1.1 CHAPTER 1

INTRODUCTION

Soil erosion is the systematic removal of soil, including plant nutrients, from the land surface by various agents of denudation (Ofomata, 1985). Water being the dominant agent of denudation initiates erosion by rain splash impact, drag and tractive force acting on individual particles of the surface soil. These are consequently transported seizing slope advantage for deposition elsewhere. Soil erosion is generally created by initial incision into the subsurface by concentrated runoff water along lines or zones of weakness such as tension and desiccation fractures. As these deepen, the sides give in or slide with the erosion of the side walls forming gullies.

During the Stone Age, soil erosion was counted as a blessing because it unearths valuable treasures which lie hidden below the earth strata like gold, diamond and archaeological remains.

Today, soil erosion has become an endemic global problem, In the South eastern Nigeria, mostly in Anambra State, it is an age long one that has attained a catastrophic dimension. This environmental hazard, because of the striking imprints on the landscape, has sparked off serious attention of researchers and government organisations for sometime now. Grove(1951); Carter(1958); Floyd(1965); Ofomata (1964,1965,1967,1973,and 1981); all made significant and refreshing contributions on the processes and measures to combat soil erosion.

Gully Erosion is however the prominent feature in the landscape of Anambra State. The topography of the area as well as the nature of the soil contributes to speedy formation and spreading of gullies in the area (Ofomata, 2000);.

1.2 Erosion Types

There are various types of erosion which occur these include

- Soil Erosion
- Rill Erosion
- Gully Erosion
- Sheet Erosion

1.2.1 Soil Erosion: This has been occurring for some 450 million years, since the first land plants formed the first soil. Even before this, natural processes moved loose rock, or regolith off the Earth's surface. Soil is naturally removed by the action of water or wind In general; background erosion removes soil at roughly the same rate as soil is formed. But 'accelerated' soil erosion, loss of soil at a much faster rate than it is formed, is a far more recent problem. It is always a result of mankind's unwise actions, such as overgrazing or unsuitable cultivation practices. These leave the land unprotected and vulnerable. Then, during times of erosive rainfall or windstorms, soil may be detached, transported, and (possibly travelling a long distance) deposited.

1.2.2 Rill Erosion: This often occurs with sheet erosion and is commonly seen in paddocks of recently cultivated soils following high-intensity rainfall. It is easily identified as a series of little channels or rills up to 30 cm deep. The process of rill erosion occurs by rainfall exceeding infiltration then a surface film of water forms (see sheet erosion). Rill erosion results from a concentration of this surface water into deeper, faster-flowing channels which follow depressions or low points through paddocks. The shearing power of the water can detach, pick up and remove soil particles making these channels the preferred routes for sediment transport. Rill erosion is often described as the intermediate stage between sheet and gully erosion.

1.2.3 Gully Erosion: Once rills are large enough to restrict vehicular access they are referred to as gullies or gully erosion. Major concentrations of high-velocity run-off water in these larger rills remove vast amounts of soil. This results in deeply incised gullies occurring along depressions and drainage lines. Removal of topsoil and subsoil by fast-flowing surface water creates abrupt deep and wide gullies, of two different kinds: scour gullies and headward erosion. In scour gullies, run-off water concentrated in rills or depressions removes soil particles through sluicing - the washing effect of running water on loose grains.

Material commonly moved is the size of fine to medium sand or may be derived from slaking, when large aggregates disintegrate upon wetting. Scour gullies are often associated with gently undulating landscapes. In headward erosion the gully extends upstream as a result of waterfall undercutting and gravitational slumping of the gully head. It is often associated with (although not confined to) steeper landscapes. In both cases gullies may widen through lateral erosion, where water undercutting causes subsequent slumping of the sides. Gully sides may also be subject to splash, sheet or rill erosion.

1.2.4 Sheet Erosion: Sheet erosion is defined as the uniform removal of soil in thin layers from sloping land. This, of course, is nearly impossible; in reality the loose soil merely runs off with the rain. Rill, Gully and Sheet Erosion are referred to as Accelerated Erosion.

1.3 Gully Erosion Process

A gully is a relatively deep, vertical-walled channel, recently formed within a valley where no well-defined channel previously existed. Some gullies are several miles long while others are as short as 100 feet. All have nearly vertical walls and contain streams which have extreme variations in discharge throughout the year. Gullies in large valleys contain streams which usually flow year round, but streams in most gullies are dry during portions of the year.

Gullies develop because of a decrease in the erosional resistance of the land surface or an increase in the erosional forces acting on the land surface. What causes gullies to form, when and where they do is poorly understood. Field and laboratory studies indicate that certain reaches of a valley are more prone to gully development than others. However the timing of the initial down cutting and which of the "most probable" reaches develops into a gully cannot be predicted with certainty.

Once a gully has formed, the processes whereby it lengthens and widens are much better understood. The upper end of a gully is marked by a headwall, a vertical scarp, separating the ungullied portion of the valley floor from the gully below. Water flows over the headwall during runoff and falls into a plunge pool at the base of the headwall. The water then erodes the base and sides of the pool, undercutting the headwall. When undercutting reaches an advanced stage the headwall fails and topples into the gully, thereby lengthening the trench. This process is repeated many times as a gully advances up the drainage way.

When first formed, most gullies are quite narrow and have vertical sidewalls. Increased pore pressure from groundwater moving toward the gully, coupled with some undercutting of the sidewalls causes deep rotational slumps along the sidewalls. If enough water is flowing through the gully to carry away the slumped material, additional slumping can occur. This causes the gully to widen. Widening also occurs when upper portions of gully walls separate and topple into the gully. This phenomena is most common following heavy spring rains and during freeze-thaw cycles in the late winter and early spring. If water intermittently flowing through the gully continues to clean out debris derived from the headwall and sidewalls, the gully continues to grow. When more debris accumulates than is transported away, the gully stabilizes and begins to fill.

Many of today's gullies are cut into alluvium, the sediment transported and deposited by flowing water in streams

1.3.1 Causes of Gully Erosion

Gully erosion occurs when water is channelled across unprotected land and washes away the soil along the drainage lines. Under natural conditions, run-off is moderated by vegetation which generally holds the soil together, protecting it from excessive run-off and direct rainfall. Excessive clearing, inappropriate land use and compaction of the soil caused by grazing often means the soil is left exposed and unable to absorb excess water. Surface run-off then increases and concentrates in drainage lines, allowing gully erosion to develop in susceptible areas.

"A number of gullies in Anambra are caused by the overflow of concrete rainwater gutters at the side of highways, leading to erosion particularly at the point where the gutter and the road meet ;that destabilizes hillsides and undermines roadbeds" (Simpson, 1990). Other causes include

- Anthropogenic causes
- Soil saturation
- Groundwater sapping

1.3.2 Effects of Gully erosion

Some of the effects caused by gully erosion are

- Dissection of property causing access and management difficulties
- Loss of productive land (gullies often occur in the most productive area of the catchment)
- Reduced amenity and property values, including destruction of farm improvements, such as fences or tracks
- Discolouration of water supply and sedimentation of waterways, dams and lower paddocks
- Provides a harbor for vermin

1.4 Overview of Anambra State

Anambra is located between latitude 5^{o} 45N to 6^{o} 45N; and longitude 7^{o} 15E to 7^{o} 45E. The state lies in the Anambra basin, the first region where intensive oil exploration was carried out in Nigeria. Anambra basin has about 6,000 m of sedimentary rocks.

The sedimentary rocks comprise ancient Cretaceous deltas, somewhat similar to the Niger Delta, with the Nkporo Shale, the Mamu formation, the Ajali sandstone and the Nsukka formation as the main deposits. On the surface the dominant sedimentary rocks are the Imo Shale a sequence of grey shales, occasional clay iron stones and Sandstone beds. The Imo Shale underlies the eastern part of the state, particularly in Ayamelum, Awka North, and Oruma North LGAs. Next in the geological sequence, is the Ameke Formation, which includes Nanka Sands, laid down in the Eocene. Its rock types are sandstone, calcareous shale, and shelly limestone in thin bands. Outcrops of the sandstone occur at various places on the higher cuesta, such as at Abagana and Nsugbe, where they are quarried for construction purposes. Nanka sands out crop mainly at Nanka and Oko in Orumba North LGA. (http://www.unu.edu)

Lignite was deposited in the Oligocene to Miocene; and it alternates with gritty clays in places. Outcrops of lignite occur in Onitsha and Nnewi. The latest of the

tour geological formations is the Benin Formation or the coastal plain sands deposited from Miocene to pleistocene. The Benin Formation consists of yellow and white sands. The formation underlies much of lhiala LGA. Thick deposits of alluvium were laid down in the western parts of the state, south and north of Onitsha in the Niger and Anambra river floodplains.
The terrain is generally varied with rugged hills, undulating slopes, gullies and waterlogged areas. In some villages of Anambra State, the Land Use Intensity Index (the ratio of cultivated land to cultivated land plus fallow) is 80%. Especially in upland areas, intensification causes loss of organic matter and nutrients, and structural deterioration.

1.4.1 Landforms and Drainage

Anambra State falls into two main landform regions: a highland region of moderate elevation that covers much of the state south of the Anambra River, and low plains to the west, north, and east of the highlands. The highland region is a low asymmetrical ridge or cuesta in the northern portion of the Awka Orlu Uplands, which trend roughly southeast to North West, in line with the geological formations that underlie it. It is highest in the southeast, about 410m above mean sealevel, and gradually decreases in height to only 33m in the northwest on the banks of the Anambra River and the Niger. At Onitsha and Otuocha, the cuesta provides well drained low land, very close to the river, thereby enabling settlements to extend to the banks of the river.

The cuesta has confined the wide and braided channel of the Niger to a comparatively narro' valley bed at the southern part of Onitsha, making an appropriate location for the construction of bridge across the river. The highlands consist two cuestas, a lower and a higher one, each with an east-facing escarpment. The two cuestas merge south of Nanka.

The lower cuesta, formed by the more resistive sandstone rocks of the Imo Shale, rises to about 150m above mean sealevel at Umuawulu and decreases in height north-westward to only 100m less than Achalla. Its escarpment faces the Mamu River plain and has a local relief of between 80m and 30m West of it, is the higher cuesta, formed by the sand stones of the Ameke Formation. Its height is above 400m in the south-east at lgboukwu and lsuofia decreasing north-westward to less than 300m; Abagana, and to only 100m at Aguleri.

They are of moderate height and they provide elevated, welldrained and attractive settlemment sites, hence they are closely settled even up their crests. Agulu, Abagana, Awkuzu, Nteje and Aguleri are some of the settlements on the crest the higher cuesta, and lfiteAwka, Mgbakwi Amanuke and Achalla are some of those on the crest of the lower cuesta. The dip slope of the higher cuesta extends westwards for over 30km and is heavily settled.

The plains lie west and north of the highland; the River Niger plain, south of Onitsha, about 9km wide, and the NigerAnambra River plain north of Onitsha, which stretches for over 36km east of the Niger, are really low plains, well below 30m above mean sea level, and are liable to flood. They are underlain by recent alluvium; and, east of the Anambra River, by the Imo Shale formation.

The plains are almost featureless, except for sporadic broad undulations, rising above the flood plains at forming sites for the farming and fishing settlement in the area. Such settlements include Nzam. Nmiata, and Anam in Anambra West LGA, and Atani, Odekpe, and Oshita in Ogbaru LGA. East of the Anambra River, a narrow and elongated sand stone ridge, projecting about 30m above the level at the plain, formed settlement sites for Anaku lgbukwu, lfite, and Umueje in Ayamelum LGA. (http://www.unu.edu)

The Mamu River plain, east of the cuesta landscape, is a little higher than the other two plains. It lies between 30 and 70m above sea level in the area and underlain by the Imo Shale, rising higher southwards. East of the Mamu River are found the more, resistant sandstone ridge, at some 50 m above the level of the plains. The extension of this ridge southward is settled by the people of Ufuma, Ajali, lsuUlo, Ezira, and Urnunze. The Anambra River rises on the Gala Plateau near Ankpa in Kogi State and, for its over 85km course in Anambra State, flows through the northern low plain where it, as well as its right bank tributaries, meander heavily, developing oxbow lakes and abandoned meander channels. Its largest left bank tributary is the Mamu River, which drains the eastern low plain on the Imo Shale Formation.

The higher cuesta forms the watershed separating the numerous east-flowing tributaries of the Mamu River from the west-flowing rivers, the Idemili, the Nkisi, and the Oyis, which drain the dip slope of the cuesta. All but one of the main rivers in Anambra state empty into the River Niger which forms the western boundary of the state and constitutes the local base level for the rivers. The exception is the Ulasi River, which rises near Dikenafai in Imo State, flows northward to Ozubulu in Anambra State and then turns round in a wide loop and heads for the Atlantic Ocean. The dip slope of the higher cuesta between Nsugbe, Onitsha, Ogbunike and Umunya is dissected by the numerous tributary streams of the MamuAnambra into a rolling landscape.

1.4.2 Vegetation and Soils

Although annual rainfall is high in Anambra State, ranging from 1,400mm in the north to 2,500mm in the south, it is concentrated in one season, with about four months of dryness, November to February. Consequently, the natural vegetation in the greater part of Anambra State is tropical dry or deciduous forest, which, in its original form, comprises of tall trees with thick under growth and numerous climbers.

The typical trees (silk cotton, Iroko and oil bean) are deciduous, shedding their leaves in the dry season. Only in the southern parts of the state, where the annual rain fall is higher and the dry season shorter, is the natural vegetation marginally the tropical rainforest type. Because of the high population density in the state, most of the forests have been cleared for settlement and cultivation.

What exists now is secondary re-growth , or a forest savannah mosaic, where the oil palm is predominant, together with selectively preserved economic trees.

Three soil types can be recognised in Anambra State. They are: (i) alluvial soils, (ii) hydromorphic soils, and (iii) ferallitic soils.

The alluvial soils are palebrown loamy soils. They are found in the low plain south of Onitsha in Ogbaru and in the Niger Anambra low plain north of Onitsha. They differ from the hydromorphic soils in being relatively immature, having no well developed horizons.

They, however, sustain continuous cropping longer than the other two types. Hydromorphic soils are developed on the Mamu plain east of the cuesta, extending northward into the eastern part of Anambra River floodplain, where the underlying impervious clayey shales cause waterlogging of the soils during the rainy season. The soils are fine loamy, with lower layers faintly mottled; while the subsoil layers are strongly mottled and spotted, containing stiff grey clay. The soils are good for yam, cassava and maize, and for rice in the more heavily waterlogged areas. The cuestas and other elevated areas under lain by sandstones and shales of the Ameke Formation and the Nanka Sands are regions of ferrallictic soils. The soils are deep, red to reddish brown loamy sands, often referred to as "red earth" or acid sands because of low fertility. They are easily eroded into gullies.

1.4.3 Ecological Hazards

The main ecological hazards in the state are accelerated gully erosion and flooding. Extensive forest clearing, often by bush burning, and continuous cropping with little or no replenishment of soil nutrients, result in the disruption of the ecological equilibrium of the natural forest ecosystem. Such a situation in a region of loosely consolidated friable soils is prone to erosion, giving rise to extensive gully formation.

In the Agulu, Nanka and Oko areas, which are underlain by the Nanka Sands, the gullies have attained spectacular and alarming proportions, turning the area into real "bad lands." Many of the gullies are at the head streams of the rivers that flow down the cuestas. The head streams carve their valleys deep into the deeply weathered red earth, developing dendritic patterns of gullies.

Such gullies are also found in Nnobi, Alor and Ideani, along the course of the Idemili River. Besides, the greater part of the state is prone to severe sheet erosion. In the low plains of the Niger and Mamu Rivers, heavy rains often result in excessive flooding, such that the undulations occupied by settlements are marooned for some months. The people resort to the use of canoes for movement and transportation. Oba Ofemili and Ugbenu on the plains of the Mamu River are sometimes, in the rainy season, cut off from others as their roads remain flooded knee deep for many weeks. The floods also cause serious damage to crops

1.5 Study Area

The areas of study would include of Anaocha, Aguata, Orumba North, Nnewi North, Nnewi South, Idemili North and Idemili South Local Government Areas in Anambra State. The environmental parameters that will be studied in relation to the erosion would be climate, vegetation, soil and water.

1.6 Problem Definition

In order to satisfy the various objectives, and hence the basic goals of this project, some important questions were stated to serve as guidelines and these thus forms the statement of task in this project the questions are:-

- What is gully erosion?
- What is GIS concept and how does it relate to gully erosion analysis?
- What is the current status of gully erosion in Anambra State?
- What are the control measures to be taken?
- What are the factors affecting control of gully erosion in Anambra State?
- Which information is needed for gully erosion management in Anambra State?

1.7 Aim and Objectives

The objectives of this project are:

(i) To discuss the Gully Erosion Hotspots in Anambra State

(ii) To present detailed information on types of gully erosion activities in Anambra State.

(iii) To create a database of erosion sites and some attribute information pertaining to erosion in a Geographic Information Systems (GIS) environment, which will show erosion processes in different parts of Anambra State?

(iv) To proffer solutions based on the information generated

1.8 SCOPE OF PROJECT

The scope of the project involves the following:

- Acquisition of data using both primary and secondary source
- Database creation of gullies and attributes of gullies
- Generation of Spatial and Aspatial queries

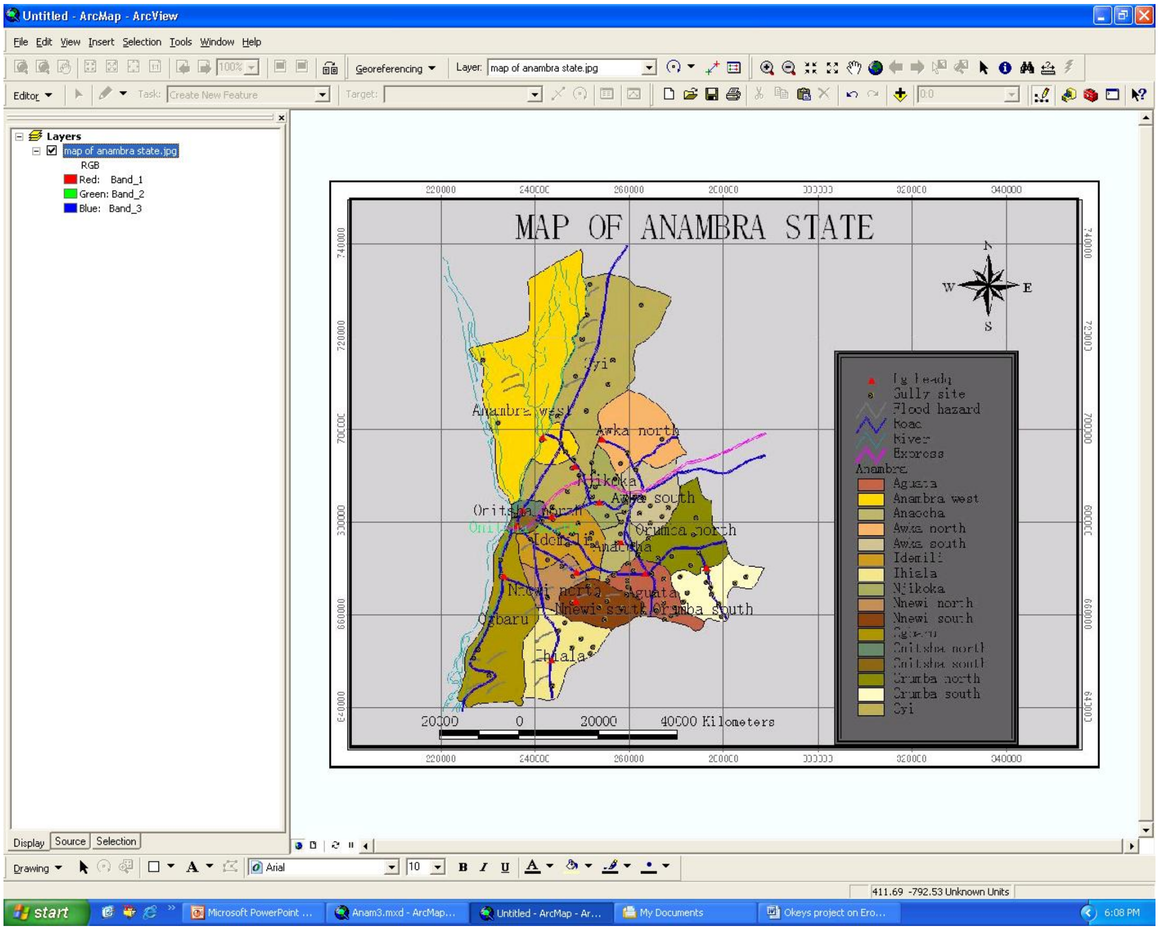


Fig1 Map of Anambra state

CHAPTER TWO

2.0 LITERATURE REVIEW

Soil erosion is a worldwide natural disaster and number of studies have been undertaken with a view to grasp a clear understanding of its origin, processes, factors, effects, and control. Experimental studies have been done through simulated rainfall conditions to assess the influence of certain factors and processes of soil erodibility under ambient and controlled conditions. The review may not be complete without considering the soil genesis and classification , soil properties and the geomorphic/climatic influences and the three facets of soil erosion. This becomes indispensable since Biological and Engineering control measures are based on soil classification, properties which in turn have climatic influences. Jenny (1941), postulated that time state factor for soil formation comprises: climate, organisms, soil, relief, parent material and time. The nature of organic and inorganic colloidal material and resultant cohesive forces binding the soil particles into aggregates are among other factors that contribute to soil erosion, Emerson (1959) Radwanski (1973) opined that the time factor could be supplemented by an additional factor and that is the degree of weathering and soil formation . The factor and sub-factor involved are primarily controlled by climate and parent rock or parent material. Gerard (1981) observed that behavior of soils as an open system where loss and reception of material and energy take place at the boundaries. Many studies have come out with results or intricacies of soil formation processes, including overlapping activities. In Buel et al (1980), they stated that the processes of soil formation is a complexity of or a sequence of events , including both complicated reactions and comparatively simple rearrangements of matter, that intimately affects the soil in which it operates. However, a number of events may take place simultaneously or in sequence to mutually reinforce or contradict each other (Rode(1962)) Simonson (1959).Soil formation processes according to Simonson (1959) comprises organic and mineral material addition to the soil as solid, liquids and gases, losses of these from the soil, translocation of materials from one point to another within the soil and transformation of mineral and organic substances within the soil. Akamigbo and Asadu (1983) opined that the parent rocks (parent materials) of sedimentary soils of Southeastern Nigeria tend to influence strongly the texture, soil reaction, acidity, basicity, soil depth, color, coarse material content and profile drainage**.**

2.1 GEOGRAPHIC INFORMATION SYSTEM (GIS)

According to *Burroughs (1986)*, technological advancements have brought about new ways through which large volumes of geographic information can be analysed and displayed faster and better. Thereby, producing a system with a set of tools for collecting, storing, retrieving at will, transforming, and displaying spatial data from the real world for a particular set of purposes. This system is known as Geographic Information System GIS.

The term Geography Information System (GIS) has come to mean a tool, a product, a technology and a science. As such, the term involves difference perceptions depending on whether the viewpoint is that of the software developer, the system marketer, the data provider, the application specialist or the academic researcher, among others. A newcomer to the field is likely to be bewildered by the multiple uses of the same terms. One of the many definitions of GIS is stated below.

GIS a is computerized tools for capturing, storing, checking, integrating, manipulating, analysing and displaying data, which are spatially referenced to the earth. It is normally considered to involve a spatially referenced and structured digital database and appropriate application's software, (*Department of Environment, 1987, Kufoniyi, O. 1998).*

Whatever way GIS is defined they reveal that:-

(1) It is a computer based system

(2) Uses spatially referenced or geographic data, and

(3) That it carries out various management and analysis task on these data, including their input and output.

GIS can be viewed as a software package, the component being the various tools used to enter, manipulate, analyse and output data. The component of a GIS include: the computer system (hardware and operating system), the software, spatial data, data management and analysis procedure and the people to operate the GIS. *(Ian Heywood, Sarah Cornelius and Steve Carver, 1998)* One of the best ways to introduce GIS is to consider the generic types of questions it has been designed to answer. These include questions about location, patterns, trends and conditions:

Where are particular features found? What geographical pattern exists? Where have changes occurred over a given time period? Where do certain conditions apply? What will the spatial implications be if an organization takes certain actions?

The Department of the Environment (1987) list the capabilities that a well designed GIS should be able to provide:

(1) Quick and easy access to large volumes of data.

(2) The ability to:

- Select detail by area or theme; Link or merge one data set; Analyze spatial characteristic of data; Search for particular characteristic or features in an area; Update data quickly and cheaply; Model data and assess alternatives.

(3) Output capabilities (maps, graphs, address list and summary statistics) tailored to meet particular needs.

In short, GIS can be used to add value to spatial data. By allowing data to be organized and viewed efficiently, by integrating them with other data, by analysis and by the creation of new data that can be operated on in turn, GIS creates useful information to help decision making.

Some authors consider that there are important elements of a GIS in addition to those common to the definition above.

Maguire (1991) offers a list of 11 different definitions. This variety can be explained, as *Pickles (1995)* suggests, by the fact that any definition of GIS will depend on who is giving it and their background and viewpoint. Pickles also considered that definition of GIS are likely to change quickly as technology and application develop further. Some of the shorter definitions give an idea of what a GIS is albeit in a superficial way. For example, *Rhind (1989)* proposed that GIS is a computer system that can hold and use data describing places on the earth's surface. *Burrough (1986)* suggests that GIS have three main elements, computer hardware, application software modules and a proper organizational context. Others such as *Maguire (1989)* stress that data are the most important part of GIS. In practice, none of the main elements (the computer system, data processing tools) will function as a GIS in isolation, so all might be considered of equal importance. However, it is perhaps the nature of the data used and the attention gives to the processing and interpretation of these data that should lie at the centre of any definition of GIS.

The functions that GIS can perform include: input, storage, management, query and analysis, manipulation and visualizations of voluminous geographic data.

There are a few industries that are realizing the value of GIS. They include: Agriculture, Banking, Education, Environment, Management, Federal Government, Forestry, Health, Insurance, Law enforcement, Logistics/Vehicle Management, Mining, Public Safety, Real Estate, Retail Business, State and Local Government, Telecommunications, Transportation, Utilities *(ESRI, 1999*).

2.1.1 The Concept of Geographic Information Systems (GIS)

2.1.1.1 What is GIS?

Geographic Information Systems (GIS) emerged in parallel with a wider application of computer technology. It is a tool that is central to geographical information technology. It is a computerized information system for the processing of data to yield information. Its main advantage is the possibility of handling large volume and complex data sets in a convenient manner.

It can be visualized as an integrated assemblage of computer hardware and software, spatially referenced data, the human operator and the fund needed for the completion of the above tasks. It permits the human operator of bring together data from numerous sources in a composite form.

2.1.1.2 Evolution of Geographic Information System (GIS)

The development of GIS started several years ago. There was the case of computer assisted mapping to increase production rate at around 1960s. Maps were kept in analogue form and spatial analysis done by visual impression. Mainframe and minicomputer based systems dominates during this period.

In the mid 80's to 1990, there was the application of DBMS in the spatial domain. There was a linkage of CAD/CAM with DBMS, thus there was dual architecture (geo-relational). There was for example, SYSTEM 9 and Info cam, which were used to integrate spatial and non-spatial data in the same structure though mainly relational.

In the early 1990's the issue of object-oriented method of data structure such as small world, and ONTOS were in existence. Even Ilustra, which is an object relational, also existed. In recent times, the complexity involved in data management has lead to a drastic evolution of several GIS computer software such as Air View GIS, ILWIS, Arclnfo, **(***Bassey Ukim, 20030),* etc.

2.1.1.3 Basic functions of Geographic Information Systems (GIS)

There are three basic functions of every GIS package, they are;

- To store and manage geographic information comprehensively and effectively.
- To display geographic information depending on the purpose of use.
- To execute query, analysis and evaluation of geographic information effectively.

2.1.1.4 Benefits of a Geographic Information System (GIS)

A very good and properly designed GIS package has the capability of providing new and flexible forms of output such as customized maps in both digital and analogue formats, reports, address lists, etc. It should be able to support quick and easy access to large volume of data, to select terrain detail from the database by area or theme, to merge one data set with another, to analyse spatial characteristics of data, to search for particular characteristics or features in an area, to update data quickly and be able to answer to complex land-related questions.

2.1.1.5 Components of a Geographic Information System.

A GIS has five basic components that work together so as to meet our various or composite needs. They are hardware, software, data, procedure and expertise.

2.1.1.5.1 Hardware

This has to do with the devices used to acquire, store, process and display the content of the digital database. The GIS relies on these for proper design.

Among the hardware are data acquisition hardware such as the GPS, total station, DIP, Stereoplotter, scanner and digitizing tables used to scan and digitize existing analogue maps, charts and drawing into the system.

Others are the host computer, keyboards, mouse, data logger and sensors for storage and manipulation of the acquired data. And finally the output hardware such as graphic screen, printer and plotter. The choice of those especially the host computer, depends on the type and nature of the GIS. A large scale GIS will need large computers and vice versa. There are other elements of this hardware that are essential for effective GIS implementation, they are;

- A processor with sufficient power to run the software; Sufficient memory for the storage of large volume of data; A good quality colour graphic monitor with high resolution; A good and quality data input and output devices; Flexible and non-computer hardware.

2.1.1.5.2 Software

This is the central nerve of every GIS implementation system. This component makes it possible to input, store, manage link, query and analyse geographical data, as well as output of data. Thus, it consists of a collection of four interrelated software subsystems, which are;

- Data collection and input software
- Data storage and retrieval software
- Data manipulation and analysis which are topological overlay, buffer generation, Adhoc query and modeling software.
- Visualization and reporting

Examples of GIS software are, ILWS, AcrView, ARCInfo, Socetset, Microstation, MGE, Microsoft, Access, Atlass GIS, IDRISI, GEO/SQL, MAP Infor, Inter Graph, SPAN, Group GIS etc.

Other software can still be added so as to provide access to additional sources of data and forms of functionality. Examples are imaging systems used to analyze satellite imagery, database management system used to store additional sets of data and CAD systems.

2.1.1.5.3 Spatial database

The data requirement for GIS implementation comes in two basic formats. They are spatial or geographic and aspatial or attribute data. Spatial data are data that contains the geographic location or position data of object in the form of a set of coordinates (X, Y, and Z) or cells defining the location of spatial object being represented in the database. The aspatial data on the other hand are descriptive sets of data that contains information or observed facts about an object type, relationship or location.

We also have data relating objects. This could be spatial or aspatial giving explicit associations between two or more spatial object. There are also conventions which are set of rules and constraints that govern the creation, content, structure and integrity of the database (*Burssey Ukim, 2003*). And finally operations, which are computerized actions (programme routines) that create, manipulate, maintain and

display the object attributes and relations.
All GIS software has been designed to handle spatial data. And spatial data are characterized by information about position connection with other features and details of non-spatial characteristics, (*Burrough, 1986*).
Geographical spaces occupied by spatial data are represented by a series of thematic layers, example, we may have cartographic maps for geology, vegetation and also a topographic map showing cultural and environmental features on the surface.
Spatial objects represented as layers objects, etc are simplified before storing them in the computer. This is done by directing geographic features as points, lines or areas, where point may represent location of features like building, restaurants, lines may represent roads, rivers, railways, while area represents sports counter air port, car parks etc.

2.1.1.5.4 Procedure

These are basically the algorithms and rules used for integrity checks, transactions, controls, database updating, etc. They are normally implemented as conventions and operations in the database. Thus, the procedure has to conform to the operation of the association or application for which the GIS package is made for.

2.1.1.5.5 Expertise

The basic aim of GIS implementation is to supply its uses with the necessary data and decision support tools. The expertises are actually the people to plan, implement and operate the system as well as making decisions based on the output. Users in GIS range from small research application user, which involves only one user in the design and implementation and output, to big establishment involving teams of staff interacting with the GIS in several ways. Thus, we have single user and multi user GIS.
There are four classes of users, they are; occasional professional with high task expertise and low system expertise), application specialist (with high task and high system expertise), computer specialist (with low task and high system expertise) and the public (with low task and system expertise) *(Eason, 1988).*

2.1.2 Geographic Information System as an Information and Decision Support System

Information refers to a data element of some kind which is useful for a particular application such as decision making process. Information and communication technologies are generally a new industrial revaluation already as significant and far - reaching as those in the past. This revolution has added new capacities to human intelligence and consequently changed the way we work, the way we live together and the way decisions are made.

An information system is defined as computer based tools for the collection, storage, analyses and retrieval of various kinds of data for decision making. GIS is thus a special type of an information system.

Conceptualized description of information systems and the relationship between information system and GIS are depicted in table 1.

GIS	**INFORMATION SYSTEM**
User + Other GIS DBMS + Application Software Spatial Database Procedure	Environment Information Processor Information Base Grammar

Table 1: Relationship between information system and GIS

In a decision making process, inadequate or insufficient information limits the options available to the decision matter *(Philip, 2004*). This is the problem to which a GIS is tailored to solve. Its ability to link spatial and aspatial data makes it perfect for the generation of more complete information for decision making.

Better information definitely leads to better decisions and to get such information the right question needs to be asked and the right questions can only be asked with the right tools. The questions we ask most times are when, where, what, why, how etc and all these questions have geographical components. Thus, it is only a GIS with its ability to link and display both spatial and aspatial data sets that is a better tool for supporting a decision making process.

GIS is the technology capable of integrating various date sets both qualitative and quantitative in a single system and thus it is a better tool for handling complex environmental issues such as tourism, which involves besides its spatial dimension, social, economic, cultural and environmental implications.

Besides the integration of various data set in a single system. GIS is an integrating technology capable of working along with other technology, such as remote sensing, GPS, CAO, etc. which further facilitate and offer more tools for sustainable planning and decision-making. It accepts data from other technologies as well as functions in conjunction will them. It is a technology that tolerates other technologies.

GIS is a dynamic tool for planners and thus, it is capable of being adjusted. It is capable of adding new data, removing old data as taste and preferences in demand change overtime. It givers room for editing. This aspects of GIS is very important for tourism development and management decision making as preference, target and taste and even cost may change in the case of development and management of tourism. So, a GIS is as dynamic as decisions arising out of change in taste and preferences overtime.

2.1.3 Development and Implementation of a Geographic Information System (GIS)

Francis W. Derby (SLIS, Vol. 64, No. 1, 2004 page 53) identified three issues involved in the development and implementation of a GIS package. They are;

1. Planning as well as budgetary considerations

2. Availability of appropriate graphical and descriptive data types, minimum standards, and management skills.
3. Constant communication among the development teams, stakeholders and potential users.

Thus, in the design of a GIS package, the entire system is developed around current and future applications that need to be supported by the system. The design involves two major steps, they are;

i. Planning and organization
ii. Design and implementation

Figure 2 shows the design philosophy of a GIS

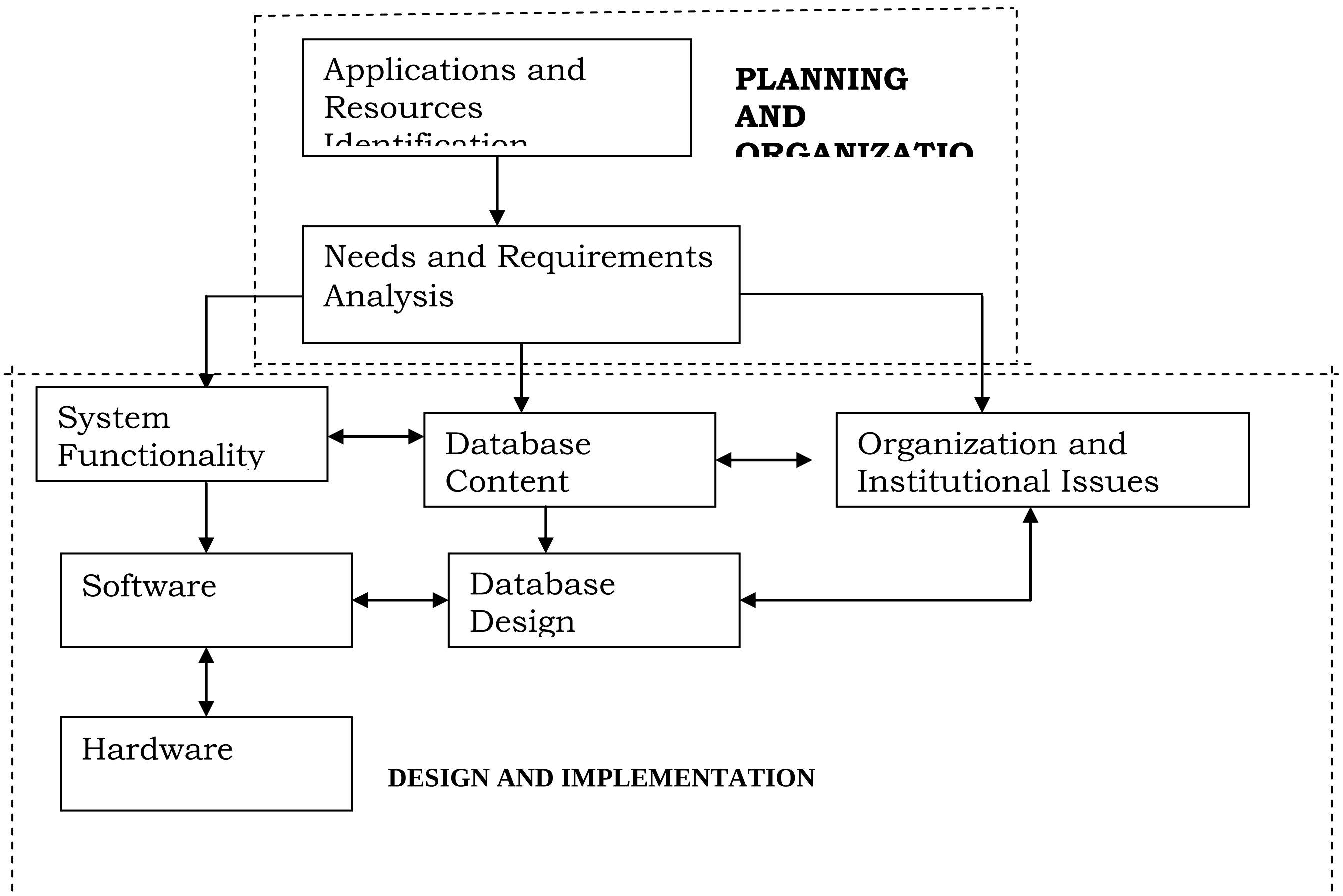


Figure 2 Design Philosophy of a GIS Package *(SLIS, Vol. 64. No. 2, PP. 53 2004)*

In the planning and organization stage, input are gotten from users such as decision makers, management staffs and the public through direct interviews or indirectly through survey and questionnaires. Data collected on user's activities and resources determines and of course forms a framework for the design and implementation of the proposed GIS system. The analysis of the data identifies the data types needed as well as their optimum resolution and required accuracy, their structure and the required capacity of the system to support the activities of multiple users. This information is very important for developing a GIS system with a functional database structure and content, efficient institutional support for implementation and in infrastructure that would be able to handle both current and future GIS information needs.

The design and implementation stage involves conceptual database design, establishment of minimal accuracy standard for graphical database and definition of minimum capability requirements for hardware, software networking and data communications.

Most times the numbers of GIS application increases over times, thus GIS systems should be designed to accommodate new data and perform more complex analysis. This implies that data should be structured in a way which ensures easy expansion of the database and facilities for the addition of new data.

2.2 GULLY EROSION STUDIES

Quite a number of Gully Erosion studies have been done in affected areas of the south-eastern part of Nigeria. They were carried out to establish major causes of the gullies, effects and solutions to be undertaken to curb such processes.

Literature reviews for Gully Erosion to be discussed include:

(a) Performance of Gully Erosion Control Measures in South-Eastern Nigeria

(b) Gully Erosion Monitoring in South-Eastern Nigeria

2.2.1 Performance of gully erosion control measures in southeastern Nigeria

The performance of gully erosion control measures in some parts of southeastern Nigeria is presented. The measures include tree planting, hydraulic regulation works that integrate a drainage network with storage ponds to cut off flood crests and lower hydraulic loads of interceptor canals, and stabilization works such as check dams on the main channels of gullies and wickerwork fences and hedges at the inner gully slopes. There is evidence that tree planting and surface regulation of surface waters is effective in controlling only shallow (15 m deep) gullies that have not cut through a saturated zone. These measures tend to fail when used for deep gullies that are greatly affected by groundwater especially when such gully floors are located in non cohesive and very permeable sands.

In the last quarter of the nineteenth century channels in some parts of Nigeria were noticed to have entrenched their valleys. These channels generally eroded into red-earth and unconsolidated geologic materials establishing prominent gullies with near vertical slopes. Increased erosion activities in the vicinity of the early gullies have continued to expand these gullies into a complex system. Some of the gullies especially those in southeastern Nigeria are now of canyon proportion, and constitute the most threatening environmental hazard in this part of Nigeria.

The most active and dangerous spots occur at Agulu, Nanka, Alor, Oraukwu, Oko and parts of Udi, Enugu and Ukehe in Anambra State. Other catastrophic gullies occur at Amucha, Isuikwuato, Ohafia, Abriba and Arochukwu in Imo State, and in parts of Uyo and Calabar in Cross River State. In all these places, with similar stratigraphic sequences of thick cohesionless sand strata overlain by a red clayey sand stratum and surface earth of either sandy loam or silty loam, intense gullying involving sudden and often catastrophic movements of large earth masses, has sent villages packing, wrecked homes, swept crops and washed roads away. The incidents of gullying have caused much concern to successive governments of Nigeria and have generated much attention among institutional and private researchers. Studies have been conducted and seminars and workshops held on the immediate and remote causes of the gullies. Based on some of the results of these studies, a number of control measures have been designed and constructed in some of the affected areas. Some of these measures have been fully or partially successful while others have woefully failed.

This review critically assesses the performance of the control measures and discusses the factors that have contributed to their success and/or failure. It is hoped that the results presented herein would be of interest to planners and designers of gully control measures in Nigeria and elsewhere where similar gully problems occur.

2.2.1.1 Causes of the Gullies

The causes of the intense gullying are evident from the results of the studies so far conducted in the area. From the much that has been postulated and written on the origin and development of the gullies, there appear to be a considerable measure of agreement.

Table 2 summarizes the opinions of the main workers.

Table 2. ***Summary of opinions of several workers regarding causes of gullying in the study are***

Author(s)	**Causes of gullying**
Floyd (1965)	Soil characteristics and human activities
Ofomata (1965)	Mainly soil characteristics, less of human activities
Ogbukagu (1976)	Mostly geologic set up and soil characteristics
Nwajide & Hoque (1979)	Topography, climate and soil characteristics
Egboka & Nwankor (1985)	Mostly groundwater conditions and soil characteristics
Uma & Onuoha (1986)	Groundwater flow conditions

The earlier workers (Floyd, 1965; Ofomata, 1965; Ogbukagu, 1976; Technosynesis, 1978; Nwajide & Hoque, 1979) have emphasized the importance of the soil and geologic materials exposed by the removal of vegetation cover and the impact of heavy rainfall on such materials. The consensus of these earlier workers is that the high intensity rainfall in the area produces high volumes of overland flow with high erosive energy. The action of the highly erosive floods on the unusually susceptible geological and soil materials produces the complex gullies. Floyd (1965) had suggested a six-stage evolution of the gullies:

(a) Intense agricultural activity leading to soil degradation and destruction
(b) Rain splash and removal of soil particles
(c) Leaching and eluviation
(d) Sheet and rill erosion
(e) Accelerated erosion and formation of gullies
(f) Mass earth movements through slumping, sliding and downhill creep leading to the complex badlands.

More recently, the effects of-groundwater and hydro-geotechnical factors have been highlighted as possible additional factors especially in the most dangerous spots where mass earth movement is the dominant mechanism. (Egboka & Okpoko, 1984) and (Egboka & Nwankwor, 1985) indicated that the active gullies are located mostly at the discharge areas of groundwater systems. The high pore-water pressures especially during the peak recharge times of the rainy season reduce the effective strength of the unconsolidated materials along the seepage faces. It has also been shown (Uma & Onuoha, 1986) that, in some areas, the high seepage forces due to the near critical exit hydraulic gradients at the various levels of seepage on the gully walls produce boiling conditions, piping and internal erosion that undermine the bases and partial bases of the gullies.

One fact is clear from the several studies and from a close field inspection of the affected areas; the development of the gullies is progressive through at least four *main* stages namely:

(a) Formation of rills,
(b) Development of incipient gullies,
(c) Formation of shallow gullies (<15 m deep), and
(d) Development of deep gullies (>15 m deep).

The main erosional activity at the first three stages involves the surficial removal of soil grains and small chunks of earth by rain splash, concentrated flood run-off along the rills and existing gullies and minor undercutting at the toe of the channels. Some of the gullies tend to stabilize at or before the third stage. Those that develop up to the fourth stage constitute the most catastrophic cases. They frequently contain groundwater seepages and springs at several horizons of their slope and their bases are formed by a thick stratum of very cohesionless and permeable white sands. The dominant mechanism at this fourth stage is sliding, slumping and soil flow involving movement of large soil masses.

The mass movements are associated with groundwater fluxes and other hydro-geotechnical factors as is evident by the seepage faces and springs at the bases and partial bases of the gullies.

2.2.1.2 Control Measures Applied

The description and interpretation of the works of earlier researchers on the general erosive processes have constituted the bases for the design and construction of the remedial measures so far adopted. Generally actions have been based on techniques capable of reducing the erosive capacity of the flood water *(i.e.* those measures that either reduce the quantity of the flood water flowing in the drainage network or reduce their velocity) and those capable of increasing the resistance of the soil relative to the erosive capacity of the flood waters.

To reduce the erosive capacity of the flood water, two types of protection measures have been adopted. The first involves the construction of hydraulic regulation works that integrate a drainage network with storage ponds to cut off flood crest and lower hydrau*lic* loads of interceptor canals. The interceptor canals, which are commonly located at the head of the advancing gully channels, drain runoff from areas adjacent to the gullies into artificial reservoirs (ponds) constructed where deep infiltration can occur. Fig.2 is a sketch of the hydraulic regulation work at Agulu, one of the dangerously gullied areas.

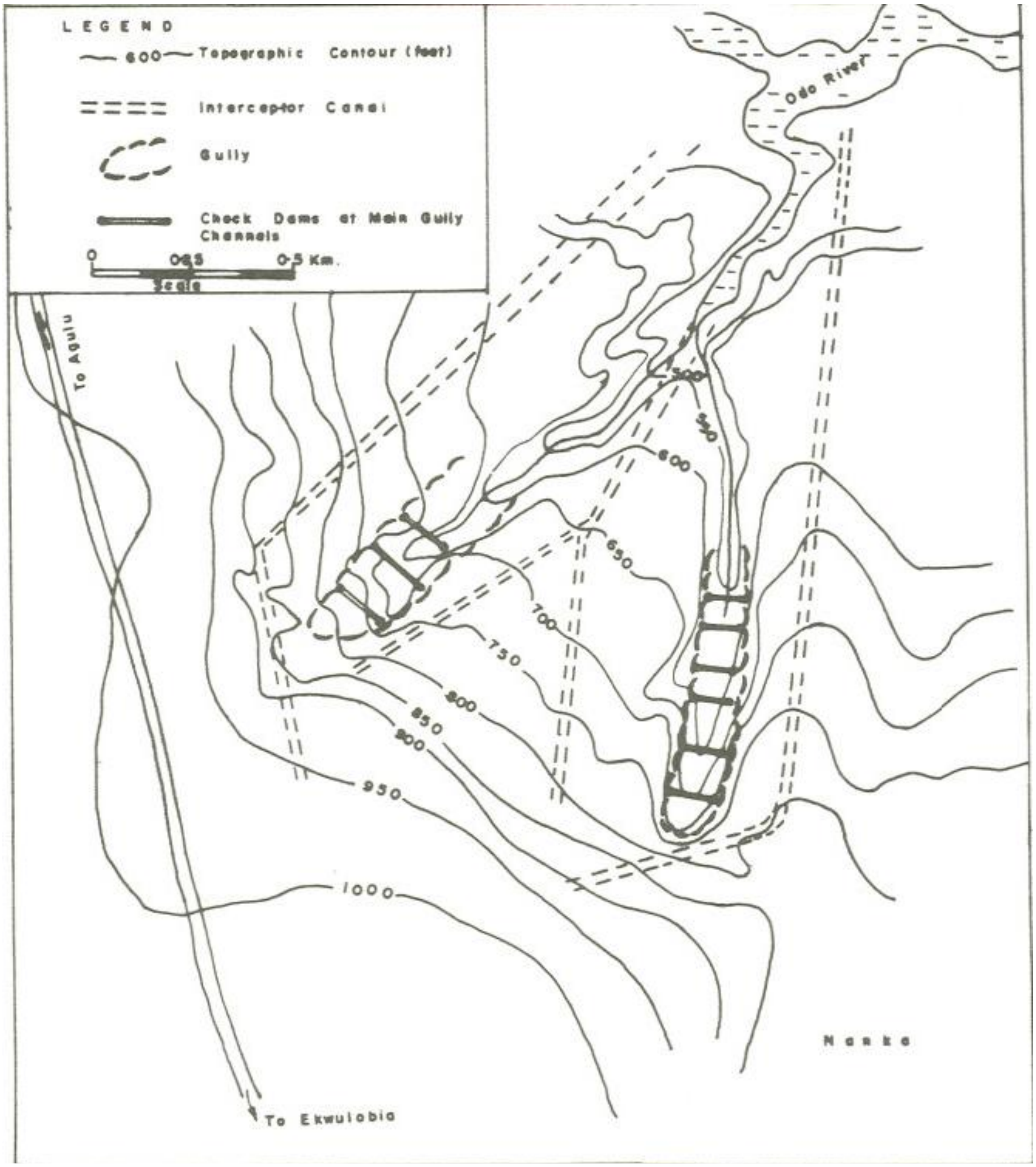


Figure 3. Sketch of the hydraulic regulation works at Agulu (Performance of gully erosion control measures in southeastern Nigeria, Okagbue & Uma)

Amatutu-Agulu Gully Erosion Control

The size of such hydraulic regulation work is based on the size of the zone that is adduced to contribute flood water to the main gully trunk. The contributing area is demarcated from a detailed elevation survey of the area. When an isolated area is too large for one set of regulation work, it is broken up into smaller units. Within the hydraulic regulation structures are stabilization works such as check dams on the main channels of gullies and revetments and hedges at the inner gully slopes.

The revetments are in the form of wicker-work fences used as stabilization work to reduce surface flows on the inner slopes of gully walls. The fences are formed by stakes about 10 cm thick driven into the ground close together (about 0.5 m - 1.0 m apart) and interwoven with braces and the like. The wicker-work fences are sometimes accompanied by tree planting to help strengthen the soil.

Tree planting is perhaps the oldest form of control measure adopted and is based on the recommendations of colonial workers. It is still used extensively in an attempt to increase the erosive resistance of the soils and to exert protection control. The trees used are those that have deep and abundant roots which are thought to be capable of binding the soil particles together. The more common ones are Cashew trees and Bamboos.

2.2.1.3 Performance of the Measures

Varied degrees of success have been achieved with the remedial measures so far adopted. In some areas, gullying has apparently stabilized after two years of the construction of the remedial measures, in some the gullying has continued but at a reduced rate while at others gullying has continued unabated despite the measures. The areas with apparent success include some gully spots around Oraukwu, Alor and Awgbu in Anambra State and some parts of Amucha in Imo State

In these areas the gullies are still shallow (i.e. less than 15 m deep) and have not cut into the cohesionless and very permeable white sands. The groundwater table is also far beyond the gully bottom as no springs or seepages are seenon the gully walls. Apparently, the effect of groundwater on the gully advancement is minimal. No recent gully activity has been observed and vegetation has started thriving on the gully slopes.

In the areas of partial success which include some upslope gully spots around Nanka and Oko, gully activities have been significantly reduced. The erosion activities are confined to surficial removal of grains and small chunks of soil at the upslope side of the hydraulic regulation structures and at the banks of the main gully trunks. Intense gully sliding appears to have subsided as indicated by the absence of large volumes of recent debris at the gully floors in those areas. These partially stabilized gullies have cut into the cohesionless and very permeable sands but the groundwater level rises above the gully bottom only during the rainy season (April to September). The areas are classed as partially successful because they appear to work well only during periods of non-saturation of the sandy horizon. For example, some spots that were assumed relatively safe during the authors' inspection visit at the end of the 1985 rainy season were beginning to show signs of yielding to gullying during the 1986 rainy season. As the surface waters appear to be well controlled, groundwater apparently has some effect on the gully propagation. In the most dangerous spots around Agulu, Nanka, Oko and Amuchu where the gullies have cut deep into the cohesionless sand and the sand horizon remains perpetually saturated, the control measures appear to have totally failed to stop the development and advancement of the gullies. Sliding and slumping have continued despite the control measures. Some of the structural framework of the remedial measures such as remnants of check dams, wicker-work fences and concrete structures of interceptor channels can be seen lying at the bottom of the new gullies in the failed mass of earth materials.

Tree planting has not helped, as surviving trees and shrubs are constantly uprooted, carried down and buried in large masses of earth materials. In these areas, gully walls are indented with springs and seepage faces; boiling spots depicting quick conditions are wide spread, all showing effects of groundwater.

2.2.1.4 Discussion

The control measures so far adopted in the gullied areas have been concentrated on regulation of surface waters (their volume and velocity), and planting *of* trees to strengthen the soil. These measures appear to have been successful in the shallow (<15 m deep) gullies cut mainly into red clayey earth; they have failed in deep gullies cut into very permeable and cohesionless sand where the gully walls are indented with springs and seepages at various horizons. This implies that the remedial measures take care of only the surface run-off, and fail to accommodate the disastrous effects of groundwater. Field inspection of the failed or failing structures reveal that most of them fail after under-cutting and piping in the foundations. Piping results from uncontrolled seepage of groundwater along with seepage forces. Uncontrolled seepage pattern leads to saturation, internal erosion, excessive uplift and seepage forces to the extent that soil particles migrate to an escape exit and cause piping and erosional failure.

Also affecting success/failure of the concrete channel structures is the termination point of such channels. In areas where the channels have been terminated into the gullies, undercutting arising from channel deepening and scouring has led to the failure of the measure. Channels terminated at the local base level of rivers tend to be free from this type of failure.

Tree planting as a stabilizing measure has been effective only on minor gullies i.e. those that have not reached considerable depths (less than 5 m). The reason appears to be explained by the fact that the disturbances in deeper gullies originate several meters below the zone of influence of tree roots. In the deep gullies whose slopes are constantly undermined by flood and internal erosion the trees close to the gully edge usually find their ways down the gully floor as soon as the slope is undermined. Also the vegetation species (Cashew and Bamboo) used so far on the gully floors have failed to thrive on saturated and sometimes running sand that characterize the floors of the deep gullies.

2.3 Gully Erosion Monitoring in South-Eastern Nigeria

Soil Erosion is an accelerated process under which soil is bodily displaced faster than it can be formed. Flood water is a major agent of erosion in South-Eastern Nigeria. Availability of data from NigeriaSat-1 has created the opportunity to use remote sensing techniques to map and monitor the spread of gullies in the area (Igbokwe, 1999).

This study demonstrates the potentials of image data from NigeriaSat-1 in mapping and monitoring of gully erosion spread in South-Eastern Nigeria with particular reference to Anambra.

One may also say that ‘Gully Erosion’ is a significant land degradation process and a source of sediment to rivers (Lemly, 1982). This sediments, together with attached nutrients, has affected downstream riverine ecosystems by smothering bed habitat, reducing diversity of bed-forms and increasing turbidity and nutrient loads (Galloway et al, 1996)

It has also been concluded that erosion from streams and gully banks can generate up to 90% of the total sediment yield from a catchment (Olley et al, 1993; Prosser and Winchester, 1996; Wallbrink et al, 1998; Wasson et al, 1998)

CHAPTER THREE

3.0 METHODOLOGY

3.1 DATA ACQUISITION

Sources of Data

The data used for this project was obtained in varied ways, and could be classified based on the nature of the data, or the manner by which the data was obtained; here we will focus on the latter parameter to draw our distinction. For GIS, the data acquisition methods are classified as either

a) Direct/Primary Methods or
b) Secondary Methods

Primary Methods

These methods involve going to the field to carry out measurements and/or observations. Primary methods include conventional ground survey methods, gps surveys and so on. This project required taking gps readings and digital photographs at the different sites gone to.

Secondary Methods

Secondary methods involve using data already acquired by another party usually (usually through the primary methods). This method is usually used when further work is being done on a location where some previous work has already been concluded.

The execution of this project involved using both acquisition methods judiciously.

3.1.1 Data Acquired for the project

The data used in carrying out this project are as follows

- Administrative map of Anambra state
- Anambra state map showing gully sites
- Journals and relevant texts
- Researches and Past projects
- Information from the Internet
- Photos of gully some sites in Anambra

3.1.2 Instrumentation

This involves the various instruments used to carry out the project. They can be classified into Field instrument and Office instrument.

(a)Field Instrument

- GPS receiver (Magellan)
- Digital camera (Canon)
- Field Book

(b)Office Instrument

This involves hardware equipment and software applications used for office work in processing in data and analysis.

3.2.0 Procedure Adopted

- The image window of the study area was processed using standard image processing techniques
- Gully sites in the area were identified and characterized
- The pattern of spread of gullies was mapped using image classification
- Accuracy was assessed using overlay technique

3.2.1 Data Processing and Mapping of Erosion Spread

3.2.2.1 Image Enhancement

- Median Filtering for smoothening homogeneous areas of the image
- Contrast Manipulations to reduce cloud cover and haze over the image
- Laplace Filter operator to sharpen the image

3.3.2.2 Identification of Gully Sites

- Line and Edge enhancement operator to highlight all linear features
- Non gully features eliminated by applying thresholds derived from known gullies, leaving gully sites and outlines.

3.3.2.3 Measurement of Geometric Characteristics of Gully Sites

- On-screen Measurement of gully parameters such as areas, lengths, widths and perimeters for major sites

3.3.2.4 Field Work (Ground Truths)

- Confirmation and the existence and correct location of the identified gullies
- Assessment of the impacts of the spreading gullies on the immediate environment
- Location of other gullies within the Study Area that were not visible on the image
- Determining approximately those geometric properties such as depths and cross-sections which were not possible on-screen
- Identification and collection of other features that might aid erosion mapping.

3.3.2.5 Delineation of Gully Sites and Features

- Image Classification was done to delineate
    - Gully Sites (Major and Minor)
    - Water Bodies (Natural and Artificial)
    - Residential Areas
    - Major Flood Channels
    - Farmlands
    - Forests/Wooded Areas
    - Sand Deposits
- Ground Samples gathered from field investigations were used as ground truths
- Due to difficulty of spectral discrimination of some features, the classification was done with a combined method of manual and supervised classification.

3.3.2.6 Findings of study

At 32m resolution of NigeriaSat-1, major gullies can be correctly identified and delineated. The major gullies can be mapped at scale of 1:100,000. At smaller scale of 1: 200,000 –1:250,000, these gullies are reduced to just short lines and points.

- Geometric Characterizations of the gullies are possible only with extensive field work
- Detail Characterization can be achieved however with higher resolution satellite image and digital terrain model
- Overall classification accuracy of 86.17% indicates some difficulty in discriminating features due to spectral quality of the image.

However this accuracy is enough to support thematic mapping at the scale of 1:200,000 – 1:250,000. This study demonstrates the potentials in mapping and monitoring of gully erosion spread in South-Eastern Nigeria, with particular reference to Anambra State. This study demonstrates the potentials of image data from NigeriaSat-1 in mapping and monitoring of gully erosion spread in South-Eastern Nigeria, with particular reference to Anambra State.

3.4 Hardware Selection

The key hardware for any GIS is the input/output computer. The computer world

is one that has been faced with fast changes as observed over the years, hence it is recommended that for any GIS project, an up to date system ought to be employed. For any GIS project the hardware forms an integral part of its accomplishment as it can be viewed as the tools of work for the GIS expert.

The configurations of the hardware used are as follows

- A Fujitsu-Siemens Laptop
- X86 Family 6 Model 13 Stepping 8
- 512 MB Random access memory (RAM)
- Processor speed of 1500Mhz (i.e. Celeron M)
- Hard disc of 60GB

Other hardware equipment used are the following

- Hewlett Packard Scanjet 6100C
- Hewlett Packard Laser Printer 1100C
- Uninterrupted Power Supply (UPS) Device

3.4.1 Software Selection

Over the years, different software companies have embarked on the production of different GIS and Mapping software hereby giving the market a wide range to select from. These range from very simple mapping programs with limited analysis tools to highly complex and powerful GIS programs. Some are raster based; others vector based while some are a combination of both. Hence the choice of the software will be dependent on the nature of the GIS project to be embarked upon. However for this project ArcView 3.2a was used for data analysis while the vectorization was done using AutoCAD 2000i.

3.4.2 Application Software

ArcView is software produced by Environmental Science Research Institute (ESRI) in the United States of America. It allows for the following, Visualization of geographic data hereby revealing hidden information. Map creation in an effective manner hereby making maps more presentable. The file types used in ArcView is called shapefiles which are simple non-topological format for storing the geometric location and attribute information of geographic features which can be viewed as spatial data. The shapefiles format defines the geometry and attributes of geographically referenced features in as many as five files with extensions that should be stored in the same project workspace. These extensions are

- .shp- the file that stores the feature geometry
- .shx- the file that stores the index of the feature geometry
- .dbf- the dBASE file that stores the attribute information of features

When a shapefile is added as a theme to a view, the database file embedded withtin the shapefile containing attributes of the object is also added to the view

Other than the GIS software AutoCAD software was also used for the editing of certain base maps used for the project. AutoCAD provides tools to help make the most one's efforts in engineering designs, reducing the time you spend accessing and working similar designs. In AutoCAD interface, layers are used, which are similar to transparent overlays. Colours, line type, line weights and plot styles are assigned to each layer, and objects placed on a layer inherit the properties assigned to the layer.

3.5 DATA CLASSES

There are two different classes of data found in most GIS and these are the spatial data which is characterized by information about position, connection with other feaures, and there is non-spatial data or attribute data or aspatial data which for instance give details of the amount of snowfall, temperature, wind speed and direction.

Spatial data, represented as either layers or objects, must be simplified before they can be stored in a computer. A common way of doing this is to classify all geographic features into three basic entities and these are points, lines and areas.

- **Points**: These are features associated with a single location that is an object that occurs at one physical location in space and which has only one reference coordinate.
- **Line**: An object which spans between points and this requires at least two reference coordinates, its start and end to define its spatial location.

- **Area**: An object, which has area and is defined by a continuous closed boundary. A number of coordinates are required to define its boundary. Area features are also known as polygons.

Basically, the methodology for this project would involve data acquisition, data conversion and data processing.

3.6 DATABASE STRUCTURING AND GIS DATABASE DESIGN

Database design involves implementation of the above structured spatial and attribute data sets. The logical structure of spatial and attribute database for the data identified above is determined.

The technique through both spatial and attribute data sets is converted into a GIS database is defined. In this way, the type and number of theme layers to be created are determined for the spatial data while the features of associated attribute database are determined. The spatial data sets were captured in vector mode as point, polyline and polygon while the attribute records were structured into tabular database. The attribute records stored additional information about the spatial features and both databases ultimately linked through a functional multi relational linkage.

Keeping both spatial and attribute databases in a single GIS database is a step towards eliminating data redundancy, inconsistency, update anomalies and data maintenance and uncertainty, which could impair data quality to give bias information about the problem under view. Besides, a well-structured database enhances the speed of data retrieval and conserves storage space among others.

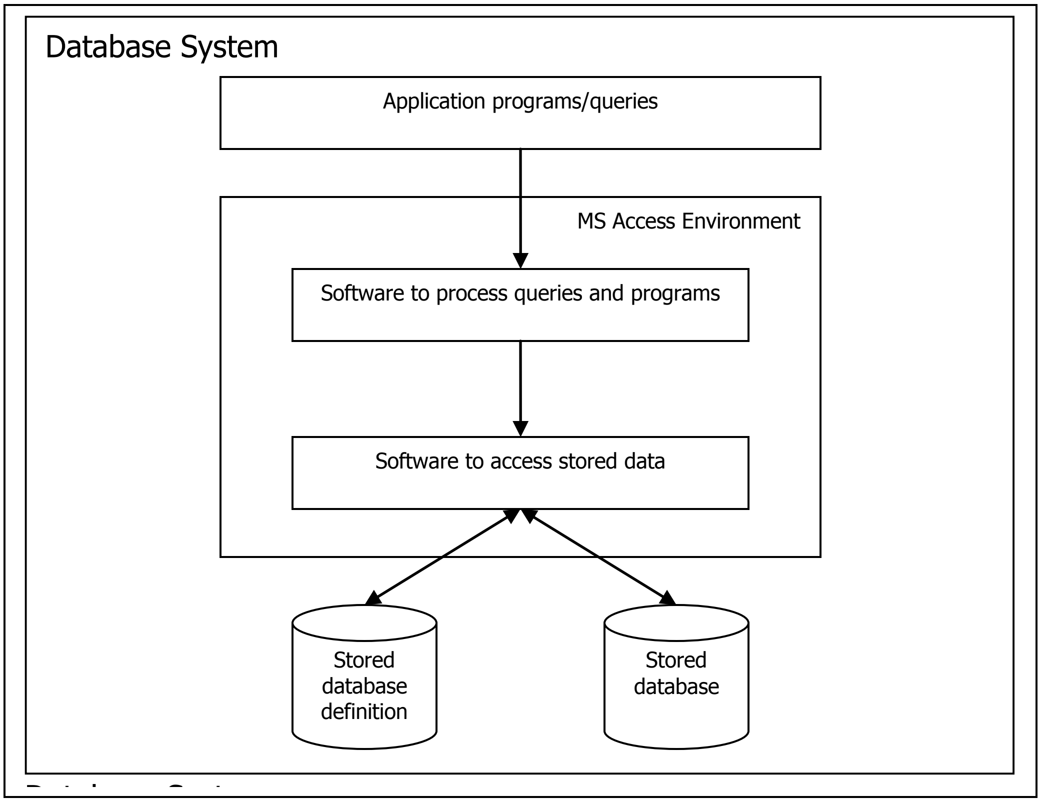


Fig 3.1: Shows an example of a database system design

Subsequently, the spatial and attribute data sets collected were structured logically for the purpose of conversion and processing. For this reason, the structure and pattern of GIS database was designed.
The spatial entities contained in the acquired spatial data are structured as point, line and polygons (Maguire, 1990) while the attribute records are structured into tabular format.
There are a number of database structures but those that have been used for attribute data in GIS are the hierarchical, network, relational and object-oriented types. The relational database structure type is the most widely used while object-oriented type is the emerging trend in GIS.

3.6.1 Hierarchical Data Structure

This is concerned about the relationship existing between data, referring to a one to many or parent child association. The parent-child relationship implies that each data element has a direct connection to a number of symbolic children, with each parent having the ability of association with their children and so on.

3.6.2 Network Structure

This stores data in a separate independent file depending on simple file structure. They are similar to hierarchical structure, the only major difference is that multiple connections between files are used. The multiple connection called pointers enable the user gain access to a particular file without having to search the entire hierarchy above the file. The structure is more rigid than hierarchical structure in that it can handle many-to-many relationship

3.6.3 Relational Data Structure

In relational structure flexibility is achieved by eliminating the hierarchy of fields. It has physical objects and logical objects that we want to store information about, and the existing relationship between the physical and logical objectives or logical entities. Each entity has attributes that describes its characteristics.

3.7 DATA CONVERSION AND PROCESSING

The data sets were collected in analogue format and require digital conversion to above specifications. Based on the above designed structure, a GIS database is created by conversion of both spatial and attributes data collected into a digital format. This process involves using hardware accessories and software packages. The process involves the following steps:

3.7.1 Analogue to Raster Conversion

The first step in conversion of spatial data is scanning of analogue map collected into raster image. In this way, an image file is created using large format scanner.
Scanner is a device that enables the scanning of a picture, line drawing, text or other graphic element into a form useable in CAD (Computer Aided Design)/GIS environment. Scanning a map is a straight forward process that converts details on the analogue map into picture element (pixel). In other words, scanning converts points, lines, areas and text on paper maps into a series of picture elements or pixels. The higher the resolution of the scanned image (more dots per square-inch), the smoother and more accurately defined the data will appear. As the dots per inch (dpi) increases, so does the file size. One of the advantages of scanning is that the user sees a digital image that looks identical to their maps.

3.7.2 Raster to Vector Conversion

The AutoCAD/Raster Design software was used to convert the scanned raster image into vector entities. It is important to highlight some of the features of this software that make ideal software for this purpose. The AutoCAD software is embedded with image processing extension (tiff 6.0) – a module used in viewing and processing image stored in .tif format. The software was used to geo referenced the image. In other words the image was registered to geographic coordinate system and projected to decimal degree coordinate data after georeferencing was in UTM (Universal Transverse Mercator) taking the zone of the study area into consideration.

3.8 ATTRIBUTE DATABASE CREATION

All theme layers created have their associated attribute databases which are geo linked to the spatial database. The attribute databases have additional information about gully information in the state. These information were inputted using Microsoft excel the information was converted from .xls to .dbf and later integrated as part of the spatial dataset

However, the combination of these spatial and attribute databases make up a typical GIS database.

3.8.1 DATA STORAGE

The spatial and attribute database files created above were all stored in a common folder to enable a well organized database. These digital files require 60mb of storage space and the the memory of the system was adequate enough (512mb). The files are also stored in removable storage devices (USB flash memory) to serve as backup.

3.9 DATA MODEL

The conceptual modeling process is aimed at achieving a clear representation of all entities (objects) and their attributes and all relationships between entities that are required to meet the foreseeable information storage and retrievable requirements (Jones, 1997). Usually a database structure is a representation of the conceptual data model often expressed in terms of diagrams, lists and arrays designed to reflect the recording of the data in computer code (Peuquet, 1990). The purpose of the logical data model is to represent the conceptual model components in terms of the computational concepts of a particular type of database. Conceptual data models can further be simplified by translating or abstracting them into data structures. The commonest data structures are hierarchical, network, relational and object-oriented as mentioned earlier; of all these, the relational model is the most widely used. In fact, in GIS applications, the non-spatial data are often represented by a relational database structure (Kufoniyi, 1995). The Relational Data Model is used in this project. Generally a relational database structure is a two-dimensional table made up of rows (also known as records) and columns (also known as fields). Each row contains a single record representing an entity or object. The relationship between all fields in a table is called a relation.

CHAPTER FOUR
4.0 RESULT AND ANALYSIS

4.1 DATA ANALYSIS

Geographical analysis from the results shows that the topography, soil texture and the population density contributed a lot to erosion in Anambra state.

There are more number of gullies in those areas that has higher gradient (example: Aguata, Aniocha e.t.c) than in those areas of level ground (example Onitsha, Ogbaru e.t.c).

Also shows that gullies are more in the areas that has loamy soil than in those areas of sandy soil and clay soil respectively and it indicates that areas with high topography has the sharpest gradient, which increases the velocity of the flood .

But Onitsha with the highest population is a strong indication that erosion will occur more, but it has the lowest number of gullies because the area is more of sandy soil and it has practically its on a level plane. Analysis shows that the topography of Onitsha has a major effect, since it is on a level plane while other areas has higher elevation with the contribution of soil type and population.

4.2 QUERY

This involves operations carried out based on the capabilities of this software, on the modeled data so as to get information for solving a particular problem. The type of query or analysis is dependent on the data model used. The information produced from the query can be for decision only.

A query or query expression is a precise definition of the kind of information we want to select. We do not always want to view all the obtainable data in our spatial type of information or view all the data (within the database) which satisfy certain criteria, which we will specify. For instance, if we need all the local government area with hotel, generally, Imo state will be required, but more specifically, local government area with hotels are needed, we thus need to “ask” the database for the required local government area. This could be done using a query.

4.3 SPATIAL & ASPATIAL QUERIES/ANALYSIS

A query expression can include multiple attributes, operations, and calculations, therefore, this make building a query expression a powerful way to select features. Generally query can be of two categories-spatial or aspatial and these depends on what we are querying for. Some methods also involves querying for both spatial and aspatial at the same time, such is called buffering.

All queries carried out are carried out to extract either spatial or aspatial based information which is or are needed to solve a particular decision based problem. The operation involved could be done on the attributes to get spatial or on the spatial to get aspatial or operation carried to get both at the same time.

4.3.1 SPATIAL QUERY

This involves finding features from their attributes in other to discover where particular features are located or see which features meets particular criteria. Thus, we use attributes (aspatial data) to locate features.

These can be achieved by using any of the following approaches:
-Selecting features on a map using the attributes which involves displaying a view or feature using the attribute or database. This can be done either by using the FIND button which finds individual features on a map or by finding important features by sorting their attributes.
-Building query expression with the ArcView Query Builder. This involves using a Query Builder to find features or group of features of interest.

Three buttons are very important in Query Builder, they are: i) New Set-which makes a new set containing the features selected in the query expression.
ii) Add To Set-this adds the feature selected in the query expression to the existing set of selected features. This is used to widen selection.
iii) Select From Set-this applies your query expression only to those features that are already selected. This is used to narrow selection.

4.3.2 ASPATIAL (DATABASE) QUERY

This asks questions about the attributes of features. It involves getting the attributes of features in the map. This is done by selecting the features or spatial entities and looking for their attributes. Thus, operations are carried out on the features in order to get their attributes or information about them in order to solve certain problems. This can be done using any of the following:
-Identifying features on the map with the mouse (identity query) in other to get their attributes.
-Selecting features of interest on the map and opening the theme table to see their attributes.

4.3.3 BUFFERING

There is a range of functions available in GIS that allow a spatial entity to influence its neighbor, or the neighbor to influence the character of an entity. The most common example is buffering, the creation of a zone of interest around an entity or set of entity. Creating buffer zones around point features is the easiest operation; a circle of the required radius is simply drawn around each point creating buffer zones around line and area features is more complicated. Some -GIS do this by placing a circle of the required radius at one end of the line or area boundary to be buffered. The circle is then moved along the whole length of the segment. The path that the edge of the circle is tangential to the line it makes. It is used to define the boundary of the buffer zone.

This method in reality involves both spatial and aspatial query. Buffering is used to carry out several query such as;

-finding features that fall inside polygons.
-finding features near other features.
-finding features that intersect other features.
The result of buffer operations performed relating to the gullies is shown below

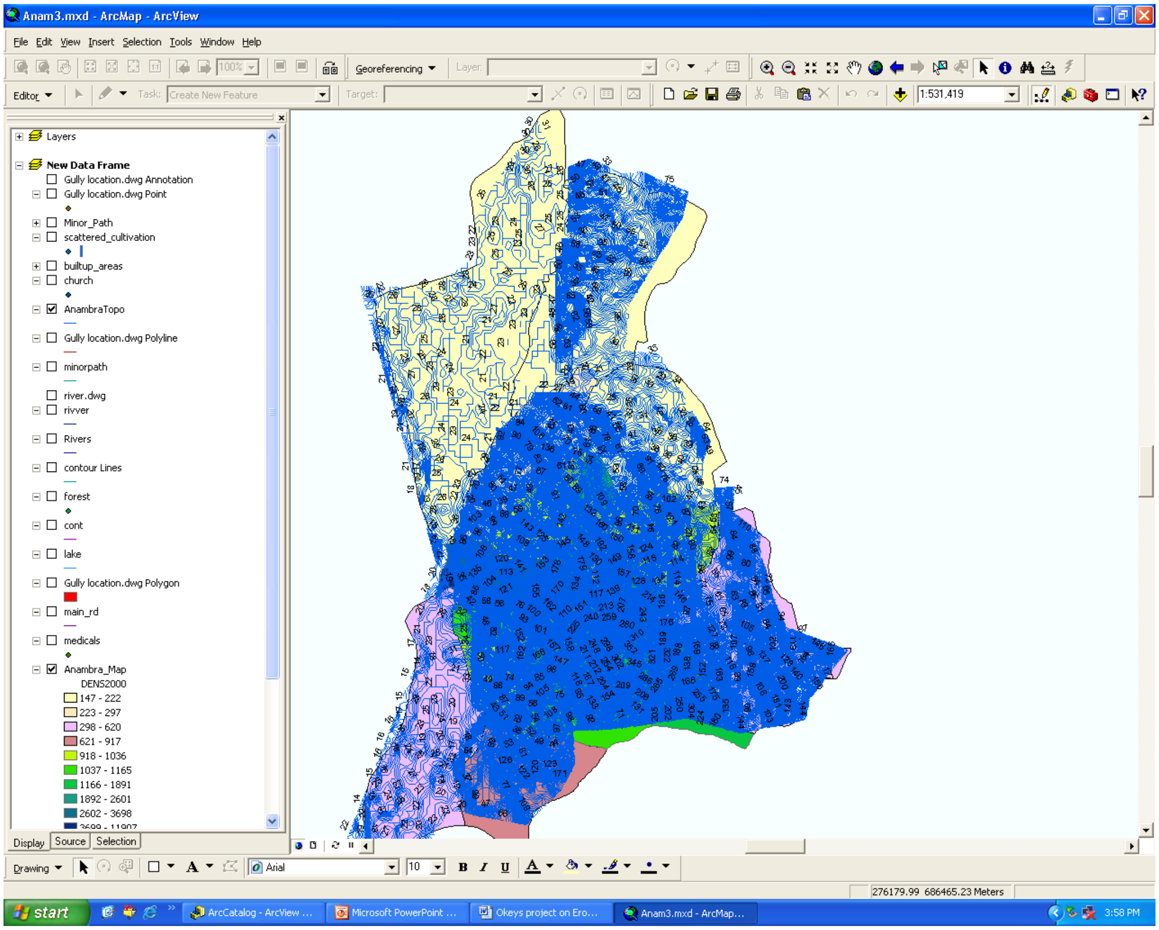


Fig 4: Map of Anambra showing the Population density and the topography

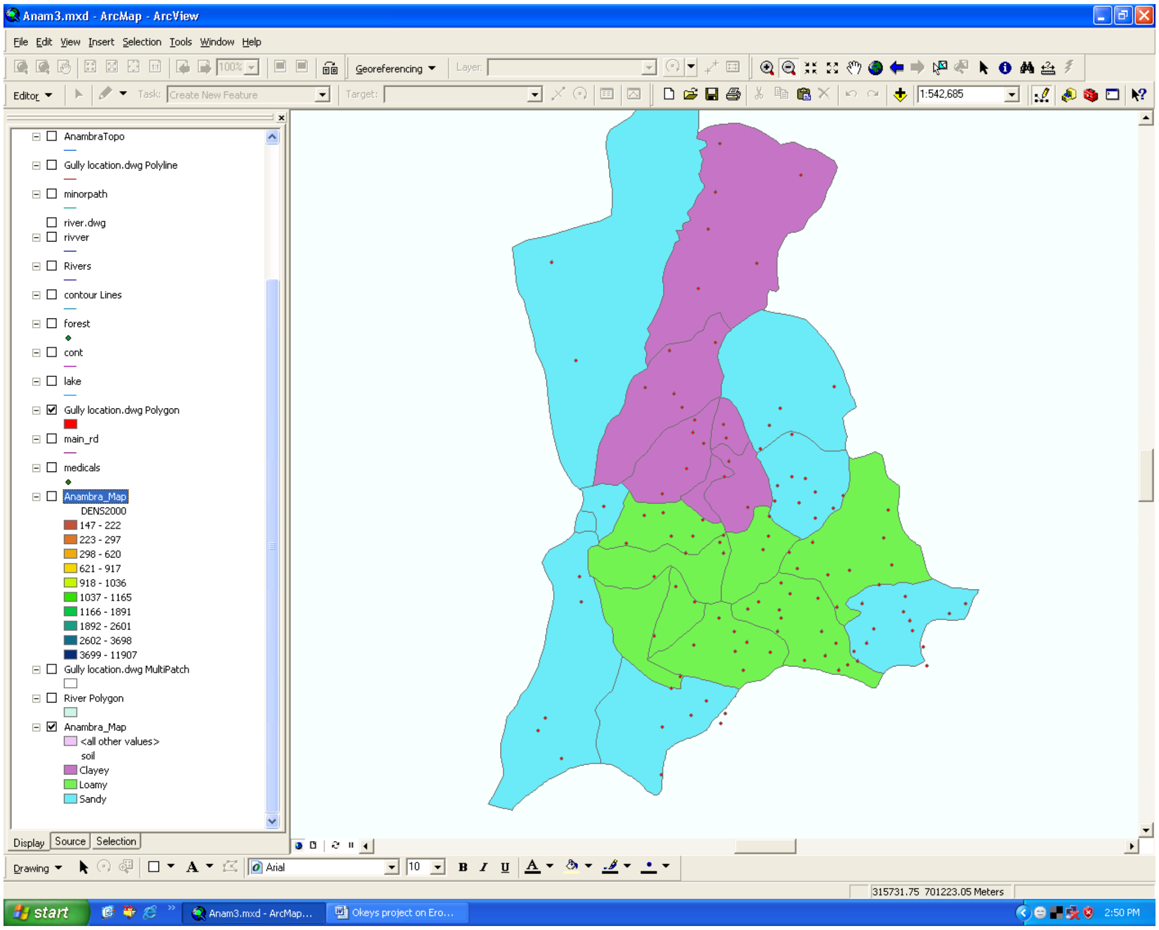


Fig 5: Map of Anambra showing soil texture and Gully erosion spots.

The deduction from this shows that population density, together with the soil types of the zone are key factor causing erosion in the state.

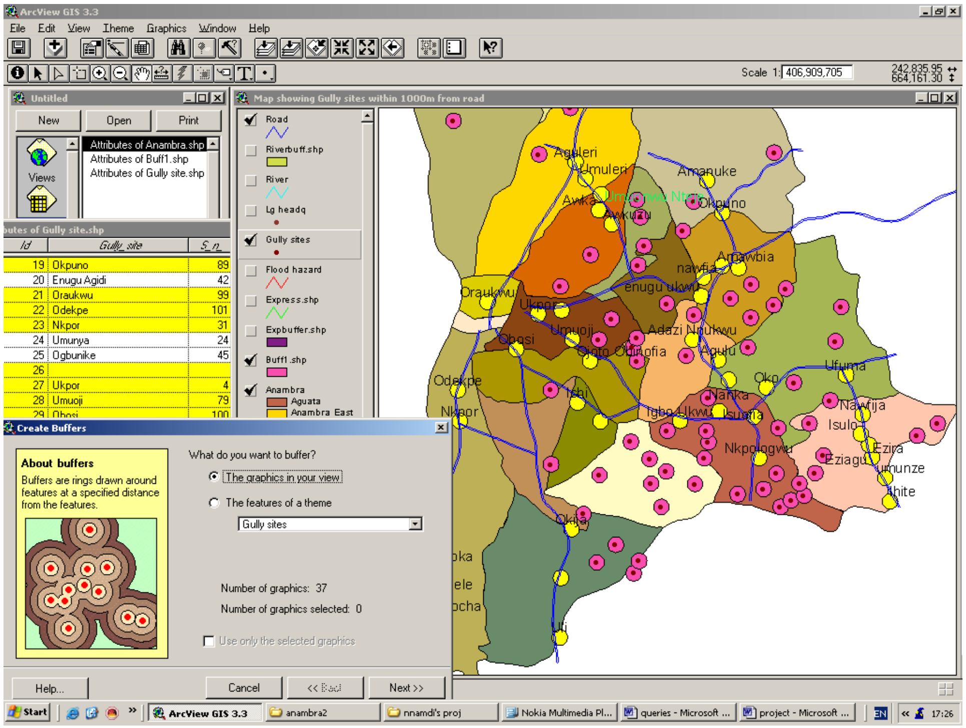


Fig 6: Map of Anambra showing buffer region of gully sites within 1000m from the road

This buffer shows that if timely actions are not taken the eroding process would cut off the access roads which would be disastrous.

Table 4: Attribute table showing some roads in Anambra State

NO	ROAD NAME	OWNERSHIP	WIDTH (m)	SUBCLASS
1	Anaku rd	local govt	7	dual carriage
2	ifite ogwari rd	local govt	7	dual carriage
3	Nibo rd	state govt	8	motorway
4	Oko rd	state govt	8	motorway
5	Bridge head rd	state govt	9	dual carriage
6	Uga st	local govt	6	Street
7	Fegge rd	local govt	7	dual carriage
8	Ozubulu rd	state govt	8	motorway
9	Aurthur Eze rd	local govt	7	dual carriage
10	Bida rd	local govt	7	dual carriage
11	Sokoto rd	local govt	7	dual carriage
12	Awka express	Federal govt	9	Toll road
13	Enamel market rd	Local govt	7	dual carriage
14	Old nkwo market rd	State govt	7	Bye-pass
15	Ozalla avenue	local govt	6	Avenue
16	Otuocha rd	local govt	7	dual carriage

17	Nawfija rd	local govt	7	dual carriage
18	Isuofia rd	local govt	5	Street
19	Nkpologwu rd	State govt	7	dual carriage
20	Okorocha rd	State govt	8	Street

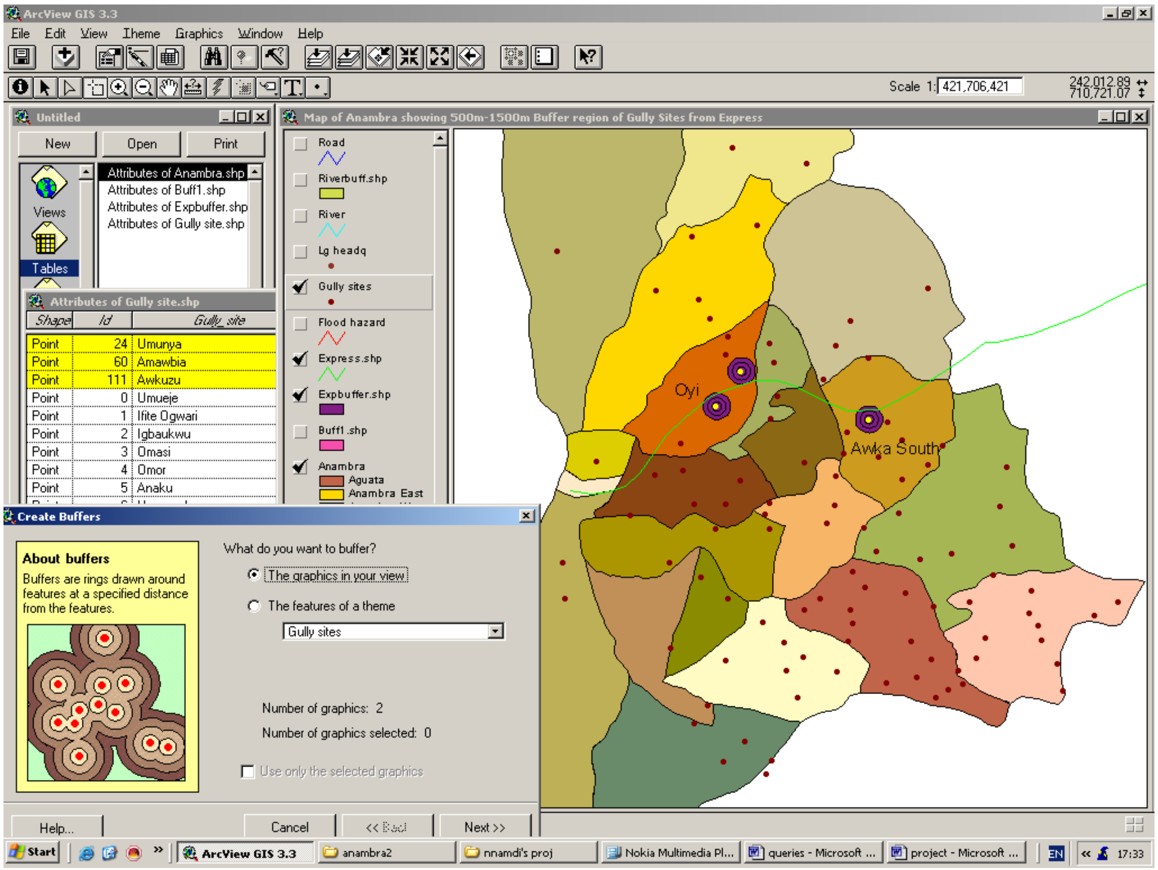


Fig 7: Map of Anambra showing 500m-1500m buffer region of gully sites from express

Fig 7a: Graph of Gully Sites in Anambra State with a Proximity Range of 1500m from Express.

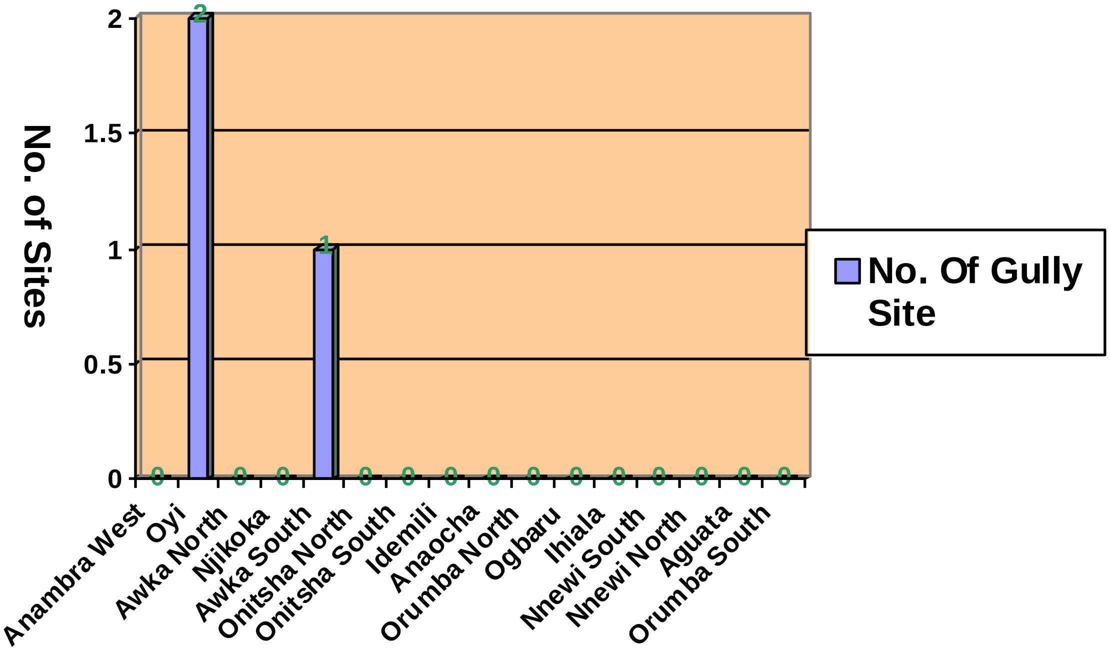
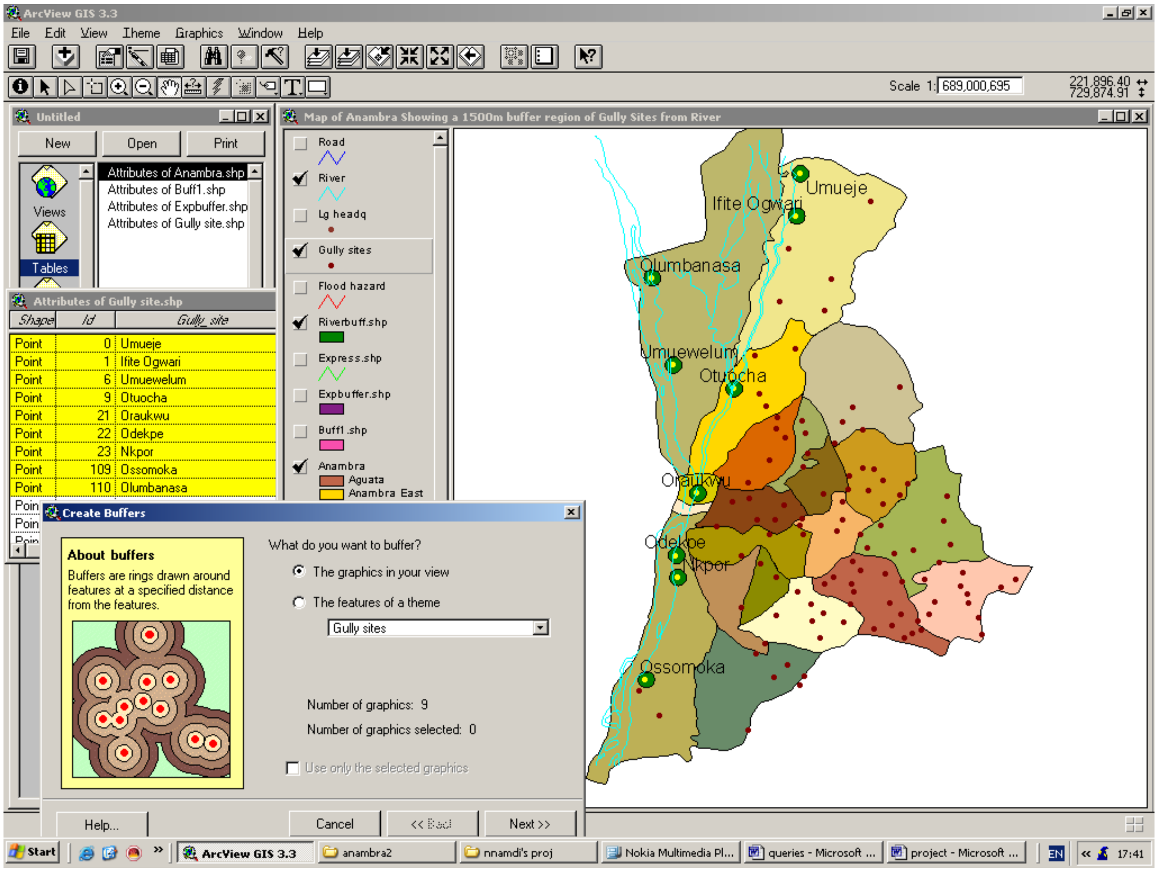


Fig 8: Map of Anambra showing a 1500m buffer region of gully sites from river



The deduction from this analysis is that the gullies found near the river due to run-off probably after rainfall can deposit sands at the river basin. It is evident that the eroding process moves along the direction of the flow of the river

Table 5 Table showing express road and its width

NAME	WIDTH_(M)
Iweka Awka express	12

4.4 METHODS OF SPECIFYING QUERIES

The methods of specifying queries in a GIS can have a highly interactive tendency. Users may interrogate a map on the computer screen or browse through databases with the help of prompts and query builders. Queries could be made more complex by combination with questions about distances, areas, and perimeter, particularly in a vector GIS, where these data are stored as attributes in the database. The methods of specifying queries for vector GIS could be

- Basic Query; Query with nested basic queries.

Queries are performed in Arcview using the Query Builder. This is triggered by clicking a button, which is a tool that transforms a series of instructions passed by the user, into

SQL (Standard Query Language), pronounced Sequel

4.4.1 Standard Query Languages

Different systems use different ways of formatting. The standard Query language (SQL) is used by many.

In query classification and translation, the delimiters “[ ]” “< >” and “& “are helpful.

This delimiter makes it possible for the query processor to identify an entity, qualifier, constraints, sub-query etc. All the delimiters are used in pairs.

4.4.2 Types of Queries

Queries can be classified into different types:

- Basic Query; Query with Nested Basic Query; Query with Multiple Constraints; Query with Special Relational Descriptor; Query by Attribute Method

1. Basic Query: **-** This is the simplest form of a query with one entity and one constraint e.g. show {Local Gov. Area} {Name _ town = Anambra West}.

The result is displayed on the map with the specified town name highlighted.

2. Query with nested Basic Queries: **-** The type of query has a nested structure. A basic query forms the innermost part of the nest structure. A larger query is formed around the basic query by prefixing a relational descriptor and an entity. Each sub-query may have only one constraints and/or parameter for the outer query. Hence, the translation of such as a query begins at the innermost basic query and proceeds outward. Example of nested basic query is shown below.

Show {Nnewi l.g.a} {containing </Ozubulu rd/{Name = Anambra State”}>

3. Queries with multiple constraints: **-** Queries with multiple constraints may require the execution of one more {possibly nested} sub-queries. At each level of nesting, all the sub-queries must be executed to obtain the necessary parameters before the execution of the next level of the query. Example of queries with multiple constraints is:

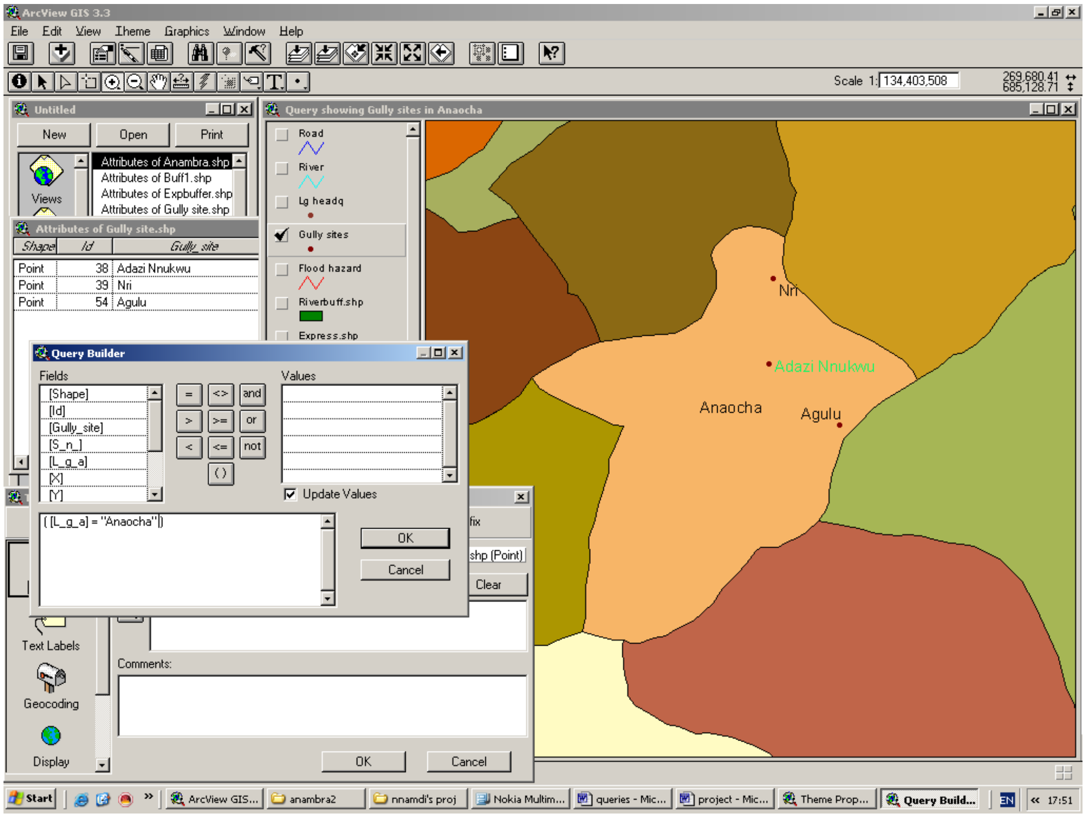
Show {Gully sites} type = “length &” within < {Oyi l.g.a} {name = “Anambra State”}. In this case, the delimiter “&” separates the constraints and is used to denote the logical AND operation.

4. Queries with special relational descriptor: **-** The delimiter “&” in this case represents the separation of two parameters for the relational descriptor between.

4.5 QUERY RESULT/ANALYSIS

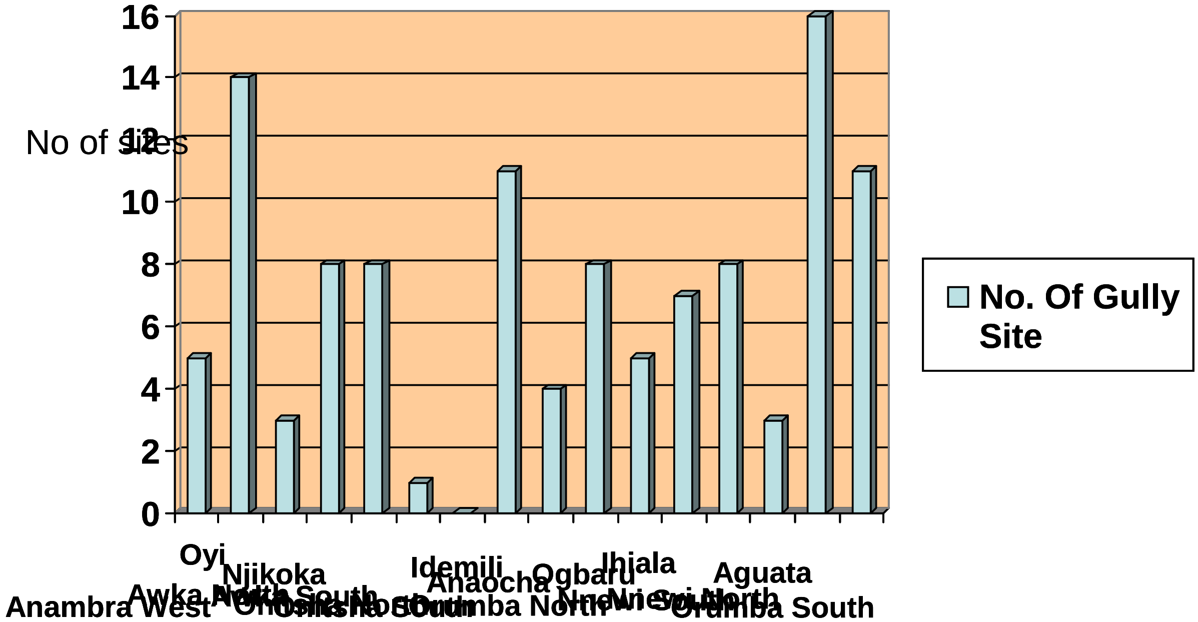
Spatial and Aspatial query results/analysis were carried out in this project, the results obtained from the various analysis performed are as follows

Fig 9 Map of Anambra Showing gully sites in Anaocha L.g.a



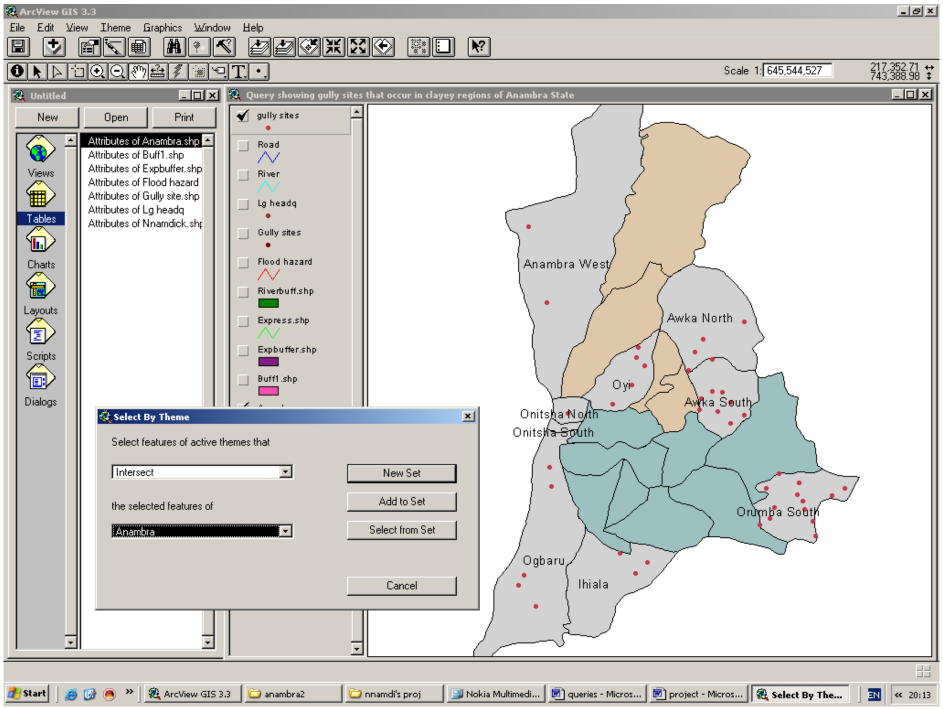
This query was performed to show the gully sites in Anaocha Local Government. The result shows a total of three gully sites in Anaocha which has a loamy soil characteristic.

Fig:9a **<u>Graph Showing Number of Gully Sites in each L.G.A of Anambra State</u>.**



From the graph it is clearly seen that Aguata Local Government Area with 16 gully sites has the highest number of gullies. Oyi l.g.a comes next with 14.

Fig 10: Query showing gully sites that occur in sandy regions in Anambra State

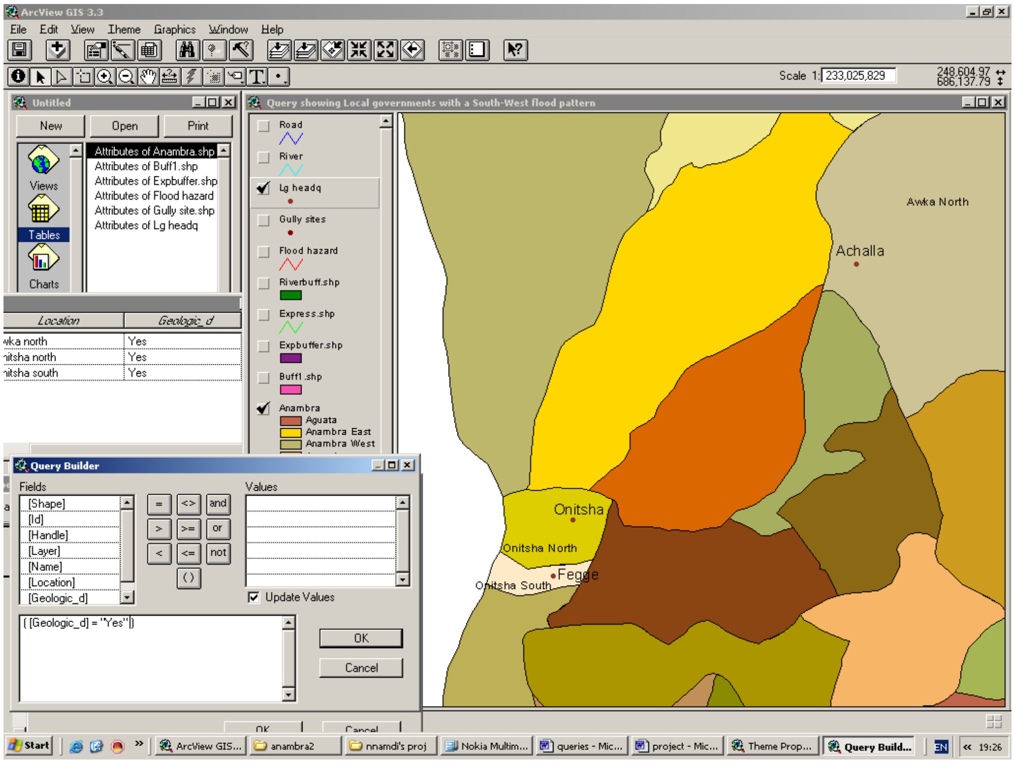


This query was performed to show gully sites that occur in sandy regions

Table 6 Table showing L.g.a and the soil texture in them

NAME	SOIL TEXTURE
Anambra west	Clayey
Oyi	Clayey
Awka north	Sandy
Awka south	Sandy
Njikoka	Clayey
Anaocha	Loamy
Onitsha north	Sandy
Onitsha south	Sandy
Nnewi north	Loamy
Nnewi south	Loamy
Ogbaru	Sandy
Ihiala	Sandy
Aguata	Loamy
Orumba north	Loamy
Orumba south	Sandy
Idemili	Loamy

Fig 11: Map of Anambra showing LGA with geologic department



This query was performed to identify the l.g.a that have geology departments the reason is to try and attribute the frequent gullies to lack of geological understanding of the soil in an area. The result shows just three l.g.a having geology departments.

Table 7 Table showing l.g.a. headquarters and existence of geologic departments

LGA HQ	LGA	ANY GEOLOGIC DEPT
Otuocha	Anambra west	No
Nteje	Oyi	No
Achalla	Awka north	Yes
Abagana	Njikoka	No
Neni	Anaocha	No
Ajali	Orumba north	No
Ekwulobia	Aguata	No
Ukpor	Nnewi south	No
Ihiala	Ihiala	No
Atani	Ogbaru	No
Nnewi	Nnewi north	No
Ogidi	Idemili north	No
Fegge	Onitsha south	Yes
Onitsha	Onitsha north	Yes

The graph clearly shows that the l.g.a with the lowest amounts of gullies are the ones that have geology departments. The l.g.a that do not have geology departments have more gullies found in them, due to the unavailaibility of Geology departments in these l.g.a they can't investigate the soil and properly check the process of soil run-off.

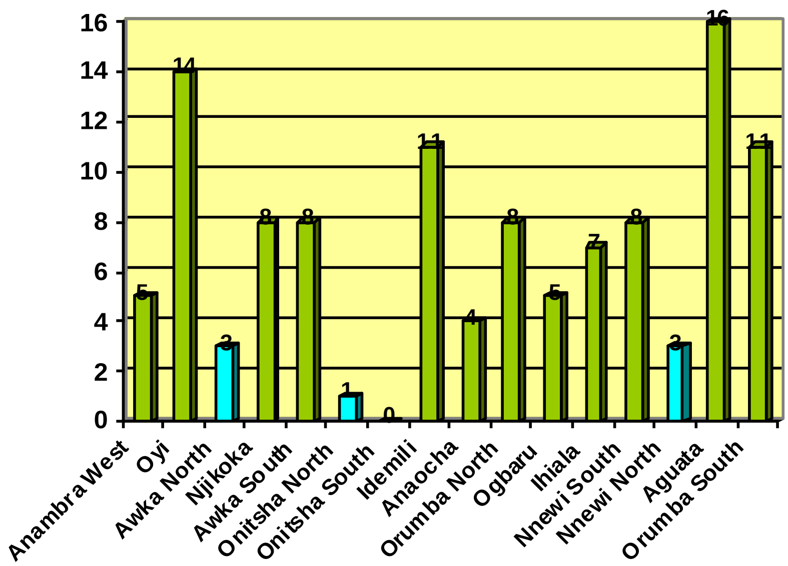
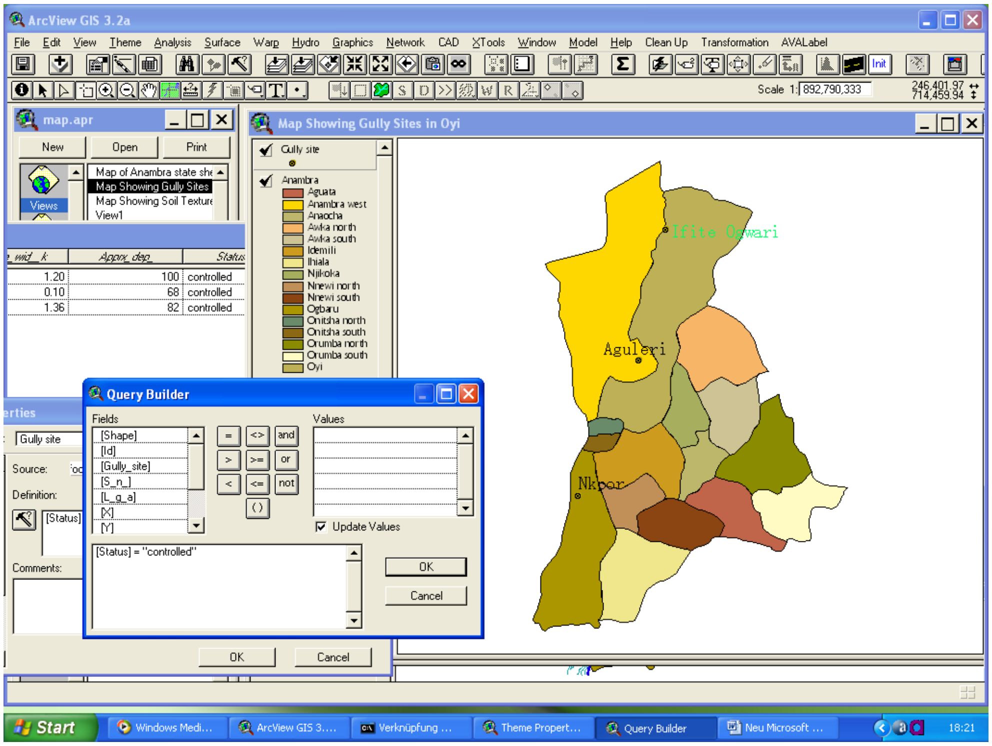
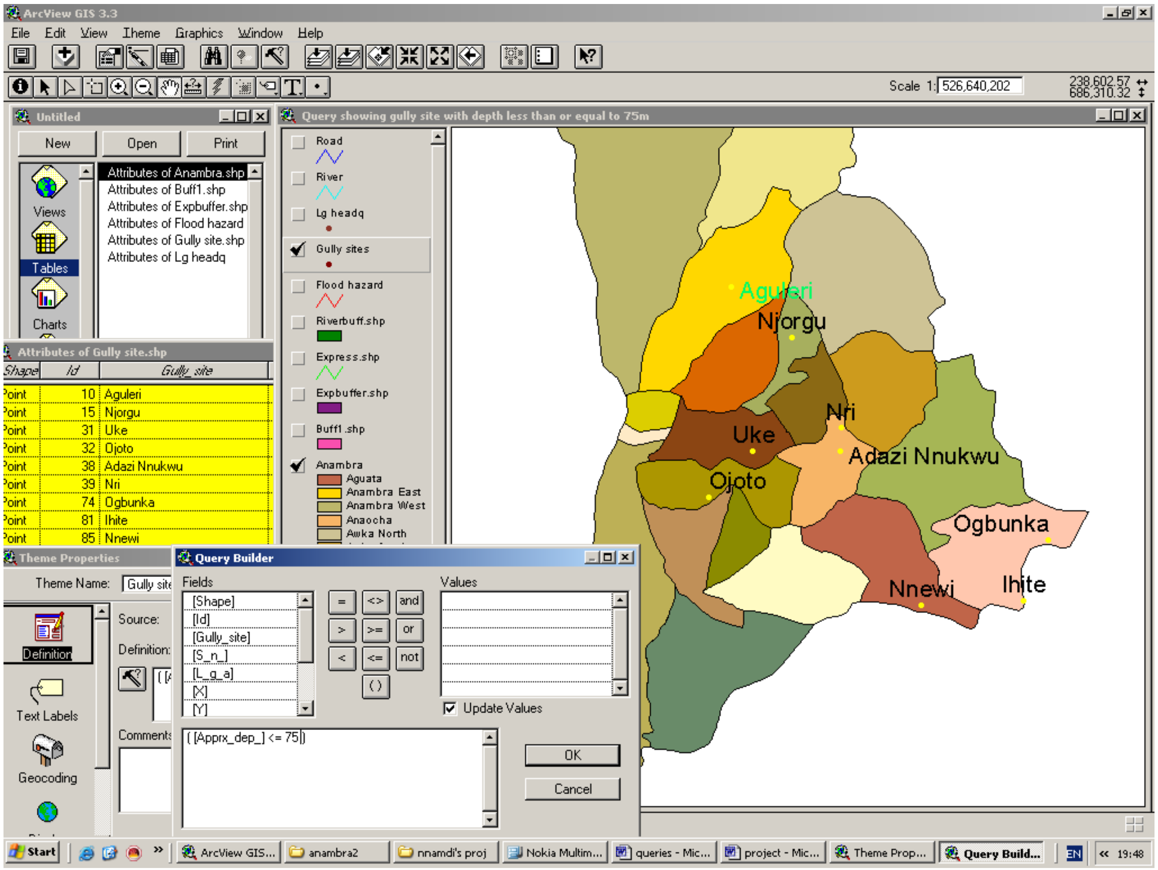


Fig 12 Map of Anambra showing controlled gully sites



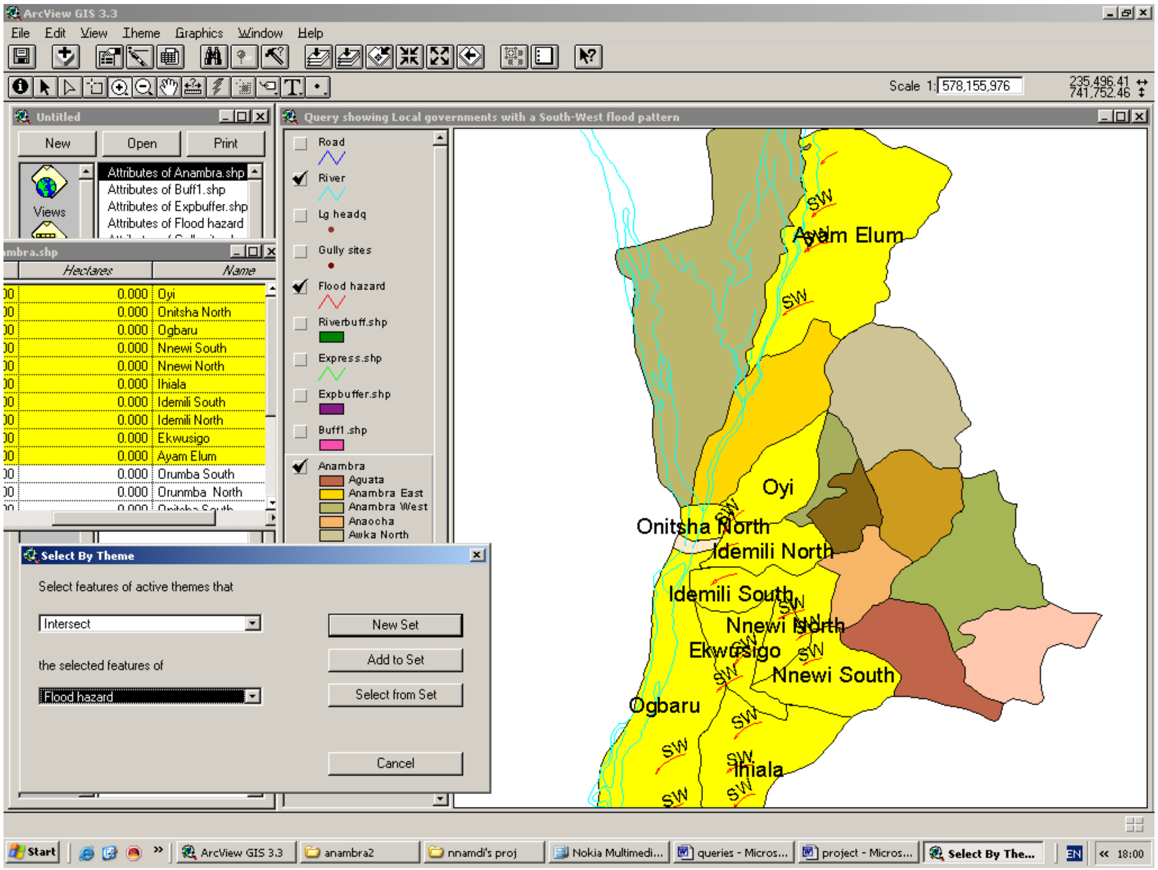
This query was performed to identify the gully sites being controlled the result shows just three sites. This result shows that there is urgent need for more control works to be carried out in other parts of the state.

Fig 13. Map of Anambra showing gully with depth less than 75m



This query was performed to show the gullies with depth of less than 75m, the result shows that 9 gullies have depth less than 75m. Relating this to the soil texture result we can see that Oyi that is predominantly clayey is not included in this particular result as clayey regions erode rapidly hence the depth would be more in such areas as against sandy and loamy parts.

Fig 14 Map of Anambra showing flood hazard in the SW direction



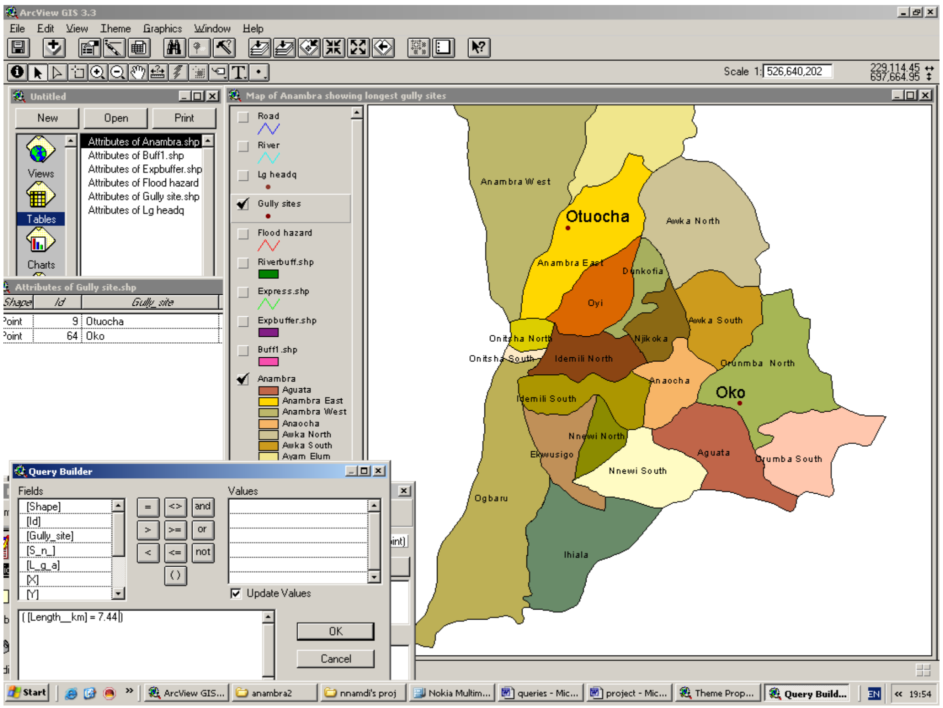
This query shows the location of flood hazards in the state and their direction in the South West. It can be seen that it is perpendicular to the flow of the Anambra river. The number of hazards in the SW direction is 17 as highlighted in the image above.

Table 8 Table showing flood hazards and their direction

DIRECTION	LOCATION	FLOOD HAZZARD
NE	Anambra west	1
NE	Anambra west	1
SW	Oyi	1
SW	Oyi	1
SW	Oyi	1
SW	Oyi	1
SW	Onitsha north	1
SW	Onitsha south	1
SW	Idemili	1
SW	Nnewi north	1
SW	Nnewi north	1
SW	Nnewi north	1
SW	Nnewi south	1
SW	Ihiala	1
SW	Ihiala	1

SW	Ihiala	1
SW	Ogbaru	1
SW	Ogbaru	1
SW	Ogbaru	1
W	Idemili	1
W	Nnewi south	1
E	Ogbaru	1
E	Ogbaru	1

Fig 15: Map of Anambra showing longest gully sites



This query shows gully site with the longest length. The result shows that there are 2 gullies having estimated long lengths as highlighted above one of the sites is located near the Anambra River this explains the major role the flow of water plays in gully formation.

Table 9 Table showing gully sites and their geometric characteristics

S/N_	GULLY_SITE	L.G.A	X	Y	LENGTH_(KM)	AVE_WID_(KM)	APPRX.DEP_
1	Agulu	Anaocha	285830.10	673542.60	4.22	2.25	150
2	Nanka	Orumba North	287193.28	671256.17	4.00	2.25	150
3	Ekwulobia	Aguata	290094.23	666458.62	7.44	3.45	120
4	Ukpor	Nnewi South	271459.97	659379.11	0.86	1.81	105
5	Oko	Orumba North	292159.17	670575.10	7.44	3.45	120
6	Alor	Idemili North	275215.35	673387.55	1.21	2.55	95
7	Uke	Idemili North	270675.18	676282.37	0.45	2.77	45
8	Umueje	Oyi	274997.99	739067.20			
9	Omasi	Oyi	287865.93	733841.49			
10	Ifite Ogwari	Oyi	274275.46	731331.77	2.50	1.20	100
11	Igbaukwu	Oyi	272861.45	725569.64			
12	Omor	Oyi	280774.89	720275.17			
13	Anaku	Oyi	271345.12	715998.32			
14	Olumbanasa	Anambra West	248142.10	720916.97			
15	Igbariam	Oyi	274077.79	707340.94			
16	Aguleri	Anambra West	267724.45	699254.60	3.20	0.10	68
17	Umuleri	Anambra West	268897.95	697104.86			
18	Umuewelum	Anambra West	252081.68	704511.49			
19	Amanuke	Awka North	284534.93	696849.23			
20	Urum	Awka North	282728.56	694297.84			
21	Njorgu	Njikoka	275951.57	692302.75	4.00	0.02	40

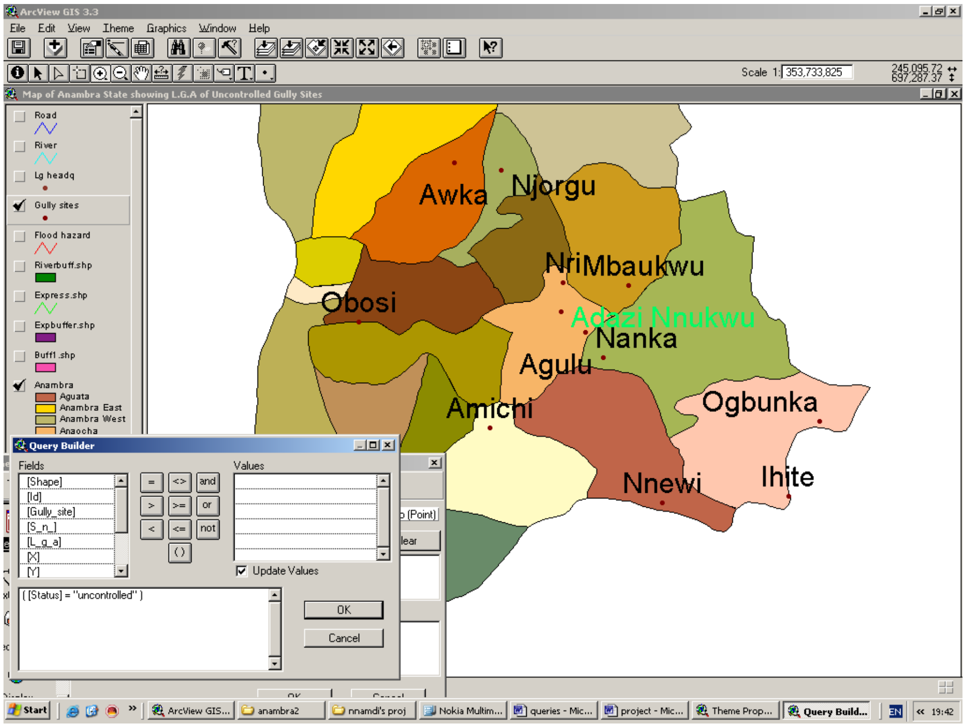
22	Awkuzu	Oyi	272306.83	691424.41			
23	Nteje	Oyi	270453.29	693132.82			
24	Umunya	Oyi	269584.01	687461.15			
25	Abba	Njikoka	276551.87	688682.26			
26	Amawbia	Awka South	286702.23	685342.05			
27	Ifite Dunu	Njikoka	275498.82	686094.69			
28	Nise	Awka South	287206.00	681491.04			
29	Mbaukwu	Awka South	290023.72	679146.49	2.00	2.50	110
30	Ideani	Idemili North	275258.59	676714.43			
31	Nkpor	Idemili North	263454.25	679621.11	2.45	1.36	82
32	Ichi	Nnewi North	267561.23	668321.60			
33	Ihembosi	Ihiala	268523.23	654306.71			
34	Ezira	Orumba South	305532.12	66149.23			
35	Uga	Aguata	288756.47	657036.82			
36	Umuchu	Aguata	294160.53	654993.62			
37	Nkpologwu	Aguata	290849.94	661512.39			
38	Amesi	Orumba South	291434.16	657377.35			
39	Agbudu	Orumba South	299272.48	661706.98			
40	Ogbunka	Orumba South	311297.44	664391.88	1.30	2.00	50
41	Umuonwu Nteje	Oyi	270685.21	695102.65			
42	Enugu Agidi	Njikoka	281397.22	690267.56			
43	Nibo	Awka South	290096.39	683657.15			
44	Nimo	Njikoka	279278.26	680906.34			
45	Ogbunike	Oyi	265572.99	683466.47			
46	Nri	Anaocha	282569.18	679542.81	0.40	1.30	71
47	Ogbu	Orumba North	289614.21	675511.87			
48	Ndiokpalanze	Orumba North	299861.41	668702.66			
49	Ufuma	Orumba North	302441.74	671835.49			
50	Nawfija	Orumba South	304338.11	666961.28			
51	Ndiowu	Orumba North	295432.05	671088.82			
52	Ogbaji	Orumba South	297759.38	665733.60			

53	Oro Eri	Aguata	284612.97	668921.08			
54	Isuofia	Aguata	285975.84	667463.01			
55	Ndiukwuenu	Orumba North	301555.87	680687.36			
56	Awa	Orumba North	300901.10	676222.94			
57	Owere Ezukola	Orumba South	314053.94	665842.10			
58	Eziagu	Orumba South	305223.99	663189.61			
59	Aguluezechukwu	Aguata	293576.31	665258.26			
60	Ikenga	Aguata	284423.49	664771.78			
61	Ebenator	Nnewi South	282979.91	658146.54			
62	Akpo	Aguata	293284.20	659128.66			
63	Achina	Aguata	296205.31	658009.77			
64	Enugu Umuonyiba	Aguata	296531.33	656706.42			
65	Akwuata Utu	Nnewi South	279262.86	659615.14			
66	Osumenyi	Nnewi South	277169.40	658390.30			
67	Ezinifite	Nnewi South	284569.55	663215.06			
68	Utuh	Nnewi South	277120.71	661366.45			
69	Amichi	Nnewi South	274291.39	663473.91	1.30	1.80	130
70	Okija	Ihiala	266692.51	652250.05			
71	Mbosi	Ihiala	270318.56	647567.17			
72	Lliu	Ihiala	274423.53	646507.54			
73	Oguaniocha	Ogbaru	249941.41	641157.44	1.80	0.50	150
74	Oguikpele	Ogbaru	245747.16	645391.66			
75	Ossomoka	Ogbaru	247001.11	647551.97			
76	Ozubulu	Nnewi North	265135.41	660532.85			
77	Ojoto	Idemili South	264793.89	670093.05	0.08	1.24	47
78	Ojoto Obinofia	Idemili South	269467.04	673884.64			
79	Umuoji	Idemili North	267259.25	676757.64			
80	Abatete	Idemili North	272318.29	679090.77			
81	Abagana	Njikoka	277199.59	684284.81			
82	Adazi Nnukwu	Anaocha	282218.92	676739.46	1.02	0.89	75

83	Ihite	Orumba South	307646.33	655917.92	3.00	0.30	60
84	Uli	Ihiala	265399.68	638574.25			
85	Igbo Ukwu	Aguata	281009.95	666246.82			
86	Ukwulu	Njikoka	275555.62	694523.29			
87	Awka	Awka South	288384.89	685747.53	5.00	0.70	95
88	Ebenebe	Awka North	292880.08	700466.05			
89	Okpuno	Awka South	286376.62	692928.97			
90	Ishiogu	Awka South	294648.74	683079.52			
91	Umuawulu	Awka South	292770.38	681177.68			
92	Isulo	Orumba South	304107.02	664267.23			
93	Umuomoku	Orumba South	298055.35	659323.25			
94	Ekwulumili	Nnewi South	284423.49	661171.86			
95	Ifite	Aguata	279403.34	664933.34			
96	Orsumoghu	Ihiala	275962.89	648114.08			
97	Ihiala	Ihiala	265837.31	645071.91			
98	Nnewi	Nnewi North	271150.12	666031.67	0.67	0.78	20
99	Oraukwu	Idemili North	274782.95	675634.27			
100	Obosi	Idemili South	260038.31	675646.14	2.25	2.25	80
101	Odekpe	Ogbaru	252547.38	669940.59			

Source: Igbokwe J. (2004). “Gully Erosion Mapping/ Monitoring in Parts of South-Eastern Nigeria”

Fig 16 Map of Anambra showing l.G.A of uncontrolled site



This query was performed to identify the l.g.a where gully sites are uncontrolled. The result shows that quite a number of gullies are uncontrolled even in parts of the state capital. The percentage of controlled to uncontrolled can be seen below as further analysis was carried out.

Fig 16a: <u>Graph Showing the Percentage of Controlled to Uncontrolled Gully Sites in Anambra State.</u>

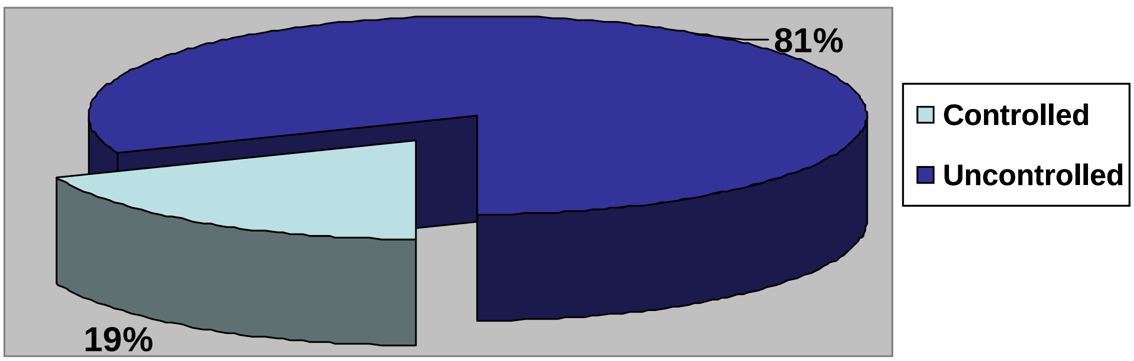
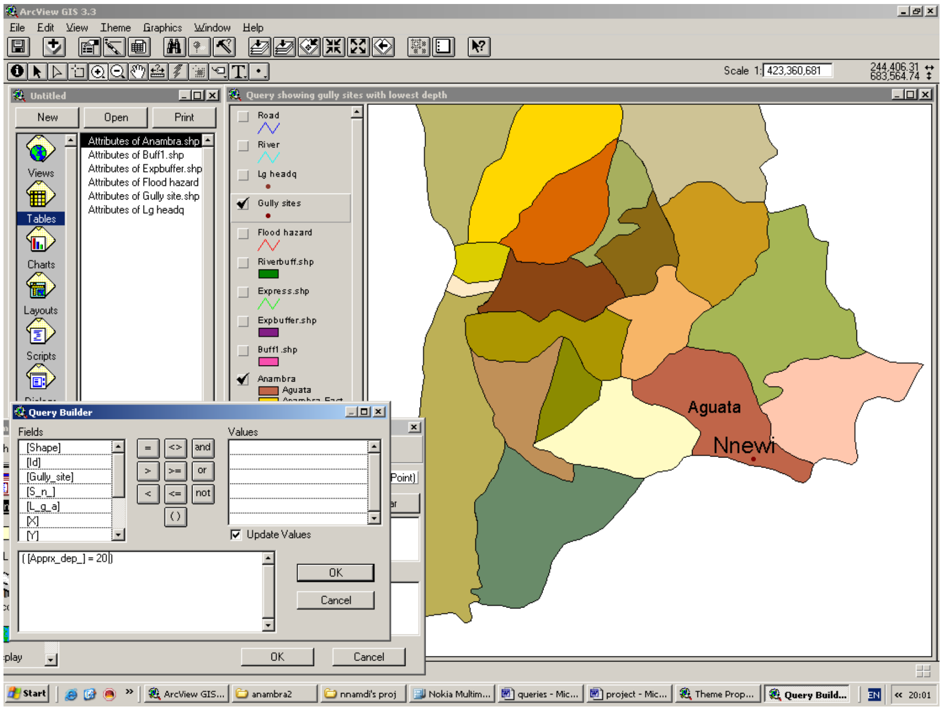


Fig17: Map of Anambra showing gully site with lowest depth



This query was performed to identify the gully site with the lowest depth, the result shows that Nnewi gully has the lowest and it can be attributed to the fact that the soil texture is not clayey and also the erosion process is not rapid owing to the non-existence of major water bodies like rivers that could cause run-off of top soil.

Fig 21: Chart Showing Lowest Depth of Gully Site in some L.G.A visited

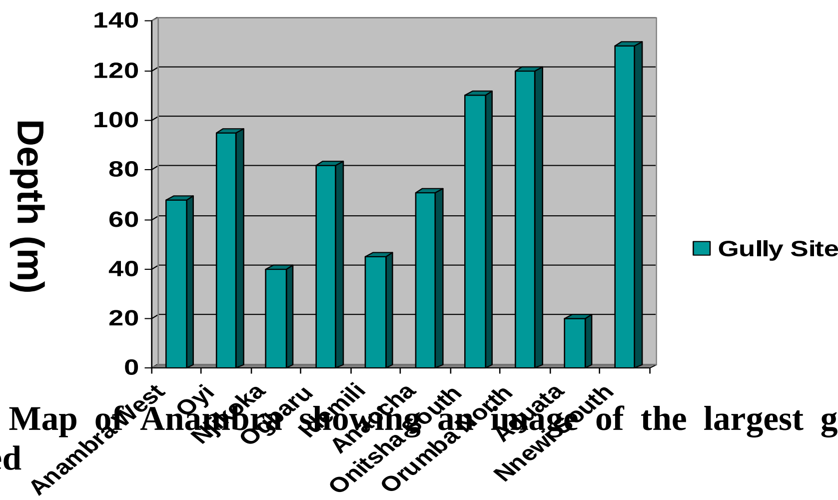
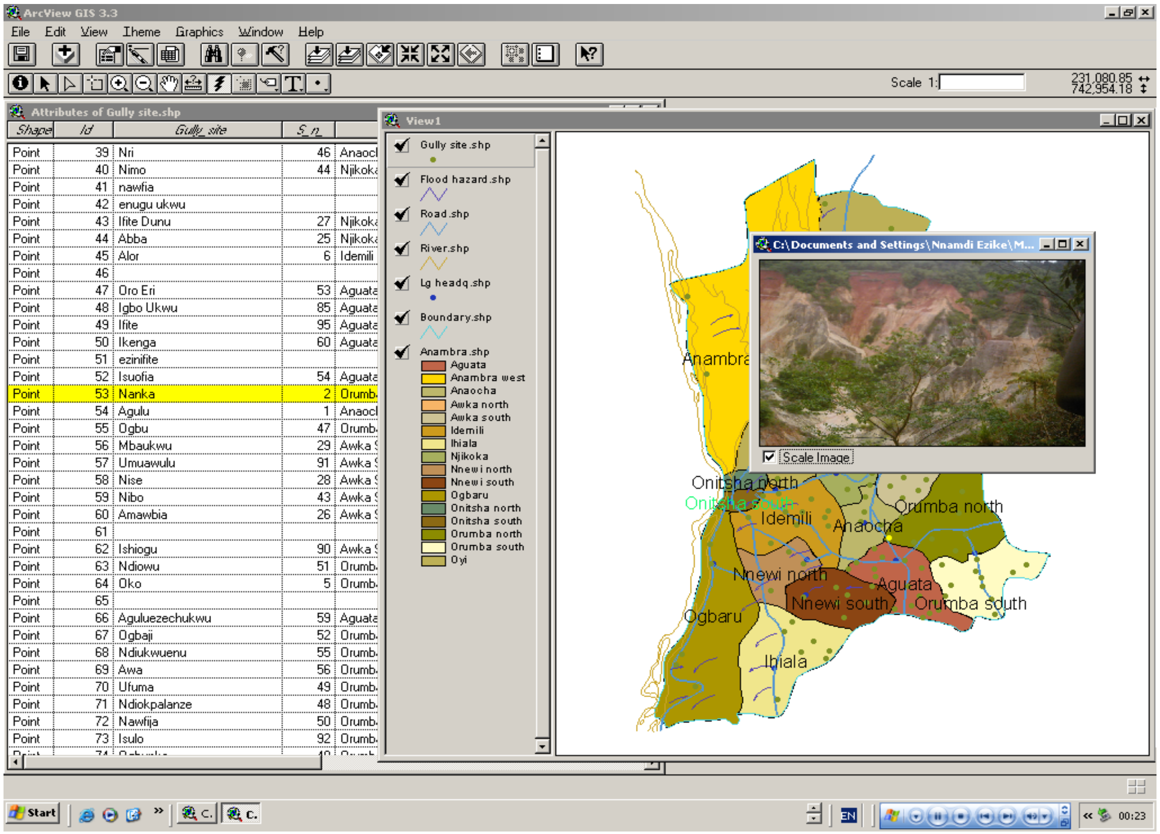
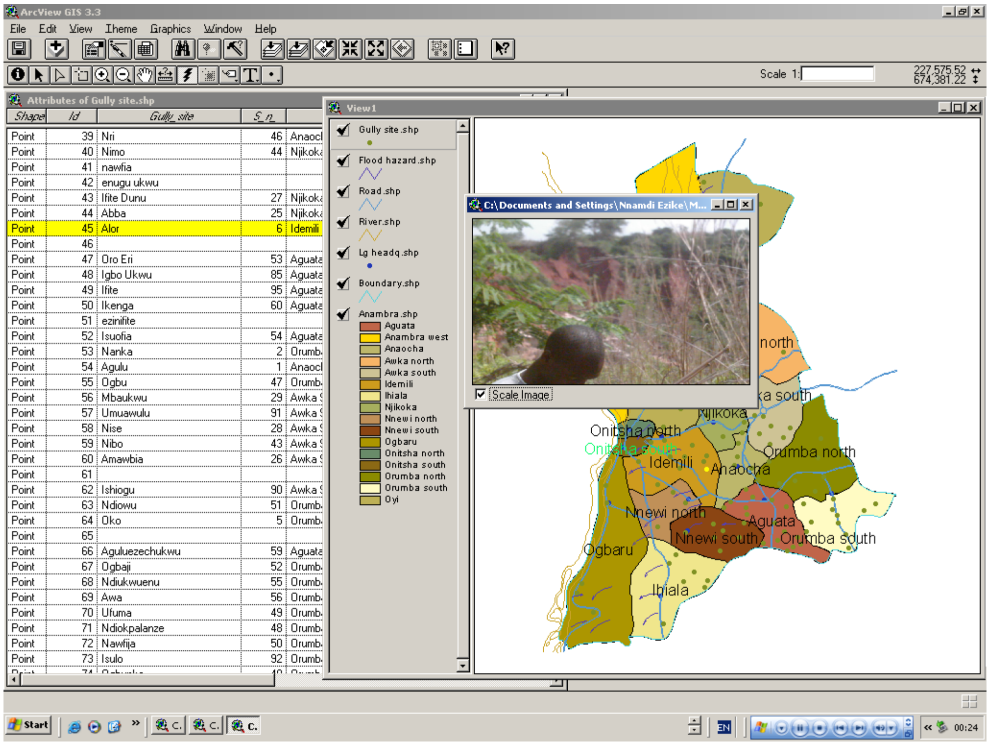


Fig 18: Map of Anambra showing an image of the largest gully (Nanka) hotlinked



This was a hotlinking operation to show the description of the largest gully site in Anambra state located in Orumba north local government.

Fig 19: Map of Anambra showing an image of Alor gully hotlinked



This was a hotlinking operation to show the description Alor gully site in Anambra state. The result shows the records highlighted in the attribute table as shown above.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

Technological advancements in the world today have led to better, efficient and effective techniques of information management. From time to time a lot of information is being generated about earth resources and effect of human activities on these resources, thus creating a need for managing and planning. The use of GIS and its related technology will help greatly in the acquisition, organization, management and analysis of these large volumes of data, allowing for better understanding of natural disasters and the importance of record keeping for future use.

From the deduction of the analysis performed it is evident that these gullies are a continuous process and occur due to the geographical surface of the state(the heights), nature of the soil in the state and high population density of the state; soil runoff which takes place after rainfall. And also excavation is becoming a major treat to erosion in the state, and I am appealing to government take serious in the state. There is a need to control these gullies in order to reduce runoff.

This project has provided a GIS Gully hotspot database for Anambra state using Arc view GIS version 3.2a The project is coming at a time when there is need for the improvement on the methods of acquisition, organization, presentation, manipulation, interpretation, management and analysis of spatial information about ecological hazards and how to tackle them in Anambra Sate thereby helping to give planning, development, management authorities there necessary assistance for decision making. The use of GIS technology will offer better and relevant ways through which geographic information can be presented.

5.2 PROBLEMS ENCOUNTERED

In the course of every project there are challenges that most be encountered. On this project the major challenges are:

- Building the GIS database to contain useful and updated data was difficult, the data contained had to be obtained from recent publications on certain activities in Anambra State.
- Cost of transportation to the sites was high and I ended up spending a lot on transport which limited movement.
- Unavailability of current and up-to-date information at the departments of survey Government House Awka, Anambra state.
- Financial constraint was another problem.

However, it is worth mentioning that through the execution of this project a good knowledge of GIS and its applications have been acquired that will be useful for other similar projects in the future.

5.3 RECOMMENDATIONS

Due to the disastrous nature of Gullies it should be controlled. With the application of GIS a control system should be put in place. Control measures based on engineering structures is required, which includes the construction of terraces, waterways, concrete structures, porous barriers e.t.c. In designing a control system the gully should be inspected to determine why it occurred, the estimation of the peak flow of water entering the gully then finally measure the size and slope of the gully.

There are certain requirements that are necessary in order to have a good and functional GIS for Anambra State.

Firstly, there must be the establishment of a GIS Database Unit at strategic locations in Imo state. It shall be responsible for the acquisition of all data to be included in the Anambra State Database from time to time.

Secondly, there must be adequate education on the use, relevance and need of GIS technology. This will also involve training (and practical exposure) of officers of this unit and other relevant government departments / Establishments on the advantage of GIS from time to time. The training will involve diverse methods of acquisition, organization, presentation, manipulation, interpretation, management and analysis of spatial information for use in Imo State.

Thirdly, there must be provision of software, hardware-personal computers (PCs) with standard GIS requirements and other relevant equipment for the use of the unit. The acquisition of appropriate texts and useful materials to help the development of these individuals is also recommended. All these would require upgrading / updating from time to time to measure up to increase functions,

Finally, a web site for the GIS erosion database for Anambra State should be created. It is recommended that further work in this field be encouraged and sponsored by both private and public agencies as well as individuals, including the government.

5.3.1 ENGINEERING MEASURES

Reclamation By Mechanical Levelling: From the findings on the gully morphology and characteristics, the land can be reclaimed by mechanical levelling. The gully floor should be first properly dried up using dewatering pumps in deeply dug bore holes. Then earth moving equipment like bulldozers and pailloaders will be used for mechanical levelling of small incipient gullies and the gradual lowering and reduction of the main gully side slopes.

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APPENDIX

List of Final Layout Maps

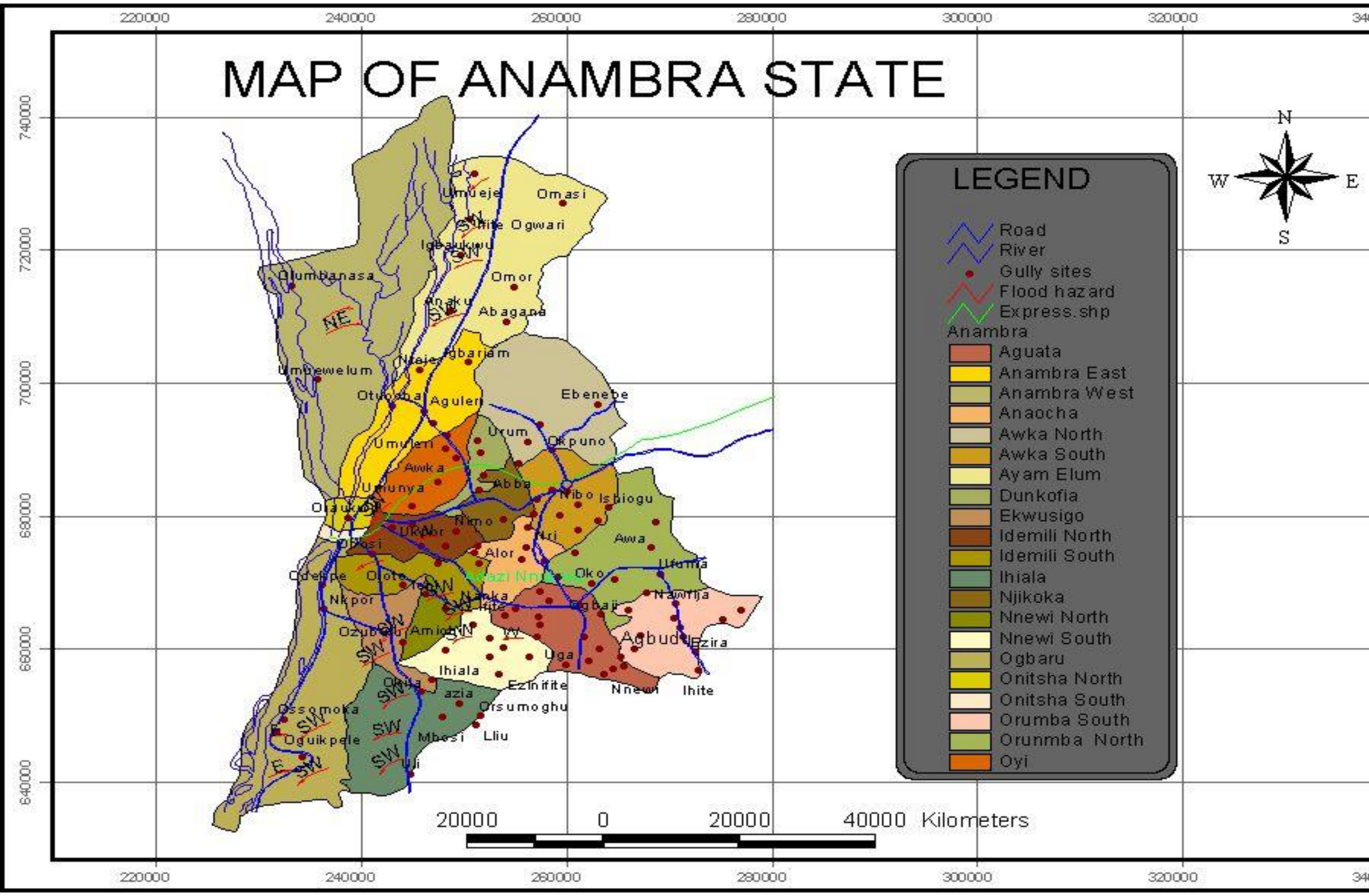
These include
1: The map of Anambra state

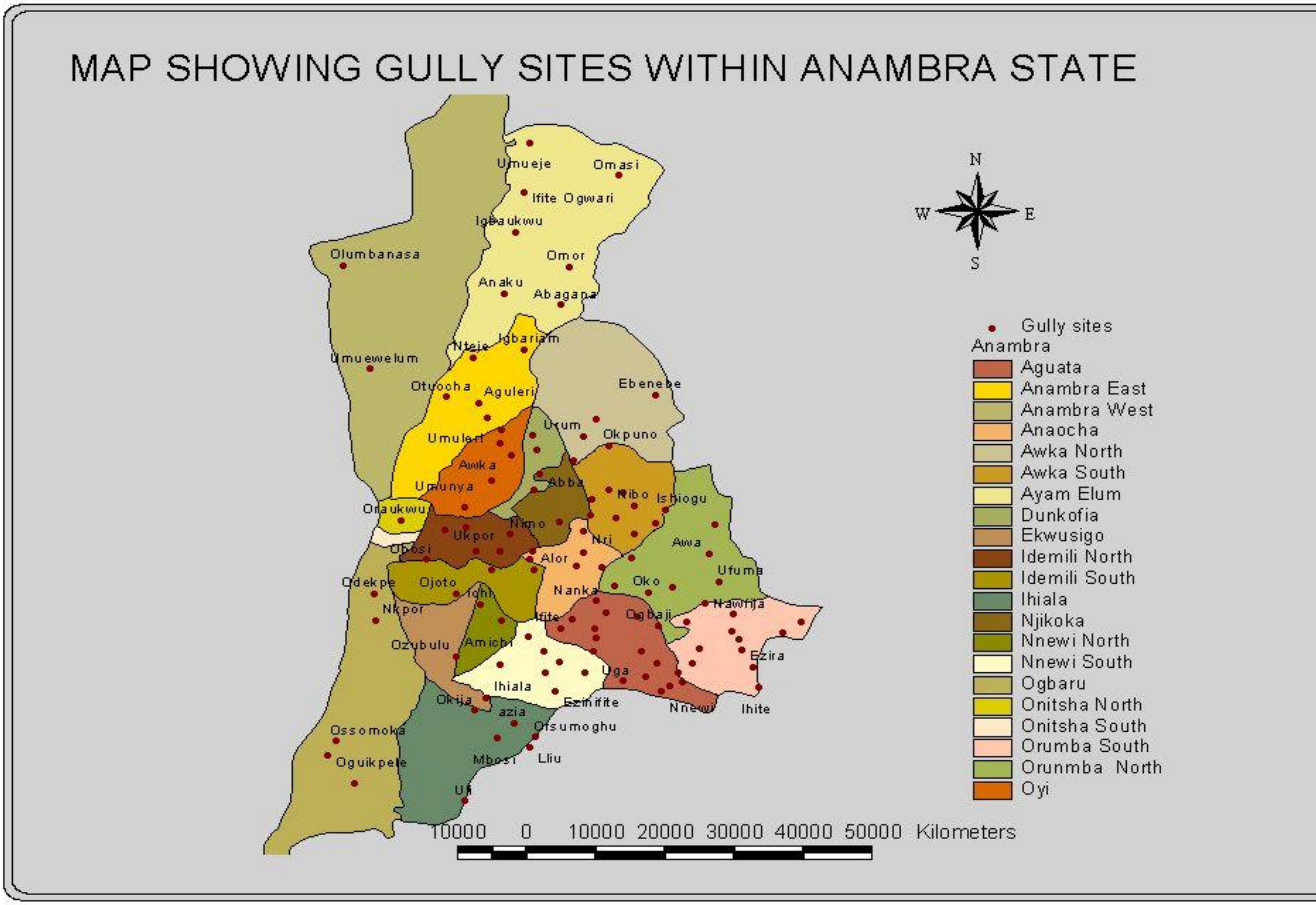
2: The map of Anambra showing the gully sites

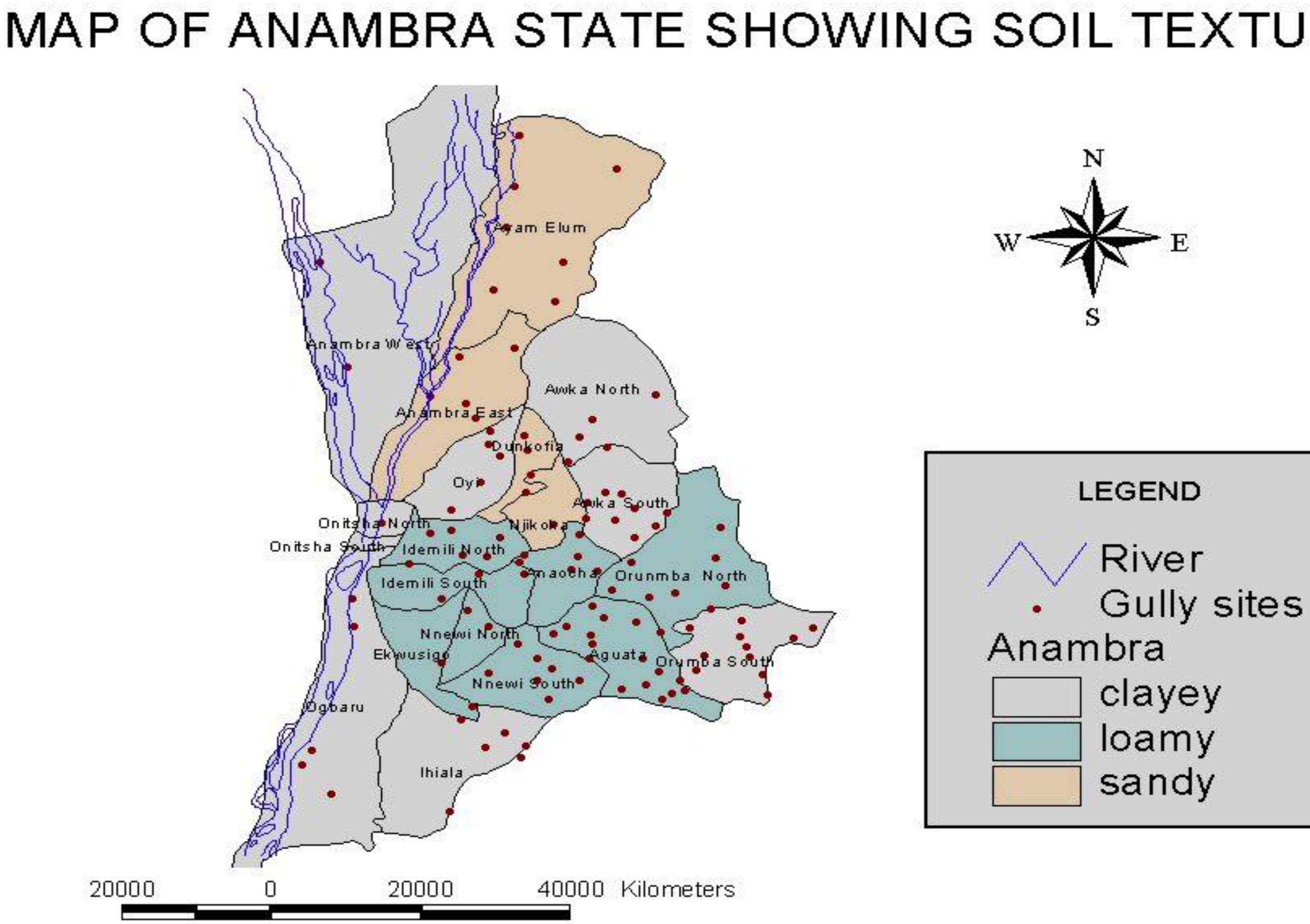
3: The map of Anambra showing the soil texture

4: The map of Anambra showing flood patterns

Respectively.


MAP OF ANAMBRA STATE
LEGEND
Road
River
Gully sites
Flood hazard
Express.shp
Anambra
Aguata
Anambra East
Anambra West
Anaocha
Awka North
Awka South
Ayam Elum
Dunkofia
Ekwusigo
Idemili North
Idemili South
Ihiala
Njikoka
Nnewi North
Nnewi South
Ogbaru
Onitsha North
Onitsha South
Orumba South
Orunmba North
Oyi
N
W
E
S
20000 0 20000 40000 Kilometers
220000
240000
260000
280000
300000
320000
740000
720000
700000
680000
660000
640000


MAP SHOWING GULLY SITES WITHIN ANAMBRA STATE
N
W
E
S
Umueje
Omasi
Ifite Ogwari
Igbaukwu
Olumbanasa
Omor
Anaku
Abagana
Nteje
Igbariam
Umuewelum
Otuocha
Aguleri
Ebenebe
Urum
Okpuno
Umuleri
Awka
Abba
Umunya
Nibo
Ishiogu
Oraukwu
Nimo
Ukpor
Nri
Awa
Obosi
Alor
Odekpe
Ojoto
Ufuma
Oko
Nkpor
Nanka
Nawfija
Ifite
Ogbaji
Ozubulu
Amichi
Ezira
Uga
Ihiala
Okija
Ezinifite
Nnewi
Ihite
azia
Ossomoka
Ufsumoghu
Oguikpele
Mbosi
Lliu
Uli
Gully sites
Anambra
Aguata
Anambra East
Anambra West
Anaocha
Awka North
Awka South
Ayam Elum
Dunkofia
Ekwusigo
Idemili North
Idemili South
Ihiala
Njikoka
Nnewi North
Nnewi South
Ogbaru
Onitsha North
Onitsha South
Orumba South
Orunmba North
Oyi
10000 0 10000 20000 30000 40000 50000 Kilometers


MAP OF ANAMBRA STATE SHOWING SOIL TEXTU
Ayam Elum
Anambra West
Anambra East
Awka North
Dunkofia
Oyi
Awka South
Onitsha North
Onitsha South
Njikoka
Idemili North
Idemili South
Anaocha
Orunmba North
Nnewi North
Ekwusigo
Aguata
Orumba South
Nnewi South
Ogbaru
Ihiala
N
W
E
S
LEGEND
River
Gully sites
Anambra
clayey
loamy
sandy
20000 0 20000 40000 Kilometers