INTEGRATED ASSESSMENT OF SOIL EROSION PROCESSES AND POLICY IN OGUTA LAKE WATERSHED IMO STATE SOUTH EAST NIGERIA

By

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Abstract

Soil erosion is one of the most severe environmental problems in Nigeria, especially in the south east region of the country. Oguta Lake watershed is one of the affected watersheds in the region because of various human activities in the area. This thesis presents a thorough assessment of soil erosion processes and policy analysis which simultaneously integrates the physical condition, socio-economic context, institutions, and policy reforms in which stakeholders are embedded. Remote Sensing (RS), reconnaissance survey, two modelling assessment techniques (RUSLE and MPSIAC models) were applied to produce land use/land cover dynamics maps and spatial map of soil erosion, and key factors responsible for soil erosion in the location. Review of environmental regulations, semi-structured interview and focus group discussion were applied and analysed using Institutional Analysis and Development (IAD) framework. Land use and land cover changes were significant during the period 1990 – 2014 as 17% of the watershed was shifted to unstable zones and, thus, contributed to soil erosion by water in the watershed. Human activities like sand mining, deforestation, overgrazing and poor crop farming practice contributed significantly to land use/cover dynamics. Consequently, 14% of the forest and pastureland cover was lost due to human activities in the watershed. The spatial soil erosion map showed that severe soil erosion class was 25-36 tonnes/h/year and covered about 18% of the watershed. On the other hand, two (2) focus group discussions and forty-four (44) semi-structured interviews were conducted with the relevant stakeholders. It was observed that poverty and unemployment were the key drivers of land misuses and environmental degradation in the watershed. Based on the Institutional Analysis and Development (IAD) result. For the land ownership and allocation, this study proposes that the powers and influence of the traditional leaders and local government staff in land allocation and ownership in the watershed should be recognised by the government to increase land use compliance as stipulated in the Land Use Act 1978. For the sand mining, this study proposes an alternative arrangement that empowers the state government to have a shared management responsibility of managing sand mining activity in the watershed. For agricultural practice, this study proposes that operational level organisations should be domiciled in the local community where soil erosion is dominant. Women should be empowered with land and have an improved official representation in agricultural management. This would eliminate the barrier of poor communication channel and promote on the ground monitoring of farming activities and compliance among farmers.

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List of Abbreviations

ADP	Agricultural Development Programme
AGNPS	Agricultural Non-point Source
AOI	Area of Interest
ARTI	Agricultural Rural M Management Training Institute
BLM	Bureau of Land Management
CBN	Central Bank of Nigeria
CORINE	Coordination of Information on the Environment
DEM	Elevation Model
DN	Digital Number
EIA	Environmental Impact Assessment
EPM	Erosion Potential Model
ERDAS	Earth Resources Data Analysis System
EUROSEM	European Soil Erosion Model
FAO	Food and Agricultural Organisation
FDALR	Federal Department of Agriculture and Land Resources
FEPA	Federal Environmental Protection Agency
FKSM	Fleming and Kadhimi Scoring Model
FMSMD	Federal Ministry of Solid Mineral Development
FSM	Factorial Scoring Mode
GIS	Geographical Information System
GLASOD	Global Assessment of Soil Degradation
JDPC	Justice Development and Peace Commission
KINEROS	Kinematic Erosion Simulation
LEPB	Local Environmental Protection Board
LISEM	Limburg Soil Erosion Model
LSCD	Lake Sediment Core Depth
LWH	Local Government Works and Housing
MauSERM	Mauritius Soil Erosion Risk Mapping
MLS	Ministry of Land and Survey
MMF	Morgan Morgan and Finney
MPSIAC	Modified Pacific Southwest Inter-Agency Committee
NALDA	Agricultural Land Development Authority

NESREA	National Environmental Standard Regulation and Enforcement Agency
NEST	Nigeria Environmental Study Team
NEWMAP	Nigeria Erosion and Watershed Management Project
NGO	Non–Governmental Organisation
NPC	Nigerian Population Commission
NPE	National Policy on Environment
NPEA	National Policy on Environment Act
PEEP	Photo-Electric Erosion Pin
PESERA	Pan European Soil Erosion Risk Assessment
PSIAC	Pacific Southwest Inter-Agency Committee
RS	Remote Sensing
RUDEP	Rural Development Projects
RUSLE	Revised Soil Loss Equation
SAR	System Aperture Radar
SEA	Strategic Environmental Assessment
SEDD	Sediment Delivery Distribution
SME	State Ministry of Environment
SMW	State Ministry of Works
SMW	State Ministry of Water Resources
SSF	Soil Surface Factors
SSY	Specific Sediment Yield
SWAT	Soil and Water Assessment Tool
TLSDF	Transport Limited Sediment Delivery Function
TM	Transverse Mercator
UN	United Nations
UNEP	United Nation Environment Programme
US	United State
USA	United State of America
USGS	United State Geological Survey
USLE	Universal Soil Loss Equation
WEPP	Water Erosion Prediction Project
WWF	World Wildlife Fund

1 CHAPTER ONE: INTRODUCTION

1.1 Soil erosion: a global problem with local impact

Soil erosion is a global environmental crisis threatening food security of many nations. However, the world media is focused mainly on problems like forest fire, biodiversity, climate, and fossil fuel without special attention to soil erosion problems as a major global environmental issue, perhaps, due to its less striking nature. But societies have collapsed in the past because of soil erosion problems. For instance, 90% of people in the East Island Pacific lost their lives due to soil erosion and soil depletion and the people turned to cannibalism (Radford, 2004). In Iceland, the people survived through poor living conditions because they lost 50% of their land to sea (Radford, 2004). Moreover, 90% of the population of Yucatan Peninsula was lost due to soil erosion problems (Radford, 2004). Still, soil erosion is a very serious problem both in developing and developed continent of the world as shown in the map presented in Fig 1-1 below. This is very worrisome because according to FAO (1998) most human foods come from land while only a few come from water. Pimentel et al. (1995) asserted that accumulation of various anthropogenic activities and man induced erosion have led to abandonment and shifting of valuable lands to unproductive lands. However, among all types of soil erosion, approximately 55% of global soil loss is caused by soil erosion by water (Bridges and Oldman, 1999 (cited in Yang et al., 2003, p. 2913). Food production on global crop has been reduced by 16% due to the menace of soil erosion and land degradation (Pimentel, 1993). This is particularly worrisome as the global current rate of erosion of agricultural land degradation has been found to be leading to massive loss in land productivity per year (Pimentel, 2006). Particularly, the increasing pressure on land use has led to regular conversion of lands from one use to another which has a strong negative effect on gross erosion (Mosaffaie et al,. 2015).

Similarly, growing population triggers ever increasing demand for food and crop land which leads to exploitation and waste of natural resources like forest, soil and water resources. Soil depletion is particularly a major issue in developing countries because major revenue is dependent on agricultural products. According to FAO (2015) over 40% of soil in Africa is degraded and this is particularly worrisome because the livelihood of 83% of Sub- Sahara African people depend on land resources. Moreover, by 2050, food production in Africa needs to increase by 100% to keep up with ever increasing population demands FAO (2015). All of these make soil erosion key environmental, social, and economic issues for many African countries, especially Nigeria the most populated African country.

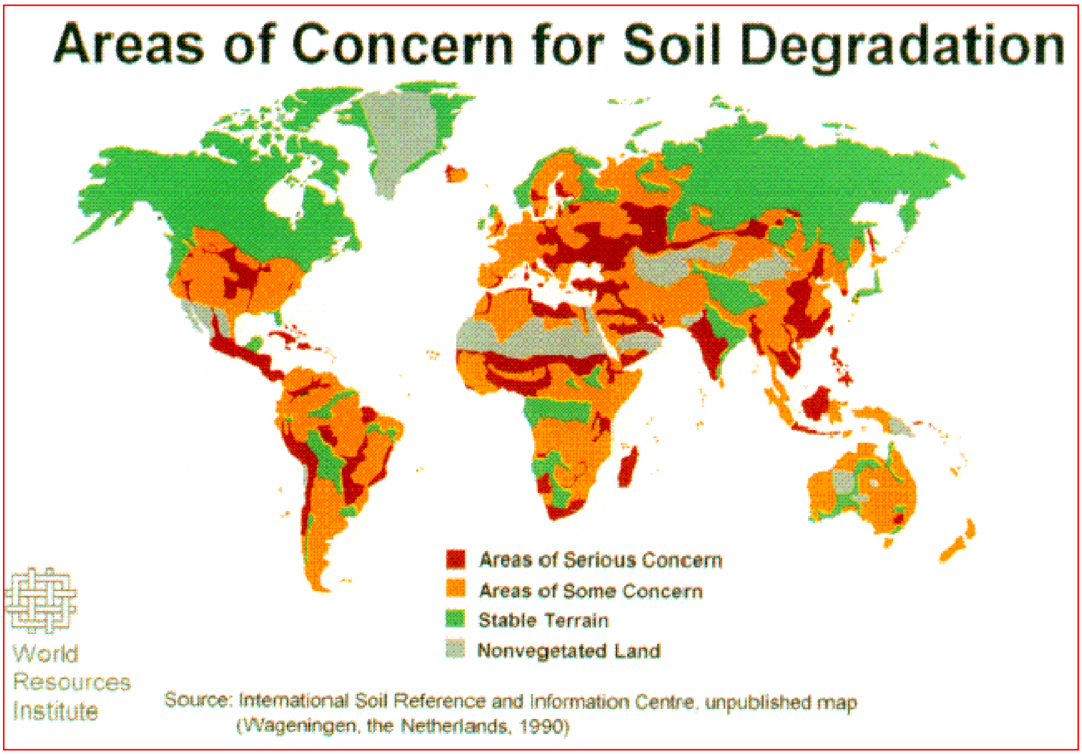


Figure 1-1 Spatial distribution of world soil degradation risk map. (Source: UNEP, International Soil Reference and Information Centre (ISRIC), wageningen, the Netherlands, 1990)

1.2 Significance of soil erosion in Nigeria

Environmental degradation was a global issue in the 20th century and has significantly increased in the 21st century due to its impact on food security, agronomic productivity, environment, and quality of life (Eswaran et al. 2001). According to Lal (2001) the processes of soil degradation include physical, chemical, and biological depletion of natural resources and soil biodiversity reduction as well as erosion of soil surface by water or wind action. According to FAO (2005) anthropogenic soil degradation is very common and its severity ranges from light to very high as follows: Light for 37.7% (342,917 km^2), moderate for 4.3% (39,440 km^2), high for 26.3% (240,495 km^2), and very high for 27.9% (255,167 km^2) (FAO,2005). Stamp (1938) opined that soil erosion is a long-standing problem and the most widespread type of soil degradation in Nigeria. Previous studies by Ologe (1988) and Igbozurike et al. (1989) have characterised the types and coverage of erosion in different parts of Nigeria as follow: in 1989, the area of 693,000 km^2 in the south were degraded by runoff-induced soil loss while in the north 231,000 km^2 were characterised mainly by wind erosion. Sheet erosion is very dominant across Nigeria while rill and gully erosion are very dominant in the south as well as the riverine areas in the north (Ologe, 1988; Igbozurike et al., 1989). In general, the climate and geology of soil in Nigeria makes detachment, redistribution, and deposition a significant part of perturbation and natural landscape-forming process. But these processes of soil erosion have been significantly impacted by long-standing anthropogenic activities in the past which involved replacing ancient shifting method of cultivation with a more intensive and unsustainable cropping systems (Lal, 1993a). According to Amangaraba et al. (2017) persistent increase in pressure on farmlands due to urbanization contributes significantly to soil erosion and land degradation in Nigeria, but this reflects the impact of increasing population as well as shifting from rural market economies to commercial market economies. For example, in Imo state south east Nigeria, the menace of human-induced soil erosion has led to destruction of social amenities like roads and electric poles; land degradation; river pollution; displacement settlement and community migration (Onwuemesi et al., 1991: Anike, 2012 and Amangabara et al., 2017). Tamene and Vlek (2008) opined that the severity of soil erosion in developing countries is because of lack of financial, technical, and institutional capacity to provide solution to the problems as often obtained in developed countries. Accoding to FMEnv (2005) the Nigeria location and its size exposed it to climatically induced hazards like erosion due to various climatic regimes and physiographical units it encompasses. The types and factors as well as the initiation and development of erosion and its severity varies from one region to another (Onwueme and Asiabaka, 1992; Idah et al., 2008). The available literature showed that erosion menace is more predominant in south east Nigeria compared to other zones of the country probably because of the climate and geology of the location as well as intense human activities in the region. South east Nigeria is characterised by both natural and human induced soil erosion which is complex in nature and varies considerably from one geographical location to the other (Igbokwe, 2004). According to Obinna et al. (2013) and Igbokwe et al. (2003) south east Nigeria is dominated by several erosion sites of various degrees distributed across member States: Abia, Anambra, Ebonyi, Enugu and Imo as shown in Fig (1-2). Although erosion has occurred throughout the history of agriculture in south east Nigeria, it has intensified in recent years. The effect of soil erosion on food security in Imo State south east Nigeria attracted international attention as many peasant farmers at different scales lost their farmlands to soil erosion (Amangaraba et al., 2017). Moreover, many households in Imo State were forced out of their homes because of the soil erosion menace (Igbokwe et al., 2008). The severity of soil erosion and its impact on economy compelled the Federal Republic of Nigeria to ask for financial intervention from the World Bank to provide solution to soil erosion challenges in seven states on a pilot basis: Abia, Anambra, Cross River, Ebonyi, Edo, Enugu and Imo. As a result of that, World Bank responded through a five hundred million ($500,000,000) erosion project (NEWMAP, 2013). The project is mainly targeted at providing a solution to gully erosion problems in south east region and Edo State in Nigeria. The project is structured in such a way that the affected states and the federal government of Nigeria make counterpart contribution to the funding. Although, the main project is still at design stage; the output of this research will be communicated to the stakeholders under the Ministry of Environment.

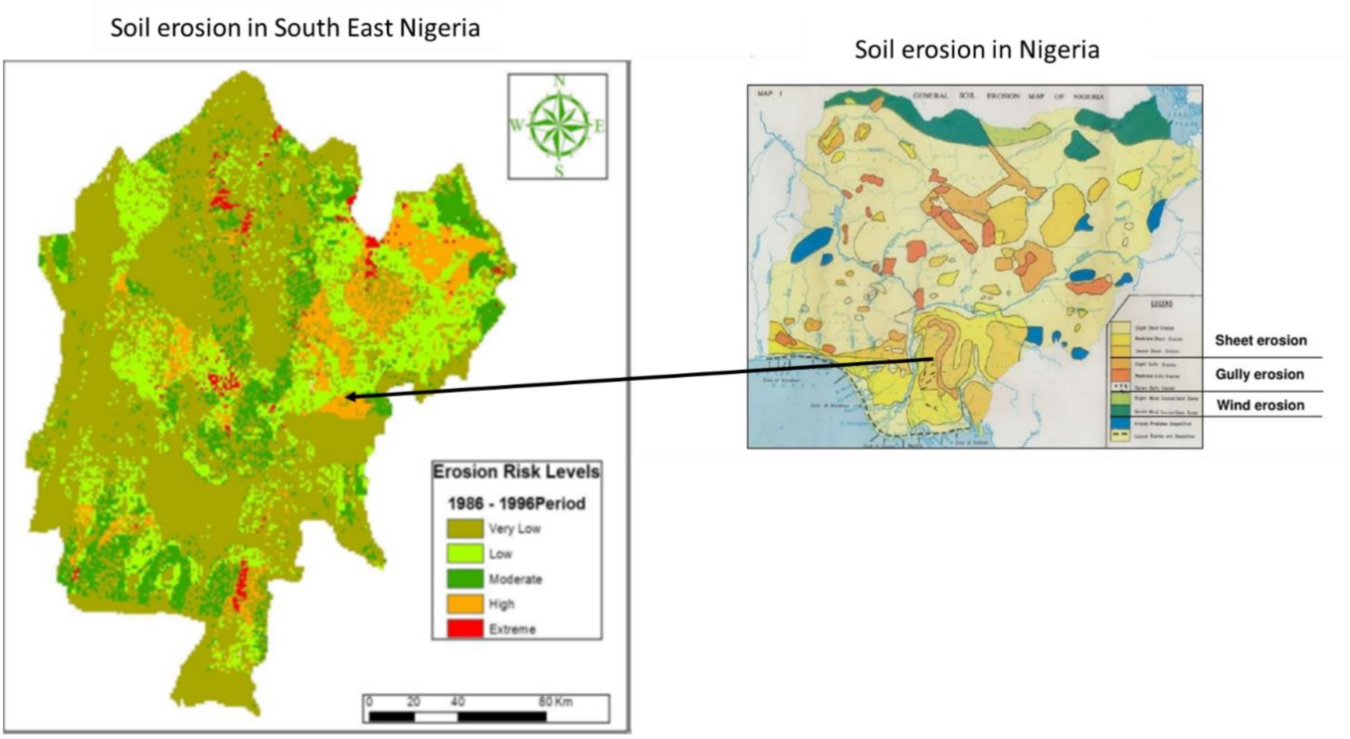


Figure 1-2 Map of South East Nigeria showing the spatial distribution of erosion risk levels from the 1986-1996 period. (Source: Obinna et al., 2013)

1.3 Methods for soil erosion studies

Although soil erosion can be caused by both wind and water, the most common type of soil erosion is caused by water mostly driven by both natural and anthropogenic factors. The importance of soil and the threats of soil erosion globally has triggered numerous soil erosion studies worldwide. However, the complex nature of soil erosion has necessitated adoption of different approaches for different spatial scale applications. For instance, Lawler et al. (2001) and Lawler (2008) used erosion pin technique known as the Photo-Electric Erosion Pin (PEEP) to monitor deposition on channel bank and soil erosion. Old et al. (2005); Sivakumar and

Wallender, (2005); Mano et al. (2009); Marttila and Klove, (2010) applied the method of sediment rating curve for their studies of soil erosion. Fornes et al. (2005) used Caesium-137 to study erosion while Russel et al. (2001) and Walling, (2005) applied sediment tracer method known as fingerprint to study soil erosion. Wicks and Bathurst (1999) ; Morgan (2001); Fentie et al. (2002); Zhang et al. (2005); Cebecauer and Hofierka, (2008); and Baggaley and Potts (2017); Sinha et al. (2018) applied different models in different regions to assess soil erosion. In recent years, multiple researchers worldwide have adopted modelling for soil erosion assessment. According to Ding and Richards (2009) the processes of sediment deposition, delivery routing and yield are better understood and connected by researchers using modelling approach. In addition, combination of different models with Geographical Information System (GIS) techniques aids to show within watershed of interest the spatial processes of soil erosion, its extent as well as its sources. Modelling appears to be time and cost effective when applying to a large-scale watershed compared to other methods like PEEP, Caesium-137 ($^{137}C_s$) and sediment tracer (Boardman, 2006). For example, error in prediction may occur by applying sediment rating curve method. The other likely problems with other assessment techniques are the quality issues as regards sediment collection methods as well as the sampling devices, which are potential problems that are likely to be encountered in developing countries.

1.4 Soil erosion models

sediment yield has been predicted in various parts of the world using different erosion models over the years (Chandramohan et al., 2015; Didoné et al., 2017) However, these models exist in various resolutions ranging from simple to complex models. In principle, appropriate soil erosion model selection depends on the following: the purpose of study, the site condition, and data availability. High resolution physically based models such as PESERA (Kirkby et al., 2008; Licciardello et eal., 2009); KINEROS (Martinez, 2007); EUROSEM (Quinton et al., 2011); SHETRAN (Ewen et al., 2002); SHESED (Wicks et al., 1996) and LISEM (Hessel et al., 2011) have been applied and proved to give more efficient results. However, to run most of these models, large input data are required to predict soil erosion. Similarly, some conceptual models have been used and proved to be effective such as SWAT (Shen et al., 2009), AGNPS (Young et al., 1989; Rode et al., 1999; Walling et al., 2003), SEMMED (De Jong et al., 1999), and MMF (Morgan, 2001; Vigiak et al., 2005 and Morgan et al., 2008). These models may not be suitable for this research context considering the followings: input data requirement, limited time frame and allocated budget. Most of the models mentioned above such as PESERA and

EUROSEM require a wide range of input parameters that are not available for this study area of poor data. Alternatively, some empirical and flexible models such as RUSLE (Wischmeier et al., 1978) and modified PSIAC (Johnson and Gembhart, 1982) require simple input data and can be integrated with GIS. Previous studies have applied RUSLE in different parts of the world. For instance, Beskow et al. (2009) combined GIS and USLE in Grande River Basin in Brazil to predict potential soil loss. Similarly, Sidorchuk (2009) applied RUSLE in the national territory of Newzealand to estimate potential soil loss. Also, some studies have successfully been carried out using modified PSIAC model technique in Spain, Italy and Iran (Verstraeten et al., 2003; Tangestani 2006 and Daneshvar and Bagherzadeh 2012). Based on the low points and high points of these models as explained above, the modelling systems RUSLE and MPSIAC were applied in this poor data study area. Particularly, the MPSIAC model was applied in this study because most process-based models do not consider gully erosion, and it was an important research task to adopt an appropriate model that includes the contribution of gully erosion for the field area. Gullying is a particularly active form of erosion in south east Nigeria.

1.5 Lake sediment core

In developing countries like Nigeria, many watersheds are faced with lots of environmental issues as a response to urbanisation and growing population. However, many human activities like sand mining could drive sediment into draining rivers and lakes thereby reducing their water storage capacity and navigation potentials. During the process of deposition in lakes, most bed load materials settle at the bottom of the lake, but some fine materials may be lost out at the lake's outflow. The ratio of the quantity of sediment deposited in a lake to the total sediment input is known as trap efficiency. In addition, some of the sediments in runoff water do not reach the drainage channel as they are deposited at the hillslope before reaching the drainage channel. Therefore, the ratio of net erosion to gross erosion in a watershed - lake system, known as sediment delivery ratio, is the link between soil erosion within the watershed and sediment yield at the watershed outlet. Based on watershed-lake system relationships, the characteristics of sediment could be interpreted in terms of processes that interact within the surrounding watershed (Dearing, 1991). The connection that exists between the watershed system and the lake system makes it possible for the environment to be reconstructed from the lake historical data. Various studies have shown that lake sediment core could provide useful information that could be linked to episodes and events that took place within the surrounding landscape (Mackereth, 1965; Foster et al., 1986). Some studies in different regions of world have applied lake sediment core method to study how human activities within the contributing watershed respond to soil erosion (Francis and Foster, 2001; Huang and O’ Connell, 2000; Wolin and Stoermer, 2005). Foster et al. (1988) applied density measurement to estimate sediment yield deposited over a specific time period by comparing and correlating levels of synchronisation in many sediment cores to convert basin-wide estimate of sediment from the watershed. However, lake sediment core has not been used by any known researcher to study soil erosion in this study area (south east Nigeria)

1.6 Social drivers of soil erosion in Nigeria

Human activities such as deforestation, sand mining and crop farming contribute significantly to overall erosion in Nigeria (Charles et al., 2004). The growing population and the transition from rural to urban settlement in the most local areas have increased the pressure on lands. In response to the growing population, unemployment has increased, and more pressure is mounted on available natural resources like land for sand mining as an alternative means of people’s livelihood. In addition, local agricultural business is rapidly growing as more rural dwellers depend solely on farming for their livelihood. However, most of these practices are unsustainable and pose potential threat to soil erosion.

1.6.1 Deforestation in Nigeria

Deforestation is a very big problem in Nigeria. In a space of five years (2000-2005), Nigeria has lost 55.7% of its primary forest (FAO, 2005). Forest is cleared for logging, timber export, subsistence agriculture and wood for fuel, which remains problematic in West Africa. Unregulated logging is widely practiced in Nigeria as most loggers cut down trees indiscriminately without planting new ones. Moreover, most rural and semi-urban dwellers depend on traditional firewood for cooking. According to the World Wildlife Fund (WWF) many trees that are cut down in forest in Nigeria are done illegally and are used as cooking fuel. Also, in most rural areas of Nigeria local hunters set forest on fire to force animal out of their hiding places. Some local farmers also practice bush burning as means of preparing their farmlands for the next planting season. Consequently, these deforestation activities expose soil to direct rainfall impact and increases the flow potential of runoff water thereby driving massive soil erosion. Moreover, the roots of large trees strengthen soil stability and serve as anchor to hold particles together, therefore removing them makes the soil prone to water erosion.

1.6.2 Sand mining activity in Nigeria

Sand mining activity is a serious environmental concern in many parts of the world such as Portugal, Botswana, Nigeria and Montreal (Borges, 2002; Madyise, 2014; and Jaramillo, 2007). In developing countries like Nigeria, it is extremely difficult to control some human activities due to high rate of unemployment and poverty, especially in rural areas. For instance, sand mining is one of the fastest growing businesses in Nigeria because of massive youth's unemployment. However, this sand mining activity is not only unsustainable but illegal as stipulated in the Nigeria Mining Act, 2007. According to Ako et al. (2014) in-stream sand mining can reduce water quality as well as degrade beds and banks. Moreover, Langer (2003) pointed out that the most common environmental impact of sand mining is alteration of land use from natural lands to excavations in the ground. Consequently, some of the excavated and abandoned mining sites would later develop into large gullies sites while others may trigger landslides. Also, sand mining involves vegetation clearing and excavation that expose the soil to the rainfall energy of raindrops which makes soil vulnerable to erosion.

1.6.3 Agricultural practice in Nigeria

The rapidly growing population and urbanisation are major reasons for the land use intensification for ever increasing food demand required to feed the population. For instance, Nigerian population is growing at 3% per annum while food production required to match this growth is only increasing by 1.5% for the past five years (CBN and NPC report 2017). In addition, 70% of Nigerians are living below poverty line (United Nations, 2012). The major driver of these changes is the continuous increase in population from 115 million in 1991 to 140 million in 2006 and now to 190 million in 2018 (Nigeria Population Commission 2018).

This has put pressure on marginal lands and consequently led to deforestation, clearing of bushes and fallows which has knock-on effect on the environment (Lal 1995a). For instance, soil degradation reduces crop yield reduction up to 90% in deep rooted plants in southern Nigeria (Mbagwu et al.,1984). Moreover, pollution of rivers, reduction in water quality and reservoir siltation are common off-site consequences of soil erosion. On the other hand, social issues such poverty, low income of local population and unemployment are linked to soil degradation and erosion. However, proper management practice and soil conservation measures is the key to maintain the soil properties and sustain food security (Ehui and Pender, 2005). Consequently, the available land has been put under pressure due to increased farming activity to provide more food for the growing population. Similarly, significant area of forest and arable lands are destroyed annually through unstainable farming practices like bush burning and logging to create more food production as well as the creation of ranches and grazing land for cattle. Moreover, land degradation and soil erosion are always linked to low scale and subsistence-oriented farming practice which is attributed to poor practice and unsustainable use of land resources such as vegetation clearing in the quest for wood fuel as well as misuse of the cultivated lands without putting conservation measures in place (Markos, 1997; Yeraswork, 2000). Yet, none of these agricultural farming activities that threaten soil erosion has been given considerable attention in Nigeria.

1.7 Land use management in Nigeria

Nigeria covers an estimated land area of about 904,000 km^2 and has a human population of over 180 million people (199 people/km^2). The use of land varies from one geographical location to the other which is dependent on the socio-economic need of the people. According to Charles et al. (2004), over 50% of Nigerian land area is covered by forest vegetation and food crops. However, most of the current land use practices in Nigeria contradicts land use policies as stipulated in the Land Use Act 1978. This is because in the rural areas, the traditional method of land ownership by birth and communal clan are still in practice as the local people depend on the land resources for their livelihood. In addition, the government do not monitor local land uses as stipulated in the Act except if there is vital natural resources discovery like oil or mineral in the area. Moreover, the Act made good provision for demarcation of the Nation's land into cities and local regions as well as fees payable for developing it and vest power to allocate lands in the hand of State Governors. However, the structure of the Act dwells more on land tenure system than land use policy (Akamigbo, 1999). Therefore, many communal and family lands which were being used and or rarely utilised were divided among individuals and families which has led to unplanned land use and fragmentation by the landowners in their bid to avoid takeover by the government. Consequently, the excesses of the Land Use Act have led to series of land degradation and soil erosion because of poor conservation and sustainable provisions (Akamigbo, 1999). Moreover, the Act dwells more on land acquisition rather than land conservation and sustainability. According to FDALR (1892), soil erosion contributes significantly to soil loss which is estimated to 25 million tonnes per year. Meanwhile, soil erosion is very significant to loss of soil fertility and productivity depletion and yet much attention has not been given to it.

1.8 Social, political and economic impact of soil erosion in Nigeria

The management of soil erosion is far beyond environmental problem as it also has serious social-economic impact on people. Also, it threatens food security as lands originally kept for farming are damaged by gully erosion and led to nutrients loss from farmlands. For instance, sand mining as one of the causes of soil erosion in Nigeria should be regulated by law most parts of the world but Whitehead (2007) revealed it is widely practiced illegally. It is becoming more worrisome and rapidly becoming an ecological problem because the demand for sand in the industry and construction increases to keep up with population and urbanisation. Human activities in the watersheds constitute several groups of actors (e.g. trade unions, farmers, sand miners, local elite, community chiefs, community residents) that are so powerful and operate independently by changing official government rules related to land ownership, access and use. However, some of these groups of powerful actors can resist enforcement attempts from the government officials and, on many occasions, they collude to share the benefits of these activities. For example, the major issues associated with sand mining activity are land ownership, access to the mining sites, right to use, benefit sharing, and because the activity is illegal, it is always controlled by the rule-in -use rather than constitutional rule. As a result of that, there is always a conflict in trying to monitor, regulate and enforce some of these activities like sand mining in south east Nigeria. Thus, it seems there is a gap in institutional arrangement between the local population needs and the government regulating bodies at different levels.

1.9 Soil conservation management in Nigeria

In Sub-Saharan Africa, studies have been carried out on soil conservation for many years by various researchers (Fournier, 1967; Greenland and Lal, 1976b; Quansah, 1990; Kayombo and Mrema, 1998; Ehrenstein, 2002) and in Nigeria, Lal (1976a, 1990). Nigeria has long tradition of soil conservation like mulching, ridge contour and shifting cultivation as a means of soil erosion control using indigenous techniques right from the pre-colonial era (Igbokwe 1996; Scoones et al., 1996). This approach was later enhanced by the British government during the colonial era as a means of soil management as they were keen on expanding commercial farming enterprises. They achieved this soil conservation through various farm policy measures and mechanical techniques, which was regulated and monitored by government.

However, during the post-colonial era, several soil conservation techniques like terracing and other mechanical methods introduced in large scale projects failed because they could not be managed by the local farmers (Stebbing, 1938; Longtau et al., 2002). After independence in

1960, attention was shifted to soil fertility issues rather than soil conservation and this was the turning point that gradually killed the culture of soil conservation as means of soil erosion control in Nigeria. Moreover, in 1980s oil boom in Nigeria further shifted government attention to oil sector as an alternative and quicker means of generating revenue, and this additionally drifted the practice of soil conservation in Nigeria as less attention is paid to agricultural sector. As such, soil conservation became local farmers' business rather than government's business and was longer regulated or monitored by government.

1.10 Historic institutional reforms in managing soil and mineral resources in Nigeria

Nigeria has abundant land and deposits of mineral resources regulated with excessive exclusionary laws with regards to inclusion of host communities in the control, ownership and management of land and the resources on it. However, a growing body of research has questioned the current centralisation of land and mineral resources policies, as this often leads to conflict between the government and host communities (Omorogbe, 2002; Bunter, 2005). Before the colonial era, local and host communities were involved in decision-making and share benefits of the resources trades in their various communities (Omorogbe, 2002). Thereafter, the colonialist declared upon their arrival that the land they were to settle in belongs to no body and people were stripped of their natural sovereignty. However, even after the post-colonial era, the political elite maintained the status quo of exploitation and expropriation of the people's natural resources without compensation of any kind. This is in accordance with Section 44 (3) of the 1999 Constitution of Nigeria, which vest the entire lands and minerals in Nigeria under the control of the federal government and state government. Similarly, the Section 1(1) of the Minerals and Mining Act, 2007, vest all the mining regulations and management controls under the Minister of Mines and Minerals Development. This top-level resource control and management without engaging communities and the people has always brought conflict and environmental degradation as well as agitations between the government and the host communities. Historically, the government response to the problems has been mixed with brutal forces to suppress these agitations, and the use of incentives through the traditional leaders (Esan, 2004). However, this approach has either resulted in loss of lives and properties through brutal response or massive corruption by the traditional and political leaders through incentive response. Thus, institutional arrangements that strike a balance between the government exclusive resources ownership rights and demands for resource control by the host communities seems to be a solution option. The Institutional Analysis and Development (IAD) framework was selected because environmental activities and soil conservation largely depend on collective actions and action arena. This type of arrangement not only guarantees participation of all stakeholders in decision-making but also ensures evaluative criteria that can inform policy reform.

1.11 Institution Analysis and Development (IAD) framework

The concept of Institutional Analysis and Development (IAD) framework was first developed by Elinor Ostrom (1990,1999) and her colleagues (Ostrom,Gardner and Walker, 1994; Kisser and Ostrom, 1982) to analyse the institutional arrangement that govern common pool resources. Institutions are persistent regularities of human action in arrangements structured by norms, rules and common strategies resolved by human interactions in a repetitive situation (Crawled and Ostrom, 1995). IAD framework has been applied widely in studying local common pool resources management (Beson et al., 2013; Clement and Amezaga, 2013; Rudd, 2004, Zerihum et al., 2017). Taking the steps of IAD framework as shown in (Fig 1-3) and applying the action arena the analysis unit allows systematic analysis linking decision-making to performance in community engagement, which provides useful guidelines to practitioners on how to improve broad environmental and soil conservation management. The primary aim of the IAD framework is to allow researchers to explore and describe how people use institutional arrangements to address shared problems and to understand the logic of institutional design (Ostrom, 1987), and by doing that develop proposal for improving institutional performance. The core step is identifying the action arena, which is composed of action situation and the actors. The action situation is the social space, where the actors interact to solve the common problems (Zerihum et al., 2017) and the focal unit of analysis. Moreover, action situation consists of participants who hold positions and who take actions considering information they have available (Ostrom, 2007; Ostrom et al., 1994). The target is the outcomes which are functions of individual series of actions, and the level of control each actor has over an action. Similarly, there is an existing link in every action situation between actions and outcomes, which makes it a preferable choice of analysis in complex environmental situations. As illustrated in Fig 1-4 the major action arena lies at operational level, where changes in policy choices directly affect the use of natural resources; for instance, in a natural resources management situation where the rules-in-use are different from the formal rules. And, in a natural resources management scenario where the resources users at the operational level do not participate in decision making. Within the context of land ownership and land use, although most farmlands in the study location are owned by individuals through family inheritance, the communal land ownership is still widely practiced by the local people. The practice of communal land ownership recognises farmlands as common pool resources which inspired the use of IAD in this research. Under the communal arrangement, the farmlands are used among the local community members and such usage is often supervised by the elders of the community. However, at the local community level, government allows farmlands to be used by the local people and gets involved in the event of land crisis. The action arena comprises the federal and state level institutions responsible for land and environmental management in Nigeria, and the stakeholders at the local level. The Federal Ministry of Lands, Housing and Urban Development, The Federal Ministry of Agriculture and Rural Development, The Federal of Mines and Mineral Development, Federal Ministry of Environment and National Environmental Standard Regulations and Enforcement Agency (NESREA) while the State Ministry of Lands and Urban Planning, State Ministry of Agriculture, Environment and Natural Resources are the key actors at the constitutional level and collective choice level respectively. On the other hand, traditional leaders, sand miners, community residents, farmers and local government staff are key stakeholders at the operational level. Therefore, IAD was used in this study to analyse the three (3) levels of government in Nigeria to strengthen and improve the policies and encourage local participation of stakeholders in decision making. Within the context of soil erosion, the roles of these stakeholders were explained in Chapter 6 while the IAD analysis was done in chapter 8.

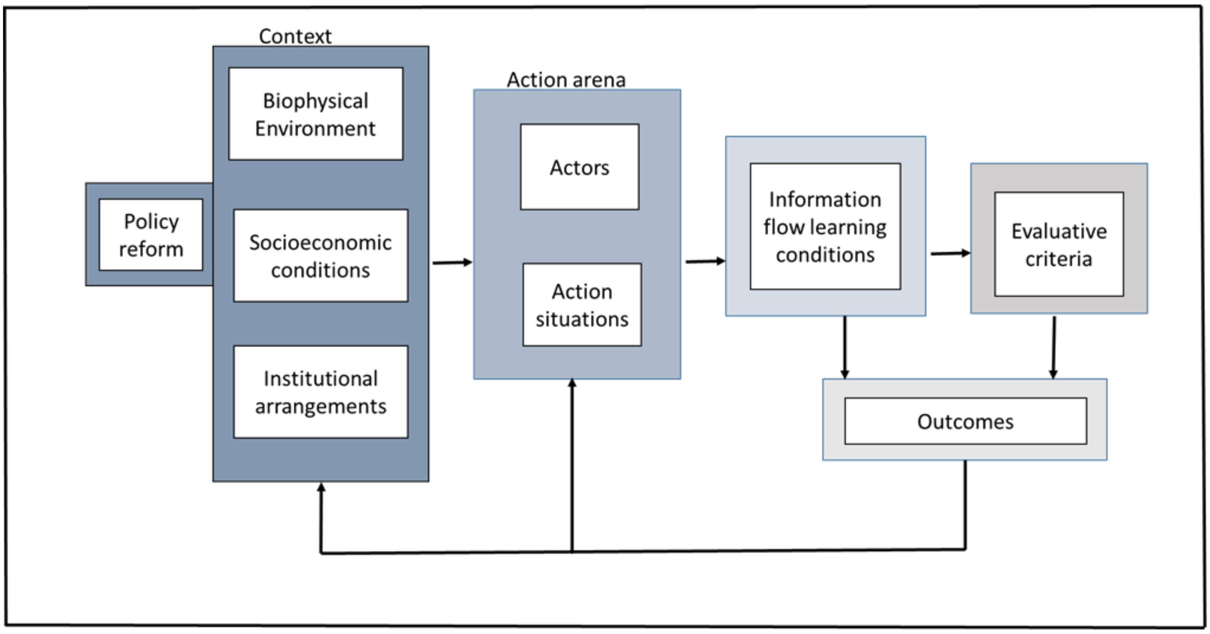


Figure 1-3 The IAD framework Source: Ostrom et al., 1994

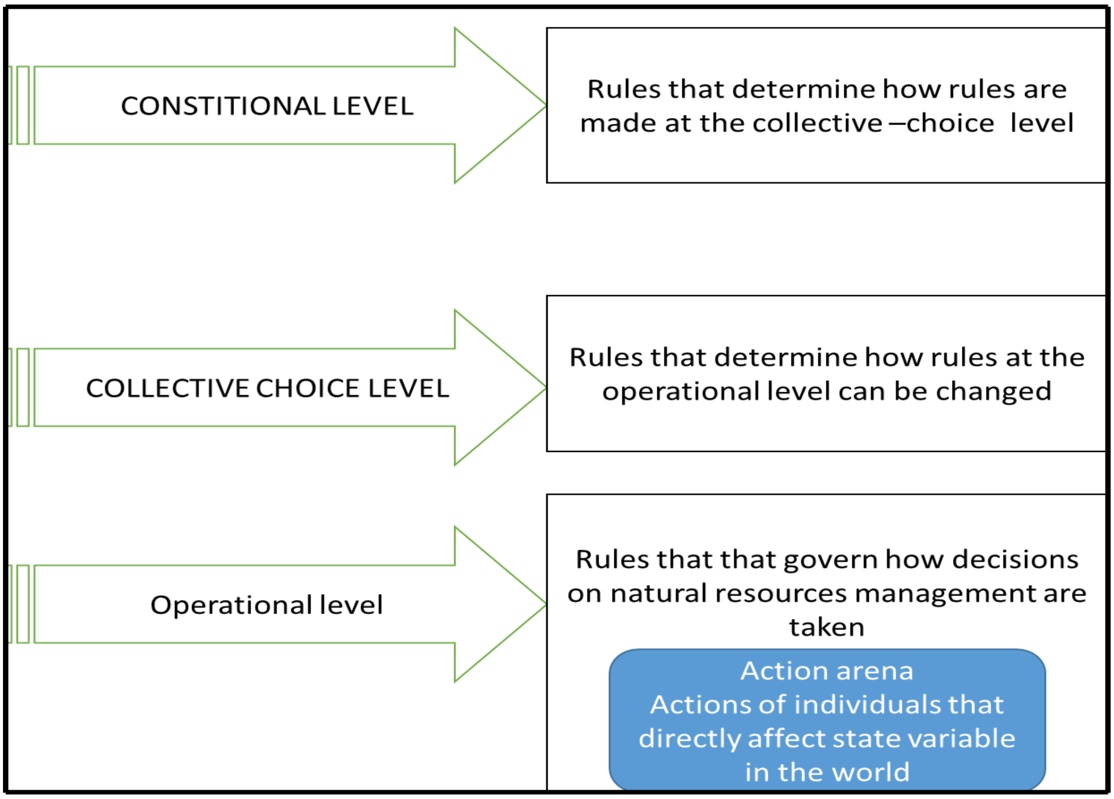


Figure 1-4 The three (3) levels of analysis in IAD framework. Source: Ostrom, 1999

1.12 Research gap

The problems of soil erosion in Imo State south east Nigeria have been studied by various researchers as highlighted in Section 1.2 above. Based on that, it can be assumed that watersheds in south east Nigeria generate sediment flux downstream. Furthermore, the spatial context such as changing land cover may have contributed to generating the high sediment problem. However, it is still unclear how the key soil erosion controls (soil properties, land use, land cover, precipitation regime, slope angle distribution, land management practice, geology, and runoff) interact to produce high erosion rates. Research on soil erosion impacted by land cover changes in south east Nigeria is very rare. In addition, no research has studied the physical and social context of soil erosion in Imo State Nigeria holistically with a view to finding a management solution.

The research challenge is to quantify erosion rates using techniques with minimum data requirements, calibrate models that can then be used for scenario analysis, and develop management policies based on the understanding of the identified drivers of soil erosion.

Therefore, this research has for the first time innovatively connected the physical and social drivers of soil erosion, using relatively simple erosion models, lake sediment core analysis and social approaches to decipher erosion characteristics and propose management policies that suit the study location.

1.13 Aim and objectives

The need for assessment of soil erosion in Oguta Lake watershed south east Nigeria informed the aim of this study. This watershed is affected by various human activities, especially sand mining. Therefore, the overall aim of the study is to combine RUSLE-GIS and MPSIAC-GIS modelling and social research techniques to spatially predict and assess social drivers of soil erosion, and thus, develop policy solutions that could minimise it in the study area. To achieve this aim, the following objectives (1-5) are presented below.

Objective1: Assess the land use and cover change dynamics in the study area and its effect on soil erosion.

Objective 2: Identify the spatial variation of soil erosion risk map and the key controlling factors which interact to generate high soil erosion rates in the study area.

Objective 3: Analyse current environmental regulatory framework for management of soil erosion in Nigeria.

Objective 4: Analyse physical and socio- economic impact of soil erosion and sand mining in the study location.

Objective 5: Develop policy reforms based on the review of the existing institutional structure and policies used for regulating erosion management in the study area.

In this thesis, the quantitative empirical models (Revised Universal Soil Loss Equation and Modified Pacific Southwest Inter- Agency Committee models) have been applied by integrating with Geographical Information System (GIS) and remote sensing approaches to predict sediment yield. And the Institutional Analysis and Development (IAD) framework was applied to develop policy solutions based on the understanding of erosion characteristics and existing management policies in the study area.

1.14 Thesis structure

This thesis in structured in nine chapters (Fig 1-5) as follow:

Chapter one introduces soil erosion under the following: general soil erosion issues, global impact of soil erosion, significance of soil erosion in Nigeria, methods of soil erosion studies, soil erosion models, lake sediment core and research aim and objectives.

Chapter two deals with general literature background for the thesis regarding soil erosion processes, soil erosion models and criticisms, lake sediment core, remote sensing, the concept of Institutional Analysis and Development (IAD) framework, qualitative research, and soil erosion management in Nigeria.

Chapter three describes the physical characteristics of the study area. It provides the materials used and various data collection techniques. It also describes site selection techniques, methods of conducting field work and data analysis.

Chapter four deals with analysis of land use and land cover change dynamics, trends and magnitudes.

Chapter five analyses soil erosion controlling factors, by using both RUSLE-GIS and MPSIAC-GIS models to estimate mean annual soil erosion rate and also generate spatial variation of soil erosion risk map of the study area. It also details how to evaluate each factor in the models and how to combine the factors in each model. Moreover, it shows the potential effects of changes in land cover on soil erosion in the study location and provides testing of sensitivity analysis of soil erosion scenarios under various assumed conditions by changing vegetation cover factor. Finally, it analyses lake sediment cores as an additional means of verifying the model results.

C**hapter six** reviews policies in place for regulating and protecting environment in Nigeria. It also looks at the strengths and weaknesses of various environmental organisations and suggest possible policy reforms and prospects.

Chapter seven focuses on social-economic impact of soil erosion and sand mining in the study location. It searches for social divers of soil erosion and economic impact of sand mining in the study area.

Chapter eight analyses the current institutions and policies used for regulating and management of soil erosion in the study location and applies the Institutional Analysis and

Development Framework. It provides useful interactions among various environmental actors at different institutional levels to enhance reforms of management policies and decisions.

Chapter nine is the conclusions of the key thesis's findings, contribution to knowledge and policy recommendations and future research needs.

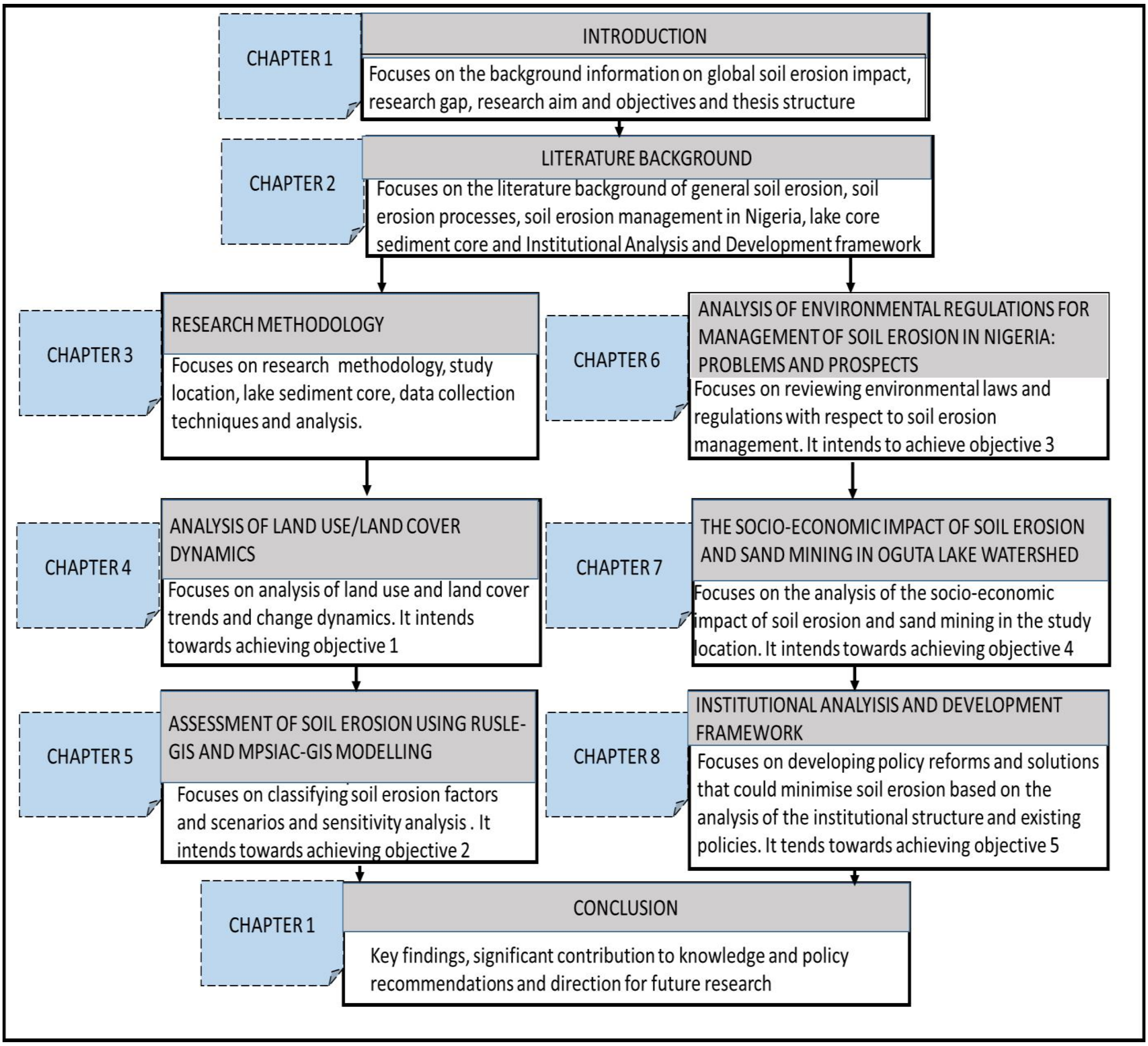


Figure 1-5 Schematic diagram of thesis structure

2 CHAPTER TWO: LITERATURE BACKGROUND

2.1 Introduction

This chapter explains the background of the followings: soil erosion processes, soil erosion model classification, lake sediment core, Remote Sensing (RS), Geographical Information System (GIS), and the concept of the Institutional Analysis and Development (IAD) Framework.

2.2 Soil erosion processes

Erosion involves the detachment and transportation of the broken rocks and materials from upstream to downstream or highlands to lowlands and delivery to the river system. Erosion results from energy transmitted from rainfall and wind (Pimentel et al., 1995). In most areas, raindrop splash and sheet erosion are the dominant forms of erosion (Wei et al., 2017). Although detachment and deposition processes of soil erosion occur simultaneously in an environment, the processes of detachment dominate on hill environment whereas processes of deposition dominate on valley. The classification of soil erosion is based on the followings: the agent of erosion; the type of site or the erosion processes (raindrop, mass wasting) (Poesen et al., 1998). Water and wind are the common agents of erosion while splash, sheet, rill, gully, and channel are the common erosion sites. Fig 2-1 shows the schematic diagram of erosion processes from detatchment to deposition. Firstly, the raindrop on hitting the soil surface detatches soil particles as splash erosion, and then accumulates as a thin layer on the surface runoff sufficient enough to initiate overland flow as sheet erosion. Then, rill erosion is developed as the flow progesses and the transport capacity of the runoff increases, the runoff starts scouring and cutting the soil leaving visible channels as it travels down the slope (Poesen et al., 2003). Similarly, as it progresses the channels walls and heads gradually increase in sizes up to a time the walls and heads will start collapsing due to gravity to form much larger gully erosion sites. Consequenyly, the runoff and sediments are often dischaged into fluivial systems like lakes, rivers, streams where it continues its off-site importance. On the other hand, sediments may be deposited within rills and gullies or beyond gullies confined at the locations where the gradient slackens (decreases). However, sediment deposited at these locations could stood there for a long time before being wethered by other tillage actvities until another erosion event is sufficient enough to re-erode it again. This cylce may continue until the runnoff and sediments find their way into a more permanent watercourse like lakes and occeans.

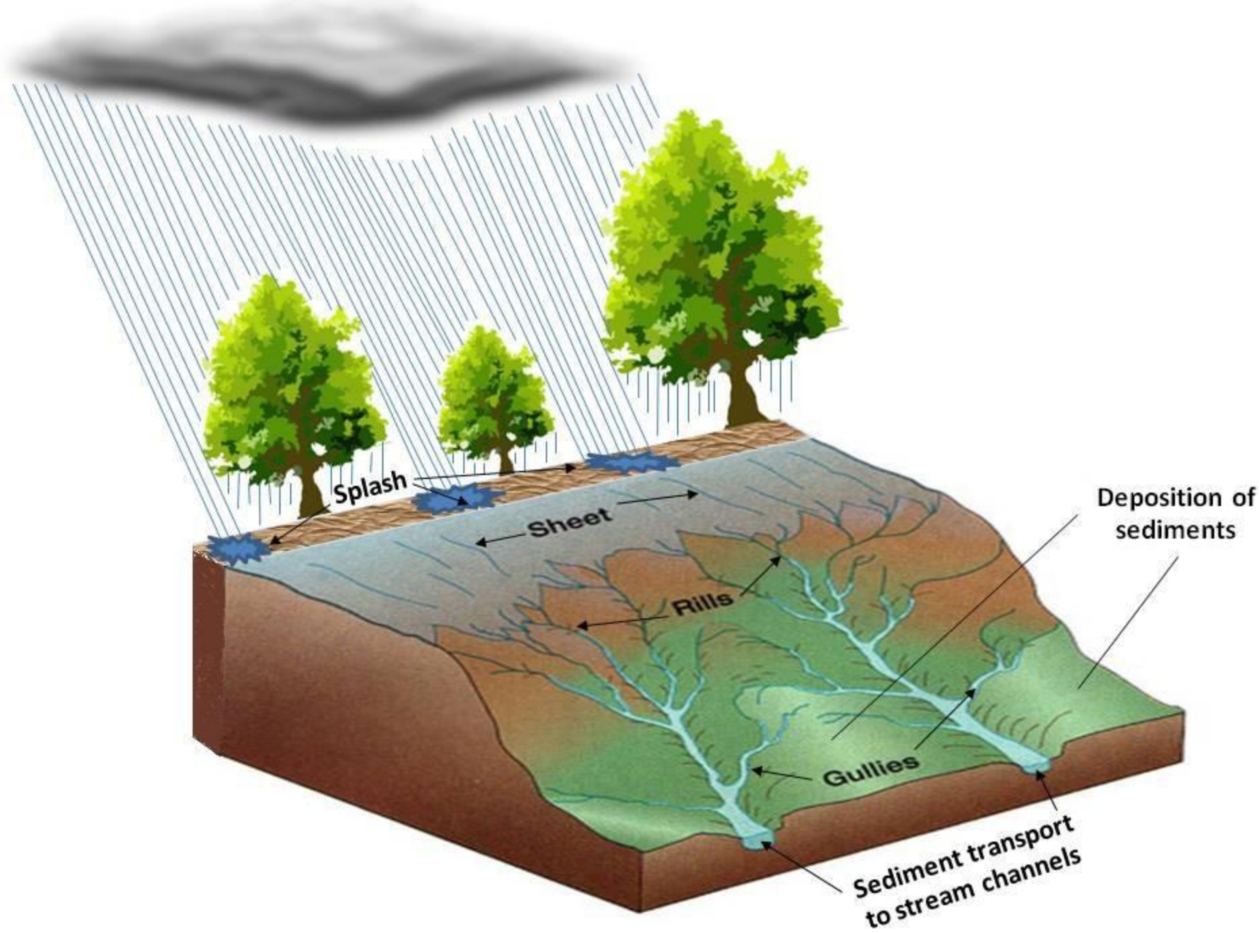


Figure 2-1 The soil erosion processes. Source: Sukho 2014.

The process of soil erosion is a natural phenomenal and the same globally. This is because so many natural factors contribute in the delivery high erosion in these locations. Soil erosion was summarised by Baver (1965) using this equation.

$$Erosion = f(C, T, V, S, H) \quad \text{Equation 2-1}$$

where C = climate, T = topography, V = vegetation, S = soil properties, H = human activities.

Climate: climate is very important in soil erosion modelling and one of the most important factors of soil erosion. As rain falls, the energy of raindrops disintegrates the soil particles and the runoff produced serves as agent for transporting sediment from one location to another.

Topography: both slope length and slope gradient have significant influence on soil erosion. There is a direct relationship between steeper and longer slope terrain and the quantity of sediment eroded. Steep slope produces high velocity runoff, thereby increasing the scouring and cutting potential of flowing water.

Vegetation cover: vegetation cover provides canopy and shields the soil from direct rain drop impact. It intercepts the rain drops and slowly releases them to the ground reducing their hitting impact on the soil surface. Also, it increases microbial activities which provides nutrient and energy to the plant and surface flow is reduced.

Soil properties: soil erodibility relies on certain soil characteristics such as permeability, infiltration, and against other soil attributes like abrasion, the soil surface forces of detachment and transportation.

Human activities: various human activities such as deforestation, over grazing, poor agricultural practice and sand mining make soil surface vulnerable to direct rainfall impact and damage the soil structure. In many cases, the operators of these activities in their quest to make a living cause soil erosion menace without care about the consequences. This factor is one of the overlooked factors, especially in developing countries, where poverty and unemployment are very high.

2.3 Soil erosion model classification

In the recent years, many soil erosion models have been used to predict soil erosion at different scales. Types of soil erosion models vary from the simplest to the most complex. Terranova et al. (2009) classified soil erosion models into the following categories:

2.3.1 Qualitative model

This is a model approach that provides intuitive understanding of the underlying issues and insights into the problem. It uses primary and secondary data sources for basic understanding of issues. This model approach is often limited by the fixed data requirement, and scale, region and purpose specific. In most cases, the focus is on the spatial distribution of erosion needed mainly for conservation and planning purposes rather than the erosion rates like in other conventional models. Therefore, the regional characteristics and data availability are used as criteria to adapt developed qualitative erosion approaches. So many approaches are available, in fact, in principle, integration of qualitative data has no standard, which makes each approach a potential option. Sukho (2014) opined in his studies that the selection of the factors and decision rules are based on the regional information of the erosion processes as well as expert judgment. Spatial unit assignment of weights based on the erosion intensity is the most common techniques used. For example, Khal et al. (2014) used Landsat TM image to assign weight to virtually delineated units. Alternatively, different erosion controlling factors can be used to assign separate weights based on their significance in the erosion processes occurring. For instance, Vrieling et al. (2002) applied the average method to assign factor weights to soil erosion risk while Jain and Goel (2002) used summation method. Also, Haboudane et al. (2002) combined the weights of factors by applying hierarchical decision. Liu et al. (2000; 2004) detected candidate pixels for soil erosion in semi-arid Spain by applying multi-temporal interferometric decorrelation images. These models use aerial photos and satellite imageries to detect the location of the gullies and the erosive consequences (Rahman, 2009). Even though qualitative model approach can be costly and time- consuming as a result of detailed reconnaissance survey, it particularly provides data for: (i) the accurate mapping of soil attributes in a varying environment (Vrieling, 2006) (ii) the automatic detection of gullies (iii) the automatic assessment of vegetation cover.

2.3.2 Semi-quantitative model

The challenges and successes of some models like conceptual and empirical models tend to stimulate other techniques when used with a holistic view towards sediment yield modelling and erosion (de Vente and Poesen, 2005). To some extent, some models that tend to fill that gap seem to exist even though they have only gained limited recognition when compared with other high-resolution models in the global literature. Interestingly, these models have advantage of combining both physical interpretation and quantitative techniques to describe a catchment and produce a quantitative sediment yield estimate (de Vente and Poesen, 2005).

Here are presented some of the most important among these models.

Pacific Southwest Inter-Agency Committee (PSIAC): This is a very popular semi-quantitative model. Its origin and development were by the Pacific Southwest Inter-Agency Committee (PSIAC) in the southwestern USA for application in the in a semi-arid region. One of its limitation is that it cannot be applied in an area less than $25m^2$ and is best for purpose of planning. The nine factors in the model characterise a watershed and the sum of the nine factors provides sediment yield index. However, the subjectivity of factors ranking became a cause for concern, and Johnson and Gembhart (1982) used mathematical equations to convert the description of the initial model to numerical quantities. This was achieved by assigning mathematical empirical relationship equations to each of the nine factors and introduced interpolations and extrapolations to control the equation to improve the accuracy of the model which is now MPSIAC model.

Factorial Scoring Model (FSM): This model is very similar to PSIAC model, though it applies five scoring factors only (Verstraeten et al., 2003 and de Vente et al., 2005). It is not as widely applied as the PSIAC and has a limited number of descriptive factors. Other semi-quantitative models include the following: the vegetation-surface material-drainage density model, the Gavrilovic model, the Erosion Hazard Units model, the CORINE erosion risk maps model, the Fleming and Kadhimi scoring model and the Global land degradation assessments model (de Vente et al., 2005). One major difference that exist between the two models is the effects of off-site and on-site erosion. Some models like PSIAC and FSM estimate yield at basin scale as well as its off-site effect while CORINE and FKSM models estimate the menace of soil erosion on-site and lack the capacity to check sediment transport. Another difference among the models is the consideration of erosion processes. The inclusion of gully and bank erosion in PSIAC model makes it unique as other models dwells on on-site effects of sheet and rill erosion. Although only through occurrence observation, PSIAC model specifically considers the effect of landslide to soil erosion. The PSIAC model specifically considers the contribution of landslides, though only through observation of their occurrence. Therefore, in terms of inclusion of soil erosion and other erosional processes, only PSIAC model and a few other models can be considered as holistic sediment yield (de Vente et al., 2005).

2.3.3 Quantitative models

This is a traditional regression model approach that depends on various factors parameterisation. Their complexity dependent on the number of factors considered as well as how complex each factor considered. However, the different levels of complexity of these models enables their three groups categorisation.

(1) Empirically based models. These models were developed based on the reconnaissance survey observations specific to the watershed where they were applied (Terranova et al., 2009). Sometimes, parameter values are calibration driven and area transferred during site experimentation (Merritt et al., 2003). The availability of USLE (Wischmeier et al., (1978) and the revised version of it (Renard et al., 2011) as well as the Sediment Delivery Distribution are frequently used models compared to the complex high-resolution models especially for soil erosion sources identification. Moreover, RUSLE is particularly used in poor data and insufficient parameter inputs situations.

(2) Physically based models. These models are mathematical driven and involve series of complex mathematical equations and relationships. Its capacity to assess both spatial and temporal processes that effect erosion through specific erosion component synthesis is argued as one of its greatest strength. These models are as follows: PESERA – Pan European Soil Erosion Risk Assessment, WEPP – Water Erosion Prediction Project, KINEROS – Kinematic Erosion Simulation (Martinez, 2007), EUROSEM – European Soil Erosion Model (Quinton et al., 2011) and LISEM – Limburg Soil Erosion Model.

(3) Conceptually based models. These models are sandwiched between physical based models and empirically based models and are viewed as a poor reflection of hydrological sediment yield processes. The models integrate relationship equations and erosion variables considering physical water erosion processes (Terranova et al., 2009). Examples of the models are: Soil and Water Assessment Tool (SWAT) (Shen et al., 2009), Agricultural Non-Point Source (AGNPS) (Young et al., 1989; Rode and Fredo, 1999), Soil Erosion 34 Model for Mediterranean Area (SEMMED) (De Jong et al., 1999), and Morgan, Morgan and Finney (MMF) (Morgan, 2001 and Morgan and Duzant, 2008).

2.3.4 Soil erosion models criticism

Even though the physical based models have high resolution and better accuracy due to reliable empirical mathematical relationships to explain numerous sedimentary and runoff processes in both mountain and channel (Kinnell, 2010), empirical and semi-quantitative models, in particular USLE and PSIAC and their modified versions are still very popular today. USLE and PSIAC models and their modified versions are very simple to apply and require less input data unlike the physically based models that always require large input data and time for calibration and validation of the required parameters. In addition to requiring a large computational power, the physically based models require large input databases which has capacity to explain spatial model variability of variable and proper strategy monitoring which would allow for variable and calibration of parameter. However, physically based models rarely have problems of interpolation and extrapolation because they are built on equations and relationships (de Vente and Poesen, 2005). In contrast, it is difficult to build a complete physical model that incorporate all processes that cause erosion all over the watershed because insufficient systematic information to explain psychical equation relationships. On the other hand, an empirical based model like RUSLE is still used to estimate sediment yield at large scale despite the limitations buried in its concept. The flexibility of this model has made its integration with GIS possible and the potential to estimate erosion at various scales (from plot to regional scales). For example, Pham et al. (2018) integrated USLE and GIS to study soil erosion in the Sap watershed in Vietnam. Their findings identified the most susceptible areas to water erosion within acceptable precision. Moreover, the model could also be applied differently, for example Thomas et al. (2018) combined the model and TLDF using GIS to estimate sediment in shadow river watershed India. Their results are similar and comparable with the previous studies from the region. In another aspect, Terranova et al. (2009) generated soil erosion risk scenarios using RUSLE and GIS in Italy. The results of the various scenarios generated informed the prevention and control measures to sustain the environment. Thus, RUSLE has proven to be substantially used to determine erosion hazards at the regional scale watersheds (Zhou et al., 2008; Bazzoffi, 2009). In addition, it also has the capacity to predict and estimate both the sources and the sediment yield at reasonable levels even though sometimes there have been misapplications and misconceptions in its use (Govers, 2011). However, no model has proven to be the most suitable approach that suits all applications (Merritt et al., 2003) and modellers often contradict themselves in some assertions about modelling methods (e.g., Kinnnell, 2008 against Parsons et al., 2008; Smith et al., 2010 against Wainwright et al., 2010). The elimination of some of the limitations of sedimet yield estimate at watershed level by semi-quanttatiev models placed them as alternatives whenever such situtations are anticipated. Semi-qunatitaive models have also been branded as expert-system appraoch because of their effectiveness in reconesessance survey erosion monitoring Boardman, (2006, p.79). In addition, de Vente and Poesen (2005) opined that the models are best used for soil erosion risk mapping if based on expert judgment. A few other researchers have applied other models in different parts of the world: CORINE was used by Le Bissonais et al. (2001) estimate the risk of soil erosion at National scale in France while MuaSERM was used by Nigel and Ruphooputh (2010) in Mauritius mainland to produce the intensity of soil erosion monthly. Moreover, in Lebanon, semi-quantitative model was used by Bou Kheir et al. (2006) to produce regional level erosion risk map. All these findings showed that semi-quantitative models can be widely applied in different environments under varying conditions.

De Vente et al. (2005) showed that the modelling techniques generated best and dependable results of specific sediment yield of varying areas in Spain. In addition, Tangestani (2006) applied EPM and PSIAC models in semi-arid environment in Afzar catchment in Iran to produce sediment yield. The soil erosion and sediment yield predicted was used to compare with the field observations and the Global Assessment of Soil Degradation (GLASOD) map. After field verification, it was revealed that the PSIAC model performed better than EPM model. However, in conditions where the database layers are very limited, the EPM model has could be used to carry out assessment rapidly and produce erosion risk map (Tangestani, 2006). Despite the shortcomings of both of RUSLE and PSIAC and their critics Kinnell (2005, 2008, 2010), they are preferred in larger scale conditions where the physically based models have limitations in erosion predictions. In addition, the equations in the physically based models tiger uncertainties due to variables complexity at national level which makes the models unreliable for planning and managing soil erosion and water resources. Also, poor data conditions in developing countries cannot support applicability of physically based models.

Therefore, inaccurate results and failures of models at this stage of model application and development should be rather viewed as routes to identify models needs and improvements (Boardman, 2006, p. 77). Parsons et al. (2008) stated that USLE has been great in erosion prediction despite its known limitations which is consistent with the views of some other researchers. However, no model fits all conditions as they have several limitations in their prediction potentials. De Vente and Poesen (2005) tried spatial capability comparison task for different model types with a view to finding the weakness and strength of each model compared (Fig 2-2). Interestingly, the compatibility of USLE and MPSIAC models with GIS has made them exceptionally powerful for studying flexible watershed sizes. The compatibility of some erosion models like USLE with GIS and remote sensing techniques makes them very powerful erosion prediction and spatial distribution analysis tools under fair cost and time (Lu et al., 2004).

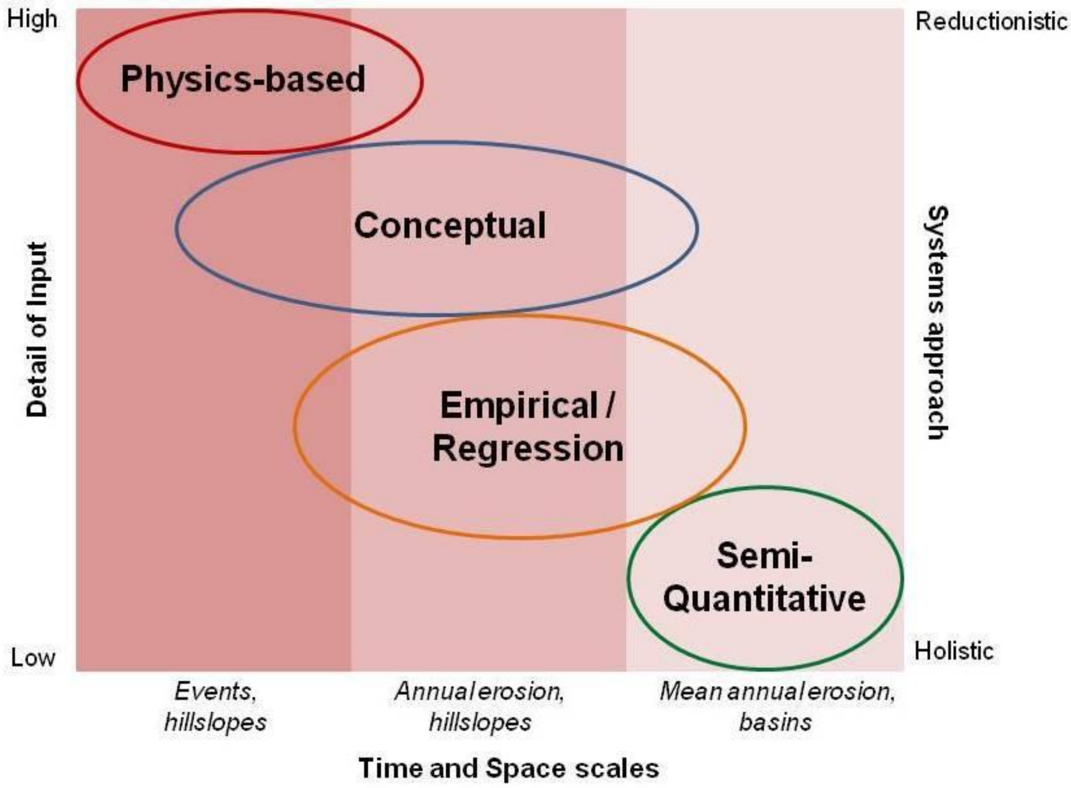


Figure 2-2 Comparison of model types with respect to scale, input requirements and kind of output. Source: de Vente and Poesen, 2005, p 119

2.3.5 Model selection

Soil erosion model selection depends largely on several factors such as the purpose of the study; the scale of the watershed; the study period and the availability of input data needed for modelling. However, on a large-scale basis, no modelling techniques has proven to identify all erosion processes and predict sediments accurately. Most of the physically based models like PESERA and WEPP are based on numerical equations and relationships which is often a problem when modelling large scale watersheds (Meusburger et al., 2010). Similarly, a dynamic model such as EUROSEM was developed for single event erosion processes using mathematical relationships and expressions, which requires large amount of data (Quinton et al., 2011; Karydas et al., 2009). Their complexity and large data requirements such as: soil shear strength; soil cohesion; soil surface roughness; infiltration rate; soil moisture content; evapotranspiration rate; rill and inter-rill erodibility; plant density; soil bulk density and sub-surface flow makes them very unpopular for researchers (Nearing et al., 2004; Morgan, 2001). Even though SHETRAN predicts erosion at basin scale, it requires large input data like soil moisture, soil texture size distribution, porosity and borehole logs (thickness and connectivity of aquifers and aquitards) to run successfully. Several meetings were held between the researcher and the supervisory team about the possibility of using SHETRAN for this research. However, it was not possible to use SHETRAN for this research because of lack of data set required to run it. Merritt et al. (2003) stated that the major weakness of physically based model is the large data requirement, which makes them very unpopular and not reliable for large-scale watershed modelling. This assertion is in line with de Vente and Poesen (2005) statement that erosion model that integrates all erosion processes on a large-scale basis is yet to be developed because of the complex and poor knowledge to describe all the processes and feedbacks in the equations and relationships. Consequently, these models may not fit into the conditions and purpose of this research based on the limitations mentioned above, especially when applied in large areas as they are often too complex to be used as operation tools. Therefore, putting the positives and negatives points of these model types into perspective as described previously, simple models like RUSLE and MPSIAC would fit into this study purpose and condition of insufficient data. Moreover, MPSIAC model was selected to have a comparable result and to incorporate gully erosion processes, which is one of the characteristics of the study site. In addition, the simplicity of these RUSLE and MPSIAC models in terms of data requirement and their potential to assess erosion on large scale basis makes them top choice for this research. . However, most times, spatial variation of erosion risk maps are more useful to the planners and decision makers than the soil loss values. Additionally, the compatibility and combination of RUSLE and MPSIAC models with GIS and Remote Sensing to produce oil erosion risk map adds another layer of preference over other models. Based on the explanations of the weaknesses and strengths of the models above, RUSLE and MPSIAC are chosen for this research.

2.3.6 RUSLE Application: spatial consideration and criticism

Most erosion studies focused on watershed scalability, perhaps from plot to watershed scales or from watershed to regional scales depending on the aim of the project. The quest for sustainable soil management for nationally or international conservation purpose has increased the demand for soil erosion model application (De Jong et al., 1999). As a result of that, the selection of suitable variety of context of soil erosion modelling techniques becomes necessary. Until today, the model and its revised version are still very popular and widely used for management decisions and research (Cohen et al., 2005; Meusberger et al., 2009; Terranova et al., 2009; Besko et al., 2009; Royal, 2007; Millward and Mersey, 1999; Pham et al., 2018; Kinnell, 2018). Wischmeier and Smith (1978) developed USLE/RUSLE model in the eastern part of USA by analysing scattered runoff plots and small data plots of over 10,000 plot years.

As seen in Equation 5.1, the model has been used to predict sediment yield (sheet and rill erosion) by considering key erosion contolling factors such as: rainfall erosivity, soil erodibility, slope length and slope sleepness,vegetation cover and conservation support practice. Even though the model was parameterised and developed in the USA, there is world wide adaptation of RUSLE under different modelling conditions (Dubber and Hedbom, 2008; Aksoy and Kavvas, 2005) because of the following reasons:

(1) RUSLE is applicable in poor data conditions and is also simple to implement, especially in developing countries (Gao, 2008).
(2) RUSLE is very flexible and can easily be combined with GIS to enable spatial display of eriosn risk maps of variuos scales and site conditions as demonstrated by Zhou et al., (2008).
(3) The model allow upscaling of watersheds up to basin scale when combined with GIS to display spatial variation of erosion risk maps. For instance, Bazzoffi (2009) used the model to demosntarate spatially distributed vegetration cover scenarios in Itaian watershed.
(4) RUSLE can reasonable predict soil loss and sediment yield as shown in the following literatures (Besko et al., 2009; Jain et al., 2009 and Pham et al., 2018; Kinnell, 2018). Conversely, there are some limitations of RUSLE application such as:
(1) RUSLE does not consider sediment deposition in the watershed. According to Kinnel (2010), there is no direct cosideration of runoff deposition in the watershed even though erosion depends largely on sediment being discharged with the flow, which leads to systematic error in the erosion prediction emerged.
(2) RUSLE does not account for gully and bank deposions as well as mass movement at watershed scale (de Vente et al., 2005).
(3) RUSLE was parameterised and developed for USA conditions, if applied at large scale in different geographical areas, some limitations need to be taken into consideration. Therefore, predicted value of soil loss should only be comparable not absolute (Kinnel, 2008; Terranova et al., 2009).
(4) RUSLE does not predict soil loss in the short term but in the mean annual term. However, when applied to predict soil loss in the event time scale, over prediction of erosion is most likely to occour (Riesse et al., 1993; Kinnel, 2010).

2.3.7 *MPSIAC Application: spatial consideration and criticism*

The growing pressure on our watersheds due to population growth, urbanisation and other human activities has great impact on soil erosion. Consequently, this has increased the demand for other erosion models that will incorporate more complex erosion processes as well as larger basins. Thus, a semi-quantitative model like the Pacific Southwest Inter-Agency Committee (PSIAC) was first developed in the USA and applied in the Walnut Gutch located southeast of Arizona, and has also been applied worldwide (Woida et al., 2001; Garg and Jothiprakash, 2012; Lida et al., 2012; Zahra et al., 2013 and Noori et al., 2018). For example, Lida et al. (2011) compared the performance of MPSIAC and RUSLE models by estimating the sediment yields in micro catchments in Iran and found that the variation in the model results was less than 5%. Also, Zahra et al. (2013) used MPSIAC model to estimate sediment yield in Afjeh & Lavarak sub-watersheds, Iran, and found that the spatially erosion map result matched the physical erosion condition on the ground. As seen in Equation 5.9, the model has been used to predict sediment yield by considering nine key erosion contolling factors such as: surface geology (Y_1), soil (Y_2), climate (Y_3), surface runoff (Y_4), topography (Y_5), land cover (Y_6), land use (Y_7), surface erosion (Y_8) and channel erosion (Y_9). The worldwide application of this model is based on the following strengths.

(1) MPSIAC model is very easy to apply in poor data areas, which makes it outstanding based on simplicity.

(2) MPSIAC model includes the widest variable of erosional processes (Meshal et al., 2017)

(3) MPSIAC model is very compatible with other soil erosion tools like GIS and remote sensing (Lida et al., (2011).

(4) MPSIAC is very flexible, and can easily upscale or downscale spatial watershed sizes, when combined with GIS.

(5) MPSIAC unlike RUSLE includes erosional processes of gully erosion and runoff variables.

On the other hand, it also has its own limitations as follows:

(1) MPSIAC just like RUSLE model does not predict soil loss at short term but at annual term. So, when applied to predict soil loss in the event time scale, it tends to over predict soil loss.

(2) The model was parameterised and developed for arid and semi-arid conditions lands in the USA. Therefore, when applied in different geographical areas, some cautions are to be

applied. Therefore, results should only be comparable not absolute (Adib, Jahani and Zareh, 2012; Ilanloo, 2012: Belete, 2013)

2.4 Lake sediment core

In recent years, the use of lake sediment core records to quantify the historical impact of environmental activities on soil erosion and sediment yield has gained worldwide attention (Dearing and Jones, 2003; Edwards and Whittington, 2001; Dearing, 1994). As a result of that, lake sediment core has become very popular and important environmental science and engineering. This reflects the willingness of scientist to connect the past environmental processes to the present condition through sediment reconstruction in order to identify and solve problems. Lake –watershed ecosystem is often the best framework to reconstruct the environment (Borman et al., 1977). Oldfield et al. (1983) opined that within the lake-watershed framework, the evaluation of its sustainability will always depend on the following: present conditions based on observations and experimental results compared to sediment analysis of human efforts; construction of the detailed history of anthropogenic impact of physical function like soil erosion (Dearing, 1983). And, finally, projecting a continuum of insight based on the historical past and present condition (Oldfield et al., 1979; Oldfield et al., 1983; Oldfield, 1993b). However, linking past and present deposition mechanisms comes with conformation of processes which makes lake sediment core especially useful in historical monitoring. Deposition of material in the lake-watershed ecosystem preservation in the sedimentary record makes it a powerful environmental reconstruction tool. This technique has significantly improved our knowledge of the spatial and temporal evolution of environmental impacts and influence of human activity on the global ecosystem, such as the early anthropogenic hypothesis (Ruddiman, 2003). The modern soil erosion rate is far beyond what it used to be in the past because of a wide range of factors interacting together such as: socio-economic factors; biophysical factors; and poor environmental policies (Xiubin et al., 2006). Increased soil erosion does not only cause on-site loss of topsoil and reduction of soil productivity but also has additionally serious off-site environmental effects (Roberts, 1994; Morgan 1995; Dearing and Jones, 2003; Lal 2001). However, the impact of anthropogenic influence on the environment has been recognised as abnormal in modern soil erosion compared to the historical past, and, because of that, the knowledge of sediment deposit pattern and sequence of off-site event is a useful information to identify sediment sources and reconstruct the environment. A descriptive and quantitative interpretation of past environmental records of sediment core in conjunction with a soil erosion model has been used by Boyle et al. (2011) as a powerful approach to study soil erosion and sediment yield. One of the simplest methods of studying lake sediment core is by use of magnetic susceptibility measurement as a proxy for studying deposition patterns. This is explained further in Section 2.5.

2.5 Magnetic susceptibility

Magnetic susceptibility measurements have been used over the years in a wide range of environmental research for identification of minerals and sources of sediments, and also for correlating the cores and the lake environment (Lees et al, 1998; Oldfield et al., 1980; Thompson, 1973; Bloemendal and deMenocal, 1989). The investigation of source of sediment generation and pattern of deposition is very important in catchment management because they have the potential to reflect series of activities within the watershed (Thompson et al., 1975; Molyneux et al., 1975; Mortion, 1979; Elner et al., 1981; Flower, 1982; Barnosky et al., 1983 and Davidson et al., 1983) However, identification of peaks along the core pattern profile, and the correlations that exist between cores is the key to linking environmental episodes like soil erosion and flooding (Mackerteth et al., 1969; George et al., 1978 and Lees et al., 1998). Sometimes, multiple environmental activities make it extremely difficult to understand the particular event responsible for changes in the core pattern, especially if the events took place at the same time. Another limitation of magnetics susceptibility is its inability to quantify the sedimentation rate as a means of checking sediment flux and reconstructing the environment. Therefore, a combination of magnetic susceptibility studies and soil erosion models, additionally provides spatial distribution of sediments in a lake watershed, which further provides alternative means of estimating sediment rate. This limitation can also be eliminated by using additional investigation techniques like remote sensing and physical measurement of sediment core depth.

2.6 Remote Sensing (RS) and Geography Information System (GIS)

In recent years, Remote Sensing and GIS techniques have been applied worldwide in mapping and spatial analysis of soil erosion because of their robustness and flexibility in integrating other erosion models (Adediji et al., 2010; Alaaddin, et al., 2010; Okereke et al., 2012; Fashae, et al., 2013 and Richard, et al., 2018). Remote sensing software’s ability to map and categorise land use makes its application to soil erosion modelling very useful and outstanding. For example, Okereke et al., (2012) used remote sensing technology to map out soil erosion sites in Okikwe Imo State south east Nigeria. They also opined that remote sensing technology could detect the shape and profile of gully erosion sites, if used effectively. Their finding also agrees with Fashae et al. (2013) who used remote sensing techniques to detect gully erosion sites in Uyo Metropolis, Nigeria. However, it is important that remote sensing images are processed using remote sensing softwares (ERDAS IMAGINE 8.7) or GIS for better understanding and interpretation of the natural colours associated with different features of interest on earth surface. For instance, Yaw and Edmond (2006), processed Landsat TM and ETM+ satellite images of Nigeria Delta region using ERDAS IMAGINE 8.7, which was later used to further analyse the spatial evolution of coastal environmental changes in the region as well as other variables of interest. Most importantly, the compatibility of RS and GIS makes them great tools for spatial erosion risk analysis. Yaw and Edmond (2006) combined Remote Sensing (RS) and GIS to analyse the spatial environmental changes as a result of human activities in the Niger Delta region of southern Nigeria. The ability of RS and GIS to map out soil erosion sites, especially gully erosion in complex watersheds makes them a top choice as the spatial analytical tools in this research. In addition, the compatibility and flexibility of RS and GIS is particularly great in spatial erosion risk analysis, which is one of the objectives of this research.

2.7 Institutional Analysis and Development (IAD) framework

Although several other institutional frameworks have been developed for the study of natural resources management such as the environmental entitlements framework and the sustainable rural livelihoods framework (Leach et al., 1999; Messer and Townsley, 2003) in terms of policy analysis, IAD framework stands out as the most distinguished and tested framework (Imperial, 1999; Carlsson, 2000). It is considered the best option for this research because it offers the advantages of combining and integrating the physical environmental processes, the rules-in-use, the formal rules and the stakeholder's interactions to drive policy changes which is one of the objectives of this research. IAD framework has been extensively applied in a range of environmental policy issues, especially natural resources management like land use and soil conservation (Ostrom, 1999 and Mc Ginnis 2011a). However, over the years, the IAD framework has gone through many changes (Kiser and Ostrom, 1982; Ostrom, 1986a, 1989, 1999, 2007, 2010, 2011; Oakerson, 1992; Ostrom et al., 1994; Ostrom and Ostrom, 2004; Ostrom et al., 2014 and Cole et al., 2014a). It has widely been applied to study people-environment interactions in managing natural resources. To ensure that rules are identified, understood and designed to enhance equity, efficiency and sustainability in the use of natural resources (Ostrom, 1990; Thomson, 1992; Leach et al., 1999 and Meinzen-Dick, 2007). In addition, through various action combinations at different community levels, it provides insights into successes and failures of natural resources management through collective actions (Lam, 1998; Sproule-Jones, 1999; Gibson et al., 2000b; and Acheson, 2006). For example, Zerihum et al. (2017) used it to analyse the institutions responsible for the management of soil conservation in North Western Ethiopia and suggested that applying a bottom-top approach and ensuring effective incentives for community participation would solve soil conservation problems. Moreover, Clement and Amezaga (2008) analysed how farmers make decisions in a land degradation context in the Northern Vietnam and opined that allowing local resource users some degrees of freedom in decision-making over natural resources management enhances sustainable environment.

In IAD, action situation lies at core of understanding institutions, which enable individuals and corporate actors to interact with each other by making choices that jointly determine the outcomes of some aspects of policy questions. Decisions and outcomes are influenced by the beliefs and incentives of individual actors, as shaped by the responsibilities and social expectations attached to any official position they hold, and by the information available to them. According to Ostrom (2010) these action situations are also shaped by the pre-existing conditions, grouped for analytical purposes into three categories: (1) the biophycal conditions (2) the social ties and cultural attributes that characterise the individuals interacting on that policy problem and the existing configuration of laws, regulations, rules, norms and shared understandings held by the participants to be relevant to deliberations on that policy arena.

Another important element of IAD is the attribute of the community. This covers various characteristics of the community such as culture, belief, trust, poverty, unemployment, population, tradition that directly affect the natural resources management (Olson, 1965; Agrawal and Goyal, 2001). Furthermore, in IAD, rules-in-use is the agreed terms of use which is enforceable prescriptions based on actions that requires or prohibited (Ostrom, 1999 p. 50). These prescriptions are could be formal and informal legal documents and collective choice rules-in-use agreed in the community orally. In Ostrom, (1999), the rules-in-use were classified into seven categories (position rule, boundary rules, choice rules aggregation rules, information rules, payoff rules and scope rules) based on their impact within the action arena. The rules-in-use can be formal or informal depending on the context and it is often common in local natural resource harvest where the local people operate under rules different from the formal rules. In developing countries, operating under informal rules often threatens environmental sustainability. Moreover, evaluative criteria are another element of the IAD framework that enables the analyst to check institutional arrangements performance. However, the interest and objective of the analyst depends on the list of criteria such as efficiency, equity, accountability, adaptability and sustainability (Ostrom, 1999).

In IAD, the emphasis lies on the ability of the local communities to have a shared management of natural resources with the top-level government. Interestingly, IAD has not only been applied widely to study common natural resources in many regions of the world (Ostrom, 1999), but also it has advanced the understanding of the key rules improving the performance of natural resources management (Thomson, 1992; Thomson et al., 1997). However, some critics have also blamed its focus on local rules and its inability to recognise underlying socio-economic historical changes (Robbins, 2003, 2004). Another scholar also stated that capital investors are responsible for shifting communal resource away from local communities, and thus, has led to environmental activities and unemployment in the community which cannot be resolved by community rule-crafting (Muddavin, 1996). Despite all these limitations, IAD framework is still the best option for a condition like Oguta Lake watershed, where land use and other similar environmental activities are inefficient and unstainable.

2.8 Gender inequality and discrimination in Nigeria

Nigeria is one of the most dynamic nations in the world within the context of religion, tradition and other social values (Chizaram et al., 2013). The institutions in Nigeria are influenced by modern democratic system as well as traditional and region believe systems (Adenyika et al., 2014). Perhaps, this has strong influence on institutional inequality and gender discrimination against women compared to the opportunities available to their male counterpart in Nigeria. Many factors such as tradition, culture, religion, and education contribute to inequality in Nigeria and the level of inequality varies from one geographical region to the other (Urther, 2016). The inequality is dominant in the northern part of Nigeria where Islam is the key religion and the local Islamic traditions set more limitations on women. The problems of inequality and gender gap in the northern Nigeria became worse under the polygamous marriage system commonly practised by the Muslim community. This marriage system always leaves women powerless and under total control of their husbands in their bid to obtain favour from their husbands in the mist of other competing co-wives. In the southern Nigeria, where this research is carried out, the story is a bit different, but gender inequality still exists (Dial, 2015). Even though the polygamous marriage is not widely practised in the southern Nigeria, the use of economic control is widely used by men in the region (Agbogu and Igbokwe, 2015). In the rural area where most households are poor, men always use land and natural resources ownership as a weapon to control their women. While the growing modern democratic system tries to close the gender gap through its fair processes, the traditional and religion believe system on the other hand places more limitations on women tied with cultural believes and values. Even though some women that acquired western education and different women groups have started challenging the gender gap and inequality, a lot of work is still needed to truly emancipate women from these problems. For example, The Women in Agriculture (WIA) programme was established to empower and protect the interest of women in Agriculture in Nigeria. Although it is still facing some bureaucratic challenges and needs proper support from the central government for proper integration. For instance, Odurukwe et al. (2006) studied the impact of WIA programme on the lives of Imo State women with a view to strengthening agricultural production and opined that suitable agricultural extension service that is gender-specific to women farmers will boost agricultural productivity. In addition, the WIA programme has impacted on family food security and increased contribution to household needs. Consequently, gender inequality affects the economy, food security, development and poverty alleviation as women are poorly represented and thus, their potentials are not properly utilised. For instance, women make up to 60-70% of agricultural labour force in Nigeria but less than 5% of women occupy official positions (World bank 2003). In addition, there is a disproportionate percentage of women in leadership positions especially at higher level (Akinrinade, 2019). Although women occupy greater percentage of agricultural operation positions, they constitute a low percentage of official agricultural positions responsible for decision making. The story is similar to the situation in other African countries. For example, Yemisi et al (2009) stated that women occupy 75% of farmer's trade union in Zimbabwe, they only occupy 5% of official positions. Similarly, in Sudan, women occupy 14% official farm union positions despite dominating the male counterparts in membership. On a wider perspective, the story is the same across most African countries, agriculture contributes up to the 21% of the GDP and women contribute 60-80% of the labour used to produce food (FAO 1995). Women do not only run household activities in Nigeria, but they also produce up to 74% of household foods and 70% of food consumed by rural families (Melaned 1996). Despite all these meaningful contributions by women, they are yet to be recognised and integrated into mainstream decision making. This is unacceptable level of inequality as this poor official representation of women in key agricultural decision-making positions does not only retard growth and development but also causes food insecurity. In ''Igbo'' region of Nigeria, lack of land ownership remains one of the major constraints of women farmers. Most of them have access to farmlands based on the discretion of their husbands or the first son of the family (Ikpeze 2015). In ''Igbo'' tradition, women do not have right to own land through inheritance as custom dictates but in rare cases, even if they own land, it is usually less fertile and smaller in size than the male counterparts. In terms of land ownership, the situation is not the same across all regions of Nigeria because of tradition and customs but in general women benefit less than their men counterparts. Despite these shortcomings, women contribute significantly to family food security and economy. For Instance, Afolabi (2008) observed through analysis of activities of rural women in Ondo State Nigeria and stated that women are the true pillar of the economy in the state. Rural women contribute significantly to food production, mange the household resources efficiently and yet they are poorly represented in key decision making. Thus, women are key to development in Africa, where greater percentage of population leaves in rural areas. Therefore, borrowing Nancy Frazer's idea on recognition, representation and redistribution as a key to social justice (Frazer, 2003, 2009). Poor recognition, representation, redistribution and lack of equal opportunity to compete have been identified as major constraints of women in Nigeria.

2.9 Chapter summary

This chapter has reviewed the following areas of knowledge relevant to the objectives of soil erosion processes, the classification of soil erosion model, criticism of soil erosion models, model selection, RUSLE application, MPSIAC application, lake sediment core, Remote Sensing (RS), Geographical Information System (GIS), and the concept of Institutional Analysis and Development (IAD) framework as they relate to soil erosion in Oguta Lake watershed. It also has pointed out some strengths and weaknesses of some of these methods.

3 CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Introduction

This chapter presents the background of the study area characteristics; the techniques used in collecting field data and the processes of data analysis. However, each result chapter is provided with a more detailed data generating, processing, and analysis procedures while this chapter further provides the general thesis design approach.

3.2 Location

Nigeria is in the West Africa, which lies between latitude 9.08^0 N and longitude 8.6^0 E within the equator and tropic of cancer respectively. Nigeria borders the Gulf of Guinea between Benin in the west and Cameroun in the east, and its land mass extends from Gulf of Guinea in the south to the Sahel in the north. It has a total area of 923,768 km^2 and a population of 118,953,000 persons in the year 2000 (year 2000 census). Nigeria is made up of six-geopolitical zones and about 400 ethnic languages across the country. The climate of Nigeria falls within the tropical zone, but it is not entirely tropical, as part the northern part of Nigeria is semi-arid, and to the south is equatorial type of climate. The two major climate seasons in Nigeria are rainy season and dry season. The rainy season is characterized by heavy rainfall from March to October while the dry season is characterized by dry sunshine from November to February. The rainfall and temperature vary from one geographical location to the other, the south east Nigeria is characterised by heavy rainfall ranging from (1800-2500 mm/year) and temperature ranging from ($20^{0\ C}$-$30^{0\ C}$). Politically, the south east Nigeria is made up of five states: Imo state, Anambra State, Ebonyi State, Abia State, and Enugu State. South east part of Nigeria has so many erosion controlling factors in common such as climate, soil type, vegetation, land use and topography (Obinna al., 2013). Thus, research results obtained from any part of south east states could be relatively applied to other areas with common erosion features. The map of the study location is shown Fig 3-1 below.

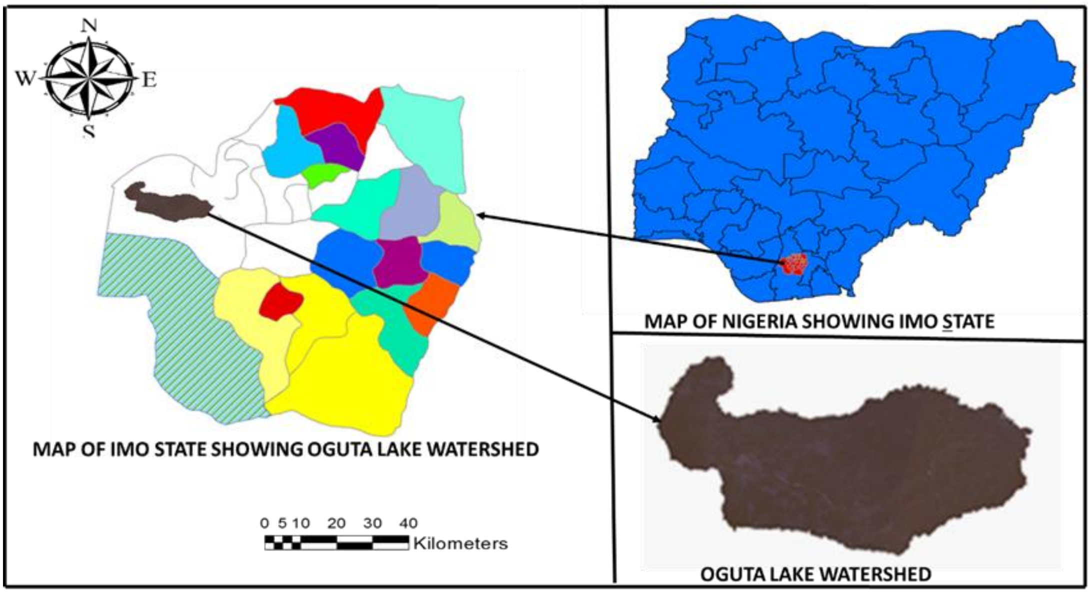


Figure 3-1 Map of Nigeria showing the study area. Source: USGS earth explorer and GIS online data

This thesis studies the assessment and soil erosion management in Oguta Lake watershed Imo State south east Nigeria. Because of various human activities in the study location, the area has problems of soil erosion, which has attracted a lot of research attention (Igbokwe, et al., 2003; Amangabara, 2014 and Emeka et al., 2015). In addition, because south east Nigeria is a tropical climate, and a very fertile land for agricultural production, most local people are engaged in agricultural activities. Meanwhile, the farmlands and settlement area are scattered, and a bit mixed up, which makes it extremely difficult to control land use and farming activities. Most farmers in the area are in subsistence model of farming who lack capacity to maintain sustainable environment and thus, are potential soil erosion drivers. Soil erosion has been exacerbated because of more population engaging in farming business, which leads to massive clearing and land use for sand mining purpose. Despite the various government organisations that are responsible for regulating and protecting natural resource conservation, such as the Ministry of Environment, the Ministry of Agriculture and the Ministry for Mines and Steel Development, the depleting natural resources issues and environmental degradation are yet to be resolved, particularly soil erosion menace. Imo State is the eastern heartland, famously known for its rich culture and tradition and it has eight (8) significant sub-watersheds: Otamiri River Watershed, Imo River watershed, Nworie River watershed, Oguta Lake watershed, Oramiriukwa River watershed, Njaba watershed, Awbana watershed, Oranshi watershed. Oguta Lake watershed is particularly famous because of its economic importance for the people of Imo State as well as its navigation potential, which made it a choice port for the evacuation of palm product during the colonial era and a marine base for the Biafra Navy during the Nigeria civil war. In addition, the stream direction and accumulation show that both Njaba and Awbana are tributaries of Oguta Lake, and thus, forms a major part of Oguta Lake watershed as shown in Fig 3-2.

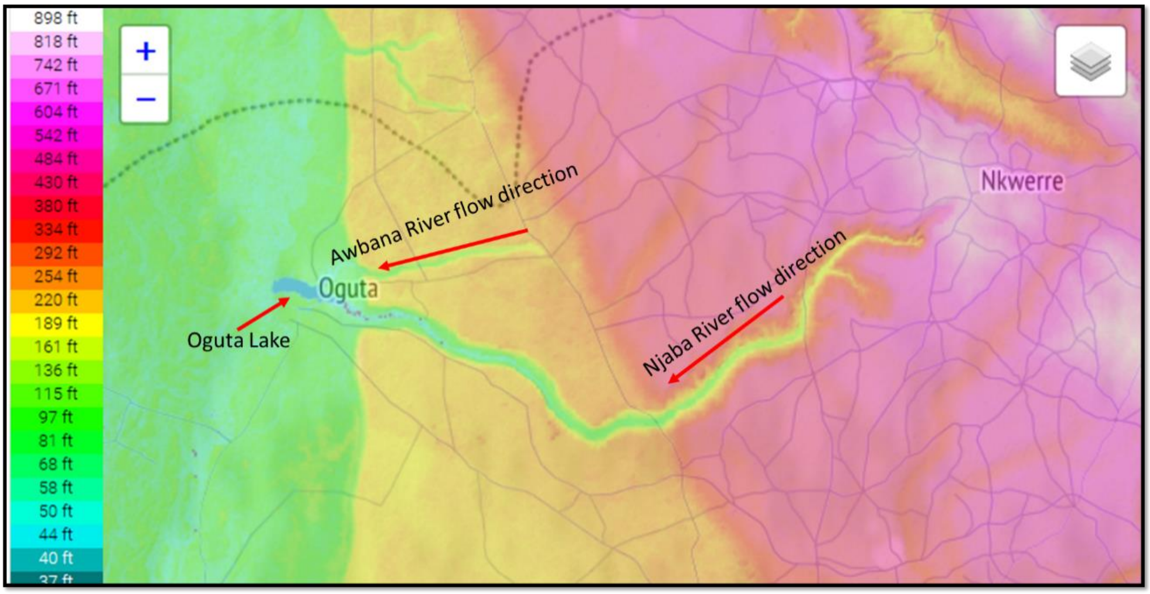


Figure 3-2The map of Oguta Lake showing Njaba River and Awbana River as its main tributaries. Source: Topographic map.com

3.3 Justification of Oguta Lake watershed

Although there are many watersheds in Imo State, Oguta Lake watershed has been chosen as the study site considering the detailed Remote Sensing (RS) mapping of erosion spots (see Section 3.5.1 for methodology) in Imo State as seen in Fig 3-3 and the economic importance of the area to the Nation. This is because the RS mapping showed that the highest concentration of the erosion spots falls within the watershed boundary compared to anywhere else in the state, moreover, the lake attracts thousands of tourists per year, thus, has strong economic importance to the community. It was not possible to study the entire state because it was too big for round reconnaissance survey considering the time and financial resources allocated for this research. Although most of the spots identified during mapping coincided with the erosion and mining sites on ground; it was found during reconnaissance survey that some spots formally identified as erosion sites were dry fish ponds and domestic wells, because it was difficult to distinguish between erosion and other similar spots in the satellite images. However, false spots were later eliminated, and the new spots identified during field survey reconnaissance and were added during image processing showing only sand mining and erosion spots as seen in Fig 3-3. In addition, the menace of erosion in Imo State and south east in general has attracted the attention of the federal and state government through Nigeria Erosion and Watershed Management Project (NEWMAP report, 2013). The area is dominated by farmers and sand miners, which are the major human activities contributing to high erosion rate in the watershed. The remarkable features of Oguta watershed are: (a) the sediment inventory in the watershed is not available and currently not being collected; (b) It is a lowland area, which is characterised by different land use patterns and cropping systems; (c) the area is dominated by local people, which drives soil erosion, particularly by their intensification of sand mining and local subsistence agriculture, i.e., slash-and-burn techniques, bush burning; (d) the traditional leadership is very strong and highly recognised by the local people. Therefore, it is very appropriate for data collection and conducting the fieldwork survey within the limited time and budget effectively.

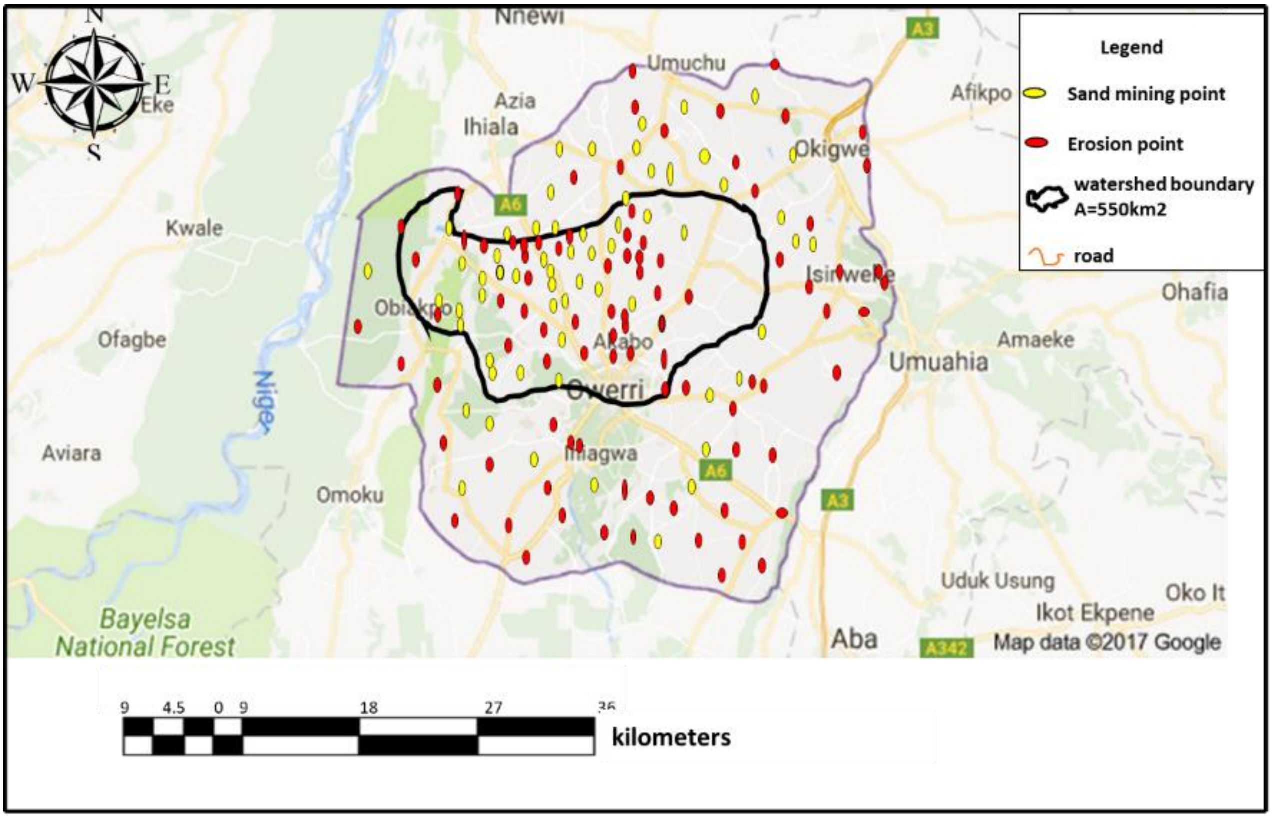


Figure 3-3 Map of Imo State showing boundary of Oguta watershed boundary and the mapped erosion and sand mining points. Source: Google Earth and GIS online

3.4 Oguta Lake watershed

Oguta Lake is the largest natural lake in Imo State Nigeria. It is presumed to have originated from a natural depression (Ita and Balogun, 1983) and currently the largest freshwater system in south east Nigeria. Geographically, the lake is 50 metres above sea level and lies precisely within the coordinates 5.71^0 N and $6.79N^0$ E in the equatorial rain belt of Nigeria. The lake is located at Oguta local government, and it is of economic value to both the government of Imo State as their source of revenue generation through tourism, and the local communities within the watershed for transportation and other commercial purposes as shown in Fig 3-4. Physiologically, the lake has a surface area of $1.8km^2$ during dry season and $2.5km^2$ during wet seasons, as well as maximum and mean depth of 8.0m and 5.5m respectively with an approximate shoreline of 10km (Nfor et al., 2012). The presence of a three-star hotel (Oguta Lake Motel) and other private hotels attracts tourists and foreigners to the lake and Imo State in general. The population of Oguta Local Government according to 2005 national census is 143,008 persons comprising 74,308 males and 68,780 females. Urban dwellers in Oguta and Awo contribute 95,000 persons with a population density of 3.5 km^2, while rural dwellers in Nkwesi and Orsu make up the remaining population with a population density of 2.3 km^2. The watershed is located within the equatorial rainforest belt and the villagers engage in sand mining and subsistence agriculture, producing palm oil, cassava, yam and other economic crops. However, poor agricultural practices and shifting cultivation has caused loss of the thick vegetative cover of the rainforest, leading to a high rate of soil detachment, transport and deposition into tributary rivers that discharge their sediments into the lake (Amagaraba, 2012). The watershed has a high annual precipitation which lies between 1800–2500 mm/year (see Section 3.5.3 Fig 3-13). The climate exhibits a dry pattern from November to February with little or no rainfall, which results in high temperatures, while the wet season occurs between March and October with a high rainfall of 375mm in September (Ita and Balogun, 1983). Hydrologically, Oguta Lake has two main tributary rivers: Njaba and Awbana River. They discharge into the lake all the year round and are the main sources of sediment to the lake. The total annual inflow into the lake from rivers and streams is about 25,800 m^3 while the annual return and overland flow into the lake is estimated to be about 69,000 m^3 and $13800m^3$ respectively (Okoro et al., 2014). One of the major challenges of Oguta Lake watershed is soil erosion which has resulted in continuous deposition sediment into the lake. Soil in Oguta Lake watershed is brownish loamy sandy soil with high moisture absorbing ability. The forest area is evergreen with laterite brown reddish soil which is very rich in organic matter with low acidity, phosphorous, potassium usage. Evergreen forest area is a reddish-brown lateritic soil, which has moderate acidity, richness of organic matter, low utilisation of phosphorus and potassium, and low soil retention.

Figure 3-4 Oguta Lake (at 05 42’ 26.9’’N and 006 47’ 54.6’’E). Source: Field reconnaissance survey conducted on August 26, 2016

3.5 The Geology and Geomorphology of Oguta Lake

Oguta Lake is believed to have originated from Quaternary and Holocene Eurasian glaciation correlated with pluvials in the tropics (Ogidi et al, 1998). It lies within the Benin formation (see Table 3-1 below) in geologic and geomorphic units of Niger Delta Basin (Etu- Efeofor and Akpodedje 1990). The watershed consists of continental sands with individual units of sandstone, gravel conglomerate with clays lenses. Previous studies have described the geology of the watershed. Egede (2013) opined that the soils from the watershed is heterogenous sands with isolated sandstones and loam-clays underlain by shale. Similarly, Ezemonye and Emeribe (2012) stated that the soils in the watershed were derived from sandstones and shales parent materials which is deep and porous with low organic matter because of high leaching rate. Ezezika and Adetona (2011) stated that the soils have low silt/clay content thus resulting in a sandy soil which is cohesionless, very permeable and very high infiltration rates. Under Benin formation, the lithology is coarse to medium sand with subordinate silt and clay lenses. The soil is weak sand units deposited during the period of paleocene and Miocene (Ogidi et al, 1998). Field observation showed the presence of unconsolidated tertiary sandy sediments with mixture poorly sorted materials and coastal plain sand.

Table 3-1 The Geologic and geomorphic units of the Niger delta basin (Etu–Efeotor and Akpokodje, 1990)

Geologic/geomorphic units	Lithology	Age
Alluvium (General)	Gravel, sand and silt	Quaternary
Freshwater backswamp	Sand, clay, some silt, gravel	Quaternary
Mangrove and salt water backswamps	Medium-fine sands, clay and some silt	Quaternary
Active/abandoned beach ridges	Sand, clay and some silt	Quaternary
Sombreiro –Warri deltaic plain	Sand, clay and some silt	Quaternary
Benin formation	Coarse to medium sand with subordinate silt and clay lenses	Miocene
Agbada Formation	Mixture of sand, clay and silt	Eocene
Akata Formation	Clay	Paleocene

3.6 Methods of conducting fieldwork and data collection

The multiple dimension nature of this research and lack of data in the study area required a disciplinary data collection approach. Thus, large volume of data was forecasted, and proper measures were put in place to properly manage the data component. For example, lack of sediment inventory data set that is required to validate the model results prompted the collection of lake sediment core samples. Therefore, multiple methodological techniques covering both physical and social dimensions was adopted based on the scope of this research as shown in Fig 3-5. The aim of physical data collection approach is as follows: (a) the aim of field reconnaissance survey was to confirm whether the erosion hotspots identified during Google Earth and Remote Sensing (RS) mapping correspond with actual field observations and also collect digital data like photographs of erosion sites and apply corrections when necessary; (b) the aim of Remote Sensing (RS) data collection technique was to collect and analyse the digital land cover and land use data, DEM used for soil erosion modelling, and to perform dynamics analysis of land use and land cover (c) the aim of the modelling and lake sediment core data collection techniques was to collect input data for modelling and verification as there was no sediment inventory in the watershed. On the other hand, the aim of the social data collection approach is as follows: (a) the aim of the semi-structured interview data collection technique was to collect primary data about the social orientation of soil erosion in the watershed and it provided opportunity to probe for themes; (b) the aim of the focus group discussion data collection technique was to collect primary data through stakeholders' discussion and interaction on the subject matter; (c) the aim of the Institutional Analysis and Development (IAD) framework was data analysis technique used for analysing institutional structures and policies responsible for managing soil erosion in the watershed. Each data collection and analysis approach were further explained under each subheading in this section.

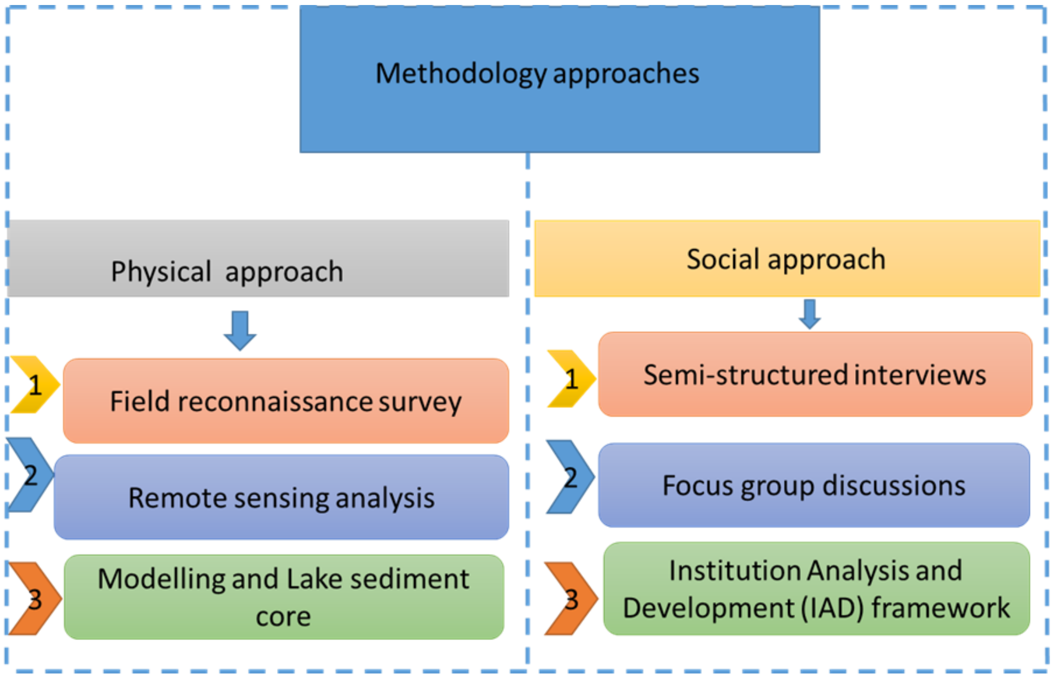


Figure 3-5 various methods of data collections and analysis

3.6.1 Pre-fieldwork activities and pilot studies

Prior to fieldwork, soil erosion spots were mapped using Google Earth Pro and Remote Sensing (RS) techniques in a desktop computer (see later Section 3.6.3). This was used as a guide for choice of site selection, and to understand the scale of the problem. In addition, a 2-day workshop was also attended by the research student in the postgraduate training centre in the School of Geography, Politics and Sociology about conducting outside study fieldwork. The workshop was a good place to meet with other field researchers, where important views were extensively exchanged on the efficacy of the chosen fieldwork techniques. During the workshop, risk assessment, ethical and confidentiality issues were also discussed extensively.

Furthermore, the need for all fieldwork equipment such as GPS, tape measure, camera, batteries, and map of the location were initially identified and collected from Newcastle University before the actual fieldwork started. In addition, couple of meetings took place comprising experienced Newcastle University staff; student and supervisory team to seek the best techniques to be used and possibility of carrying out the research. A semi-structured interview question prompt and guide were also discussed with the supervisory team (see later appendix). These questions were tested and refined based on some of the limitations observed. Initial contacts via email and telephone were established with some of the organisations identified as potential stakeholders. This discussion was to understand the procedures and processes of requesting for interviews with their members of staff. In addition, a signed letter of introduction from the supervisory team was also obtained to enable the researcher gain access to both the study location and identified organisations, especially the traditional leader of the community.

3.6.2 Field reconnaissance survey method of data collection

The aim of field reconnaissance survey was to verify if the erosion hotspots identified during Google Earth and Remote Sensing (RS) mapping correspond with actual field observation and collect digital data like photographs of soil erosion and sand mining sites. The first fieldwork reconnaissance survey was conducted during December 2015 and January 2016 with the help of the watershed field map. Upon arrival in Nigeria, the traditional leader of the community and the local government chairman where the study took place were visited with the letter of introduction to ask for access to the watershed. Thereafter, a ground truth survey was conducted using various types of equipment such as: GPS, map of the area, digital camera, and measuring tape were used to collect and record erosion spots and their actual location in the watershed. The identified erosion hotspots in the study area are described as follows: (a) Fully developed gully erosion formed along drainage channel (see Fig 3-7 (a)). Observation showed that the gully was formed by concentrated runoff flow that discharges into Njaba River, one of the tributaries of Oguta Lake. The gully channel is characterised by presence of mobile bed materials, few vegetations on the gully bottom and sparsely distributed vegetation on the gully walls. The active gully width is almost equal to the gully bottom width is about 1meter wide. It is rectangular shaped with fully developed active gully walls. Gully erosion stabilisation like of use of highly resistance erosion materials could minimise the gully rate (b) Gullies formed by in-land sand mining activities as shown in Fig 3-6 below. Observation showed that gullies within the sand mining site (see Fig 3-6 below) were formed by human pressure on land and vegetation during sand mining activities. The high intensity rainfall and concentrated runoff on the exposed soil surface initiated the formation of the gullies. Removal of vegetation and topsoil makes land vulnerable to high intensity rainfall and concentrated runoff. The gullies are characterised by irregular shape with smooth bare walls, absence of vegetation on the floor of the gullies and presence of mobile bed materials. The gully rate could be minimised by planting high resistance grass in gully bed and walls. (c) Riverbank erosion formed by runoff flow on bare ground surface (see Fig 3-7 (b)). The Gully erosion is located at the bank of Njaba River, one of the major tributaries of Oguta Lake. Observation showed that the gully was formed by concentrated runoff discharging into Njaba River. The gully is characterised by smooth non vegetated active gully walls and presence of mobile bed materials. Although the gully is not yet fully developed, it could develop to a classic gully channel if gully stabilisation is not applied. Strengthening the bank high resistance vegetation could slow down the gully rate. (d) Gully erosion formed by in-stream sand mining activities as shown in Fig 3-8 below. The gully was formed by the sand mining activities. Observation showed that exposed soil surface developed to gully erosion. (e) Unpaved road used as truck park is highly susceptible to soil erosion (Fig 3-9 a). The unpaved truck park is exposed to direct rainfall impact, accumulated runoff flow could probably trigger gully formation due to presence of loose soil materials on soil surface. Proper road pavement could protect the soil from direct rainfall impact. (f) Gully erosion triggered by failed road drainage channel (Fig 3-9 b). Observation showed that the gully was formed by failed roadside drainage channel. Presence of peak flood marks on the gully wall reveal that peak floor discharge on the poorly constructed drainage channel may have caused the collapse of the structure. There is presence of mobile bed materials behind the broken concrete drainage walls where sediment deposition started due to reduction of runoff velocity. Further description of erosion sites is detailed in Chapter 7. For example, a ground confirmation of in-land sand mining spot formally identified using RS is shown in Fig 3.6. In addition, spots of gullies, unpaved roads, bank erosion collapsed drainages and other erosion prone areas were identified during field survey. In total, fifty-seven (57) infrastructures (see later Chapter 7 damaged by gully erosion were collected and documented. GPS with 3-metre accuracy was used to collect all the point-coordinates within the watershed boundary (Magellan, 2013). The range of 0.5m-30m deep erosion are referred to as gullies because they are not easily removed by ordinary tillage activities and have adverse effect on tillage farmlands. Therefore, this study has identified as many gullies and sand mining points as possible within the watershed. As can be seen in Fig 3-7 (b), the eroded bank of perennial river (flow all year round) and its tributary rivers were specially observed when the streams had shown evidence of erosion.

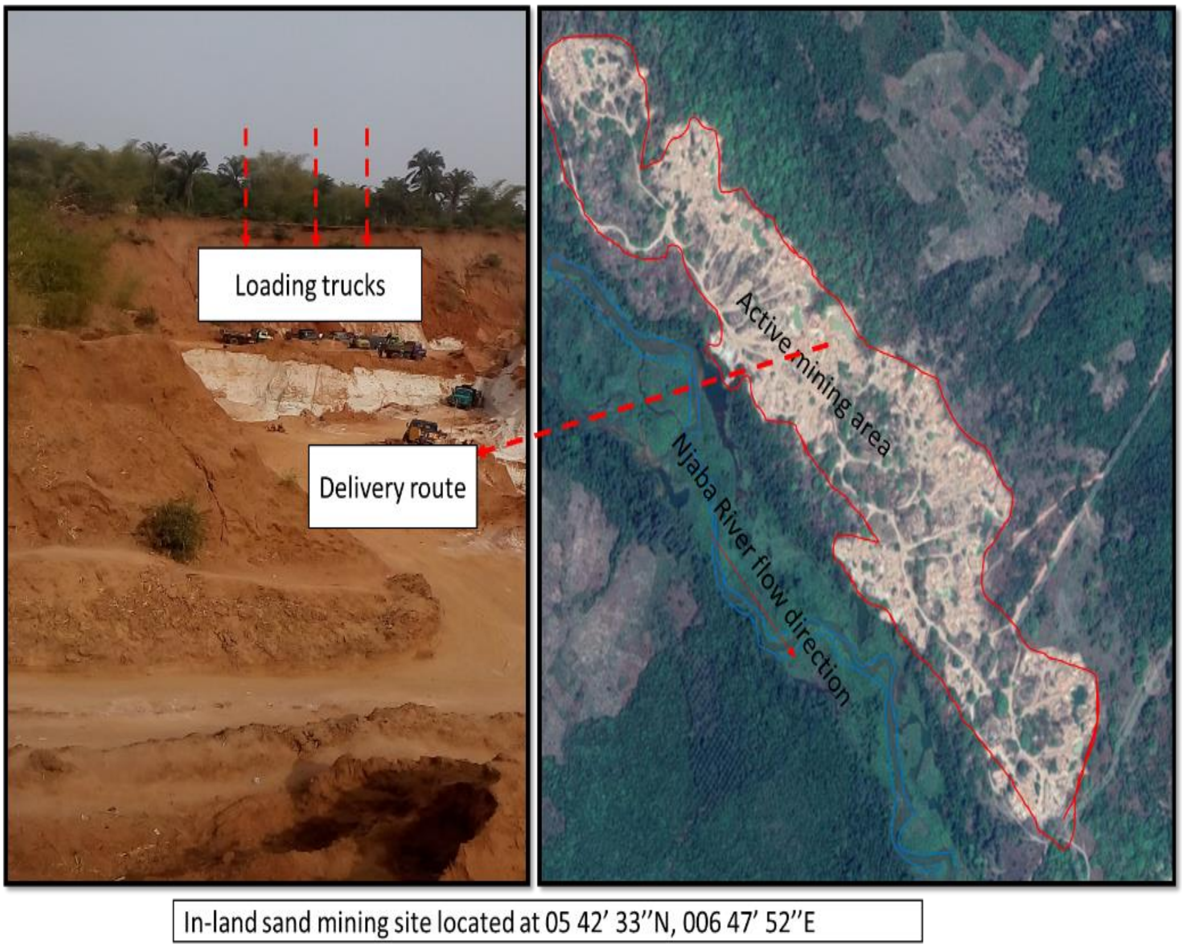


Figure 3-6 Remote sensing image and corresponding ground photo image of active inland sand mining In Oguta Lake watershed. Source: Field survey reconnaissance conducted on January 20, 2016

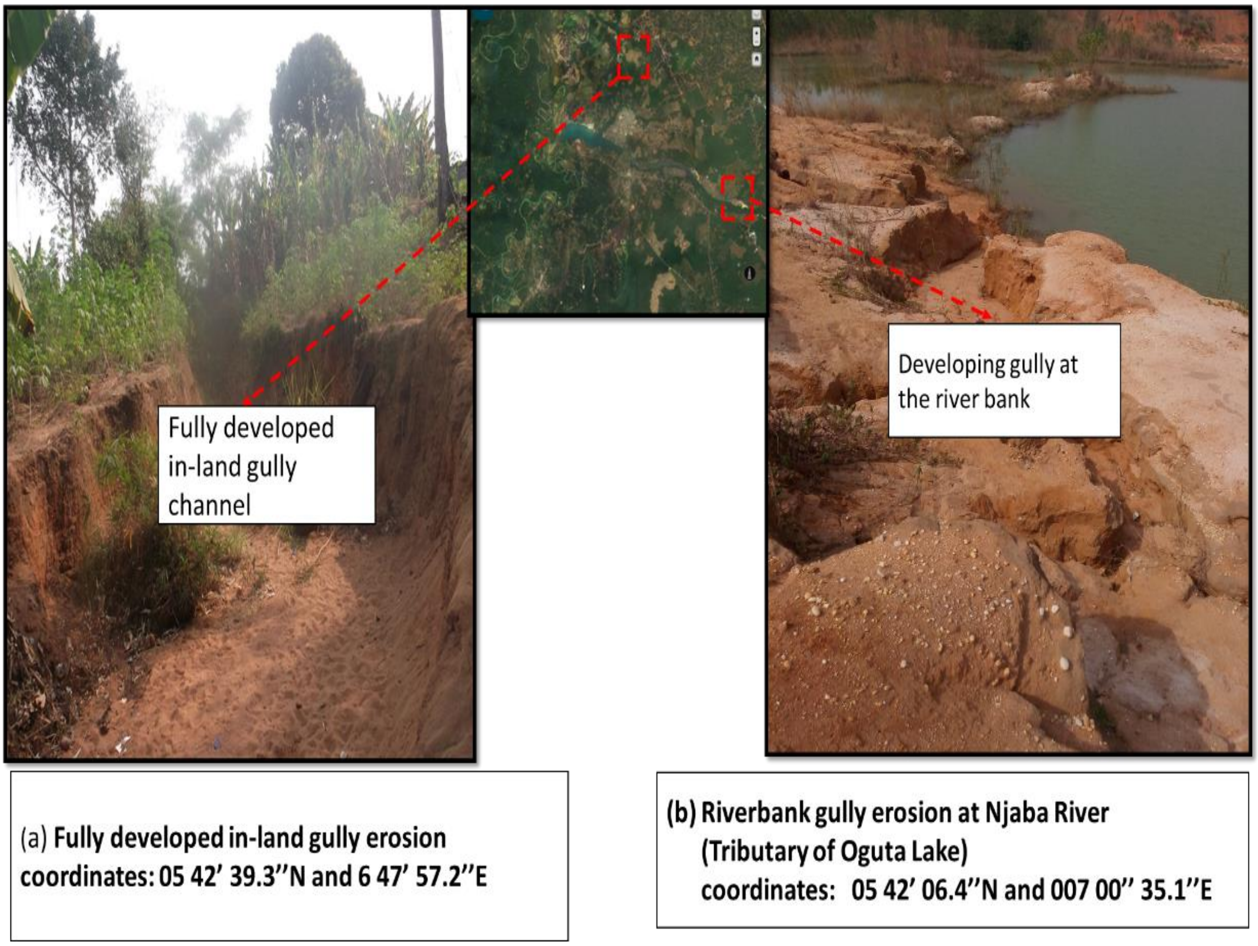


Figure 3-7 Remote sensing image and corresponding ground photos image of both riverbank and inland gully erosion in Oguta Lake watershed. Source: Field survey reconnaissance conducted in January 2016

Moreover, special attention was given to potentially vulnerable areas of riverbank mining sites in order to inspect the level of damage and the techniques used by the miners as shown in Fig 3-8. A greater preference was given to rivers that are tributaries of Oguta Lake as well as their ability to produce sediment flux downstream. Field observation showed that some of the riverbanks have lost their stability and thus, collapsed into the river while some have gradually developed into gullies due to bank encroachment, bank gullies and rainfall impact.

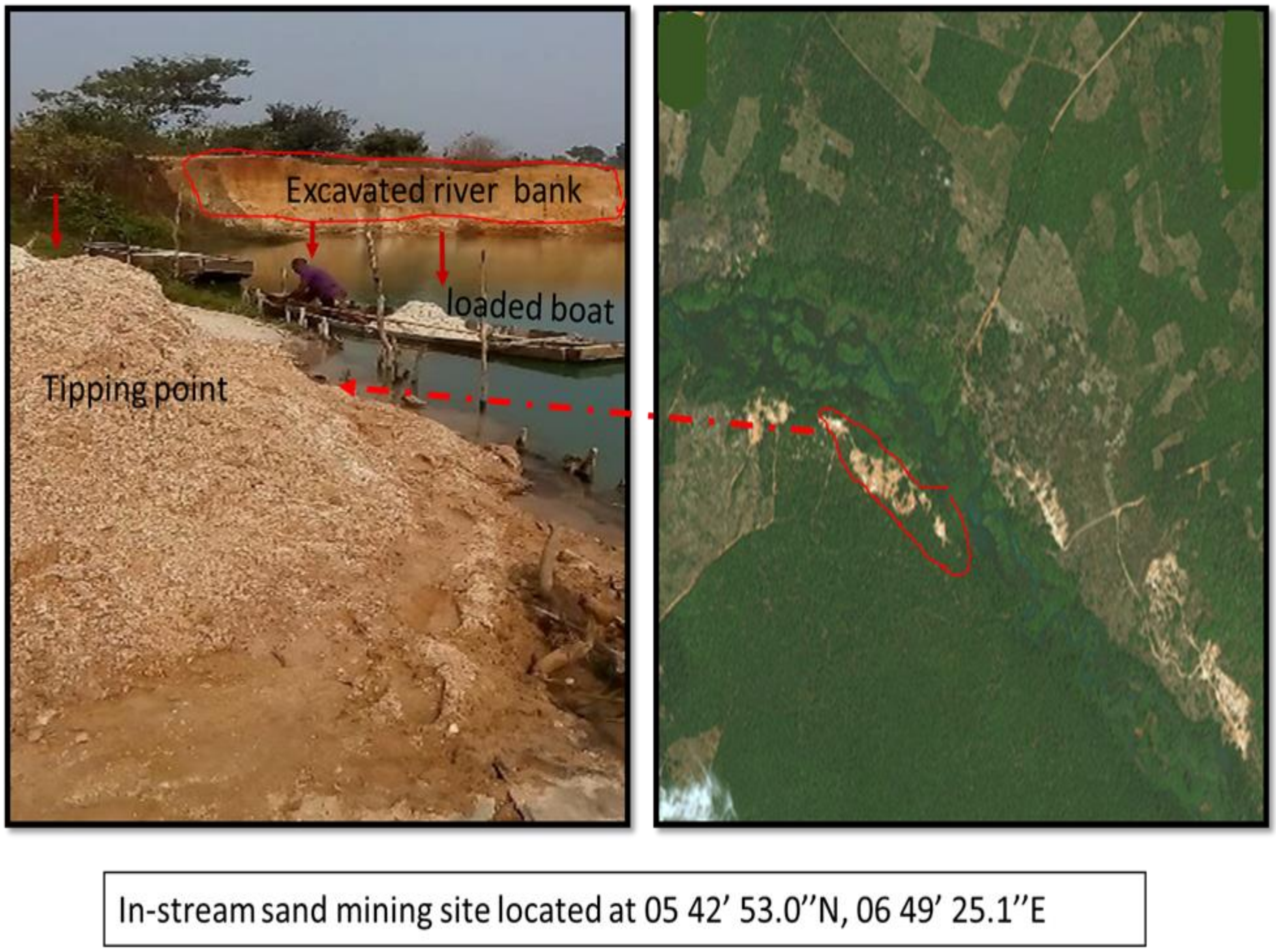


Figure 3-8 Remote sensing image and corresponding ground photo image of active in-stream sand mining In Oguta Lake watershed. Source: Field survey reconnaissance conducted on January 21, 2016

Unpaved roads were identified within several local roads and footpaths in the watershed. It is very common in a developing nation like Nigeria, especially in the rural communities. The unpaved road shown in Figure 3-9 (a) is particularly important in this research because it is used as a meeting and picking centre for the sand miners and a park for truck drivers, which provided opportunity to speak to sand miners in a group. In this research, unpaved road was categorised as a bare ground area for easy application in the models.

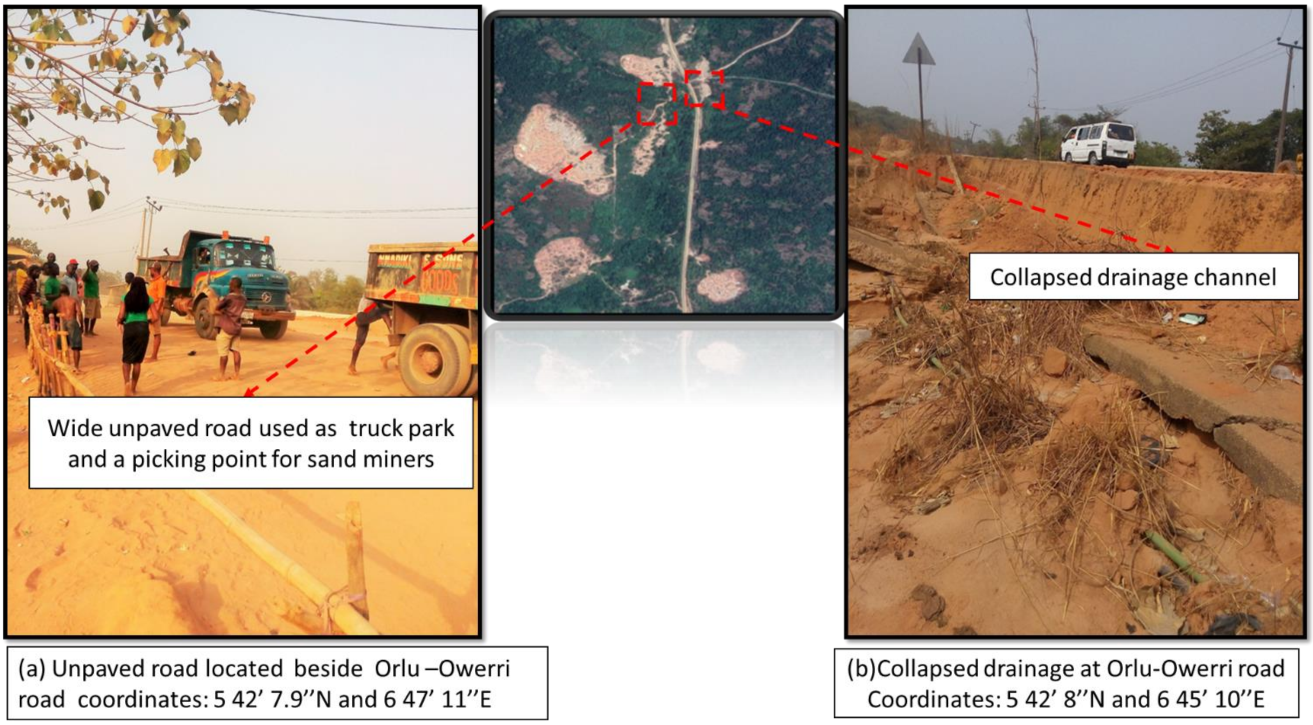


Figure 3-9 Remote sensing image and corresponding ground photo image of an unpaved road and a collapsed drainage channel in Oguta Lake watershed. Source: Field survey reconnaissance conducted on January 21, 2016

The limitations and difficulty encountered during data collection using this technique were spotting and accessing the erosion sites. Although the Google Earth and satellite images provided the coordinates of the locations, it was difficult to locate the actual spots in the field during fieldwork. However, landmarks such as highways, schools, rivers, and market nearest to these sites were used with the help of handheld GPS to locate the spots. Also, the 3-meter accuracy of the GPS used helped in searching and accurate location of the spots. Transportation to the erosion sites was a challenge as most of the sites do not have access road for cars. However, the motorcycle transport in the location popularly known as ‘okada’ was used to access the erosion sites.

3.6.3 Remote sensing method of data collection

The aim of Remote Sensing (RS) data collection technique was to collect land use and land cover data, DEM used as input parameter for soil erosion modelling and to perform dynamics analysis of land use and land cover. Landsat and Digital Elevation Model (DEM) data set were freely downloaded from (http: earthexplore.usgs.gov) as shown in Table 3.2 and Table 3.3. Prior to field trip to the study area, the Landsat-7 TM, Landsat-7 ETM+ and DEMs multispectral images acquired were set free from inherent distortion through satellite image rectification (Gao, 2008). For the purpose of long-term insight of erosion risk in the watershed, twelve (12) Landsat-7 TM and ETM+ during the period 1990-2014 and three (3) DEMs during the period 2006-2014 were obtained from the USGS. The imageries were processed using GIS 10.2.2 and ERDAS IMAGINE 2014 software in order to easily identify any features and coordinates (e.g. waterbodies, bares ground, road junctions, sand mining spots and gully spots) as referenced in Universal Transverse Mercator (UTM) map (Jones and Vaughan, 2010). To enhance the image quality, histogram equalisation technique was used to improve the colour display. Maximum likelihood supervised classification technique to ensure that images are converted to thematic land cover class. As explained in Lillesand and Kiefr, (2000), maximum likelihood classifier applies the probability of a pixel value to belong to a particular class through a scatter gram and classifier. This classification technique estimates means and variances of various classes, and thus, calculates the possibility of pixels falling into given classes. (Perumal and Bhaskaran, 2010). Geometric corrections analyses were processed in ERDAS 2014 software in an image format. After that, geo-referencing, mosaicking, and selecting of subset based on Area of Interest (AOI) were processed. Moreover, pixel signatures were assigned to satellite data set and the land area was differentiated into four main classes based on unique Digital Number (DN) value associated with different elements of landscape. The outlined feature groups observed were water body, forest and pastureland, bare and unpaved roads, and urban and cultivated lands as shown in Table 3.4. The classes were differentiated by adopting and assigning unique colour identity to a class. Spectral signatures were recorded using pixel enclosed their corresponding polygons. Thereafter, maximum likelihood algorithm on the images was applied using supervised classification techniques. This was done by subjecting data images to percentage area coverage for each class in GIS using the spatial analyst tool (zonal statistical table). In order to reflect the spectral reflectance and discriminate characteristics of materials on surface of the earth such as soil, vegetation, and water through raw image extraction (Fig 3-10). For example, Fig 3-11 shows a true colour composite (red, blue and green) of land cover image of Oguta Lake watershed, which was later classified using maximum likelihood classification in GIS. In addition, DEM was used to outline the boundary of the watershed, topography and the elevation of points in the study area at a given spatial resolution. Furthermore, the sub-basin parameters such as the flow direction, flow accumulation, stream features, stream network, and slope length were obtained from the Digital Elevation Model. The step-by-step approach used to develop, analyse, quantify and interpret the map are parented in Fig 3-12. The data set were used as input parameters in

RUSLE/MPSIAC modelling in Chapter 5, and for land use/land cover analysis of trends and change dynamics in Chapter 4.

Table 3-2 The details of Landsat bands used for this study for this study

Scene	path	Row	Acquisition date	sensor
1	188	56	01/08/2014	TM
2	188	56	10/08/2014	ETM+
3	188	55	05/08/2011	TM
4	188	56	14/10/2010	ETM+
5	188	57	13/11/2009	ETM+
6	188	55	05/10/2009	TM+
7	188	56	10/08/2009	ETM+
8	189	56	05/06/2005	TM+
9	189	55	05/07/2005	ETM+
10	189	57	06/07/2005	ETM+
11	189	57	01/05/1990	TM
12	189	57	05/10/1990	ETM+

Table 3-3 The details of DEMs, soil data and precipitation data used for this study

Data	Acquisition date
GTOP30	01/10/2006
SRTM 30	05//10/2014
Aster30	12/10/2007
WorldClim	15/12/2005

Table 3-4 Description of land use land cover classes

No	Land use / land cover class	Description
1	Water body	Land area that is occupied by surface water, it includes ponds, stream, rivers, lakes, open wells
2	Pasture and forest land	Land area covered by pasture grasses and dense natural forest it consists of mixture of indigenous bushes, trees species, and grasses
3	Urban and cultivated land	Sparsely distributed rural settlement with cultivated lands attached to households. Trees around homestead mangoes, bananas and oranges
4	Bare land and unpaved roads	Sparsely vegetated land area with very scanty vegetation on land surface. It consists of area that is highly vulnerable to soil erosion due to direct rainfall impact, such as unpaved roads and footpaths, and areas exposed by human activities.

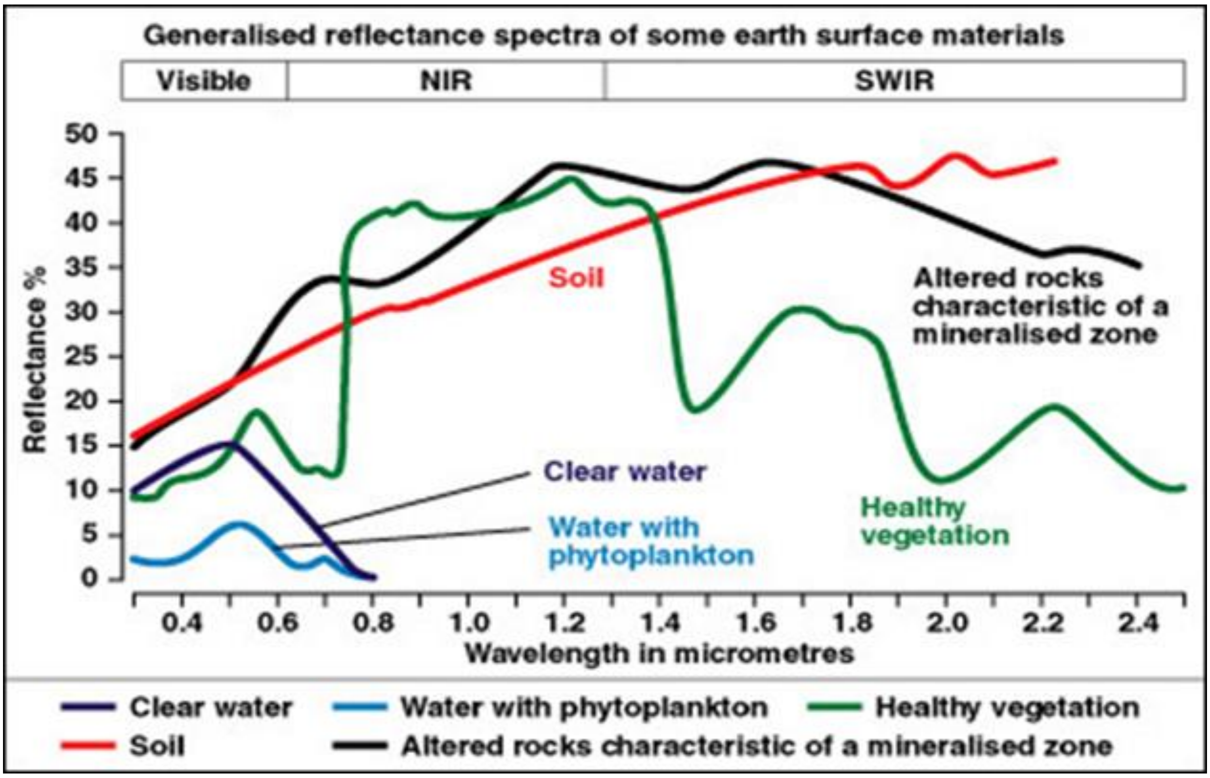


Figure 3-10 Spectral reflectance curves for vegetation, water, soil and altered rocks. Source: RSAC – Remote Sensing Applications Consultants, 2013

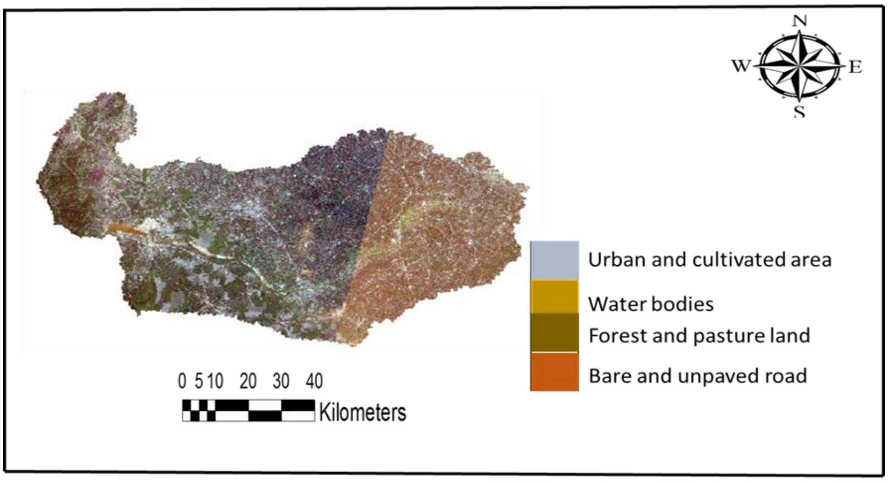


Figure 3-11True colour composite of Landsat-7-ETM+ showing the watershed boundary and Land cover classes. Source: USGS earth explorer

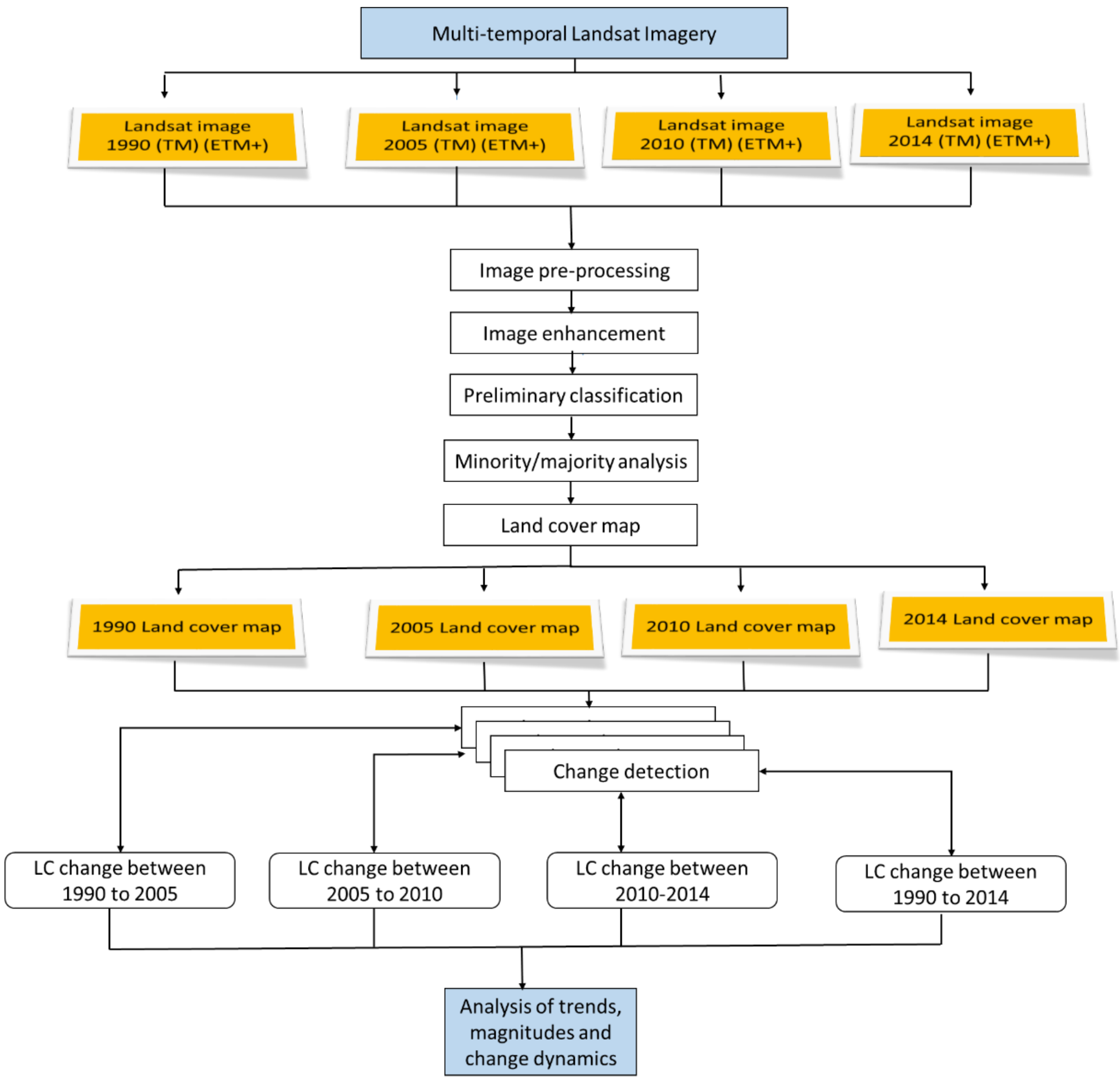


Figure 3-12 General methodology for the classification of land cover class

The secondary data (e.g., rainfall data, and river discharges, soil data and) were obtained from Imo State government and Ministries and Anambra-Imo River Basin Development Authority Nigeria. Digital soil data were obtained from United States Geological Survey website (https://www.usgs.gov). Rainfall data analysis showed that Owerri (the capital of Imo State) is the third most abundant rainfall city in Nigeria as shown in Fig (3-13)

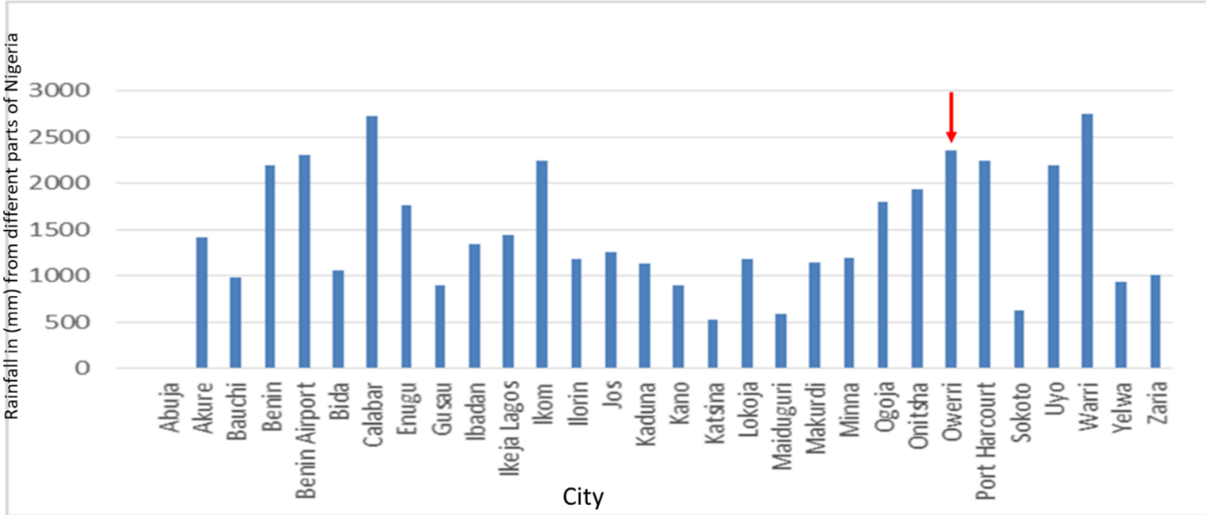


Figure 3-13 Annual rainfall from different parts of Nigeria
Source: Data collected from Anambra-Imo River Basin Development Authority Nigeria

The challenges encountered during this data collection technique were presence of unclear satellite images from the domain sites and administrative protocols of accessing secondary data from government ministries and agencies. These challenges were resolved through data enhancement using both GIS and ERDAS IMAGINE. The cloud covering the satellite images was reduced after the data enhancement operation. A letter of introduction with Newcastle University official letterhead from the supervisory team requesting for access and data from the relevant ministries and agencies eased the administrative protocol of accessing secondary data.

3.6.4 Data collection based on lake sediment coring

The aim of this research was to collect data for verifying the modelled results and check for evidence of erosion upstream of the lake through sediment core description and analysis. The sampling fieldwork started after meeting with Dr.Regnald of University of Nigeria, Nsukka, who assisted in bringing ideas on how to construct a corer locally. Because of lack of information on Oguta Lake bathymetry, sampling locations were selected based on the research purpose and features of the lake. A 9m long by 50mm diameter carbon galvanised round hollow steel coring device was constructed locally by J.P Welding Services in Nigeria. The coring device is made up of four members tightly joined by connections and a plastic pressure tube of 1.7m long by 40mm diameter was gently inserted into the mouth of the coring device for the purpose of retrieving the core samples as shown in Fig 3-14. Both ends of the plastic tube were covered with light balloon material to prevent water from entering the tube during penetration. The coring was done on two boats joined together side by side by wood connections. To enhance stability, the boats were anchored with two 25 litre gallons of water connected with marine rope and dropped on the lakebed. The coring was done by hammering and continued until no further penetration and retrieved gently by pulling from both boats. Samples were collected after several field trials at the shallow section of the lake and corrections were made accordingly. The field observations showed that the lake has varying depths at chosen sampling points as there was no bathymetric survey information, except the knowledge of the depth of deepest section of the lake, prior coring expedition. Therefore, before sample collection, the depths of the sampling points were measured using a calibrated wooden tape and recorded in a field record booklet. Duplicate cores were retrieved from each sampling location to provide additional sediment for multiple analyses if needed, and also as a backup in case of any damage during transportation or storage. In total, four sampling points were selected as shown in Fig 5-15. Two (2) of the sampling points (core 1 and core 2) were collected on August 11, 2016 at the discharge points of Njaba River and Awbana River at the depth of 5.8m and 6.2m. This was to enable the investigation of the impact of human activities on erosion in their respective watersheds. The second two (2) sampling points (core 3 and core 4) were collected on August 12, 2016 at the delta region in the middle of the lake and at a point further downstream of the lake at the depth of 7.6m and 7.8m respectively. This was to check the impact of the delta region on the sediment, and the possible changes on the sediments as they move downstream. The collected sediment core samples were of varying lengths and colours due to the penetrating capacity of the corer at different sampling locations (5.8m, 6.2m, 7.6m and 7.8m). The sediment cores collected at both Njaba River inflow section and Awbana River inflow section were light coloured and comprise mainly of white sand. On the other hand, the cores collected at the centre of the lake are dark coloured and comprise mainly of clay particles.

The plastic tube containing the core sample was pulled out gently from the coring device and then, thereafter, the mouth of the tube was covered again with balloon material. This procedure was repeated for all the sampling stations and the samples were transported and stored temporarily in a refrigerator at the Federal University of Technology laboratory.

The core samples were later transported to Newcastle University for further storage and analyses. The cores were first tested for magnetic susceptibility by scanning the samples in Whole Core Scanning Sensor (MS2C). The aim of this magnetic susceptibility test was to investigate core sedimentation pattern and possibly link it with the physical characteristics of the sediment core, as well as the activities in the watershed. The major focus on the core sedimentation pattern was the peaks annotated with “T”, which represent transitions and changes in sedimentation. To further describe the physical characteristics of the sediment, the cores were split into two equal half, and one portion was saved for further analysis. The cores were described based on colour and texture to correlate them to each other, and to the environment. And most importantly, to establish evidence of erosion and land use activities in the watershed. In addition, the average length of the core samples was used to estimate the sedimentation rate in the lake, which was compared with the modelling sedimentation rate result.

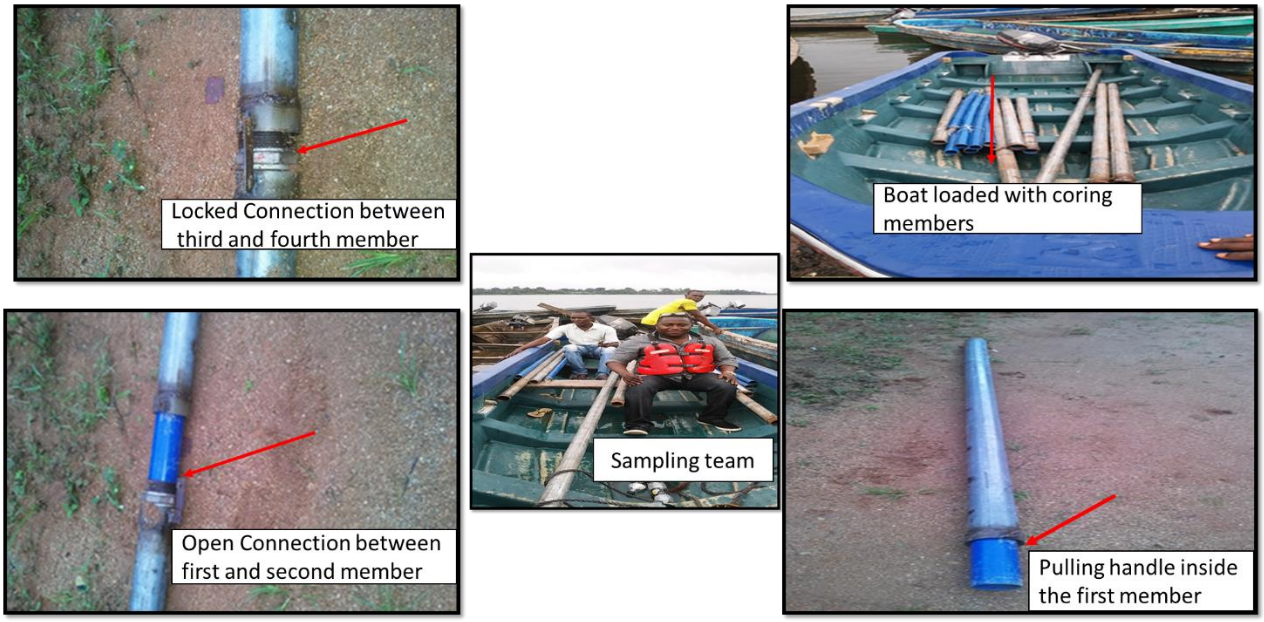


Figure 3-14 Coring members showing method of connections and the sampling team

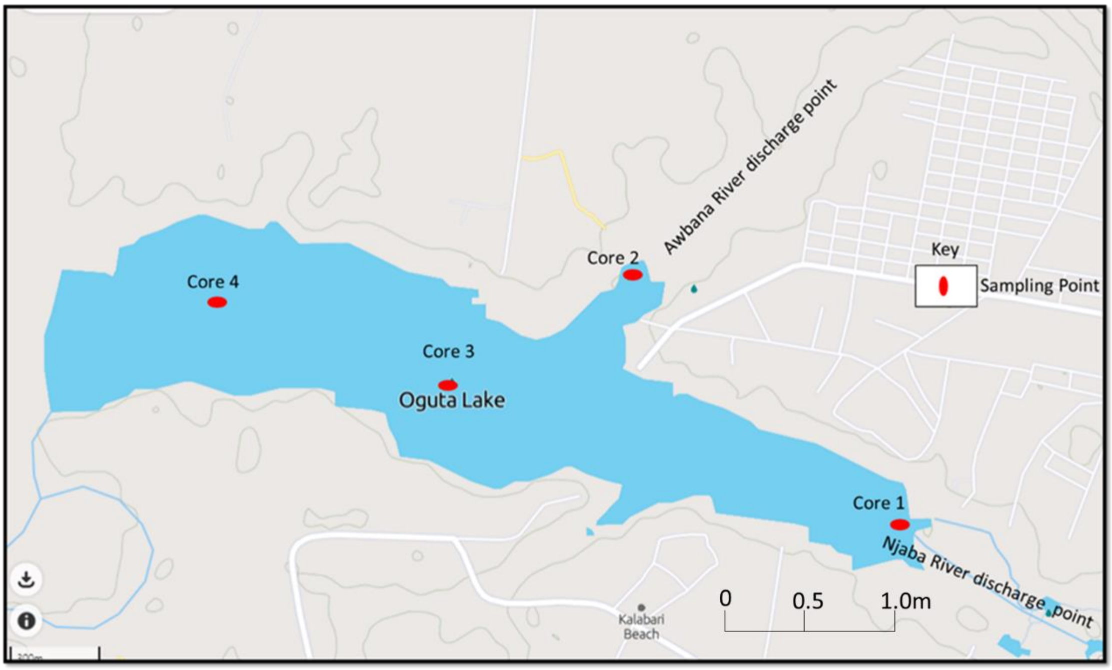


Figure 3-15 Oguta Lake sampling locations. Source: Google Earth

The challenges encountered during data collection using this technique were construction of local coring equipment, transportation and storage of core samples as well getting access to the lake. In order to resolve these challenges, the researcher and Dr. Reginald brainstormed on how to construct corer locally and met with J.P Welding Services with design of a potential corer. After the meeting, the corers used were constructed after two trials versions were tested for efficacy and corrections applied accordingly. The core samples were securely transported in a car boot and stored in the refrigerators at the Federal University of Technology Owerri to provide optimum temperature as well as maintain the core quality. Also, access to the lake was granted for coring after submission of the letter of introduction to the local government authority and meeting with the local government chairman and Marine Police at the lake.

3.6.5 Data collection based on focus group discussion and semi-structured interview

In this research, focus group discussions and semi-structured interviews were conducted to have a deeper understanding of the social orientation of soil erosion issues and the historical trends of land use changes in the study area. The interviewees were selected after extensive stakeholder mapping.

They were conducted in three stages: (1) the pre-interview stage; (2) the interview stage; (3) the post interview stage.

The pre-interview stage:

- The interviewees were contacted to confirm the appointments.
- The interview guide was reviewed
- The interviewer arrived ahead of the scheduled meeting time and waited for the interviewees

Interview stage:

- The interviewer chatted with the interviewees to reintroduce the purpose of the interview in order to reconfirm their consent.
- The interviewer made sure that the time frame for each question was maintained.

The post interview stage:

- The records were checked and collated.
- Thank you, message was sent to the interviewees.
- The key points raised by the interviewees were identified.
- The data set were transcribed using NVIVO software.

Following the stakeholders identified during the literature search, some adjustments were made based on field observations to enhance a representative data. The researcher observed that community chiefs and elders (traditional leaders) have huge custodian influence on the community management and there was need to include them as separate stakeholders. This group of stakeholders also served as gatekeepers to other community participants who are less educated. Before the participants for semi-structured interviews and focus group discussions were recruited in this project, proper ethical guidelines were strictly adhered with special reference to consent and confidentiality.

3.6.5.1 Consent

Consent gaining is the first step towards a potential participant. The issue of consent was the first step towards recruiting target participants and this was achieved through a proper explanation of the research aims and objectives via the project information sheet. The consent forms were distributed to the target participants directly with special emphases on their voluntary participation and their rights to withdraw from the projects any time during the project duration. Some less educated participants that accepted verbal consent during the researcher's recruitment explanations but later declined to sign the consent form because they believed that signature is only required from someone during land exchange. Such category of participants withdrew voluntarily from participation and more participants were recruited based on their voluntary participation and consent.

3.6.5.2 Confidentiality

The confidentiality of the data and anonymity of participants' identities were extensively discussed with participants prior to their involvement in the research. In addition, the confidentiality issue was cited in the consent form to ensure that the participants have document that reflects such agreement which could be enforced if abused. The participants will not only be informed of the outcome of this research but will also be informed of the possible dissemination of information from the research. Debriefing was one of the major component parts of the consent form signed and was strictly observed at the end of the project.

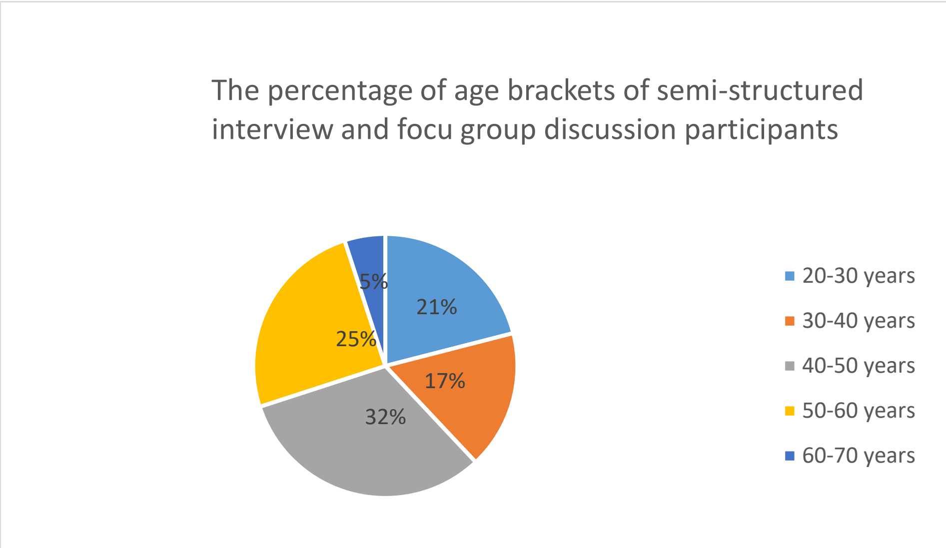
3.6.5.3 Sampling

Non-probability sampling techniques was chosen because there is no existing sampling frame which could suggest a probabilistic sampling option. Non-probability sampling provides a wide range of alternative judgements based on selecting cases linked with both purpose and reasons. Even though, there are numerous non-probability purposive sampling options such as theoretical sampling, extreme case sampling, and critical case sampling, however, this research adopted heterogeneous purposive sampling technique. This means selection of participants with diverse occupation, roles, gender and interest like farmers, sand miners, traditional leaders, government officials and household, based on the researcher's judgement to provide maximum variation in the data collected. This sampling approach significantly assisted in describing and explaining the key themes that emerged from the data. Participants were selected after analysis of potential stakeholders based on their occupation and interest. Interviewees were informed that their participation were voluntary and based on potential contribution to soil erosion management. At the local level, the researcher ensured that both men and women participated on focus group discussions and interviewees to ensure a better data quality and representation. However, there were more official male participants than female because of apparent gender inequality and discrimination against women in the study location. Women are poorly represented on key government positions, and thus a few women participated at this level (see Appendix B-1 and B-2). In addition, stakeholders were selected based on their background, experience, interest, influence, roles, responsibilities as well as their eagerness to participate and officially represent their organisation's views in managing erosion in Imo State, South East Nigeria. Additionally, the age bracket of the participants ranged from 20-70 years old to ensure that participants are adult who are knowledgeable enough to address soil erosion issues. The breakdown of the age brackets and gender of the participants are shown in Fig 3-16 and Fig 3-17 below. Even though women engage massively in agricultural activities; they are not eligible to contest for traditional leadership in the community. Also, sand mining is often regarded as male job and, thus, it is a male dominated profession in the study location.

Meanwhile, women are actively engaged in various environmental activities like collection of firewood and forest products as well as grasses for farm animals. Most of these activities also take place in sand mining sites simultaneously, however, integrating women as part of this stakeholder would potentially yield a more robust information on the impact of these activities on soil erosion. In addition, women maintain and run families, and are always domiciled in the villages more than their men counterparts, their representation in this type of stakeholders would provide a better historic view of sand mining activities in the study location since most sand miners are youths. For example, a local resident woman provided the information below during an interview:

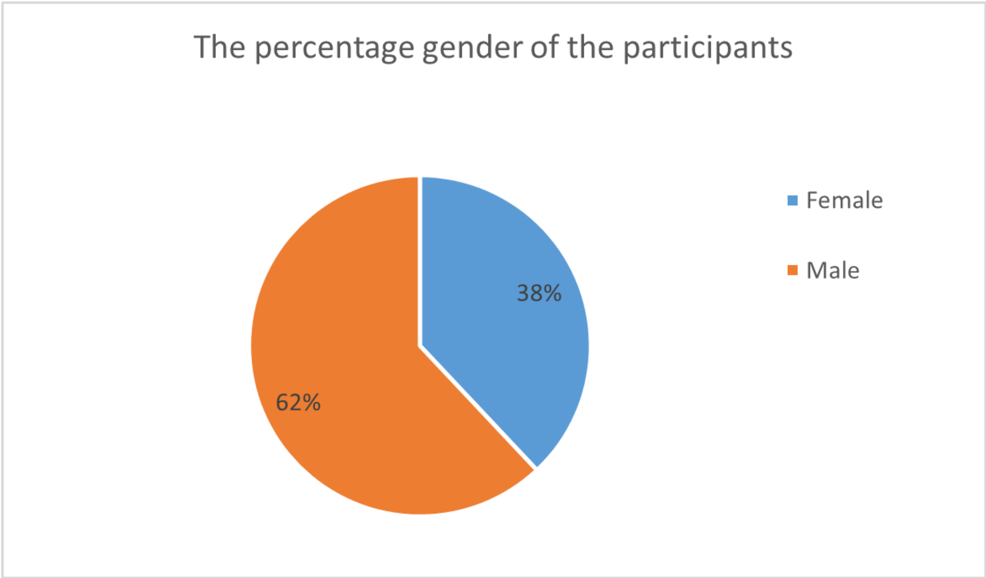
> *''I came to live here in 1980 with my husband, this place was like forest with few scattered residential buildings, but children of this community grew up and started building houses and farming intensively. I think, that is why today, we are facing problems of soil erosion and land degradation in our farmlands and homes''*

The information in the quote above is very vital when searching for historic view of soil erosion which will help in future management decision making. In addition, it is a culture in Igbo land (South East Nigeria) women are more connected to domestic affairs than men, however, not recognising their presence or participation in key decision making could lead to incomplete data. For example, women are dominant in farming activities in the study area, thus, their contribution regarding the impact of farming to soil erosion is vital. Fig 3-18 below shows key human activities in the watershed and their potential benefits and impacts on soil erosion. . Observation showed that most of these activities are carried out by local people in their bid to make a living regardless of the environmental consequences. Even though these activities (deforestation, sand mining, grazing, crop farming) provide means of livelihood to most local population, they contribute significantly to soil erosion, food insecurity, landscape destruction and bare ground surface in the watershed as shown in Fig 3-18 below. For example, sand mining generates income and employment to the youths in the community, but its activities reduce land available for farming and increase soil erosion watershed. Similarly, tree logging (deforestation) for forest and firewood generates income and employment for the local population, it leaves the soil surface vulnerable to soil erosion and destroys the landscape.



N = 44

Figure 3-16 The breakdown of the percentage of the age bracket of the participants in semi-structured interview



N = 44

Figure 3-17 The breakdown of the percentage gender of the participants in semi-structured interview

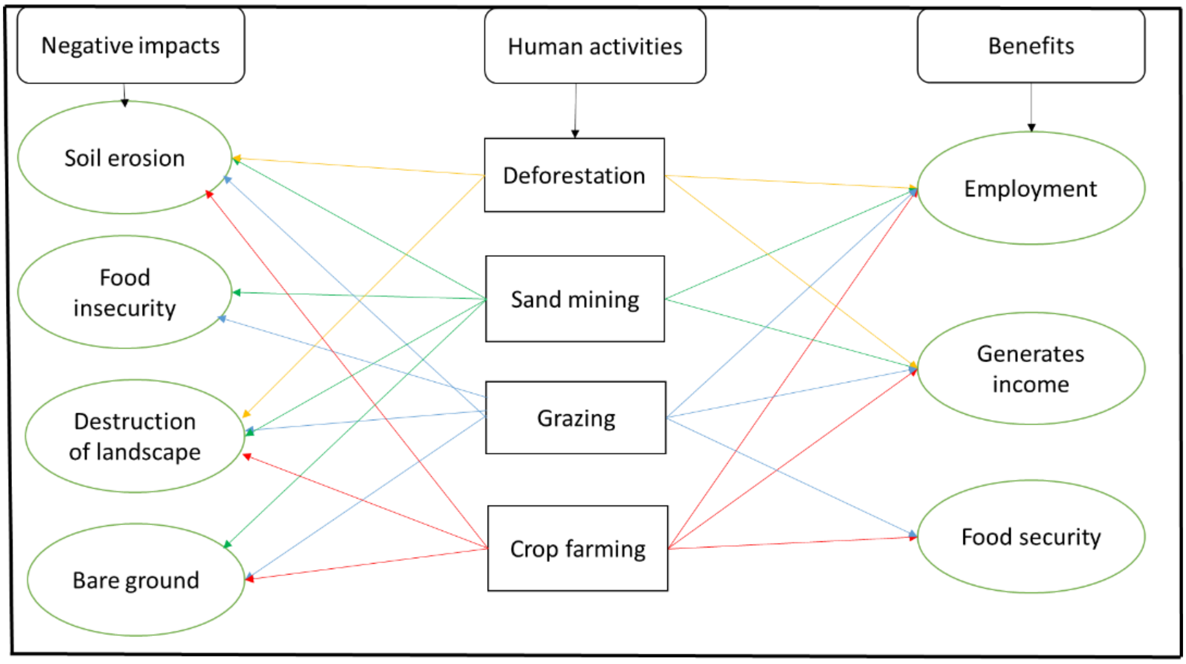


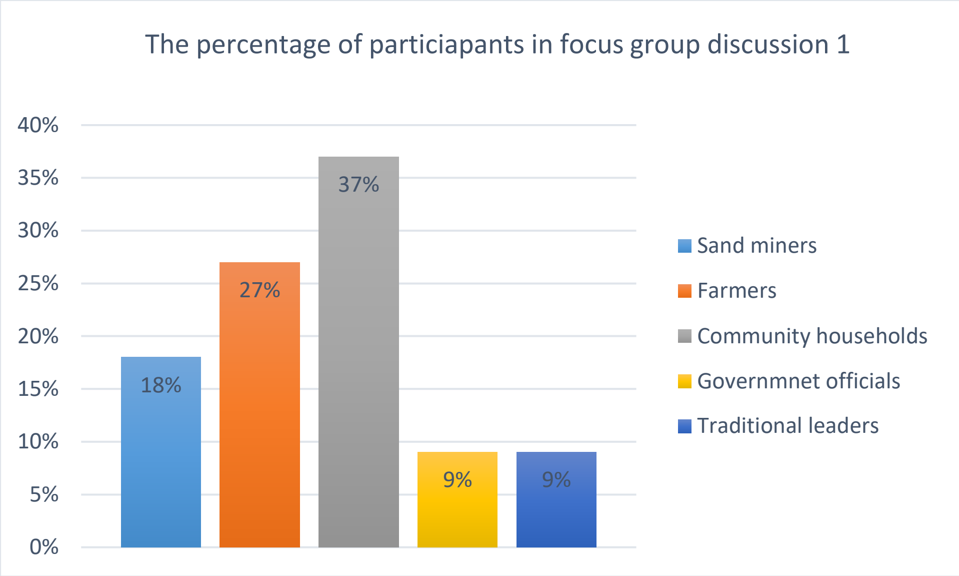
Figure 3-18 Analytical structure of key activities on ground and their potential impact on soil erosion.

There were basic questions which helped in selecting various stakeholders' groups such as who causes erosion? Who manages erosion? And who is affected by erosion? The answers to these questions gave rise to selections of participants from various stakeholder groups such as sand mining operators, farmers, traditional leaders, community households and various government organisations responsible for regulating and enforcing erosion issues in Nigeria. However, in this research the stakeholders that are classed as community households are members of the community that are neither farmers nor sand miners. All the farmers and sand miners that participated in the research are members of the community and households but with special stake as farmers and sand miners in the research. However, their responses were kept open, though, their interviews were based on their roles and interests. This approach aided a proper understanding of the wider view of the subject while maintaining the focus of the research. The focus group took place in the communal village square after approval from the community elders.

3.6.5.4 Focus group discussion

Because of diverse social orientation of erosion in Nigeria, focus group discussion was chosen as one of the methods of data collection to obtain the views and perception of various stakeholders. Puchta and Potter (2004) stated that focus group comprise two key elements: the participant's perception about the research topic and the moderator focused on how to discuss the perception. It is informal discussion of topic among selected group of participants (Wilkinson, 1998). This approach focuses on open interactions and perception sharing among the selected participants in a very conducive environment (Krueger and Casey 2009). This approach is unique when compared with other approaches, in this method, the participant's interactions and responses are welcomed and often guided ensure focus is maintained. In addition, participants are selected based on their expert knowledge and characteristics that links them to the research topic. The participants are often encouraged to share their unbiased views without coercion to any form of target result. Normally, several discussions are conducted with similar participants to allow trends and patterns to emerge during data analysis.

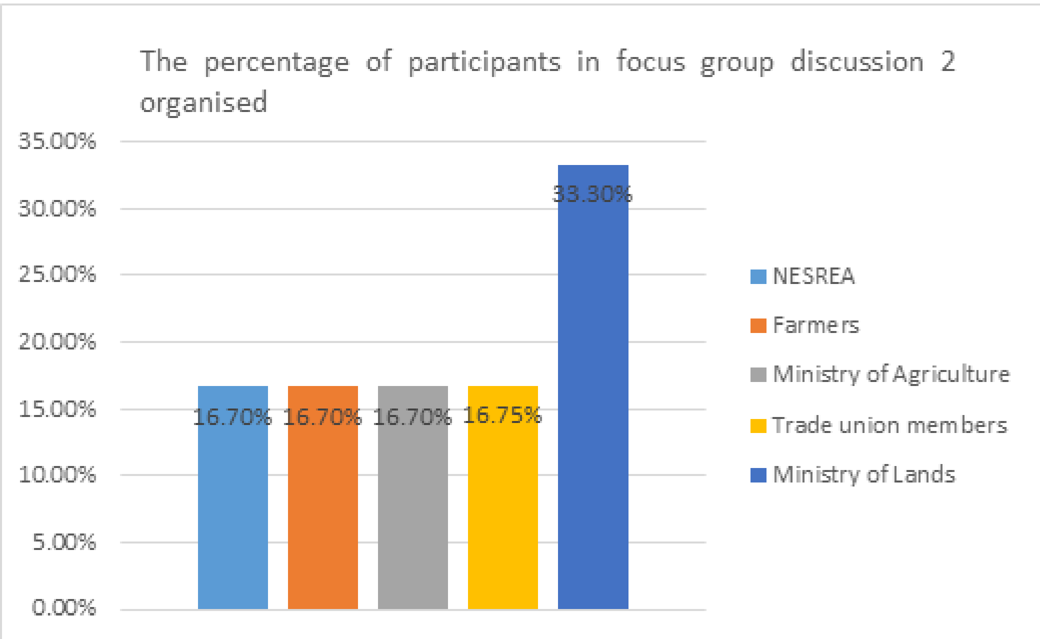
During the research, the researcher moderated the focus group discussions to make sure the groups discussions were kept within the boundaries of causes, effect and management of soil erosion in Nigeria. This is because there is no trained moderator in the study location and there was no resource to travel with a trained moderator from UK and no time to train one during the fieldwork in the study location. In addition, the researcher engaged participants in meaningful discussions and guided the discussions towards data that helped in answering research questions but did not influence the outcome of the group's opinions. The first focus group discussion was conducted during the first fieldwork in December 2015 while the second focus group discussion was conducted during the second fieldwork in August 2016. The data obtained from focus group discussions were notes taken by the researcher (facilitator) as the discussion continued. It was impossible to bring all the stakeholders together for a single focus discussion due to distance barrier and the location of the study site. Thus, one focus group discussion was conducted in the local community popularly known as village square while the second focus group discussion was conducted in the city (Federal Ministry block) in order to eliminate distance barrier and the cost of transportation for the participants. This split arrangement provided opportunity for wider understanding of the social erosion issues and the way they interact. The aim was to engage different groups of stakeholders in an informal discussion about soil erosion and its causes in the study location. The participants were recruited strictly by invitation using the information sheet, consent form (see section 3.6.5.1) and the gatekeeper. Emphasis was laid on their voluntary participation and their right to withdraw at any time during the research. To avoid any form of coercion, the aims and objectives of the research and as well the confidentiality of the information they provided were well explained in the information sheet prior to their recruitment. The gatekeeper recruited in the research is informal and has no special hold on the participants. It was necessary to engage gatekeeper who is more educated and has a better understanding of what research means as well as in a better position to engage the hard-to-reach participants. This group of participants have trust issues with government; however, they perceive such invitation as an attempt by government to grab their indigenous lands. The gatekeeper served as a route to accesses participants who always have trust issues with government. Prior to gatekeeper's involvement in the research, their extent and limit of involvement was discussed and agreed with the researcher. This was to avoid influencing the information the participants will provide. Most importantly, to avoid dictating or influencing the direction the research will take by the gatekeepers. On the other hand, their participation brought access and trustful relationship between the researcher and participants. The focus group one (1) comprises eleven (11) participants, two (2) sand miners, three (3) farmers, four (4) community households, one (1) government official and one (1) traditional leader. The percentage of the participants is shown in Fig 3-19 below.



N = 11

Figure 3-19 The percentage of the participants in focus group discussion 1

The focus group two (2) comprises six (6) participants, one (1) senior staff from the Ministry of Environment; one (1) senior staff from the Ministry of Agriculture; one (1) farmer; one (1) trade union member; and two (2) senior staff from the Ministry of Lands. The percentage of the participants is shown in Fig 3-20 below.



N = 6

Figure 3-20 The percentage of the participants in focus group discussion 2

It was important to include senior government staff members in the group in order to harness their management experience. The researcher took part during the discussion as the facilitator, providing information about the research purpose and engaging the participants meaningfully while ensuring that the discussion does not slip- off the research objectives.

3.6.5.5 Conducting semi-structured interviews

Semi-structured interview was considered most appropriate for this research to allow flexibility in questioning during interview. In addition, it integrates the social–cultural and regulatory dimensions into the research by selecting participants from diverse stakeholders (different gender, occupations, roles and interest). This interview techniques offers unique flexibility to predetermined questions modification as the researcher deems appropriate. According to Robson (2002), this technique allows wording to be changed, particularly when the researcher view it to be inappropriate. This was to explore more information and better explanations from the interviewees in relation to the research questions and objectives. Semi-structured interviews were conducted to integrate the social-ecological, cultural, organisational, and regulatory dimensions in understanding management of soil erosion. This technique was selected mainly because it allowed for flexibility and modification set of original questions based on the researcher's discretion and perception. The flexibility in questions across various interviewees enhanced data quality (Robson, 2002) and provided opportunity to obtain large amount of relevant information about the knowledge/experience of the respondents by direct questioning in relation to the research objectives. It did not only provide opportunity for the participants to express themselves via spontaneous questions but also provided opportunity for a more relaxed atmosphere for conversation. Furthermore, literature information on the use of semi-structured interview strengths and weaknesses were obtained from Denzin and Lincoln, (1994); Coffey and Atkinson, (1996) and Warren, (2012). Even though, a wide range of data collections options exist, semi- structured interview offered a better opportunity for participants to provide their views in an unbiased way as it relates to the issue under discussion (King, 2004).The interviews were conducted in accordance with the pre-planned questions and intermediate prompted questions based on the participants' responses. Most interviews were conducted in people's homes, offices, workplace and fields. The length of time spent on the interviews varied depending on the circumstances for the session, on the average, the interviews lasted for 40 minutes to 1hour per session, although the original plan allocated per session on the template was a little bit less than the actual time spent (see appendix B). The aim of the interview's sessions was primarily focused on the history of erosion, causes of erosion, impact of erosion menace and management of erosion to enhance a wider understanding of the watershed processes in the context of soil erosion. The interviews were conducted using English language, Pidgin English and Igbo local language. There was no language barrier during interviews as the interviewees were asked to choose the language of their choice because the researcher is very proficient in the use of the three languages (English, pidgin and Igbo language). The absence of any interpreter enhanced smooth conversion, and the face-to-face approach enhanced naturalness, rapport, comprehension, interest, and attention (Irvine et al., 2013). The face-to-face approach also helped in deep understanding of gestures, body languages in exploring issues. In the first trip to Nigeria, a total of 20 interviews were conducted while in the second trip to Nigeria a total of 24 interviews were conducted as shown in Fig 3-21. The percentage of the participants in semi-structured interview is shown in Fig 3-22 below. Some of the interviews were recorded in the form of audio and while some were written text as some participants were not comfortable with audio recording. Some interview records were transcribed using NVIVO software while some non-English interviews were directly translated in English by listening to the audio recordings directly. Translation using NVIVO offered the advantage of both listening to the interviews several times and pausing at intervals to make notes as the interviews progressed. The data obtained from semi-structured interview formed the basis for the analysis in Chapter 7 and Chapter 8 respectively.

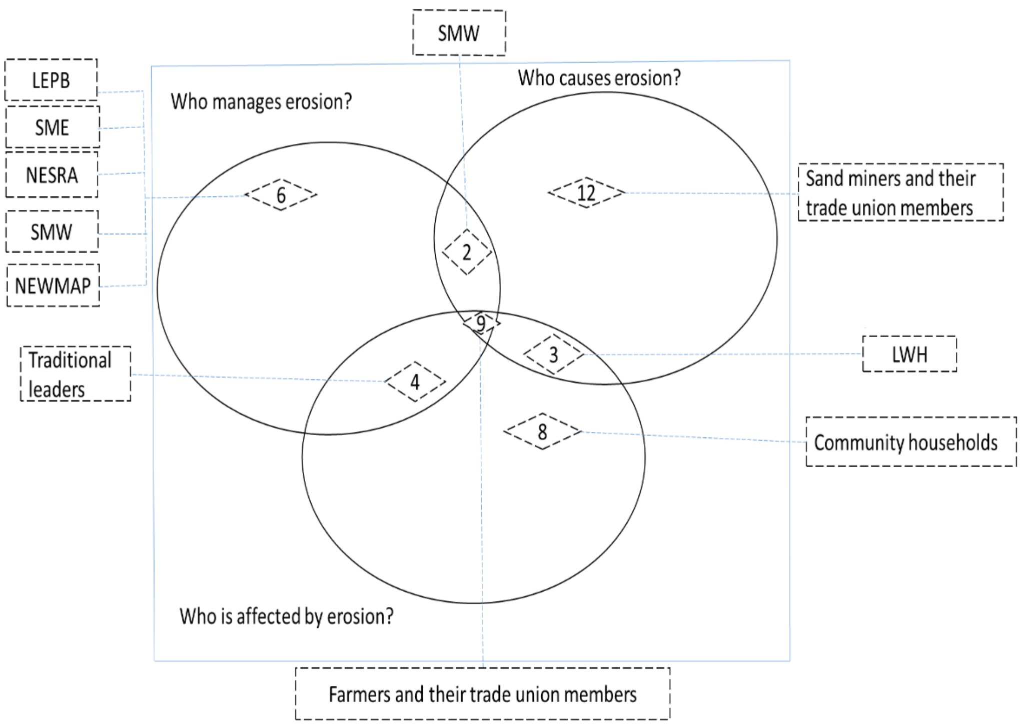


Figure 3-21 The number of participants selected from a spectrum of stakeholders responsible for soil erosion management in the study location.

Where:

NEWMAP = Nigeria Erosion and watershed Management Project

SME = State Ministry of Environment

LEPB = Local government Environmental Protection Board

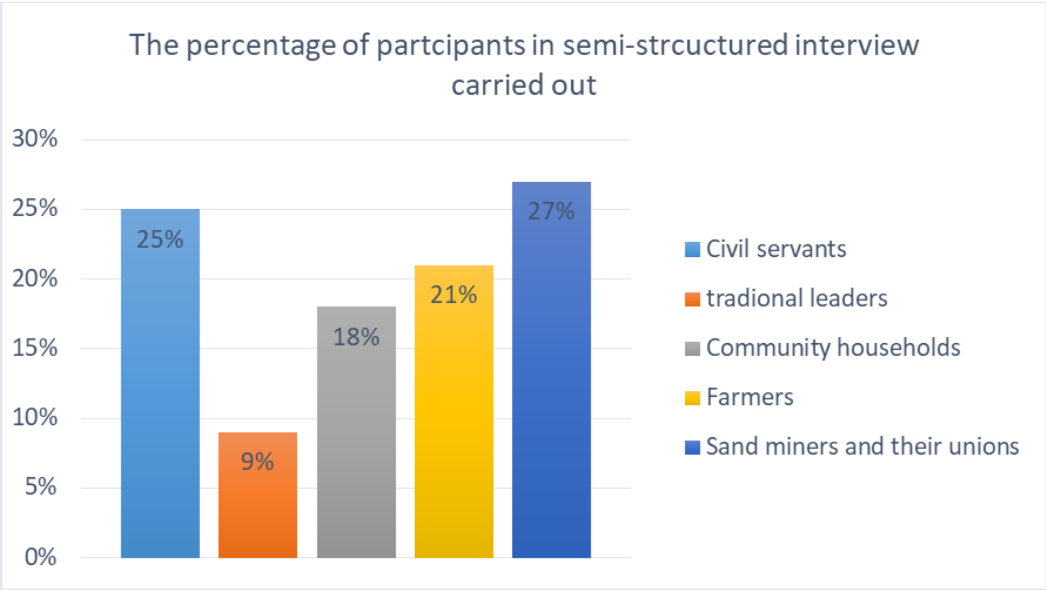
SMW = State Ministry of Works

SMW = State Ministry of Water Resources

NESRA = National Environmental Standard Regulation Agency

LWH = Local Government Works and Housing

The Number 9 in Fig 3-21 represents the number of farmers and their union members while the number 2 State Ministry of Works staff members who participated in the research. Farmers and their union members participated in triple capacity; it was important to highlight the importance of the input from this group of participants. This is because poor farming activities could cause soil erosion, farmlands are affected by soil erosion, and good farming activities could as well control erosion. Their input was very vital in this research. On the other hand, Participants from State Ministry of Work was participated in dual capacity, both as cause of soil erosion and as possible soil erosion prevention techniques. This is because it was observed during field reconnaissance survey that most drainage works were poorly terminated, consequently, that triggered gully erosion in most sites. However, a properly constructed drainage channels prevents erosion by conveying runoff water to the designated locations without causing erosion. It was important to have input from this group of participants.



N = 44

Figure 3-22 The percentage of the participants in semi-structured interview carried out

The limitations and challenges encountered during the interview processes were as follows: Travelling to the case country, time consuming nature of recruiting participants as well as seeking consent, suitable places for conducting interviews and long interview time, explanation of confidentiality and anonymity of the data, data management and storage. These challenges were initially envisaged and dealt with through proper planning of journeys, use of gatekeeper, prior visitation of the location before the main interview, allocation of time for each interview, access to the interview location, and proper explanation of data confidentiality and anonymity. In this data collection technique, the following challenges were encountered during the interviews, translation and transcribing and were dealt with as follows: Firstly, the language barrier was eliminated by the researcher's proficiency in the three languages commonly used during the interview (English, Pidgin and Igbo language). Igbo Language was particularly helpful during the interview with the local villagers because many of them don't have formal educated and do not understand English language. However, the researcher's proficiency in the three languages used aided the translation of Igbo and Pidgin to English language. Also, the use NVIVO software also aided the transcribing of audio records. The transcribing and translation of audio records offered advantage of listening to the records for couple of times as well as advantage of the use of pause and play option whenever unclear voices arise. However, some participants turned up late for the interview and focus group discussion, but the researcher was patient and used the opportunity to chat with those that turned up on time. It was a bit time consuming to listen several times to the audio recordings but it enhanced data familiarisation.

3.7 Data analysis processes

Data analysis processes of implementing the result chapters of this thesis are explained in brief in this chapter. Further analysis description has been included in each result chapter. Data analysis processes estimating soil erosion rate in RUSLE-GIS model and MPSIAC- GIS model as well as the processes of generating a spatial distribution of erosion risk map from both models are detailed bellow. In addition, data analysis processes of effect of change in bare ground area in the watershed (future scenarios analysis) and data analysis of interviews and focus group discussion.

3.7.1 Data analysis processes of estimating soil erosion rate in RUSLE

The six controlling factors in RUSLE including rainfall-runoff erosivity, soil erodibility, slope length, slope sleepiness, cover management, and supporting practice were used in this study as shown in Fig3-23. In this research, a simple empirical relationship between the yearly average erosivity index (Ram) and the corresponding annual average of rainfall amount (Ham) for tropical West Africa region was used (Roose,1977). This relationship has been verified in over 20 rainfall recording stations in West Africa and is enough to permit the use of the Universal Soil Loss Equation (USLE) in West African countries (Roose,1977). In this research, the rainfall data for Imo State from 2005 to 2015 was used to compute the erosivity index. Rainfall erosivity map was computed based on the distribution of rainfall in the rain gauge stations across Oguta Lake watershed using kriging tool in GIS. This regression approach is supported by previous research that has demonstrated relationship among rainfall variables and slope using regression (Boer et al., 1993; Meusburger et al., 2012 and Mello et al., 2013). In this research, there were no direct field data collections and measurements of soil properties because of the time scale and financial resources required to accomplish it. Therefore, the secondary data used in this study were the soil erodibility data which were collected from the Ministry of Land and Survey (MLS), Imo State, Nigeria and the digital soil data set from the United States Geological Survey website (https://www.usgs.gov). The soil erodibility was computed for the entire state using the soil erodibility nomograph method and was then extracted in the GIS environment using extraction by mask tool. LS factor was computed based DEM with 30m spatial revolution. The DEM was digitally generated from the United States Geological Survey website (https://www.usgs.gov**)** and was extracted using extraction by mask tool in GIS environment. The DEM was the key input parameter for estimating various hydrological parameters such as filling, flow direction, flow accumulation, stream features, and stream order and basin shape. The flow direction and accumulation were used as key input variables in computing both slope steepness and slope length using slope analysis tool in GIS. In this study, a supervised image classification of maximum likelihood was used to classify land use/land cover of the watershed using the RUSLE guide table. The Landsat TM imagery (path/row: 188/56) acquired in August 2014 (rainy season) was used to generate the C factor layer for Oguta Lake watershed. The image acquired during the rainy season was used because erosion potential is likely to be maximum during the rainy season and minimum during the dry season, which means images acquired during the dry season may introduce discrepancy in results that may not suit management decisions. In the study location, there was no specific conservation support practice established because most farmers cultivate different parts of their land with different crops in the communal farmlands. The ‘P’ values that were applied in this research ranged from 0.5 to 1, which reflects the conditions in the watershed such as ridge contour, mould farming, and fallow condition as stipulated in USLE guidelines. The most common and widely used conservation practice used in the watershed is ridge contour.

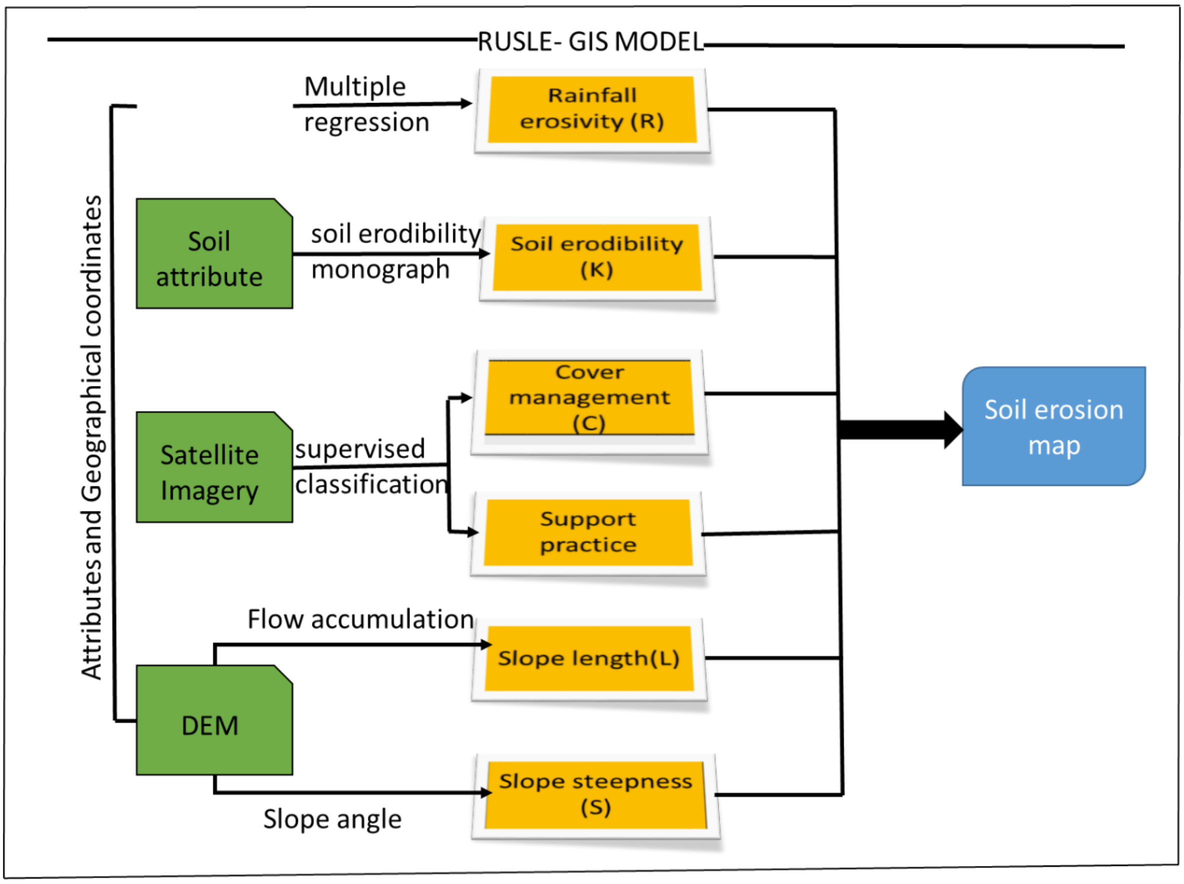


Figure 3-23 The Processes of estimating soil erosion rate using the six controlling factors of RUSLE model.

3.7.2 Data analysis processes of estimating soil erosion rate in MPSIAC

The model parameters were initially determined by ranking scores based on physical description of the watershed. However, the subjectivity of factors ranking became a cause for concern, and Johnson and Gembhart (1982) converted the descriptive concept of the first model into numerical amounts by assigning mathematical empirical relationship equations to each of the nine factors in MPSIAC model. In this model, the soil erodibility value in USLE is used as an input parameter in the soil factor equation while annual runoff volume and stream peak discharge were used as input parameters in the runoff factor equation. The nine factors include: Surface geology (Y_1), soil (Y_2), climate (Y_3), surface runoff (Y_4), topography (Y_5), land cover (Y_6), land use (Y_7), surface erosion (Y_8) and channel erosion (Y_9) are shown in Fig 3-24. The total soil erosion is the sum of nine factors in MPSIAC model. However, Johnson and Gembhart (1982) introduced interpolations and extrapolations to control the equation in order to improve the accuracy of the model as follows. Where the parameters X_1- X_9 in Fig 3-17 are as follows: X_1 = surface geology erosion index, X_2=soil erodibility factor, X_3=6-hour rainfall with a 2-year return period, Qp= specific peak discharge (m^3/s.km^2) (i.e. flood peak discharge) R=annual runoff depth (mm), X5=percentage of the average basin slope, X_6=percentage of land without vegetation i.e. % of bare ground, X_7=percentage of canopy cover i.e. percentage of canopy cover each land unit, X_8=total surface soil factor scoring in BLM, X_9=gully erosion scoring in BLM. where BLM is the Bureau of Land Management. The gully scoring was done according the surface soil factor in USA Bureau of Land Management (BLM) table.

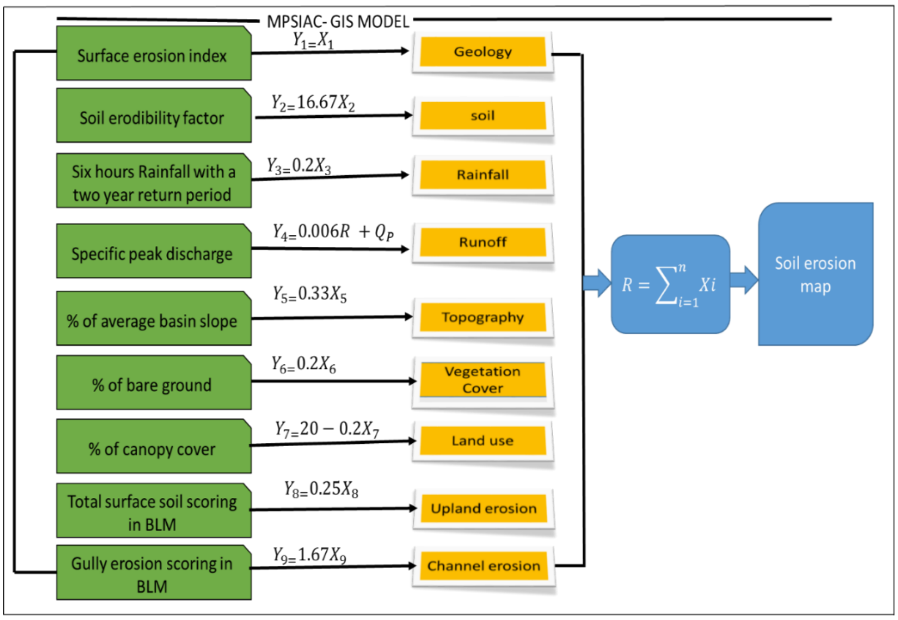


Figure 3-24 The Processes of estimating soil erosion rate and erosion risk map based on nine controlling factors of MPSIAC model

3.7.3 Data analysis effect of change in bare ground area in the watershed (future scenarios analysis)

Data analysis processes of effect of change in bare ground area was investigated using both the RUSLE and MPSIAC modelling. The aim of this analysis was to investigate any possible future land use/ cover change scenarios in the watershed that may impact on soil erosion. In both models, the scenario analysis was investigated by increasing and decreasing bare ground area by 10%, 20% and 40% in a GIS environment while other factors are unaltered. This was done by pixel by pixel converting 10%, 20%, and 40% of pasture and forest area into a bare ground area in the model, which means exposing areas formally covered by vegetation to direct rainfall impact. Conversely, the same steps were repeated by pixel by pixel converting 10%, 20%, and 40% of bare ground area into a pasture and forest area, which means covering areas formally exposed to direct rainfall impact by vegetation. Moreover, a sensitivity analysis was conducted to check the sensitivity of land cover in the watershed by plotting percentage change in soil loss against percentage in bare soil using the three scenario results. This analysis was conducted to see if applying support practice in the watershed will have any effect on the magnitude of the soil erosion in the watershed.

3.7.4 Data analysis of interviews and focus group discussion

In this research, an inductive approach to data analysis was used due to the diverse social orientation of soil erosion in Nigeria. Even though, a deductive approach offers advantage of incorporating theoretical perspective in area of research subject, it could lead to premature closure to the issue being investigated and also may not yield sufficient answers to address the research objectives. Thus, an inductive approach will offer more opportunity to explore for themes and concentrate on key issues that link the research questions and objectives (Glaser and Strauss, 1967; Schatzam and Strauss, 1973; Corbin and Strauss, 2008 and Yin, 2009). An inductive approach also offers advantage of early data analysis with the aim of developing policy framework to guide subsequent works. In this research, data analysis helped in making sense of the collected data, which involved arranging and preparing data for analysis, exploring data for themes, and generating meaning from the data. In a wider context, data analysis also involves presenting the data and interpreting the result in a format that will easily be understood (Creswell and Clark, 2011). Data was primarily collected via interviews and focus group discussions, which provided opportunity for early analysis through active repeated data reading, exploring for themes, data cleaning, and data reduction. The complex nature of this research influenced the analytical techniques adopted based on the research objectives. In this section, the following methods of data analysis were utilised: thematic analysis, direct interpretation and document content analysis as shown in Fig 3-25. The data set were applied in identifying causes of erosion, review of environmental regulatory framework, analysing institutions and developing policy solutions.

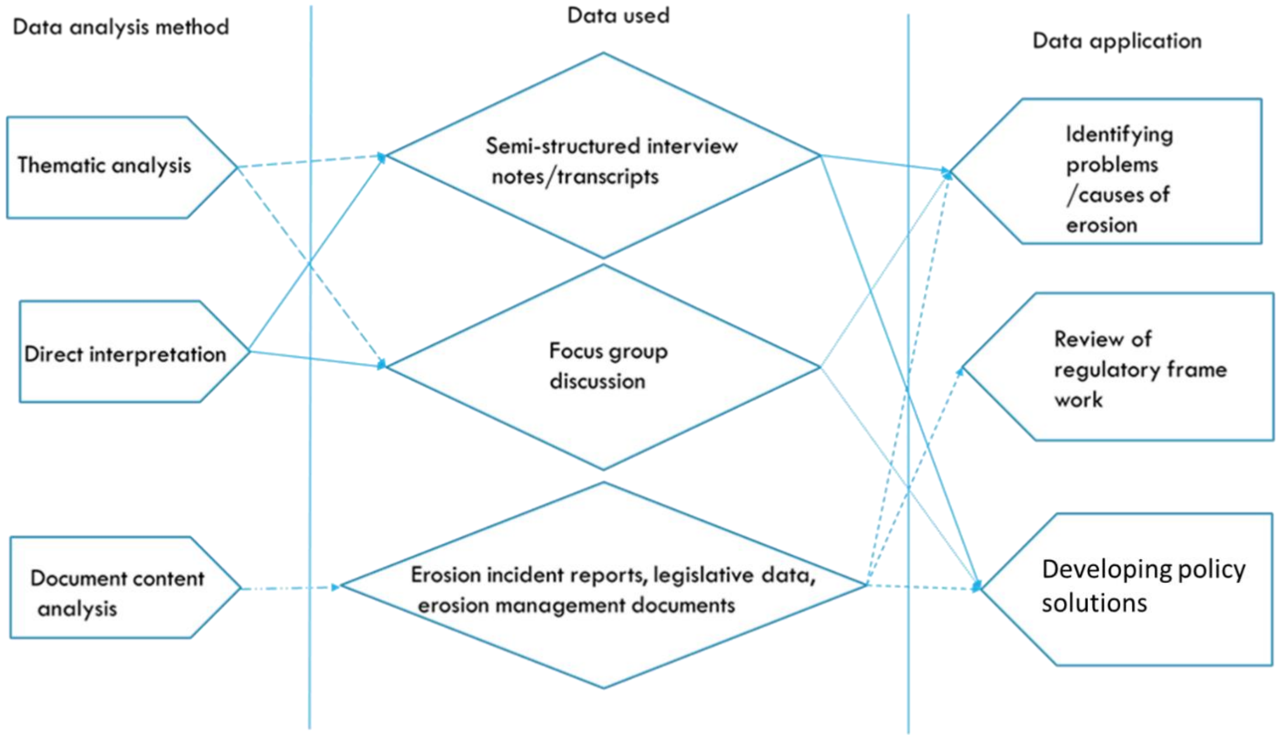


Figure 3-25 Data analysis method, data used and their application in this research

3.7.4.1 Direct data interpretation

Primary data analysis was done using direct interpretation. The aim was to establish discussion themes in a dynamic setting that address objectives. This technique was applied because of the social and complex orientation of soil erosion as well as the need for high quality data.

Institutional Analysis Development (IAD) element of this study was evidently supported by quotes selected directly from the interviews, field observations, and reconnaissance notes from fieldwork and fieldwork pictures which provided information used to propose policy reforms (see later chapter 8).

3.7.4.2 Document content analysis

This technique involves the use of codified common sense to analyse the content of a document (Robson, 2002). Various data set in document form such as erosion incident reports, legislative reports and erosion management document were also analysed using document content analysis. For instance, legislative document was analysed using document content analysis to analyse the regulatory framework of environmental management and stakeholder classification (see Chapter 6). Themes were coded with the guide from objectives in such way that codes linked to various laws and their limitations as well factors affecting their implementation. Document content analysis was used as evidence to support analysis of the regulatory framework responsible for the management of soil erosion in Nigeria.

3.7.4.3 Thematic analysis

Thematic analysis is a very common method of qualitative data analysis because of its potential to analyse and report themes as well as its patterns identification ability (Braun and Clarke, 2006). However, previous researchers viewed this analytical approach differently. For example, Holloway and Todres (2003) viewed the technique as a way of 'thematising meanings' and commonly used generic skills shared across qualitative analysis. On the other hand, Boyatzis (1998) viewed it as a tool used across different methods rather than a specific method. Similarly, Ryan and Bernard (2003) viewed it as process performed within 'major' analytic traditions (such as grounded theory), rather than a specific approach. The first step involved codes sorting into potential themes and collating them to form set of themes. Newly formed codes and themes are read and refined to make more sense. At this point similar codes are combined to form themes based on stakeholders' relationships. The next phase involves refining and revisiting set of themes which involves collapsing themes together, separating themes, dropping off some themes to form a more cohesive themes in order to fit into the research objectives. Thematic analysis was used identify the causes and problems of soil erosion in study area. Table 3-4 shows the application of this method in data analysis.

Table 3-5 Thematic analysis phases: adopted from Braun and Clarke (2006)

Phases	Description of the process
Data familiarisation	Transcribing data, reading and re-reading the data, noting down initial ideas.
Generating initial codes	Coding interesting features of the data in a systematic fashion across the entire data set, collating data relevant to each code
Searching for themes	Collating codes into potential themes, gathering all data relevant to each potential theme.
Reviewing themes	Checking if the themes work in relation to the coded extracts and the entire data set, generating a thematic 'map' of the analysis.
Defining and naming themes	Ongoing analysis to refine the specifics of each theme, and the overall story the analysis tells, generating clear definitions and names for each theme
Producing the report	Selection of vivid, compelling extract examples, final analysis of selected extracts, relating back of the analysis to the research question and literature, producing a scholarly report of the analysis.

3.8 Chapter summary

This chapter has presented the research design of the thesis which showed the processes of data collection and analysis and how they fit into the thesis. It has also presented the study area context, the processes of site selection, soil erosion modelling techniques and model selection together with description of the study area. Lake coring and interview techniques have been discussed and characterised. The fieldwork data collected based on remote sensing method and field reconnaissance survey have been characterised and explained. The next chapter estimates the effect of land use land cover changes in the watershed and how it effects soil erosion.

4 CHAPTER FOUR: ANALYSIS OF LAND USE AND LAND COVER CHANGE DYNAMICS USING GIS AND REMOTE SENSING (RS) DURING 1990 TO 2014 IN OGUTA LAKE WATERSHED

4.1 Introduction

As this research considers using soil erosion models to estimate and spatially analyse land cover change scenarios in Oguta Lake watershed, it is necessary that the historic land use and land cover change trends and dynamics is analysed to see how the watershed has evolved over time. This provides a context and reference cases for the modelling in Chapter 5. To analyse land use and land cover changes in different time periods over the past twenty-four years in Oguta Lake watershed, twelve sets of multi-spectral Landsat-TM and Landsat-ETM+, with spatial resolution of 30m (acquisition dates: 01/08/2014, 10/08/2014,05/08/2011, 14/10/2010, 13/11/2009, 05/10/2009, 10/08/2005, 05/06/2005, 05/07/2005, 06/07/2005, 01/05/1990, 05/10/1990) were used. The chapter covers the current land use and land cover change dynamics and their causes and concludes with a discussion of the changes.

4.2 Land use/cover map

The land use/land cover map was classified using supervised image classification of maximum likelihood approach. One of the limitations of this classification approach is its inability to accurately classify specific cover features in the study location. For instance, different pastures and trees have different cover potential but this classification technique assumes that they all have same cover potential, which in reality is not true (Gobin et al., 1999). It was not possible to identify individual cover feature in the watershed due to the watershed scale. This raises concern about the uncertainty of over or under estimation of land use/cover change using the maximum likelihood classification. However, it is considered appropriate classification technique when scaling up from field scale to watershed scale and regional scale, thus, grouping of land cover features of maximum likelihood becomes necessary. The area coverage for each class was analysed pixel by pixel using the zonal statistical table tool in GIS and the result is shown in Fig 4-1. The classification showed that 25% of the watershed is bare ground and unpaved road, which is the most vulnerable area to soil erosion, while 39% is urban and cultivated lands, which are slightly vulnerable to soil erosion. Although 36% (5% water bodies + 31% forest and pastureland) of the watershed is relatively stable as regards soil erosion, the implication of 64% (25% +39%) of the watershed being under moderate to severe vulnerability to erosion cannot be underestimated. The map showed that the section of the watershed upstream of the lake has greater area coverage of the forest and pasture lands which could be attributed to less human activities in the area. This finding corresponds with field observation which revealed that human activities are more dominant with the proximity of the lake and its tributaries, especially sand mining activity. And for a population that depends on land for its livelihood, continuous increase in land area vulnerable to soil erosion could lead to future food insecurity and biodiversity loss (UN report on biodiversity loss, 2019). This assertion agrees with Lambin et al. (2003) who opined that in order to meet the requirement of food demand, cultivated land has to be increased in all parts of the world at the expense of forest, shrubs and bushes, especially in developing countries in which a majority of its inhabitants depend on agriculture for their livelihood. To show clearly how this substantial vulnerability to erosion evolved over time due to various activities in the watershed, the historic land use and land cover maps are presented in Section 4.3, Fig 4-2 below.

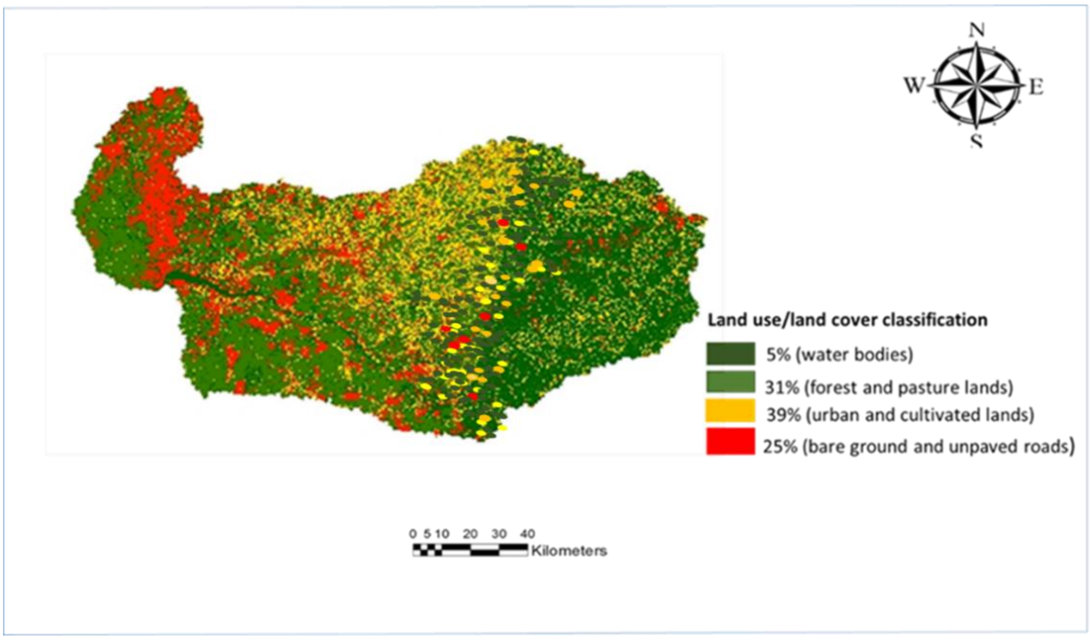


Figure 4-1 Land use/land cover classification map of Oguta Lake watershed

4.3 Land use land cover change dynamics

In total, four land use/cover classes were presented: water bodies, forest and pasture lands, urban and cultivated lands, bare ground, and unpaved roads as shown in Fig 4-2. The group classes are further discussed in detail as follow in the next section.

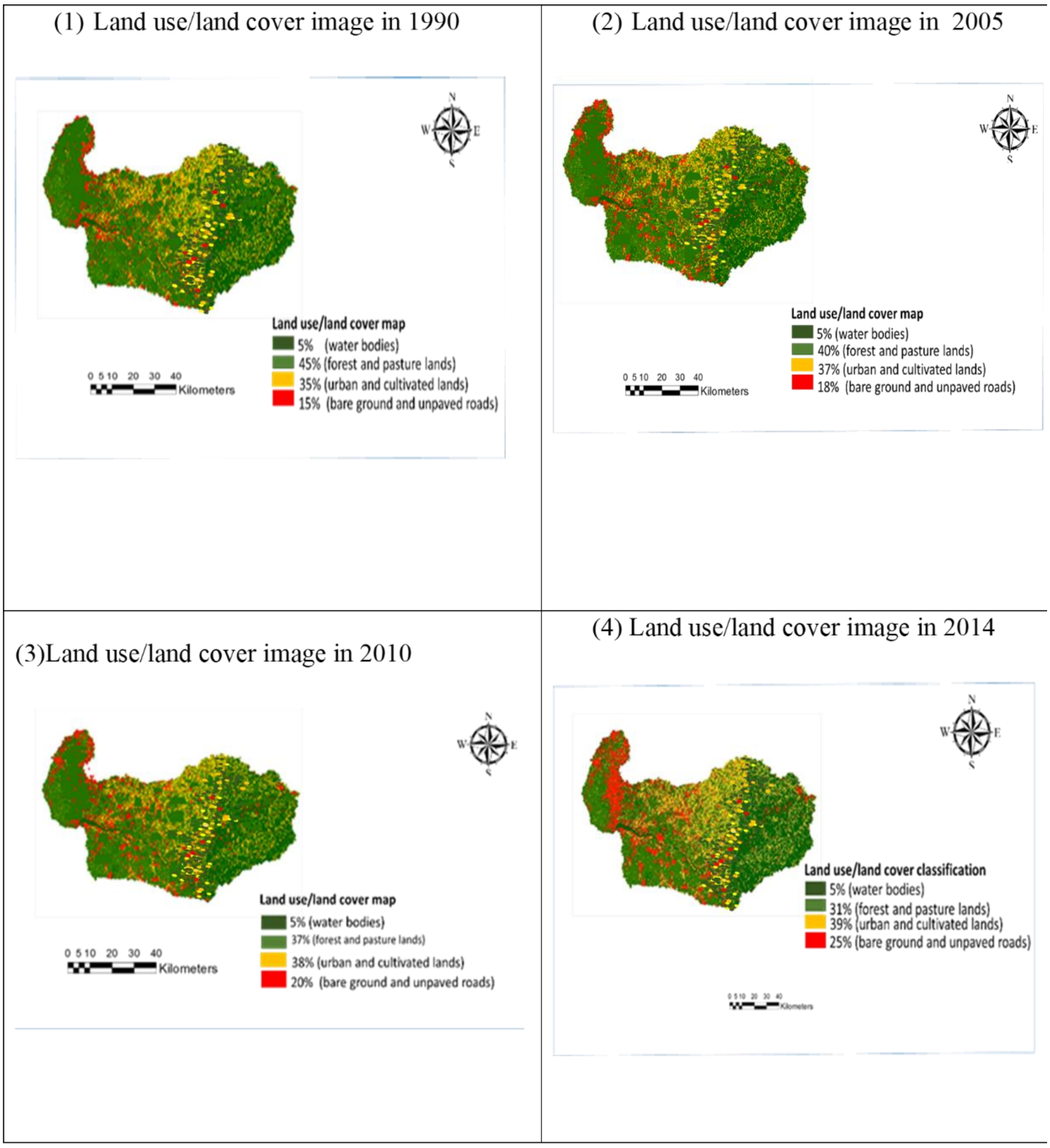


Figure 4-2 Evolution of land use/land cover changes in the study area 1990-2014

4.3.1 Forest and pastureland

This is an area which was once densely covered with natural forest and pastures which are mainly vegetative trees, shrubs, grasses, plantations and bushes. However, it was found that substantial changes have evolved over time in the study location. From 1990 to 2014, forest and pastureland area decreased continuously while some other feature classes like urban and cultivated and bare and unpaved roads increased continuously. For example, in 1990, the percentage of forest and pasture lands was 45% and has decreased to 40% in 2005. This 5% decrease in forest and pasture area could directly be linked to population increase, expansion of agricultural land and other anthropogenic factors like sand mining. Similarly, in 2010 and 2014, the percentage of forest and pasture lands has decreased to 37% and 31% respectively which reflect a total of 8% and 14% decrease in forest and pasture lands area in the watershed. This finding agrees with Austine et al. (2016) who demonstrated that built up area continuously gained from other land use and land cover throughout the study period. Similarly, Iwuji et al. (2017) demonstrated in their land use and land cover analysis in Imo State that built-up area increased significantly while vegetation cover reduced significantly over a period of 13 years. This trend could be linked directly to various human activities in the watershed, which is a very common practice in developing countries. In addition, a semi-structured interview conducted with a local resident on the 24th January 2016 provided as follows:

''I came to live here in 1980 with my husband, this place was like forest with few scattered residential buildings, but children of this community grew up and started building houses and farming intensively. I think, that is why today, we are facing problems of soil erosion and land degradation in our farmlands and homes''

This is a clear case of increasing pressure on forest and pasture lands due to expansion of farmlands and urbanisation (Fasote et al., 2016). Soil erosion is closely associated with a decrease in forest and pasture lands not only because of the increase in the volume of runoff produced but also because of direct rainfall impact on the soil surface which has the potential to trigger splash and sheet erosion. Obviously, increased runoff causes intensive sheet erosion and further extends to formation of rills and gullies depending on its potential (Tesfa et al., 2016). This is particularly common in developing countries of the world, where most of the local population depend on natural resources like land and forest for their livelihood.

4.3.2 Urban and cultivated lands

Urban and cultivated lands area substantially increased over time in the watershed, and this could be linked to increasing population in the study area. However, because of the subsistence and small-scale farming commonly practised in the watershed, most of the farmlands are located in the settlement areas. Thus, urban and cultivated lands were grouped together as a common feature class in the watershed. The result showed that urban and cultivated lands occupied 35%, 37%, 38% and 39% of the watershed in the 1990, 2005, 2010 and 2014 respectively. However, the implication of this 4% increase over a period of 24 years indicate that urban and cultivated lands has progressively increased at the expense of forest and pasture lands in the watershed. Consequently, 4% of the watershed has shifted from stable condition to unstable condition which further puts the watershed at high risk of soil erosion and land degradation. This finding is in line with Pabi (2007) who stated that increasing demand for farmland as a result of increasing population in developing countries puts more pressure on land and forest resources and it is mainly driven by the quest to keep up with the food and shelter demand by the local population. Similar studies elsewhere suggested that population growth results in change of land cover class through time (Turner, 2009). Likewise, Shiferaw (2011) opined that limited access to off-farm employment opportunity has made farmers engaged in clearing of forest and further conversion of other land uses to farmland. In addition, the observation from the semi-structured interview conducted with the local farmers on 25th August 2016 about land use and cover dynamics provided the following:

> *''My family and I are crop framers, I have a lot of inherited lands, where I farm crops, that is my business and it is growing because I cultivate more lands every year, I train my children in school from the proceed of the farm business. Life is difficult in the rural area, and we do not have government jobs to earn a living''*

This phrase 'it is growing because I cultivate more lands every year' from the response above clearly shows that watershed vulnerability increases every year. This is a clear reflection of the progressive increase in the urban and cultivated lands in the land use/ land cover changes as shown in Fig 4-2. Even though growing population has been a long-standing problem of developing nations, provision of sustainable housing and agricultural policies by the government could potentially minimise the impact it has on the environment.

4.3.3 Bare ground and unpaved roads

There is a continuous and significant increase in the percentage area coverage of the bare ground and unpaved roads from 15% in 1990 to 18% and 20% in 2005 and 2010 respectively and to 25% in 2014. The figures show that it took 20 years (1990-2010) for the first 5% increase in area of bare ground and unpaved roads but only 4 years (2010-2014) for the next 5% increase. It is uncertain what triggered this acceleration. Although a field survey conducted in January 2016 showed evidence of massive sand mining activities in some lands originally allocated for crop farming, other anthropogenic activities could also be linked to this massive change. Also, the presence of foot paths and unpaved roads linking newly built homes in the watershed could be linked to this alarming and massive increase in land use and land cover change. In addition, observation showed that the land cover and land use change episodes could be linked to massive bare ground, unpaved road and the boom in the sand mining business in 2011 (semi-structured interview August 2016). Other anthropogenic activities such as forest logging, farm erosion and building construction may have also contributed to the changes because population growth puts more pressure on land resources.

4.3.4 Water bodies

In this study water bodies include ponds, streams, rivers and lakes. This was the only land use and land cover feature in the watershed that remained the same over time. This unchanged area could be because the satellite data were collected during the rainy season of each year when the water bodies were at their peaks and cover maximum area on the ground surface. Also, the groundwater table in the watershed is very high (near the ground surface) and most residents have private wells which reduces the number of people that depend on surface water for domestic use. In addition, the demand for surface water from water bodies are generally low during the wet season as most of the local population use rainwater harvested from their various homes for domestic activities. The percentage of land cover changes at different date is summarised in Table 4.1 below. It can be seen that it was only forest and pasture area that gradually decreased throughout the period. This is because all land use and land cover area remained unchanged or increased at the expense of land forest and pastureland area (UN report on biodiversity loss, 2019).

Table 4-1 Land use and land cover percentages at different dates

Land use/land cover class	Initial % cover 1990	% cover 2005	% cover 2010	% over 2014
Water bodies	5	5	5	5
Forest and pasture lands	45	40	37	31
Urban and cultivated land	35	37	38	35
Bare ground and unpaved roads	15	18	20	25

4.4 The causes of land use and land cover dynamics

This section analyses the causes of land use land cover dynamics in relation to human activities in the watershed. Previous studies have argued whether population growth drives land use/ land cover changes (Allen and Barnes, 1985; Geist and Lambin, 2001). While Allen and Barnes (1985) opined that most of the deforestation occurs by the push of population growth and poverty to invade, slash, and burn the forest along the roads, Angelsen and Kaimowitz (1999) suggested that population growth is never the sole and often not even the major underlying cause of forest-cover changes. However, it is difficult to generalise the causes of land cover and land use changes knowing that different watersheds have different characteristics as well social factors driving them. In this study, however, the critical issue is that the forest-cover changes are largely driven by lack of economic opportunities and linked to social and policy issues. Thus, the watershed has been subjected to both formal and informal land use that can cause soil erosion and land degradation as summarised in Fig 4-3. Land use has been defined formally in 4 classes. The explanation for the change in percentage cover lies not in deliberate or planned operations by an overall authority but informal activities undertaken by the local population according to their perceived interests and with no thought for the aggregate effect or for the interactions between activities. For example, informal land use such as: grazing, sand mining and deforestation, unregulated farming activities in the watershed put the land use under much more intense pressure, and unstable condition leading to bare ground, and thus, vulnerable to soil erosion (Hecht, 1985). Moreover, the informal land use activities are often not monitored by the government which leads to a more intensive land use and a as consequence triggers soil erosion and land degradation. For example, government policy prohibits open grazing under Grazing Reserve Law 1965, but this law is often not implemented simply because of the interest of top government officials in cattle business. The law states that grazing can only done in a piece of rangeland that the government approved for such purpose making ensure that all the soil conservation guidelines followed. However, in practice, this piece of legislation is often ignored as the armed headers migrate from one location to another to feed their heads destroying landscape and croplands. Consequently, this illegal practice does not only trigger crisis between crop farmers and herders but also leads to soil erosion as forestlands and pasturelands are exposed to direct rain drop impact. Ironically, these law breakers have full protection of the government at federal level and that is why enforcement is always overlooked. In addition, the interest of some key government officials mostly from the northern part of Nigeria in cattle business coupled with the fact that most of these herders work for them encourages illegality. Secondly, deforestation is widely practised in Nigeria despite the prohibition under 1988 National Forest Policy Act. Under the Act, forestry is recognised as the management and utilisation of forests as renewable natural resources. In addition, the Act provides the implementation strategies required to achieve forest goals and targets using their resources and products. Such strategies include sustaining forest reserves through replacement of fallen forest trees and enforcement of forest laws. There is a provision for forest guards who are legally employed by government to protect the forest against deforestation and other illegal use of forest, but the effectiveness of their operational monitoring is often questionable, especially in the local areas. It was observed during the interview that the forest guards operate available in the cities, meanwhile forest are dominant in the local communities and villages. Most times, overgrazing, deforestation, and sand mining are products of unmonitored informal land use activities in the watershed which are the main drivers of environmental unsustainability. The informal land use activities are discussed in the section below.

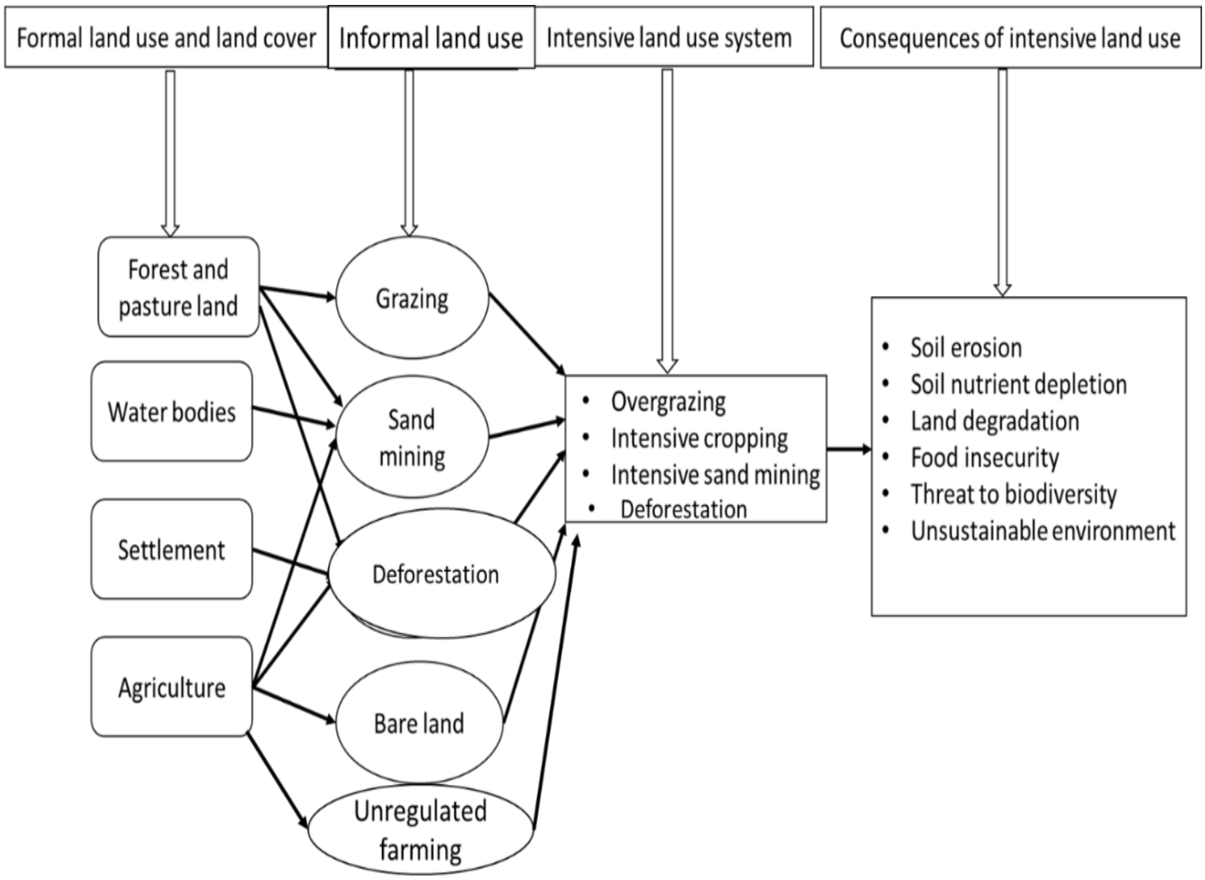


Figure 4-3 The link between the cause and consequence of land use land cover change in Oguta Lake watershed

4.4.1 Sand mining

Observation showed that sand mining is one of the fastest growing businesses in Nigeria, especially in south eastern Nigeria, where the demand for sand is very high because of urbanisation and population growth (Grove, 1951). However, sand mining activity threatens environmental sustainability. For instance, it destroys vegetation, and thus, shifts land cover condition from forest and pastureland to bare ground land as shown in Fig 4-4. It can be seen clearly from the satellite images of mining sites (A, B, C and D in Fig 4.4) that both subsurface and topsoil of formally densely vegetated areas have been converted to bare ground condition. Satellite images, A, B, D in Fig 4-4 are active mining sites located very close to Njaba River, which is the main tributary river of Oguta Lake watershed. The satellite image C is the location within the lake which has evidence of abandoned mining site close to the lake itself. Overall, observation revealed that the scale of sand mining in the location depends on the number of operators and the date mining started, which determines the level of land use change. The scale of sand mining determines the extent of land degradation and alterations in the watershed. Meanwhile, sand mining is prohibited in these areas, which were formally allocated for farming. Tamunobereton-ari et al. (2011) opined that sand mining destroys vegetation and makes soil vulnerable to erosion. Similarly, Saviour (2012) explained that sand mining degrades surface soil and destroys shrubs that protect the soil from both runoff and rainfall impact. Furthermore, field observation showed that sand mining activities have degraded the original features of some parts of the watershed which may not be easily re-established in the short to medium term even when mining activities ceases. This is because the dynamics of the environment and the functioning of the ecosystem had been changed by the sand mining activities (Gubbay, 2003) and would take a while to reconstruct. But there is a social dimension to this problem. The fact that the demand for sand for construction purpose is very high and unemployment in the local community is very high as well makes it even more difficult to stop sand mining activity in near future. Thus, the implication of this is that more land area would be converted to bare ground and, thus, the watershed would become more vulnerable to soil erosion. In as much as sand demand is on the increase, the mining activities will also be on the increase, therefore, it is important to consider potential government policy measures that could reverse this trend. Higher level government policy decisions could potentially influence the individual decision of sand mining operators in the watershed. Likewise, Blaikie et al. (1987) in their work demonstrated that local land-use change is often the result of higher-level decisions.

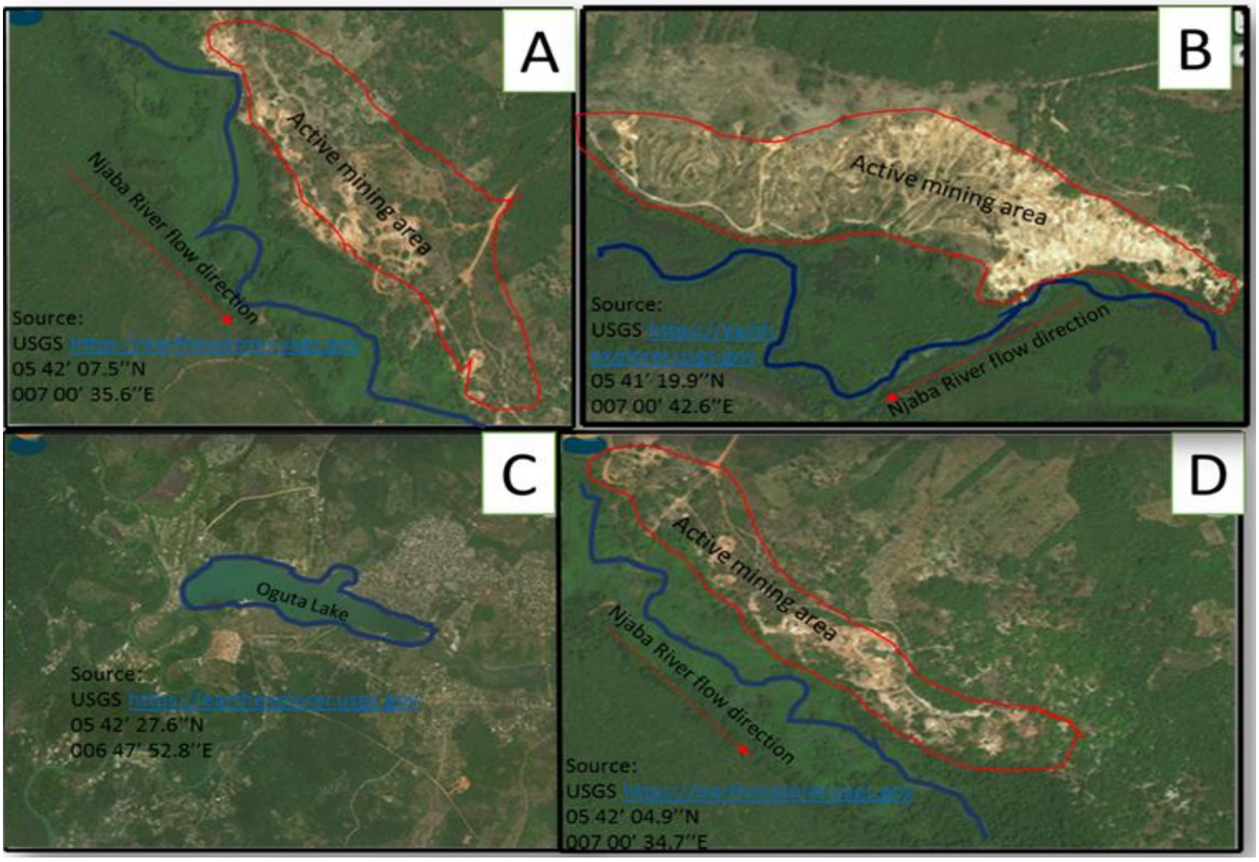


Figure 4-4 Satellite image of sand mining site in the watershed in 2010. Source: USGS: https//earth explorer.usgs.gov. See text for explanation of A, B, C, D.

4.4.2 Grazing

Grazing of livestock leads to land use and land cover changes by depleting the vegetation cover on the soil surface (Emeka et al., 2015). Even though open grazing is considered illegal according to the Grazing Reserve Law 1965, it is widely practised by the pastoralists in the watershed who move about with their cattle in search of forage (semi-structured interview 26th August 2016). And because it is illegal and often not monitored, there is no official post grazing recovery plan that could check land use /land cover changes. Cattle are the most common livestock attracted by the presence of lake and rivers in the watershed for their hydration and their concentration points are always more vulnerable to land cover change than everywhere else due to trampling and feeding. Consequently, overgrazing by cattle causes removal of vegetation cover and exposes land to bare ground conditions. But, in general, overgrazing is mostly caused by improper land use, overstocking, intensive grazing, and lack of proper land management. Consequently, overgrazing causes the grasses and plant residual matter to decline and further contributes to land degradation and soil erosion. Also, the trampling on forage land by large numbers of farm animals accelerates the death of plant and vegetation cover. This is because animal especially cattle prefer to gather at specific areas like next to a water body and thus, deplete the vegetation in such area leaving the soil surface bare and vulnerable to soil erosion. Moreover, in drier areas, a higher percentage of pasture and vegetation is destroyed and, because of the long period of the dry season in Nigeria, recovery is always prolonged.

Overall, overgrazing contributes significantly to land degradation, loss of valuable plant species, soil erosion, and a shift from pastureland to bare land. However, it could be regulated and operated in the form of ranching, which is the international recognised standard practice. For example, Rheff (2020) pointed out that planting perennial trees on pasturelands could minimise soil erosion. Similarly, Samuel et al. (2017) demonstrated in an experiment how effective Bermuda grass could minimise soil erosion. In south east Nigeria, Ogunlela and Makanjuola (2000) recommended cashew trees, bamboo trees, Bermuda grass, buffalo grass star grass, and vetiver grass for erosion control. In a similar study, Ihuoma et al. (2016) found a high survival rate and growth of Bermuda grass in south east Nigeria as an excellent grass for erosion control. Planting these erosion resistant grasses, and sustainable management of ranching lands (grassland enclosure) could minimise soil erosion. On other hand, cattle ranching if mismanaged could flatten the soil and minimise its ability to absorb water and nutrient as well as degrade the soil through excessive stamping. But sustainable ranching system planted with resistance grass species like Bermuda grass and proper rotation of cattle would minimise erosion impacts. Thus, the rate of conversion of pastureland to bare ground and land degradation could be minimised.

4.4.3 Deforestation

Observation showed that deforestation and informal land use such as tree for logging firewood and timber contribute immensely to land cover and land use changes. Although, deforestation is considered illegal in Nigeria, it is still widely practised by the local people, who depend on natural resources to survive. However, deforestation directly reduces the land canopy cover in the watershed, which not only increases the runoff but also exposes the soil surface to raindrop impact. Bathurst and Iroume (2014) demonstrated that sediment yield increases following logging/deforestation in a watershed. Likewise, Abbas et al. (2010) pointed out that land use and land cover change significantly increase the surface runoff, soil erosion, land degradation and sedimentation, which leads to a decrease in productivity and famine. This is even worse when a large population of people depend on land and other natural resources for survival.

In fact, for a local community of people that depend so much on natural resources for their livelihood, deforestation is expected to increase in the future. There are social orientations to this problem such as unemployment, poverty and population growth that need to be addressed and, without resolving these social issues, it will be extremely difficult to stop deforestation in the watershed. For example, it was observed from the semi-structured interview on August 17, 2016, that some of the youths in the study location engage in the timber logging business because of large scale unemployment in the community. Meanwhile, according to government regulations, deforestation is prohibited in some of the affected forest areas.

4.4.4 Bare ground

Bare ground is mainly a product of various land misuses in the watershed such as bush burning, slash and burn farming techniques, deforestation, building and road construction, unpaved roads, overgrazing and tillage. However, most of the activities in the watershed are not regulated by the government because most their policies are often not monitored and implemented, consequently, detrimental land use and land cover changes always increase the bare ground area (Tesfa et al., 2015). However, bare ground is the most vulnerable land cover condition due to raindrop impact and high volume of runoff that follows rainstorms. By implication, a continuous increase in bare ground area means that more runoff, and thus, massive soil erosion and land degradation would increase in the watershed. In addition, a bare ground condition has offsite effects such as sedimentation and pollution of water bodies and, thus, affects the quality of water as well as aquatic life in the watershed.

Conversely, if land managers adopt a reforestation and grassing programme in the affected area for a long period of time as a conservation technique, the land cover would gradually reverse, and erosion would possibly be minimised. In addition, putting proper measures to halt illegal and other unsustainable land use activities in the watershed would significantly minimise the current rise in the bare ground area.

4.4.5 Unregulated farming

The watershed is characterised by various crop farming activities operated and manged by the local people. Although farming is legalised in the study location, lack of regulation by the government as well as awareness of sustainable farming techniques contributes to land use and land cover changes. For instance, the slash and burn method of land preparation decreases the vegetation cover and exposes the soil surface to raindrop impact. Similarly, bush burning as widely practised in the watershed destroys the vegetation cover as well as the root system of plants and, thus, triggers land use and land cover changes. In addition, poor tillage and terrace practice by the local farmers unsustainably contributes to bare ground conditions in the farmlands. For example, clearing vegetation and breaking the top crust of the soil in preparation for the next farming season as commonly practised in the study location, initiates land use and land cover changes, and could potentially result in a bare ground condition. However, unsustainable farming practice is expected to get worse in the future according to the focus group discussion observation (August 2016) that more local population, especially the youths are joining farming business because of lack of employment in the area. Although a large proportion of the local population depend on crop farming for their livelihood, the techniques and processes of farming remain a huge threat to the land cover in the watershed. However, lack of proper environmental regulation and poor sensitisation of the local population on sustainable farming techniques and processes by the government contribute significantly to this problem.

4.5 Discussion of land use and land cover change dynamics

The change in land use land cover class may result in land degradation and soil erosion depending on the direction of the change. For example, if a dense forest land cover class rapidly changes into farmland, bare land and grazing land through human activities, the land will be more susceptible to massive erosion and degradation (Tegene, 2002; Maitima et al., 2009; Tesfa et al., 2015).On the other hand, if a farmland or bare ground changes into grass land or perhaps into forest land through conservation practice, the land will be less susceptible to soil erosion and degradation. However, according to the land use and land cover classified image of change detected between 1990 and 2014, forest and pastureland has significantly been converted to urban and cultivated land and bare ground in the watershed. This significant change indicated how land use and land cover change can accelerate soil erosion, land degradation and other environmental problems. This result is in line with the finding of Abbas et al. (2010) who pointed out that land use and land cover change can significantly increase soil erosion and land degradation. Similarly, Tesfa et al. (2015) explained that rapid conversion of forest land into farmland triggers massive soil erosion and land degradation in a watershed. An increase in bare ground condition in the watershed means a decrease in the vegetation cover and soil fertility in the watershed, which decreases crop production and, thus, increases food insecurity. Similarly, an increase in bare ground condition in the watershed means an increase in soil erosion, which directly cause sedimentation and pollution of water bodies downstream.

Moreover, the implication of a continuous increase in urban and cultivated land means reduction in forest and pastureland area, which means that more land would be put at risk of soil erosion in the future. This is because during the period 1990 to 2014 the increase in urban and cultivated land area and bare ground area all resulted from a decrease in forest and pastureland area only. In addition, a population of local people that is on a steady increase and of whom the vast majority depend on natural resources for their livelihood means that more forest and pastureland could be degraded in the future. Conversely, a positive land use and land cover change, though in a long term, such as adopting soil conservation practice, could potentially minimise soil erosion and land degradation in the watershed. This is demonstrated further by analysing the future land cover condition scenario analysis in detail in the next chapter (Chapter 5, Section 5.2.6 and 5.3.3). Furthermore, poor government policies and lack of implementation of existing ones contributed to this land use and land cover changes as analysed in detail in Chapter 6 of this thesis.

4.6 Chapter summary

In the last twenty-four years land use and land cover dynamics have undergone numerous changes in the Oguta lake watershed. It was observed that forest and pasture lands have rapidly given way to urban and cultivated land, and bare ground. By contrasts, water bodies remained unchanged throughout the period of investigation. The significant decrease in area covered by the forest and pastureland has been attributed to various anthropogenic activities in the watershed. However, the land use and land cover dynamics extend beyond onsite implications and have offsite environmental implications such as soil erosion, land degradation, sedimentation and water pollution. The continuous decrease in forest and pastureland in the watershed probably means that conservation practice was not applied within the period of investigation. Informal land use practices such as grazing; sand mining and deforestation are widely practised and thus contributed to conversion of forest and pasture lands to bare ground condition. The increase in population and urbanisation were also linked to land use and land cover changes in the watershed. A positive land use and land cover policy based on formal Land Use Act 1978 and adopting a proper soil conservation practice such as mulching, reforestation, conservation tillage and proper crop management (leguminous cover crop and residue management) could reverse the trend of these changes in the watershed.

5 CHAPTER FIVE: ASSESSMENT OF SOIL EROSION USING RUSLE-GIS AND MPSIAC-GIS MODELLING IN OGUTA LAKE WATERSHED

5.1 Introduction

Having analysed land use / land cover dynamics in Chapter 4, this chapter presents a predicted spatial soil erosion risk map and changes in land cover in Oguta Lake watershed. The aim of this chapter is to assess the soil erosion potential in Oguta Lake watershed, with special focus on the impact of land cover changes using both RUSLE-GIS model and MPSIAC-GIS model. The following research questions will be addressed:

- How significant is soil erosion in Oguta Lake watershed?
- How can land cover changes contribute to high erosion in Oguta Lake watershed?
- Can applying conservation practice minimise soil erosion in Oguta Lake watershed?

According to the information available in the literature, this research is the first time the concept of GIS-integrated soil erosion models is being used to study soil erosion in Oguta Lake watershed. It was noted that previous studies laid emphasis on mapping soil erosion vulnerable areas and impact of soil erosion in southeast Nigeria e.g. Okereke et al. (2012); Ndukwe et al. (2013); Ogwuche et al. (2013); Amangabara (2012): and Eze (2010). However, none of these researches assessed soil erosion using RUSLE- GIS and MPSIAC-GIS based models. Okereke et al., (2012) mapped gully erosion but were limited to using a remote sensing technique and GIS in a case study of Okigwe area southeast Nigeria. Amangaraba, (2012) analysed some failed gully erosion controls works and highlighted some concerns such as poor drainage design and use of inferior materials in drainage construction as the causes of gully failures. Ndukwe et al., (2013) were limited to surveying and mapping gully erosion sites as a means of controlling gully erosion for a case study in Onitsha Anambra State, Nigeria. Eze, (2010) discussed extensively the negative impact of soil erosion on water resources quality. Even though these researches have shaped contextual understanding of the soil erosion severity in south east Nigeria, they have failed to explore soil erosion inducing factors and the way they combine in its location. However, the potential contributions and insights soil erosion modelling offers have not been explored in this location by any known research. This chapter, therefore, sets out to assess soil erosion using both RUSLE- GIS and MPSIAC- GIS models with special interest in understanding the impact of land cover changes on soil erosion. This study illustrated the importance of understanding the contribution of soil erosion factors and the way they combine in its location to produce soil erosion. The information and conclusion from this chapter will form part of the policy proposition options (in Chapter 8).

Section 5.2 explains the method and evaluation of RUSLE model, Section 5.3 explains the method and evaluation of MPSIAC- GIS models, Section 5.4 discusses the model results.

5.2 Method and Evaluation of RUSLE-GIS Model

Revised universal soil loss equation (RUSLE) is a globally accepted empirical soil erosion model used for estimating soil erosion (Renard et al., 2011). The RUSLE equation was originally developed by (Wischmeier et al., 1978) see equation 5-1. This model was originally parameterised for the USA, and most of its equations were developed for local USA conditions. However, extensive work has been carried out worldwide to adopt RUSLE suitability for other local conditions, which has resulted in new and slight alterations in the equations (Dubber and Hedbom, 2008).

$$A = R \times K \times LS \times C \times P \qquad \text{Equation 5-1}$$

where A is the average soil loss ly (sheet and rill erosion) (tonnes ha^{-1} yr^{-1}), K is the soil erodibility factor (tonnes h MJ^{-1} mm^{-1}), R is the rainfall-runoff erosivity factor (MJ mm ha^{-1} h^{-1} yr^{-1}), C is the cover management factor, LS is the slope length and slope steepness factor and P is the conservation support practice factor.

5.2.1 RUSLE-GIS application

The six factors in RUSLE model were evaluated in a GIS environment as shown below.

<u>Evaluation of Rainfall erosivity factor (R factor)</u>

In addition to rainfall amount and distribution, the energy load of a rainstorm is a crucial component in estimating rainfall erosivity (Gobin et al., 1999). Thus, the daily and hourly records of storm events are needed to estimate the intensity and kinetic energy of rainstorms, which may not always be available in poor data conditions. However, several authors (Thomas 1994; Lal and Elliot, 1994) attest to the more torrential and erosive nature of rainstorms in tropical environments compared with temperate climates, hence the erosive index EI_{30} (Wischmeier and Smith, 1978) is deemed less effective for tropical regions (Gobin et al., 1999)

Therefore, a simple empirical relationship exists between the yearly average erosivity index (Ram) and the corresponding annual average of rainfall amount (Ham) for tropical West Africa region (Roos, 1977).

$$Ram/Ham = 0.5 \pm 0.05 \qquad \text{Equation 5-2}$$

This relationship has been verified in over 20 rainfall recording stations in West Africa and is sufficient to permit the use of the Universal Soil Loss Equation (USLE) in West African countries (Roose, 1977). In this research, the rainfall data for Imo State from 2005 to 2015 was used to compute the erosivity index based on Equation 5.2.

Rainfall erosivity map was computed based on the distribution of rainfall in the rain gauge stations across Oguta Lake watershed using kriging tool in GIS. This regression approach supports previous researches that have demonstrated relationships between precipitation and topographical variables such as latitude, longitude, and slope using regression (Boer et al., 1993; Meusburger et al., 2012 and Mello et al., 2013).

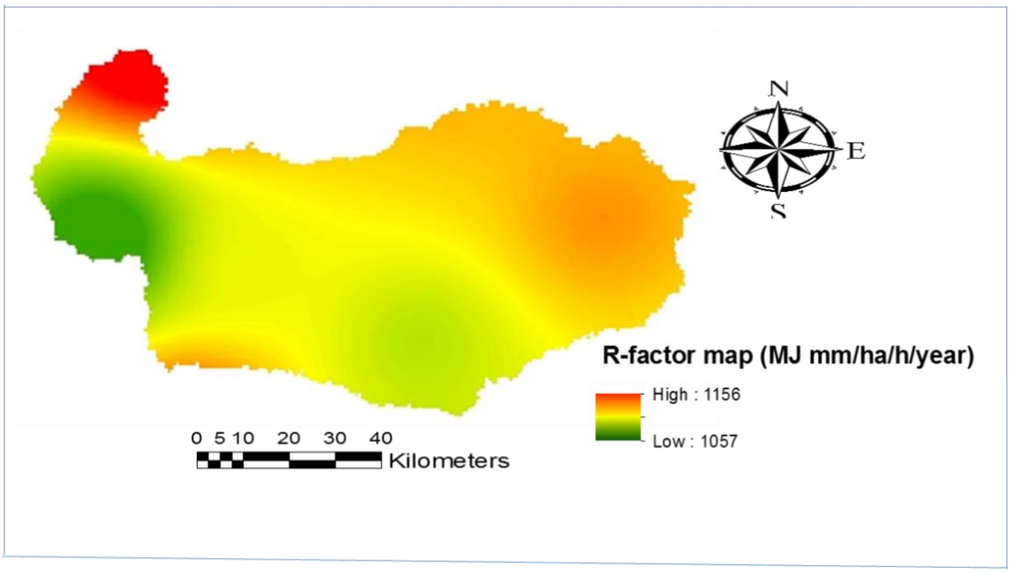


Figure 5-1 Spatial distribution of rainfall erosivity in Oguta Lake watershed

Fig 5-1 shows the spatial distribution of rainfall erosivity on the Oguta Lake watershed derived using kriging regression tool in GIS. The R value ranges between 1156 and 1057 MJ mm ha^{-1} h^{-1} yr^{-1}, which reflects the slight rainfall variation in the watershed.

Evaluation of soil erodibility factor (K factor)

Soil erodibility is the classification of soil properties according to susceptibility to soil erosion. In addition to the laboratory tests, (Wischmeier et al., 1978) suggested a reference plot of about 100 square meters, with a 9 percent slope and treated the plot as a bare-tilled fallow without addition of any organic matter for three years.

In a unit plot circumstance

$$K = A/R(tonnes\ h\ MJ^{-1}mm^{-1}) \quad \text{Equation 5-3}$$

where A is the annual sediment yield (tonnes ha^{-1} yr^{-1}) and R is the rainfall erosivity factor MJ mm ha^{-1} h^{-1} yr^{-1}. The other factors such as slope length L, slope steepness S, cover management C and support practice P under unit plot circumstances are equal to one. There are several methods/equations for estimating K values in a watershed such as the soil erodibility nomograph method developed by (Wischmeier et al., 1978) and Williams et al., method developed by (Williams et al., 1983) as explained below:

- In the Soil erodibility nomograph method developed by Wischmeier et al. (1978), K is obtained from the five characteristics of soils such as: the relative percentage of silt plus very silty sand, percentage sand, percentage organic matter, soil structure and soil permeability as input variables in the Equation 5.4 (Wischmeier et al., 1978; Wang et al., 2001). Alternatively, these properties and the K value can be obtained from the soil nomograph chart.

$$K = (2.1 \times 10^{-4})(12 - OM)MM^{1.14} + 3.25(S - 2) + 2.5(P - 3) \div 0.0759 \quad \text{Equation 5-4}$$

where OM = % organic matter content, M = particle size parameter [(% silt + very fine sand) × 100 - % clay], S = soil structure class (1 = very fine granular, 2 = fine granular, 3 = medium granular, 4 = blocky), permeability class (1 = rapid, 2 = moderate to rapid, 3 = moderate, 4 = slow to moderate, 5= slow and 6 = very slow)

Alternatively, these properties and K value can be obtained from Figure 5.2 below.

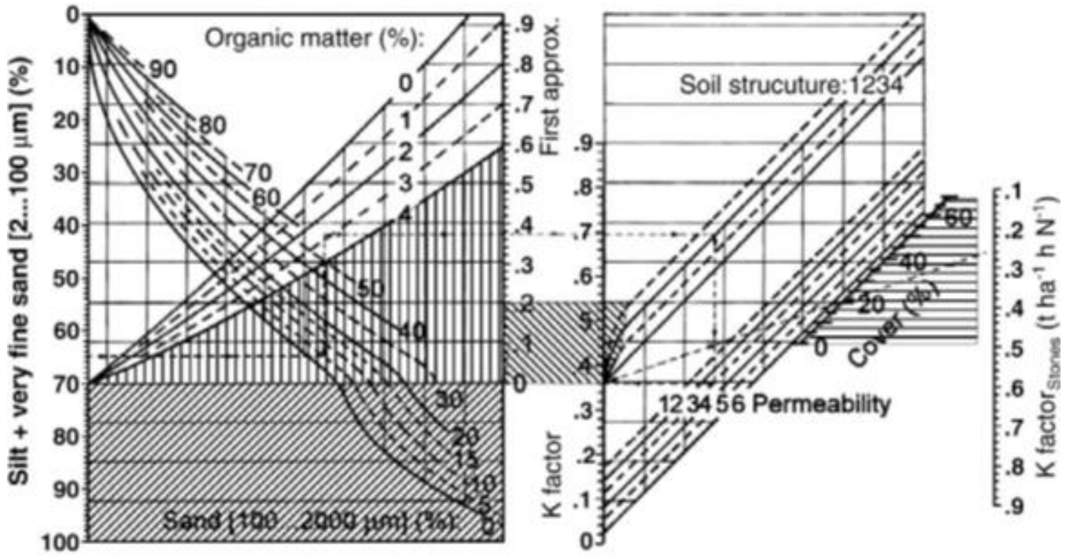


Table 5-1 Soil erodibility nomograph adopted from Wischmeier and Smith (1978)

- Williams et al.'s method: Williams et al. (1983) came up with an empirical relationship for estimating soil erodibility K using integrated effects of rainfall, runoff and infiltration on soil loss, accounting for the influences of soil properties on soil loss during storm events on upland areas (Williams et al., 1983).The K value was calculated by using the EPIC (Erosion-Productivity Impact Calculator) (Renard et al., 1997) formula.

$$K = \left[0.2 + 0.3EXP\left(0.0256Sd\left\{1 - \frac{Si}{100}\right\}\right)\right] \times \left(\frac{Si}{\{CL + Si\}}\right)^{0.3} \times \left[1.0 - \frac{0.25C}{C + EXP\{3.72 - 2.95C\}}\right] \times 1.0 - 0.7\left(1 - \frac{Sd}{100}\right) \Big/ \frac{}{1 - \frac{Sd}{100} + exp\left(-5.51 + 22.9\left\{1 - \frac{Sd}{100}\right\}\right)]}$$ Equation 5-5

where Sd, Si, CI and C represent sand (%), silt (%), clay (%) and carbon (%) respectively.

In this research, there were no direct field data collections and measurements of soil properties because of the time scale and financial resources required to accomplish it. Therefore, the secondary data used in this study were the soil erodibility data which were collected from the Ministry of Land and Survey (MLS), Imo State, Nigeria and the digital soil data set. The soil erodibility was computed for the entire state using the soil erodibility nomograph method as described in Equation 5.4), which was then extracted in the GIS environment using extraction by mask tool.

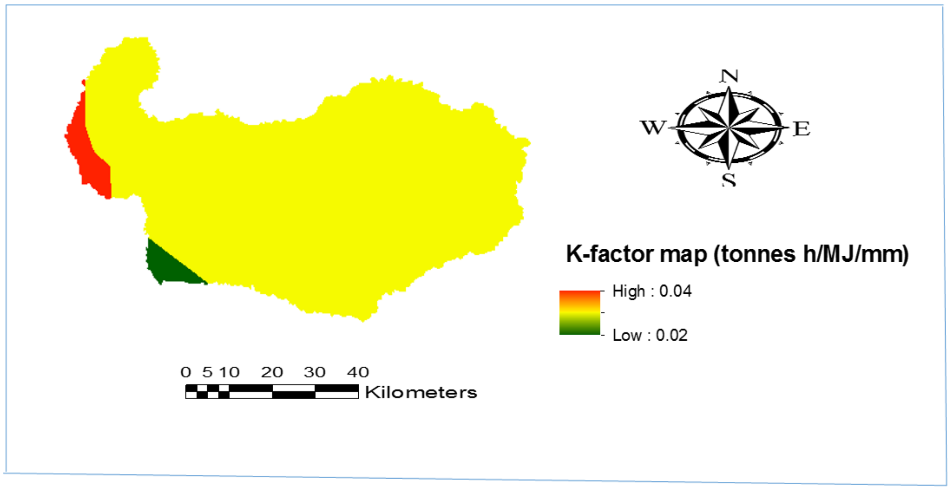


Figure 5-2 Spatial distribution of soil erodibility in Oguta Lake watershed

Fig 5-3 shows that soil erodibility values in the watershed rage from 0.02-0.04 tonnes h MJ $^{-1}$ mm^{-1}. The range of erodibility values shows that the soil belongs to the class of silty loamy-sandy loamy, which has relatively low erodibility values.

The result agrees with previous researches on the range of soil erodibility in Owerri, Imo State (Peter et al., 2008; Chukwuocha, 2015).

Evaluation of slope length and steepness factor (LS factor)

The LS is a factor in RUSLE that combines the topographic effect of both slope length and slope steepness in driving soil erosion. According to Wischmeier and Smith (1978), slope length is the distance from the point of origin of overland flow to the point where the slope gradient decreases enough for deposition to begin. In RUSLE, the slope length (L) is a dimensionless factor because it is a ratio of the horizontal length of the actual field plot divided by the unit field plot length, raised to the power m. In mathematical expression:

Equation 5-6

$$L = (\lambda/22.13)^m$$

where λ is the horizontal slope length; 22.13 is the unit plot length in meters, m is exponent slope length variable that depends on slope steepness. The value of m ranges from 0.5 to 0.3, as 0.5 for slope > 5%, 0.4 for slope between 4% & 3% and 0.3 for slope < 3%. The slope steepness (S) is also a dimensionless factor that estimates topography inclination with reference to the sea level. Slope steepness is mathematically combined with the slope length in RUSLE calculations. The basic equation for estimating slope steepness was originally developed by Wischmeier and Smith (1978).

Equation 5-7

$$S = 65.41 \sin^2\theta + 4.56\sin\theta + 0.065$$

where θ *is* the slope angle in degrees.

Then, a topographic index equation was also developed by Wischmeier and Smith (1978)

Equation 5-8

$$LS = (L/22.13)^n \times (0.065 + 0.045 \times S + 0.0065 \times S^2)$$

where L is the slope length, S is the slope steepness and n is the exponent variable that has values between 0.1 and 0.7 depending on the value of S. The result obtained from using this approach to estimate LS factor is quite similar to previous studies on soil erosion in Nigeria (Gobin et al. 1999; Chukwuocha, 2015). In this study, the LS factor was computed based on the digital elevation model (DEM) with 30m spatial revolution. The DEM was digitally generated from the United States Geological Survey website (https://www.usgs.gov) and extracted by mask tool in GIS environment.

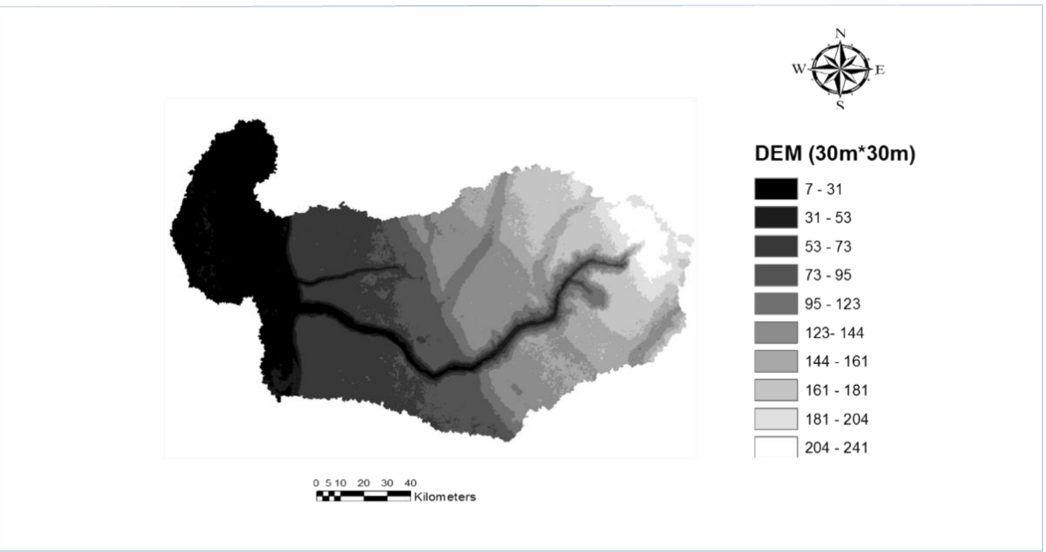


Figure 5-3 Digital Elevation Model (DEM) with 30m spatial resolution for Oguta Lake Watershed

The digital elevation model shows the terrain representation of the watershed and helps in extraction of geographical information from the watershed. The DEM in Fig 5-4 above was the key input parameter for estimating various hydrological characteristics of the watershed as shown in Fig 5-5 below:

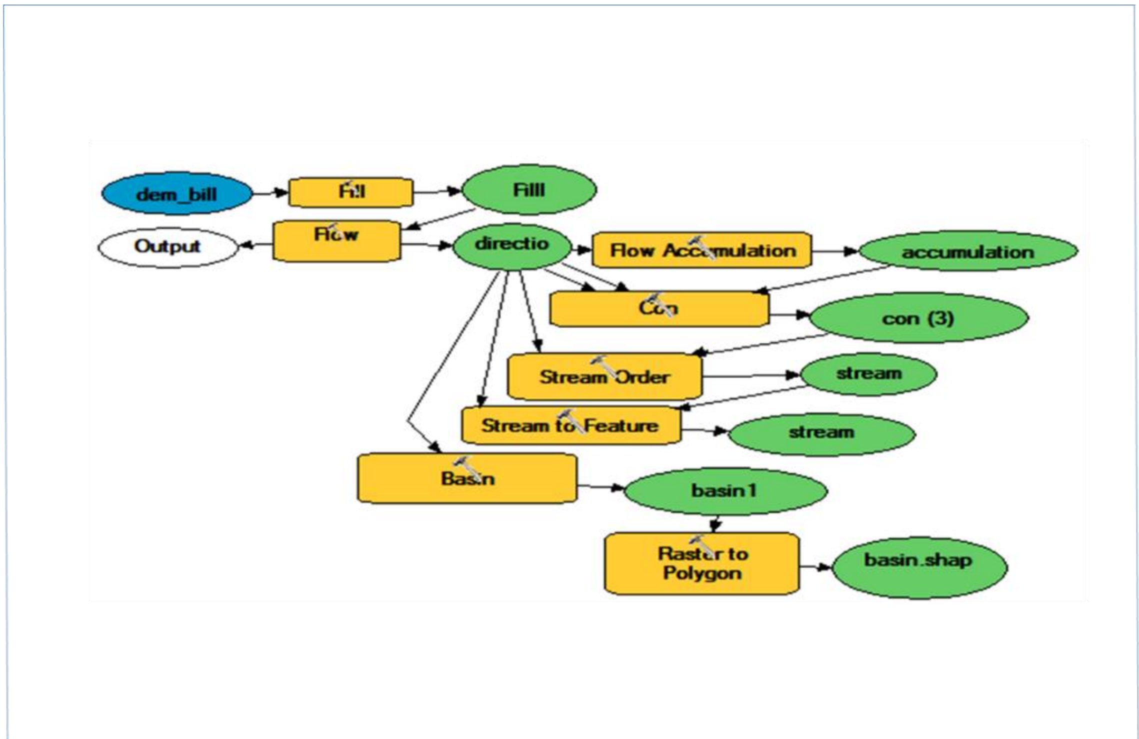


Figure 5-4 Processes of estimating LS factor in GIS environment

Fig 5-5 shows a series of hydrological mathematical computations performed in GIS for estimating different erosion parameters: filling, flow direction, flow accumulation, stream features, and stream order and basin shape. Some of these parameters were directly used to estimate the slope length and slope steepness. In addition, the computation of these parameters was important not only in estimating the slope characteristics of the watershed but also in delineating the shape of the watershed. The flow direction and accumulation were used as key input variables in computing both slope steepness and slope length using slope analysis tool in GIS.

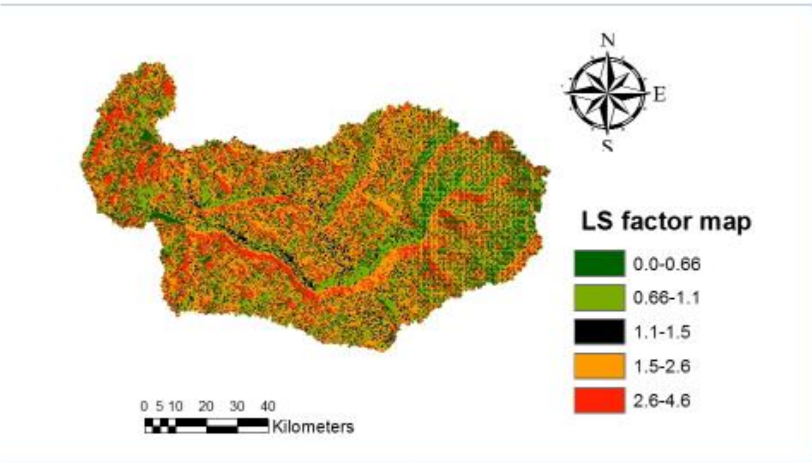


Figure 5-5 Spatial distribution of topographic factor (LS factor) in Oguta Lake watershed

Fig 5-6 shows significant variation in spatial topographic erosion potential in the watershed. Topographic spatial distribution of soil erosion in the watershed shows significant soil erosion in some parts of the watershed. In this study, topography is classified as a natural factor, which could only be controlled by applying support practice such as terrace farming, strip cropping, ridge contouring. However, ridge contour farming was adopted as the specific support practice (p-value) according to the local slope gradient of watershed.

Evaluation of land cover factor (C factor)

Cover management factor is determined by a combination of crop type and the tillage method in the catchment (USLE guidelines). However, Wischmeier et al. (1978); and Kefi et al. (2012) defined C factor as a ratio of soil loss cropped under specific conditions to the corresponding soil loss from a continuously tilled fallow area. This is practically applicable in agricultural farmlands, where the cropping system and management practices provide additional protective canopy cover on the ground surface thereby reducing soil erosion (Arekhi et al., 2012). However, in a developing country like Nigeria, it was difficult obtain the C factor based on the specific crop type because of the mixed crop farming system. Remote sensing satellite imagery has been widely used in estimating C factor at the watershed and regional scale (Ndukwe et al., 2013; Nwankwo and Nwankwoala, 2018). Satellite imagery classification approach could potentially introduce error in C factor as the classification of the images is based on either supervised or unsupervised images, which group land cover based only on likelihood classification. However, this group classification does reflect the protection potential of individual crops in the watershed, bearing in mind that different crops have different erosion protection potential (Gobin et al., 1999).

In this study, a supervised image classification of maximum likelihood was used to classify land use/land cover of the watershed using the RUSLE guide table. The Landsat TM and Landsat ETM+ imagery acquired in August 2014 (rainy season) was used to generate the C factor layer for Oguta Lake watershed. The image acquired during the rainy season was used because erosion potential is likely to be maximum during the rainy season and minimum during the dry season, which means images acquired during the dry season may introduce discrepancy in results that may not suit management decisions.

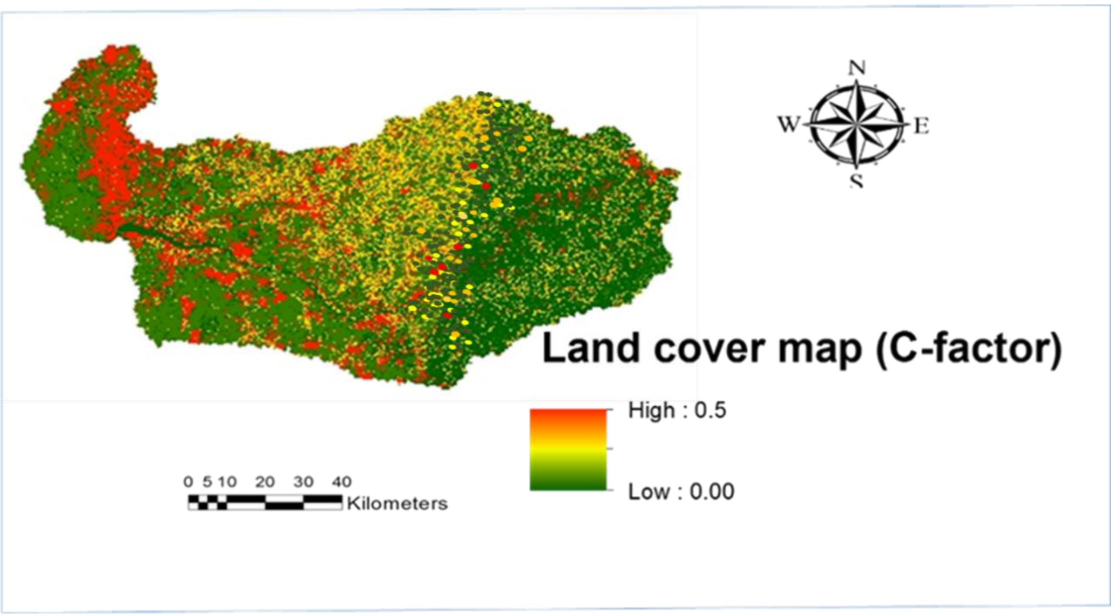


Figure 5-6 Spatial distribution of land cover (C-factor) erosion potential in Oguta lake watershed

Fig 5-7 shows significant spatial variation in erosion potential in the watershed. The most vulnerable land cover area in the watershed is the bare land and unpaved land which covers a significant area of the watershed while the least vulnerable land use is the water bodies which covers the smallest area of the watershed. Urban and cultivated land cover cause relatively moderate erosion and cover a small area of the watershed while pasture and forest land cover cause very slight to slight erosion and cover the largest area of the watershed.

Evaluation of conservation support practice factor (P factor)

In RUSLE, the conservation support practice P is the ratio of specific support practice with the corresponding soil loss with the slope tillage (Beskow et al., 2009; Arekhi et al., 2012). In the scenario where there is no support practice applied (fallow land), the value of P=1, while other conservation support practices like contouring, strip cropping, terrace cropping, and retentions ditches are used to minimise soil erosion based on the location and characteristics of erosion in the watershed (USLE guidelines). In the study location, there was no specific conservation support practice established because most farmers cultivate different parts of land with different crops in the communal farmlands. However, during the reconnaissance survey, it was observed that most farmers applied ridge contour farming while few farmers applied mould (heap) farming approach in their bid to minimise soil erosion. Therefore, specific P-value of 0.5 for ridge contour farming was used to estimate conservation support P by finding the ratio of specific support practice (ridge contour farming) with the corresponding soil loss with slope. Ridge contour used by local farmers in the study area reduces the slope length and overland flow which increases the infiltration capacity of soil. Presence of ridge contour reduces sediment yield in the watershed by reducing the velocity of runoff.

Some farmers-built earth bunds and placed bundles of tree branches at regular intervals as sand traps to retard soil erosion. In some private farmlands, farmers-built enclosures around their farmlands as their effective soil conservation approach, while some farms were left fallow.

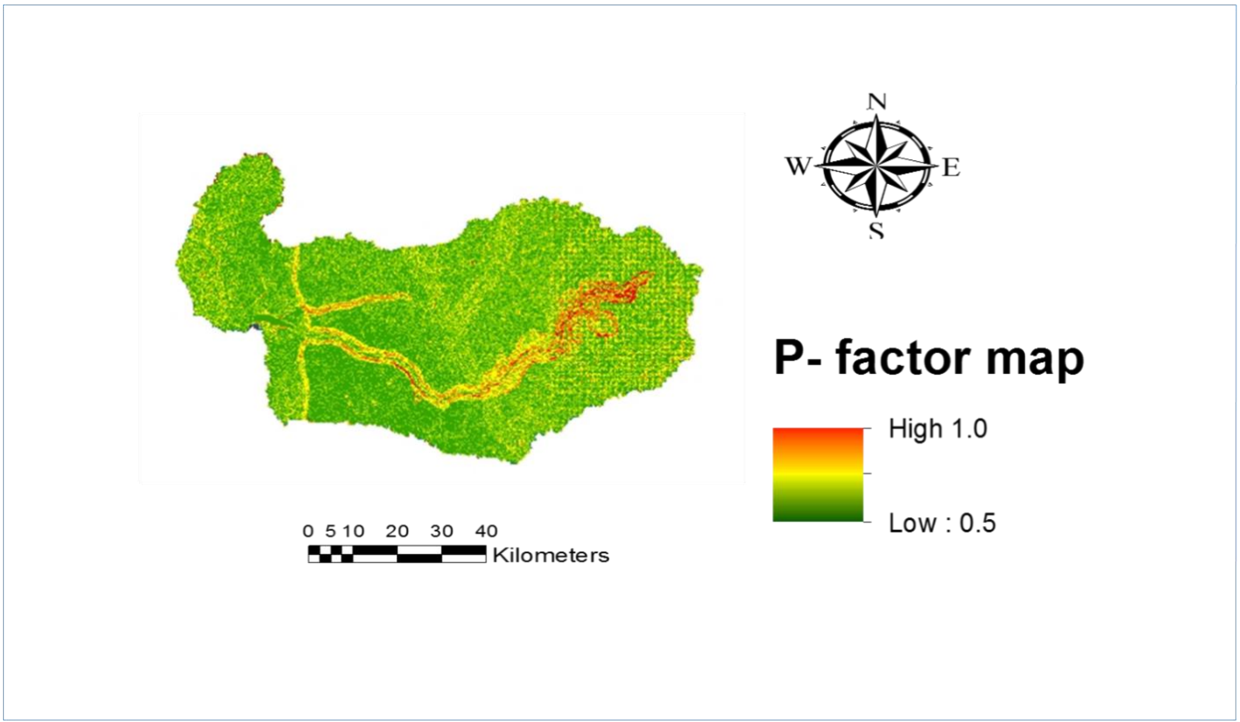


Figure 5-7Spatial distribution of conservative support practice (P-factor) erosion potential in Oguta Lake watershed

Fig 5-8 shows significant potential erosion along the course of the major tributary river (Njaba River), which means conservation support attention such as bank protection could minimise soil erosion in the watershed.

5.2.2 Spatial variation of annual sediment yield in the watershed

The spatial magnitude of the annual sediment yield was computed by multiplying the six factors according to RUSLE guidelines as seen in Fig 5-9. The range of minimum and maximum values of soil erosion ranged from 8-11 tonnes ha^{-1}year^{1} for low yield areas to 25-36 tonnes ha^{-1}year^{1} for high yield areas respectively, while the mean sediment yield is 21 tonnes ha^{-1}year^{1}. However, the spatial distribution of erosion was shown in a range of minimum and maximum values to highlight areas that may need management attention. This result agrees with both remote sensing imageries and the ground-point field samplings in the watershed, which highlighted high erosion and hence predicted sediment yield in some areas. In addition, the high erosion areas from the predicted erosion result correspond with some identified sand mining points and unpaved roads, which were classified vulnerable due to surface soil exposure to direct rainfall impact. In this research, the spatial distribution of erosion in Oguta Lake watershed may be more reliable than the magnitude of the sediment yield, given that there is no sediment inventory in the watershed to calibrate and validate the predicted result. Even though the magnitude of the predicted sediment yield may have some validity challenges, the spatial distribution of severe erosion areas would give useful insight in proposing some management decisions, which is the main purpose of this work.

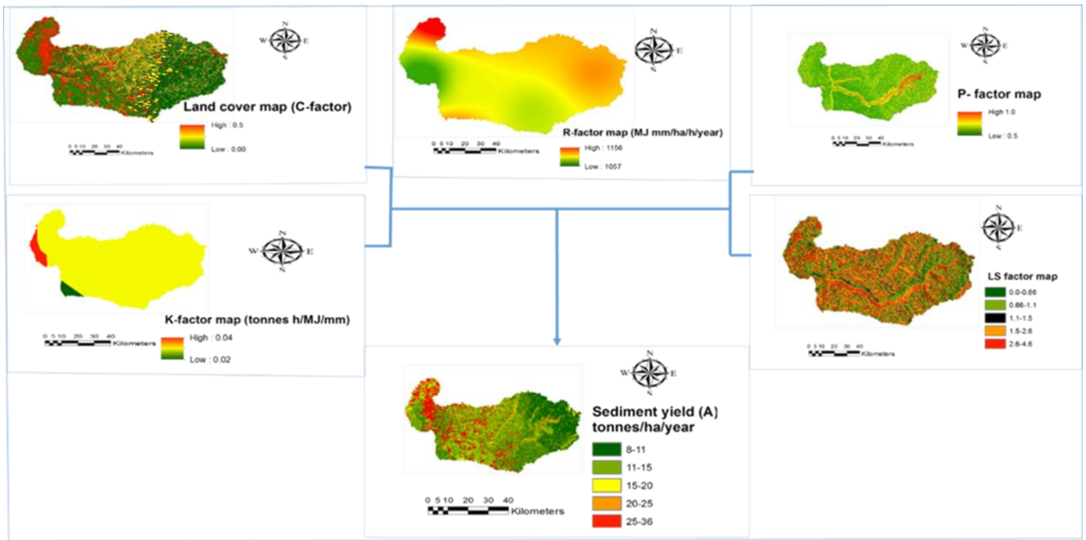


Figure 5-8 Spatial distribution of sediment yield in Oguta watershed, derived from RUSLE (A=RKLSCP)

5.2.3 Spatial variation of soil erosion intensity risk derived from RUSLE model

The classification of erosion in the watershed was based on grouping according to USLE guidelines aimed at highlighting different erosion intensity in the watershed. There are other criteria for erosion classification such as FAO (2006) and classification based on the physical condition of the watershed. The intensity of soil erosion in the watershed ranged from very slight for the least susceptible areas to severe for the most susceptible areas to soil erosion. It was found as seen in Fig 5-10 and Table 5-1 that up to 33% (heavy + severe) of the watershed is vulnerable to erosion, 14% of the watershed is moderate while 53% (very slight + slight) of the watershed is relatively stable. Even though over half of the watershed is relatively stable, 18% of the watershed produces erosion magnitude up to 36 tonnes/ha/year which is significant and would require immediate soil conservation measures to minimise erosion in the watershed.

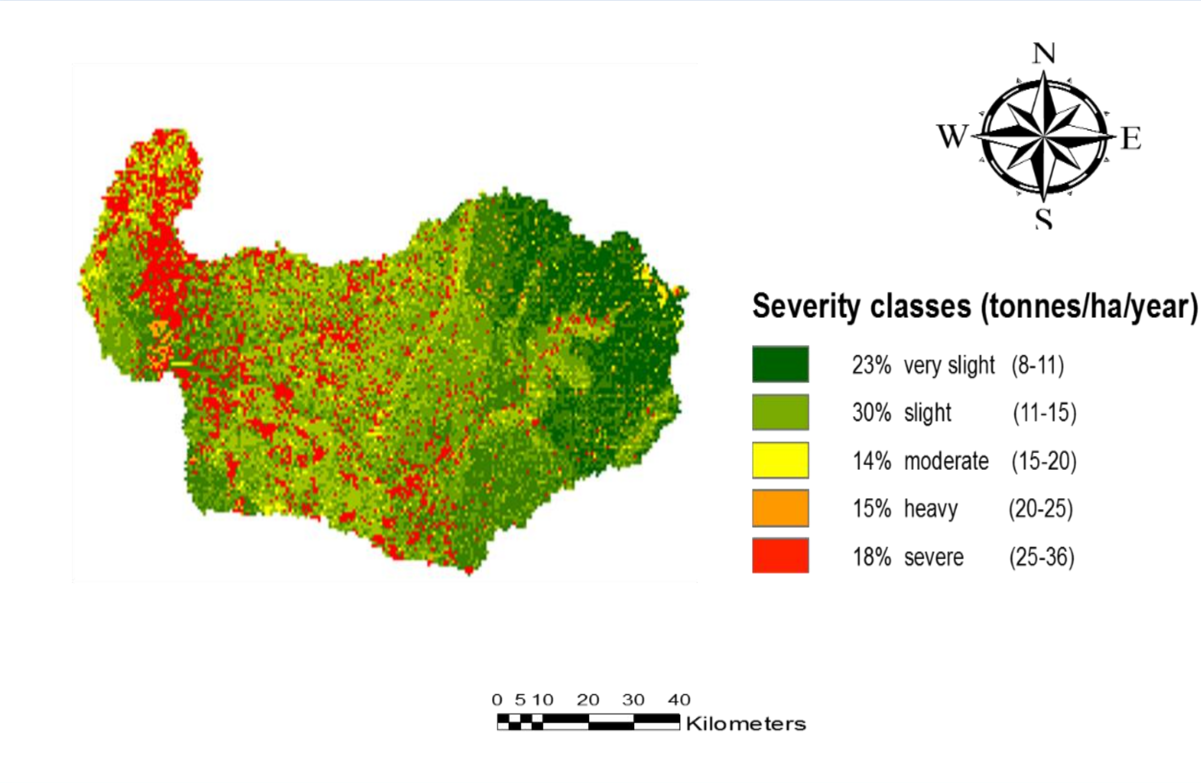


Figure 5-9 Spatial variation of erosion intensity risk in Oguta Lake watershed

Table 5-2 Classification of soil erosion severity coverage and ranges of soil loss from USLE guidelines

Watershed size	**Sediment yield (tonnes/ha/yr.) /Severity classes**					**Total**
	8-11	11-15	15-20	20-25	25-36	
	very slight	slight	moderate	heavy	severe	
Area (km^2)	126.5	165	77	82.5	99	550
% of total area	23	30	14	15	18	100

5.2.4 Comparing the identified severe erosion points collected on ground with spatial soil erosion risk map

Figure 5.11 shows that there is a reasonable match between the predicted severe erosion areas and the actual field-identified vulnerable areas such as sand mining, riverbank, gully development and unpaved roads. In addition, the vulnerable areas from recent satellite imageries correspond to both the severe areas in the sediment yield map and the vulnerable points from the actual field samplings. These points were verified using the longitude and latitude points plotted in both GIS and ERDAS IMAGINE environment. This correspondence further strengthens potential application of the spatially predicted soil loss in developing management policies and strategic planning.

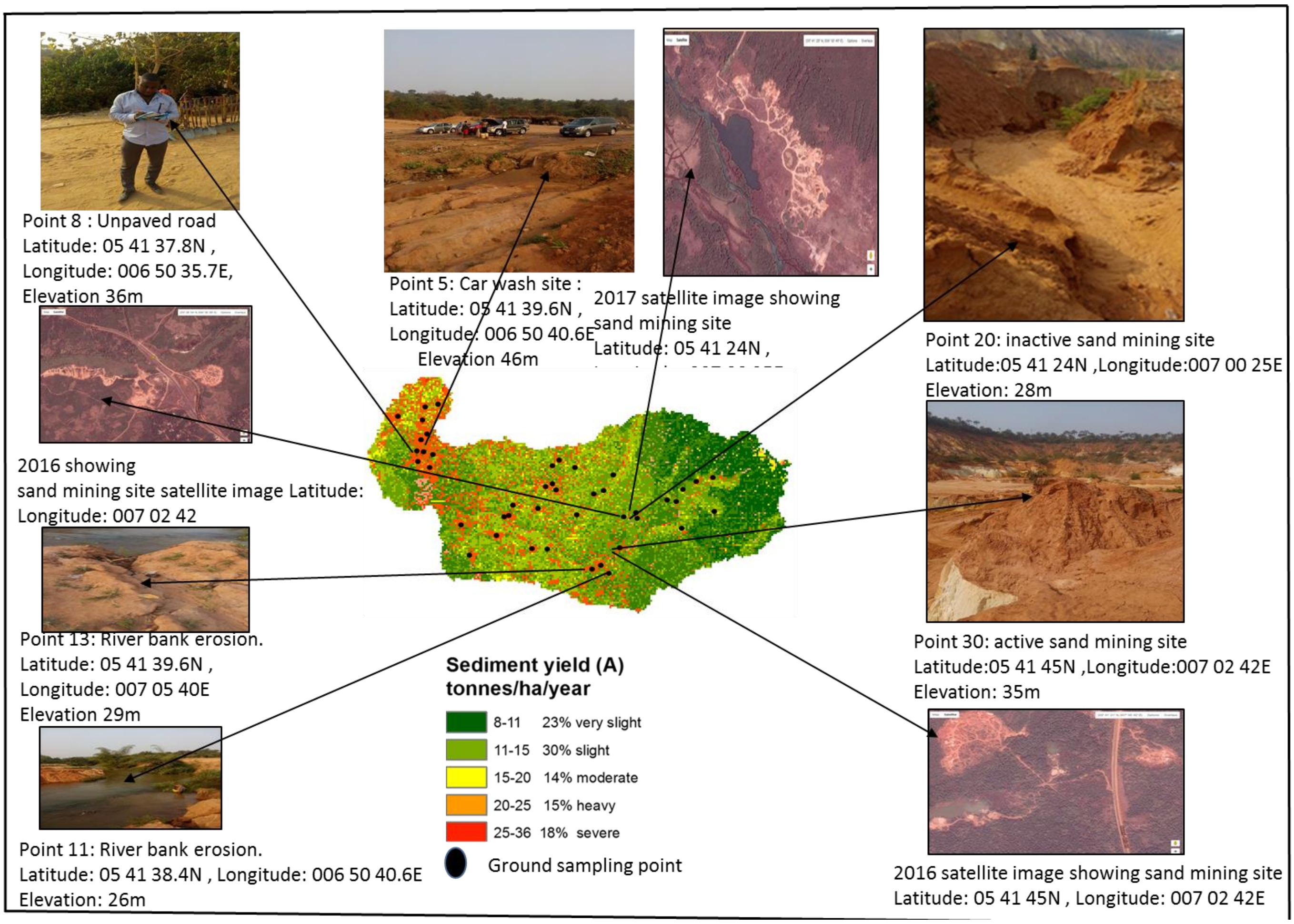


Figure 5-10 Comparing the predicted severe erosion areas with both the vulnerable points from actual field samplings and satellite imageries

5.2.5 Investigating the effect of land cover changes on soil erosion

Changes in land use could significantly affect soil erosion at a basin scale (Diodato, 2006). Considering the aim of this research, emphasis was laid on human induced factors such as land use/land cover activities that could be controlled. As such, as land cover image acquired in August 1990 was used to replace the land cover image acquired in August 2014 in RUSLE model to investigate the effect of land cover change on soil erosion. The C-factor map in Fig 5-12 derived from land cover satellite imagery of 1990 showed that only 15% of the watershed was vulnerable to soil erosion while in 2014 (after 24 years) the vulnerable area has increased to 25%. Even though, the reconnaissance survey conducted in the watershed for the period December 2015-January 2016 revealed that sand mining has significantly increased watershed vulnerability, there may be other possible human activities such as intense farming and urbanisation that may have contributed to this increased watershed vulnerability. However, it not yet known how much land cover changes have contributed to soil erosion in Ugota Lake watershed. Thus, Fig 5-12 and Fig 5-13 showed some comparable features of the predicted soil erosion from land cover map of both 1990 and 2014 in RUSLE model. Interestingly, there are significant changes in both severity and magnitude of soil erosion from 1990 to 2014, which could be linked to land cover changes. For this period of 24 years, 70% (very slight to slight) of stable watershed area has been reduced to 53%, shifting 17% of the watershed area to unstable zone while 30% (moderate–severe) of the unstable watershed area has increased to 47%, which means that this trend could lead to much more sediment yield in the watershed if allowed to continue. However, introduction of conservation support practices could significantly reduce vulnerable areas in the watershed.

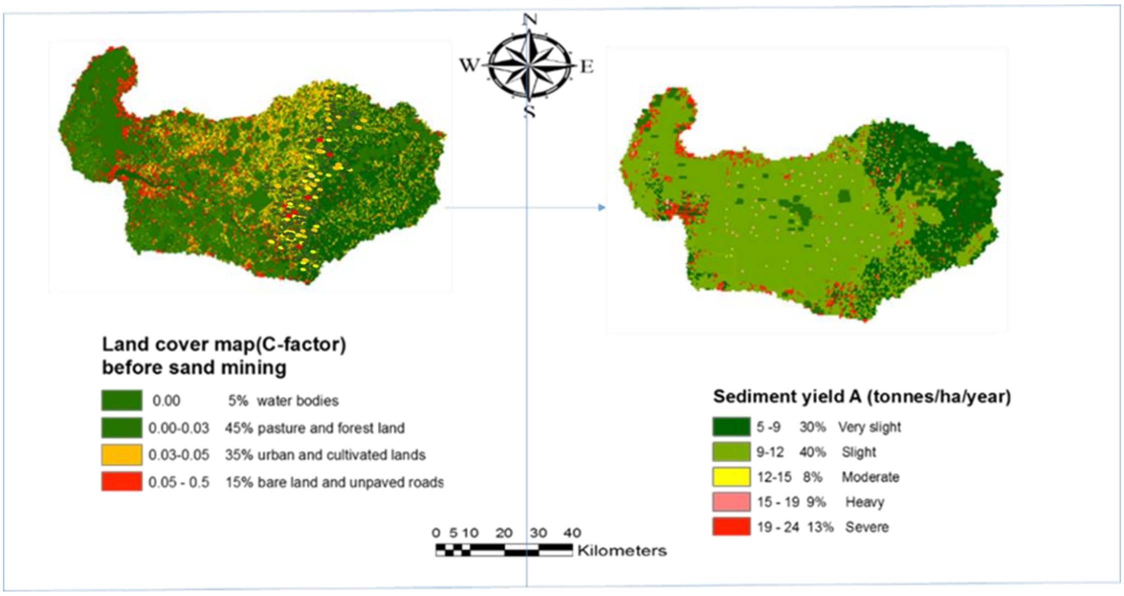


Figure 5-11 The magnitude of soil loss derived from land cover map of 1990 in RUSLE model

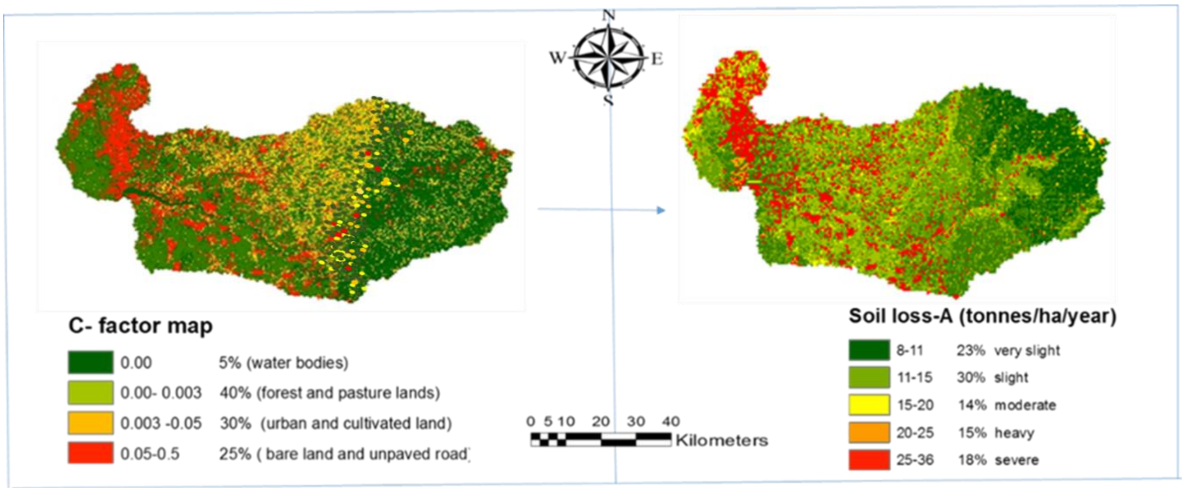


Figure 5-12 The magnitude of soil loss derived from land cover map of 2014 in RUSLE model

5.2.6 The effect of change in bare ground area in the watershed (future scenarios analysis)

In this research, scenario analysis was used to investigate land cover change in RUSLE model under various assumptions that are expected to occur in the future. This was done by pixel by pixel converting 10%, 20%, and 40% of pasture and forest area into a bare ground area in the model, which means exposing areas formally covered by vegetation to direct rainfall impact. Thus, it was found that sediment yield increased by 19%, 31%, and 50% across the watershed for the 10%, 20% and 40% increase in the bare ground area as evidenced in Fig 5-14. These scenario results simply indicate a need for concern regarding soil erosion in the watershed, which is likely to take place in the future if bare land increases. On the other hand, the second scenario was carried out by pixel by pixel converting the same percentage of bare ground area into a pasture and forest land in the model. This simply means protecting formally exposed bare ground areas from direct rainfall impact using vegetation cover. As a result of this, the sediment yield reduced by 19%, 25% and 44% across the watershed for the 10%, 20% and 40% reduction in the bare ground area as evidenced in Fig5-15. These results indicate that, despite other factors, magnitude of sediment yield is very sensitive to change in land cover as illustrated in Fig5-16, which means applying soil conservation support practice in the watershed could minimise soil erosion.

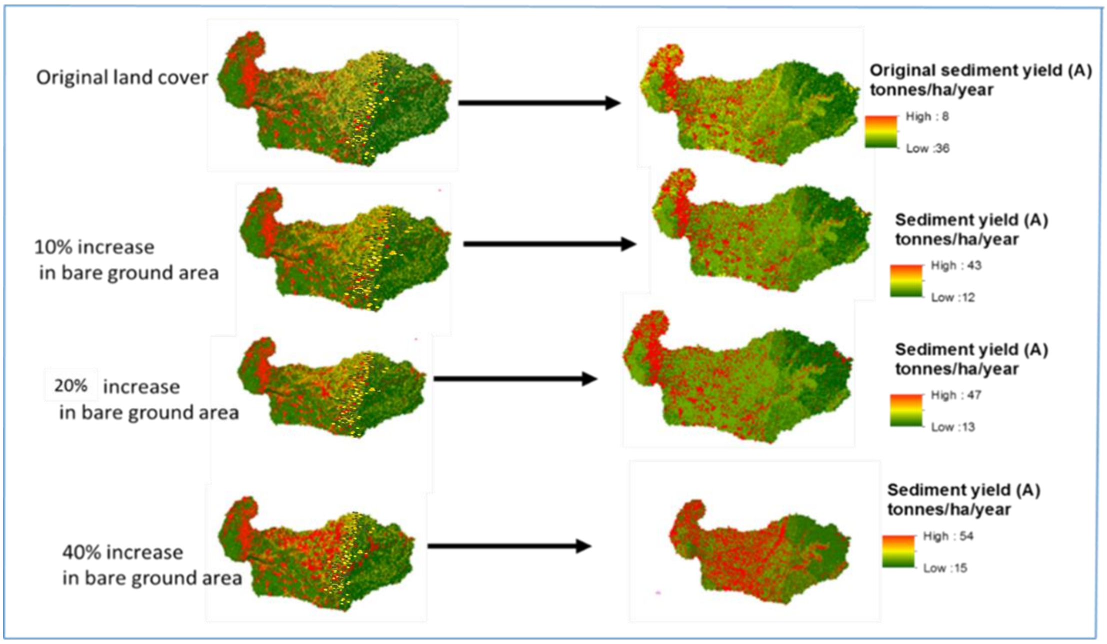


Figure 5-13 Illustration of soil erosion risk scenario analysis obtained by increasing bare ground area based on assumptions regarding expected future events in RUSLE model

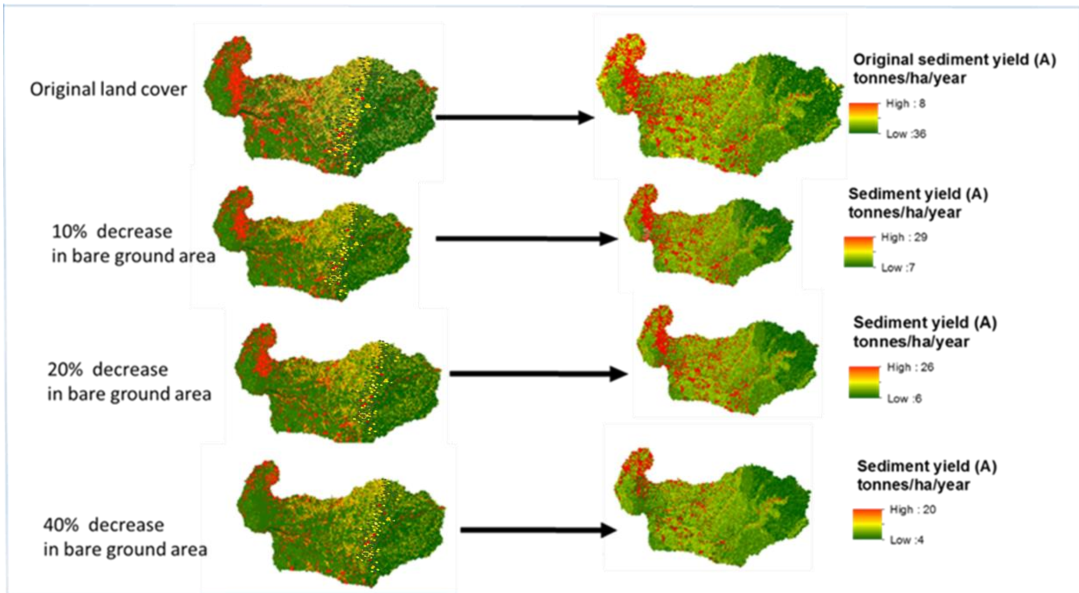


Figure 5-14 Illustration of soil erosion risk scenario analysis obtained by decreasing bare ground area based on assumptions regarding expected future events in RUSLE model

RUSLE MODEL

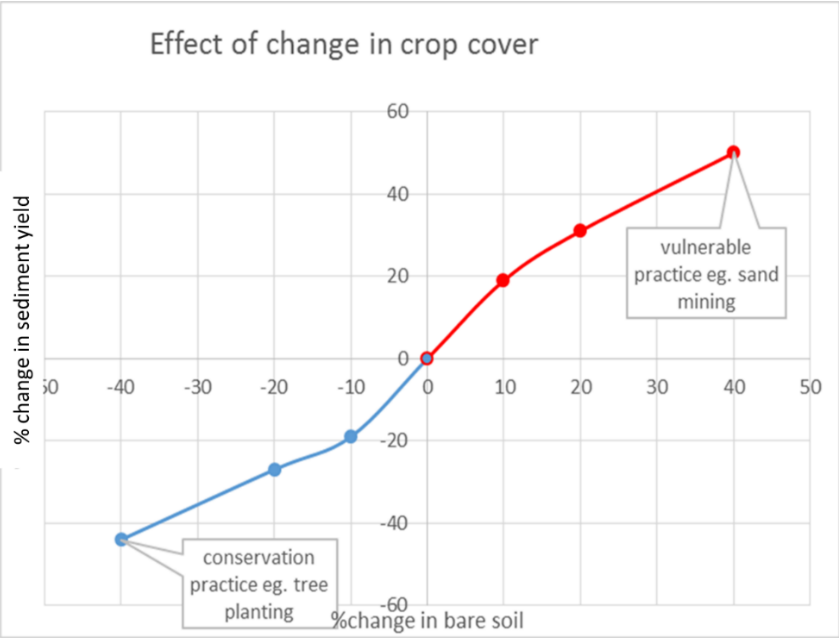


Figure 5-15 Illustrating the sensitivity to and consistency of change in bare ground area in sediment yield using RUSLE model

5.3 Method and Evaluation of MPSIAC model

The Pacific South Inter Agency Committee model (PSIAC) was first developed in the USA and applied in the Walnut Gulch watershed located southeast of Arizona**.** The model parameters were initially determined by ranking scores based on physical description of the watershed. However, the subjectivity of factors ranking became a cause for concern, and Johnson and Gembhart (1982) converted the descriptive concept of the first model into numerical amounts by assigning mathematical empirical relationship equations to each of the nine factors in MPSIAC model. In this model, the soil erodibility value in USLE is used as an input parameter in the soil factor equation while annual runoff volume and stream peak discharge are used as input parameters in the runoff factor equation. The nine factors include: Surface geology (Y_1), soil (Y_2), climate (Y_3), surface runoff (Y_4), topography (Y_5), land cover (Y_6), land use (Y_7), surface erosion (Y_8) and channel erosion (Y_9). The total soil erosion is the sum of nine factors in MPSIAC model as follows:

$$R = \sum_{i=1}^{n} X_i$$ Equation 5-9

where R is the total ranking value (in cubic meters per square kilometre per year) and X_i is the value of each factor in the model. However, Johnson and Gembhart (1982) introduced interpolations and extrapolations to control the equation to improve the accuracy of the model as follows:

$$Q_{S=18.60e^{0.0360R}}$$ Equation 5-10

where Q_S is the rate of sediment yield in cubic meters per square kilometre per year and R is the total ranking value in cubic meters per square kilometre per year? Table 5-2 below shows the various MPSIAC model factors equations and the input parameters.

Table 5-3 Nine MPSIAC factors and their modification equations developed by Johnson and Gembhart (1982)

Erosion factor	Modified factor equations	Parameters
Surface geology	$Y_1=X_1$	X_1 = surface geology erosion index
Soil	$Y_2=16.67X_2$	X_2=soil erodibility factor
Rainfall	$Y_3=0.2X_3$	X_3=6-hour rainfall with a 2-year return period
Runoff	$Y_4=0.006R+10Q_p$	Qp = specific peak discharge ($m^3/s.km^2$) (i.e. flood peak discharge) R=annual runoff depth (mm)
Topography	$Y_5=0.33X_5$	X5=percentage of the average basin slope
Vegetation cover	$Y_6=0.2X_6$	X_6=percentage of land without vegetation i.e. % of bare ground
Land use	$Y_7=20-0.2X_7$	X_7=percentage of canopy cover i.e. percentage of canopy cover each land unit.
Upland erosion	$Y_8=0.25X_8$	X_8=total surface soil factor scoring in BLM
Channel erosion	$Y_9=1.67X_9$	X_9=gully erosion scoring in BLM

where BLM is the Bureau of Land Management

5.3.1 Application of MPSIAC model

The nine factors in the MPSIAC model were evaluated in a GIS environment as follows.

<u>Surface geology factor (Y_1)</u>

The surface geology (Y_1) of the watershed was evaluated based on the resistance of soil surface to erosion (X_1) as follows:

$$Y_1 = X_1 \quad \text{Equation 5-11}$$

Where Y_1 is the surface geology factor and X_1 is the level of resistance of soil surface to erosion. The score is determined based on the degree of surface resistance to erosion on a scale of 1 (for the most resistant face) –10 (for the most sensitive face) according to MPSIAC guidelines. The scoring was based on the Pacific Southwest condition; its application in Nigeria may lead to uncertainty in the sediment yield result. According to de Vente at al. (2005) who successfully applied PSIAC in Spain, they opined that when applying the model in another location a new relationship needs to be established based on the condition of the location. But this was not possible in this research because of lack of sediment inventory in the study location to calibrate and validate the model. In this study, the surface geology scaling factor was determined based on field survey information, and according to the local condition of Imo State Nigeria (Etu et al., 1990). The surface geology was divided into consolidated material, loose unconsolidated alluvium and stream channel/lake plain sand, which reflects the surface condition of the watershed as seen in Fig 5-17 and Table 5-3. In this study, it was found that a large surface area of the watershed is made up of loose unconsolidated alluvium, which contains significant amount of both shale and conglomerate. Moreover, the lake side and stream channel are the most susceptible surface to soil erosion due to lake sand and human activities along the lake side. The consolidated soil has the highest resistance to soil erosion because of high phyllite content but it just covered a very small portion of the watershed. Overall, surface geology contributes significantly to soil erosion in the watershed, especially under bare ground conditions.

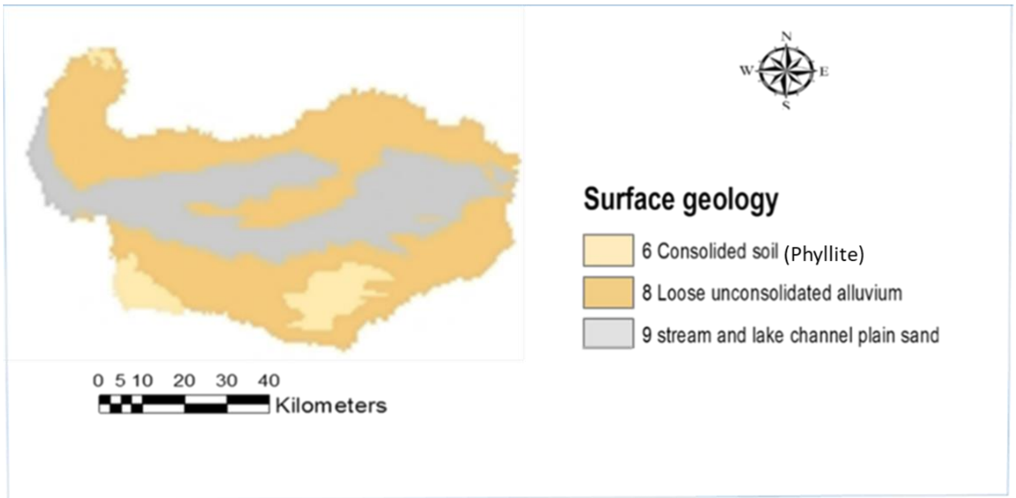


Figure 5-16 Geology map of Oguta Lake watershed

Soil factor (Y_2)

The soil factor was determine based on soil erodibility according to the USLE model, which was estimated using equation 5-12.

$$Y2 = 16.67K \quad \text{Equation 5-12}$$

Where Y_2 is the soil factor and K is the soil erodibility obtained according to USLE guidelines. Soil erodibility K was obtained by finding the percentage of sand, silt and clay, moisture content, soil permeability and soil structure in the USLE model as shown in Fig 5-18. The soil factor is very low because of the low soil erodibility value estimated using USLE equation. This could be linked to good soil properties and high draining potential of the soil in the watershed.

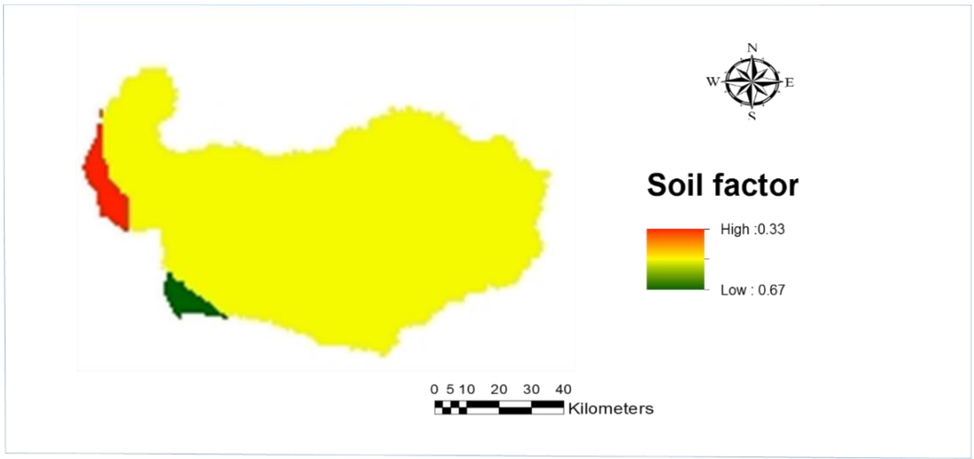


Figure 5-17 Soil map of Oguta Lake watershed

Rainfall factor (Y_3)

The rainfall factor was determined based on rainfall intensity in the watershed using the following formula:

$$Y_{3=} 0.2P_2 \quad \text{Equation 5-13}$$

where Y_3 is the rainfall factor and P_2 is the 6- h rainfall with a return period of 2 years measured in millimetres. In this study, the rainfall record of 10 years (2005-20015) was used to determine the rainfall factor. The rainfall record was classified into three main layers based on the rainfall depth (53mm, 71mm, and 78mm) distribution in the watershed and was then applied in GIS environment using Equation 5.13 to generate the rainfall map of the watershed as seen in Fig 5.19. The rainfall distribution was highest at the topmost elevation and lowest towards the watershed outlet. This spatial distribution of rainfall in the watershed agrees with findings of (Markos et al., 2009), who demonstrated that rainfall increases with increase in altitude. In this study, the possible range of rainfall factor is high compared with the range of values in the model, which could be linked to the tropical rainfall condition of the watershed.

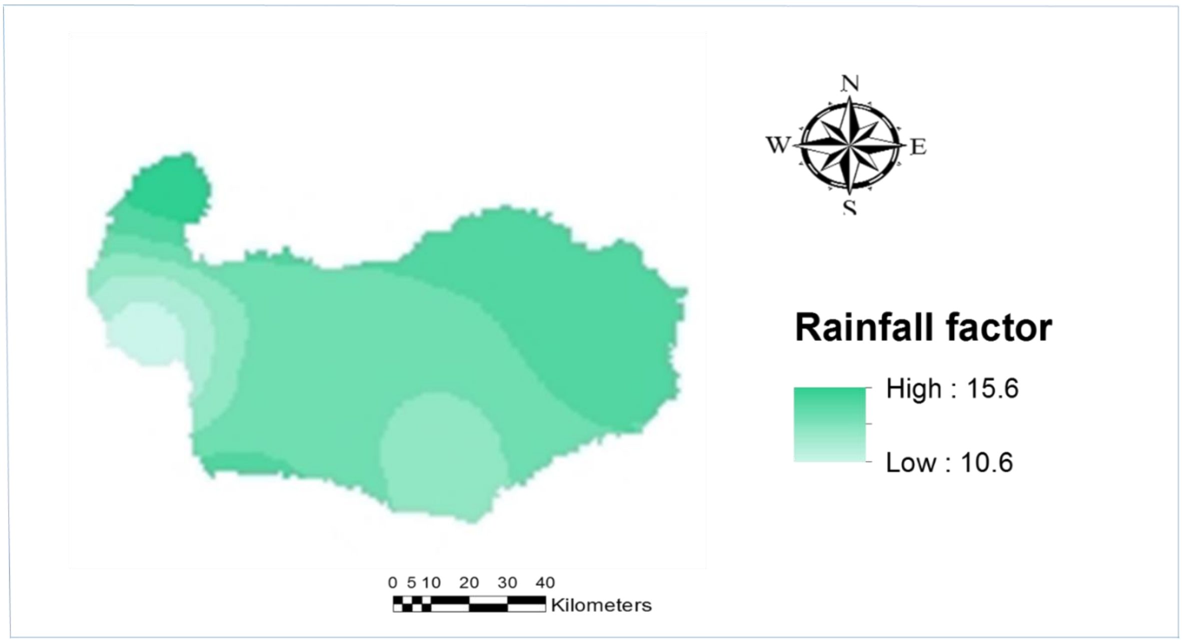


Figure 5-18 Rainfall map of Oguta Lake watershed

Runoff factor Y_4

The runoff factor was estimated based on the discharge, and annual runoff depth in the watershed as shown in Equation 5-14

$$Y_4 = 0.006R + 10Q_P \qquad \text{Equation 5-14}$$

where R is the annual runoff depth measured in millimetres and Q is the specific peak discharge measured in cubic meters per square kilometre per second. In this study, average rainfall depth was estimated based on the rainfall record in the watershed while the specific peak discharge was estimated by dividing flood peak discharge by watershed area. Therefore, runoff potential was estimated by grouping the watershed into classes starting from the highest elevation to the lowest elevation at the watershed outlet. For clarity, the watershed units were compressed into 3 units: 270 km^2, 160 km^2 and 120km^2 under the assumption that runoff potential increases as the elevation decreases. The specific peak discharge and annual runoff elevation were used to estimate the runoff factor map using Equation 5-14 as seen in Fig 5-20. Just like the rainfall factor, the high values of runoff factor could be justified by the model being applied in the tropical region with both high rainfall depth and intensity.

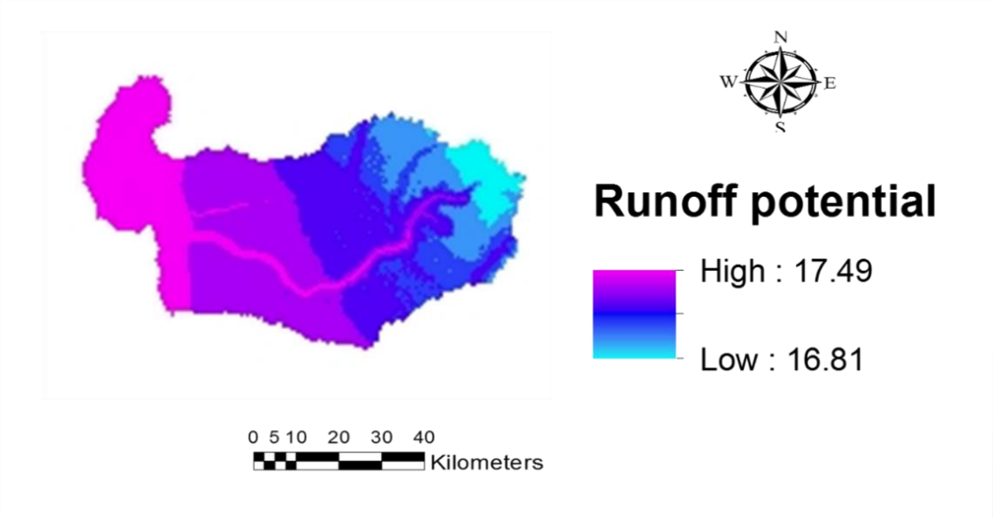


Figure 5-19 Runoff potential map of Oguta Lake watershed

Topography factor Y5

The topography factor is estimated based on the average percent of slope steepness as shown in Equation 5-15

$$Y_5 = 0.33S$$ Equation 5-15

where Y_5 is the topography factor and S is the slope steepness in percentage. Slope was estimated using the DEM of the watershed in a GIS environment, which was applied in the MPSIAC equation to estimate the topography factor. The flow direction and accumulation were estimated in a GIS environment and were used as input parameters for estimating the slope steepness. The slope steepness values varied from 4.3% for the flattest area to 12.9% for the steepest area. The steepness values were applied in a GIS environment using Equation 5.15 to generate the topography map of the watershed as seen in Fig 5-21. The spatial result varied from 1.42 for the flattest area to 4.26 for the steepest area, which shows that slope of the watershed has the potential to drive significant erosion.

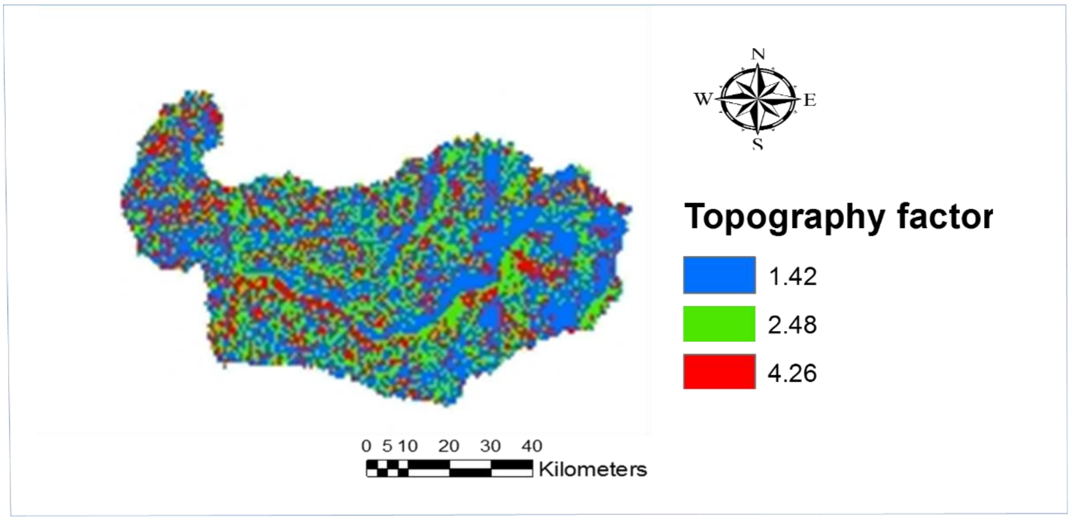


Figure 5-20 Topography map of Oguta Lake watershed

Land cover factor (Y6)

Land cover is characterised by surface coverings such as litter, vegetation and rocks (Johnson and Gembhert, 1982) and is estimated using equation 5-16

$$Y_6 = 0.2P_b \qquad \text{Equation 5-16}$$

where Y_6 is the land cover factor and P_b is the percentage of bare ground at each land unit. In this study, the Landsat TM imagery (path/row: 188/56) acquired in August 2014 (rainy season) and information generated during field visits were used to classify the land cover.The land cover was divided into three major land units: pasture and forest lands/water, residential lands and cultivated lands. The land cover factor map in Fig 5-22 was generated based on the percentage of bare ground cover in GIS environment using Equation 5.16. In the cultivated land unit, it was assumed that different crops have the same potential to offer protection to the soil, which in reality is not true, knowing that different crops offer different protection potentials to the soil. It was difficult to specifically group crops according to their species and protection potential due to the mixed farming practised in the watershed. In addition, pasture and forest land were also grouped together under assumption that different trees and shrubs have same erosion protection potentials, which may likely introduce error, bearing in mind that different trees and shrubs have different soil protection potentials. The complexity of Landsat imagery used for classification could not allow trees and shrubs to be identified individually, hence grouping canopy cover was the option used to close the gap.

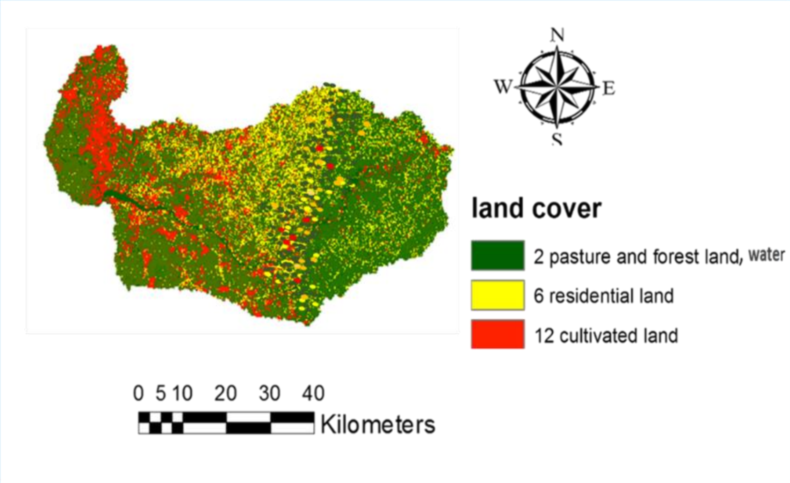


Figure 5-21 Land cover map of Oguta Lake watershed

Land use factor (Y7)

Land use is estimated based on the percentage of canopy cover in the study area using Equation 5-17.

$$Y_7 = 20 - 0.2P_C \quad \text{Equation 5-17}$$

Where P_C is the percentage of canopy cover in each land unit. In this study, a combination of Landsat TM imagery of August 2014, field visits and topographic map were used to classify the land use in the watershed. The land use was divided into the three main land units: pasture and forest lands/water, residential land, cultivated/construction /mining/unpaved roads. The land use factor map shown in Fig 5-23 was generated based on the percentage of the canopy cover in GIS environment using Equation 5.17.

It was assumed that cultivated land, construction land, and mining and unpaved road produce the same soil erosion amount in the watershed, because it was difficult to trace some of the land use practice in some exposed soil areas. Even though these grouped land use have different erosion potential, they all have the potential to expose soil to direct rainfall impact. Furthermore, the assumption made in estimating erosion in pasture and forest land/water unit in land cover factor was also made in land use factor to reduce the complexity of treating trees and shrubs erosion protection potentials individually but was grouped as low erosion area.

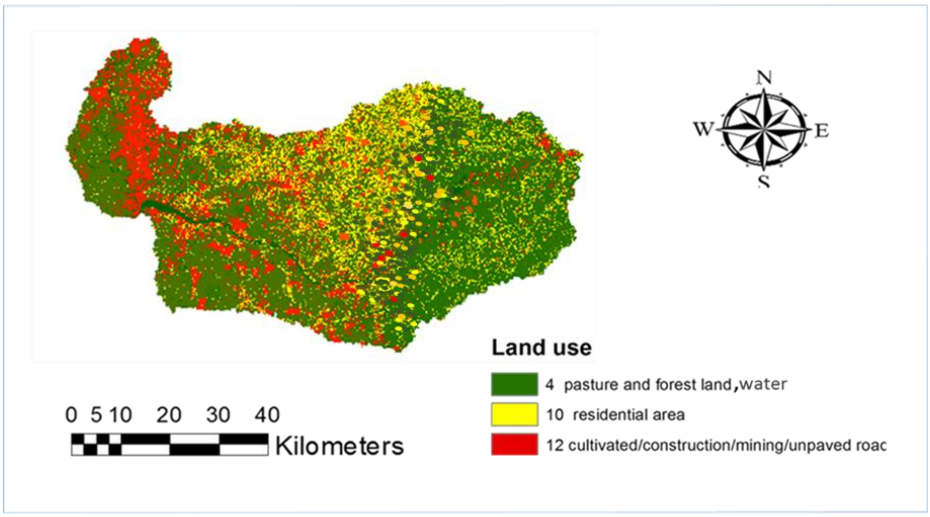


Figure 5-22 Land use map of Oguta Lake watershed

Upland erosion factor (Y_8)

Upland erosion is the factor in the MPSIAC model that describes the current erosion condition in the study area based on the US Bureau of Land Management (BLM) method. To estimate upland erosion factor, seven soil surface factors (SSF) are considered and scored according to BLM method such as surface soil mass movement (1-14), surface leaf crop covering (1-14), surface rock fragments covering (0-14), surface stoniness (0-14) surface rill (0-14), surface streams(0-15) and surface gully erosion (0-15) according to equation 5-18 and 5-19.

$$Y_8 = 0.25SSF \qquad \text{Equation 5-18}$$

$$SSF=\sum_i^7 SSFi \qquad \text{Equation 5-19}$$

Where Y_8 is the upland erosion factor and SSF is the soil surface factors. In this study, the SSF scores were determined based on information from field survey and Landsat TM imagery of the watershed. The total SSF was obtained from the sum of individual soil surface factor scores, and then applied in the upland erosion factor Equation 5-18, which was used to generate the upland erosion factor map as seen in Fig 5-24. During the upland erosion analysis in GIS, it was observed that all the depression surfaces including river channels were identified as potential upland erosion. This was because the GIS environment could not differentiate gullies from the river channel, but this should not be a problem as surface stream was one of the soil surfaces factors in upland erosion factor.

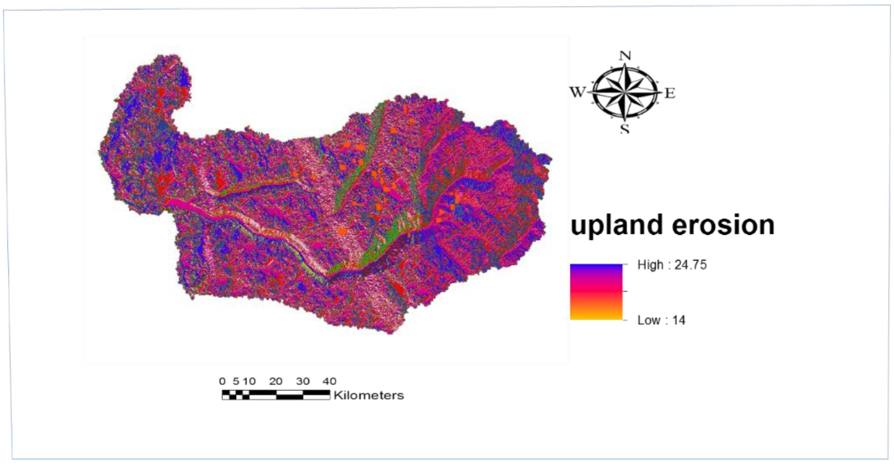


Figure 5-23 Upland erosion map of Oguta Lake watershed

Channel erosion factor (Y_9)

Channel erosion factor is obtained based on the gully erosion factor in BLM method as shown in Equation 5-20.

$$Y_9 = 1.67SSF.g \quad \text{Equation 5-20}$$

where Y_9 is channel erosion factor and SSF.g is the gully erosion value according to BLM method. The SSF.g values were determined based on observation and gully features in the watershed. Then, based on SSF.g values, channel erosion factor was estimated using equation 5-20 as presented in Fig 5-25. To achieve this, stream features were extracted from the flow direction raster in GIS environment, which was matched with both the Landsat TM imagery and field survey records. Due to the non-homogeneity of river channels in the watershed, SSF.g was scored as follows: the minor stream channel with little evidence of erosion SSF. according to BLM, Minor stream channel SSF.g = 7.5; Disturbed stream SSF.g = 10 and mainstream channel SSF.g =15.

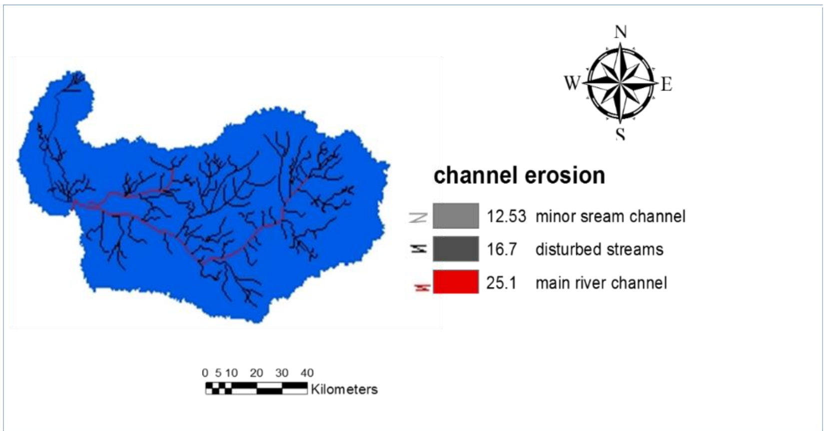


Figure 5-24 Channel erosion map of Oguta Lake watershed

5.3.2 *Spatial distribution of sediment yield in Oguta lake watershed derived from MPSIAC model*

In this study, the total ranking value was calculated by adding up the scores of each factor to obtain R-value using Equation 5- 9 as presented in Table 5-3. However, the multiple values of Xi assigned to the same factor based on the attributes of the watershed was to reflect the non-homogeneity of the watershed. It was important to classify these factors in accordance with both field observation and data record knowing that the severity of soil erosion in the watershed is not uniform, which should be reflected in the model result. Furthermore, the sediment yield (Qs) was estimated using Equation 5.10 in order to control the accuracy of interpolations and extrapolations of values assigned to different factors in the MPSIAC model. In this study, GIS was used to spatially analyse and distribute the sediment yield pixel by pixel based on the 30m*30m resolution mapped at the scale of the whole watershed as presented in Fig 5-26. The range of minimum and maximum values of soil erosion ranged from 248-279(m^3 km^{-2} $year^{-1}$) for very slight yield erosion areas to 1118-1399 (m^3 km^{-2} $year^{-1}$) for severe yield erosion areas respectively, while the mean sediment yield is 991 (m^3 km^{-2} $year^{-1}$). The sediment yield was classified based on the MPSIAC model guideline ranging from very slight (least susceptible area to soil erosion) to severe (the most vulnerable area to soil erosion). It was found that 27% of the watershed is under severe erosion; 8% of the watershed is under heavy erosion; 11.5% of the watershed is under moderate erosion; 36% of the watershed is under slight erosion while 17.5% of the watershed is under very slight erosion as seen in Table 5-4. These figures show that 27% of the watershed is highly vulnerable to erosion and could produce erosion as high as 1399 (m^3 km-^{2} $year^{-1}$) while only 17.5% of the watershed is highly stable. This means that the ratio of highly vulnerable area to highly stable area is high and could result in much more soil loss if the trend continues. Thus, a good soil conservation support management practice may reduce the watershed vulnerability considering the impact of soil erosion driving factors and the way they combine in its location.

Table 5-4Attribution of nine soil erosion factors in the watershed using MPSIAC model

Factors	Attributes	Symbols	Scores
Surface geology	Consolidated soil	Y_1	6
	Loose unconsolidated alluvium		8
	Stream channel and costal plan sand		9
Soil **Y2 = 16.67K**	Very deep well drained sandy loam, sandy clay, clay loam and sometimes gravely subsoil	Y_2	0.33
	Well drained soils, loamy sand to sandy loam over sandy clay subsoil		0.49
	moderately deep well drained soils, sandy loam to silt loam surface over fine sandy loam		0.67
Climate **$Y_3 = 0.2P_2$**	Rainfall intensity with a return period of 2-years(53mm)	Y_3	10.6
	Rainfall intensity with a return period of 2-years(71mm)		14.24
	Rainfall intensity with a return period of 2-years(78mm)		15.6
Runoff	Rainfall runoff for a hydrological unit 1	Y_4	16.81
Y4 = 0.006R+10Q	Rainfall runoff for a hydrological unit 2		17.14
	Rainfall runoff for a hydrological unit 3		17.49
Topography	For average percentage slope of 4.3%	Y_5	1.42
$Y_5 = 0.33S$	For average percentage slope of 7.5%		2.48
	For average percentage slope of 12.9%		4.26
Land cover	% of bare ground in the *pasture*/ forest land/water 10%	Y_6	2
$Y_6 = 0.2P_b$	% of bare ground in the residential land 30%		6
	% of bare ground in the cultivated land 60%		12
Land use	% of covering in the pasture / forest land/ water 80%	Y_7	4
$Y_7 = 20-0.2Pc$	% of covering in the residential land 60%		
	% of covering in the cultivated/mining/construction and unpaved		8
	road area 40%		12
Upland erosion	Erodible surface (sum of SSF=56)	Y_8	14
$Y_8=0.25SSF$	Slightly moderate erodible surface		
	(sum of SSF=60)		14.75
	highly erodible surface		
	(sum of SSF=99)		24.75
Y_9=1. 67SSF.g	Minor stream channel (SSF.g=7.5)	Y_9	12.53
	Disturbed stream (SSF.g=10)		16.7
	Mainstream channel (SSF.g=15)		25.1

Table 5-4 Ranking values, sediment yield, surface area, percentage of class and sedimentation class in Oguta watershed.

Ranking values (m3 km-2 year-1)	Sediment yield values (m3 km-2 year-1)	Surface area (km2)	% from the total watershed (%)	Sedimentation class
0-25	248-279	96.25	17.5	Very slight
25-50	279-559	198	36	Slight
50-75	559-839	63.25	11.5	moderate
75-100	839-1118	44	8	High
100-125	1118-1399	148	27	Severe

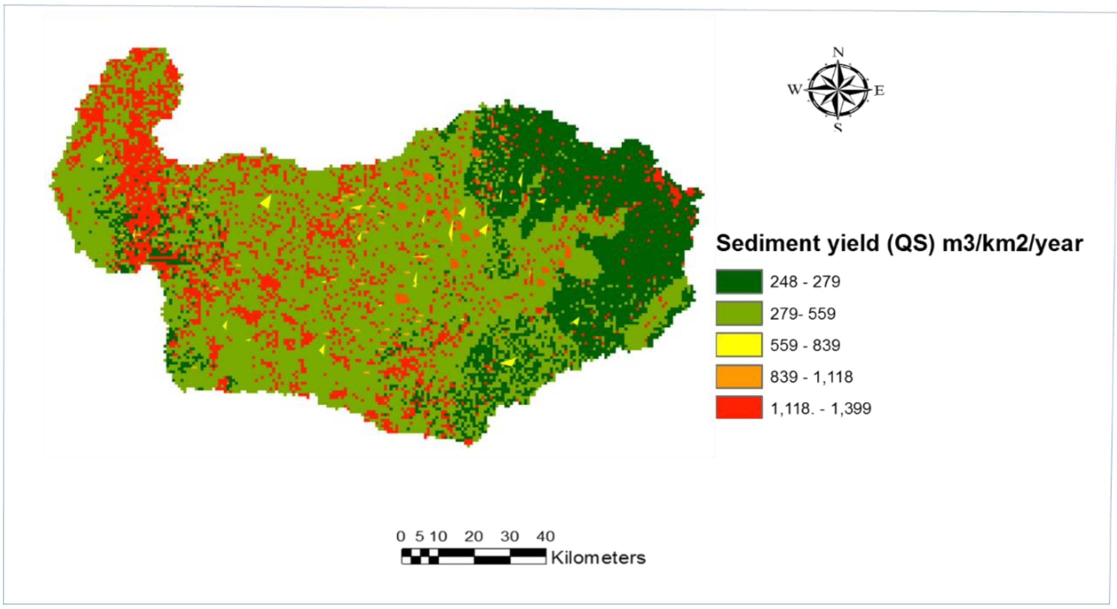


Figure 5-25 Spatial distribution of sediment yield in Oguta watershed, derived from MPSIAC model

5.3.3 The effect of change in bare ground area in the watershed (future scenarios analysis)

Just like in RSULE model, scenario analysis was repeated in MPSIAC model by increasing and decreasing bare ground area by 10%, 20% and 40% as presented in Fig 5-27 and 5-28 respectively. The aim of this analysis was to investigate any possible future land cover scenario in the watershed that may impact on soil erosion. This was done by pixel by pixel converting 10%, 20%, and 40% of pasture and forest area into a bare ground area in the model, which means exposing areas formally covered by vegetation to direct rainfall impact. It was found that sediment yield increased by 25%, 33%, and 46% across the watershed for the 10%, 20%

and 40% increase in the bare ground area. These scenario results simply indicate a need for concern regarding soil erosion in the watershed, which is likely to take place in the future if bare ground increases. On the other hand, the second scenarios were carried out by pixel by pixel converting the same percentage of bare ground area into a pasture and forest land in the model. This simply means protecting formally exposed bare ground areas from direct rainfall impact using vegetation cover. As a result of this, the sediment yield reduced by 25%, 30% and 41% across the watershed for the 10%, 20% and 40% reduction in the bare ground area. These results indicate that, despite other factors, change in land cover is highly sensitive and could influence the magnitude of sediment yield as illustrated in Fig 5-29. Therefore, applying soil conservation support practice in the watershed could minimise soil erosion.

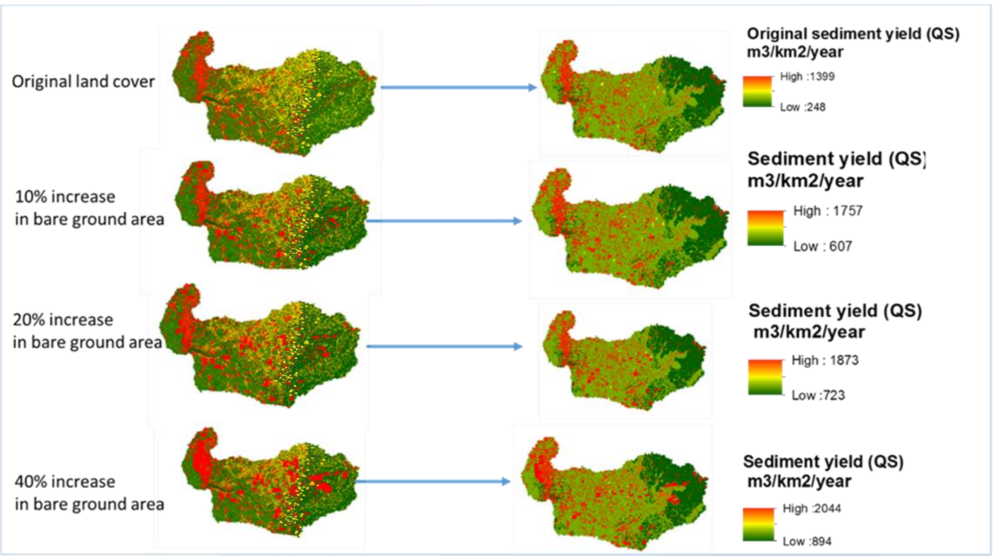


Figure 5-26 Illustration of soil erosion risk scenario analysis obtained by increasing bare ground area based on assumptions regarding expected future events in MPSIAC model

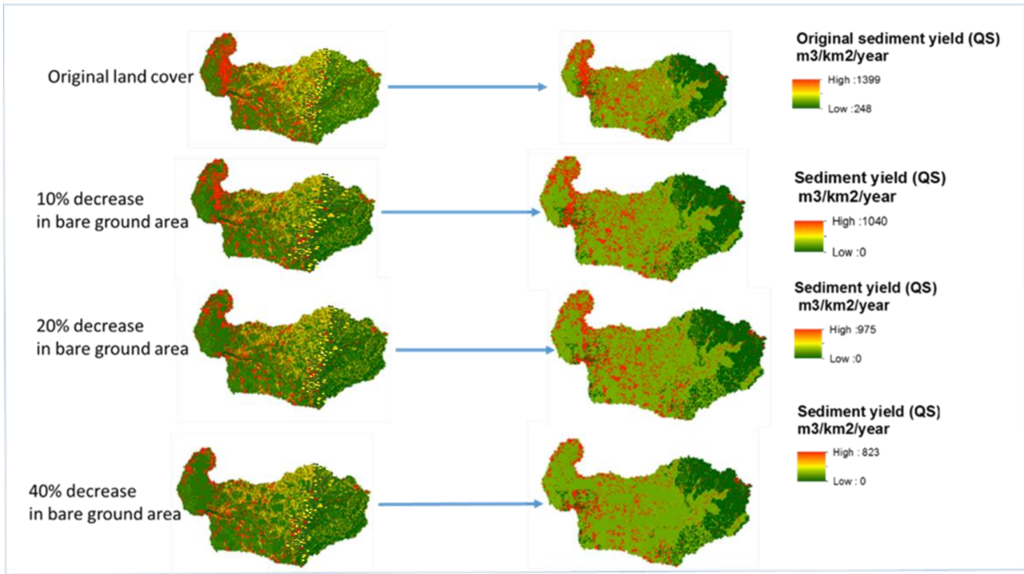


Figure 5-27 Illustration of soil erosion risk scenario analysis obtained by decreasing bare ground area based on assumptions regarding expected future events in MPSIAC model

MPSIAC MODEL

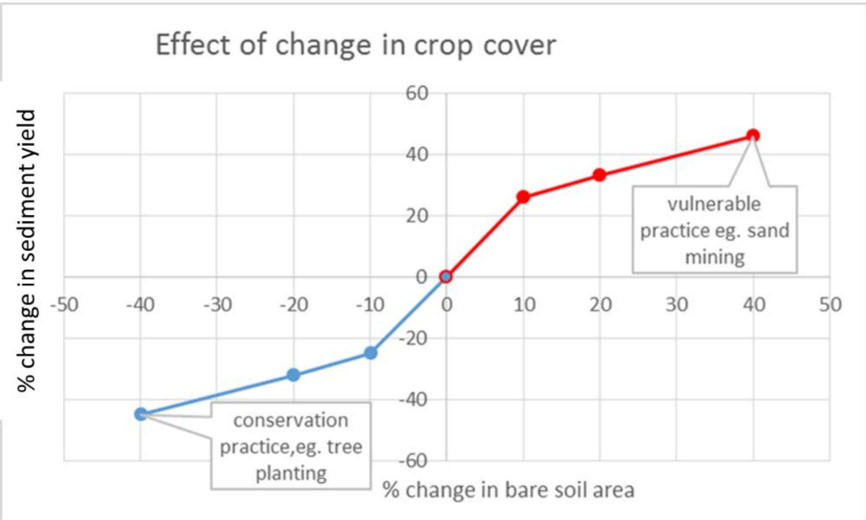


Figure 5-28 Illustrating the sensitivity to and consistency of change in bare ground area in sediment yield using MPSIAC model

5.4 Comparing the modelling results

The average sediment yield values obtained from RUSLE modelling and MPSIAC modelling were 21 tonnes/ha/year and 16 tonnes/ha/year as seen in Table 5-5. Even though there was no record of sediment inventory from the study site to validate these results, the closeness of average sediment yield values from the models gives an insight on the performance of the models. Interestingly, the sediment range within the high plus severe class from both models covered 33% and 35% of the total watershed, which correspond reasonably with field evidence as seen in Fig 5-11. According to De Vente and Poesen (2005), the advantage of applying MPSIAC model is the low data requirements, and the fact that practically all significant erosion processes are considered, makes it special and suited for estimating sediment yield in poor data area. It was easier to apply MPSIAC model because of the low data requirements and empirical equations assigned to different factors unlike the RUSLE model that requires complex slope and soil erodibility computations. The fact that these models were developed for US conditions makes the data used in this study uncertain, and therefore uncertainties in these results are highly likely. For instance, the use of rainfall data from a tropical rainforest region gave high values of climate factor and runoff factor in MPSIAC model because the model was parameterised for semi-arid region. On the other hand, both models grouped land cover as units rather than individual components, which in reality does not reflect the erosion protection potentials of individual components. For instance, cocoyam leaf which is one of the dominant crops in watershed has a better cover protection than the cassava leaf but both crops were grouped into cultivated land unit. This approach may have introduced over estimation or underestimation of erosion in the watershed, knowing that the models were developed based on specific crop cover potentials and the model results are comparable but not absolute.

5.5 Model verification

In soil erosion modelling, it is very important that the predicted sediment yield is compared with the actual sediment inventory from the watershed in order to measure the performance of the model. However, in this study, there was no record of sediment inventory in the watershed, which made it impossible to measure the performance of the models using actual measured sediment inventory. Alternatively, the performance of the two models were verified by comparing the results of the predicted sediment yields with sediment yield measured from Lake Sediment Core Depth (LSCD) as shown in Table 5-5 below. The percentage differences between the predicted sediment yields from both RULSE-GIS and MPSIAC–GIS modelling and the calculated sediment yield from the Lake Sediment Core Depth (LSCD) were assessed using equation by Horowitz (2003).

In this study, calculated sediment yield from the lake core sediment was assumed to be 100% and the same as a measured sediment yield since it was calculated from the sediment record in the lake. Using Equation 5.21, a negative percentage difference implies underestimation while a positive percentage difference implies overestimation.

$$\% \, difference = \frac{(predicted - measured\ value)}{measured\ value} \times 100$$ Equation 5-21

For RUSLE-GIS modelling:

$$\% \, difference = \{(21 - 11) \div 11\} \times 100 = 91\%$$ Equation 5-22

For MPSAIC-GIS modelling:

$$\% \, difference = \{(16 - 11) \div 11\} \times 100 = 45\%$$ Equation 5-23

The percentage difference between the two modelling results:

$$\% \, difference = \{(21 - 16) \div 16\} \times 100 = 31\%$$ Equation 5-24

$$\% \, difference = \{(16 - 21) \div 21\} \times 100 = -24\%$$ Equation 5-25

Thus, the % difference between the predicted yield from RUSLE-GIS modelling and calculated sediment yield from LSCD led to overestimation of the mean annual sediment yield of up to 91% and while MPSIAC-GIS modelling led to overestimation of the mean annual sediment yield of up to 45%. The high percentage difference in the two models shows that the modelling results could be within the range of actual sediment yield since the lake sediment core depths were only limited to the penetrating capacity of the corer. On the other hand, the percentage difference between RULSE-GIS and MPSIAC–GIS modelling was within the range of -24% to 31%, which is relatively close considering the uncertainties in the application of the models. The sensitivity and risk scenarios analysis conducted showed that both models were sensitive to land cover change which could be responsible for the close sediment yield values. Additionally, the mean specific sediment yield rates for other watersheds in Nigeria and other African countries are also presented in Table 5-6 below. It can be seen that the predicted sediment yield from these two models and the measured sediment yields from these watersheds are comparable.

5.5.1 Calculation of sedimentation rate from the Lake Sediment Core Depth (LSCD)

The dimension of the Oguta Lake according to (ILEC, 2015): Surface area during rainy season= $5km,^2$ surface area during dry sea= $1.8km^2, m$aximum depth= $8m,$

mean depth = $5.5m$, the length of the longest core = $1.17m$, the length of the shortest core = $0.85\ m$. Average surface area of the lake:

$$(5 + 1.8) \div 2 = 3.4\ km^2 \quad \text{Equation 5-26}$$

Average volume of the lake:

$$3.4 \times 10^6 \times 5.5 = 1.87 \times 10^7 m^3 \quad \text{Equation 5-27}$$

Maximum volume of sediment is the surface area of the lake multiplied by depth of longest sediment core:

$$3.4 \times 10^6 \times 1.17 \times 1.6 = 6.4 \times 10^6\ tonnes \quad \text{Equation 5-28}$$

Minimum volume of sediment is the surface area of the lake multiplied by the depth of shortest sediment core:

$$3.4 \times 10^6 \times 0.85 \times 1.6 = 5.44 \times 10^6\ tonnes \quad \text{Equation 5-29}$$

The range of sediment volume and sediment rate:

For ten years period: No of years =10yrs   watershed area 550km^2

$$(5.44 \times 10^6 + 6.4 \times 10^6) \div 2 = 5.9 \times 10^6\ tonnes \quad \text{Equation 5-30}$$

$$(5.9 \times 10^6) \div (10 \times 550 \times 100) = 11\ tonnes/\text{ha/year} \quad \text{Equation 5-31}$$

5.5.2 Comparing sediment yields from both models

The results from both models are close (see Table 5.5 below) despite different erosion processes. It is likely that soil erodibility (K) used as input parameter in both models contributed significantly to the sediment yield. This could have contributed to the closeness of the results considering the key contribution of soil erodibility to soil erosion in the watershed. Furthermore, application of soil erosion models and watershed sediment yield involves many assumptions and processes that do not really reflect the actual field conditions, perhaps, uncertainty in the model results. Moreover, direct validation of these models results with measured sediment yield was not possible because of lack of sediment inventory in the watershed. Even though these results were compared with the lake sediment core depth, and other measured and predicted sediment yields elsewhere in Nigeria and Africa. The extent of deviation or closeness of these predicted sediment yields to the actual measured sediment yield is still unknown.

Table 5-5 The predicted sediment yields from the models and Lake sediment Core

Method of estimation	*Sediment yield*
RUSLE-GIS	21 tonnes/ha/year
MPSIAC-GIS	16 tonnes/ha/year
Lake Sediment Core Depth (LSCD)	11tonnes/ha/year

Oguta Lake watershed area is 550km^2 .

The sediment delivery ratio is ca. (52%)11/21. The SDR represents the efficiency of Oguta Lake watershed in delivery sediments from the point of erosion to the lake outlet. However, the SDR is affected by a number of factors such as the size of the watershed, land use , particle size, channel density, topography and sediment source. Due to lack of sediment inventory in most watersheds in Nigeria, there is no known SDR of any watershed in the south eastern part of Nigeria to compare with that of Oguta Lake watershed. However, Nyssen et al. (2009) found the SDR of MZZ watershed in Ethiopia to be 60% and 21% in 2000 and 2006 respectively. Recently, Gurmu et al. (2021) found the SDR of Arata-Chufa and Ketar watershed to be 26% and 18% respectively. These results may not compare well with SDR of Oguta lake watershed even though it is SDR from Africa. This is because these watersheds in Ethiopia are different from Oguta Lake watershed. For instance, MZZ watershed is mountainous which obviously has different topography effect compared to Oguta Lake. A short and steep slope like MZZ watershed would deliver more sediment than a watershed with a long complex slope (a combination of convex, concave and flat surfaces). Thus, comparing SDR from different watersheds should be done with caution, although, SDR may correlate well if applied in a watershed with similar characteristics in the same region.

It is important to estimate the contribution of gully erosion (SL gully) to overall soil loss and sediment production. Since gully erosion was identified as a significant contributor to the gross erosion during field observation, it will be very interesting to calculate gully contribution to sediment production. This can be achieved by measuring the cross-section of the identified gully channels with a minimum depth of 1cm and minimum length of 10m as well as their total lengths (Poesen et al. 1996; Vandaele and Poesen 1995). Then, the eroded volume of soil can be calculated and compared with the total sediment production in the watershed. i.e. SL gully

=100 (ratio between SL gully and SL rates due to interill, rill, and gully erosion (Poesen et al.2003)).

5.5.3 Comparing both model results with measured and predicted results from other watersheds

This section compared the predicated sediment yield with sediment yield obtained from other environmental conditions and regions. First, the predicted sediment yields are compared with measured sediment rate from different parts of Africa and Nigeria (see Table 5-6 below) under different environmental conditions (Vanmaereke et al ., 2014). In Nigeria, Milliman and Fansworth, (2011) measured sediment yield in Ogun and Niger State and got erosion rate of 23.4 tonnes/ha/year and 18.82 \tonnes/ha/year respectively. These sediment yield values are comparable to the predicted sediment yield of 21 and 16 tonnes/ha/year (see Table 5-5 below) from both models despite different environmental conditions. Similarly, FAO (2008) measured sediment yield in northern part of Nigeria (Zamfara State) at the rate of 38tonnes /ha/year. This result also compares with the predicted sediment yield from both models. Also, in Uganda, Ryken (2010) measured sediment yield of 25 tonnes/ ha/year which is very close to the predicted models. Synonymously, studies on similar watersheds in Nigeria and other African countries revealed similar high erosion rate. For example, Adediji and Adepoju (2010) predicted sediment yield of 17.75 tonnes/ha/year in Katsina State Nigeria which is very close to the predicted sediment yield from both models. Similar study was done by Dike et al. (2018) in Imo State Nigeria and a close sediment yield of 36tonnes/ha/year was estimated. In West Africa, Akpolo et al. (2020) predicted sediment yield of 16.24 tonnes/ha/year in Benin which is very close to the predicted sediment yield from both models. Recently, Gurmu et al. (2021) predicted sediment of 18tonnes/ha/year in Ethiopia which compared very well with both models. The models compared very well with both measured and predicted sediment yields from Nigeria and other Africa countries.

Table 5-5 Measured sediment yields from different parts of Nigeria and Africa

Country	Location	latitude	longitude	Sediment yield (tonnes/ha/year)	Reference
Nigeria	Zamfara	12.3213	4.1999	38	FAO, 2008
Nigeria	Ogun	6.5755	3.4388	23.4	Milliman and Fansworth, 2011
Nigeria	Niger	4.7212	6.7858	18.2	Milliman and Fansworth, 2011
Mozambique	Zambezi	-18.7587	36.2512	36.9	Milliman and Fansworth, 2011
Niger	Sirba	13.7316	1.6049	24.8	Amogu, 2009
South Africa	Korinte	-33.9986	21.1657	33	Rooseboom et al., 1992
Sudan	Nile	21.7920	31.3709	38	Dedkov and Mozzherin, 1984
Uganda	Koga	-0.5788	30.4506	25	Ryken, 2010; Ryken et al., 2013
Zimbabwe	Mchingwe	-20.1967	29.5085	35	FAO, 2008

Source: Vanmaercke et al., 2014

5.5.4 Estimating the lifespan of the lake

Oguta Lake is a closed lake, there is no spillway and overflow. The trap efficiency of Oguta lake is 100% because as a closed lake it is assumed that there is no sediment loss. The implication of closed lake is that continuous sedimentation shortens the lifespan of lake. Based on Lake Sediment Core Depth, the lifespan of Oguta Lake is estimated as follows: T*he average volume of lake =*$1.87 \times 10^7 m^3$ *, the volume of sediment deposited per year*

$$688 \times 550 = 3.784 \times 10^5 m^3 \text{ /year} \quad \text{Equation 5-32}$$

If 3.784×10^5 $is\ deposited\ per\ year,$ then :

$$1.87 \times 10^7 \div 3.784 \times 10^5 = 49.418 \approx \text{ 49 years} \quad \text{Equation 5-33}$$

Therefore, it will probably take 49 years to fill the lake based on the depth of core samples.

5.5.5 Description of lake sediment cores

Physical description of the sediment cores based on texture and colour as well as whole core sensor scanning test were carried out to understand the characteristics of the sediment cores and the pattern of deposition of the sediment cores. It was found by physical description that there were significant changes in colour and texture from upstream to downstream sediment cores as described and presented in Table 5-7 below. Moreover, the whole core sensor scanning showed evidence of irregular deposition pattern of the sediment cores as presented in Fig 5-30-5-33 below.

Table 5-7 Description of sediment core colour and texture

 **Core 1**	The sediment core is very light in colour from 0 cm up to 43 cm, with some traces of brown sediment sparsely distributed within the light-coloured zone. Interestingly, there is a colour change from light to brown from 43 cm to the end of the sediment core. This shift in colour could be linked to erosion episode caused by human activities in the watershed. In the brown sediment core region, a noticeable colour change occurred at the 68 cm depth, which could also be linked to erosion event since the colour change was not continuous throughout the depth of the sediment core. Feeling the sediment core by hand and visually inspection, it was observed that a significant proportion of the sediment core comprise sand particles. The high sand content may be linked to sand mining activities and gully erosion upstream of the point where the sediment core was collected. It is also possible that the core sediments were recently deposited since the coring was done at the peak of rainy reason.
 **Core 2**	The sediment core showed a uniform light brown colour throughout the entire length with some traces of very dark brown colour at 1 cm, 17cm and 46cm. The uniform colour may be attributed to sediment transport downstream and the sediment reworking process in the lake, while the traces of dark brown colour could be linked to storm event like flooding or erosion in the watershed. It was observed by hand feeling and visual inspection that the sediment core is a mixture of sand and clay particles, which is one of the properties of a reworked sediment core. In comparison with both the upstream and downstream core sediment, it appears darker than the upstream and lighter than the downstream sediment core.
 **Core 3**	The sediment core is dark brown with some traces of light-coloured sediment from 0cm to 37cm. Interestingly, there was a sharp change in colour from dark brown at 37cm to deep dark brown, which maintained uniform colour throughout the remaining length of the core. It is possible that the dark brown colour of the upper part of the core may be due to watershed disturbances like sand mining or perhaps a transition from sandy to clay sediment since the upper part of sediment was freshly deposited. Following the colour and texture trend, the upper part of the sediment core is dark brown and closer in colour to the closest sediment core collected upstream while the lower part of the sediment core is deep dark brown and closer in colour to the core collected downstream. These changes could be linked to bioturbation and sediment reworking.
 **Core 4**	The sediment core is very deep dark brown in colour with traces of light brown core sediment from 47 cm to 73 cm. The uniform colour may be linked to sediment reworking and mixing since the sampled point was located downstream with no evidence of farming within the vicinity. It is also possible that the very deep dark colour may be attributed to the age of the core sediment, bearing in mind that the sediments move downstream. However, the traces of light brown core sediment may have been caused by past changes in the watershed. There is a sharp contrast in both colour and texture between this sediment core and other sediment cores collected upstream, it is very dark and relatively uniform and comprise mainly clay particles compared to other cores that are lighter and contain a significant proportion of sand.

5.5.6 Whole sediment core scanning sensor (MS2C)

The main purpose of this magnetic susceptibility test was to investigate core sedimentation pattern and possibly link it with the physical characteristics of the sediment core as well as the activities in the watershed. The main aim of examining the sedimentation pattern was to look out for peaks and transitions, as annotated with "T" in Fig 5-30– 5-33.

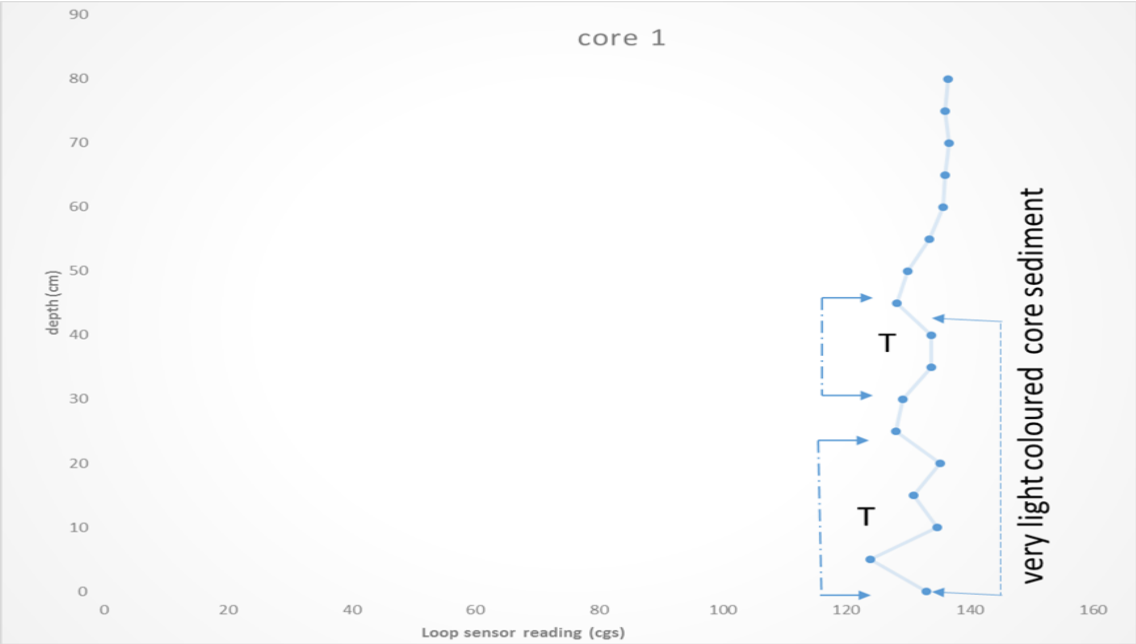


Figure 5-29 MS2C whole core traces for core 1 near Njaba River inflow section of Oguta Lake

In core 1, the peaks and transitions could be possibly linked to episodes of erosion in the watershed, which correlate well with both colour and texture of the core sediment. As can be seen from the deposition pattern of core 1 as presented in Fig 5-30, the peaks started from 0 cm up to 45 cm which matched very well with very light colour of the core 1 sediment core up to 43cm. The remaining part of the sediment core from 43cm to 80cm maintained almost a linear pattern which also correlate well with a uniform light colour sediment core throughout the remaining length of the core. These peaks and change in core sediment colour could be linked to erosion, since there is evidence of erosion linked to sand mining activities very close the sediment core collection point.

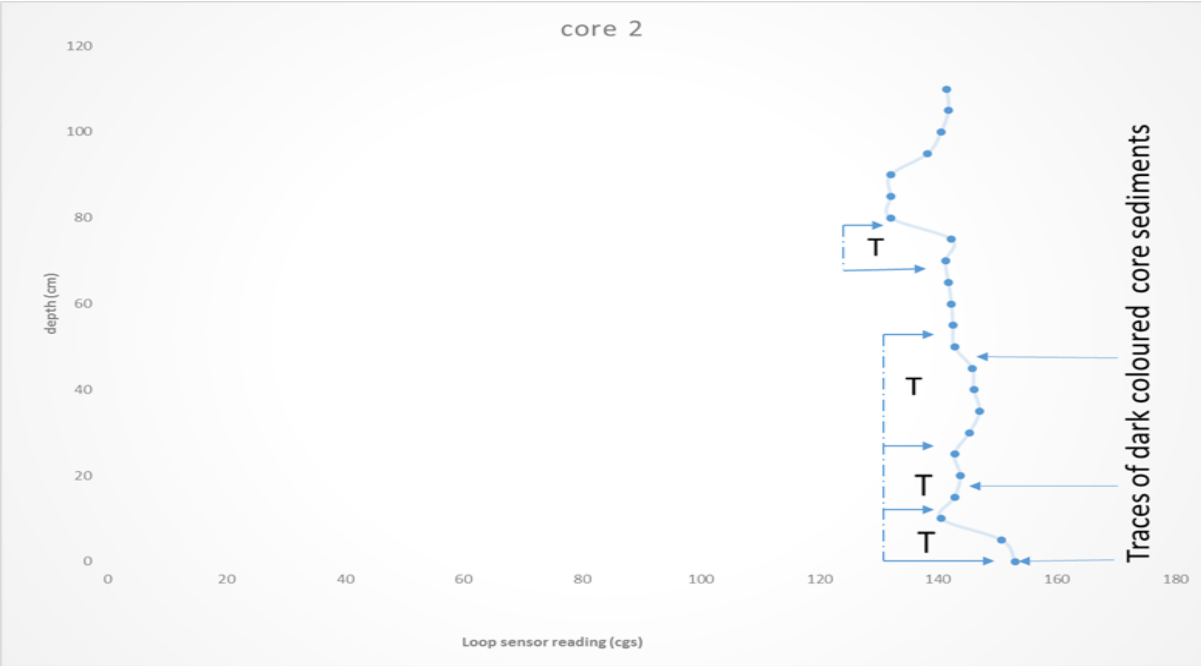


Figure 5-30 MS2C whole core traces for core 2 near Awbana River inflow section of Oguta Lake

It was found that the peaks and transitions of deposition pattern were almost regular which correlates well with the uniform colour throughout the length of the sediment core as presented in Fig 5-31. Moreover, the traces of dark coloured sediment core matched with the peaks in the sediment core deposition pattern. In addition, there is a significant match in deposition pattern between core 2 and core 1 up to 43 cm which represent upper surface sediment core. This core to core and peaks to colour match in pattern could be linked to a wider erosion episode since sediments move from upstream to downstream.

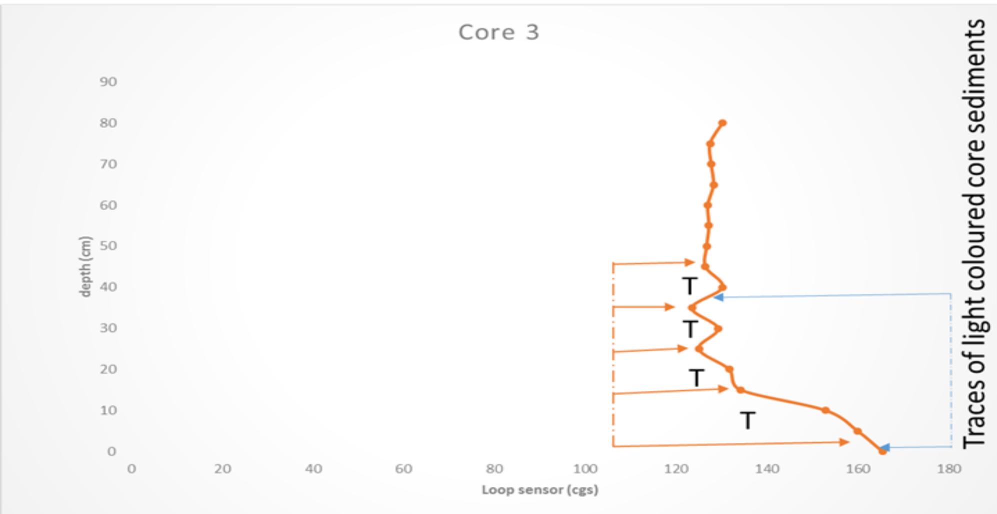


Figure 5-31 MS2C whole core traces for core 3 at 100m from Awbana River inflow section of Oguta Lake

There were transitions and peaks from the surface of the sediment core up to 40cm which correlate well with light brown colour of sediment core up to 37cm. Within this length of change in pattern, various peaks were annotated as seen in Fig 5-32. This changes in deposition pattern may be linked to erosion events in the watershed. The remaining length of the core sediment maintained a linear pattern which also reflects the uniform sediment core colour. In a wider context, the deposition pattern of the first three sediment cores (core 1, core 2, core 3) showed several peaks from the surface up to 37cm, which may be linked to human activities like sand mining in the watershed, since sand mining only started in 2005.

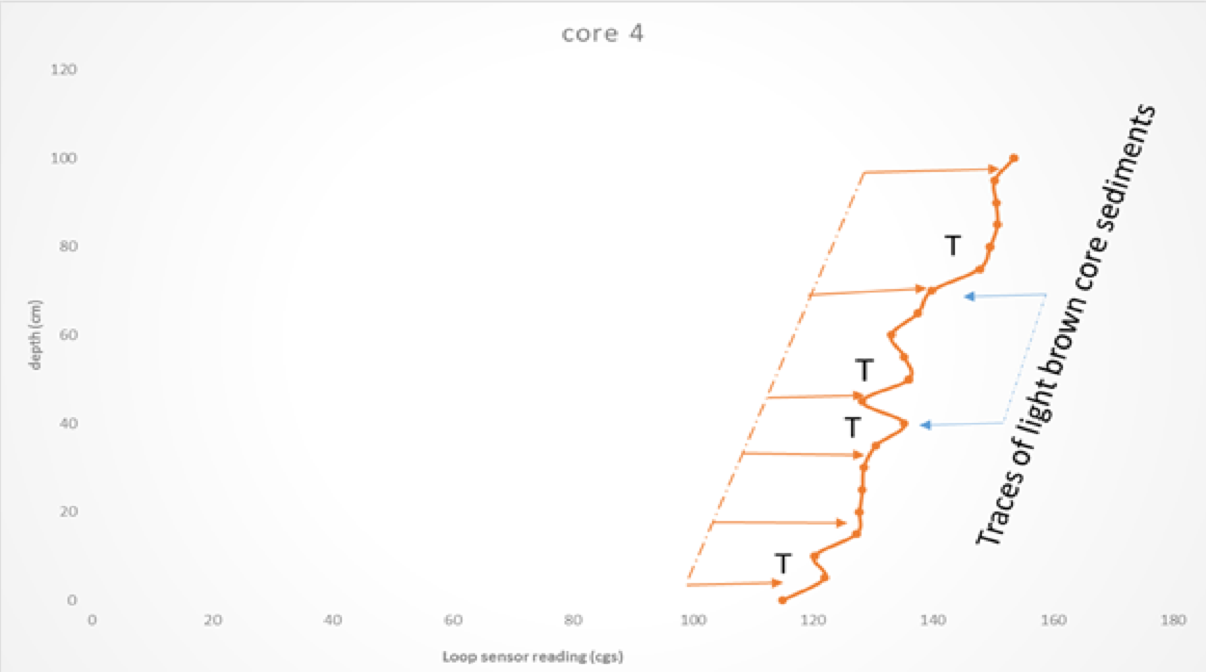


Figure 5-32 MS2C whole core traces for core 4 at the centre of Oguta Lake

In core 4, there was a regular pattern throughout the length of the core sediment with some peaks at various points as presented in Fig 5-33. Some of these peak points matched well with the traces of light brown sediment core from 47 cm up to 73 cm. Therefore, it is possible that these changes in deposition pattern and colour are likely to be erosion events triggered by human activities in the watershed. Even though, other activities may be responsible for this deposition pattern changes, it could be linked to erosion activities upstream, knowing that detachment, transportation and deposition took place both in the lake and outside the lake.

5.5.6.1 Comparison between the sediment core colour and the whole core scanning sensor results (MS2C)

Magnetic susceptibility of all the sediment cores showed some changes in pattern at some points along the sediment cores which correspond significantly with the colour changes. For instance, the identified peaks in magnetic susceptibility indicates that coarser particle sizes contain a greater concentration of ferromagnetic minerals. On the other hand, the finer sediment cores consist more of lager diatom content which mainly contain silt and clay particles. Sandy layers are associated with the identified peaks which correlated well with sediment colour changes as shown presented in Fig 5-30 - 5-33.

In all the sediment cores, there is a significant match between the sediment core colour changes and the peaks in magnetic susceptibility values. This match could be established as a likely erosion events in the watershed. One interesting thing about all these sediment cores is that they showed some peaks from 0cm up to 40cm which could be linked to recent erosion events or perhaps human activities in the watershed. It is also possible that the upper surface sediment cores are less diluted with the diatoms than the deep sediment cores because the deep sediment cores may have likely undergone series of sediment reworking. Sediment core 1 showed a wide range of peaks which could be linked to a sandy sediment source from Njaba River because of the various sand mining sites near its vicinity. It was observed during field survey that sediment materials moved from abandoned sand mining site into Njaba River which could be linked to this sandy sediment core. Some peaks could also be linked to other autochthonous activities in the lake rather than erosion episodes. There are lots of ongoing biogenic activities in the lake which could have affected the ferromagnetic properties of the sediment cores. For instance, the peaks in core 3 and 4 may be linked to paramagnetic or possibly the formation of ferromagnetic greigite on organic matter (Snowball &Thompson, 1988).

5.6 Discussion

The soil erosion model results and the scenarios analysis were discussed and interpreted based on the following findings.

5.6.1 Spatial distribution of erosion in Oguta Lake watershed

The spatial erosion distribution in both models showed that most of the soil erosion risk areas (heavy + severe risk classes) are under bare ground area which could lead to much more soil erosion hazards in the future if unchecked. As suggested by land cover scenario analysis in this study, providing vegetation cover to high-risk areas may not possibly provide permanent solution to the soil erosion menace without addressing some of the current illegal land use practice in the watershed. However, the interviews conducted in the study area revealed that most of the people engaging in soil erosion threatening activities were unemployed youths who see these activities as the only means of earning a living. For instance, over five hundred youths engage in sand mining activities in the watershed as their daily routine business, and they are not likely to stop their operation unless other employment alternatives are provided. Moreover, the activities of local crop and livestock farmers also put the watershed at risk of soil erosion by engaging in unsustainable activities capable of exposing soil to direct rainfall impact. For instance, indiscriminate grazing of livestock in the watershed does not only reduces the canopy cover of shrubs by farm animals feeding on them but also leads to loss of soil by trampling as they move around the watershed in search of food. In addition, bush burning and timber logging which are widely practised in the watershed have the capacity to cause pore clogging by thick ash layers developed because of serious fire and, thus, reduce the canopy thereby increasing runoff and exposing soil to direct rainfall impact. To address these issues, a proper land use legislation and watershed management practice that could eliminate these illegalities and as well fit into the local condition of the study area is required.

5.6.2 Land use change effect on soil erosion

Historic changes in land use and land cover have significant impact on soil erosion in Imo State south east Nigeria (Chukwuocha, 2015). Various findings from this research elucidate clearly that land cover changes have had a significant effect on soil erosion in Oguta Lake watershed over the last 10 years (2005-2015). In particular, land use activities such as sand mining, unpaved roads and construction work that have the potential to expose bare ground in the watershed have great influence on soil erosion. This finding was further illustrated by assuming some land cover future scenarios in both models, which reveals up to 19%, 31% and 46% increase in soil erosion for 10%, 20% and 40% increase in bare ground area. However, the Landsat cover imagery of 1990 and 2014, which were used as input parameter in this study further supports that land cover changes greatly influence soil erosion in Oguta Lake watershed. The simulations showed that sediment yield shifted from 24 tonnes/ha/years in the 1990 to 36 tonnes/ha/years in the year 2014, which could probably be linked to various human activities in the watershed such as converting forest land to agricultural land, converting estate land to sand mining land, urbanisation, bush burning, tree logging and livestock grazing. These findings agree with previous work by (Chukwuocha, 2015),(Chukwuocha and Igbokwe 2014) whose study found that bare ground has significant impact on soil erosion in Imo State Nigeria.

5.6.3 Scenarios sensitivity analysis

Six future land use scenarios were examined in both models under various expected assumptions summarised as follows: In the first scenario, three experiments were performed, which showed that increase in bare ground area (by 10%, 20%, and 40%) significantly increased soil erosion in both models. In this first scenario using RUSLE, it shows that 10%, 20% and 40% increase in bare ground area can lead to up to 19%, 31% and 50% increase in soil erosion for a period 2005 to 2015. On the other hand, conducting the same scenarios analysis using MPSIAC model showed a similar increase of up to 25%, 33% and 46% of soil erosion for the same period of 2005 to 2015. This similarity and consistency in the model results could be linked to the fact that both models investigated increase in bare ground area. In other words, the bare ground area coverage is a major factor in determining erosion and both models respond in a similar manner to the changes in the amount. These results also highlighted further how sensitive bare ground area could be in driving soil erosion. The implication of these results is that continuous activities such as sand mining in the watershed could lead to much more soil erosion in the future. This scenario analysis agrees with previous work by Nearing et al. (2005), who showed that soil erosion increases with decrease in soil surface protection. In the second scenario, three experiments were performed, which showed that decrease in bare ground area (by 10%, 20%, and 40%) significantly reduced soil erosion in both models. This scenario is used to demonstrate situation where current soil exposing activities are stopped and vegetation are planted in the bare ground areas to minimise soil loss. Based on RUSLE model, it showed that 10%, 20% and 40% decrease in bare ground area can lead to up to 19%, 25% and 44% reduction in soil erosion for a period 2005 to 2015 while MPSAIC showed that reducing bare ground area by the same amount can lead to up to 25%, 30% and 41% reduction of soil erosion for the same period. Just like in the first scenario, the results are quite similar and consistent in both models but changed by different magnitude, which could also be linked to same bare ground area being investigated. These scenarios results suggest, applying soil conservative support practice by planting vegetation could significantly reduce soil erosion in Oguta Lake watershed. This scenario also supports previous work by Nearing et al. (2005), who showed that soil erosion could significantly be reduced by protecting the soil surface.

5.6.4 Potential management practices on soil erosion in Oguta Lake watershed

The result revealed that land cover factor, especially bare ground (without vegetation cover) greatly affects soil erosion at severe level (36 tonnes/ha/year). However, it is important that effective soil conservation and management measures be adopted to prevent the negative erosion risk in the watershed. In proposing a management practice on bare ground land, priority is given to protection of forest by restoration (tree planting) through afforestation and reforestation. Reforestation is the replanting of formally existing forest which has been cut down because of deforestation while afforestation on the other hand is the planting of trees in a non-forest area (Foryth, 2005). In addition, replanting of native grasses and crops in the bare ground area of the abandoned sand mining site will reintroduce a natural barrier that will prevent soil from being washed away by runoff and protect the soil from direct rain drop impact. In order to suit local climate conditions and soil properties in the Oguta Lake watershed, indigenous forest trees and grass species like legumes, palm trees, cashew trees, bamboo trees, Bermuda grass, buffalo grass star grass, and vetiver grass should be planted as recommended by (Ogunlela and Makanjuola, 2000). According to Ogunlela et al. (2000) there are varieties of these species of forest trees and grasses that have high survival rate for forest restoration and excellent erosion control in south east Nigeria. In a similar study, Ihuoma et al. (2016) found a high survival rate and growth of Bermuda grass in south east Nigeria as an excellent grass for erosion control.

Observations during field work revealed that lands that are meant for agricultural and settlement purposes are turned into bare grounds due to intensive sand mining activities without efficient post mining replanting plan which results in gully erosion development. According to Ogunlela et al. (2000), planting legumes species grasses on abandoned sand mining sites will not only add nitrogen to the soil but will also provide the much-needed protection against rain drop impact on soil surfaces. IAD could be used to provide a framework for analysis of interactions between different actors (land reclamation) including effect of exogenous factors.

5.7 Chapter summary

Soil degradation is considered a major problem in developing countries, including Nigeria, which has limited financial and technical resources to study them. The Oguta Lake watershed has encountered series of problems, because of sand mining activities that have led to bare ground lands in the watershed. It is believed that sand mining activities can increase soil erosion and sediment flux into rivers and lakes.

This chapter aimed to use RUSLE–GIS and MPSIAC-GIS modelling to estimate soil erosion rate on a 30-m resolution grid cell for the Oguta Lake watershed south east Nigeria. To achieve this aim, three specific objectives were designed: firstly, apply the Revised Universal Soil Equation (RUSLE) and Modified Pacific Southwest Inter- Agency Committee (MPSIAC) with GIS to evaluate the potential sediment yield for the Oguta lake watershed south east Nigeria; secondly to identify the high erosion risk areas and examine the key controlling factor affecting an area of severe soil erosion in the study area.

Integration of the models and GIS techniques were successfully applied. The thematic raster map of individual erosion factors in RUSLE modelling are rainfall erosivity (R), soil erodibility (K), slope length and steepness (LS), cover management (C) and conservation support practice (P), while that of MPSIAC modelling are geology (X_1), soil (X_2), topography (X_3), climate (X_4), runoff (X_5), land cover (X_6), land use (X_7), surface erosion (X_8), and channel erosion (X_9) and, were all derived based on 30-m resolution grid cells. In general, it is very clear from the results of this study that RUSLE and MPSIAC in conjunction with GIS is a very powerful model to spatially make quantitative and qualitative assessments of soil erosion risk for conservation management purpose.

The RUSLE and MPSIAC factors were calculated using the local data that was specifically collected for Oguta Lake watershed. The modelling results illustrate that the mean annual soil loss rate is high. Sediment yield in RUSLE modelling ranged from 8-36 tonnes/ha/year while the average sediment yield is 21tonnes/ha/year. On the other hand, the sediment in MPSIAC modelling ranged from 248- 1399 m^3/km^2/year while the average sediment yield is 991 m3/km^2/year.

The results from spatial distribution of erosion revealed that soil erosion has significantly affected Oguta Lake watershed, especially in the bare ground areas. It was also found that land cover changes have significant influence on soil erosion in Oguta Lake watershed, especially by converting pasture and forest area to bare ground area. However, six soil erosion sensitivity scenarios were investigated based on the assumptions that could occur in the future and it was found that more areas of the watershed may be at risk of vulnerable soil erosion if bare ground area is increased in the future.

6 CHAPTER SIX: ANALYSIS OF ENVIRONMENTAL REGULATIONS FOR MANAGEMENT OF SOIL EROSION IN NIGERIA: PROBLEMS AND PROSPECTS

6.1 Introduction

Before analysing the institutions responsible for management of soil erosion in Oguta Lake watershed (in Chapter 8) it is necessary to review the whole environmental organisations to see how the policies and regulations interact with the specifics of how erosion management and soil conservation enhance environmental sustainability. This chapter:

- Identify and review the laws and organisations responsible for soil erosion management in Nigeria.
- Identify and discuss the problems and prospects.

Chapter 6 sets out to review the organisations responsible for management of soil erosion in Nigeria under different levels of government. IAD uses the terms institutions and organisation in a manner consistent with the distinction made by Douglas North where institutions are the underlying rules of the game and organisations are seen as participants in situations structured by rules. The dataset used for this review were collected as a document content such as erosion incident report, legislative report and erosion management document (see Chapter 3 Section 3.7.4.2). Some datasets are available online (NEWMAP report 2013) while others were collected from ministries and agencies. Data was collected and coded until enough information was obtained and coded (see Chapter 3 Section 3.7.4.2). The implementation and failure of implementation of each organisation laws and policies is discussed in each subsection bellow. Conflict, bad governance and overlap of institutional laws are discussed in section 6.4 below. Although Nigerian government operates under a multi-level structure, it is still very necessary to analyse this structure to understand how different government levels cooperate and complement each other in managing Nigerian's environment. First and foremost, government institutions in Nigeria are classified into three main tiers: federal government, state government and local government as shown in Fig 6-1. This institutional structure is enshrined in the 1999 Constitution, which is the fundamental law that controls most of the Nigerian laws. The federal government manages the country's financial affairs and federal laws as well as contributing financially to the state government for developmental purposes. On the other hand, the state government makes state laws, and controls the affairs of the local government (Richard et al., 2015).

In some cases, the state government runs the operational activities of the local government because of weak local government institutions and because it controls its finances. Meanwhile, local government was designed to be independent and autonomous in its operational activities as stipulated in the 1999 Constitution. For example, Asaju (2010) opined that it is the responsibility of the local government to make its laws, control its boundaries, and enforce its activities as enshrined in the 1999 Constitution. Similarly, Asaju (2010) asserted that it is the responsibility of the federal government to supervise and monitor the activities of the local government. Potentially, this would reduce exploitation and a ’commando’ attitude of the state government. In practice, though, the operational responsibility of the local government is often neglected and abused by the state government (Olowu, 1998; Richard et al., 2015).

Moreover, the proximity of local government to the local people put them in a position where they can easily articulate and aggregate the demands of the people. For example, Richard et al. (2015) suggested that government institution that operate at the lowest level is more likely to be attached to the needs of the people and the environment. But, without monitoring, the autonomy of local government will not provide a complete solution to the environmental problems in Nigeria because of endemic corruption in the local government (Agbo, 2010). However, functional, transparent and well monitored institutions across the three levels of government would put operational responsibility of local government under check by creating a proper feedback mechanism (Adeyemi, 2012). Under this current structure of Nigerian government some of the institutions are shared between different levels of government, while most institutions are managed by the federal government. Even though the structure seems to work well in a democratic society, implementation and enforcement challenges have adversely affected some institutional goals in Nigeria (Bartholomew et al, .2013).

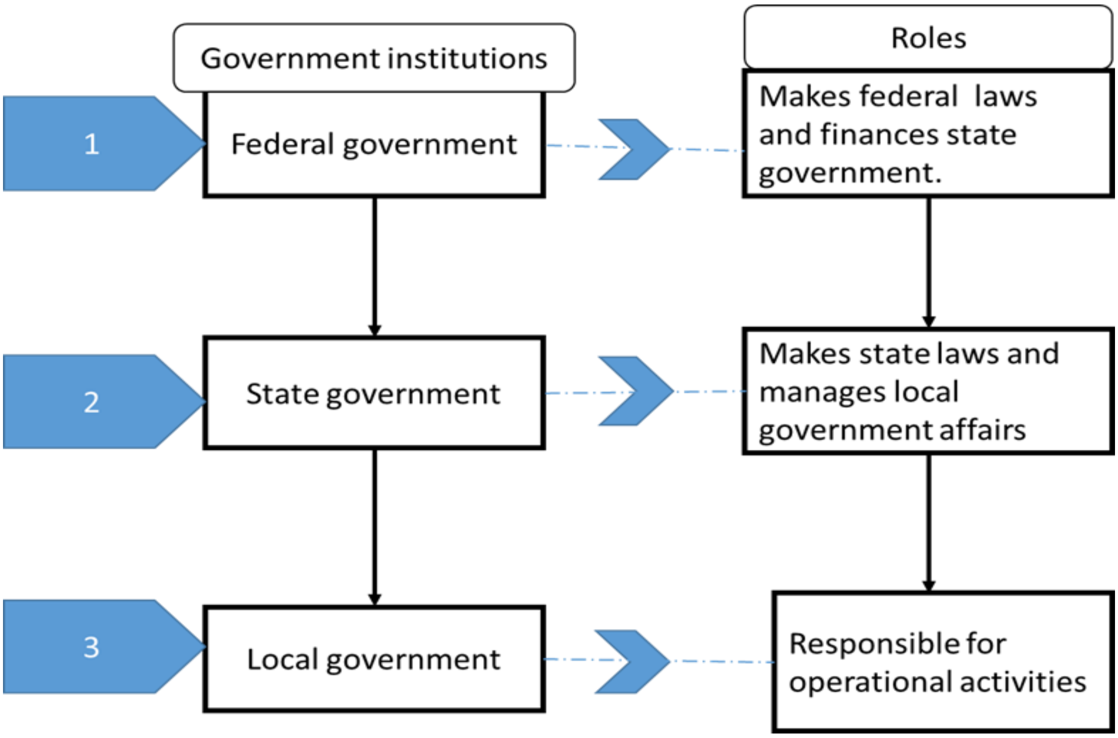


Figure 6-1 The hierarchical structure of the federal republic of Nigeria

In the context of soil erosion, which is directly managed by the Ministry of Environment and shared between federal and state institutions, it is extremely important to analyse some of the institutional pitfalls and the social factors driving them (Iyanda et al., 2016). For example, the increase in human environmental activities at the community level influences the management of soil erosion in Nigeria. Potentially, any unsustainable land use activity in the watershed poses erosion risk for the environment and the challenge for any responsible government is to balance this concern with the environmentally sustainable development goals. This can be done only through the establishment of adequate regulatory institutions charged with monitoring and enforcement responsibility. Therefore, this chapter analyses the environmental laws and regulations applicable to the management of soil erosion Nigeria.

6.2 The Nigerian constitution

Most of Nigeria's institutional laws are directly enshrined in and linked to Nigeria's 1999 Constitution as the apex law, especially the environmental laws. These laws recognise the importance of improving and protecting the environment for the citizens. Referring to Section 20 of the Nigerian Constitution, the primary objective of the Nigerian State is protecting and improving the environment and safeguarding the land, forest, water, air and wildlife of Nigeria (Igbuzor, 2003; Onyenekewa, 2011). Part of the constitution in Section 16 (2) stipulates that states should plan and direct their policies to promote growth and economic development. Similarly, part of the constitution in Section 17 (2) (d) states that exploitation of natural or human resources of any form for whatever reason other than the goal of the community shall be prevented (Onyenekewa, 2011). All these high sounding environmental constitutional provisions are rarely followed in practice. For example, Ifeanyi (2002) noted that the deficiency of Nigeria's constitutional provisions for environmental protection is their non-justiciability. For example, in Oguta Lake watershed, natural resources like soil is being continuously exploited by the sand miners against these constitutional provisions. Yet, they have not been sanctioned by the laws protecting these vital resources.

However, the active involvement of the federal government in managing environmental activities through ministries and agencies means that the federal government is accountable for the erosion menace in Nigeria. But both federal and state government organisations have encouraged some soil degradation activities by comprising and colluding with environmental operators (interview 19th January 2016). Similarly, the constitution of Nigeria vests the regulation and protection of the environment in the government, meanwhile the same government through others of its activities is responsible for environmental degradation. Section 6.3 follows on this discussion with an analysis of organisations responsible for management of erosion in Nigeria.

6.3 Organisations responsible for management of soil erosion in Nigeria: stakeholder mapping

Many complex institutions responsible for monitoring and enforcement of the substantive provisions of institutions in Nigeria are often overlapping (Onyenekewa, 2011). This section evaluates various organisations responsible for monitoring and enforcing land, agricultural and, the environment in Nigeria. The first step is identification of all relevant organisations followed by critical evaluation of their role in environmental regulations and management of soil erosion in Nigeria.

Figure 6-2 shows a pictorial representation of key stakeholders and their roles in management of soil erosion in Nigeria. It can also be seen from the figure that some stakeholders are accountable while others are mere participants at the operational level. Ideally, local government council is responsible for operational management of the environment within its jurisdiction but the command and control by the federal and state government have made it less functional. To illustrate this further, the complex laws and regulations resulting in overlaps of functions and conflicts of interests among various organisations are shown in Fig 6-2.

One of the glaring examples of this overlapping function is the Federal Ministry of Environment, and the State Ministry of Environment, Agriculture and Natural resources; both are responsible for management of erosion in Imo State. However, there is no clear operational boundary or a complementary plan between the two ministries. Also, collapsing of three different ministries into one ministry at the state level is another source of confusion as it makes it difficult to connect directly with sole federal ministries.

Therefore, the current structure has failed to address environmental problems at the local communities, due to overlapping and conflicting roles, which often result in poor implementation and an enforcement deficit. In addition, lack of clear boundaries, roles, and formal rules between the state and federal government has also led to unsustainable environmental activities, especially at the community level. Both federal and state ministries compete for roles, especially the ones that are beneficial to their various organisations (focus group discussion, August 2016).

On the other hand, the local government, which is a bottom tier government, is yet to gain its independence from the manipulation of the state government. The autonomy of local government in key areas such as land, mineral, agricultural management has not been truly autonomous due to exploitations by federal and state organisations (Igbuzor, 2003; Asaju, 2010). Similarly, Richard et al. (2015) explained that the problem of local government in Nigeria is even more compounded by the state government’s unbridled interference in its affairs. For example, all the key organisations responsible for erosion management in Nigeria are either federal or state based without any functional government representation at the local level. Meanwhile, erosion itself is more dominant in the local communities than in the cities, where these ministries are based. This is a typical case of placing the cart before the horse in management of soil erosion in Nigeria.

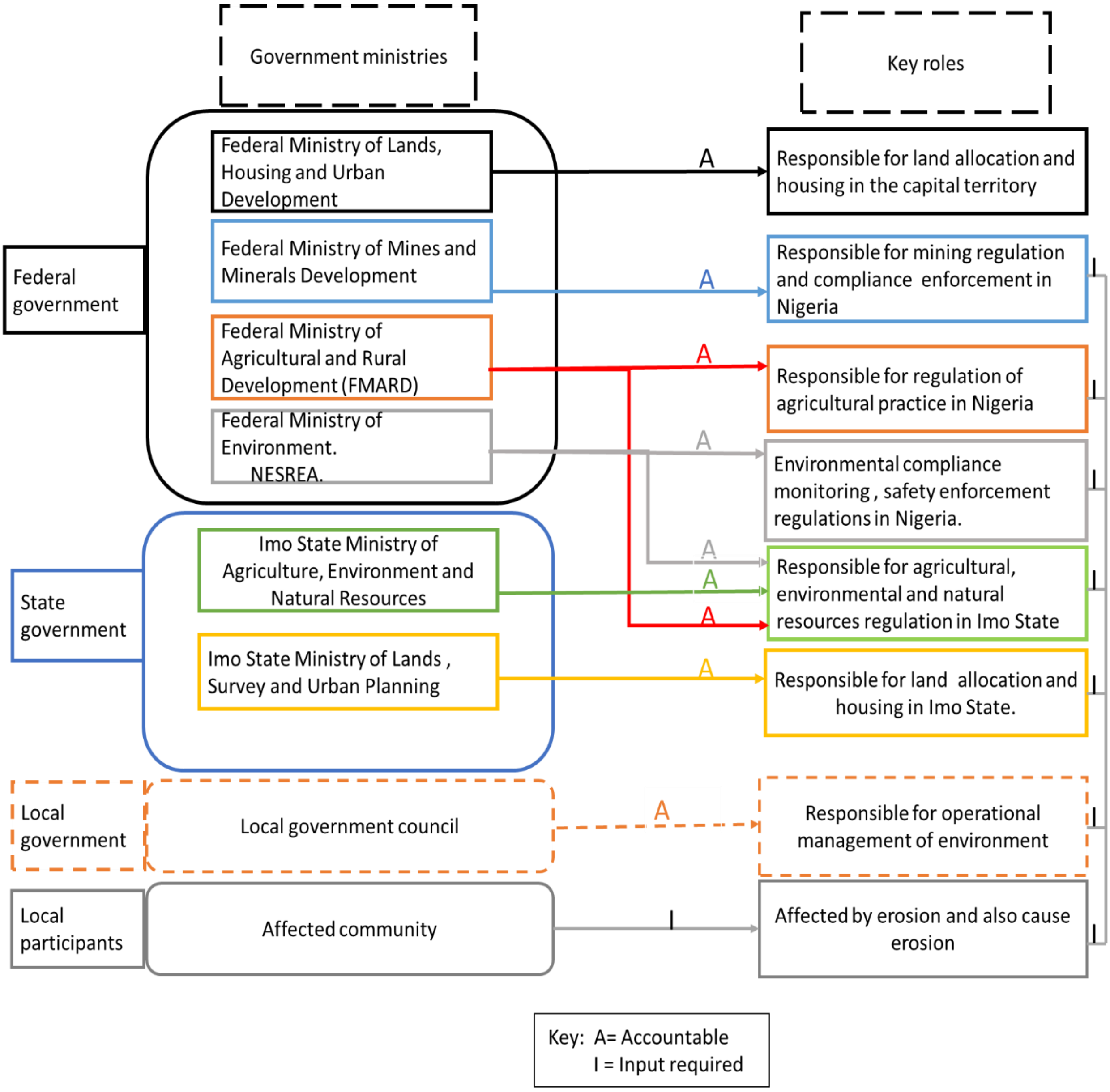


Figure 6-2 Stakeholder classification and their roles in erosion management

The federal government is responsible for management of environmental activities according to the constitutional provisions. As the apex government, it is responsible for maintaining sustainable environment in Nigeria through its laws and policies. It is the sole responsibility of the federal government to manage and enforce all environmental activities within the federal capital territory. In addition, the organisations under Federal government perform complementary roles with the state government organisations to ensure sustainable environment at state level. For example, NESREA under federal government has branches in all 36 states of the federation for complementary roles with the state ministry of environment of every state in Nigeria (See the discussion in Section 6.4 below). The leaders and managers of the officers under federal government are chosen either by democratic election or by appointment by the president. The leaders are elected by the people while organisation managers are appointed by the leaders. The state governors are elected by the citizens of the state while the managers of the state organisations are appointed by the state governors. The Federal and state government perform complementary roles under some organisations while the federal government remits monthly finance allocation to the states to ensure adequate financial capacity to perform their functions. Similarly, the federal and state government were originally designed to perform complementary roles with local government to ensure it performs its operational responsibilities. According to the 1999 Constitution, the local government was designed to be autonomous and should be managed by local government chairperson. According to the 1999 constitutional provision, the local government chairperson is elected just like the governors and president. The chairperson receives monthly financial allocation from the state government and is responsible for operational management of the local government affairs. There is no official and formal obligation between local chairperson and traditional organisations but there is always an informal communication between the two leaders, especially when reaching out to the local villagers on land issues. It is the responsibility of the local government chairperson to manage the environmental activities within his/her jurisdiction. Although, the classification of stakeholders and their roles in soil erosion management included the local government, there is still questions about the non–functionality of its operational responsibility (as highlighted with dashed lines in Fig 6-2). This is because instead of state and federal government to cooperate and complement the activities of the local government as originally arranged by the constitutional provisions, they command and control its management responsibility, which often leads to an unsustainable environment (Onyenekewa, 2011). For example, the Federal Ministry of Mines and Minerals Development is responsible for issuing mining permits and regulating mining activities in Nigeria. However, lack of representation at the state level and local government compromises its ability to monitor and police operational mining activities, especially in rural communities. In addition, there are overlaps and duplication of functions of institutions on two levels: the federal and state level. All of this makes erosion management a big issue in Nigeria, especially in the local communities, where the stakeholders have zero contribution in decision–making. As shown in Fig 6-2, it can be seen clearly that all the organisations responsible for soil erosion management are either federal or state managed. Some of the shared roles between the federal and state government have not been well managed, due to unclear regulatory jurisdiction and poor communication. For example, the National Environmental Standard Regulation and Enforcement Agency (NESRA) and Imo State Ministry of Environment are yet to harmonise operational jurisdiction in managing erosion in Imo State. Similarly, it is expected that the Federal and State Ministry of Agriculture will work together towards achieving national agricultural sustainable goals but in practice they do not complement each other and thus, do not have a shared sustainable development agenda (focus group discussion August 2016). Ordinarily, shared responsibility is ideal for environmental management, but it is best when the institutions are strong and goal oriented.

Therefore, in Nigeria, duplication of ministries that do not complement each other at different levels of government has not only created conflict of interests but also causes overlap across different government levels. In addition, poor communication and lack of feedback mechanism are the major problems affecting environmental organisations at different levels in Nigeria. For example, the non-active local government system in Imo State, and indeed most states in Nigeria is one reason why erosion is more dominant in local communities than in the cities (Onyenekewa, 2011). Of course, there are issues of accountability and integrity among federal and state government officials who are responsible for allocation and management of resources of local government and weak local government institution has made the situation worse.

Thus, strengthening the communication channel among the three tiers of government and allowing the local government to contribute to management of its environmental activities as enshrined in the 1999 Constitution is a key step to minimising environmental degradation. In addition, government's recognition of local stakeholders in decision-making, especially the local traditional leaders and resource users, as a key part of government will reduce the misuse and conflict often encountered in local communities. Most importantly, the roles of different tiers of government should be clearly defined, communicated, monitored and enforced by the federal government as enshrined in the constitution. The sections below are analyses of environmental laws and regulations responsible for the management of environmental activities and erosion in Nigeria and the administrative units in charge of them.

6.3.1 The Mining and Mineral laws

This section will review mineral and mining laws in Nigeria: the Nigeria Mineral and Mining Law, Act No 34 of 1999, and the Nigeria Mineral and Mining Act 2007. The Nigeria Mineral and Mining Act 2007 was enacted on March 16, 2007, and repealed the Mineral and Mining Act, No.34 of 1999 to ensure that solid minerals are well protected from exploration and exploitation in Nigeria. Some sections of the law are relevant to Nigeria's environmental sustainability plan, within the context of soil erosion management. Firstly, the 2007 Mining

Act states that federal government is responsible for the management of mineral properties in Nigeria and prohibits illegal of exploration of minerals. The Act further stipulates that minerals found in commercial quantities on Nigeria lands belongs to the Federal government according to the Land Use Act of 1978. Quarrying under the Act applies in relation to all naturally occurring quarriable minerals, such as clay and sandstone, which may also be lawfully extracted under mining leases, and it is made clear that only title holders can carry out mining activities on Nigerian lands. On the other hand, Sections 2 and 3 of the Act protect society and environment from the adverse effect of unapproved mining practices, and also introduce adequate measures to discourage illegal mining by establishing mines field Police and providing maximum fines and sentences for illegal miners. However, the provisions of the Act sound great and comprehensive as regards maintaining a sustainable environment but implementation and enforcement deficit challenges are still unresolved. For example, Ako et al. (2014) opined that lack of regulations leads to illegal sand mining and destruction of landscape. Obviously, a developing nation like Nigeria with high rate of unemployment and poverty will always face challenges of natural resources abuse and environmental degradation. But this could be minimised through effective and efficient government policies that meets the needs of these environmental operators.

In contrast, substantive evidence showed that most of the environmental related organisations not only compromise on the discharge of their duties but also encourage environmental damages (interview 27th August 2016). For instance, Adedeji et al. (2014) assessed the impact of inland sand mining in parts of Ogun State, Nigeria, and asserted that government agencies collect levies from illegal sand miners to offer them permits to operate without considering the environmental consequences. Paradoxically, this is clear evidence that the government that made constitutional laws also undermine them through its various institutions. Although these sections of the Act are clearly defined, they are rarely applied and enforced in practice, which has caused high levels of environmental degradation and massive soil erosion in Nigeria.

Moreover, there is scant evidence that this Act addresses specifically the issue of soil erosion, which is one of the major environmental problems in Nigeria. Perhaps, this was because soil erosion had not become a major issue in Nigeria at the time of enacting the Act or was just an oversight by the actors. Implementation and enforcement deficit are the two major issues threatening mining environmental sustainability in Nigeria. Even though the administration of the Act is solely vested in the hands of the Minister, it is still very unclear how this administrative role is being exercised at state and local community level in relation to soil erosion prevention, since there is no unit of this ministry at these levels.

6.3.2 Land Reforms in Nigeria

The promulgation of Land Use Act of 1978 radically undermined and changed the traditional land tenure system (ND-HERO, 2006). It empowered the state governors and local government chairpersons to have ultimate power and control over urban and non–urban lands areas respectively. On the other hand, it limited the local people's right to lands as mere occupants, which they can transfer only with the consent of the governor. However, in the pre-colonial era, land ownership was by traditional rights, which allowed individuals and community to own land by inheritance, as governed by the traditional leaders and the heads of families. The repealing and replacing of the traditional means of land ownership with the Land Use Act of 1978 was the greatest cause of conflict between the government and the local people (Ezenwa and Abere, 2010). The Act was later enshrined in the 1979 Constitution and later in the 1999 Constitution in order to protect it from series of amendments from subsequent government regimes. According to the Act, the state governor is responsible for the allocation and management of lands within the urban territory of the state, while the local government chairperson is responsible for allocation and management of land in the rural areas. But in practice, land management in the local communities is entirely under the control of traditional leaders and heads of families and, thus, land allocation operates under dual conflicting policies in which lands in the local areas are under rules-in-use, while lands in the cities are under formal rules. This causes conflict between the local people and the government, as the local people believe only in the traditional method of land allocation as part of their culture and lifestyle (Ezenwa and Abere, 2004). Within the context of land use in Nigeria, the focus group discussion conducted on 24th August 2016 revealed that the Act is rarely enforced and has led to illegal use and misuse of land resources. Even though at the federal government level the Land Use Act is perceived to have all the necessary provisions to conserve land resources through sustainable land use, the indigenous people have not accepted it willingly as they regard it as unjust piece of legislation designed to deprive them of their traditional and legitimate ownership of their lands (ND-HERO, 2006). However, local people still operate traditional land ownership method where land use is managed by customary provisions, where each household is responsible for management of their lands regardless of the environmental implications. Observation showed that local people care more about their croplands and houses than the wider erosion implications. In practice, local people keep and manage their lands for their livelihood, but government only shows interest when there is special discovery like mineral and sand on the land. Local people use their lands primarily for housing (shelter) and farming (subsistence farming) would always resist any attempt by government to take over their lands. Ministry of Lands and Survey as the ministry responsible for land allocation and management not only neglects its roles as clearly spelt out in the Land Use Act, but also encourages illegal activities such as sand mining for its selfish gains. Moreover, the local government chairperson, who according to the Act has sole responsibility for rural land allocation and management, has not gained independence yet from the state government. In the context of environmental degradation, which has a clear link with land misuse, there is need for land use reforms to decentralise the powers of the state governors on land management. In the new reforms, power would be shared between the top government stakeholders and the local stakeholders, especially the traditional leaders and the local community people to ensure that land users are checked and regulated for compliance. There is also a special need to organise regular sensitization programmes in the rural areas to sensitise village land users, especially farmers and sand miners about the Land Use Act, and possible penalties for offenders.

6.3.3 The Federal Ministry of Land, Housing and Urban Development

The evolution of Nigeria's National Housing Policy (NHP) started in the year 1928 during the colonial administration following an outbreak of bubonic plaque in 1928 in Lagos. Since then, a couple of housing programmes have been initiated in accordance with the growing population of Nigeria. In the year 2002, The Ministry of Land, Housing and Urban development was established to ensure adequate and sustainable housing delivery as well as maintenance of sustainable living environment for all Nigerians. Interestingly, in the year 2006 the current and latest NHP was established and repealed the 1991 NHP that was in existence prior to the establishment of the ministry. In addition, the Nigerian State made provisions through Section 16(1) (d) of the 1999 Constitution to provide appropriate and conducive shelter to all Nigerians under the Fundamental Objectives and Directive Principles of State Policy. In addition, under the housing policy guidelines, there are provisions for ensuring a sustainable environment through Environmental Impact Assessment (EIA) compliance monitoring and regulations. Even though these sustainable housing policy guidelines exist on paper, in practice they are rarely implemented. Consequently, land degradation from housing activities remains one of the major environmental problems in Nigeria. In the context of environmental sustainability and soil erosion, the recent survey conducted in Nigeria during 7th December 2015 -30th January

2016 showed that illegal building of structures in both local and urban areas in a quest for shelter by an ever-increasing population has caused significant erosion in the watershed. Therefore, in order to reverse this trend, the current housing policy guidelines should be implemented and enforced accordingly. In addition, housing projects in Nigeria should be assessed according to Environmental Impact Assessment (EIA) guidelines to ensure they are not erosion threats before approval and commencement of work.

6.3.4 The Federal Ministry of Environment

The Federal Ministry of Environment is responsible for ensuring that all developments and industrial processes are carried out according to the prescription of standard national guidelines for environmental sustainability. The Ministry is therefore responsible for ensuring compliance monitoring environmental activities and degradation management in Nigeria. Under this ministry, the National Policy on Environment Act (NPEA) was enacted in 1991 and guidelines were established for ensuring a sustainable environment. In addition, the key monitoring of developmental projects to suit the environment and social issues are carried out using Environmental Impact Assessment (EIA) Act No. 86 of 1992. Even though, Nigeria has established Federal Ministry of Environment, which repealed the FEPA Act, they still face the challenges of implementation of the FEPA Act (Onyenekenwa, 2011). The Act, in performing this role, introduced a set of guidelines for conducting and reporting EIA studies and made it compulsory for project developments. The Ministry has established a sectorial guideline for each sector with all the necessary requirements for EIA. Infrastructural development project is one of the major sectorial guidelines which is regularly applied to proposed intervention project. Similarly, the National Environmental Standard Regulation and Enforcement Agency (NESREA) was established in 2007, as the section of the ministry responsible for environmental compliance monitoring, and enforcement of all environmental activities capable of polluting or degrading the environment. However, implementation and enforcement of these Acts remain a big challenge facing Nigeria’s environment, especially in the rural communities.

6.3.4.1 The National Policy on Environment Act (NPEA)

Nigeria formulated its first National Policy on Environment Act in 1991, and it was later revised in 1999 to accommodate some of the 1999 Constitution provisions. Then, in 2016 (seventeen years later) it was revised again to reflect current issues and concerns emerging from the environment resulting from the ever-increasing Nigeria’s population. NPEA is established to guide the guide and manage the environment and the natural resources of the country through a new holistic framework.

Its target is to ensure a sustainable development through its sectorial strategic policy statements and actions. The policy is enhanced through the obligation to protect the environment as stipulated in Section 20 of the Constitution of the Federal Republic of Nigeria 1999. It stipulated that Nigeria shall protect and improve its environment, land and forest (NPEA, 2016). Yet, environmental degradation and land misuse are still major challenges in Nigeria. Federal Republic of Nigeria signed up to various international treaties and conventions governing environmental issues. However, it is on this framework that the National Policy on the Environment rests. The following are the main goals of the Act (Ifeanyi, 2002).

- Securing a sustainable environment adequate for health and safety, and wellbeing; conserving natural resources and sustainable environment for the benefit of present and future generations.
- Raising public awareness and promoting understanding of the essential linkages between the environmental resources, and developments and encouraging individual and community participations in environmental improvement efforts.
- Maintaining and enhancing the ecosystems and ecological processes essential for sustaining the functioning of the biosphere to preserve biological diversity.
- Co-operating with other countries, international organizations and agencies to achieve optimal use, and effective abatement of trans-boundary environmental degradation.

However, some of the provisions of this Act are also duplicated in the State Ministry of Environment provisions, without a clear boundary of operations, and complementary plan. Lack of feedback mechanisms and poor participation of local stakeholders in environmental matters are issues that need to be addressed.

6.3.4.2 Environmental Impact Assessment (EIA) Act of 1992

Globally, environmental impact assessment is a regulatory tool responsible for investigating the potential impacts of proposed projects on both the human and the natural environment. However, EIA ensures proper assessment, identification and measures to mitigate negative impacts of projects as described in Sections 1 and 2 of the Act. Ethically, all projects flagged as EIA projects should pass through EIA scrutiny, and a proper permit to commence should be based on health and safety considerations. In Nigeria, EIA responsibilities are presently vested in the Federal Ministry of Environment (FME) established in the year 1999, which repealed the then Federal Environmental Protection Agency (FEPA) Act of 1990.

Its role is to ensure that all lands in the country are protected from industrial and developmental activities on the environment. However, Onyenekewa (2011) stated that the EIA in Nigeria is characterised by the followings:

- Lack of an effective monitoring and enforcement unit in the Federal Ministry of Environment (FME).
- Absence of follow-up guidelines and lack of feedbacks feedbacks through follow-ups.
- Lack of cooperation between Federal Ministry of Environment (FME) and state environmental institutions.
- Absence of clear responsibilities for what happens to environmental management plan, and concealment or selective interpretation of quantitative or qualitative information about impacts.
- Evidence of conspiracy between agency regulators and their industry client to actively subvert the original intention of legislation and legislators.

In Nigeria, EIA agencies are controlled to some extent by the industries captured by powerful interests. Consequently, they enforce law, apply policy and report data in a manner that is desirable to those interests (Onyenekewa, 2011). By doing so, the legitimacy of the EIA agency is compromised, and developers substantially evade the law. Moreover, lack of EIA regular update has also affected its effectiveness, for example, since its inception, EIA has only been amended once in 1999 meanwhile the host ministry that has gone under couple of updates in recent years, including creation of NESREA. In addition, poor environmental awareness, and lack of people's participation in policy formulation and implementation contribute to poor EIA process in Nigeria. Nwafor (2006) opined that Strategic Environmental Assessment (SEA) as it is applied to Environmental Impact Assessment (EIA) principles to policies, plans, and plans is yet to receive a mandatory status in Nigeria. Consequently, Nigeria's environment is characterised by ecological problems such as soil degradation and soil erosion due to increased pressure on the environment. Therefore, these outstanding concerns contribute to the dwindling environmental protection in Nigeria. In Nigeria, laws may be apparent and laudable on paper but rarely implemented and enforced in practice (Onyenekewa, 2011). For instance, the Section 2 of the Act that stipulates the guidelines for sand mining and agriculture projects which are major agents of soil degradation about environmental health and safety has not been given considerable attention. Even though, the EIA Act exists, poor implementation and enforcement have hampered its potentials for environmental health and safety. Furthermore, there is a real need for a sensitisation programme, especially in the rural areas, where large scale sand mining and agriculture are practised.

6.3.4.3 National Environmental Standard Regulations and Enforcement Agency (NESREA) Act of 2007

The need to adequately protect the environment gave birth to Federal Ministry of Environment in 1999. This was established to collate fragmented agencies responsible for environmental matters in order to ensure a proper environmental management through its sound policies and regulations. The Act established NESREA as the key regulator of the environment under Section 2, NESREA Act 2007. This Act specifically performs the roles of the then Federal Environmental Protection Agency (FEPA) Act established in 1990 as the Nigeria environmental regulator. The only difference in this two Acts is that NESREA Act has enforcement rights while the FEPA Act has no enforcement right. The role of NESREA is to ensure that policies, legislation, standards, and guidelines are complied with and enforced as stipulated by law. Their jurisdiction covers a very broad area such as water quality, environmental health and sanitation, land degradation as defined their policy documents and legislations. In the context of soil erosion and environmental degradation, it is specifically mentioned under Section 7 of the Act that the carrying capacity of the lands in watersheds should be maintained by every landowner or user by using soil conservation measures. In addition, Section 7 of the Act stated that the Agency shall, with respect to watersheds control erosion, landslides, siltation and sediment by ensuring that good land management is adopted in those vulnerable areas. Even though, these sections of law are very apparent (on paper), their implementation and the enforcement compliance deficit must be addressed. Moreover, as a very recent Act, there is a special need for a proper awareness campaign and sensitisation of the public to its existence. Most importantly, as a federal agency, there is need for collaboration with Imo State Ministry of Environment to ensure that their goals complement each other for a sustainable environmental management in Nigeria.

6.3.5 The Federal Ministry of Agriculture and Rural Development (FMARD)

This ministry is responsible for regulating agricultural practices and forest resources all over Nigeria. Over the years, it has gone through evolutionary changes through merging and demerging with other ministries. The latest demerging was in April 2010 from the Federal Ministry of Agriculture and Water Resources to the Federal Ministry of Water Resources, and now to the Federal Ministry of Agriculture and Rural Development. Even though the ministry has rural development as part of its mandate, this is often neglected by the federal government, especially since the discovery of oil in Nigeria. Thus, the practice of agriculture in the rural areas is not only unsustainable but also not monitored by government. Meanwhile, the Soil and Natural Resources Conservation Act of 1989 was established specifically for the conservation of soil and natural resources by formulating and implementing policies on the natural resources of the nation. Similarly, the Forest Conservation Act of 1958 was initially established specifically to address soil conservation problems in Nigeria. But, sadly, these Acts were enacted, and therefore controlled by the federal government without complementary laws at the state and local government levels. Consequently, deforestation and abuse of soil by the local farmers during farming in the rural areas are often not monitored. This is one of the drivers of erosion in Oguta Lake watershed.

6.3.5.1 The Soil and Natural Resources Conservation Laws in Nigeria

The Natural Resources Conservation Act 1989 is the natural resources conservation that empowered the Conservation Council to address soil and natural resources conservation through policy formulation and implementation on projects and programmes. This was immediately followed by the Federal Environmental Protection Agency Act 1990, and the revised version of the National Policy on Environment (NPE) 1999, which were established to protect the environment from degradation. It applies stringent policy guidelines to promotes natural resources conservation management in the country. Later on, it was subsumed by the current Federal Ministry of Environment that houses both the National Environmental Standard Regulation and Enforcement Agency (NESREA) 2007 and the Environmental Impact Assessment Act (EIA) 1992. These two units of the ministry are responsible for maintaining a sustainable environment and for ensuring that the environmental impact assessment must be carried out first on projects to check any likely dangerous impact on the environment before they are executed. The Act's main purpose is to protect all lands in the country from environmental effects of industrialisation and development activities. Despite all these policy guidelines, it has failed to address key conservation issues in Nigeria, especially at the community level. In Nigeria, agricultural activities are major agents of soil degradation, meanwhile one of the objectives of soil conservation is to boost agricultural production. However, the current soil conservation arrangement has failed to educate the local farmers on how to optimise soil conservation by adopting a sustainable practice. For example, adopting shifting cultivate practice and avoiding bush burning would potentially minimise soil erosion. But due to lack of agricultural extension services to educate the local farmers on effective soil conservation techniques, current farming practice bush burning is unsustainable. However, adopting enhanced conservation techniques like mulching, terrace farming and stone bunding (highly slopy area) through proper training would minimise soil erosion.

6.3.6 Imo State Ministry of Environment, Agriculture and Natural Resources

The ministry is a combination of the Ministry of Agriculture and the Ministry of Environment rolled into one without complementary plans with the Ministry of Environment and the Ministry of Agriculture at the federal levels. However, the structure generates conflict between the agricultural sector and the environmental sector because of the overlapping and the lack of complementary functions within the federal government agencies. While it is statutorily required by the environmental agencies to work with other agencies on issues and concerns relating environmental and conservation of natural resources protection, it is unclear how this ministry complements similar ministries at the federal government level (Christopher et al., 2009).

For example, Imo State Environmental Protection Agency regulates and enforces all the environmental activities in Imo State while on the other hand, the National Environmental Standard Regulation and Enforcement Agency (NESREA), as a federal government agency, also regulate and enforces the same environmental activities in Imo State. This is a typical case of the saying that too ‘’many cooks spoil the broth’’. These issues of overlapping and complementing function are discussed further in section 6.4.

6.3.7 Imo State Ministry of Land, Survey and Urban Planning

The ministry is responsible for land allocation in Imo State according to the guidelines stipulated in the Land Use Act 1978. The policy objectives of the ministry are to process all instruments evidencing ownership and possession of land and real estate in the state. However, the ministry has failed to recognise the local government chairperson’s right to manage lands within its jurisdiction as stipulated in the Act. For instance, one of the interviews conducted on the 17th of August 2016, about land ownership in Imo State provided the following:

> *‘’The governor is responsible for allocation of all the lands within the state territory, and has sole right to issue certificate of occupancy to individual or entity that meets the requirements’’*

This response contradicts the provisions of Land Use Act of 1978, which empowers the local government chairperson to manage land within its own territory. Also, it was made clear in the Act that lands within the federal capital territory are to be managed by the federal government while those lands within the state urban territory are to be managed by the state government.

In addition, it further stated clearly that lands within the local government territory are to be managed by the local government for its developmental purposes. But in practice this shared land management stipulated in the Act is rarely practised just because of the command-and-control attitude of the state governors. Consequently, lands at the local communities have been subjected to illegal uses and unchecked abuses by the local users.

6.4 Conflict, bad governance, and overlap of institutional laws

Following the review of environmental institutions in Nigeria, duplication and overlaps of function can occur at the federal and state level. There are numerous overlapping responsibilities and functions of ministries responsible for monitoring, enforcement, and protection of the environment in Nigeria. For instance, the conflict between the Federal Ministry of Environment and the State Ministry of Environment is mainly motivated by overlapping functions. While the State Ministry of Environment is supposed to complement the Federal Ministry Environment on environmental matters, the extent of their collaboration is still very unclear. For instance, Nwafor (2006) opined that lack of inter-ministerial cooperation and coordination between the Federal Ministry of Environment and the State Ministry of Environment in Nigeria causes poor communication among the internal departments in the ministries. In addition, FMSMA (2004) reported that the processing of EIA is federal government's responsibility, but the role of the state ministries is still inconsistent and unclear. Similarly, there is lack of clarity on the roles of the federal and state ministries in monitoring and enforcement of federal and state environmental laws and regulations. The roles and responsibilities of the Federal Ministry of Solid Mineral Development (FMSMD, 2004) and the Federal Ministry of Environment in managing sand mining is still confusing and unclear. For example, FMSMD (2004) reported that little attempts have been made to sort out different roles of federal ministries in the licencing of prospectors and in the enforcement of regulations at the mines and quarries. Also, weak institutional capacity such as EIA training and facilities for environmental protection; poor expert knowledge of environmental legislation are setbacks to environmental management in Nigeria. Ebigbo (2008) explained that Nigeria is very good at making sound policies, but poor implementation is the problem. In addition, huge resources are wasted on the processes of developing faultless policies in Nigeria as systemic corruption always mess the implementation in most cases. Moreover, for NESREA as the regulatory agency under the Federal Ministry of Environment, there is still confusion as regards the boundary of operation between its roles and that of the Imo State Environmental Protection

Board. Their monitoring, enforcement and regulations jurisdictions are unclear and divided. Moreover, FMSMD (2004) stated that the relationship between the federal and state ministries /agencies, and the local government is discontinuous and inconsistent and lacks proper communication channel. This discordance in the communication and relationship among three levels of government intensely limit their performance in managing Nigerian environment. In a multi-level system of government like Nigeria, there is always a perceived problem of jealousies and rivalries resulting in top-bottom legislation and management resources, but this would not be a much problem if the institutions are strong and effective.

In addition, there is still the possibility of conflict between the Imo State Environmental Protection Board and the local government environmental management unit. Potentially, conflict between the State Ministry of Agriculture and the Federal Ministry of Agriculture is highly possible because of unclear regulatory jurisdiction. Although, not constitutionally recognised, the conflict between the local communities and State Ministry of Lands about land ownership and allocation is a further demonstration of how lack of comprehensiveness and poor awareness of regulatory framework can affect compliance. This is also a demonstration of how a poor regulatory framework can affect monitoring and enforcement. Furthermore, managing EIA in a complex and multi-level government system like Nigeria is problematic, and often accompanied by conflicting mandate, role and responsibilities among the ties of government. The problem often results from inconsistencies, overlaps, duplication of roles and mandate as specified in the constitution and legislation, which govern federal-state-local government relationships. Consequently, the management of the Nigeria's environmental impact assessment processes among three levels of government is always faced with jurisdiction challenges. Though, clear provisions in the EIA Act 86 of 1992 for decentralisation of EIA roles to various levels in managing the EIA process in Nigeria, the mandate of the state is still very unclear (Onyenekewa, 2011).

Therefore, integrated federal and state environmental agencies with clear complementary regulatory responsibilities would reduce the issues of conflicting and duplication responsibilities. In addition, this would also reduce the conflict of interest often experienced between the federal and state agencies. Furthermore, even with this current regulatory framework, well-coordinated policies, and application of formal rules rather than rules-in-use by the relevant stakeholders in regulating environmental activities could significantly reduce conflicts and overlapping functions. For example, some of the conflicts within the environmental agencies could potentially be resolved if they develop their guidelines with the inputs of all stakeholders across all levels of government, especially input from the operational level stakeholders. Collaborative partnership of all the agencies will not only enhance regulation and enforcement on a wider scale but will also align interest with the Federal Ministry of Environment as the top government organisation responsible for the management of environment and erosion in Nigeria.

6.5 Chapter summary

A comprehensive analysis of environmental regulatory laws responsible for management of soil erosion as a key environmental problem in Nigeria has been carried out. The pieces of legislation applicable to environmental monitoring, and compliance enforcement in the context of local environmental activities have been reviewed. It was found that there are key limitations within the framework that affects its performance such as existence of numerous overlapping functions, poor policy implementation and enforcement deficit, lack of inter-ministerial cooperation, lack of complementary roles at different levels of government, and conflicting regulatory functions among ministries.

The chapter also suggests some regulatory amendments that could improve performance, such as stakeholder collaborations, complementary roles, and engagement of local stakeholders at the operational level in environmental management and sensitisation of local people about environmental laws.

7 CHAPTER SEVEN: THE SOCIO-ECONOMIC IMPACT OF SOIL EROSION AND SAND MINING IN OGUTA LAKE WATERSHED

7.1 Introduction

In Nigeria, soil erosion has a devastating effect on many people's lives and destroys essential infrastructures built for economic development and poverty alleviation. Indeed, over one hundred million dollars ($100,000,000) damage is estimated annually from gully erosion mostly in the south east Nigeria (NEWMAP 2013). Specifically, in the Oguta Lake watershed, gully erosion severely contributes to environmental problems, and thus, undermines socio-economic growth and development. Thus, this chapter set out to analyse the following:

- The socio-economic and environmental impact of soil erosion and sand mining in Oguta Lake watershed.
- The cost- benefit analysis of sand mining in Oguta Lake watershed.

Soil erosion affects a wide range of infrastructure worldwide, especially in a development country where it is dominant and where the expertise to tackle them is lacking (Abegbunde et al. 2006; Ofamata, 2007). In this study, semi-structured interviews and focus group discussions were used to obtain information on the social orientation of soil erosion in the study area. Observation showed that there is a strong link between social characteristics of the community residents and soil erosion in the watershed. For instance, it was observed from the focus group discussion (focus group discussion August 2016) that large scale dependence of the rural population on natural resources and increase in human activities exacerbate soil erosion in the watershed, which could be linked to widespread poverty and growing population in the study location. Therefore, both people's lives and the environment have been affected by the menace of soil erosion and land degradation in the watershed. This observation is similar to the findings of studies elsewhere that have identified the impact of soil erosion on infrastructure and the environment in Imo State (Amagaraba et al., 2017; Aja, et al., 2017). Amangaraba et al., (2017) observed that communication between villages is disrupted because of roads and bridges being washed away by gull erosion. Similarly, Kerenku et al., 2017 stated that gully erosion has affected infrastructure facilities, particularly electric poles, culverts and bridges in Gboko Benue State, Nigeria. And for a population of people that is always increasing, by implication, soil erosion is expected to increase in the future if no policy measures are put in place. The next section specifically addresses the impact of soil erosion on infrastructure and the environment in Oguta Lake watershed.

7.2 The impact of soil erosion on infrastructure and the environment

Soil erosion affects infrastructures worldwide and yet the perception and impact by the wider society is not well spread (Amagaraba et al., 2017). A total of fifty-seven (57) vulnerable infrastructures were identified across the watershed during reconnaissance survey carried out in this study as shown in Table 7-1. Similar studies by Mbaya (2016) reported that over 200 houses and culverts were destroyed by gully erosion menace in Gombe State. However, it was further observed that the initiation, development, and advancement of the gullies were mainly caused by a wide range of human factors such as drainage failure and poor termination of culvert direction and other human activities.

Table 7-1 The type and number of infrastructures affected by soil erosion in Oguta Lake watershed

No	Affected infrastructure type	No of infrastructures
1	Roads and streets	21
2	Bridges and culverts	3
3	Residential and commercial buildings destroyed	11
4	Drainage channels	8
5	Number of electric poles	14

Source: Author’s fieldwork 2016.

For example, most drainage failures resulted from poor construction work such as use of poor-quality materials for construction and poor drainage design. This observation agrees with Hudec et al. (2006) findings which stated that most gully erosion sites in southeast Nigeria are caused by poor termination of drainage channels. Likewise, Onu et al. (2010) opined that most gully erosion sites along the major roads in the southeast Nigeria were caused by poor civil engineering works. Beyond destruction of drainages channels, failed drainages also affect highway roads and street structures as the runoff that was originally designed to flow within the drainage channel diverts and gradually washes away road subgrades. For instance, Fig 7-1(A and C) shows a failed drainage channels caused by poorly constructed drainage channel along the Orlu-Owerri road in the watershed. Consequently, the subgrade of the roadsides has been exposed and, thus, the depth of the gullies has progressively deepened because of runoff. This finding agrees with Amagaraba et al. (2017) who reported that transport routes and bridges in Imo State were affected by gully erosion along the drainage lines. And considering the rate of urbanisation and population growth in the study location, potentially, there could be danger of further infrastructural failures which could lead to complete destruction of the roads in the future.

Figure 7-1 Remote sensing locations and field photos of mining sites and infrastructures affected by gullies in Oguta Lake watershed. Source: author's fieldwork and USGS https://earthexplorer.usgs.gov 05 42' 06.8''N 006 00' 36.2''E

In addition, poor civil engineering construction works (Abdulfatai et al., 2014) such as bridges, culverts, and electric poles contribute significantly to the failure of those infrastructural failures. For example, Figure 7-2 (C) shows a constructed bridge across the express road connecting Owerri and Onitsha, which has been affected by gully erosion. It could be the combined effect of bare ground condition of the bridge base and the runoff that triggered the gully erosion and the fact that the surface of the bridge is unpaved may have also massively contributed. Consequently, continuous runoff flow on the bridge base could lead to the collapse of the bridge in the future if no remediation measure is applied. Similar studies by Kerenku et al. (2017) reported that gully erosion destroyed bridges and drainages in Gboko Benue State. However, a simple civil engineering finishing work such as surface pavement or lawn planting could have prevented the gully initiation. In addition to poor civil engineering construction works, though not yet visible, the nearness of massive sand mining sites to the highway road could have effect on the subgrade of the soil layer holding the structures in the future as shown in Fig 7-1 (B) and Fig 7-2 (B). However, the fact that most sand mining sites are increasing in sizes due to continuous mining activities could make the road condition get worse in the near future if policy measures are not applied. In addition, instream sand mining in the watershed have caused a lot of channel incisions along the bank of Njaba River and also on the bridge piers beside the river as shown in Fig 7-2 (C). Furthermore, observation showed that some of the residential buildings in the study location were destroyed (Amangaraba, 2017) by gully erosion triggered by poor channelling of drainage lines to residential areas. Similar studies by Ibitoye and Adegboyega (2012) stated that human activities such as construction works involving haphazard erection of buildings on steep terrains, ineffective or uncompleted drainage projects encouraged concentration of runoff and gullies. Thus, during heavy storms, most homes are flooded, and houses destroyed due to runoff from poorly terminated culverts and gullies (Igwe, 2012; Ume et al., 2014). Also, the nearness of cultivated lands to residential houses makes it easy for ephemeral gullies from cultivated lands to encroach people's houses during heavy storm events. However, a properly constructed drainage channel along the highway would have prevented those infrastructural failures and the gullies that accompany them. Also, keeping cultivated lands away from people's homes would minimise ephemeral gully encroachment to residential buildings. Thus, constructing infrastructures according to specified standards and monitoring them regularly would significantly reduce the rate of gully erosion along highways and structural failures in the watershed.

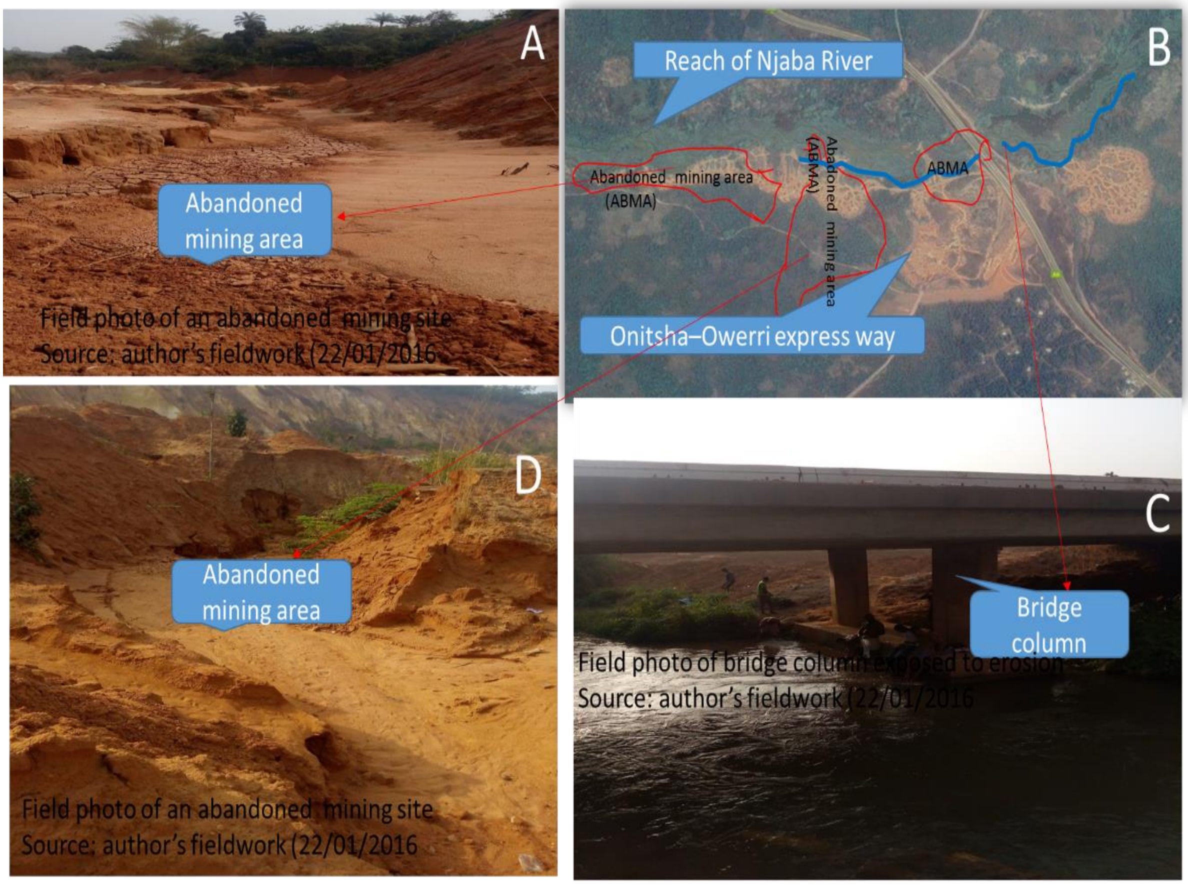


Figure 7-2 Remote sensing locations and field photos of mining sites and infrastructures affected by gullies in Oguta Lake watershed. Source: USGS https://earthexplorer.usgs.gov 05 42' 06.8''N 007 00' 37.1.''E

7.3 The social characteristics of local population in the study area

Because of the diverse anthropogenic activities that drive soil erosion in the watershed, it is necessary that the social characteristics of the local people is analysed to see how they are linked to soil erosion and soil degradation in the study location. The aim of diamond ranking is to highlight the importance of each theme in relation to soil erosion as well as facilitate discussion. Although diamond ranking is mostly applied in educational and teaching (Brown, and Fairbrass, 2009); it was applied in this research to enhance visual data presentation and also to facilitate discussion of the themes in relation to soil erosion (Rocket and Percivel, 2002). Its strength lies in the premises of ranking items and discussing them according to their importance to the subject matter as there is no right or wrong way of doing it. Therefore, Fig 7-3 shows a diamond ranking of the key social issues and observations that emerged during the semi-structured interviews and focus group discussions carried out in this study.

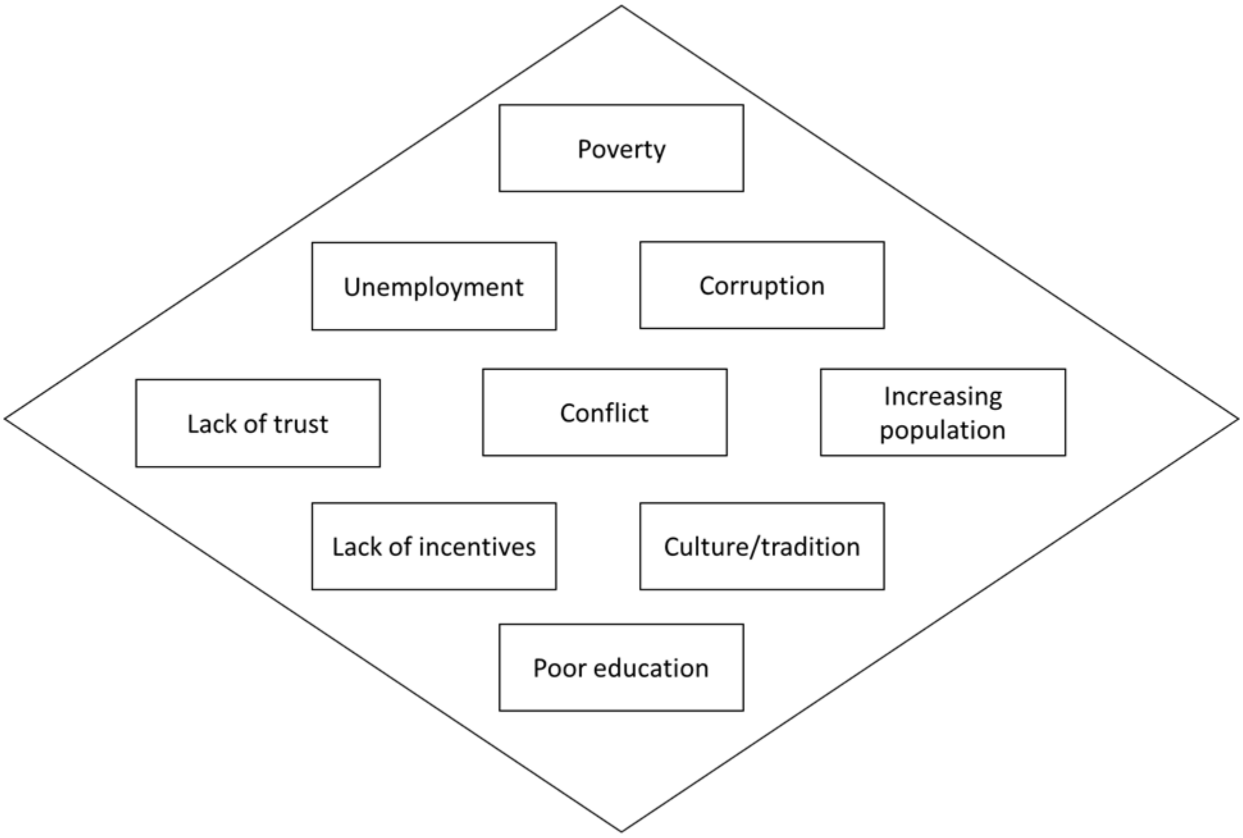


Figure 7-3 Diamond ranking of key issues and observations from semi-structured interviews and focus group discussions

The data analysis and selection of themes were done in NVIVO, but the diamond ranking was done based on the number of times each theme emerged during NVIVO analysis as well as their impact on soil erosion. It can be seen from Fig 7-3 that poverty is the most critical issue in the study location while poor education is the least ranked issue. However, there are other social issues such as powerful people and traditional belief system, but the issues highlighted in the diamond ranking are more critical and enough to characterise the local population regarding the subject matter. However, the presence of powerful groups such as trade union and traditional leaders cannot be ignored. Government needs to engage with them in monitoring of operational activities in the watershed while ensuring the participation of other stakeholders.

Firstly, it was observed that most of the residents are living under chronic poverty and, thus, depend massively on natural resources for their livelihood (Amangaraba et al., 2017; Jungle et al., 2008). Even though other issues contributed to soil erosion problem, poverty was flagged and ranked as the most critical and driving issue linking the people to other issues mentioned. Consequently, it was found from the local population figure that about 80% of the rural population depends on land resources for their livelihood and over 50% of the youth is unemployed However, if poverty is minimised or possibly eliminated in the future through employment and incentives from the government, some other issues highlighted would potentially be eliminated as well. It was observed that most of the youths in the community did not go beyond secondary school level because free education stopped at that level and their parents could not afford their university education. Therefore, they blamed lack of qualification and skills for their unemployment status and believe that do not have capacity to compete for jobs in the cities. Locally, youths in the community engage massively in sand mining land and other natural resources activities and would always fall back to them for a living in the event of no job in the community. Although, most of these activities like sand mining and deforestation are against government policies, the operators often confront or in most cases collude with the regulators to operate on them illegally. For example, one of the semi-structured interviews conducted with a sand miner provided as follow:

> *''Sand mining here (Oguta Lake watershed) is considered legal by us and government is aware of our mining business. We share revenue generated across all stakeholders involved; government have their own percentage, in the past we had conflicts with government but now we are in harmony''.*

This is a typical case of corrupt government officials because observation showed that none of the sand miners have mining permit and according to the State Ministry of Lands and Survey, most of the sand mining lands were originally allocated for crop farming. Thus, their mining business violates the Land Use Act 1978 and the Mineral and Mining Act of 2007 but most times these laws are not enforced because the government officials responsible for regulating these activities often collude with the operators for their personal gains. Similarly, the traditional leaders that serve as a communication channel between the government and the residents in the event of environmental issues like soil erosion in the watershed also collude with government officials for their personal gains. This is the cause of mistrust between the community residents and the traditional leaders. Going further, observation showed that farmers in the study location widely believe that complaints about erosion in their farmlands to the government through their traditional leaders are always compromised and not given the desired attention by the government. Meanwhile, the local traditional leaders are supposed to serve as a trusted communication channel between the community residents and the government as they did in the past. Although, they have the custodian powers to manage the local people and relate any of their concerns to the government authority, observation showed that they have repeatedly colluded with the government officials on environmental and natural resources issues for their financial gains. For example, one community residence interviewed provided the following:

‘’We have complained repeatedly through our traditional leaders to the government about sand mining in our farmlands, but our complaints have not been given a favourable consideration’’

Meanwhile, traditional leaders are beneficiary of sand mining activity, and thus, may not like to undermine the business. This is a typical case of being a judge in one’s own case. This, in particular, has led so many farmers to state of hopelessness because a good number of them lack capacity to progress their complaints to the government on their own and even if they attempt to do so, they would be redirected by the government to follow the proper communication channel.

Furthermore, there is persistent conflict between the pastoral farmers and the crop farmers in the study area about open grazing which is called herders-farmers clash by the Nigerian government. Sometimes, it leads to violent clashes, injuries and even loss of farm animals lives in the watershed. This unresolved conflict is threatening the food security of the local people because crop yield is significantly affected due to the damage done as a result of the free movement and feeding on crops by farm animals (Nwachukwu et al., 2011). However, a simple ranching system could potentially eliminate this problem if government introduce a compulsory ranching system for all the local pastoral farmers in the study site. Potentially, this would resolve the existing crisis between the two groups, improve the quality of meat from livestock, improve crop yield and most importantly minimise soil erosion.

Furthermore, large and ever-increasing population of the local people contribute massively to natural resources depletion and environmental degradation through farming and sand mining in the watershed (Okpala, 1990). Even though increasing population is not something that can be controlled easily in the study location because traditionally, most local households believe that having many children is wealth and thus, would like to have more children to increase their chances of being wealthy (Izuogu et al., 2015). However, introduction of capped benefits and incentives based on limited number of children by the government may likely control population growth. In addition, provision of quality education by government to the local people might shape their thinking and thus, potentially control population growth.

Also, poor quality and lack of education contribute to increase in environmental activities in the watershed as many of them lack the necessary qualifications and skills to secure white-collar jobs and, thus, depend on the natural resources for their livelihood. Although, primary and secondary education is free in the state, the quality is appalling and is yet to be made compulsory for children of all ages (Izuogu et al., 2015). And because government does not monitor education, the youths are vulnerable to all forms of exploitation by their parents and the wider public. For example, focus group observation showed that some sand mining operators engage in the business particularly to support their families even when they are still in secondary schools and in some extreme cases completely drop out of school to become full time sand miners. This has significant impact on the environment as more youths engage in environmental activities for their livelihood.

Lastly, the culture/tradition does not regard women as landowners in the community and when their husbands die, their sons are always regarded as the legitimate landowners. Meanwhile, farming is often dominated by women and youths in the community and would contribute significantly in any future soil conservation programme in the watershed. However, women are always afraid of losing their husbands' lands to their husbands' brothers in the event of death of their husbands if they did not have male children in their households. For instance, one of the semi-structured interviews conducted with a local resident widow provided as follow:

''I lost my husband ten (10) years ago and because I did not have a male child, all my husband's lands have been stripped off me by his brothers except where I am living now. I have no land of my own to farm, I can only farm on lands that used to be mine under my husband brothers' permission''

This interviewee is a typical victim of circumstance of being a widow and not having a male child. Particularly, the fear of not having a male child has led to so many women giving birth to up to ten (10) children in their bid to have a male child (Izuogu et al., 2015). This is because it is widely believed by the local people that having male children means consolidating women's marriage as well guaranteeing their future in their husband's homes. Sometimes, women's problem of being unable to have male children starts from their own husbands in the form of threats of sending them back to their fathers' home if they fail to have male children and sometimes even opting for a second wife. Consequently, this makes some women do extraordinary things to have their own male children. However, this tradition does not only put pressure on population but also increases poverty as more children are born without plan and resources to give them quality upbringing. Thus, this culture of classing women landless in the community often make them feel second class and could potentially hinder their voluntary participation in soil conservation activities and management if government comes up with a plan. In addition, the powerful group like trade union members and traditional leaders should be engaged in operational monitoring of activities in the watershed. They would form part of the bottom-up arrangement since they are always with the local population, thus, their engagement would improve the trust between the local population and government. It would be very difficult for government to address anthropogenic aspect of soil erosion issues in the watershed without first addressing some of these key issues highlighted in Fig 7-3. Therefore, engaging the residents in decision-making, provision of incentives and benefits to the local people and recognition of women as legitimate landowners among other issues highlighted would reduce dependence on natural resources and thus enhance proper land and environmental management in the watershed.

7.4 The people's perception about soil erosion in Oguta Lake watershed

The observations from semi-structured interviews and focus group discussions showed that the people's perception about soil erosion in the watershed is diverse and sometimes even contradicting. While some of the participants believed soil erosion started 20-25 years ago; most of them said that soil erosion started over 30 years ago and progressively got worse over time. This finding agrees with Grove (1949) who reported that soil erosion started around 1948 in Imo State. Similarly, Oformata (1985) claimed that soil erosion in the region dated back to 1948. However, the findings from this study suggest that the current rate of soil erosion may have been accelerated by the anthropogenic activities in the watershed. For example, increasing population has triggered urbanisation which has reflected in the road and drainage construction, construction of houses (Amangraba et al., 2017) and thus, could have contributed the current prevalent rate of gully development (Igbokwe et al., 2008). Additionally, the increasing rate of sand mining and deforestation in the watershed may have contributed massively to the current rate of soil erosion.

The observations further showed that most participants attributed the current state of soil erosion to sand mining activity while others believed it was caused by farming, deforestation, grazing, bare ground condition and poor road construction activities. However, one of the greatest causes of soil erosion in the watershed from the modelling results and field reconnaissance survey carried is bare ground condition, which is directly linked to other identified factor like sand mining and deforestation. However, there is a contradiction among local stakeholders about the causes of erosion in the watershed, especially between sand miners and farmers. While some farmers believe that sand mining activity is the main cause of soil erosion; some sand miners, on the other hand, believe that crop farming activity is the main cause of soil in the watershed. Although, both crop farming and sand mining contributed to soil degradation and soil erosion in Oguta Lake watershed, sand mining in the watershed is significant and has caused much more erosion in the watershed than crop farming and could even get worse in the future. For instance, observation revealed that in 2005, there were only two (2) inland sand mining sites with about ten (10) operators, but in 2016, the number has increased to over 30 mining sites with over 500 operators in the watershed. And being a booming business in the area, more lands are highly likely to be converted to sand mining sites in the future. Also, considering the increasing population, unemployment and poverty more local people may likely join sand mining business in the future. However, the danger is that the rate of conversion of the marginal and croplands to sand mining land is rapidly increasing, and lands are converted to sand mining lands as soon as quality sand are discovered underneath them. This is because land for sand mining business can easily out-compete land for agricultural business based on quick money and immediate financial turnover, but it is not sustainable.

However, the problem is that land reclamation back to previous agricultural use is often difficult, especially if it involves re-creating crop land after the soil has been scraped away and stored (Power et al., 2013). Thus, sand mining activity seems to be greatest threat to soil erosion in the watershed because it causes bare ground condition, reduces canopy cover, causes land degradation and soil instability, and sometimes develops into gully erosion sites. The next section will discuss the environmental effect of sand mining in the study location.

7.5 Environmental effect of sand mining, loading and transportation activities in Oguta Lake watershed

Sand mining pose danger to the environment and human health (Power et al., 2013). And because sand mining often involves excavation of open pits covering acres of land, there is a possibility of production of small dusty pollution could affect human health (Umeugochukwu et al., 2013).

Similarly, transportation of sand from mining sites to their desired destinations could be hazardous to human health because of air pollution. This is because during transportation of sands from sites to destinations, trucks with loaded sands are left uncovered and some top layer particles are highly likely to be blown away by the wind, and thus, polluting the environment (see Fig 7-4 below). Moreover, transportation of sand can lead to significant road congestion, road safety hazards, damage to local public roads that were originally designed for light weight cars. For example, heavily loaded truck could present a potential hazard to general population health because of diesel emissions from the internal combustion engine. And because there is no available air quality monitoring system that could potentially check the particulate pollution level from the sand mining sites to know if it exceeds the air quality standard, the people and environment are always at the risk of these diesel emissions.

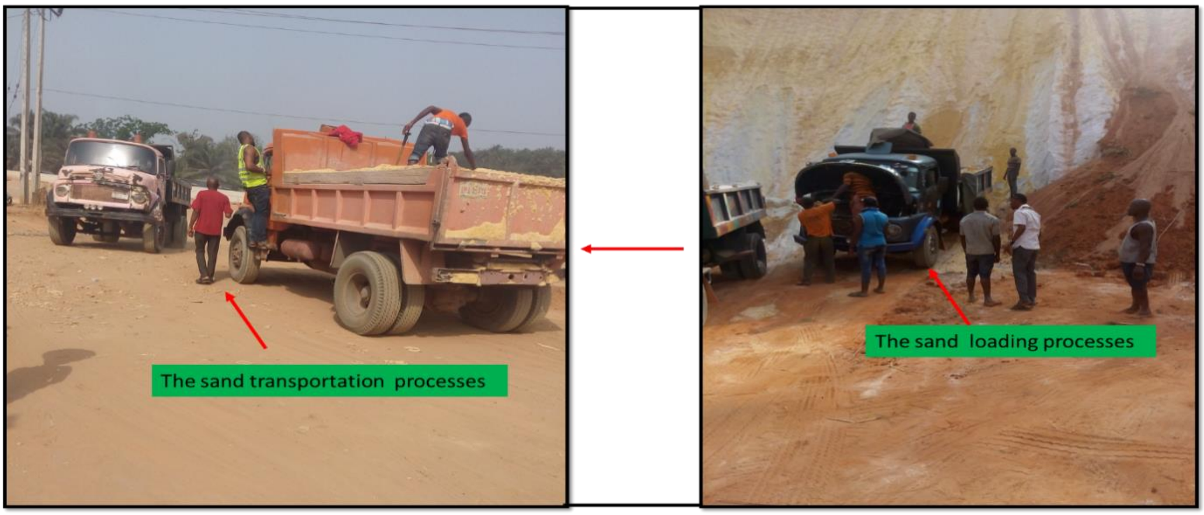


Figure 7-4 The loading and transportation processes of sand mining. Source: author's fieldwork: 05 42' 06''N 007 04' 3.9''E and 05 42' 07''N 007 08' 37''E

Furthermore, other activities such as scarring of landscape with pits and destruction of surface and groundwater resources could lead to more potential destructions in the watershed (see Fig 7-5 below). And for a watershed that is famously known for its tourist attraction, all of these including health risks could discourage potential tourists from vising the famous Oguta Lake, and consequently undermining the local economy. Moreover, the large-scale extraction of stream bed materials through mining and dredging beyond the sediment budget of a river could lead to erosion of channel boundaries which affects the general morphology of the channel. This could lead to collapse of riverbanks; the loss of adjacent structures; upstream erosion due to the increase in the channel slope and changes in the deposition pattern. Moreover, sand mining activities such as unplanned dumping of materials and possible oil leaks from trucks affect the quality of water downstream and could poison aquatic animals. Even though it has been highlighted in this study that sand mining could potentially damage human health and the environment, following the mining and other environmental regulations could potentially reduce these environmental risks and damage to the environment. Therefore, regulation and enforcement of all environmental laws and sand mining according to the Mining and Mineral Act 2007 and EIA Act 1992 would potentially minimise the environmental risks and misuse of resources. Also, selection of the most appropriates sites backed with sediment budgeting plan, imposing strict emission rules, mandating post mining reclamation rules and covering loaded trucks appropriately could also potentially reduce the environmental risks of sand mining. The next section is the cost-benefit analysis of sand mining business in the watershed.

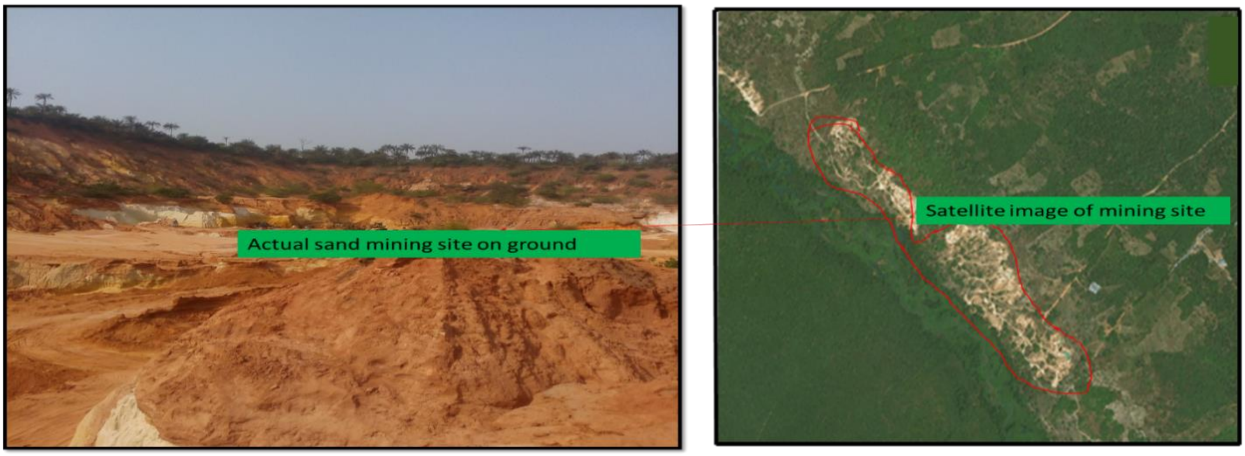


Figure 7-5 Satellite and field images of sand mining site in the watershed. Source: USGS https://earthexplorer.usgs.gov 05 42’ 07’’N and 007 01’ 36’’E and author’s fieldwork

7.6 Environmental effect of agricultural activities in the watershed

Subsistence agriculture is widely practised in the watershed as many local populations depend on it for their livelihood. However, the practice is always not sustainable due to lack of expert knowledge among the local farmers and poor regulation by the government. One of the main causes of deforestation and logging is clearing for crop farming in the watershed. According to Hance (2008) 54% of deforestation is due to slash and burn farming techniques; 19% is due to over heavy logging; 22% is due to growing sector of palm oil plantation and the remaining 5% is due to cattle ranching. Similarly, Alain (2000) opined that deforestation can result from a combination population pressure and stagnation economic, social and technological conditions of the location. Clearing of vegetation and shrubs during land preparation for farming alters the stability of the soil structure and the land cover system which can change its ability to protect the soil against rainfall drop impact. Also, the traditional tillage system commonly practised in the watershed destroys the soil structure and exposes the subsoil to direct rain drop impact and soil erosion. In addition, various agricultural chemicals that are used for crop farming become pollutants through use and misuse (Alufohai et al., 2013). For example, pesticide and other chemicals that drift in the soil through its application contaminate the groundwater and some cause air pollution through spray drifts which are very dangerous to human health. Also, soil degradation occurs in the form of soil erosion in farmlands which sometimes develop into gully sites. For example, Fig 7-6 shows developing gully along the road leading to farmlands in the watershed which was caused by runoff that comes from the farmlands in the watershed. However, the use of poor farming techniques by the local farmers and lack of monitoring of agricultural activities in the watershed contribute significantly to soil erosion in watershed. For example, bush burning that is widely practised in the watershed does only destroy the vegetation that provides protection to the soil but also destroy the micro-organisms that help in decomposing of organic matter in the soil. But the local farmers consider it as the cheapest and quickest option available to them and always opted for it. Consequently, the soil has been exposed to various forms of misuses and alterations which causes soil degradation and soil erosion in the watershed. Thus, regulation and enforcement of all environmental laws and agricultural laws and EIA Act 1992 would potentially minimise soil erosion in the watershed. Also, establishment of units of agricultural organisations and extension services responsible for operational monitoring of farming activities as well as creation of awareness to local farmers would potentially minimise misuse and land degradation in the watershed.

Figure 7-6 Gully development along road leading to farmlands in the watershed. Source: Author's fieldwork: 05 42' 05''N 007 02' 35.8''E

7.7 Cost-benefit analysis of sand mining in the watershed

Following the operational records of volume of sand excavated, revenue generated and sharing percentages in the watershed; an analysis of cost-benefit was carried out in order to understand the overall impact on local economy and the people. This would allow decision- makers and environmental managers to make future decision on the management of mining activity in the watershed, and thus, make amendments when necessary. However, the available data does not represent a holistic view of the mining activity in the watershed because some sand mining union leaders do not keep records of their business activity while others refused the researcher access to their records. Trade union was formed to protect the interest of the sand miners by communicating with government with one and stronger voice. It is informal and does not belong any government level. Observation showed that, the union also sanction members who are going against their rules by appropriating fine and suspension. Although illegal, sand miners pay money to government officials through the leadership of their union. This analysis is based on data from ten (10) mining sites in the watershed, however, it is considered fair enough to provide a rough idea of the cost-benefit analysis of the sand mining in the watershed. In addition, even though sand mining started in 2005 in the watershed, they started operating in union in 2011, and thus, the data set available started in 2011 until 2016 when the data was collected. Thus, the analysis was based on 2011 to 2016 data only and does not represent the entire period of sand mining in the watershed.

7.7.1 The volume of sand excavated in the watershed

Fig7-7 shows the volume of sand excavated per year which was obtained from a cumulative of daily truck loads excavated. It can be seen from the chart that yearly volumes increased progressively from 57,000 m^3/year in 2011 to 62,000 m^3/year in 2013, then, in 2014, the volume decreased significantly to 44,000 m^3/year because of the closure of some of the sites due to deaths of sand miners caused by cliff falls and violent clash among sand mining operators. Progressively, in 2015 the volume significantly increased to 70,000 m^3/year, which was the highest recorded volume ever. Then, in 2016, 42,000 m^3/year was already excavated as at August (8 months), potentially a higher volume may be recorded at the end of the year. This is because field observation showed that sand mining is more intense during the dry weather than wet weather, as the operators enjoy drier pits, as their trucks are less likely to get stuck on the muddy roads. Also, sand mining operators are always scared of soggy weather, and do not operate in their full capacity on wet days. In addition, more sand is demanded by the construction workers and builders during the dry weather than wet weather because dry weather always favours construction work in the location. In general, more volume of sand is excavated during the dry weather than the wet weather for the reasons mention above. Therefore, the trend in Fig 7-7 clearly indicates that higher volume of sands could potentially be excavated in the future years if sand mining continues. Even though sand mining business generates employment and revenue for the youths and other local people; the consequences of continuous sand mining in watershed without post mining plan cannot be underestimated. Firstly, there is possibility of the abandoned sites developing into massive gully erosion, which could even trigger landslides in the future. However, the cost of fixing major erosion projects like gully and landslide sites could run in millions of dollars, which could even exceed the total fund generated from the mining business. Secondly, conversion of farmlands to sand mining sites could result in food insecurity in the future, especially for a local population of people that depend massively on subsistence farming and natural resources for their livelihood. Also, for a watershed famously known for its tourism potential, continuous sand mining could potentially render it aesthetically unpleasant for tourists to visit. Potentially, there is possibility of achieving a balance between sand mining in the designated areas and sustaining the environment by regulating and enforcing sand mining activity according to the Mining and Mineral Act 2007 and environmental laws in Nigeria. The next section is the analysis of the financial implication of sand mining in the study location.

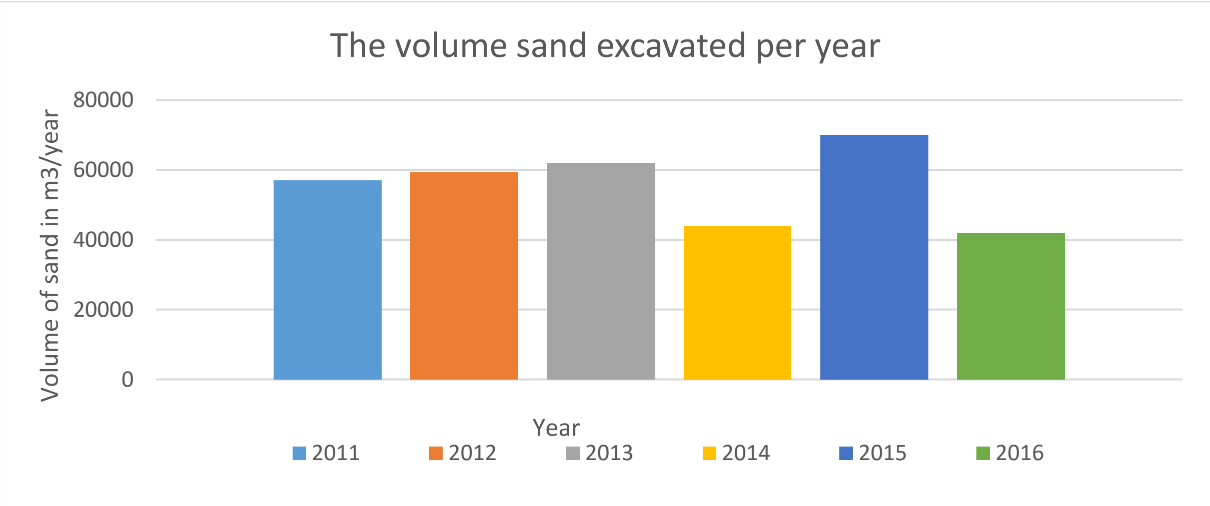


Figure 7-7 The volume of sand excavated per year in Oguta Lake watershed

The geometric graphics of sand mining areas traced on the satellite image (see Fig 3-6, Fig 3-8; Fig 4-4 A,B,D; Fig 7-1, Fig 7-2, Fig 7-5) were converted to shapefile using convert graphics to shapefiles in ARCGIS window. The created projectable shapefiles were used to calculate the area of the geometry using ‘calculate geometry tool in GIS’. The area of the geometry of the sand mining site calculated represents the area of watershed affected by the sand mining. The estimated sand mining area is $14460m^2$ = $14.46km^2$ = 1446ha. However, a more reliable method of area estimation by actual field measurements could not be done in this study due to time and cost constraints. The soil loss by sand mining per year: In 2011, the volume of soil excavated = $57{,}000m^3$, builk density of dry soil = $1.67tonnes/m^3$ (ranges from 1.5 -1.8 depending on the nature of soil). In this study, it is assumed to be $1.67tonnes/m^3$

Soil loss by sand mining in 2011 =	57000 *1.67tonnes /1446ha	= 65 tonnes/ha/year
Soil loss by sand mining in 2012 =	59000*1.67tonnes /1446ha	= 68 tonnes/ha/year
Soil loss by sand mining in 2013 =	62000 *1.67tonnes /1446ha	= 72 tonnes/ha/year
Soil loss by sand mining in 2014 =	44000 *1.67tonnes /1446ha	= 51 tonnes/ha/year
Soil loss by sand mining in 2015 =	70000 *1.67tonnes /1446ha	= 81 tonnes/ha/year
Soil loss by sand mining in 2016 =	42000 *1.67tonnes /1446ha	= 49 tonnes/ha/year

Average sediment loss by sand mining = 64 tonnes/ha/year

Soil loss by sand mining is significant and contributes massively to soil loss in the watershed. The soil loss of 64 tonnes/ha/year by sand mining is above soil loss rates by RUSLE-GIS and MPSIAC-GIS erosion processes. Perhaps, soil loss by sand mining is controlled by the activities of sand miners only while other soil loss rates are dependent on natural processes and factors.

7.7.2 The financial implications of sand mining in the watershed

Figure 7.8 shows that the amount of money generated from the sand mining business per year is directly proportional to the volume of sand excavated per year. The amount of money generated each year was obtained from the cumulative daily truck sales in the watershed, which served as the unit of production. As can be seen in the Figure 7-8, in 2015, a total of N162, 000,000 (£343,923.29) was generated, which was the highest amount of money ever generated per year based on the record available. Even though the environmental operators and the stakeholders believe that sand mining is very significant to the local economy, the impact of activities associated with sand mining on the environment is huge and could even cost much more than the perceived benefits. For example, Okoroafor et al, 2017 stated that that in most states within the south eastern region of Nigeria, human interference with the environment through continuous excavation of borrow-pits (pit or hole dug for the purpose of removing sand used in construction) and anthropogenic activities result in distortion/removal of soil vegetative cover which are pivotal to soil erosion. And for a location that has been flagged up as one of the gully erosion prone areas by the government, a proper EIA prior to sand mining would minimise the potential impacts associated its operational activities. The next section is the analysis of how the sand mining revenue is shared among the stakeholders.

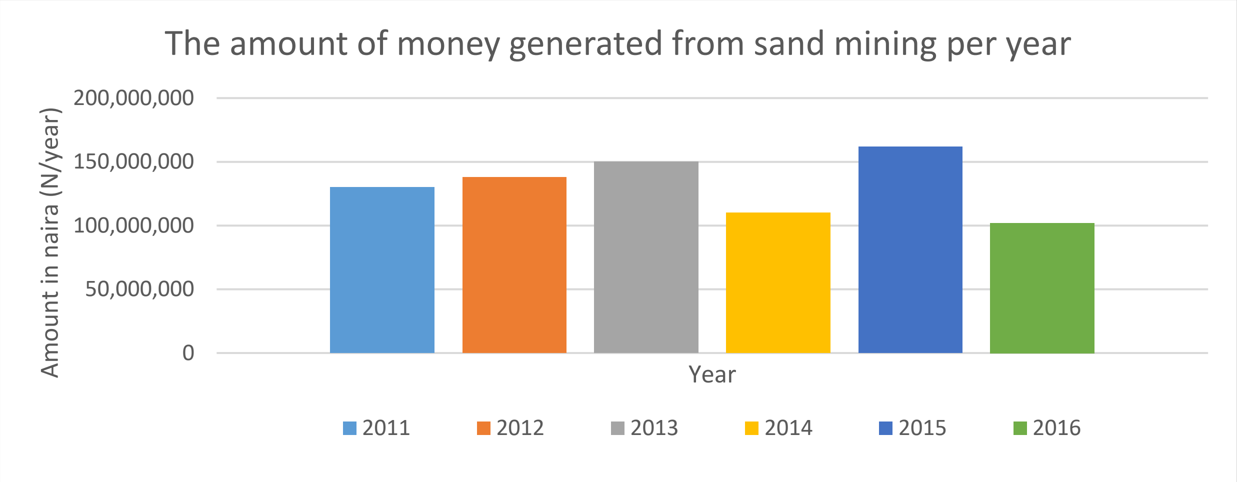


Figure 7-8 The amount of money generated from sand mining per year

7.7.3 The percentage revenue received by each group of stakeholders from the sand mining business

This section sets out to analyse the percentage revenue sharing among sand mining stakeholders in Oguta watershed and its implication. The sand mining revenue is shared among five (5) groups of stakeholders based on the percentage sharing formula (semi-structured interview, January 2016). It can be been seen from Fig 7-9 that transporters receive the highest share of the revenue (50%) while government receives the lowest revenue (7%), meanwhile government is responsible for regulating and enforcing sand mining activity in the watershed. Other stakeholders such as: owners (landowners), loaders and trade union member receive 22%, 11% and 10% respectively. The sharing formula was structured in such a way that both traditional leaders and government leaders, who are supposed to protect the environment and local people are included in the revenue sharing, and this often compel them to compromise their duty to protect and enforce environmental offenders. The sharing arrangement was spruced in such way that traditional leaders and sand mining leaders are grouped as trade union stakeholder, and thus, are powerful enough to control and subdue local complaints about the environmental effect of sand mining activity. Also, observation showed that government officials, who have the enforcement responsibility to sanction illegal sand miners collude with the trade union stakeholders and would turn blind eyes on environmental issues. Observation showed that even the 7% allocated to government goes to private pockets because sand mining is illegal and often not captured in the government revenue and budget. Funny enough, transporters receive the highest share of the sand mining revenue, meanwhile most of the transporters are non-indigenes of the community, and potentially may not face the consequences of soil erosion and environmental degradation associated with sand mining in the watershed. In addition, their trucks emit high level of toxic gases and yet, transporters do not pay any form of tax to the government or local people to compensate for the polluted environment. However, it is not against the law to operate inter-community truck transportation service in the study location, but formal introduction of levy or tax would generate money for the community and government to cushion the effect of environmental damage caused by their services. This analysis clearly shows that even though sand mining is perceived as a boost to the local economy, the bulk of the revenue goes to transporters (mainly foreigners) who do not contribute to community development in any form. Potentially, a government regulated sand mining would prioritise environmental sustainability through proper EIA compliance monitoring and budgeting. For example, imposition of heavy tax to miners could potentially discourage sand mining operators from the business, thereby minimising soil erosion and environmental degradation in the watershed.

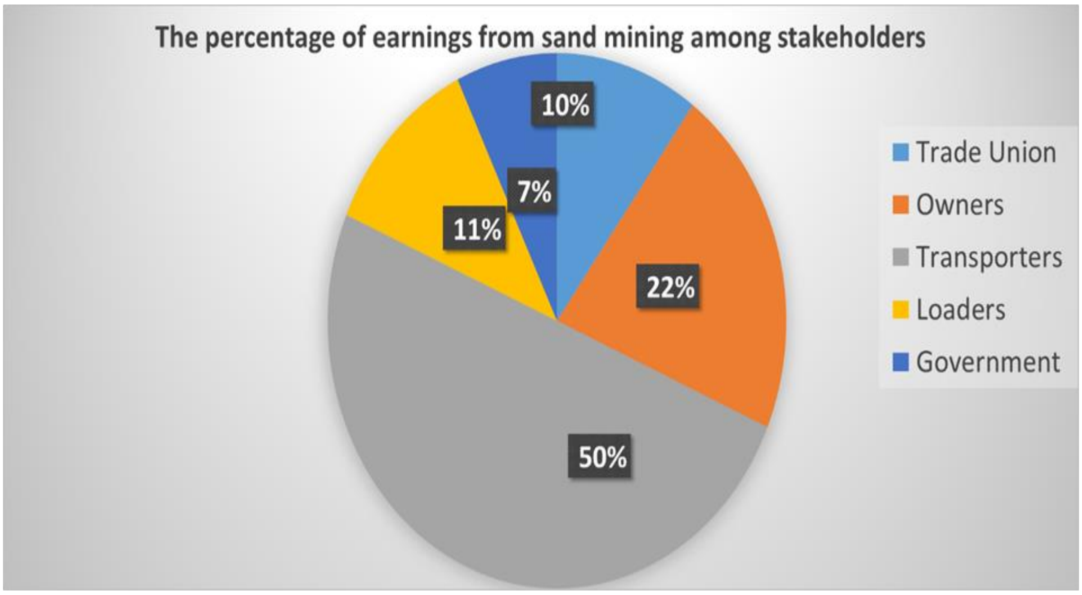


Figure 7-9 The percentage of earnings from sand mining revenue per stakeholder

7.8 Chapter summary

A comprehensive analysis of socio-economic impact of soil erosion and sand mining in Oguta Lake watershed has been carried out. It was found that the various infrastructures such as bridges, drainages and highways are affected by soil erosion. On the other hand, it was found that various social factors such as poverty, unemployment, increasing population, conflict, corruption, and lack of trust, lack of incentives, poor education and culture/tradition are drivers of soil erosion in the watershed. The current rate of soil erosion could be attributed to massive rate of urbanisation and anthropogenic activities going on in the watershed, which is a reflection of the social characteristics of the local people. A cost-benefit analysis showed the government, the environment and the local people do not benefit as much as transporters from the sand mining business. A proper EIA and standard design of civil engineering projects were recommended prior to their execution. On the other hand, provision of incentives and engagement of local people in decision–making could potentially reduce their dependence on natural resources. Most importantly, it was suggested that regulation of environmental activities according to the specified guidelines through enforcement compliance monitoring would potentially reduce misuse of resources.

8 CHAPTER EIGHT: APPLYING THE INSTITUTIONAL ANALYSIS AND DEVELOPMENT FRAMEWORK TO EROSION MANAGEMENT IN THE WATERSHED

8.1 Introduction

Having studied the physical and social characteristics of soil erosion in south east Nigeria in the previous chapters, this chapter presents institutional reforms for management of erosion in Oguta Lake watershed. It is aimed at combining the knowledge of erosion management in Nigeria and the current institutional arrangements under which it is managed. Thus, a reformed institutional arrangement that reflects the characteristics of soil erosion in the study location is developed. This chapter addresses the following research questions:

- Is the current institutional arrangement effective in the context of soil erosion management of Oguta Lake watershed?
- Can applying a reformed institutional arrangement minimise soil erosion in Oguta Lake watershed?

Previous studies in Nigeria focused on individual level of soil conservation effort to protect their local farmlands from erosion in Nigeria (Adesina et al., 2002; Anyawnu, 1996; Lal, 1976b). However, some of these practices are unstainable, and triggered much more erosion in the farmlands due to lack of monitoring and regulation by government. A bottom-up erosion management arrangement that involves local community participation and the government at different levels has not been explored by any known researcher in the Oguta Lake watershed. Therefore, this chapter sets out to introduce a new blend of institutional arrangement, which involves government at different levels and the participation of the local community for effective soil erosion management.

8.2 Critics of institutional management of soil erosion in Nigeria

The two government recognised approaches to soil erosion management in Nigeria are through soil conservation and land use management. Soil conservation in Nigeria started during the pre-colonial era by the indigenous community in their own little capacity and was later enhanced by the colonial government as means of commercialising agricultural business. However, during the pre-colonial era, soil conservation was not too much an issue because it was organised and managed by local people, in a small scale for protection of their farmlands (Igbokwe, 1996 and Scoones et al., 1996). On the other hand, the colonial model of soil conservation in Nigeria was successful for several social factors such as force labour and coercion by the colonial masters. Moreover, the colonial model was characterised using brutal forces and blame game on local people by the colonial masters. Later, the post-colonial model of soil conservation was initially great, because so much attention was paid to agriculture as the major source of government revenue in Nigeria. In addition, it attracted a lot of foreign aid from World Bank; so, the conservation programme was well financed but gradually it became a mess after the oil boom in 1980s the government diverted revenue generation attention to oil sector. In a bid to save the situation, federal government through the Federal Environmental Protection Agency (FEPA) in 1998 introduced the following strategies for land and soil conservation (Akamigbo, 1999). Firstly, government established guidelines for land use and soil management, and the necessary framework to implement them. Secondly, it introduced a regulation for controlling the activities of agricultural mechanisation such as land preparation and tillage techniques in order to minimise soil erosion. Lastly, a proposal was drafted for increasing public awareness through workshops and seminars on the dangers of soil degradation, its seriousness, causes and remedies. Conversely, government did not pay much attention to land use compliance in the 1960s and early 1970s as vastmost local people depended on agriculture for their livelihood. However, in the year 1978 the Land Use Act was enacted to regulate land use in Nigeria because of the growing pressure on land. Under the Act, there are stipulated guidelines for land ownership, allocation, and its use as well as necessary enforcement sanctions for the offenders.

However, in Nigeria formulation of laudable programmes and policies is often not a problem; it is the implementation that is an issue (Charles et al., 2004). Sadly, lack of follow-up policy implementation limited the performance of these programmes, especially during the military era. Moreover, frequent changes of government have made the matter worse, as implementation of soil conservation policy was often ignored, simply because agriculture does not generate huge revenue to government. This in particular has made possible improvement of soil conservation in Nigeria difficult, if not impossible, especially at the community level.

In addition, the current land use and allocation in Nigeria operate on a double method of ownership: the traditionally recognised method and the constitutionally recognised method.

This land ownership arrangement in particular, has become a huge cause of conflict and distrust between the government and the local people.

Consequently, the current soil conservation practice and land use in Nigeria are facing the following shortcomings. First and foremost, technical failure in soil conservation techniques as many local farmers practice soil conservation without following the soil conservation policy guidelines. Secondly, many soil conservation techniques in-practice do not fit in with the government agricultural guidelines because the practises of local farmers is often not monitored. And lastly, unstainable land uses, because they are not monitored by the government institutions, especially at the operational level. In a country like Nigeria that depends so much on agriculture to feed its population, priority should be placed on soil conservation and land management as a means of ensuring sustainability and food security. For instance, when the World Bank withdrew its funding in support of agricultural extension services in Nigeria, it was expected that the government would increase their budget on extension education, so that soil erosion management education and awareness can reach every farmer in the country to minimise mismanagement of soil (Oladele, 2004). Furthermore, there should be well-defined guidelines that include both local participation and the government at different levels in soil conservation technologies in Nigeria.

8.3 The biophysical environmental conditions of Oguta Lake watershed

The physical environmental conditions of the watershed are characterised by different forms of human induced activities that drive soil erosion as shown in Fig 8-1. Even though there are many other biophysical environmental conditions in the watershed, this section will specifically address soil erosion and those anthropogenic activities driving it. The watershed is characterised by different types of erosion such as rill erosion, inter-rill erosion and gully erosion at various range of classes (Okorafor et al., 2018). However, these major activities have been identified as the major causes of erosion in the watershed: land use, agricultural and sand mining activities.

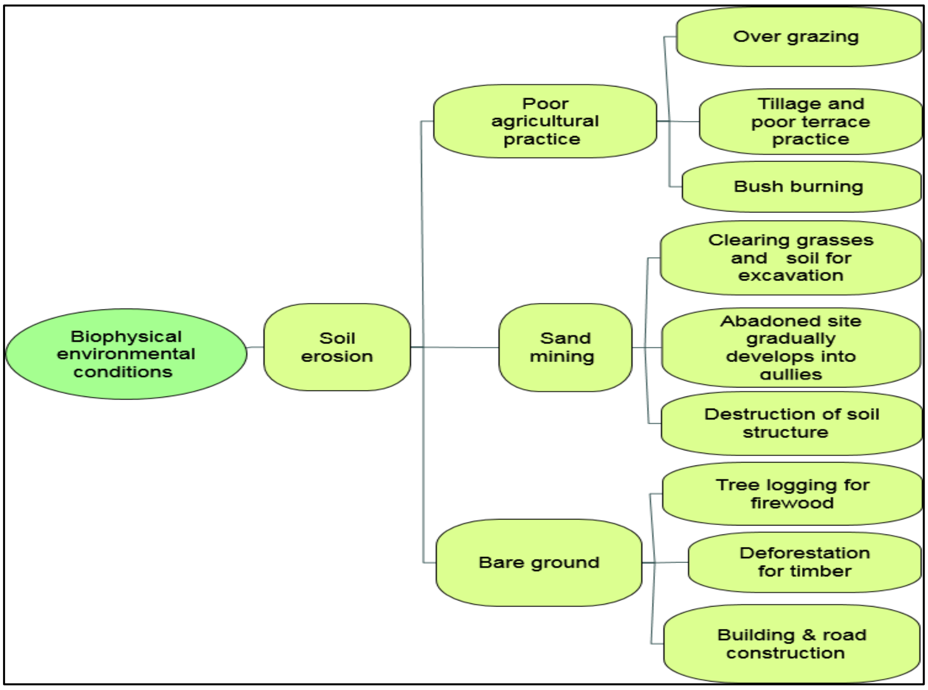


Figure 8-1 Identified drivers of soil erosion as the biophysical environmental condition of the watershed

8.3.1 Poor agricultural practice in Oguta Lake watershed

Bush burning practice is one of the drivers of soil erosion in Oguta Lake watershed. The interviews conducted during fieldwork revealed that vast majority of farmers in the watershed prefer this method of land preparation as they consider it cheap, and relatively easy to accomplish. However, most of the farmers are ignorant of the effect of this approach on soil due to poor erosion awareness education by the government. For instance, one of the farmers interviewed on the 18th of January 2016 about bush burning practice during the fieldwork responded as follows:

> *‘’This is the easy way we prepare our lands for the next farming season, so that the ashes from the grasses and shrubs will add nutrient to the farmland against the next farming season’’*

This response clearly shows that the farmer is only interested in quick way of preparing and adding nutrient to the farmland without considering the potential effect on the environment. This is an indication that the farmer is ignorant of the effect of bush burning and, thus, needs to be educated on the potential effect of bush burning in the watershed. This activity does not only expose the soil to direct rainfall impact but also causes the soil to be less stable by loss of the root system biding the soil particles together allowing the soil to wash away. Bush burning particularly affects shallow-rooted plants such as shrubs and bushes as shown in Fig 8-2, their root system is within the zones of unstable soil particles and serves as a binding medium to hold the soil in place. Thus, destruction of the root system by fire makes soil highly vulnerable to soil erosion.

Figure 8-2 Exposing soil to erosion by bush burning as a means of preparing land for crop farming. Source: author's fieldwork on 18/01/2016

Second, open grazing system is another agricultural method commonly practiced by pastoral farmers to feed their farm animals in the watershed. This method allows pastoral farmers to move freely with their cattle foraging in the watershed and this often leads to overgrazing. This activity drives soil erosion in various ways such as removing native grass, exposing bare topsoil, decreasing aeration, decreasing water infiltration, and decreasing grass growth and survival as shown in Fig 8-3. Moreover, the soil structure can be destroyed by overgrazing by compaction of the soil by the animals, thereby reducing infiltration and increasing potential runoff. However, a regulated ranching system has not been explored in this region of the country as practiced in the developed parts of the world. Therefore, a proper functioning institutional arrangement across different levels of government, particularly the local government, and the pastoral farmers for easy monitoring and feedback communications seems to be a possible solution. Furthermore, engaging and educating the local pastoral farmers on the sensitivity of overgrazing to soil erosion through agricultural extension services will improve farmers' awareness of dangers of overgrazing.

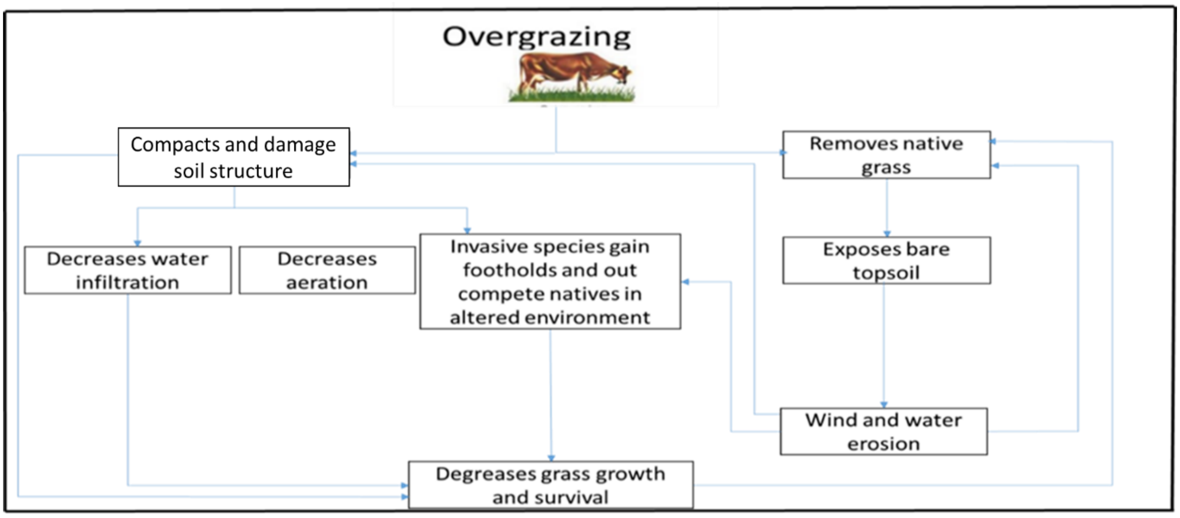


Figure 8-3 various processes of exposing soil to erosion by overgrazing

Lastly, poor tillage practice is widely used in the watershed as another means of preparing farmlands for the next cropping season. However, most farmers are unaware of the effect of poor tillage practice on soil erosion due to poor education and lack of awareness creation by the government agencies. Provision of adequate soil conservation training by the government will likely increase the awareness of new technologies and measures that will enhance sustainable practice (Obetta and Nwagbo, 1991). For instance, one of the farmers interviewed on the 19th of January 2016, about poor tillage awareness and government financial assistance on improved tillage method provided as follow:

> *''.... I am not aware of any other method of tillage except the one I learnt from my father, which we are practising in this community; government official has neither told us any other method to use in this community nor assisted us in any financial capacity''*

This response indicates that there is an awareness gap that needs to be filled by the government agencies, and this could potentially be achieved by engaging and educating the local farmers on sustainable tillage practices. Moreover, government aids and incentives to local farmers could encourage a wider participation because most farmers are poor and may not afford to adopt improved soil conservation technologies within their limited resources (Njoku, 1991).

8.3.2 Sand mining activity in Oguta Lake watershed.

The initial stage of in-land sand mining is clearing of grasses and shrubs, followed by excavation of topsoil to reach the target sand materials. This activity does not only remove the native grasses and shrubs that serve as protection to the soil from the direct rainfall impact, but also remove the top crust part of the soil, which has high resistance to erosion as shown in Fig 8-4. The different layers of soil exposed by sand miners during mining activities are vulnerable to erosion, especially during heavy storm events. In addition, sand mining alters the original structure of the soil by destroying the soil profile and weakening the inter-molecular forces that bind the soil particles together, thereby making soil susceptible to soil erosion.

The most disturbing concern is that most of these lands were originally allocated by the traditional leaders to the local community people for agricultural purpose, but they have been converted to sand mining by the local landowners without any approval by the government. For instance, one of the focus group discussions conducted on the 20th of August 2016 about sand mining activity and its impact on soil erosion provided as follow:

> *''We inherited this land from our fathers, and we are mining on it to improve our standard of living; we send our children to school from the sand mining business, since we do not get any financial help from the government''*

This response is an indication of government's lack of engagement with the local community to understand their needs and put it into plan. However, the Mining Act of 2007 made a provision for a mining permit granted to local community residents in a small scale but must be documented and regulated by the Federal Ministry of Solid Minerals Development. But, in this case, it is a typical institutional failure. This is because there are clear provisions and pre-conditions for engaging in mining business such as obtaining individual lease permits for both small- and large-scale miners, as well as area permit. Thus, this sand mining activity violets both the Land Use Act of 1978 and the Nigeria Mineral and Mining Act of 2007, and therefore, is liable to sanctions by the Ministry of Solid Minerals Development and the Ministry of Lands. However, a reformed government structure that put the needs of the local people into consideration, through their participation in soil conservation activities, compliance monitoring, and most importantly sanctions to offenders is likely to put an end to illegal sand mining and soil degradation.

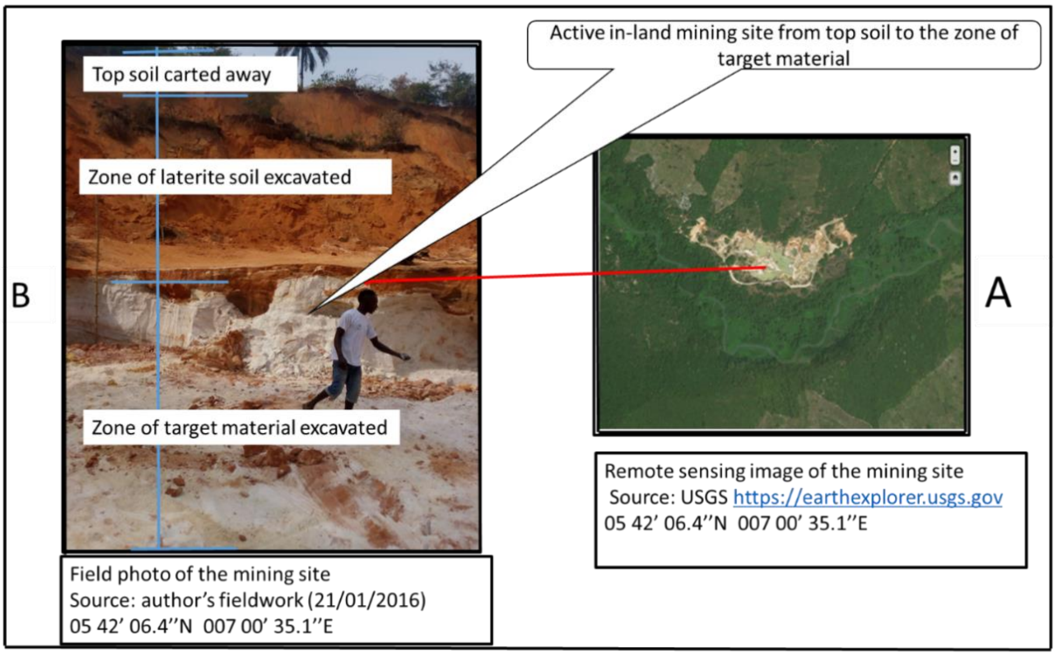


Figure 8-4 Different layers of soil exposed to direct rainfall impact during inland sand mining activity

Another noticeable issue with sand mining activities that drives erosion in the watershed is abandoned sand mining sites. It was noticed that, when miners saturate (exhaust) a particular site, they abandon it for the next mining site and it gradually develops into gully erosion, especially during the rainy (wet) season as shown in Fig 8-5. A well government regulated sand mining activity would require post- mining plan to protect the land against gully development, such as a landfill plan and a tree planting plan. Alternatively, a recreation facility plan that could even create employment and generate revenue for the government.

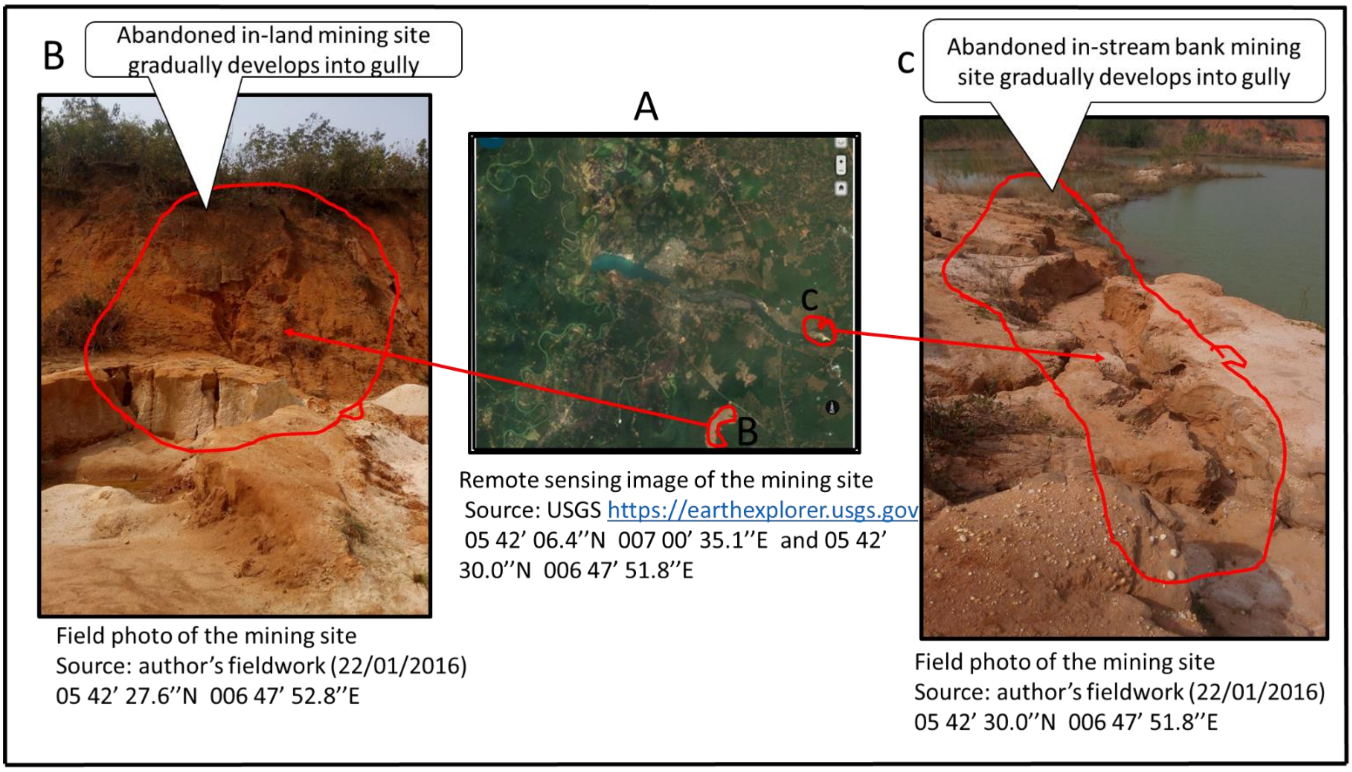


Figure 8-5 Abandoned inland and in-stream mining sites gradually develop into gully.
Source: author's fieldwork on 21/01/2016

8.3.3 Bare ground cover condition in Oguta Lake watershed

A combination of reconnaissance survey conducted in the watershed and the modelling result in Chapter 5 flagged bare ground cover condition as a very sensitive factor that drives soil erosion in the watershed. Bathurst et al., (2014) generalised that reducing forest However, many factors are responsible for this bare ground condition. A key one is forest logging: there is a widespread practice of felling forest trees by the local people, because of high market demand for timber products in the watershed. Most activities that lead to bare ground cover condition are human induced and could be properly regulated, and thus could be managed, if the institutions responsible for management of forest were strong and effective. However, the forest cover offers protection to the soil against direct rainfall impact and removing them makes the soil vulnerable to erosion, as can be seen in Fig 8-6. For instance, one of the local community residents interviewed on the 24th of January 2016 on awareness of soil erosion provided as follows:

> *‘’When we returned home after the civil war in 1970, there was no problems of soil erosion, but since they started felling trees and building houses; erosion has become a very big problem in our community’’*

This is an indication that soil erosion was not a problem in the community until after 1970s, and this clearly shows that deforestation activity is one of the drivers of soil erosion in the watershed. Sadly, most of the deforestation activities are conducted against the National Forest Act of 1958; and the Natural Resources Conservation Act of 1989, which protect the forest from illegal use and overharvest. In addition, the Acts also made conservation provisions for selective tree felling and replacement plans to ensure sustainability. Therefore, government ability to provide social packages to local people would reduce their dependent on local forests. In addition, stepping up compliance monitoring of forest laws and engaging the local people in decision making could further minimise deforestation activity in the watershed.

Figure 8-6 A collection of timber product in the watershed ready for transportation for processing

Source: author's fieldwork on 24/01/2016

Second, tree logging for firewood is a very common practice in the watershed because most local community residents depend on firewood for cooking food, and also do not have access to cooking gas. Provision of gas supply to the local community by the government would reduce their dependence on firewood, thus reducing firewood related logging activity in the watershed. Lastly, building and road construction projects were identified as massive drivers of soil erosion in the watershed, because most of these projects were carried out without EIA approval, especially individual projects like residential buildings and farm buildings. In particular, lack of estate plans and poor land use compliance in the watershed have led to land use conversions such as locating residential buildings in areas allocated for farmlands. Sadly, EIA is often neglected by individuals because government does not monitor or sanction offenders for non–compliance especially at the operational level, and consequently, the watershed is increasingly being subjected to misuse. A strict compliance monitoring of projects execution according to EIA guidelines for soil conservation in the watershed would minimise soil erosion. In addition, land use policy compliance monitoring in the watershed will check illegal conversion of lands for other purposes.

8.4 Attributes of the community

The interviews conducted during the fieldwork revealed sound evidence of distrust between local level stakeholders and the top policymakers. Therefore, to build this trust, there is need for participation of the traditional leaders, the trade-unions, and the local people in decision-making, as this will foster cooperation and unity among stakeholders. For example, it was difficult for me as a researcher to access the local people without the approval of the traditional rulers, who acted as gate keepers. Simply because, as a foreign person, it was difficult for the local people to believe that I was not sent by the government. During the interviews, it was observed that the local traditional leaders complained about empty promises from government officials, especially during the election period. Having this in mind, it would be very difficult to rebuild trust in the future without their own participation in decision-making. Moreover, poverty and unemployment are two major social issues in the community (see Section 7.3 Chapter 7). The high level of poverty and unemployment among the local stakeholders, especially the farmers, local residents and sand miners have increased their dependency on natural resources to earn a living. Thus, without provision of alternative means of livelihood by the government, it would be difficult to either disengage or redirect these set of stakeholders from their soil degradation activities. This is because over 50% of the local population in Oguta Lake watershed depends on land resources for its livelihood (interview, 16 August 2016). Because of the strong cohesion and homogeneity among local stakeholders, their participation as a block in decision- making, would check corruption and imposition, which are the major attributes of the top-level government officials.

Therefore, the attributes of the community at all levels, is one of the major causes of erosion in the watershed. For example, Table 8-1 shows the results of analysis of interviews and focus group discussions conducted during fieldwork as discussed in Section 7.3 Chapter 7. Findings confirm that the narrative on a spiral of population pressure, poverty, unemployment, corruption, lack of trust and conflict still prevail among local stakeholders and policy makers. To resolve these issues, there is need for policy elites and the local stakeholders to build strong and mutual relationship aimed at achieving sustainable environment.

Table 8-1 Predominant storylines on the main challenges in the soil erosion management in Oguta Lake watershed

Stakeholders	Problems	Causes	Likely solutions
Government staff	Poor understanding of roles Neglect Exploitation	Conflict Corruption	Clear role Monitoring Sanctions
Local farmers	Bush burning Overgrazing Poor tillage practices	Poor education Incentives Poverty Lack of trust	Erosion awareness Incentives Social programmes Engagement in decision-making
Sand miners	Excavation Bush clearing Land degradation	Poverty Youths unemployment Lack of trust	Incentives Erosion awareness Job creation
Trade unions **Powerful people**	Lead environmental activity	Conflict and use of brutal forces Lack of trust	Engage them in community-based leadership role Engagement in decision-making
Community residents	Deforestation Tree logging Environmental degradation	Population pressure Poverty Unemployment Lack of trust	Social benefit Local gas supply Employment Erosion awareness Engagement in decision-making
Traditional leaders	Inequality in land allocation Lead local people	Culture Corruption Lack of trust	Monitoring Equal land allocation Engagement in decision-making

8.5 Rules-in-use (informal rules)

Even though the federal and state formal rules have been great in terms of policy decision, there implementation and representation at the operation level is currently lacking. However, the application of informal rules by the local resource users based on their own terms often threatens environmental sustainability. For example, as explained in Section 6.3.2 in Chapter 6, the Land Use Act of 1978 is currently not in use at the operational level, instead the informal traditional method of land allocation and ownership controlled by traditional leaders is in use. This is one of the causes of controversies and conflicts between the government and the local people. Similarly, as explained in detail in Chapter 6, the agricultural laws and environmental laws such as the Conservation of Agricultural Resources Act NO 43 of 1983; the Natural Resources Act, 1989; the repealed Federal Environmental Protection Agency (FEPA) Act of 1999, now National Environmental Standard Regulation and Enforcement Agency (NESREA) Act of 2007 and Environmental Impact Assessment Act of 1992 were all enacted and aimed at achieving a sustainable environment. But their lack of representation, monitoring, and enforcement, especially at the operational level has significantly reduced their performance. In addition, the Nigerian Minerals and Mining Act 2007, which was passed into law on March 16, 2007 to repeal the Mineral and Mining Act of 1999 was established to regulate all mining activities in Nigeria but the structure, particularly its lack of representation at the state level has it made less functional. Proper management of soil in a developing nation like Nigeria requires regular monitoring of formal rules compliance and awareness creation. This is because vast majority of local resources users at the operational level lack basic knowledge of erosion and its consequence. Therefore, there is need to identify action arenas at the different institutional levels to check these policy oversights.

8.6 Action arenas

Following the analysis and identified erosion drivers in the watershed, rules- in- use, and attribute of the community; an assessment of action arenas in line with Ostrom's IAD framework is narrowed into three basic arenas associated with soil erosion management activities in the study location as shown in Fig 8-7.

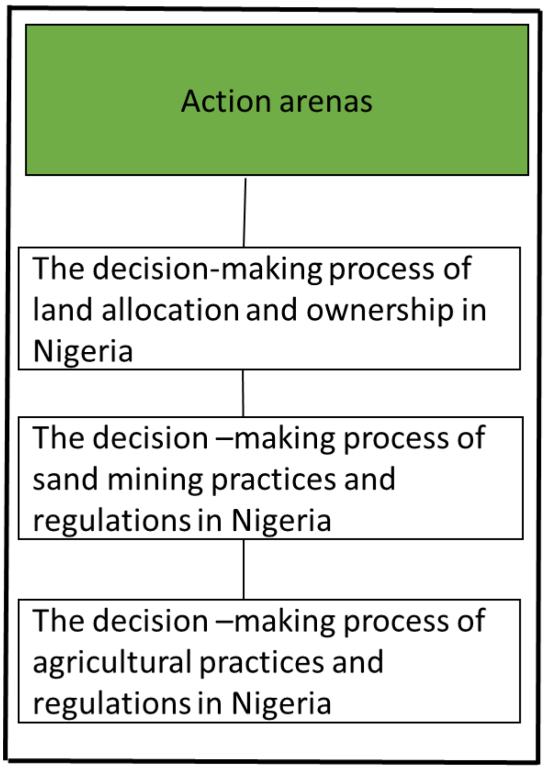


Figure 8-7 Identified actions arenas driving erosion in the watershed

8.6.1 The decision-making processes of land allocation and ownership in Nigeria

The process of land allocation and ownership in Nigeria generate a lot of controversies and conflicts among different stakeholders due to weak institution regulating it. For instance, while the local community members and traditional rulers still believe and operate the customary method of land ownership by inheritance in which land is allocated to individuals and communal clans by the traditional leaders; government on the other hand is operating a constitutional-based land allocation system, which stipulates that all lands belong to state government for allocation and sharing according to the Land Use Act of 1978. This contrast between formal rules and rules-in-use is the long-standing cause of conflict between the local people and the government, which makes it difficult for the local people and government to work together towards achieving sustainable land use in the watershed. Past approaches by the government to engage the local people about land allocation and documentation failed because of the lack of trust that exists between the two stakeholders. For instance, one of the local residents interviewed on the 27th of January 2016 about land ownership in the watershed, provided as follow:

''I inherited this land from my father, and it does not belong to the government or anyone else; the money I generate from businesses I do in

the land is what I use to take care of my family. In the past, government took people's land to build estate buildings for rich people, and promised them job compensation but never fulfilled their promise''

This response clearly shows that the interviewee believes that government has no control over his inherited land, and thus, cannot trust the government. This is because the interviewee believes that previous government regimes did not fulfil their promises on land use to the local people and would never trust the government. However, this hard-line position is often not good for sustainable land use. So, finding a mutual balance between the local landholders and government would reduce their engagement in unsustainable land use activity like sand mining. Moreover, some people, who are landless in the community may not participate in soil conservation activity, if government comes up with a soil conservation plan, because they believe they will not benefit from it. This reflects a kind of community- level power dynamics as well socio-cultural norms in the community (Zerihum et al., 2017). For a sustainable land use to work effectively in this location, land allocation and ownership policy needs to be restructured in such a way that local landholders will be recognised by government to save the land from further degradation. Also, landless people in the community should be given access to land, so that they will comply with the land use policy, as most of them are already self-engaged in illegal sand mining activity. In addition, social-cultural factors also exist as women are regarded as landless set of people in the community. Even though they participate massively in farming activity and, thus, are potential soil conservation agents, they are often not regarded by their husbands and male counterparts as rightful owners of the land. This tradition and custom of treating women as minority in the community may hinder their participation, as their husbands may likely dictate their positions in achieving a sustainable land use. Fig 8-8 shows the formal and informal structure of landownership structure in Imo State. At the federal level and state level, land ownership is regulated by the 1999 Constitutional provisions and Land Use Act of 1978. At these levels, individuals and cooperate organisations buy land through the government and certificate of occupancy is issued to that effect. It is the officially recognised legitimate method of land ownership in Nigeria. Disputes and mismanagement of lands at these levels are dealt with according to the provisions of Land Use Act of 1978 and the court of law. However, the Act seems not to function properly at local government level, where multiple land ownership system exists. The traditional land ownership system that empowers the indigenous people to own land through inheritance and the official government certified land ownership system through certificate of occupancy. These two conflicting land ownership systems is because of weak local government system controlled by the state government. As shown with yellow line in figure 8.8 below, the Imo State Ministry of Lands, Surveying and Urban planning allocate lands to individual within the local government territory which is against the constitutional provisions and Land Use Act 1978. On the other hand, the local traditional leader (Eze) ensures that lands within the local government jurisdiction are allocated to the local indigenous people through family and communal inheritance. This dual land ownership system is the sources of dispute between the local people and government, whenever government want to use land within the local community. In the past, local land ownership was not a big issue because as a developing nation, local lands were less in demand by the government officials except lands for common public facilities like markets, schools, and churches. So, lands were under the control of local people and the dispute then was less. Now, urbanisation and population are growing, the need for land is rising for developmental purposes. The problem is that these lands and their indigenous owners are not registered or documented by the government. So, government rely mainly on the information provided by the traditional leader (Eze) to justify the ownership claims of the indigenous people. Even though the local indigenous people lack the necessary documents to back their land ownership claims, they have the trust of their elected Eze, who is their spokesperson. In addition, the local indigenous land ownership system is gender biased as women are left out in their land inheritance system, meanwhile women dominate their men counterpart in local farming and household activities. The 1999 Constitutional provisions and Land Use Act 1978 empowers women to buy and own land like their men counterpart, but the traditional land ownership system prohibits such freedom. This is unacceptable as this undermines women's contribution to food security and development. Women work so hard to feed family through their daily farm and household activities in the community. So, empowering them with land ownership and recognition of their valuable contribution to the society would enhance environmental sustainability and development.

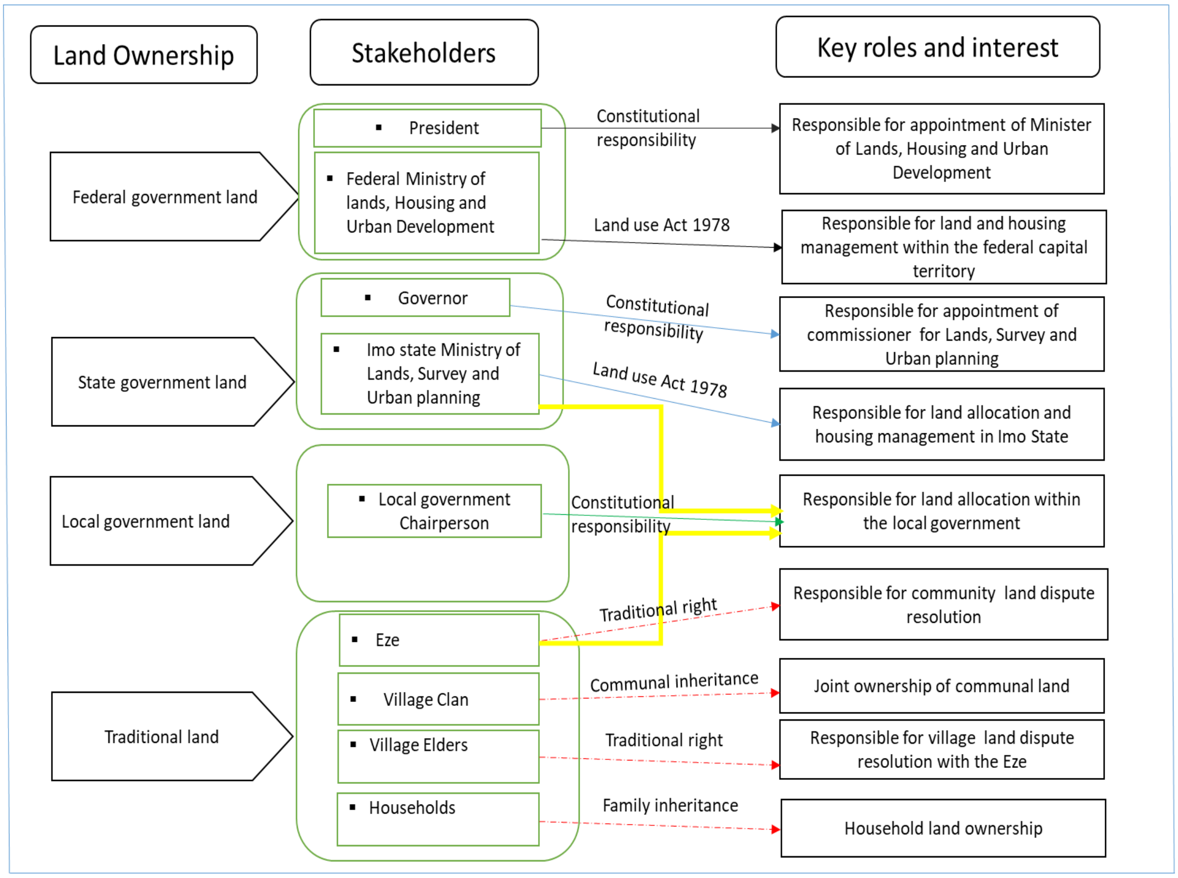


Figure 8-8 The formal and informal structure of land ownership in Imo State

Most importantly, a community level sustainable land use can only be achieved, if it is aligned with local priority plans and needs. Thus, a new land use policy arrangement structured to accommodate both the local stakeholders and the government participate in decision-making is a key step to achieving sustainable land use. Most importantly, strengthening compliance monitoring and sanctioning land use offenders according to the Act, would probably reduce land degradation. In addition, government needs to build the culture of trust with the local people and ensure that they benefit from their local land use plans.

8.6.2 The decision- making processes of sand mining practice in Nigeria

The Nigerian Minerals and Mining Act 2007, which was passed into law on March 16, 2007 repealed the Mineral and Mining Act of 1999 as explained in Section 6.3.1 Chapter 6, is responsible for regulating all mining activities in Nigeria. The Act was established for the purposes of regulating the exploration and exploitation of mineral materials in Nigeria, under the mandate of Minister of Mines and Minerals Development. According to the Act, the federal government is solely responsible for all mining activity across all the 36 states of the federation plus the Federal Capital Territory (FCT), which excludes the state governors from the mining regulatory and management rights in their respective States. In addition, the Act established pre-conditions for commencement of development of mining lease areas as follows. First, the holder of a mining lease shall not commence any extraction of minerals resources on the mining lease area until after the submission and approval by the mine's environmental compliance department. This approval is according to the environmental impact assessment studies and mitigations plans as required under applicable environmental laws and regulations (Odujinri and Adefulu, 2010). However, vast majority of sand miners do not comply with this directive, probably because the Environment Impact Assessment (EIA) unit does not regularly monitor its territory and sanction environmental offenders. Therefore, this poor compliance would improve if government could strengthen its EIA Act by creating a wider environmental awareness to sand miners and regularly monitor its territory for compliance. Similarly, the holder of a mining lease shall not commence any extraction of minerals resources on the mining lease area until the conclusion of a community development agreement by the mine's inspectorate department (Odujinri and Adefulu, 2010). Here, the community protection comes into force but sadly, the miners do not comply with this directive because they operate illegally and, thus, do not have any community development plans to guarantee sustainable and safe environmental practice. All these illegal operations are possible because the Mining Act is not effective and requires further strengthening to accommodate state level monitoring, rather than sole management by the federal government. For instance, one of the state government staff interviewed on the 25th of July 2016, about sand mining activity in the watershed, provided as follow:

''According to the constitution, it is the federal government's responsibility to monitor mining activities in the state, but the state government bears all the environmental impacts of sand mining, the community traditional leaders always complained to us about erosion in their community; they never complained to federal government, because they do not have capacity to complain to them''

This shows that the current institutional arrangement is poor and inappropriate, hence requires proper restructuring, to enhance proper communication channel between the operational-level and federal-level institutions. However, this federal-operational level management arrangement has always led to mining management conflict because the local people are not familiar with the federal government management arrangement. However, this disconnection of the state government from mining mandate does not only breeds corruption but also leads to language barrier (challenges) as most federal government officials are not local language proficient and, thus, find it very difficult to even communicate with the local miners. The staff of the State Ministry of Lands always took advantage of this poor arrangement to exploit the local sand miners by collecting bribes from the mining proceeds and offering them assurance of continuous mining operation. Moreover, some of the sand miners are not even aware of the different between the federal and state government officials and thus cannot differentiate which is which. For example, one of the sand miners interviewed on the 29th of August 2016, about the legality of sand mining in the watershed, provided as follow:

''I have been mining here for up to ten years and no body from government has issued warning to us about unauthorised mining activity, rather government officials come here daily to collect their own share from the mining proceed''

This response clearly shows that state government officials are really exploiting the local miners and have taken the advantage of the absence of federal government staff to enrich themselves to the detriment of the environment. Alternatively, a new institutional arrangement that connects the federal, state, and operational level institutions should be considered. To achieve this, a collective action based institutional arrangement that is interdependent, participatory and community driven seems to be good a choice for this study location. This could be done by creating a monitoring and feedback network in the form of system checker across all levels of government that puts all the stakeholders in check. Empowering state government to co-monitor sand mining activities with the federal government would increase compliance and minimise misuse see Fig 8-9 below. Decentralising sand mining regulations to state level and enforcing sand mining activities at the operational level would minimise land degradation in the watershed. Providing designated area for mining and ensuring that people with mining permit are allowed access to mining would reduce misuse and overharvesting of sand. Also, government needs to engage with local government chairperson to monitor sand mining activities in the watershed. In addition, women and local people should be engaged in operational monitoring of sand mining activities to improve communication channel among relevant stakeholders as they would be on ground to communicate relevant information to the top stakeholders for their necessary enforcement actions. By doing so, all the environmental and land use activities carried by the operational stakeholders will be put in check by the relevant stakeholders, and offenders will be sanctioned accordingly. Most importantly, creating alternative source of income or social benefit package for the local miners would reduce their dependent on sand mining. This new arrangement would likely check exploitation, monitor compliance, and provide feedback mechanism, to ensure that mining guidelines are followed. The abandoned mining site should be restored by ensuring that local stakeholders participate in the land reclamation activities.

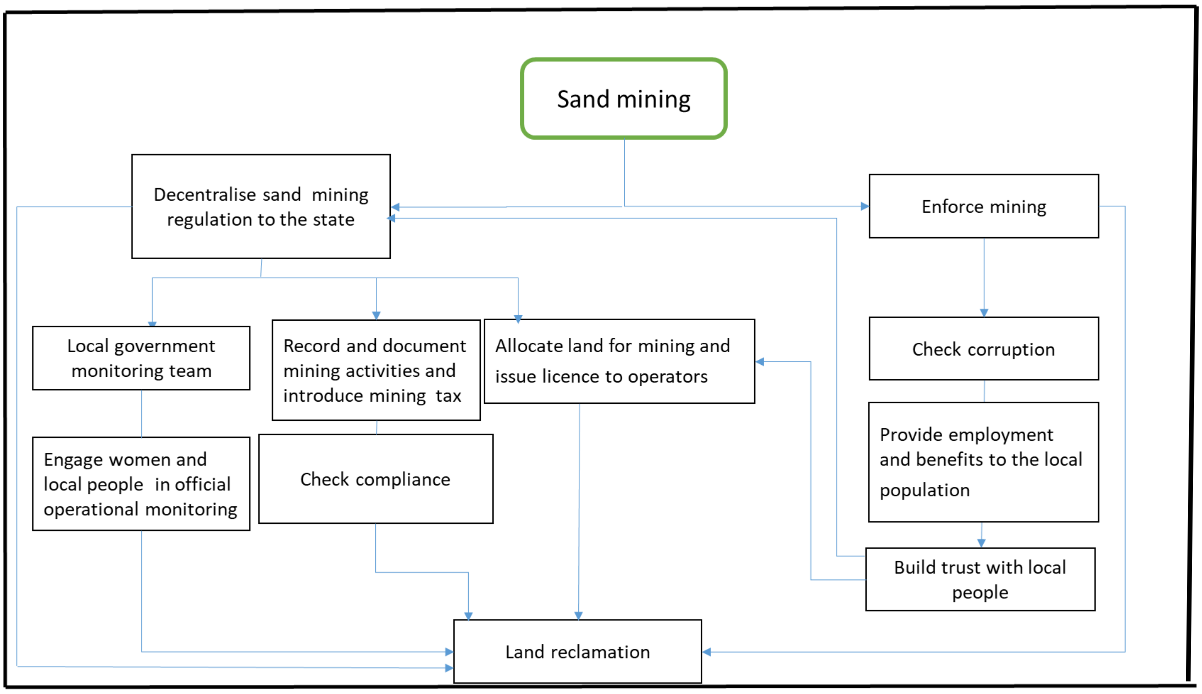


Figure 8-9 The recommended structure for regulating and minimising sand mining activities in the watershed

8.6.3 The decision-making processes of agricultural practice in Nigeria

The Minister of Agriculture, under Section 29 of the Conservation of Agricultural Resources Act NO 43 of 1983 is responsible for regulating agricultural practices in Nigeria. In addition, the Federal Environmental Protection Agency (FEPA) produced a revised version of the National Policy on Environment in the year 1999 and introduced NESREA in the year 2007, aimed at achieving sustainable environmental development in Nigeria. Particularly, to secure a quality environment adequate for good health and wellbeing of Nigerians; conservation and sustainably use the environment for the benefit of future generations. And to raise public awareness and promote understanding of the essential linkages between the environment and the people through community engagement and participation. However, lack of implementation of these laws and guidelines has not only led to conflicts but also created a route to environmental degradation. For instance, conflicts between pastoral farmers and community residents; pastoral farmers and crop farmers; farmers and the government are all due to poor policy implementation. (Ingawa et al., 1999; Blench et al., 2003). Sadly, these complex conflict issues have been a long-standing problem in Nigeria across ethnic and region lines that have led to environmental degradation. Firstly, poor awareness of the agricultural best practices and soil conservation approaches among crop farmers are the major issues threatening soil erosion in the watershed. For example, bush burning is the commonest method of preparing farmlands for the next farming season in the watershed, due to its relatively low cost in terms of labour and materials. It is not only because the farmers are poor and do not have capacity to adopt a more sustainable and conservative approach but also because the rich and large-scale farmers lack basic education and technologies capacity to apply these soil conservative procedures. Moreover, failure of the pastoral farmers to adopt a sustainable ranching system as practiced globally is another big threat to soil erosion in the watershed. These pastoral farmers move freely in the watershed in search of forage and water for their livestock, especially within the proximity of the water bodies (Magadza, 1986). Consequently, the soil in the watershed gradually and steadily washes away downstream, causing sedimentation in the lake without any replenishment or restoration plan upstream. All these problems would not have existed if there were strict compliance monitoring and enforcement of agricultural and soil conservation laws in the watershed. To fix these problems, there is need for engagement of stakeholders at different levels, especially the local community people, who are the most environmental operators. Firstly, local farmers should be sensitised by Agriculture extension workers about the best and sustainable agricultural practice; engaged in a community-based soil erosion awareness campaign; engaged in a technology-oriented training and be part of government incentives to enable them to participate in soil conservation programme. This approach will not only equip the local soil conservation workers with the relevant skills but also protect their interest via input and benefit sharing. As can be seen in Fig 8-10, empowering women with land and providing them with adequate training would improve sustainable practice. This is because women are dominant in local farming but are landless, thus, providing them with land, training and engaging them in official monitoring of farming activities would boost their confidence and participation in sustainable farming. Engaging operational stakeholders like women will improve bottom-up monitoring and communication to the top-level government.

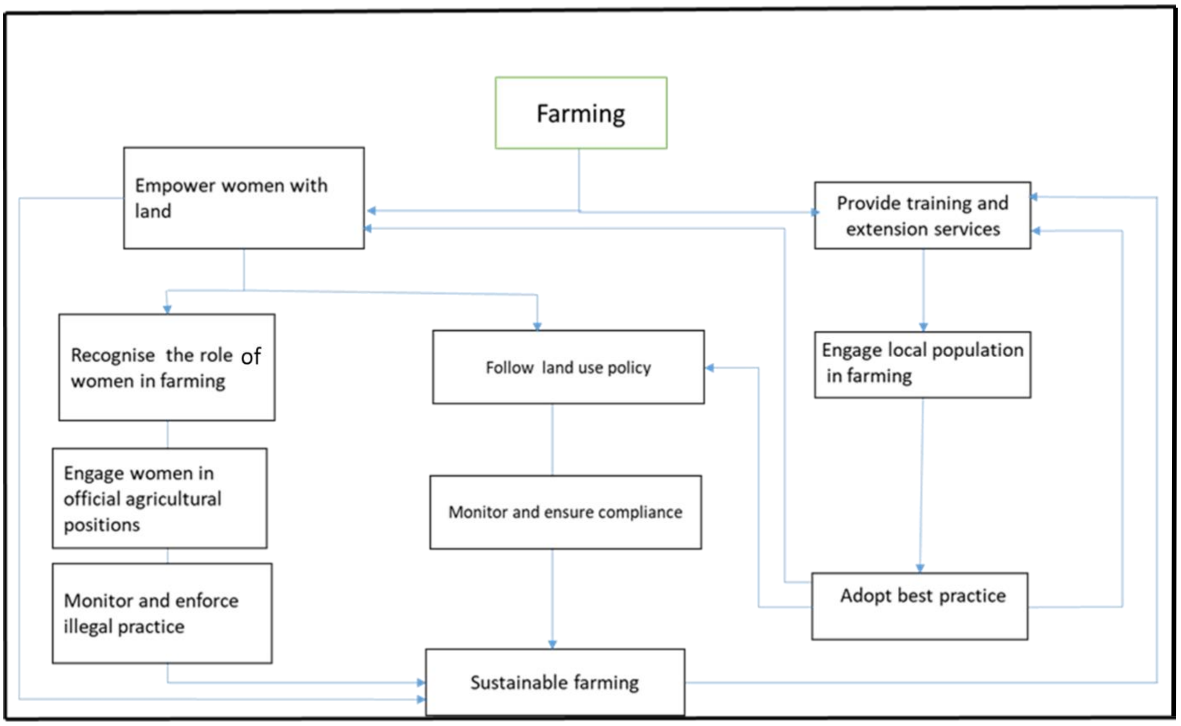


Figure 8-10 The recommended structure for regulating farming practice in the watershed

8.7 Pattern of interaction

In Ostrom et al. (1994), its pattern of interaction included an assessment of market structure, information flow and political participation, but in this research, it has been adjusted to strengthening and improving policy designs, by reforming and encouraging stakeholders local participation in decision-making. This would allow the community participants to have a say and make useful contributions to matters that concern them. According to Junge et al. (2011), the initial design of soil conservation system in Nigeria was structured in such a way that all decision making occur at the higher administrative level, without reasonable input from the local community. For instance, major soil conservation organisations like Agricultural Development Programme (ADP) in Maiduguri, Federal Environment Protection Agency (FEPA) in Kaduna and Maiduguri, Agricultural Land Development Authority in Maiduguri, and the Rural Development Projects (RUDEP) in Kaduna and Oshogbo are all Federal level decision making institutions. However, this arrangement simply means that local level stakeholders have little or no power to influence, what they are required to do in the soil management activities. Trippett et al. (2007) opined that sustained participation and support in the soil conservation activities are only possible, when members in local community feel that their concerns are reflected in the process and also have a say, as well as see how the end product will benefit them.

8.8 Strengthening and improving current institutional arrangements

Changing federal/ state rules-in-use, as well as acting upon the actors, information flow and incentives can significantly improve institution efficiency. For instance, the local land allocation and ownership system in the watershed is governed by the traditional rulers and is only recognised by the local people but not by the constitution. This discrepancy is a huge cause of conflict between the local people and the government, thus modifying the constitutional rule to accommodate the land needs of the local people, would minimise illegal land use. Moreover, the Mining Act of 1978, does not empower the state government to monitor the mining activities in the watershed but, the state government staff are the people on-ground controlling mining activities in the watershed. However, this absence of federal staff has led to series of exploitations of the miners by the state government staff for their personal gains. However, this gap does not only breed corruption but also generates conflict and confusion between the local people and the government. Lastly, the agricultural management and conservation laws are all federal and state-based institutions, without a representative voice at the operational level. All these are the causes of neglect, exploitation, and over-influence of particular actors on the policy processes. However, developing precise policy amendments and reforms on these areas necessitate an in-depth analysis of the federal / state rules governing the policy processes, which ordinarily is extremely difficult to perform for anyone outside the central policy making arena. This study proposes institution reforms by introducing additional actors and rules- in- use at the state level, as well as reforming individual actions at the operational level (shaded boxes Fig 8-11) aimed at achieving a sustainable soil erosion management.

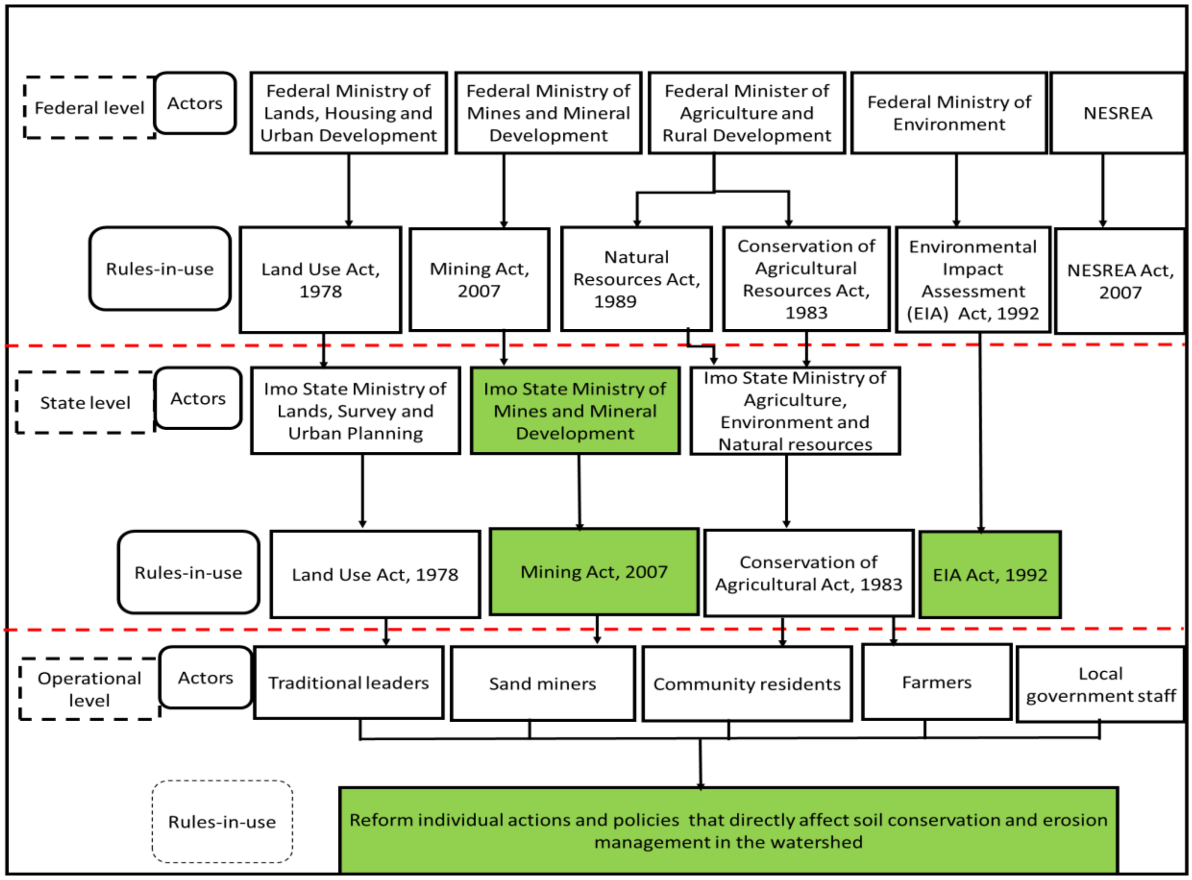


Figure 8-11 A Schematic diagram of different institutional levels showing action arena in the shaded boxes

8.8.1 Reforming current land allocation and ownership institution in the watershed

The current local land allocation and ownership controlled by the local traditional leaders has been linked to massive land degradation and bare soil conditions in the watershed (Akamigbo, 1999). This is because the current land use by the local people contradicts the land use policy as stipulated in the Land Use Act of 1978. For instance, the policy directs that land should be allocated to its most suitable uses such that land suitable for agriculture is used solely for that purpose and bad lands should be protected against further damage (Charles et al., 2004). In addition, the National Policy on Environment of 1999 further established guidelines for land use and soil management, and the necessary framework to implement them. But in this context, the local land users do not comply with any of those policy guidelines and, thus, convert local lands for unsustainable uses via their activities. Even though most land users at both the federal and state level comply with the Act, there is still need for land use compliance at the operational level, in particular, to check illegal conversion of lands for other purposes that are not sustainable (Igbozurike, 1981). A new policy amendment that recognises the powers of the traditional leaders and local government staff in land allocation and ownership in the watershed will not only minimise conflict but also will increase land use compliance. For a community that has trust issues with the government, such arrangement will likely enhance co-operation and participation among stakeholders about achieving a sustainable land use. For instance, one of the local landowners interviewed on the 30th of August 2016, about illegal use of land in the watershed responded as follow:

''……this land was allocated to me by the traditional leader of my community, who is in control of all lands in this community but not by any government officials that are always looking for lands to grab''

It will be difficult to shift the hard-line position of the interviewee without engaging the local traditional leaders in the community. Thus, any attempt by government to enforce the Land Use Act of 1978 in the community without going through traditional leaders could escalate to conflict. According to the focus group discussion conducted on 26th August 2016 about land ownership in the community; it is widely believed by the local landowners that every move by the government to reach out to them about land issues is an intention to grab their lands. Also, most of them do not see themselves as part of government and always position themselves as enemy of the government on land resources issues. Therefore, it is unlikely that this believe will change soon, unless stakeholders like their traditional leaders, whom they can relatively trust are engaged in decision- making. Similarly, it will be extremely difficult for government to stop the local people from illegal land use activities without providing alternative source of livelihood for them. This is because the level of unemployment is high and many local people depend on land for their livelihood, especially the youths. To solve this dilemma, government needs to create social packages and incentive benefits for the local people to enable them to at least release the lands that are under illegal use. For landholders, documentation of their lands through the traditional leaders and local government staff as well engaging them in an incentive-based soil conservation activity is a key step to encourage their participation in soil erosion management activities. For the landless youths, should be granted access to farmlands, and other social benefits, through the traditional leaders and local government authority. This will boost their recognition as part of the community, and hence increase their participation in soil conservation activities. By doing so, the population of youths available for illegal land use would reduce significantly. Furthermore, recognition of women by government to have equal land rights with their male counterparts would significantly encourage their participation in soil conservation activities. In addition, government ability to create non-farm employment in the area would reduce over dependency on local land resources for earning a living.

8.8.2 Reforming current sand mining institution in the watershed

The current top control of mining and mineral laws in all Nigerian states, by the federal government in accordance with the Mining Act 2007 has led to poor management of sand mining activities in the watershed. Currently, there is high level of non-compliance by the local sand miners as the interview conducted on 19th January about the legality of sand mining in the area revealed that over 90% of local miners has neither mining permit nor area permit. However, the permit documents are the only official documents recognised by the Act to grant a person access to mining area and the right to mine. Yet, the current weak and poorly structured institution controlled solely by the federal government has not been able to enforce the activity of the local miners.

Therefore, this work has proposed an alternative arrangement that empowers the state government to have a shared management responsibility of managing sand mining activity in the watershed as shown in Fig 8-8. This new proposed amendment will not only enhance on-ground monitoring of sand mining activity but also strengthen the relationship between the state government and the local miners, which is lacking under this current arrangement. In addition, the current mandate arrangement is full of controversies and conflicts, because the local miners are yet to understand the clear role difference between the federal and state government. This is because the federal government believe that the local people are poorly educated and lack capacity to engage in meaningful conversation and decision making and finds it difficult to engage them in conversation and dialogue on environmental issues. Interestedly, observation from the interview conducted on the 18th August 2016 showed that the easiest way for government to seek audience of the sand miners is through their traditional leaders and trade-union leaders. This releases their dilemma of fear and perceived threat of invasion by the government. Moreover, their perception of government approach to soil conservation is so negative that only local leaders like the trade union groups and local traditional leaders can engage them with the government. However, this new proposed amendment is a tripartite arrangement that encourages local miners' participation in decision making, and thus, enhances their understanding of the structure that manages sand mining activity in the watershed. In particular, language barrier has always discouraged federal government engagement with the local sand miners often as both stakeholders do not understand each other's language. Therefore, the inclusion of the state government members of staff, who are very proficient in both Igbo and English language, under this new arrangement would significantly resolve the language barrier.

Furthermore, it is extremely important for government to look at the welfare circumstances of these sand miners collectively, and roll-out a social package that will encourage illegal miners to participate in soil erosion management activity, rather than sand mining, especially people that operate in prohibited areas. For the abandoned mining sites, it is also important for government to employ miners in site restoration programmes like tree planting and landfill activity since they are familiar with the terrain. This will particularly check further development of gullies as well enhance soil formation in the watershed.

8.8.3 Reforming current agricultural institution in the watershed

The current agricultural policies are controlled mainly by the federal government, without paying much attention to agricultural activities at the operational level. Thus, there is need modify this current institutional arrangement to accommodate input from stakeholders at the operational level. In addition, current practice contradicts the purpose of Conservation of Agricultural Resources Act of 1983; the National Agricultural policy of 1988 and the Natural Resources Act of 1989, which their main roles are to protect and sustain the environment. Particularly to apply the following strategies for land use and soil conservation (Akamigbo, 1999): to provide guidelines for traditional grazing systems, to reduce environmental degradation through overgrazing; to increase public awareness on the dangers of soil degradation; and to regulate agricultural mechanisation, and other land preparation techniques in order to reduce soil erosion. But, sadly, none of these policy guidelines is in-use at the local communities, where agricultural practice is dominant, simply because of poor compliance monitoring and enforcement, and lack of participation of the local people in decision-making. Similarly, the EIA Act of 1992 is only active at federal level but has failed to meet the environmental protection needs at the local community level. For example, one of the EIA staff interviewed on the 27th of August 2016, about EIA compliance at the operational level responded as follow:

‘’We do not go to communities because they do have financial capacity to pay for EIA assessment fees and, we run office based on the internally generated revenue; so how do we even fuel our vehicles to the rural communities’’

The simple narrative is that EIA workers are more interested in looking at the environmental dangers on federal level projects and those environmental activities that would generate more revenue for the establishment and often lose sight of the operational level environmental activities and project damages. Even though open grazing is prohibited in the study location; it should be enforced and strengthened to protect farmlands from livestock invasion as well as protects the soil against overgrazing. To achieve this, a ranching system monitored by government and controlled by the local pastoral farmers in form of public-private partnership would minimise erosion caused by local pastoral farmers. And because erosion rarely occurs in the city; it would be extremely difficult for the managers at the federal level to understand the level of urgency, so, this study proposes that operational level organisations should be domiciled in the local community, where soil erosion is dominant. This would eliminate the barrier of poor communication channel and promote on ground monitoring of farming activities. For example, it was observed during the interviews that most of the local farmers were not aware of the Environment Impact Assessment (EIA) Law, simply because of the poor awareness creation and monitoring by the top-level government. This gap in representation at the community level where all the farming activities take place could only be addressed by providing EIA unit at the operational level that would work hand in hand with the top-level unit. Similarly, another local farmer interviewed on the 27 August 2016, about awareness of agricultural sustainable practice provided as follow:

''I started farming in this community at the age of 16 and now I am 52-year-old; I have never received any advice or training from government officials on how to protect or conserve the environment''

Meanwhile, under the Conservation Act, there is a provision for farm extension training and even incentives to farmers to adopt soil conservation technologies, but compliance is always an issue. According to Andersen and Lorch (2001), it is extremely important to educate and provide farm incentives to local farmers to encourage their participation in soil conservation activities, knowing that poverty and land degradation are linked together. Provide technological oriented trainings and sensitization programmes to farmers by Agriculture extension workers Moreover, key agricultural organisations that are supposed to be located at least in every state to protect the environment, and promote good agricultural practices are all centralised and controlled by the federal government. For instance, the Agricultural Development Programme (ADP); Agricultural Land Development Authority (NALDA); Rural Development Projects (RUDEP) and Agricultural and Rural Management Training Institute (ARTI) are all federal level organisations and lack representation at the local level. Thus, there is need to decentralise at least a unit of each of these organisations to the operational level for effective grassroots management of agriculture in Nigeria. In terms of rationale, the Agricultural and Rural Management Training Institute is responsible for identification of management training needs in agriculture and rural development organisations throughout Nigeria. And also, to develop and implement training programmes to meet the needs of managers in the agricultural and rural development sector for the benefit of local farmers. However, the disregard for community-based farmers by the top government staff contributes to poor implementation of these policies, which was originally designed to benefit the local people. Therefore, lack of local farmers' participation in decision- making in these organisations has placed them in a rule-taking position, which most times are not in their best interest. In addition, the majority of agriculturally based non-governmental organisations (NGOs) that work with the local people in Nigeria are federal level government based and are rarely in contact with the local farmers. For example: The Justice Development and Peace Commission (JDPC) and the Nigerian Environmental Study Team (NEST) are federal based NGOs and so, they rely mainly on information from agents that may not be reliable.

Thus, localisation of units of these organisations at the operational level to ensure that all stakeholders participate in decision–making by engaging local farmers and, thus, would increase compliance, and potentially reduce soil erosion in the watershed. Moreover, provision of farm incentives and extension services to local farmers would encourage their participation in soil conservation activities (Godwin et al., 2003). Provide technological oriented trainings and sensitization programmes to farmers by Agriculture extension workers and locate key agricultural organisations at least in every state to protect the environment and promote good agricultural practices.

8.9 Chapter summary

This chapter has successfully reviewed and analysed the effectiveness of institutional arrangement responsible for soil erosion in Oguta Lake watershed. Various institutional lapses such as: contradicting traditional and government method of land ownership and allocation using informal rule and constitutional rule; lack of constitutional empowerment of state government in managing the sand mining activities in Nigeria; and lack of representation of EIA Act and agricultural organisations at the operational level. This study has proposed the following reforms. Firstly, the recognition and empowerment of the traditional leaders and activating the local government system in land allocation and ownership in the study location. This reform would potentially enhance land use compliance and check local misuse which is one of the aims of the Land Use Act 1978. Secondly, constitutional empowerment of state government in the management of sand mining in the watershed has been proposed to fill in the management and institutional structural gap that currently exist. This reform would potentially check language barrier and corruption among the federal and state government officials. Lastly, the representation of EIA unit and agricultural organisation at the operational level has been proposed. Potentially, this reform would minimise unsustainable environmental activities in the watershed through compliance monitoring.

The next chapter forms the conclusion of the study, assessing whether final results have matched initial objectives, drawing conclusions, presenting policy reforms and opening directions for further research.

9 CHAPTER NINE: CONCLUSIONS

9.1 Introduction

This chapter presents the overall conclusions of this study. The conclusions are based on the research aim and objectives. The chapter also presents the contribution of the research to the management of soil erosion in Oguta Lake watershed Imo State south east Nigeria. The chapter concludes by reflecting on the contributions of the research and makes recommendations for future research.

9.2 Summary of main finding

The overall aim of the study is to combine field observations with RUSLE-GIS and MPSIAC-GIS modelling and social research techniques to spatially assess the impact and social drivers of soil erosion and, thus, propose policy reforms that could minimise it in the study area. The research focused on the analysis of the physical and social characteristics of soil erosion in Oguta Lake watershed. To this aim, the research successfully applied both physical and social research techniques to assess soil erosion in Oguta Lake watershed. In particular, the physical and social drivers of soil erosion were analysed and policy reforms that could minimise unsustainable human activities and soil erosion in the watershed were proposed. Several objectives were defined and addressed in the thesis chapters as follows.

9.2.1 Conclusion of chapter 4: achieving objective 1

Chapter 4 addressed objective 1 which was to assess the land use and cover change dynamics in the study area and its effect on soil erosion. It was important to analyse how the watershed has evolved over the past few years in order have an insight on the activities that drive the changes and its impact on soil erosion. Based on that, twelve set of multi-spectral Landsat-TM and Landsat-ETM+ with spatial resolution of 30 m were analysed. The classification of the current land cover changes showed that 25% of the watershed is bare ground and unpaved road, which is the most vulnerable area to soil erosion and while 39% is urban and cultivated lands, which is slightly vulnerable to soil erosion. It was found that 36% of the watershed is relatively stable to soil erosion but 64% of the watershed was classed under moderate to severe erosion. The findings reveal that the watershed is relatively unstable and vulnerable to soil erosion. The land use and land cover change dynamics analyse further reveals that forest and pasture lands have been significantly converted to urban and cultivated lands, bare ground and unpaved roads classes. Overall, 14% of forest and pastureland was converted to other land classes in a period of 24 years. The implication of this change is that 14% of the watershed has moved from stable condition to vulnerable condition in relation to soil erosion and land degradation. Also, the causes of land use and land cover dynamics were analysed in order to understand how anthropogenic activities in the study location drive watershed changes. Based on that, a conceptual linkage of cause and consequence of land use and land cover changes was established. It was found that various informal land use activities such as grazing, sand mining, deforestation, bare ground, and unregulated farming were responsible for the land use and land cover changes. Particularly, sand mining activities caused significant land use and land cover changes as it was observed that marginal and agricultural lands were converted to sand mining lands. It was also observed that there is a social orientation to land use and land cover changes as most of the local population are poor and unemployed and thus, they depend solely on land resources for their livelihood. Consequently, continuous shift from stable to vulnerable land could lead to much more food insecurity in the future. The chapter concluded by recommending a positive land use and land cover practice based on formal land use and soil conservation practices in the watershed.

9.2.2 Conclusion of chapter 5: achieving objective 2

Chapter 4 addressed spatial variation of soil erosion risk map and the key controlling factors driving it. It also addressed scenarios and sensitivity of land cover changes which provided useful insight into future land cover conditions in the watershed. The chapter began by applying RUSLE and MPSIAC modelling to predict soil erosion in the watershed. The models utilised RUSLE and MPSIAC equations and factors to estimate soil loss in the watershed. The RUSLE modelling factors are rainfall erosivity (R), soil erodibility (K), slope length and steepness (LS), cover management (C) and conservation support practice (P); while that of MPSIAC modelling are: geology (X_1), soil (X_2), topography (X_3), climate (X_4), runoff (X_5), land cover (X_6), land use (X_7), surface erosion (X_8), and channel erosion (X_9) and were all derived based on 30-m resolution grid cells. In general, it is very clear from the results of this study that RUSLE and MPSIAC in conjunction with GIS are very powerful models to spatially make quantitative assessments of soil erosion risk for conservation management purpose. Erosion risk map for each factor in both models was produced and the factors were later combined to produce the overall risk maps using the modelling equations. The results from RSULE modelling showed that the range of minimum and maximum values of soil erosion ranged from 8-11 tonnes $ha^{-1}year^{1}$ for low yield areas to 25-36 tonnes $ha^{-1}year^{1}$ for high yield areas respectively, while the mean sediment yield is 21 tonnes $ha^{-1}year^{1}$. The sediment yield classification showed that up to 33% (heavy + severe) of the watershed is vulnerable to erosion, 14% of the watershed is moderate while 53% (very slight + slight) of the watershed is relatively stable. On the other hand, the result from MPSIAC modelling showed that the range of minimum and maximum values of soil erosion ranged from 248-279(m^3 km^{-2} $year^{-1}$) for very slight yield erosion areas to 1118-1399 m^3 km^{-2} $year^{-1}$ for severe yield erosion areas respectively, while the mean sediment yield is 991 m^3 km^{-2} $year^{-1}$. The sediment yield was classified based on the MPSIAC model guideline ranging from very slight (least susceptible area to soil erosion) to severe (the most vulnerable area to soil erosion). It was found that 27% of the watershed is under severe erosion; 8% of the watershed is under heavy erosion; 11.5% of the watershed is under moderate erosion; 36% of the watershed is under slight erosion while 17.5% of the watershed is under very slight erosion. The findings from both models revealed that significant area of the watershed is under erosion and, thus, conservation practices should be applied.

Again, RUSLE scenarios analyses carried out showed that sediment yield increased by 19%, 31%, and 50% across the watershed for the 10%, 20% and 40% increase in the bare ground area; while sediment yield reduced by 19%, 25% and 44% across the watershed for the 10%, 20% and 40% reduction in the bare ground area. Similarly, MPSIAC scenarios analyses carried out showed that sediment yield increased by 25%, 33%, and 46% across the watershed for the 10%, 20% and 40% increase in the bare ground area; while sediment yield reduced by 25%, 30% and 41% across the watershed for the 10%, 20% and 40% reduction in the bare ground area. Based on the findings, applying soil conservation support practice could potentially minimise future soil erosion in the watershed.

Lack of sediment inventory made it impossible for the models to be properly verified but the compared modelling results were close to each other which suggested that the models might have performed well. Also, the Lake Sediment Core Depth (LSCD) and modelling results from other watersheds in Nigeria and Africa were compared with the modelling results and the results were relatively close. However, the spatial variation of erosion risk map showed high erosion risk areas in the watershed which is considered more important in this research than the magnitude of the sediment yield. The chapter concluded by revealing that land cover changes and soil erosion have significantly affected Oguta Lake watershed, especially in the bare ground areas.

9.2.3 Conclusion of chapter 6: achieving objective 3

Chapter 6 addressed objective 3 which was to analyse current environmental regulatory framework for management of soil erosion in Nigeria. The analysis revealed the existence of institutional structures and apparent laws which can be applied to the context of operational environmental management in Nigeria. Various laws such as Land Use Act (1978); the National Policy on Environment Act (1991); Mineral and Mining Act (2007): NSEREA Act (2007) can be considered key regulations relating to environmental protection. While EIA Act (1992) can be applied for proactive environmental risk management before project execution. Based on the analysis from the regulatory perspective various key stakeholders were identifies such as National Environmental Standard Regulations and Enforcement Agency (NESREA); the Federal Ministry of Environment (FME); the Federal Ministry of Land, the Housing and Urban Development (FMLHUD); the Federal Ministry of Agriculture and Rural Development (FMARD); the Federal Ministry of Mines and Mineral Development (FMMMD); the Imo State Ministry of Environment, Agriculture and Natural Resources and the Imo State Ministry of Land, Survey and Urban Planning. The pieces of legislations and statutory interest of the identified stakeholders shaped the policy reforms proposed in Chapter 8.

However, the analysis did find that the current regulatory structure remains incomprehensive and lacks capacity as well. Consequently, the structure contributes to duplication, overlaps and lack of complementary roles, poor policy implementation and enforcement deficit, lack of inter-ministerial cooperation, and conflict of interest among various regulators. These result in poor implementation of laws and ineffective enforcement of environmental laws at the grassroots. The chapter concludes by suggesting some regulatory amendments that could improve performance such as stakeholder collaborations, complementary roles, and engagement of local stakeholders at the operational level in environmental management and sensitisation of local people about environmental laws.

9.2.4 Conclusion of chapter 7: achieving objective 4

Chapter 7 addressed the analyses of physical and social economic impact of soil erosion and sand mining in the study location. The chapter began by analysing remote sensing images, field reconnaissance survey, semi-structured interview data and focus group discussion data collected. A total of fifty-seven (57) infrastructures failures were identified across the watershed using both reconnaissance survey and remote sensing technique. These include: 21 roads and streets, 3 bridges and culverts, 11 residential and commercial buildings, 8 drainage channels and 14 electric poles. Observation revealed that some of these failures did not entirely result from gullies but from poor construction works carried in the watershed. On the other hand, it was found that social issues contributed massively to soil erosion problems in the watershed. The analysis of observation from semi-structured interviews and focus group discussions showed that poverty, unemployment, corruption, lack of incentives, lack of trust, conflict, population growth, and lack of incentives, culture/tradition and poor education contributed massively to soil erosion and environmental degradation in the watershed. This is because most of the local people depend on land and natural resources for their livelihood mainly because of high rate of poverty and unemployment in the study location. Sand mining activity was particularly identified as the greatest threat to soil erosion in watershed and, thus, its effect on the environment was analysed. It was found that sand mining activity threatens environmental sustainability and is linked to the following environmental menace: damages the landscape, reduces the water quality, destroys channel morphology, causes air pollution and affects human health.

Also, from the cost-benefit analysis carried out and it was discovered that, although sand mining business generates employment and revenue for the youths and other stakeholders involved; the negative impact of sand mining activity such as abandoned sand mining sites that have developed into massive gullies could cost much more than the perceived benefit to fix. This is even more worrisome, as further analysis showed that the government that is responsible for fixing erosion problems and environmental problems only gets 7% of the mining revenue while 50% of the revenue goes to the transporters, who may not share the consequences of the mining activity in the watershed. Also, conversion of farmlands to sand mining sites could lead to food insecurity in the future and this will particularly affect the lives of the local people that depend massively on subsistence farming and natural resources for their livelihood. Economically, for a watershed famously known for its tourism potential, continuous sand mining could potentially render it aesthetically unpleasant for tourists to visit, which will affect the economy and the life of the people. The chapter concluded by recommending a regulated sand mining in the watershed according to the Mining and Mineral Act 2007 and EIA Act (1992) to potentially reduce the environmental risks of sand mining.

9.2.5 Conclusion of Chapter 8: achieving objective 5

Chapter 8 addressed objective 5 which was to develop policy reforms based on the review of the existing institutional structure and policies using Institutional Analysis and Development

(IAD) Framework. The analysis started by analysing the following: the biophysical environment, the attributes of the community, the rules-in-use, and the action arenas. Particularly, the decision-making process of land allocation and ownership; sand mining practices and regulations; agricultural practices and regulation were reviewed. The analysis found that the Land Use Act 1978 as recognised by the constitution and the traditional method of land allocation and ownership were responsible for conflict and misuse of land resources in the study location. Particularly, the contradiction that exist between the current land use by the local people and the constitutionally recognised Land Use Act 1978 is the main cause of land misuses, especially converting local lands for unsustainable uses like sand mining. However, a government reform that recognises the powers of traditional leaders in allocation and ownership was proposed and thus, could potentially reduce land misuse and conflict often associated with land allocation and ownership. Also, a government reform that activates the operational responsibilities of local government system through autonomous environmental management and regulation will reduce misuse and corruption among state government officials. The analysis also found that the absence of the Ministry of Mines and Mineral Development at the state level contributes to poor ground monitoring and enforcement deficit of sand mining activities in the watershed. Thus, this work has proposed an alternative arrangement (Introduction of Ministry of Mines and Minerals Development at state level) that empowers the state government to have a shared management responsibility of managing sand mining activity in the watershed. This would potentially eliminate language barrier often encountered by the federal government and encourage inclusive management of sand mining activity by all the stakeholders. Finally, the analysis reviewed agricultural institutions and found that the absence of agricultural organisations at the community level contributes to soil erosion and environmental degradation in the watershed. Particularly, lack of EIA and private NGOs at the community level led to environmental degradation and soil erosion. Thus, a reform that encourages representation of an EIA unit and agricultural organisations at the community level was proposed as it would potentially minimise environmental degradation and soil erosion in the watershed.

9.2.6 Overall conclusion

The physical and social characteristics of soil erosion in Oguta Lake watershed have been extensively assessed and characterised using modelling, remote sensing, reconnaissance survey, lake sediment core, interview techniques and Institutional Analysis and Development (IAD) Framework. It was found that bare ground condition, anthropogenic activities and weak institutions and policies were responsible for high soil erosion rate and environmental degradation in the watershed. Particularly, sand mining caused significant soil erosion in the watershed due to exposed soil surface during sand mining and abandoned sand mining sites. The thesis analysed institutional structures and presented institutional reforms which can be used to minimise soil erosion in the watershed using Institutional Analysis and Development (IAD) Framework.

The main finding of this research is that anthropogenic activities is the main driver of soil erosion in the watershed, and this can be mitigated by appropriate policy reforms.

From the physical perspective, various land use change dynamics were responsible for growing soil erosion menace in the watershed. Particularly, informal land use activities such as sand mining, deforestation, overgrazing contributed significantly to this land use and land cover changes dynamics. Also, conversion of forest and pasture lands to other land uses contributed massively to land use and land over changes.

The modelling results showed that soil erosion is high and covered significant portion of the watershed. However, from the scenario analyses carried out, it was found that bare ground condition caused significant soil erosion in the watershed. Also, the sensitivity analysis carried out showed that bare ground is sensitive to soil erosion in the watershed.

On the other hand, the research showed that the scale of the problems of soil erosion stems from governmental and regulatory level down to the operational and community level management of resources. In particular, it was found that unsustainable environment was largely influenced by lack of clear roles, conflict and lack of capacity, lack of complementary roles, duplication of roles and overlaps of regulatory institutions. This revealed the need to strengthen organisations at the operational level to improve implementation and performance.

From the socio-economic perspective, it was found that soil erosion and sand mining affect a wide range of infrastructures in the watershed. This is caused by both poor civil engineering construction and gully erosion. It was observed that various attributes of local population such as poverty, unemployment, lack of incentives, population growth, culture/traditions, lack of trust, corruption, conflict, and population growth contribute significantly to soil erosion menace in the watershed. The research also revealed that various human and environmental risks such dangerous emissions, destruction of landscape and poor water quality were linked to sand mining activities in the watershed. Sand mining was found to be economically ineffective; even though some local operators earn their living from the business. Particularly, because government representatives receive only 7% while transporters receive 50% of the revenue generated from sand mining.

The research highlighted the need to introduce some policy reforms aimed at improving the management of soil erosion in the watershed. Firstly, the current Land Use Act 1978 should be reformed to encourage input from local stakeholders especially the traditional leaders and the local government as this would bridge the trust gap between the local land users and the top-level government officials. The good relationship that exists between local stakeholders and environmental operators would enhance operational monitoring of environmental activities and compliance among local resources users in the watershed.

Also, the Ministry of Mine and Mineral Development should be replicated at the state level in a complementary fashion to enhance on ground monitoring of sand mining activities in the watershed. This will not only eliminate the language barrier that currently exist between the federal level staff members and the local sand miners but also check corruption that currently exist among the state government officials. One of the greatest challenges in the watershed is compliance monitoring, however, engaging local stakeholders like traditional leaders and women at the bottom level for monitoring of sand mining activities would improve the communication channel up to the entire top interconnected government system. Women are connected to local activities more than their men counterpart, so engaging them in monitoring activities would improve the watershed sustainability.

Finally, EIA and other identified agricultural organisations should be domiciled at the operational level, where soil erosion is dominant to enhance awareness, monitoring, and compliance enforcement.

Overall, the research has successfully assessed and characterised the physical and social aspects of soil erosion in Oguta Lake watershed. The proposed policy reforms need to be applied and implementation by the decision-makers and environmental managers to enhance environmental sustainability. However, the policy reforms may come with some challenges of replicating complementary laws at state and local level knowing that various interests may arise.

9.3 Contribution of research

This research contributes to knowledge in various ways, specifically to the novel approach of physical and social assessments of soil erosion and policy reforms in Oguta Lake watershed

Imo State south east Nigeria. Firstly, the research has provided a pictorial view of various land use and land cover change dynamics in the watershed, which is one of the main drivers of soil erosion in the watershed. In addition, the research identified the causes and suggested possible solutions that could enhance environmental sustainability.

Moreover, the research has produced spatial erosion risk map for the study area, which could be used by the decision–makers and environmental managers for environmental planning and management. The soil erosion map identified high risk areas which would help the decision-makers and managers to make informed management decision on minimising erosion in the watershed. It would also help them to a have an idea of the scale of the problem which would potentially help in planning and budgeting. Also, the future scenarios analysis provided a useful insight into potential future environmental condition of the study area which provides opportunity for proactive management decisions and planning.

From the regulatory perspective, the research explored the soil erosion and environmental regulation and highlighted some of the pitfalls and prospects. This provided a better understanding of the structural and regulatory context of the problems, upon which various policy improvements were recommended. Also, the research revealed various socio-economic problems like poverty, unemployment, poor education, increasing population, lack of incentives that were linked to soil erosion and sand mining in the study area and the anthropogenic factors driving them. This is particularly useful for planning and operational management of the environment and the local people because most of the local people depend on natural and environmental sources for their livelihood.

Finally, in this research, the concept of Institutional Analysis and Development (IAD) Framework was used to propose some policy reforms within the context of land ownership and allocation; sand mining and agricultural practices based on the identified pitfalls in the current institutional structure and policies.

9.4 Direction for future research

The physical and social assessment were deliberately adopted to grasp a holistic and comprehensive understanding of soil erosion characteristics and problems in order to ensure that no major component of the problem is missed out. However, because of the complex nature of soil erosion, data scarcity and time constraints, this research includes some gaps which deserve attention for further research.

Firstly, there is need to analyse, and model identified gullies using head cut dynamic approach. Even though one of the modelling approaches adopted in this research captured gully erosion factor; it failed to analyse the gully head cut rate and profile which are considered essentials for proper understating of gully characteristics. However, a continuation of this research that will explore the gully head cut rates; controls on gully head cut height; and morphology of gully longitudinal profile would give erosion characteristics a refined conclusion.

The research highlighted the need for sediment inventory in the watershed which is very important for model calibration and verification. A further field-based research that will involve sediment collection and measurement will not only close the current model calibration and verification gap in the study location but will also open a window for model development based on the local condition of the watershed.

Finally, the initial plan of this research was to organise a workshop with the stakeholders and disseminate the final output of this research and the proposed policy reforms. This is was not possible because of time and cost constraints associated with this research. With these constraints, the research will now be communicated through the project sponsor, i.e. TET Fund Nigeria. However, a continuation of this research would be to work with the identified stakeholders to deploy the policy reforms proposed. Hopefully, it would provide a more refined conclusion and improve the evidence of its practical application.

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Appendix

Appendix A

Fig A-9(1-8) show various human activities and gully erosion menace in the watershed.

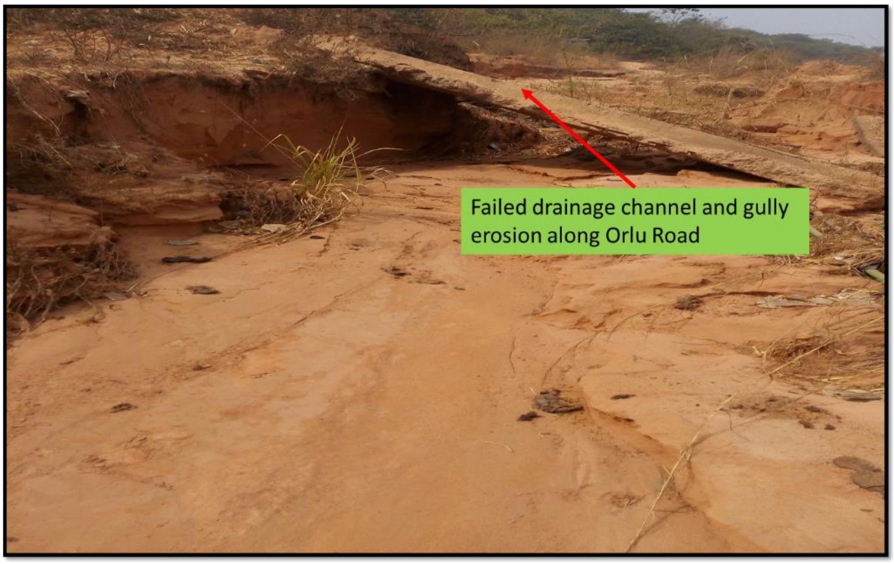

Figure A- 9-1 Failed drainage channel and gully erosion along Orlu Road, Owerri

Source: Author's fieldwork

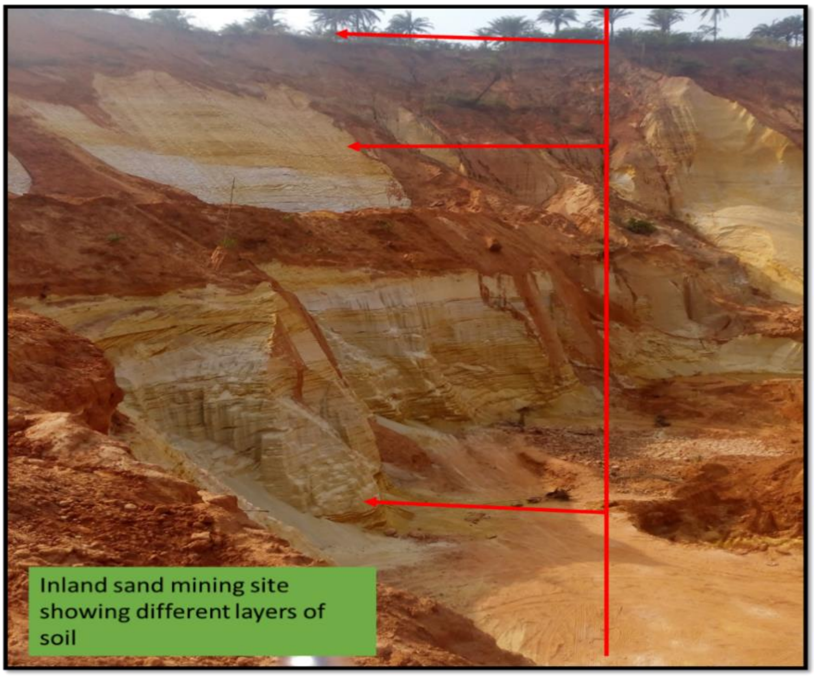

Figure A- 9-2 Inland sand mining site showing different layers of soil and topsoil
Source: Author's fieldwork

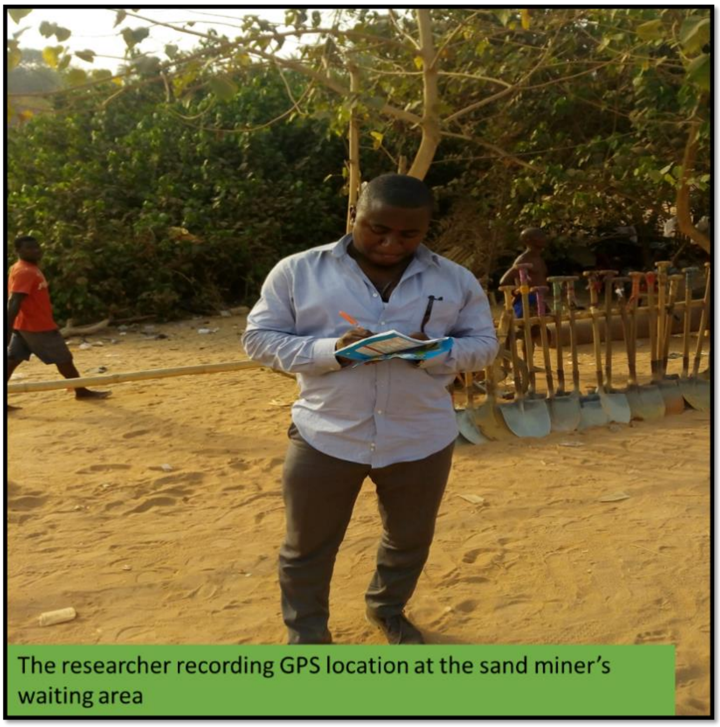

Figure A-9-3The researcher taking records at the sand miner's picking point
Source: Author's fieldwork

Figure A-9-4 Njaba River showing exposed soil banks and gully erosion cracks
Source: Author's fieldwork

Figure A-9-5 Abandoned gully erosion site showing exposed groundwater table. Source: Author's fieldwork

Figure A-9-6 Developing gully erosion at the bank of Njaba River. Source: Author's fieldwork

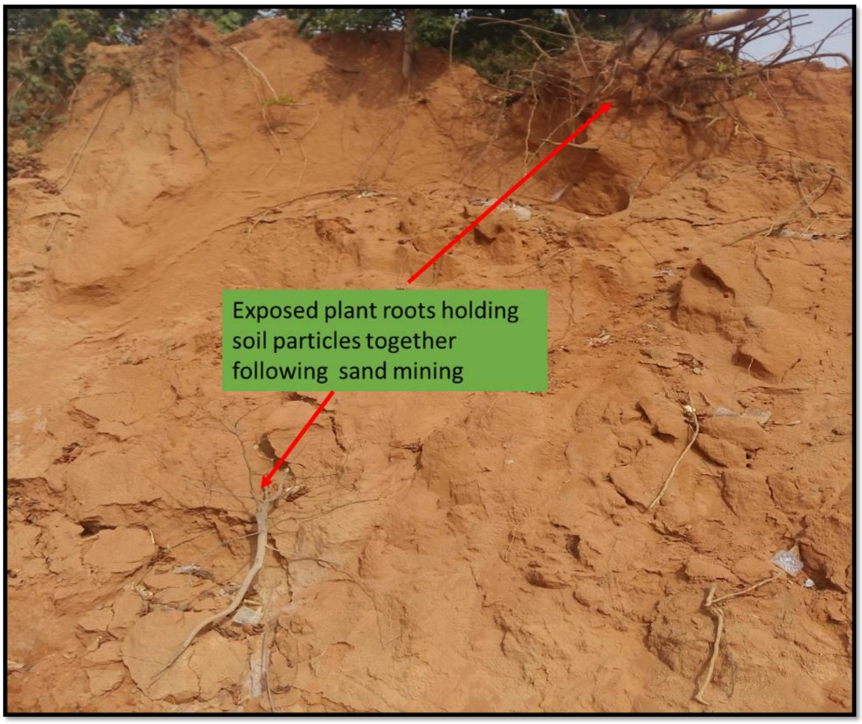

Figure A-9-7 Exposed vegetation root at the sand mining site along Orlu Road, Owerri
Source: Author’s fieldwork

Figure A-9-8 Cracks and gully development along the foot path of Njaba Riverbank
Source: Author’s fieldwork

Appendix B

The reference code for focus group discussions and semi-structured interview participants are as shown in Table B-9-1 and B-9-2 respectively.

Table B-9-1 The reference list for focus group 1(shaded section) and focus group 2 participants

Code	Organisation	Classification	Role
1-FG1	NESRA (M)	Regulator	Field officer
1-TL1	Community leader (M)	Traditional leader	Community leader
1-CM1	Community resident (M)	Household	Community resident
1-CM2	Community resident (F)	Household	Community resident
1-CM3	Community resident (F)	Household	Community resident
1-CM4	Community resident (F)	Household	Community resident
1-SM1	Sand miner (M)	Sand miner	Loader
1-SM2	Sand miner (M)	Sand miner	loader
1-FM1	Farmer (F)	Farmer	Crop farmer
1-FM2	Farmer (F)	Farmer	Crop farmer
1-FM4	Farmer (M)	Farmer	Livestock Famer
2-FG1	Federal Ministry of Environment (M)	Regulator	Field manager
2-FG2	Federal Ministry of Agriculture (F)	Regulator	Secretary
2-SG1	State Ministry of Lands (M)	Regulator	Manager
2-SG2	State Ministry of Lands (M)	Regulator	Field Engineer
2-TM1	Trade union (M)	Trade union	Chairman
2-FM1	Farmer (F)	Farmer	Crop farmer

TableB-9-2The reference list for semi–structured interview participants

Code	Organisation	Classification	Role
INT1	Sand miner (M)	Sand miner	Loader
INT2	Sand miner (M)	Sand miner	Loader
INT3	Sand miner (M)	Sand miner	Loader
INT4	Sand miner (M)	Sand miner	Union member
INT5	Sand miner (M)	Sand miner	Union member
INT6	Sand miner (M)	Sand miner	Union member
INT7	Sand miner (M)	Sand miner	Driver
INT8	Sand miner (M)	Sand miner	Driver
INT9	Sand miner (M)	Sand miner	Site owner
INT10	Sand miner (M)	Sand miner	Site owner
INT11	Sand miner (M)	Sand miner	Site owner
INT12	Sand miner (M)	Sand miner	Driver
INT13	NEREA (M)	Regulator	State coordinator
INT14	Community resident (F)	Household	Community resident
INT15	Community resident (M)	Household	Community resident
INT16	Community resident (F)	Household	Community resident
INT17	Community resident (F)	Household	Community resident
INT18	Community resident (F)	Household	Community resident
INT19	Community resident (F)	Household	Community resident
INT20	Community resident (F)	Household	Community resident
INT21	Community resident (F)	Household	Community resident
INT22	Local government (F)	Regulator	Secretary
INT23	Local government (M)	Regulator	Supervisor
INT24	Local government (M)	Regulator	Supervisor
INT25	Local government (M)	Regulator	Chairman
INT26	State Ministry of Works (F)	Regulator	Secretary
INT27	State Ministry of Works (M)	Regulator	Field Engineer
INT28	State Ministry of Environment (M)	Regulator	Deputy director
INT29	State Ministry of Environment (M)	Regulator	Field Engineer
INT30	State Ministry of Environment (M)	Regulator	Head of Department
INT31	Community leader (M)	Traditional leader	Community leader
INT32	Community leader (M)	Traditional leader	Community leader
INT33	Community leader (M)	Traditional leader	Community leader
INT34	Community leader (M)	Traditional leader	Community leader
INT35	NEWMAP (F)	Operator	Operation manager
INT36	Farmer (F)	Farmer	Crop farmer
INT37	Farmer (F)	Farmer	Union member
INT38	Farmer (M)	Farmer	Union leader
INT39	Farmer (F)	Farmer	Crop farmer
INT40	Farmer (F)	Farmer	Crop farmer
INT41	Farmer (F)	Farmer	Livestock farmer
INT42	Farmer (F)	Farmer	Livestock farmer
INT43	Farmer (F)	Farmer	Livestock farmer
INT44	Farmer (M)	Farmer	Union member

Template for interviews

Interviews were conducted with an interview template which served as a guide to the subject matter.

The interview questions were based on: who manages soil erosion, who is affected by soil erosion and who causes? Further questions were asked about awareness of soil erosion and the history of land use land cover changes in the watershed.

The template for environmental managers and regulator.

Management understanding: Time target 30-45mins.

The aim of this interview is to obtain insight about management of soil erosion and environment in the study location. The questions about erosion management were asked and their corresponding consequences.

List of initial questions

Introduction and research aim. Explanation on how this interview is of importance to the research.

- Tell me about your department, position and how it fits into the general structure of the organisation.
- How do you carry out your functions?
- Soil erosion has been a very big problem in Nigeria especially in the south east zone. Some of these issues are as a result of poor environmental management. What is your experience about lapses in management of soil erosion in the study location?
- What are the corresponding consequences of poor management of the environment especially soil erosion?
- What are you doing about poor awareness of soil erosion and its menace by the local environmental operators?
- What do you think of land degradation extent in Oguta Lake watershed?
- What are your plans on reducing land misuse and soil degradation by the local environmental operators?
- Based on the consequences, it is clear that your organisation's objectives are not being achieved. What is the cause and how are going to deal with the problem?
- What are the management and technical challenges that face dealing with soil erosion problem?
- In terms of policy structure, do you think that your policies are robust enough to deal with operational environmental challenges and land misuse?
- What do think could be changed to improve environmental sustainability in Oguta Lake watershed.

The template for environmental operators, traditional leaders and local residents

Soil erosion awareness and its consequences: Time target 15-30mins.

The aim of this interview is to obtain insight on soil erosion awareness, causes, consequences and possible remediation strategies in the study location. The questions about how human activities drive soil erosion and their corresponding consequences were further asked.

List of initial questions

Introduction and research aim. Explanation on how this interview is of importance to the research.

- Tell me about yourself, what do you do for a living?
- Are you aware of soil erosion in this community?
- What do you think are the main causes?
- Do you know when it started?
- What is government doing to stop it?
- Do you think they are doing enough to stop it?
- What do you think they should do?
- In your capacity, what are you doing to stop it?
- Are you aware that your work could cause erosion?
- If yes, how do you manage it to minimise its impact
- Is there anything the community is doing apart from government trying to minimise soil erosion in this community?
- Do you think community is doing enough to minimise soil erosion?
- Do you have any worries about soil erosion in this community?
- What else do you want government to do apart from what they have done before?
- Do you think government is cooperating with the demand of the local people?