PHYSIOCHEMICAL AND HEAVY METAL PROPERTIES OF GULLY EROSION SITE IN EVBHOMORE COMMUNITY, BENIN CITY, EDO STATE

BY

ODOH PATRICK CHIKWADO

LSC2003077

DEPARTMENT OF ENVIRONMENTAL MANAGEMENT AND TOXICOLOGY

FACULTY OF LIFE SCIENCES

UNIVERSITY OF BENIN

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AN UNDERGRADUATE PROJECT WORK SUBMITTED TO THE DEPARTMENT OF ENVIRONMENTAL MANAGEMENT AND TOXICOLOGY, FACULTY OF LIFE SCIENCES, UNIVERSITY OF BENIN, BENIN CITY, EDO STATE, NIGERIA; IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR AWARD OF BACHELOR OF SCIENCE (B.SC.) DEGREE IN ENVIRONMENTAL MANAGEMENT AND TOXICOLOGY.

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CERTIFICATION

This is to certify that this research titled "**PHYSIOCHEMICAL AND HEAVY METAL PARAMETERS IN EVBHOMORE GULLY, BENIN CITY"** was carried out by **"ODOH PATRICK CHIKWADO"** with matriculation number **"LSC2003077"** and presented to the Department of Environmental Management and Toxicology, Faculty of Life Sciences, University of Benin, Benin City; in partial fulfillment of the requirements for the award of Bachelor of Science (B.Sc.) in Environmental Management and Toxicology. It was conducted under suitable conditions, was carefully supervised and subsequently approved as having met the requirements for the award of Bachelor of Science degree in Environmental Management and Toxicology.

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Mr. H. C. AMUJIRI **Date**

(Project Supervisor)

________________________ ________________________

PROF. (Mrs.) E. T. AISIEN **Date**

(Head of Department)

DECLARATION

I “**ODOH PATRICK CHIKWADO**” declare that “**PHYSIOCHEMICAL AND HEAVY METAL PARAMETERS IN EVBHOMORE GULLY, BENIN CITY**” is my own work and that all sources that I have used or quoted have been acknowledged by means of complete references and that this work has not been submitted before for any other degree at any other University.

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ODOH PATRICK CHIKWADO   **Date**

DEDICATION

I dedicate this project to Almighty God for His endless love, grace and provision. He has been my strong pillar, my source of strength, wisdom and inspiration. I also dedicate this project to my lovely sister Mrs. Hope Idemudia Edokpaigbe, who has encouraged me and supported me throughout my academical journey.

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ABSTRACT

This study assessed the physiochemical and heavy metal properties of gully erosion site in Evbhomore Community, Benin City, Edo State. Water and soil samples were collected into sterile plastic container to avoid additional contamination before taken to the laboratory for physicochemical and heavy metal analysis following standard procedures. Physicochemical characteristics of soils samples showed that clay ranged from 24.00 ± 1.92 - 36.00 ± 2.96 %, silt (24.00 ± 1.92 - 33.00 ± 2.83 %), sand (33.00 ± 2.83 - 51.00 ± 3.89 %). pH ranged from 6.70 ± 0.50 - 7.88 ± 0.93, organic matter (0.91 ± 0.37 - 2.00 ± 1.00 %), organic carbon (0.51 ± 0.25 - 0.89 ± 0.37 %) and total nitrogen (0.01 ± 0.00 - 0.05 ± 0.00 %). Electrical conductivity ranged from 4.12 ± 1.45 - 4.81 ± 0.36 µS/cm, available phosphorus (150.00 ± 5.00 - 180.00 ± 5.74 mg/kg) and total exchangeable bases (1.60 ± 0.42 - 1.99 ± 0.69 cmol/kg). In soil samples, cadmium values ranged from 0.16±0.13 - 0.30±0.13mg/kg, Lead (1.26 ± 0.33 - 3.50 ± 0.51mg/kg), Zinc (25.12 ± 2.82 - 79.02 ± 3.29 mg/kg), Copper (27.89 ± 2.49 - 63.08 ± 3.68 mg/kg), Iron (191.16 ± 5.07 - 212.16 ± 5.92 mg/kg) and Manganese (10.80 ± 0.49 - 18.00 ± 0.81 mg/kg). Soil and land cover contributed 12% and 6% respectively to gully erosion in the study area. The occurrence of soil erosion risk in the study area has also been on the increase and is not limited to a particular area but all part causing serious land degradation affecting a wide variety of soils prone to crusting and/or piping. The widths and depths of gully erosion increased with the increase in slope gradient and decrease with increase in percentage of vegetation cover, especially during the rainy season and confirm that soil erosion in the study area has altered vegetation cover, ground slope, slope length and shape. There is therefore the need for protective strategies and measures for sensitive management of the environment to reduce erosion rates and increasing water conservation.

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

The Nigerian gully erosion crisis has been underway since before 1980. It is an ecological, environmental, economic, and humanitarian disaster resulting in land degradation, as well as the loss of lives and properties worth millions of dollars. The estimated number of gullies in the country is at 3,000 (Njoku *et al.,* 2016). Gully erosions occur due to sandy soil being unable to withstand the runoff and eventually eroding away, leaving gaping gullies that swallow homes and other infrastructure. Gullies and areas exposed to erosion in South Eastern Nigeria tripled from about 1.33% (1,021 km^2) in 1976 to about 3.7% (2,820 km^2) in 2006, making the region the most affected in the country. The South East region of Nigeria has long suffered erosion, mostly as a result of heavy rainfall leading to flooding. The change in climate has been referenced as the cause. Many farms, homes and other buildings have been affected (Rzymski *et al.,* 2014).

Environmental contamination arises from human activities like the improper disposal of chemicals and microbiological materials at landfill sites, emissions from vehicles, and the incineration of waste. This issue is a significant concern, particularly due to the rise in economic activities and industrialization, which have led to a notable increase in contamination (Slessarev *et al.,* 2016). Anthropogenic and industrial actions have given rise to environmental hazards. The reckless disposal of their waste has led to contamination, rendering the environment unsuitable and water bodies unsafe for human consumption. Additionally, erosion poses a significant threat to the environment, especially when construction plans are not adequately situated (Amujiri and Ekaye, 2023). Soil, a dynamic natural entity shaped by pedogenic processes and rock weathering, is comprised of mineral and organic components. It possesses physical, chemical, and biological attributes that influence various soil processes, making it conducive for agricultural practices and other objectives. Soils play a pivotal role in maintaining ecological stability. However, the presence of contaminants can compromise their quality, leading to potential issues. Contaminants such as heavy metals (lead, arsenic, chromium, cadmium, and mercury) pose risks to human health when consumed in high concentrations due to their toxicity and potential carcinogenic properties (Apollo *et al.,* 2018). Heavy metals, defined by their density exceeding 5 g/cm^3 , adversely affect the environment and living organisms.

Even at low concentrations, heavy metal contamination can have detrimental effects on the environment and human health due to its persistence, toxicity, and ability to accumulate. These metals can persist in nature, entering the food chain through plants and animals, as well as water bodies, which poses a considerable risk to human health. The origin of heavy metals in the environment can be both natural and anthropogenic. Anthropogenic sources include the application of manures, sewage sludge, fertilizers, and pesticides (Kraal *et al.,* 2017). These substances can impact heavy metal dynamics by altering soil physicochemical properties such as pH, organic matter content, organic carbon levels, and the bioavailability of heavy metals in the soil. In the Ifite area, groundwater is the primary water source. However, due to improper waste disposal and various forms of pollution entering water bodies, groundwater contamination has become an issue. Solid waste, soil erosion, and wastewater from residential and industrial zones infiltrate groundwater through leaching. Groundwater contamination arises from chemical leaching from industrial activities, agrochemical discharges, septic tank leakage, leachate seepage from dumpsites, and underground soil erosion, particularly during the rainy season. The extent of contamination depends on factors such as topsoil structure, borehole water depth, percolation rate, and precipitation patterns (Komar and Zeebe, 2016).

Gully erosion occurs when surface water runoff removes soil along drainage lines. This environmental degradation can result in the loss of useful land that is utilized for farming, domestic, industrial, and other purposes. Additionally, it can cause damage to properties and even lead to loss of life. According to Hosseinpur and Pashamokhtari (2013), Anambra State in the Southeastern region of Nigeria has the highest number of active gullies, with many of them having failed gully-control measures. The gullies in this area can be described as catastrophic, as they are very deep and wide, with some even stretching for tens of kilometres. In fact, they could be better referred to as canyons. Gullies in Anambra State have been attributed to a variety of factors by workers. Some suggest that human activities have influenced natural and geological processes, while others believe that gullies are linked to concentrated runoff processes. Panagos *et al.* (2013) pointed to anthropogenic activities like rapid urbanization, rural-urban migration drift, overpopulation, indiscriminate dumping of household waste in drains, emission of ozone layer-depleting gases/burning of fossil fuels, hazardous industrial waste products, and heavy tropical rains as remote causes of gully erosion and flooding in the area.

Zambelli and Ciurli (2013) believed that roads without proper drainage or catchment pits, unguided cultivations that cause flooding, indiscriminate channelling of flood water on sloped terrain, intense rainfall on metal roofs without drains, large cracks in hills that form flood channels, and poor drainage systems are all contributing factors to gully erosion. Akuro (2012) discussed the prevailing factors in the state that contribute to gully erosion, including topography, climate, vegetation, geology, soil, and human factors. Costard (2012) points out that annual dynamic fluctuations in the groundwater table are another important factor that enhances gully initiation and growth in the area. According to Singh *et al.* (2012), topography plays a significant role in the development of gullies in the region. NESREA (2011) suggests that the sequence of the contribution of soil erodibility factors to gully erosion frequency is slope > plasticity > cohesion > friction > population density, with percentage contributions of 30%, 23%, 20%, 18%, and 9%, respectively. Gully erosion is a major environmental problem that threatens the sustainability of both plants and animals in the world, and a large area of land in Anambra State is at risk. Obidimma and Olorunfemi (2011) stated that only a few of the erosion menace is under control. WHO (2011) noted that an increase in hydraulic heads can enhance gully development through an increase in flow rate, and seasonal expansion and contraction of impermeable clayey and/or shaly materials can also increase the rate of gully development. USEPA (2009) attributed gully erosion in Anambra State to the interaction of water flow with geological materials and the chemistry of the water and/or soil, as well as geotechnical properties and other anthropogenic factors. Jones *et al.* (2008) recommended preventive measures as the best strategy to keep erosion and other environmental problems at bay in Anambra State, while [6] highlighted the significance of the underlying geology, specifically the Imo shale, in controlling gully development. The phenomenon of gully erosion is rock-type dependent, with some rocks being more susceptible to erosion than others.

1.2 Statement of Problem

Gully erosion generally degrades land and affects not just plants and animal but is capable of taking away human's life, though it a natural disaster but ways of preventing it can be thought about. Gully erosion seems to be a factor of discourse every rainy season because maybe the government have decided to pay deaf ears to this menace, sometimes because they must have tried to work on it but the solution was not long lasting and they thought intervening again will just be a total waste of money thereby feeling discouraged. Finally, several studies has been carried out on the effect of erosion on agricultural produce but not even a single research has been carried out on the effects of gully erosion on the environment a case study of in Evbhomore community in Benin City.

1.3 Significance of the Study

Erosion generally degrades land and affects not just plants and animal but is capable of taking away human's life, as such this study will be of immense benefit to the entire in Evbhomore community in Benin City in the sense that it will enable the ministry of environment to come up with a strategy on how to handle gully erosion in not just Evbhomore community but in other neighbouring communities of Edo State that are also facing gully erosion challenges. Finally, the study will contribute to the body of existing literature and knowledge to this field of studies and basis for further research.

1.4 Aim and Objectives

The aim of this study is was determine the physiochemical and heavy metal properties of gully erosion site in Evbhomore Community, Benin City, Edo State.

The objectives of the study were to:

1. determine the physiochemical properties of soil and water of the gully erosion site
2. determine the heavy metal characteristics of soil and water of the gully erosion site
3. determine the impact of human activities on the gully erosion site

CHAPTER TWO

LITERATURE REVIEW

2.1 Gully Erosion

Gully erosion is one of the most destructive soil/land erosion processes; within a short period of time the topsoil and the underlying unconsolidated rock substrate are removed by runoff, resulting in the formation of a steep-sided channel deeper than 2 m, with an abrupt gully headcut and numerous thresholds in the channel thalweg (Arai and Sparks, 2007). This landform is commonly known as a ravine (gully), albeit it bears different names across the Globe (e.g., arroyo or coulee in USA, uvrag in Russia, burone or fosco in Italy, ravin in France, donga in South Africa, lavaka in Madagascar, nullah in India, etc.). Due to the typically high gully development rates, these landforms have significant impact on vast farmland areas. Furthermore, they deliver large amounts of sediments to rivers and reservoirs. Gully erosion is regarded as an indicator of desertification; the main causes of which are allegedly global climate changes and anthropogenic pressure (Joshi *et al.,* 2007). However, experimental studies on gully erosion commonly lacked the ampleness of those dedicated to surface sheet erosion, even in Europe. Gully erosion rate estimates showed that gullying is responsible for a large extent of the topsoil loss in small catchments, ranging to as high as 90 % or above in numerous instances.

The greatest threat to the environmental settings of southeastern Nigeria is the gradual but constant dissection of the landscape by soil erosion by water. Although the incipient stages of soil erosion through rill and interrill are common and easily managed by the people through recommended soil conservation practices, the gully forms have assumed a different dimension such that settlements and scarce arable land are threatened. Therefore, gully erosion problems have become a subject of discussion among soil scientists, geographers, geologists, engineers and social scientists. Mann *et al.* (2002) indicated that gully erosion types are the most visible forms of erosion in Nigeria mainly because of the remarkable impression they leave on the surface of the earth. Again Osuji and Nwoye, (2007) remarked that more than 1.6% of the entire land area of eastern Nigeria is occupied by gullies. This is very significant for an area that has the highest population density 500 persons per km^2 in Nigeria. Before the 1980's the classical gully sites in the region were the Agulu, Nanka, Ozuitem, Oko in Aguata area, Isuikwuato and Orlu. With the increased development activities the number and magnitude escalated thus making many government administrations within the region to set up soil erosion control with different names in different states. At the last count the Federal Government of Nigeria has started showing interest in ecological problems in the country including the control of the gullies which has reached more than 600 active sites in the region (Thyssen *et al.,* 2007). The gullies are also a visible manifestation of the physical loss of the land due to erosion. Long before now a lot of attention has been focused on the control measurers. As early as the 1930s, the colonial government in Nigeria has undertaken a campaign of tree planting with the main objectives of controlling erosion especially on the steep slopes of upland landscapes in the region. Ever since then there has been a constant enquiry as to the causes of these catastrophic erosion.

Most researchers have shown that the environmental factors of vegetation, geology, geomorphology, climate in the form of rainfall which is very aggressive in the region and the soil factor all contribute in the erosion problem and their development. The consequence of the soil erosion is loss of land for agriculture and for habitation (Watling, 2006). During some slides caused by gully formation, lives have been lost while some communities have been separated because of deep and very wide gullies that may reach in some cases 12 m deep and more than 1.5

km long like the Nanka/Agulu gully complexes or in Oko in Aguata, Anambra State. Crop yields have been reduced, thus creating problem in the "green revolution" campaign.

2.2 Gully Typology

Gullies are ranked and classified according to a variety of criteria reflecting both the diversity of control factors and the genetic processes and evolution of these landforms; thus, we believe it is necessary to discuss first the most relevant aspects regarding gully classification. The following classes of gullies were identified as typical for the Romanian territory (Ridgwell and Zeebe, (2005): continuous gullies1 and discontinuous gullies2 are types of landforms which indicate the stage and pace of gully evolution; the gully planform may provide clues regarding their origin and the relation to the type of rock deposit whereby they were incised; the location of gullies within drainage basins/catchments is relevant when determining the type of ephemeral runoff, the role of drainage upstream of the gully headcut or the occurrence of piping conditions (Costard *et al.,* 2003). According to these criteria, several types of gullies were established: valley floor gullies, whereby the evolution is linked to the valley concentrating the runoff/discharge; valley origin gullies which develop headwards along the channel of the valley and may evolve into valley gullies; hillside gullies located on the hillslopes, independent of the valley channel. Furthermore, gullies can be ranked according to their cross-section ranging from U-shaped gullies to V-shaped gullies, with many intermediate types. The shape of the cross-section is related to the resilience of rock deposits to erosion and the nature of geomorphic processes (Rădoane, 2002).

The topography of South Eastern Nigeria determines its vulnerability to water erosion. There are three types in the area: plains and lowlands, uplands, and highlands. The highlands, which consist of cuesta landscapes, are resistant to erosion due to their soil composition, but they serve as paths for the water to runoff and erode the lowland areas. A geomorphologist, G. Ofomata, discovered a relationship between the slope of the hills and the severity of the erosion occurring. On a 15 percent slope, there was a much greater total soil loss than on a compared 1 percent slope. Regardless if they are convex or concave, the sloped lowlands are at risk, due to their poor soil characteristics and the angle at which the soil can erode (Sahrawat *et al.,* 2002).

2.3 Gully Distribution

The distribution of gullying processes was studied in Romania mainly based on the inventory of gully erosion landforms from the Moldavian Plateau. Buzău Subcarpathians, Southern Subcarpathians and Getic Piedmont, Brașov Depression etc (Pitman and Golovchenko, 2001). One of the most elaborate investigations of this kind was conducted and was further enhanced by employing advanced research techniques, albeit on a smaller scale, by Stângă (2011). The Moldavian Plateau, delimited roughly by Siret and Prut watercourses, amounts to approximately 25,000 km^2 and comprises the most extensive areas affected by polymorphic land degradation processes. According to official reports from 2010, of the 3,372,916 ha of land undergoing severe erosion in Romania, this region accounts for no less than 33.5 % (www. anpm.ro), which can be attributed to the mixed action of control factors, namely: The regional geology consists mainly of poorly consolidated Sarmatian rock formations, as well as Pliocene deposits in the southern sector of the Plateau (Jobbágy and Jackson, 2000). The following sequence of main lithological complexes unfolds southward: Buglovian Bessarabian, composed predominantly of loamy marls; Kersonian, comprising of marly clays and sands; Meotian, consisting of clay and sands interbedded with sands and tuff; Pontian–Romanian, comprising of gravel and sands (Fig. 16.2, the location of these lithological entities is shown in the inset). The relief shaped on this substrate consists of numerous consequent river valleys whereby the hillsides often exceed 300 m up to 500 m in length and their gradients typically range between 20 and 30 %. The climate elements which control gullying processes are temperature and precipitation quantized in the shape of the hydrothermal coefficient (APHA, 1999). When this coefficient assumes value between 1.25 and 2.50, the most favorable conditions for gullying are met, and the Moldavian Plateau ranks within this interval. The dynamics of land use/land cover in Moldova throughout the past two centuries indicates that forested areas decreased from 75 % to as little as 25 %. Currently, forests account for just 15 % of the total study area (EEA, 2007). Agricultural uses are prevalent, with an "atomization" of the agricultural farms amounting to about 45,000 parcels, with an average surface of 0.7 ha, and the frequently up- and down-slope farming (Stângă, 2011). Over 9000 gullies were inventoried in this region, such that 36 % of the 1 km2 squares each contain at least one gully. Whereas the number of gullies per unit area (1 km^2) commonly ranges between 2 m and 4 m, in some instances it can be as high as 20 m.

2.4 Formation of Gully Erosion

Gully erosion can progress through a variety and combination of processes. The erosion processes include incision and bank erosion by water flow, mass movement of saturated or unsaturated bank or wall material, groundwater seepage - sapping the overlying material, collapse of soil pipes or tunnels in dispersive soils, or a combination of these to a greater or lesser degree (Anati,1999). Hillsides are more prone to gully erosion when they are cleared of vegetation cover, through deforestation, over-grazing or other means. Gullies in rangelands can be initiated by concentrated water flow down tracks worn by livestock or vehicle tracks. The eroded soil is easily carried by the flowing water after being dislodged from the ground, normally when rainfall falls during short, intense storms such as during thunderstorms.

A gully may grow in length by means of headward (i.e. upstream) erosion at a knick point. This erosion can result from interflow and soil piping (internal erosion) as well as surface runoff. Gully erosion may also advance laterally by similar methods, including mass movement, acting on the gully walls (banks) and by developing 'branches' (a type of tributary).

Gullies reduce the productivity of farmlands where they incise into the land, and produce sediment that may choke downstream waterbodies, and reduce water quality within the drainage system and lake or coastal system (FEPA, 1991). Because of this, much effort is investeinto the study of gullies within the scope of geomorphology and soil science, in the prevention of gully erosion, and the in remediation and rehabilitation of gullied landscapes. The total soil loss from gully formation and subsequent downstream river sedimentation can be substantial, especially from unstable soil materials prone to dispersion.

When water is directed over exposed ground, gully erosion happens, removing soil near drainage lines. This may result in issues like divided properties, loss of arable land, diminished amenities, and decreased property values. Additionally, it can lead to sedimentation, discoloration of the water supply, and the creation of a haven for rodents (Ademoroti, 1996). Water rushing over exposed, naked soil creates gullies and ridges that erode rock and soil. When water rushes across exposed terrain, it erodes or pushes dirt away, creating rills. Gravity causes rift erosion to occur on a downward slope, with steeper slopes generating greater water flow. Sandier terrains are more commonly affected by rills, which are most prevalent during the rainier months. Gullies develop when a rill is neglected for an extended period of time, thickening and expanding as soil erosion persists (FEPA, 1991)

The factors influencing gully erosion were investigated in Zaria, Kaduna state, Nigeria, utilizing SRTM data, soil samples, rainfall data, and satellite imagery. The findings indicated that the factors that had the biggest effects on gully erosion were slope (56%) and rainfall (26%), land cover (12%), and soil (6%). The investigation came to the conclusion that soil loss was significantly influenced by a particular component (Njoku *et al.,* 2016).

2.5 Causes of Gully Erosion

Gullies are majorly caused by surface runoff. The erosion occurs notably in gullies, which grow wider and deeper with each rainfall. Many of the gullies have become ravines, which can be dozens or hundreds of feet deep. Some natural processes can bring about gullies, such as heavy rainfall, poor soil infiltration and unfavorable catchment shape (Rzymski *et al.,* 2014). The process of gully formation is expedited by the types of soil in South Eastern Nigeria: sandy clay and loamy sand. These are soil types that have greater amounts of sand than clay, loam, or silt. The soil type or texture determines how water flows through it. Soil types with predominantly sandy characteristics allow for pockets of space that water easily moves through. For this reason, sandy soils do not have the ability to hold nutrients and support plant life. Without plants extending their roots into the soil and solidifying it, the chances of soil erosion increase even more. Since erosion plays a large role in soil depletion in this area, it is important to consider fertilization and irrigation when attempting to grow crops (Slessarev *et al.,* 2016). Climate in Nigeria has an extreme impact on the gully formations. For an area that is predominantly dry, the intensity of the rain often leads to flooding and large amounts of water in one location. The rainfall in Nigeria can be considered aggressive, with large raindrop sizes and high amounts being released at once. The texture of soil cannot support the water and thus erodes away, and with no vegetation, the process is sped up. However, in Nigeria, the more significant causes of gully formation can be largely attributed to human activities such as (Apollo *et al.,* 2018):

Poor road design, construction and abrupt termination of drains: When drains are not properly terminated, the flow in them, usually with high pressure, will disperse the earth below, causing gullies rather than flow to lower catchment areas. Poor waste management practices: poor waste management practices such as dumping of refuse into drains and waterways prevent the proper flow of water. This practice results in flooding and if unchecked, it can lead to erosion of the top layer of the soil. Unsustainable land use practices: practices such as improper sand mining strips away the top soil and tilling process associated with crop cultivation loosens the top soil, creating paths for runoff (Amujiri and Ekaye, 2023). Though concentrated in several towns and states in the south-eastern part of the country, the crisis affects all Nigerians indirectly. Homes and structures routinely collapse, as the gullies expand with each rainy season. Unchecked, the phenomenon will eventually transform the region into a badland.

2.6 Field Runoff Gullies

Usually gullies from field runoff form in the same place year after year, especially in tilled fields. Tillage destroys soil structure and reduces the residue cover, leaving the soil surface more prone to erosion and runoff. While the tillage does fill in the gully, each time the gully washes out again, the soil is lost from the gully and from along the sides of the gully as that soil was used to repair the gully (Kraal *et al.,* 2017). Rather than repairing the gullies every year, use terraces to intercept the runoff and grass waterways or underground tile lines to carry the runoff from the field without causing more erosion. These terraces and waterways or tile lines need regular maintenance to keep them functioning properly so they can handle heavy rainfall events.

Producers can keep more water in their fields by improving soil structure with continuous no-till and leaving residue on the soil surface to reduce crusting. This allows more water to be infiltrated into the soil, decreasing runoff and reducing the formation of rills and gullies. While no-till and residue management are fairly effective at reducing sheet and rill erosion, gully erosion can still take place when concentrated flows exist. Whenever rainfall rates exceed infiltration rates, especially on saturated soils, other runoff control methods may still be needed to carry the water away safely (Komar and Zeebe, 2016).

2.7 Concentrated Water Flows

Gullies are caused by concentrated flows, either from field runoff and small rills combining together into larger flows or from runoff coming onto the field from a concentrated source. Examples include water from a road culvert dumping into a field, runoff from farmsteads or other areas with reduced infiltration, from terraces over-topping because of reduced carrying capacity, or from field runoff from many crop rows combining together on end rows, especially when end rows are planted next to a waterway and the runoff cannot enter the waterway (Hosseinpur and Pashamokhtari, 2013).

2.8 Effects of Gullies

The effect of gullies in an environment cannot be overemphasized. The loss of fertile farmland due to gully erosion is a serious environmental problem that lowers crop quality and may cause famine and food shortages. It also causes the soil to lose organic content, which has an impact on plant viability. As items washed from fields end up in rivers, streams, or vacant land, erosion also contaminates the ecosystem. Because of increased population expansion and increasing land demand, erosion is also a threat to the natural ecosystem, encroaching on natural forests.

Important assets including homes, power poles, and water pipelines are also destroyed (Panagos *et al.,* 2013).

2.9 Prevention of Gullies

Effective land management techniques can prevent gullies. These techniques include keeping vegetation along drainage lines, using more water, classifying drainage lines as distinct land classes, stabilizing erosion, preventing vermin, distributing runoff evenly, keeping soil organic matter levels high, and avoiding over cultivation. These tactics guarantee uniform rates of penetration and robust plant coverage (Zambelli and Ciurli, 2013).

One serious environmental problem endangering sustainable development is gully erosion. Gullying prevention and control methods are dispersed, lacking, and have low success and efficacy rates. This review attempts to make a valuable contribution to effective gully prevention and management techniques by combining information from previous research. It is possible to stop the creation of gullies by changing the way land is used, conserving water and soil, or implementing specific actions in areas with concentrated flow. Plant leftovers and other vegetation barriers can prevent erosion, although their usefulness is limited. The biophysical environment, terrain, climate, and geomorphology are examples of external elements that affect gully prevention and control (Akuro, 2012).

2.10 Stabilising Gullies

In order to lessen scouring, sediment buildup, and revegetation, stabilizing gullies entails altering water flow. Water can be securely moved from the natural level to the gully floor using a variety of structures, including drop structures, pipe structures, grass chutes, and rock chutes. Along steep gully floors, structural modifications can be required. Vegetation can reestablish itself thanks to sediments deposited over flatter gradients. Until the restoration is finished, damaged areas should be walled off (Costard *et al.,* 2012).

2.11 Gully Remediation in Nigeria

Eastern Nigeria's people and ecology are seriously threatened by gully erosion. A research project that focused on 370 families and nine risk regions evaluated the region's gully erosion issues. The greatest perceived problem, according to the results, was biodiversity loss, whereas damage to properties, roads, and walkways was ranked as the least important issue. This implies a notable variation in the average evaluations across impacted individuals, underscoring the necessity for long-term repair approaches (Singh *et al.,* 2012). Reducing soil loss, raising public knowledge of environmental issues, passing environmental legislation, and giving residents funds to strengthen their coping mechanisms are all advised by the study.

In Agulu-Nanka, Southeast Nigeria, a study looked into the geoenvironmental causes driving gully erosion. It focuses on catchment management for gully erosion and geotechnical analysis. Through fieldwork, data was gathered utilizing GIS and GPS methods. According to the study, gully erosion occurs throughout, with Nanka/Oko having the highest concentration. Variations in length and depth are shown by the gully characteristic map, emphasizing the necessity of considering gully vulnerability and giving erosion hazards immediate attention (NESREA, 2011).

2.11.1 Grassed Waterways

When concentrated flows exist, the soil needs extra protection to keep it from washing away. A permanent grassed waterway will help protect and anchor the soil. The waterway should be sized to handle maximum flows and field operations should go into the waterway so water can flow into the grassed area. End rows should not be planted alongside a waterway because that will hinder water flow into the waterway. (NRCS can help with the technical design, sizing, and layout of grassed waterways.) The waterways need periodic maintenance to keep them functioning properly and care must be taken with herbicide applications so as not to damage the grass stands (Obidimma and Olorunfemi, 2011).

2.11.2 Annual Cover Crops

While grassed waterways are fairly effective in handling concentrated flows, many producers don't like to take land out of crop production with waterways. In no-till with reduced runoff contributing to concentrated flows, many producers are using annual cover crops to replace permanent grassed waterways. Any gullies in the concentrated flow areas are filled in and shaped after harvest and then a fall cover crop is seeded (WHO, 2011). In addition to the residue produced and the improved soil structure, the cover crops provide roots to anchor the soil and dissipate the energy of the flowing water, particularly in the off season when the regular crop isn't growing. When herbicides are applied to the next crop, the cover crop is killed and the roots and residue are left behind to help protect the soil. The next crop adds to the roots and canopy to further reduce the chances of erosion. After the next harvest, another cover crop is planted in the flow areas to keep the soil anchored and protected.

2.11.3 Artificial gullies

Artificial gullies are formed during hydraulic mining when jets or streams of water are projected onto soft alluvial deposits to extract gold or tin ore (USEPA, 2009). The remains of such mining methods are very visible landform features in old goldfields such as in California and northern Spain. The badlands at Las Medulas for example, were created during the Roman period by hushing or hydraulic mining of the gold-rich alluvium with water supplied by numerous aqueducts tapping nearby rivers. Each aqueduct produced large gullies below by erosion of the soft deposits. The effluvium was carefully washed with smaller streams of water to extract the nuggets and gold dust.

2.12 Termination of Gullies

Gully initiation is the result of localized erosion by surface runoff, often focusing on areas where forest cover has been removed for agricultural purposes, uneven compaction of surface soils by foot and wheeled traffic, and poorly designed road culverts and gutters (Jones *et al.,* 2008). Termination of gully processes requires water-resource management, soil conservation, and community migration. Gully erosion is localized in the Coastal Plain Sands, Nanka Sands, and Nsukka Sandstone of the Anambra-Imo basin region. The most affected deposits are unconsolidated or poorly consolidated and have short dispersion times. Public education is essential for a sustainable termination strategy, and collaboration between the government, donors, the private sector, and rural people is crucial.

In 2010, President Goodluck Ebele Jonathan made a request to the World Bank Nigeria office for assistance in addressing the challenges of gully erosion, emerging Land degradation and environmental insecurity in the country (Arai and Sparks, 2007). This request resulted in the formation of the Nigeria Erosion and Watershed Management Project (NEWMAP), an eight-year multi-sectoral project aimed at addressing gully erosion in the Southern Nigeria and land degradation in the Northern Nigeria. The development objective of the NEWMAP is to reduce vulnerability to soil erosion in targeted sub-watersheds with a portfolio of US$508 million plus an additional financing of $400 million.

Before this intervention, several interventions failed to address the challenge of gully erosion mainly because of inefficiencies in designing proper structures and lack of commitment by the locals to take action. However, in some areas like Madona gully site, Awhum community Enugu State, and Okudu community Imo State, some sustainable interventions base on good practices were employed. These interventions addressed the problem of gully erosion in those areas.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area

The study was carried out in Iyoha community in Ovia North East Local Government Area of Edo state. Iyoha is an urban community with a population of over hundred thousand people. The community lies approximately between longitude 50'E and between latitude 4 degrees 45'E and 7degrees 30'N, the peasants producing large quantities of food stuffs including yam, cassava, cocoyam and various vegetable crops. The people of Iyoha community are Christians and African Traditional Religionist (ATR) of deities such as Olokun, Ogun, Shango and Oronmilla. Their marriage and death ceremonies are streamlined alongside these religions. The main language of the people is Edo

3.2 Sample collection

Water and soil samples were collected from 3 selected different locations within gully erosion site in Evbhomore Community, Edo State, Nigeria. A total of 12 samples were collected within month of July to August, 2023. The samples were collected into sterile sampling bottles and were transported to the laboratory in ice-pack for physicochemical and heavy metal analysis.

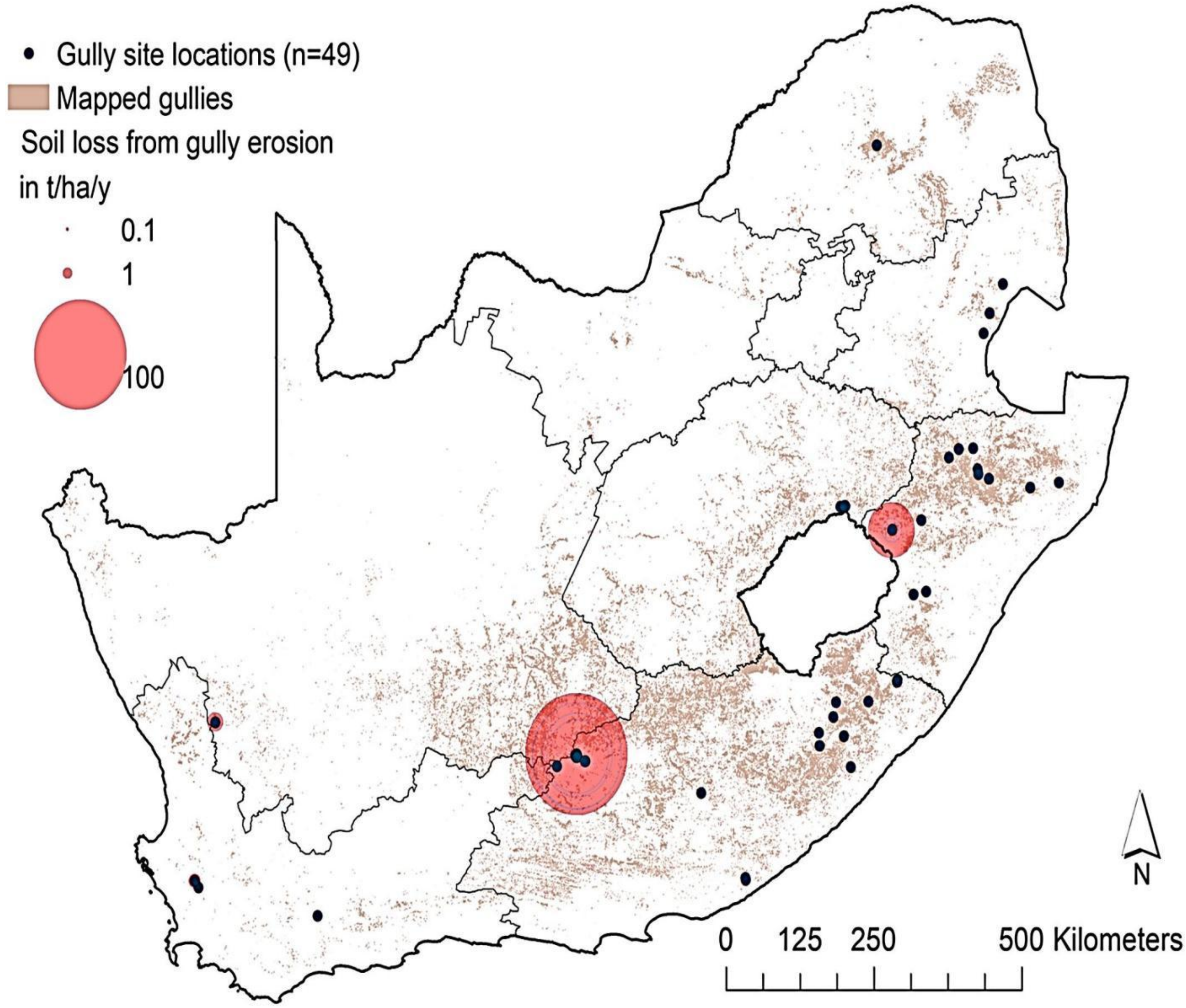

Figure 3.1: Map of Study Area

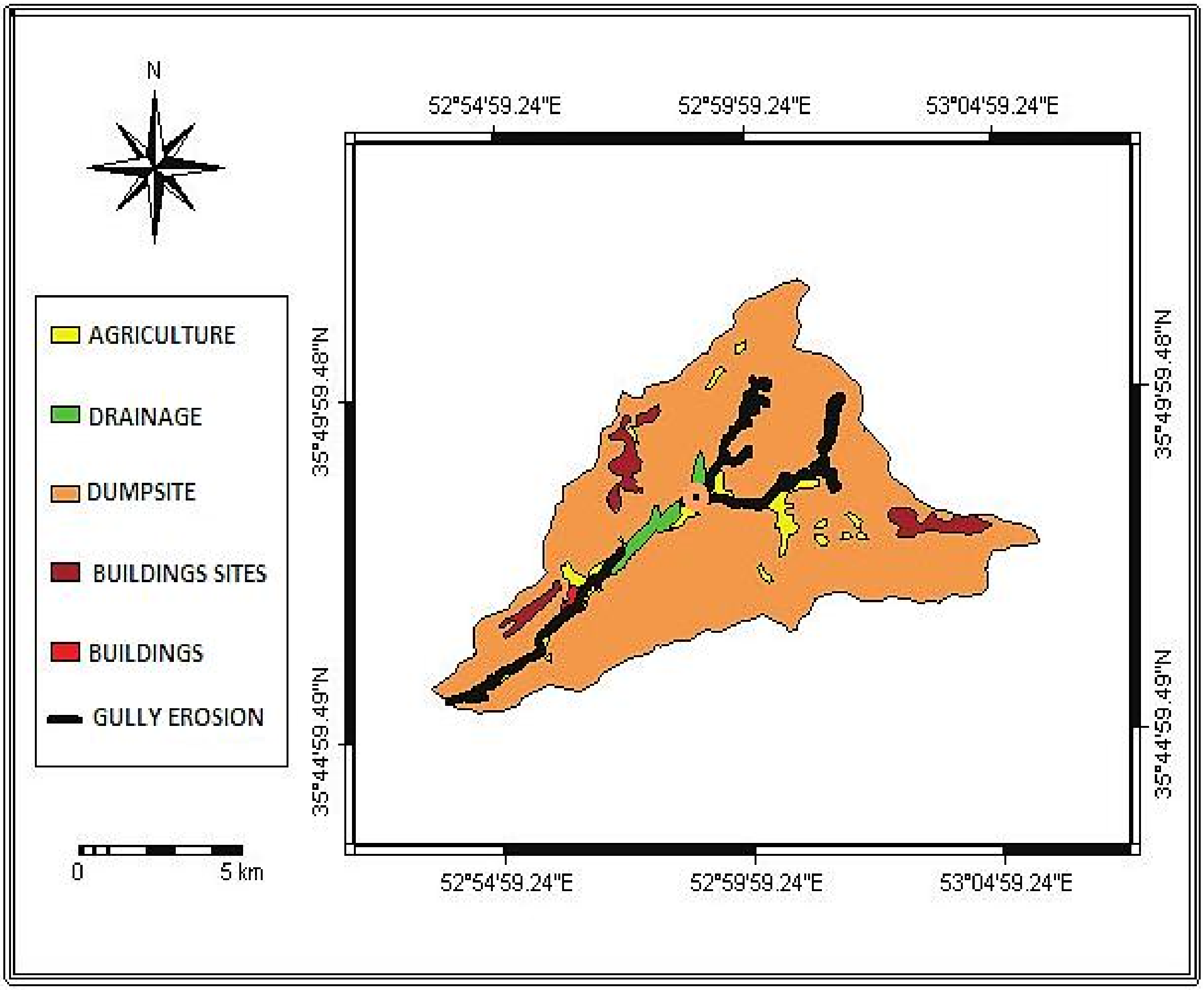

Figure 3.2: Map of gully erosion site in Evbhomore community in Ovia North East Local Government Area of Edo state

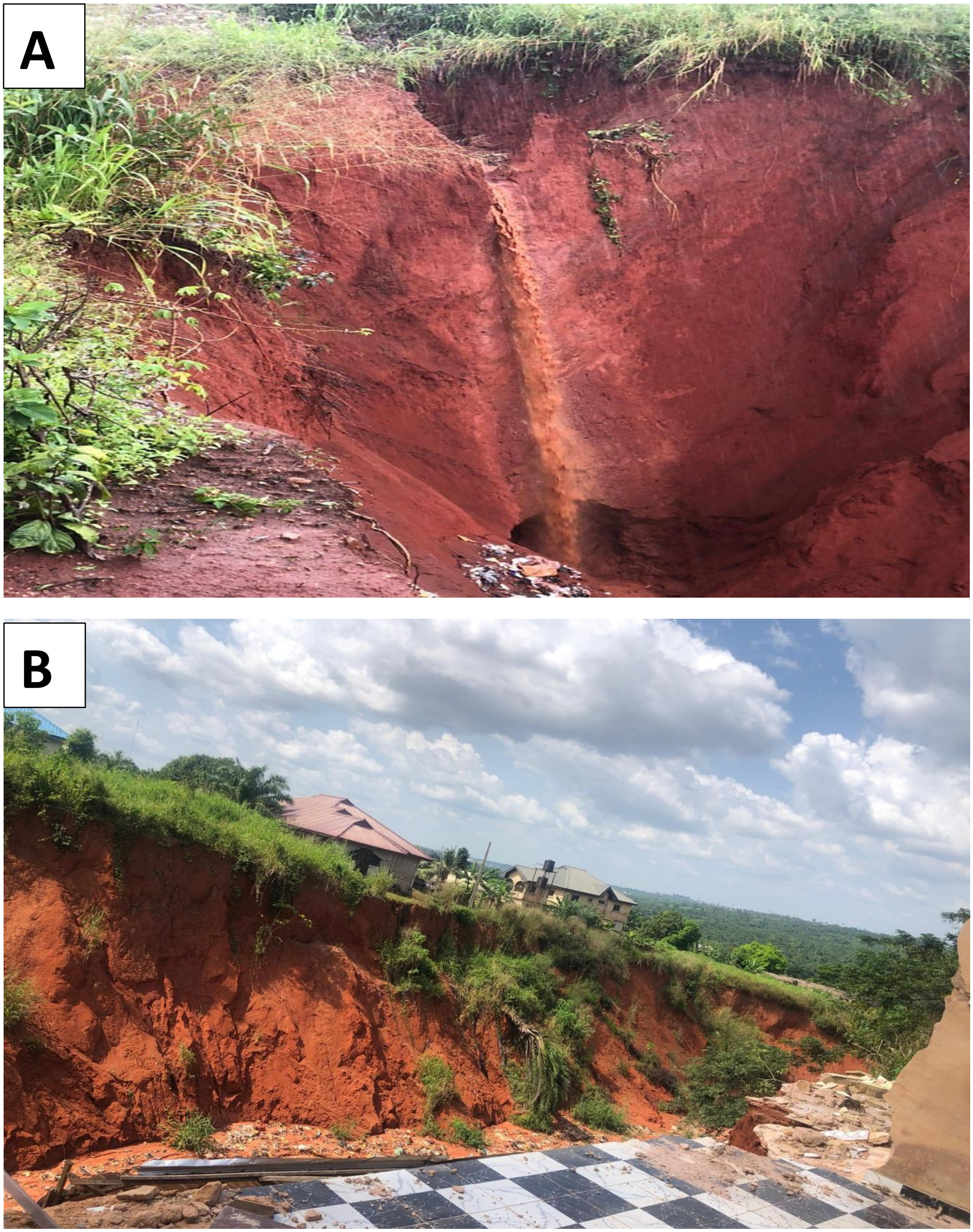

Plate 3.1 A and B: Gully erosion site in Evbhomore community in Ovia North East Local Government Area of Edo State

Plate 3.2: The back view of the gully erosion site in Evbhomore community in Ovia North East Local Government Area of Edo State

3.3 Physicochemical Analysis: According to APHA (2005)

3.3.1 Determination of Temperature

Apparatus required: Thermometer- 0.1^{o} C division.

Procedure: Temperature measurement is made by taking a portion of the wastewater sample (about 1litre) and immersing the thermometer into it for a sufficient period of time (till the reading stabilizes) and the reading is taken, expressed as °C.

3.3.2 Determination of pH

The colorimetric indicator method can be used only for approximate pH values.

Apparatus required:

pH indicator (BDH) method: BDH Indicator (Universal Indicator) and test tubes.

Electrometric method: Glass electrode, reference electrode (mercury/calomel or silver/silver chloride) and pH meter.

Procedure:

Colorimetric method: About 10ml of the sample is taken in a wide mouth test tube, 0.2ml of BDH indicator is added, and shaken gently. The color developed is matched with the chart and the pH noted.

Electrometric method: The pH is determined by measuring the Electro Motive Force (E.M.F) of a cell comprising an indicator electrode (an electrode responsive to hydrogen ions such as a glass electrode) immersed in the test solution and the reference electrode (usually a mercury/calomel electrode). Contact between the test solution and the reference electrode is usually got by means of a liquid junction, which forms a part of reference electrode. E.M.F of this cell is measured with pH meter that is a high impedance voltmeter calibrated in terms of pH. The electrode is allowed to stand for 2 minutes to stabilize before taking reading for reproducible results (at least ±0.1 pH units).

3.3.3 Determination of Electrical Conductivity

Apparatus required: Conductivity meter

Procedure: The electrode of the conductivity meter is dipped into the sample, and the readings are noted for stable value shown as ms/cm

3.3.4 Determination of Total Solids

Apparatus: Evaporating dishes-100ml porcelain dish, steam bath, drying oven, desiccator, Monopan balance and measuring jars.

Procedure: A known volume of the well-mixed sample (50ml) is measured into a pre-weighed dish and evaporated to dryness at 103° C on a steam bath. The evaporated sample is dried in an oven for about an hour at 103-105° C and cooled in a desiccator and recorded for constant weight.

Calculation:

Total solids = $\dfrac{(W_1-W_2)\ (1000)}{}$

(mg/l) Sample volume (ml)

W_1 = Weight of dried residue + dish
W_2 = Weight of empty dish

3.7 Determination of Total Hardness

Apparatus required: Lab glassware-burette, pipette, conical flask, beakers etc.

Reagents:

i. Buffer solution: 16.9 g of ammonium chloride and 1.25g of magnesium salt of EDTA is dissolved in 143ml of concentrated ammonium hydroxide and diluted to 250ml with distilled water.
ii. Eriochrome black-T indicator: 0.5 g of Eriochrome black-T indicator is dissolved in 100g of triethanolamine.
i. Standard EDTA titrant: 0.01M or Ng AR grade EDTA is dissolved in distilled water and diluted to 1000ml and is standardised against standard calcium solution, 1ml = 1mg $CaCO_3$.
ii. Standard Calcium Solution: 1.0g of AR grade $CaCO_3$ is weighed into a 250ml conical flask, to which 1+1 HCl is added till all $CaCO_3$ is dissolved completely. 200ml of distilled water is added and boiled to expel carbon-di-oxide, and diluted to 1000ml. 1ml = 1mg $CaCO_3$.

Procedure: Exactly 50ml of the well-mixed sample is pipetted into a conical flask, to which 1ml of ammonium buffer and 2-3 drops of Eriochrome black -T indicator is added. The mixture is titrated against standard 0.01M EDTA until the wine red colour of the solution turns pale blue at the end point.

Calculation:

(T) (1000)

Total hardness = ---------------
(mg/l) V

Where, T = Volume of titrant
V = Volume of sample

3.3.5 Determination of Calcium Hardness

Apparatus required: Burettes, pipette, conical flask, beakers and droppers.

Reagents:

i. Sodium hydroxide (8%): 8g of sodium hydroxide is dissolved in 100ml of distilled water.
ii. Murexide indicator (ammonium purpurate): 0.2 g of murexide is ground well with 100g of sodium chloride thoroughly.
iii. Standard EDTA titrant, 0.01M: 3.723 g of EDTA (disodium salt) is dissolved in distilled water and made up to 100ml with the same.

Procedure: A known volume (50ml) of the sample is pipetted into a clean conical flask, to which 1ml of sodium hydroxide and 1ml of iso-propyl alcohol is added. A pinch of murexide indicator is added to this mixture and titrated against EDTA until the pink color turns purple.

Calculation:

$$\text{Calcium as Ca (mg/l)} = \frac{T \times 400.5 \times 1.05}{\text{Sample taken, ml}}$$

Where, T= volume of titrant, ml

$$\text{Calcium hardness (mg/l as } CaCO_3) = \frac{T \times 1000 \times 1.05}{\text{Sample taken, ml}}$$

3.3.6 Determination of Magnesium Hardness

Procedure: Magnesium hardness can be calculated from the determined total hardness and calcium hardness.

Calculation:

Magnesium = (T - C) x 0.243 (as mg/l)

where, T = Total hardness mg\l (as $CaCO_3$)

C = Calcium hardness mg\l (as $CaCO_3$)

3.3.7 Determination of Phosphates

Apparatus required: Spectrophotometer, lab glassware, hot plate and Nessler's tube.

Reagents:

i. Ammonium molybdate reagent: 25g ammonium molybdate is dissolved in 175ml distilled water. 280ml concentrated sulphuric acid is added to 400ml distilled water and cooled. Molybdate solution is added and the mixture diluted to 1000ml.
ii. Stannous chloride reagent: 2.5g fresh stannous chloride is dissolved in 100ml glycerol, heated on water bath and stirred with the glass rod to hasten dissolution.
iii. Standard phosphate solution:219.5 mg of dried AR potassium hydrogen phosphate is dissolved in distilled water and made up to 1000ml, where 1ml = 50.0 μ g. of phosphate. 10ml of the stock solution is made up to 1000ml to give 1ml = 0.05 mg. Standards of strength ranging from 0 (blank) to 0.05mg/l at intervals of 0.01mg is prepared by diluting the stock with distilled water.

Procedure: To 50ml of the filtered sample, 4ml of ammonium molybdate reagent and about 4-5 drops of stannous chloride reagent is added. After about 10 min but before 12 min, the colour developed is measured photometrically at 690nm and calibration curve is prepared. A reagent blank is always run with same treatment with distilled water as sample. The value of phosphate is obtained by comparing absorbance of sample with the standard curve and expressed as mg/l.

Calculation:

$$\text{Phosphates} = \frac{\text{Absorbance of sample X Conc. of Std X1000}}{\text{Absorbance of Std. X Sample taken}} \text{ (as mg/l)}$$

3.3.8 Determination of Sulphates

Apparatus required: Nephelometer, magnetic stirrer, Nessler's tubes and lab glassware.

Reagents:

i. Conditioning reagent: 50 ml of glycerol was mixed in a solution containing 30 ml of conc. hydro chloric acid, 300ml distilled water (10% HCl), 100 ml of 95% ethyl alcohol or isopropyl alcohol and 75g NaCl.
ii. Barium Chloride
iii. Standard sulphate solution:147.9mg of AR grade sodium sulphate was dissolved in distilled water and made up to 1000ml, to give 1ml = 100mg sulphate.

Procedure: 100ml of the sample is filtered into a Nessler's tube containing 5ml of conditioning reagent. About 0.2g of barium chloride crystals is added with continued stirring. A working standard is prepared by taking 1ml of the standard, 5ml of conditioning reagent and made up to 100ml, to give 100 NTU. The turbidity developed by the sample and the standards are measured using a Nephelometer and the results are tabulated.

Calculation:

Sulphate = (Nephlometric reading) (0.4) (Dilution Factor) (as mg/L)

3.3.9 Determination of Dissolved Oxygen

Method 1: Membrane electrode method

Apparatus required: Oxygen-sensitive membrane electrode and lab glassware.

Procedure: The calibrations are carried out following the manufacturer's calibration procedure. The electrode is dipped into the sample, and the reading noted.

Method 2: Winkler's method

Apparatus required: BOD bottles-300ml capacity, sampling devices, lab glassware - measuring cylinder, conical flasks, etc., and Bunsen burner.

Reagents:

i. Manganese sulphate: 480g of manganous sulphate tetrahydrate is dissolved and made up to 1000ml with distilled water (Discarded if it changes colour with starch).
ii. Alkaline iodide-azide reagent: 500g of sodium hydroxide and 150g of potassium iodide along with 10g of sodium azide (NaN_3) is dissolved and made up to 1000ml with distilled water.
iii. Conc. sulphuric acid
iv. Starch indicator: 0.5g of starch is dissolved in distilled water and boiled for few minutes.
v. Stock sodium thiosulphate: 24.82g of sodium thiosulphate pentahydrate ($Na_2S_20_2$. $5H_2O$) is dissolved in distilled water and made up to 1000ml.
vi. Standard sodium thiosulphate (0.025N): 250ml of the stock sodium thiosulphate pentahydrate is made up to 1000ml with distilled water to give 0.025N.

Procedure: The samples are collected in BOD bottles, to which 2ml of manganous sulphate and 2ml of potassium iodide are added and sealed. This is mixed well and the precipitate allowed to settle down. At this stage 2ml of conc. sulphuric acid is added, and mixed well until all the precipitate dissolves. 203ml of the sample is measured into the conical flask and titrated against 0.025N sodium thiosulphate using starch as an indicator. The end point is the change of colour from blue to colourless.

Calculations:

203ml because (200) (300)/ (200-4) = 203ml.
1ml of 0.025N Sodium thiosulphate = 0.2mg of Oxygen

$$\text{Dissolved} = \frac{(0.2)\ (1000\ \text{ml of Sodium thiosulphate})}{\text{Oxygen (as mg/l)}\ 200}$$

3.3.10 Determination of Biological Oxygen Demand

Apparatus required: BOD bottles - 300ml capacity, air incubator - to be controlled at 20 ^{o}C -\+ 1 ^{o}C, oximeter and magnetic stirrer.

Reagents:

Preparation of dilution water:To 1000ml of water, 1ml each of phosphate buffer, magnesium sulphate, calcium chloride and ferric chloride solution is added, before bringing it to 20 ^{o}C and aerating it thoroughly.

Procedure: The sample having a pH of 7 is determined for first day DO. Various dilutions (at least 3) are prepared to obtain about 50% depletion of D.O. using sample and dilution water. The samples are incubated at 20 ^{o}C for 5 days and the 5th day D.O is noted using the oximeter. A reagent blank is also prepared in a similar manner.

Calculation:

$$BOD = \frac{(D_1 - D_2) - (B_1 - B_2) \times f}{p \text{ (in mg/l)}}$$

D_1 - 1st day D.O of diluted sample
D_2 - 5th day D.O of diluted sample

P - Decimal volumetric fraction of sample used.

B_1 - 1st day D.O of control

B_2 - 5th day D.O of control

3.3.11 Determination of Total Dissolve Solid (TDS) and Total Suspended Solids (TSS)

Apparatus

i. Balance, analytical

ii. 250ml conical flask

iii. Dessicator

iv. Plastic funnel, medium size

v. Filter paper, No. 1, Whatman

vi. Oven

Procedure

i. Oven- dry a Whatman filter paper No.l (15cm) and a 250ml conical Flask in an oven at 50^0C for 5 hours.

ii. Therefore, weight of residue (TSS) = (X2-X1) g.

iii. Then TSS (mg/I) - (X2 - XI) x 1000 x 10

Calculation

Weight of empty conical flask = Xg

Weight of flask + Residue -Yg

Weight of Residue (TDS) = (y-X)g

Then TDS (mg/I) = (Y-X) x 1000 x 10

3.3.12 Determination of Nitrate

Ten milliliter of digest was transfer into fifty milliliter flask, two milliliter of brucine and ten milliliter of concentrated sulphuric acid were added.The mixture was mixed and allow to stan for ten minutes. Stock working standards of 0,2,4,6,8 and 10 ppm were prepared and treated in similar way. The optical density (OD) of the samples and standard were taken at 470nm (Onyeonwu 2000).

Calculation

$$NO_3\ (mg/kg) = \frac{OD \times SR \times Colour\ Vol \times Ext.vol}{Weight\ of\ sample \times Vol.taken}$$

3.4 Determination of Heavy Metals Concentration

Methods of Preparing Reagents Used

i. Copper standard solution - One (1) gram of copper (Cu) was dissolved in 7ml of nitric acid in volumetric flask and made up to required volume with deionized water.
ii. Lead standard solution - One (1) gram of lead (Pb) was dissolved in 7ml of nitric acid in volumetric flask and made up to required volume with deionized water.

iii. Cadmium standard solution - One (1) gram of cadmium (Cd) was dissolved in 7ml of nitric acid and water in volumetric flask and made up to required volume with deionized water.
iv. Manganese standard solution - One (1) gram of manganese (Mn) was dissolved in 7ml of nitric acid in volumetric flask and made up to required volume with deionized water.
v. Zinc standard solution - Half (1/2) gram of zinc (Zn) was dissolved in 7ml of nitric acid in volumetric flask and made up to required volume with deionized water.
vi. Nickel standard solution - Approximately (2) gram of nickel (Ni) was dissolved in 7ml of nitric acid in volumetric flask and made up to required volume with deionized water.
vii. Working standard solution - dilute standard with 0.1m HNO_3 to a range of standard that covers the concentration of the element to be determined

a. Water – Deionized
b. Nitric acid – 65% (w/w)
c. Nitric acid – 0.1m. Dilute 7ml concentrated HNO_3 in deionized water and make up to 1 litre. This was used for cleaning all glass wares.

Procedure

i. Weigh 1.09 air-dry sample into a 250ml calitration digestion tube
ii. Add 3ml concentrated HNO_3 (in the fume hovel), similar with care, place tubes with the help of a stand on the hot plate.
iii. Allow to heat for a period.
iv. Add 4ml concentrated $HCLO_4$ and heat almost to dryness.
v. Remove tube and allow cooling to room temperature.

vi. Add little deionized water and filter through whatman No 42 filter paper and bring it to 25ml volume.

vii. Prepare reagent blank same way.

viii. Determine Copper, Nickel, Zinc, Manganese, Lead and Cadmium by using Atomic absorption spectrophotometer.

3.6 Data Analysis

Statistical analyses were done using general descriptive statistics, one-way analysis of variance (ANOVA) at the P<0.05 significant level. If significant differences were found, Duncan's multiple range and SNK analysis were used to locate the significant differences among the different experimental groups. Significant difference was defined at P<0.05 using a computer software (Microsoft Excel). The statistical package for social scientists (SPSS) was also used.

CHAPTER FOUR

RESULTS

The physicochemical characteristics of surface water at Evbhomore gully erosion site is presented in Table 4.1. The physicochemical parameters analysed for the six stations shows that the range of physicochemical parameters for the six stations are as follows: Air temperature (28.30±2.75 – 29.50±2.87 °C), water temperature (25.20±2.02 – 27.00±2.63 °C), turbidity (3.10±0.24 – 4.20±0.46 NTU), pH (6.10±0.28 – 6.35±0.30), salinity (20.00±1.00 – 21.0±1.10 g/l), total dissolved solids (38.00±2.89 – 50.00±3.65 mg/l), electrical conductivity (65.00±3.72 – 100.00±5.00 µS/cm), total suspended solids (15.00±0.48 – 20.00±1.00 mg/l), Biochemical oxygen demand (12.00±0.28 – 20.00±1.00 mg/l), chemical oxygen demand (50.10±3.64 – 65.30±3.41 mg/l) and dissolved oxygen (3.00±0.22 – 4.00±0.25 mg/l), respectively.

Table 4.1: Physicochemical characteristics of surface water from sampling stations at Evbhomore erosion site

Physicochemical Parameters	Unit	Month of July			Month of August			NESREA
		Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Limit
Appearance	Sighting	Colourless	Colourless	Colourless	Colourless	Colourless	Colourless	
Odour	Smell	Slight odour	Slight odour	Slight odour	Slight odour	Slight odour	Slight odour	
Air Temperature	°C	28.50 ± 2.72^{a}	29.20 ± 2.82^{b}	29.30 ± 2.86^{b}	28.30 ± 2.75^{a}	29.20 ± 2.86^{b}	29.50 ± 2.87^{b}	-
Water Temperature	°C	25.20 ± 2.02^{a}	26.00 ± 2.03^{b}	27.00 ± 2.63^{c}	25.50 ± 2.41^{a}	26.1 ± 2.04^{b}	27.00 ± 2.63^{c}	-
Turbidity	NTU	3.50 ± 0.27^{a}	4.10 ± 0.45^{b}	3.10 ± 0.24^{a}	3.60 ± 0.29^{b}	4.20 ± 0.46^{a}	3.10 ± 0.24^{b}	5
pH		6.35 ± 0.30^{a}	6.20 ± 0.29^{a}	6.10 ± 0.28^{a}	6.34 ± 0.31^{a}	6.20 ± 0.29^{a}	6.10 ± 0.28^{a}	6.0- 9.0
Salinity	g/l	20.00 ± 1.00^{a}	20.00 ± 1.00^{a}	21.0 ± 1.10^{a}	20.00 ± 1.00^{a}	20.00 ± 1.00^{a}	21.00 ± 1.10^{a}	0.5
Total Dissolved Solids	mg/l	44.00 ± 3.50^{b}	50.00 ± 3.65^{c}	39.00 ± 3.09^{a}	45.00 ± 3.59^{b}	50.00 ± 3.56^{c}	38.00 ± 2.89^{a}	10
Electrical Conductivity	µS/cm	85.00 ± 4.02^{b}	65.00 ± 3.72^{a}	100.00 ± 5.00^{c}	84.00 ± 4.00^{b}	65.00 ± 3.72^{a}	101.00 ± 5.10^{c}	40
Total Suspended Solid	mg/l	18.00 ± 0.45^{b}	20.00 ± 1.00^{c}	15.00 ± 0.48^{a}	$19.00 \pm 0.91b^{c}$	20.00 ± 1.00^{c}	15.00 ± 0.48^{a}	10
Biochemical Oxygen Demand	mg/l	12.00 ± 0.28^{a}	14.00 ± 0.31^{b}	20.00 ± 1.00^{c}	12.00 ± 0.28^{a}	15.00 ± 0.48^{b}	20.00 ± 1.00^{c}	50
Chemical Oxygen Demand	mg/l	60.00 ± 3.43^{b}	50.10 ± 3.64^{a}	65.20 ± 3.32^{c}	61.00 ± 3.12^{b}	50.20 ± 3.18^{a}	65.30 ± 3.41^{c}	35
Dissolved Oxygen	mg/l	3.00 ± 0.22^{a}	3.80 ± 0.46^{b}	3.70 ± 0.51^{b}	3.10 ± 0.20^{a}	3.80 ± 0.39^{b}	4.00 ± 0.25^{c}	4

Values are mean ± SEM. n=3, Mean values with similar superscripts within each row are not significantly different, P>0.05.

The physicochemical characteristics of Evbhomore gully erosion soil is presented in Table 4.2. The physicochemical parameters analysed for the six stations showed that the range of physicochemical parameters for the six stations were as follows: clay (24.00 ± 1.92 – 36.00 ± 2.96 %), silt (24.00 ± 1.92 – 33.00 ± 2.83 %), sand (33.00 ± 2.83 – 48.00 ± 3.50 %), pH (7.50 ± 0.90 – 7.88 ± 0.93), organic matter (0.91 ± 0.37 – 1.55 ± 0.41 %), organic carbon (0.51 ± 0.25 – 0.88 ± 0.29 %), total nitrogen (0.01 ± 0.00 – 0.02 ± 0.00 %), electrical conductivity (4.12 ± 1.45 – 4.24 ± 1.50 μS/cm), available phosphorus (159.00 ± 5.31 – 167.01 ± 5.63 mg/kg), total exchangeable bases (1.60 ± 0.42 – 1.74 ± 0.60 cmol/kg), calcium (1.20 ± 0.15 – 1.21 ± 0.17 mg/kg), magnesium (0.40 ± 0.00 – 0.40 ± 0.00 mg/kg), sodium (0.02 ± 0.00 – 0.04±0.00 mg/kg) and potassium (0.06 ± 0.00 – 0.07 ± 0.03 mg/kg) respectively.

Table 4.2: Physicochemical characteristics of soils from sampling stations at Evbhomore erosion site

	Month of July			Month of August		
Physicochemical parameters	**(Station 1)**	**(Station 2)**	**(Station 3)**	**(Station 4)**	**(Station5)**	**(Station6)**
Soil Colour	Brownish	Brownish	Brownish	Brownish	Brownish	Brownish
Soil Texture	Clayey/sand	Clayey/sand	Clayey/sand	Clayey/sand	Clayey/sand	Clayey/sand
Clay (%)	25.00 ± 2.01^{b}	25.00 ± 2.01^{b}	34.00 ± 2.85^{bc}	24.00 ± 1.92^{a}	25.00 ± 2.01^{b}	36.00 ± 2.96^{c}
Silt (%)	24.00 ± 1.92^{a}	28.00 ± 2.72^{b}	30.00 ± 2.75^{bc}	24.50 ± 1.96^{a}	28.00 ± 2.72^{b}	33.00 ± 2.83^{c}
Sand (%)	48.00 ± 3.50^{c}	43.00 ± 3.05^{b}	33.00 ± 2.83^{a}	48.00 ± 3.50^{c}	46.00 ± 3.10^{bc}	35.00 ± 2.88^{ab}
pH	7.80 ± 0.93^{c}	7.70 ± 0.91^{b}	7.70 ± 0.91^{b}	7.50 ± 0.90^{a}	7.70 ± 0.93^{b}	7.88 ± 0.93^{c}
Organic Matter (%)	1.52 ± 0.40^{c}	0.99 ± 0.38^{b}	1.03 ± 0.39^{c}	1.55 ± 0.41^{c}	0.91 ± 0.37^{a}	1.06 ± 0.40^{c}
Organic Carbon (%)	0.87 ± 0.35^{c}	0.77 ± 0.37^{b}	0.61 ± 0.26^{a}	0.88 ± 0.29^{c}	0.78 ± 0.34^{b}	0.51 ± 0.25^{a}
Total Nitrogen (%)	0.02 ± 0.00^{a}	0.02 ± 0.00^{a}	0.01 ± 0.00^{a}	0.02 ± 0.00^{a}	0.02 ± 0.00^{a}	0.01 ± 0.00^{a}
Electrical Conductivity (µS/cm)	4.22 ± 1.55^{b}	4.12 ± 1.45^{a}	4.13 ± 1.46^{a}	4.24 ± 1.50^{b}	4.13 ± 1.46^{a}	4.13 ± 1.46^{a}
Available Phosphorus (mg/kg)	159.00 ± 5.31^{a}	159.00 ± 5.31^{a}	167.00 ± 5.63^{b}	159.03 ± 5.11^{a}	159.03 ± 5.11^{a}	167.01 ± 5.63^{b}
Total Exchangeable Bases (cmol/kg)	1.61 ± 0.44^{a}	1.60 ± 0.42^{a}	1.70 ± 0.58^{b}	1.61 ± 0.44^{a}	1.61 ± 0.44^{a}	1.74 ± 0.60^{b}
Calcium (mg/kg)	1.20 ± 0.15^{a}	1.20 ± 0.15^{a}	1.21 ± 0.17^{a}	1.20 ± 0.15^{a}	1.20 ± 0.15^{a}	1.21 ± 0.17^{a}
Magnesium (mg/kg)	0.40 ± 0.00^{a}	0.40 ± 0.00^{a}	0.40 ± 0.00^{a}	0.40 ± 0.00^{a}	0.40 ± 0.00^{a}	0.40 ± 0.00^{a}
Sodium (mg/kg)	0.03 ± 0.01^{a}	0.03 ± 0.01^{a}	0.02 ± 0.00^{a}	0.04 ± 0.00^{a}	0.03 ± 0.01^{a}	0.02 ± 0.00^{a}
Potassium (mg/kg)	0.07 ± 0.03^{a}	0.06 ± 0.00^{a}	0.06 ± 0.00^{a}	0.07 ± 0.03^{a}	0.06 ± 0.00^{a}	0.06 ± 0.00^{a}

Values are mean ± SEM, n=3, Mean values with similar superscripts within each row are not significantly different, $P>0.05$.

The heavy metal properties of surface water at Evbhomore gully erosion site for the month of March is presented in Table 4.3. The range of heavy metal content for the six stations is as follows: Cadmium (0.001±0.0 – 0.002±0.0 mg/l), lead (0.001±0.0 – 0.002±0.0 mg/l), zinc (1.5±0.0 – 2.0±0.0 mg/l), copper (0.001±0.0 – 0.001±0.0 mg/l), iron (0.001±0.0- 0.002±0.0 mg/l) and manganese (0.001±0.0 – 0.001±0.0 mg/l) respectively.

Table 4.3: Mean values of some heavy metals in surface water from sampling stations at Evbhomore erosion site

Parameters	Unit	Month of July			Month of August			NESREA Limit
		Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	
Cadmium (Cd)	mg/l	0.001 ± 0.0^{a}	0.001 ± 0.0^{a}	0.001 ± 0.0^{a}	0.001 ± 0.0^{a}	0.001 ± 0.0^{a}	0.001 ± 0.0^{a}	
Lead (Pb)	mg/l	0.001 ± 0.0^{a}	0.001 ± 0.0^{a}	0.001 ± 0.0^{a}	0.002 ± 0.0^{a}	0.001 ± 0.0^{a}	0.001 ± 0.0^{a}	0.01- 0.1
Zinc (Zn)	mg/l	1.5 ± 0.0^{a}	1.8 ± 0.0^{b}	1.6 ± 0.0^{a}	1.7 ± 0.0^{a}	1.8 ± 0.0^{b}	2.0 ± 0.0^{c}	5 – 15
Copper (Cu)	mg/l	0.001 ± 0.0^{a}	0.001 ± 0.0^{a}	0.001 ± 0.0^{a}	0.001 ± 0.0^{a}	0.001 ± 0.0^{a}	0.001 ± 0.0^{a}	0.05- 1.5
Iron (Fe)	mg/l	0.002 ± 0.0^{a}	0.002 ± 0.0^{a}	0.001 ± 0.0^{a}	0.002 ± 0.0^{a}	0.002 ± 0.0^{a}	0.001 ± 0.0^{a}	20
Manganese (Mg)	mg/l	0.001 ± 0.0^{a}	0.001 ± 0.0^{a}	0.001 ± 0.0^{a}	0.001 ± 0.0^{a}	0.001 ± 0.0^{a}	0.001 ± 0.0^{a}	

Values are mean ± SEM. Mean values with similar superscripts within each row are not significantly different, $P>0.05$.

The heavy metal properties of surface water at Evbhomore gully erosion site for the month of March is presented in Table 4.4. The range of heavy metal content for the six stations is as follows: Cadmium (0.001±0.0 – 0.002±0.0 mg/l), lead (0.001±0.0 – 0.002±0.0 mg/l), zinc (1.5±0.0 – 2.0±0.0 mg/l), copper (0.001±0.0 – 0.001±0.0 mg/l), iron (0.001±0.0- 0.002±0.0 mg/l) and manganese (0.001±0.0 – 0.001±0.0 mg/l) respectively.

Table 4.4: Mean values of some heavy metals in surface water from sampling stations at Evbhomore erosion site

		Month of July			Month of August			
Parameters	Unit	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	NESREA Limit
Cadmium (Cd)	mg/l	$0.001±0.0^{a}$	$0.001±0.0^{a}$	$0.001±0.0^{a}$	$0.001±0.0^{a}$	$0.001±0.0^{a}$	$0.001±0.0^{a}$	
Lead (Pb)	mg/l	$0.001±0.0^{a}$	$0.001±0.0^{a}$	$0.001±0.0^{a}$	$0.002±0.0^{a}$	$0.001±0.0^{a}$	$0.001±0.0^{a}$	0.01- 0.1
Zinc (Zn)	mg/l	$1.4±0.0^{a}$	$1.5±0.0^{b}$	$1.5±0.0^{a}$	$1.9±0.0^{a}$	$1.8±0.0^{b}$	$2.5±0.0^{c}$	5 – 15
Copper (Cu)	mg/l	$0.001±0.0^{a}$	$0.001±0.0^{a}$	$0.001±0.0^{a}$	$0.001±0.0^{a}$	$0.001±0.0^{a}$	$0.001±0.0^{a}$	0.05- 1.5
Iron (Fe)	mg/l	$0.002±0.0^{a}$	$0.002±0.0^{a}$	$0.001±0.0^{a}$	$0.002±0.0^{a}$	$0.002±0.0^{a}$	$0.001±0.0^{a}$	20
Manganese (Mg)	mg/l	$0.001±0.0^{a}$	$0.001±0.0^{a}$	$0.001±0.0^{a}$	$0.001±0.0^{a}$	$0.001±0.0^{a}$	$0.001±0.0^{a}$	

Values are mean ± SEM. Mean values with similar superscripts within each row are not significantly different, P>0.05.

CHAPTER FIVE

DICUSSION

This study investigated the physicochemical characteristics and heavy metal properties of Evbhomore gully erosion site in Benin City. The results of the physicochemical analysis carried out on surface water samples from six stations showed that the turbidity ranged from 2.70 – 4.20 NTU. This range is lower than NESREA limit of 5 NTU. Mann *et al.* (2007) reported a range of 0.5 to 1.0 in drinking water. Changes in turbidity could be due to phytoplankton, sediments from erosion, re-suspended sediments from waste discharge, algae growth and urban runoff. Wijnen *et al.* (2014) stated that excessive turbidity in drinking water is aesthetically unappealing as it supports the growth of pathogenic organisms if not treated, thereby leading to waterborne disease outbreaks, which have caused significant cases of intestinal diseases throughout the world. The concentrations of salinity in water samples across the six stations ranged from 20 – 21.00 g/l. Anati (1999) reported a range of 50–80 mg/l in surface water. He stated that salinity affects the chemistry of natural waters and biological processes within it. The reason for the salinity value obtained in the present study could have been caused by natural processes such the accumulation of salt from rainfall over many years or from the weathering of rocks. People exposed to high salinity water seemed to lack awareness regarding salinity-inducing health effects. Van Niekerk *et al.* (2014) confirmed that by drinking saline water, people suffer from various health problems including high blood pressure, diarrhea, cholera, skin diseases, and infant growth, and mortality (Amujiri and Ekaye, S2022).

The range of temperature of water samples of the study area was 24.20 – 28.10 °C. Temperature in this study was found within permissible limit of WHO (30 °C). Ezeribe *et al.* (2012) reported 29 °C for well water in Nigeria. The concentration of TDS in present study was observed in the range of 38.00 – 50.00 mg/l and it is above the limit of 10 mg/l for NESREA standards. Similar values were reported by (Singh *et al.,* 2012), drinking water of Turkey. High values of TDS in ground water are generally not harmful to human beings, but may affect persons who are suffering from kidney and heart diseases. Water containing high solid particles may cause laxative or constipation effects. According to NESREA standards, EC value should not exceed 40 µS/cm. The current study showed that EC value was 65.00 – 101.00 µS/cm. A similar value was reported by Thyssen *et al.* (2007) in drinking water. These results clearly indicate that water in the study area was not considerably ionized and has the lower level of ionic concentration activity due to small dissolve solids.

Results of this study show that the concentration of iron in water ranged from 0.001 – 0.002 mg/l, while in soil it was from 191.16 – 211.16. This is in agreement with reports made by some researchers (Zambelli and Ciurli, 2013; Watling, 2006). These results did not meet the NESREA standards maximum limits of 100 mg/kg concentration of iron in soil. Iron is necessary for living organism functioning hence found in all human, animal tissues and in plants cells. The total amount of iron in human body lies between 110 and 140 g. Iron is vital for human body functions like heart protection, regulation of blood pressure, protein dissolution, muscle contraction, nerve stimulus etc (Amujiri and and Ekaye, 2022). Iron deficiency may led to depression, muscle weakness, heart rhythm disorder etc. According to NESREA standards the permissible limit of iron is 100 mg/1. Zinc is essential for proper functioning of living organisms. The human body contains about 25 g of zinc. According to NESREA standards, the permissible range of zinc should be 30 mg/l. In this study zinc ranged from 1.50 – 3.0 in water and 25.11 – 79.02 in soil. Similar values were reported by Thyssen *et al.* (2007) for drinking water and soil.

The results showed that concentration of iron in soil was higher than the standard limit of NESREA.

Results showed that the concentration of cadmium ranged from 0.001 – 0.001 in water and 0.16 – 0.29 in soil. These results indicate that the concentration of cadmium in this study was within the acceptable limit of NESREA (3 mg/l). Cadmium is one of the most toxic metals and caused itai-itai disease in Japan evidenced by bone distortions and pains. The sources of cadmium are industrial waste, fertilizers etc (Amujiri and Ekaye, 2022).

In this study, the values of lead ranged from 0.001 to 0.002 mg/l. It is lower than the standard limit of 0.01 – 1.0 mg/l approved by NESREA 2011. Rzymski *et al.* (2014) reported that lead is toxic to living organisms including man. Its toxicity is exerted even in small amounts. Pb impairs the proper functioning of the reproductive and nervous systems, including kidney damage, high blood pressure and anemia (WHO 2011).

Diseases related to contamination of drinking-water constitute a major burden on human health. Interventions to improve the quality of drinking-water provide significant benefits to health. Water is essential to sustain life, and a satisfactory supply must be available to all (Pitman and Golovchenko, 2001). Improving access to safe drinking-water can result in tangible benefits to health. Every effort should be made to achieve a drinking-water quality as safe as practicable. Excessive amount of physical and chemical parameters accumulated in surface water and soil in the present study can affect human health (Amujiri and Ekaye, 2022).

The research finding above is similar to that of Qi (2011), who assessd soil erosion risk in the hillygullied area of Luoyugou watershed in Tianshui and observed that the probability of soil erosion had higher growth rate without vegetation cover than that having vegetation cover. Similar to findings by Gebreyesus, Tesfahunegn and Paul (2014) in Northern Ethiopia catchment.

Also in most parts of the watershed (>80%), the model predicted soil loss rates higher than the maximum tolerable rate (18 t ha−1 y−1) estimated for Ethiopia. John et al. (2014) evaluated soil erosion risk in the basement complex terrain of Akure Metropolis, Southwestern Nigeria and found that most parts (91.4%) of the metropolis fell within the very low to low risk zones with tendency for erosional features. Soil erosion in the study area also altered vegetation cover, ground slope, slope length and shape, thereby influencing soil erosion rate leading to the formation of gullies and rills erosion. It also leads to significant soil loss and degradation, destruction of physical infrastructures such as buildings, drainages, roads and culverts especially. This demonstrates the importance of remote sensing data and GIS in successfully enabling rapid, as well as detailed, assessment of soil erosion risk/hazards (Kouli et al., 2009). Steep slope, high rainfall, poor soil management, poor cover management and support practices, deforestation and land clearing in Zaria for agricultural, urbanization and infrastructural development have resulted in widespread of soil erosion over the land surface as equally attested to by Abbas and Lamido (2012).

Soil as a contributory factor controlling gully erosion in the study area is in tandem with Le Bissonnais (1996) who indicated that soil erodibility increases when silt and fine sand fraction increases and clay decreases. The overbearing effect of slope on the cause of gully erosion in the study area is in conformity with the findings of Ezechi and Okagbue (1999). The areas with very high were as the result of clay content between 9 and 30% and are the most susceptible to erosion (Richter and Negendank, 1977; Evans, 1980). From the study, erodibility of different soils causes erosion damages as confirmed by Renschler and Harbour, (2002). Also, Bewket and Sterk (2003) reported that soil erosion in south-eastern Nigeria was the results of field scale erosion by soil moisture in addition to infiltration rates which was also discovered by this research. Based on the study result, it could be said that the study area has risk to soil erosion as the area exhibited high risk of soil loss.

5.1 Conclusion and Recommendation

The results obtained from this study indicate the presence of pollutants in the soil and water samples analysed in the study. Based on the result from the four criteria (slope, rainfall, soil and land cover); slope (56%) had a high contribution to soil erosion. Soil and land cover contributed 12% and 6% respectively to gully erosion in the study area. The occurrence of soil erosion risk in the study area has also been on the increase and is not limited to a particular area but all part causing serious land degradation affecting a wide variety of soils prone to crusting and/or piping. The widths and depths of gully erosion increased with the increase in slope gradient and decrease with increase in percentage of vegetation cover, especially during the rainy season and confirm that soil erosion in the study area has altered vegetation cover, ground slope, slope length and shape. There is therefore the need for protective strategies and measures for sensitive management of the environment to reduce erosion rates and increasing water conservation.

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