AN ITEGRATED APPLICATION OF REMOTE SENSING, GLOBAL POSITIONING SYSTEM AND GEOGRAPHIC INFORMATION SYSTEM TECHNIQUES IN ASSESING THE IMPACT OF GULLY DEVELOPMENT ON FARMLANDS IN FARIN LAMBA, RIYOM LGA, PLATEAU STATE, NIGERIA.

By

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M.TECH/SSSE/925/2003/2004

DEPARTMENT OF GEOGRAPHY
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FEDERAL UNIVERSITY OF TECHNOLOGY (FUT)
MINNA

July, 2005

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A THESIS
SUBMITTED TO POST GRADUATE SCHOOL OF FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA IN PARTIAL FULFIIMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF TECHNOLOGY (M.TECH) IN REMOTE SENSING

July, 2005

DECLARATION

I, BITRUS AKILA DANG of the department of Geography, school of science and science education, Federal university of Technology, Minna do solemnly declare that this research work presented for the award of master of technology (M.Tech) in Remote sensing was carried out by me, under the supervision of my supervisor DR. OKHIMAMHE A.A. of the department of Geography, School of Science and Science Education, Federal University of Technology, Minna, Niger State.

03-03-2006

BITRUS AKILA DANG DATE

CERTIFICATION

This is to certify that **BITRUS AKILA DANG** of the Department of Geography, Federal University of Technology Minna did conduct a research on the impact of Gully erosion on Farmlands on the plateau (A case study of Farin Lamba in Riyom local government area of Plateau State) of Nigeria and is approved as it affects farming practice and reduction in farm size, for the partial fulfilment for the award of master of Technology (M.Tech.) in Remote sensing.

....	30/05/06
DR. OKHIMAMHE A.A. SUPERVISOR	DATE
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DR. M. T. USMAN HEAD OF DEPARTMENT	DATE
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Dr.S.A. MASHI EXTERNAL SUPERVISOR	DATE
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PROF.J.A. ABALAKA DEAN POSTGRADUATE SCHOOL	DATE

DEDICATION

This research work is dedicated to Almighty God for his grace that is sufficient and to my entire family members.

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ABSTRACT

Gully erosion is responsible for significant soil loss from catchments areas of Riyom Local Govt Area. Vast lands in Farin Lamba of Riyom Local Govt. area are dissected by gullies, destroying farmland, thus contributing to downstream sedimentation. The study involves an assessment of the impact of gully development on farmlands in Farin Lamba area. It also involves mapping and measurements erosion parameters which were employed on aerial photographs, satellite imagery of different periods and previous lands degradation reports. The above objectives were achieved by employing GPS, scanning of analogue maps/photographs at a resolution of 400 dpi and digitization. However, a mosaic of the scanned aerial photographs was created to show the area at a glance for better working condition. Land use interpretation was based mostly on cover data provided by photo interpretation keys and farming pattern. A drainage map was obtained from the topographical map and contours for generation of digital elevation model of the area. Using the software ILWIS, delineation of gully areas was possible by digitising the aerial photo which were characterised into partial, completely eroded, bare surfaces etc. The fieldwork carried out was able to supplement the age of the photo/satellite data. Similarly the satellite image was classified. To allow GIS to play its role, a database was created. The analysis was carried out using the same software to obtain histograph, slope, flow direction etc. The land use/cover map from the 1981 photos shows an increased vegetation cover of agricultural practice on the reclaimed area on the slopes. Gully erosion is seriously devastating farmlands and it is a threat to farmers in Farin Lamba such that in the next 10 decades, if nothing is done to avert the situation, the available land would be taking over or consumed by gullies.

LIST OF FIGURE

LIST OF PLATES

Title **Page**

LIST OF TABLES

Title **Page**

TABLE OF CONTENT

CHAPTER TWO

CHAPTER THREE

CHAPTER FOUR

CHAPTER FIVE

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF THE STUDY.

Farin Lamba in Riyom Local Government Area of Plateau state suffers intense problem of gully erosion. The development of gully system in this area has been favoured by the topography that generates active runoff. Surplus runoff is usually concentrated in hillside ditches that flow into main drainage channels or directly into gullies. This favours formation of gullies at ditches or outlet points in a manner the gully network enlarges linearly. Then the gullies grow by deepening into unconsolidated tertiary deposits. Mass movement on sidewalls produce parallel widening of gullies. (Martnez-Casasnovas 1998). Farin Lamba happens to be close to the road from Jos to Akwanga. From the road, one could see the danger posed by gully erosion to the farmers as it destroys the land. It was observed that because of the pressure on the land, even those parts that have been destroyed or eroded, washed into the valley are being cultivated again with crops like (coco yam and maize).With the increasing population, there lies a problem of scarce farmland. All forms of gullies drain into River 'Got' which is a tributary to River Werram that finally flows into River Dep to form the famous Dep Falls. Also, while the farmers should have been using modern farming implement (Tractor), but because of uneven nature of the land created by erosion, farming is by traditional method that is labour intensive.

Overseas Development Institute (ODI: 1999) described the process of land degradation on the plateau as the outcome of the continuous over exploitation and mismanagement of soil resources through deforestation, mining activities, overgrazing, clearance of land for agricultural purposes with disregard to slope and topography of the land. Gully erosion causes several types of damages on the plateau. From agricultural perspective, the greatest impact of gullying is the dissections and reduction of parcels, the increase of slope, the damage of infrastructure (paths ways and erosion control infrastructure), the damage of crops and the more difficulty mechanical labours. From a soil landscape perspective, fertile soil layers are removed and terrain is highly dissected. This damage is non-recoverable in a short to middle term. (Martinez-Casasnovas: 1998)

Gully erosion is a terminal and cancerous ecological disease that destroys lands that developed over hundreds or thousands of years. Most agricultural lands and wetlands have been rendered useless by gully erosion. Because of the volume of sandy silt that has been deposited on top of the former rich soil, such soil never accept any fertilizer since it quickly leaches out as soon as it is applied. (Egboka1999).

1.1. Types of Soil Erosion

Generally, Soil erosion has sub-component that eventually add up in the ecological devastation process. Basically, there are three types of erosion, viz: Sheet erosion, Rill erosion and Gully erosion.

a) Sheet Erosion

This is the most common form of erosion. Sheet erosion or soil outwash is generated by runoff that spreads out over land as a blanket of water, moving down the gradient. Sheet erosion eventually breaks into fingers like rill erosion as it picks up more energy down the slope.

(b) Rill Erosion

Rill erosion easily develops into large geometrical entities called channels or channel erosions that can be demarcated into small observable dimensions of length, width and depth. Around streams and river slopes, bank erosion is predominant, whereby the sides and slopes of riverbank may break away and wash down by running water.

(c) Gully Erosion

Gully erosion is an advanced stage of rill erosion, just as rill is often the result of sheet erosion. Gullies are larger than rills and cannot be fixed by tillage. This type of erosion is favoured by rainfall characteristic, lithology and land uses with partial soil cover. In some areas, gullies have reached such a magnitude that some of the features are glaring such as size, form, pattern and even density. Gullies are most widely spread in parts of Nigeria, particularly in the southeast, south-south and middle belt. The study area is within the middle belt. The severity of this gully erosion is not yet properly understood, well focussed or appreciated by Nigerian environmentalist. The processes of gully erosion are primarily dependent on water driven force. Gully erosion is said to be responsible for moving vast amounts of soil, irreversibly destroying farm land, hence reduction in sizes.

Egboka (2004) described the problem resulting from gully erosion in the eastern part of Nigeria to include human, material, political, psychological, sociological and economic.

Most road networks in the southeast are destroyed every year, particularly during the rains. They are washed away, cut in places, gullied, moved away into the bush by landslide, eroded or channelled into erosion pots. Some roads have become flood channels while drains, where they exist, have been washed away. Erosion dissect the terrain leading to unevenness and where soil parent material is exposed, it is necessary to fill before any construction and other infrastructured work such as buildings, bridges, roads etc can be carried out. The site reclamation situation could be very expensive thereby increasing the overall cost to about 40%. Sometimes, Engineers and builders design and construct roads without considering the implications and destructive effects of gully erosion on the long run. NEPA and NITEL lines are usually damaged during rainy seasons. Some bridges are moved away, houses, churches, villages, schools, markets, playground, open spaces, ancient forest and trees in various towns and communities have been destroyed.

Agricultural lands are either reduced in size or covered with sand and are infertile. As farmlands are destroyed by erosion, the increasing farming population cannot find suitable lands to grow their crops. This may be followed by fragmentation of the remaining good land and in turn results in over exploitation of the land with declining output unless the fertility is improved by planting cover crops such as beans that helps in nitrogen circulation in the soil or application of manure/fertilizer to improve the lost nutrients.

Gully erosion is a serious land management issue in many parts of the world (Prosser etal, 1996) and considerable effort has gone into monitoring gully development and militating against property damage and losses due to gullying. It constitutes a menace to countries such as Australia, India, Turkey and Japan etc. In Nigeria however, the problem is most precarious in Anambra state that people had to relocate from their places of abode, up to three or four times in the last thirty five years as they ran away from the advancing gullies that carried away their homes. Billions of naira and hundreds of human lives have been lost (Egboka, 2004).Closely related to the situation in Anambra state is Farin Lamba gully erosion incidences in Riyom local government of plateau state. Studies related to the mapping of the extent of gully eroded areas, the estimation of gully erosion rates or examining the pattern and growth of gullies in relation to farmland using geospatial techniques such as Remote Sensing and Geographic Information Systems are required as control measures must be established over the study area.

Remote sensing and GPS are technologies that are satellite-based systems for data acquisition that can be useful in measurement for hazard assessment. It is believed that remote sensing systems can significantly contribute to solving this environmental problem. Satellite remote sensing also provides the means for a cartographic inventory of degraded (i.e. environmental sensitive) areas, and it is virtually the only data source which permits a repeated monitoring of land degradation dynamics.

Remote sensing is a powerful technique for the collection of spatial data that can be analysed and converted into information for problem solving. Mapping represents an important pre-requisite for drafting and implementing development plans and policy/decision making. GPS, another instrument for this study, uses a constellation of 24 satellites to determine the horizontal and vertical position of a place with a little less accuracy of one to five meters. It enables you to identify and record the location of problem or event that will affect production of soil fertility and even active erosion sites. Remote sensing and GIS support spatial analyses of all kinds. Remotely sensed data can be fed regularly into GIS for analyses, in which case they are complementary techniques. GIS is a computer system capable of acquiring, storing, retrieving, processing, analysing and displaying geographical data, (Jones, 1997).

1.2 STATEMENT OF THE PROBLEM

Gully erosion is the most visible form of erosion affecting farmland. It often moves rapidly, cutting into the lands resulting to large amount of debris being carried away, and that leads to lost of productive land, affects soil fertility, land accessibility- in terms of using mechanical implements or impede tillage operations and tracks are cut off becoming death traps for both man and animals. The overall result of this is reduction in both farm size and agricultural yield, leading to poverty in the community and the country at large. However, various methods can be used to redress the effect of gully erosion. Traditional ridge making across the slope that is highly labour demanding, tree or hedge planting and crop cover practicing are possible ways of arresting this menace. Though, few people are actually adopting these measures thereby making the problem to be prevalent.

Remote sensing, however, is a very useful tool for hazard assessment, which can estimate the geographic distribution and enable measurement performed on the images. It is a powerful technique for the collection of such spatial data. The data is collected, analysed and converted into information for problem solving or decision-making. For example, the SPOT stereo images has been demonstrated in mapping and terrain assessment aimed at hazard and disaster mitigation (Ndukwe, 1998). Remote sensing can be incorporated into GIS by interfacing the data with other spatially referenced information. GIS is a powerful tool for turning large volume of spatial data into useful information for decision-making. Global positioning system (GPS) can be used to pinpoint the location (dereference) of hazard data collected and provide accuracy of one to three meters. GPS enables you to identify and record the location of problem or event that will affect production including soil fertility, siltation and active erosion sites.

1.3 AIM AND OBJECTIVES.

1.3.1 Aim

The aim of this study is to examine the extent of damage that has been done to agricultural farmland by gullies on the plateau and predict the trend using RS, GIS and GPS techniques. The extent of this damage if not examine, no solution would be proffered and subsequently the entire land would be lost or reduced in size resulting in poor productivity leading to poorvity in the land.

1.3.2 Objectives

The following specific objectives are set to achieve the above stated aim:

1. Mapping of the land use with the view to show farming patterns.

2. Mapping the drainage pattern, slope map (DEM) and soil types.

3. Identifying and delineating the type, width and depth of gullies.

4. Compare 1 – 3 above within a GIS environment in order to determine the extent of the impact of gully erosion on farmlands over the years and classifying the extent of risk to the farmlands.

1.4.0 DESCRIPTION OF THE STUDY AREA

1.4.1 Geographical Location

The study area is situated between Farin Lamba and Riyom town, the headquarters of Riyom local government area in plateau state. It is about 50km from Jos, the state capital, and the test site is approximately 25km² in area, with the geographical coordinates between latitudes 09° 38′ 50¨N to 09° 41′ 48°¨N and longitudes 08° 48′ 00¨E to 08° 47′ 46¨E. (Fig.1.1)

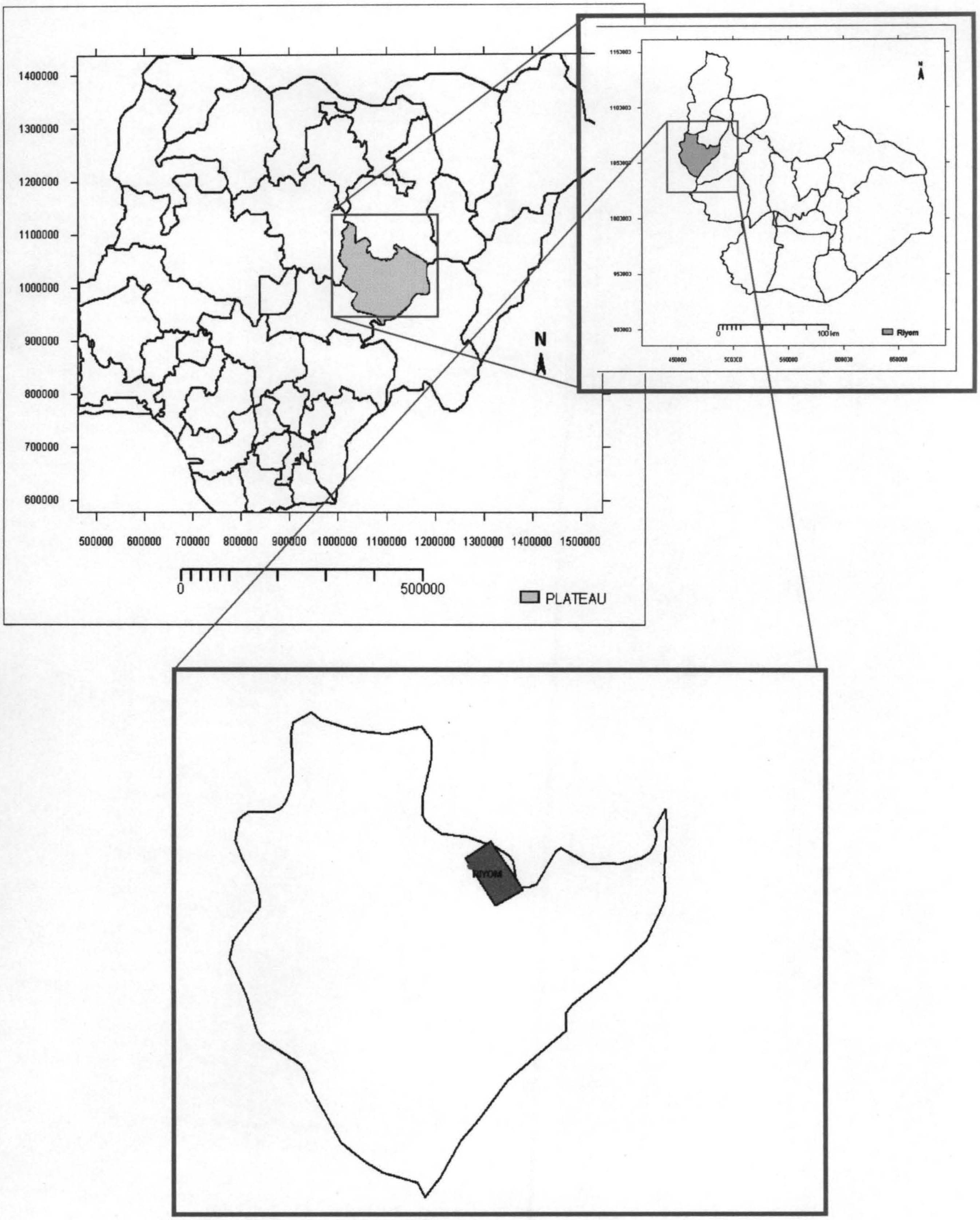


Figure: 1.1 Location map

1.4.2 Climate

1.4.2.1 Rainfall

The climate is influenced mainly by topography resulting in orographic type of rainfall. The Plateau is a watershed where no river from outside supplies water. Rainfall is the main source of water, in which, supplies and availability of water on the plateau fluctuate with wet and dry seasons. Olowolafe (1995) showed that water surplus occurs between April/May to September/October, while the remaining period of the year is dry season (See table 1. 1). Because of the altitudinal differences, mean annual rainfall varies from one place to another on the Jos plateau.

Table 1.1 monthly rainfalls

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Jos	0.0	0.0	1.5	133.3	107.6	306.0	339.4	304.8	210.8	92.8	0.0	0.0

Source: Kuru Station,Jos

River `Got` and several streams drain the area that flow mostly during rainy periods and no flow drain the study area during the rest of the year. The flows of streams on the plateau are affected by watershed factors such as drainage area, shape, soil, vegetation cover, slope, and elevation. Table 1.1 is the rainfall data obtained from kuru station, Jos (station No 090844) for 2002. The average annual rainfall in Jos is 125mm and the peak of rains is usually between July-August. Torrential showers give rise to large runoff water thereby creating serious drainage problems such as gully erosion.

1.4.2.2 Temperature

The high plateaux of Jos exhibit very mild weather conditions throughout the year except for the months of March and April. ODI (1999) identifies that the prevailing air and soil temperature in the area are suitable for the production of dry land crops such as maize, sorghum, millet and Irish potatoes.

1.4.2.3 Relative Humidity

As with temperature, there are some seasonal variations in relative humidity of the area. However, there is close relationship between rainfall and humidity whereby plants can beneficially absorb moisture from unsaturated air, that is to say humid air increases photosynthetic rate.

1.4.2.4 Topography

The area is a geological island of volcanic formation (Odi 1999). This range from planation surfaces to measured inselbergs, alluvial landscape and rocky hills. Olowolafe (1995) also identified three broad physiographic units on the plateau as undulating terrain, dissected terrain, and hilly/mountainous landscape. This is referred to as an `erosion relic` (Odi: 1999) and it's found at a general level of 3000m above sea level. The geomorphologic processes responsible for the attainment of the plateau height, Olowolafe (1995) explained this in terms of continual denudation process of the resistant nature of close concentration of the granite rocks, particularly the younger granite. This type of topography enhances the active generation of runoff, flood, and gully erosion. Erosion processes in the area is further enhanced by the regional climate, characterised by irregular and often extremely high rainfall. Heavy rainfall often results in severe erosion and high rate of soil loss (Jag, 1999). Other factors include mining activities, overgrazing and farming practice on the hilly sides. River 'Got' constitutes a watershed of rivers flowing into rivers Kaduna and Benue.

1.4.3 Soil

The Council for Technical Corporation in Africa (ATCA) modified the soil map of Africa as an attempt to study the soil on the plateau at a regional level. Their report shows that lithosols are the most extensive soil on the plateau. Other studies carried out in some selected fadama areas in riyom revealed the dominance of combisol and Chromic cambisol in area underlain by volcanic materials as shown on map of 1:250,000, (Oluwolafe, 1995).

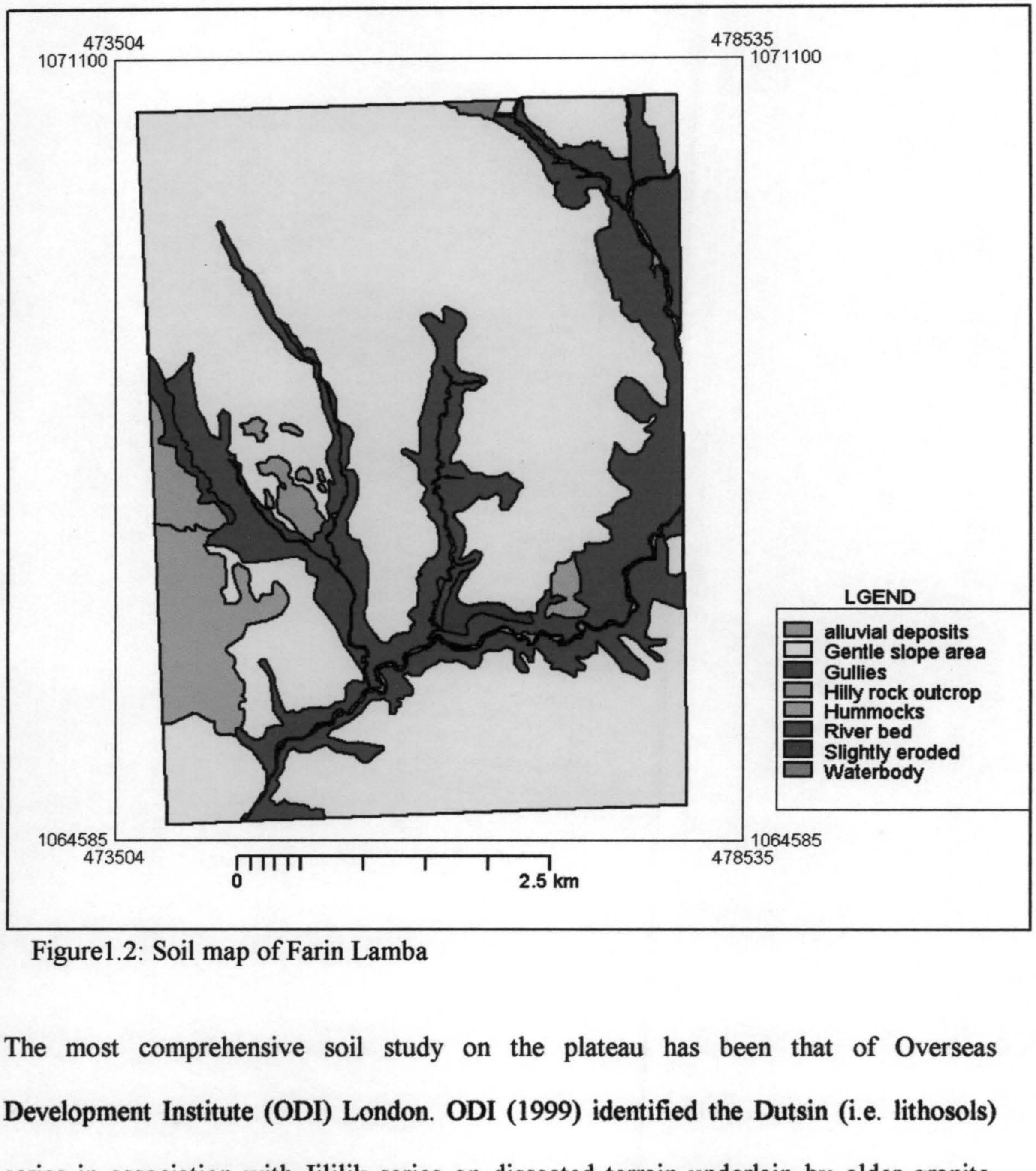


Figure1.2: Soil map of Farin Lamba

The most comprehensive soil study on the plateau has been that of Overseas Development Institute (ODI) London. ODI (1999) identified the Dutsin (i.e. lithosols) series in association with Jililik series on dissected terrain underlain by older granite, migmatites and gneiss. The lithosols are very shallow sandy soils of variable colour. The Jililik series are ferralic cambisols of deep imperfectly drained stony rocks. Soils developed from volcanic rocks are confined to the Jos plateau. The soils are well-drained and shallow, with texture consisting of loamy sand to sandy loam top soil (0-20cm) over orgillic subsoil which make traditional tillage easy (an advantage to the farmers). However, the sandy nature with characteristic weak surface aggregation makes the soil susceptible to gully erosion processes. The soil texture description within the study area is based on the U.S.D.A description of soil texture as fine earth fraction (particles less than 2mm diameter).

Distribution of the major soil types in Farin lamba shown in figure 1. 2. Most parts of Riyom is covered by lithosol series in association with jililik series underlain by older granites and migmatites derived from the geological basement complex rock. The higher areas in elevation of Riyom are associated with the exposed older granite which forms the generator of running water with increased precipitation. Recent interpretation further revealed the following:

i. **Hilly and rocky Areas**: - These are also boulders and smaller fragments of rocks. Elevation ranges from 1173.48m to 1371.60m above sea level. The unit is sparsely vegetated mainly due to grazing activities in the area.

ii. **Gently slope area**: - The gently sloping areas are mostly made up of laterite and are used for cultivation. Crops like Irish potatoes, maize, millet and accha dominates the agricultural land in Riyom and environs.

iii. **Hummocky area**: - Hummocks are usually areas rising slightly higher than the agricultural land, covered mostly with grasses and are used for grazing.

iv. **Gullies**: - Gullies are degraded land as a result of materials transported away by water. Consist mostly of small and deep holes and does not support vegetation and it impedes agricultural activities. Where little water is stored, it's used for dry season farming and supporting livestock as drinking spots.

v. Alluvial deposit: - Alluvial deposits are deposited materials that are finally deposited by water. Mostly made up of sand and coarse and does not support crops but can be can be used for construction purposes especially channelling water.

1.4.4 Vegetation and Landuse

The plant cover is associated with the climate, the most important soil erosion factor. It protects the soil against the action of falling raindrops and increases the degree of infiltration of water into the soil, maintains the roughness of the soil surface, reduces the speed of the surface run-off, and binds the soil mechanically (Pilesjo, 1992). As long as the vegetation cover is unbroken, whether it is made of forest, bush, savannah, and pasture land, or simple mulch, erosion and run-off are small despite the erosivity of the rain, slope steepness and soil instability. The vegetation covering the study area consist mainly of grasses and dotted with artificial plants such as cactus planted around some of the farmlands near the settlement. However, there are traces of mountain vegetation around, disturbing the plant cover, e.g. through the burning of grasses, especially late in the dry season, significantly increases run-off along with the solid contents. However, when the soil is totally exposed, erosion become catastrophic; resulting in increase soil loss. Therefore, the dense vegetation cover, either natural or cultivated, is the best protection against soil erosion. The area has a poor vegetation cover and fluctuating rainfall, hence susceptible to high soil loses by water erosion.

Land use in the area can be divided into: mining, traditional cultivation, (mainly accha, Irish potatoes, maize, and millet), local quarrying and grazing. An activity that reduces the vegetation cover also increases the risk of soil erosion. In this area, the reduction in vegetation cover is mainly caused by harvesting for firewood, grazing, and bush burning. It has been noticed that recovery of vegetation in this area is slow during the dry season, while overgrazing around corrals and watering places is common which results in local distraction of vegetation. Burning of grass, bushes and trees is generally practiced in the middle belt of Nigeria. Investigation using Landsat satellite imagery revealed that about 40 to 60 percent of all the land was affected by drought of 1973 (Pilesjo, 1992). Also increased agricultural activities lead to large bare surface areas after the harvesting period and increase the risk of soil erosion. In most cases recently harrowed and sowed areas have a level and soft surface, and run an increased risk of erosion.

1.5 JUSTIFICATION FOR STUDY

Lack of sufficient information about lost of farmlands as a result of erosion necessitates this study. The study area, an agricultural area for crops like maize, millet, and Irish potatoes that are produced in a large quantity, has been under threat by gully erosion. The cultivation of these crops has favoured accelerated development of water erosion processes. The expansion of gullies can be seen glaringly in the maize and Irish potatoes farms, causing serious problems to farmers in terms of reduction of farm size, bad accessibility, generation of marginal areas and soil loss, among others (plate1: Erosion encroach into farmland).

Plate 1: Erosion destroying farmland in Farin Lamba

Environmental degradation on the Plateau has engaged public interest for a long time and only in the few years that Nigerians have become erosion conscious, as it is the case in the eastern part of the country. It is noteworthy that Smuts (1995) said "that erosion is the biggest problem confronting Nigeria and that there is only one solution, the education of public opinion". We should bear in mind that what is now desert was once the granary of the world, it is a gradual process. The case is the same as the erosion process have signal Nigerians of what it would become if nothing is done. As of 1999 only a draft national policy was available on the control of soil degradation. The mandate of the Federal ministry of water resources development covers only huge conservation projects as drainage of highways, coastal erosion, landfills, desertification control and alike. ADPs remain the only government agency involved in agriculture related Soil and Water Conservation (SWC).

The task of remote sensing is to collect, analyse and convert remotely sensed data into various types of information for problem solving or decision-making. The information offers long-term investment and decisions are made in the quickest and cost effective way. Hazards can pose real danger to life and property and in particular, gully erosion can cause loss of valuable agricultural lands, increased incidence of poverty among the rural people of the affected area, depletion of the economic base etc. The extent of damage so assessed can be used for compensation purpose and or give a clue to causes and necessary precaution taken to reduce or prevent future occurrences. For example United Nations Disaster Relief Organization (UNDRO) based in Geneva relies on remote sensing information for assessment and quantification of damages caused by natural hazards or man's activities (Ndukwe, 1997). With the launch of the Nigeria sai-1, the issue of non availability of data is addressed. The data from the satellite has been validated by using it to successfully map gully erosion in the eastern part of the country. The availability of this data has posed a challenge to Nigerian scientist to carry out research work with the view to solving most of the environmental problem such as flood that robe people of their lives and properties, just as erosion has been depriving people of their farmland and crops.

At the end of this study, the community within the study area would be aware of the danger ahead if nothing is done immediately either as a community or a 'cry- out' to government. Immediate action can stop further erosion processes and will protect the remaining land from being destroyed. As the only source of livelihood to the peasant farmers, using the land effectively would improve their standard of living and therefore abundant foods, rather certain percentage of the land and even with crops are lost yearly. The extent of agricultural land that has been damaged by erosion would be known with the view to reducing the effect on farmland. It became necessary because the peasant farmers depend purely on the land as the only source of livelihood and to crown it, true form of wealth is the land and this should be guarded, protected and preserved.

1.6 SCOPE AND LIMITATIONS OF THE STUDY

This study focuses on the impact of gully erosion on farmland on an area between Farin Lamba and Riyom villages. The geographical area falls within latitudes 09° 38¨ 50´´N, 09° 41¨ 48´´N and longitudes 08° 47¨ 46´´E, 08° 48¨ 00´´E.The scope of the study covers an approximate area of about $25km^2$. The technologies of remote sensing and GIS that are relatively fast, accurate and cost effective would be used. The investigation and subsequent analysis would focus on the extent gully erosion has damaged the wealth (land) of the community. However, no soil test would be conducted, but all information about soil would be based on the previous soil map and other reports.

The available aerial photographs did not cover the intended area of study. The intended area of study was reduced; just exactly where the photographs covered. The photographs have a large scale and are of high resolution at scales 1:10000. As a result of drift during photograph acquisition, it became very difficult for perfect fitting during the mosaicing process. Every attempt at mosaicing resulted in a mismatch, even after georeferencing and cropping. After several attempts, it was minimised to an acceptable level for mapping.

Another limitation was the cost of acquiring very high resolution imageries such as QUICKBIRD, IKONOS and SPOT panchromatic which could have been good enough for this type of study. However, the available satellite imageries were Landsat (ETM) and Nigeria sat-1 with spatial resolution of 30m and 32m respectively. Their resolutions are not adequate enough, thereby imposing another limitation based on the difficulty in identifying some of the minor gullies. This however necessitated the use of aerial photographs in conjunction with GPS. For this kind of study, a higher resolution satellite would have been been preferred. Another problem was during the image classification when settlements and water bodies were classified as being the same, probably because the satellite image was acquired at a time immediately after the rains when the roofs of settlements were still wet. Settlements were deliberately overlooked since the focus of the study is on erosion.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This chapter is devoted to the review of relevant literature on the use of technologies of remote sensing, geographic Information system (GIS) and Global Positioning System (GPS) as tools in tackling or solving the problem of gully erosion, among other environmental problems and its impact on agricultural land. Because of the pressure on the land, this has drawn the attention of scientist world wide into research as to how to preserve or protect the land from further degradation.

Betts and DeRose (1995) used digital elevation models as a tool for monitoring and measuring gully erosion in Palmers ton North, New Zealand. Three sites were selected. Manguta, Huanui and Waipaoa. Separate DEM were constructed for each of the three sets of available aerial photography and on a 5m grid. Ground control was achieved in the field with a GPS differentially corrected to an accuracy of ± 1m. All forms of calculations and manipulation were achieved using Orthomax. Gullies were delineated on-screen, aided by stereoscopic analysis of the original photographs and were defined as areas of active erosion and were measured. To measure gully erosion from one DEM to the next; the recent DEM was subtracted from the earlier DEM to create a differenced image. Minus errors, negative pixel values in the differenced images represent erosion, while positive pixel values represent aggradations or tree growth and stable ground is represented by zero values. However, systematic errors were noticed resulting from the differenced images. They discovered that the success of the method used in the study was highly dependent on the quality of the input imagery and the pre-processing stage. Factors that influence the quality of DEM include photographic scale, camera calibration, scanners and ground control. They concluded that if due attention is paid to these factors, DEMs constructed from aerial photography can detect and accurately measure even small changes in surface features for just a little effort.

2.1 Gully and Riverbank Erosion

Gully erosion has acquired diagnostically, severe destructive features that must be treated seriously. The process of gully erosion is primarily water driven. Soil erosion, through channel and bank erosion, grows actively and may end up as gullies or gully erosion, (Igbokwe, 2004).Gullies continue to expand, widen and deepen into greater and older but more devastating gullies. Another aspect of soil erosion is bank erosion which occurs at the banks of streams, rivers etc. The land could be degraded as a result of loss in soil fertility, soil erosion and scarification.

The southern part of Australia suffers from gully and riverbank erosion, which serves as the dominant source of sediment supply to streams. The dominant erosion processes in Queens land vary from sheet wash erosion, to gully erosion over much of southern Australia and stream bank erosion in eastern Victoria. Researches revealed that less than 5% of potential 1.2billion tones of soil moved each year on hills slopes, and this is predicted to contribute to stream sediment loads. About 325,000km of gullies across the assessment area has eroded 4.4billion tones of sediment since European settlement.

Targeted restoration is required along streams and rivers where sediment and other riparian issues limit rivers' health, (Andrew etal (2001).

Many farmers in Ontario have already made significant progress in dealing with soil erosion problem on their farms. However, because of continued advances in soil management and crop production technology, they have maintained or increased yields in spite of soil erosion. Awareness usually occurs only when property is damaged and productive areas of soil are lost. (Wall, etal, 2004)

The Australian National Land Water Resources Audit (NLWRA) has produced predictions of gully extent across large areas of Australia, based upon extensive measurements from aerial photographs. It was successfully carried out via the generation of numeric rule - based predictive models for four regions of Australia. The prediction of the extent of gully erosion should be useful in regional planning of erosion control. NLWRA traced gullies on 428 stereo photo pairs. The analysis of the physical landscape of different areas was achieved using the selected aerial photographs. Lithology and rainfall distribution maps were used to ensure that a variety of landscape types were represented in the model. Using mirror stereoscopes, gullies were mapped onto transparency. Gullies were defined on the photographs as steep walled, poorly vegetated, incised channels with a small catchment area (<10km2). Measurements were taken on a regular grid of 5 to 10km spacing across the area, resulting in over 13000 sample points and at each sample point, 1km2 was examined. These measurements were being converted to soil erosion rate by considering the volume of soil removed to form the gully and its approximate age. It was observed that 0ne kilometre of gully would then produce 10,000 cubic metres (approximately 15000 tones) of sediment per km2 of land. This study reveals that spatial modelling techniques can be successfully used to predict gully erosion extent at the continental scale (Andrew, etal 2001).

Again, gully erosion map of some other more closely settled areas of Australia has been generated, covering some 1.7million km2. Gully density measurements were obtained from aerial photographs and previous land degradation reports. Because of the large degree of variability that occurs in natural processes such as gully erosion, accurate results require intensive mapping. The resultant gully density map shows the spatial pattern of gully erosion and demonstrates that gully erosion is a significant process on a National scale. This provides a useful tool for erosion control and river restoration, and in assessment of the extent of degradation (DNRE, 2001).

(Vandekerchhove, etal1996) tested ephemeral gully erosion model in Mediterranean environment and discovered that ephemeral gully erosion is the most important source of sediment production in upland areas. Despite the importance, only few physically based models have been developed to predict soil loss due to ephemeral gullying. Ephemeral gully erosion takes into account detachment of soil due to flowing water that transport sediments and changing channel dimension. The input parameters were defined as drainage area, watershed length, and concentrated flow length. Together with the input parameters, also depth, width and length of the ephemeral gullies were measured using Deferential Global Position System (DGPS) and folding rule respectively. It was however concluded that Ephemeral Gully Erosion Model (EGEM) is not capable of predicting ephemeral gully cross-section for the study area. For further research focus should be given to gully parameters. Nearly 20% of the total land in the region of Shiwaliks is under gullies (Kukal and Sur, 1992). It dissects the fields, impedes the tillage operation, damages agricultural and recreational land etc.

The Department of Science and Technology, New Delhi tried to examine the pattern and growth of gullies in relation to farmlands in foothill of Shiwaliks. A survey was conducted in 2002 in the region of Shiwaliks to study and map out the extent and distribution of gullies in the area. The study shows that the first order gullies constituted 57 to 85 percent of the total gullies, whereas the second order ranged between 15 to 33 percent in the area. Also about 60 to 89% of the total length of gullies was represented by first order gullies and 12 to 27% length was represented by the second order gullies. Thus, both length and number of gullies were dominated by first order gullies which are a neglected lot while deciding on control measures. This information would enable researchers to use the tool to advice the farmers on alternatives to reduce the gully erosion (GISdevelopment.net, 2004).

Kukal and Matharu (1998) in their own research studied the behaviour of gullies in relation to catchments characteristic of the foothill of the lower Shiwaliks. Gully erosion is responsible for significant soil loss in Shivaliks vast lands. First, the researchers divided the catchment areas into three landscape units, though differing in shape and size. A detailed field survey for gully erosion was carried out in the catchments. The catchments were divided into grids of 50x50m² on a contour map of scale 1:1000. Each gully was sketched on the map by measuring the distance from the pegs laid out in the grids. The areal (length and width) measurements were recorded to calculate the various shape indices. The whole area was graded on the basis of degree of slope steepness from the prepared slope maps of the catchments. Based on shape, catchment III was most prone to erosion followed by catchments I and II, which means the average slope of III, was the greatest (3.9.5%), followed by I (38.0%) and II (35.9%). However, sparse vegetation also helped in concentration of run-off water leading to rills and gullies. It was also identified that soil erodibility of both surface and Subsurface soils of the gully beds was highest in catchment III followed by II and I respectively. Gullies in the region are a function of catchment characteristics. The mean length of gullies increased with increasing order, thereby signifying the faster growth of higher gullies. This can be checked by controlling the gullies of lower order than of higher order. The need to protect the steep slopes cannot be over emphasised as they will likely result to the initiation of more gullies in the area.

Martines – Casasnovas (1996), in his work on gully erosion mapping using remote seneing, techniques in Anoia-Penedies region, NE Spain, noticed the gullies expansion to vineyard parcels that leads to reduction of their size, accessibility problems, marginal areas and soil loss. He said, other research work did not focus on the assessment of present activity of gullies that is important from the point of view of predicting near future gully erosion. It is important to note that rill and inter rill erosion by means of remote sensing is usually difficult. However he used the Normalized Difference

Vegetation Index (NDVI) method that can be inferred from the vegetation cover percentage on their walls. It is a ratio between NIR and Red bands whereby vegetation is enhanced and topographic effect minimized to create the illumination difference. The gully erosion mapping helped in identifying areas of higher activity, differentiating badlands and gully walls with distinct vegetation cover. The vegetation cover percentage can be estimated according to Martinez-Casasnovas (1996), using:

$$NDVI = PVI \times NDVIv + (1 - PVI) \times NDVIs$$

Where, NDVIi: NDVI of pixel i

NDVIv: NDVI of a complete vegetated pixel

NDVIs: NDVI of bare soil

PVI: percentage of vegetation covers in pixel i

The equation assumes that the reflectance registered by the sensor for a specific pixel is due to the mixed response of the vegetation cover and the soil surface present in that pixel.

Also (Bocco, etal 1990) tested gully erosion modelling using GIS and geomorphologic knowledge in two areas of Mexican volcanic Belt (Tlalpujahua and hausca), where agriculture is practiced on the gentle slope terrain and erosion prone areas. Using standard photo interpretation techniques, gully eroded areas were found to be glaring on the enhanced SPOT stereo images and land use. The study revealed that about 75% of gully erosion in the areas of agriculture occurs on slopes, less than 15% and nearly 50%

between 5 to 10%. This finding became possible through interpretation of results obtained using GIS procedures.

2.2 African situation

Pilesjo (1992) investigated the potential use of remote sensing, digital elevation models (DEM) and Geographic Information System (GIS) for soil erosion analyses in semi- arid environments in Ethiopia. He focused on the possibilities of estimating the four parameters known to be the most important for soil erosion caused by water in semi- arid environment. These parameters include field cover, rainfall erosivity, and slope gradient and slope length and were used in exemplifying the extent the input scale and data type may influence the estimated soil loss, using Universal Soil Loss equation (USLE). The study revealed that errors in field data dominate the errors in the satellite data, and that it is possible to use traditional regression method for field cover estimation using remote sensing data. No significant deference in terms of accuracy of the field cover estimation using Landsat MSS, Landsat TM and SPOT XS were found. The principal component analyses method was adopted for the estimation of rainfall erosivity through estimation of mean annual rainfall. Also the topographical factors were estimated from digital elevation models based on topographical maps at deferent scales (1:50, 000, 1:250,000, and 1:200,000).Significant differences between the factors estimated at deferent scales were found. He discovered that if the modified USLE was based on MSS data and a topographical map with a smaller scale (1:250,000), it yielded higher values of estimated soil loss than if it was based on Landsat TM data and topographical map with larger scale (1:50,000).

FAO (2003) conducted an aerial survey of soil erosion in Zimbabwe using the technology of remote sensing and GIS discovered that about 18000km^2 was severely degraded. The study revealed that 15300km^2 of this is in "communal lands", while 2700km^2 of this degraded land through erosion was in land of large scale farming enterprises. Analysis of 8500 aerial photographs further shows the following erosion categories in Zimbabwe.

15% is very severely eroded

13% is severely eroded

19% is moderately eroded

53% is in relatively good condition.

Based on estimates of rate of soil loss, existing depths of productive soil and minimum soil depth required for acceptable crop yield, a sample model was presented. The model predicted that one area of granitic sand was good for 10 years for maize, and 30 years for sorghum. A study of more than 30 countries conducted by FAO showed that most of the farmlands in these countries are losing nutrients through erosion than could be replaced by applying fertilizer or other control measures. FAO concluded that well-managed maize growing land loses 900t/km^2/year, small community farms loses 3600t/km^2/year.

2.2.1 Nigerian Situation

Many people are aware that Nigeria is currently under threat of physical land degradation through varying degrees of erosion, the most devastating being gullying. Much concern has been shown towards these phenomena the world over and several scholars have devised indices to determine the rate of degradation and quantify the amount of soil lost. In a study of soil degradation in Nigeria conducted by Federal Department of Agricultural Land Resources (FDALR), the widely applied index, the Universal Soil Loss Equation (USLE) was adopted as:

$$E = R.K.L.S.C.p$$

Where E = mean annual soil loss in tones/acre/year

R = the erodibility index of rainfall.

K = soil erodibility index.

L = slope length factor.

S = slope steepness factor.

C = crop factor.

P = conservation (land management) practice factor.

The various factors have to be empirically determined for any given location to know the soil properties which will help in determining the management method to be adopted. However, while this could provide a good measure of soil loss per year, it gives no indication of the extent or spread of erosion to determine the extent of degradation in Nigeria. Remote sensing approach was employed. Visual interpretation was carried out using satellite image maps (SIM) derived from SPOT XS (20m) satellite data from (1993 to 1995) and partly Landsat TM (30m) data. The data was resampled to fit the Nigeria topographical map series at scale 1: 250,000 (FDALR, 1999). Efforts were made to ensure that uncertainties in the interpretation were resolved through field checks; navigation to the feature to be checked upon was by use of available maps and hand held GPS.

The creation of interpretation key was an iterative process in which repeated field checks were done using maps, compass and GPS to identify features that could pose difficulties to the interpreter. However, two layers of interpretation on the Nigerian conditions were obtained from this interpretation. The first was the streams and the second was the soil condition, which indicated the extent of gullying in the country (FDALR, 1999). True form of wealth is the land and should be guided, protected and preserved. In 1945, the Government of the then Northern Nigeria appointed a committee to make an investigation into the causes of soil deterioration and the means of rehabilitating and improving the soil on the plateau. The committee recommended contour ridging to be taught, leaving grass strips along the contour lines at intervals, mulching and the use of grass floor, the aforestation of hillsides and restriction of grazing on them, the protection of farm trees, the planting of wind breaks and hedges on farm boundaries etc. (Odi, 1999:2).

Tukur and Ray (1998) identified the problem of land degradation on individual farmland within the locality of Michika: 55% Farm activities, 17% water erosion and 16% fertilizer exhaustion. The presence of gullies and rills erosion was accelerated by poor farming practice (clearing for cultivation) combined with terrain and heavy rainfall. It is good that the farmers are already enlightenened on the consequences of the land degradation, since the success of any soil conservation programmed depends on how much of the problem mean to the farmers. They suggested that the improved land preparation and cropping method, if adopted by the farmers especially the fairly educated ones, would reduce the land degradation. They have involved ADADP who introduced them to using vertiver grass because they compliment hill terracing that was practiced in the past. Presently a sizeable number of farmers are now engaging in practicing conservation measures including cover cropping and ridging across the slope.

Igbokwe (2004) identified Gully as the most prominent feature in the landscape of most part of eastern Nigeria. The topography of the area, the nature of the soil as well as the activity of man contributes to the speedy formation and spreading of gullies in the areas. During rainy season, large areas of agricultural lands and lives in some cases are lost to the spreading gullies. Availability of remotely sensed data from NigeriaSat-1 has created the opportunity to use the remote sensing technique to map and monitor the spread of gullies in the area. The gully sites identified and the pattern of spread of gullies was mapped using image classification method. On-screen measurement of gully parameters (lengths, widths and perimeters), followed by groundtruthing to confirm the existence and correct location of the identified gullies. At 30metre and 32metre resolution of Enhance Thematic Mapper (ETM) and NigeriaSat1, major gullies were correctly identified and delineated, and it was also discovered that about 3.77% (12km^2) of land was lost to gully erosion (Igbokwe, 2004)

2.2.2 Plateau situation

Overseas Development Institute (ODI: 1999) described the process of land degradation on the plateau as the outcome of the continuous over exploitation and mismanagement of soil resources through deforestation, mining activities, overgrazing, clearance of land for agricultural purposes with disregard to slope and topography of the land. Gully erosion causes several types of damages on the plateau. From agricultural perspective, the greatest impact of gullying is the dissections and reduction of farmlands, the increase of slope, the damage of infrastructure (paths ways and erosion control infrastructure), the damage of crops and the more difficulty in mechanical labours. From a soil landscape perspective, fertile soil layers are removed and terrain is highly dissected. This damage is non-recoverable in a short to middle term. (Martinez-Casasnovas: 1998). The fallow periods under shifting cultivation have become short to restore fertility in the area. The original cropping cycle of 10-15 years has been reduced to 5 years. Farin Lamba shows strong indication of irreversible soil erosion damage on the plateau.

Jone (1995) estimated that 316Km^2 (4% of the Plateau area) is covered with tin mining scars, leading to gully erosion. He also identified and mapped approximately 7,250Km^2 of active gullies representing a total volume of soil loss of about 100million tons. This type of research reveals facts that ought to put farmers and government on their footing with the view to taking the appropriate steeps to avert future occurrence. Frequent changes in the environment, either naturally or artificially, requires monitoring for assessment and control. Gully erosion, as one of the most serious environmental problems, has attracted the attention of many scientists World-wide. Various research works have revealed the extent of destructions to lives and properties as a result of this menace. And many more countries of the world are still suffering.

2.3 Preventive and Control Measures

Man is meant to overcome most ecological/environmental problems especially with the development of modern science and technology. All that is required at this stage in Nigeria is the will and the funds to support solve the problems. The engineering, agro forestry and the sociological techniques should be considered in the process depending on the degree of destruction. These techniques can be applied singly, jointly or in groups, depending on the available funds.

The main processes that usually recognised as governing the mechanics of gully erosion are down cutting and head cutting. The most effective way of gully control measures have been traditionally addressed to stabilise both the channel gradient and channel head cuts. In addition to these processes in Riyom, the two main facts that determine the retreat of gully walls towards agricultural lands and those new gullies developing are basically related to how the Jun-August runoff and infiltration water is managed.

The retreat of gully walls in the study area is mainly caused by mass movements and slips that are produced in the saturated zone of gully walls. This is caused by infiltration and accumulation of water in the lower parts of the parcel (Plate5). To avoid the saturation of water in gully bordering areas, the interception of the sub-surface water flow by means of belt drainage system along the border between the parcel and the gully is suggested or proposed.

Another process of gully wall retreat and extension of the gully network through the most farmlands are mainly caused by the concentration of water in drainage channels or in natural concave areas. The outlet of these channels is located in the border between the farmland and gullies. During high intensity rainfalls, the length of the water flow on the outlet of drainage channels produces the erosion on the gully wall border and the development of new gullies towards headwater areas. These new gullies usually experiment a rapid growth due to the high relative relief with respect to the base level of the main gully. On the other hand, the free way out of water in the border of parcels may constitute waterfalls. The free fall and run off water on the gully wall erodes the base, and the upper part of the wall finally falls by gravity. A proposed solution for this problem is the canalization of runoff water from the present outlets to the gully water courses. However, proposed measures should be complimented with others to reduce the menace. Another is that vegetation is one of the primaries long term means by which gully erosion can be controlled. It means all gullies need to be fenced from livestock and are revegetated along the gully floor, sidewalls and surrounding areas. However, this might be difficult to establish vegetation on gully sidewalls due to moisture stress, but carrying out irrigation could get vegetation established there by reducing the menace to a great extent if not total prevention. In addition, sidewalls could be revegetated and the surrounding areas with trees and grasses. Diversion of structures could be effectively used to control gully erosion if the runoff water can be safely diverted away from the gully head with contour drains by designing. Properly designed diversion structure may serve as the only means to stopping head ward advance in many gully systems.

CHAPTER THREE

MATERIALS AND METHODOLOGY

3.1 Introduction

Gully eroded areas which are clearly depicted on stereo aerial photographs, can be mapped using standard photo interpretation techniques. Since satellite based remote sensing is an appropriate tool for covering large areas frequently, it is of great interest to investigate the potential of remote sensing methods for studying gully erosion. Remotely sensed data could offer fast and cost effective measurements over a large areas (Pilesjo, 1992).The spectral resolution contained in the colour composite of Landsat ETM aids in land cover and land use mapping .The data could be resampled to fit into topographical sheet of scale 1:50000.

When using remote sensing, location data is necessary in geometrical correction of satellite data and in positioning of field features. Localization is also a common problem when working with Geographic Information System (GIS). The use of GPS for navigation and positioning has increased in the recent times. Since the use of GPS is increasing, and it is sometimes assumed that the errors connected with GPS measurements are negligible, it is important to investigate the magnitude of positioning errors. Existing maps were also incorporated in the GIS database. Simple GIS procedures make it possible to georefernce and quantify these features .Also it allow the mapping of geomorphic defined landscape units. A topographic map permits the construction of digital elevation model (DEM) and derivation of slope gradient map.

By combining the appropriate maps, (land use/cover, slope gradient and terrain mapping units), the eroded area can be determined quickly using GIS and decision can be made. Attention can now be paid to the more affected areas with the view to finding a solution to adopt to combat the menace. Both mapping and monitoring represent important pre-requisite for drafting and implementing developmental plans for sustained use of land resources on the plateau.

3.2 MATERIALS

Materials used are:

(a) Global Position System

(b) Images

- Aerial photographs
- Landsat ETM

(c) Mirror stereoscope

(d) Topographic map

(e) Soil map

(f) 30m Measuring tape

(g) Terrestrial Camera

3.2.1 GPS

The Global Positional System GPS comprises of 24 orbiting satellite that provide instantaneous navigation/ position information to anyone. Garmin 12 GPS, tracts satellite 20,000km above the earth, and the complete constellation will include 24 satellites.

Garmin 12 can obtain a position in either two dimensions (Latlon) or in three dimensions (latlon and altitude). Errors of ±5 metres or less in estimating the antenna altitude can be ignored.

3.2.2 Images

3.2.2.1 Aerial Photographs

The use of aerial photographs, panchromatic black and white at a scale of 1: 10,000,focal length of 152.24, flying height 1522.4m, taken in 9TH November,1981 when the weather was clear, hence better resolution aiding interpretation of areas with high gully activity. Twelve overlapping aerial photographs covering the study area are of run 3 and run4 with 60% side lap and 20% lateral lap. They were sourced from ministry for Lands and survey, Jos. Field work and Landsat ETM (2001) were used to supplement the edge of the aerial photographs.

3.2.2.2 Landsat ETM

The Landsat ETM image of July, 2001, acquired during the rainy (wet) season, when most vegetation and crops are at their peak of greenness made it easy for classification. Launched in 1982, it acquires images in seven bands with a temporal resolution of 16days, spatial resolution of 30m and swath of 185 by 170km. Data was obtained from national centre for Remote sensing, Jos.

3.2.2.3 Other data used

The study area was extracted from a **topographical map** of 1: 50,000 with contour interval of 50m. The mapping was done from aerial photographs taken in October 1956, published in 1961 and reprinted in 1971 as Naraguta sheet 168SE. This aided in the generation of digital elevation model for the area.

Soil map covering the study area was obtained by interpreting the 1981 aerial photographs using the mirror stereoscope (see table below). The soil erodibility (K) values were obtained by digitizing the generated soil map from aerial photos at scale 1:10,000. Lining tape of 30m long was used essentially for measuring widths and depths of short gullies. Integrated and Water Information System (ILWIS) software was used for the data processing and analysis, and Arcview for the presentation or output.

Table3.1: Type of data and sources.

Data type	Year	Month	Resolution	Scale	Sources
Aerial photographs	1981	Nov.		1:10000	State Min. of land and Survey, Jos
Landsat ETM	2001		30		NCRS, Jos
Topographic map	1964			1:50,000	State Min. of land and Survey, Jos
Soil map	2003	May		1:100000	Geography Dept. Unijos
GPS points, measurements, photographs	2004	July/Sept			Field observation

3.3 METHODS

3.3.1 Global Positioning System

The GPS and the reference points were transformed from geographical coordinates (WGS84), which is the out put from the GPS receiver, to the Universal Traverse Mercator (UTM) projection (zone 32). This was done for the purpose of adjusting the errors in metres, which makes them independent of their localization on the earth surface. However, the differences between the reference point and the GPS points were calculated and presented as errors in both horizontal and vertical directions.

3.3.2 Field data collection

During the field work, conducted in July/August, 2004, measurements were made to determine the location of gullies (see plate2.1) and the location of four calibration points used in the geometric correction of the aerial photographs and Landsat ETM imagery.

A Garmin 12 GPS was used. The measurement was based on sampling because some gullies are too deep, thus difficult to perform meaningful measurement.

A Garmin 12 GPS was used. The measurement was based on sampling because some gullies are too deep, thus difficult to perform meaningful measurement.

Plate 2.1 Fieldwork at one of the active erosion area

For the data to be presented for final analysis, it is very important to go to the field. This is to confirm the existence and correct locations of the identified gullies and assess the impact of the gullies on the farmlands and the immediate environment (See plate 1.1). At this point, active eroded areas, semi-active and stable areas were noted by taking the GPS points. To locate other gullies within the study area that could not be visible on the image (See plate 2.1).

3.3.3 Oral interview

An oral interview was conducted using farmers who cultivate crops in the active erosion areas. It concerns the crop yield for three years. They could remember these things vividly because of the menace erosion have thrown them into. There were several questions ask, but because I was only interested on the crop yield, I recorded just that as you will see there responses much later.

3.3.4Geometric corrections

In order to locate the gullies, especially, those not identified on the satellite imagery, and make the satellite data geometrically compatible, geometric corrections were carried out. All geometric corrections were applied on radiometrically corrected satellite data. The geometric correction of the Landsat ETM data was carried out; four points positioned with the GPS were used as ground control points. The points were taken at easily identifiable spot, both in the field and in the Landsat imagery. Before using ground control point, they had to be transformed from latlon (WGS84) coordinates (GPS output) into Universal Traverse Mercator (UTM) coordinates (preferred projection). When using a UTM projection, the coordinates are presented in metres instead of degrees, minutes and seconds (as with WGS84).The UTM projection was chosen since it results in pixel with equal areas, independently of their position in the satellite image. The transformation was achieved with software TOPO.

3.3.5 Data acquisition/capture

Since the satellite imageries are in digital format, the analogue topographical and soil maps were converted into digital format by scanning and digitizing onscreen. The map sheet was scanned with a resolution of 400 dots per inch (dpi).Since the maps were scanned, they automatically assumed a raster format and were imported into ILWIS software environment. The coordinates that were in inches were transformed into UTM projection and zone 32 using ILWIS software.

3.3.6 Digitization

Digitization is the conversion of analogue map into a digital map (Analogue to Digital). There exist a number of digitizing techniques. The common techniques used are manual digitizing from digitizing tablet or on- screen digitizing using a backdrop of the actual map or imagery. Both techniques however, require manual tracing of features from a digitizing tablet or on- screen with the help of a hand-held cursor. Manual on-screen digitizing, also called heads-up digitizing, has the advantage that old vector data can be displayed on top of the backdrop in order to detect changes.

Selecting a digitizing technique depends on the quality and content of the map sheet. For example, for complex documents full of detail and symbols (like topographical maps, aerial photographs), manual digitization is preferred, while automatic digitization is preferred for documents with few type of information. For this project, on-screen digitization was adopted. From the file menu, a coordinate system was created and a coordinate system projection, ellipsoid, datum and the zone selected. Also minimum and maximum values for x and y coordinates entered as follows:

Minimum X =473672.97

Maximum X =478593.68

Minimum Y =1064695.38

Maximum Y =1070852.99

All the scanned maps were georefernce to correspond to the digital image. The contours were digitizatised successfully on-screen. The standard process of digitization was followed to achieve the maximum accuracy required to execute a project. The accuracy of the output depends solely on the data conversion and hence for decision making. Subsequently, themes were created in layers (contours, drainage, settlements,) for better management of the data.

Aerial photographs were scanned with a resolution of 400dpi.Mosaicking of aerial photographs was successfully carried out in the ILWIS environment using common tie points or overlapping points for georeferencing purposes. Georeferencing was done in preparation for digitization. Themes were created (bare land, vegetation, degraded land, farmland, and settlement). Pilesjo (1992) showed that soil erodibility factor (K) can be obtained from existing soil maps. The borders of the various soil units with deferent soil erodibility were digitised. The polygons created were then rasterised and geometrically corrected to the other data layers included in the Universal Loss Soil Equation adopted for Plateau conditions

3.4 Data Processing

The image window of the study area was processed using the standard image processing techniques. Restoration, rectification, enhancement and classification of themes such as water body, bare surfaces, vegetation, degraded land, rock and settlement (see 3.4.2).

3.4.1 Identification of gully sites on the Image.

Gully sites in the study area were identified and characterised on the satellite Image into partial or completely eroded. Partial means control measures can be applied with 90 percent success, while completely eroded means all materials have been transported in a large volume away from its position. The pattern of spread of gullies as well as land use was mapped using image classification method. The software performs these operations automatically by specifying the command. The next command allows non-gully features to be eliminated by applying threshold derived from known gullies, leaving sites and outlines.

3.4.2 Delineation of gully sites and features

The mosaicking of the aerial photographs provided a planimetric correct base map, from which gully areas could be accurately measured. Gullies were delineated on- screen aided by stereoscopic analysis of the original photographs, and were defined as areas of actively eroding, bare surfaces that were contiguous, the incised channel system that drain them, vegetation cover/farmland and settlements. Land use interpretation was based mostly on cover data provided by photo interpretation key and the farming pattern also aided interpretation. Gully sites (major and minor) Image classification was equally done to delineate into classes as mentioned above

Fig: 3.1a Aerial photograph 1981

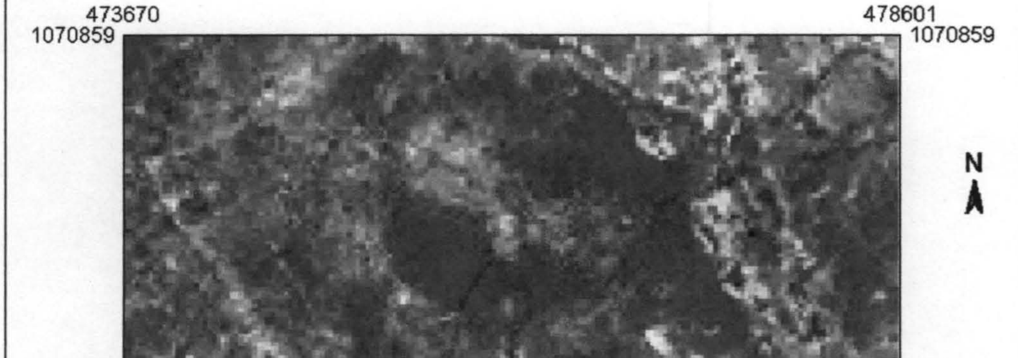


Fig. 3.1b: Satellite imagery 2001 (Landsat ETM)

3.4.3 Measurement of geometric characteristic of gully sites.

On-screen measurement were conducted of gully parameters such as area, lengths, widths and other interested features that were investigated during field work. Using the measurement tool, all gully sites visible on the image were measured. Physical measurement of some of these geometric parameters, such as depths and width which were not possible on-screen were achieved.

3.4.4 Data base creation

To allow GIS play its role, a database was created. GIS is a computer based system capable of acquiring, storing, retrieving, processing, analysing and displaying the geographic data.

3.4.5 Digital Elevation Model Generation

The topographical characteristic of a point in a three dimensional land surface and its drainage are commonly required in soil erosion modelling. Topographical map covering latitudes 09° 38' 50"N, 09° 41' 48"N and longitudes 08° 47' 46"E, 08° 48' 00" E was used in the study. The area's minimum elevation is 1173.48metres and the maximum elevation is 1371.60metres. The vector data was then rasterised in ILWIS software environment and was drape on the satellite image covering the study area.

3.4.6 Slope map

A slope gradient map was generated based on elevation data digitized from the topographic map. Contours were digitized at 15 metres interval. Based on the nature of the relief, all the contours were digitized and the slope map was constructed or achieved by rasterizing the contours, that is vector to raster techniques and this would aid in determining the eroded terrain per land use classes as presented in the next chapter.

CHAPTER FOUR

RESULTS AND ANALYSIS

4.1 Introduction

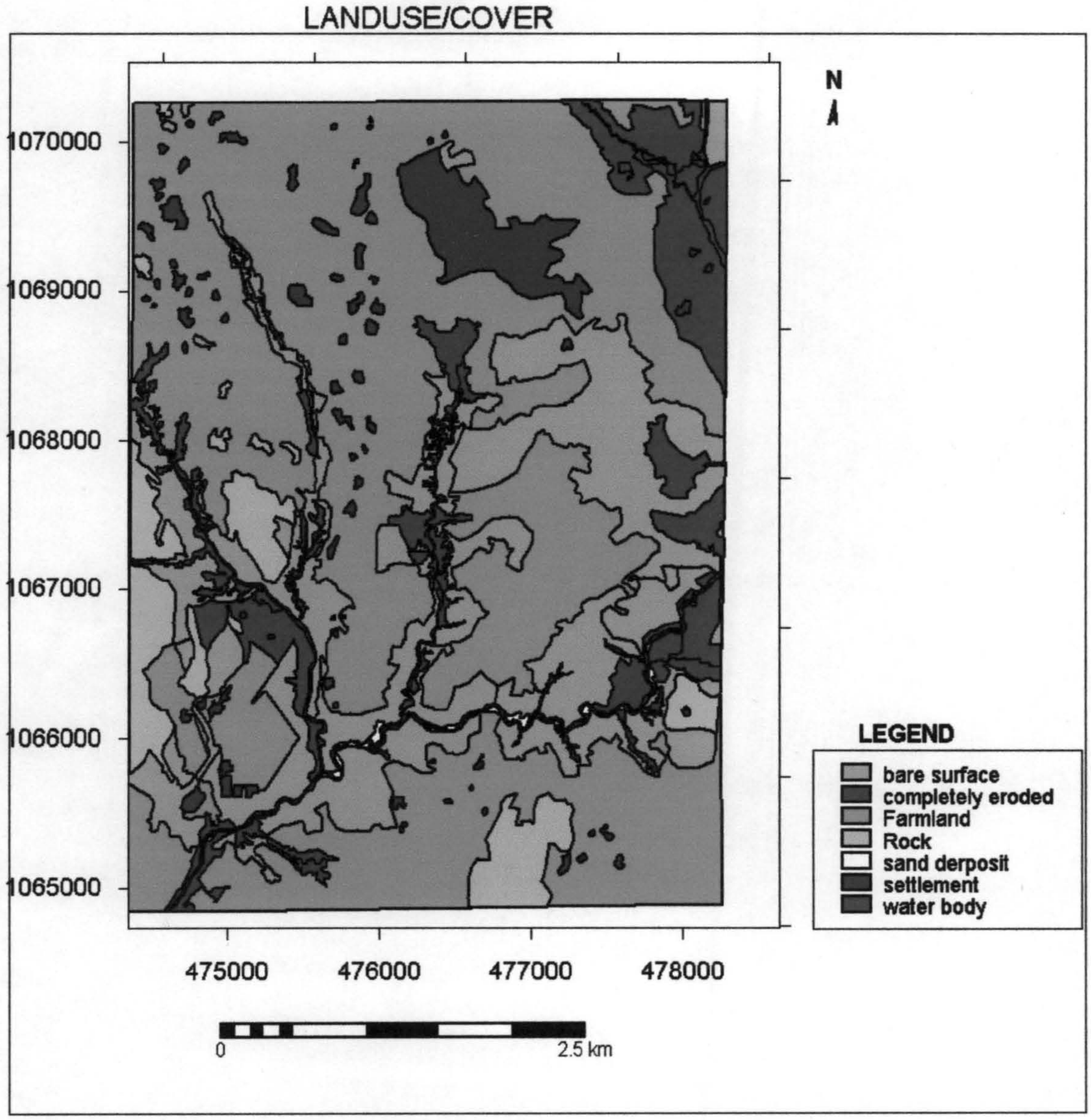
The gully erosion problem in the area is described by characteristic of gully network density, pattern, gully-eroded area, gully-eroded volume and side wall vegetation cover. A map of gullied terrain was derived from the aerial photographs.

The calculation of the rate of erosion was made by the analysis of multi-temporal data in the sample area. This estimation attempted to portray an average growth rate, the areas of new gully development and expansion. The presences of rill erosion at farm level are potential for gullying as shown by the development of new gullies. The estimation of the growth of existing gullies and the amount of retreat of gullies can easily be measured. Therefore, the potential for erosion by retreat of heads and walls of existing features is considered as an unexplored new approach on the basis of the use of remote sensing and GIS techniques.

4.2 Results, Analysis and Discussion

4.2.1 Land use

From the interpretation of aerial photographs of 1981, a land use/cover map was produced (Figure 4.1).It was observed that there was increased vegetation cover and agricultural practice on the reclaimed areas on the slopes. Another important thing to note is that the crops are not looking healthy due to the lost of essential nutrients in the soil (plate 4a and b)



. **Fig.4.1: Land use/cover map of the study area**

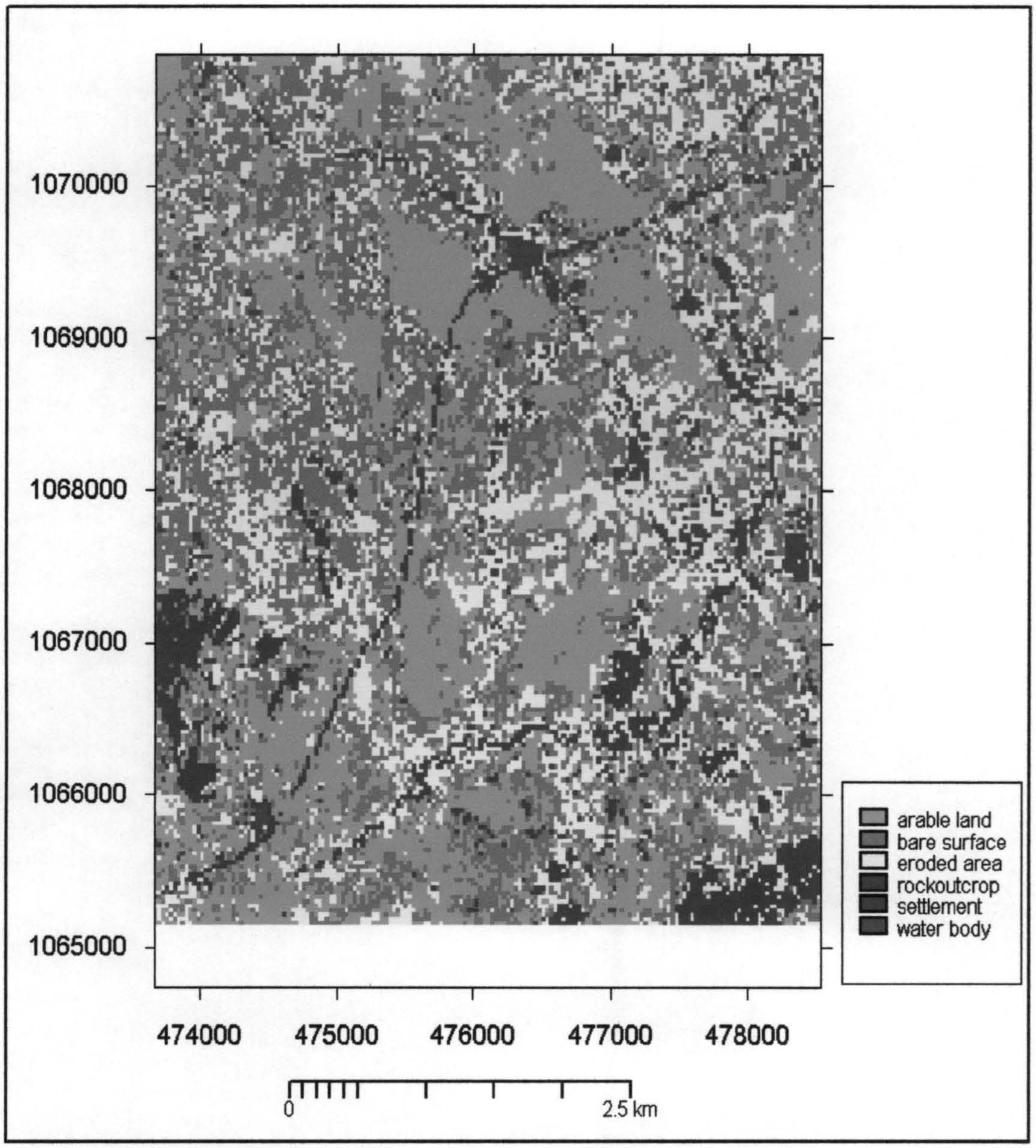


Figure : Classified Image

The total area affected by the retreat of gully walls on farmlands, considering a period of 20 years, is 252.46Ha. The estimated rate of gully erosion is 12.123ha year-[1] along the perimeter of the gullies. The rate at which farmlands are destroyed is alarming as it poses a great danger to farmers that own these farms. Agricultural land employs about 80 percent of the population in Riyom due the soil fertility that supports crops like maize, Irish potatoes, Acha, Millet and vegetables such as Tomatoes, Cabbage, green beans, etc as is the case in most parts Plateau state. The implication of this is that more pressure on the land resulting to poverty and subsequently increasing rate of conflict. Plate 4a and b revealed that farmers are beginning to reclaim part of the eroded areas by cultivating within the affected area. This is because only a little of the useful land is left for cultivation. The traditional farming method could account for most of the erosion processes as the origin is from the farmlands.

Plate 4a

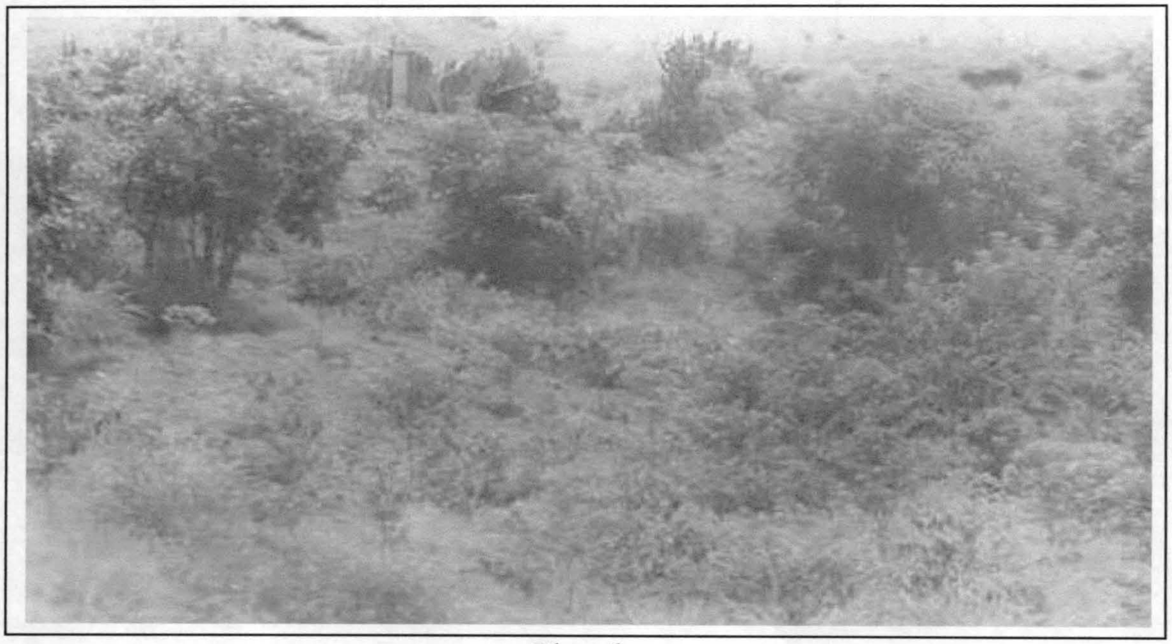


Plate4b

Plate 4a and b: Cultivation inside the gully

4.2.1 Drainage Network

The drainage network system of Farin Lamba area shows a different characteristic in the various landscape units (Figure 4.1). The underlying parent material affected extent of dissection of the drainage pattern. On river 'Got' however, are the presence of residual deposits along the river sides especially where erosion is still active (plate4.1) characterised by network of deep gullies. The estimated gully- eroded volume, in the recent times seems to be impressively increasing as the eroded materials are transported and of course without replace ment. Although the landscape units analysed have similar drainage density values, it was observed that the density per type of drainage element, eroded gully areas and volume were observed (Table 4.1).

Table 4.1: Drainage density and gully-eroded areas in the main landscape.

Landscape Unit	Area of the unit Km^2	Type of drainage network element	Drainage Density km /Km^2	Gully eroded area(with respect to landscape unit)
Hilly area [A]	50.95	• River bed • Medium size gully • V-shaped valley	2.70 10.72 1.58	9.6
Gentle slope(central area) [B]	21.51	-Large gullies -Medium size gullies -Riverbed -Others	25.69 5.60 7.81	25.7
Low areas(eastern area) [C]	51.94	-Large gullies -Medium size gullies -Others	25.43 14.82 5.65	16.9

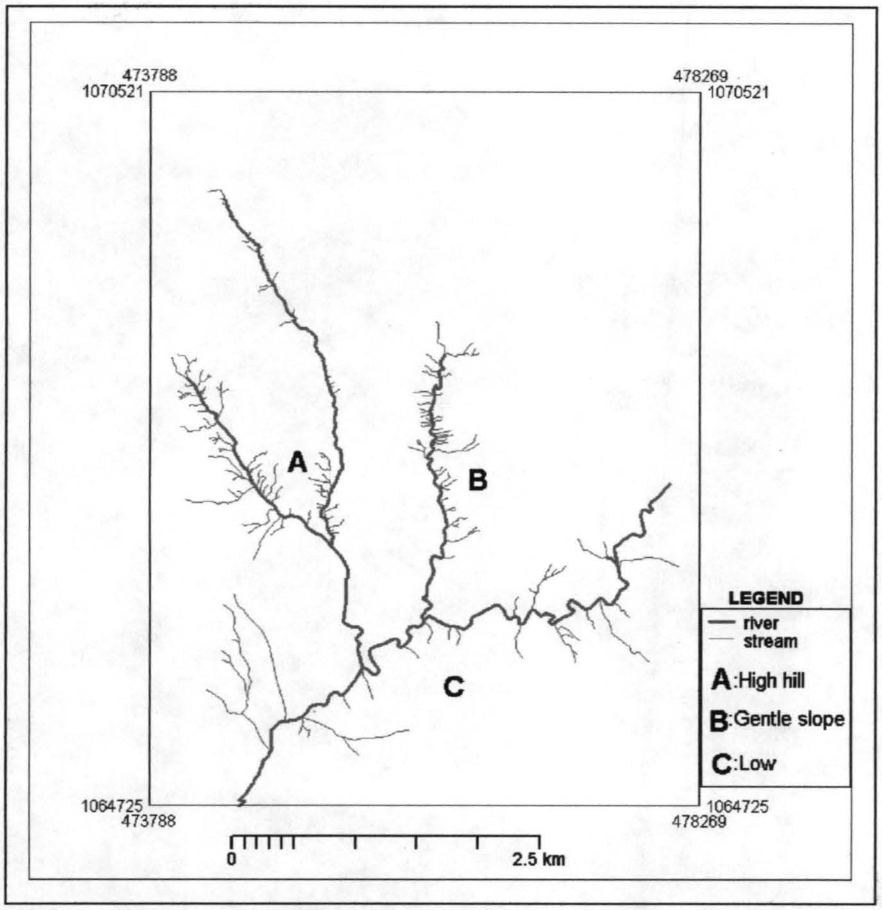


Figure 4.1: Drainage network of the study area.

The cross-sectional dimensions of mapped large gullies ranged between 14.12 to 53.25m depth and 22.99m to 420.34m width, can be an indication of the magnitude of the studied phenomena. All the landscape units show gully erosion problems. The highest degrees of erosion are found on the gentle slopes. The lowest degree of gully erosion is found in the hilly unit and this can be termed as moderate. The type of material present in every landscape unit accounts for this difference in erodibility. The hilly unit consists of hard granite, the parent material while the gentle slope consists of mostly agricultural activities. Nevertheless, terraces are frequently cut by gullies (plate 4.2).About 70 percent of the total area is made up of gullies that are classified as severely eroded and covered by low vegetation, mostly grasses. Also, approximately 20 percent of the gully-eroded area was classified as bare surface, with little or no vegetation. The remaining 10 percent is made up of the rock outcrop and hills.

Table 4.2: Erosion activity class and main erosion processes on gully walls in Riyom LGC.

Erosion activity class	Erosion Processes on gully walls
Severely eroded	- sheet erosion - Bank erosion and wall failure by toppling
Partially eroded	- Sheet erosion (low intensity of processes).
Partially eroded-stable	- Caving due to soil saturation - Undercutting by parcels drainage flow.

Source: Dang (2005)

The gullied terrain consists basically of relatively deep valley side (usually between 15 - 20m deep). Gullied terrain can be conveniently interpreted on the basis of tone, shape and pattern. Gullies have high reflectance, are irregularly shaped and present recent geomorphic features on depositional area. The areas classified as severely eroded are the actual active areas shown by the processes of wall failure (Plate 2). Lateral expansion of gullies is accelerated by the side wall falling resulting from infiltration or over saturation.

Plate4.2: Expansion of sidewall

Plate 4.3: Head scarp recession

The drainage system of the parcels concentrates the flow in few outlets. The water flows within the border of the gullies especially during high intensity precipitation. Also the accumulation of runoff at gully bordering areas produces soil saturation.

This becomes an indicator, the bases of gully walls and produces the wall failure. This later indicates circular slips that result on the falling of gully walls as is the case in plate 1. The existence of vegetation cover reduces mainly sheet erosion; hence soil losses decrease on sidewalls. However, it does not imply that gullies stop growing into different branches since other erosion processes occur. Such processes may be easily detected from a high resolution remote sensing data.

4.2.2 Slope

The table 4.3 shows that greater than 80 percent of the erosion on originally grass-covered terrain occur on slopes between 0 to 5°. Most of the remaining 25 percent (slopes greater that 5°) occur on the hilly terrain. This analysis helps us to clarify a particular pattern regarding land use/cover and erosion in the denuded metamorphic rocks and also on the slope areas. Erosion occurs more on the gentle slopes compared with the rest of the areas due to the nature of the parent material made up basically of soil. Water flows from the hilly unit (made up granite as parent material) with a great speed and on approaching the gentle slope, (made up of soil) cannot stand the pressure and is detached by the moving water easily. Therefore the topography contributes a lot to the detachment of soil material in Riyom area.

Table 4.3: Erosion variation as per slope class

Slope class	Ha	Eroded area percentage (%)
0 - 5	5631.48	89.41
6 – 10	463.12	
11 -15	122.12	1.95
16 -20	47.73	0.76
21 – 25	22.30	0.35
25 -30	11.40	0.18

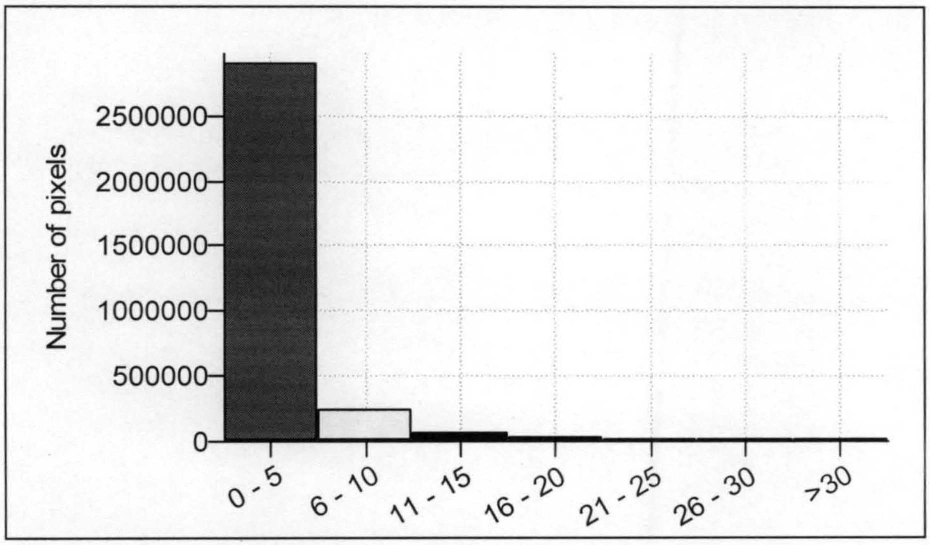


Figure 4.2: Gully erosion on arable land per slope range

4.2.3 Rate of materials losses in catchment B

The Digital Elevation Model (DEM) draped on the satellite image, clearly shows the most down cutting, mass movement and bank erosion active areas as well as areas that received materials as a result of mass movement (Figure 4.4:Digital terrain model). The most active down cutting processes can easily be located at the heads of the gullies on catchment B (Plate 5: Active down cutting and mass movement). The heads rapidly try to reach the local base level, producing a big deepening. During the study period, the head of the gully deepened and increased to approximately 35m.

Plate 4.4: Active down cutting and mass movement

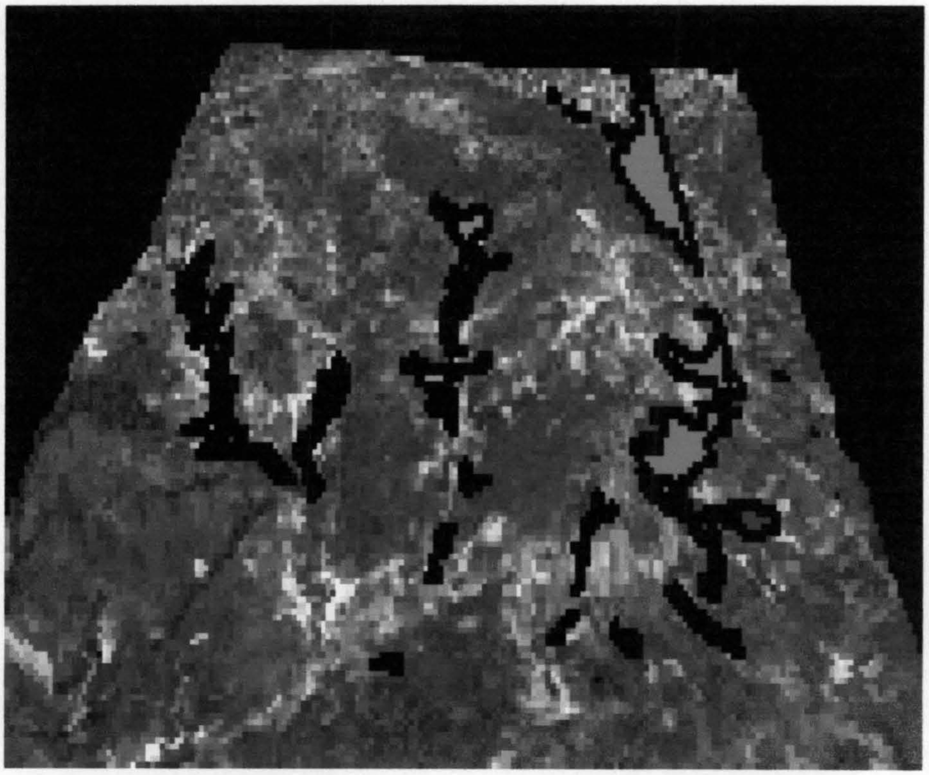


Fig. 4.4: DEM,

4.2.4 Impact of soil types

The soil texture was found to consist of fine earth fraction and coarse particles and very suitable for cultivation. The aggregated nature of the soil appear to make it very susceptible to gully erosion, so that contour ploughing and strip cropping on the contour should be encouraged, even on moderate slopes. Since lithosols or litthosolic soils are common in the area, they are porous and therefore aid water in transporting them away from their original position. The soil is however adapted to a variety of wide range of crops. The main crops in the area are basically Irish potatoes, maize, cocoa yam, millet, accha, guinea corn and some cassava is also grown.

4.2.5 The Extent of gully growth between 1981 to 2001

Change analysis was performed in one of the catchment areas called overlay operation or map calculation where area calculated was compared with marginal difference noticed.

The analysis of changes in the gullies in terms of width and length showed an apparent reduction of the total area mapped length of gullies. Importantly too is the filling of gullies by farmers to achieve bigger parcels or reclaim back the same parcels lost to erosion (plate 4.2). The need to maintain the land becomes necessary as the population keep increasing which means more pressure on the land that remains unchanged.

Table 4.4: Changes as measured on imagery and field

	Measurement on	Width	Length	Differences	
				Width	Length
1	Image	194.34	268.62	0.92	-0.67
	Field	195.26	267.95		
2	Image	99.81	325.94	0.71	-2.33
	Field	100.52	323.61		
3	Image	89.02	278.65	1.1	-0.65
	Field	90.12	278.00		
4	Image	45.93	259.76		
	Field	46.10	261.54	0.17	1.78
5	Image	25.16	305.38	1.16	9.87
	Field	24.00	315.25		
6	Image	22.99	498.86	0.51	-1.1
	Field	23,50	497.76		

Source: Dang (2005)

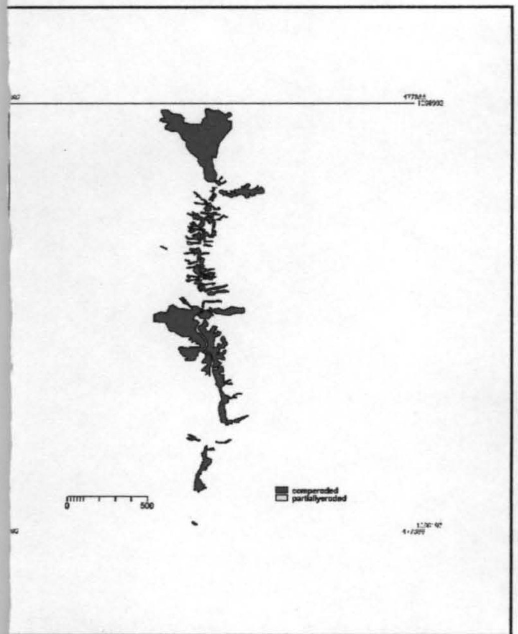


Fig.4.5 Erosion map of catchment B

Plate 7 Catchment B

4.3 GIS Analysis

4.3.1 Identifying and delineating the type of gully.

Geographic information systems (GIS) help to ask questions such as where is what? To know the location of the problem and the nature of the problem could help decision makers in terms of funding during implementation. This can be achieved through spatial query analysis of the database. Figure4.6 below shows information about one of the active erosion spot

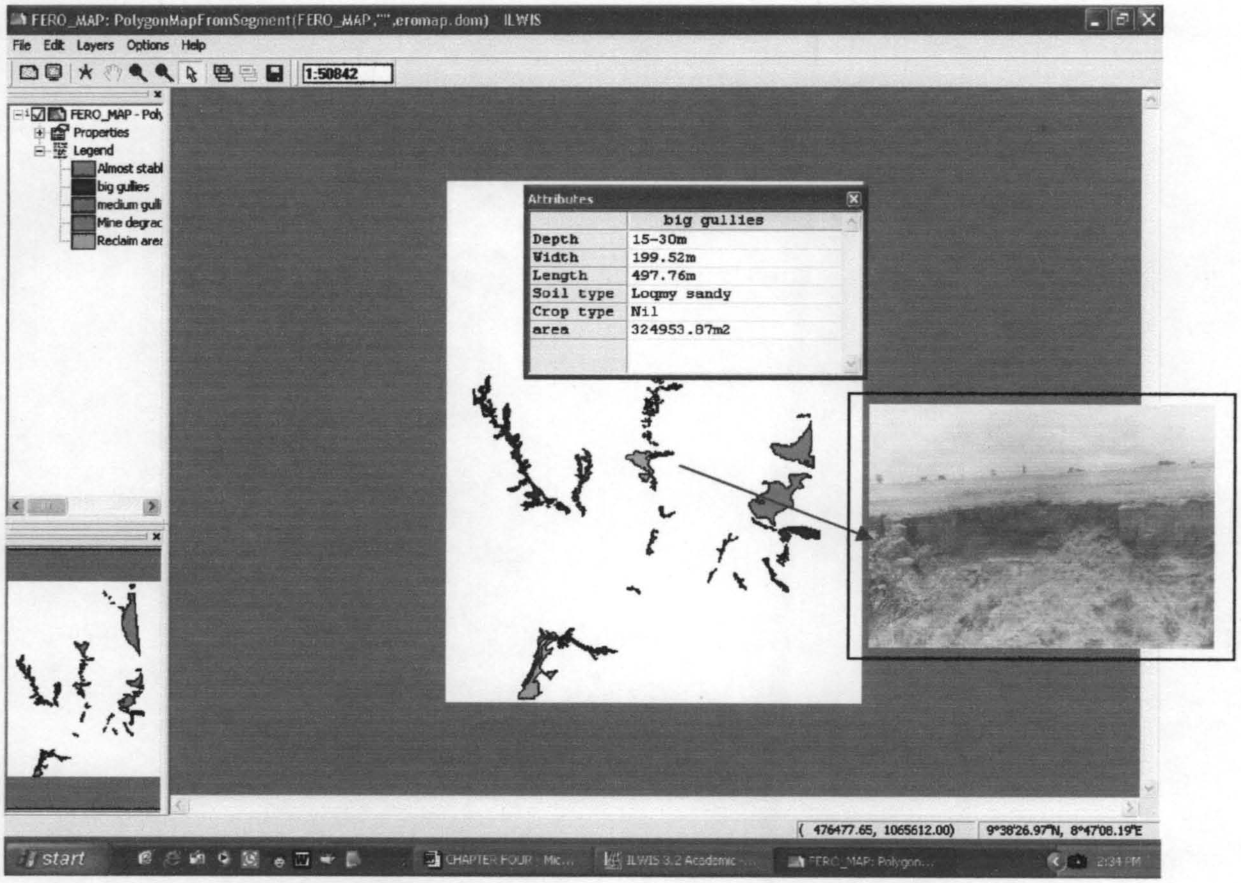


Fig.4.6: GIS Database of the active erosion area

4. 3 3. The risk of development of new gullies.

The gully initiation risk model developed by Meyer and martinez-Casasnovas 1998) was adopted. The study here reveals significant differences on the risk of new gully development in the deferent landscape units. The difference could be the result of distinct relief characteristic and soil properties. The landscape unit with the highest risk development of new gullies is the gentle slopes. This is where agricultural activities are prominent and covers about 80 percent of the total land. The parent material (the steep slope) of the hilly area is resistant to erosion processes so that water flows at a considerable speed without actually causing friction within the soil structure to loose, until it gets in contact with the soil on the gentle slope. The landscape with the lowest degree risk is the steep slope that consists of hard parent material. During the rains, the runoff water from the hills disintegrates the soil structure as it moves down the slope carrying materials along resulting in the development of new gullies in agricultural parcels.

Figure 8: Development of new gullies

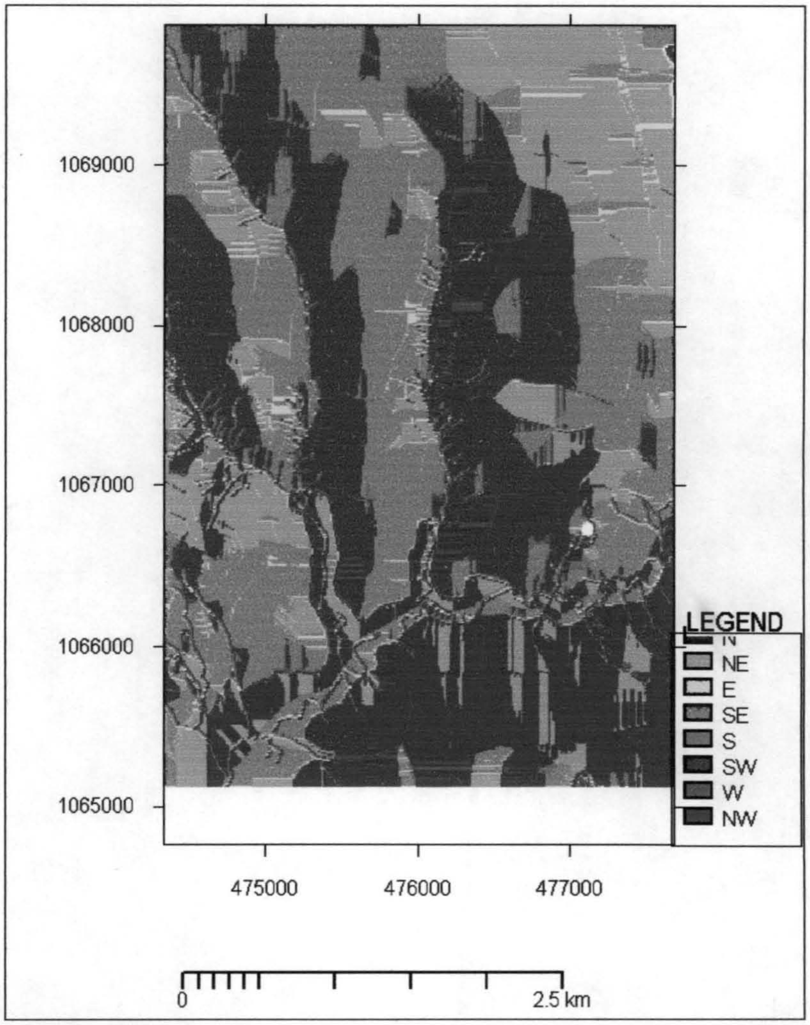
4.4 Impact of gully erosion

4.4.1 Possible erosion prone area

The study revealed that the highest degree of erosion occur on the gentle slopes while the lowest is on the hilly area. The type of parent material accounts for this type of unfamiliar situation. The hilly areas are made-up of hard granite while the gentle slopes consist of soil, where agricultural activities occur. The traditional method of farming did not take into account the flow direction resulting in accelerated erosion processes.

4.4.2 Flow direction

Hydrological flow was achieved by the combination of DEM estimation and the drainage map. This totally agrees with the fact that water erodes mostly the gentled slope as it flows down the slope. The parent material accounts for such structure since little or no water erosion takes place on the exposed granites.



Flow direction

Figure 4.7

Figure4.7 indicates that small slopes are most affected by erosion coupled with the fact that cultivation is actively practiced in these areas. Although the cultivation is traditionally done but it looses the top soil such that erosion is accelerated as water detaches the materials and deposits it elsewhere. The map shows the direction that supports where and why erosion is active, although attributed to the soil texture.

4.4.3 Farmland sizes

(a) Reduction in land productivity for agriculture: Gully erosion destroys the land permanently such that it becomes sub-marginal and no longer useful for any purpose. It was estimated that over 1.7million tons of soil may have been lost annually to erosion on the Plateau. From the findings of this study about 252.46Ha of farmland was lost to erosion in the past 20 years (50% of agricultural land). The change analysis also revealed that if nothing is done, in less than 10 decades, all arable land would be taken over by gully erosion. This is because new gullies keep coming up. It equally has an advert effect on grazing land side by side cultivation. Livestock requires vast land for grazing which has drastically been reduced by the process of erosion and the deep gullies also becomes death traps to the animals.

b. Reduction on Crop yield

The crops cultivated on bush farms in Farin Lamba of Riyom L. G. A. include millet, Irish potatoes, maize and vegetables. The prevalent farming system are mixed or multiple cropping. Only Accha is mono-crop and on exceptional cases millet. Livestock keeping is yet another mixed farming system. The table below shows different in yield of some product based on an interaction with some of the local farmers.

Table 4.5: Estimated Annual Production of some selected crops near erosion zone

Crops	Period 2001-2003		
	2001	2002	2003
Millet	4542 Metric tons	3767 Metric tons	3680 Metric tons
Irish Potatoes	15720	13100	11871
Maize	1892	1400	1259
Accha	2865	1930	1500
Cocoa yam	140tons	Nil	Nil

Source: Dang (2005)

The products in terms quantity and quality keep decreasing year after year, resulting from the menace of erosion. This certainly would have an adverse effect on the economy of the community, state and the country at large. The need to protect the land can not be neglected or overlooked, but a priority of individuals, communities and government at large. Reduction in agricultural production means food shortage; high food prices and famine adversely affect nutrition and health of the population leading to decline of labour productivity. As farmlands are destroyed by erosion, the increasing farming population cannot find suitable lands to grow their crops. This may be followed by fragmentation of the remaining good land and in turn result in over exploitation of the land with declining output unless the fertility is improved by planting cover crops or application of manure/chemical fertilizer.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS.

5.1 Summary

Gully erosion is one of the phenomena that cause several types of damages on the plateau especially as it affect agricultural land. The greatest impact of sullying is the dissections and reduction of farmland sizes, the damage of crops and increases slope that poses danger to both plants and animals.

The study involves an assessment of the impact of gully development on farmlands in Fari lamba area of Riyom LGA. The study also involves mapping and measurements using aerial photographs and satellite imagery of different periods. It was achieved by employing RS, GPS and GIS integrated. Using ILWIS software, delineation of gully sites was possible by digitizing on-screen all themes required. Physical measurement of some of these geometric parameters which were not possible on-screen were achieved to supplement the age of the data. The analysis was also carried out using the same software where by various maps; tables' charts etc. were obtained.

Figure 4.1 shows that about 252ha of land has been lost to erosion in the past 20 years (50 of agricultural land). The estimated rate per year is 12.123ha. The change analysis also revealed that if nothing is done, in less than 10 decades, all arable land would be taken over by gully erosion. The implication is that farmlands are reduced in sizes, more pressure on the land and subsequently increasing rate of conflict between farmers, farmers and herdsmen.

Table 4.1 shows percentage of eroded area per landscape. The greatest being the gentle slope with 25.7% of the total eroded area and this is where agricultural activities occur. The cross-sectional dimension ranged between 14.12 to 53.23m depth and 22.99 to

420.34m wide. The highest degree of erosion is found on the gentle slopes, while the lowest degree is on the hilly units. The material present in every landscape account for this difference in erodibility.

Table 4.3 shows that greater than 80% of erosion occurs on grass-covered terrain on slopes between 0 to 5%. This analysis helps us to clarify a particular pattern regarding land use/cover, erosion and slope. The topography also contributes to the detachment of soil material. At the time of this study, the head of the gully deepened and increased to approx. 35m (see plate4.4). Change analysis in the gullies in terms of width and depth showed an apparent expansion and deepening in the area mapped (Table4.4).

Figure 4.7 indicates the direction of flow coupled with soil texture, supports active erosion. Table 4.5 gives an estimated annual production of some selected crops for the period of three years (2001-2003). The table revealed that they keep decreasing in quantity and quality due to the menace of erosion. Reduction in agricultural products means food shortage, affects nutrition etc.

From the findings of this study, about 252Ha of Land was lost to erosion in the past 20years (50% of agricultural Land). The change analysis also revealed that if nothing is done, in less than 10 decades, all arable Land would be taken over by gully erosion. This would also affect grazing Land.

The crops cultivated on farms in Farin Lamba include millet, Irish potatoes, Maize, Accha etc.

5.2 **Conclusion**

The success of the approach used in this study area highly depends on the quality of the input imagery and attention to pre-processing. Pre-processing and processing processes of the imagery such as georeferencing, geometric corrections, radiometric corrections, classifications etc, and the precision of ground control points can influence the results.

The study revealed that gully erosion is seriously devastating farmlands in farin Lamba area such that by the next 10 decades, the whole farmlands would be destroyed by gullies. Measures of gully erosion control are traditionally addressed and seem to be ineffective in the area. They include poor management of June to august run-off and infiltration water, lack of stabilising both channel gradient and channel head cut etc. The technique can be applied singly, jointly or in groups depending on the available funds. Indeed all that is required at this stage in Nigeria is the political will and the funds to support solve the problem. However, Government have attempted to control gullies in the area as it affects major roads and not farmlands. No farmer no feature.

5.3 Recommendations

Based on the findings of this research work, the following recommendations are suggested:

(a) Erosion control programmes should involve a sub- catchment management strategy where gullies are controlled as group-units instead of tackling individual gullies.

(b) Encourage more detailed studies and investigations to be carried out to produce maps, designs/reports on gully erosion sites for remedial work; and make this available to decision makers who can tour the affected areas with the view to appreciating the degree of the problem better and that can guide them in terms of funding.

(c) Federal, State and Local Government Areas in conjunction with community based farms to come-up with laws regarding soil and gully erosion control mechanism in civil construction to tackle the menace.

(d) The farming methods in the erosion- prone areas should be addressed by adopting newer techniques such as contouring that would channelled the water accordingly. The Ministry of Agriculture (Federal, State and L.G.A's) should guide all farmers on how to go about it through their extension workers.

(e) Government attention be drawn to the uncontrolled failing of trees and clearing of bushes/forest, excessive bush burning, uncontrolled grazing on lands by cows and goats etc should be controlled or properly managed.

(f) Another approach is the massive awareness campaign (press, radio, TV, news papers workshops etc) should be embarked upon within and outside the country in order to tell the world at large the menace of erosion problem for support in terms of funds.

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