ANTHROPOGENIC FACTORS THAT CAUSES GULLY EROSION AND ITS IMPACT ON THE ENVIRONMENT AND LAND: A CASE STUDY OF IGUOBAZUWA COMMUNITY

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A RESEARCH WORK SUBMITTED TO THE DEPARTMENT OF HEALTH, SAFETY AND ENVIRONMENTAL EDUCATION, FACULTY OF EDUCATION, UNIVERSITY OF BENIN, BENIN CITY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF A BACHELOR OF SCIENCE (B.SC.ED) DEGREE IN ENVIRONMENTAL EDUCATION

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CERTIFICATION

We the undersigned, certify that this research project was carried out by **Onyinyechi Sarah OTUNJI** with the matriculation number **EDU1804289** in the Department of Health, Safety and Environmental Education, Faculty of Education, University of Benin, Benin City in partial fulfillment of the requirements for the award of a Bachelor of Science (B.SC.ED) Degree in Environmental Education.

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Date

DEDICATION

This project work is dedicated to God almighty for his steadfast and unfailing love.

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ABSTRACT

The research work investigates the anthropogenic factors the causes gully erosion and its impact on the environment and land of Iguobazuwa in Ovia South West Local Government Area of Edo State. Four (4) research questions were raised to guide this study. The population of this study comprised of all residents in Iguobazuwa Community which has a total number of one hundred and thirty eight thousand and seventy two (138,072) and purposive random sampling technique was adopted to select one hundred (100) respondents for this research. Descriptive survey research design was adopted for the study and a structured questionnaire was used after being validated by the project supervisor and two other experts from the Department of Health, Safety and Environmental Education. Data collected was analyzed using percentage computation.

The study concluded that although gully erosion is a natural process, cause by natural phenomenon such as wind, precipitation and others, human activities contributes highly to the gully erosion situation and such activities are increasing day by day. The gully erosion in iguobazuwa community is caused mainly by the activities of members of the community such as; improper land use, poor drainage system, poor agricultural practices and dumping of refuse into water channels there restricting the flow of water. The community is aware of the problems posed by gully erosion and are supportive of measures to control this situation. In order to successfully implement measures to control gully erosion, proper enlightenment and awareness program on the factors, effect and control of gully erosion should be provided for the community. Also the government should see the gully erosion situation as a case of emergency and attend to it immediately at its early stage before it gets worsen and nothing can be done about it.

Based on the findings it was therefore recommended that; Buildings should be constructed in compliance of approved environmental standards, the government alone should not be in charge of trying to control the situation, individuals and members of communities are expected to play their own role in the control of gully erosion, they are expected to work hand in hand with the government and dumping of refuse into drainage system and water channels should be prohibited.

CHAPTER ONE

INTRODUCTION

Background to the Study

Erosion is one of the surface processes that forms the earth landscape and also constitutes one of the major global environmental problems. Soil erosion occurs when soil is removed through the action of wind and water at a greater rate than it is formed. Soil is seriously impacted upon or disturbed when rain falls on any part that is not protected by vegetation cover and where there are no roots to bind the soil together. Soil erosion is identified as one of the key challenges that impact on diverse sectors of our human existence ranging from the depletion of top nutrient rich soils, lowering agricultural productivity and volume storage depletion of reservoirs through sedimentation (Gupta 2010, Coulombo, 2010; Wang et al, 2013). Apart from being a global environmental threat, soil erosion is One of the most serious threats facing world food production. Soil erosion reduces the productivity of agricultural lands by removing nutrient rich topsoil and exposing less desirable subsoil. This results in a loss of organic matter and nutrients causing a reduction of fertility and water-holding capacity. The loss of soil from land surfaces by erosion is widespread and reduces the productivity of all natural ecosystem as well as agricultural, forest and pasture ecosystems. With the current increase in growth of the human

population, soil erosion, water availability, climate change due to burning of fossil fuel and loss of biodiversity rank as the prime environmental problems throughout the world. Igwe (2012) asserted that the gradual but constant dissection of the landscape by soil erosion, which threatens settlements and scarce arable land as the greatest threat to the environmental settings of Nigeria.

Erosion is the wearing or washing away of the top soil or soil surface. It is the removal of soil particles from the surface of the earth, transportation of these particles, and deposition of the particles by the action of wind and water. Soil erosion is identified as one of the key challenges that impact on diverse sectors of our human existence ranging from the depletion of top nutrient rich soils, lowering agricultural productivity and volume storage depletion of reservoirs through sedimentation (Gupta, 2010, Coulombo, 2010 & Wang, 2013). While erosion is a natural process, human activities have increased by 10-40 times the rate at which soil erosion is occurring globally. Erosion can occur at different rates depending on the slope of the land. The steeper the slope, the greater the intensity of the water flowing across the surface and its capacity to transport and erode soil.

Soil erosion is a common disaster that can be caused by nature because of the soil properties and also by man as a result of improper environmental Management (Ejaz et al., 2010). With the current increase in growth of human population, soil erosion, water availability, climate change due to burning of fossil fuel and loss of biodiversity rank as the prime environmental problems

throughout the world. Human activities such as removal of of vegetation cover, deforestation, and diversion of runoff into drainage channels, blockages of channels for housing development, use of burrow pits for building sands and stones and farming activities are factors that accelerates erosion in Nigeria. However, gully is virtually the most Impressive of all types of erosion .

Gully erosion is a major type of erosion and the most impressive of all in the sense that it tends to have a great impact on man and the environment than any other type of erosion. In Nigeria, gully erosion contributes to one of the major sources of land issues because it has led to decrease in soil nutrients, loss of lives and properties, and has contributed to flooding especially flooded roads thereby affecting motorists. Gully erosion contributes to each of the three main problems of the world and causes damage with an annual cost to the nation estimated at 100 million in 1990. Unfortunately since the 1980s till date, the situation of soil erosion has not abated instead it has exacerbated such that Nigeria has active gullies currently (Igwe & Fukuoka, 2010,Nwankwo,2018). Gully erosion is a significant problem in rural settings, where the land is often more vulnerable to soil erosion due to factors such as agricultural practices, deforestation, and inadequate soil conservation measures.

Gullies are permanent erosional forms that develops in many parts of the world, particularly in arid and semi-arid environments. Gullies function as sediment sources, stores, and conveyors that link hillslopes to downstream channels. Gully erosion is usually distinguished

from the boarder term ‘watercourse erosion’ by the path the erosion follows, which is normally along an overland flow path rather than along a creek. Prior to the occurrence of the gully erosion, the overland flow path would likely have carried only shallow concentrated flows conveying storm water runoff to a down-slope watercourse. Gully erosion, however, can also occur within a watercourse, typically within the upper reaches, and typically resulting from an active ‘head-cut’ migrating rapidly up the valley. Gully erosion is best characterised as a ‘bed instability’ that subsequently causes in ‘bank instabilities’. Unstable banks maybe the most visible aspect of gully erosion; but stabilisation of a gully normally needs to start with stabilisation of the gully bed. Most gullies start out as shallow overland flow paths that carry flows only during periods of heavy rainfall. An extraordinary event of some type causes an initial erosion point or ‘nick’ point to form somewhere along the drainage path. A bell-shaped scour hole sometimes forms at the head of the gully, which is usually deeper than the immediate downstream gully bed. Human land use, especially changes in land use, may accelerate gully expansion by head cutting, side wall collapsing, piping, floor erosion and other processes, which lead to widespread degradation and potential damage to human structures and activities. (Aber,2010) Gully erosion is a widespread and often dramatic form of of soil erosion caused by flowing surface water .It is a severe level of erosion. Gully erosion is an advanced stage of rills erosion. Rills are localized washes or channels created when water concentrates into small

rivulets in the field. The little streams or rills carry more soil as they pick up speed or grow in size. Rills when neglected develop in size and become gullies. Rills can be up to 0.3m deep. If they become any deeper than 0.3m, they are referred to as gully erosion. Thus, rill erosion is often described as the intermediate stage between sheet and gully erosion. Sheet erosion is the planar removal of surface soil by the action of either raindrop splash, shallow flows of surface water or even wind. The Soil Conservation Society of America defines a gully as a channel or miniature valley cut by concentrated runoff but through which water commonly flows only during and immediately after heavy rains.

Gully erosion is caused by unwise human activities such as deforestation, overgrazing, and unplanned construction activities. Gully erosion whether huge or small can definitely be controlled and prevented. The causes of gully erosion are poorly understood it's effect are clearly seen in some areas. Research has shown that gully processes had happened in the past even without human interference or influence. Therefore the concept of gully erosion can either be naturally induced or artificially induced, or a combination of both. But the artificially induced or human made (due to human activities) gully erosion is more rampant. Like in other states of the world, gully erosion is one of the major environmental issues facing Nigeria. Hence, the purpose of this study is to identify the anthropogenic (human made) factors that causes gully erosion and

it's impact on the land and environment of Iguobazuwa community, Edo state and importantly to identify means in which such factors can be controlled to prevent future gully formation.

Statement of the Problem

Erosion is a major issue that leads to degradation of land and loss of quality of land. Not only does it affect land but it can also affect crop productivity, animals and is even capable of taking human life. Edo state is one of the states amongst others that is affected by gully erosion. Although gully erosion is a natural disaster, the human (anthropogenic) factor that contributes to the formation of gullies are more, but these factors (anthropogenic) caused by human activities can be managed or controlled .

The causative agents of erosion are both geologic and anthropogenic. Geologic forces occurs due to natural phenomena such as; water, ice or glacier, wind, or gravity. Anthropogenic forces include deforestation, unsustainable farming practice, uncontrolled grazing practices, poorly constructed drainage system, path and road construction. Gully erosion is seen to be a major concern during the rainy season, this can be due maybe to negligence of the government or perhaps they have tried to input several measures to control it but all to non avail and they have decided not to waste anymore resources on a non profitable venture.

Several measures have been adopted by the government and even individuals such as mechanical methods of back filling, sand bagging, construction of channels and construction of speed breakers, while the biological control measures include trees and crop planting, to curb the

problem of gully erosion. Several researches have been done on gully erosion and it's impact on land. But despite these measures adopted and researches done by some researchers yet the problem still remains. Various researches have been carried out by other researchers on the impact of erosion on the environment and the various factors contributing to it but emphasis has been placed on the natural causes and it's impact on agricultural land. Not many researches have been done on the human (anthropogenic) factors that causes gully erosion and it's impact on the environment and land not only the agricultural land but on both the non-agricultural and agricultural land.

Through a careful observation and informal conversation with some of the community members, it was discovered that there is a lack of awareness of the human factors that contributes to the development of gullies in the community and it's impact on the environment. Thus, this work is geared towards enlightening the community members on those human factors and activities that contributes to the development of gullies so as to control such activities thereby reducing the development of gullies.

Research Questions

1. What are the activities of the members of iguobazuwa community that contributes to the formation of gullies?

2. To what extent will gully erosion impact on the health of people in iguobazuwa community?
3. To what extent will gully erosion affect the environment in iguobazuwa community?
4. What are the possible ways to control gully erosion in iguobazuwa community?

Purpose of the Study

The purpose of this study is to investigate those human activities that contributes to the problem of gully erosion in Iguobazuwa community Ovia South West, Edo State ; their impact on the land and the environment and also outline possible ways to control these problems.

The specific objectives are:

1. To identify the human factors that causes gully erosion in the study area.
2. To discuss how gully erosion impact the environment and land .
3. To investigate possible ways of controlling the problem .
4. To assess the extent to which gully erosion affect the community members.

Significance of the Study

The findings of this study are expected to be of value to the following stakeholders:

Researchers: The various issues raised in this study is likely to lead to the involvement of various researchers in obtaining more knowledge from various perspectives. The findings of this study

could form a basis for further research to other researchers and help the researcher to understand deeply the major consequences of gully erosion.

Community members and the general public: This study will help to know the extent at which the residents of Iguobazuwa community participate in unhealthy activities that lead to gully erosion in the area and it's impact on the environment. It will also enlighten the general public on ways through which gully erosion can be reduced in the area.

Scope and Delimitation of the Study

This study was carried out to determine the anthropogenic factors that causes gully erosion and it's impact on the environment and land; in a community in Ovia South West Local Government Area of Edo State. Therefore this study is delimited to Iguobazuwa community.

Limitations of the Study

One of the limitations of this study is that the questionnaire was only useful for educated respondents which is a flaw and as such could not collect enough data. Data could only be collected from the educated indigenes while the uneducated ones could not successfully complete the questionnaire without the guidance and assistance of the researcher, hence making the process time consuming and setting a limitation to the number of respondents that can be reached.

Definition of Terms

Soil Erosion: The wearing away of the land surface by physical forces such as rainfall, runoff water, wind, ice, temperature change, and gravity.

Gully Erosion: A landform created by running water,mass movement, or a combination of both eroding sharply into soil.

Rills Erosion: It occurs when runoff water forms small channels as it concentrates down a slope.

Land Degradation: The process in which the value of the biophysical environment is affected by a combination of human induced processes acting upon the land.

Anthropogenic: Influence of human being on nature.

Drainage channels: A natural or constructed watercourse or channel, having a definite bed and sides or banks, through which water flows.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

This chapter deals with the review of relevant and related literature from various scholars on the anthropogenic factors that causes gully erosion and it's effect on environment and land. The literature review would broaden our knowledge on the research topic for better understanding in this area of study. It is very important to have an outline of the few and inter related area to be reviewed. It shall be discussed under the following sub heading.

- Concept of soil erosion
- Concept of Gully erosion
- Factors that contribute to gully formation
- Problems associated with gully erosion
- Effects of gully erosion on land and environment
- Solutions to gully erosion in Nigeria
- Summary of related literature review

Soil erosion is a universal phenomenon. Most states in Nigeria is subjected to soil erosion and other forms of land degradation. Soil erosion is one form of land degradation along with soil compaction, low organic matter, and loss of soil structure, poor internal drainage, salinization (the process of increasing the salt content of the soil) , and soil acidity problems. These other

forms of land degradation usually contribute to accelerated soil erosion. Low soil moisture leads to erosion by wind and excess water leads to leaching of nutrients.

Concept of Soil Erosion

The soil is the top layer of the earth's surface. It is made up of dirt and rock. It is filled with air and life, a variety of organisms, like insects and earthworm, live in soil, it is a home for diverse organisms that. For plants, soil serves as a store house of water and minerals needed for their growth. It also provides shelter to many animals that live on or in the soil. Without soil, there would be no grass, no crops, no trees, no food for us and other animals.

Soil Erosion

Soil erosion is the detachment and movement of soil material. The process may be natural or accelerated by human activity. Depending on the local landscape and weather conditions, erosion may occur either gradually (very slow) or rapidly. In other words, soil erosion is a naturally occurring or human induced process that affects all landforms. In agriculture, soil erosion refers to the wearing away of a field's topsoil by the natural physical forces of water and wind or through forces associated with farming activities such as tillage. The problem of soil erosion exists all over the country.

Soil erosion is a naturally occurring process on all land. The agents of soil erosion are water and wind, each contributing a significant amount of soil loss each year. Soil erosion maybe a

slow or gradual process that continues relatively unnoticed, or it may occur at an alarming rate causing serious loss of topsoil. The loss of soil from farmland may be reflected in reduced crop production potential, lower surface water quality and damaged drainage networks. Detachment and transportation of top soil particles by wind and / or water is known as soil erosion (Shi, 2012) . The process of soil erosion is made up of three parts which are:

• Detachment: This is when the topsoil is actually “detached” or "removed" from the rest of the ground.

• Movement: This is when the topsoil is relocated or moved to another area.

• Deposition: Where the topsoil ends up after this process.

Classification of Soil Erosion

Soil erosion can be classified into the following;

According to Origin: Soil erosion can broadly be categorized into two types which are; natural or geological erosion and accelerated erosion.

Natural or Geological or Normal Soil Erosion

When the top soils are gradually removed under normal conditions of physical, biotic and hydrological equilibrium, it is called normal erosion and at times, it is also called geological erosion, it takes place steadily but for a long time and then slowly develops into the present

topographic features like valleys, plains, streams, channels etc. It is a very slow process in which complete equilibrium is maintained between soil removal and soil forming processes.

The normal erosion tends to produce wavy or undulating land surface with alternating ridges and depressions. This is accomplished mainly by means of slow migration of soil particles from soil surface in successive rains. In arid region, such as places in the extreme northern part of the country, wind during the long dry season is an important factor for normal erosion. Nature requires on an average about 1000 years building up 2.5cm of top soil, but wrong farming methods may take place only a few years to erode it from lands of average slope (Weil, 2016) .

Under natural undisturbed conditions an equilibrium is established between the climate of a place and the vegetative cover that protects the soil layer. Vegetative covers like trees and forests reduce the transportation of soil materials and act as a check against excessive erosion. A certain amount of erosion, however, does take place even under the natural cover, this erosion is called geologic erosion, it is a slow process and is compensated by the formation of soil under the natural weathering process. Its effect are not of much consequences as far as agricultural lands are concerned.

Accelerated Soil Erosion

It occurs due to disturbance in natural equilibrium by the activities of man and animals through land mismanagement, destruction of forests, over grazing etc. When the removal of soil

does not keep harmony with the soil formation and the soil removal is much faster than the soil formation, it is called accelerated soil erosion.

When land is put under cultivation, the natural balance existing between the soil, its vegetation cover and climate is disturbed. Under such condition, the removal of surface soil due to natural agencies such as wind and water, takes place at faster rate than it can be built by the soil formation process. Erosion occurring under these condition is referred to as accelerated erosion. Its rates are higher than geological erosion. Accelerated erosion depletes soil fertility in agricultural land.

According to Erosion Agents: Soil erosion is broadly categorized into different types depending on the agent which triggers the erosion activity. Below are some of the agencies or mechanism of soil erosion;

- Water erosion
- Wind erosion
- Biotic erosion

Water Erosion

Soil erosion caused by rainfall is the application of energy from two distinct sources namely ;

(i) The falling raindrops and

(ii) The surface flow.

The energy of falling raindrop is applied vertically from above, where as that of surface flow is applied more or less horizontally along the surface of the ground. The major role of the falling of raindrop on ground is to detach soil particles, where as that of the surface flow is to transport the soil.

The falling of raindrop also makes an essential contribution onto the movement of the soil on unprotected sloping lands during the period of heavy impact storms, by splashing large quantities down the slope.

Soil erosion caused by water can be categorized into different forms, such as;

(i) Splash erosion,

(ii) Sheet erosion,

(iii) Rill erosion,

(iv) Gully erosion,

(v) Ravine erosion,

(vi) Landslides, and

(vii) Stream-bank erosion.

i. Splash Erosion: The removal of soil particles due to rain drops is called splash erosion.

ii. Sheet Erosion: Sheet erosion is the removal of a thin uniform covering of top productive/surface soil from large areas, often from field, more or less, during every rain

which produces a run-off. This type of erosion is very insidious (occurs in a subtle and gradual way but with very harmful effects), since it keeps the cultivator almost ignorant of its ill-effect. It is also known as death of farmers.

iii. Rill Erosion: When runoff starts, channelization begins and erosion is no longer uniform. Raindrop impact does not directly detach any particles below flow line in rills but increases the detachment and transportation capacity of the flow. Rills are small channels, which can be removed by timely normal tillage operations.

iv. Gully Erosion: It is a more prominent type of erosion in which heavy rainfall, rapidly running water and transporting water may result in deeper cavities or grooves called gullies. Gullies may be 'V shaped or 'U' shaped. Gullies cut large fields into small fragments and, in the course of time, makes them unfit for cultivation . Continuous flow of water through gullies further deepens the grooves and may ultimately result in ravines.

v. Ravines Erosion: It is a prolonged and advanced stage of gully erosion which leads to ravines found in deep alluvial soils. It is nothing but deep and wide gullies. Ravines are 15 to 30 cm deep and with steep vertical sides.

vi. Landslides or Slip Erosion: This type of soil erosion is caused by heavy rainfall and it occurs in sloppy lands, such as mountains and hilly areas with slope greater than 20%. In this type of erosion, when the running water percolates through the crevices of rocks

great masses of soils and loose rocks lying on the steep slopes slip downward. The immediate cause of a slide may be an earthquake, or a heavy rainfall, which unduly saturates the ground or part of road.

vii. Stream Bank Erosion: It is most active on the banks of swollen rivers. During the rainy season when fast running water streams take turn in some other directions, they cut the soil and make caves in the banks. As a result of this, quite often large masses of soil becomes detached and washed away from the banks and are deposited at places in course of streams.

Wind Erosion

Wind erosion takes place normally in arid and semiarid areas devoid of vegetation, where the wind velocity is high. The soil particles on the land surface are lifted and blown off as dust storms. When the velocity of the dust bearing wind is reduced, coarser soil particles are deposited in the form of dunes, and thus fertile lands are rendered unfit for cultivation. In other places, fertile soil is blown away by winds and the subsoil is exposed, as a result the productive capacity of the soil is considerably reduced. Lifting and abrasive action of wind results in detachment of tiny soil particles from the granules or clods. The impact of these rapidly moving particles dislodge other particles from clods and aggregates. These dislodged particles are ready for movement. Movement of soil particles in wind erosion is initiated when the pressure by the

wind against the surface soil grains overcomes the force of gravity on the grains. Wind is responsible for three types of soil movement in the process of wind erosion. They are known as ;

(i) saltation

(ii) suspension and

(iii) surface creep.

1. Saltation : The major portion of soil carried by the wind is moved in a series of short bounces called “saltation”. The soil carried in a saltation consists of fine particles ranging from 0.1 to 0.5 mm in diameter. About 50-75% of soil erosion by wind is carried out by saltation. Saltation is caused by the direct pressure of wind on soil particles and their collision with other particles. After being pushed along the ground surface by the wind, the particles leap almost vertically in the first stages of saltation.

2. Suspension : Movement of fine dust particles smaller than 0.1 mm diameter by floating in the air is known as suspension. Soil particles carried in suspension are deposited when the sediment at on force is greater than the force holding the particles in suspension. This occurs with decrease in wind velocity. Suspension usually may not account for more than15% of total movement.

3. Surface creep : Soil particles, larger than about 0.5 mm in diameter but smaller than 3.0 mm, are too heavy to be moved in saltation but are rolled and sliding along the surface by the pressure of wind and hitting during saltation. About 5-25% of soil erosion are carried out by surface creep.

About 90% of the total soil movement in wind erosion is below the height of 30 cm and about 50% of it is within 5 cm of the ground level.

Biotic Erosion

The biotic agencies causing soil erosion are;

1. Excessive grazing, deforestation, undesirable forest biota, and mechanical practices by man are important factors which cause soil erosion. Deforestation is the most common factor which is responsible for soil erosion.

2. Grazing is yet another destructive biological factor for the soil erosion. Cattle and sheep during the summer graze the forest vegetation and make the soil bare.

3. Shifting cultivation is a major problem in hilly sides, they are usually noted in the mountains which are geographically young and degraded into soil easily and the whole of the land is covered with a thick mantle of tropical forest vegetation. The removal of the forest or bush cover by felling and burning for shifting cultivation and the resulting exposure of the bare soil to rams and sun, cause enormous soil losses especially on hill slopes. Both surface layer of the soil and large quantity of plant nutrients are washed away under the influence of intense rainfall. Fields on steep slopes are cultivated and top soil is washed away by rains. The loss of soil is too much and the fields become uncultivable.

4. Forest fires are responsible for burning down forest trees on a huge scale.

5. Faulty agricultural methods ; Sometimes farmers do not have a care towards leveling and terracing of their upland fields. Rainfall washes away the top soil and results in erosion.

6. Over-grazing by cattle causes removal of vegetation cover of the soil.

Causes of Soil Erosion

There is no single unique cause that can be held responsible for soil erosion or assumed as the main cause for this problem. There are many underlying factors responsible for this process, some induced by nature and others by humans. The main causes of soil erosion can be enumerated as:

(1) Destruction of Natural Protective Cover by

(i) Indiscriminate cutting of trees,

(ii) Overgrazing of the vegetative cover and

(iii) Forest fires.

(2) Improper Use of the Land

(i) Keeping the land barren subjecting it to the action of rain and wind,

(ii) Growing of crops that accelerate soil erosion,

(iii) Removal of organic matter and plant nutrients by injudicious (very poor) cropping patterns,

(iv) Cultivation along the land slope, and

(v) Faulty methods of irrigation.

Concept of Gully Erosion

The Nigeria gully erosion crisis has been ongoing since before 1980, and affects communities both large and small. It is an ecological, environmental, economic, and humanitarian disaster resulting in land degradation, loss of lives, and properties worth millions of naira. The estimated number of gullies in the country is at 3,000. They occur due to sandy soil being unable to withstand the runoff and eventually eroding away, leaving gaping gullies that swallow homes and other infrastructure. Gully erosion is an advance stage of rill erosion as rill erosion is the advanced stage of sheet erosion. It is the most spectacular form of erosion. Any concentration of surface runoff is a potential source of gully erosion. The Soil Conservation Society of America defines a gully as "a channel or miniature valley cut by concentrated runoff but through which water commonly flows only during and immediately after heavy rains. It may be dendritic or branching or it may be linear, rather long, narrow and of uniform width". The distinction between ravine, gully and rills is that of size. A gully is too large to be filled by normal tillage practices. A ravine is a deep narrow gorge. It is larger than a gully and is usually worn down by running water.(Michael and Ojha, 2012).

Gully erosion is a widespread and often dramatic form of soil erosion caused by flowing surface water. It consists of open, unstable channels that have been cut more than 30 centimetres deep into the ground. Gullies are an important part of the soil erosion process and their occurrence and development may cause serious problems to a region's economy. Gully erosion is the removal of soil and soft rock as a result of concentrated runoff that forms a deep channel. Gully erosion is defined as the erosion process whereby runoff water accumulates and often recurs (that is occurring periodically or repeatedly) in narrow channels and, over short periods, removes the soil from this narrow area to considerable depths. According to Amangabara (2012), gully erosion is the terminal phase of a four-stage erosion process involving splash, sheet, rill, and gully. The process begins by water falling as raindrops and flowing on the soil surface. Splash erosion results when the force of raindrops falling on bare or sparsely vegetated soil detaches soil particles. It was observed that gullies are important part of soil erosion process and their occurrence and development may cause serious problems to a region's economy. Gully is normally formed on very steep land, where water running downhill cuts a channel deep into the soil. Gullies are steep-sided eroding watercourses that are subject to ephemeral flash flood during rainstorms. It also occurs where there is a sudden fall. According to Eseigbe and Ojeifo (2012), gully erosion is a serious form of soil degradation often involving an initial incision in to the subsurface, by concentrated runoff along lines or zones of weakness such as tension and

desiccation fractures. These narrow incisions are subsequently widened and elongated by sidewall processes and headward erosion. Aderemi and Iyamu (2013) observed that gullies may also be initiated at the local base level streams and rivers by the combined effects of seepage forces, subterranean erosion and liquefaction. Gullies of this type develop into gigantic negative relief features by progressive liquefaction, flowage, progressive tension fracturing, slumping and landslides. Gully erosion is essentially a slope failure phenomenon operating under the influence of hydrodynamic, gravitational and body forces. Slope failure can also proceed through flowage, sliding and slumping, and toppling. Ekpenyong (2013), observed that the rates of these failures which culminate to gully advance and lateral expansion are more during periods of heavy precipitation.

Gully erosion is a form of land degradation characterized by the formation of deep channels or gullies caused by the excessive removal of soil by water. While natural factors play a role in gully erosion, anthropogenic activities have been recognized as significant contributors to its occurrence and severity. Gully erosion is the removal of soil along drainage lines by surface water runoff. Unless steps are taken to stabilise the disturbance, gullies will continue to move by headward erosion or by slumping of the side walls. Gully erosion is a result of the interaction of land use, climate and slope. It occurs on many different soils and landforms in Nigeria. A gully is a landform created by running water, mass movement, or more commonly a combination of both

eroding sharply into soil or other relatively erodible materials, typically on a hillside or in river floodplains or terraces. Gullies resemble large ditches or small valleys, but are metres to tens of metres in depth and width and are characterised by a distinct 'headscarp' or 'headwall' and progress by headward (i.e. upstream) erosion. Gullies are commonly related to intermittent or ephemeral water flow usually associated with localised intense or protracted rainfall events, or snowmelt. Gullies can be formed and accelerated by cultivation practices on hillslopes (often gentle gradient) in farmland, and they can develop rapidly in rangelands from existing natural erosion forms subject to vegetative cover removal and livestock activity.

Gully erosion is a significant environmental threat throughout the world and affects multiple soil and land functions. There is ample physical evidence of intense gully erosion occurring at various times in the past in different parts of the world. Gullies are one of the few sources of morphological evidence in the landscape of past phases of intense soil erosion, reflecting the impact of environmental change (especially due to interactions between geomorphological features, changes in land use and extreme climatic events). Gully erosion represents a major sediment source, although gully channels often occupy less than 5 % of the area of a catchment. The development of gullies increases run-off and sediment connectivity in the landscape, hence increasing the risk of flooding and reservoir sedimentation. Assessing interactions between environmental change and land degradation is a key issue for environmental scientists, land

managers and policy-makers. Over recent decades, significant progress has been made in understanding gully erosion, its controlling factors and associated processes. However, many research questions remain, including gullying mechanisms, human impacts on gully erosion and gully control measures. These questions pose major challenges to the scientific community (Poesen 2011). Gully erosion is a potentially lethal geomorphological process and thus constitutes a major threat to life and property. Hence, geomorphologists can play vital roles in decreasing the threats posed by gully erosion.

Gullying is one of many natural processes that shape the surface of the earth and represents a manifestation of catchment instability. It is only when gullies threaten humankind that they represent a hazard. In the vast regions of Europe, Asia and America, for example, gully erosion might be the most important geomorphic natural hazard. Under these circumstances, geomorphologists face major challenges in making society aware of the impacts of gully erosion. There are two generally accepted definitions of "hazard." The first refers to a potentially damaging process or situation (such as a landslide or gully). The second definition is more technical and refers to both processes and the probability of occurrence in a unit of time of a given magnitude event . However, population pressure and specific human activities (such as deforestation, improper land use and agricultural practices) have generally increased land degradation and particularly the hazard of gully erosion. From this perspective, gully erosion

hazards could be natural, human-induced or both. Some studies emphasized that phases of gully erosion in historical periods were directly related to intensive agricultural land use and more erosive rains (Dotterweich 2012; Dotterweich et al. 2012).

Gully erosion causes numerous environmental and socio-economic consequences, and most of them are negative (Marzolff et al. 2011; Ionita 2011). Gullies reduce the productivity of farmlands where they incise into the land, and produce sediment that may choke downstream water bodies, and reduce water quality within the drainage system and lake or coastal system. Because of this, much effort is invested into the study of gullies within the scope of geomorphology and soil science, in the prevention of gully erosion, and 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. The initiation and development of both ephemeral and permanent gullies can be regarded as an indicator of land degradation .Gully development decreases the extent of agricultural land, can decrease farm productivity by incision into land and/or depleting soil resources and can thus decrease crop yields (Zgłobicki et al. 2015; Ionita et al. 2011). Negative economic effects of gully erosion have been reported in numerous case studies (e.g. Kuhlman et al. 2010; Yitbarek et al. 2012; Frankl et al. 2013).

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 (deepest part of a channel) , 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 (M. Rădoane and N. Rădoane, 2017). Gully erosion is regarded as an indicator of desertification, the main causes of which are allegedly global climate changes and anthropogenic pressure (Torri and Poesen 2014).

Losses of large volumes of soil through gully formation lead to serious environmental, societal, and economic problems for human societies. Gully erosion causes in-site and downstream environmental degradation. Human activities in arid and semi-arid areas accelerate gully occurrence that alters Earth's landscapes and affects human-environmental sustainability (Garosi et al., 2018). Usually gully erosion is known as anthropogenic alteration of landscapes, resulting in a serious threat to global agricultural sustainability through loss of productive

capacity (Vanwalleghem et al., 2017). Since gullies can be a large source of watershed sediment yield, they negatively affect water quality (Wang et al., 2020). Siltation of drainage network and reservoirs, and damage to transport networks and infrastructure are consequences of intense gully erosion (Fox et al., 2016). Furthermore, gullies may lead to negative socio-economic consequences, driven by damage to infrastructure and transport routes (e.g., roads and rail routes), and siltation of reservoirs. Nearly 41% of the Earth's surface covered by arid and semi-arid environments, and comprising about 2 billion inhabitants, is sensitive to gully erosion (MEA, 2005). Huge soil losses from permanent gullies have been reported around the word. In semi-arid and arid regions, gully erosion contributes up to 70% of all transported sediments (Zhao et al., 2013). Thus, it is critical to identify triggering factors of gully formation and determine land predisposition to gully erosion in semi-arid regions.

Gully formation processes are dynamic and regulated by a broad variety of features (Castillo and Gómez, 2016). Although commonly triggered or accelerated by climate events (e.g., extreme rainfall leading to high runoff or droughts which decimate protective vegetation), most gully erosion is driven by land use changes and unsustainable human activities, due to their impact on drainage and infiltration conditions. Human activities are an inherent part of the earth system that affect geomorphological and hydrological processes, although their consequences in the subfield of gully erosion are not yet understood. In the Anthropocene period, gully erosion is

becoming a ubiquitous phenomenon, particularly on agricultural land, driven by: overgrazing of rangelands , intensive farming systems which reduce soil organic matter and soil structural stability; and irrigation drainage systems . In forest land uses, gullying is driven by wildfires (Galang et al., 2010), deforestation (Gholami, 2013), and construction of access infrastructure, since they damage vegetation cover and thus facilitate gully erosion (Castillo and Gómez, 2016). Gullies have been also observed in urbanized and developed environments, mainly due to soil compaction, construction activities, and unlawful habitations without adequate municipal infrastructure (e.g., roadways and sanitation facilities). The initiation of gullies is often linked to the road construction and other axial runoff conveyors (e.g., lanes or tracks), since they receive and concentrate runoff from larger surfaces and thus influence the development and geometry of gullies (Imwangana et al., 2014). Therefore, different factors controlling and influencing the development of gullies, such as topography, physical properties of soil, lithology, climate, rainfall, and land use need to be considered for gully erosion assessment.

Several attempts have been made to investigate the contribution of natural and anthropogenic factors to gully occurrence. For instance, Samani et al. (2010) determined the influence of factors on gully formation using a multiple regression. Bergonse and Reis (2016) applied a regression method to scrutinize the role of different factors potentially affecting the location of large gullies in Portugal. In addition, Mararakanye and Sumner (2017) assessed the influence of factors

contributing to gully erosion using the information value (InfVal) statistics in the Mpumalanga province of South Africa. Rahmati et al. (2017) used a conditional probability (CP) model for identifying the spatial relationship between gullies and the geo-environmental factors. However, statistical methods need the classification of each factor and this procedure may provide uncertainties. The impact of contributing factors to gully erosion has not yet been investigated using machine learning models. On one hand, a full understanding of complex and long-term interactions between human activities and the natural geomorphodynamic processes needs powerful artificial intelligence techniques (Suman et al., 2016). On the other hand, gully erosion should be assessed and interpreted on the basis of its historical occurrences, to provide a deeper insight on gully causative factors, drivers, and their effects (Vanwalleghem et al., 2017).

Stages of Gully Erosion

Gullies are not formed overnight, rather they develop over a period of time, passing through four different and distinct stages. These stages are important from view point of both growth rate of gullies and their control measures. The main processes in the development of gullies are waterfall erosion and channel erosion. These two erosions are commonly found in the same gully. The extension of the gully head is usually by waterfall erosion; while the scouring of bottom and sides which enlarges the depth and width of gullies is by channel erosion. Gullies usually start

with channel erosion. When an overfall develops at the head of the gully, the gully continues to develop by waterfall erosion. The gully development is recognized in four stages:

Formation Stage: This is caused by downward scour of top soil. Scouring of top soil in the direction of general slope occurs as the runoff water concentrates. It normally proceeds slowly where the top soil is fairly resistant to water erosion.

Development Stage: This is caused by upstream movement of the gully head and enlargement of the gully in width and depth. The gully cuts to the lower horizon of sub-surface soil and the weak layer of parent material is easily removed. The upstream head of the gully/channel looks like a waterfall. This is the most detrimental stage of gully erosion. The gully cuts to the C-horizon of soil, and the parent materials are removed rapidly as water flows.

Healing Stage: Vegetation starts growing in the gully. This starts with beginning of growth of vegetation in the gully. This is prelude to stabilization of gully. By now, gully completes its menace of destruction.

Stabilization Stage: Gully reaches a stable gradient, gully walls attain a stable slope and sufficient vegetation cover develops over the gully surface to anchor the soil and permit development of new topsoil.

Formation

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. 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).

Classification of Gullies

Gullies can be classified based on three factors such as their size, shape (cross section) and formation of branches or continuation.

Based on Size (depth and drainage area)

Gully classification based on the size is presented in the table below

CLASSIFICATION	DEPTH (m)	DRAINAGE AREA (ha)
Small	< 1	< 2
Medium	1 to 5	2 to 20
Large	> 5	> 20

Based on Shape

The classification of gullies based on shape include;

U-SHAPED: These are formed where both the topsoil and subsoil have the same resistance against erosion. Because the subsoil is eroded as easily as the topsoil, nearly vertical walls are developed on each side of the gully. U-shaped gully erosion, also known as valley erosion or fluvial erosion, refers to the formation of U-shaped channels or valleys through the action of water flow. It is a common process of erosion that occurs in various landscapes, particularly in areas with steep slopes and abundant rainfall.

Formation: U-shaped gullies are formed through a combination of several erosional processes. It typically begins with the development of a small V-shaped channel, which is formed by the concentrated flow of water along the slope. This initial channel is often created by rainfall runoff or the convergence of multiple small streams.

Headward Erosion: Once the u-shaped channel is established, the erosive forces, such as the impact of flowing water and the scouring action of sediment particles, start to concentrate at the head or origin of the channel. This leads to the process known as headward erosion, where the channel extends its length backward into the slope, gradually deepening and widening it.

Downcutting: As the channel extends backward, it begins to downcut into the underlying soil and rock layers. The erosive forces remove material from the channel bed and banks, deepening the gully. This downcutting process is often more pronounced during high-intensity rainfall events or periods of increased water flow, as they deliver more energy to erode the channel.

Bank Erosion: Along with downcutting, bank erosion plays a significant role in shaping the U-shaped gully. As the water flows through the channel, it exerts lateral pressure on the channel's banks. Over time, this pressure can cause the banks to collapse and erode, contributing to the widening of the gully.

Soil Erosion: U-shaped gully erosion also involves the removal of soil from the channel and its surroundings. The force of the water can detach and transport soil particles, leading to soil erosion. This erosion process further contributes to the widening and deepening of the gully.

Sediment Transport: During intense rainfall events, U-shaped gullies can experience rapid water flow, capable of carrying significant amounts of sediment. The eroded soil and rock fragments

are transported downstream, leading to the deposition of sediment in lower-lying areas, such as floodplains or rivers.

Feedback Loop: As the gully deepens and widens, it creates a self-reinforcing feedback loop. The increased channel dimensions allow more water to flow through, which, in turn, amplifies the erosive forces and further accelerates the gully erosion process.

U-shaped gully erosion can have significant ecological and environmental impacts. It can lead to loss of fertile topsoil, degradation of agricultural land, alteration of hydrological patterns, and habitat destruction for plant and animal species. Therefore, effective erosion control measures, such as terracing, revegetation, and sediment trapping, are often implemented to mitigate the negative consequences of U-shaped gully erosion.

V-SHAPED: These gullies develop where the subsoil has more resistance than topsoil against erosion. This is the most common form of gully. The V-shaped gully erosion is characterized by the formation of deep, narrow channels with steep sides that resemble the letter "V." It typically occurs in areas with concentrated flow of water, such as during heavy rainfall events or when water runoff is channeled through a specific path. The process of V-shaped gully erosion can be explained in the following steps:

Sheet Erosion: Initially, water flows over the surface of the soil, causing sheet erosion. This means that the top layer of soil is gradually removed and transported by the flowing water.

Rill Erosion: As the sheet erosion progresses, small channels known as rills are formed. These rills are shallow and often less than a foot in depth. They usually develop in areas where the water flow concentrates, such as along natural depressions or in areas where vegetation is sparse.

Rill Widening: Over time, the rills deepen and widen due to continuous water flow. The erosive force of the water is concentrated in the center of the channel, leading to vertical erosion and steepening of the channel walls.

Headcut Formation: As the rill erosion continues, a more significant feature called a headcut is formed. The headcut is an abrupt change in the slope of the channel and marks the beginning of a gully. It usually occurs where the gradient of the land is steeper or where there is an obstruction in the flow path, causing the water to concentrate and erode the soil more intensely.

Gully Development: The headcut moves upstream over time, leading to the extension and deepening of the gully. The vertical erosion by the flowing water creates steep, V-shaped sides.

TRAPEZOIDAL: These gullies are formed where the gully bottom is made of more resistant material than the topsoil. Below the bottom of gully, the subsoil layer has much more resistance to get eroded and thus the development of further depth of gully is restricted. Trapezoidal gully

erosion is characterized by the formation of wider and more open channels with gently sloping sides, resembling the shape of a trapezoid. It occurs in areas with higher flow volumes and prolonged erosion processes. The process of trapezoidal gully erosion can be explained as follows:

Initial Rill Formation: Similar to V-shaped gully erosion, trapezoidal gully erosion starts with sheet erosion and the formation of shallow rills.

Rill Deepening and Widening: As water continues to flow, the rills deepen and widen over time due to the erosive force of the water. However, in trapezoidal gully erosion, the widening is more pronounced compared to V-shaped gully erosion.

Side Erosion and Slope Failure: As the rills widen, the sides of the gully become more susceptible to erosion. The flowing water undermines the stability of the slopes, leading to slope failure and slumping of the soil material.

Channel Enlargement: The combination of erosion at the gully sides and slope failure leads to the gradual enlargement of the gully channel. The widened channel has gently sloping sides, which give it the trapezoidal shape.

Continued Erosion: Once a trapezoidal gully is formed, it can continue to deepen and widen if the erosive conditions persist. This can result in further slope failure and removal of large amounts of soil.

Both V-shaped and trapezoidal gully erosion can have significant environmental impacts, such as loss of fertile topsoil, decreased agricultural productivity, and alteration of the landscape. Therefore, effective erosion control measures and land management practices are crucial for mitigating these types of erosion and preserving the integrity of the land.

Based on the Formation of Branches or Continuation

Gully erosion can also be classified based on formation of branches and these include;

Continuous Gullies: These gullies consist of many branches. A continuous gully has a main gully channel and many mature or immature branch gullies. A gully network is made up of many continuous gullies. A multiple-gully system may be composed of several gully networks. Continuous gully erosion, also known as progressive or linear gully erosion, occurs when a gully gradually deepens and widens over time, resulting in a continuous channel. It typically starts as a small, shallow depression caused by the concentration of surface water flow. Over time, the erosive forces of water intensify, deepening the gully and causing it to extend further downslope.

Continuous gullies often follow natural drainage lines or paths of least resistance. The process of continuous gully erosion involves several stages:

Initiation: The initial stage involves the formation of a small depression or incipient gully due to the concentration of water flow.

Expansion: The gully enlarges as water flow becomes more concentrated, leading to increased erosion and deepening of the channel.

Headcut Migration: The headcut is the uppermost point of the gully where water enters. It migrates upstream as erosion continues, causing the gully to lengthen.

Channel Widening: As the gully deepens, the sidewalls collapse due to gravity and erosion, leading to channel widening.

Continuous gully erosion is often a result of human activities, such as improper land use, deforestation, overgrazing, and inadequate erosion control measures. It can have severe consequences, including loss of agricultural land, destruction of infrastructure, and degradation of ecosystems.

Discontinuous Gullies: These may develop on hillsides after landslides. They are also called independent gullies. At the beginning of its development, a discontinuous gully does not have a distinct junction with the main gully or stream channel. Flowing water in a discontinuous gully spreads over a nearly flat area. After some time, it reaches the main gully channel or stream.

Independent gullies may be scattered between the branches of a continuous gully, or they may occupy a whole area without there being any continuous gullies. Discontinuous gully erosion, also known as ephemeral or headcut gully erosion, is characterized by the formation of isolated gullies that occur sporadically throughout a landscape. Unlike continuous gullies, which are connected and form a continuous channel, discontinuous gullies are separate and do not have a continuous flow path. Discontinuous gullies typically form in areas with variable soil types, slope gradients, or land cover. They are often associated with intense rainfall events or concentrated runoff from specific areas. Discontinuous gullies can appear and disappear depending on the occurrence of these triggering events. They are commonly found in arid or semi-arid regions, where sporadic heavy rains cause intense localized erosion. The process of discontinuous gully erosion involves similar stages to continuous gully erosion, but on a smaller scale and with individual gullies:

Initiation: An initial depression or headcut forms due to the concentration of water flow, often caused by a localized runoff source.

Erosion and Expansion: The headcut deepens and the gully expands as water flow intensifies during rainfall events.

Migration: The headcut migrates upslope, lengthening the gully. However, the gully remains isolated and does not connect with other gullies.

Discontinuous gully erosion can result in soil loss, sedimentation of downstream areas, and alteration of drainage patterns. It can also impact agricultural productivity and pose a threat to infrastructures such as roads and buildings.

Both continuous and discontinuous gully erosion are significant environmental challenges, and their prevention and control require effective land management practices, including the implementation of erosion control structures, reforestation, terracing, and proper land use planning.

Factors that contributes to Gully Erosion

Gully erosion is a natural process that occurs due to various environmental factors. It is characterized by the formation of deep and narrow channels (gullies) in the landscape, often resulting from the excessive runoff of water. The primary causes of gully erosion can be attributed to geological, climatic, and human-induced factors.

Natural Factors

The natural causes of gully erosion include;

1) Geological factors: Geological formations play a significant role in gully erosion. The presence of soft, erodible materials, such as clay or loose sediments, is more susceptible to erosion than hard rock formations. The geology of an area can influence how water interacts with the landscape and the rate at which erosion occurs.

2) Climatic factors (Precipitation) :

(a) Monthly distribution of rainfall

The duration of wet and dry seasons cannot be deduced from total annual rainfall. The monthly distribution of rainfall is more significant than total annual rainfall because of its effects on the growth of vegetation, as well as the fact that it gives some indications about rainfall intensity. In humid regions with uniform distribution of rainfall, surface erosion, including gully formation, may not be a serious problem because vegetation grows throughout the year. However, in areas that do not have uniform rainfall, the vegetation (especially grass) dries up during the prolonged dry season (3 to 5 months or more). If the land is not properly used, or if forest or grass fires occur during the dry period, it cannot sufficiently hold rainwater and so the increased surface run-off in the rainy season produces large scale landslides and gullies.

(b) Rainfall intensity and run-off

There is a relationship between rainfall intensity, rate of run-off, density of vegetative cover, and the size of a catchment area. This relationship is generally expressed in equations.The Rational Formula which is used in engineering designs for gully and torrent control is a good way to demonstrate this relationship. If the amount of rainfall is more than the holding capacity of the soil, there will be an increase in surface run-off, followed by surface erosion and gullying. In

some tropical and subtropical countries, after the soil is completely saturated, almost all of the rainfall turns into run-off during the wettest months, which include the monsoon season, tropical cyclones and especially typhoons. It rains intensively for two or three days without stopping during each typhoon period and the increased run-off causes landslides, huge gullies and devastating floods. In continental and temperate-climate countries, prolonged rains of moderate intensity (duration several days). or short, intensive rain storms lasting from 15 to 90 minutes (maximum rainfall intensity about 3mm/minute), cause landslides, gullies and floods because of the increased run-off in the watersheds.Torrential floods, which generally occur after the short, intensive rain storms, destroy agricultural lands, residential areas, roads, irrigation ditches and canals at the base of the valley below a deteriorated watershed. Rainfall intensity and run-off rates (peak flows) are expressed in milliliters per hour or minute and cubic meters per second, respectively. In designing engineering measures such as check dams or diversions in gully and torrent control, the rate of run-off is more important than the amount of run-off.

(c) Rapid snowmelts

Rapid snowmelts turn into high run-off. This increased surface run-off acts as a cutting agent and produces gullies. Like prolonged rains of moderate intensity and short intensive rain storms, rapid snowmelts cause destructive floods. Rainfall intensity and distribution are crucial factors affecting gully erosion. Areas with high-intensity rainfall or seasonal storms can generate a large

amount of runoff, leading to increased erosion. Gully erosion may occur as a result of continuous and heavy rainfall- the greater the intensity and duration of a rainfall, the higher the erosion potential. The impact of raindrops on the soil surface can break down soil sediments and disperse the sediment to down streams. Prolonged and heavy rain events can result in soil saturation, reducing its ability to absorb water and increasing the likelihood of surface runoff and erosion. Climate change can also impact gully erosion patterns. Changes in precipitation patterns and increased frequency of extreme weather events can exacerbate erosion processes, altering the rate and severity of gully formation.

3) Topographic factors: The topography of the land influences gully erosion. Steep slopes facilitate rapid water flow, leading to increased erosive force. Similarly, the convergence of runoff from multiple directions can concentrate water flow and accelerate erosion. The size and shape of a drainage area, as well as the length and gradient of its slopes have an effect on the run-off rate and amount of surface water. Therefore, all topographic characteristics should be studied in detail before gully control work begins.

(a) Shape of catchment

Long catchment's gathering time (time of concentration) will be longer, its corresponding intensity lower, and its maximum run-off rate (Q max, cubic m/second) less. This explains why,

if all other factors are equal, long narrow catchments have fewer flash floods than square or round catchments.

(b) Size of catchment

The larger the catchment, the greater the amount of run-off. The catchment area of a gully can be measured easily and accurately by using a 1/10 000 scaled map. If it is not available, a map can be prepared after surveying the catchment area of the gullies and torrents with a theodolite or transit. Mapping continuous gullies or gully networks can also be undertaken by surveying the closed traverses with a clinometer (0-90 degrees), handcompass (0-360 degrees) and 50 m measuring tape.

(c) Length and gradient of the slope

On long slopes, there is generally an accumulation of water towards the base. To prevent the gully formation, this water (run-off) should be conducted safely downhill over a long distance to stable, natural water courses or vegetated outlets. Otherwise, the water should be infiltrated into the ground by land treatment measures such as contour ditches (infiltration trenches), level terraces (gradoni), wattling, staking, etc.

The steeper the slope, the higher the velocity and erosive power of the run-off. Watershed land treatment measures not only reduce the amount of surface water, but they also decrease its velocity, and so its erosive power.

4) Vegetation cover and soil characteristics: Vegetation cover and soil stability are vital in preventing gully erosion. Dense vegetation can reduce the impact of rainfall on the soil surface, improving infiltration and reducing surface runoff. The roots of plants also help bind soil particles together, enhancing soil stability. Deforestation or removal of vegetation, either due to natural causes like wildfires or human activities like logging, can increase surface runoff and erosion risk, leading to gully formation. The role of vegetative cover is to intercept rainfall, to keep the soil covered with litter, to maintain soil structure and pore space, and to create openings and cavities by root penetration. This is best achieved by an undisturbed multistory forest cover. Under special conditions, however, a well-protected, dense grass cover may also provide the necessary protection. In general, it is management and protection rather than the type of the vegetative cover which determines its effectiveness in gully control. Any vegetation which is well-adapted to local conditions and which shows vigorous growth may be used. In some cases, these may be broadleaf species, in others conifers, tall grasses, etc. In critical areas, it may be necessary to exclude any use of the protecting vegetation. Whenever possible, however, it is desirable to establish a vegetative cover which serves a dual purpose, for example, provision of

fodder, fuelwood, fruit, etc. In soil properties the following seven soil classes are based on soil texture: sand, loamy sand, sandy loam, loam, silt, loam, clay loam and clay. The infiltration rate increases from clay to sand (for loamy sand 2.5-5 cm/hour), but resistance against erosion decreases.

5) Natural disturbances: Natural events such as earthquakes, landslides, volcanic eruptions, or even large animal activity can contribute to the initiation of gullies by altering the landscape's topography or disturbing the soil and vegetation cover.

6) Concentrated runoff from steep lands flowing into cleared drainage depressions: The steeper slope, the lesser the infiltration of water hence, soil erodes more on steeper slopes than on grounds that have mild slope; this happens more on areas where there is increase speed of run off.

7) Unstable soils in drainage lines: Lighter particles of soil such as very fine sand, silt, clay and organic matter are easily removed by the rain splash and runoff water; to move larger sand and gravel particles to be washed away, heavy raindrops and heavy flow of run off are required.

Above are some of the natural causes of gully erosion, but for the sake of this study, we will be deliberating more on the human induced causes.

Anthropogenic Factors

Anthropogenic factors of gully erosion are those activities of man and animals that leads and contributes to the formation and development of gullies. Some anthropogenic factors include;

1) Land clearing:

Tree clearing, even if replaced by other vegetation such as grass or crops, can significantly alter the runoff characteristics of a catchment, and as a result, cause long-term changes to downstream waterways. Specifically, de-forestation has the potential to:

- reduce rainfall infiltration;
- reduce the volume of stormwater temporarily retained on plant leafs and surface mulch;
- increase the frequency and duration of both low and high-flows within streams;
- increase the total annual volume of stormwater runoff;
- alter the health and biodiversity of instream ecology.

It has long been observed that changes in vegetation cover, including de-forestation as a result of land clearing and bushfires, can result in significant changes to the annual flow of stormwater from catchments.

Even though erosion is a natural aspect of all waterways, the basic aim should be to avoid an unnatural acceleration or deceleration of this erosion. Stream flows at or near the bankfull

flow rate are normally considered to have the greatest influence on channel erosion; however, gully erosion can be advanced by both the frequent low-flows and the infrequent flood flows.

The impacts of land clearing are more likely to affect minor waterways such as gullies and creeks. There are generally four types of creek systems: clay-based, sand-based, gravel-based and spilling (rocky) creeks. Each of these waterways will respond differently to land clearing. Replacing deep-rooted plants with grass can result in an increase in the volume and frequency of runoff. Hills cleared of vegetation can result in a permanent increase in runoff resulting in gully erosion. A sudden change in grass density can alter the flow path of surface runoff, which can cause a change in the way stormwater enters an adjacent waterway. As a result, lateral bank erosion can be initiated within the waterway ultimately resulting in the formation of a gully.

2) Construction and Urbanization:

The expansion of urban areas and construction projects can lead to increased impervious surfaces and altered drainage patterns. Stormwater runoff from these surfaces can erode soil and contribute to gully development (Zhao et al., 2016). Urbanisation can have a similar influence to that of deforestation. The effect, however, is more commonly observed as ‘accelerated creek erosion’ rather than gully erosion. Significant changes can occur to the size of waterways following the growth of poorly managed urbanisation. The extent of these changes primarily depends on the type and degree of changes to the catchment hydrology. In order to minimise the

risk of accelerated creek erosion, consideration must be given to those measures that will minimise changes to:

- the annual volume of stormwater runoff;
- the frequency and duration of near-bankfull flows; and
- the peak discharge of those stream flows greater than or equal to the bankfull flow rate.

The focus of stormwater management programs, however, should not be to just reduce changes to the annual runoff volume, but to reduce changes in the runoff volume of those storms that are likely to contribute to near-bankfull flows. Thus the focus will likely be on storms with an average recurrence interval (ARI) of between 1 in 1 year and 1 in 10 years. It should also be noted that an increase in the frequency and duration of low-flows within a waterway (i.e flows less than the 1 in 1 year ARI) may increase the stress on in stream aquatic ecology and habitats. Consequently the only way to minimise the risk of both accelerated creek erosion, and a decline in urban aquatic habitats, is to minimise changes to the natural water cycle, including the frequency, duration, velocity, volume and peak discharge of rainfall events of all stream flows. In urban areas this can usually be achieved, in part, by:

- adopting the principles of Water Sensitive Urban Design;

i. minimising changes in impervious surface area, particularly on highly porous soils;

ii. decreasing the percentage of directly connected impervious surfaces;

iii. maximising stormwater infiltration;

iv. using rainwater harvesting to minimise changes to runoff volume;

v. adopting stormwater ‘retention’ rather than ‘detention’ systems.

It is not possible to accurately predict the response of natural, earth-lined waterways to changes in catchment hydrology. Past history has shown that in the absence of major flow control systems (i.e. dams and retention basins), urban creeks typically expand from around a 1 to 2 year ARI bankfull capacity, to around a 5 to 10 year ARI bankfull capacity following urbanisation. Rather than reduce the risk of accelerated creek erosion, stormwater ‘detention’ practices can actually increase this erosion by increasing the duration of near-bankfull flows. As a result, modern stormwater management practices now focus on stormwater retention and stormwater harvesting.

3) Exposure of weak subsoil:

Gully erosion is often triggered by the exposure of a weak subsoil layer beneath a streambed. Exposure of the weak subsoil layer can result from natural erosion processes, or human activities. Examples of such human activities include:

• accelerated channel erosion resulting from deforestation or urbanisation;

• exposure of the weak subsoil during the construction of a watercourse crossing;

• exposure of the subsoil during channel realignment or extensive weed control activities. If the exposed subsoil is dispersive (e.g. a sodic soil), then the resulting gully erosion is normally both deep and highly mobile. Weak subsoils can include non-cohesive sandy soils, slaking soils (soils that readily collapse when wet), and dispersive soils (soils that readily collapse and cloud the water when wet). Sodic soils (high in sodium content) are one of the most common forms of dispersive soils.

4) Culvert construction:

The construction of culvert crossings can initiate gully erosion in two ways. Firstly, the culvert can cause the unnatural concentration of surface flows downstream of the culvert . This change in the concentration and/or velocity of flows can initiate channel erosion that eventually forms into a gully. The gully then migrates upstream towards the culvert. Secondly, a recessed culvert can act as a 'nick' point within the floodplain, from which gully erosion propagates. In situations where a road surface is constructed close to the elevation of a floodplain, one of the ways of getting up-slope floodwaters to pass under the roadway is to construct a drainage channel that collects up-slope floodwaters and passes it through the culvert to a downstream drainage channel. If poorly designed and/or constructed, the upstream drainage channel can act as a nick point in the floodplain from which one or more gullies can form. This form of gully erosion can be prevented by either:

• constructing a stable drainage channel and/or drop inlet upstream of the culvert,

• constructing the culvert crossing such that the road raises up over the culvert, rather than the culvert being recessed below the floodplain.

The latter solution can be expensive and difficult to achieve on high-speed roads, but is one of the best ways of addressing this problem in areas containing highly dispersive subsoils.

5) Construction of unstable drainage channels:

Gully erosion can also be caused by the construction of an unstable drainage channel. A drainage channel that is too steep will result in excessive flow velocities, potentially resulting in gully erosion. A drainage channel that has an unstable outlet into a downstream watercourse can result in the initiation of gully erosion at the channel outlet. A drainage channel that is cut into unstable, highly erodible soils can also initiate gully erosion. Soil erosion resulting from excessive flow velocities is not always going to take the form of gully erosion. In some cases the erosion is best described as bed and/or bank scour. The existence of gully erosion within an existing creek or drainage channel would be evident by the formation of a well-defined channel (the gully) that is recessed below the natural or constructed channel bed. This recessed gully would have steep, unstable banks, and a well-defined gully head.

6) Deforestation and Vegetation Removal:

When forests are cleared or vegetation is removed for agriculture, logging, or urbanization, it exposes the soil to direct rainfall impact. Without the protective cover of vegetation, rainwater can erode the soil more easily, leading to increased runoff and gully formation (Roose et al., 2010).

7) Unsustainable /Improper Land Use Practices:

Poor land management practices, such as overgrazing, improper crop cultivation, and uncontrolled mining, can disturb the soil structure and increase its susceptibility to erosion. Over time, this can lead to gully formation. In developing countries, rapidly-increasing populations usually migrate upland to occupy forests or rangeland. Most migrants cut trees, burn litter and grasses, and cultivate hillsides without using conservation measures. After a few years, the productivity of the soil is lost because of sheet, rill and gully erosion, and the land is abandoned. This kind of cultivation, (slash and burn or shifting cultivation) is repeated by farmers on other hillsides until the land loses its productivity there as well. Thus, the whole of an area may be completely destroyed by gullying as the gully heads advance to the upper ends of the watershed.

8) Improper Road Construction:

Construction of roads and highways without proper consideration of erosion control measures can contribute to gully formation. Road cuts and fills can alter natural drainage patterns,

leading to concentrated runoff that may initiate gullies (Rios-Gonzalez et al., 2015). If road cuts and fill slopes are not revegetated during or immediately following road construction, gullies may form on both sides of the road. Inadequate drainage systems for roads (small number of culverts, insufficient capacity of road ditches, etc.) are a major cause of gullying. Widening operations along roadsides do not often follow road construction but, where widening is practiced, the operation usually causes landslide erosion and then gullying during the first rainy season.

9) Inadequate Water Management:

Poor water management practices, such as improper irrigation techniques and inadequate drainage systems, can lead to waterlogging and soil saturation. Excess water can accelerate erosion processes, including gully formation (Zhang et al., 2012).

10) Climate Change:

While not a direct anthropogenic factor, human activities such as burning fossil fuels and deforestation contribute to climate change. Changes in precipitation patterns and increased intensity of rainfall events due to climate change can exacerbate gully erosion processes (IPCC, 2014).

11) Mining Activities:

Mining operations can disturb large areas of land, leading to the removal of vegetation and soil cover. The exposed soil is then susceptible to erosion by rainfall, which can result in gully formation (Boulton et al., 2018). Mining Underground (block cave) mining is another factor that can cause gullying. Initially, cracks in the ground and soil creep (a kind of gravity erosion) are observed in the mining areas. Then, during rainy seasons, gullies are formed. Gullying in open-pit mining areas is also a big problem in many countries.

12) Agricultural Intensification:

Intensive agricultural practices, such as excessive use of fertilizers and pesticides, can alter soil properties and reduce its resistance to erosion. Moreover, large-scale irrigation can lead to waterlogging and soil degradation, promoting gully erosion (Wang et al., 2020).

13) Poor Waste Management:

Improper disposal of waste and the lack of effective waste management systems can result in the accumulation of debris in natural drainage channels. This debris can obstruct water flow and contribute to gully erosion during heavy rainfall (Biswas et al., 2019).

14) Dam Construction and Reservoir Sedimentation:

Building large dams can modify river flow dynamics and sediment transport downstream. The lack of sediment supply can lead to channel incision and gully erosion in the affected areas (Hilton et al., 2018).

15) Overgrazing:

Overgrazing removes too much of the soil's protective vegetal cover and trampling compacts the soil; thus the infiltration capacity of the land is reduced. The increased run-off, caused by the insufficient water holding capacity of the soil, produces new gullies or enlarges old ones.

16) Forest and grass fires:

Many forest fires are caused by the uncontrolled burning used in shifting cultivation These fires can easily spread into the forest and destroy the undergrowth and litter. Grass fires are usually ignited by farmers near the end of the dry season in order to obtain young shoots for their livestock or new land for cultivation. On slopes, the soil that is exposed after forest and grass fires is usually, gullied during the first rainy season.

17) Livestock and vehicle trails:

Gullies are also formed on livestock and vehicle trails that run along hillsides. This is because the traffic on them compacts the soil and reduces the water holding capacity.

18) Destructive logging In forest regions:

Logging with tractors down slopes can lead to gully erosion, because the run-off becomes concentrated along the skid trails. Highland logging with slack cables also causes gullying on forest land.

These are some of the main anthropogenic factors contributing to gully erosion. It's important to implement sustainable land management practices and erosion control measures to mitigate the impacts of gully erosion on the environment and communities.

Problems associated with Gully Erosion

The problems often associated with gully erosion include:

• the loss of significant quantities of sediment from the valley resulting in a potential loss of productive land;

• permanent changes to local groundwater levels and resulting changes to vegetation adjacent the gully;

• sedimentation problems within downstream waterways and the associated ecological problems, including loss of aquatic habitat;

• increased turbidity within permanent pools and flowing waters;

• increased potential for creek erosion within downstream waterways due to increased sediment flow;

• the potential release of soil salts and acidic runoff into receiving waters;

• water quality issues within downstream dams and waterways associated with the nutrients and metals attached to the released sediments;

• the economic costs associated with the de-silting and rehabilitating of downstream water bodies.

Effects of Gully Erosion on Land and Environment

The effects of gully erosion in Nigeria are enormous and similar to those in other part of 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 that can lead to famine.

ii) Treat 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.

iii) Effect on Properties: Several properties whose value cannot be quantified, 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). On a separate note, Committee on Erosion and Ecological matter recently discovered 15 gully sites in Bida, Niger State of Nigeria (NTA Minna News, Wednesday 17th July 2013). Apart from untimely evacuation from these gully sites, infrastructural facilities such as pipelines, utility cables, roads and houses also suffer from these hazardous events.

iv) Effect on Life: Many lives have been lost as a result of the problem of gully erosion. Some either fell into these gullies and sustained various degrees of injury or died. Some instances have also been reported where people are drowned in some of the gully sites. About 23 people have been reported in the past few years to have lost their lives in a single event of gullying activities in Ibori, Ugbalo, Ewu-Eguare, Idogalo and Oludide communities of Edo State, Nigeria. Millions of people have been displaced and evacuated their homes following the gully incidences. The gully erosion in Oko community in Anambra State has created a deep gully and wide crater,

threatening to sweep away the homes of about 826 families as this channel is continuously expanding at an alarming rate. (imostateblog, 2012)

v) Isolation of Villages and Towns: Gully erosion has resulted in the separation of adjacent villages and towns as it may involve collapse of the bridges linking them together. This has had negative impacts on such areas since some facilities such as schools, hospitals and water supplies shared by the affected neighbouring communities may become inaccessible. Transportation of farm produce has also been affected and this also often leads to loss of agricultural products especially the perishable ones. Traders who also go to these areas for their trade are also cut off from their normal day-today business .

vi) Bad Land: Gully erosion has given rise to infertile and barren land that may need to be reclaimed. This usually brings untold hardship to the inhabitants if the land is still inhabitable but has been severely affected. Anambra State has lost over 30 percent of her land, and over 40 percent of the total area of land and homes are being threatened by the menace according to the Anambra State Ministry of Environment.

Solutions to Gully Erosion in Nigeria

Prevention is better than cure, they say. Thus, prevention of the processes or mechanisms that result into 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 incipient (at an early stage) are most effective when erosion is still at an early stage (Obidimma and Olorunfemi, 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. Thus, these factors and others should be carefully examined in the erosion-prone regions of the country in a bid to better design preventive measures. Other measures that could be used to curb the menace of gully erosion are suggested as follows:

i) As earlier mentioned, poor farming techniques were found to be a contributing factor to the growth of gully erosion. Improved farming practices that reduce the gully erosion processes to the barest minimum therefore should be encouraged.

ii) Refuse dump along the river courses impede the flow of water leading to flooding especially during heavy rainfall. Therefore, dumping of refuse on the river channels and floodplains should be prohibited. Government at all levels should enact and enforce laws to deter such activities.

iii) Cultural method (also called vegetative techniques by Simpson, 2010) of erosion control has been found to be a cheap and effective method of Planting of plantain and banana on the floodplains have also been found to be effective in controlling erosion. Grasses species such as

Eulaliopsiss binata (Babiyo), Neyraudia reynaudiana (Dhonde), Cymbopogon microtheca (Khar), Saccharum pontaneum (Kans) and Thysanolaena maxima (Amliso), Arunduella nepalesis (Phurke) and Themeda species have been suggested by Ojha and Shrestha (Ojha and Shrestha, 2007) as suitable especially for slope stability .

iv) Education and Awareness: Raising awareness among rural communities about the causes and consequences of gully erosion can lead to more sustainable land management practices (Lima et al., 2019). Adequate awareness of effects of human activities, general enlightenment campaign on the dangers posed by gully erosion and human activities that promote them.

v) Efforts should also be made by relevant authorities to enact a law against location of engineering structures on waterways.

vi) The government at all levels in Nigeria should take it as matter of urgency to yield to addressing issues relating to erosion especially gully erosion at an early stage so as to avoid loss of lives of Nigerian people and their properties.

vii) Terracing: Terracing is a soil conservation technique that involves constructing level or nearly level areas on steep slopes to create steps that can slow down water flow and reduce erosion. Terraces can be made using stones, bricks, or other materials. Studies have shown that terracing can effectively reduce gully erosion (Nearing et al., 2017).

viii) Vegetation and Afforestation: Planting trees and establishing vegetation cover can play a crucial role in controlling gully erosion. Plant roots help bind soil particles together, making it more resistant to erosion. Afforestation, which involves planting trees on barren land, can significantly reduce erosion rates (Ellison, 2019).

ix) Cover Crops: Planting cover crops during the off-season can protect the soil from raindrop impact, reduce surface runoff, and enhance water infiltration. This practice has been found effective in reducing gully erosion (Kuhn et al., 2018).

x) Check Dams and Gabions: Check dams are small structures built across gullies to slow down water flow and trap sediment. Gabions are wire mesh baskets filled with stones that can stabilize gully walls and prevent further erosion. Research has shown that check dams and gabions can effectively control gully erosion in rural areas (Fryirs et al., 2017).

xi) Contour Plowing: Plowing along the contour lines of the slope can reduce the speed of water flow and prevent gully formation. This practice has been successfully used in various regions to control erosion (Zhang et al., 2016).

xii) Soil Conservation Practices: Implementing soil conservation practices like no-till farming, mulching, and cover cropping can help preserve soil structure and reduce erosion rates (Derpsch et al., 2014).

xiii) Land Use Planning: Proper land use planning that takes into account the topography and soil characteristics of the area can help minimize erosion risk and prevent gully formation (Li et al., 2018).

xiv) Integrated Watershed Management: Managing entire watersheds as interconnected systems can be more effective in controlling erosion compared to isolated approaches (Vanmaercke et al., 2018).

Summary

Intensive gully erosion development in arid and semi-arid regions of the world underpin the need for conducting research to investigate how human activities and geo-environmental factors affect gully erosion occurrence. Nigeria and elsewhere in the world suffer from the havocs of gully erosion, it has now become a major global issue. \Gully erosion is most advance and detrimental form of erosion which may be defined as removal of soil by running water with the formation of channels that cannot be smoothed out by normal tillage process. The rate of gully erosion process depends on runoff producing characteristics of watershed, disposal characteristics, alignment, size and shape of gully and slope of channel formed due to gullying. The development of gully takes places by different processes e.g. waterfall erosion, channel erosion, alternate freezing and thawing and through slides or mass movement of soil in the gully. Gullies are not formed overnight, rather, they develop over a period of time, passing through four

different and distinct stages e.g. formation stage, development stage, healing stage and finally stabilization stage. First two stages are very active stage of gullying. Gullies may be classified based on shape and size. Based on cross-section shape the gullies may be V-shape or U-shape. According to gully depth and drainage area gullies are classified as small, medium and large. Planning and controlling gully erosion is basically controlling runoff for its safe disposal. Outgoing runoff from drainage area may be controlled by diversion of runoff around the gullied area and conveyance of runoff through gullies. Conveyance of runoff through gullies involves, development of stable shape, selection of vegetation and changing gullies into grassed waterways. Two types of gully control structures e.g. temporary and permanenl are employed to facilitate the establishment of vegetation or to provide protection at points thal can not be adequately protected in any othcr way. Main temporary structures are brush wood check dams, loose rock check darns and woven-wire-check dam. Among permanent structures chute spillway, drop spillway and pipe inlet spillway are generally used.

The causes of gully erosion in Nigeria include both natural and anthropogenic sources. The impacts include loss of human and animal lives, loss of properties and land resources. Some of the solutions that are proffered include improved farming techniques, cultural method of gully control, land use planning, terracing, cover crops, contour ploughing, vegetation and aforestation, soil conservation practices and enactment of laws against any activities that favour gully growth.

The government at all levels in Nigeria and the stakeholders in environmental management such as State Ministry of Environment and Federal Ministry of Environment should also sensitize Nigerians on the causes, impacts and problems of gully erosion. However, poor or lack of implementation of research findings and recommendations seem to hinder complete evaluation of proposed solutions. For instance, in some cases where an effort is made, poor quality of work usually lead to even greater erosion, as in the case of road construction probably due to poor supervision, poor funding and corruption. Though we have little or no control on the natural causes of gully erosion especially those related to the underlying geology, the individuals and relevant stakeholders should discourage all practices that are capable of initiating or speeding the phenomenon in Nigeria. If all the suggested solutions are carefully looked into, it is believed that the incidence of gully erosion in Nigeria would be drastically reduced and the security of the lives of Nigerians and their properties will be guaranteed. It is very essential to note that the effectiveness of these measures may vary depending on the specific environmental and geographical conditions of the area experiencing gully erosion. Therefore, it is advisable to conduct a site-specific assessment and tailor the solutions accordingly. However it is important to note that some lands that has been damaged by erosion can never be reclaimed no matter the efforts made, gully erosion can render lands barren, useless and abandoned.

CHAPTER THREE

METHODOLOGY

This chapter describes the method and procedures adopted in carrying out the study on Anthropogenic factors that causes gully erosion and it's impact on the environment and land in Iguobazuwa community, Ovia south west local government area, Edo state. The method of the study adopted will be discussed under the following subtopics :

2. Research design
5. Population of the study
6. Sample and Sampling techniques
7. Research instrument
8. Validity of the instrument
9. Reliability of the instrument
10. Method of data collection
11. Method of data analysis

Research Design

The research design used for this study was the descriptive survey research design. Descriptive survey research is a type of analysis that focuses on outlining the feature of the population or issue (Siedlecki, 2020). Data are collected in a qualitative manner and analyzed

using quantitative procedures. It involves studying a group of people or event by collecting and analyzing data from only a few people considered to be a representative of the entire group.

Population of the Study

The population of the study was 138,072 (one hundred and thirty eight thousand and seventy two) comprising of 72,113 (seventy two thousand one hundred and thirteen) males and 65,959 (sixty five thousand nine hundred and fifty nine) females. (National population census 2006).

Table 1 : shows the population structure of the study

Gender	**Population size**	**Percentage population**
Males	72,113	52.2%
Females	69,959	47.8%
Total	138,072	100

Sample and Sampling Techniques

The sample size is one hundred (100) persons. The purposive random sampling technique was used for this study to select one hundred (100) persons which constitutes 60% and 40% total population respectively. Sixty (60) persons were selected randomly from the males and fourth (40) persons were selected randomly from the females of the total population.

Research Instrument

The research instrument used in the collection of data for this study is the questionnaire. The questionnaire was designed by the researcher in a way to provide reliable and relevant information used for the study. It comprises mostly of structured close ended question. It consists of two sections, section A&B. Section A comprises of questions on demographic data designed to collect information on the personal data of the respondent such as age, sex, e.t.c. The section B comprises questions based on the anthropogenic factors that causes gully erosion and it's impact on the environment and land. The items were constructed by the researcher using the modified Likert scale of summated rating of Strongly Agreed (SA),Agreed (A), Disagreed (D), Strongly Disagreed (SD).

Validity of the Instrument

To ensure face and content validity of the instrument, the instrument was given to the researcher's supervisor and two (2) other experts in the Department of Health Safety and Environmental Education in the Faculty of Education. Their comments and suggestions were taken into account for the final draft of the instrument.

Reliability of the Instrument

To establish the reliability of the instrument that was used for the study, the split half method was employed. The instrument was first administered to ten residents of iguobazuwa community

randomly selected, who will not be part of the sample population. The split half method on the basis of Odd and Even number was used. The instrument after administration was divided into odd and even numbers and result of each half is treated as an alternative form of the same measurement. The Cronbach's alpha Co-efficient was used to measure the consistency between the two set of score. A reliability co-efficient of 0.82 was obtained which shows that the measure of consistency is high and the instrument is reliable.

Method of Data Collection

The researcher personally administered the instrument to the respondent residents of Iguobazuwa community with two other research assistants. The respondents will be briefed on the purpose of the research and the questionnaire administered to them. The questionnaire when completely filled by the respondents will immediately be retrieved by the researcher to ensure maximum return of the instrument.

Method of Data Analysis

The completed questionnaire was analyzed using percentage computation.

CHAPTER FOUR

PRESENTATION OF RESULTS AND DISCUSSION OF FINDINGS

This chapter deals with the analysis of data collected from respondents and the interpretation of findings based on the research questions raised. One hundred (100) copies of questionnaire was administered and retrieved from respondents. The method used for the data analysis is the simple percentage.

Presentation of Result

Section A : Demographic Data of Respondents

Table 1: Frequency and percentage Distribution of Sex of Respondents

Sex	Number of respondents	Percentage (%)
Male	60	60%
Female	40	40%
Total	100	100%

Table 1 ; shows that sixty percent (60%) of the respondents are males while flirty percent (40%) of them are females.

Table 2 : Frequency and Percentage Distribution of Age of Respondents

Age	Number of respondents	Percentage
15 - 25 years	38	38%
26 - 40 years	39	39%
41 - 47 years	11	11%
48 - 57 years	8	8%
58 years above	4	4%
Total	100	100%

Table 2 ; shows that thirty eight percent (38%) of the respondents falls between the ages 15-25, thirty nine percent (39%) falls between 26-40, eleven percent (11%) falls between 41-47, eight percent (8%) falls between 48-57 and four percent (4%) falls between 58 years and above.

Section B : Data on Statement Items

Research Question 1: What are the activities of the members of iguobazuwa community that contributes to the formation of gullies.

Table 3: Frequency and Percentage Distribution of Activities that Contribute to Gully Formation

S/N	Statement items	SA (%)	A (%)	D (%)	SD (%)	Total (%)
1	Gully erosion is a dramatic form of erosion caused by flowing surface water	55 (55)	35 (35)	7 (7)	3 (3)	100 (100)
2	Poor drainage contributes highly to gully erosion	60 (60)	32 (32)	5 (5)	3 (3)	100 (100)
3	Construction of buildings along water channels contributes to gully erosion	48 (48)	35 (35)	14 (14)	3 (3)	100 (100)
4	Poor agricultural practices can result in gully erosion	33 (33)	40 (40)	18 (18)	9 (9)	100 (100)
5	Dumping of waste into drainage system causes gully erosion	55 (55)	34 (34)	10 (10)	1(1)	100 (100)

Table 3 ; shows those activities of the members of iguobazuwa community that contributes to gully erosion. In statement item one, (55%) respondents strongly agreed and (35%) respondents agreed that gully erosion is a dramatic form of erosion caused by flowing surface water, (7%) respondents disagreed and (3%) respondents strongly agreed. This indicates that the highest

number of respondents (55%) strongly agreed that gully erosion is a dramatic form of erosion caused by flowing surface water.

In statement item two, (60%) respondents strongly agreed and (32%) respondents agreed that poor drainage system contributes highly to gully erosion, (5%) respondents disagreed and (3%) respondents strongly disagreed. This reveals that the highest number of respondents (60%) strongly agreed that poor drainage system contributes to gully erosion.

In statement item three, (48%) respondents strongly agreed and (35%) respondents agreed that construction of buildings along water channels contributes to gully erosion, (14%) respondents disagreed and (3%) respondents indicated the strongly disagreed option. This clearly shows that the highest number of respondents (48%) strongly agreed that construction of buildings along water channels contributes to gully erosion.

In statement item four, (33%) respondents strongly agreed and (40%) respondents agreed that poor agricultural practices can result in gully erosion, (18%) respondents disagreed and (9%) respondents strongly disagreed. This clearly indicates that the highest number of respondents which is (40%) agreed to the statement item.

In statement item five, (55%) respondents strongly agreed and (34%) agreed that dumping of waste into drainage system causes gully erosion, (10%) respondents disagreed and (1%)

respondent strongly disagreed. This clearly indicates that the highest number of respondents which is (55%) strongly agreed to the statement item.

Based on the analyses above, it can be deduced that flowing surface water, poor drainage system, construction of buildings along water channels, poor agricultural practices and dumping of waste into drainage system all contribute to gully formation.

Research Question 2 : To what extent will gully erosion impact on the health of the people in iguobazuwa community.

Table 4: Frequency and Percentage Distribution of Extent of Gully Erosion Impact on Health

S/N	Statement items	SA (%)	A (%)	D (%)	SD (%)	Total (%)
6	Death rate due to gully erosion is on a high increase each passing day	31 (31)	43 (43)	14 (14)	12 (12)	100 (100)
7	Gully erosion exposes one to malaria	54 (54)	39 (39)	3 (3)	4 (4)	100 (100)
8	Gully erosion increases the amount of dust carried by wind ,which not only act as air pollutant but also carries tuberculosis	38 (38)	32 (32)	20 (20)	10 (10)	100 (100)
9	Gully erosion attributes to numerous cases of injury due to accident	54 (54)	38 (38)	3 (3)	5 (5)	100 (100)
10	Gully erosion pollutes water supply leading to cholera	51 (51)	39 (39)	5 (5)	5 (5)	100 (100)

Table 4; shows the extent to which gully erosion will impact on the health of the people in iguobazuwa community. In statement item six, (31%) respondents strongly agreed and (43%) respondents agreed that death rate due to gully erosion is on a high increase each passing day, (14%) respondents disagreed and (12%) respondents strongly disagreed. This clearly indicates that the highest number of respondents which is (43%) agreed to the statement item.

In statement item seven, (54%) respondents strongly agreed and (39%) respondents agreed that gully erosion exposes one to malaria, (3%) respondents disagreed and (4%) respondents strongly disagreed. This reveals that the highest number of respondents (54%) strongly agreed to the statement item.

In statement item eight, (38%) respondents strongly agreed and (32%) respondents agreed that gully erosion increases the amount of dust carried by wind, which not only act as air pollutant but also carries tuberculosis, (20%) respondents agreed and (10%) respondents strongly agreed. This shows that the highest number of respondents (38%) strongly agreed to the statement item.

In statement item nine, (54%) respondents strongly agreed and (38%) respondents agreed that gully erosion attributes to numerous cases of injury due to accident, (3%) respondents disagreed and (5%) respondents strongly disagreed. This shows that the highest number of respondents which is (54%) strongly agreed to the statement item.

In statement item ten, (51%) respondents strongly agreed and (39%) respondents agreed that gully erosion pollutes water supply leading to cholera, (5%) respondents disagreed and (5%) respondents strongly disagreed. This reveals that the highest number of respondents (51%) strongly agreed that gully erosion pollutes water supply leading to cholera.

Based on the analyses above, it can be deduced that exposing one to malaria, increase in the amount of dust carried by wind, which not only act as air pollutant but also is a carrier of tuberculosis, numerous cases of injury due to accident and pollution of water supply leading to cholera and increase in death rate are the extent to which gully erosion impacts on the health.

Research Question 3: To what extent will gully erosion affect the environment in iguobazuwa community.

Table 5: Frequency and Percentage Distribution of Extent of Gully Erosion Impact on the Environment

S/N	Statement items	SA (%)	A (%)	D (%)	SD (%)	Total (%)
11	Gully erosion is a big threat to the environment	63 (63)	24 (24)	9 (9)	4 (4)	100 (100)
12	Gully erosion renders the soil infertile	40 (40)	39 (39)	14 (14)	7 (7)	100 (100)
13	Gully erosion renders roads non motorable	68 (68)	20 (20)	9 (9)	3 (3)	100 (100)
14	Land affected by gully erosion can never be reclaimed	26 (26)	31 (31)	22 (22)	21 (21)	100 (100)
15	Gully erosion restricts the economic growth of a community	37 (37)	36 (36)	16 (16)	11 (11)	100 (100)

Table 5; shows the extent to which gully erosion will affect the environment in iguobazuwa community. In statement item eleven, (63%) respondents strongly agreed and (24%) respondents agreed that gully erosion is a big threat to the environment, (9%) respondents disagreed and (4%) respondents indicated the strongly disagreed option to the statement item. The data shows the highest number of respondents which is (63%) strongly agreed that gully erosion is a big threat to the environment.

In statement item twelve, (40%) respondents strongly agreed and (39%) respondents agreed that gully erosion renders the soil infertile, (14%) respondents disagreed and (7%) respondents chose the strongly disagreed option to the statement item. This indicates that the highest number of respondents (40%) strongly agreed that gully erosion renders the soil infertile.

In statement item thirteen, (68%) respondents strongly agreed and (20%) respondents agreed that gully erosion renders roads non motorable, (9%) respondents disagreed and (3%) respondents indicated the strongly disagreed option to the statement item. This shows that the highest number of respondents which is (68%) strongly agreed that gully erosion renders road non motorable.

In statement item fourteen, (26%) respondents strongly agreed and (31%) respondents agreed that land affected by gully erosion can never be reclaimed, (22%) respondents disagreed and

(21%) respondents strongly agreed to the statement item. This shows that the highest number of respondents strongly agreed that land affected by gully erosion can never be reclaimed.

In statement item fifteen, (37%) respondents strongly agreed and (36%) respondents agreed that gully erosion restricts the economic growth of a community,(16%) respondents disagreed and (11%) respondents strongly disagreed to the statement item. This shows that the highest number of respondents strongly agreed that gully erosion restricts the economic growth of a community.

Based on the above analyses, it can be deduced that rendering soil infertile, making roads non motorable, restriction of economic growth and total destruction of lands are some of the extent to which gully erosion impacts on the environment.

Research Question 4: What are the possible ways to control gully erosion in iguobazuwa community?

Table 6 : Frequency and Percentage Distribution of Possible ways to control gully erosion

S/N	Statement items	SA (%)	A (%)	D (%)	SD (%)	Total (%)
16	Government alone should be responsible for gully erosion control	30 (30)	9 (9)	33 (33)	28 (28)	100 (100)
17	Planting of trees and cover crops helps to check gully erosion	41 (41)	35 (35)	16 (16)	8 (8)	100 (100)
18	Disposing of waste along water channels should be prohibited	61 (61)	29 (29)	8 (8)	2 (2)	100 (100)
19	Farmers should be encouraged to practice crop rotation	50 (50)	38 (38)	9 (9)	3 (3)	100 (100)
20	Proper enlightenment on gully erosion should be provided to communities	70 (70)	22 (22)	6 (6)	2 (2)	100 (100)

Table 6; shows the possible ways of controlling gully erosion. In statement item sixteen, (30%) respondents strongly agreed and (9%) respondents agreed that government alone should be responsible for gully erosion control, (33%) respondents disagreed and (28%) respondents strongly disagreed to the statement item. This indicates the highest number of respondents disagreed that government alone should be responsible for gully erosion control.

In statement item seventeen, (41%) respondents strongly agreed and (35%) respondents agreed that planting of trees and cover crops helps to check gully erosion, (16%) respondents disagreed and (8%) respondents strongly disagreed to the statement item. This data indicates that the highest number of respondents strongly agreed that planting of trees and cover crops helps to check gully erosion.

In statement item eighteen, (61%) respondents strongly agreed and (29%) respondents agreed that disposing of wastes along water channels should be prohibited, (8%) respondents disagreed and (2%) respondents strongly disagreed to the statement item. This reveals that the highest number of respondents strongly agreed that disposing of wastes along water channels should be prohibited.

In statement item nineteen, (50%) respondents strongly agreed and (38%) respondents agreed that farmers should be encouraged to practice crop rotation,(9%) respondents disagreed and (3%) respondents strongly disagreed to the statement item. This shows that the highest number of respondents strongly agreed that farmers should be encouraged to practice crop rotation.

In statement item twenty, (70%) respondents strongly agreed and (22%) respondents agreed that proper enlightenment on gully erosion should be provided to communities, (6%) respondents disagreed and (2%) respondents strongly disagreed to the statement item. This indicates that the highest number of respondents strongly agreed that proper enlightenment on gully erosion should be provided to communities.

From the table analyses, it can be deduced that planting of trees and cover crops, prohibition of waste disposal along water channels, encouraging farmers to practice crop rotation and proper enlightenment on gully erosion

Discussion of Findings

From research question one, the findings revealed that flowing surface water, poor drainage system, construction of buildings along water channels, poor agricultural practices and dumping of waste into drainage system are some of the activities of iguobazuwa community that contributes greatly to gully erosion. This study agrees with Vanwalleghem (2017) who stated

that gully erosion is also known as anthropogenic alteration of landscapes, resulting in a serious threat to global agricultural sustainability through loss of productive capacity and Biswas (2019) who stated that this debris (wastes) can obstruct water flow and contribute to gully erosion during heavy rainfall.

From research question two, the findings revealed that increased death rate, malaria, increase in the amount of dust carried by wind which not only act as air pollutant but also carries tuberculosis, numerous cases of injury due to accident and pollution of water supply leading to cholera are some of the extent to which gully erosion impact on the health of the community members. This study agrees with Michael and Ojha, (2012) who stated that gully erosion is an ecological, environmental, economic, and humanitarian disaster resulting in loss of lives, injuries and spread of numerous illnesses.

From research question three, the study revealed that rendering roads non motorable, soil infertility, restriction to economic growth and threatening the environment are some of the extents to which gully erosion affect the environment. This study is in line with Marzolff and Ionita (2011) who stated that gully erosion causes numerous environmental and socio-economic consequences, and most of them are negative.

From research question four, the study revealed that planting of trees and cover crops, proper disposal of wastes, good agricultural practices and proper enlightenment are possible gully control measures. This study is in line with Roose (2010) who stated that without the protective cover of vegetation, rainwater can erode the soil more easily, leading to increased runoff and gully formation and Lima (2019) who posits that raising awareness among rural communities about the causes and consequences of gully erosion can lead to more sustainable land management practices.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

This chapter covers the summary, conclusions drawn from the various findings and recommendations made by the researcher.

Summary

The purpose of this study was to investigate the anthropogenic factors the causes gully erosion and its impact on the environment and land of iguobazuwa community and to assist in future remedial measures of the gully situation.

Four (4) research questions were formulated in the course of the study and they are;

1. What are the activities of the members of iguobazuwa community that contributes to the formation of gullies?
2. To what extent will gully erosion impact on the health of people in iguobazuwa community?
3. To what extent will gully erosion affect the environment in iguobazuwa community?
4. What are the possible ways to control gully erosion in iguobazuwa community?

Literature pertinent to the study was reviewed. To give answers to the research questions, structured questionnaire was constructed which contains items that provide demographic data and items to elicit responses to the research questions.

The research design used in the study is the descriptive survey research design and the population consists of 138,072 (one hundred and thousand and seventy two) residents of iguobazuwa community and a total of one hundred (100) residents were selected using the purposive random sampling technique. The questionnaire used for the study was validated by the project supervisor and two other experts from the department of Health, Safety and Environmental Education. Their criticism were taken into consideration and corrections were made before the final copy of the questionnaire was produced.

The data collected was analyzed using simple percentage computation. Based on the data analyzed, the following were the findings;

Findings

1. From research question one, the findings revealed that activities such as; poor agricultural practices by farmers, poor or lack of drainage system, construction of buildings along water channels and dumping of waste into drainage system by residents of iguobazuwa community contributes greatly to the formation of gullies.

2. From research two, it was revealed that numerous cases of injury due to accident, increase in death rate, pollution of water supply leading to cholera and even increases the amount of dust carried by wind, which not only act as air pollutant but also carries tuberculosis are the extent to which gully erosion impacts on the health of the residents.
3. From research question three, it was deduced that gully erosion is a threat to the environment and impacts negatively on the environment by rendering soil infertile, restricting the economic growth of a community and destroying roads and making it non motorable.
4. From research question four, It was revealed that planting of trees and cover crops to act as wind breaker, engaging both the government and citizens to participate in gully control measures, proper land use and enlightening the public about the causes, dangers and control of gully erosion are the possible ways of controlling gully erosion in iguobazuwa community.

Conclusion

Based on the findings of the study, the researcher concluded that although gully erosion is a natural process, cause by natural phenomenon such as wind, precipitation and others, human activities contributes highly to the gully erosion situation and such activities are increasing day

by day. The gully erosion in iguobazuwa community is caused mainly by the activities of members of the community such as; improper land use, poor drainage system, poor agricultural practices and dumping of refuse into water channels there restricting the flow of water. This gully erosion situation has had major impact on the community members and the environment, it has destroyed major road in the community thereby limiting the movement of the community members and making it almost impossible to transport their goods to the market. It has also led to a lot of infertile land and low crop yield. During the rainy season, this situation has led to loss of life of both children and adults and has been known to cause accidents.

The community is aware of the problems posed by gully erosion and are supportive of measures to control this situation. In order to successfully implement measures to control gully erosion, proper enlightenment and awareness program on the factors, effect and control of gully erosion should be provided for the community. Also the government should see the gully erosion situation as a case of emergency and attend to it immediately at its early stage before it gets worsen and nothing can be done about it.

Recommendations

Based on the findings in this study, it is therefore recommended that;

1. The government at all levels in Nigeria and the stakeholders in environmental management such as State Ministry of Environment and Federal Ministry of Environment should also sensitize Nigerians on the causes, impacts and problems of gully erosion.
2. The government at all levels in Nigeria should take it as matter of urgency to yield to addressing issues relating to erosion especially gully erosion at an early stage so as to avoid loss of lives of Nigerian people and their properties.
3. In addressing the gully erosion situation, the government alone should not be placed in charge of trying to control the situation, individuals and members of communities are expected to play their own role in the control of gully erosion, they are expected to work hand in hand with the government. They can do this by preventing the early stage of gully erosion from worsening further by filling the ditches with sand bags or stones.
4. Buildings should be constructed in compliance of approved environmental standards, efforts should also be made by relevant authorities to enact a law against location of engineering structures on waterways.
5. Refuse dump along water channels impede the flow of water leading to flooding especially during heavy rainfall. Therefore, dumping of refuse into drainage system and

water channels should be prohibited. Government at all levels should enact and enforce laws to deter such activities. Monitoring teams should be mobilized to ensure complete compliance of such laws and failure to comply should attract punishment or fine.

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APPENDIX

UNIVERSITY OF BENIN UGBOWO, BENIN CITY, EDO STATE

FACULTY OF EDUCATION

DEPARTMENT OF HEALTH, SAFETY AND ENVIRONMENTAL EDUCATION

QUESTIONNAIRE ON ANTHROPOGENIC FACTORS THAT CAUSES GULLY EROSION AND ITS IMPACT ON ENVIRONMENT AND LAND IN IGOUOBAZUWA COMMUNITY OVIA SOUTH WEST LOCAL GOVERNMENT AREA,EDO STATE

Dear respondent,

I am an undergraduate of the above mentioned institution and I am carrying out a research on anthropogenic factors that causes gully erosion and its impact on environment and land in iguobazuwa community. The study is a prerequisite for the partial fulfilment for the award of Bachelor of Science Education (Bsc.Ed) Degree in Health, Safety and Environment. Your response will be strictly used for academic purpose and you are hereby assured that all information supplied will be treated confidentially. Kindly assist by providing the correct option to the question asked below.

Thank you.

Instruction: Please, tick the correct option (✓) to the question provided below

SECTION A :Demographic Data

12. AGE : 15-25 ( ) 26-40 ( ) 41-47 ( ) 48-57 ( ) 58 and above ( )

13. SEX : Male ( ) Female ( )

14. MARITAL STATUS : Single ( ) Married ( ) Separated ( ) Divorced ( )

3. RELIGION : Christian ( ) Muslim ( ) Traditional ( )

4. OCCUPATION : Student ( ) Self-employed ( ) Employed ( ) Civil servant ( )

SECTION B

Instruction: Please tick (✓) the correct option below.

NOTE: SA= Strongly Agree, **A**= Agree, **SD**= Strongly Disagree, **D**= Disagree.

Activities that Contribute to Gully Formation					
S/N	**ITEMS**	**SA**	**A**	**D**	**SD**
	Gully erosion is a dramatic form of erosion caused by flowing surface water				
	Poor drainage system contributes highly to gully erosion				
3	Construction of buildings along water channels contributes to gully erosion				
4	Poor agricultural practices can result in gully erosion				
5	Dumping of waste into drainage system causes gully erosion				
	Extent of Gully Erosion Impact on Health				
6	Death rate due to gully erosion is on a high increase each passing day				
7	Gully erosion exposes one to malaria				
8	Gully erosion increases the amount dust carried by wind, which not only act as air pollutant but also carries tuberculosis				

9	Gully erosion attributes to numerous cases of injury due to accident				
10	Gully erosion pollutes water supply leading to cholera				
Extent of Gully Erosion Impact on the Environment					
11	Gully erosion is a big threat to the environment				
12	Gully erosion renders the soil infertile				
13	Gully erosions renders roads non motorable				
14	Land affected by gully erosion can never be reclaimed				
15	Gully erosion restricts the economic growth of a community				
Possible Ways to Control Gully Erosion					
16	Government alone should be responsible for gully erosion control				
17	Planting of trees and cover crops helps to check gully erosion.				
18	Disposing of waste along water channels should be prohibited				
19	Farmers should be encouraged to practice crop rotation and fallowing				
20	Proper enlightenment on gully erosion should be provided to communities				