GEOTECHNICAL ASSESSMENT OF GULLY EROSION SITE IN UMUAGOR URUALLA, IMO STATE SOUTH EASTERN NIGERIA

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CERTIFICATION

This is to certify that this work **"GEOTECHNICAL SOIL ASSESSMENT OF GULLY EROSION SITE IN UMUAGOR URUALLA, IMO STATE SOUTH EASTERN NIGERIA"** was carried out by **OTUMCHERE VICTORIA NNEOMA (20134872138)** in partial fulfillment for the award of the degree of (M.Sc) in the Department of Environmental Technology, School of Environmental Sciences, of the Federal University of Technology, Owerri.

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DEDICATION

This research work is dedicated to Almighty God.

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ABSTRACT

Erosion is one of the major environmental hazards currently ravaging the southeastern part of Nigeria, especially Imo-state. This present study was conducted to assess the impact of Umuagor-Urualla gully erosion site. Analysis of undisturbed soil samples collected at three distinct positions (surface, subsurface and base of the gully) showed that the liquid limit and plastic limit for sample 1 was NP (non-plastic), with Plasticity Index of 0%, while the Plasticity Index for samples 2 & 3 were 12% and 18% respectively, average shear strength was 177.8 KN/m^2, average bulk density was $1.8mg/m^3$ and dry unit weight was $1.6mg/m^3$. Advanced Geosciences inc. ID software was used to process the vertical electric sounding (VES) result which showed that the resistivity of the underlying material ranged from 671ohm-m to 3684ohm-m; with an average depth of 7.5m. These results showed that the incidence of gully erosion in Umuagor-Urualla is predominantly controlled by the nature of the underlying material (shale and silt stone). Thus adequate drainage channelization from the advancing gully head into Orashi River is recommended.

Key words: *erosion, vertical electrical sounding, hazards, plasticity index.*

CHAPTER ONE

INTRODUCTION

1.0 BACKGROUND OF THE STUDY

A geo-hazard is any geological state which has the potential to create widespread damage such as earthquake, erosion, flood, landslides etc. The occurrences of geo-hazards within the environment can adversely affect man's well being, the environment, and leads to financial, environmental and or human losses. The resulting loss depends on the capacity of the population to support or resist the disaster, and their resilience (Amangabara, 2012).

"Erosion" comes from erodere, a Latin verb which means "to gnaw". Erosion gnaws away at the earth like a dog at a bone. Erosion is the process by which the surface of the earth is worn away by the action of water, wind, glaciers and waves etc. It is the process by which the agents of soil erosion wear away or carry away soil materials and transport it from one locality to another where it is eventually deposited (Grosh, 1994).

Erosion, though a natural process is often intensified by anthropogenic activities. On the other hand, soil erosion remains the world biggest environmental problem that affects the sustainability of both flora and fauna indirectly all over the world.

Over 60% of the soil on earth is said to have displayed degradation phenomena as a result of soil erosion, salinity and desertification (Okin, 2002).

Soil erosion is a gradual process that occurs when the actions of water, wind and other factors eat away and wear down the land, causing the soil to deteriorate or disappear completely (Amangabara, 2012). It is the removal of soil particles from one place to another. It occurs from region to region and based on the type of clay minerals present in the soil. It is usually, an accelerated process under which soil is bodily displaced and transported away faster than it can be formed. Rain striking the ground helps to break soil particles loose and then the runoff carry away loosed soil. This means, soil erosion starts with rain droplets, which dislodge soil particles, removing them and eventually depositing them at a new location entirely different from the original site of displacement.

On a global scale, soil erosion is greatly associated with misuse of the land where the soil is inadequately protected by a plant cover. Other factors that contribute to soil erosion include: geology, geomorphology, climate, soil texture, nature and bio-diversity of the area (Ofomata, 1988).

Gully erosion is the terminal stage of soil erosion, which can assume great dimensions. It has led to abandonment of ancestral homes, loss of farmlands leading to increase in rural-urban migration and pollution, siltation and flooding due to reduced capacity of drainage systems. Numerous definitions of gullies have

been proposed in the past (Albert, 2006). These range from simple statements that a gully is a well defined water worn channel (Monkhouse and small, 1978). Gully erosion is therefore, an advanced stage of erosion and it is accelerated by increased impervious surface (Amangabara, 2012). It is however, the most prominent feature in the landscape of Imo State and most communities in the state have a tale of woe as a result of ever increasing hazard posed by gullies. Hence, there is an urgent need to assess the level of geotechnical index properties that could possibly aid gully erosion if left unchecked in Ideato North Local Government Area of Imo State, Nigeria.

1.1 STATEMENT OF PROBLEM

Plate1: Google Earth Image of Umuagor, Urualla Gully, Ideato

Soil erosion is one of the prominent environmental hazards currently ravaging the land surface of Southeastern part of the country, especially Imo State.

Soil is one of the valued ecosystem components, resources, that performs the following functions: food production, filtering and transformation, physical and cultural environment for man, source of raw materials (EU, 2004). The loss of these resources / functions, through land degradation processes such as erosion is a serious environmental problem. Soil erosion is greatly accelerated by anthropogenic activities ranging from excavation of red earth and sand during sand regolith, mining, uncontrolled population growth, construction of roads without adequate drainage channels to poor land use pattern, poor agricultural practices.

The geology of Umuagor Urualla is composed of weak and friable soils which are poorly consolidated. During rainy season, the inhabitants of the area especially those living very close to the erosion site are greatly affected by the landslides and slumping resulting from the gully incidence; this usually results to loss of ancestral homes, agricultural land as well as economic trees. The cumulative impact leaves the inhabitants homeless, jobless and miserable. Consequently, the threats posed by gaping and daunting large gullies to farmlands, roads and human settlements are so numerous. Several areas in Imo State have been devastated by different types of soil erosion ranging from rill erosion, sheet erosion to gully erosion. The incidence of gully erosion is a common phenomenon in Urualla community which has several negative effects on the physical, psychological and economic growth of the inhabitants.

1.2 AIM AND OBJECTIVES

The aim of study is to assess the geotechnical index properties that result to gully erosion in Urualla (Umuagor), Ideato North Local Government area, Imo State. The aim was realized through the following objectives;

1. To assess the cause of gully erosion in Umuagor Urualla.
2. To identify the factors affecting gully erosion formation.
3. To map out depth and geometry of the gully.
4. To identify the various land use pattern in Urualla.
5. To measure environmental hazards associated with the gully.
6. To determine drainage direction.

1.3 JUSTIFICATION OF THE STUDY

Assessment of geotechnical index properties has the potential to x-ray the causes of gully erosion in a region, as well as factors affecting gully erosion formation and as such, serves as a reference tool to individuals and researchers in the field of environmental science in the control of erosion especially within Umuagor Urualla gully erosion site in Ideator North Local Government of Imo State.

1.4 SIGNIFICANCE OF THE STUDY

The study on geotechnical soil assessment of umuagor-urualla gully is significant for the following reasons:

1. The result of this study shall provide a baseline data for further studies on erosion.
2. It will assist in the identification of various anthropogenic activities / factors that influence gully erosion and take adequate precautionary measures to control it.
3. It will help the government and relevant agencies in the design of appropriate gully control measures

1.5 SCOPE OF THE STUDY

This study will focus on assessing the level of geotechnical index properties (Moisture content, Atterberg limit,Bulk density, Grain size and Shear strength) contribution to gully erosion in Umuagor Urualla gully erosion site in Ideator North local Government area, Imo State.

1.6 LIMITATIONS OF THE STUDY

The limitations encountered during this research work include

1. Financial constraints
2. Dearth of research materials.
3. Poor road network leading to the gully site.

CHAPTER TWO

LITERATURE REVIEW

2.1 CONCEPT OF SOIL EROSION

Soil is the earth's fragile skin that anchors all life on earth. It consists of various species that create a dynamic and complex ecosystem and is one of the most vital resources to humans. Soil is the top layer of the earth which generally supports the growth of vegetation; it is made up of the following elements: loose organic materials, organic matter or humus, soil water, air and microorganisms or bacteria (Iloeje et al., 1999).

Soil is a dynamic natural body on the surface of the earth in which plants grow, composed of mineral and organic materials and living forms (Idah et al., 2008). It is a mixture of minerals, organic matter, gases, liquid and myriad of organisms that can support life (Dorren et al., 2004).

Soil is the unconsolidated mineral or organic material on the immediate surface of the earth and serves as a natural medium for the growth of land plants, storage of water, supply and purification, modifier of atmosphere and habitat for organisms that take part in the decomposition and creation of habitat for other organisms (Aina et al., 1997). It is sediment dominantly composed of transported and deposited material resulting from soil erosion.

2.1.1 SOIL EROSION

The word “erosion” is derived from a Latin verb “erodere” which means “to gnaw”. Erosion gnaws away at the earth like a dog at a bone. Soil erosion is a natural occurring process that affects all land forms (Lal, 1990).

In agriculture, soil erosion refers to the wearing of fields top soil by the natural physical forces of water and wind or through forces associated with farming activities such as tillage. Erosion, whether it is by tillage, Water or wind involves three distinct actions such as soil detachment, movement and deposition. Top soil, which is high in organic matter, fertility and soil life, is relocated elsewhere “on-site” where it builds up over time or is carried “off-site” where it fills in drainage channels. Soil erosion reduces cropland productivity and contributes to the pollution of adjacent water courses, wetlands and lakes (OMAFRA fact sheet 2013). Soil erosion is caused by non-infiltrated water that runs off a field. It is astonishing that often the process of soil erosion and water infiltration into the soil is not well understood by this group of individuals – scientists, environmentalists, farmers and the masses. Erosion occurs naturally but, is often made worse by human land clearing activities or practices; erosion takes away soil in layers and the first layer of the soil to erode in croplands in topsoil (Lal, 2001). Despite scientific and empirical evidence explaining these processes, many people still

think that the soil has to be loosened by tillage to increase water infiltration and reduce run off.

According to Nyakatawa et al (2001), soil erosion is a major environmental problem worldwide. Soil erosion by water and runoff is often accepted as an unavoidable phenomenon associated with agriculture on sloping land but, soil loss by erosion or runoff is not an unavoidable process. According to Lal (1982), (Fox and Bryan, (1999) and (Grosh and Jarrett, 1994), occurrence of erosion damage on cultivated land is merely a symptom of inappropriate land use within that ecological environment. It is not nature (slope and rainfall intensity), but rather irrational methods of farming used by man which are responsible for erosion and its negative consequences. Thus, farmers can, through the utilization of site specific and adopted farming systems and management practices, effectively control erosion, reduce runoff and increase water infiltration on their lands (OMAFRA factsheet, 2013).

Runoff water is lost to crops while, infiltrated water can be effectively used by plants which is very necessary in dryer climates. Most conventional farming practice in use in most parts of the world have negative consequences in soil and water preservation as well as the general conservation of the environment. This is due to misuse of soil, monoculture, absence of cover crops and the use of tillage

tools that leave the soil bare and pulverize it excessively; leaving it in such a condition that it can be easily carried away by heavy rains (Parsons et al; 1994).

The utilization of inadequate technologies that are not adapted to site specific conditions (slope and rainfall intensities) results in runoff, soil erosion and subsequent land degradation. Hence, the consequence of traditional cultivation methods is the gradual loss of soil and fertility until the land becomes unproductive. The inability of agricultural managers and landowners to understand the significance of erosion as well as intensive weathering under hot, humid conditions, has resulted to the widespread distribution of weak, badly eroded and infertile soils all over the tropics and subtropics (Kerchof, 2000). But the same process has also happened in more temperature climates (such as united states, Russia etc). Eroded, unproductive and abandoned land as well as advanced signs of desertification is silent testimonies of this phenomenon all over the world. Besides making agricultural soil unproductive, erosion of agricultural land and runoff results in the deposition of soil particles in unwanted areas (sedimentation of roads, creeks, rivers, lakes, dams etc) with all its negative consequences for traffic, the generation of electric power, the delivery of drinking water, leisure areas, etc; resulting in important expenditures for the government as well as for society as a whole (Onu, 2011).

Furthermore, the importance of erosion control is not restricted to the maintenance of the productive potential and fertility of soils for future generations; it is also an effective means to ensure employment in rural areas and reduce rural exodus (Derpsch et al; 1991). Efficient erosion control is therefore very advantageous from the ecologic and social perspectives, besides being highly significant from an economic point of view.

2.1.2 SOIL EROSION PROCESS

Soil erosion is a worldwide phenomenon which ravages large areas of land particularly in high rainfall or windy locations (Amangabara, 2013). Soil erosion has been documented from the earliest of times as severe environmental hazard (Poesen et al; 1996; Kakembo et al; 2010; Tebebu et al; 2010). Recent estimates suggest that about seven percent (7%) of the world's topsoil is lost yearly to erosion in all ramifications, infact, the World Resources Institute claims that Burkina Faso loses 25 tonnes of soil per hectare per year (Waugh, in Kalu 1995).

Soil erosion occurs when soil particles are carried off by water or wind and deposited somewhere else. Erosion begins when rain or irrigation water detaches soil particles. Relf (2001) stated that when there is too much water on the soil surface, it fills surface depression and begins to flow. With enough speed this surface runoff carries away the loosed soil. Thus, the energy or force generated by the rain drop or flowing water has the ability to cause detachment and

transportation of soil particles and this ability is referred to as Erosivity of the water (Lal. 1998).

This process of detachment of soil particles by rain drops is shown in the diagram below:

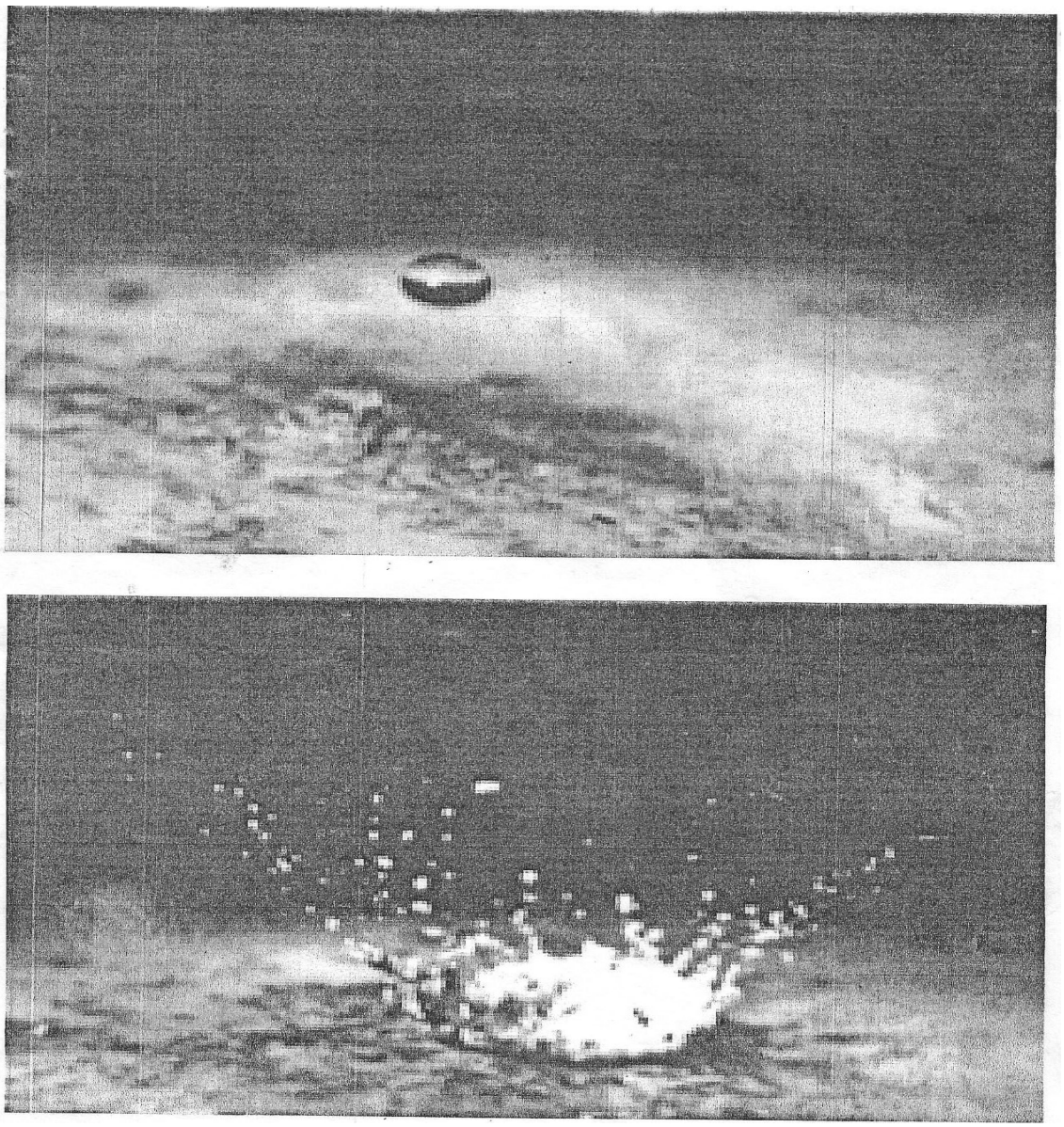

Fig: 2a and Fig 2b Soil Erosion Processes

Figures 2a and 2b: the impact of raindrops upto 6mm (0.24 inch) in diameter bombard the soil surface at impact velocities of up to 32km per hour (20 mph). This force throws soil particles and water in all directions on a distance of upto 1m (3.3 feet).

Runoff and erosion start with raindrop impact on bare soil surface. Soil splash seen on fence posts, or on walls in a field or plot of bare soil,is evidence of the force of large raindrops striking bare soil. (Harold, 1972), reported that in one year, raindrops deliver to an acre of land an impact energy equivalent to 20tons of TNT (50 t/ha dynamite). The impact of falling raindrops disaggregates the soil into very fine particles, which clog soil pores and create a surface seal that impedes rapid water infiltration as shown in figure 2.1

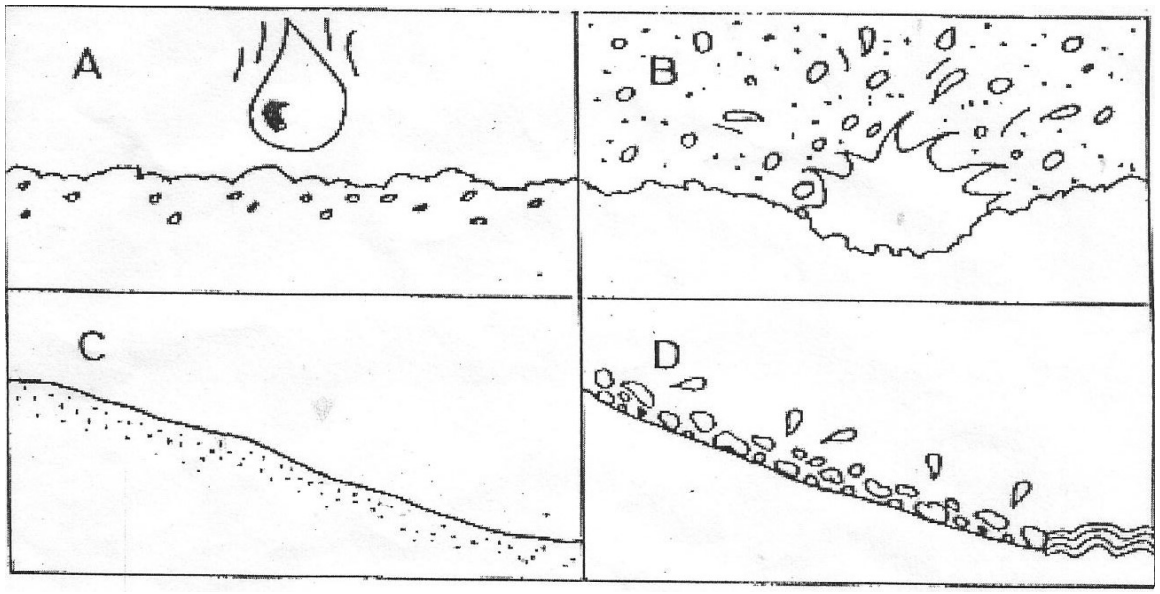

Figure 2.1: Soil Erosion Processes

2.1.3 PHASES OF THE EROSION PROCESS

The impact of rain drops on the bare soil surface (A). causes the detachment of small soil particles (B), that clog the pores and form a surface sealing (C). The water that runs off carriers soil particles, which are deposited down slope when the runoff velocity is reduced (D).

(Derpsch, et al., 1991)

Due to surface sealing, only a small portion of rainwater can infiltrate into the soil; most of it runs off over the soil surface, therefore is lost to plants and causes erosion damage when flowing down the slopes. On the other hand, when the soil is covered with plants or plant residues, the plant biomass absorbs the energy of falling raindrops and rainwater flows gently to the soil surface where it infiltrates into soil that is porous and undisturbed.

In this way, soil cover impedes the clogging of soil pores (figure 2.1). The drying of surface sealing, results in soil crusting, which may hinder or impede the germination and emergence of crop seeds. Soil crusting only develops under a condition of bare soil. Soils highly susceptible to crusting do not present this problem once no-tillage and permanent cover systems are used.

2.1.4 SOIL EROSIVITY

Erosivity is an expression of the ability of an agent of erosion to cause soil detachment and its transportation (Amangabara, 2012). It is the measure of the potential ability of soil, regolith, or other weathered material to be eroded by rain, wind or surface runoff.

According to Lal, (2011) erosivity is the driving force of erosion agents that cause soil detachment and transportation. Historically, the term erosivity was first associated with an R- factor (rainfall-runoff erosivity factor) in the universal soil loss equation (USLE) (OMAFRA fact sheet). The factors that influence erosivity include:

i. Climate, especially rainfall intensity and duration

ii. Velocity of the runoff, which in turn is influenced by the volume of the runoff and the slope. Thus, any factor (natural or human) which tend to concentrate runoff or increase the slope are indirectly contributing to erosion (Amangabara, 2012). It should also be noted that sediment load of the runoff is an important factor in erosivity, since the sediment itself has scouring effects on the flow channels.

2.1.5 SOIL ERODIBILITY

One key parameter for modeling soil erosion is the soil erodibility, expressed as the k-factor in the widely used soil erosion model, the universal soil loss equation (USLE) and its revised version (RUSLE). The k-factor, which expresses the susceptibility of a soil to erode, is related to soil properties such as organic matter content, soil texture, soil structure and permeability (OMAFRA fact sheet).

According to Amangabara (2012), erodibility is a measure of the soil's susceptibility to detachment and transportation by the agents of erosion. Although, soil resistance to erosion depends in part on topographic position, slope steepness and the amount of disturbance created by man, for example, during tillage the properties of the soil are the most important determinants.

Erodibility varies with soil texture, aggregate stability, shear strength, infiltration capacity, organic and chemical content (Morgan, 1986).

By definition, it is an estimate of the ability of soils to resist erosion, based on the physical characteristics of each soil.

Generally, soils with fast infiltration rates, high level of organic matter and improved soil structure have a greater resistance to erosion. Soil erodibility process is influenced by soil properties (soil texture and structure, especially with respect cohesiveness, particle size distribution, structural stability, organic matter content

and nature of clay minerals); degree of ground cover, infiltration capacity of the soil and nature of the underlying substratum characteristics also affect soil erodibility (Amangabara, 2012).

2.2 FACTORS OF SOIL EROSION

The major variables affecting soil erosion are climate, soil, vegetation and topography. Of these, the vegetation and to some extent, soil may be controlled. The climatic factors and the topographic factor, except slope length are beyond the powers of man to control (Amangabara, 2012). In other words, these factors can be simplified into the following:

i. The amount and intensity of rainfall and wind velocity.
ii. Topography with special reference to slope of land.
iii. Physical and chemical properties of soil.
iv. Ground cover, its nature and extent

2.2.2 AMOUNT AND INTENSITY OF RAINFALL AND WIND VELOCITY

Rainfall is the most forceful factor causing erosion through splash and excessive runoff. Raindrop erosion is splash, which results from the impact of water drops, directly on soil.

Although the impact of raindrops on water in shallow streams may not splash soil, it does cause turbulence, providing a greater sediment carrying capacity. Large drop may increase the sediment carrying capacity of runoff as much as 12times (OMAFRA fact sheet). The greater the intensity and duration of a rainstorm, the higher the erosion potential.

2.2.3 TOPOGRAPHY WITH SPECIAL REFERENCE TO SLOPE OF LANDS

Slope accelerates erosion as it increases the velocity of flowing water. Small difference in slope makes big difference in damage.

According to the law of hydraulics, a four time increase in slope doubles the velocity of flowing water. This doubled velocity can increase the erosive power four times and carrying capacity by 32 times.

According to Amangabara (2012), topographic features that influence erosion are degree of slope, length of slope and size and slope of the watershed. Obviously, the steeper the slope, the greater the erosion for a number of reasons: there is more splash downhill, there will be more runoff and it will flow faster, there will be increase in flow velocity; while on a flat surface, raindrop splash soil particles randomly in all directions, on sloppy ground, more soil is splashed down slope

than up slope. The extent of erosion is not just proportional to the steepness of the slope, but rises rapidly as the slope increases (Hugo, 2009).

2.2.4 PHYSICAL AND CHEMICAL PROPERTIES OF SOIL

The soil properties that influence erosion include: soil structure, texture, organic matter, moisture content, density or compactness and the amount and kind of salts present. Some soils erode more readily than others under the same conditions. There is less erosion in sandy soil because water is absorbed readily due to high permeability. More organic manure in the soil improves granular structure and water holding capacity. As organic matter decreases, the erodibility of soil increases. Fine textured and alkaline soils are more erodible (OMAFRA factsheet).

Generally, soil detachability increases as the size of the particle increase but soil transportability increases with decrease in particle size. Clay particles are more difficult to detach than sand, but are more easily transported on a level land and much more rapidly on slopes (Agrinfo factsheet).

2.2.5 GROUND COVER, ITS NATURE AND EXTENT

The presence of vegetation ground cover retards erosion. Therefore, it is important to maintain the soil covered with plants or with plant residue all year round, avoiding exposure to climatic agents (Dresch et al., 1991). Forests and grasses are

more effective in providing cover than cultivated crops. Vegetation intercepts the erosive beating action of falling raindrops, retards the amount and velocity of surface runoff, permits more water flow into the soil and crates more storage capacity in the soil. It is the lack of vegetation that creates erosion permitting condition (OMAFRA facts).

2.3 TYPES OF EROSION

Soil erosion can be divided into two very general categories" geologic erosion and accelerated erosion.

GEOLOGIC EROSION

This refers to the formation of and loss of soil simultaneously which maintain the balance between formation and various loses.

It occurs where soil is in its natural environment surrounded by its natural vegetation. This has been taking place naturally for millions of years and has helped create balance in uncultivated soil that enables plant growth (Amangabara, 2012). It is normal process which represents the erosion of soil in its normal condition without influence of human being. It is also known as natural or normal erosion. The various topographical features such as existence of stream channels, valleys etc are the results of geologic erosion.

ACCELERATED EROSION

This is an excess of geologic erosion. It is human induced erosion as a result of land use practices such as poor farming methods, over grazing, deforestation and urbanization. Accelerated erosion takes place by the action of water (and ice) known as hydrological erosion, air (wind) known as wind erosion (castenmiller, 1988). Wind erosion occurs in desert areas and hydrological erosion consists of splash (rain drop erosion), sheet, rill, gully, stream bank erosion, glacial erosion, snow erosion and anthropogenic erosion. In accelerated erosion, various forces involved include:

i. Attacking force of water or wind which remove and transport the soil particle from one place to another.

ii. Retarding forces of water or wind which resists the erosion. In general, accelerated erosion is known as soil erosion or erosion. Accelerated erosion is broadly categorized into two namely: water erosion and wind erosion.

WIND EROSION

This is the process of detachment, transportation and deposition of soil particles by the action of wind. Basic causes of wind erosion include:

(i) Soil is loose, finely divided and dry.

(ii) Soil surface is smooth and bare

(iii) Wind is strong to detach the soil particles from soil surface.

WATER EROSION

Water erosion comes in different forms with various causes while the causes of erosion by water are generally natural, human impact will always play a role. Thus, water erosion includes: rain drop erosion, sheet erosion, rill erosion, gully erosion and stream bank erosion.

RAINDROP EROSION

Raindrop erosion is also known as splash erosion. It results from soil splash caused by the impact of falling raindrops. Small soil particles are detached and sent airborne through the impact of raindrops on soil. According to Brady (1974) and (Farell et al., 1974), splash erosion is the loosening of soil bond, in which the loosened and separated particles may be subsequently removed by surface runoff. The major effect of surface flow of water is to carry off the soil loosened by splash erosion.

SHEET EROSION

Sheet erosion is the removal of the fairly uniform layer of soil from the land surface by the action of rainfall and runoff. Raindrops break apart the soil structure and its moved down slope by water that flows overland as a sheet rather than definite channels. This occurs frequently during cloud bursts.

RILL EROSION

According to Amangabara, (2012), Rill erosion is the incipient stage of gully erosion. It is immediate between sheet and gully erosion. Most of it occurs on recently cultivated soils where runoff water concentrates in streamlets as it passes downhill. This is the removal of soil along small but visible channels. The channels are several centimeters in depth. This process develops small, short-lived, concentrated flow paths. These paths create a sediment source and delivery system for hill slope erosion. As sediment load increases, ability of the flowing water to detach more sediment decreases. Areas where precipitation rates exceed soil infiltration rates are more prone to this type of erosion.

GULLY EROSION

According to Foster, (1988) gullies are channels caused by concentrated flow and which become so large that they cannot be crossed with farm implement. When formed, gullies could be sufficiently large enough to disrupt farming operation and too large to be filled during normal cultivation (Kirchof, 2000).

Gully erosion is the removal of soil by excessive concentration of running water, resulting in the formation of channels ranging in size from 30cm to 10cm. It is the terminal stage of soil erosion, which can assume great dimensions. It has led to abandonment of ancestral homes, loss of farmlands leading to increased rural exodus, pollution, siltation and flooding due to reduced capacity of drainage

systems. Numerous definitions of gullies have been proposed in the past (Gregong and Walling, 1974). These range from simple statements that a gully is “a well defined water worn channel” (Monkhouse and small, 1978), a definition that could apply to most rivers through to more comprehensive descriptions such as that given by Brice (1966), who regards a gully as “a recently extended drainage channel that transmits ephemeral flow, has steep sides, a steepy sloping vertical head scarp, a width greater than about one foot and a depth greater than about two feet.

According to Fellicana, (2008), gully erosion is an incised cut step-sided channel, with an eroded head cut and slumping side walls. Gully itself is a relatively deep vertical walled channel previously existed (Beths, 1993). Gullies occur when water is channeled across unprotected land and washed the soil along the drainage lines. Several distinguishing characteristics of gullies are noted by Limeson and Kwaad (1980); firstly, gullies are developed where water is concentrated and this may be a direct or indirect result of man’s activities; secondly, gullies typically form in unconsolidated deposits and deeply weathered materials; thirdly, gullies are characterized by intermittent flows that rarely; if ever reach bank-full levels and fourthly, gullies are generally recent features in the landscape and may exhibit phases of rapid growth and finally gully erosion is an advanced stage of erosion and its accelerated by increase in an impervious surface, which provides fast overland flow/runoff.

2.4 AREAS OF ACTIVE GULLY EROSION IN NIGERIA

Gully erosion is the most impressive and striking type of erosion. It has been recognized as one of the major global environmental problems. Many states in Nigeria are currently under the threats of this phenomenal process, south-eastern part of the country being the most affected (Abdulfatai et al., 2014).

According to Amangabara, (2012) states where gully erosion is very predominant in Nigeria include: Anambra state especially the Agulu-Nanka area, Imo State especially the Orlu area, Ideato area (Ideato North-Umuagor-Urualla, Umuturu-Urualla, Umuikpa-Urualla, Umuahirihia-Urualla etc), Abia state, Enugu state, Akwa-Ibom state, Ebonyi state, Edo state, Ondo state, Delta state, Kwara state and River state (Etche Local Government Area).

2.5 CAUSES OF GULLY EROSION

Due to high prevalence of gully erosion in the southeastern part of the country as earlier noted, the region has attracted more attention of a number of researchers to unravel the causes of gully erosion. Thus, works from these areas become imperative. Gully erosion can be caused in a number of ways, having different mechanisms, modes and conditions of formation; some of which are directly

related to the underlying geology and the severity of the surface processes operating on the surface geology and soil cover (Ezechi and Okagbue, 1989).

Observations have also shown that gully erosion, in Nigeria, is more predominant in the sedimentary terrains and perhaps in the basement/sediment contact areas.

Thus, the prevalent occurrence in southeastern Nigeria where most of the gullies take the advantage of the loosely consolidated and sometimes friable rocks such as the Bende Ameke formation in Ideato area of Imo state. Some of the identified natural causes of gully erosion include: tectonism and uplift, climatic factors, geotechnical properties of soil among others (Abulfatai et al, 2014). Anthropogenic causes include farming and uncontrolled grazing practices, deforestation, mining activities and civil works (Asiabaka et al., 1991).

2.6 IMPACTS OF GULLY EROSION

In Nigeria, the impacts of gully erosion are enormous and similar to that obtainable elsewhere in the world and they include:

i. **LOSS OF FARMLAND:** A vast area of farmlands has been lost due to the menace of gully erosion while others are at their various stages of destruction leading to drastic decrease in agricultural productivity and ultimately food shortage and can lead to famine.

ii. **THREAT TO VEGETATION:** The gully erosion in Nigeria has resulted in loss of vegetation as its continuous expansion encroaches into areas that are hitherto forest leading to falling of trees and exposure of more surface areas to gully activities. The phenomenon if allowed to continue and remains unchecked may ultimately lead to climatic changes locally or globally (Abdulfatai et al., 2014).

iii. **EFFECT ON PROPERTIES:** Gully erosion, as an environmental hazard, has numerous adverse effects on properties. Several properties whose value cannot be quantified accurately here have been destroyed and others are under treat by this menace especially houses and other properties located on the floodplain.

About 10 houses have been lost in a single event of gully erosion in Auchi area of Edo state. Besides, it was reported recently that over 450 buildings are lost in Edo state of Nigeria as a result of erosion (NTA News, Sunday 6th July 2013).

iv. **EFFECT ON LIFE:** So many human lives have been lost as a result of the menace of gully erosion. Some either fell into these gullies and sustained various degrees of injuries or died. Cases have been reported where people are drowned in some of the gully sites. The gully erosion in Urualla community in Imo State has created a deep gully and wide crater,

threatening to sweep away the homes of so many families as this channel is continuously expanding at an alarming rate.

v. **EFFECT ON SOIL:** In a study by Asiabaka and Boers (1988), a group of farmers in southern Nigeria perceived declining soil fertility as the most serious impact of erosion, followed by declining yield of crops and destruction of farmland, in that order. Gully erosion has given rise to infertile and barren land that may need to be reclaimed.

2.7 SOIL EROSION IN SOUTHEASTERN NIGERIA – A REVIEW

Erosion is one of the surface processes that sculptor the earth's landscape and constitutes one of the global environmental problems. In Nigeria, the erosion problem is particularly acute in the south-eastern ecological zones where high intensity rainfall combines with non-cohesive soil structure to make erosion one of the most serious environmental hazards in the areas.

The problem of erosion in the south-eastern ecological zone is not new. Efforts aimed at checking it date as far back as to the 1920's with establishment of Udi forest reserve in 1929 (Akpokodje, et al., 2010). Similarly, several studies have been carried over the decades on the erosion problem in southeastern Nigeria, Asiabaka 1988; Igbozunike 1990; Adeniji 1990).

Southeastern states where gully erosion is prevalent include: Anambra state especially the Agulu-Nanka area, Imo-state especially the Orlu-Ideato area, Enugu

state, Ebonyi state, Akwa-Ibom state, Edo state, Delta state, Rivers state especially Etche local government area, cross river state, kwara nand Ondo states.

The magnitude of the erosion problem in southeastern Nigeria is indeed great. About 3000 gully sites were said to have been reported in Imo state, (Asiabaka and Boers 1988) about 59 in Akwa Ibom (Etukudo 1988), 130 in Cross Rivers (Asiabaka et al., 1990, Task Force on flood and erosion control calabar, 1991), more than 700 in Anambra state (Ofomata, 1984). The most serious gully erosion in Imo state includes: Okwudor, Orlu, Urualla especially Umuagor-Urualla, Amucha and Ikeduru. In Cross Rivers State, the most serious ones are Marina Road Calabra, Ikot Ansa and Obubra (Amangabara, 2012).

In other words, most 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 have been brought under control (Owense et al., 2000).

In comparison with gully erosion, sheet erosion covers an even under area of southeastern Nigeria, and its influence is more pervasive. There is hardly any community in southeastern Nigeria where sheet erosion is not occurring, particularly on farmland (Amangabara, 2012), sheet erosion continuously washes away the productive top soil over large tracts of arable land.

2.8 CONCEPT OF GEOTECHNICAL INDEX PROPERTIES THAT RESULT TO GULLY EROSION

For a better understanding of this research work, it is necessary to carefully explain the concept of geotechnical index properties that result to gully erosion, starting with Assessment, it is defined by an English Dictionary as the process of assessing, an appraisal, evaluation or estimation of something (Webster's all-in-one Dictionary and thesaurus 2008 edition).

2.8.1 GEOTECHNICAL

This is the practical application of geological science in civil engineering, mining and other engineering disciplines that are concerned with construction occurring on the earth surface or with the ground. Holtz and Kovaccs, (1981) defined it as a branch of civil engineering concerned with the engineering behavior of the earth materials. According to Collins English Dictionary (2015), geotechnical is the application of technology to engineering problems caused by geological factors.

2.8.2 INDEX

According to Webster's all-in-one dictionary and thesaurus (2008 edition), index is s device that serves to indicate a value or quantity; a guide for facilitating references.

Index is a sign or measurement that something else can be judged by or to make a statistics of documents, the content of a book (2005 edition, oxford dictionary).

2.8.3 PROPERTIES

According to Webster's all-in-one dictionary and thesaurus (2008 edition), properties refers to quantity peculiar to an individual or thing; it is the attribute, characteristics or features of a thing.

Hence, assessment on geotechnical index properties that result to gully erosion refers to the process of assessing, estimating or evaluating the behavior of the earth materials and the measurement of the characteristic attribute possessed by the germinal stage of soil erosion which is known all over the world as "Gully Erosion". According to Nyakatawa et al., (2001) soil erosion is a major environmental problem worldwide. Gullies are problems in the humid tropics especially when communities affected generate a significant amount of its Gross Domestic product (GDP) from agricultural related activities (Ibitoye et al., 2008). Their occurrences have caused severe loss of soils, particularly for agricultural productivity in many parts of Nigeria (Okagbue and Uma, 1987; Jeje and Agu, 1982). It also affects development because infrastructures such as houses, roads and many others are being destroyed yearly and this in turn constitutes an environmental menace (Idah et al., 2008). To effectively tackle this problem, there is a need to evaluate those Geotechnical Index Properties such as;

i. Plasticity index

ii. Shear strength

iii. Natural moisture content

iv. Bulk and dry unit weight

v. Grain size distribution that greatly contribute to gully formation within a given ecological zone if left unchecked.

2.9 CONCEPT OF GULLY EROSION

Gullies are among the most hazardous of natural disasters. It is the terminal stage of soil erosion, which can assume great dimensions; resulting in land degradation, lowering agricultural productivity, displacing communities, loss of farmland leading to rural exodus, (Ogbonna, 2012).

Gully erosion usually occurs near the bottom of slopes and is caused by the removal of soil and soft rock as a result of concentrated runoff that forms a deep channel or gully. They are larger than rills and cannot be fixed by tillage (Hilborn, 1985). Water running downhill cuts a channel deep into the soil and where there is a sudden fall, a gully head forms at the lower end of the channel and gradually works its way back uphill. Gullies can be active (actively eroding) or inactive (stabilized). The former, according to Poesen et al., (2003), can occur where the erosion is actively moving up in the landscape by head-cut migration. The causes of gully erosion are poorly understood but the processes and factors involved in its

growth and degradation are well known (Beths, III 1985). The research has shown that gully processes have happened in the past even without human influence or interference. Thus, the phenomenon of gully erosion is either naturally-induced or artificially-induced, or both (Abdulfatai et al., 2012). Like in other parts of the world, gully erosion is one of the major environmental challenges facing Nigeria. South-eastern part of Nigeria is more affected than its north eastern counterpart (Abdulfatai et al., 2012). Gullies are considered active as long as erosion keeps the sides bare off vegetation; they are inactive when they have been stabilized by vegetation (Amangabara, 2012). Anambra state has the most active gullies in Nigeria where Agulu, Nanka and Oko communities of the state are the worst hit (Abdulfatai, 2012).

2.9.1 FORMATION OF THE GULLY EROSION

According to World Bank report (2013), the Umuagor Urualla erosion site started so many years ago as narrow channels of rill erosion and metamorphosed into gully erosion. This statement was made by the chairman of Urualla council of chiefs and former vice-chancellor of Imo-state University, Prof. Thomas Ndubuizu; who was spearheading local efforts briefed the delegation during the joint World Bank-FAO team that visited Imo State. While conducting the team round the gully sites, the chairman of the council of chiefs noted that some of the root causes of the problem include uncontrolled flooding from neighboring Osina

and Akokwa communities, and pointed out that since Urualla was bounded by the Anambra/Imo river basin, excess rainfall could be channeled to the river thereby alleviating the problem. The indigenes of the area had wanted to tackle the problem, but were constrained due to paucity of fund.

2.9.2 EFFECTS AND CHALLENGES OF GULLY EROSION

Southeastern Nigeria is affected by massive and expanding gully erosion, an advanced form of land degradation. Gully erosion is responsible for the widespread degradation of arable land, destruction of buildings, transportation and communication systems, contamination of water supply, isolation of settlements, migration of communities etc.

World Bank (1990) recognized three main environmental problems facing Nigeria: soil degradation and loss, water contamination and deforestation. In addition, six other problem areas were identified: gully erosion, fishery loss, coastal erosion, wildlife and biodiversity losses, air pollution and the spread of water hyacinth (UNDP, 1997).

The problem of gully erosion has formed a subject for serious consideration since the early 1920s. It has continued to attract minder attention than before and has formed a topic for spirited speeches by legislators, government functionaries at all levels, the academia and private individuals (Amangabara, 2013). Several studies have also been carried out over the decades on the problems of gully erosion in

southeastern Nigeria for example Asiabaka and Boers (1988), Igbozurike (1990); Adeniji (1990), Onu, (2001).

2.10 PROPOSED SOLUTION TO GULLY EROSION IN NIGERIA

Prevention is better than cure, they say thus, prevention of the processes or mechanisms that result to or advance to gully erosion should be of paramount importance to all the stakeholders in environmental management in the country. Control measures to stem gully erosion that are insipient are most effective when erosion is still at an early stage (Obidinma and Olonenfemi, 2011). Organic carbon, chemical properties, textural characteristics and moisture content of the soil have been suggested as the most useful factors to be considered in a detailed survey and control of gully (Osadebe and Enuvie, 2008). Thus, these factors and others should be carefully examined in the erosion-prone zones/regions of the country in a bid to better design preventive measures (Abdulfatai, 2012). Other measures that could be used to curb the menace of fully erosion as suggested by Abdulfatai (2012) include:

1. Improved family practices that reduce the gully erosion processes to the barest minimum such as crop rotation, strip cropping or terracing, contour plowing should be encouraged since poor family techniques have been found to be a contributing factor to the growth of gully erosion.

2. Strict legislation against dumping of refuse on the river channels and floodplains since refuse dump along the river courses impede the flow of water leading to flooding especially during heavy rainfall.
3. Cultural method (also called retentive technique by Simpson, 2010) of erosion control has been found to be cheap and effective method (Abdulfatai, 2012). Planting of plantain and Banana in the floodplains have also been found to be effective in controlling erosion. Grasses species such as *Eulaliuopsiss binata (Babiyo), Neyraudia reynaudiana (Dhonde), cymbopogon microtheca (Khar), saccharum pontaneum (Kans) and Thysanolaena maxima (Amliso), Aninduella nepalesis (Phurke) and themeda* species have been suggested by Ojha and Shestha (2007) as suitable especially for slope stability.
4. There should be general enlightenment campaign on the dangers posed by gully erosion and human activities that promote them as inadequate awareness of effects of human activities on both floodplain and river channels contribute to misuse of these areas.
5. Efforts should be made by relevant authorities to enact a law against location of engineering structures on waterways.
6. The government at all levels in Nigeria should take it as a matter of urgency to yield to addressing issues relating to erosion especially gully erosion at an

early stage so as to avoid loss of lived of Nigerian people as well as their properties.

CHAPTER THREE

3.1 DESCRIPTION OF THE STUDY AREA

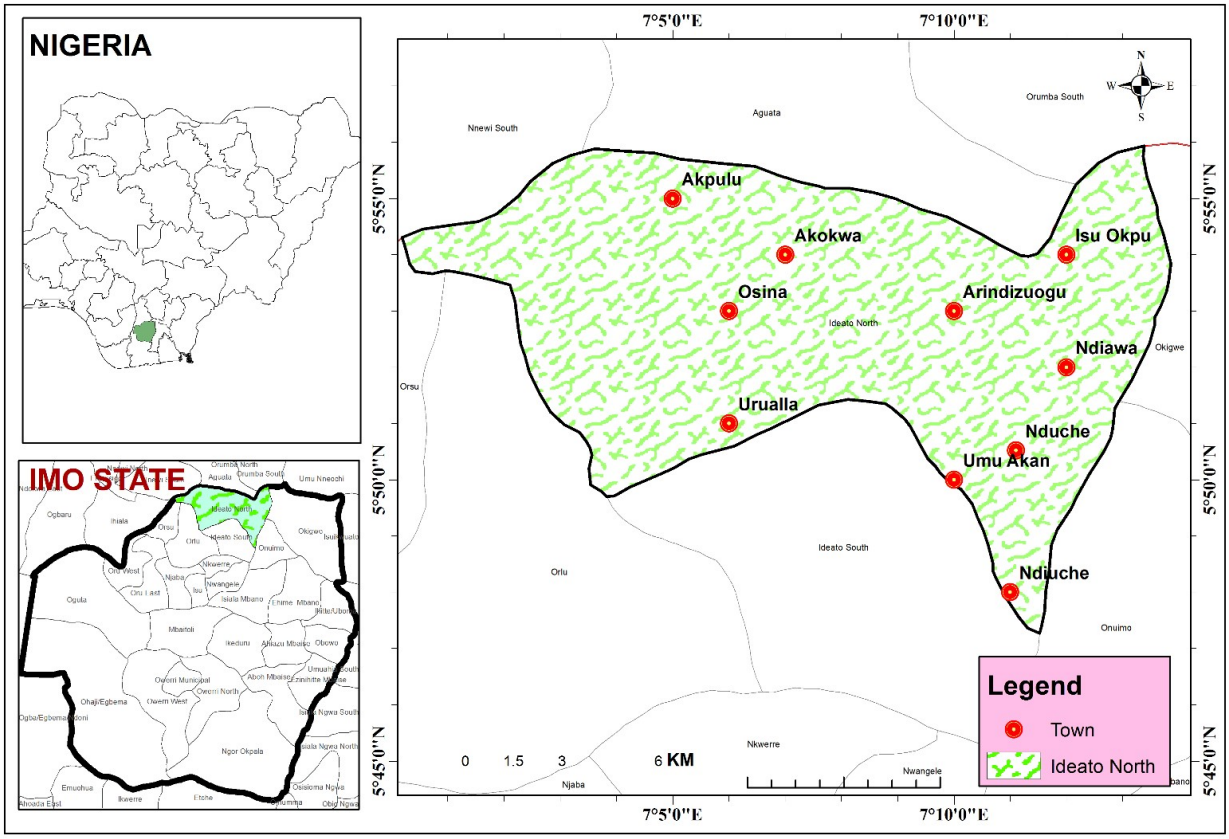

Fig 3.1 Map of Ideato North LGA showing the Study Area (Urualla)

The study was conducted at Umuagor- Urualla which is located in Ideato North L.G.A of Imo-state.

Basically, there are four (4) villages that constitute Urualla town. These are: Umuago, Ezemazu, Uzoakoli and Ozu. Urualla is bounded in the east by Osina, in the west by Ihitte Owerri (Orsu L.G.A), in the north by Obodoukwu and in the

south by Obiohia/Umuchima (Ideato south L.G.A). The dominant occupation of the people is farming which yield agricultural products such as cassava, yam, cocoyam, palm produce as well as other food/cash crops.

The geology of Umuagor Urualla is underlain by Bende-Ameki formation (Eocene) which is part of the Anambra basin. It is composed of weak, friable soils which are poorly consolidated. The main river bodies/streams include: Orashi river, Umunwa and Iyinta streams.

3.1.1 PHYSIOGRAPHIC CHARACTERISTICS

3.1.2 TOPOGRAPHY

The topography of Umuago Urualla is undulating making the flow irregular. The Umuago Urualla gully has a length of about 1,998m; width at the top of 16m and depth of 27.5m is on an elevation of 139m. The land slopes at approximately 2^0 to 7^0. Further down the gully and close to Orashi river (where runoff flows into0, there is a major crustal depression which may have been caused by either ancient tectonic activity or erosion processes. The area constitutes a bad land which has stabilized. However, part of the run-off from the Umuagor gully empties into the crustal depression and the slopes are gradually getting destabilized. The gully trend is north-east-south west and is the major contributor of natural disaster in the area, control measures have been attempted and none appears to work (Amangabara, 2012).

3.1.3 CLIMATE

The climate in the study area is characterized by two main seasons: rainy season and dry season. The rainy season lasts between the months of April to October characterized by thunderstorms while the dry season (harvest season) extends from November to March annually.

3.1.4 VEGETATION

The study area falls within the rainforest belt and characterized by growth of tall trees amidst thick undergrowth. Some identified vegetations found within the gully complex include; *Persea americana (Avocado), Anacardium occidentale (cashew), Mangifera indica (Mango), Elaeis guineensis (oil palm) Bambusa vulgaris (Bamboo) etc.*

3.1.5 DRAINAGE

The drainage is mainly dentritic pattern. The rivers in Urualla include: Urashi River, Iyinta and Umunwa streams. The dentrific pattern formed by streams in the area is due to the bedrock lithology. Streams flow north east with 2nd order with Orashi as the major drainage basin.

3.2 GEOLOGY OF THE STUDY AREA

The geology of Umuago Urualla is composed of Bende Ameke formation, which is composed of weak, friable soils that are poorly consolidated. The geologic

formation supported growth of forest and agriculture which are practiced in fertile soils under the two climate regime experienced in the study area (rainy season and dry season). The soil profile unit consists of poorly sorted consolidated sand of variegated color; yellow to brown on weathered surface, white to milky white on fresh surface to reddish clay.

3.2.1 DESCRIPTION OF GULLY COMPLEX

The Umuago Urualla gully complex shows the existence of tracts of base lands devoid of topsoil from sheet and gully erosion crisis crossing farmlands. The gully constitutes major natural disaster in the area. Towards Orashi village, houses close to the gully are just about 11 and 14m away from the gully, control measures put in place in the past seem not to be effective.

3.3 HUMAN CHARACTERISTICS OF THE STUDY AREA

This section focuses on the occupation and settlement pattern of the indigenes of the area.

3.3.1 OCCUPATION

There is active farming in the area; the people of Umuago-Urualla southeastern Nigeria are primarily dependent on arable agriculture and livestock rearing for their economic sustenance. Major crops grown in the area include; cassava, maize, yam, melon, cash crops found in the area; oil palm, banana, plantain, mango,

oranges and cashew. Plantations of these cash crops are found at different locations within the study area, there is sand mining activity within the gully complex. Some indigenes of the area are traders, hunters, beehive farmers as well as civil servants.

3.3.2 SETTLEMENT

The settlement pattern of the area is rural settlement; the community is involved predominantly in primary activities such as farming, lumbering and mining. Mud and thatched roof houses were found in the area while some houses were built with concrete blocks. Farmlands are located near the villages, however, vegetable gardens were found around the homes.

3.4 ENVIRONMENTAL RECONNAISSANCE SURVEY

3.4.1 FIELD INVESTIGATION

This involves the identification of the environmental settings and situation within the study area.

3.4.2 ENVIRONMENTAL MONITORING

This involves monitoring and recording of events and changes within the study area.

3.4.3 MEASUREMENT OF CROSS SECTIONAL AREA

Google earth was used to measure the cross sectional area of the gully.

3.5 SUBSURFACE COMPLEXITY OF GULLY AREA (GEOPHYSICAL SOIL SURVEY)

OHMEGA– 500 Electrical Resistivity Equipment was used to conduct a vertical Electrical sounding (VES).

Schlumberger configuration was used for a total spread (L) of 320m. VES station was located close to the gully, with the traverse running normal. A distance of 160m (L/2) was covered on the right of traverse towards Obiohia and another 160mm (L/2) was run on the left towards Umunwanado, in each traverse.

All necessary precautions required in geo-electric measurement were duly considered. The survey lasted approximately 1hr 30mins in each location under favorable weather condition.

3.5.1 FIELD TECHNIQUES

Transmitter electrodes (A, B) were used to inject current into the ground. The current flow between A and B is measured with the potential electrodes (M, N) (Figure 1)

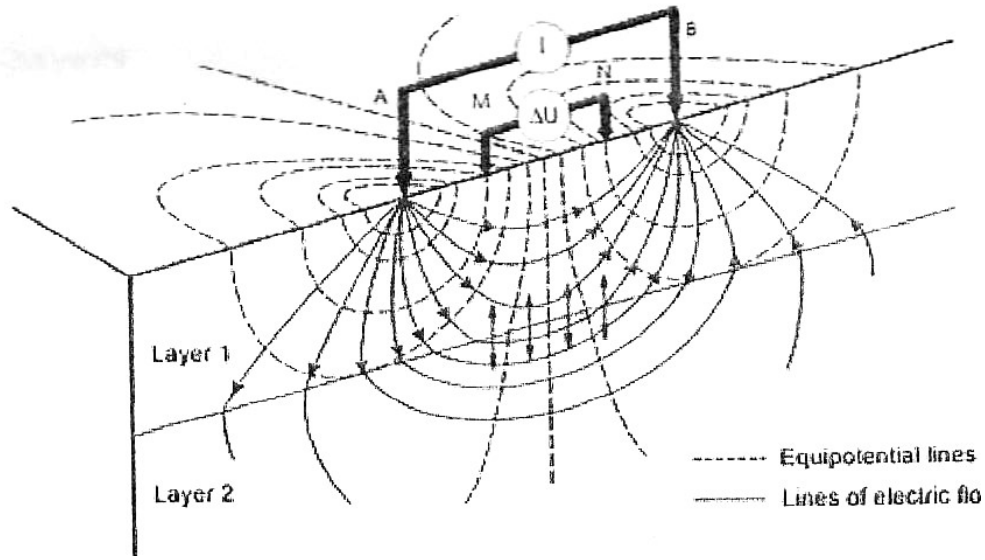

Figure 3.4: 4-point-measurement electric flow field

Several 4-point-measurements are taken where the receiver electrodes M,N remain in place and the transmitter electrodes are symmetrically extended outwards. Thus, the current penetrates successively deeper into the ground. When the current flow sinks to a layer with different electrical conductivity, the current flow field is deformed, this can be measured at the receiver electrodes M,N. From this data, a layer model based on the electrical conductivity of the different subsurface materials is calculated.

3.5.2 DATA PROCESSING

All field data have been subjected to full computer processing techniques, applying the schlumberger computer automatic analysis package, and the Advanced Geophysics Incorporation (AGI) ID resistivity analytical software.

Apparent Resistivity (pa) = $\pi(AB12)^2 - (MN/2)^2{}_{xR}$ / MN

$\Rightarrow \pi(AB12)^2 - (MN/2)^2{}_{xR}$ / MN (ohm-m)

AB/2 = current Electrode spread

MN/1 = Potential Electrode spread

Thus, Apparent Resistivity Equation (1) can be expressed as follows:

Pa = k ≠ R (Ω-m), (1)

Where: k = geometric factor; $\pi(AB/2)^2 - (MN/2)^2{}_{(m)}$ / MN

R = field resistance = 1/v (ohms)

I = current passed to the earth through electrodes, and V = voltage.

3.6 SOIL CHARACTERISTICS OF THE GULLY (ERODIBILITY INDICES)

The effect of soil characteristics on gully development was determined to ascertain if there is any spatial variability along the profile of the gully. To that extent, the gully was segmented along a 1000m length and on each segment of the gully wall relatively undisturbed soil samples were collected at three distinct properties (The soil profile unit is characterized by poorly sorted sand of variegated colour: yellow

to brown on weathered surface, white to milky white on fresh surface to reddish clay) including the top, midway and the gully bottom to make a composite for the determination of moisture content (Alterberg limit) soil texture, structure and bulk density.

3.6.1 COLLECTION OF SOIL SAMPLES:

Three undisturbed soil samples for geotechnical engineering studies were collected using a hand auger at three locations (1, 2 and 3) and depth of 10cm and distance of 40m from the gully wall. The three locations were chosen inorde to obtain a composite and to ascertain if there is any spatial variability along the profile of the gully. The samples were put inside sample bags and were sent to laboratory for analysis.

LABORATORY TEST

Different tests were carried out to assess the geotechnical soil properties of Umuagor Urualla gully erosion site. These tests include:

1. Moisture content determination
2. Bulk and dry unit weight
3. Alterberg limits determination
4. Grain size analysis
5. Determination of shear strength.

MOISTURE CONTENT DETERMINATION

Moisture contents of the soil samples were determined using the drying method. It is the ratio of the weight of water present to the weight of dry soil in a given soil mass (Miltal and shilkla, 1985). This test covers the determination of MC of soil as a % of its dry unit weight.

APARATUS:

Moisture content container, Electric oven (Temperature 105^0 C- 110^0C) and Weighing balance.

PROCEDURE:

The moisture container was washed with clean water, dried and weight recorded as W_1. The weighing balance was adjusted and cleaned and different soil specimen was taken each from the samples, placed in the container, weighed and their respective weighs recorded as W_2. The moisture content container and its contents were oven dried. Respective weighs of container + dry soil sample taken after 24hrs were recorded as W_3.

CALCULATION: % MOISTURE CONTENT

$$W\ (\%) - \frac{W_2 - W_3}{W_3 - W_1} \times 100$$

Where, W_1 - Weight of container (g)

W_2 - Weight of container + Wet soil (g)

W_3 - Weight of container - dry soil (g)

W - Moisture content in %.

ATTERBERG LIMITS TEST

Alterberg limits are basic measure of the critical water contents of a fine – grained soil such as its shrinkage limit, plastic limit and liquid limit. Shrinkage limit is the water content where further loss of moisture will not result in any more volume reduction. Shrinkage limit is much less commonly used than the liquid and plastic limit. The test to determine shrinkage limit is ASTM international D4943. Plastic limit (PL) is moisture content at which the soil is non plastic, is determined by rolling out a thread of the fine portion of a soil on a flat, non-porous surface. Liquid limit (LL) is the water content at which the behavior of a clayey soil changes from plastic to liquid. However, the transition from plastic to liquid behavior is gradual over a range of water contents, and the shear strength of the soil is not actually zero at the liquid limit. The precise definition of the liquid limit is based on standard test procedures described below.

APPARATUS:

Moisture content container, Oven (100^0C-105^0C), Cassagrande grooving tool, Distilled water, Spatula for soil mixing, No 40 sieve, Plastic squeeze bottle (for dispensing minute quantities of water, Weighing balance, Glass plate.

PROCEDURE:

A sample of about 250g of soil passing the #40 sieve was used the soil sample was placed on a glass plate and mixed with distilled water using spatula. The paste was place into an airtight container and sealed with adhesive tape. The paste was left for 24hrs on a dry surface to allow water permeate through the soil mass. The paste was removed from the container after maturing. Then, the soil was remixed with spatula for about 10mins; the paste was pressed against the side of the cup of cassagrande device, to avoid trapping air.

A groove was cut through the sample using grooving tool. Below were applied to the paste by turning the crank handle of the machine at a steady rate of two revolutions per second; so that blows required closing the groove was noted. The process was repeated on the paste at three different moisture contents respectively and the corresponding number of blows noted. The moisture content of the paste in each case was also determined using standard methods.

CALCULATION

Using a semi-log graph, the moisture content was plotted against the corresponding number of blows. The best straight line fitting the plotted points was drawn; and this was referred to as the "flow curve". The ordinate representing 25 blows was drawn to meet the flow curve. From the point of intersection, a vertical line was drawn to meet the abscissa. This valve of moisture content was read off and recorded as the liquid limit (LL).

DETERMINATION OF PLASTIC LIMIT (PL)

A quantity of the soil paste (after remixing above) was placed in the glass plate; the paste was kneaded and then shaped into a ball. The ball was molded between the fingers and rolled between the palms of the hands so that the warmth of the hand slowing dries it. When slight cracks appeared on the surface, the balls were divided and rolled further, until each approach a diameter of about 3mm, the moisture content of the balls were determined. The average moisture content of the balls were computed and recorded as plastic limit (PL).

DETERMINATION OF PLASTICITY INDEX (PL)

The plasticity index (PI) was computed using the formular below:

P1 = LL – PL

Where, LL = liquid limit (%)

PL = plastic limit (%)

PI = plasticity index (%) is the size of the range of water contents where the soil exhibits plastic properties. PI characterises the soil.

SHEAR STRENGTH

This determines the shearing strength of the soil sample in order to determine the relative effect of movement due to load that will be imposed on the soil. It aids in the determination of cohesion and angle of internal friction of the material.

APPARATUS

Direct shear machine, Vernier calipers, Timer (stop watch), Small level.

PROCEDURE

Soil samples were carefully hemmed to the size of the shear box ring; the dimensions of the sample (length, width and height) were measured with venier calipers. The sample was placed in the cell of the shear box and a load was hung on it. The machine was adjusted properly and readings were taken from the dial guage at intervals of 30secs; this reading was taken until the sample fails; the process was repeated twice with heavier loads.

From the data generated, the normal stress and the shear stress against normal stress was plotted on a graph sheet; a line of best fit was drawn from the plots. The

intercept of the line on the ordinate and the angle it makes with the abscissa (slope) were determined. The intercept represents the cohesion (c) while the slope represents the angle of internal friction (ϕ).

GRAIN SIZE DISTRIBUTION ANALYSIS

This experiment was used to determine the grading of the geological materials in the soil and identification of the clay mineralogy and relative proportions of different sizes of particles. Wet sieving method was used.

APPARATUS:

i. British standard test sieve: 2.0mm, 1.18mm, 0.85mm, 0.60mm, 0.425mm, 0.30mm, 0.15mm, 0.075mm and pan.

ii. Sieve brushes

iii. A metal glass tray

PROCEDURE

A 60.0g sample was obtained and immersed in an evaporating dish containing some quantity of water and a dispersing agent (sodium hexametaphosphate); for dispersing clay and other soil types. The content was left for 24hours to soften the clay particles. Washing was done to ensure complete separation of fines. Clay fines were washed off with more water. This process continued until sample left was free from fines. The free fine material inside the evaporating dish was carefully

placed inside a container and put in an oven to dry at temperature of 105-110°C over night. The sample was brought out of the oven; and the dry soil was passed through a nest of the complete range of sieves to cover the sizes of particles present down to the 0.075mm. This operation was carried out by a mechanical sieve shaker.

CALCULATION

A soil sample could be well graded or poorly graded. A soil sample is said to be well graded when the soil contains particles of a wide range of sizes and has a good representation of all sizes from the least to the biggest sieve.

A soil sample could be said to be poorly graded if the soil sample does not have a good representation of all sizes of particles from the least to the biggest sieve size. Coefficient of uniformity (cu) is a measure of particle size range and its given by the equation.

$$Cu = \frac{D_{60}}{D_{10}}$$

Where D_{60} = grain diameter at 60% passing

D_{10} = grain diameter at 10% passing

For coefficient of curvature CC, it is calculated by the equation below

$$Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}}$$

Where, D_{30} = grain diameter at 30% passing

D_{10} = grain diameter at 10% passing

D_{60} = grain diameter at 60% passing

CRITERIA FOR GRADING SOILS

The following criteria are in accordance with the unified soil classification system: for a gravel to be classified as well graded, the following criteria must be net:

$Cu > 4$ & $1 < Cc < 3$.

If both of these criteria are not met, the gravel is classified as poorly graded or GP if both of these criteria are met, the gravel is classified as well graded GW.

For a sand to be classified as well graded, the following criteria must be met:

$Cu \geq 6$ & $1 < Cc < 3$.

If both of these criteria are not met, the sand is classified as poorly graded or SP but if both of these criteria are met, the sand id classified as well graded or SW.

CHAPTER FOUR

RESULT AND DISCUSSION

4.1 Relief of the Study Area

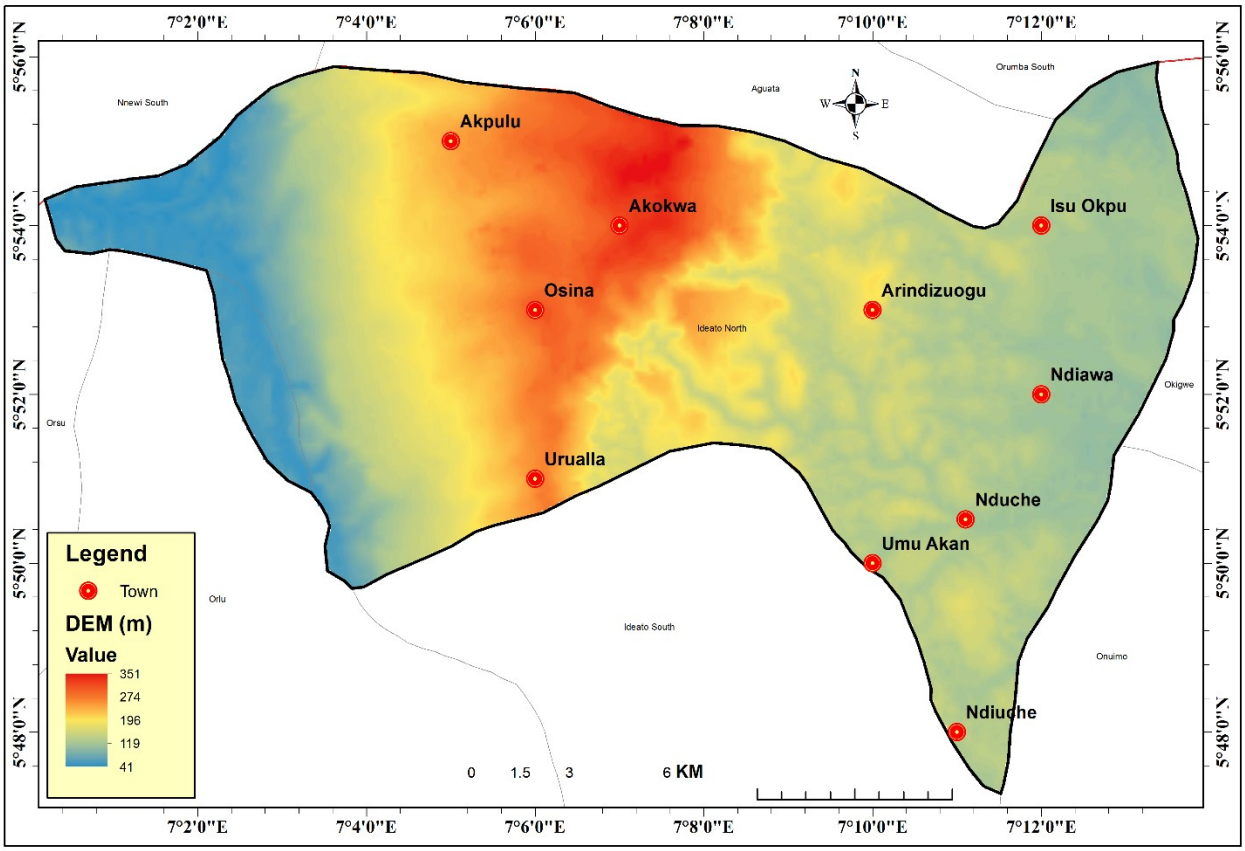

Fig 4.1 Digital Elevation (showing Relief) of Ideato North

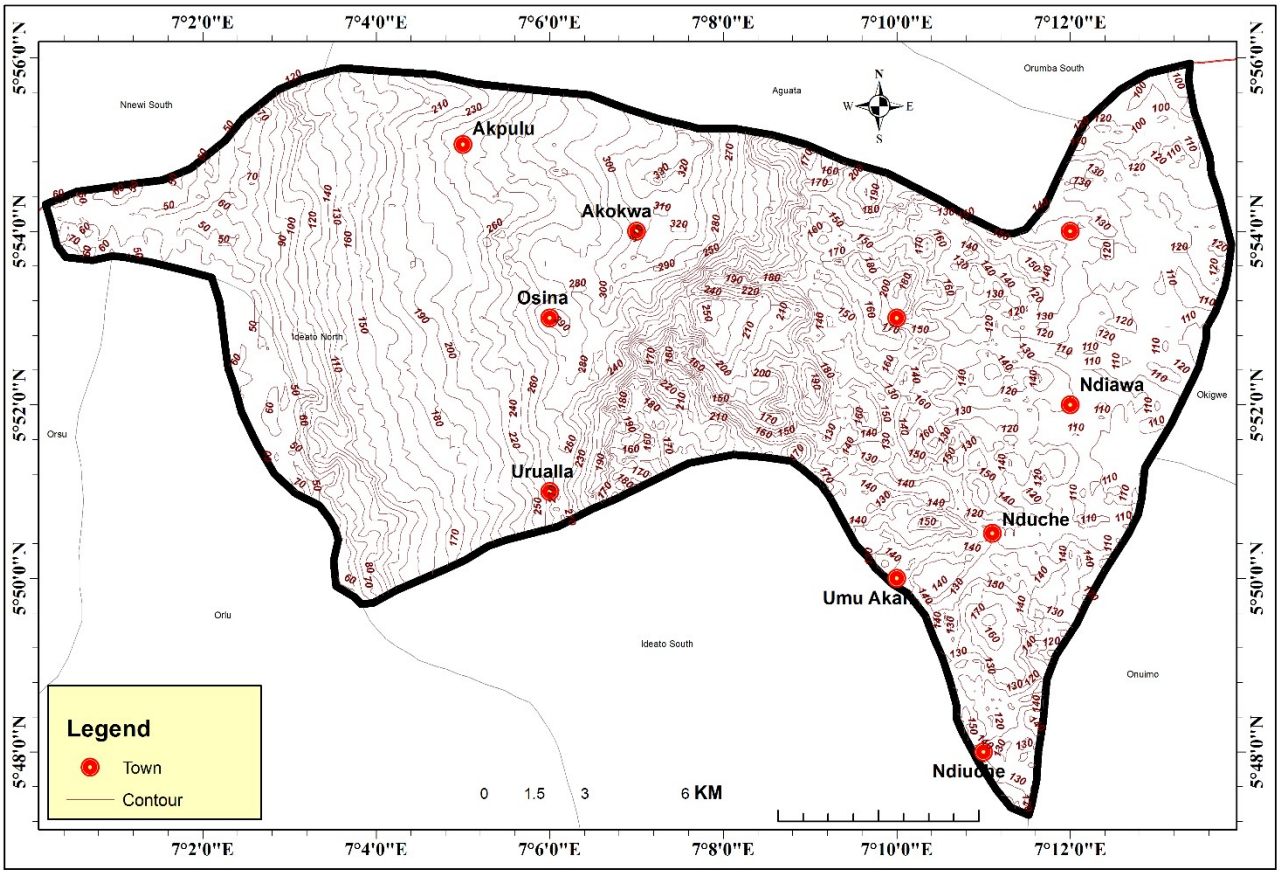

Fig 4.2 Contours of Ideato North

Fig 4.1 and 4.2 show the relief of the study area inclusive of the gully. The area is generally characterized by a highland region with elevation as high as 351m above mean sea level (msl). The community where the study gully is located itself is about 349m above msl (fig 4.1) The spacing of the contour lines (fig 4.2) show that the relief is gentle on the North-west facing flank while it is rugged and almost steep escarpment on the South-East Flank.

Geologically, this highland region appears to be a low asymmetrical ridge or cuesta of the Awka – Orlu-Okigwe Uplands, which trend roughly North West to North East, in line with the geological formations that underlie it which is believed to be part of the Lower Benue trough. A careful examination of fig 4.1 also showed that it forms the watersheds which drain the dip slope of the cuesta. The Orashi (Ulasi) River (and its smaller tributaries), which rises near Dikenafai in Imo State, flows northward to Ozubulu in Anambra State and then turns round in a wide loop and heads for the Atlantic Ocean.

4.2 SUBSURFACE COMPLEXITY OF GULLY AREA

4.2.1 Soil Characteristics of the Gully Erosion Site

This section presents results of GIS generated soil map and laboratory analyses of soil samples collected at each segment of the Urualla gully erosion profiles to determine their variability and how this in a way has influenced the development and growth of the gully

Fig 4.3 (below) is a GIS generated map of the study area and it shows that there are three soil type in this LGA namely Lixisols, Fluvisols and Gleysols which are of the Paleocene, tertiary age. However, the predominant soil type and which covers the study gully site at Umuagwo-Urualla is fluvisol. According to the Food and Agricultural Organization (FAO) World Reference Base for Soil Resources, fluvisol is a genetically young soil in alluvial deposits The soils have a clear

evidence of stratification, soil are weakly developed, but a distinct topsoil horizon may be present while lixisols are soils with subsurface accumulation of low activity clays and base saturation, they develop under intensive tropical weathering conditions, both of these soil types might have been laid down with Shale during the transgressive period that followed the Cretaceous.

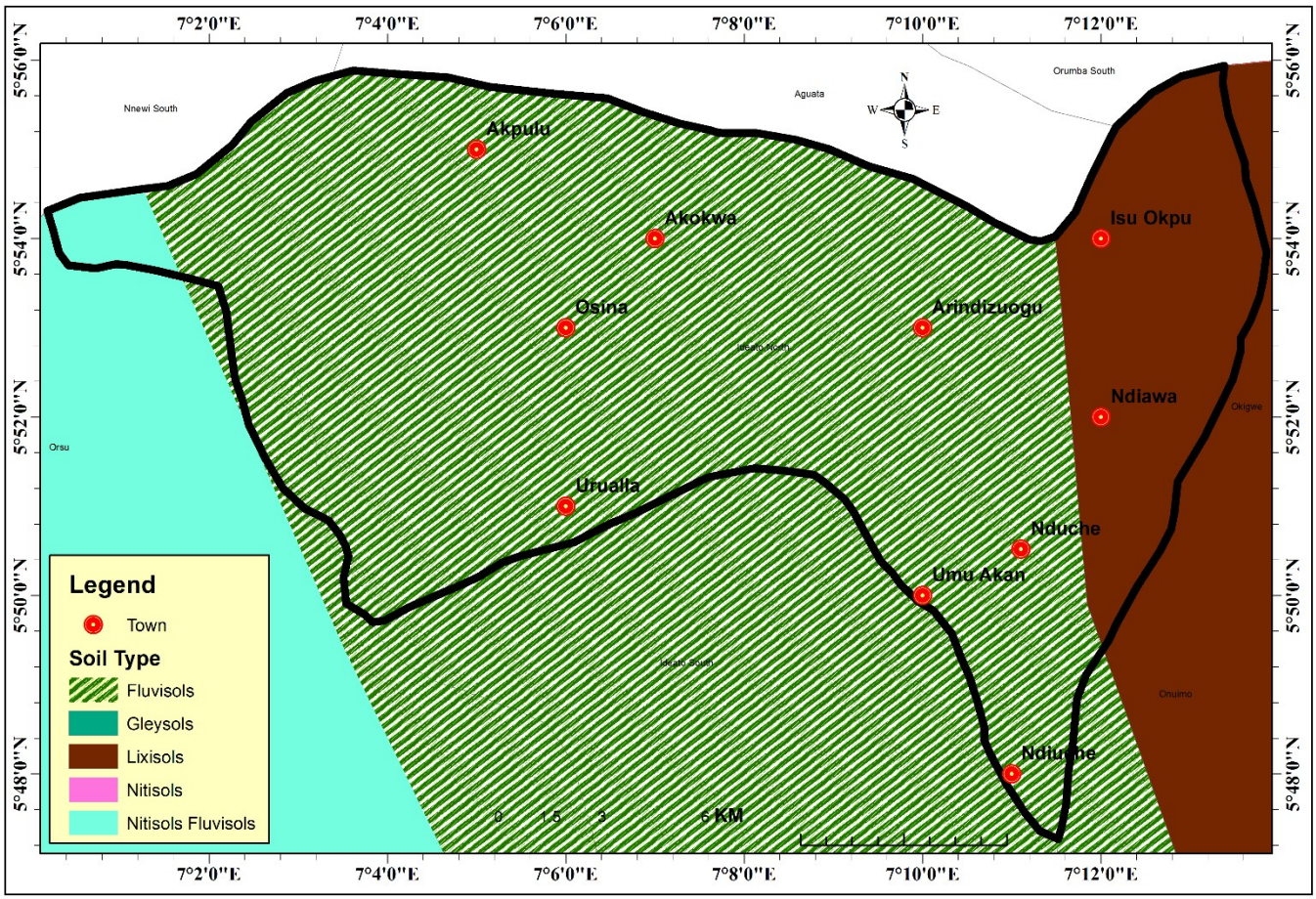

Fig4.3 Soil Map of Ideato North

4.2.2 Soil Consistency (Atterberg Limit) of gully Erosion Site

Soil consistency test generally describes the physical condition of the soil at the various moisture contents as evidenced by their behaviour towards mechanical stress, the soil consistency test conducted for this project is the Atterberg limits test. These, are widely used as a means of estimating the plastic properties of soil in other to determine their structure

The result of soil consistency (Atterberg limit) and their interpretation guide is presented in the followed tables below; The first gully segment is composed of loose soil materials and the soil sample is susceptible to erosion, Second segment is composed of weak friable soil with a weak angle of repose while Third segment has weak angle of repose and soils are erodible.

Table 4.1**:** Laboratory result of soil consistency (Atterberg limit)

Gully segment	LL(%)	PL(%)	PI(%)	Permeability
1	NP	NP	0	$2.3X10^2$
2	20	8	12	√√
3	28	10	18	√√

Table 4.2: Guide to interpretation of Plastic Limits

Plastic limit of soil	Plasticity
< 35%	Low
35% - 50%	Intermediate
< 50%	High

Table 4.1 shows that the liquid limit and the plastic limit for sample 1is NP (Non plastic),samples 2 & 3 is 12% and 18% respectively while the permeability is $2.3x10^2$. The corresponding table (Table 4.2) shows that soils with less than 35% plasticity is low, >50% is high .Based on this table, the plasticity index is therefore non plastic. The plasticity index therefore is zero %. The implication is that the soil of the gully from where the sample was taken is loose, unconsolidated and friable. Comparing this result with the result of VES table 4.6, the soil can be described as either sandy clay or sandy silt.

4.2.3 Soil Shear Strength

Shear strength is a term used in soil mechanics to describe the magnitude of the shear stress that a soil can sustain. The shear resistance of soil is a result of friction and interlocking of particles, and possibly cementation or bonding at particle contacts. The laboratory results are presented below

Shear strength (τ) = C + tan Φ σn

C = Cohesion

Φ = Angle of internal friction

Sample	Cohesion (KN/m^2)	Angle (Φ) of Int. friction (Degrees)	Max normal Stress (σ n) (KN/m^2)	Shear strength (τ) C+ σ n tan Φ (KN/m^2)
Lateritic	3	24	177.8	

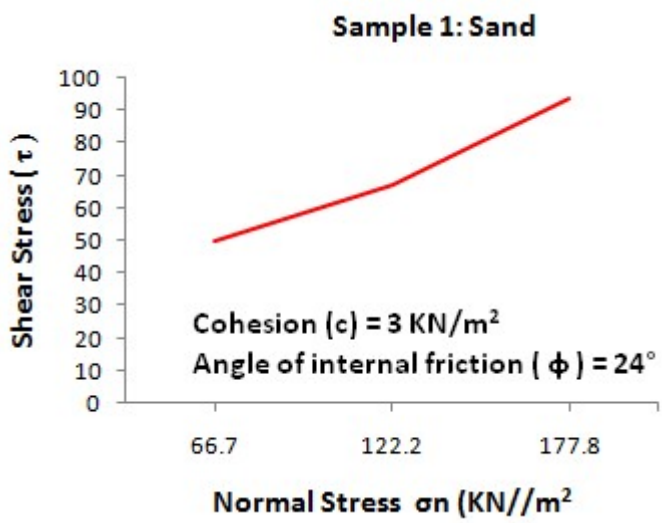

Fig 4.4 Shear Stress vs Normal Stress for Sample 1

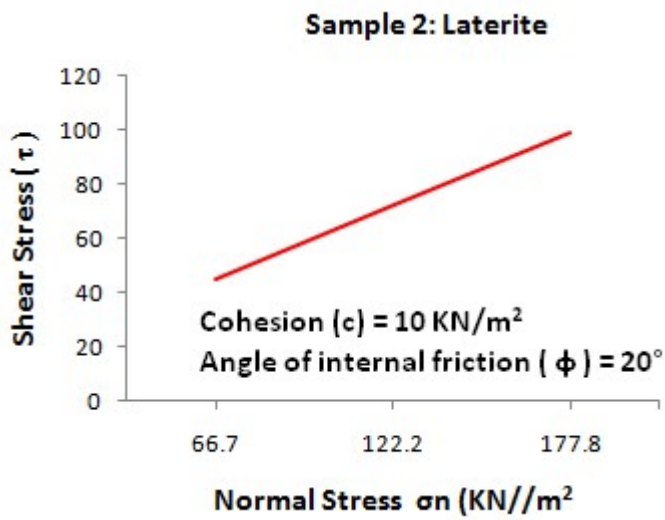

Fig 4.5 Shear Stress vs Normal Stress for Sample 2

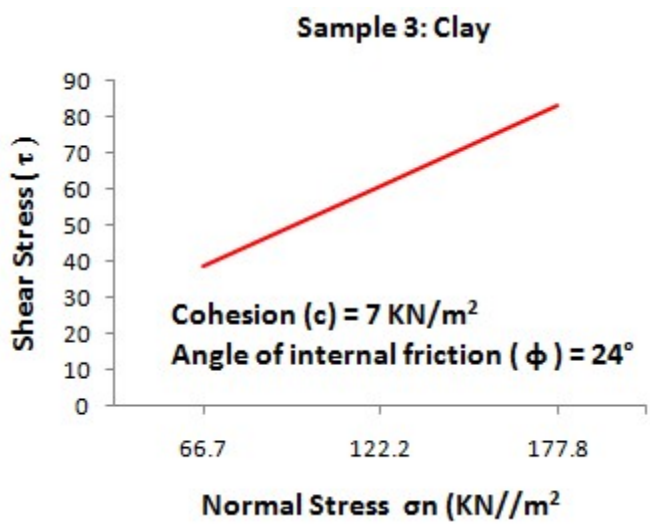

Fig 4.6 Shear Stress vs Normal Stress for Sample 3

Table 4.3: Shear strength

Gully segment	Shear strength (kpa)	Cohesion (kpa)	int. friction (°)
1	177.8	3	24
2	√√	10	20
3	√√	7	24

The result shows that shear strength was uniform for all the samples at c=10KN/m^2, taken at an angle of internal friction of 22^0. Usually, the angle of internal friction (angle of repose) is considered weak and subject to failure when it is between 20-35^0. The result shows that the angle of internal friction of all samples has an angle of 22^0 cohesion is 10 kpa, shear strength 177.8 kpa. This can be interpreted to mean that the soil shear strength is weak and can easily be dislodged and transported away by force of erosivity. This is usually an indication of sandy soil which has very weak cohesion materials.

4.2.4 Grain Size Distribution

Table 4.4 is derived from Fig. 4.1 (Gradation curve) and from the table, the soil sample is predominantly sandy.

Table 4.4 Grain Size Distribution

Gully segment	grain size dist.			CU	CC	Grade
	D_{10}	D_{30}	D_{60}			
1	0.09	0.14	0.3	3.33	0.36	Poor
2	0.09	0.14	0.64	2.11	0.36	Poor
3	0.6	1.15	1.20	2.0	0.83	poor

CU- coefficient of uniformity is a measure of particle size range and its given by the equation : CU- $\frac{D60}{D10}$

CC- Coefficient of curvature and its given by the equation : CC- $D^{(30)^2}/_{D10\ x\ D60}$

From the table above and the Grain-size distribution curves (appendix 4.1) it can be seen that all the soil samples collected in the Urualla gully are about 80% coarse grained (medium grained sand) and 20% fine (Silt). Their Cu is on the average 3.3 while their Cc ranged between 0.079 – 0.80 indicating that they are poorly graded and susceptible to erosion. Usually a well graded soil will have a Cc>5 provided its Cu is between 1 and 3, in this case, the result is not showing so, this is an indication that the grain size is coarse and makes a poorly graded soil.

According to the Unified Soil Classification System, a soil is coarse-grained if more than 50% fraction is retained and if more than 50% of the coarse fraction is retained on the No.4 sieve, it is regarded as gravel. If 50% of the coarse fraction passes the No.4 sieve, it is sand. Clean sand with little or no fines is well graded sand. Gravelly sands are gravelly with little or no fines which are characterized by Cu $D_{60}/D_{10}>6$. It is sand with a mixture of fines and poorly graded when it does not meet the criteria as stated above. Poorly graded silty sands or clayey sands will have a P.I. <4 and P.I >7 accordingly. The soil on gully can generally be classified as coarse grained clean poorly graded sands with little fines.

Furthermore, the values of Cc greatly differ from 1.0 indicating grain sizes missing between D60 and D10 and with the large Cu it clearly show that the soil is more of coarse grained than fine and comparing with percentage passing indicates that the D60 and D10 (which is also known as effective size) differ appreciably (Appendix table 4.1). The conclusion drawn from this tables is that these soils are coarse grain (sandy soil) with very little fine. Placing them with permeability values and the Atterberg limits, there is a strong positive correlation, indicating its strong susceptibility to detachment and erosion.

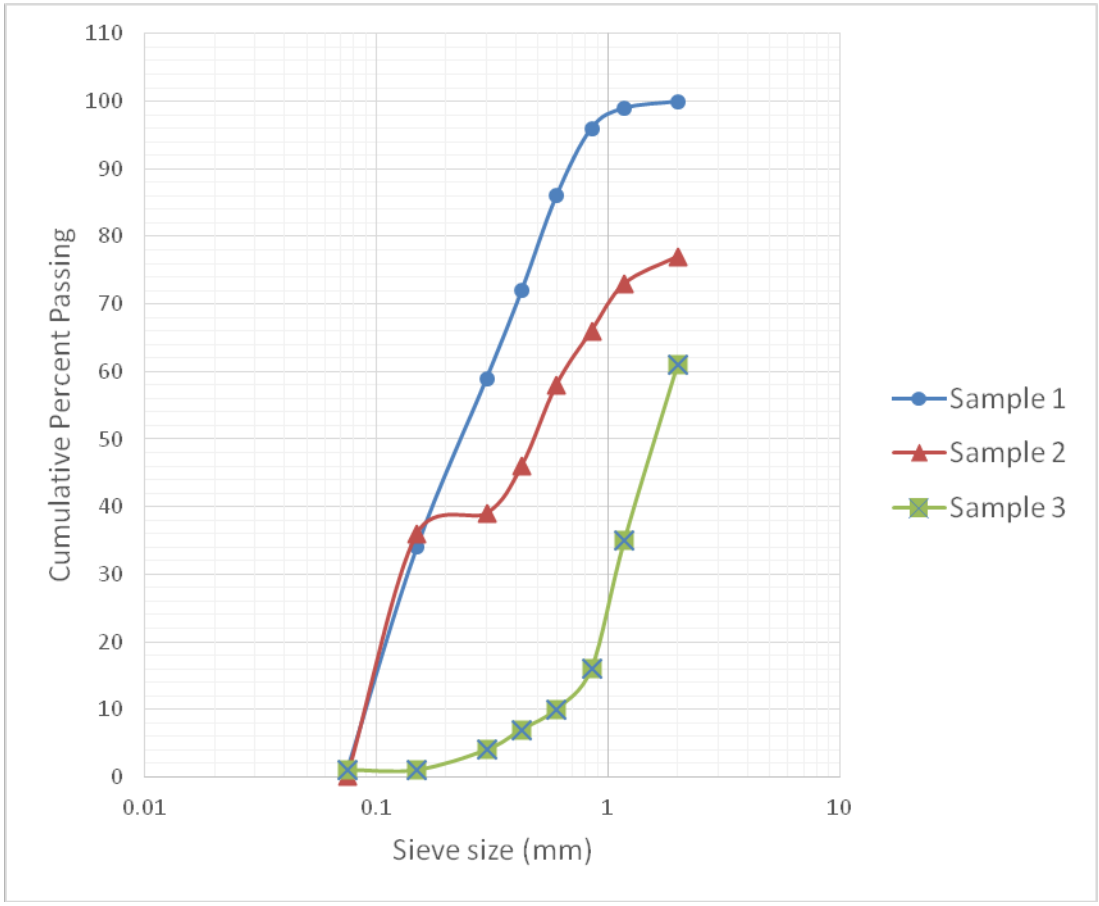

Fig.4.7 Gradation curve

4.2.5 Moisture Content

Table 4.5 Natural moisture content determination

	Sand	Laterite	Clay
Can identification no	24	31	17
Wt of wet soil + can (g)	30.9	30.0	34.1
Wt. of dry soil + can (g)	29.7	28.2	32.0
Wt. of can (g)	19.1	17.1	21.2
Wt. of dry soil (g)	10.6	11.1	10.8
Wt. of water (g)	1.2	1.8	2.1
Water content, w (%)	11.3	16.2	19.5

From the result, bulk density is 1.8mg/m^3 and dry unit weight is 1.6mg/m^3, water content for sand 11.3%, laterite 16.2% and clay 19.5%.

4.2.6 Vertical Electric Sounding Results (VES)

Fig 4.7 below is the gully area map showing the VES lines, the study gully itself and the direction of the flow of groundwater while Fig 4.8 is Results of Vertical Electric Sounding (VES) of the Umuagwo gully erosion site at Urualla showing the subsurface geology and depth of erosive material as well as the lithology and the water table saturated zone where tables 4.6 and 4.7 are derived below

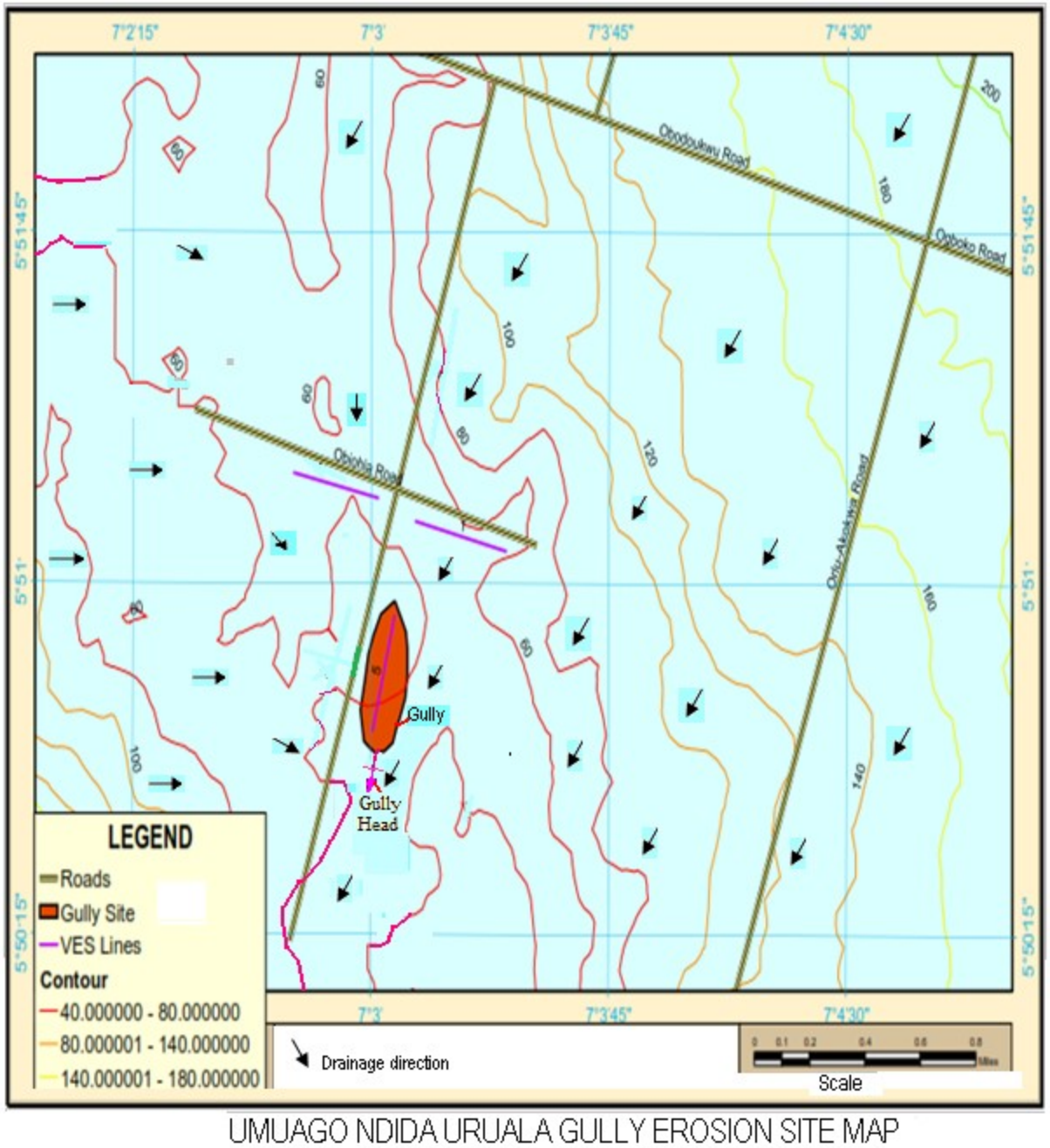

Fig 4.8 VES Lines & Contour of Umuago Gully Erosion Site

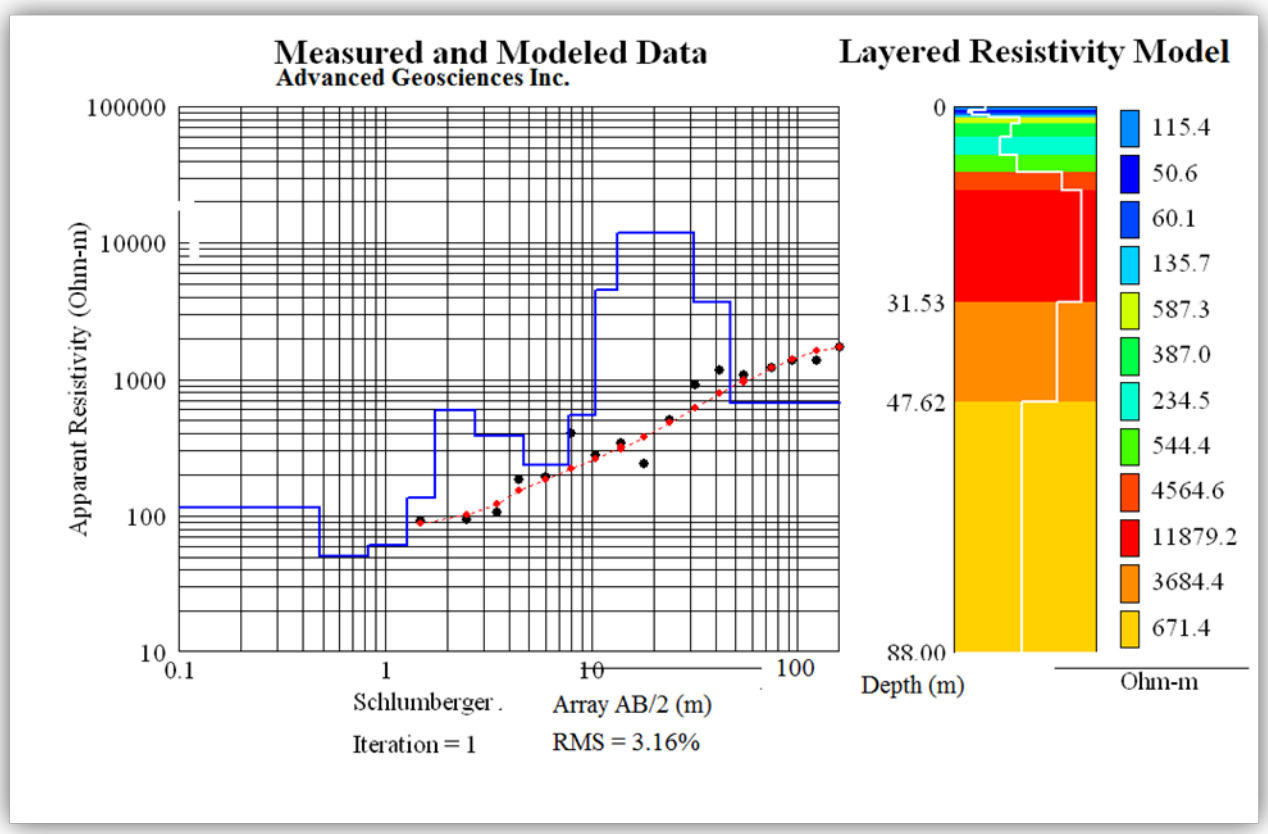

Fig4.9 Umuagor – Urualla Erosion VES

The analytical result presented by the AGI 1D Software and the Schlumberger Automatic analysis package (Fig 4.7) revealed twelve geo-electric layers (Table 4.6) which were constrained to 8 sub-layers (Table 4.7).

Table 4.6 Geo-electric Layers of Umuagwo-Urualla Gully

Layer	ohm-m	Thickness (m)	Bottom depth (m)
1	115.41	0.484	0.484
2	50.60	0.347	0.831
3	60.10	0.448	1.279
4	135.70	0.479	1.758
5	587.34	0.986	2.745
6	387.01	1.988	4.733
7	234.45	3.026	7.759
8	544.37	2.716	10.475
9	4564.57	3.013	13.488
10	11879.21	18.045	31.533
11	3684.44	10.088	47.621
12	671.43		

Table 4.7 Geo-electric layers (Constrained)

Layer	Depth (m)	Resistivity (ohm-m)	Lithology	Colour
1	0.83	115	Topsoil	Mixed blue
2	2.7	587	Silty sand	Green
3	7.7	234	Sandy clay	Blue
4	10.4	544	Silty sand	Green
5	13.4	4564	Sandstone	Red
6	31.5	118.79	Shale sandstone	Red
7	47.6	36.84	Siltstone	Off red
8	>88	671	Shale	Yellow

From the VES result, the subsurface complexity indicates that the gully is underlain by shale and siltstone which overburden is constituted by sandy or loose soil materials. The implication is that the top sandy formation is very permeable to a depth of about 32.5m where shale formation begins to predominate forming a semi-impermeable layer to the infiltrating water.

4.3. Landuse/Landcover in the Gully Area

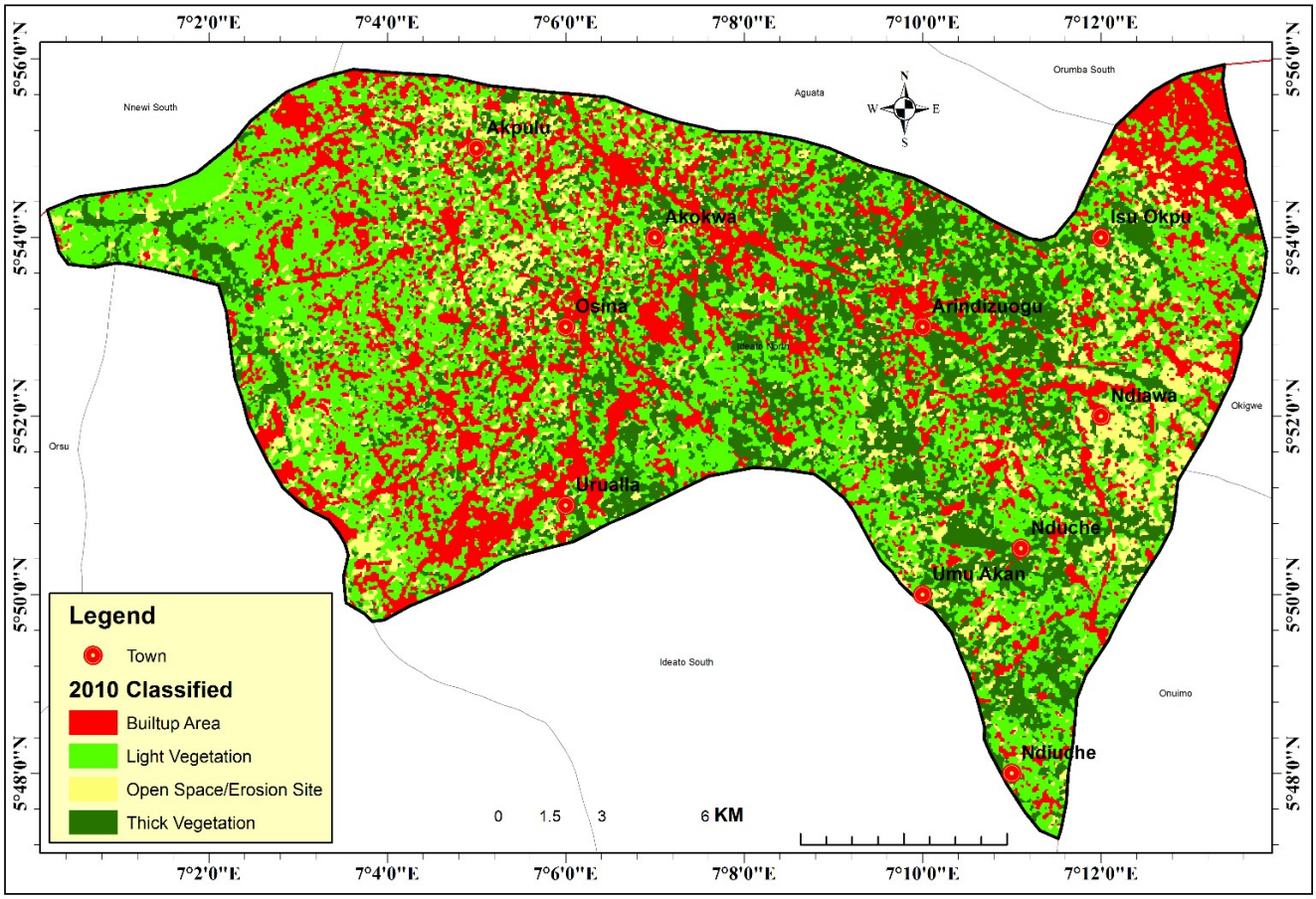

Fig 4.10 Landuse/Landcover of Ideato North LGA

Class	Area(Km²)	Percent (%)
Builtup Area	47.8	25.3
Light Vegetation	75.6	39.6
Thick Vegetation	45	23.5
Open Space/Erosion Site	22.2	11.6
Total	190.6	100

Overall Accuracy	(342578/447412) 76.5%
Kappa Coefficient	0.6698

The landuse/land cover classification of our study area shows that Built-up area is 25.3% of all the available land in Ideato North LGA while light vegetation(farms and sparse vegetation) is 39.6% (75.6km^2) One striking feature of the classification result is that 22.2km^2 (11.6%) is occupied by either open space and or gully erosion. One notable feature is that these occur in and around light vegetation an indication that anthropogenic activities such as farming is a major contributor to the formation of gully erosion.

4.4 Discussion

4.4.1 Gully Erosion Mechanism (Processes and Factors of Urualla Gully erosion)

Success at controlling the occurrence of gully erosion largely depends on the process governing their formation. Several processes have been described in the literature in different part of the world where gully erosion occurs. For example in Australia, according to Crouch *et al.*, (1986) gullies are formed from tunnel (piping) erosion. Tunneling is an insidious and enigmatic process involving the hydraulic removal of subsurface soil, causing the formation of underground passageways (i. e. tunnels) in landscapes. A gully remains when relatively long sections of the surface soil collapse into the tunnel.

From the field survey and laboratory investigation, it was observed that the Urualla gully might have been developed and continue to grow by atleast two dominant processes which can occur in isolation or in combination with one another. The processes include:

4.4.1.1 Gullies formed as a result of Nick Point Formation/Slumping

Most gullies in high elevation area with gently sloping, start out as shallow overland flow paths that carry flows during periods of rainfall (fig. 4.10)At some point in the sheet flow (typically, where the gradient dips) i.e. when the topographic threshold is reached, a nick point is formed along the drainage path. This nick point may develop into a bell-shaped scour hole (especially if there is a difference in lithology of the underlying soil structure), which is usually deeper than the immediate downstream gully bed. The nick point occurs at the downstream end of the gully and usually at significant change in grade along the flow path, such as the point where the overland flow spills into watercourses (rill formation). Head cut begins and causes the head of the gully to migrate up the valley forming the gully (Fig 4.11)

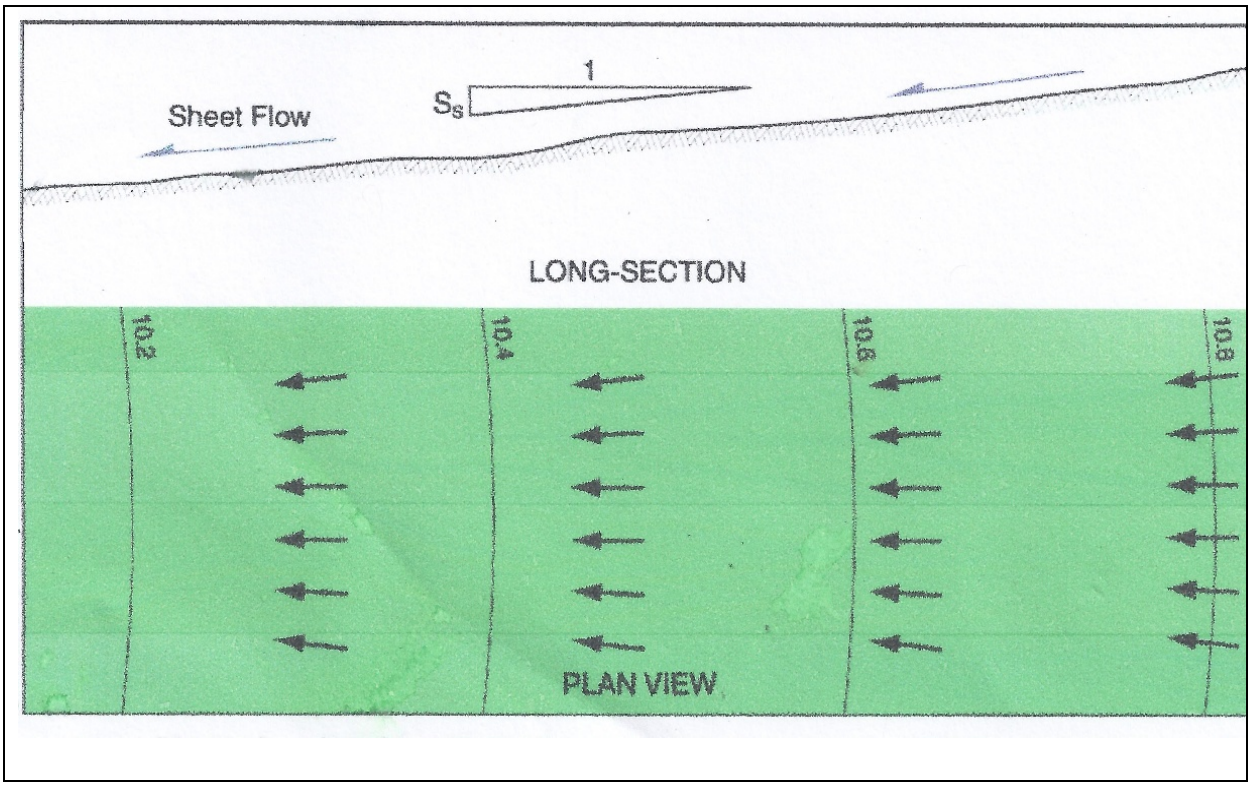

Fig 4.11 Land Profile before the commencement of gully erosion (Source. Amangabara, 2014)

Continuous rainfall and overland runoff expands the channel from rill into gully in both length and width.

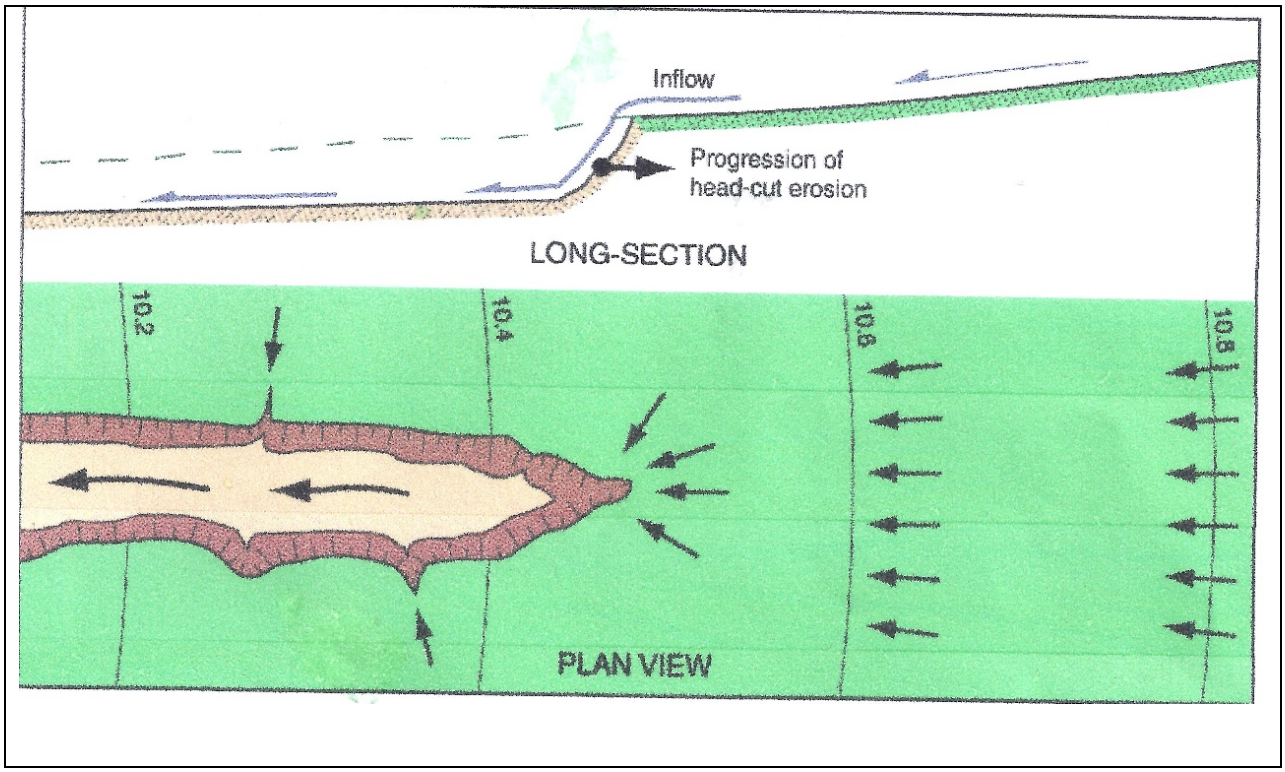

Fig 4.12 Initial stages of gully erosion showing the migration of the gully head up the valley after the initial formation of a "nick" point somewhere along the drainage line. This action of runoff is aided by the soil type. The underlying geology of the study area which outcrop as gravely, poorly sorted sandy loam soil makes it easy for water to flow through and continue the erosion. consequently, the further the gully migrate up the valley, the higher and less stable the gully banks become and with continuous rainfall the gully banks get saturated and slumps, a process referred to as gravity erosion. The Urualla is on a geologic formation that is porous, non-sorted, sandy and gravelly; aided by high topography with gentle sloping and adequate rainfall.

4.4.1.2 Gullies formed from Dry & cracking/Slumping (Gravity Erosion)

Prior to the initial formation of the gully, it is believed that because of the little cohesive/binding materials in the Urualla gully soil, the top soils have a tendency to swell during the raining season and dry during the dry season leading to alternate cracking and drying of the soil. Extreme drying of the top soil results in the extensive cracking that allows lines to cut through on the surface and provide channel for water flow. In areas where sand and shale are the dominant geologic formation the sands are unconsolidated, loose, friable and poorly cemented with thin shale layers as can be seen from the laboratory result. The sands are very permeable while the shale are not, such that during the wet season, the high permeable sandy formation receives sufficient water from surface runoff which causes the water table to rise resulting in high groundwater flow rates saturating the sands and shale formation below the water table affecting their strength. Then during the dry season, the water table falls as a result of hydraulic head decay (Fig 4.8 and Table 4.9) this produces decreased flow rates, and an increase in the depth of the unsaturated zone.

According to Akpokodje *et al.,* 1986; Okagbue&Ezechi 1987; Okagbue, 1988, and Hudec *et al.,* 2005 in areas where there are overlying lateritized soils the less permeable clay layers are lubricated and saturated with water. The clays subsequently expand and lose their shear strength (Fig 4.4 – 4.7 and Table 4.3). As

a result of the shale being thoroughly saturated after many days of rainfall, the clay minerals swell and develop a tendency to slide. Large masses of sand underlain by the plastic shale slide down dip into the gully, with the shale acting as a lubricant

(fig 4.12 & 4.13)

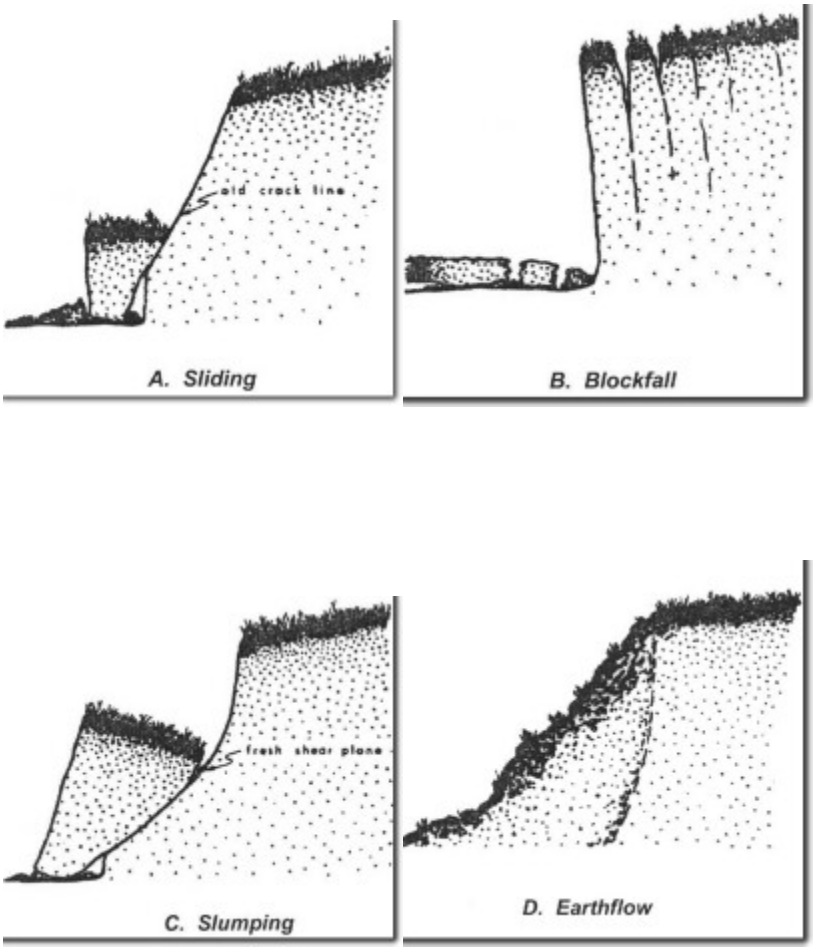

Fig 4.13. Different types of soil/slope failure (Gravity Erosion) resulting from saturated soil forming gullies

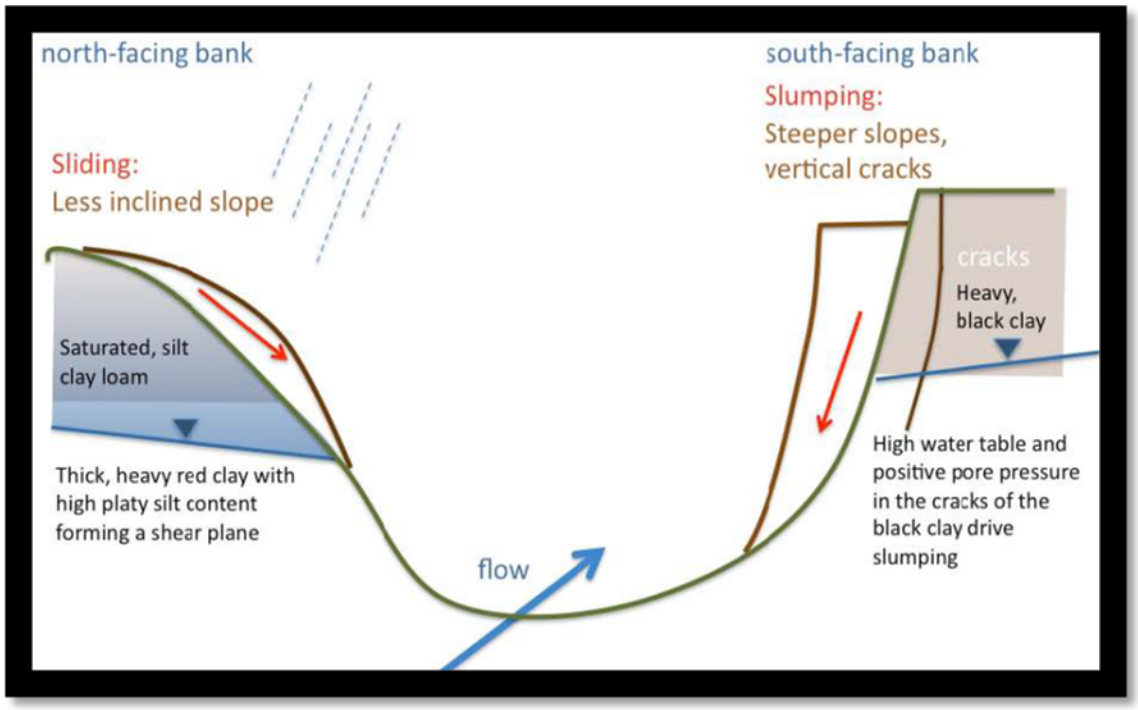

Fig. 4.14 Lateral bank failure & Undercutting Process

One fact is clear from literature and from a close field investigation of Urualla gully; the development of the gullies usually do not follow strictly the generalized stages of sheet, rill, and gully erosion. Sheet erosion may occur but is generally not spectacular before a gully erosion forms. In agreement with Okagbue and Uma (1987) we can rather submit that Urualla gully erosion is rather progressive through the following stages:

(a) Formation of rills,

(b) Development into incipient gully,

(c) Shallow gully<15 m deep), and

(d) Deep gullies (>15 m deep).

The main erosional activity at the first three stages involves the surficial removal of soil grains and small chunks of earth by rain splash, concentrated flood run-off along the rills and existing gully and minor undercutting at the toe of the channels.

4.4.2 Factors of Gully development and Growth

Serious researches have been conducted by many researchers following the observations in the early 1920s of channels entrenching their valleys that generally erode into red-earth and unconsolidated geologic materials establishing prominent gullies with near vertical slopes; and these channels, expanding into complex systems, constituting the most threatening environmental hazard in this part of Nigeria. According to Amangabara (2012), from the much that has been postulated and written on the origin and development of the gullies, there appear to be a considerable measure of agreement among the early researchers for example Floyd, 1965; Ofomata, 1965; Ogbukagu, 1976; Technosynesis, 1978; Nwajide & Hoque, 1979 have emphasized the importance of the soil and geologic materials exposed by the removal of vegetation cover and the impact of heavy rainfall on such materials. The consensus of these earlier workers is that the high intensity rainfall in the area produces high volumes of overland flow.

Researchers in the 1990s and 2000s have improved upon the works of the early researchers and have concluded that groundwater (pore pressure) and slope etc are

key ingredients, with very few looking at the possibility of the influence of the underlying geology (Onu, 2012). Therefore the description and interpretation of the works of earlier researchers on the general erosive processes in the south eastern part of Nigeria (mostly Anambra State and some part of Abia State) have generally constituted the bases for the design and construction of the remedial measures so far adopted (Amangabara, 2012).

From field observation, we believe that the underlying cause of the development of Urualla gully is a combination of plethora of factors which may include the soil,geology, erosivity, slope & elevation etc.

4.4.2.1 Soil Erodibility Factors

The findings on the soil physical properties gave credence to the assumption that the nature of the soil as a result of the underlying geology is the principal factor responsible for the massive gully erosion in our study area. The principal variable of soil erodibility factor is the soil structure which is reflected in the Consistency (Moisture content/Atterberg limits), shear strength, and bulk density. For example, soil consistency (moisture content/Atterberg limits) shows that they are none plastic, meaning they have no binding materials in the soil and as such they are less cohesive. These findings as expected reflected in the Plasticity Index (P.I). The P.I values are low indicating that cohesion (binding of grain particles) is low. Poor

binding or poor cohesion in soil tend to disaggregate when in contact with moving water under the force of gravity.

Bulk density of soil show that the average bulk density of the area is 1.8g/m^3 and this finding is in agreement with the works of Obasi and Ijeoma (1991); Hudec *et al.,* (2006) and Onu, 2011 that have found similar result for the area. The standard measurement for bulk density is 1.6g/m^3 when soil bulk density is above this limit it tends to hardened up the soil. There are two possible scenarios that can result from this: first, the compaction will lead to cracks on the soil surface during the Dry season and during the raining season, these cracks will form the channels for water to flow and since most of the underlying geology is gravely and poorly sorted, erosion will begin to occur by the formation of rills, incipient gullies and gullies a process known as dry and cracking (Secondly, when the underlying formation is shale or lateritic, as a result of the leaching of silica in the sand alongside sodium, potassium and calcium by percolating water; iron, aluminum oxides and hydroxides stay behind, the clay mineral will swell, increase in volume, become plastic and cover the pore spaces preventing percolation and infiltration resulting in excessive surface overland flow and at a threshold velocity of 3.0 – 3.5cm/s cause the soil to slide because it is saturated and weakened (Amangabara, 2014).

Bulk Density, Atterberg limits and Permeability are characters that influence the Shear Strength of any soils. The way and manner grains are packed is important as it governs the angle of repose or internal friction of the soil. The shearing resistance (the threshold point at which a soil can fail) for sand is 20˚ - 35˚.

Soil Texture is another very important variable that influence erosion in the area. From the preceding discussion, the dominant soil type is sandy soil which is poorly sorted and in some cases gravely. Coarse grain soils have little to no binding materials and as such allow quick passage of water which ultimately enhances sediment transportation. The sandstone units are porous and permeable and have less "fines' than the clay/shale units. Water infiltrates/percolates and flow through the top soil and sand units readily but get trapped in the sand/shale interface. The clay/shale units' serves as barriers to downward water flow and therefore confine water to certain sand units which creates two undesirable conditions, namely: excess overland flow (runoffs) and high pore-water pressure build-up in the sands.

This excess overland flow subject the thin soil horizon to stress and sooner or later breaks the thin and fragile soil horizon thereby initiating soil erosion. The entrapped water in the porous and permeable loose sands (low in "fines" which ordinarily serves as cementing materials) leads to high pore-water pressure build-up. This is in turn leads to low shear strength of the interface and reduce the shear resistance at this boundary and cause the surface to be slippery and finally results

in the sliding and slumping of the sand units. Keller (1978) ascribed the real cause of most translational slide to the potential of materials to slide upon long weak, clay layers and not to be immediate heavy rains which saturate the earth material

4.4.2.2 Triggers of Gully erosion in our Study Area.

Thus far we have been able to clearly show that the principal factors of soil (gully) erosion in Imo State is the nature and condition of soil predicated upon the underlying geologic formation. Rainfall intensity and amount as well as the relief (elevation/terrain altitude, length and type of slope) do play significant role once the soil is erodible. In simple term, what we mean here is that a major factor governing the occurrence of gullies in Urualla is the presence of erodible material in those landscape positions where concentrated surface or subsurface runoff can occur; i.e. confined alluvial deposits, unconsolidated sediments and deeply weathered rocks and sediments.

Typically, geologic erosion may not be catastrophic in the immediate term, however, when the erosion is enhanced or accelerated the product is usually catastrophic. Accelerated erosion is activated by both nature and human activities. The human components in soil erosion are connected with poor engineering and agricultural practices and other land use activities. Only the most severe rainfall and large hailstorm events will lead to overland flow in a forest, if the trees are

removed by logging, infiltration rates become high and erosion low to the degree the forest floor remains intact. The landuse/landcover (fig 4.9) show how greatly thick vegetation have given way to light vegetation.

CHAPTER FIVE

5.0 SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 SUMMARY OF FINDINGS

The assessment on geotechnical index properties that result to gully erosion in Umuagor-Urualla is the aim of this research work. The holistic approach of this assessment process is aimed at evaluating the behavior of the earth materials and measurement of soil characteristics of the gully.The soil samples obtained from the area have weak angle of repose (22^0) and are subject to failure.

Also, the soil samples are coarse and are poorly graded. This clearly shows that the study area is geologically underlain by weak, unconsolidated and friable shale (Bende Ameke formation) which is part of the Anambra basin; and gully erosion is due to sliding.

It is therefore evident that gully erosion in Umuagor-Urualla is the major cause of rural exodus within the area as most ancestral homes have been lost due to erosion and most farmlands rendered unproductive.

5.2 CONCLUSION

Based on the findings of this study, it can be concluded that the geology of Umuagor-Urualla is susceptible to erosion and if adequate control measures are not

put in place, the negative impacts of gully erosion will assume more dangerous dimension in years ahead.

5.3 RECOMMENDATIONS

Prevention of the processes or mechanisms that result into or advance to gully erosion should be of paramount importance to all stakeholders in environmental management in the country. Control measures to stem gully erosion that are insipient are most effective when erosion is still at an early stage.

- Channelization of run-off into nearby Orashi River to prevent the formation of Ephemeral gully.
- Cultural method (Vegetative techniques) of erosion control should be encouraged. Planting of plantatain, banana and bamboo trees as well as Grasses species such as *panicum maximum, Pennisetum purpureum, imperata cylinderica and Arunduella nepalesis*.
- The Government at all levels in Nigeria should take it as a matter of urgency to address issues relating to erosion especially gully erosion at an early stage so as to avoid loss of lives of Nigerian citizens and their property.

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APPENDIX I

NATURAL MOISTURE CONTENT DETERMINATION

	sand	Laterite	Clay
Can Identification No.	24	31	17
Wt. of wet soil + can (g)	30.9	30.0	34.1
Wt. of dry soil + can (g)	29.7	28.2	32.0
Wt. of can (g)	19.1	17.1	21.2
Wt. of dry soil (g)	10.6	11.1	10.8
Wt. of water (g)	1.2	1.8	2.1
Water content, w, (%)	11.3	16.2	19.5

BULK AND DRY UNIT WEIGHT (p_b & p_d) DETERMINATION

Wt. of Ring + Sample (d)	291.4	298.6	288.2	
Wt. of Ring (g)	163.3	163.3	163.3	
Wt. of sample (g)	128.1	135.3	124.9	
Volume of sample (g)	72.0	72.0	72.0	
Bulk unit wt. (p_b) (mg/m^3)	1.78	1.88	1.74	
Dry unit wt. (p_b) (mg/m^3)	1.60	1.62	1.45	
Dry unit wt. (p_b) (KN/m^3)	16.0	16.2	14.5	

APPENDIX II

Summary of Atterberg Limit Test on Laterite

Property	Quantity
Liquid limit	20%
Plastic limit	8%
Plasticity index	12%
Bulk density	1.88mg/m^3

Summary of Atterberg Limit Test on Clay

Property	Quantity
Liquid limit	28%
Plastic limit	10%
Plasticity index	18%
Bulk density	1.744mg/m^3

APPENDIX III

DETERMINATION OF SHEAR STRENGTH

a) DIMENSIONS OF SAMPLES

Length of sample (L) = 60mm

Width of sample (W) = 60mm

Height of the sample (H) = 20mm

Area of sample A, = L x W = 3600mm^2 = 0.0036m^2

Volume of sample, V, = L x W x H = 7200mm^3

b) NORMAL STRESS (σ) COMPUTATION (FOR SAMPLES)

(1) Load (kg)	(2) Load (KN) (1) ÷ 100	(3) Area (m^2)	(4) (KN/m^2) (2) ÷ (3)
24	0.24	0.0036	66.7
44	0.44	0.0036	122.2
64	0.64	0.0036	177.8

c) SHEAR STRESS (τ) COMPUTATION

(1) Sample	(2) Load (kg)	(3) Max. H.R	(4) (3) x 0.002	(5) (4) x 0.88 (KN)	(6) (5) ÷ A (KN/m^2)
SAND	24	102	0.204	0.180	49.9
	44	137	0.274	0.241	07.0
	64	192	0.384	0.338	93.9
LATERITE	24	92	0.184	0.163	45.4
	44	149	0.298	0.262	72.8
	64	203	0.406	0.357	99.2
CLAY	24	80	0.16	0.141	39.1
	44	125	0.25	0.22	61.1
	64	170	0.34	0.30	83.1

COMPUTATION OF SHEAR STRENGTH

Sample	C (KN/m^2)	Φ (0)	σ_n (KN/m^2)	T KN/m^2
SAND	3	24	177.8	82.2
LATENITE	10	20	177.8	74.7
CLAY	7	24	177.8	86.2

Note:

1. C = Cohesion (KN/m^2)
2. ϕ = Angle of internal friction (0)
3. σ_n = Maximum normal stress KN/m^2
4. τ = Shear strength (KN/m^2).

APPENDIX IV

Sieve Analysis for Sample 1

Sieve sizes (mm)	Mass of soil retained (g)	Percent retained	Cumulative Percent passing	Cumulative percent retained
2	0	0	100	0
1.18	0.3	1	99	1
0.85	1.6	3	96	4
0.6	6	10	86	14
0.425	8.2	14	72	28
0.3	7.6	13	59	41
0.15	14.8	25	34	66
0.075	20	33	1	99
Pan	1.4	2		

Sieve analysis of Sample 2

Sieve sizes (mm)	Mass of soil retained (g)	Percent retained	Cumulative Percent passing	Cumulative percent retained
2	10.2	23	77	23
1.18	1.6	4	73	27
0.85	2.9	7	66	34
0.6	3.5	8	58	42
0.425	5.1	12	46	54
0.3	3.1	7	39	61
0.15	1.3	3	36	64
0.075	15.9	36	0	100
Pan	43.6			100

Sieve Analysis for Sample 3

Sieve sizes (mm)	Mass of soil retained (g)	Percent retained	Cumulative Percent passing	Cumulative percent retained
2	1.2	39	61	39
1.18	0.8	26	35	65
0.85	0.6	19	16	84
0.6	0.2	6	10	90
0.425	0.1	3	7	93
0.3	0.1	3	4	96
0.15	0.1	3	1	99
0.075	0	0	1	99
Pan	0			100