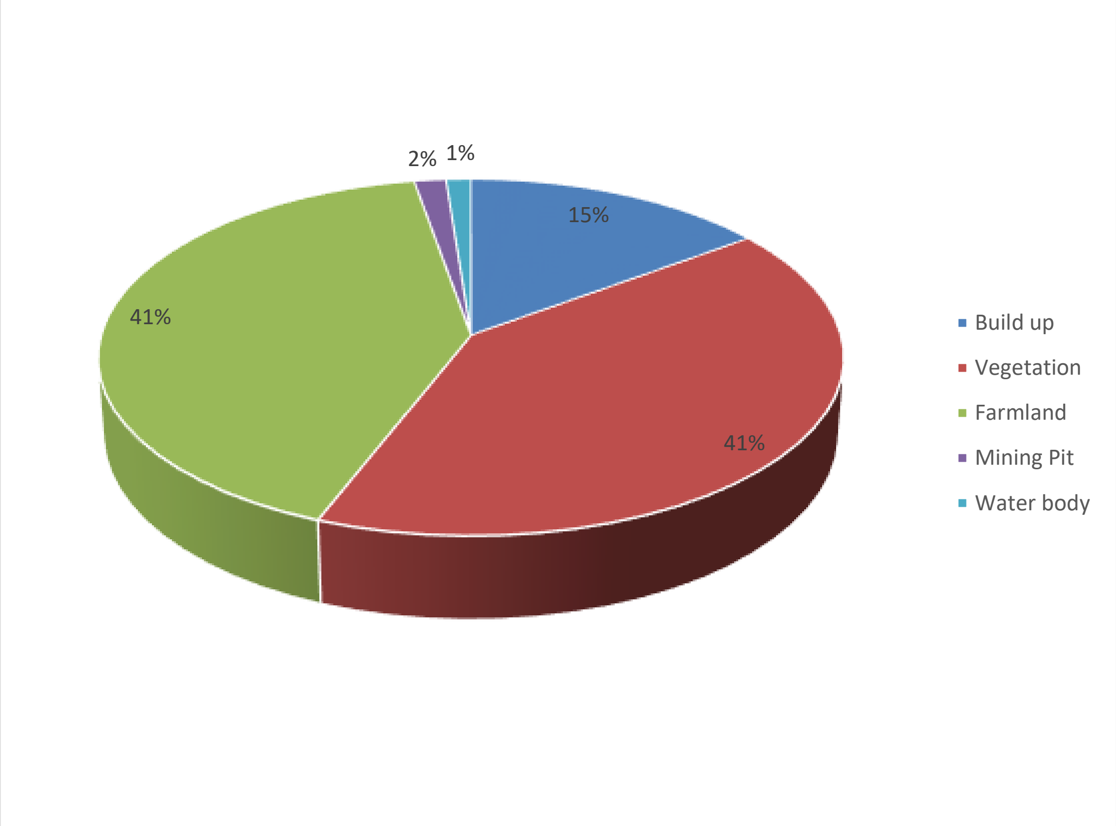


Figure 4.13: Mean (%) Land Use and Cover Distribution for Awe

4.2.2 Classification and analysis of land use and land cover of Obi

4.2.2.1 *Classification and analysis of 1986 land use and cover satellite imagery of Obi*

The result in Figure 4.14 showed the maximum likelihood of supervised classification of the study area which revealed the area level of covered by five categories of features identified (farmland, built-ups, water body, vegetation and mining pit). It was revealed that farmland, vegetation and built-up zones have the largest area coverage of 486.232km² (50.56%), 369.8991km² (38.46%), and 104.53km² (10.87%) of the total area respectively, while water body and mining pit covered the smallest area with about 0.9387km² (0.09%) and 0.1377km² (0.014%) of the total area as shown in (Table 4.3).

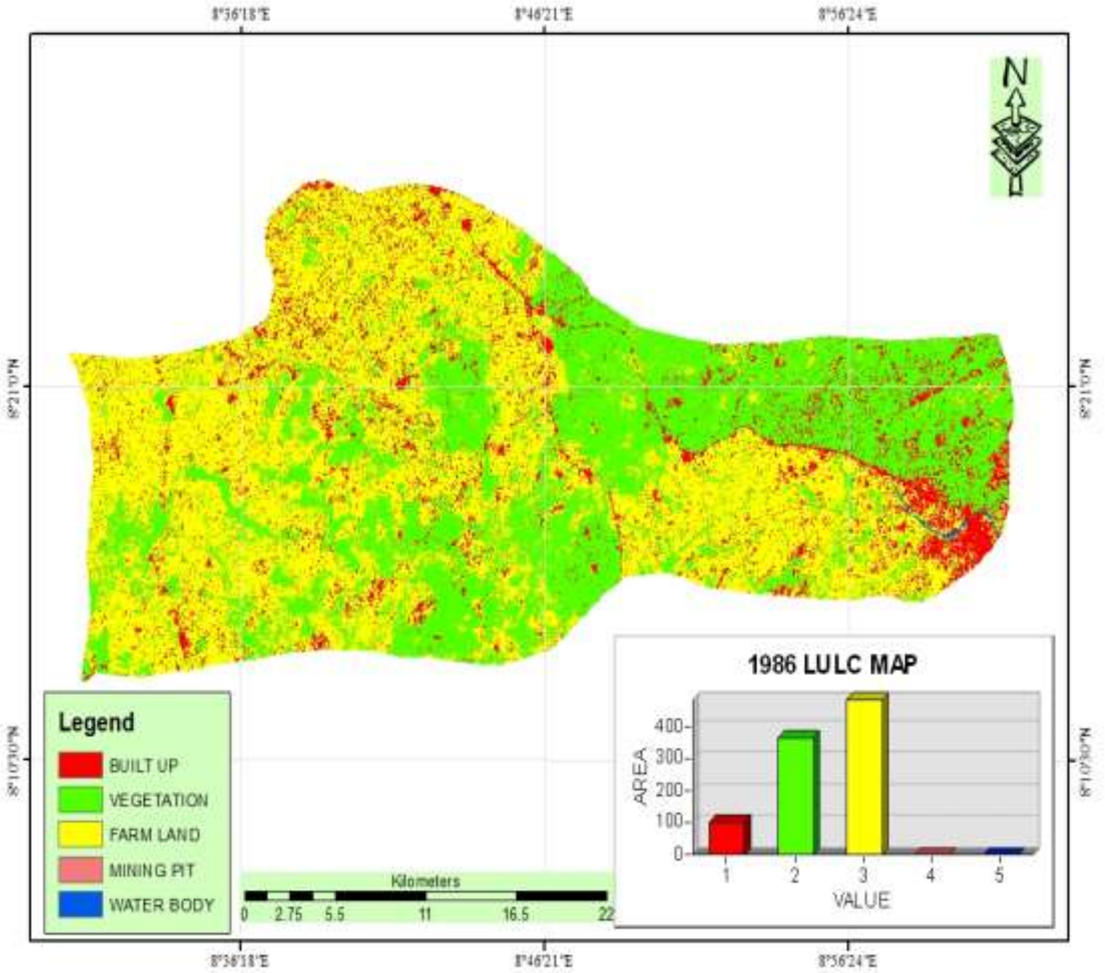


Figure 4.14 Land Use and Land Cover in Obi 1986

4.2.2.2 *Land use and land cover of Obi in 1996*

Figure 4.15 showed the maximal likelihood of the supervised categorization of the area under study for 1996 indicating the extent of land area covered by five categories of features (water body, built-ups, mining pit, vegetation and farmland). It is revealed that built-up, vegetation and farmland areas have the largest area coverage of 142.933km² (14.86%), 381.209km² (39.64%), and 436.163km² (45.35%) of the total area of land used respectively, while water body and mining pit covered the tiniest area of approximately 1.338km² (0.14%) and 0.112km² (0.011%) of the total area as shown in (Table 4.3).

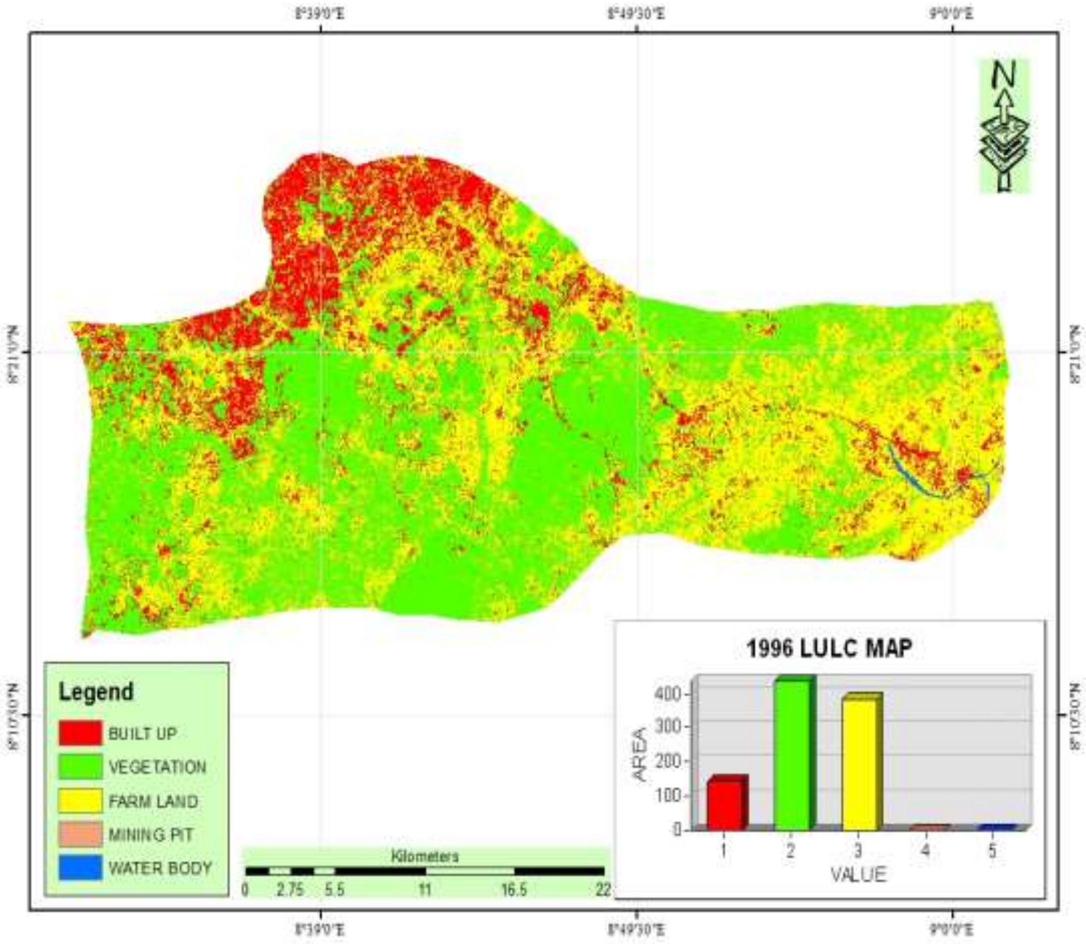


Figure 4.15: Land Use and Land Cover in Obi 1996

4.2.2.3 *Land use and land cover of Obi in 2006*

The result in Figure 4.16 indicates the maximal likelihood of the supervised categorization map of the area under study for 2006 which indicates the extent of LULC change of five categories of features identified as (built-ups, vegetation, farmland, mining pit and water body). It is revealed that Farmland, vegetation, and built-up areas have the largest area coverage of 428.577km² (44.57%), 334.137km² (34.75%), and 193.099km² (20.08%) of the total area respectively, while water body and mining pit covered the smallest area with about 1.338km² (0.14%) and 0.112km² (0.011%) of the total area as shown in (Table 4.3).

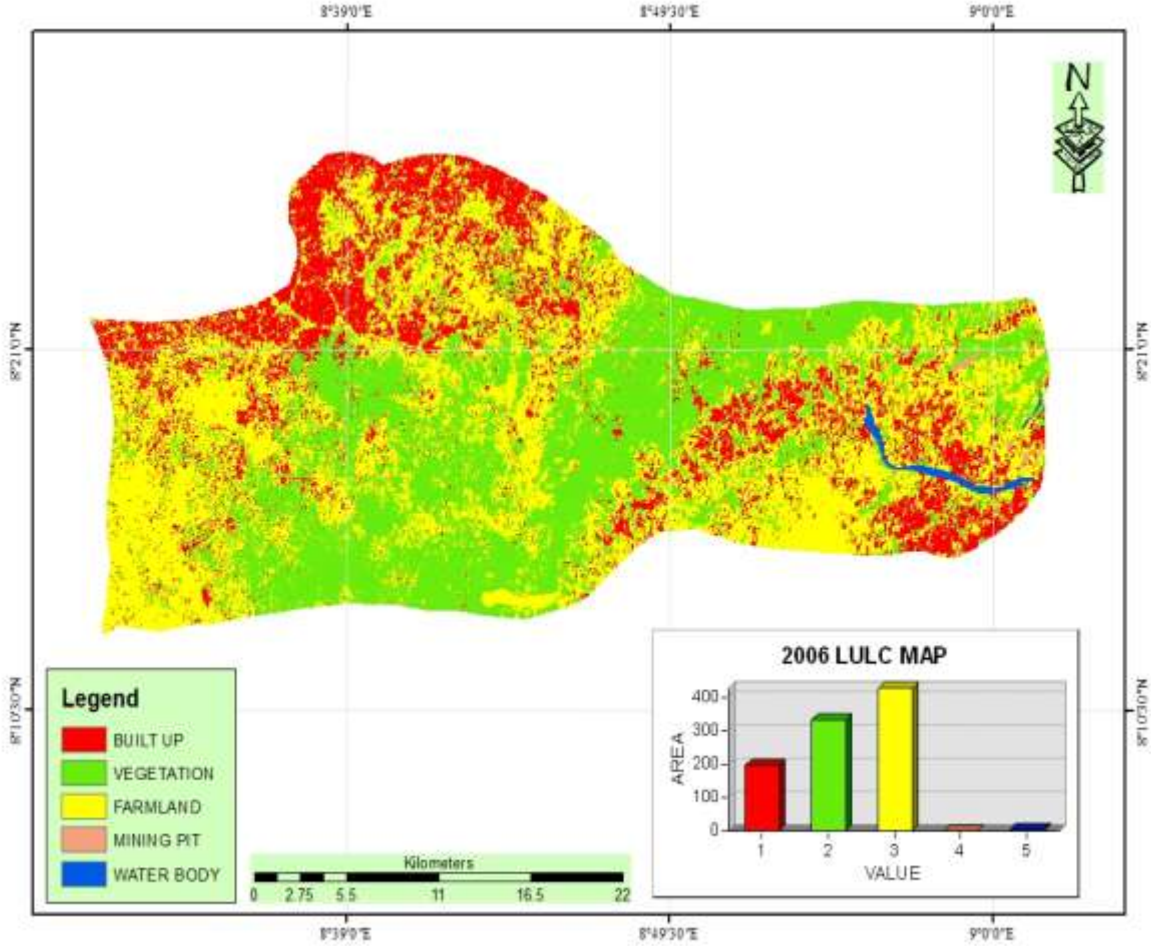


Figure 4.16: Land Use and Land Cover in Obi 2006

4.2.2.4 *Land use and land cover of Obi in 2016*

Figure 4.17 showed that maximum likelihood of the supervised categorization of the area under study for 1996 which illustrations the extent of area covered by the five identified classes of land utilization features (built-ups, vegetation, farmland, mining pit and water body). The result revealed that vegetated area, built-up and farmland have the largest coverage of 333.59km² (34.69%), 313. 909km² (32.65%), and 308.152km² (32.05%), while water body and mining pit covered the tiniest land area [approximately 4.631km² (0.48%) and 1.292km² (0.13%)] of the total study area as presented in (Table 4.3).

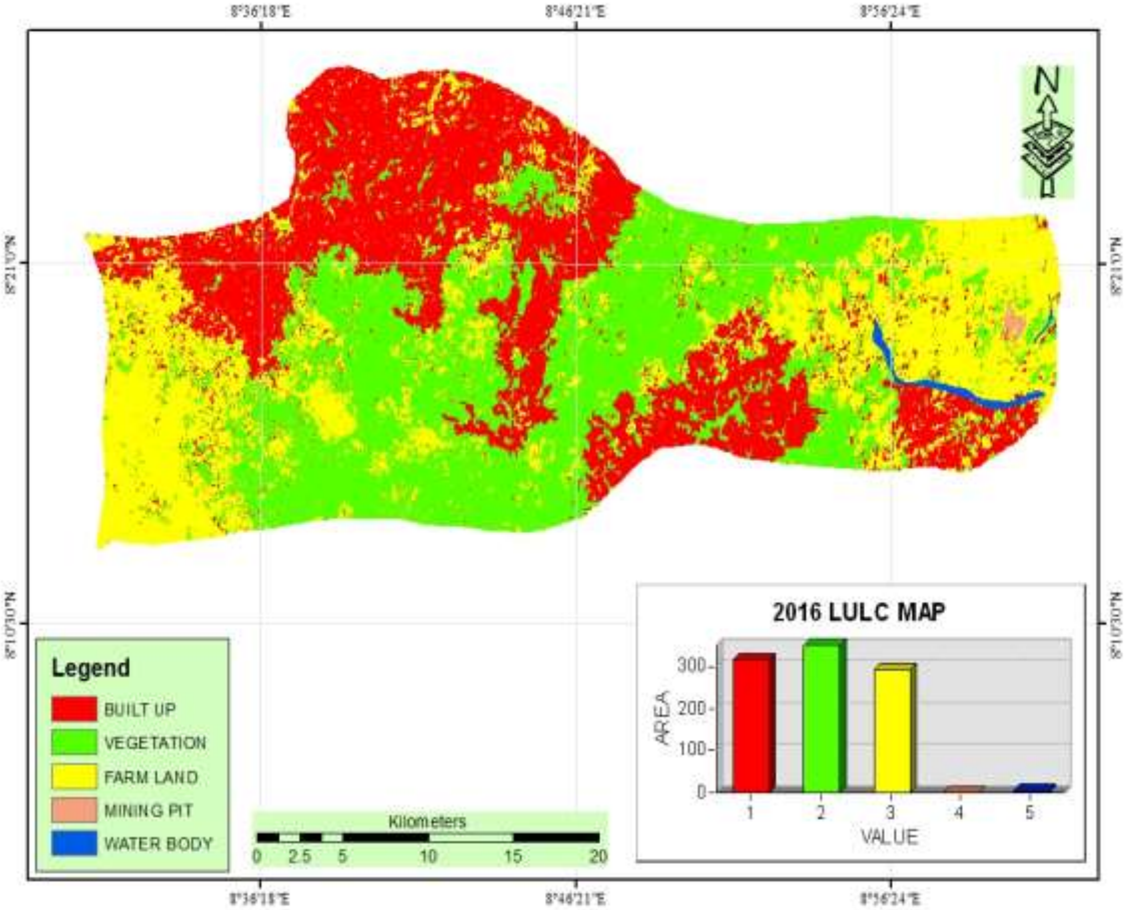


Figure 4.17: Land Use and Land Cover of Obi 2016

Table 4.3: Distribution of Land Use and Land Cover of Obi (1986, 1996, 2006 and 2016)

LULC	**1986**		**1996**		**2006**		**2016**	
Land Cover Category	Area (Sq.km)	Area covered (%)	Area (Sq.km)	Area covered (%)	Area (Sq.km)	Area covered (%)	Area (Sq.km)	Area covered (%)
Build-up	104.5296	10.87	142.9326	14.86	193.0995	20.08	314.3394	32.68
Vegetation	369.8991	38.46	436.1625	45.35	334.1367	34.74	329.2506	34.24
Farmland	486.2322	50.56	381.2085	39.64	428.5773	44.56	291.0375	30.32
Mining pit	0.1377	0.0.01	0.1116	0.02	1.2807	0.13	22.3182	2.32
Water body	0.9387	0.09	1.3383	0.14	4.5972	0.47	4.6557	0.48
Total	961.7373	100	961.7373	100	961.7373	100	961.7373	100

The result in Figure 4.18 also showed Geo-Tagged images of the mining site at Obi local government area; in Adudu lead and zinc are mined in large quantity.

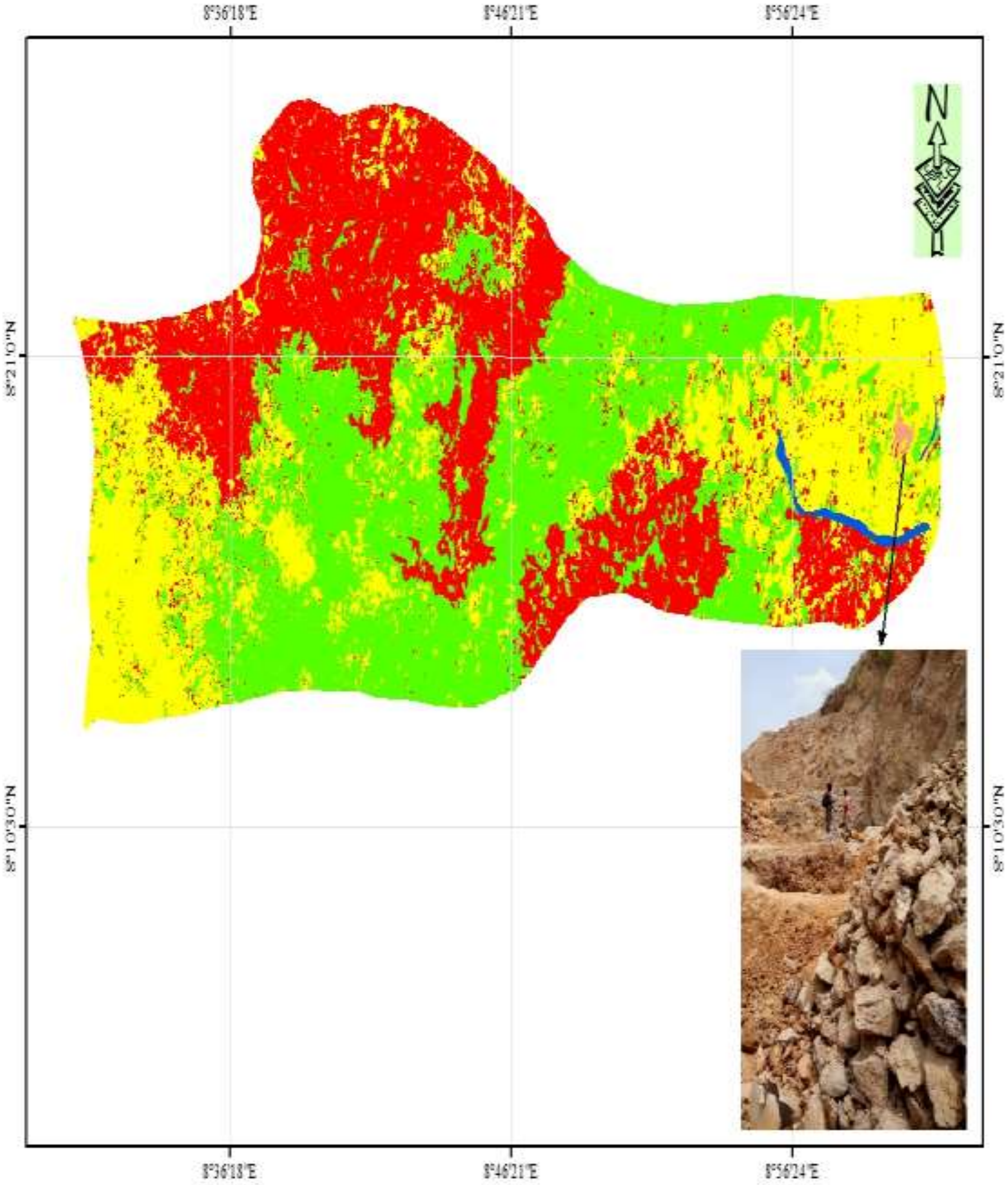


Figure 4.18 Geo-Tagged Degraded Mining Site 2016

Additionally, figure 4.19 shows the mean land use and land cover distribution for Obi while and figure 4.20 shows the mean percentage distribution of the various land use and land cover of Obi.

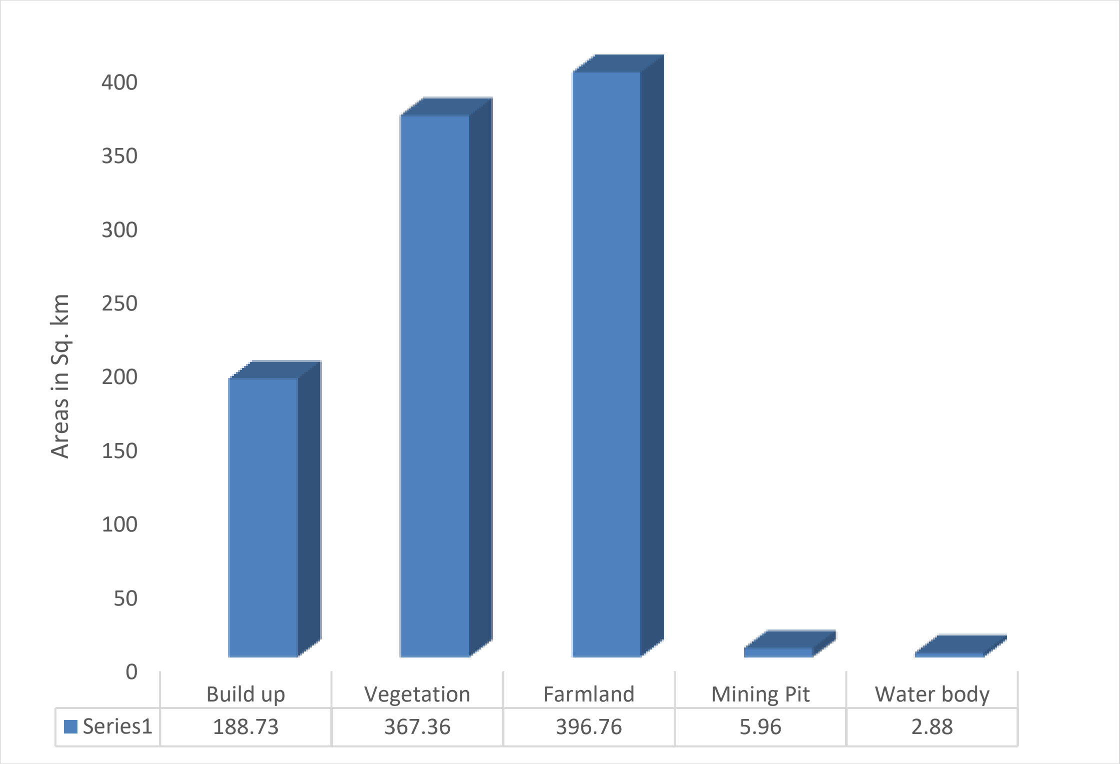


Figure 4. 19: Mean Land Use and Cover Distribution for Obi

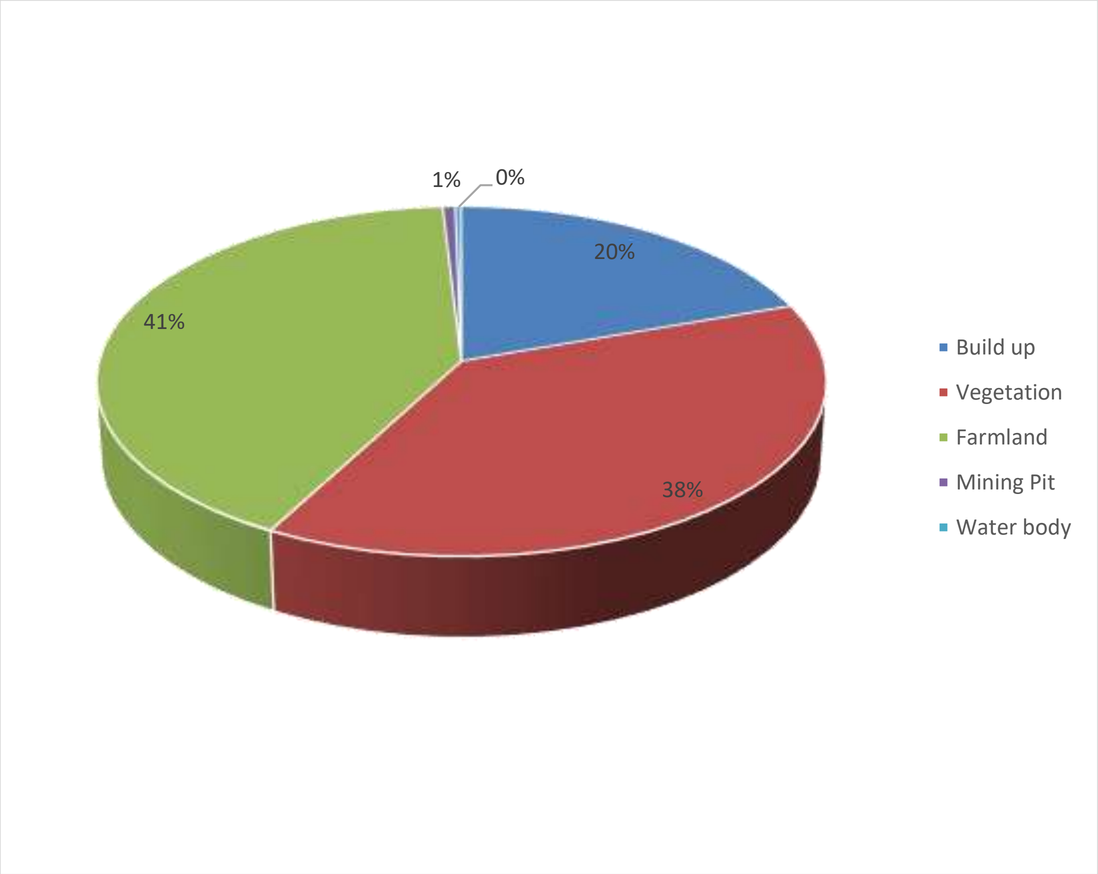


Figure 4.20 Mean (%) Land Use and Land Cover Distribution for Obi

4.2.3 Classification and analysis of land use and cover of Keana

4.2.3.1 *Classification and analysis of land use and cover Keana base on 1986 satellite imagery*

Figure 4.21 represents the land cover and use in the area under study in 1986. It described five (5) classes of land uses and land covers (built-up areas, vegetation, farmland areas, mining pit and water body). The land use and cover categorized revealed farm land as dominant 506.1591Km^2 (47.71%) followed by vegetated land 446.9679 Km^2 (42.13%), built up 96.237 Km^2 (9.07%) while mining pit 1.0701 Km^2 (0.10%) and water body covered 10.5255 Km^2 representing (0.99%) of the total study area are less.

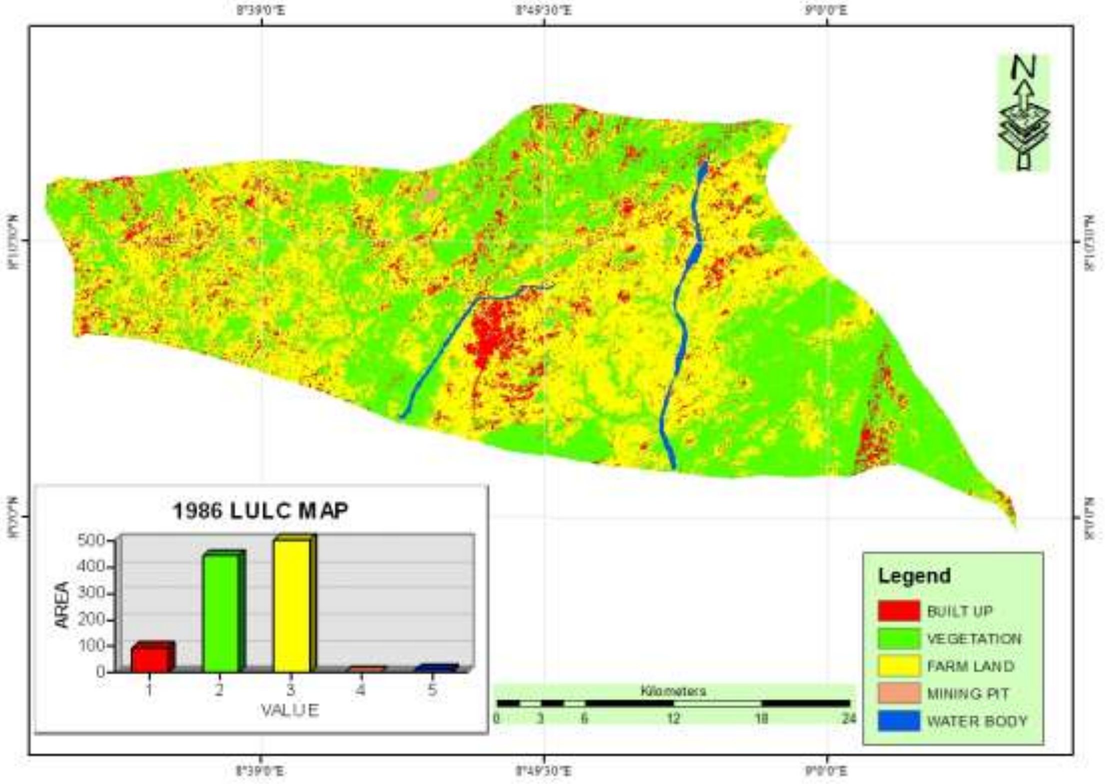


Figure 4.21: Land Use and Land Cover in Keana 1986

4.2.3.2 *Land use and land cover of Keana in 1996*

Figure 4.22 illustrates the land use and cover of the area under study for the year 1996. Farm land covered 564.2451 Km^2 (53.18%) followed by vegetated land 332.4321 Km^2

(31.33%)], farm land has the largest area covering 564.2451 Km^2 (53.18%) compared to 506.1591Km^2 (47.71%). An increase of 58.086 Km^2 (5.7%) was recorded in contrast to what obtained in 1986, Built-up land covered 151.7355 Km^2 (14.29%). Mining pit covered 2.1924 Km^2 (0.21%) and water body covered an area of 10.4904 Km^2 (0.99%) and therefore found the smallest area. However, when it was compared to 1986 land use and land cover of the study area had undergone significant changes as displayed in Figure 4.22.

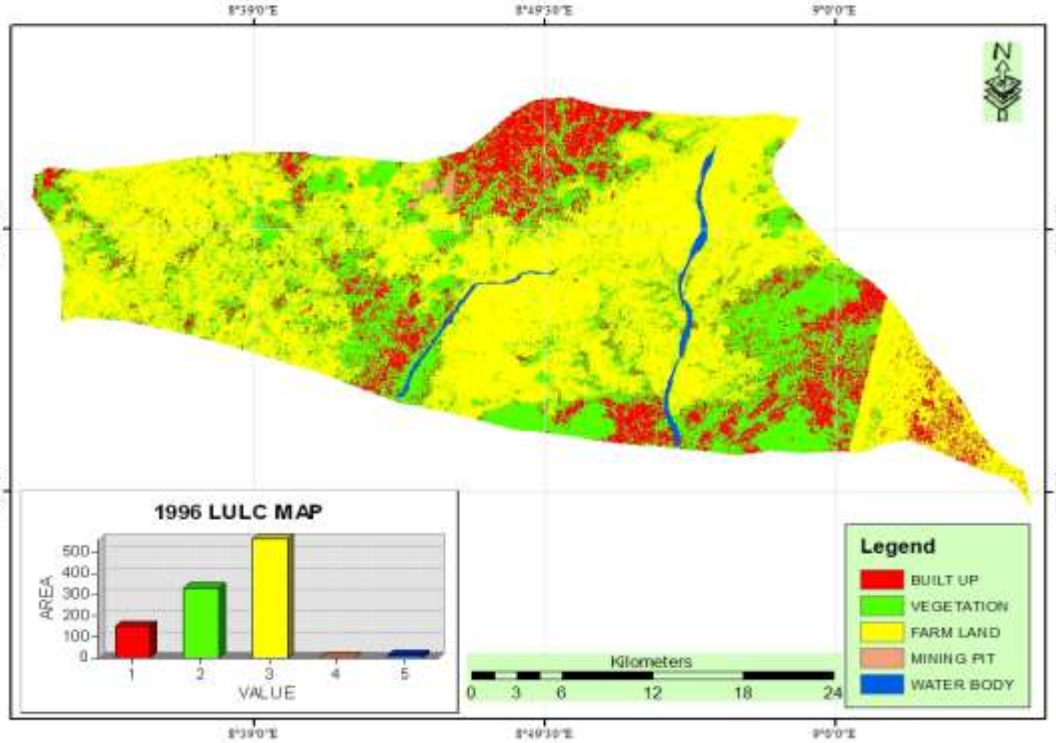


Figure 4.22: Land Use and Land Cover in Keana 1996

4.2.3.3 *Land use and land cover of Keana in 2006*

Figure 4.23 showed the land use and land cover map of the study area for the year 2006. Findings reveals that farmland covered 520.8093 km^2 (48.08%) followed by vegetation covering 369.4095 km^2 (34.81%), Built-up covered 159.3576 km^2 (15.02%) whereas water bodies covered 10.485 Km^2 (0.99%), and mining pits cover was the least area of about 1.071 Km^2 which represents 0.11% of the total study area. This shows that the change between (1996-2006) indicate that built-up, farmland and water bodies have increased by 10.73%, 4.1%, and 0.85 % respectively, while vegetated land decreased by 10.58%, and mining pit remained relatively stable 0.09% implying that large area of land were cultivated during the timeframe as seen on Figure 4.25 which shows an increase in human activities.

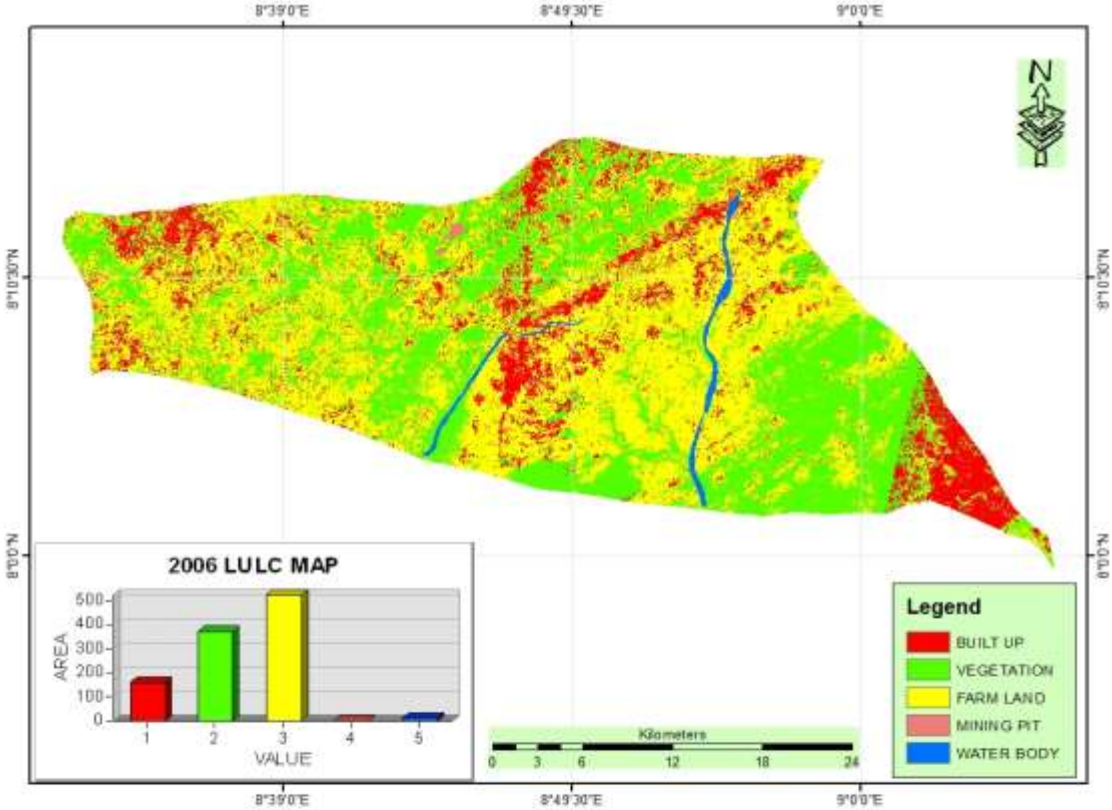


Figure 4.23: Land Use and Land Cover in Keana 2006

4.2.3.4 *Land use and land cover of Keana in 2016*

Furthermore, the land use and cover categorization for 2016 showed there was drastic change that have occur among the different land use and cover types. It revealed that areas that built-up have continued to increase at the detriment of other land use category due to influx of people into that area. It increased from 159.3576 km^2 (15.02%) in 2006 to 245.3697 (23.13%) and vegetation cover reduced from 369.4095 Km^2 (34.81%), to 301.5603 Km^2 (28.43%) in 2016 due to deforestation activities in the area. while Farmland covers reduces from 520.8093 km^2 (48.08%) in 2006 to 497.2662 km^2

(46.88%) of the total area whereas water bodies cover 10.5624 Km^2 (0.99%), and finally mining pit to 6.0552 km^2 (0.57%) of the total area as presented in Figure 4.24

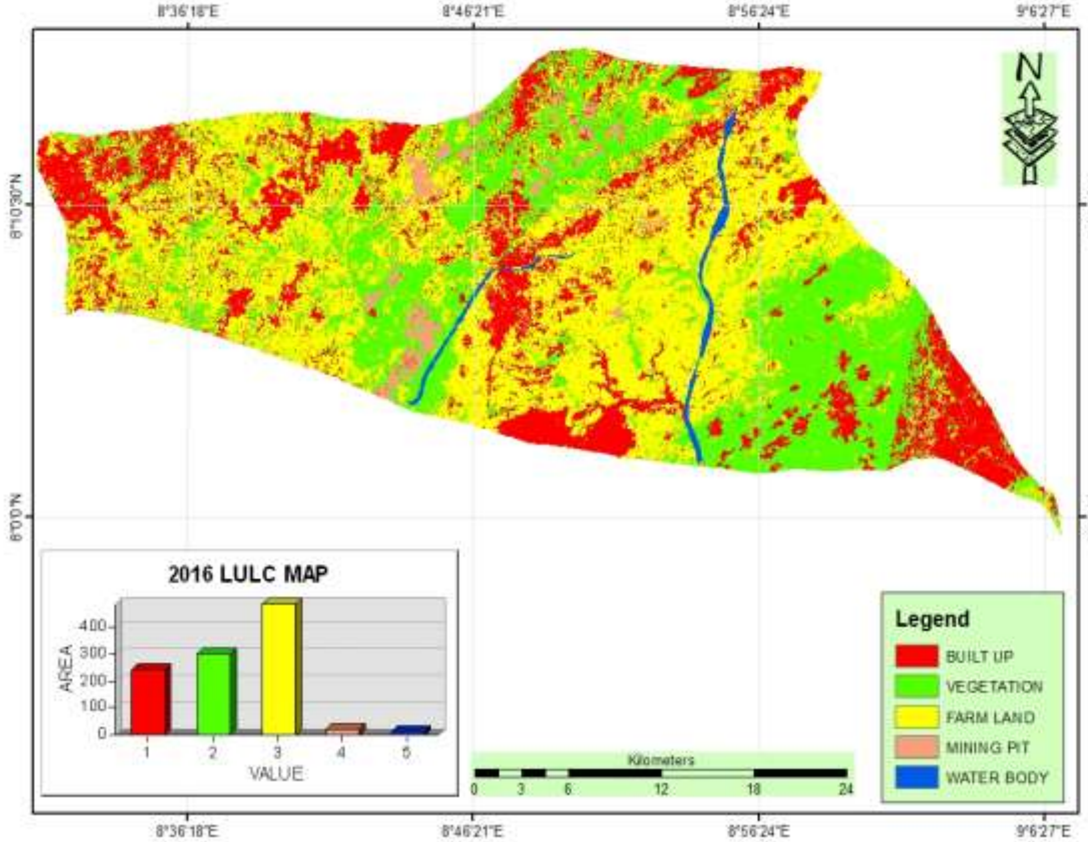


Figure 4.24: Land Use and Land Cover in Keana for 2016

Table 4.4: LULC Distribution of Keana (1986, 1996, 2006 and 2016)

LULC	**1986**		**1996**		**2006**		**2016**	
Land Cover Category	Area (Sqkm)	Area covered (%)	Area (Sqkm)	Area covered (%)	Area (Sqkm)	Area covered (%)	Area (Sqkm)	Area covered (%)
Build-up	96.237	9.07	151.7355	14.29	159.3576	15.02	242.821q8	22.89
Vegetation	446.9679	42.13	332.4321	31.33	369.4095	34.81	300.627	28.34
Farmland	506.1591	47.71	564.2451	53.18	520.8093	49.08	484.5438	45.68
Mining pit	1.0701	0.10	2.1924	0.26	1.071	0.11	22.0824	2.08
Water body	10.5255	0.99	10.4904	0.98	10.485	0.98	10.5768	0.99
Total	1060.9596	100	1060.9596	100	1060.9596	100	1060.9596	100

Similarly, the result in Figure 4.25 shows some of the degraded land at the various mining site at Keana LGA of Nasarawa state. Some of the mining site in Keana are Kuduku mine (Lead and Zinc), Otume mining pit (Baryte) Otume mining pit abandoned (Baryte), Pinega mine pit (Lead and Zinc) Pinega abandoned, Akiana (salt mine) and Virgin field (lead, Zinc, Copper and iron).

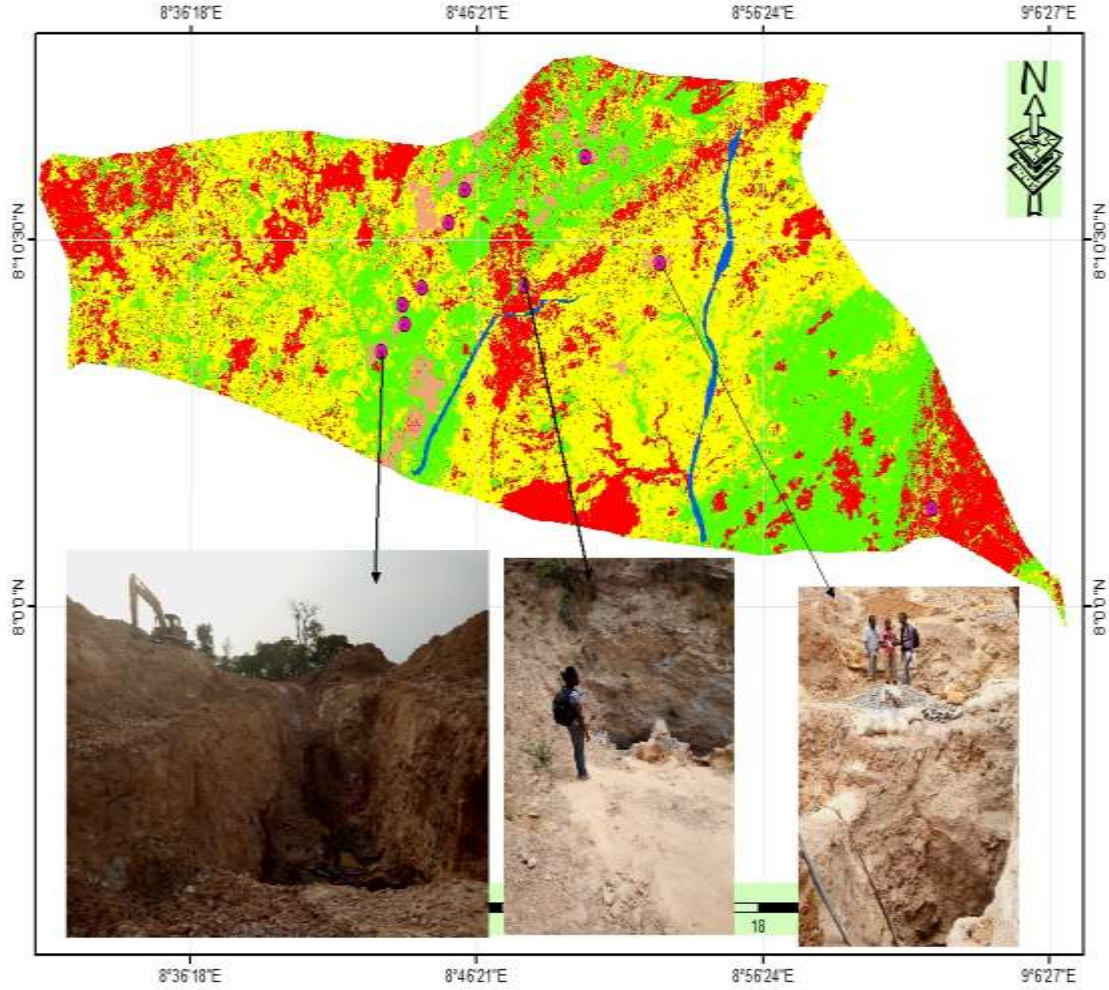
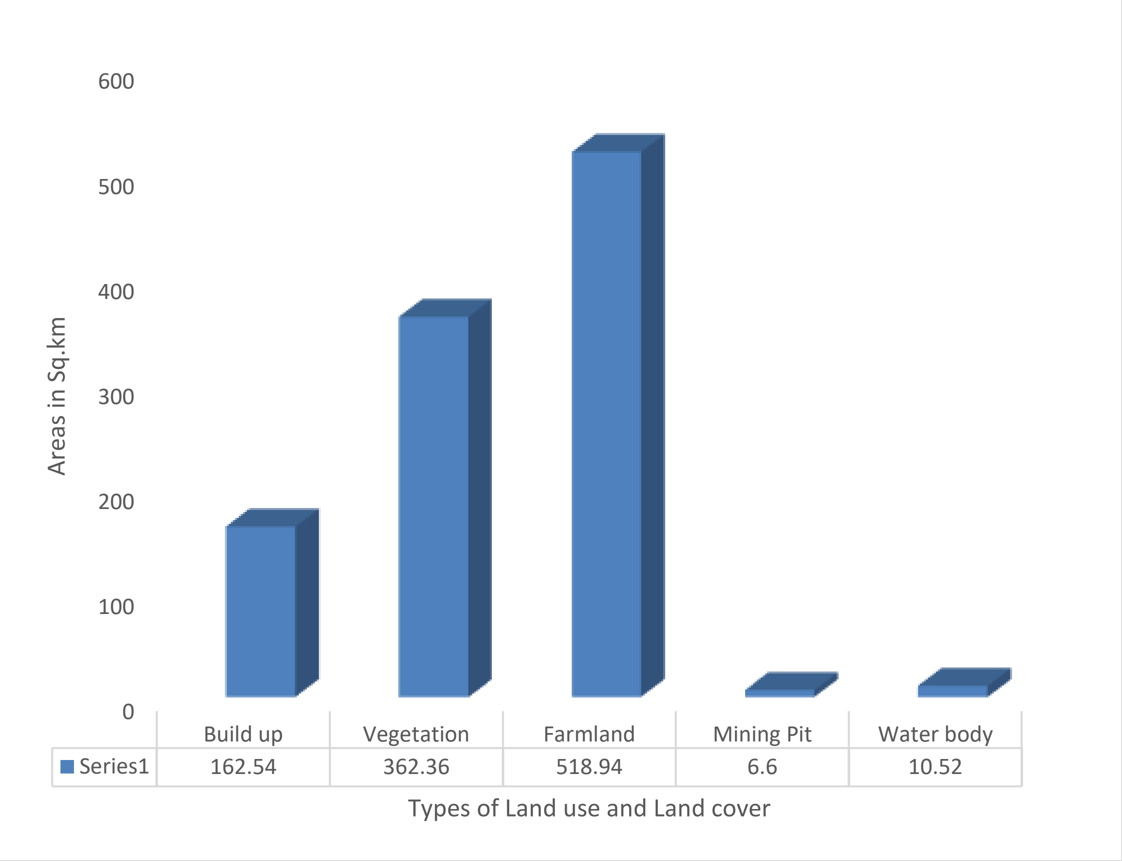


Figure 4.25: Geo-Tagged Degraded Land

Additionally, figure 4.26 shows the mean land use and land cover distribution for Keana while and figure 4.27 shows the mean percentage distribution of the various land use and land cover of Keana.



4.26: Mean Land Use and Land Cover Distribution for Keana

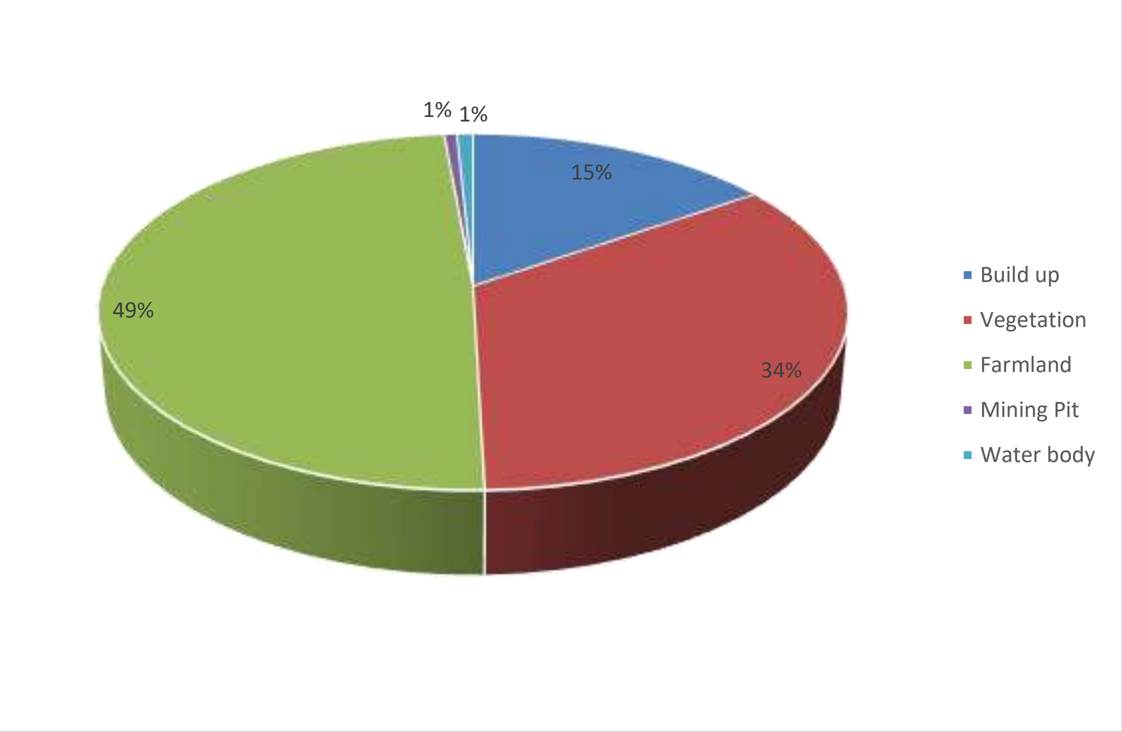


Figure 4.27: Mean (%) Land Use and Land Cover Distribution of Keana

4.3 Assessment of the Sustainable, Mitigative and Adaptable Strategies in the Management of Artisanal Small-Scale Mining in the Study Areas.

A total of four hundred (400) questionnaires were administered in three mining sites within the area of study. A total of 319 representing 79.9 7 % questionnaires were returned as filled. Obi region had the highest percentage of respondents (100%) while Keana recorded 82.57% and Awe recorded 75.79 % responses as shown in Table 4.5.

Table 4.5: Responses on the Impacts ASM Activities across the Study Areas

Mining Areas	Number of administered Questionnaires	Number of returned Questionnaires	Rate of response (%)
Awe	179	136	75.97
Keana	218	180	82.57
Obi	3	3	100
Total	**400**	**319**	**79.75**

4.3.1 Demographic and socio-economic characteristics of the populations

The gender, age, marital status, educational level, length of stay and employment are all socioeconomic variables that influence how the population perceives the impact of mining in the studied locations. The Demographic Features of ASM Operators revealed that artisanal mining is practiced by people from all walks of life in the research locations. Men, women, and children of various levels are among them.

Table 4.6: Demographic Characteristics of the Populations

Gender	**Frequencies**	**Percentage (%)**
Male	226	70.85
Female	93	29.15
Total	319	100
Educational Level		
Formal education	28	8.78
Primary school	63	19.75
Secondary school	156	48.90
Tertiary	72	22.57
Total	319	100
Job Schedule		
Paid labourers	183	57.37
Pit/mine	69	21.63
Financier	40	12.54
Others	27	8.46
Total	319	100
Duration of Mining Activities		
Less than 1 year	28	8.78
1 – 5 years	47	14.73
5 – 10	85	26.65
above 10 Years	159	39.18
Total	319	100
Age		
less than 18 years	49	15.36
18 – 30 Years	80	25.07
31 – 40 Years	170	53.29
more than 40 Years	20	6.27
Total	319	100

4.3.2 Distribution of age of artisanal miners in the areas studied

Table 4.6 showed the age range of miners across the study areas. about 16% of the respondent are within the ages range of 18 years. 25% of the respondents are within the age range of 18-30 years. The explanation for this high proportion might be linked to the low entry barriers to ASM as a source of income, which has attracted a diverse group of people of all ages to mining operations. Individuals in the productive age group of 31-49 years, who account for 53 percent of the respondents, are the most actively involved in ASM, according to the results.

According to the research finding, the number of people that engage in ASM decreases as they become older. Table 4.6 illustrates this tendency, with the number of people participating in ASM dropping dramatically as they approached 50 years of age. This trend can be attributed to the fact that ASM operations are labor demanding, including extremely laborious procedures that need only the most basic and rudimentary instruments. This would certainly need physically capable personnel.

The data also showed that child labor is used in ASM in the research regions, with children under the age of 18 working primarily with their parents or guardians (Plate I) whereas (plate II) indicates the researchers having interaction with women and children. The implications of children and youths actively participating in ASM revolve around the fact that it has an impact on their development by limiting their possibilities to obtain formal education compared to their peers who do not participate in ASM activities. This is in line with the work of Anene *et al.* (2018) who carried out similar work on impacts of ASM activities in parts of Niger State.

Plate I: Arrow Showing Underage Child on Mining Site

Plate II: Researcher Interacting with the Women and Children

4.3.3 Gender distribution among the ASM Operators

Findings from the respondents based on gender revealed that there are more males who engage on mining activities than females within these study areas. This was mirrored in the facts that 226 of the 319 unsystematically selected participants were male, accounting for 70.85 % of the total, whereas 93 % were female. This is due to the fact that ASM activities are labour demanding and include highly tedious chores, necessitating greater energy. The large number of males working in ASM operations might also be linked to the active character of ASM activities, which necessitate a lot of manual labour. This is on top of the fact that, by nature and tradition, women are more likely to stay closer to their homes to care for their children than males, who are far more mobile in their hunt for a family's source of income. Plate III shows women washing the dirt's from mineral mined.

PLATE III: Women Working at Mining Site in Awe

4.3.4 Educational level of ASM operators in the study areas

9% of the respondents do not have formal education. Also, 20% of the respondents have attained primary education, whereas 49% of the respondents attended secondary school (Table 4.62). The reason for this high percentage of secondary school leavers could be attributed to lack of finance to continue their tertiary education. Further, 22% of the respondents attended tertiary education. Most of them are pit or mine owners who paid the labourers to carry out mining activities. The survey also found that miners who do real mining operations in the mines, such as panning, excavating, carrying materials, processing, and other manual duties, have relatively minimal education.

In certain situations, the proprietors of the crushing/milling machinery and baryte sellers looked to have completed higher education. It was determined that the majority of the miners had dropped out of school owing to a lack of funds to continue. However, a lack of knowledge is a significant barrier to miners being more effective in their profession. Their attitude toward matters concerning their health and safety reflects this. They are unconcerned about the harmful consequences of improper usage of some solid minerals or their job on their health, the general environment and the community.

a. Duration of miners in the business of mining

Based on duration of mining activities across the study areas, findings revealed that (39.18%) have been into mining activities for more than 10 years this includes pit/mine owners as well as financier etc. Also, (26.65%) have been into mining activities between 5 – 10 years, (14.73%) have been into mining activities between 1- 5 years while (8.78%) respondents are less than a year into mining activities (Table 4.10).

Similarly, majority of the populations (57.37%), in the study areas are paid labourers, this is a means of livelihood for most paid labourers. Majority of them have no formal education and might not have the will to even bargain for higher pay. This is because most of the miners are paid between ₦2000.00 to ₦3000.00. Plate IV shows Barytes and other Mineral ready for sale/transportation to buyers from different parts of the country.

PLATE IV: Barytes and other Mineral ready for Sale/Transportation

per day despite the stresses and tedious nature of the job. (21.63 %) are Pit/Mine owners who engage the services of the paid laborers to mine the various minerals in the pit (12.54 %) are financier who have the financial power as well as provide the machineries and equipment needed for the mining activities while others are (8.46%).

Additionally, based on marital status, majority of the respondents 57.99 % are married men and women who engage in mining activities, 27.89 % are single. These are majorly strong men that dig the pit and mine the minerals, 8.78% are divorced while 5.33% are window who engage in mining activities as a means of livelihood.

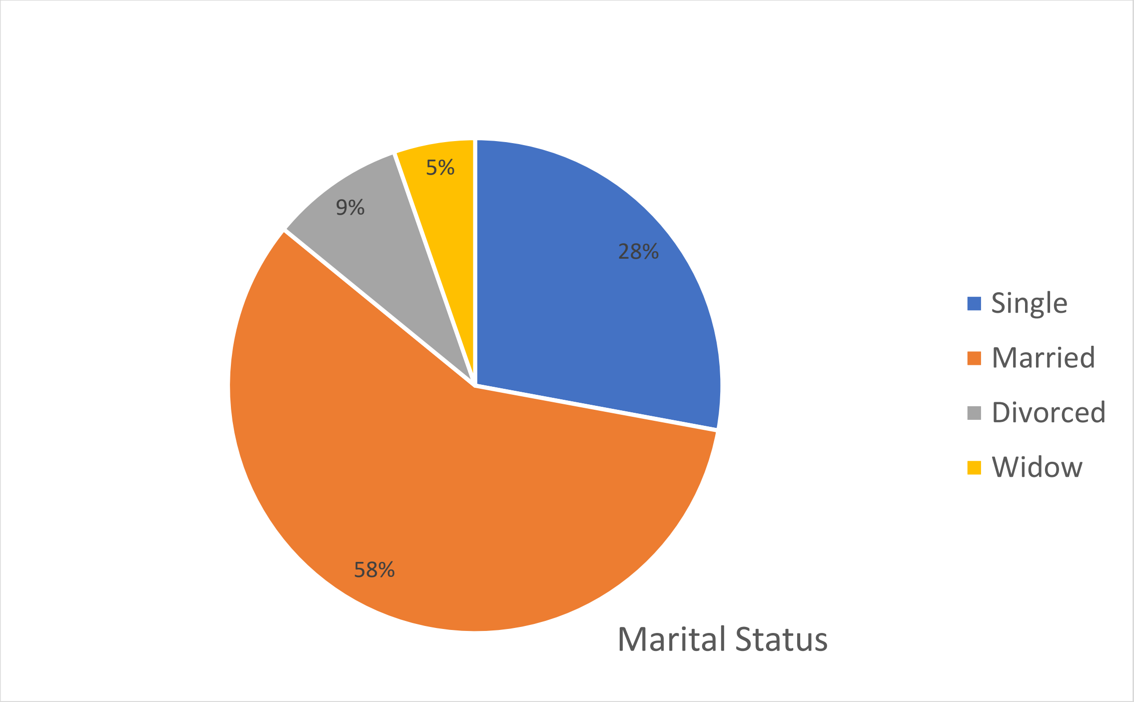


Figure 4.28: Marital Status of Respondents

4.3.5 Environmental effects of ASM activities across the study locations

Table 4.7 shows responses of respondents on the environmental effects of ASM activities on the biophysical environment across the study locations. It indicates that (9.40%) respondents agree that ASM activities has strongly positive impact on the environment. (4.39%) agrees that ASM activities has Positive impact. (25.08%) respondents of ASM activities have negative impact. (61.13%) agrees that ASM activities has strongly negative impact.

Similarly, 10.34% of the respondents are of the opinion that river siltation due to ASM activities have a strongly positive impact on the environment. Table 4.7 showed that 8.87% of the respondents agreed to positive impact, (4.70%) has no impact whereas (20.06%) there is high negative impact while (56.11%) agrees that river siltation usually occurs as a result of ASM activities in the areas which also result to the pollution of the rivers making it unsafe for consumption.

Table 4.7: Environmental effect of ASM activities across the study locations

Impact of ASM on biophysical environment	Strongly positive Impact	Positive impact	No Impact	Negative Impact	Strongly Negative Impact
Land degradation.	30(9.40%)	14(4.39%)		80(25.08%)	195(61.13%)
River siltation.	33(10.34%)	28(8.87%)	15(4.70%)	64(20.06%)	179(56.11%)
Physical disruption of landscape.	10(3.13%)	18(5.64%)	15(4.70%)	78(24.45%)	198(62.07%)
Direct dumping, tailings and effluent into rivers.	25(7.84%)	42(13.17%)	8 (2.51%)	94 (29.47%)	150(47.02%)
Abandonment of mining sites	18(5.64%)	22(6.89%)	6(1.88%)	83(26.02%)	190(59.56%)
Erosion from mining sites.	13(4.08%)	25(7.84%)	9(2.82%)	87(37.27%)	185(57.99%)
Loss of biodiversity.	14(4.39%)	16 (5.02%)	12(3.76%)	94(29.47%)	183(57.37%)
Deforestation in order to access mining sites.	9 (2.82%)	8 (2.51%)	3(0.94%)	98(30.72%)	201(63%)
Noise pollution.	20(6.23%)	18(5.64%)	7(2.19%)	105(32.92%)	179(56.11%)

Furthermore, 3.13% are of the opinion that physical disruption of landscape has a strongly positive impact on the areas, 5.64% respondents agree to positive impact, 4.70% has no impact, 24.45% has negative impact while 62.07% respondents agrees that ASM activities has a strongly negative impact on the landscape of the study areas.

Also, the impacts of ASM activities as a result of direct dumping and tailings and effluent into rivers can never be over–emphasized. This is because 47.02% of the respondents agrees that this ASM activities results in direct dumping and tailings and effluent into rivers which makes the water no longer safe for consumption whereas 29.47% agrees that ASM actives led to direct dumping and tailings and effluent into rivers while 2.51% says there is no impact. This is shown on plate V and VI.

Plate V: Effluent from the Mining Pit into flowing River

Plate VI: Direct Dumping of Tailings and Sluicing in flowing River

In addition, based on the Abandonment of mining sites, 59.56% of the respondents agrees that Abandonment of mining sites is one of the most common features in the mining areas and it has a very strong negative impact because the land might be useful again for farming settlement. This is because the site might not have any minerals again therefore it will be abandoned for another site. 26.02% respondents agree that there is a high negative impact of the abandonment while 1.88% says there is no impact. Plate VII on the other shows abandoned mine site by implication degrading the land and making it unfertile land for agricultural production. Also, Plate VIII indicates degraded landscape resulting to erosion route from mine site

Plate VII: Abandoned Mine Site

Based on the impact of erosion from mining sites, 57.99% are agrees that ASM activities usually result to deep gully erosion in the study areas making it to have a very strong negative impact. 37.27% also agrees that ASM activities has a negative impact on the environment which result to erosion while 2.82% respondents say based on their understanding there is no impact of erosion on the mining sites.

Plate VIII: Degraded Landscape Resulting to Erosion Route from Mine Site

Based on loss of biodiversity on ASM sites, 57.37% respondents say ASM activities has strong negative impact on biodiversity because most of the trees and animals are killed and destroyed to give way for mining in the areas which leads to environmental degradation and in turn increase climate change and risk in the areas. 29.47% says mining activities has a high negative impact on the environment of the study areas this is because the destruction of the trees in the areas can result to increase in land surface temperature in the area. 3.76% of the respondent says there is no impact because mining takes place in a small area while there are other vast areas where biodiversity can still be found.

Based on noise pollution due to machines and equipment use in mining areas, 56.11% respondents say noise pollution have a strong negative impact on the environment. This is because the noise gives them sleepless night and headache whereas other says they have to increase their voice when talking to their colleagues most especially when the machines are being put into use. 32.92% respondents say there is a high negative impact on the environment while 2.19% say there is no impact.

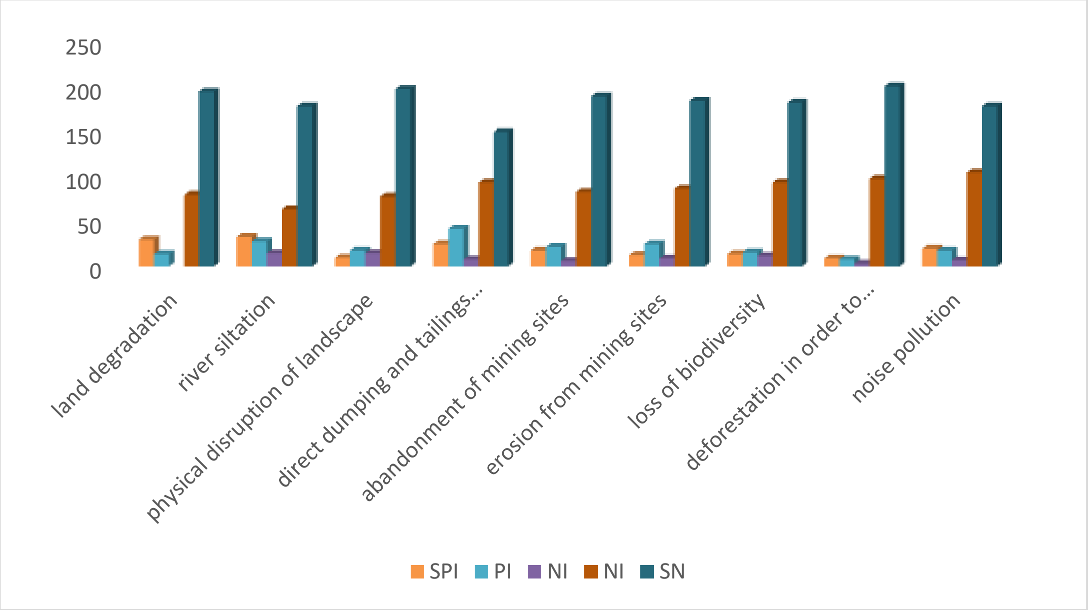


Figure 4.29: Impact of ASM on biophysical environment

4.3.6 Impact of ASM on the socio-economic environments

Table 4.8 shows the summary of responses from the respondents, it deals with the impact of ASM activities on the socio-economic environment across the study locations. It indicates that 82.13% respondents agree that ASM activities has strongly positive impact on the socio-economic activities of the people in the environments in terms of local employment of the people who come there to seek means of livelihood. 32.60% agrees that ASM activities has Positive impact on the study locations as men women, youth and even children are seen partaking in one form of activities or the other on the mining sites. 5.96% respondents say ASM activities has negative impact. 8.78% agrees that ASM activities has strongly negative impact on the socio-economic activities of the locations. This can be attributed to the fact that most of them reported that their farmlands were destroyed during ASM operations (see plate IX).

Plate IX: Degraded Farmland due to ASM Activities

Table 4.8: Impact of ASM on the Socio-Economic Environments

Impact of ASM on the socio-economic environments	Strongly positive Impact	Positive impact	No Impact	Negative Impact	Strongly Negative Impact
Local employment.	262(82.13%)	104(32.60%)	-	19(5.96%)	28(8.78%)
Resettlements of displaced persons.	76(23.82%)	14(4.39%)	20(6.27%)	34(10.66%)	175(54.86%)
Family relationship.	168(52.66%)	87(27.27%)	9(2.82%)	30(9.40%)	25(7.84%)
Relationship with neighbouring villages.	180(56.43%)	69(21.63%)	12(3.76%)	18(5.64%)	40(12.54%)
Child labour.	52(16.30%)	40(12.54%)	20(6.27%)	58(18.18%)	149(46.71%)
Access to finance and resources.	209(65.52%)	78(24.45%)		14(4.39%)	18(5.64%)
Local business development.	198(62.07%)	101(31.66%)		15(4.70%)	5(1.57%)

Furthermore, the table reveals that 23.82% respondents agree that ASM activities has strongly positive impact on Resettlements of displaced persons. 4.39% agrees that ASM activities has Positive impact on the study locations. 6.27% respondents say there is no impact, 10.66% respondents say ASM activities has negative impact. 54.86% agrees that ASM activities has strongly negative impact on the resettlements of displaced persons across the locations. This can be attributed to the fact that most of the displaced persons said that solid minerals were found on their land had to start all over in terms of building their house, farm land among other things. Hence, some of the inhabitants are traumatized, sick and some even result to death.

Based on family relationship as a result of ASM activities in the study locations 52.66% respondents agree that ASM activities has strongly positive impact on family relationship. 21.63% agrees that ASM activities has Positive impact on the study locations. 2.82% respondents say there is no impact, 9.40% respondents say ASM activities has negative impact. 7.84% agrees that ASM activities has strongly negative impact on family relationship and on the study locations.

Also, based on Relationship with neighboring villages 56.43% respondents agree that ASM activities has strongly positive impact on Relationship with neighboring villages. Example of such relationship between neighboring villages is Abuni village and Adudu village. This is because during the field visit, we were told that the Adudu mining site belongs to Abuni village. With this kind of relationship, the village also begins to benefit from the minerals found in the community thereby increasing their standard of living. 21.63% agrees that ASM activities has Positive impact on the study locations. 3.76% respondents say there is no impact, 5.64% respondents say ASM activities has negative impact. 12.54% agrees that ASM activities has strongly negative impact on relationship with neighboring villages and on the study locations. Plate X reveals Abuni mining sites cooperative

Plate X: Abuni Mining Site Office

Based on child labour as a result of ASM activities in the study locations 16.30% respondents agree that ASM activities has strongly positive impact on child labour. 12.54% agrees that ASM activities has Positive impact on the study locations. 6.27% respondents say there is no impact, 18.18% respondents say ASM activities has negative impact. 46.71% agrees that ASM activities has strongly negative impact on child labour and on the study locations. This can be attributed to the fact that in most of the ASM site visited children are seen working along with their mothers. This will in turn affect the children as their counter-part in other part of the state or country are in schools whereas their case is different. Plate XI shows under aged children working in mining site

Plate XI: Children working in Mining Sites

Based on Access to finance and resource of ASM activities in the study locations 65.52% respondents agree that ASM activities requires a lot of capital for the mining business therefor finance has strongly positive impact on ASM activities. 24.45% agrees that finance of ASM activities has Positive impact on the study locations. 4.39% respondents say ASM activities is hindered by finance and other resources. 18(5.64%) agrees that finance and other resources in ASM activities has strongly negative impact on the study locations.

In addition, based on Local business development 62.07% respondents agree that ASM activities has strong positive impact on Local business development across the study locations. This is because in ASM sites like Abuni, Adudu, Wuse, vein 17 business activities are carried out, most of the business include selling of foods, drinks, transportation, charcoal, firewood etc. 31.66% agrees that ASM activities has Positive impact on the study locations in terms of local business. 4.70% respondents say ASM activities has negative impact while 1.57% agrees that ASM activities has strongly negative impact on Local business development in the study locations

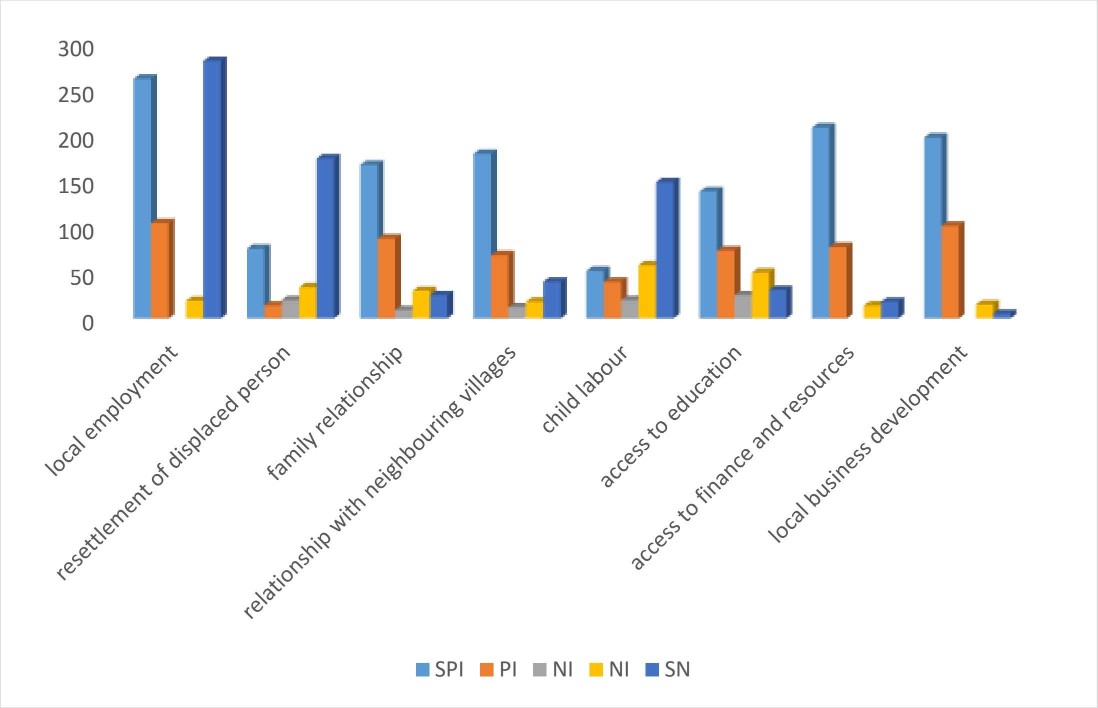


Figure 4.30: Impact of ASM on socio economic activities

4.3.7 Impact of ASM on health and environments

Artisanal mining has different consequences on human health. Table 4.9 reported a number of these effects.

a. Effects of noise and vibration

First, 3.13% of the respondents are of the opinion that ASM activities causes noise pollution has strongly positive impact on the environment. 4.70% agreed that ASM activities has positive impact. 31.35% respondents are of the opinion that ASM activities has negative impact whereas 58.31% agreed that ASM activities has a very strongly negative impact on the health and environment in terms of effects of noise and vibration. Most of the noise and vibrations come from the machines used during drilling of holes for explosive to break the rocks for easy mining as indicated on plate XII and XIII, the holes are usually from 10 metres deep.

Plate XII: Interaction with the Miners

Plate XIII: An Explosive Pit

b. Exposure to mercury and other chemicals

Also, based on the impact of ASM activities to exposure to mercury and other chemicals, 1.57% respondents are of the opinion that ASM activities has strongly positive impact on the environment, 5.96% agreed that ASM activities has positive impact, 1.89% has no impact on human health and environment where as 28.53% respondents say ASM activities has negative impact and 62.07% agrees that ASM activities has strongly negative impact on the health and environment across the study areas.

Table 4.9: Impact of ASM on Health and Environments

Impact of ASM on health and environments	Strongly positive Impact	Positive impact	No Impact	Negative Impact	Strongly Negative Impact
Effects of noise and vibration.	10(3.13%)	15(4.70%)	8(2.51%)	100(31.35%)	186(58.31%)
Exposure to mercury and other chemicals.	5(1.57%)	19(5.96%)	6(1.89%)	91(28.53%)	198(62.07%)
Physical injury within the mines due to rock falls and mine collapse.	17(5.33%)	13(4.08%)	1(0.31%)	99(31.03%)	179(56.11%)
Exposure to substance abuse which can cause mental and organ damage.	5(1.57%)	7(2.19%)	3(0.94%)	140(43.89%)	164(51.41%)
Spread of HIV/AIDS.	4(1.25%)	6(1.88%)	5(1.57%)	128(40.13%)	176(55.17%)
Accident with machinery.	3(0.94%)	8(2.51%)	6(1.88%)	113(35.42%)	189(59.43%)

c. Physical injury within the mines due to rock falls and mine collapse

In addition, based on the impact of ASM activities on the Physical injury within the mines due to rock falls and mine collapse, 1.57% respondents are of the opinion that ASM activities has strongly positive impact on the environment. 5.96% agreed that ASM activities has positive impact, 1.89% agreed to no impact on human health and environment while 28.53% respondents agreed that ASM activities has negative impact and 62.07% agreed that ASM activities has strongly negative impact on the health and environment across the study locations.

d. Health and substance abuse

The impact of ASM activities on the exposure to substance usage which can cause mental and organ damage; findings from respondents indicates that 1.57% respondents agreed that ASM activities has strongly positive impact on substance abuse, 2.19% agreed that ASM activities has positive impact. 0.94% has no impact on human health and substance use, 43.89% respondents agreed that ASM activities has negative impact while 51.41% agreed that ASM activities has strongly negative impact on the health and substance use across the study locations. The study on the operations and health impacts found that residents of the study area suffered from skin diseases, malaria, colds, catarrh, diarrhea and fever.

e. Spread of HIV/AIDS

On the impact of ASM activities on the spread of HIV/AIDS, 1.25% respondents are of the opinion that ASM activities has strongly positive impact on the environment, 1.88% agreed that ASM activities has positive impact. 1.57% agreed to no impact on human health and environment 40.13% respondents are of the opinion that ASM activities has negative impact. 55.17% agreed that ASM activities has strongly negative impact on the health and environment across the study locations.

f. Accident with machinery during mining activities

Based on the impact of ASM activities on accident with machinery during mining activities, 1.25% respondents agree that ASM activities has strongly positive impact on the environment. 1.88% agreed that ASM activities has positive impact. 1.57% say no to impact on human health and environment; 40.13% respondents agreed that ASM activities has negative impact. 55.17% agrees that ASM activities has strongly negative impact on the health and environment across the study locations, an example of such machine is indicated on plate XIV.

Plate XIV: Some Equipment used for Mining

4.3.8 Impact of ASM on water resource

Table 4.10 indicates the responses based on impact of ASM activities on water resources. 1.88% of the respondent agreed that ASM activities have strong positive impact on water resources. 2.82% agreed that ASM activities has positive impact. 7(2.19%) say no impact on sources of drinking water, 44.51% respondents agreed that ASM activities has negative impact. 62.38% agreed that ASM activities has strong negative impact on water resource across the study locations.

Table 4.10: Impact of ASM on Water Resource

Impact of ASM on water resource	Strongly positive Impact	Positive impact	No Impact	Negative Impact	Strongly Negative Impact
Effects on sources of drinking water.	6(1.88%)	9(2.82%)	7(2.19%)	142(44.51%)	199(62.38%)
Sedimentation of water resources.	4(1.25%)	2(0.63%)	3(0.94%)	160(50.16%)	150(47.02%)
Pollution of surface water.	3(0.94%)			162(50.78%)	154(48.23%)
Water borne diseases.			9(2.82%)	144(45.14%)	166(52.04%)

Furthermore, based on the sedimentation of water resources, Table 4.10 indicates that 1.25% respondents agree that ASM activities has strongly positive impact on Sedimentation of water resources. (0.63%) agrees that ASM activities has Positive impact. 3(0.94%) say no impact on Sedimentation of water resources, (50.16%)

respondents say ASM activities has negative impact. (47.02%) agrees that ASM activities has strongly negative impact on water resources across the study locations.

Also, on pollution of surface water as a result of mining activities Table 4.10 indicates that (0.94%) respondents agree that ASM activities has strongly positive impact on water resource. (50.78%) respondents say ASM activities has negative impact. (48.23%) agrees that ASM activities has strongly negative impact on water resource and the environment across the study locations, this is shown on plate XV.

Plate XV: Pollution of Surface run-offs due to Sluicing

In addition, Table 4.11 further indicates that 2.82% of the respondents agree that ASM activities has impact on water borne diseases. 45.14% of the respondents agreed that ASM activities has negative impact. 52.04% agreed that ASM activities has strong negative impact on water borne diseases and the environment across the study locations.

4.3.9 Adaptation strategies in the management of artisanal and small-scale mining in the study areas.

71.43 % of the miners strongly agreed that the practice of backfilling of mining pit would have a strong positive impact on the mine's sites as indicated on Table 4.11. Exactly 75 % are of the opinion that water de-sedimentation would have a strong positive impact on mine sites while 6.25 % agreed that there will be strong negative impacts on the mine sites. Also, 71 % and 73 % of the respondents think that reclamation, reseeding and chemicals management respectively will have a strong positive impact on environmental management activities. Plate XVI and XVII showed the focus group discussion with mine owners based on the sustainable methods to adopt for mining areas.

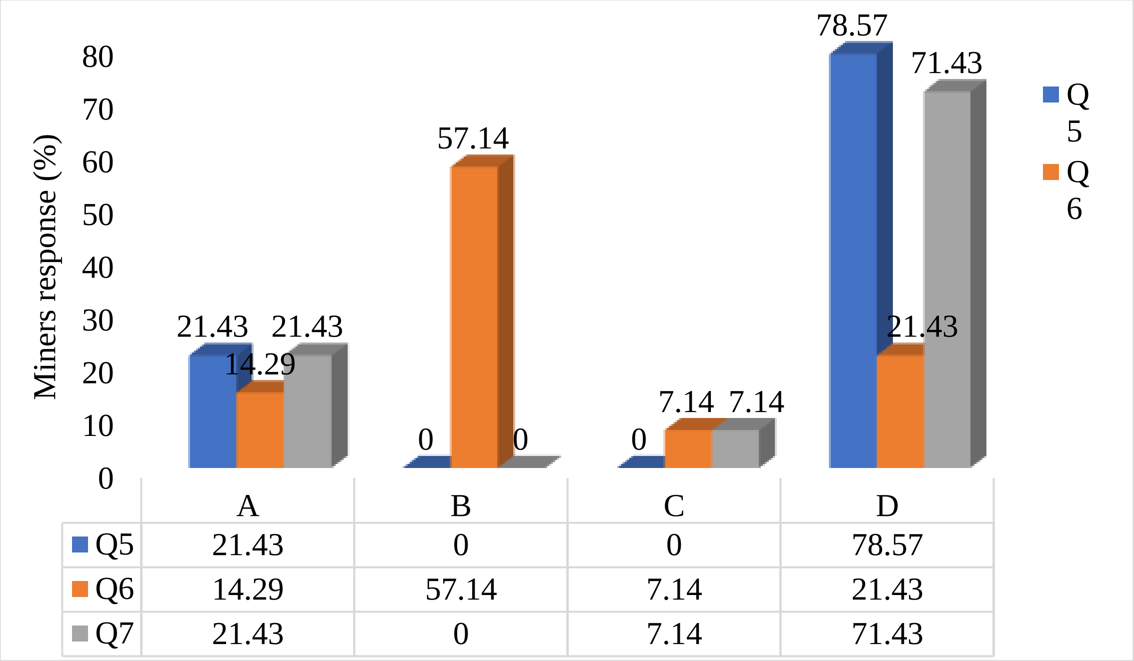
Table 4.11 AS Miners Response to Environmental Management Activities

Environmental Management Activities by AS Miners	5-Strong positive impact	4-Positive impact	3-No impact	2-Negative impact	1-Strong negative impact
1. Practice of pit backfilling	71.43	19.05	0	9.52	9.52
2. Water de-sedimentation	75	6.25	6.25	6.25	6.25
3. Reclamation and reseeding	70.59	11.76	5.88	11.76	0
4. Chemicals management	73.33	6.67	6.67	13.33	0

Plate XVI: Focus Group Discussion

Plate XVII: Focus Group Discussion

The result in Figure 4.31 shows that miners' responses to ways of improving soil retention, water quality and air quality in the mining sites. To each of the three questions, 78.57%, 71.43% and 57.14% representing option D of Q5 reduce deforestation and major landscape changes, B of Q6 improve sustainable access to water and D of Q7 educate miners on sustainable environmental and health impacts were favorite responses.



	A	B	C	D
■ Q5	21.43	0	0	78.57
■ Q6	14.29	57.14	7.14	21.43
■ Q7	21.43	0	7.14	71.43

Figure 4.31 Miners' Responses to Ways of Improving Soil Retention, Water Quality and Air Quality in the Mining Sites

The result in Table 4.12 shows miners' responses to question on mitigative measures of ASM on the Environment. 84.62 %, 84.62 %, 91.66 % and 90.91% strongly agreed with the questions "do you agree measures should be taken to minimize damages to land or soil reclamation, restoration and retention?" "If 'no' to 1, do you agree there is/are reasons for not taking measures to reduce impacts on the environment?" "Do you agree miners should pay or accept levies to reduce environmental damages?" and "Do you agree authorities should speak to miners about the impacts of mining on the environment?".

Table 4.12: AS Miners Responses to Mitigative Measures on Environment

Mitigative measures activities of ASM Site on the Environment	5-Strongly agree	4-Agree	3-Undecided	2-Disagree	1-Strongly disagree
Do you agree to measures taken to minimize damages to land or soil reclamation/restoration/retention?	84.62	0	7.69	0	7.69
If 'no' to 1, do you agree there is/are reasons for not taking measures to reduce impacts on the environment?	84.62	15.38	0	0	0
Do you agree miners should pay or accept levies to reduce environmental damages?	91.66	8.33	0	0	0
Do you agree authorities should speak to miners about the impacts of mining on the environment?	90.91	9.09	0	0	0

However, during one-on-one interaction with the owner of virgin field mining company Mr. Mohammed Isiaka, he highlighted some of the challenges hindering the actualization of sustainable managements of the mining site to government policies which do not favor the mine owners. Royalty is paid every year to the people as well as license fee to the government without geological map to show the locations of the minerals in terms of volume in the area, the expenses are all incurred by them. also, the cost of buying the latest equipment for mining is very expensive making sustainability of mining difficult. He further referred to South African and other African countries who have utilized satellite remote sensing to identify and map out the type of minerals, volume as well as the exact location of the mineral which makes it more profitable when engaged in solid mineral mining operation business. Plate XVIII to XX indicates in-depth interview with stakeholders on mining on the study locations.

Plate XVIII: In-depth Interview with a Mine Owner.

Plate XIX: In-depth Interview with a Miner.

Plate XX: In-depth Interview with an Expert

4.4 Environmental Degradation Outlook as Compared to National Environmental Standards.

4.4.1 Results of physical/chemical parameters of water

The samples of water samples obtained from water bodies surrounding and outside mining/processing regions were analyzed in this part and provided in two sections which include physical and chemical parameters.

4.4.2 Impact of local mining on water

4.4.2.1 *Water pH*

The result in Figure 4.32 shows that the pH values are less than the stipulated limit of 9. The result further reveals that samples of the wet season have lower pH value ranging from 6.8 in WSV to 7.9 SHR while samples of the dry season range from 8.1 in VN1 to 8.9 in SHR and WSV. This indicates that there was no significant difference of the pH value across the study locations for both the dry and wet season when compared. This means that the values are within the permissible limit as prescribe FME of Nigeria, however, drinking natural alkaline water is generally considered safe, but the consistently higher pH in the water in dry season could be as a result of the artificial alkaline in the low water level during the dry season, since it contains heavy minerals. Artificial alkaline water, on the other hand, should be treated with caution since it likely contains fewer beneficial minerals than its high pH would suggest and may include pollutants. Prior to the findings, it was not clear that the water from the locality is not contaminated as a result of mining activities in the study areas.

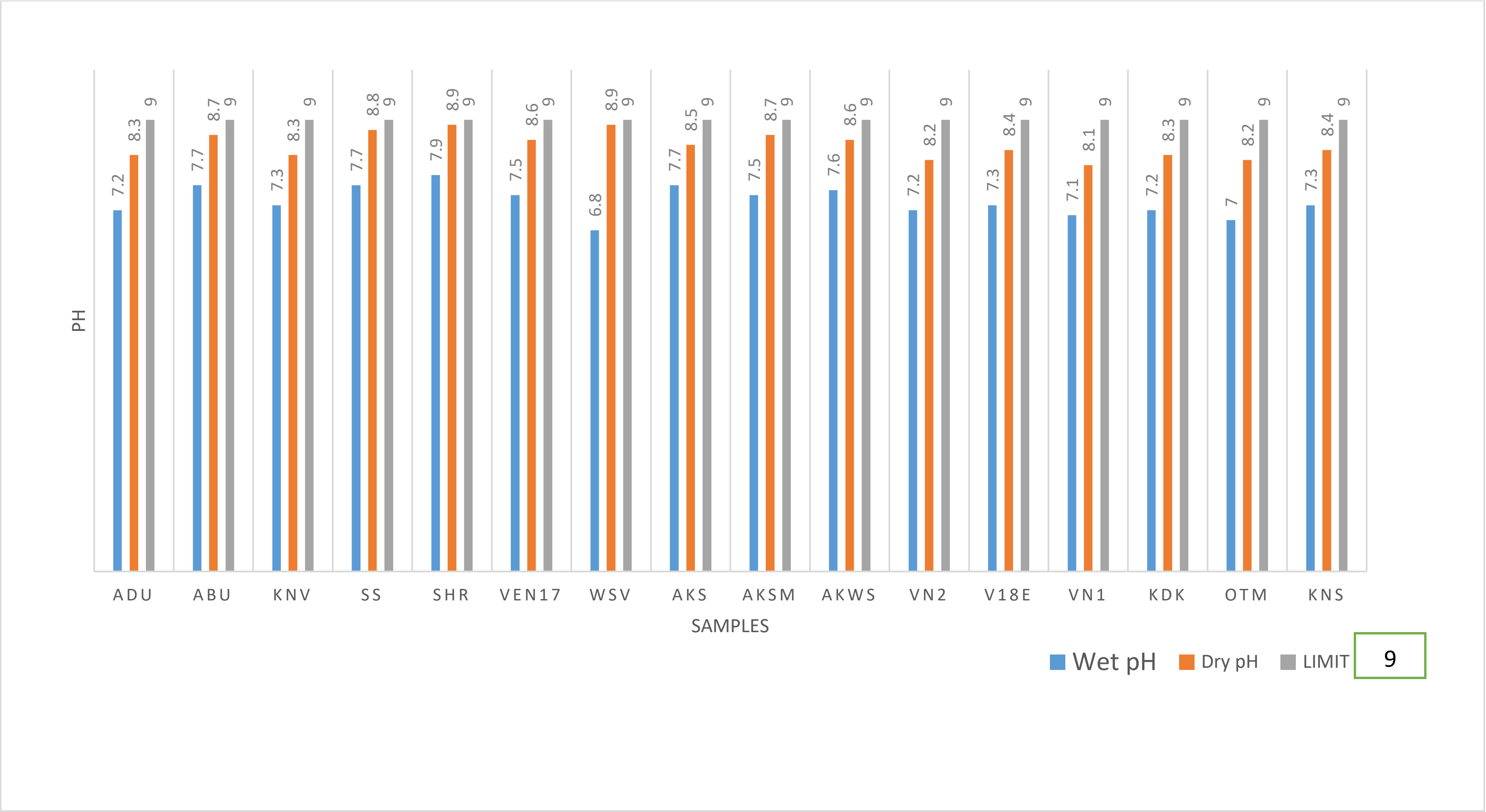


Figure 4. 32: Comparison of Ph in Dry and Wet Seasons Across the Study Areas

4.4.2.2 *Temperature*

The result in Figure 4.33 Reflects the temperature of the various mining sites across the study areas, it shows that the temperature of the sampled areas is lower in both wet and dry season when compared to standard limit. Findings shows that the temperature of the various mining sites are below the 40-degree Celsius permissible limit as prescribe FME of Nigeria. Only AKSM has the highest value of 37.9 degree Celsius in dry season while the raining season was 25 degrees Celsius which are below the permissive limit.

4.4.2.3 *Total dissolved solid (TDS)*

Figure 4. 34 reveals that ABU to WSV and VN2 to OTM has lower permissible limit as prescribed by FME of Nigeria when compared to the standard limit of 500mg/l. TDS values in both wet and dry season are lower than of 500mg/l. This implies that the waters across the identified study locations have low particles which encourage the people to utilize the water for one purpose or the other. In addition, study locations like ADU, AKS, AKSM, AKWS and KNS has higher TDS values greater than the standard limit of 500mg/l which can have serious health implication, for instance AKS and AKSM have the highest value of 4970 and 1597mg/l. This indicates very high concentration of salt; Salinity is defined as the weight of the total dissolved non-organic solids when carbonates and bicarbonates are converted to oxides and all the bromides and iodines have been replaced by an equivalent amount of chloride. In water samples with very high TDS concentrations can cause cells shrinks. These changes the ability of the organism to move about in a water column, resulting in floatation or sinking beyond the normal levels.

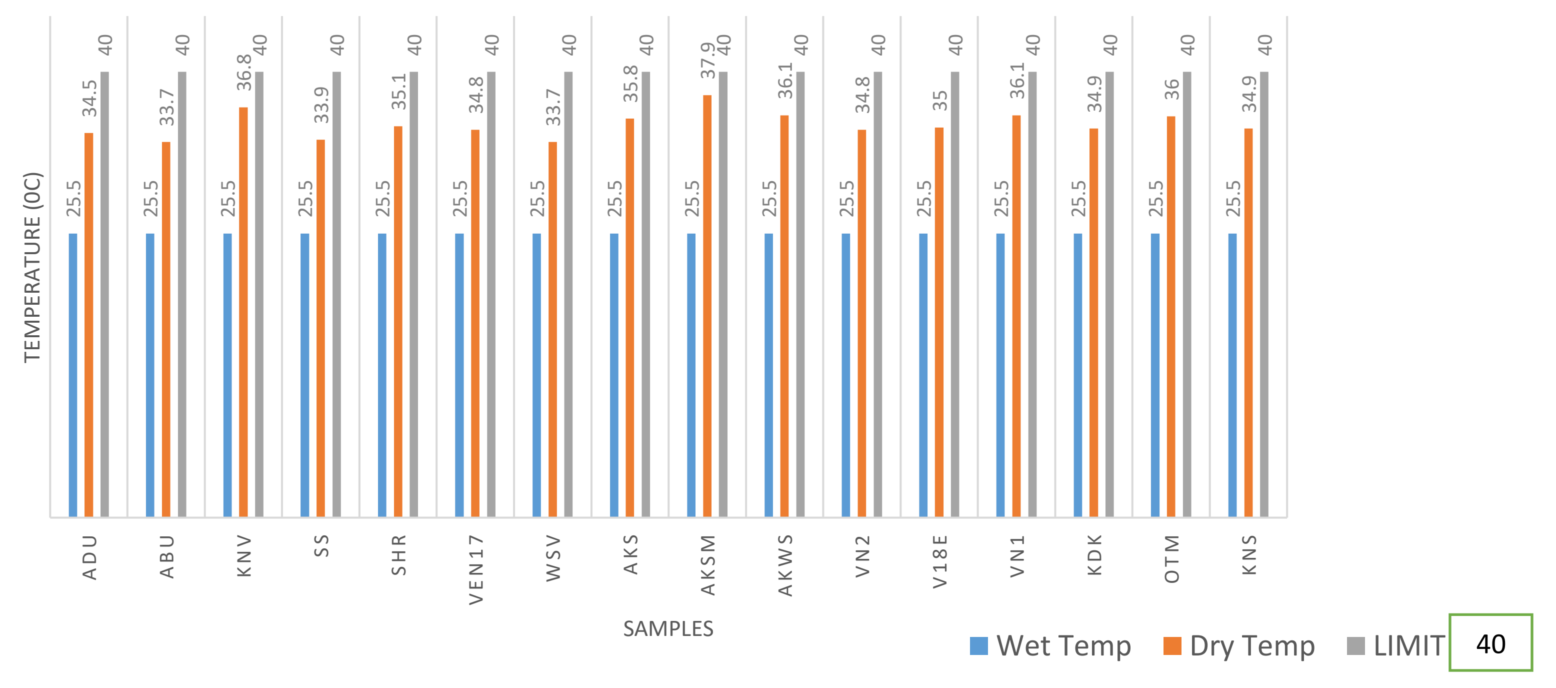


Figure 4. 33 Comparison of Temperature in Dry and Wet Seasons Across the Study Areas

4.4.2.4 *Electrical conductivity*

Figure 4.35 Shows the E.C for both dry and wet seasons across the study areas, the result reveals that ABU, KNV, SS, SHR, VEN17, VN2, VI8, VN1, KDK and OTM has low E.C values for wet and dry season respectively. On the other hand, ADU, AKSM, AKWS and KNS has higher E.C which is higher than the standard limit 1000S/m. Dissolved salts like potassium chloride and sodium chloride have a big impact on this. The electrical conductivity (EC) of roughly 0.3 S/m was recorded which points to the salt effects on the health of crops and freshwater aquatic creatures.

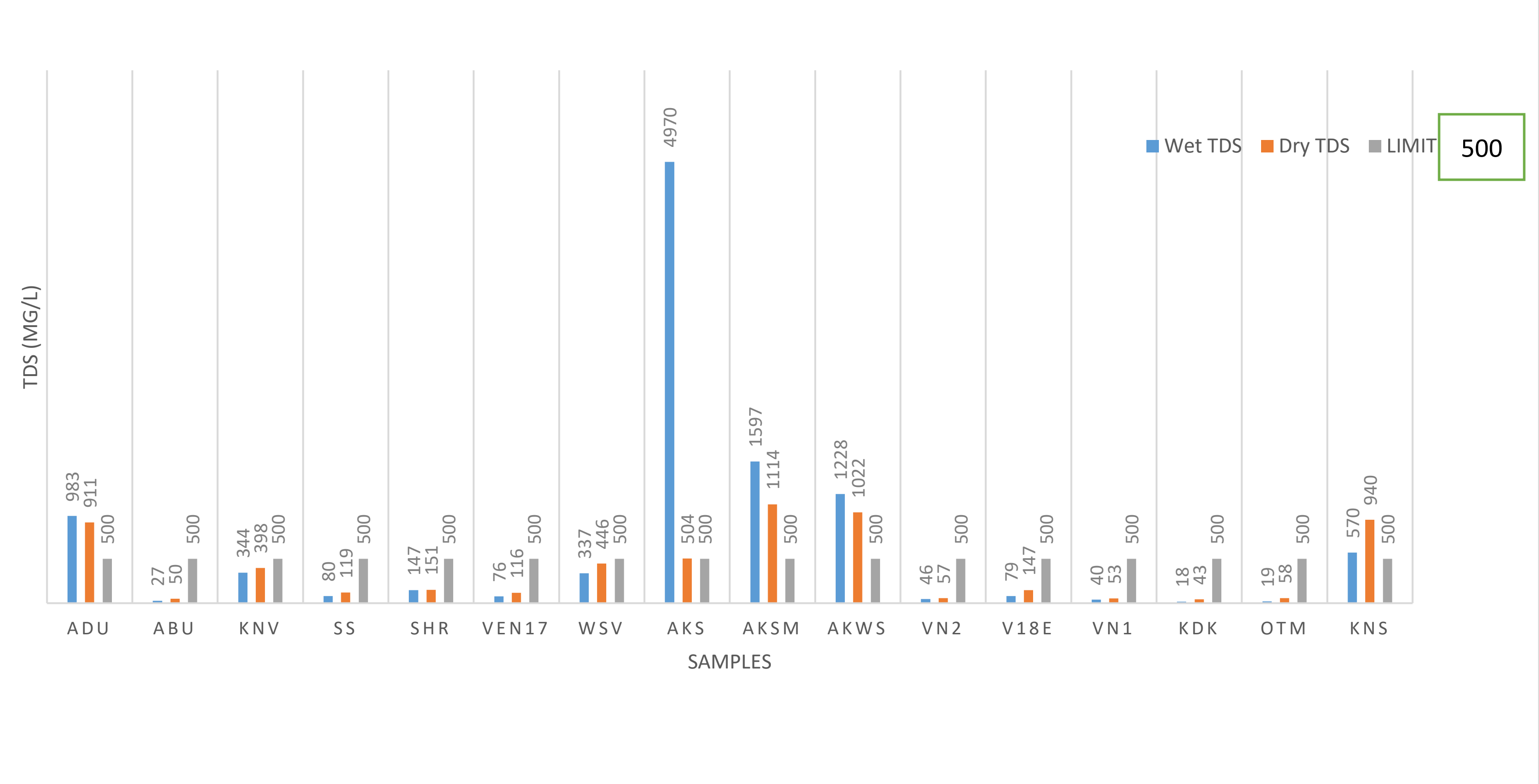


Figure 4. 34: Comparison of TDS in Dry and Wet Seasons Across the Study Areas

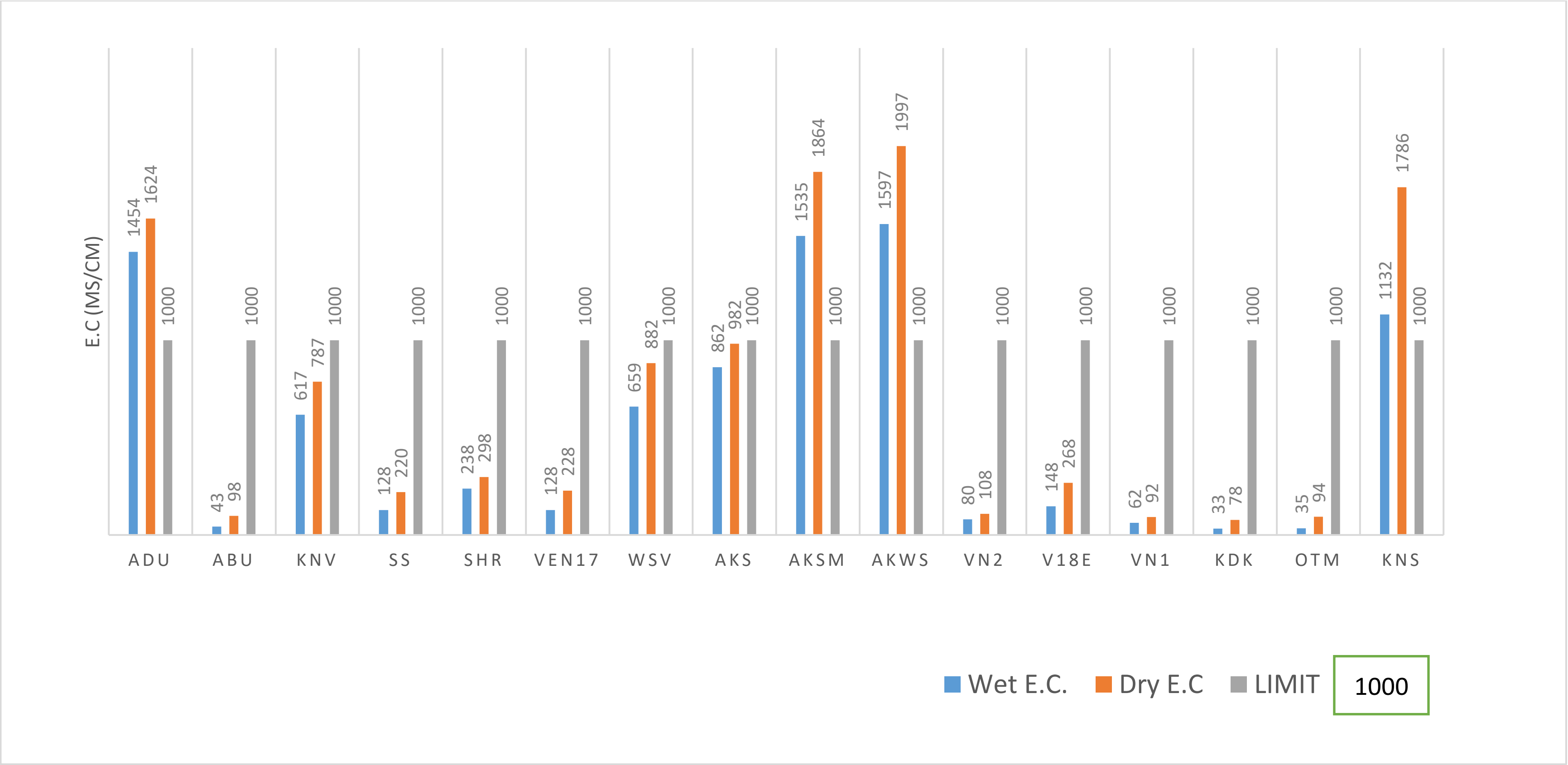


Figure 4. 35 Comparison of E.C in Dry and Wet Seasons Across the Study Areas

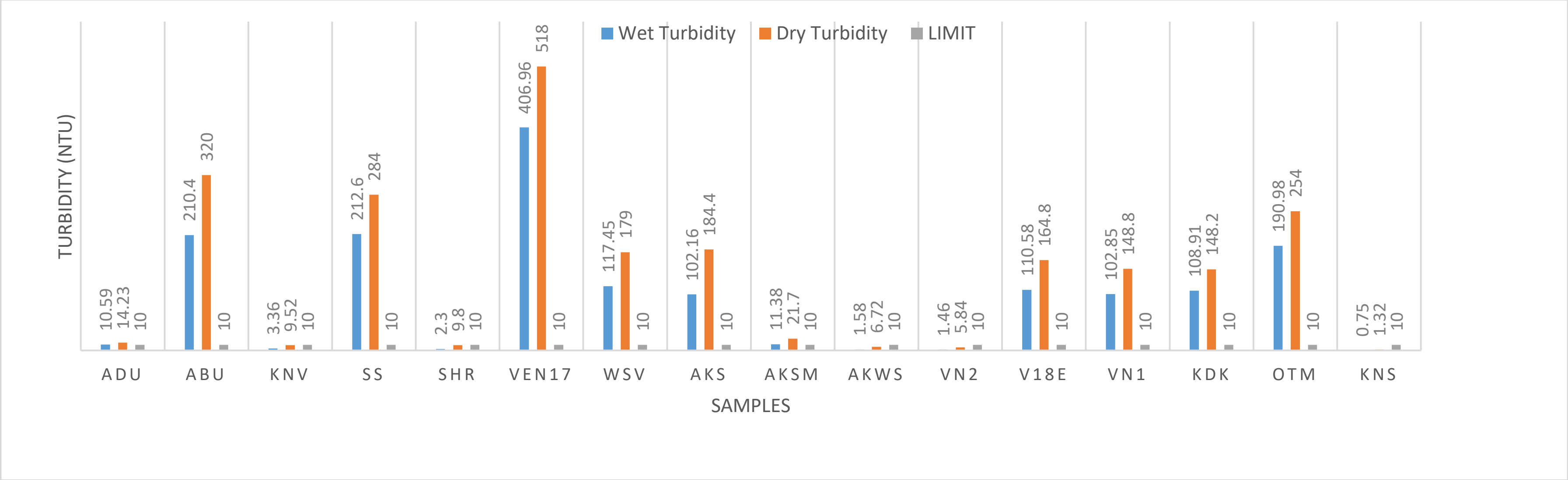


Figure 4. 36: Comparison of Turbidity in Dry and Wet Seasons Across the Study Areas

4.4.2.5 *Total suspended solids (TSS)*

Figure 4. 36 Shows the TSS concentration in water across the various mining sites for both wet and dry season, findings reveal that locations such as ADU, SS, VEN17, AKS have higher TSS value in both wet and dry season above the standard limit of 10mg/l. On the other hand, the remaining locations of the mining sites have lower TSS value which is less than the limit by implication the TSS concentration on the water is low.

4.4.2.6 *Turbidity*

Figure 4.37 Shows the comparison of turbidity in both dry and wet season across the study areas with the federal ministry environmental (FME). The results indicate that during the wet season KNV, SHR, AKWS, VN2 and KNS has turbidity level which was less than the standard limit of 5(NTU) indicating that the turbidity level is good for the environment of the various locations. On the other hand, the dry season result shows different result showing higher values.

Similarly, ABU, SS, VEN17, WSV, AKS, V18, VN1, KDK and OTM has a very high values which is very far from the FEPA standard of 5(NTU). The implication of these is that the water contain debris which is not safe for human consumption and other purposes, the debris is mainly from the mining activities and the villages in most of the mining communities use this water for domestic purpose and farming these have great health implication.

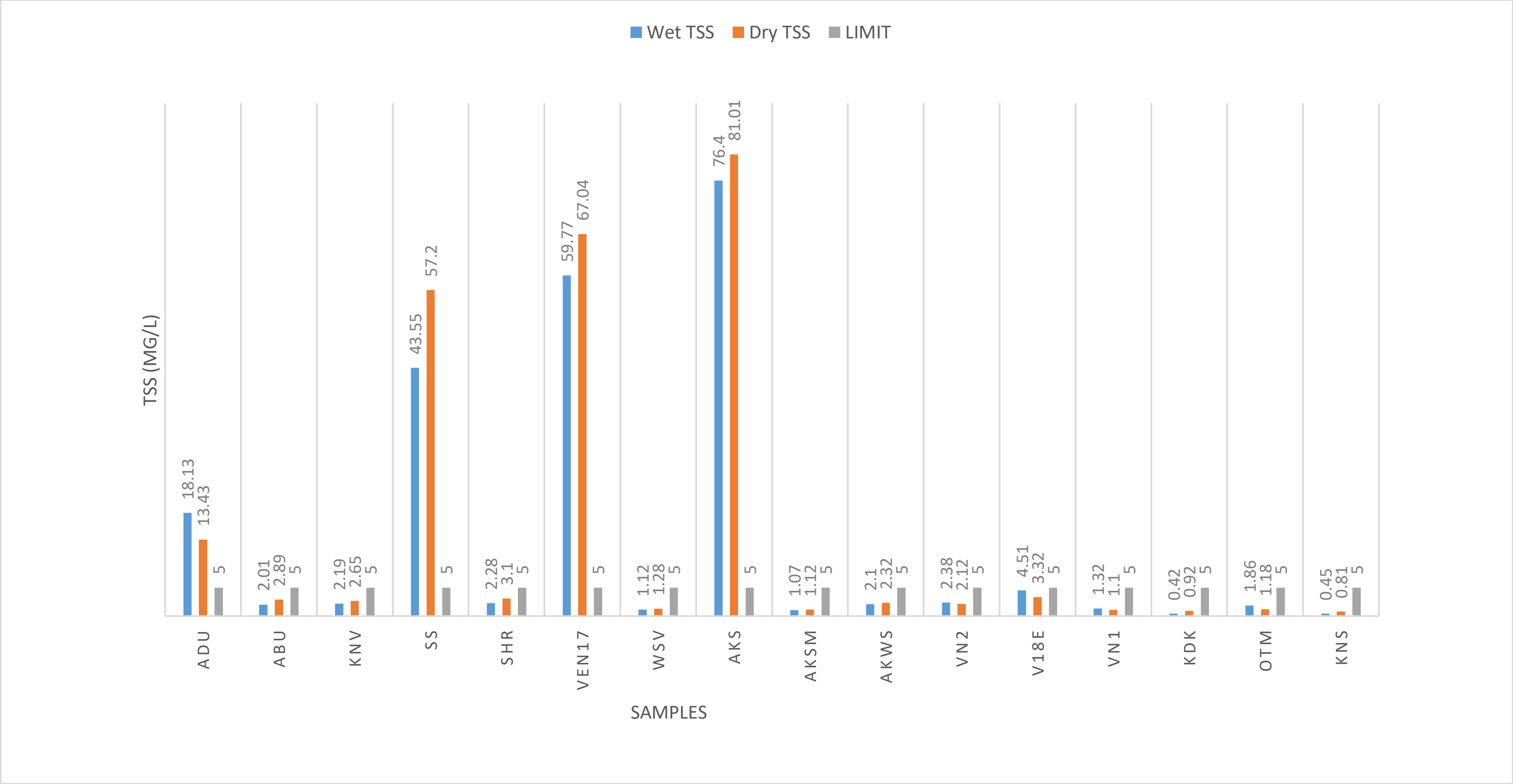


Figure 4. 37: Comparison of TSS in Dry and Wet Seasons Across the Study Areas

4.4.2.7 *Dissolved oxygen (DO)*

Figure 4. 38 shows comparison of DO in dry and wet seasons with the standard, results shows that the wet season has the highest DO values across the locations than the dry season data except for AKS where both wet and dry season has the same DO values of 8.9mg/l. finding further reveals the values are above the standard limit of 7.5mg/l. This indicate that the DO is a bit higher than limit which makes the water unsafe for consumption considering the health implication.

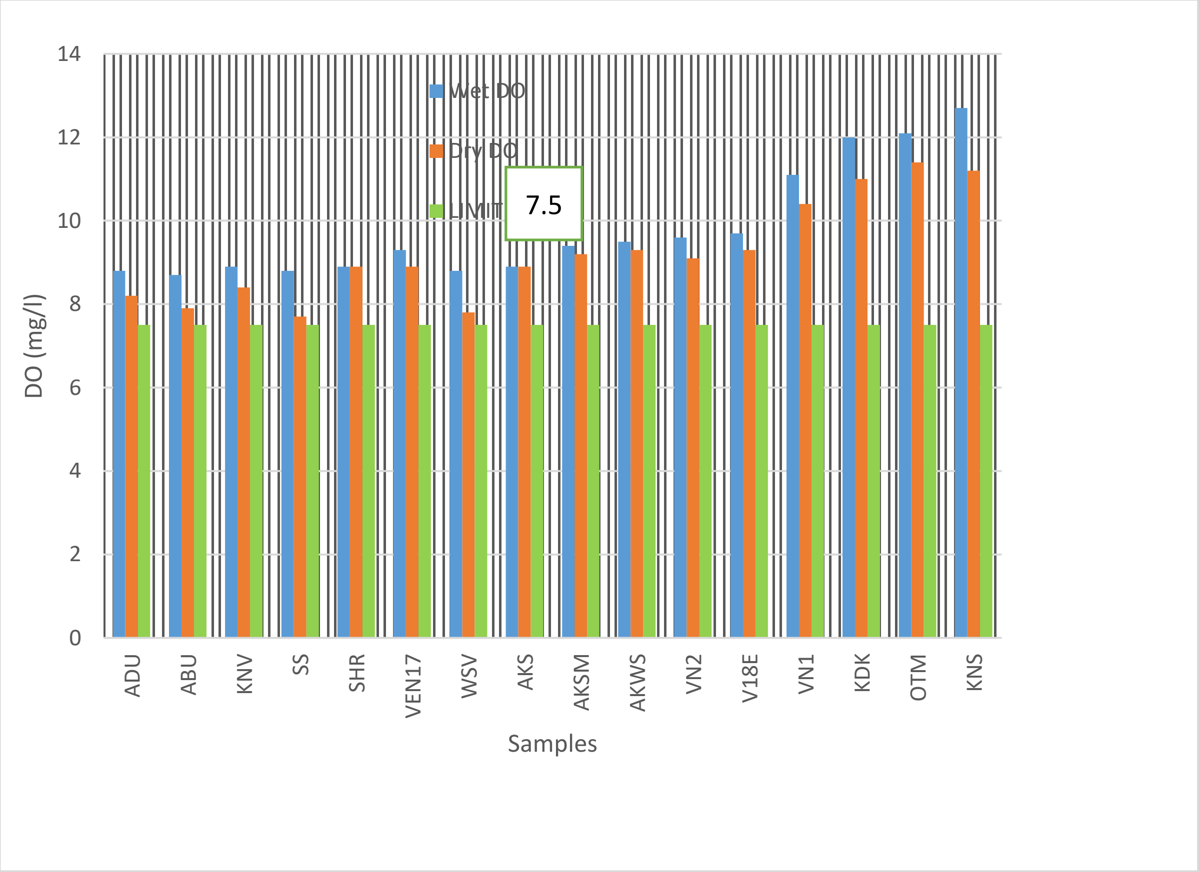


Figure 4.38: Comparison of DO in Dry and Wet Seasons Across the Study Areas

Results on table 4.13 shows that E.C, Turbidity, TDS, DO have above FEPA standard limit during the wet season whereas table 4.14 reveals that during the dry season, E.C, Turbidity, TSS and DO were above the standard limit set by FEPA.

Table 4.13: Results of Physical and Chemical Analysis of Surface Water for Wet Season

Parameter	**ADU**	**ABU**	**KNV**	**SS**	**SHR**	**VEN17**	**WSV**	**AKS**	**AKSM**	**AKWS**	**VN2**	**V18E**	**VN1**	**KDK**	**OTM**	**KNS**	**AVG.**	**FEPA**
pH	7.2	7.7	7.3	7.7	7.9	7.5	6.8	7.7	7.5	7.6	7.2	7.3	7.1	7.2	7	7.3	7.38	9
Temp	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.50	40
E.C.	1454	43	617	128	238	128	659	862	1535	1597	80	148	62	33	35	1132	546.94	1000
Turbidity	10.59	210.4	3.36	212.6	2.3	406.96	117.45	102.16	11.38	1.58	1.46	110.58	102.85	108.91	190.98	0.75	99.64	10
TDS	983	27	344	80	147	76	337	4970	1597	1228	46	79	40	18	19	570	660.06	500
TSS	18.13	2.01	2.19	43.55	2.28	59.77	1.12	76.4	1.07	2.1	2.38	4.51	1.32	0.42	1.86	0.45	13.72	5
DO	8.8	8.7	8.9	8.8	8.9	9.3	8.8	8.9	9.4	9.5	9.6	9.7	11.1	12	12.1	12.7	9.83	7.5

Table 4.14: Results of Physical and Chemical Analysis of Surface Water for Dry Season

Parameter	**ADU**	**ABU**	**KNV**	**SS**	**SHR**	**VEN17**	**WSV**	**AKS**	**AKSM**	**AKWS**	**VN2**	**V18E**	**VN1**	**KDK**	**OTM**	**KNS**	**AVG.**	**FEPA**
pH	8.3	8.7	8.3	8.8	8.9	8.6	8.9	8.5	8.7	8.6	8.2	8.4	8.1	8.3	8.2	8.4	8.5	9
Temp	34.5	33.7	36.8	33.9	35.1	34.8	33.7	35.8	37.9	36.1	34.8	35	36.1	34.9	36	34.9	35.3	40
E.C	1624	98	787	220	298	228	882	982	1864	1997	108	268	92	78	94	1786	712.88	1000
Turbidity	14.23	320	9.52	284	9.8	518	179	184.4	21.7	6.72	5.84	164.8	148.8	148.2	254	1.32	141.90	10
TDS	911	50	398	119	151	116	446	504	1114	1022	57	147	53	43	58	940	383.06	500
TSS	13.43	2.89	2.65	57.2	3.1	67.04	1.28	81.01	1.12	2.32	2.12	3.32	1.1	0.92	1.18	0.81	15.09	5
DO	8.2	7.9	8.4	7.7	8.9	8.9	7.8	8.9	9.2	9.3	9.1	9.3	10.4	11	11.4	11.2	9.23	7.5

Table 4.15: Concentration (PPM) of Heavy Metal in the Soil Samples

S. No	**Metal**	**Soil Samples**																
		ADU	**ABU**	**KNV**	**SS**	**SMHR**	**VEN 17**	**WSV**	**AKS**	**AKSM**	**AKWS**	**VN2**	**V18E**	**VN1**	**KDK**	**OTM**		**Upper Cont. Crust**
		Conc.	**Conc.**	**Conc.**	**Conc.**	**Conc.**	**Conc.**	**Conc.**	**Conc.**	**Conc.**	**Conc.**	**Conc.**	**Conc.**	**Conc.**	**Conc.**	**Conc.**	**Ave. Conc.**	**Conc.**
1	Fe	2377	2351	1736	11.98	1787	2082	2188	2088	1963	2271	2241	2068	2131	1.2533	0.16	1829.4	3.5
2	Pb	0	778.5	0	81.83	0	0	0	0	0	0	0	0	216.6	0	0	71.80	20
3	Zn	12.74	730.7	50.87	11.33	22.33	12.74	5.503	14.59	8.86	51.3	15.09	21.51	71.57	0.913	0.933	68.73	71
4	Cu	40.89	58.63	41.55	0	1.013	50.76	12.3	13.49	5.073	9.64	20.05	32.42	13.13	0	0	19.93	25
5	Hg	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		
6	Mn	1888	1927	1482	114.9	339	901	35.89	284.31	18.57	45.5	41.25	0	34.34	29.24	19.067	477.34	600
7	As	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		
8	Cd	0.553	2.40	0	0.753	0.823	1.637	0.887	1.02	1.033	0.65	0.29	1.353	1.217	1.263	1.163	1.00	98
9	Co	111.3	127.8	52.52	13.41	22.34	29.66	25.31	24.09	18.57	45.5	41.25	34.34	29.24	17.47	19.02	40.79	10
10	Cr	102.8	92.8	29.86	5.03	7.27	14.15	22.66	17.8	8.647	33.2	35.61	12.42	9.22	0	0	27.18	35
11	V	0	5.72	8.04	5.09	7.13	9.45	27.12	36.68	13.56	11.7	9.48	20.89	22.42	18.64	17.11	14.20	60
12	Ni	87.02	68.329	10.51	0	0	3.643	0	0	0	0	11.57	0	9.267	0	0	12.69	20

NB: ND = Not Detected, PPM = Parts Per Million, Conc. = Concentration, Concentrations in the Upper Continental Crust adapted from (Taylor and McLennan, 1995).

4.4.3 Results of heavy metal concentration of soil sample analyzed

4.4.3.1 *Concentration (PPM) of heavy metal in the soil samples analyzed*

The observed background concentrations of heavy metal in the earth's Upper Continental Crust, as gathered by Taylor and McLennan 1995, which show element concentrations devoid of anthropogenic activity, were utilized as reference (background) materials for this investigation. Because there are no national soil quality recommendations or standards for heavy metal in soils in Nigeria, the comparisons in this study must be made using other known controls for heavy metal concentrations in soils as background (control) soils (Iyaka and Kakulu, 2011).

Table 4.16: Geo-accumulation Index vis-à-vis Reference Materials

S. No.	**Soil**	**Index of Geo-accumulation (Igeo); Fe as the reference material**											**(Igeo)**
	Samples	**Fe**	**Pb**	**Zn**	**Cu**	**Hg**	**Mn**	**As**	**Cd**	**Co**	**Cr**	**V**	**Ni**
1	ADU	12.44	0	9.24	9.41	ND	19.53	ND	5.18	9.54	11.23	0	10.18
2	ABU	12.42	13.34	15.08	9.93	ND	19.56	ND	7.29	9.74	11.08	7.84	9.83
3	KNV	12.30	0	11.23	9.44	ND	19.18	ND	0	8.45	9.45	8.33	7.13
4	SS	11.98	10.091	9.06	0	ND	19.40	ND	5.62	6.48	6.87	7.67	0
5	SHR	12.03	0	10.04	4.07	ND	17.05	ND	5.74	7.22	7.41	8.19	0
6	VEN17	12.25	0	9.23	9.73	ND	18.46	ND	6.74	7.63	8.37	8.56	5.60
7	WSV	12.32	0	8.02	7.68	ND	13.81	ND	5.86	7.40	9.05	10.08	0
8	AKS	12.25	0	9.43	7.81	ND	16.80	ND	6.06	7.33	8.70	8.93	0
9	AKSM	12.16	0	8.71	6.40	ND	12.86	ND	6.08	6.95	7.66	9.08	0
10	AKWS	12.37	0	11.25	7.33	ND	14.15	ND	5.41	8.25	9.60	8.87	0
11	VN2	12.35	0	9.48	8.38	ND	14.01	ND	4.24	8.10	9.70	8.57	7.27
12	V18E	12.24	0	9.99	9.08	ND	0	ND	6.47	7.84	8.18	9.71	0
13	VN1	15.60	11.496	11.73	7.77	ND	13.75	ND	6.31	7.61	9.22	9.81	6.95
14	KDK	1.55	0	5.43	0	ND	13.51	ND	6.37	6.86	0	9.54	0
15	OTM	1.42	0	5.47	0	ND	12.90	ND	6.25	6.99	0	9.42	0

NB: ND = Not Detected, Conc. = Concentration, PPM = Parts Per Million, Concentrations in the Upper Continental Crust adapted from (Taylor and McLennan, 1995).

4.4.3.2 *Results of I_{geo} of the soil samples*

The research areas were assessed on the basis the amount of contamination owing to the occurrence of the designated heavy metal in the individual soil samples, as shown in Tables 4.6. The calculated Igeo of the specified heavy metal in soil samples is reported as follows.

a. Adudu mining area

Results of soil analysis shows that the processing areas at Adudu is heavily polluted with Fe, Zn, Cu, Mn, Cd, Co, Cr and Ni having got an Igeo values of 12.44, 9.24, 9.41, 19.53, 5.18, 9.54, 11.23 and 10.18 respectively. Similarly, lead was not detected in Adudu. The results however, showed absence of Hg and As. The complete lack of lead in Adudu indicates the absence of gold ore, which is tightly linked to lead as an accessory mineral. These findings in Adudu contradict those found from contaminated regions in Zamfara State's Anka and Bukkuyum LGAs, where significant quantities of Zn, Pb and As were observed by Tsuwang *et al*. (2014).

b. Abuni mining area

Results of soil analysis revealed that the area where processing take place in Abuni was strongly polluted with Fe, Pb, Zn, Cu, Mn, Cd, Co, Cr, V and Ni having got an Igeo values of 12.42, 13.34, 15.08, 9.93, 19.56, 7.29, 9.74, 11.08, 7.84 and 9.83 respectively while Hg and As were not detected. These findings are consistent with those obtained from contaminated regions in Zamfara State's Anka and Bukkuyum LGAs, where elevated Pb and Zn concentrations were observed (Tsuwang *et al.,* 2014; Okiei *et al.,* 2010). The tailings, which are the by-products of ore processing were packed with copper, lead, and other related heavy metal because of the high concentrations of some heavy metal found in the soil samples from the rivers where the process water effluents run into.

c. Keana virgin (KNV) mining area

Soil samples analysis revealed that ore processing region of KNV was strongly polluted with Fe, Zn, Cu, Mn, Co, Cr, V and Ni having got an Igeo values 12.30, 11.23, 9.45, 19.18, 8.45, 9.45, 8.33, and 7.13 respectively, Pb, and Cd has zero values while Hg and As were not detected. Mn has the highest concentration in the area with a value of 19.18 while the least was Co with a value of 8.45.

d. Saunin sarki (SS) mining area

The analysed soil samples result revealed that ore processing region at **Saunin Sarki** was heavily polluted with Fe, Pb, Zn, Mn, Cd, Co, Cr and V having got an Igeo values 11.98, 10.09, 9.06, 19.40, 5.62, 6.48, 6.87 and 7.67 respectively, Cu and Ni has zero values while Hg and As was not detected.

e. Sohon rami (SHR) mining area

Soil samples analysis showed that the area where ore was processed at **Sohon Rami** was heavily polluted with Fe, Zn, Cu, Mn, Cd, Co, Cr and V having got an Igeo values 12.03, 10.04, 4.07, 17.05, 5.74, 7.22, 7.41 and 8.19 respectively, Pb and Ni has zero values while Hg and As was not detected.

f. Vein 17 mining area

Soil samples analysis showed that the area where ore was processed at **Vein 17** was heavily polluted with Fe, Zn, Cu, Mn, Cd, Co, Cr, V and Ni having got an Igeo values 12.25, 9.23, 9.73, 18.46, 6.74, 7.62, 8.37, 8.56 and 5.60 respectively, Pb has zero value while Hg and As was not detected.

g. Wuse vein (WSV) mining area

Soil samples analysis showed that the area where ore was processed at **WSV** was heavily polluted with Fe, Zn, Cu, Mn, Cd, Co, Cr, and V having got an Igeo values 12.32, 8.02, 7.68, 13.81, 5.86, 7.40, 9.05 and 10.08 respectively, Pb and Ni has zero values while Hg and As was not detected.

h. Akiri salt (AKS) mining area

Soil samples analysis showed that the area where ore was processed at **AKS** was heavily polluted with Fe, Zn, Cu, Mn, Cd, Co, Cr, and V having got an Igeo values 12.25, 9.43, 7.81, 16.80, 6.06, 7.32, 8.69 and respectively.

i. Akiri salt mine (AKSM) mining area

Soil samples analysis showed that the area where ore was processed at AKSM was heavily polluted with Fe, Zn, Cu, Mn, Cd, Co, Cr, and V having got an Igeo values 12.16, 8.71, 6.40, 12.86, 6.08, 6.95, 7.66 and 9.83 respectively.

j. AKWS mining area

Soil samples analysis showed that the area where ore was processed at AKWS was heavily polluted with Fe, Zn, Cu, Mn, Cd, Co, Cr, and V having got an Igeo values 12.31, 11.25, 7.33, 14.15, 5.41, 8.25, 9.40, and 8.87 respectively,

k. Vein 2 mining area

Soil samples analysis showed that the area where ore was processed at VN2 was heavily polluted with Fe, Zn, Cu, Mn, Cd, Co, Cr, V and Ni having got an Igeo values 12.35, 9.48, 8.38, 14.01, 4.24, 8.10, 9.70, 8.57 and 7.27 respectively.

l. Vein 18E mining area

Soil samples analysis showed that the area where ore was processed at VN18E is heavily polluted with Fe, Zn, Cu, Cd, Co, Cr and V having got an Igeo values 12.23, 9.10, 9.08, 6.47, 7.84, 8.17, and 9.71 respectively, Pb, Mn and Ni has zero values while Hg and As were not detected.

m. Vein 1 mining area

Soil samples analysis showed that the area where ore was processed at VN1 was strongly polluted with Fe, Pb, Zn, Cu, Mn, Cd, Co, Cr, V and Ni having got an Igeo values 15.60, 11.50, 11.73, 7.77, 13.75, 6.31, 7.61, 9.22, 9.81, and 6.95 respectively, while Hg and As were not detected.

n. Kuduku (KDK) mining area

Soil samples analysis showed that the area where ore was processed area at KDK was strongly polluted with Fe, Zn, Mn, Cd, Co, and V having got an Igeo values 1.55, 5.43, 13.51, 6.37, 6.86 and 9.54 respectively.

o. Otume (OTM) mining area

Soil samples analysis showed that the area where ore was processed at KDK was strongly polluted with Fe, Zn, Mn, Cd, Co, and V having got an Igeo values -1.42, 5.47, 12.90, 6.25, 6.10 and 9.42 respectively, Pb, Cu, Cr, and Ni has zero values while Hg and As was not detected.

Table 4.17: Contamination Factors vis-à-vis Reference Materials

S. No.	Soil	Contamination Factors (CF)											
	Samples	Fe	Pb	Zn	Cu	Hg	Mn	As	Cd	Co	Cr	V	Ni
1	ADU	77.83	0	0.021	0.187	ND	0.361	ND	0.000646	1.276	0.337	0	0.499
2	ABU	4515.73	268.85	6.956	1.584	ND	2.169	ND	0.017	8.648	1.791	0.064	2.307
3	KNV	6.204	0	0.007	1.674	ND	2.485	ND	0	5.283	0.859	1.348	0.528
4	SS	164.109	1.35	0.053	0	ND	0.063	ND	0.003	0.443	0.048	0.028	0
5	SHR	-304.074	0	0.187	0.024	ND	0.336	ND	-004	1.328	1.237	0.068	0
6	VEN17	-615.53	0	0.185	2.05	ND	-1.55	ND	0.017	3.069	0.148	0.163	0.188
7	WSV	-646.866	0	-0.126	0.798	ND	0.97	ND	0.015	4.101	1.051	0.732	0
8	AKS	-253.914	0	0.087	0.229	ND	0.202	ND	-0.004	1.025	0.216	0.781	0
9	AKSM	-299.223	0	0.67	1.083	ND	0.017	ND	6.843	0.991	0.132	0.121	0
10	AKWS	-736.838	0	0.820	0.438	ND	0.086	ND	-0.007	5.167	1.076	0.221	0
11	VN2	-126.473	0	0.417	1.573	ND	0.135	ND	5.803	8.089	1.995	0.309	1.134
12	V18E	-125.774	0	0.064	0.276	ND	0	ND	-0.03	0.731	0.076	0.075	0
13	VN1	-1099.55	19.50	1.820	0.948	ND	0.103	ND	0.022	5.281	1.317	0.674	0.837
14	KDK	0.319	0	0.011	0	ND	0.043	ND	0.011	1.557	0	0.277	0
15	OTM	0.038	0	0.011	0	ND	0.026	ND	-0.009	1.574	0	0.236	0

4.4.3.3 *Results of contamination factors vis-à-vis reference materials of the soil samples*

a. Adudu mining area

Soil samples analysis showed that the area where ore was processed at Adudu was strongly polluted with Fe, Zn, Cu, Mn, Cd, Co, Cr and Ni having got an EF values 77.83, 0.02, 0.19, 0.36, 0.000646, 1.276, 0.34 and 0.50 respectively.

b. Abuni mining area

Soil samples analysis showed that the area where ore was processed at Abuni was heavily polluted with Fe, Pb, Zn, Cu, Mn, Cd, Co, Cr, V and Ni having got an EF values 4515.73, 268.85, 6.96, 1.58, 2.67, 0.02, 8.65, 1.79, 0.06 and 2.31 respectively.

c. Keana Virgin (KNV) mining area

Soil samples analysis showed that the area where ore was processed at KNV was strongly polluted with Fe, Zn, Cu, Mn, Co, Cr, V and Ni having got an EF values 6.20, 0.01, 1.67, 2.49, 5.28, 0.86, 1.35 and 0.53 respectively.

d. Saunin sarki (SS) mining area

Soil samples analysis showed that the area where ore was processed at SS was strongly polluted with Fe, Pb, Zn, Mn, Cd, Co, Cr, and V having got an EF values 164.12, 1.35, 0.05, 0.06, 0.003, 0.44, 0.05, and 0.03 respectively.

e. Sohon rami (SHR) mining area

Soil samples analysis showed that the area where ore was processed at SHR was heavily polluted with Fe, Zn, Cu, Mn, Cd, Co, Cr, and V having got an EF values -304.07, 0.19, 0.02, 0.34, -004, 1.33, 1.24, and 0.07 respectively.

f. Vein 17 mining area

Soil samples analysis showed that the area where ore was processed at VEN17 was strongly polluted with Fe, Zn, Cu, Mn, Cd, Co, Cr, V and Ni having got an EF values -615.53, 0.19, 2.05, -1.55, 0.02, 3.07, 0.42, 0.16 and 0.19 respectively.

g. Wuse vein (WSV) mining area

Soil samples analysis showed that the area where ore was processed at WSV was heavily polluted with Fe, Zn, Cu, Mn, Cd, Co, Cr and V having got an EF values -646.87, -0.13, 0.80, 0.97, 0.02, 4.10, 1.05 and 0.73 respectively.

h. Akiri salt (AKS) mining area

Soil samples analysis showed that the area where ore was processed at AKS was strongly polluted with Fe, Zn, Cu, Mn, Cd, Co, Cr and V having got an EF values -253.91, 0.09, 0.03, 0.20, -0.004, 1.03, 0.22, and 0.78 respectively.

i. Akiri salt mine (AKSM) mining area

Soil samples analysis showed that the area where ore was processed at AKSM was strongly polluted with Fe, Zn, Cu, Mn, Cd, Co, Cr and V having got an EF values -299.22, 0.67, 1.08, 0.02, 6.84, 0.99, 0.13 and 0.12 respectively.

j. AKWS mining area

Soil samples analysis showed that the area where ore was processed at AKWS was also heavily polluted with Fe, Zn, Cu, Mn, Cd, Co, Cr and V having got an EF values -736.84, 0.82, 0.44, 0.09, -0.007, 5.17, 1.08 and 0.22 respectively.

k. Vein 2 mining area

The analysis of soil samples revealed that the ore processing area at VN2 was strongly polluted with Fe, Zn, Cu, Mn, Cd, Co, Cr, V and Ni having got an EF values -1255.47, 0.42, 1.57, 0.14, 5.80, 8.09, 1.10, 0.31 and 1.13 respectively.

l. Vein 18E mining area

The analysis of soil samples revealed that the ore processing area at V18E was strongly polluted with Fe, Zn, Cu, Cd, Co, Cr, and V having got an EF values -125.77, 0.06, 0.08, -0.03, 0.73, 0.08 and 0.08 respectively.

m. Vein 1 mining area

The analysis of soil samples revealed that the ore processing area at VN1 was strongly polluted with Fe, Pb, Zn, Cu, Mn, Cd, Co, Cr, V and Ni having got an EF values -1099.55, 19.50, 1.82, 0.95, 0.10, 0.02, 5.28, 1.32, 0.67 and 0.84 respectively.

n. Kuduku (KDK) mining area

The analysis of soil samples revealed that the ore processing area at KDK was strongly polluted with Fe, Zn, Mn, Cd, Co, and V having got an EF values 0.32, 0.01, 0.04, 0.01, 0.56, and 0.08 respectively.

o. Otume (OTM) mining area

The analysis of soil samples revealed that the ore processing area at OTM was strongly polluted with Fe, Zn, Mn, Cd, Co, and V having got an EF values 0.04, 0.01, 0.03, -0.01, 1.57 and 0.04 respectively.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Baryte, Copper, Lead, Salt, Baryte with shoots of copper and Charcoal, Low grade Iron and Sandstone are mined in the study areas.

Mean land use and land cover change for the study locations keep changing at an alarming rate of 41%, 38% and 34% for Awe, Obi and Keana local government areas respectively for the within the four epoch of the year 1986-2016. Socioeconomic study revealed that activities increased as the population and mining activity increases. However, if the current trend of degradation of the environment continues without measures to curb the situation at hand, there could be an imbalance in the ecosystem.

Soil samples analyzed to determine the presence and concentration of heavy metal (in ppm) of Fe, Pb and Co indicated that Pollution Load at the various mine sites in Awe, Keana and Obi local Government areas were consistently higher than the upper continental crust concentrations (UCCC), and the enrichment/geo-accumulation factors were strongly higher than the limits of ≥6 and >=5 respectively. These results in the various location does not agree with that obtained from polluted areas in Anka and Bukkuyum LGAs of Zamfara State where high concentrations of Pb, As and Zn were reported (Tsuwang *et al.,* 2014).

Average mean results of physical parameters in the various sites were greater than the federal ministry of environment standards for DO, TDS, TSS, EC, pH and Turbidity respectively while Temperature was low. Based on the findings of this research; it can be deduced that: Water de-sedimentation will have strong positive impact on the water quality for humans, flora and fauna. The practice of backfilling of mining pit will have strong positive impact on the mining sites. Concurrent reclamation should be adopted by the mining sectors to achieve a sustainable and successful post-closure outcome.

Adoption of soil retention practice through ornamental plants for water quality and air quality in the mining sites will reduce deforestation and major landscape changes. Improved awareness on sustainable access to water and education of miners on sustainable environmental and health impacts will improve socio-economic activities in mining communities. Conclusively, much has not been studied and documented on thorough impact and associated health risks of artisanal and small-scale mining activities in Nasarawa State, Nigeria as their activities is on the increase and are carried out without recourse to mining standards making these activities unsafe and unsustainable.

5.2 Recommendations

The recommendations from this study are proffered to address mining needs, land use trends, environmental management plan and regulatory standard occasioned of ASM in Nigeria.

a. The Nigerian Geological Survey Agency (NGSA) should review the mineral ore map of the study area to update the ores mined in the study area.
b. Extension service workers should target training on mineral ore mine planning and design with emphasis on the safety and health of miners, also, MIREMCO should consider using trained educators/staff to administer on regular basis the extension service programmes on mining practices
c. A review of the current methods of mining and ore processing in terms of skill needs, safety and environmental protectionis urgently needed; Conducting training needs analysis will inform the methods and nature of technical interventions to be administered to the ASM operators with the use of remote

sensing and GIS tools as this would enhance identification of areas that are degraded, their rate and extent.

d. Comprehensive and collaborative grassroot sensitization should be initiated by Ministry of Mines and Steel Development, Non-Government Organizations and Town Planning agency to conscientize mine stakeholders and the communities on the dangers of environmental degradation, and Mining Cadastre Office in the state should move to restore, backfill and reclaim the abandoned mining pits for other economic activities.

e. Artisanal mineral ore mining in the areas should be paused while thorough environmental auditing of the areas conducted.

f. The use of the rivers by the mine workers should be discouraged. Government should provide appropriate number of water collectors/reservoirs to extract water from filled mines to serve as alternatives.

g. MMSD should synergize with the traditional leaders in collaboration with LGA authorities, and establish an ASM desk office at each LGA in Nasarawa State. This will create a feedback mechanism for better mine fields monitoring.

h. MMSD should rid the mining sector of speculators who hoard mineral titles and have no technical/financial capacities to develop mining projects but instead encourage artisanal miners to work illegally on their leasehold.

i. Any intervention programme such as credit or grant facilities meant for the miners should be directed to the real miners and not to proxies, also, MMSD should offer intervention programmes to real miners and hosts communities to ensure sustainable mining activities to control pollution.

j. MMSD should conduct each state EIA to cover the entire concession rather than requiring individual cooperatives to conduct EIA, also, consideration of concessions should be made to accommodate registered cooperatives that exploit same minerals.

It is therefore recommended that adoption of environmental management plan for miners, operators and workers which will reduce the rate of land degradation from ASM activities in the study area and continuous monitoring by regulatory authorities and stakeholders should be intensified to protect our environment.

5.3 Contribution to the body of Knowledge

The study established that baryte, copper, lead, salt, baryte with shoots of copper and charcoal, low grade iron, and sandstone are mined in the study areas.

The study also revealed alarming changes in land use and land cover of the study locations at the rates of 41%, 38% and 34% for Awe, Obi and Keana local government areas respectively within the four epochs of 1986 to 2016; indicating that Awe is the most degraded due to ASM activities.

The study further revealed that iron was highly concentrated and was above the Upper Continental Crust (UCCC) limit of 3.5. For Zinc, most sites recorded less than the UCCC of 71ppm but Abuni (ABU) and VNI with 730.7ppm and VN1 71.57ppm respectively were above the UCCC standard. For Copper (Cu) ADU, ABU, Keana Vein, and Vein 17 (VN17), and Vein 18 recorded values of 40.89ppm, 58.63ppm, 41.55ppm, 50.76ppm and 32.42ppm respectively above the UCCC limit of 25ppm. Lead (Pb) was absent in most of the sites, but locations like ADU, Sauni Sarki with 778.5ppm, Sauni Sarki (SS), and and Vein 1 (VN1) with 778.5ppm, 216.6ppm and 81.83ppm respectively were far above the UCCC standard of 20ppm.

Furthermore, for water quality, the study also established that, the temperature of water at the various mining sites were below the 40-degree Celsius permissible limit as prescribed by the Federal Ministry of Environment of Nigeria; with only AKSM recording the highest value of 37.9 degree Celsius in dry 25 degrees Celsius during the dry season. Lastly, the study showed that ADU, AKS, AKSM, AKWS and KNS had Total Dissolved Solids (TDS) values greater than the standard limit of 500mg/l, which can have serious health implications.

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APENDIX A

Department of Geography,

Federal University of Technology,

Minna, Niger state.

Questionnaire on the Impact of Artisanal and Small-Scale Mining in Parts of Nasarawa state, Nigeria

Dear Respondent,

My name is Madaki A. Josephine, a post graduate student of geography department, Federal University of Technology, Minna, Niger state. I am conducting research on the Impact of Artisanal and Small-Scale Mining in Parts of Nasarawa state, Nigeria. This questionnaire is designed to elicit information on some issues related to the subject of study, you are kindly requested to respond by ticking the most appropriate option or supply the relevant answer to the question asked in the space provided. All information supplied will be used purely for academic research and shall be treated with utmost confidentiality.

Thank you