# ASSESSMENT OF GULLY EROSION AT ANGUWA BIRI IN BOSSO AREA OF NIGER STATE AND DESIGN OF ITS CONTROL CHANNEL

BY

ANIH, ONYEBUCHI DAVID

MATRIC No. 2004/18353EA

BEING A FINAL YEAR PROJECT REPORT SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF ENGINEERING (B. ENG.) DEGREE IN AGRICULTURAL & BIO-RESOURCES ENGINEERING, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGER STATE.

FEBRUARY, 2010

## DECLARATION

I hereby declare that this project work is a record of a research work that was undertaken and written by me. It has not been presented before for any degree or diploma or certificate at any university or institution. Information derived from personal communications, published and unpublished work were duly referenced in the text.

______________ 19/02/2010

Anih, Onyebuchi David Date

## CERTIFICATION

This project titled "Assessement of Gully Erosion at Anguwa Biri, Bosso Local Government Area of Niger State and Design of its Control Channel" by Anih David Onyebuchi, meets the regulations governing the award of the Degree of Bachelor of Engineering (B. Eng.) of the Federal University of Technology, Minna, and it is approved for its contribution to scientific knowledge and literary presentation.

| | |
|---|---|
| Mr. A. Halilu<br>Supervisor | 17/2/10<br>Date |
| Engr. Dr. A. A. Balami<br>Head of Department<br>Agric and Bioresources Engineering | 17/02/10<br>Date |
| External Examiner | 9/2/2010<br>Date |

## DEDICATION

This project work is dedicated to the Glory of Almighty God, who made it possible for me to conduct the project work and achieve my goal without hindrance.

## AKNOWLEDEMENTS

I give an unreserved praise and glory to God almighty, beside which there is no other God, the most merciful, the creator who in his infinite mercy inspired, guided and directed me throughout the period of my studies and carried me through this work.

I am indebted to my supervisor, Mr. Halilu Adamu for taking his time to go through this project, despite other academic works at his disposal. I am very grateful for this selfless sacrifice in occasionally editing and criticizing this work in a constructive manner.

I give gratitude to the head of the department Dr. A. A. Balami and other staff of the department which includes; Dr. O. Chukwu, Dr. N. A. Egharevba, Dr. B. A. Alabadan, Dr. D. Adgidzi, Engr. Dr. G. Agidi, Engr. P. Adeoye, Engr. J. Jiya, Engr. Sadeeq, Engr. Dr. P. A. Idah, Engr. Adamu, Engr. (Mrs.) B. Orheva, Engr. Solomon, Engr. Adebayor, the Laboratory Technicians and Non-Academic Staff of the department For their contribution to my knowledge during my study.

So much thanks goes to Engr. Mohammed Nakodi Ibrahim of Niger State Ministry of Agric and Natural Resources for his selfless sacrifice in assisting me throughout the project period.

To my father Mr. Onyebuchi Anih, and my mother Mrs. Ndidi Anih, I owe a million thanks for your love, care, moral and financial support. My regards goes to my brothers; Ebuka Anih, Ifeanyi Anih, and my beloved sisters; Mrs. Chioma Ononugbo, and Ms. Onyinye Anih.

Finally, my immeasurable appreciations to my course mates and friends Iyaji Leonard, Iyodo Edward, Lucas Henry, Anonuso Justice, Anumiri Chukwuma, Obi Samson, who all made my stay in campus a memorable one.

# ABSTRACT

This study represents the study of gully erosion in Anguwa Biri area of Bosso Local Government of Niger state and the design of its control channel. The length and width of the gully were analyzed and annual rainfall records of Bosso (Minna) 1999-2009 were collected. Properties of soil samples of the area were collected and tested. The gully was found to have a length of 230metres, top width of 6.67m, base width of 2.67m and depth of about 2m. The soil samples were found to be generally sandy, silt and underlain by weakly developed claying sub-soil and most predominantly sandy loam. A concrete lined control channel was designed to control the gully. The design channel has a flow depth of about 2m and 1.5m by breath.

## TABLE OF CONTENTS

## List of Tables

## List of Figures

**List of Plates**

## NOTATIONS/ABBREVIATIONS

| | | |
|---|---|---|
| m | - | metres |
| $m^2$ | - | metre square |
| $m^3 / s$ | - | cubic metre per second |
| min | - | minutes |
| Ha | - | Hectares |
| mm/hr | - | millimeter per hour |
| FAO | - | Food and Agricultural Organization |
| NCRI | - | National Cereals Research Institute. |
| NIMET | - | Nigeria Meteorological Station |

## List of Appendices

# CHAPTER ONE

## 1.0. INTRODUCTION

### 1.1. Basic Background

Soil erosion is the process of removal or loosening and wearing away (transporting) of soil and its component materials by running water or wind and depositing them in another place. Wind cause erosion in arid and semi-arid areas like Sahara and some parts of Northern Nigeria. In Northern Nigeria, erosion is caused by both wind and water. When rainfalls, a part or the water enters the soil, in what is called the process of infiltration, the other part runs off and does not enter the ground immediately but flows down the slope as sheet wash. The running water picks up and carries away particles of soil. As the water collects in rills and its volume and speed increases, the water is able to erode and carry increasingly greater amount of soil. Ultimately, the rill deepens into a gully. Gully erosion is a highly visible form of soil erosion that affects soil productivity, restricts land use and can threaten roads, fences and buildings. Gullies are relatively steep-sided watercourses which experience ephemeral flows during heavy or extended rainfall. Soil eroded from the gullied area can cause siltation of fence lines, waterways, road culverts, dams and reservoirs. Suspended sediments, which may have attached nutrients and pesticides, can adversely affect water quality. These fine colloidal clay particles remain in suspension and may clog groundwater aquifers, pollute water courses and affect aquatic life. Controlling gully erosion can be difficult and costly. It may be justified on better quality soils where there is a reasonable chance of success or where a road or building is threatened by an advancing gully.

In the past, problems of soil erosion were peculiar to certain Nigeria ecological zones. Today, the problem has been spatially distributed across the various ecological belts of Nigeria.

Features of soil erosion, especially gully erosion are now a common land mark in all parts of Nigeria and from the above analysis different agent causes erosion but man aggregates it. Apart from the fact that erosion constitutes a menace to the environment and its destruction of infrastructures and highways etc it also creates a major problem on Agricultural soils, thereby interfering tremendously with the mass food production campaign. However soil erosion is one of the most important physical and socio-economic problems that affect our development in this part of the globe. Halilu H (2000)

## 1.2. Statement of Problem

In spite of erosion being an age old problem, never the less it is presently taking a new dimension because of its great impact which inherently cause and arouses feelings of concern considering the fact that many productive farmlands are turning into unproductive area due to human and animals unchecked activities on lands which consequently renders such portion of land barren. The magnitude of the problem of Gully erosion in Anguwa Biri has caused a lot of damage to villages and semi-townships beside it also causes damage to relatively important public facilities, properties, and serious damage to farmlands and residential buildings.

The foregoing reason moved me to study gully erosion at Anguwa Biri Bosso Local Government of Niger state.

## 1.3. Objectives

1. To study and ascertain the cause of gully erosion in Anguwa Biri, Bosso local government.
2. To design an effective drainage channel.

## 1.4. Justification of Study

Efforts to control gully erosion have achieved only limited success, because of lack of most of the control measures; the non-involvement of the rural communities in the planning, implementation, and coordination of management strategies; and absence of a national policy on erosion control. In the past, problems of soil erosion were peculiar to certain Nigeria ecological zones. Today, the problem has been spatially distributed across the various ecological belts of Nigeria. Features of soil erosion, especially gully erosion are now a common land mark in all parts of Nigeria and from the above analysis different agent causes erosion but man aggregates it.

However, controlling gullies over large areas of poor soils may be impracticable. For this reason, prevention is far better than control.

## CHAPTER TWO

## 2.0. LITERATURE REVIEW

### 2.1. Erosion Disaster

One of the major environmental problems in the world today is erosion. Nigeria too is affected by this problem since erosion has become a global issue. Gully erosion is the more obvious form of soil erosion because of its remarkable visible effects on the landscape. They develop easily in areas of soft bedrock and often rapidly grow into enormous gullies. Areas of spectacular gully erosion in Nigeria are Anambra, Akwa-Ibom, Cross-rivers, Imo, Plateau, Bauchi, Abia and Sokoto states. Gully erosion is particularly severe in Abia, Imo, Anambra, Enugu, Ondo, Edo, Ebonyi, Kogi, Adamawa, Delta, Jigawa and Gombe States. Anambra and Enugu states alone have over 50 active gully complexes, with some extending over 100 metres long, 20 metres wide and 15 meters deep. Halilu .H. (2000)

### 2.2. Types of Erosion

The types of erosion which occur in Northern Nigeria are Sheet Erosion, inter-rill erosion, Rill Erosion and Gully Erosion and these erosion types are related in such a way that one erosion leads to the formation of another. If sheet erosion is not controlled, rill erosion may develop at a fast rate. If rill erosion is not controlled in time then gully erosion will develop. There are three main agents of erosion that damages the land in northern Nigeria. First of all we have running water can be in form of streams, rivers, rainfall, and flood and run off. Its ability to erode lies on its intensity and speed with which it moves across the soil. During the movement it dislodges, loosens and carries away the soil material. Man is another agent of erosion, which have contributed to the soil erosion mainly during the last century. As used here, the term man includes men, women, boys and girls. Man causes erosion through his activities such as poor farming habits, sand dredging and other mining activities, unwillingness to build water channels, and removal of trees and grasses. Generally man is an accelerator of erosion through his activities. Wind can loosen and carry sand, rock and dust particles for a long distance before depositing them. (Bruce 2006).

This type of erosion is common in the Northern part of Nigeria sometimes before heavy rains in South-eastern Nigeria.

## 2.3. Rate of Erosion

The two types of erosion based on their rates of activity are natural erosion and accelerated erosion.

Natural Erosion is the process by which the land or soil material would normally be eroded without disturbance or influence by human activity. It varies from place to place. This process is usually very slow and sometimes imperceptible. The rate of erosion is small.

Accelerated Erosion is the increased rate of erosion that often arises when man alters the natural system by various land use practices and engineering constructions. The problem of soil and gully erosion is largely the problem of man accelerated erosion. It is fast and very dangerous.

## 2.4. Causes of Erosion

Erosion is both a natural and manmade environmental disaster. Several factors can cause erosion however; they can be divided into two major groups known as Natural Factors Man Made Factors. Natural factors include rainfall, run offs, streams, river flows, and wind. Man made factors are activities of man which help erosion to occur or to increase its severity. The activities of man which help erosion to occur are as follows:

Burning of bushes exposes the soil to direct impact of rainfall when the grasses and bushes are destroyed by fire. Cutting of trees like burning of bushes exposes the soil to direct rainfall impact. During rainfall, the trees usually catch the rain drops first and protect the soil by reducing the velocity at which the rain gets to the ground. Quarrying which involves removal of soil, sand, laterite and other natural building materials from hills or pits or sides of a river or stream. This causes erosion especially in hilly areas. Bad farming habits include burning the bushes before cultivation and total removal of all grasses or weeds or crops thereby leaving the ground bare thereby causing erosion. Bad construction habits causes erosion by blocking of water or flood channels or gutters by building houses across them or roads across them without providing alternate routes for the flowing water to use. Making farm ridges or mounds parallel to the slope of the ground or hill initiates creations of rill and gullies. Building roads without providing wide and deep gutters on both sides of the road creates conditions for concentrated uncontrolled water runoff resulting in destroying of the road and developing of new gullies. Also neglecting maintenance effort like maintenance of roads or gutters causes their vulnerability to running water thereby causing erosion. Schwab F. Elliot (1993)

## 2.5. Gully erosion

This is the removal of soil by excessive concentration of running water, resulting in the formation of channels ranging in size 0.3m to 10m or more. These large channels cannot be destroyed by normal cultivation or ploughing. During heavy rain, the rain water rushes down these gullies, increasing their width, depth and length. Within a few years, an entire landscape may be filled with a network of gullies. Large areas of fertile lands thus get swallowed by the ever increasing gullies and are rendered uncultivatable. Gully erosion is more spectacular than other types of erosion.

Four stages of gully are generally recognized:

Formation stage consists of the gradual removal of the topsoil in a downward direction thus forming channels. At this stage the topsoil is moderately resistant to erosion.

Development stage consists of upstream movement of the gully head and enlargement of the gully width and depth.

Healing stage occurs when vegetation begins to grow in the gully.

Stabilization stage occurs when the gully reaches a stable gradient. The gully reaches a stage gradient. The gully walls reach a stable slope and vegetation cover spreads over the gully surface. Mustapha (2009)

## 2.6. **Formation and Growth of Gullies**

Gully erosion is caused when run-off concentrates and flows at a velocity sufficient to detach and transport soil particles. More commonly, however, the direct impact of raindrops on soil particles causes their detachment and gradual downhill movement - splash erosion. Sheet erosion is barely detectable in the short term because it is a gradual process. However, over a long period, the consequent exposure of roots and subsoil can be easily observed. Rill erosion is the removal of soil by surface-flows that either form small, shallow channels or streamlets - neither is deeper than 30 cm. Because of its higher surface-flow velocities, rill erosion has a greater capacity than sheet erosion to remove and transport soil. Still, because they are small, rills can easily be eliminated by normal tilling or ploughing. FAO (2008)

Gullies are formed where many rills join and gain more than 30 cm depth. The rate of gully erosion depends on the run-off-producing characteristics of the watershed: the drainage area; soil characteristics; the alignment, size and shape of the gully; and the gradient of the gully channel. Gullies are very destructive and cannot be eliminated by tilling or ploughing because of their depth. A gully develops in three distinct stages; waterfall erosion; channel erosion along the gully bed; and landslide erosion on gully banks. Correct gully control measures must be determined according to these development stages. In the full range of gully evolution, sheet erosion is the fore-runner, and then follows the incidence of incision and slope failure. The debris from the upper part fills the bottom part of the gully, thus modifying the channel section. Subsequently the debris is washed off by running water and the process of undercutting of gully side continues. When this undercutting is sufficiently developed to unstable a large wedge of soil, a major slope failure occurs. The process of geological denudation of the soil or rock mass is essentially an accelerator, incision and slope failure being the real major factors responsible for the formation of ground craters, or gullies. While erosion is a necessary prerequisite to gully evolution, slope failure appears to be the determinant of gully size and rate of evolution. Observations show that most gully slopes fail after a sustained rain storm, which normally has the effect of increasing the weight of the soil from which the disturbing force is derived while, on the other hand, it reduces the shearing resistance of the soil which restrains failure. Soils which have some degree of cohesiveness not only offer greater resistance to fluvial erosion, but they also provide more stable gully slopes. Most gully slopes in Nigeria are generally very steep and sometimes approach being vertical because of the lateritic soil types, and since steeper slopes are less stable than more gentle ones, gully slopes experience frequent, but minor failures. If a section is cut from the surface of the ground to the bottom part, three main horizons or layers can be seen. Such cross section is called soil profile. The topmost horizon is called the "A" horizon or top soil. In this horizon farmers cultivate their crops. It is usually dark or brownish black or it could have spotted pink colour. Many animals visible and invisible live there. Immediately below the A horizon there is another horizon called the "B" horizon or sub-soil. Foundations or houses are made in this layer. It is reddish and tap roots of big trees like iroko can penetrate into this horizon. In tropical areas, the "B" horizon can be quite extensive, and is called 'laterite'. The deepest part of the soil is called the "C" horizon. Many heavy mineral matter are brought here in solution by infiltrating rain water. It has a boundary with the bedrock (geologic formation) which can be whitish sandstones or blue clays. In any locality you may not have all the horizons present. Erosion may have removed one or more of the horizons, such a place is said to have truncated soil profile. During erosion, the top part of the soil is gradually and continuously removed. With time the B and C horizons are affected also. If all of the A horizon is removed by erosion the B horizon is then exposed and if all of B horizon is removed then the C horizon is exposed. Sometimes all of the soil is removed and the geologic formations are exposed as in big gullies. Nature does not allow any vacancy in its operations so when any horizon is lost due to erosion the formation of that horizon is immediately started. Soil formation is a cyclic process which takes a long time. If the rate of removal is larger than the rate of soil formation, then the result is the poor agricultural yield, bad land topography, deep gullies, damaged roads, destabilized houses, and many other problems. Bruce Carey (2006)

Gullies may be developed in watercourses or other places where run-off concentrates. In cultivation or pastures, advanced rill erosion can develop into gully erosion if no protective measures are taken. Cattle pads can be a starting point for a small rill that can develop into a large gully .A watercourse is ordinarily in a state of balance where its size, shape and gradient are suitable for the flows it carries. If the balance is disturbed, for example by larger than normal flows, gully formation may begin. Gullies generally create far more capacity than they need to accommodate the run-off they are likely to carry. Widening of the gully sides may occur by slumping and mass movement especially on the outside curve of meanders. Scouring of the toe slope can lead to mass failure of the side of the gully under gravity. This soil is then washed away by subsequent flows. Active gully sides are usually vertical but may adopt an oblique shape once they start to stabilise. This process may occur naturally but can be hastened by the adoption of various gully treatment measures. Run-off may enter a gully from the sides, causing secondary gullies or branching resulting in a 'badlands' effect. The gully floor may be subject to further down-cutting as secondary gullies advance up the channel. Sediment deposition below gully heads results in a "steps and stairs" pattern. While peak flows from intense rainfall causes considerable gully erosion, the prolonged low flows resulting from an extended wet period can also create problems. Constant trickle flows through a drainage line can saturate the soil in the trickle zone making it structurally weak and very susceptible to erosion. The constant wet conditions may also weaken the vegetation which then provides less resistance to erosion. Gully depth is often limited by the depth to the underlying rock which means that gullies are normally less than 2 m deep. However on deep alluvial and colluvial soils gullies may reach depths of 10 to 15 m. Bruce Carey (2006)

## 2.7. Classification of Gullies

Gullies are classified under several systems based on their different characteristics.

### 2.7.1. Gully classes based on size

Gully classification system is based on size – small gully where depth is less than 1m and drainage area is less than 2ha. Medium where depth is between 1- 5m and drainage area is between 2-20ha and large gullies which have depth of more than 5m and drainage area of more than 20ha. FAO (2008)

### 2.7.2. Gully classes based on shape

This system classifies gullies according to the shape of their cross-sections.

(a) U-Shaped gullies 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.

(b) V-Shaped gullies develop where the subsoil has more resistance than topsoil against erosion. This is the most common gully form.

(c) Trapezoidal gullies can be formed where the gully bottom is made of more resistant material than the topsoil. FAO (2008)

### 2.7.3. Gully classes based on continuation

Continuous gullies consist of many branch gullies. A continuous gully has a main gully channel and many mature or immature branch gullies. A gully network (gully system) is made up of many continuous gullies. A multiple-gully system may be composed of several gully networks. Discontinuous gullies 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. FAO (2008)

## 2.8. Triggers for Gully Development

Gully development may be triggered by cultivation or grazing on soils susceptible to gully erosion, increased run-off from land use changes such as tree clearing in a catchment or construction of new residential areas, run-off concentration caused by furrows, contour banks, waterways, dam by-washes, stock pads, fences, tracks or roads, improper design, construction or maintenance of waterways in cropping areas, poor vegetative cover e.g. from overgrazing, fires or salinity problems, low flows or seepage flows over a long period, down-cutting' in a creek (causes gullies to advance up the drainage lines flowing into it), diversion of a drainage line to an area of high risk to erosion e.g. a steep creek bank or highly erodible soils. Bruce Carey (2006)

## 2.9. Prevention Measures

Regular monitoring is essential to detect early stages of gully formation. A range of measures to prevent the development of gullies is described below.

### 2.9.1. Property Development

Property development involves managing catchments to ensure run-off is not increased, assessing the land's capability to ensure it is suitable for the proposed use and location and construction of roads, fences and laneways so that they cause minimal concentration and diversion of run-off. Bruce Carey (2006)

### 2.9.2. Grazing Management

Grazing management involves maintaining adequate pastures cover by better stock management, preparation to fence off and exclude stock from land vulnerable to gully erosion, location of watering points, stockyards, shade areas and gates away from gully-prone areas and leveling or creation of gaps in the poorly maintained contour banks to safely disperse the run-off thereby preventing rilling and gullying. Bruce Carey (2006)

### 2.9.3. Cropping Management

Cropping management involves control of erosion on sloping, cultivated land by stubble retention and the construction and maintenance of contour banks and waterways, construction of waterways to appropriate specifications and stabilize and maintain them, ensuring that contour banks discharge into waterways at safe locations and spreading flood flows on cultivated floodplains and avoiding practices that concentrate flood flows. Bruce Carey (2006)

### 2.9.4. Urban development and Management

This involves avoiding the development of bare, compacted areas that may occur in school grounds or other heavily trafficked areas, avoid developing steep sites and drainage lines, minimizing soil disturbance, stockpile and re-spread topsoil and revegetate affected areas and construction of flood detention systems below high run-off areas. Bruce Carey (2006)

### 2.9.5. Using Vegetation

Vegetation provides protection against scouring and minimizes the erosion risk by reducing flow velocity. As velocity falls, sediment is deposited forming an ideal environment for new vegetative growth. However, gullies can be a harsh environment in which to establish vegetation. They dry out very rapidly and usually have infertile sub-soils. Indigenous species should be considered, especially in an area where it is not desirable to introduce exotic species. However, a number of exotic grasses and other species are well established in our agricultural lands and have been used with great success for controlling erosion. Vegetation that grows vigorously with a spreading, creeping habit is preferred. Obtain local advice to see if a proposed plant has a weed potential in a particular area. Fencing the gullied area is highly desirable. Stocks are attracted to gullied areas, especially if they include shade trees. These areas are then subject to heavy grazing and compaction. If it is available, some form of irrigation is desirable to assist in the establishment of vegetation. An initial application of a mixed fertiliser aids in rapid establishment of an effective cover. Trees are desirable in the areas surrounding gullies but are not likely to be successful in stabilising an actively eroding gully head. Trees growing in gullies should not be too dense and should have an open canopy to allow protective vegetation to grow on the soil surface. Where subsurface flows are contributing to gully erosion, trees in the area above the gully head should assist by helping to dry out the soil profile and provide structural support to sub-soils prone to slumping. The practicability of shaping a gully depends on its size and the amount of fill needed to restore the gully to its desired shape. Steep gully sides can be reshaped. Topsoil should be stockpiled and re-spread over exposed areas to ensure the rapid establishment of vegetation. Annual crops such as millet (summer), oats or barley (winter) can be used to provide a quick cover. It may be possible to temporarily divert water from the battered gully while grass is establishing Gullies in cultivation can be filled when constructing contour banks. The banks must have sufficient capacity where they cross old gully lines as this is a common site for contour bank failure. Bruce Carey (2006)

## 2.10. **Gully Control Measures**

Gully control is one of the most important restoration methods used in watershed management, and timing is an essential element. The field work in all structural and vegetative control measures selected should be completed during the dry and early rainy season. This is the most important aspect of gully control - especially in tropical and subtropical countries. Otherwise, the incomplete structural work can easily be destroyed during the first rainy season. In addition, vegetative measures such as the planting of tree seedlings and shrub and grass cuttings cannot begin until structural work is complete. Each continuous gully in a gully system should be regarded as a basic treatment unit, and all the control measures in that unit should be finished before the rainy season. (FAO 2008)

## 2.11. **Selection of Gully Control Measures**

For a continuous gully, the main criteria for selecting structural control measures are based on the size of the gully catchment area, the gradient and the length of the gully channel. The various portions of the main gully channel and branch gullies are stabilized by brush fills; earth plugs; and brushwood, log, and loose-stone check dams. In upstream watersheds with very steep slopes, the gradient of the main gully channel can easily reach 100 percent or even 125 percent. In using these standards, there is not much difference between the gullies located in mountain watersheds and those in rolling lands. In rolling lands, the highest gradient of a main gully channel may be 30-40 percent. In nearly-flat areas (agricultural and rangelands on foothills), this gradient is much less than 30-40 percent. The remaining criteria are the length of the main gully channel's portions (100 m or less and 900m) and the catchment area of the gully portions (two ha or less and 2-20 ha). They are the same for gullies located on rolling land and in nearly-flat areas. FAO (2008)

## 2.12. **Runoff Design Equation**

Q max = 0.028CIA (Highway Design Manual 1976)

Where:

Q: Run-off rate or discharge expressed in $m^3/s$

C: Run off Coefficient (varies from 0.20 to 0.50 depending on the type of land use and topography).

I: Rainfall intensity, based on the concentration time of the flowing water from the limit of the catchment to the site where the check dam is to be constructed. Rainfall intensity is calculated according to the maximum (one hour) rainfall intensity (I, mm/hour) which has a frequency of 5 to 10 years for that area.

A: The catchment area of the gully above the proposed check dam expressed in square kilometers or hectares.

Use of the rational formula is possible only when a rainfall intensity (I, mm/hour) map of the country with the frequency of 5, 10, 25, 50 and 100 years is available.

If there is no intensity map for the country, the following discharge formulas must be used instead: Kresnik, or the general run-off equation and Manning velocity formula. (Highway Design Manual 1976)

## CHAPTER THREE

## 3.0. MATERIALS AND METHODS

### 3.1. Description of Study Area

The Gully site at Anguwa Biri is located on latitude $9^0$ $39^1$N and longitude $006^0 32^1$E (Global Positioning System). Anguwa Biri is situated at the North – Eastern part of Minna with an area of about 547.45Km. (Cadastral Map of Bosso)

Minna lies within a region of tropical savanna climate with distinct wet and dry seasons, the wet and dry seasons. The state is invaded by two distinct air mass, one from the northern dry and continental origin, the Sahara air mass. The other is from the Atlantic in the Southern moist cool and equatorial maritime in nature. Annual rainfall distribution pattern shows the rainfall season is between April and October covering a period of six months. Monthly rainfall in excess of 400mm occurs in Minna and environs therefore, good climatic and favourable weather throughout the year for crop production. Its inhabitants are mostly farmers and civil servants. Minna lies on a valley bed at the eastern end from Gurusu, a hilly part to the north with a gentle slope from the west and south. Most of its environs are prospective farmlands which due to its situation and location is prone to erosion because with constant farming activities uphill or downhill and other various human activities, the soil particles are tempered hence they become loosen and rainfall or wind could wash away the top soil surface. The topmost part of the soil at Anguwa Biri study area being on a gentle slope is prone to being shifted, moved and washed away leaving the topsoil bare and unprotected, hence making it vulnerable to erosion which if not adequately checked and stopped, will degenerate into serious gully erosion eroding the entire area.

## 3.2. Preliminary Survey

The entire terrain was surveyed and analyzed to obtain the length, width and depth of the gully, the impact of the gully erosion on the area, topography and soil type in order to work out design of engineering works and derive possible solutions for preventive measures to check the problem.

## 3.3. Soil Investigation

Soil samples were collected randomly from six (6) spots on the gully at distances 10 meters and depth of 30 centimeter and labeled 1, 2, 3 .....30. The soil samples collected were taken to the National Cereals Research Institute (NCRI), Badeggi, Niger State where they were assessed for permeability, through Particle Size Analysis using hydrometer method to know the type and class of soil and therefore know the rate at which infiltration will occur. These data's were used to design the drainage channel for Anguwa Biri gully erosion site.

## 3.4. Physical Properties of the Soil Samples

The soil is stratified and heterogeneous in nature and its structure and texture varies with depth. The survey carried out showed that the soil samples collected were generally sandy, silt and underlain by weakly developed claying sub-soil most especially sandy loam. The soil have high natural fertility but very sensitive to erosion, ferruginous soil is observed to be in abundant in sit region, they have low water holding capacity and so are susceptible to drought. Under forest condition they are water logged due to the clay sub-soil. It is stratified by the deposition of different materials in the layers, which possess different permeability characteristic.

## 3.5. Particle Size Analysis

Particle size test was determined using hydrometer method. Sieves can be used to separate and determine the content of the relatively large particles of the sand and silt separates but they are unsatisfactory for the separation of clay particles from the silt and sand.

After the hydrometer readings have been obtained, the percentage of sand, silt and clay were determined and placed in one of the twelve major textural classes, using the textural soil triangle shown on appendix. The texture of the soil was expressed with the use of class names (clay loam, silt clay loam, silt loam, sandy clay loam, sandy loam and loamy sand).

## 3.6. Photograph of Site

Photograph of the site was taken at different parts of the gully showing the effect of the erosion on the area is listed on appendix.

# CHAPTER FOUR

## 4.0. RESULT AND DISCUSSION

### 4.1. Rainfall Data

Mean monthly rainfall for Minna for ten (10) years from 1999-2009 were obtained and the total average over the period were used to compute intensity.

**Table 4.1: - Mean Annual Rainfall Data for Minna (1999-2009)**

| Month/Year | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1999 | | | | | | | | | | | 0.00 | 0.00 |
| 2000 | 0.3 | 0.00 | 0.00 | 3.6 | 135.9 | 161.0 | 208.8 | 308.5 | 303.0 | 153.4 | 0.00 | 0.00 |
| 2001 | 0.00 | 0.00 | 0.00 | 93.9 | 139.0 | 331.7 | 244.6 | 230.2 | 298.8 | 25.7 | 0.00 | 0.00 |
| 2002 | 0.00 | 0.00 | 5.7 | 98.88 | 42.6 | 201.0 | 143.2 | 226.5 | 260.6 | 180.3 | 0.3 | 0.00 |
| 2003 | 0.00 | 5.7 | 0.00 | 17.4 | 114.6 | 203.0 | 123.0 | 191.6 | 188.2 | 192.4 | 2.3 | 0.00 |
| 2004 | 0.00 | 0.00 | 0.00 | 32.2 | 151.9 | 194.9 | 210.3 | 211.4 | 241.5 | 77.6 | 0.00 | 0.00 |
| 2005 | 0.00 | 0.00 | 0.00 | 49.1 | 87.0 | 207.0 | 294.2 | 127.8 | 216.6 | 94.8 | 0.00 | 0.00 |
| 2006 | 11.2 | 0.00 | TR | 29.9 | 195.0 | 107.7 | 229.7 | 317.1 | 360.5 | 172.1 | 0.00 | 0.00 |
| 2007 | 0.00 | 0.00 | 0.4 | 73.1 | 156.6 | 123.9 | 314.0 | 310.1 | 330.2 | 11.51 | 0.00 | 0.00 |
| 2008 | 0.00 | 0.00 | 0.00 | 40.2 | 146.8 | 132.7 | 305.1 | 244.3 | 258.9 | 141.2 | 0.00 | 0.00 |
| 2009 | 0.00 | 0.00 | 0.00 | 42.8 | 101.4 | 108.9 | 246.8 | 497.6 | 273.5 | 85.2 | | |
| **TOTAL** | 11.5 | 5.7 | 6.1 | 481.1 | 1270.8 | 1771.8 | 2319.7 | 2665.1 | 2731.8 | 1134.21 | 2.6 | 0.00 |
| **MEAN** | 1.15 | 0.57 | 0.61 | 48.11 | 127.1 | 177.2 | 232.0 | 266.5 | 273.2 | 113.4 | 0.26 | 0.00 |

**Source: (Metrological Department Minna Airport (1999-2009)**

4.2. **Rainfall Intensity Data**

The highest rainfall amount from each month and its duration is recorded. The rainfall intensity is calculated and the maximum is obtained from the graph of return period, intensity and duration.

**Table 4.2 Rainfall Intensity Computation (1999-2009)**

| Year | Max Rainfall (mm) | Duration (hrs) | Intensity=Rainfall Amount/duration(mm/hr) |
|---|---|---|---|
| 1999 | 0.0 | 0.0 | 0.0 |
| 2000 | 308.5 | 3.58 | 86.17 |
| 2001 | 298.8 | 3.20 | 93.38 |
| 2002 | 260.6 | 2.89 | 90.17 |
| 2003 | 203.0 | 2.14 | 94.85 |
| 2004 | 241.5 | 2.50 | 96.6 |
| 2005 | 294.2 | 3.00 | 98.1 |
| 2006 | 360.5 | 4.89 | 73.72 |
| 2007 | 330.2 | 4.75 | 69.52 |
| 2008 | 305.1 | 3.40 | 89.73 |
| 2009 | 497.6 | 5.30 | 93.89 |

**Source: (Metrological Department Minna Airport)**

**Table 4.3: Percentage of sand, silt, clay and textural class**

| Sample Description | Sand % | Silt % | Clay % | Textural Class |
|---|---|---|---|---|
| Soil 1 | 53.52 | 22.00 | 24.48 | Sandy clay loam |
| Soil 2 | 61.52 | 24.00 | 14.48 | Sandy loam |
| Soil 3 | 79.52 | 6.00 | 14.48 | Loamy sand |
| Soil 4 | 49.52 | 26.00 | 24.48 | Sandy clay loam |
| Soil 5 | 71.52 | 18.00 | 10.48 | Sandy loam |
| Soil 6 | 69.52 | 12.00 | 18.48 | Sandy loam |
| Soil 7 | 73.52 | 16.00 | 10.48 | Sandy loam |
| Soil 8 | 71.52 | 18.00 | 10.48 | Sandy loam |
| Soil 9 | 78.52 | 13.00 | 8.48 | Loamy sandy |
| Soil 10 | 77.52 | 14.00 | 8.48 | Loamy sand |
| Soil 11 | 65.52 | 16.00 | 18.48 | Sandy loam |
| Soil 12 | 53.52 | 30.00 | 14.48 | Sandy loam |
| Soil 13 | 54.23 | 22.00 | 21.00 | Sandy clay loam |
| Soil 14 | 79.34 | 11.00 | 9.00 | Loamy sandy |
| Soil 15 | 49.52 | 20.00 | 30.48 | Sandy clay loam |
| Soil 16 | 57.52 | 28.00 | 14.00 | Sandy loam |
| Soil 17 | 47.52 | 20.00 | 32.48 | Sandy clay loam |
| Soil 18 | 77.52 | 8.00 | 14.48 | Sandy loam |

| | | | | |
|---|---|---|---|---|
| Soil 19 | 85.52 | 6.00 | 8.48 | Loamy sand |
| Soil 20 | 67.52 | 6.00 | 26.48 | Sandy clay loam |
| Soil 21 | 81.52 | 10.00 | 8.48 | Loamy sand |
| Soil 22 | 77.52 | 12.00 | 10.48 | Loamy sand |
| Soil 23 | 83.52 | 7.00 | 9.48 | Loamy sand |
| Soil 24 | 69.50 | 24.00 | 10.50 | Sandy loam |
| Soil 25 | 77.52 | 13.00 | 9.48 | Loamy sand |
| Soil 26 | 79.52 | 10.00 | 10.48 | Sandy loam |
| Soil 27 | 69.40 | 18.00 | 13.48 | Sandy loam |
| Soil 28 | 77.52 | 8.00 | 14.48 | Sandy loam |
| Soil 29 | 62.52 | 19.00 | 18.48 | Sandy loam |
| Soil 30 | 70.52 | 17.00 | 12.48 | Sandy loam |

The textural soil class was obtained from the textural soil triangle. Once the sand, silt and clay distribution was measured, the soil was assigned to a textural class based on the textural soil triangle. Within the textural triangle are various soil textures which depend on the relative proportion of soil particles.

From the above table it can therefore be inferred that the soil is predominantly sandy loam.

4.3. **Run-off Coefficient**

This is the ratio of rainfall intensity to its duration. This is dependent on the following factors: Rainfall intensity, topography, duration, nature of soil and land use.

The area under study is relatively uniform in character regarding terrain vegetation and land use. Glenn (1993)

**Table 4.4: - Value of runoff coefficient for urban residential area**

| | Runoff coefficient for Hydraulic Soil Groups | | | |
|---|---|---|---|---|
| Urban Residential | A | B | C | D |
| 30 percent of area impervious | 0.30 | 0.40 | 0.45 | 0.50 |
| 70 percent of area impervious | 0.50 | 0.60 | 0.70 | 0.80 |

**Remark:** The description of the site goes with item (1) then coefficient (c) is 0.40

**Source:** (Highway Design Manual 1976)

Hydraulic Soil Groups

A Well drained sands and gravels with a high water transmission rate.

B Moderately to well drained, moderately fine to moderately coarse texture with a moderate transmission rate.

C Poor to moderately well-drained, moderately fine to fine texture with slow transmission rate.

D Poorly drained clay soil with a high swelling potential, permanent water table, clay pans or shallow soils over nearly impervious material with a very slow transmission rate.

Lambert (1999)

### 4.4. Channel Design

The dimensions obtained from the survey of the gully and the Nigeria Highway design manual was used for the analysis. Considering the longitudinal profile of all drainage routes obtained from the survey of gully site. The gully at Agwan Biri has a length of 230meters, slope of 0.02%, top width 6.67meters, base width 2.67meters and depth of about 2m.

### 4.5. Time of Concentration

The time of concentration of watershed (Tc) was calculated using the equation –

$$Tc = 0.0197 L^{0.77} S^{-0.385}$$ [High Way Design Manual 1976]

Where:

Tc - Time of concentration

L - Maximum length of gully in meter

S - Watershed slope

$Tc = 0.0197 \times (230)^{0.77} \times 0.02^{-0.385}$

$= 0.0197 \times 65.846 \times 4.509$

Tc= 6 minutes

### 4.6. Design Equation

Q = 0.028CIA

Where:

Q – Run-off rate $m^3/s$

C – Run-off coefficient

I – Rainfall intensity (mm/hr)

A – Catchments area for watershed

$Q = 0.028CIA$

$C = 0.40$

$A = 290m \times 44m = 11600m^2 = 1.16ha$

$I = 115mm/hr$

$Q = 0.028 \times 0.40 \times 115 \times 1.16 = 1.49\ m^3/s$

## 4.7. Rectangular Channel Design

$$Q = AV = \frac{A(R^{2/3}S^{1/2})}{n}$$

$$R = A/P = \frac{bd}{2(b+d)}$$

Ven Te Chow (1978)

Where:

Q – Run-off rate $m^3/s$

A – Surface area ($m^2$)

V – Velocity m/s

R – Hydraulic gradient

S – Slope

n – Manning's coefficient (depends on material)

## 4.8. Design Calculation

Final run off rate was calculated after trial test of variables; width and depth (b, d) to obtain an equivalent run off rate (discharge).

$b = 1.5m$

$d = 2m$

$n = 0.016$ (FHWA Hydraulic Engineering Circular No5 – for concrete box culvert)

s = 0.02 Ven Te Chow (1978)

$$R = \frac{A}{P} = \frac{b \times d}{2(b+d)}$$

$$= \frac{1.5 \times 2}{2(1.5+2)}$$

$$= \frac{3}{7}$$

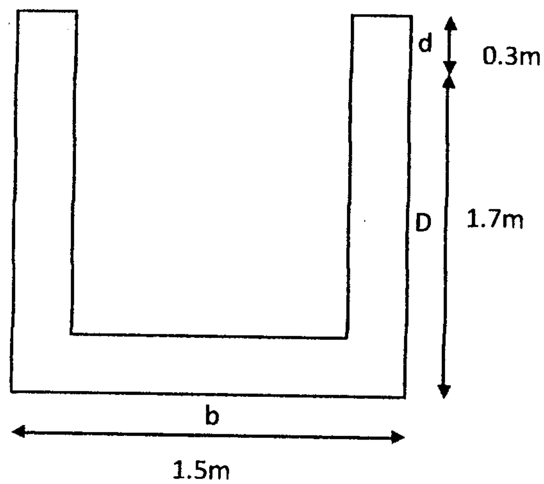
R = 0.4285

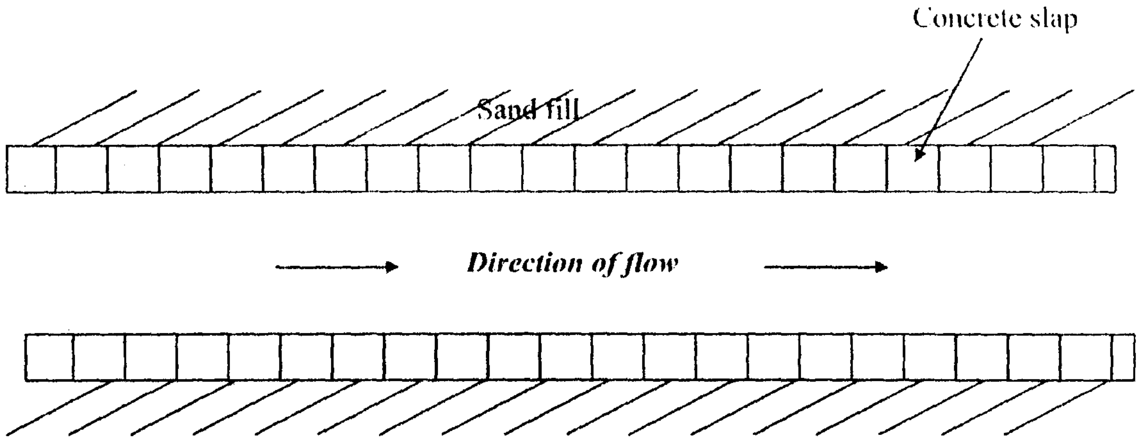
$$Q = \frac{3(0.4285^{0.667} \times 0.002^{0.5})}{0.016}$$

$$Q = \frac{3(0.008655)}{0.016}$$

$Q = 1.62 m^3/s$

## 4.9. Design Drawing



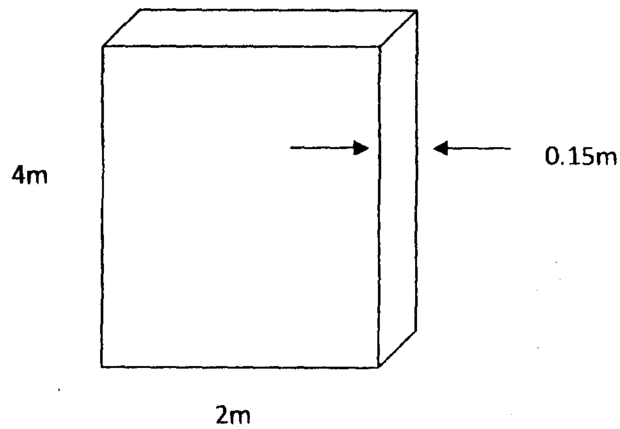



**Plan View**

## 4.10. Material Costing

The costing of the materials used in this design is based on the present market cost and their value may vary due to standards of company prices.

$$Area = L \times b \times thickness$$
$$= 4 \times 2 \times 0.15$$
$$= 1.2m^2$$




Cost per $1m^2$ = N6, 000

$1.2m^2$ = 1.2 x 5, 000 = 7, 200

Number that will cover total length

Total length = 230/2 = 115 pieces

115 x N7, 200 = N828, 000

For opposite side = 828,000 x 2 = N1, 656, 000

Area = L x B x thickness

5 x 2 x 0.15 = 1.5m$^2$

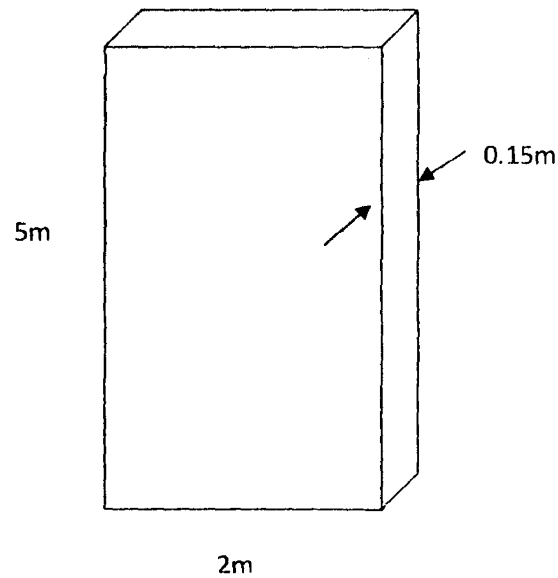
Cost per 1m$^2$ = N7, 000

1.5m$^2$ = 1.5 x 7, 000 = N10, 500

Number that will cover total length

Total length = 230/5 = 46 pieces

46 x 10, 500 = N483, 000




Total material cost = N (1, 656, 000 + 483,000) = N2, 139, 000

# CHAPTER FIVE

## 5.0. CONCLUSION AND RECOMMENDATION

### 5.1. Conclusion

The Anguwa Biri gully site in Bosso Minna, Niger state was surveyed and found to cover the distance of 230metres, top width of 6.67m, base width of 2.67m and depth of about 2m which would lead to a severe problem if not checked or controlled.

Soil samples were collected randomly from six (6) spots on the gully at distances 10 meters and depth of 30 centimeter and labeled 1, 2, 3 .....30. Once the sand, silt and clay distribution were measured, the soil was assigned to a textural class based on the textural soil triangle to determine that the soil is generally sandy, silt and underlain by weakly developed claying sub-soil and most predominantly sandy loam.

Concrete lined control channel were designed to control these gully using a measurement flow depth of about 2m and 1.5m by breath. The designed channel will eliminate the gully and its impacts, thereby making available otherwise threat to residence and farming activities that would have been lost due to gully effect. Generally, gully erosion is caused due to the hydraulic force of water cutting deep into the soil and human activities.

### 5.2. Recommendation

The need to curtail these consequences of gully erosion has been widely recognized and various soil conservation measures, concrete structures and effective drainage facilities have to be taken at various levels to bring an end to the problem.

The development of gullies in the area could be minimized by encouraging planting of cover grasses in the building surroundings rather than cement paving of the surface which further makes the ground impervious.

Since gullies result from the intensive scouring action of concentrated runoff, an effective measure is to reduce the velocity of the runoff and encourage infiltration. This can be achieved by encouraging the planting of cover grasses in the building surroundings and in the inter-spaces between buildings rather than cement paving and concretization of surface which make the ground more impervious.

# REFERENCE

Brady, N.C. (1990): The Nature and Properties of Soils. Macmillan Publishing Company, NY, NY.)

Bruce Carey (2006): Natural Resource Sciences. www.nr.qld.gov.au

FAO (2008): Watershed Management Field Manual-Gully control.

www.fao.org/docrep/006/AD082E/AD082e01.htm

Federal Highway Authority (FHWA): Hydraulic Engineering Circular No 5

Glenn, O. Schwab *et.al* (1993): Soil and Water Conservation Engineering, John Wiley & Sons, publishers. 4th Edition USA.

Halilu H. (2000): Environmental Problem, cause, effect and solution.

High Way Design Manual (1976)

Lambert, K.S. and David, W.R. (1999): Land drainage and Design of Agric Drainage Systems)

Mustapha, H.I. Lecture notes (2009): Gully Erosion and Control.

Nigerian Meteorological Agency, (NIMET), Minna Airport, Minna, Niger State.

Schwab Fangmeier Elliot Frevert (1993): Soil and Water Conservation Engineering

Ven Te Chow: Open Channel Hydraulics.

# APPENDICES

## Appendix A: Photographs of site.

**Plate 3.0: Gully effect on soil.**

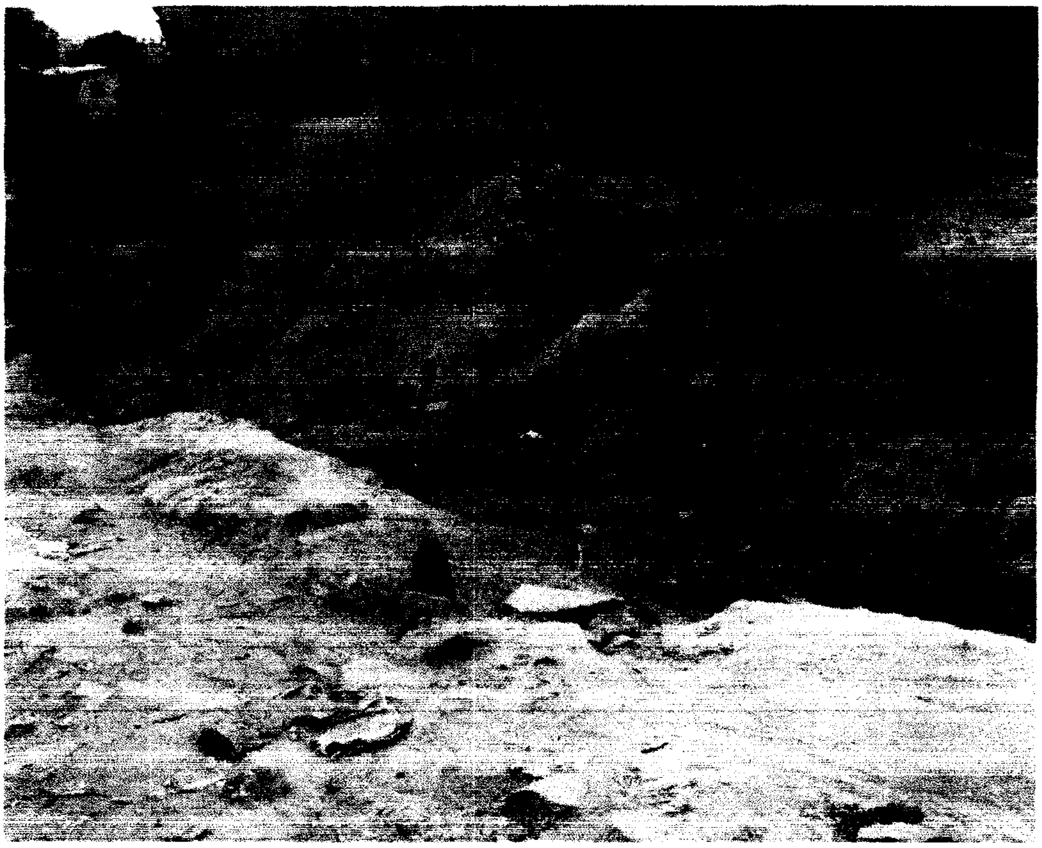


**Plate 3.1: Gully destroying residential building.**

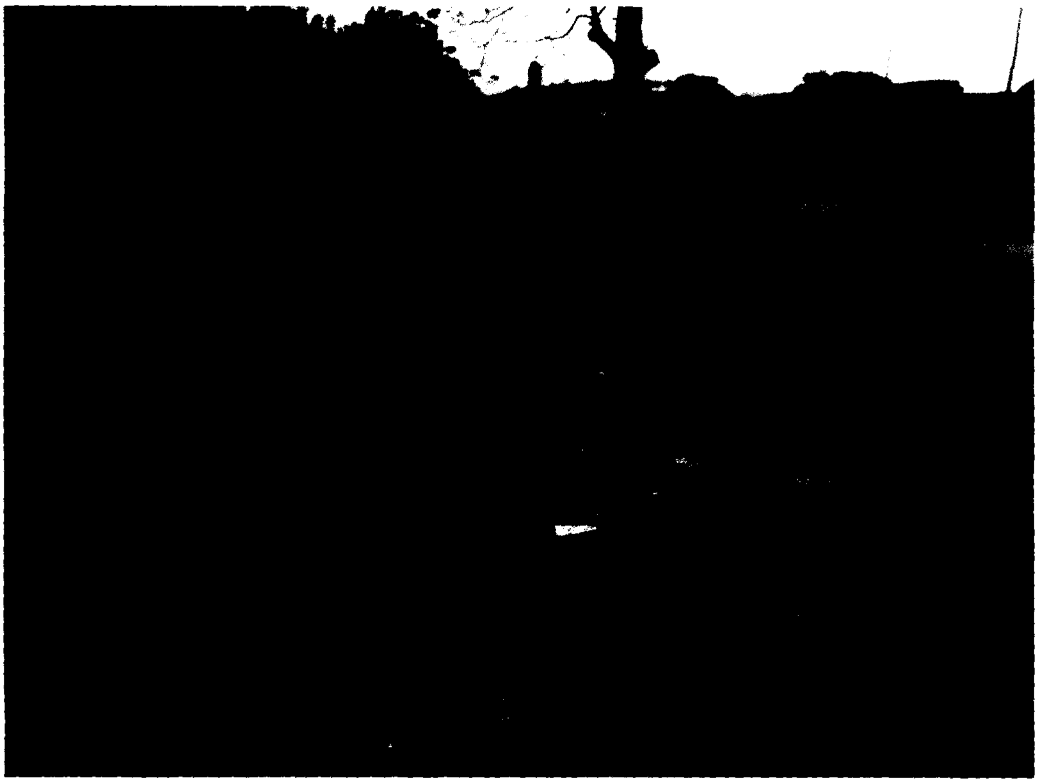


**Plate 3.2: Gully eating up trees and natural vegetation**

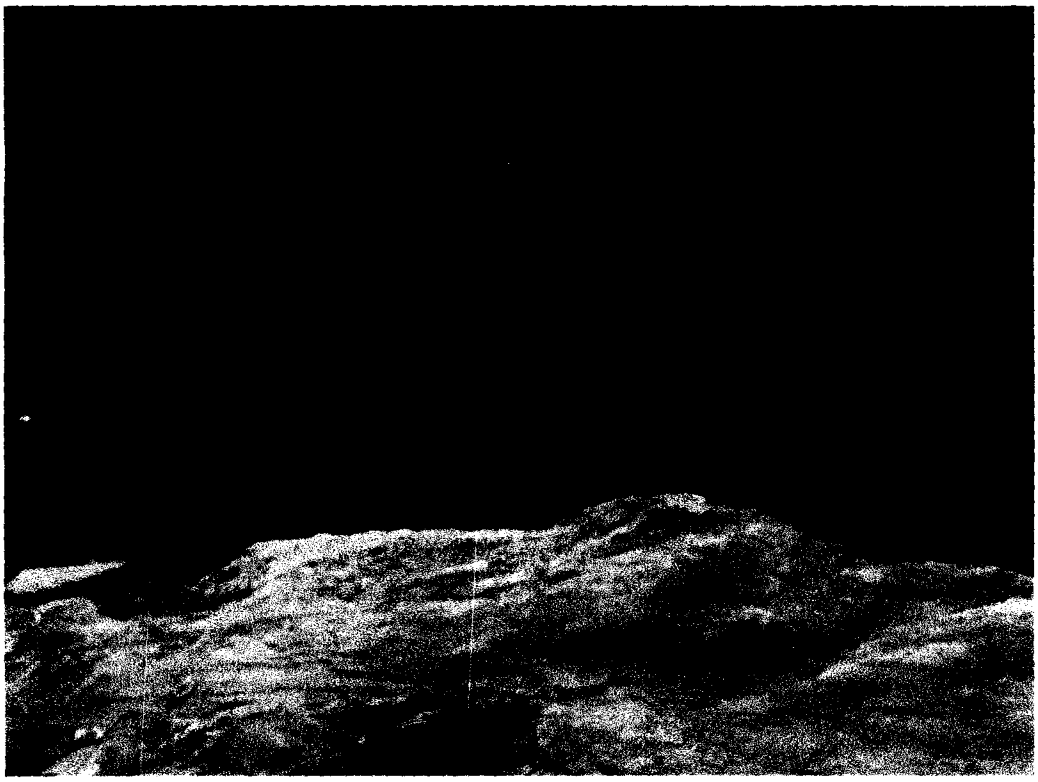


**Fig 3.3: Gully affecting layers of soil**

**Appendix B: Particle Size Analysis**

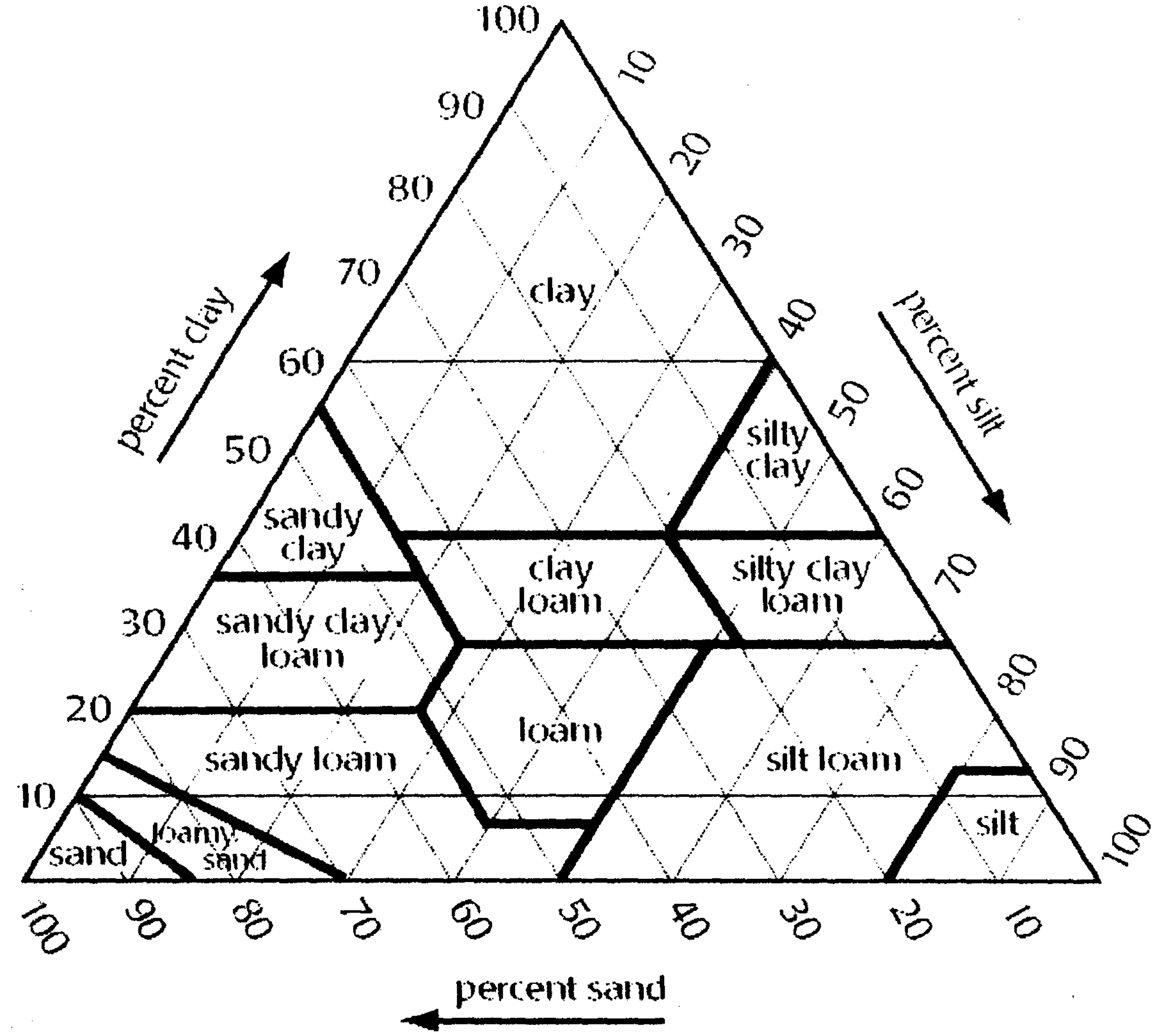



**Fig 4.0: Proportions of sand, silt, and clay in the basic soil- textural classes.**

Source: (Brady, N.C. 1990. The Nature and Properties of Soils. Macmillan Publishing Company, NY, NY.)