ADDIS ABABA UNIVERSITY

COLLEGE OF NATURAL AND COMPUTATIONAL SCIENCES

CENTRE FOR ENVIRONMENTAL SCIENCE

EFFECT OF LAND USE LAND COVER CHANGES ON SOIL EROSION AND SOIL PHYSICO-CHEMICAL PROPERTIES IN UPPER EYIOHIA RIVER WATERSHED, NIGERIA

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A THESIS SUBMITTED TO CENTRE FOR ENVIRONMENTAL SCIENCE IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN ENVIRONMENTAL SCIENCE

JUNE, 2018

ADDIS ABABA, ETHIOPIA

ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

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Effect of Land Use Land Cover Changes on Soil Erosion and Soil Physico-Chemical Properties in Upper Eyiohia River Watershed in Nigeria

By

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A Thesis Presented to the Graduate Programs of the Addis Ababa University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Environmental Science

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June, 2018

ACKNOWLEDGEMENTS

My profound gratitude goes to my advisor Dr Eyasu Elias for his sustained tireless support, guidance and motivation throughout the research period. Sincerely, I remain greatly indebted to INTRA-ACP AFIMEGQ project funded by European Union (EU) for their inestimable kind gesture for providing technical, administrative and financial support for my study .To my family (Ota's family), I acknowledge their invaluable support in all ways throughout the study. I particularly thank my parents for cheering me on to the finishing line. It is not possible to exhaustively mention each one of those that played instrumental role in seeing this work get to this level. I want to appreciate all the staff in soil science and environmental laboratory, Abakaliki for their unwavering support in soil data analysis. My appreciation is also extended to Okafor Henry in NIMET for his assistance in getting rainfall data.

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CAS	College of Agricultural Science
ERDAS	Earth Resources Data Analysis System
FAO	Food and Agricultural Organization
GIS	Geographic Information System
GPS	Global Positioning System
Ha	Hectare
IPCC	Inter Governmental Panel on Climate Change
IUSS	International Union of Soil Science
Km	Kilometer
LULCC	Land Use Land Cover Change
NGOs	Non Governmental Organization
NIMET	Nigeria Meteorological Agency
NPC	National Population Commission
RUSLE	Revised Universal Soil Loss Equation
SOC	Soil Organic Carbon
t/ha/yr	ton per hectare per year
UNEP	United Nation Environmental Program
USDA-ARS	United States Department of Agriculture-Agricultural Research Service
USLE	Universal Soil Loss Equation
UTM	Universal Transverse Mercator
WRB	World Reference Base

ABSTRACT

Effect of Land use Land Cover Changes on Soil Erosion Losses and Soil Physico-Chemical Properties in Upper Eyiohia River Watershed**,** Nigeria

Ota Henry Obiahu

Addis Ababa University, 2018

The study was conducted to assess and estimate the impact of land use land cover changes on soil erosion losses and physicochemical properties in the upper Eyiohia river watershed in Nigeria. The Revised Universal Soil Loss Equation (RUSLE) parameters were integrated with satellite remote sensing and geographical information systems (GIS) as a useful tool to determine the extent and mean annual soil losses. Land Use Land Cover Change within the study period (1996 and 2016) indicates that cultivated land increase by 3400 ha, settlement by 2300 ha, bare land by 2600 and grazing land 300 ha while forest has significantly declined by area coverage of 8600 ha. The change is brought about by land conversion from forest to farmlands and growing demand for food from ever increasing population substantiated from survey questionnaire administered to 100 respondents. Results shows that the mean soil loss in 2016 was higher in cultivated land 48.34 $t\ ha^{-1}\ y^{-1}$ *followed by forest (36.92* $t\ ha^{-1}\ y^{-1}$*), bare land (19.40* $t\ ha^{-1}\ y^{-1}$*), settlement (8.02* $t\ ha^{-1}\ y^{-1}$*), and grazing land (14.48* $t\ ha^{-1}\ y^{-1}$*). Soil with erosion severity classes of high, very high, severe and very severe jointly accounted for 96% of the total soil loss of the entire Eyiohia watershed covering 83% of the total area while the remaining 4% is under low ris categories. Result on Selected physicochemical properties as affected by different Land use type indicate that BD, TP, AWC, FC, Mn and Zn were significantly different* $p<0.05$ *between land use types as a result of different management/conservation practices on each land use type linked mainly to land use land cover change over time, others includes population pressure and shortage of cultivable land. Stratified questionnaire on local perception of observed causes of soil erosion indicates that land use land cover change and population pressure were mentioned by 47% and 31% of the respondents respectively with the majority of which are located in the lower stream sub-watershed*

Keywords: *GIS, LULCC, Soil Erosion, Soil Physico-Chemical Properties*

1. INTRODUCTION

1.1.Background of the Study

Soil erosion in the South-eastern part of Nigeria has been identified as the most threatened environmental hazards in the country. Secondary data on the study area traced its origin to some 30 years ago when development began to creep into the region, following Nigeria's oil boom of the 1970s (Albert *et al.,* 2006). Soil erosion represents the detachment and transport of soil particles from top soil layers, resulting in degrading soil quality and reducing land productivity. Soil erosion remains the world's biggest environmental problem, threatening sustainability of both plant and animal in the world. Over 65 percent of the soil on earth is said to have displayed degradation phenomena as a result of soil erosion, salinity and desertification (Okin, 2002)

Land use and land cover changes pose significant economic and environmental risks worldwide. According to Turner *et al*. (1995), most of the earth's surface is already modified, except those areas that are peripheral in location or are fairly inaccessible. Land use change in Africa accounts a conversion of 75 million hectares of forest to agriculture and pasture between the years 1990 and 2010 (FAO, 2010). More importantly, in West Africa, nearly 13 million hectares of original forest were lost over the same 30 year period and the remaining forest is fragmented and continued to be under threat (FAO, 2010).

At different spatial and time scales, vegetation cover helps in protecting the soil from harsh climatic conditions mostly soil erosion. The presence of dense vegetation affords the soil adequate cover thereby reducing the loss in macro and micro nutrients that are essential for plants growth and energy fluxes. However, the continuous conversion of vegetal areas to non-vegetal surfaces reduces soil productivity as a result of increased soil erosion and changes in moisture content. Indeed, the concentration of nutrient in the soil is depleted when vegetation is destroyed through numerous anthropogenic activities such as deforestation and land preparation for agricultural production, and road construction among others (Elliot, 2003; Thornley and Cannel, 2000).

The change in forest cover to other forms of land cover such as plantation and grassland results in the tremendous modification of canopy cover, thereby making the area affected susceptible to soil erosion; this affects the stock of soil organic carbon (SOC). The conversion of forest ecosystem to other forms of land cover may decrease the stock of SOC due to changes in soil moisture and temperature regimes, and succession of plant species with differences in quantity and quality of biomass returned to the soil.

Besides, soil erosion is accelerated by human activities and this has become a serious environmental problem. Although there are many factors that influence soil erosion, plant cover and land use have been considered as the most important factors affecting on the intensity of soil erosion (Leh *et al.*, 2011). Land use change has a manifold environmental impact by negatively affecting water supply, reservoir storage capacity, agricultural productivity and fresh-water ecology of the region (Arabinda *et al.*, 2010).

Modeling soil erosion provides a sophisticated tool for selection of appropriate soil conservation practices and estimating the rate of spatial soil erosion loss and identifying best management practice and land uses land cover change of the watershed, best supporting practices which this study focuses on, goes a long way to arrest, address and reduce the rate of off-site and on-site impact. There are many soil erosion models and among them, the Universal Soil Loss Equation (USLE) is the most widely known and used empirical soil loss model all over the world (Wischmeier and Smith, 1965, 1978). Later in the 1980's the United States Department of

Agriculture-Agricultural Research Service (USDA-ARS) modified the model to the Revised Universal Soil Loss Equation (RUSLE), which was an improved version of universal soil loss equation (USLE) incorporating new approaches and corrections of the USLE limitations.

1.2 General Objective of the Study

The general objective of this study was to assess and estimate the impact of land use land cover changes on soil erosion and physicochemical properties in the upper Eyiohia river watershed in Nigeria.

1.3 Specific Objectives

1. To quantify the land use land cover changes over three decades (1996, 2006 and 2016) as proximate causal factor of soil erosion loss

2. To estimate soil erosion rates under different land use practices

3. To examine the effect of LULCC on soil erosion and selected soil physicochemical properties

1.4 Research Question

1. How did the patterns of land use land cover changed in the upper Eyiohia sub-watershed over the past 20 years (1996-2016)?

2. How does land use and land cover change affects soil erosion rates and soil physico-chemical properties

3. Which land use types mostly affect soil erosion rates and physicochemical properties of the soil? And what are the management changes needed to address these problems?

1.5 Statement of Problem

In Nigeria, the population dramatically rose from 116million in 1991 to 140million in 2006 (NPC, 2006). A major challenge in environmental research is to understand and describe the effects of land use change on the socio-economic structures and the environment (Vitousek, 1994). Given that the land use land cover are expected to change because of human activities in the future (IPCC, 2007), it is important to examine the potential effects of these changes on soil erosion potential and physiochemical properties of the soil at a watershed scale.

According to Leh *et al*. (2011), soil erosion is directly affected by land use change, which is generally taken as proximate cause of land degradation. Therefore, modelling of land use change is important with respect to the estimation of soil erosion and degradation. All these studies have identified a strong influence of land use land cover changes on soil erosion and sediment transport rates. The expansion of agricultural land in the upper Eyiohia river watershed of southeast Nigeria to support the rapid increase of the population has resulted in the degradation of forest and soil resources. This affects the ecological balance of the watershed system. The mountainous nature of the study area is covered with fragmented natural and manmade forests, whereby number of small and medium streams originates. Land use land cover detection is therefore necessary for the assessment of potential environmental impacts and developing effective land management and planning strategies.

The study is set out to find out the extent of land use/land cover changes over the past twenty years (1996-2016) and check its contribution to soil loss and change in physicochemical properties of the soil in the region. Such an understanding has a number of benefits, including the development of appropriate mitigation strategies to restore soil productivity, thereby alleviate the recurrent poverty in the region.

In Afikpo North Local Government Area of Ebonyi State, just like in other parts of Nigeria, change in land use cover is an emerging phenomenon as a result of the state government's drive to making the state the ideal tourism destination in Nigeria, trees are felled from the watershed that makes way for grasses, such a practice could be ecologically unwise in terms of its ability to suppress soil erosion. A conservative assessment in the study area shows the distribution of known soil erosion sites in different stages of development to be 700 (Igbokwe *et al*., 2003; Egboka, 2004), the statistics are not exhaustive enough as new sites are developing during each rainy season due to forest clearing and various soil management practices in the study area

The population of Afikpo is estimated at 672,000, according to the Nigerian 2006 Census (NPC, 2006), in the study area, the impacts of land use land cover change on environmental resources has been rarely performed which makes this study pertinent and timely as the people are predominantly farmers producing rice, cassava, yam, vegetables, palm oil, cocoyam, etc. They are also fishermen, hunters and a good number of them deal on timbers. Besides, the natural resource potential of Afikpo North, Ebonyi state requires site-specific and judicious natural resource conservation and management planning.

The fact remains that much of the land and its resources of upper Eyiohia River sub-watershed are located in undulating and rugged landscapes under fragile ecosystem which are consequently susceptible to various forms of natural resource degradations. Inappropriate land management practices made the upper Eyiohia River catchment vulnerable to soil erosion, which has negatively impacted the watershed health and the livelihood of local inhabitants. Therefore, it is important to understand the functioning of this sensitive catchment and its soil erosion response under different land use and land cover change conditions since there is no record of soil control measure in the area over many decades.

1.6 Justification of the Study

Today, the rate of soil erosion exceeds the rate of soil formation over wide areas resulting in the degradation and loss of soil. The findings of the study will help different stakeholders such as the Ebonyi state ministry of agricultural officials, experts, communities and development agents to design strategies, investment programs and projects that could bring positive synergies to restore land productivity, enhance food security and avert the vicious cycle of poverty and natural resource degradation by indicating key priority areas for conservation in the area. Furthermore, the analysis will contributes to the general knowledge on the impacts of land use and land cover changes on soil erosion potential within the upper Eyiohia River watershed local inhabitants.

This is essential for the long term progress because of the scarcity of secondary data at the farm and household level to address the problems of LULC change on natural resources. It is, therefore, imperative to analyze R, K, C, LS and P factors with respect to the Afikpo North setting, since the physical conditions in Afikpo North, Nigeria such as topography, weather, vegetation and soil types are very much different from other neighbouring states. Therefore, modelling of spatial soil erosion in the study area will subsequently reduces sediment yield discharged to the lower river.

Few attempts have been made to assess the extent and severity of soil erosion and erodibility potential in the study area and tackle the problem at a broader scale have proved abortive due to the undulating and severe nature of the terrain, lack and unavailability of research data in the upper Eyiohia River watershed. The research is proposed at addressing the incessant clashes between herdsmen and farmer for continued struggle for greener pasture as a result of soil fertility decline and land use land cover change, it will also help to propose and recommend mitigation measures to combat the negative impacts of gradient and land use and land cover change on soil loss and physicochemical properties of the soil. These are the gaps and more that the study intends to fill.

2. REVIEW OF LITERATURE

2.1 Land Use Land Cover Change and the Links

The alteration of the earth‘s land surface due to human action is unprecedented (Lambin *et al.*, 2003). Changes in land use and land cover are among the most important processes for the understanding of the pace, magnitude and spatial reach of changes of the earth's surface and immediate sub-surface as a result of human impact (Meyer and Turner, 1994). Before discussing the relationship of land use and land cover, causes and consequences, it would be better to define the four terms that are central in the context of this thesis to establish a common consensus of the terminologies used. According to IGBP (1997), land cover is also defined as ―the physical characteristic of earth‘s surface, captured in the distribution of vegetation, water, desert, ice and other physical features of the land, including hose created solely by human activities such as mine exposures and settlement‖.

Land use refers to the purposes for which humans exploit the land and its resources (Turner *et al.*, 1995). Land use is the intended employment of management strategy placed on land cover type by human agents or land managers. Forest, a land cover, may be used for selective logging, for resource harvesting, such as rubber tapping, or for recreation and tourism. Shifts in intent and/or management constitute land-use changes (IGBP, 1997).

Land use change is defined to be any physical, biological or chemical change attributable to management, which may include conversion of grazing to cropping, change in fertilizer use, drainage improvements, installation and use of irrigation, plantations, building farm dams, pollution and land degradation, vegetation removal, changed fire regime, spread of weeds and exotic species and conversion to non-agricultural uses.

Land use change is the proximate cause of land cover change. The driving forces to this activity could be economic, technological, demographic, scenic and/or other factors (Turner *et al*., 1995). Hence, Land Use and Land Cover dynamics is a result of complex interactions between several biophysical and socio-economic conditions which may occur at various temporal and spatial scales.

Land use and land cover change (LULC) is commonly grouped into two broad categories: conversion and modification (Meyer and Turner, 1994). Conversion refers to a change from one cover or use category to another (e.g. from forest to grassland). These changes in land use and land cover systems have important environmental consequences through their impacts on soil and water, biodiversity and microclimate (Lambin *et al*., 2003).

2.2 Causes of Land Use Land Cover Change

The exact factors that drive land use and land cover changes in a given area are not perfectly itemized (Meyer and Turner, 1994), however, land use and land cover is never static and it constantly changes in response to the dynamic interaction between underlying drivers and proximate causes. Proximate (direct) causes are immediate actions of local people in order to fulfill their needs from the use of the land. These causes include agricultural expansion, wood extraction, infrastructure expansion and others that change the physical state of land cover. At the proximate level, land-use and land-cover change may be explained by multiple factors rather than a single variable (Geist and Lambin, 2002). Underlying driving forces, i.e. including demographic pressure, economic status, technological and institutional factors, influence land cover/use in combination rather than as single causations (Turner and Meyer, 1994). The sources of underlying causes are at regional and national levels such as districts, provinces, or countries. Underlying causes are often external and beyond the control of local communities.

2.3 Soil property Variation along a Toposequence

Any variations in the geomorphic and hydrologic processes in soils as an integral part of land surface influence the pedogenic processes and soil properties through their effect on differential distribution of water, sediments and dissolve materials (Brunner *et al*., 2004). Soil properties on a toposequence differ due to degree of detachment, transportation and deposition of soil materials. Understanding soil properties and their variation is important for their sustainable utilization and proper management.

The concept of toposequence, which involves processes that cause properties differentiation along hillslopes and among soil horizons have improved evaluating the interaction of pedogenic and geomorphic processes (Gessler *et al*., 2000).

Gessler *et al*. (2000) found that variations of some soil properties could be related to the slope steepness, length, curvature and the relative location within a toposequence. Both studies suggest that the assessment of the hill slope sequence helps to understand variations of soil properties in order to establish relationships among specific topographic positions and soil properties. Asadi et al. (2012) found that the integrated effect of topography and land use determined soil properties. Topography is a relevant factor controlling soil erosion processes through the redistribution of soil particles and soil organic matter (Cerdà and García Fayos, 1997).

2.4 Soil Erosion and its Causes

Erosion as it affects man and its environment is natural and as old as the earth itself (OMAFRA Staff, 2003). It is seen as the gradual washing away of soil through the agents of denudation which include, wind, water and man (Abegunde el al, 2003). These denudating agents loose, wear away, dislodge, transport and deposit wear off soil particles and nutrients in another location.

The process of soil erosion could be slow and continues unnoticed, or it may occur at an alarming rate causing serious loss of top soil. Relevant to this work as it affects the study area is soil erosion by water. Under soil erosion by water, its classification depends on its level and degree of formation. This classification includes sheet, rill, gully erosion and channel stream.

Anthropogenic activities involving deforestation, overgrazing, intensive cultivation, soil mismanagement, cultivation of steep slopes, and urbanization accelerate the soil erosion hazard. Land use and management, topography, climate, and social, economic, and political conditions influence soil erosion. In developing countries, soil erosion is directly linked to poverty level. Resource-poor farmers lack means to establish conservation practices. Subsistence agriculture forces farmers to use extractive practices on small size farm (0.5–2 ha) year after year for food production, delaying or completely excluding the adoption of conservation practices that reduce soil erosion risks (Lal, 2007). The leading three causes of accelerated soil erosion are: deforestation, overgrazing, and mismanagement of cultivated soils. About 35% of soil erosion is attributed to overgrazing, 30% to deforestation, and 28% to excessive cultivation (FAO, 1996)

2.4.1 Deforestation /land Cover Change

Forests provide essential ecosystem services such as soil erosion control, ecosystem stabilization, and moderation of climate and energy fluxes. Forests also provide wood, food, medicines, and many other wood-based products. Excessive logging and clear-cutting, expansion of agriculture to marginal lands, frequent fires, construction of roads and highways, and urbanization are the main causes of denudation for example in Brazil alone, annually about 2.3 Mha of forest were removed between 1990 and 2000 (GEO, 2006). About 15 Mha $year^{-1}$ of forest are cleared annually worldwide and the rate of soil erosion is projected to accelerate with increase in deforestation (UNEP, 1997). Forests are disappearing more rapidly in developing than in developed countries (UN, 2005). Selective logging and shifting cultivation represent another 15 million ha (million ton of hectare) of forest year-1. About half of the deforested areas are left bare. Runoff and soil erosion rates are high from deforested areas. Deforestation removes the protective vegetal cover and accelerates soil erosion. In sloping lands, clearing of forest for agriculture can increase soil erosion by 5- to 20-fold (Benito *et al*., 2003).

2.4.2 Loss of Vegetation Cover

Herds of cattle and sheep are often concentrated on the same piece of land for too long in many livestock farms thus resulting in overgrazing and repeated trampling or crushing, and soil displacement during traffic. Removing or thinning of grass reduces the protective cover and increases soil erosion particularly on steep slopes or hillsides. Overgrazing reduces soil organic matter content, degrades soil structure, and accelerates water and wind erosion. Trampling by cattle causes soil compaction, reduces root proliferation and growth, and decreases water infiltration rate and drainage.

2.4.3 Mismanagement of Cultivated lands

Expansion of agriculture to sloping, shallow, and marginal lands is a common cause of soil erosion. Intensive agriculture and ploughing, wheel traffic, shifting cultivation, indiscriminate chemical input, irrigation with low quality water, and absence of vegetative cover degrade soils. Removal of crop residues for fodder and bio fuel and industrial uses reduces the amount of protective cover left on the soil surface below the level adequate to protect the soil against erosion. Intensive cultivation accelerates water runoff and exacerbates soil erosion, which transport nutrients and pesticides off-site, declining soil and water quality

2.4.4 Rainfall Intensity and Runoff

Both rainfall and runoff factors must be considered in assessing a water erosion problem. The impact of raindrops on the soil surface can break down soil aggregates and disperse the aggregate material. Lighter aggregate materials such as very fine sand, silt, clay and organic matter can be easily removed by the raindrop splash and runoff water; greater raindrop energy or runoff amounts might be required to move the larger sand and gravel particles.

2.4.5 Soil Erodibility Potential

Soil erodibility is an estimate of the ability of soils to resist erosion, based on the physical characteristics of each soil. Generally, soils with faster infiltration rates, higher levels of organic matter and improved soil structure have a greater resistance to erosion. Sand, sandy loam and loam-textured soils tend to be less erodible than silt, very fine sand, and certain clay textured soils. Soil in the study area is made of fine red sand. This makes it more vulnerable to erosion during run offs. Past erosion has an effect on a soil's erodibility for a number of reasons. Many exposed subsurface soils on eroded sites tend to be more erodible than the original soils were, because of their poorer structure and lower organic matter.

2.4.6 Slope Gradient and Length

Naturally, the steeper the slope of a field, the greater the amount of soil loss from erosion by water. Soil erosion by water also increases as the slope length increases due to the greater accumulation of runoff. Consolidation of small fields into larger ones often results in longer slope lengths with increased erosion potential, due to increased velocity of water which permits a greater degree of scouring (carrying capacity for sediment). The study area is dissected with many rivers and streams due to the undulating nature of the land. There are hills, plateaux, pene-planes and valleys, which give way to these rivers and streams that flow down the slopes in the study area. Some of these served as tributaries and distributaries to river Niger that pass the area before emptied into the Atlantic Ocean

2.5 GIS and Modeling Soil Erosion

GIS software capabilities are useful in themselves, but they become much more important when they are combined into various kinds of other analytical models. These include resource allocation, population forecasting and spatial distribution, land-use forecasting, transportation, and site selection models (Dangermond, 1992).

Modeling in a GIS environment refers to creation of a digital database that can interact with a mathematical model. For example in a GIS environment, planners can correlate land cover and topographic data with a variety of environmental parameters relating to such indicators as surface runoff, drainage basin area, and terrain configuration. Computer-based information can also be used to refine such models as the USLE. The result is reasonable predictions of agricultural pollutant loads and the potential transport of nonpoint source pollutants based on watershed parameters, such assoil, slope, vegetative cover, and area (Walsh, 1983).

Remote sensing data have been one of the most important data sources for studies of land cover spatial and temporal changes. In fact, multi temporal remote sensing datasets, processed and elaborated, allow to map and identify landscape changes, giving an effective effort to sustainable landscape planning and management (Dewan and yamaguchi, 2009).

Following image classification as part of the change detection process, accuracy needs to be assessed to evaluate the degree of acceptability of the classification process. A standard accuracy assessment procedure for baseline land cover products involves the use of the error matrix and the standard procedure for one-point-in-time land cover products can be extremely difficult to apply to multi-temporal change analysis products (U.S EPA, 1999).

2.6 Soil Erosion in South-Eastern Nigeria

More than 1,000 erosion sites exist in Southeastern Nigeria with Anambra State being the worst hit as a result of the topography and the nature of soil in the area and intense forest conversion to agriculture. There are more than700 erosion sites in Anambra state alone (Ofomata, 1984). The worst hit sites are found in Agulu, Nanka, Alor, Nnewi, Ideani Oraukwu, Oko Nkpor, Ekwulobia/ Oko, Alo, Uke, Ojokoto/Oba and parts of Udi, Enugu and Ukehe in Anambra State. Other catastrophic gullies occur at Amucha, Isuikwuato, Ohafia, Abriba and Arochukwu in Imo State, Umuchiani in Ikwulobia in Anambra State,and few settlements in Uyo and Calabar in Cross River State.

During the Oil Boom era in Nigeria in the early 1970s, people excavated soil for constructions and with time, the sites became channels for run-off rain waters that produced deep and wide canals. In other words, some of the gullies have existed for more than 50 years and new ones are springing up daily. Similar cases have been recorded in other parts of the world, although some had been brought under control (Owens et al, 2000). The then development activity had since constituted a major ecological problem in parts of South-eastern Nigeria. Dugout pits, created from soil excavation activities, have produced deep craters and gullies due to perennial erosion from torrential tropical rain. The situation of erosion is particularly pronounced in the ecologically vulnerable areas of south-eastern Nigeria where population densities and least land per capita ranks among the highest in rural Africa, (Onu, 2006). The menace of soil erosion especially gully in no doubt represents a major ecological challenge facing most states in Nigeria especially Anambra, Imo, Ebonyi, Abia and other states in the humid tropical regions of southern Nigeria, (Ume *et al*., 2014).

The development of gullies causes the loss of a great amount of soil and can be considered as one of the principal causes of geo-environmental degradation in the South-eastern Nigeria. Researches previously conducted in Imo, Ebonyi, Abia and Anambra States show that gully incidences generate between 4.2 and 10 m 3/ha/year of sediments, which constitute about 45–90 % of total sediment production on agricultural lands (Ogbonna and Ijioma, 2010).

Soils of the south-eastern Nigeria have high soil erodibility potential and are classed as structurally unstable, (Idowu and Oluwatosin, 2008), therefore erosion forms a major type of soil degradation in the area. In south-eastern Nigeria the soils are naturally prone to erosion due to their fragile nature and ease of leaching being mainly ultisols and alfisols, (Oguike and Mbagwu, 2009). Both physical, socioeconomic and anthropogenic factors as well as deficient agricultural production practices are believed to have aggravated and exacerbated the erodibility of the soils in the region. Construction of roads and building also impact soil erosion in human society. This is clearly seen in South-eastern Nigeria and Wisconsin, United States of America among others (Ofomata, 1984; Owens, 2000).

Table 1 Distribution of Erosion sites in Southeastern Nigeria

States	No. of Gullies	Condition	Control Measures
Anambra	700	Mostly active	Not successful
Abia	300	Some active	Not successful
Ebonyi	250	minor gully sites	No records
Enugu	600	Some active	None
Imo	450	Some active	Not successful

Source: Igbokwe *et al*., 2003; Egboka, 2004

3. MATERIALS AND METHODS

3.1 Description of Study Area

3.1.1 Location

Upper Eyiohia river watershed lies between longitude 7°5'1"E and 8°0'0"E and latitudes 5°5'5"N and 6°0'0"N within the Afikpo syncline of the Cross River basin of the Benue Trough (figure 1). The watershed occupies an area of 54,200 ha (542 km^2) and made up of 35 communities. Afikpo is a hilly area despite occupying a region low in altitude, which rises 106.68m above sea level (Whiteman, 1982).

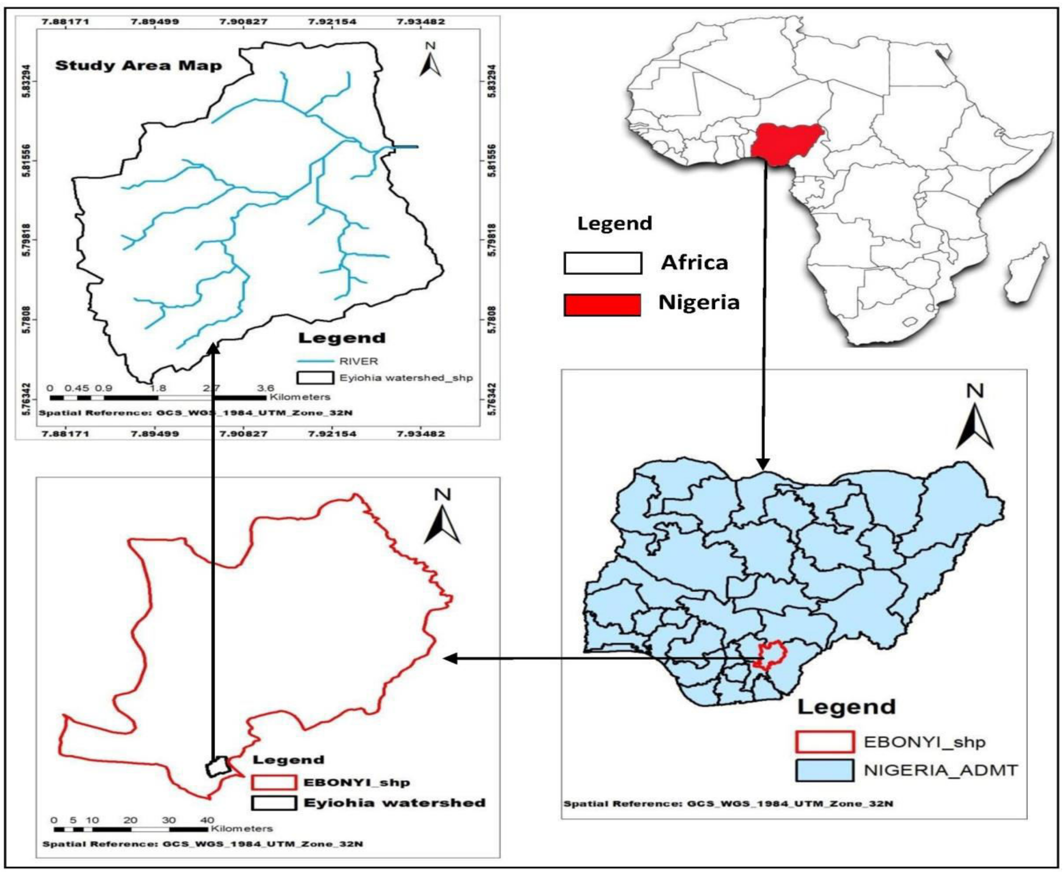

Figure 1 Map of Eyiohia river watershed in Afikpo Ebonyi State

3.1.2 Geology, Soil and Climate

The study area consists of highly undulating sandstone ridges and shale low lands, trending in a NE-SW direction (Ukaegbu and Akpabio, 2009). The geology of northeast of Afikpo basin consists of two major lithostratigraphic units , namely, the sandstone ridges and low-lying shales, each of which forms significant component of the Middle Albian Asu River Group and Turonian Ezeaku. The area is also marked by two significant angular unconformities; one inter formational between the Asu River Group and Ezeaku Formation, and the other intraformational within the Ezeaku Formation (Ukaegbu and Akpabio, 2009). The soil belongs to two dormant soil groups Nitosols (NT) and Gleysols (GL) (IUSS WRB, 2014). The mean annual rainfall in the area ranges between 1200 -2022 mm and the minimum and maximum temperatures are 25.0°C and 27.2°C, respectively. Relative humidity is 80% during the rainy season but declines to 60% in the dry season (ODNRI, 1989).

3.1.3 Vegetation and Land Use

The Land use types /vegetation mapped in the study area consist majorly of cultivated land, forest land, bare land, Grazing land, and settlement. Gmelina arborea (*Gliricidia sepium*) and oil palm trees (*Elaeis guineensis*) consist about 75 of the total tress population cutting across of the entire watershed which are currently owned and maintained by four major clans (Ibe Omaka, Ibe Utara, Ibe Uri and Ibe Ogbaga) that make up the community. The lower and upper sub catchment watershed has been left under intense cultivation and grazing for livestock (especially the Fulani herdsmen) has totally left larger portion of the study area without vegetation (Bare). Shrubs with grasses and scattered trees have naturally covered these units. Grasses covering the undulating valley and plains provides grazing land for livestock. The cultivated land, which predominates the land uses, are scattered all over the catchment areas including the steep mountain slopes, undulating valley, foot hills and plains. In general, about 39% of the watershed area is completely covered by natural and planted vegetation at present.

3.2 Study Methods and Models

The study involved three research elements vis-à-vis land use land cover change analysis; erosion rate estimation and household survey on soil management and coping mechanisms

3.2.1 Remote Sensing Data Acquisition

Digital satellite imagery of the years 1996, 2006 and 2016 were used to generate thematic maps of the sub-watershed and image correction. The multi-temporal Landsat images used for LULCC detection are provided in Table 2 below.

Table 2 Multi-spectral Satellites Image Sources

Space craft	Spatial Resolution	Path/Row	Acquisition date	Source
Landsat 05	30 M	188/056	14/11/1996	USGS
Land Sat 04	30 M	188/056	17/12/2006	GLCF
Landsat 08	30 M	188/056	04/9/2016	USGS

3.2.2 Land use Land Covers Change Analysis

The ultimate goal of digital image processing was to classify (group) images into various categories or thematic or land use cover classes. The procedure followed during the land use land cover classification phase of image processing involved two steps: image enhancement and image classification. The multi temporal raw satellite data was imported to ERDAS Imagine 14 image processing software for image enhancement and classification. Digital image processing techniques try to improve the interpretability of images by highlighting different features of interest in the data.

Quantification of the rate of change has been applied to generate information about the land use/land cover change of the study area. Using functions in the ERDAS Imagine software (Version14) and GIS areas covered by each land cover type for the various periods were compared. The directions of the changes (positive or negative) in each land cover type years 1996, 2006 and 2016 were determined. The comparison of the LU/LC statistics assisted in identifying the change in percent, trend and rate of change between 1996 and 2016 and was calculated by dividing observed change by sum of changes multiplied by 100 (Trend).

3.2.3 Image Classification and Accuracy Assessment

The image classification analysis involved unsupervised and supervised classifications. Unsupervised classification was done prior to the field survey and labelling was undertaken by visual observation for differentiating various land-use/land-cover categories in the study area. After field survey was completed, the various land use/land cover types were delineated using maximum likelihood supervised image classification method. In the supervised classification, the maximum likelihood method was used since the method quantitatively evaluates both the variance and covariance of the category spectral response patters when classifying an unknown pixel.

Accuracy assessment is critical for a map generated from any remote sensing data. Error matrix is the most common way to present the overall accuracy, user's and producer's accuracies, and the Kappa statistic method was used to derive the error matrices. Accordingly the sample size for the accuracy assessment is found to be 138. Those points which are accessible were checked on ground and others were checked by creating reference points on the raw image using ArcGIS

10.1 (Appendix 6). The overall accuracy and kappa analysis were used to perform a classification accuracy assessment.

3.3 Digital Elevation Model (DEM)

The elevation of the Eyiohia watershed ranged from 10 m - 97m. The DEM was used to estimate slope gradient, flow direction, flow length and flow accumulation for the study, using ArcGIS 10.1, the slope length and slope steepness (LS) factor required by RUSLE was calculated.

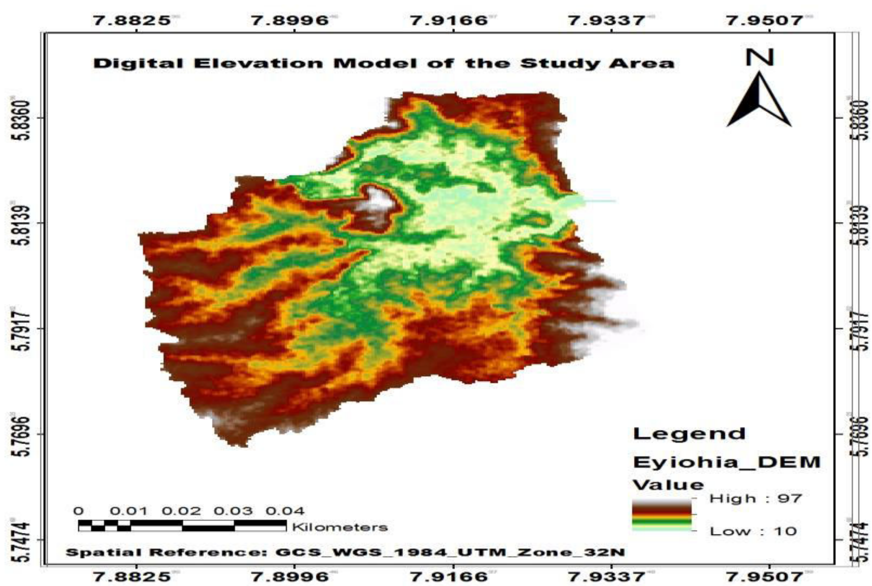

Figure 2 Digital Elevation Model of the study area

3.4 RUSLE Model Description for Soil Erosion Quantification

Estimation of soil loss rates and changes was examined at each land management units for both upstream and downstream sub-catchment areas of the watershed. The Revised Universal Soil Loss Equation (RUSLE) was used to quantify soil loss in different land use categories.

RUSLE is a hybrid used for soil erosion prediction which combines the empirical, index-based Universal Soil Loss Equation (USLE) and process-based equations for the detachment, transport, and deposition of soil particles (Foster, 2005). The model estimate soil loss from a combination of six factors as given below

A=R*K*LS*C*P..Eq. 1

Where

A is the computed spatial average annual soil loss, usually on yearly basis (t ha^{-1} y^{-1});

R is the rainfall-runoff erosivity factor (MJ mm ha^{-1} h^{-1} y^{-1});

K is the soil erodbility factor (t ha^{-1} h^{-1} ha^{-1} MJ^{-1} mm^{-1});

LS is the slope length-steepness factor (dimensionless);

C is the cover management factor (dimensionless); and

P is the conservation practices factor (dimensionless)

3.4.1 Rainfall Erosivity (R-factor)

The rainfall erosivity factor (K) data were collected from Nigeria Meteorological Agency, Abakaliki (NIMET) Ebonyi state, Nigeria developed from daily rainfall amount collected from 9 meteorological stations (Uwana, Amasiri, Ehugbo, Ibi, Abakaliki, Akpoha, Izzi, CAS and Ozziza) covering all the ecological zones in the study area within 30 years time series from 1986-1999, 2006 and 2016. The daily rainfall was used to calculate rainfall erosivity map. Provided that KE (kinetic energy of the rain) > 25, where P is mean annual precipitation (Morgan, 1974; Morgan, 1994).

$$R = 9.28 \times P - 8838 \text{...Eq.2}$$

After computing the averaged 10 years rainfall data of each metrological station, kriging method of interpolation using ArcGIS spatial analyst tool was used to generate an estimated surface erosivity map from the scattered set of point data into surface.

The output of rainfall erosivity as shown in Figure 3 and Table 3 below revealed that the spatial distribution of the computed rainfall erosivity increased over time from 1996 to 2016, and the values ranges from 1113.31 to 1259.31 MJ mm ha^{-1} h^{-1} y^{-1} for the year 1996, 1123.29 to 1569.86 MJ mm ha^{-1} h^{-1} y^{-1} for the year 2006, and range from 956.03 to 1680.64 MJ mm ha^{-1} h^{-1} y^{-1} for the year 2016.

Table 3 mean annual rainfall for the three study periods.

S/N	Rainfall Stations	Long.	Latitude	Rainfall mean (1996)	Rainfall mean (2006)	Rainfall Mean (2016)	R-factor 1996	R-factor 2006	R-factor 2016
1	Uwana	$7^0$8’92”	$5^0$8’56”	987.89	1104.55	1151.33	329.62	1412.22	1846.34
2	Amasiri	$7^0$9’35”	$5^0$8’32”	1075.27	999.38	1160.43	1140.51	436.25	1930.79
3	Ehugbo	$7^0$8’98”	$5^0$8’07”	993.82	1328.63	1091.79	384.65	3491.69	1293.81
4	Ibi	$7^0$8’52”	$5^0$7’85”	1219.87	961.83	986.53	2482.39	87.78	316.99
5	Abakaliki	$7^0$9’26”	$5^0$7’75”	996.324	1129.40	1618.64	407.89	1642.83	6182.98
6	Akpoha	$7^0$9’57”	$5^0$8’02”	1270.22	1165.33	1301.43	2949.64	1976.26	3239.27
7	Izzi	$7^0$8’66”	$5^0$8’35”	968.88	1112.15	1285.79	153.21	1482.75	3094.13
8	CAS	$7^0$9’13”	$5^0$7’89”	1038.11	1343.67	1535.12	795.66	3631.26	5407.91
9	Ozizza	$7^0$9’26”	$5^0$8’17”	1360.50	1507.54	1843.3	3787.44	5151.97	8267.82

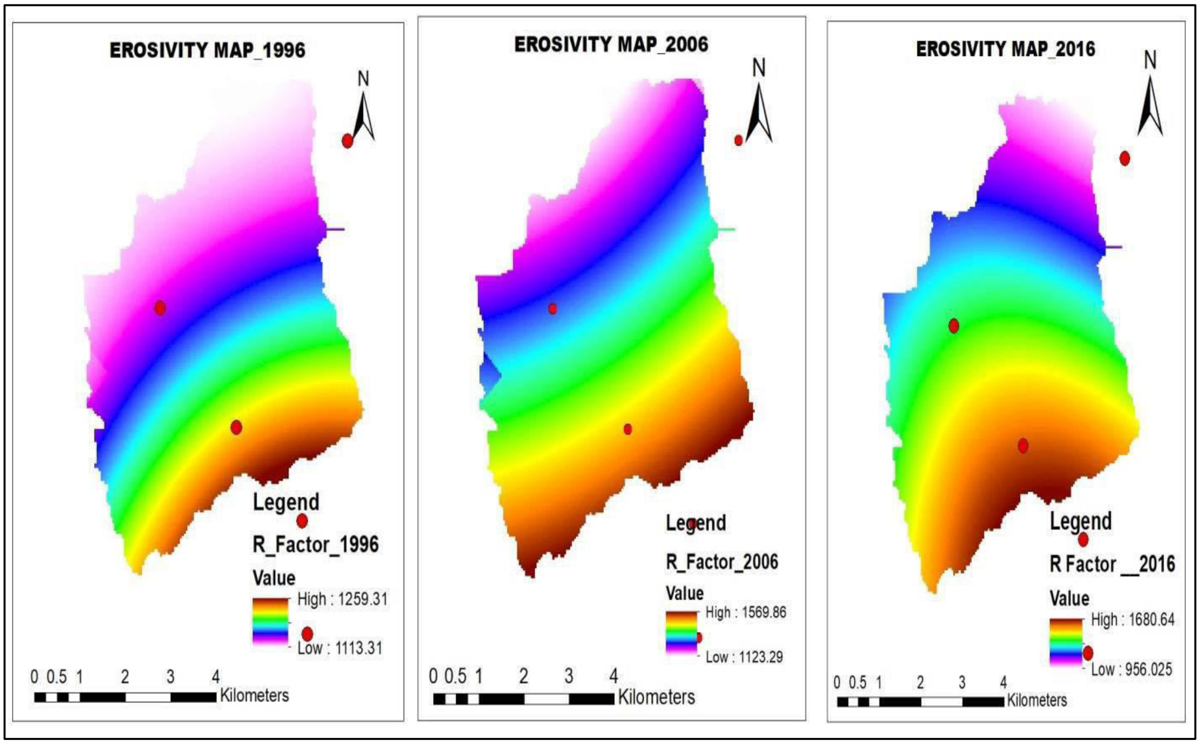

Figure 3 R-factor Map of 1996, 2006 and 2016 years

3.4.2 Soil Erodibility Data (K-factor)

Soil erodibility factor is a parameter that represents the integrated average annual value of the total soil and soil profile reaction to a large number of erosion and hydrologic processes such as detachment and transport by raindrop impact, surface flow, localized deposition due to topography, tillage induced roughness and rainwater infiltration into the soil profile (Romkens et al., 1997).

The soil erodibility factor (K) values was obtained from K-factor index data table (Stone and Hilborn, 2012) based on percentage (%) organic matter content and texture class of the study area. Soil map was extracted from World Reference Base map (2014), to analyze the soil erodibility factor. The polygon shape file of the study area was overplayed on the world soil data base raster map and then extracted then erodibility value were assigned for each of the soil types,.

Table 4 Soil Erodibility Factor (K)

Soil Types	Colour	K-factor	% Coverage
Gleysols (GL)	Gray/brownish	0.63	87.4
Nitosols (NT)	Yellow / reddish	0.47	12.6

Higher values of soil erodibility indicate its higher susceptibility to erosion. The soil erodibility in the watershed ranges from 0.47 to 0.63 ton t ha^{-1} h^{-1} ha^{-1} MJ^{-1} mm^{-1} covering a total percentage area of 12.6% and 87.4% respectively.

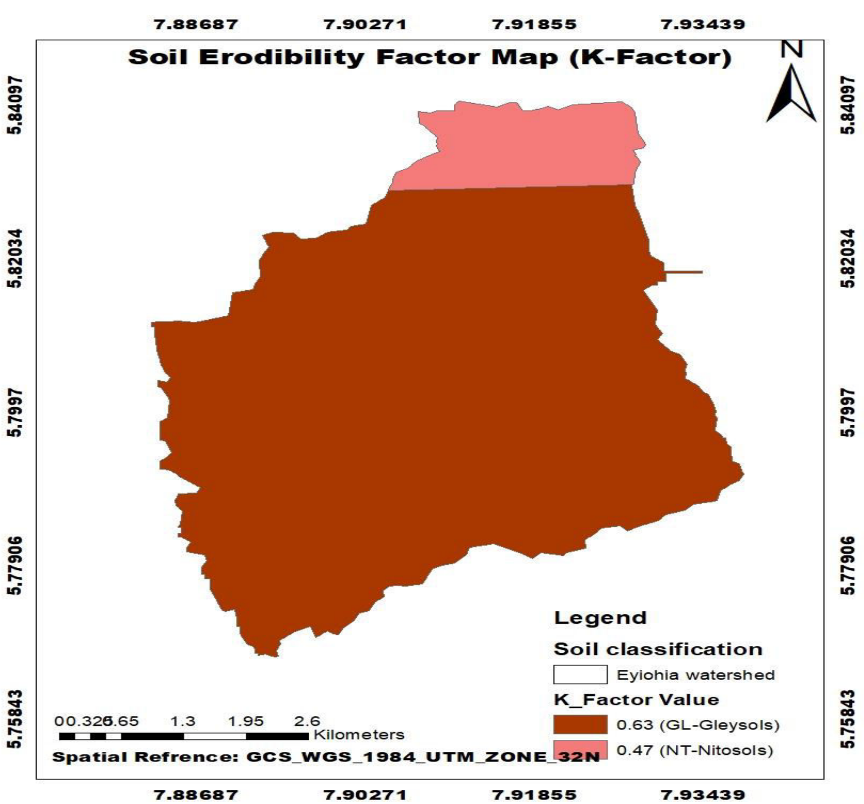

Figure 4 Map of Soil Erodibility Factor (*k*)

A total of two dominant soil types were identified (IUSS WRB, 2014) Gleysols (GL) and Nitosols (NT) with appropriate K values assigned to each soil types as shown in table 4 above.

3.4.3 Slope Length and Slope Steepness Data (LS- Factors)

The slope length and slope steepness are important factors that controls the rate of soil erosion and are therefore critical in the modelling of erosion at the watershed scale (Angima*et al.,* 2003). Computation shows that the slope of the watershed range in value between 0 – 34.532 and was derived from the DEM (Fig 2).

The slope length-steepness factor (LS) was computed for the watershed by using spatial analysis extension in ARCGIS 10.1. Sink in the DEM was identified and filled. The filled DEM was used to determine the flow direction and flow accumulation in grid form. The LS factor grid was then estimated as proposed by (Moore and Burch, 1986a and b; Engel, 2005) and described as follows

LS=Pow (“flowacc”*[cellresolution]/22.1,.4)*Power(Sin(“slope”*0.01745))/0.09,1.4)*1.4...Eq.3

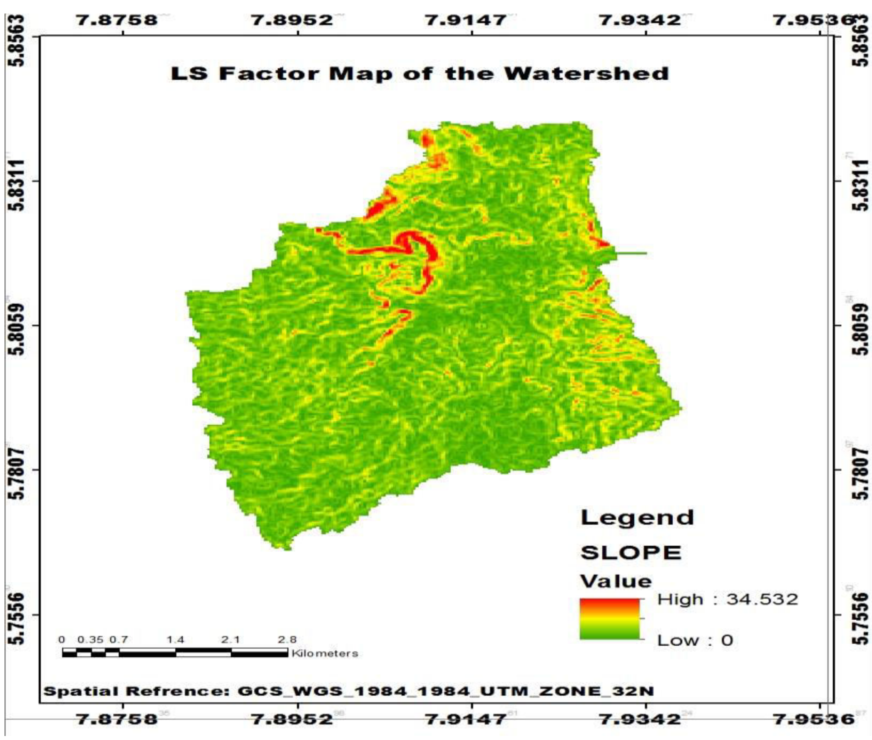

Figure 5 LS Factor Map.

3.4.4 Cover Management Data (C- Factor)

The cover management factor (C) was generated as proposed by De Jong (1994), to generate the cover management factor using the Normalized Difference Vegetation Index (NDVI) which indicates land vegetation vigour and health. In this study, the original satellite images for the year 1996, 2006 and 2016 with their reflectance values in bands green, red and near-infrared, were converted to NDVI for the corresponding years. The NDVI expressed as:

$$NDVI = \frac{(rNIR - rRed)}{(rNIR + rRed)} \text{....................................Eq.4}$$

$$C = 0.431 - 0.805 \times NDVI \text{...........................Eq5}$$

Where rNIR is the reflectance value in near-infrared band; rRed is the reflectance value in visible red band.

Table 5 Land use land cover class and C – factor values of the year

LULC types	Area in different years			C-Factor Values
	1996	2006	2016	
Cultivated land	21,100	22,100	24,500	0.09
Forest area	18,600	15,300	10,000	0.04
Bare land	12,000	12,700	14,600	1.00
Grazing land	1,400	1,500	1,700	0.07
Settlement	1,100	2,600	3,400	0.34
Total	54,200	54,200	54,200	

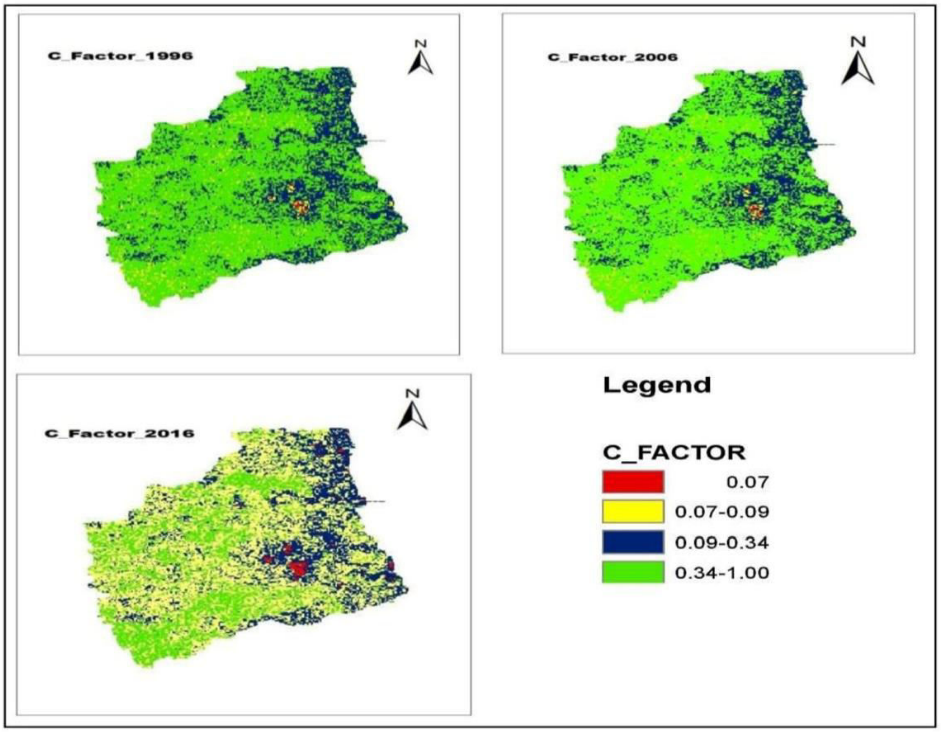

Figure 6 Map of C - factor value.

3.4.5 Support Practice Data (P -Factor)

The support management factor represents the protection offered by the erosion control structure and practices such as terracing, contouring, and ridging, strip cropping, and subsurface drainage, as well as other runoff and erosion control structures that reduce the rate and amount of runoff And the lower the value the more effective the conservation practices are as show in figure 7 below

The support practice (P) was generated based on P-values suggested by Wischmeir and Smith (1978) which considers only two types of land uses (agricultural and non-agricultural) and land slopes. Because of the difficulty of finding reliable information on conservation practices employed by farmers and the probability of lacking permanent management practices. Thus, the agricultural lands were classified and different P-value was assigned while all non-agricultural lands were assigned a P-value of 1.00 to produce P map for 1996, 2006 and 2016 with their corresponding images

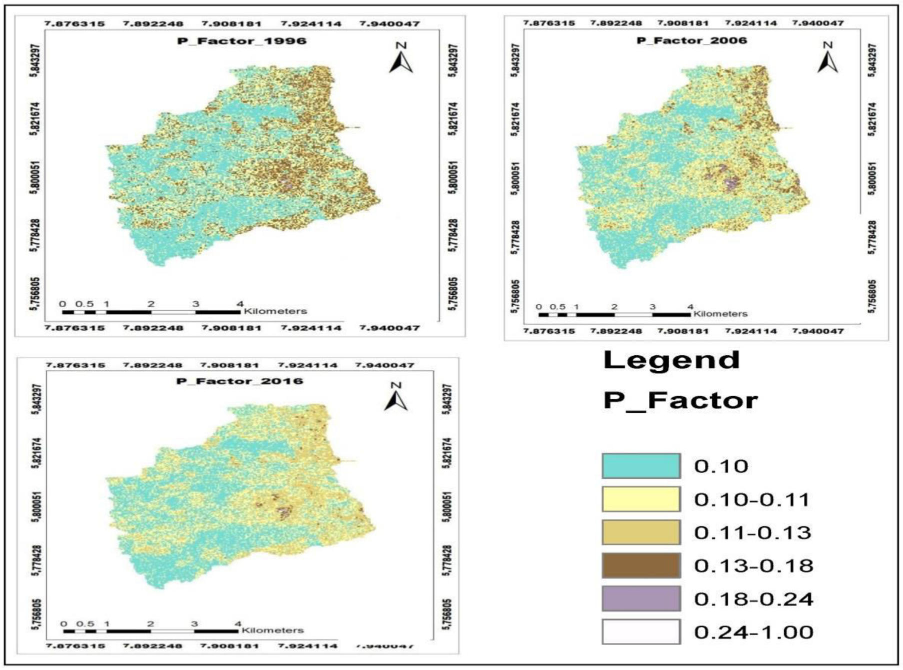

Figure 7 P– factor map of the watershed.

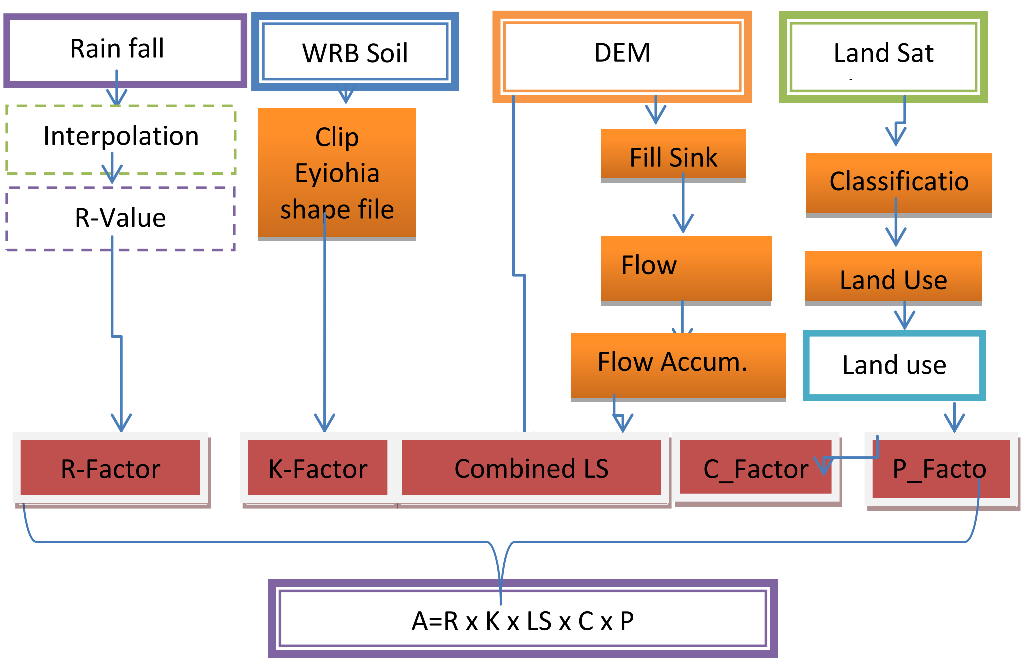

Figure 8 General flow chart

3.5 Characterization and Delineation of Land Use and Management Practices

The land use and management practices within the watershed was characterized by virtual observation and delineated by mapping and measurement on both upstream and downstream sub-catchment watershed.

3.6 Characterization of Selected Physico-Chemical Properties of Soils

Soil samples were collected from each of the identified LULC categories to determine selected physical and chemical properties. The soil samples were taken to Chemistry and physical laboratory in department of soil science and environmental management, Ebonyi State University, Abakaliki, to determine selected physical and chemical properties. The purpose was to examine the variability in soil properties as affected by land use land cover types. The watershed was delineated into two topographical units (Upstream and downstream sub catchment watershed), each of the topographical position were geo-referenced with a hand held global positioning system (GPS) receiver which also gave the altitude of sampling points and the distance from one another. And in upstream and downstream, important land use types (cultivated, grazing and forest lands) were identified for soil characterization and sampling, in each land use type in upstream and downstream, three composite soil samples were collected to a depth 30 cm and replicated three times and a total of eighteen soil samples were collected to determine selected physical and chemical properties. These include:

3.6.1 Soil Physical properties

The soil physical properties determined were soil texture, bulk density (g cm^{-3}), water holding capacity i.e., field capacity at 1/3 bar and the permanent wilting point (PWP) at 33 bars, Particle density (PD) and Total porosity (TP). Soil Bulk density was determined using the Blake and

Hartge (1986) method. Total porosity (TP) was calculated from bulk density values with particle density (P_D) of 2.65gcm^{-3}. Soil texture was determined and analyze for as described by Bouyoucos (1951) hydrometer method using sodium hexametaphosphate (calgon) as dispersant. Available water capacity (AWC) was calculated as the differences between Water as retained at field capacity (FC) and permanent wilting point (PWP) and was determined using the saturation water percentage-based on estimation models of Mbagwu and Mbah (1998). Particle density (PD) was determined by the wet-sieving method of Kemper and Rosenau (1986)

$$TP\ [1-(B_D/P_D] \times 100 \ldots\ldots\ldots\ldots Eq.6$$

$$PD = \frac{\text{Weight of soil retained on sieve} - \text{weight of sand}}{\text{Total Sample Weight} - \text{Weight of sand}} \ldots\ldots\ldots\ldots Eq.7$$

3.6.2 Soil Chemical Properties

Soil pH- in water (pH-H_2O) was determine using pH meter, organic carbon (OC: %) was determined according to Nelson and Sommer (1982**)** procedure, Total nitrogen (TN %) was determine using micro-kjedhal procedure according to Bremner (1996)**.** The content of available phosphorus (AP mg kg^{-1}) was determined using the Bray-2 method as described in Page et al. (1982). Exchangeable bases (Ca, Mg, Na, K: cmol kg^{-1}) and cation exchange capacity (CEC: cmol kg^{-1}) were determined using atomic absorption method and flamephotometer to extract sodium and potassium (Ohiri and Ano ,1985)**.** In the leachate, exchangeable calcium and magnesium were determined using the titration method as described by Mba (2004)**,** the extractable micronutrients: Zn, Cu, Fe and Mn were extracted using 0.1M HCl solution Osiname et al. (1973) and determined on an atomic absorption spectrophotometer at appropriate wavelength.

3.7 Questionnaire on Local Perceptions of Soil Erosion Problem

Stratified (upstream and downstream) questionnaire was administered with 50 representative households each in the upper and lower streams of the watersheds giving a total of 100 respondents. Respondents were selected from areas where extensive changes in land use land cover were observed within both upstream and downstream sub eyiohia watershed study area.

The questionnaire captured information of soil erosion problems, soil management practices and land use land cover change. The goal of the stratified questionnaire was to find relationships between farmers and farm attributes and whether farmers perceived they had a problem with soil loss

Quantitative data analysis is helpful in evaluation because it provides quantifiable result and it is easy to understand data. The first process carried out after data entry was tabulation of results for the different variables in the data set to get a comprehensive picture of what the data looks like and assist in identifying patterns. The questionnaire data was analyzed using descriptive statistical tools of percentages.

3.8 Statistical Analysis

Soil physical and chemical properties laboratory results were analyzed using SPSS statistical extension to determine significant difference among means in upstream and downstream and to detect significant variation in mean as affected by land use types.

4. RESULTS AND DISCUSSION

4.1 Land Use and Land Cover Change Detection

Figure 9 presents the land use land cover pattern of the watershed during the period between 1996 and 2016. The results general increase in the area of cultivated fields between 1996 and 2016 that changed from 22,100 ha (40.77%) in 1996 to 24,500 ha (45.20%) in 2016. Forest land covered about 18,600 ha from the entire watershed in 1996 but decreased to 15,300 ha in 2006 and 10,000 ha in 2016. The change is brought about by land conversion from forest to farmlands (Table 6). From the data it can be seen that cultivated land increase by +3400 ha, settlement by +2300 ha, bare land by +2600 and grazing land +300 ha while forest has declined by area coverage of -8600 ha. Error matrix and Kappa analysis were used to perform a classification accuracy assessment and accordingly overall accuracy of the data is 89.86% and

overall kappa coefficient was computed which is 0.8677 (Appendix 6) and from the result the interpretation can be taken as accurate result for further analysis.

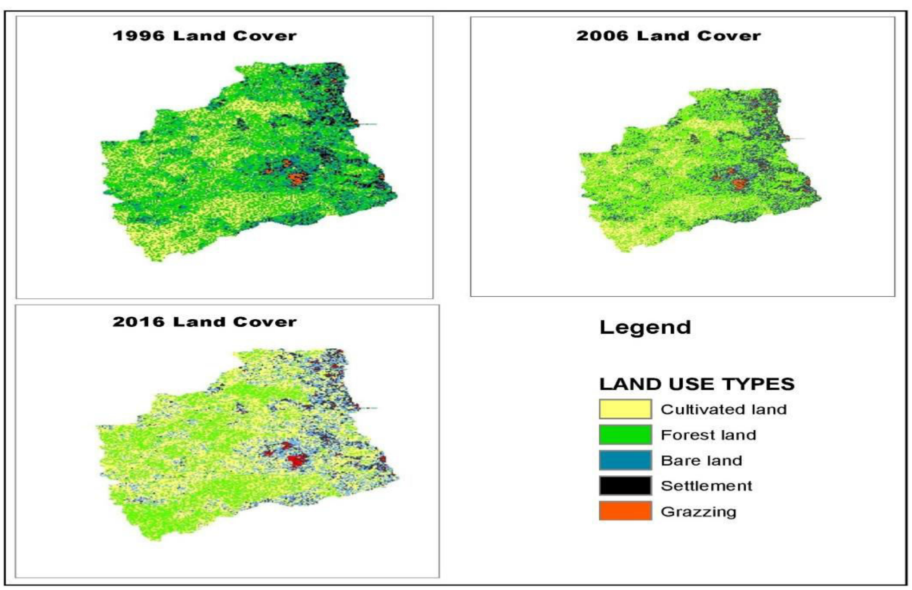

Figure 9 Land Use Land Cover map of Eyiohia

The underlying drivers of observed change in land use with dramatic increase in cultivated area at the expense of forest area could be linked to growing demand for food from ever increasing population. This is also in agreement with questionnaire survey with the residents as discussed above.

Table 6 land use land cover changes

LULC types	1996		2006		2016	
	Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)
Cultivated land	21,100	38.9	22,100	40.77	24,500	45.20
Forest land	18,600	34.3	15,300	28.23	10,000	18.45
Bare land	12,000	22.1	12,700	23.43	14,600	26.94
Grazing land	1,400	2.5	1,500	2.78	1,700	3.14
Settlement	1,100	2.0	2,600	4.80	3,400	6.27
Total	54,200	100	54,200	100	54,200	100

4.1.1 Rate of Change of Land Use Land Cover

Land use land cover change rate analysis revealed that cultivated land, bare land, settlement and grazing land have increased by 5.90%, 4.58%, 4.06%, and 0.55% respectively with corresponding rate of change of +170, +130, +115 and +15 ha per year, while forest area has significantly decreased by 18.86 % with corresponding rate of change of -430 (Table 7 and Figure 10).

Table 7 land use land cover rate of change over time

Land use Types	Year		Land use Changes over time		Rate of Change (ha yr^{-1})
	1996	2016			
	Area in (ha)	Area in (ha)	Area (ha)	Area (%)	
Cultivated	21,100	24,500	+3400	5.90	+170
Forest area	18,600	10,000	-8600	18.86	-430
Bare land	12,000	14,600	+2600	4.58	+130
Grazing land	1,400	1,700	+300	0.55	+15
Settlement	1,100	3,400	+2300	4.06	+115
Total	54,200	54,200			

Source: Satellite images interpretation, (**-**) indicates decreases (**+**) indicates increases

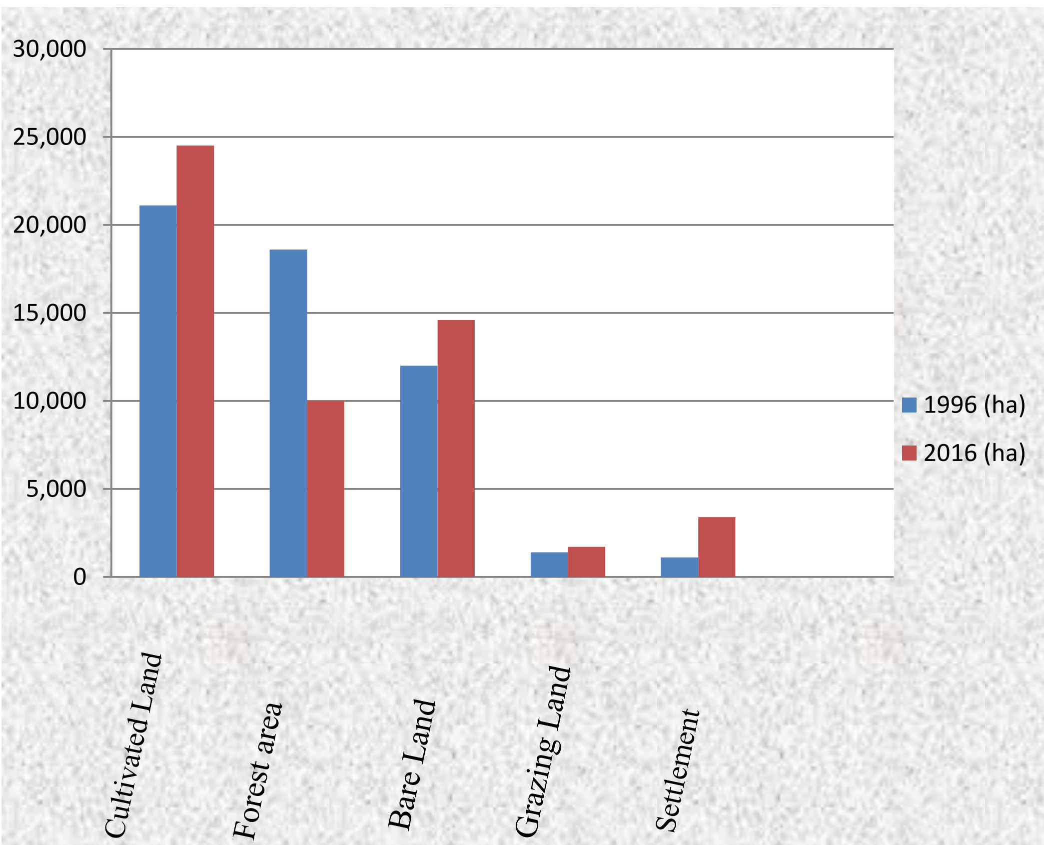

Figure 10 Graph Land use/land Change

4.2 Soil loss by Land-use/land-Cover Type

In order to determine and evaluate soil erosion potential in Eyiohia watershed on each land use types, the soil loss map of 1996 and 2016 were correlated and cross tabulated , the RUSLE model was run for 1996 and 2016 separately. During each model run, all parameters remained constant, except C and P factors, which changed according to the LULC of respective year. Since the C-factor in the RUSLE model directly depends on land use land cover. Results shows that the mean soil loss in 1996 and 2016 among the land use types were higher in cultivated land followed by forest land.

The high reduction of forest predominantly caused by cultivation activities has practically reduced the protective function of the land, and has led to dramatic increase of soil loss in the watershed from 1996 to 2016 which have negatively impacted on the soil productivity and other ecosystem.

Table 8 Mean Annual Soil Loss from each land use over time

Land use Types	Mean Annual soil Loss ($t\ ha^{-1}\ y^{-1}$)		Change of soil loss ($t\ ha^{-1}\ y^{-1}$)
	1996	2016	
Cultivated land	26.44	48.34	21.9
Forest area	19.30	36.92	17.62
Bare land	14.60	19.40	4.80
Grazing land	6.10	8.02	1.92
Settlement	12.11	14.48	2.37

During the two study periods, the trend of mean soil loss in the study area indicates sharp increase from 1996 to 2016 in cultivated and forest land compared to other land use types. Soil loss change detections from 1996 to 2016 shows 21.9 $t\ ha^{-1}\ y^{-1}$ increased in cultivated land followed by forest land 17.62 $t\ ha^{-1}\ y^{-1}$, bared land 4.80 $t\ ha^{-1}\ y^{-1}$, grazing land 1.92 $t\ ha^{-1}\ y^{-1}$ and settlement 2.37 t ha^{-1} y^{-1} (table 8). However, increased soil loss in the cultivated areas from 1996 to 2016 was not surprising because area of cultivation increased by +3400hectare which also triggered reduction of forest area by -8600 with other land use types changes, and large cultivated area means larger areas are mostly disturbed and exposed to different erosion agents which also lead to significant reduction of forest area with consequent increase in its means soil loss from 1996 to 2016

4.3. Selected physicochemical properties under Different Land use Type

4.3.1 Soil Physical Properties under different Land use Type

Results indicate that the soils are sandy loam in texture with mean sand, silt and clay fractions of 53%, 30% and 17% receptively and there was no significant difference among land use types in particle size distribution of the soil (Table 9). The similarity in texture class across all land use types reflects homogeneity in parent materials (chiefly sandstone) and the fact that texture is inherent property of the soil that cannot be changed by land use in short period of time. The mean values of bulk density (BD) and particle density (PD) were 1.38 g cm^{-3} and 4.4 g cm^{-3} respectively while total porosity (TP) by volume was 48% indicating good physical conditions and free drainage in the soil. There was significant difference in BD and TP among land types with the highest mean BD values (1.4 g cm^{-3}) in the cultivated fields and grazing lands and the lowest (1.29 g cm^{-3}) in the forest lands. On the contrary, the highest mean value of TP (51.5%) under forest lands and the lowest (46%) under grazing lands suggesting the trampling effect of cattle increasing bulk density while at the same time reducing total porosity and water infiltration. This might be due to soil bulk density and soil total porosity which is inversely related which has huge implications for runoff and soil erosion losses as can be seen in the subsequent sections. The findings are in agreement with Lemenih et al., (2005) and Selassie,

(2005) who reported progressive increase in bulk density due to deforestation, grazing and continuous cultivation.

The mean water holing capacity (WHC) of the soil at field capacity (1/3 bar), permanent wilting point (PWP 33 bar) and available water capacity (AWC) were 22, 11 and 10 which is rated as low and showing no significant difference between land use types. The low water holding capacity and plant available water content of the soil is consistent with the high TP and sandy nature of the soil which may contribute to increased runoff and soil erosion hazards.

4.3.2 Soil Chemical Properties under different land use types

Results indicate that the mean organic carbon, total nitrogen and available phosphorous were 1.42%, 0.10% and 19.8 mg kg^{-1} and showing no significant difference between land use types, organic carbon and total nitrogen is rated as low while available phosphorus is rated high. Low organic carbon and total nitrogen could be attributed to continuous cultivation without fallow, and high rate of mineralization due to high temperature (tropics) and crop removal during harvest by farmers without proper incorporation of crop residue into the soils. The range of mean available phosphorus is not in consistent with the findings of Ekundayo (2004) who reported mean value of 10 mg kg^{-1} soil of south-eastern Nigeria. The mean soil pH value is 4.64 and shows no significant difference between land use types and showing very strongly acidic which could be as a result of depletion of basic cations to drainage in runoff generated from accelerated soil erosions

4.3.3 Exchangeable bases under different land use types

Results indicate that the mean cation exchange capacity (CEC), calcium (Ca) and potassium (k) were 6.9 cmol kg^{-1}, 3.5 cmol kg^{-1} and 0.1 cmol kg^{-1} which is rated as low and showing no statistical difference between land use types. Low CEC, Ca and k have however been reported for most Nigerian soils (Akinirinde and Obigbesan, 2000; Uzoho *et al.,* 2007) and are attributed to soil erosion losses by the high tropical rainfall as well as low content in the parent rock, therefore suggesting that the finding of this study is in conformity. The mean values of magnesium and sodium were 1.9 cmol kg^{-1} and 0.1 cmol kg^{-1} which is rated as medium (balanced) and showing no significant difference between land use types.

Table 9 Mean values of selected physico-chemical properties of soils as affected by land use type

Parameter	Forest land	Cultivate land	Grazing land	Mean	Satd. Error	P-value	F-value	Sign (0.05)
Physical properties								
Sand (%)	52.56	51.56	56.23	53.46	1.95	0.600	0.529	ns
Silt (%)	32.07	30.40	27.07	29.85	2.926	0.779	0.254	ns
Clay (%)	15.37	18.03	16.70	16.70	1.89	0.849	0.166	ns
BD (g cm^{-3})	1.29	1.41	1.44	1.38	0.023	0.05	3.683	*
PD (g cm^{-3})	4.50	4.43	4.30	4.41	0.201	0.922	0.081	ns
TP (V %)	51.47	46.95	45.85	48.08	0.854	0.039	4.053	*
Water holding capacity								
• FC (1/3 bar)	20.74	20.59	25.07	22.13	2.110	0.481	0.769	ns
• PWP (33 bar)	9.52	9.85	14.17	11.18	1.542	0.411	0.943	ns
• AWC	11.22	10.74	10.90	10.90	0.347	0.820	0.202	ns
Chemical properties								
• pH –H20	4.87	4.37	4.68	4.64	0.175	0.509	0.707	ns
• OC (%)	1.64	1.42	1.18	1.42	0.218	0.691	0.379	ns
• TN (%)	0.127	0.09	0.084	0.103	0.016	0.534	0.655	ns
• AP (mg kg^{-1})	23.92	19.82	20.60	19.82	1.653	0.574	0.577	ns
Cation exchange capacity and bases (cmol kg^{-1})								
• CEC	5.8	5.46	5.84	5.70	0.193	0.182	1.911	ns
• Ca	3.73	3.23	3.63	3.53	0.195	0.555	0.613	ns
• Mg	1.83	1.99	2.13	1.98	0.105	0.523	0.678	ns
• Na	0.12	0.13	0.07	0.11	0.016	0.309	1.271	ns
• K	0.12	0.11	0.11	0.11	0.007	0.971	0.029	ns
Micronutrients (mg kg^{-1})								
• Fe	25.95	40.07	33.99	33.27	0.771	0.000	28.103	*
• Mn	39.23	66.9	54.75	53.67	2.952	0.006	7.320	*
• Zn	0.25	1.80	0.11	0.99	0.72	0.046	4.072	*
• Cu	0.46	1.49	0.99	0.98	0.210	0.167	2.024	ns

4.3.4 Micronutrient under different land use types

The mean values of iron (Fe) and manganese (Mn) were 33.3 and 53.6 mg kg^{-1} which is rated as high and showing significant difference ($P<0.05$) between land use types with the highest mean Fe values in the cultivated lands (40.1 mg kg^{-1}) and grazing lands and the lowest (25.9 mg kg^{-1}) in the forest lands, also the highest mean values of Mn was recorded in cultivated lands (66 mg kg^{-1}) and grazing lands and the lowest in forest lands (39.2 mg kg^{-1}). High Mn in the study area implies that Mn content is above the critical available range of 3 to 5 mg kg^{-1} reported by Lindsday and Norveil (1978). These figures suggest that Mn content of the soils is high and cannot be a limiting factor to successful crop production. On the contrary, the mean values of Zinc (Zn) and cupper (Cu) were 0.99 and 0.98 mg kg^{-1} which is rated as medium and low respectively, although zinc shows significant difference between land types with the highest mean value in cultivated lands (1.80 mg kg^{-1}) and lowest in grazing fields (0.11 mg kg^{-1}) and forest areas, this conforms to the findings of Mustapha et al. (2011) in Gombe state, Nigeria of irregular distribution of Zinc in the same land use types

4.4 Selected physico-chemical Properties of soils between upstream and downstream

4.4.1 Soil Physical properties

Results indicate that the soils are sandy loam in texture with mean sand, silt and clay fractions of 53%, 30% and 17% receptively showing significant difference between upstream and downstream (Table 10). The highest mean sand fraction (57.4%) was observed in the upstream and the lowest in the downstream (49.5%). On the contrary, the highest mean silt fraction (35.3%) was in the downstream and the lowest (24.35) in the upstream. The mean clay fraction is 16.70% showing no significant difference between upstream and downstream. Why the soils are more sandy in the upstream is possibly due to selective removal of fine particles by runoff water from upper slopes that deposited in the downstream.

The mean bulk density and particle density were 1.38 and 4.41 g cm^{-3} and showing significant difference (P=0.003, 0.000) respectively between upstream and downstream with the highest mean BD value (1.45 g cm^{-3}) in the upstream compared to the lowest (1.31 g cm^{-3}) in the downstream. In contrast, the highest mean value of particle density (4.99 g cm^{-3}) was in the downstream and the lowest (3.82 g cm^{-3}) in the upstream. This possibly suggests the presence of relatively less clay fraction in the downstream which therefore increased soil particle density. In line with this, Achalu et al. (2012) revealed that decrease in clay fraction increase particle density through its positive effect on soil aggregation. The mean value of total porosity by volume is 48% indicating free and better drainage system network in the soil and showing significant deference (P=0.004) between upstream and downstream with highest mean value (51%) in downstream and lowest (45%) in upstream.

The mean water holing capacity (WHC) of the soil at field capacity (1/3 bar), permanent wilting point (PWP 33 bar) and available water capacity (AWC) were 22, 11 and 10 which is rated as low and showing no significant difference between upstream and downstream. The low water holding capacity and plant available water content of the soil is consistent with the sandy nature of the soil which may contribute to increased overflow and soil erosion risk.

4.4.2 Soil chemical properties

Results indicate that the mean values of soil pH, organic carbon and total nitrogen were 4.64, 1.42%, and 0.10% respectively and showing no significant different between upstream and downstream while soil pH shows very strongly acidic (4.64). The mean value of available phosphorous is 21.45 mg kg^{-1} and shows significant difference between upstream and downstream with highest mean value (20.8 mg $kg^{-1)}$ in the downstream compared to the lowest (18 mg kg^{-1}) in the upstream and the differences lies in the land use practice and fertilizer application between upstream and downstream.

4.4.3 Soil Exchangeable bases

The mean values of soil cation exchangeable capacity, calcium, magnesium, sodium and potassium are 5.73, 3.53, 1.98, 0.11 and 0.11cmol/kg respectively and showing no significant different between upstream and downstream

4.4.4 Soil micronutrient

The results indicate that the mean values of Manganese (Mn), Zinc (Zn) and Cupper (Cu) were 53.7, 0.98 and 0.99 mg $kg^{-1}$and showing significant different between upstream and downstream with highest mean Mn value (63.4 mg kg^{-1}) in the downstream compared to the lowest (44.9 mg kg^{-1}) in upstream. The highest mean Zn value (1.69 mg kg^{-1}) was in the downstream compared to the lowest (0.28 mg kg^{-1}) in the upstream sub watershed. Cupper also shows highest mean value (1.46 mg kg^{-1}) in downstream and the lowest (0.5 mg kg^{-1}) in upstream. However, the mean value of Iron (Fe) is 33.3 mg $kg^{-1}$and showing no significant different between the upstream and downstream. The highest mean values of Mn, Zn and Cu recorded in the downstream than in the upstream could be linked as a result of toposequence, which involves processes that cause soil properties differentiation along hill slopes, this is in agreement with the statement made by Gessler *et al*., (2000) in his finding, he stated that soil properties on a slope differ due to degree of detachment, transportation and deposition of soil materials accelerated by soil erosion.

Table 10 Mean values of selected physico-chemical properties of soils between upstream and downstream watershed

Parameter	Upper strea	Lower stream	Mean	Satd. Error	P-value	F-value	Sign (0.05)
Physical properties							
Sand (%)	57.40	49.51	53.45	1.686	0.033	5.472	*
Silt (%)	24.35	35.33	29.84	2.522	0.045	4.736	*
Clay (%)	18.24	15.15	16.70	1.809	0.406	0.729	ns
BD (g cm^{-3})	1.45	1.31	1.38	0.020	0.003	12.225	*
PD (g cm^{-3})	3.82	4.99	4.41	0.129	0.000	23.659	*
TP (V %)	45.44	50.73	48.08	0.784	0.004	11.367	*
Water holding capacity							
• FC (1/3 bar)	21.32	22.85	22.08	1.507	0.184	1.453	ns
• PWP (33 bar)	11.28	11.08	11.18	1.584	0.950	0.004	ns
• AWC	10.04	11.77	10.90	0.262	0.872	0.010	ns
Chemical properties							
• pH –H20	4.44	4.84	4.64	0.171	0.261	1.359	ns
• OC (%)	1.15	1.69	1.42	0.206	0.207	1.728	ns
• TN (%)	0.09	0.11	0.103	0.016	0.474	0.538	ns
• AP (mg kg^{-1})	18.03	24.86	21.45	1.425	0.029	5.738	*
Cation exchange capacity and bases (cmol kg^{-1})							
• CEC	5.50	5.96	5.73	0.209	0.845	3.274	ns
• Ca	3.22	3.84	3.53	0.180	0.104	2.973	ns
• Mg	2.08	1.88	1.98	0.104	0.349	0.932	ns
• Na	0.09	0.13	0.11	0.016	0.251	1.421	ns
• K	0.11	0.11	0.11	0.006	0.986	0.000	ns
Micronutrients (mg kg^{-1})							
• Fe	31.49	35.05	33.37	1.56	0.271	1.299	ns
• Mn	44.90	62.44	53.67	3.39	0.01	6.789	*
• Zn	0.28	1.69	0.98	0.237	0.009	8.968	*
• Cu	0.50	1.46	0.99	0.196	0.026	6.016	*

4.5 Extent and Rate of Soil Erosion in Eyiohia Watershed

The results indicate that, the amount of soil loss in the entire eyiohia watershed is about 6,895,691 t ha^{-1} $y^{-1.}$ Soil erosion potential of the sub watershed in the year 1996 ranged from 0.0 to 789.07 t ha^{-1} y^{-1}soil erosion rate for the entire watershed was estimated to be 78.9 t ha^{-1} y^{-1}. With this rate, the amount of soil lost during the 1996 scenario accounts to be 4,276,791 t ha^{-1} y^{-1}

from 54200 ha. Soil erosion output for the year 2006 ranges from 0.0 to 811.54 t ha^{-1} y^{-1} and the mean annual soil loss for the entire watershed was estimated to be 101.37 t ha^{-1} y^{-1}. Soil loss in 2016 was estimated to be in the range of 0.0 to 859.3ton/ha/year (figure 11). The mean soil loss for the entire watershed was calculated to be 127.22 t ha^{-1} y^{-1} and the total soil loss in the watershed in 2016 was calculated to be 6,895,691 t ha^{-1} y^{-1}. The result in sum, shows that soil erosion rate increased from 1996-2016 which could be link in part to increase in rainfall erosivity factor.

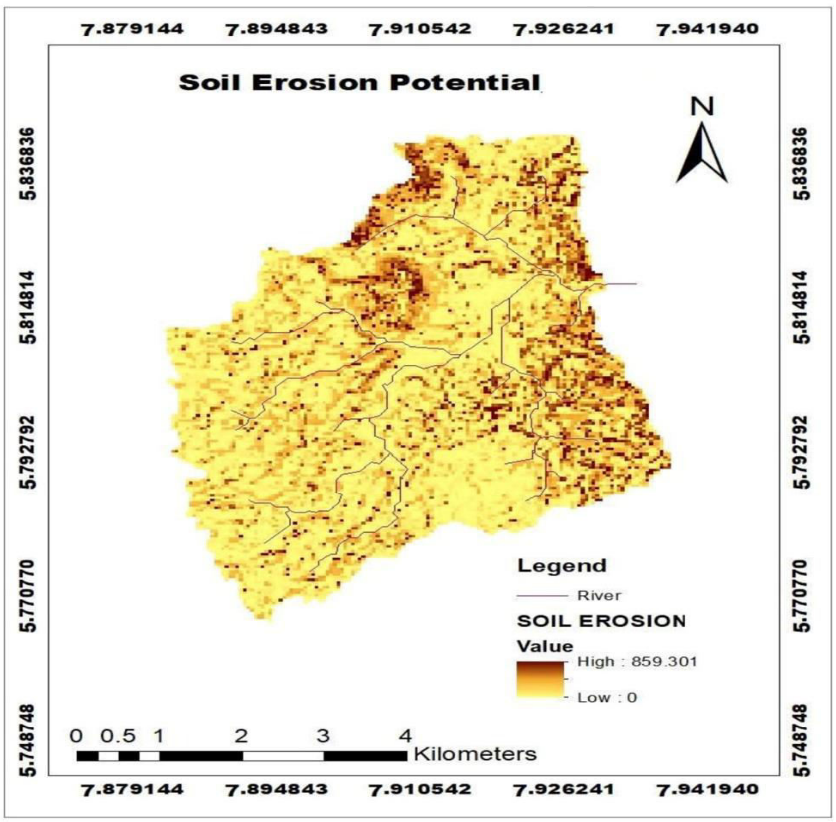

Figure 11 Map of Soil Erosion Potential 2016

4.6 Hotspots of Soil Erosion in Eyiohia sub-Watershed.

The potential soil loss map for 2016 was classified into six soil erosion risk classes in ArcGIS environment (table 14) below. Based on the estimated annual soil loss rates of the model and the severity classes proposed by Bewket and Teferi (2009) this method of severity classes has mostly been used in Nigeria.

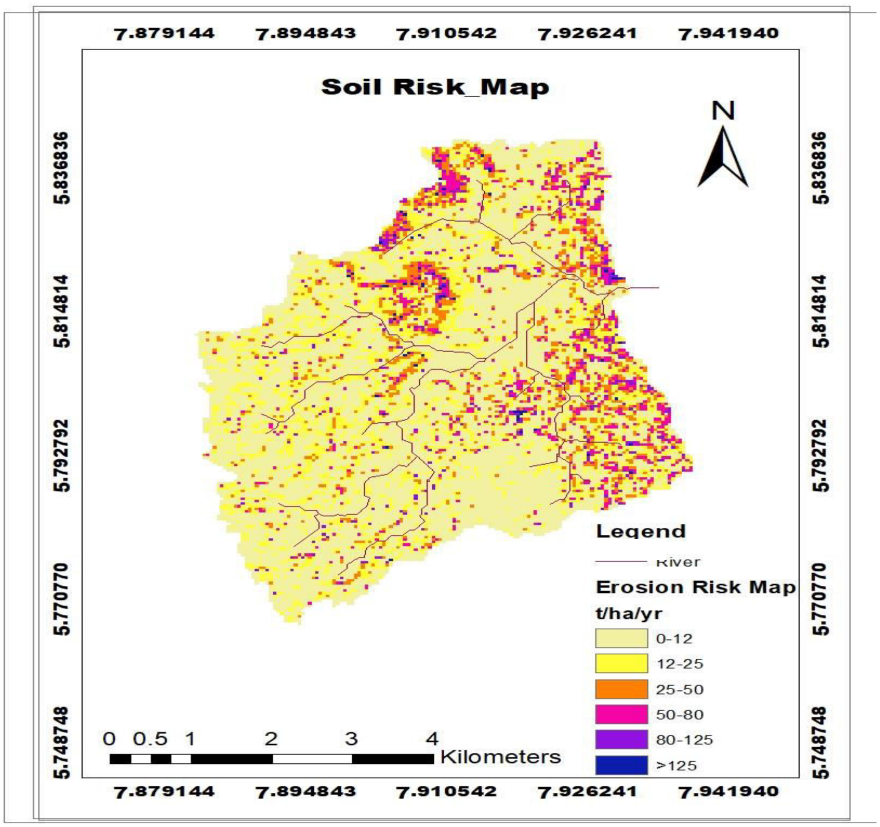

Figure 12 Map of erosion Risk Classes

The results (Table 11) showed that about 29% of the entire study area has a soil loss value of less than 12 t ha^{-1} y^{-1} and is classified as low risk. Based on the 2016 potential soil erosion severity class, it is conclude that the watershed is potentially prone to soil erosion risk since majority of the area (71%) ranged from very sever to moderate risk categories. However, due to the existing human activities, soil and climatic factor, the watershed had experienced high to very sever soil erosion problem. Assessment of erosion risk map above (figure 12), the spatial locations of the high spot area for soil erosion in the study revealed that the potential soil loss is typically greater along the steeper slope of the upstream. The downstream of the watershed shows the least vulnerable to soil erosion

Accordingly, areas of ‘high’, ‘very high’, ‘severe’, and ‘very severe’ are the critical areas that require urgent soil erosion control and water conservation measures. If measures are not applied on the areas identified as risk, the agricultural production in these areas will be severely affected, and this will consequently result in food insecurity, and herdsmen/farmer crisis in this study area will continue to be a daily occurrence.

Table 11 Soil Loss and Risk Categories

Soil Loss range ($t\ ha^{-1}\ y^{-1}$)	Risk Categories	Area (Km^2)	Area (%)
0-12	Low	157.18	29
12-25	Moderate	125.34	23.13
25-50	High	95.19	17.56
50-80	Very high	78.44	14.47
80-125	Severe	59.57	10.99
>125	Very severe	26.28	4.85

First and foremost, prioritization of the eight sub-watersheds involves ranking the different sub-watersheds according to the order in which they ought to be taken up for conservation management and erosion control by consideration the amount of soil loss occurring in those area. Figure 13 below shows the eight sub watersheds in the study area.

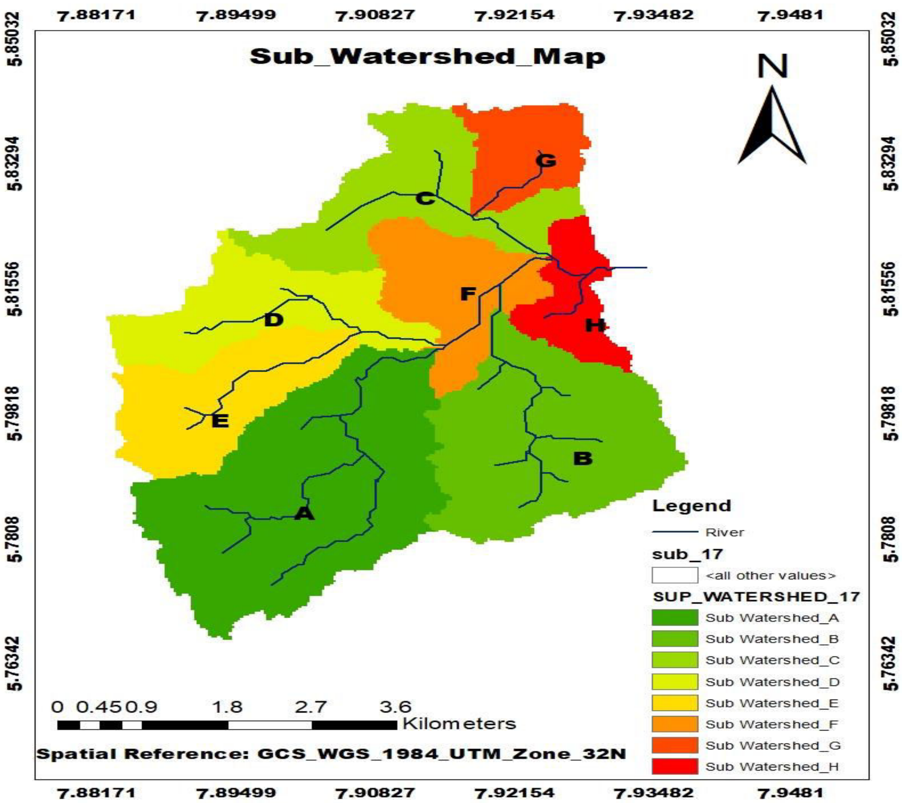

Figure 13 Map of the Sub watershed

Table 12 Sub Watersheds and its Corresponding Soil Loss

Sub Watershed Ranking	Area (Km^2)	Area (%)	Average soil loss t ha^{-1} y^{-1}	Percentage of total soil loss
A	146.5	27.03	105.75	12.31
B	114.7	21.16	279.87	32.57
C	85.4	15.76	198.51	23.10
D	53.3	9.83	118.42	13.78
E	51.9	9.58	23.97	2.79
F	38.4	7.08	9.98	1.16
G	27.3	5.04	47.10	5.48
H	24.5	4.52	75.7	8.81

4.6.1 Prioritization for Sub-watershed Treatment

RUSLE was applied for the identification and prioritization of the critical sub-watersheds on the basis of 2016 potential soil loss. According to this classification, an erosion risk map based on the distribution of soil loss over Eyiohia River sub watershed was prepared. The ranges of the erosion rates and their suggested classes were inferred for identification of the critical sub-watersheds.

Table 13 Erosion risk and prioritization classes of sub watersheds for conservation

S/No	Soil Loss range ($t\ ha^{-1}\ y^{-1}$)	Risk Categories	Priority classes	Sub watershed	Area (Km^2)
1	0-12	Low	VI	F	38.4
2	12-25	Moderate	V	E	51.9
3	25-50	High	IV	G	27.3
4	50-80	Very high	III	H	24.5
5	80-125	Severe	II	AD	199.8
6	>125	Very severe	I	BC	200.1

The critical sub-watersheds were then prioritized related to management scenarios for reducing soil loss. A particular sub-watershed got top priority due to various reasons, but often the intensity of land degradation and soil loss are used as the basis.

Table 13 above showed that sub watershed "B" & :C" are classified under very sever soil erosion risk class, while sub watershed "A" & "D" are classified under severe erosion risk class and sub watershed "H", "G", "E" and "F" are classified under very high, high, moderate and low erosion risk class respectively.

According to the study result, areas which are classified as very severe erosion class covers an area of 200.1 $Km^{2,}$ while area of severe, very high, high, moderate and low covers an area of 199.8 km^2, 24.5 km^2, 27.3 km^2, 51.9 km^2 and 38.4 km^2 respectively

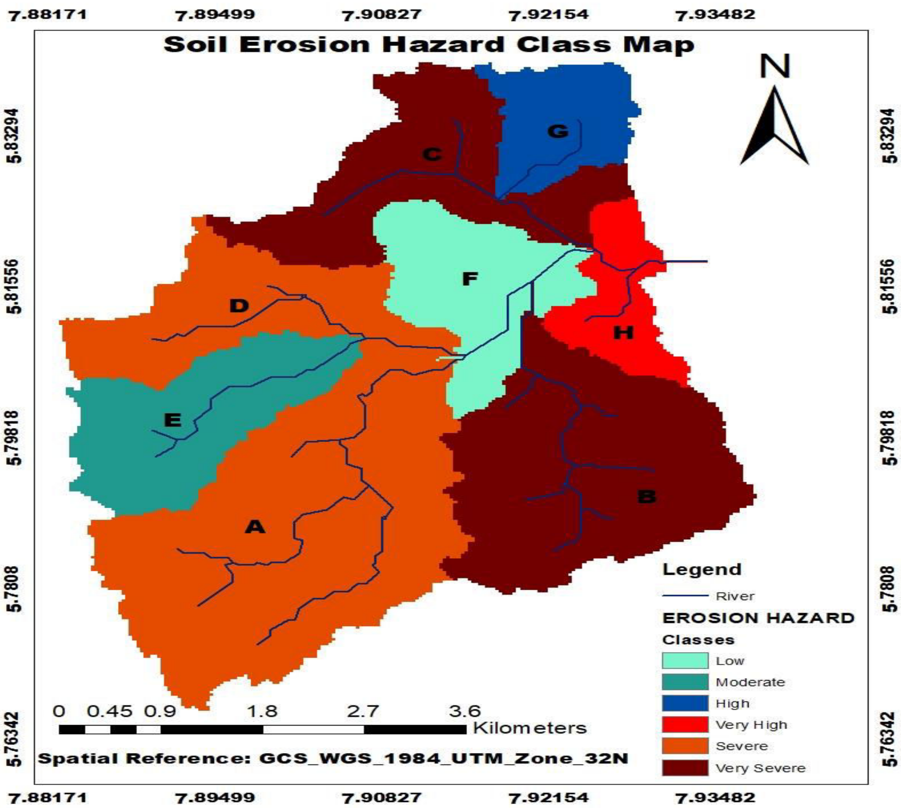

Figure 14 Map of Erosion Risk classes per sub watershed Level

Based on table 13 and figure 14 Results revealed that soil with erosion severity classes of high, very high, severe and very severe jointly accounted for 96% of the total soil loss of the entire eyiohia sub-watershed covering 83% of the total area. Analysis showed that top priority for soil conservation measures must be given to sub-watershed B" & :C" under priority (I) in the first stage for immediate conservation and erosion control and sub-watersheds "A" & "D", "H", "G", "E" and "F" can be considered for second, third, fourth fifty and sixty phase respectively for holistic conservation/management measures for better ecosystem functioning. The implication is that there is need to design appropriate land management practices so as to bring the amount of soil loss in all areas of the Eyiohia sub-watershed down to below the maximum tolerable soil loss value.

4.7 Soil Loss Tolerance

Soil loss tolerance (known as 'T-values' in soil science) is the maximum level of soil erosion that will permit crop productivity to be sustained at economic levels indefinitely (FAO 1986). Rose (1994) established annual soil loss tolerable limits to 10 t ha^{-1} y^{-1} for tropical region. Therefore, from the level of soil tolerance limits recommended by Rose (1994), the means annual soil loss for the study area for 1996, 2006 and 2016 with their corresponding mean value of 78.9 t ha^{-1} y^{-1}, 101.37 t ha^{-1} y^{-1} and 127.22 t ha^{-1} y^{-1} respectively were intolerable based on the model soil erosion estimation and hence conservation measures are required.

4.8. Local Perceptions of Soil Erosion and Causal Factors

Perception on soil erosion problem and causal factors varied between sub-watersheds (Table 14). When asked, "what are the most common environmental problems in the watershed are?", local communities listed soil erosion, flooding, landslides and soil fertility decline as the top priority environmental problems. The problem of soil erosion and consequent soil fertility depletion were mentioned by 46% and 36% of the respondents respectively with the majority of which are located in the upstream sub-watershed (Table 14). In regard to severity of soil erosion, 68% of the respondents experience very severe with the majority of farmers in the upstream. Respondents in the lower sub-watershed reported that they have been experiencing slight to moderate level of erosion.

With regard to effects of soil erosion, 45% of the respondents identified soil fertility decline as a principal and most important effect followed by decline crop yield (37%), loss of cultivable land (12%) and flooding (6%). The majority of farmers who identified soil erosion and subsequent reduction in soil fertility status are located in the upstream sub-watershed (Table14). This is because soil properties on a toposequence differ due to degree of detachment, transportation and deposition of soil nutrients down the slope. Understanding this variation along slope is important for farmers and for sustainable utilization and proper management of soil at different slope position. Care must be taken to provided proper soil erosion control and better management practice otherwise this may lead to total or partial displacement of people

Table 14 Farmers perception on soil erosion and crop production

Description	Number		Total
	Upper stream (n=50)	Lower stream (n=50)	
Environmental problem			
Soil erosion	31	15	46
Flooding	7	8	15
Landslide	2	1	3
Soil fertility decline	10	26	36
Soil severity			
Slightly eroded	4	11	15
Moderately eroded	9	8	17
Very severe	37	31	68
Soil erosion effect			
Soil fertility decline	30	15	45
Decline in crop yield	16	21	37
Frequent flooding	1	5	6
Loss of cultivable land	3	9	12

In regard to the causal factors of soil erosion, 47% of the respondents indicated land use land cover change as the immediate cause (Table 15). The underlying causes identified by 31% respondent is population pressure resulting in land fragmentation and shortage cultivable land as indicated by 34% and 44% of respondents respectively. Poverty was also mentioned by 6% of the respondents as causal factor through its effects in limiting people capacities to invest in land and soil fertility management inputs. This perception was widespread among the respondents located in the lower stream sub-watershed.

Other casual factor of soil erosion included were, shortage of cultivable land with majority at the upstream followed by land fragmentation and shortage of grazing land (13%), while cultural practice was said by 9% of the respondents to be contributing to least cause of soil erosion with majority in upstream sub- watershed.

Table 15 Observed causes of soil Erosion over time

Description	Number		Total
	Upper stream (n=50)	Lower stream (n=50)	
Underlying cause			
Population pressure	15	16	31
Poverty	2	4	6
Land use land cover change	22	25	47
Urbanization	11	5	16
Proximate cause			
Shortage of grazing of land	4	9	13
Shortage of cultivable land	26	18	44
Land fragmentation	19	15	34
Cultural practice	1	8	9

4.1.1 Farmers Coping Mechanisms

Result on farmers copping mechanism is presented in table 16 below. Farmers responded on the types of soil amendment practice to improve soil fertility decline, 46% and 42% of respondents mentioned that they use composted manure and mulch as the major coping mechanisms to augment soil fertility and increase crop yield. The use of inorganic fertilizer was reported by 12% respondents; the low adoption of fertilizer could be as a result of high price. Farmers responded also on the types of conservation/management method to improve soil fertility decline caused by soil erosion, 44% of respondents said crop rotation is the common conservation/ management approach they use which majority are located at the upstream. 24% of respondent also pointed out that they use traditional ditch method as a conservation/management measures to mitigate the impact of soil erosion and cope soil fertility decline which majority are in lower stream sub watershed.

Result further indicates that tree planting and terracing were ranked the least copping strategies in the study area. Therefore more have to be done in this regard. It is therefore, important that the extension workers, NGOs and other relevant government parastatals need to train and increase awareness level of the problem and disseminate other lasting copping measures in the area regarding the severity of soil erosion and land use land cover change problems.

Table 16 Farmers coping mechanism

Description	Number		Total
	Upper stream (n=50)	Lower stream (n=50)	
Soil amendment practice			
Use of inorganic fertilizer	5	7	12
Use of compost manure	19	27	46
Mulch	26	16	42
Conservation/management measure			
Terracing	3	1	4
Contour ploughing	4	4	8
Traditional ditches	9	15	24
Bunds	3	4	7
Tree planting	3	1	4
Crop rotation	25	19	44
Strip cultivation	3	6	9

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The land use land cover change in the upper Eyiohia river sub-watershed has resulted in prevalent soil erosion over the land surface and variation in selected soil physicochemical properties. The extent and rate of soil erosion losses occurring in the area have continued to show an increasing and is now a major cause for concern. Increased trend in the mean soil erosion rate in the study period (1996 and 2016) is as a result of most importantly land use land cover change and rainfall erosivity showing significant increase from 1996 to 2016, other combined factors include soil erodibility, slope length-steepness, cover management and management practise over time. Higher mean annual soil loss in cultivated fields and forest areas during the two study periods is brought about by land conversion from forest to farmlands thereby causing further extension in area of cultivated. The cultivated land is expanding with the highest magnitude with an expense of other land use land cover classes.

Significant mean difference seen in selected soil physicochemical parameters of the soil under different land use types is as a result of (not limited) different management and conservation practices on each land use type chiefly linked to land use land cover change over time, others include population pressure and shortage of cultivable land and have inclusively lead to accelerated soil erosion losses in the watershed. Significance mean differences detected in selected soil physicochemical as affected by sub watershed (upstream and downstream) show a strong relation to variation in degree of slope as upstream showing steep slope compared to the downstream which is slopping and has particularly caused significant difference in selected physicochemical properties between upstream and downstream due to differences in soil surface removal, transportation and deposition. Exchangeable bases (CEC, Ca and K), organic carbon and total nitrogen is rated low in the studied area and are presently inadequate to sustain the current land use.

Application of RUSLE model integrating with climatic, soil, topographic and remotely sensed data within a GIS environment was found very helpful in quantifying the past and present LULC and soil erosion status from which an appropriate planning could be made for the future. These tools could thus be applied in other parts of the country for assessment of LULC changes and delineation of erosion-prone areas for prioritization of areas for conservation. The study had some limitations of its own and attempts have been made to optimize some of them. Few among them are difficulty of finding reliable data on conservation practices employed by farmers and lacking permanent management practices, time constraint, difficulty in soil sample collection due to insecurity in the area as a result of incessant herdsmen and farmer clashes.

5.2 Recommendations

The results of land use change/cover-type, soil erosion risk, severity and soil physicochemical properties can assist decision-makers in identification of priority areas and providing a basis for a comprehensive management and sustainable land-use intervention/policy and enhancing watershed rehabilitation and productivity so as to improve the livelihoods of the community. Based on the results of this study, the following recommendations are proposed for immediate action.

- Since Organic Carbon, total nitrogen, calcium, potassium and cation exchange capacity are low in the study area and therefore require build-up of these nutrients in the soils. Measures to improve their replenishment may include, cultivation across slope, farm fallow, prevention of indiscriminate burning of vegetation and encourage practices of incorporating organic residues into the soil.

- Building farmers' capacity to improve their land through active participation by providing soft loans and subsidizing agricultural inputs would have a positive impact on sustainable land management practices in the study area.
- Top priority for soil conservation measures must be given to sub-watershed "B" & "C" under priority (I) in the first stage for immediate conservation and erosion control
- Awareness creation among the society on optimum use of natural resources, practicing appropriate conservation systems, minimizing driving forces such as population pressure and land use land cover change and their respective benefits is so important for sustainable land resource management.
- It is important to note that the steepest slopes show high risk of soil erosion losses, it is therefore recommended that further study be undertaken to establish the suitable soil and water conservation measures that should be implemented in these areas as well as the whole water-shed.

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Appendix 1. Abakaliki station

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1986	0	0	76.1	99.9	187	262.4	444.4	225	198.3	177.4	0	0
1987	7.7	1.7	54	177.7	134.6	133.3	288.2	265.5	179.6	88.2	1	17
1988	11	8.8	44.4	76.3	120	164.7	250.9	257	219.1	101.8	0	8.9
1989	0	0	18	55.8	118.3	163.3	234.1	249	281.5	118.6	0	0
1990	0	0	0	0	0	0	0	0	0	83.7	0	0
1991	0	11.1	34.8	98.3	191	158.6	212.8	255.9	278.5	92.7	0	2.1
1992	0	0	31.3	66.7	135.8	136.9	216.4	213.4	217.6	66.6	16.2	0
1993	0	0	0	0	0	0	0	0	0	0	0	0
1994	9.1	11	78.9	101.8	267,8	456.7	289.2	459.7	321.5	222.2	0	0
1995	15	0	87.9	108.7	266.1	209	567.2	342.8	166	0	0	14.9
1996	0	0	0	41.6	211.8	198.3	276	341.6	210.3	120.7	0	0
1997	0	12.8	47.3	187.9	205.1	232	355.7	193.7	234.6	143.2	0	0
1998	8.9	1.2	0	0	0	0	0	0	284.2	177.3	54.3	0
1999	3.9	12.5	21.2	53	97.5	144.7	231.8	250	229.7	170.6	12.2	0
2000	17.7	4.2	18.5	42.4	111.7	208.8	321.7	341.6	467.1	244	2	9
2001	1.8	0	0	0	0	321.5166.8	432.6	300.5	421.7	51.8	0	0
2002	14.3	23	6	166.3	71.3	222.8	432.1	244.1	341.7	155	0	0
2003	0	10.5	56.7	130.8	105.1	179.6	348.1	250	231	0	0	0
2004	1	0	34	64.3	228.4	299.3	251.7	208.6	0	0	0	0
2005	X	X	X	X	X	X	X	X	X	X	X	X
2006	13	65.8	188	87.6	276.9	239.7	167	245.8	307.5	0	11	2.2
2007	13.7	89.3	0	134.8	283.1	344.9	349.2	563.9	233.4	0	56.3	0
2008	0	0	0	128.3	333.3	271.9	433.6	366	227.2	139.7	102.4	29.6
2009	23.8	7.6	0	79.3	299.6	387.6	433.5	286.6	377.6	178.6	22.2	18.2
2010	6.4	77.3	39.4	189.3	244.3	343.1	277.6	453.4	291.1	144.2	0	34
2011	19.7	0	61.6	48.4	265	542.7	311.1	341.7	250	0	0	0
2012	0	0	0	45.3	191.4	243.7	247	212.3	2437	98.4	10	2.8
2013	0	15.1	0	37.2	243.1	382.4	267.3	227	187.6	177.2	19.8	14.3
2014	2.7	11.3	78.8	56.3	189.3	211.8	298.6	267.3	307.3	97.4	0	0
2015	12.7	0	0	0	0	0	0	312.4	277.3	231.8	0	0
2016	31.3	1.4	89.3	177.4	289.4	208.3	211.9	287.3	271.3	111.1		21

Appendix 2.Ehugbo station

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1986	5.6	15.4	44.2	44.6	90.2	131.4	234.9	178.1	215.6	93.7	14	0
1987	0	14.7	35.2	26.3	84.4	133.3	198.7	270.1	153.8	88.9	0	0
1988	6.7	14.8	25.2	76.6	100	164.7	250.9	257	219.1	101.8	0	8.9
1989	0	0	18	55.8	118.3	163.3	234.1	249	281.5	118.6	0	0
1990	4.3	0	5.3	64.5	112.8	137.7	252.6	217.1	189.5	83.7	13.7	14.5
1991	0	11.1	34.8	98.3	191	158.6	212.8	255.9	278.5	92.7	0	2.1
1992	0	0	31.3	66.7	135.8	136.9	216.4	213.4	217.6	66.6	16.2	0
1993	0	7.1	38.9	52.3	112.8	161.1	297.9	234.4	274.3	65.4	19.8	5.5
1994	9.1	0	18.4	90.2	108.8	188.4	294.8	271	234.4	128.3	11.2	0
1995	4	0	42.1	71.6	112.4	234.1	221	252.1	166	108.3	16	4.3
1996	0	14.5	41	87.1	247.9	235	203.2	251	230	106	10	3.4
1997	3.5	0	37.3	103.8	347	376.5	401.6	193.7	202	132.4	23.8	6
1998	4.6	0	25.9	156.3	412.5	254.8	285.2	224.8	555.6	105.1	12.7	3.4
1999	3.9	12.5	21.2	53	97.5	345.8	231.8	250	312.3	244.8	12.2	9.9
2000	4.2	0	14.9	42.4	111.7	182.6	498.6	246.8	386.7	200	23	2.1
2001	3.9	23.9	20.2	63.7	106.8	166.8	389.9	224.7	381.9	211.3	11	2.7
2002	7	0	27	59.7	85.4	133.6	323.7	209.3	238.1	252.4	10.4	2.2
2003	15	10.5	22.1	130.8	105.1	183.8	214.2	299	232.6	109.4	17.3	3.8
2004	7	7	19.5	64.3	144.6	277.4	251.7	208.6	388.1	79.6	18.5	4
2005	X	X	X	X	X	X	X	X	X	X	X	X
2006	1.9	23.7	41.3	78.9	223.4	143.7	145.9	345.8	432.1	131.9	0	0
2007	0	0	0	0	277.9	145	287.8	431.1	198.5	0	0	0
2008	0	0	27.5	39	243.9	209.6	254.6	255	227.2	117.3	0	11.2
2009	0	0	0	123.8	250.4	345.9	178.9	345.7	534.9	456.4	11	0
2010	4.7	0	112	134	56	150	298.1	177.8	206.6	212.4	0	45
2011	8.1	4	77.7	45.8	188.4	212.3	178	257.8	188.4	234.8	33	56
2012	0	0	0	0	0	0	178.6	197.3	289.1	89.4	0	0
2013	11.4	1.1	23.3	79.4	111.1	109.6	123.9	244.2	194.3	222.3	11	0
2014	0	18.3	11.4	20.3	187.9	166.8	222.5	183.4	211.4	40	0	0
2015	0	3.2	3.3	37.7	133.3	189.9	208.4	200.3	192.4	188.3	1.2	1.4
2016	0	0	0	11.9	177.7	100.1	178.8	291.5	179.4	151.9	14.8	34.5

Appendix 3. Ozizza Station

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1986	0.6	0	34.8	194.4	283.8	256.4	401.5	329.8	224.7	187.3	0	0
1987	0	0.7	0	97.2	188.1	321.7	300.6	254.2	223.7	190.9	0.7	11
1988	4.5	0.1	68.6	198.6	256.3	340.6	311.3	321.9	544.8	187.4	0	1.4
1989	6.7	1.8	77	108.6	217.4	321.9	399.4	380.2	409.6	83.3	0	3.4
1990	0	0	65.4	122.1	89.4	267.6	347.9	311.2	321.9	104.3	0	0
1991	1.8	0	89.5	54.2	187.3	267.1	320	170.1	345.5	34.6	1.7	0
1992	12.6	2.5	25.6	111.1	231.4	209.6	167.4	222.7	367.1	109.5	12.7	7.6
1993	11.5	2.6	78.6	112.4	84.2	213.6	187.9	320.6	111.7	89.5	0	2.5
1994	0	0	0	115.3	210.2	188	331.7	180.4	333.8	90.9	0	0.8
1995	1.8	0.7	78.5	109.6	321.5	220.5	187.6	261	56.4	92.6	0.3	1
1996	0.5	0	21.7	57.8	91.5	277.9	267.4	161.1	340.2	191.4	0	1.7
1997	0	0	34.6	67.5	182.2	198.6	285.4	228.8	374.6	103.5	0.7	2.8
1998	4.7	0.8	56.3	0	0	0	249.6	130.6	657.9	78.1	0.8	0
1999	1.8	2.7	56.9	76.4	118	201.8	342.3	120	321.7	167.8	0	0
2000	0	0	0	232.8	241	198.3	341.3	380	356.3	348.6	51.6	6.4
2001	0.6	11	0	0	327.3	322.8	457.8	567.6	677.9	177.5	0	13
2002	0.8	0	11	0	234.7	455.8	563.2	340	678.9	230	0	17.8
2003	0	0	0	0	207.3	342.6	207.8	311.1	422.7	186.4	0	0
2004	0	41.5	0	175.3	281.6	421.6	355.3	421.5	653,7	140	0	0
2005	X	X	X	X	X	X	X	X	X	X	X	X
2006	0.8	2.5	56.8	160	321	211.9	265.3	326.5	271.8	67.9	0.7	1.5
2007	0.8	6.7	76.4	164.2	322.8	399.1	675.4	345.9	543.2	86.8	0	0
2008	0	0	0	287.4	366.7	432.3	443.4	311.4	341.7	45.2	0	0.8
2009	0	0	0	0	345.9	549.2	377.4	520.1	390.7	43.9	21	1.8
2010	5.8	16	98.4	267.3	653.4	441.4	311.8	320.7	410.2	221.6		0
2011	1.6	0	0	0	267.3	347.6	419.4	444.2	398.4	87.5	0	0
2012	3.8	22	109.4	467.3	385.2	571.6	354.6	345.7	339.9	110	0.8	31
2013	0	0	181.6	320.1	331.4	420.7	567.3	375	278.1	188	0	0
2014	0.7	0	0	250.3	254.4	218.6	378.7	181.6	310.7	432.1	0	0
2015	1.9	16	51.5	180	115	250.2	170	189.3	239.6	89.4	0	0
2016	0.6	0.7	12	18	251	189	280	341.6	231.8	0	0	0

Appendix 4. Statistical Significance

Tests of Between-Subjects Effects

Source	Dependent Variable	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[k]
Corrected Model	Sand	.033	.255	5.472	.594
	Silt	.045	.228	4.736	.534
	Clay	.406	.044	.729	.127
	B_density	.003	.433	12.225	.907
	T_Porosity	.004	.415	11.367	.886
	Mean waight diameter	.000	.564	20.659	.989
	Water Stable Aggregate	.004	.407	10.993	.875
	Field Capacity	.001	.507	16.453	.967
	Permanent wilting point	.950	.000	.004	.050
	Water hoilding capacity	.000	.592	23.182	.995
Intercept	Sand	.000	.984	1004.970	1.000
	Silt	.000	.897	140.004	1.000
	Clay	.000	.842	85.226	1.000
	B_density	.000	.996	4521.845	1.000
	T_Porosity	.000	.996	3758.909	1.000
	Mean waight diameter	.000	.986	1161.026	1.000
	Water Stable Aggregate	.000	.991	1733.443	1.000
	Field Capacity	.000	.966	461.222	1.000
	Permanent wilting point	.000	.757	49.788	1.000
	Water hoilding capacity	.000	.944	269.509	1.000
watershed	Sand	.033	.255	5.472	.594
	Silt	.045	.228	4.736	.534
	Clay	.406	.044	.729	.127
	B_density	.003	.433	12.225	.907
	T_Porosity	.004	.415	11.367	.886
	Mean waight diameter	.000	.564	20.659	.989
	Water Stable Aggregate	.004	.407	10.993	.875
	Field Capacity	.001	.507	16.453	.967
	Permanent wilting point	.950	.000	.004	.050
	Water hoilding capacity	.000	.592	23.182	.995
Error	Sand				
	Silt				
	Clay				
	B_density				
	T_Porosity				
	Mean waight diameter				
	Water Stable Aggregate				
	Field Capacity				

Appendix 5. ANOVA

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F
Corrected Model	Sand	280.056[a]	1	280.056	5.472
	Silt	542.302[b]	1	542.302	4.736
	Clay	42.936[c]	1	42.936	.729
	B_density	.092[d]	1	.092	12.225
	T_Porosity	125.876[e]	1	125.876	11.367
	Mean waight diameter	6.230[f]	1	6.230	20.659
	Water Stable Aggregate	13.572[g]	1	13.572	10.993
	Field Capacity	672.222[h]	1	672.222	16.453
	Permanent wilting point	.180[i]	1	.180	.004
	Water hoilding capacity	694.402[j]	1	694.402	23.182
Intercept	Sand	51434.936	1	51434.936	1004.970
	Silt	16032.436	1	16032.436	140.004
	Clay	5020.020	1	5020.020	85.226
	B_density	34.196	1	34.196	4521.845
	T_Porosity	41625.742	1	41625.742	3758.909
	Mean waight diameter	350.154	1	350.154	1161.026
	Water Stable Aggregate	2140.106	1	2140.106	1733.443
	Field Capacity	18843.876	1	18843.876	461.222
	Permanent wilting point	2248.969	1	2248.969	49.788
	Water hoilding capacity	8072.969	1	8072.969	269.509
watershed	Sand	280.056	1	280.056	5.472
	Silt	542.302	1	542.302	4.736
	Clay	42.936	1	42.936	.729
	B_density	.092	1	.092	12.225
	T_Porosity	125.876	1	125.876	11.367
	Mean waight diameter	6.230	1	6.230	20.659
	Water Stable Aggregate	13.572	1	13.572	10.993
	Field Capacity	672.222	1	672.222	16.453
	Permanent wilting point	.180	1	.180	.004
	Water hoilding capacity	694.402	1	694.402	23.182
Error	Sand	818.889	16	51.181	
	Silt	1832.222	16	114.514	
	Clay	942.444	16	58.903	
	B_density	.121	16	.008	
	T_Porosity	177.182	16	11.074	
	Mean waight diameter	4.825	16	.302	
	Water Stable Aggregate	19.754	16	1.235	
	Field Capacity	653.702	16	40.856	

Appendix 6 Accuracy Analysis (kappa statistics)

Kappa

Observed Kappa	Standard Error	.95 Confidence Interval	
0.8677		Lower Limit	Upper Limit
Method 1	0.0335	0.802	0.93234
Method 2	0.0337	0.8017	0.9337

0.9716 maximum possible unweighted kappa, given the observed marginal frequencies

0.8931 observed as proportion of maximum possible

Proportions of Agreement

Category	Maximum Possible	Chance Expected	Observed	.95 CI of Observed Lower Limit	.95 CI of Observed Upper Limit
1	0.9783	0.1974	0.82	0.6808	0.9095
2	0.9429	0.1404	0.7436	0.5757	0.864
3	0.9615	0.1018	0.8214	0.6242	0.9328
4	1	0.0781	0.9048	0.6817	0.9833
5	0.8571	0.0491	0.8571	0.5615	0.9749
Composite	0.9783	0.2333	0.8986	0.8326	0.9414

	G data							
	Class name	Cultivated land	Forest area	Bare land	Settlement	Grazing land	Total	User accuracy
Map data	Cultivated	41	4	0	1	0	46	89.1
	Forest area	3	29	1	0	0	33	87.9
	Bare land	1	1	23	0	0	25	92.0
	Settlement	0	1	0	19	0	20	95.0
	Grazing	0	0	2	0	12	14	85.7
	Total	45	35	26	20	12	138	
	Producer accuracy	91.1	82.86	88.5	95	100		

Appendix 7

EFFECT OF LAND USE LAND COVER CHANGES ON SOIL EROSION LOSSES AND SOIL PHYSICO-CHEMICAL PROPERTIES IN UPPER EYIOHIA RIVER WATERSHED, NIGERIA

Introduction

The objective of this stratifield questionnaire is explore the extent land use/land cover change, on soil properties and soil loss and ultimately on people's livelihoods within Eyiohia watershed in Afikpo North over the past 30 years. The study is conveyed for academic purpose. Hence, the outcome from the various focused group discussions will be treated with utmost confidential and cannot be traced to the persons who provided them.

Thank you in advance for your cooperation.

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I. Identification

1. Administrative Unit: **State** Ebonyi State: Local Government Area (**L.G.A**): Afikpo North
2. Name of community (upstream & downstream)________
3. Village Name _____________________

2.0 Perceptions on Land use/Land cover change

2.1 if there have been land use/ land cover change in the past 30 years, what is the trends and trajectories of the change

S/N	Land use type/ change in:	Increase	Decrease	No change
1	Crop land			
2	Forest			
3	Bare land			
4	Settlement			
5	Grazing			

3.0 Causes of the observed land use/land cover change

3.1 What are the underlying causes?

a. Population pressure
b. Poverty
c. Low crop yield
d. Urbanization/industrialization

3.2 What are the proximate causes?

a. Shortage of grazing land
b. Shortage of cultivable land
c. Land fragmentation
d. Cultural practice

3.3 Following the land use/land cover change, which environmental problems are very common in your area?

a. Soil erosion
b. Flooding
c. Landslide
d. Soil fertility decline

3.4 If soil erosion is the most common environmental problem considering land use land cover change as the casual factor. How severe is it?

a. Slightly eroded
b. Moderately eroded
c. Severe
d. very severe

3.5 What are the consequences of the severe soil loss due to land use land cover change?

a. Decline in soil fertility
b. Decline in crop yields
c. Frequent flooding
d. Loss of cultivable area?

3.6 What is the trend of soil erosion on your farmland?
a.) Increasing b.) Decreasing c.) No change

4.0 Impact of land use land covers change/consequences on the rural livelihood

4.1 On which land section you face severe erosion

a. Cultivated land
b. Forest land
c. Grazing land
d. Bare land
e. Settlement area

4.2 Did you observed any decreased in farm size as a result of soil erosion
1. Yes 2. No

4.3 What are the major problems or constraints for crop production in your farm as a result of land use land cover change?

a. Land is too steep
b. Small size of farm land
c. Decline in soil fertility

5.0 Perception on coping strategies

5.1 Do you use some kinds of practices to maintain or enrich soil fertility

1. Yes 2. No

5.2 If yes, which of the amendments do you use?

a. Use of inorganic fertilizers
b. Use of compost manure
c. Use of mulch

5.3 Do you receive support like funds for coping strategies

1. Yes 2 No

5.4 List four main staple crops that you grow in order of highly cultivated

RANK 1-4

a. Cassava ☐
b. Maize ☐
c. Vegetable ☐
d. Yam ☐

5.5 which of the following is the best management/conservation method that best control soil loss and boost farm yield for

Conservation/management measure	Yes	No
Terracing		
Contour ploughing		
Traditional ditches		
Bunds		
Tree planting		
Crop rotation		
Strip cultivation		

Thanks for you kind cooperation!