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Research Paper

Analysis of Temporal Dynamics of Gully Erosion in EFAB Estate, (Queens and Verizon Estate) In Federal Capital Territory Nigeria

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ABSTRACT
Soil erosion is one of the threats to the sustainability of our environment. The issue of gully erosion is of major concern in Nigeria. The incidence of gully erosion in EFAB Estate of Queens and Verizon areas of F.C.T Abuja has assumed alarming proportions thereby gaining recognition as an ecological disaster zone for land owners. The study employed integrates Remote sensing, Geographical Information System (GIS) and Ground surveying techniques for use in analyzing the spatial-temporal characteristics and determine the dangers and of risk associated with soil erosion has remained both a geomorphological and environmental threat to gully vulnerable settlements in EFAB Estate of Queens and Verizon areas of Federal Capital Territory Abuja. the spatial expansion of gully sites in the study areas of gully erosion in the state. The study revealed that the gullies were affected by severe erodibility in the Queens gully a Length of Creek = 425.71m(4.26km), Area 65480.97m, Total Volume of Loss Soil 149,759.87 CU.M., Depth Difference = 2.29m and Verizon gullies having a Length of Creek = 327.42m(3.27km) Area 19,928.50m, Total Volume of Loss Soil 121,735.34 CU.M., Depth Difference = 6.11m of the rate of gully expansion in the areas. Future prediction of the impact of the gullies includes loss of properties, siltation of the river. The non-regression analysis (SPSS) and buffer allowed predicting the future extents and impacts of the gully erosion. Application of the methodology to other areas of Land Cover Land Use mapping and further risk -temporal analysis of the entire study area incorporating the factors affecting gully erosion were recommended among others.

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I. INTRODUCTION

Background to the Study

The biosphere layers of the earth constitute the layer where the activities of both micro and macro-organisms take place (Jimoh, 1999). It is on this layer that the activities (mining, quarrying, agriculture, constructions, lumbering, among others) of man in his environment take place giving little attention to their implications on the environment, such as soil erosion. Soil erosion is one of the threats to the ideal sustainability. It is a complex dynamic natural process by which productive surface soils are, through the action of erosive agents, detached, transported and accumulated in a distant place resulting in exposure of subsurface soil and sedimentation in reservoir. Possible agents are water, wind, gravity, and anthropogenic perturbations (Lal, 2001).

Across the globe, water is the most common erosive agent. The types of erosion caused by water include sheet, pinnacles, channel, rills, gully erosion etc. Soil erosion processes by water comprise: splash erosion, which occurs when soil particles are detached and transported as a result of the impact of falling raindrops; sheet or inter-rill erosion, which removes soil in thin layers and is caused by the combined effects of splash erosion and surface runoff; rill erosion, which is the disappearance of soil particles caused by concentrations of flowing water; and gully erosion, that occurs when the flow concentration becomes large and the incision deeper and wider than with rills (Morgan, 2005). Gully dynamics are however not limited to runoff processes only, but can be greatly influenced by sub-surface flow, tunneling and side-wall failures

(Bocco, 1991). Biophysical factors that regulate erosion processes include climate, soil, terrain and ground cover (Lal, 2001). The importance of each individual factor is not always the same, but depends on regional characteristics, the specific erosion process under consideration, and the spatial and temporal scale studied.

Soil erosion is the removal of soil materials and/or soil nutrients by surface run-off from different points of origin to other locations (Jimoh, 1999). Soil erosion is as a result of a situation in which soil is removed at a rate faster than that at which new soil is formed. It is defined as the process that leads to the general degradation of the ground surfaces.

Soil erosion is a dynamic geomorphic event operating on the landscape. This geomorphic event may degenerate into sheet, rill or gully types of erosion. Sheet erosion is essentially a process that involves the uniform removal of soil surfaces, which is when the soil surface is undergoing a uniform degradation. Rills are parallel grooves of little depth covering the land

surface which can easily be filled through normal cultivation. Formation of rills is one of the consequences of flow water. Sheet and rill erosion are the initial stages of gully erosion representing the incipient stage of the development of gully erosion.

The main soil erosive agents for gully erosion in the tropics is rainfall, some of the attributes of rainfall are; intensity, duration, drop-size, amount and frequency. Other factors that contribute to the occurrence of soil erosion in the tropics includes soil type and its characteristics, topography, geology, cultural practice carried out in the region and conservative practice applied to the land (Faniran & Jeje, 1983).

However, it is the combined effect of these factors of gully erosion that makes its operation and consequences dangerous and therefore of great importance to man. Gully erosion has considerably initiated landscape destructions

Gully erosion is an advanced stage of rill erosion where surface channels have been eroded to the point where they cannot be smoothed over by normal tillage operations. Often, gullies can be prevented if good land conservation measures are practiced. Good tillage and cropping practices increase the absorptive capacity of the soil resulting in fewer run-offs and also protect the land surface from erosion. Surface and tile water should be conveyed from lands through proper waterways so as not to create potential gully problems. Buffer strips should be located at potential gully start points such as open ditches or deep depressions.

At geological time-scales there is a balance between erosion and soil formation (Tricart & Kiewietde, 1992), but at many locations worldwide disequilibrium currently exists between the two processes. This disequilibrium is called accelerated soil erosion and is principally caused by anthropogenic land use changes like deforestation and agricultural practices. Globally, soil erosion by water is the most principal land degradation problem. It generates strong environmental impacts and high economic costs by its on-site effects on arable land, man's property, roads and off-site effects on infrastructure and water quality.

Soil erosion (in particular gully erosion) is of great concern to humanity as it affects food production through land degradation, limits the supply of hydropower through siltation of reservoirs and causes catastrophic floods damaging huge area of low-lying fields and human settlements, *etc*. Many other problems are also created by soil erosion like deposition of unfertile material on cultivated lands, harmful effects on water-supply, fishing, sedimentation of canals and rivers and the destruction of fertile agriculture land. Gully erosion is one of the major environmental problems in some part of Nigeria. It is likely to become even more severe due to climatic changes, population growth, deforestation, unplanned land use, uncontrolled urban development, uncontrolled grazing, lack of good drainage system, lack/poor of erosion management/control system and land cultivation without using specific control techniques. (Authors work). For integrated water resources management, knowledge of soil erosion processes active within the landscape is of fundamental importance. Particularly gully erosion which contributes significantly to the total sediment yield of a catchment because of the spatial and temporal heterogeneity of gully erosion.

To mitigate these effects and reduce soil erosion, soil and water conservation strategies are required at different spatial scales and at different organizational levels (Morgan, 2005). Spatial information on the importance of erosion at different scales is necessary for defining effective strategies and prioritizing conservation efforts.

Gullies are generally defined by their channel depth, which for permanent gullies can range from 0.5 to 30m (Soil Science Society of America, 2001). They are also one of the most destructive forms of erosion, destroying soil, undermining infrastructure, damaging agricultural fields, altering transportation corridors, and lowering water tables (Valentin et al.2005). Furthermore, their damage is difficult to reverse. Gully erosion dramatically affects sediment budgets and flux rates, and influences stream dynamics as evidenced from data on hydrographs (Costa & Bacellar, 2007).In addition, in some areas gully erosion is directly linked to changing climatic conditions (Chaplot et al., 2005).

Statement of the Problem

Today, reducing natural resources, especially soil and water, is one of the major problems and major threats to human life and is one of the most important environmental problems worldwide that has intensified in recent years, with increasing population and the alternation of human activities (see Kirkby et al, 2009; Magliulo, 2012; Nampak, et al, 2018; Zhang et al, 2018). Gully Erosion, in part, explains soil erosion. Soil erosion is described as an accelerated process under which soil is bodily displaced and transported away faster than it can be formed. The agents of soil erosion are principally running water, glaciers, waves and wind. Despite technological advancement, erosion menace remains a major problem in Nigeria. Loss of lives, properties, houses, fertile soil and forests, destruction of roads and infrastructure, displacement of population amongst others are the impacts of gully erosion.

Though several erosion controls measures have been initiated, however climatic changes, uncontrolled Urbanization, deforestation, lack of good drainage system, unplanned land use, increase in population, excessive pressure on farmland for agriculture, bad agricultural practices, weakened gully walls, etc. greatly undermine these control measures. Also, some of the control's measures did not take into account the properties (location, geology, relief, land use etc.) of the region hence are inappropriate for the region.

The Queens and Verizon EFAB gullies erosion is a disaster and represents a wide area being eaten away gradually and continuously by the landslide cum gully advancement processes which if appropriate control measures are not taken, may eventually destroy the entire land of EFAB Estate.

As part of the steps/'ingredients of gully prevention, control, management and monitoring, there is need to examine the gully erosion sites as well as their spatial extent (size), spatial distribution and topological relationships of gullies, current rate of gully expansion and formation; analyses the similarities of geological, soil, topographical and climatic properties of the gully sites and determine trend in the properties; and buffer threatened areas.

According to the data from United Nations research, the world's population is growing at a rate of 1.8% per year and it is expected to rise from 8 billion in 2025 to 9.4 billion in 2050 (UNEP, 2017). This increase in world population would demand the need for food, water, forage, and others, which consequently would add huge pressure on land exploitation, non-standard exploitation, and eventually lead to an increase in erosion rates (Magliulo, 2012). Soil erosion is one of the factors that endangers water and soil (Magliulo, 2012). Soil erosion by water, such as gully erosion, is considered as a major cause of land degradation around the world (Rizeei, et al, 2016 & Nampak, et al, 2018).

It leads to a range of problems, such as desertification, flooding and sediment deposition in reservoirs (Mojaddadi, et al, 2009 & Zhang, et al 2018) the destructive effects on the ecosystem reducing soil fertility, and imposes huge economic costs (Zabihi, et al 2018). Gully erosion is typically defined as a deep channel that has been eroded by concentrated water flow, removing surface soils and materials (Kirkby & Bracken, 2009). The amount of moisture and its changes as a result of the dry and wet seasons is a main parameter in creating cracks and grooves in fine-grained clay formations containing clay and silt, and ultimately developing rill erosion and gullies (Torri, et al; 2012).

The alternation of warm and dry seasons makes it possible to create cracks, in the formation of fine grains, in warm seasons with the drying of the land and the wilting of the vegetation, and these cracks at the time of the first sudden rainfall concentrate the runoff and therefore cause rill and Gully erosion to emerge (Mccloskey, et al., 2016). Gully Erosion occurs when the erosion of the water flow or the erodibility of the sediments or the formation of the area is higher than the geomorphological threshold of the area ((Mccloskey, et al 2016). Mapping gully erosion systems is essential for implementing soil conservation measures (Zhang, et al; 2018).

Gully Erosion Varaiables that influence gully occurrence are rainfall, topography-derived factors such as elevation, slope degree, slope aspect, and plan curvature, lithology (Rahmati,et al; 2017), soil properties (Dube, et al; 2014), and Land Use/Land Cover (Zakerinejad & Maerker, 2015). The distribution of precipitation affects the hydraulic flow and moisture content of the soil, and the erosion strength of the flow and soil resistance to erosion is different before and after erosion (Mccloskey, et al 2016). Depth and morphology of the cross section of the gullies are controlled by soil erodibility features of the geological layers of the area. The characteristics of the region's soil affect the subsurface flow and the phenomenon of piping erosion, and the pipes cause a gully when their ceiling collapses ((Torri, et al; 2012). Susceptibility maps of Gully Erosion are essential for conservation of natural resources, and for evaluating the relationship among gully occurrence and relevant Gully Erosion Variables (Rahmati,et al; 2017). Several models have been applied to assess soil erosion and gully erosion rate in a quantitative and qualitative way, such as the Universal Soil Loss Equation (USLE) (Magliulo, 2012).

Ephemeral Gully Erosion Model (EGEM) (Barber & Mahler, 2010), and Chemicals, Runoff, and Erosion from Agricultural Management Systems (CREAMS) (Leonard, et al; 1987).Within the soil conservation research field, the distribution of soil erosion is one of the primary sources of information. This is also relevant for Gully Erosion; however, in the above-mentioned methods, spatial distribution and dynamics of gullies has not been addressed. Remote sensing-based methods to identify Gully Erosion have been developed (Liaw & Breiman, 2018), including with Random Forest machine learning, though they serve more to validate susceptibility models and to explain the actual erosion presence and distribution.

In recent years, scientific research for susceptibility analysis of Gully Erosion, and work on the statistical relationships between Gully Erosion Variables and the spatial distribution of gullies, have been addressed using various statistical and machine learning methods including bivariate statistics (BS) (Magliulo, 2012), weights-of-evidence (WoE) (Dube, et al; 2014), index of entropy (I of E) (Zabihi,et al, 2018), logistic regression (LR) (Meyer & Martınez-Casasnovas, 1999), information value (IV) (Conforti, et al, 2011) random forest (RF) bivariate statistical models (Svoray, et al, 2012), maximum entropy (ME) (Zakerinejad & Märker, 2014), analytical hierarchy processes (AHP) ((Svoray, et al, 2012),

Soil erosion remains a dynamic geomorphic event operating on the landscape (Ojo & Johnson, 2010). In spite of technological advancement, erosion menace still remains a major problem in Nigeria especially in Abuja, the federal capital city. The yearly heavy rainfall has very adverse impacts altering existing landscape and forms. Such landforms create deep gullies that cut into the soil. The gullies spread and grow until the soil is removed from the sloping ground. Soil erosion when formed expand rapidly coupled with exceptional storm or torrential rain down the stream by head-ward erosion gulping up arable lands and critical national infrastructure in the city of Abuja. No known studies have examined the spatial and temporal dynamics of gully erosion menace in the capital city of Abuja. This is the gap which this work seeks to unravel.

Aim and Objectives

The aim of the study was the analysis of the temporal dynamics of gully erosion of EFAB Queens and Verizon estate, Federal Capital Territory Abuja of Nigeria using GIS and remote sensing techniques. The above aim will be achieved through the following objectives;

1. Identify from the topographic Survey of the erosion site to produce spot height, contour models of the gully's alignment map and 3D wireframe design of the areas.
2. Determine the spatial and temporal extents of the gully erosion sites of (1986- 1999, 2010 and 2020)

Research Questions

Arising from the gap identified, the conceptual questions which this study examined includes the following.

1. What is the topographic Survey of the erosion site to produce spot height, contour models of the gully's alignment map and 3D wireframe design of the areas?
2. What is the spatial and temporal extents of the gully erosion sites of (1986- 1999, 2010 and 2020)?

II. METHODOLOGY

GIS Database Modelling and Creation

In achieving the objectives of the study, a geographic database of the gully sites was created using ArcCatalog. To achieve this, the following stages of database creation were performed.

Conceptual Data Modelling

A Conceptual modelling of the spatial database was performed in this study. This involves;

1. The identification of entities relevant to the gully site database while ensuring that they have multiple occurrences and are unique. The entities identified were Gully sites, Towns, local government areas, Settlement and vegetation.
2. Identification of attributes of each entity which served as a guide in the collection of data. The entities types and attributes used for this study are listed in table 3.1. Determination of the relationships between the entities.

Logical Data Modelling

Logical data modelling is the process by which the conceptual model schema is consolidated, refined and converted to a system-specific logical schema. At this stage, the conceptual schemas will be manually mapped into logical schema, figure 3.1 below shows the Logical Schema of the entities used for this study.

Also, the primary and foreign keys will be identified to ensure entity integrity constraint which requires that the column for the primary key should not contain any null value and all the values in the column will be unique.

Local Government area

LG_ID	LG_name	LG_Area

Towns

T_ID	T_name	LG_ID

Gully sites

G_ID	LG_ID	T_ID	G_len	G_dep	G_area	ST_ID	W_ID

Road

Rd_ID	Rd_name	Rd_Type	Rd_Status

Settlements

ST_ID	ST_name	LG_ID	T_ID

Water body

W_ID	W_name	LG_ID	T_ID

Logical Schema of the Entities
(Source : spatial analysis with modification by authors' work)

Sources of Data and Method of Data Collection
Primary and Secondary Data Acquisition
The researcher depended heavily on primary data from the field, however secondary data shall be gotten from books maps journal etc. The flowing maps topography map of Abuja on a scale of 1:50,000 and 1: 100,000 and the administrative map of Abuja, showing the elevation contours are imaginary lines connecting points having the same elevation on the surface of the land above or below a reference surface, which is usually mean sea level. The interviews were carried out in Hausa and English language in order to further explain the questions and so that the indigenes/ inhabitants understand the questions in their local language for easy response.

Table 1: Data Collection Techniques are shown in the table below.

	Raster	**Vector**
Primary	Satellite remote sensing images, Digital aerial photographs, LiDAR (LaDAR) datasets	Ground survey data • GPS measurements • Survey measurements TOPO survey data
Secondary	Scanned maps DEMs from maps, orthophotos	Digitizing of Topographic maps Toponymy data sets from atlases

Ground Survey Techniques

The gullied areas for the different periods was mapped using the satellite images and the boundaries of the eroded areas was drawn as polygon for each period using ArcGIS Editor Tool. The polygon for each year shows that the Queens and Verizon Gully erosion site is Y- shaped 3D wireframes as shown in Fig 5 and figure 6 of the results respectively. The different polygons for the different periods was compared using the Erase Function of ArcGIS Analyst Tool Overlay function and present.

Data was captured through two major processes. The first method was through direct field survey measurement. Various field survey techniques were applied using the GPS and Total Station to capture the planimetric and height coordinate information in Universal Transverse Mercator system relevant for the gully's horizontal and vertical alignment. Other relevant details within 50m buffer to the gullies were also captured using the total station equipment. The second data acquisition technique employed was through the application of remote sensing. High resolution quick bird image was obtained through which further details including features close to the gullies and the gullies plan views were captured by digitizing them.

1. Global Positioning System (GPS) Observations

The Garmin GPSmap 76 handheld GPS was used to obtain the coordinates of part of the gully edges and points used as controls for ground truthing. All positioning were referenced to the Zone 32N of the Universal Transverse Mercator Clarke 1880 (Modified) Spheroid.

Spot elevation along with points coordinates of the gullies where obtain from the GPS and Total station surveys using the in-built software in the total station system with the GPS derived coordinates as control/ reference points. Based on the computed points coordinates and elevations, the morphology parameters including length, width, depth, and areas of the gullies along with total soil loss was determined.

Table2: GPS Observation

S/N	GULLY SITES	NORTHINGS (mN)	EASTINGS (mE)	HEIGHTS
1	**QUEENS**	1007459.81 1007434.22	320533.41 320596.97	467.54 464.61
2	**VERIZON**	1005684.27 1005693.94	320209.96 320212.42	447.99 447.86

2. Total Station Observation

The processed data from the Total Station were stored in the Notepad of Microsoft Office and the values of Eastings, Northings and elevations coordinates were later exported into AutoCAD environment from which gully lengths, surface areas and volume of washed materials were determined using the geo-statistical tool of the software. The average of the gully width recorded in all measured points in a gully channel represents the gully width. From the value of Z coordinates, that is, heights obtained at the gully shoulders (L1, R1) and corresponding Z coordinates of gully floor (C1, C2, C3…), gully depths (D1, D2, D3….) was determined by subtracting the value of gully floor (center of the gully or at various points in case of Y-shaped gully) from the half of the summation of the values of the gully shoulders. This procedure was followed to determine the depth of all the points measured for the entire gully length. Also, topographic information was obtained by downloading the ASTER DEM of the catchment via the internet

a. Test of Total Station EDM

For the purpose of this test, a base line of 400m long was divided into four sections of 100m long as shown in figure 1

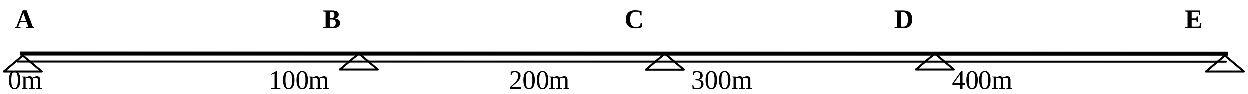

Figure 1: showing Test of total station

(Source: Dodson,A.1978 with modification by authors)

The total station and target were set up, centered and leveled at points A and E respectively. The target was sighted; bisected and linear measurement made three times and booked. In the same manner the distances AB, BC, CD, DE and EA were measured. Table 3 shows the result of the test.

Table 3: Total Station Edm Calibration Test

Section	A-E (m) (1)	A-B (m) (2)	B-C (m) (3)	C-D (m) (4)	D-E (m) (5)	E-A (m) (6)
Distances in meters	400.008	100.002	100.002	100.008	99.997	400.008
	400.011	100.003	100.006	100.006	99.996	400.009
	400.010	100.002	100.004	100.005	99.993	400.007
Total	1200.029	300.007	300.012	300.019	299.986	1200.024
MEAN	**U= 400.010**	**V= 100.002**	**W= 100.004**	**X= 100.006**	**Y= 99.995**	**Z= 400.008**

$V + W + X + Y) - \left(\frac{U+Z}{2}\right) = 0$……………………. equation 1

After the test, the results showed a discrepancy of 0.002m which has no significant effect on a third order job, as a result, it was ignored.

b. Horizontal Collimation Error Test

The Total Station was set over a point and the necessary temporary adjustments were done. Horizontal collimation test menu was accessed. This test was done by sighting and bisecting a well-defined vertical target about 100m away and taking the horizontal readings on face left and face right. This process was repeated for three more targets at approximately 100m from the instrument setup. The result of an analysis of the observation shows that the total station was in good adjustment order.

c. Vertical Index Error Test

This adjustment ensures that the vertical circle reading is exactly 90° (perpendicular to the instrument collimation line) only if the line of sight is truly horizontal. Any deviation from this figure is termed vertical index error.

The Total Station was set over a point and necessary temporary adjustments (centering, leveling and focusing) satisfactorily done. The vertical index error test was carried out by sighting a target at a distance of about 100m on face left. The vertical circle reading was recorded and on face right the target was sighted and bisected again and the vertical circle reading recorded.

The process was repeated for three more targets at approximately 100m from the instrument setup.

Analysis of Collimation and Vertical Index Data

The readings obtained during the calibration were reduced to obtain the new horizontal collimation and vertical index errors as shown in table 4 below

Table 4: Horizontal Collimation and Vertical Index Data

S/N	FACE LEFT		FACE RIGHT		Horizontal	Vertical
	Horizontal º ‘ ‘‘	Vertical º ‘ ‘‘	Horizontal º ‘ ‘‘	Vertical º ‘ ‘‘	(FR-FL) º ‘ ‘‘	(FL+FR) º ‘ ‘‘
1	66 00 02	90 00 33	246 00 04	269 59 18	180 00 02	359 59 51
2	127 11 55	90 00 57	307 12 00	269 58 49	180 00 05	359 59 46
3	87 08 46	89 59 39	267 08 55	270 00 15	180 00 09	359 59 54
4	194 16 46	89 56 59	14 16 38	270 02 58	180 00 08	359 59 57
				MEAN	180 00 06	359 59 52

Table 5: Index and Collimation Test Analysis

	Index Error	Collimation error
Old	+7"	5"
New	-04"	03"

From the results of the test, it was ascertained that the total station was in good condition and could be used to achieve the required accuracy for the project.

a. In-situ check (verification of controls

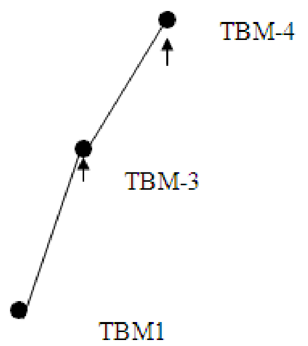

Figure 2: In-Situ Check for Control Diagram

The results of the observations as shown in Table 3 and Table 4 respectively, confirmed that the controls were still in their original positions and are therefore the instrument is suitable for use.

Table 6: In-Situ Check Results for Designed Coordinate Controls

S/N	SHELL/ LOCATION	DESIGNED COORDINATES		OBSERVED COORDINATED		∆E	∆N
		EASTING	NORTHING	EASTING	NORTHING		
1.	ANIEZE LOC-1	459026	199141	459050	199174	24	33
2	ANIEZE LOC-3	461657	197934	461660	197929	3	5
3	ANIEZE LOC-4	460030	198446	460040	198439	10	7

The Computation of the gully depth shows that the Computation of soil loss was achieved based on the volume. This was done at every 25- and 50-meters internals of the gullies using the formula below. (Depth difference was obtained).

Sectional Area = 1/2(Top Width + Bottom Width) x Sectional Distance ……………………………… (2)

Cut Volume = Sectional Area x Cut Volume … … … … … … … (3)

Conventional surveying and mathematical methods were employed in the calculation that was involved in this exercise. The following are some mathematical methods that can be use in the calculation of mean of material.

Conversion of Analogue Maps to Digital Format

Scanning

Existing maps of the area obtained were already scanned and saved as Tagged image File format (.tif) and Joint Photographic Experts Group (jpeg) which is supported by the ArcGIS software used for vectorization. Speckle removal, Skew corrections and other corrections were carried out to improve the image quality before vectorization.

The scanned maps were then imported into ArcGIS for processing.

Geo-Referencing

Using the Geo-referencing tool in ArcGIS, each map was Geo-referenced using the coordinates of the edges and center. The hardcopy maps were geo-referenced to the Zone 32N Universal Transverse Mercator coordinate system which was the coordinate system of the GIS database and output data. The image of the study area from Google was imported into ArcGIS and geo-referenced.

Screen Digitizing

Screen digitizing was employed and each of the geographic features of interest was digitized as Layers in ArcGIS using the Digitizing tool. The digitized features were properly labelled and symbolized. Data conversion errors (graphical data editing) was corrected manually and automatically using the editing functions of ArcGIS. The graphical data editing includes; topology building, data editing and error corrections, joining of adjacent layers.

Satellite Image Processing

The satellite image data providers had already performed the analysis of the image statistics - spatial, temporal, spectral and radiometric resolution (image Examination, detection, recognition, identification), Image pre-processing – removal of systematic errors and noise, resampling (Image restoration and rectification). The downloaded images was in geo-tiff file format and were compressed (in .gz format), using the 7-zip software the images were extracted. The boundary coordinates of the area of interest were plotted in ArcGIS and named 'Project boundary'.

III. Result And Discussion

Topography Survey of the Erosion Site

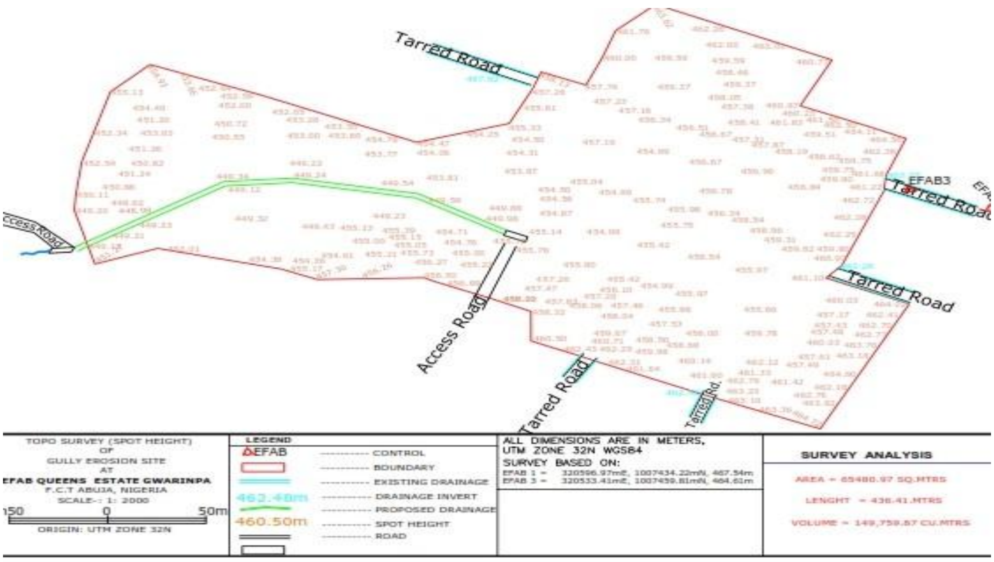

Fig 1: Showing Topography Survey of the Spot Height of the Queen Gully Site

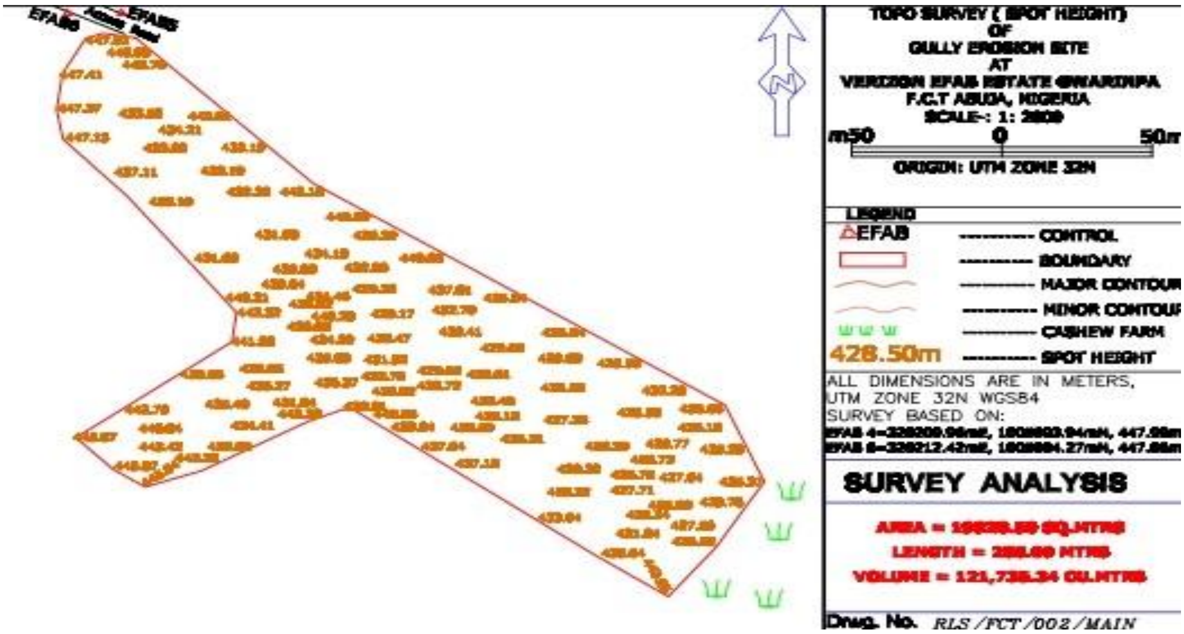

Fig 2: Showing Topography Survey of The Spot Height Model of Verizon Gully Site

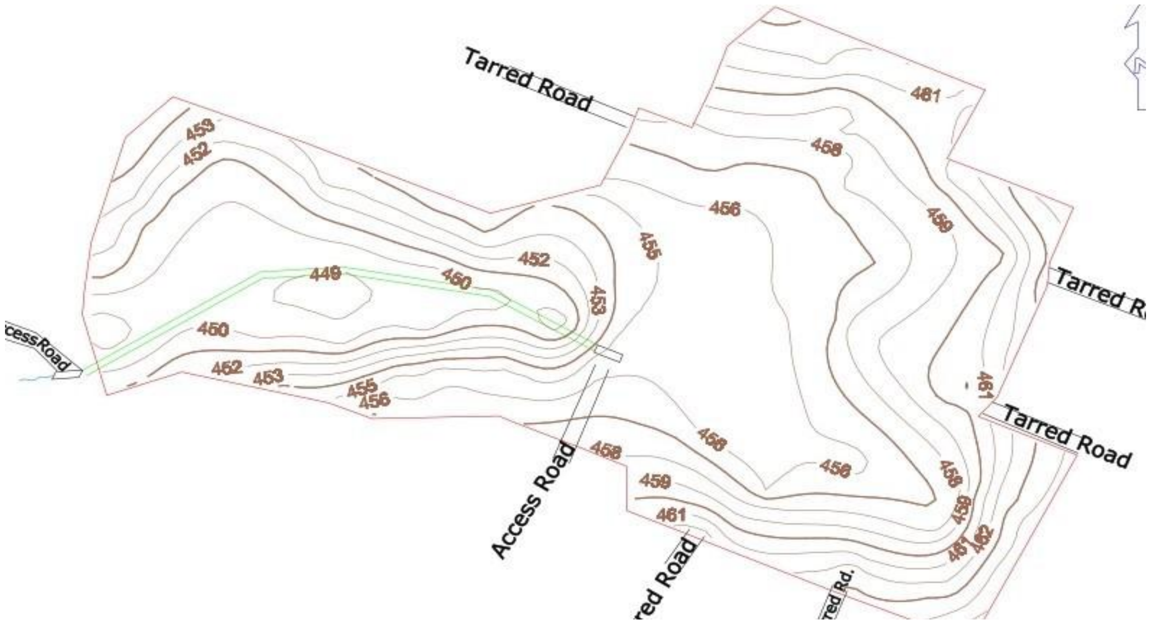

Fig 3: Showing the Contour Model of Queens Gully Sites

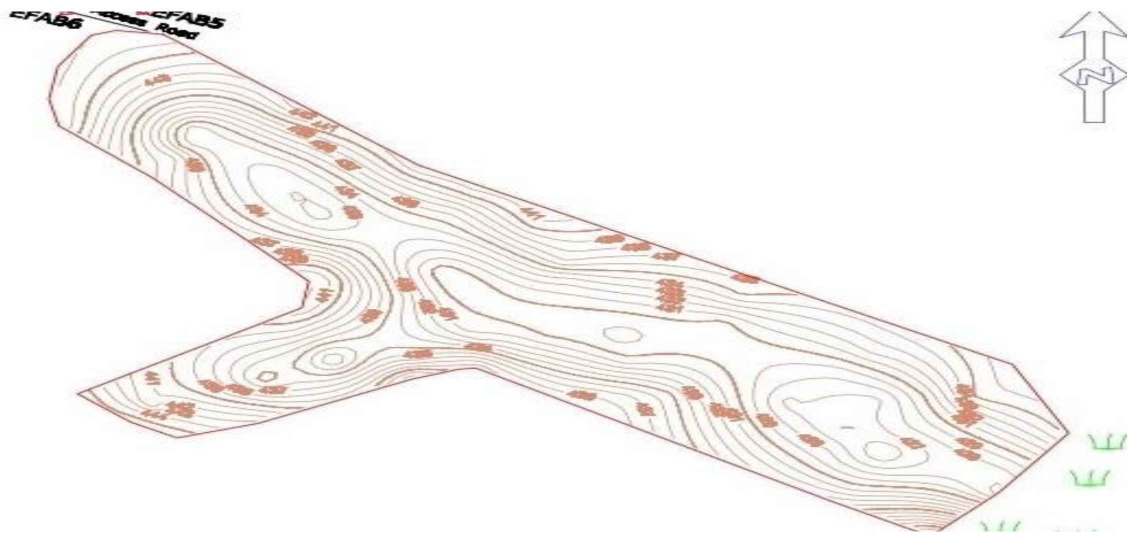

Fig 4: Showing the Contour Model of Verizon Gully Site

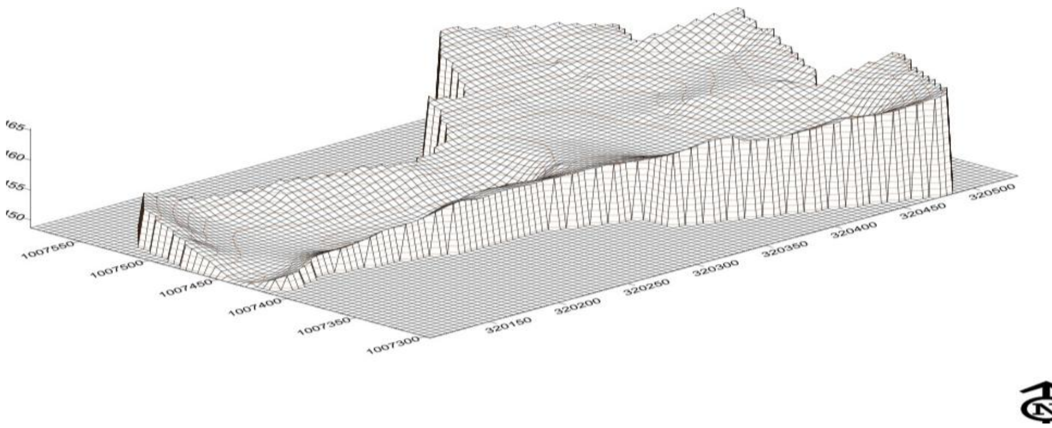

Fig 5 :3D Wire Frame of Gully Erosion Site at Queens Estate Gwarinpa, Kasena F.C.T Abuja Nigeria.

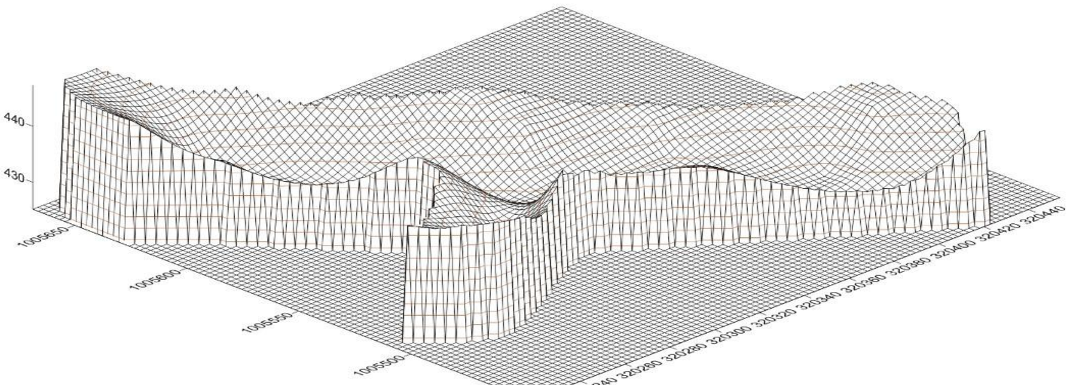

Fig 6: 3D Wire Frame of Gully Erosion Site at Verizon Estate Gwarinpa Kasana Fct Abuja Nigeria

Discussion of Findings for Ground Survey Techniques

The results of the comparison which shows the difference in spatial extents of gully erosion development. While the underlying reason for 3D wire frame result shown in figure 4.5 and figure 4.6 below is that the deposits accumulated gradually from the end of the gully channel to the head and at the same as the vegetation was settling in the gullies. For gully width, depth, and cross-section area, there were turning points for their means, medians and the percentiles in the stable processes of gullies, which indicated that the diminishing processes of gully width, depth, and cross-section area were not continuous when the gullies changed from (relatively) active to slightly stable. However, the discontinuous decrease in gully width, depth, and cross-section area did not change the overall situation where the gullies tended to be stable, which may because the lateral and vertical erosion phenomena in the gullies remained active along with the deposits accumulating at the end of the gully. Thence, the effect of the deposition process was more intensive than that of lateral and vertical erosion. For this reason, the gully width, depth, and cross-section area experienced a slight increase, but these processes did not interrupt the stable progression of the gully.

Results
Calculation of the Actual Depth of the Gully (Survey Data)
Queens Gully
Length Of Creek = 425.71m(4.26km)
Area 65480.97m
Total Volume of Loss Soil 149,759.87 /**Area** 65480.97 =
Depth Difference = 2.29m
Verizon Gully
Length Of Creek = 327.42m(3.27km)
Area 19,928.50m
Total Volume of Loss Soil 121,735.34 /**Area** 19,928.50 =
Depth Difference = 6.11m.

The project coordinates for each erosion site was exported into personal Geo database as shape files in Arc GIS environment. The shape files created for the elevation data was then added and a Triangulated Irregular Network (TIN) created using the Z coordinates. Digital Elevation Models DEM was then generated by converting the TIN into Raster. Contour lines in fig 4.2 and4.3 was generated using the created TIN to interpolate for the contours with the aid of 3D analyst extension, from the contours, the slopes was generated as necessary. The pixel size of the DEM was 1m. The contours for the two gullies are presented in Figure 4.2, and 4.3 showing the contours of queens and Verizon erosion gully respectively.

Arc Scene was then used for the visualization of the 3D wire frame as shown in fig 5 and fig 6 model generated respectively. Also, it represents the triangulated Irregular Network for the same sites. The result of the processing are these maps showing the topographic details of the catchment areas of the two erosion sites (Queens and Verizon), at Gwarinpa FCT Abuja, for 3D wire frame analysis and design was analysis to be able to see the undulation flow of the gully shapes in figure 4.5 and fig 4.6. 4.2. It also shows the topographic survey of the spot height models pattern. Figure 4.3a and 4.3b shows a joint catchment map, of the topographic map of the study area showing the contours and the details including the two erosion sites.

The results of field observation showed that the erosion rates in the selected gullies for detailed studies are intense. If the position of the gully heads can be predicted and if erosion rates of the gullies are measured, measures can be taken to protect the areas from further gullying. The areas of the gully's ranges are; Area for queen's gully ranged from 65,480.97sqm and Verizon gully = 19,928.50sqm, and the volume of soil loss varied from for queens= 149,759.87 cu.m. and volume for Verizon = 121,735.34 cu.m. length of queens = length 403.99m to Length 425.71m between the 34 years considered and Verizon. Length varies from 309.73-327.42 m, in the two gullies studied. This was found to be as a result of improper channeling of storm runoff from different directions into the gully head along with the unprecedented intensity of rain fall between 1986 – 2020.

Discussion of Findings for Remote Sensing Techniques
This section unravels the result of the different operations undertaken to achieve the aim of the study using Remote Sensing techniques.

Thematic Mapping
The use of suitable data format (vector or raster) represents the result of the classification. NDVI maps shows the result of the image classification for 1999, 2010 and 2020. Image classifications performed pixel-based classification system with the maximum likelihood algorithm within ILWIS software.

Land Use Land Cover Mapping
The result of the image classification on each NDVI image of each period is a land cover land use map of the study area. Gully areas, depth of the gullies, loss of volume of the soil loss and vegetation was identified as the different land use/cover categories. The descriptive statistics model graph presents the graphs of the area covered by each of the identified gully Land cover categories of 1986-1999, 2010 and 2020 periods present the Land cover Land use maps.

Result for Remote Sensing Techniques
Thence, with the aid of ArcGIS Data Management Tool (Raster processing option; clip function) as shown in Fig 4.7, the downloaded images scenes of 180x180km was clipped to 41.17x22.87km using the project

boundary rectangle and each image was saved as '*period band* clip' (period being the year of the image, band being the band of the acquired image and clip to show that it has been clipped e.g'1986_b1_clip' for the clipped band 1 image of 1986 period). A total of 2 severe gullies was identified in the area. The risk assessment in figure 19 and figure 20 shows that the precipitations 1986 - 1999 were reduced in quantity (annual average values of 569–580 mm at the queens and Verizon gullies). At values under 580 mm per year, the gully is relatively stable

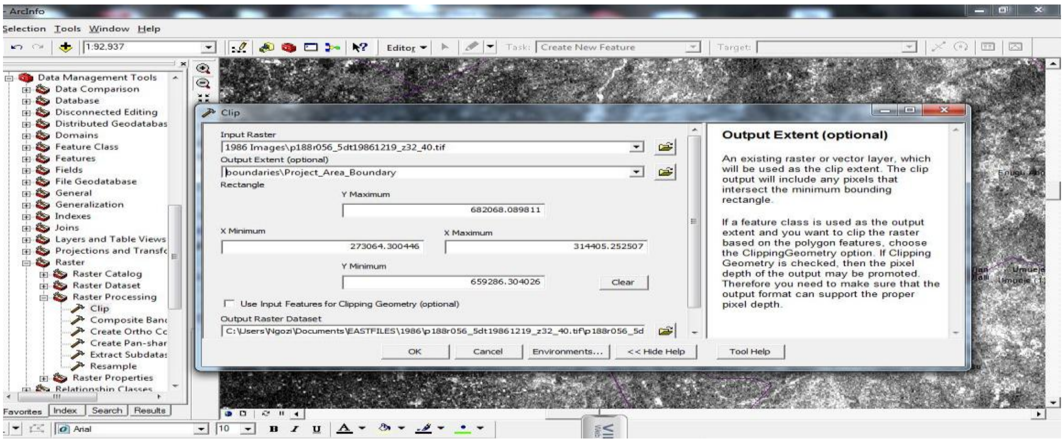

Figure 7: ARCGIS Data Management Tool (Raster Processing Option; Clip Function)

Bands 2, 4, and 1 of the clipped images for each period create a colour composite image for each period using the Colour composite function of the ArcGIS Data management Tool as shown in Fig 4.5 and saved as '*period*_ccb*abc*_clip' (period being the year of the image, cc to show that it's a colour composite and b*abc* being the 3 bands used for the colour composite creation and the order e.g. 1986_ccb342_clip for the composite image of sub mapped 1986 period using bands 3, 4 and 2). Pattern recognition and image classification and thematic mapping was carried out on the imageries in order to acquire the required information in ArcGIS environment. Vectorization and further GIS based analysis of the erosion sites was also performed.

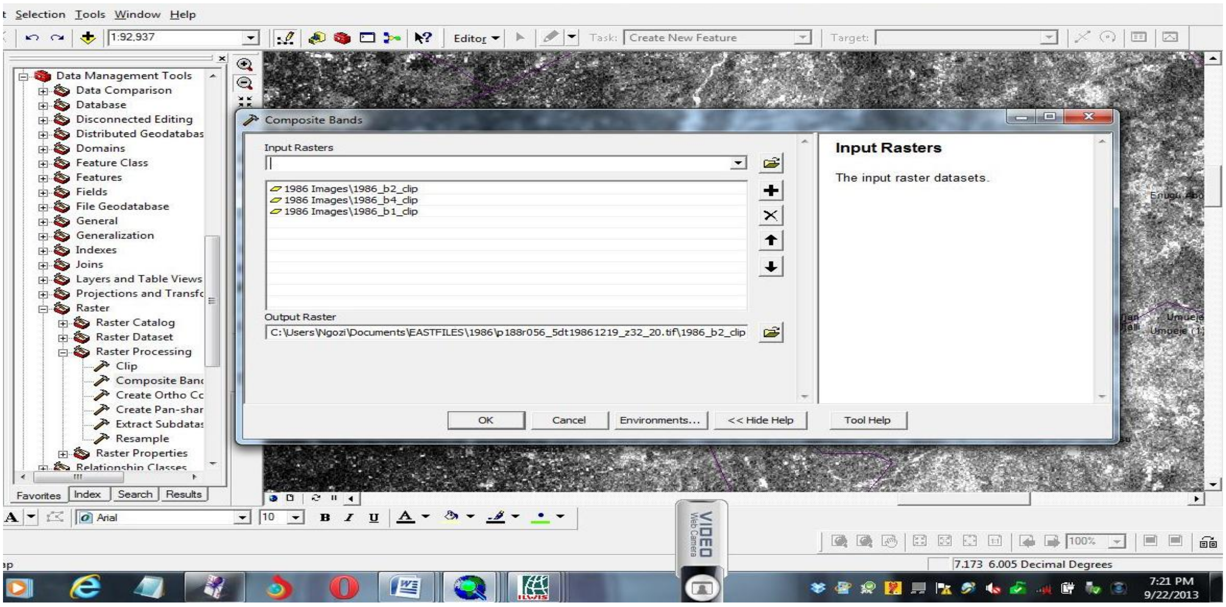

Figure 8:Color Composite Function of The ARCGIS Data Management Tool

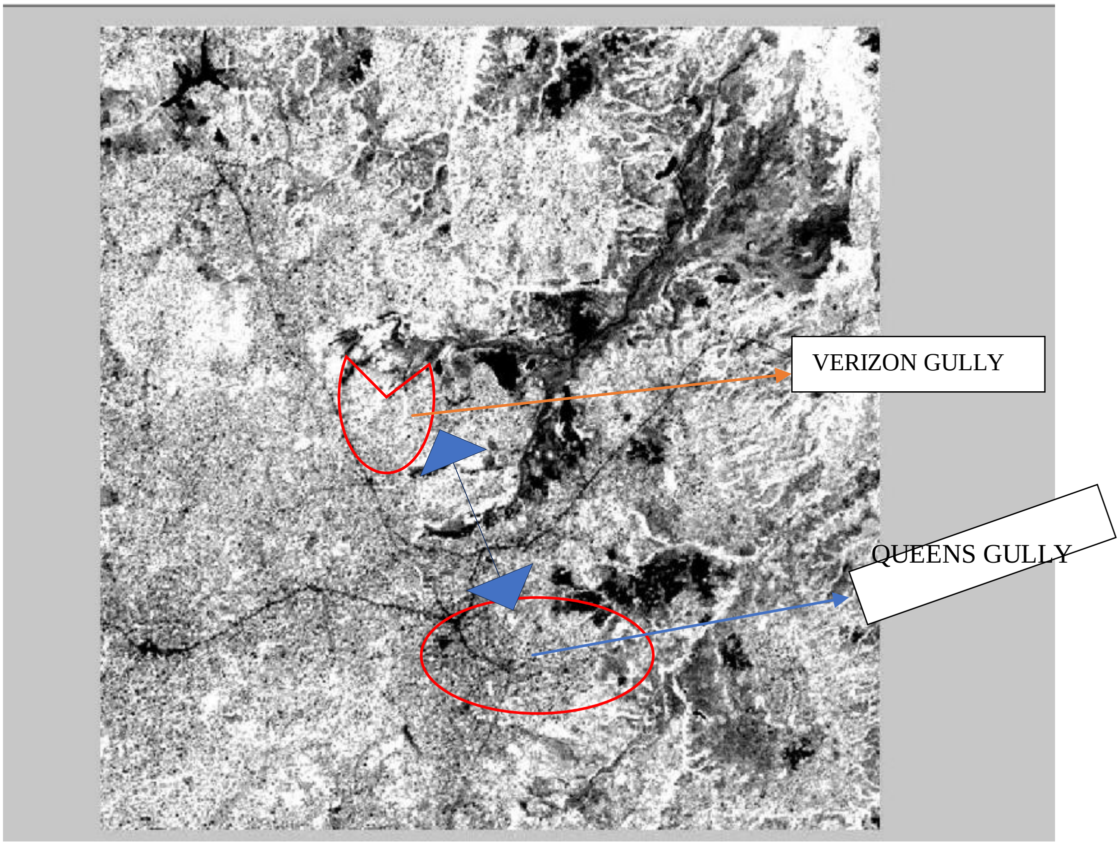

Figure 9: NDVI Image of the Study Gully Sites (1986 Verizon & Queens)

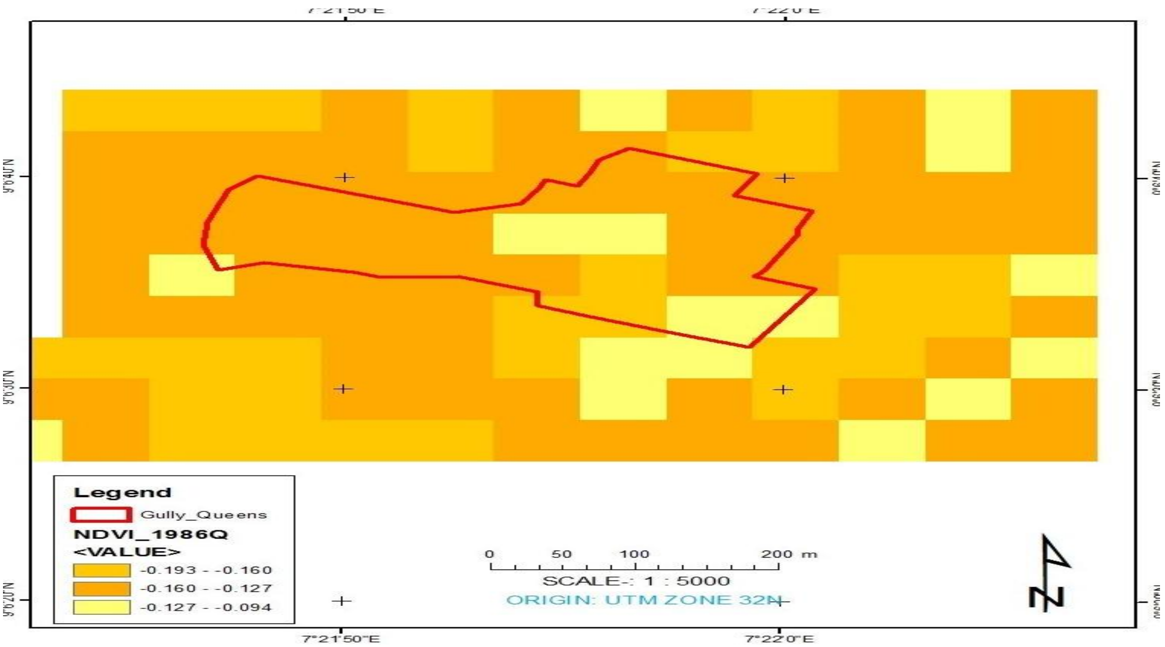

Figure 10. NDVI Map Showing the Queens Gully Site of 1986

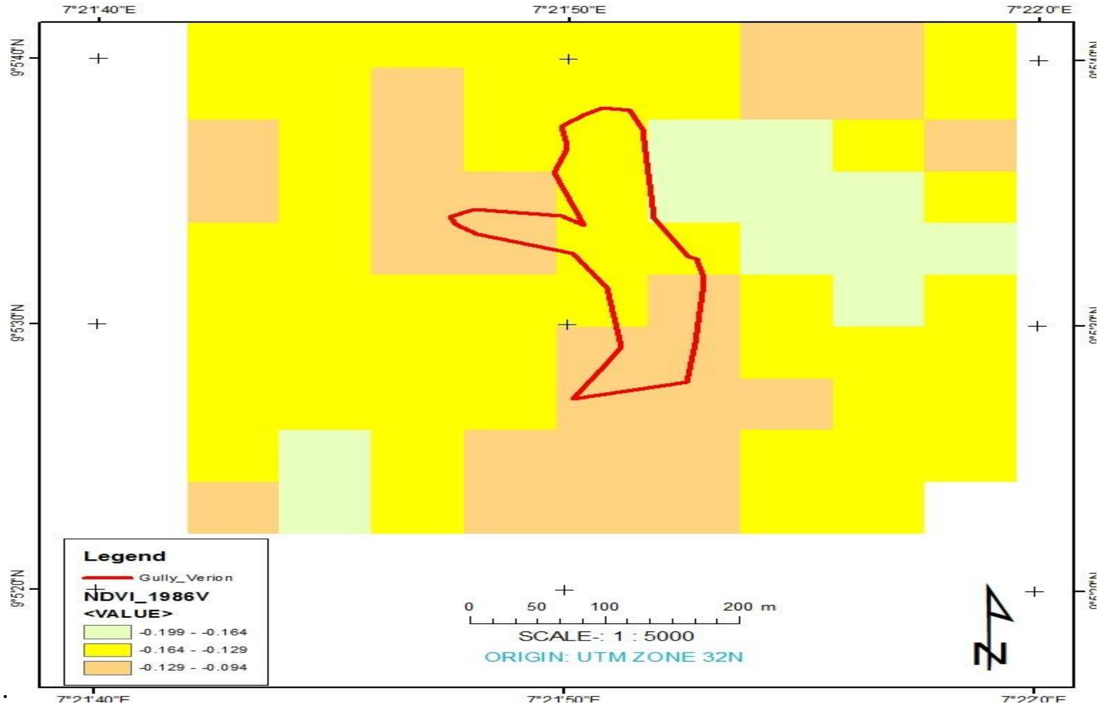

Figure 11: NDVI Map Showing the Verizon Gully Site of 1986.

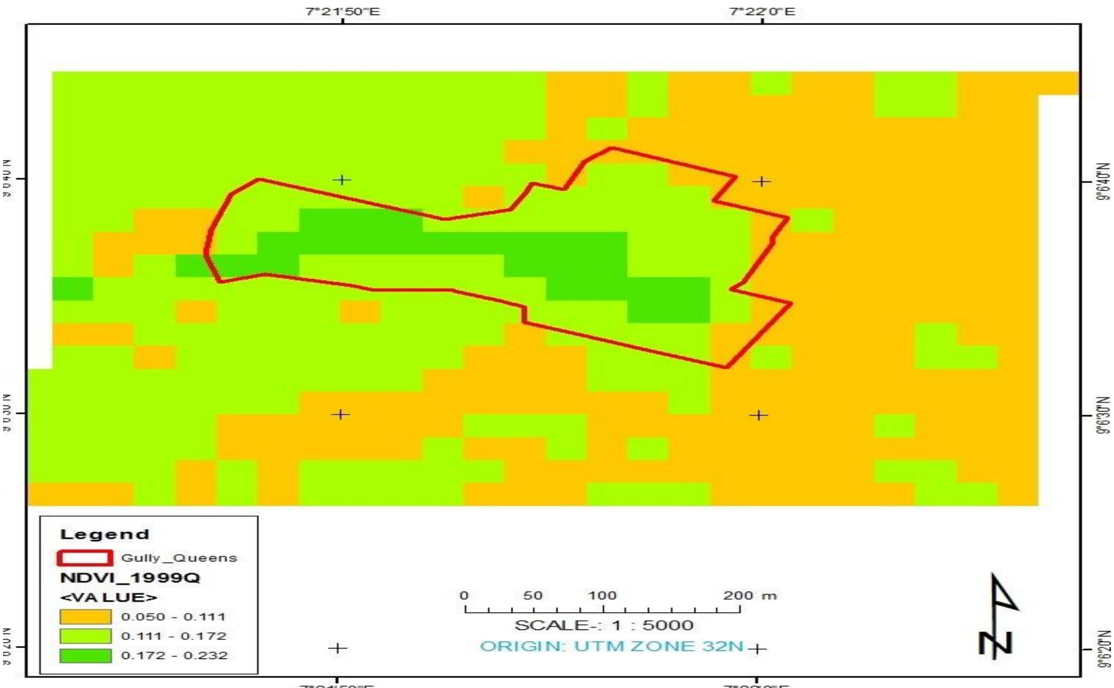

Figure 12: NDVI Map Showing the Queens Gully Site of 1999

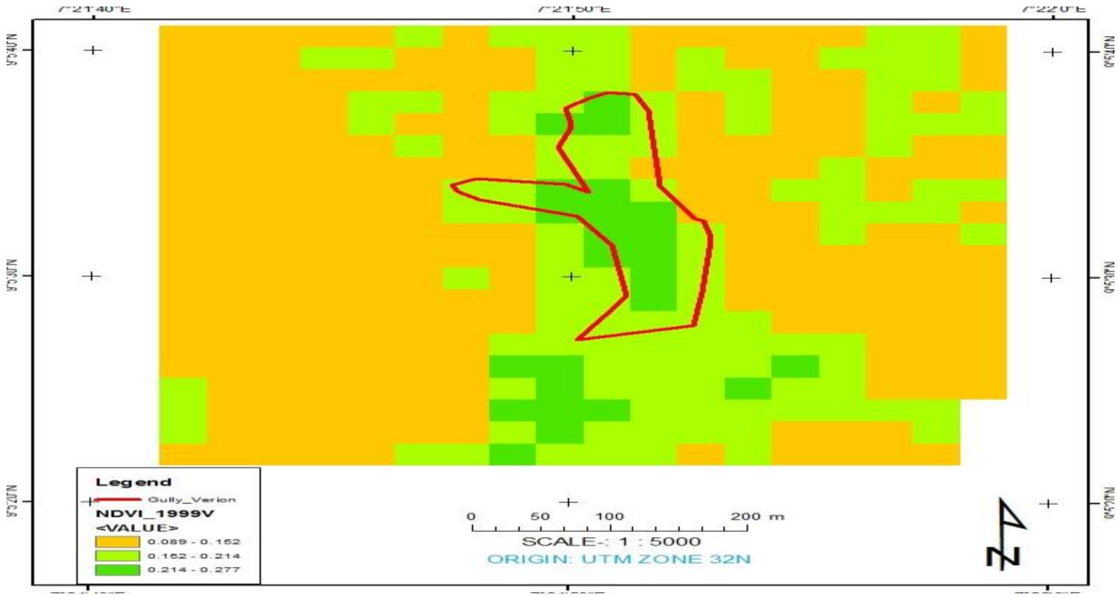

Figure13: NDVI Map Showing the Verizon Gully Site of 1999

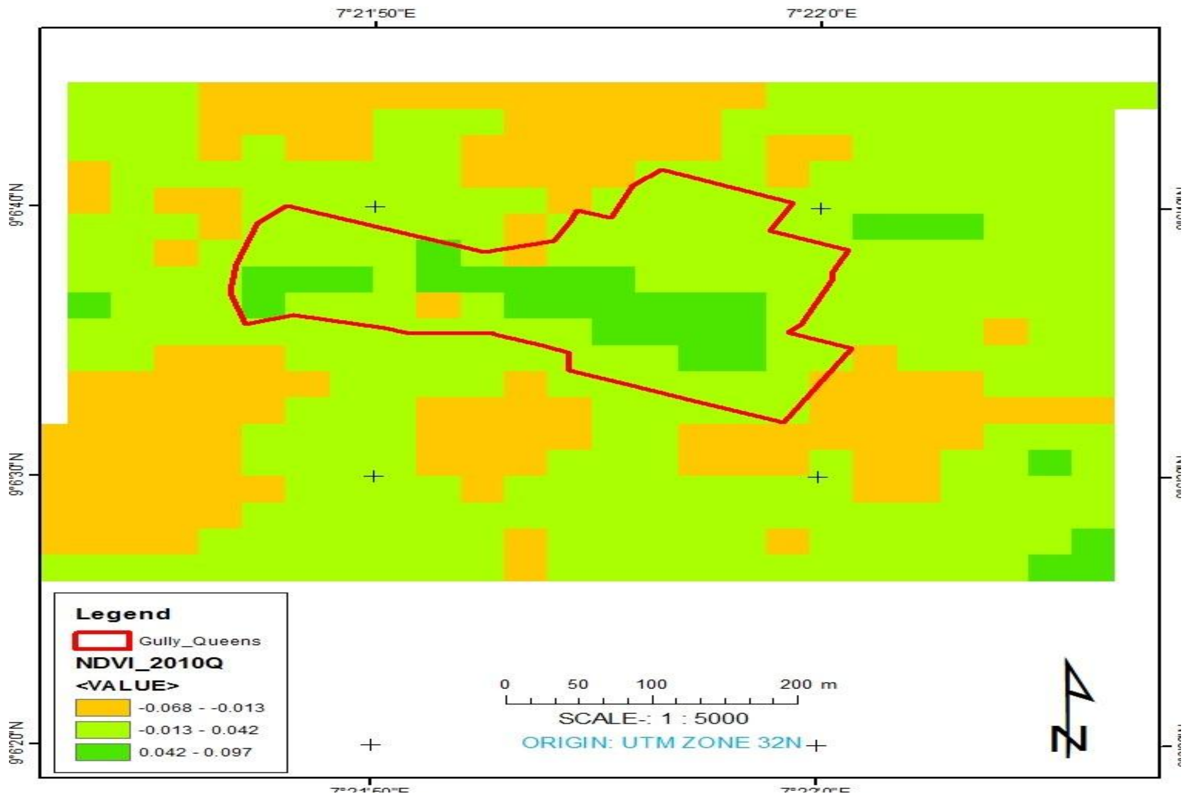

Figure 14. NDVI Map Showing the Queens Gully Site of 2010

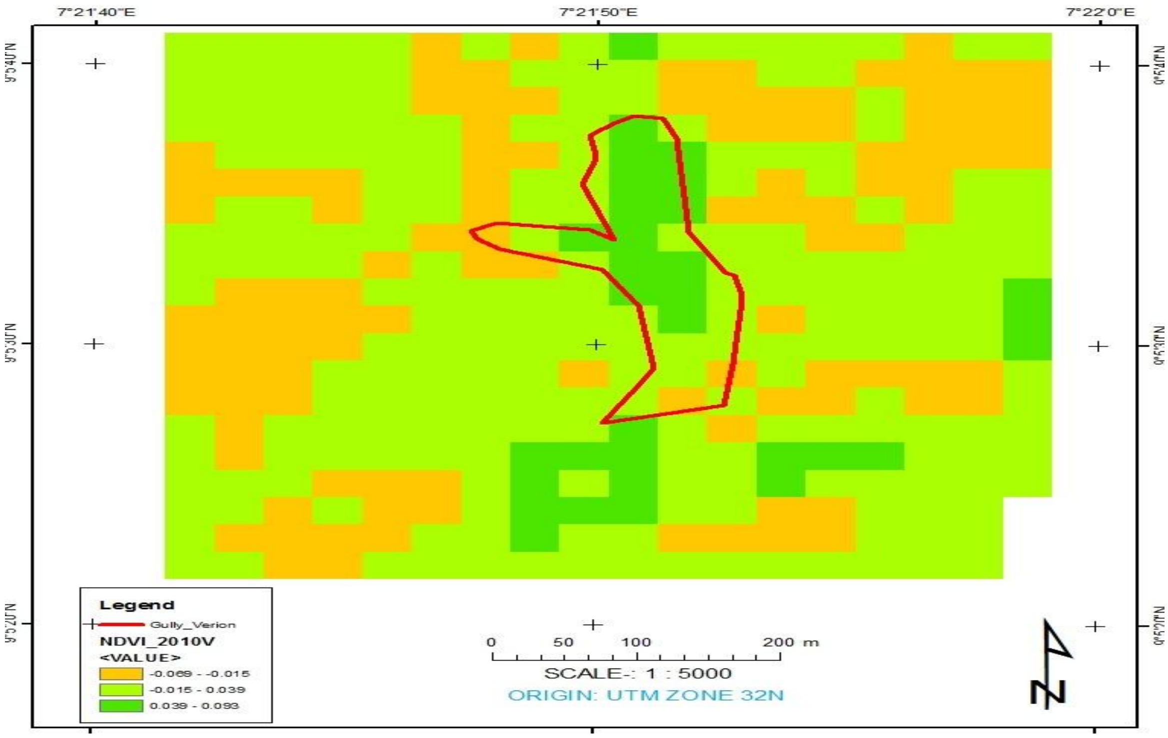

Figure 15: NDVI Map Showing the Verizon Gully Site of Study Area For 2010

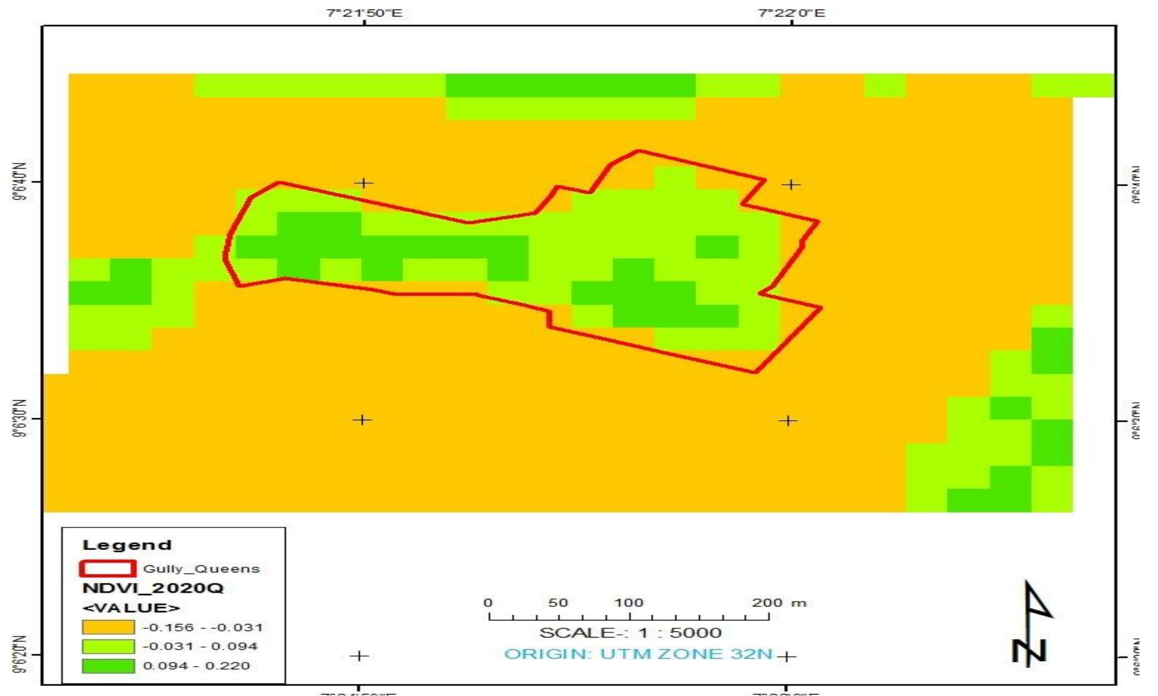

Figure 16: NDVI Map Showing the Queens Gully Site of Study Area For 2020

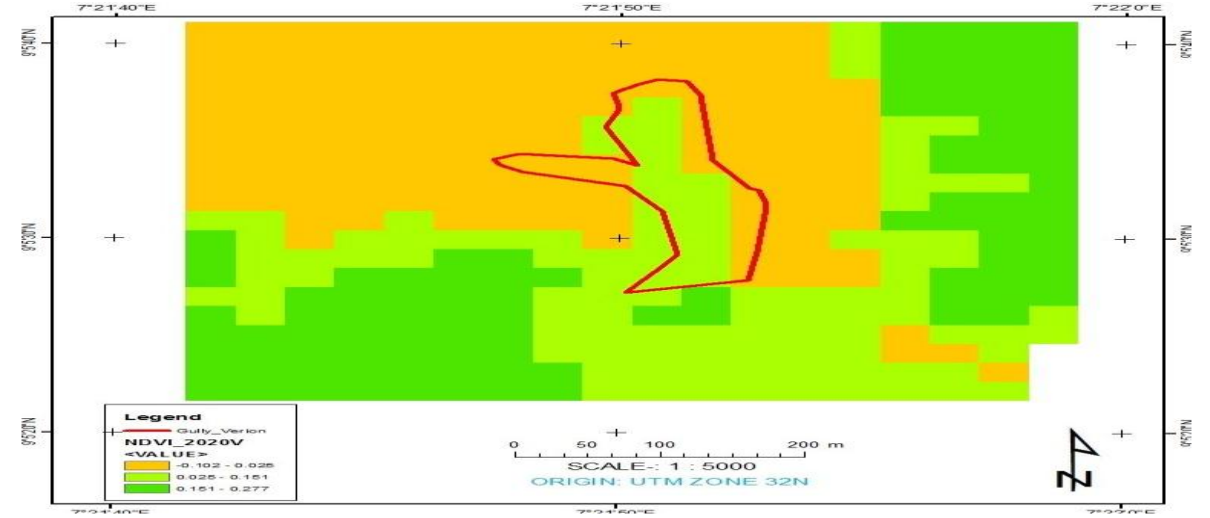

Figure 17: NDVI Map Showing the Verizon Gully Site of Study Area for 2020.

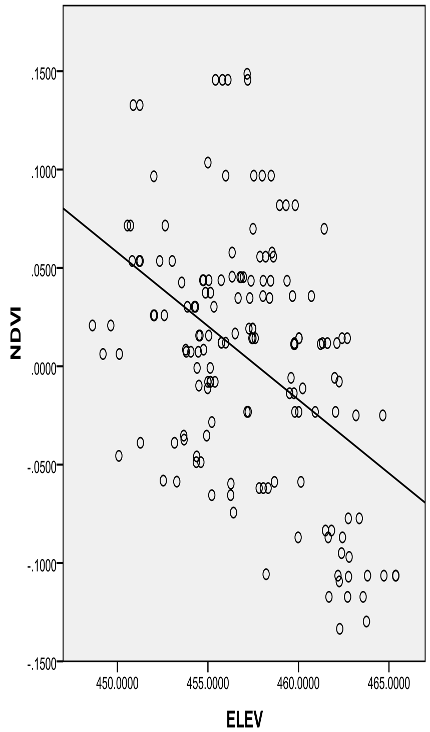

Figure 18: Descriptive Statistics Model Graph Between NDVI and Elevation

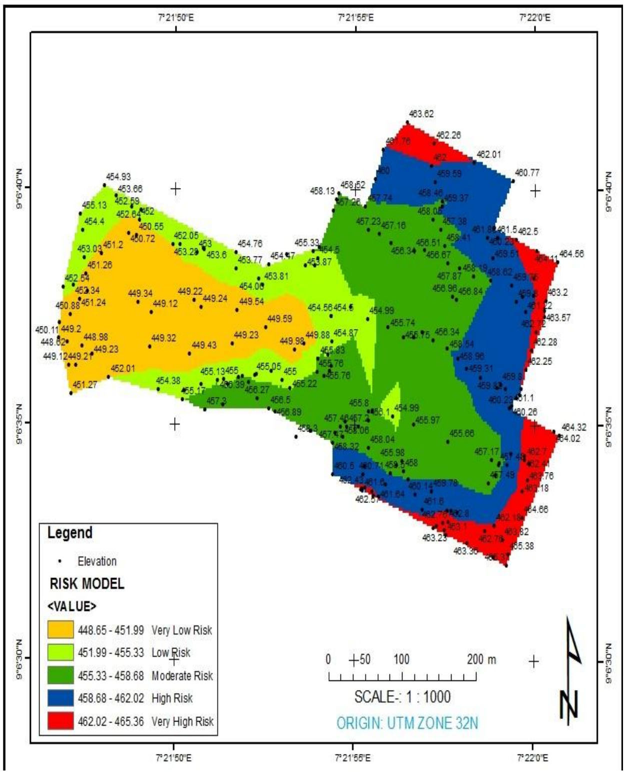

Fig 19: Risk Model Classification for Queen Gully of the Study Area

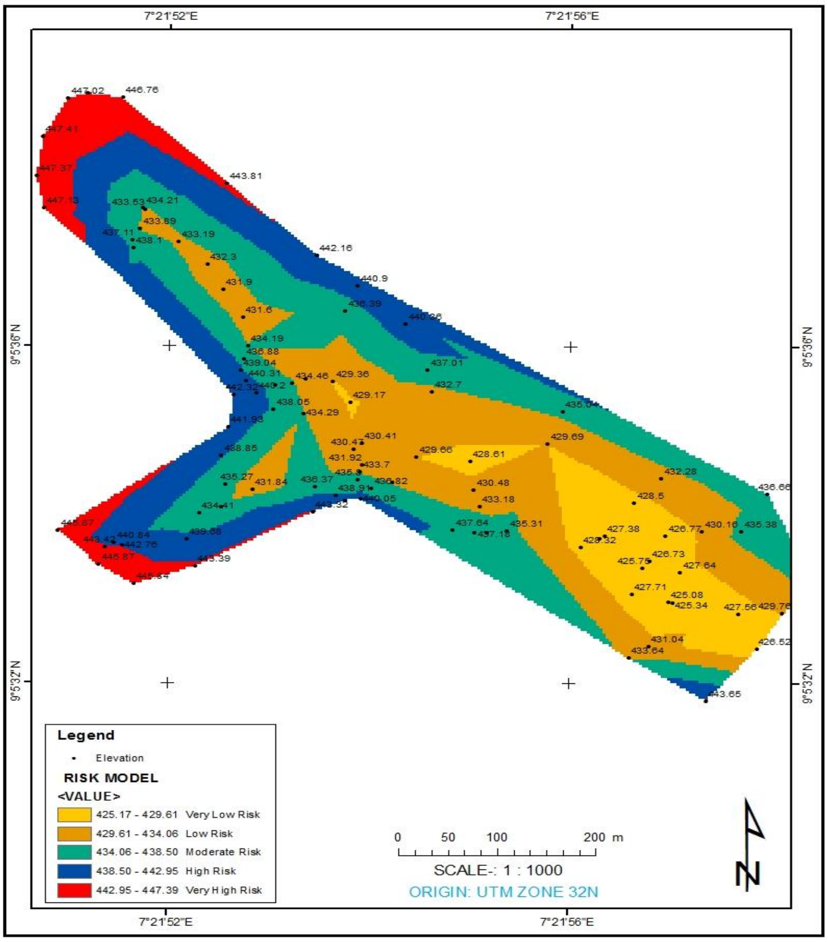

Fig.20: Risk Model Classification for Verizon Gully of the Study Area.

IV. CONCLUSION

Remote sensing and lately Geographical Information Systems (GIS) have played an important role in the mapping of existing gully erosion and in the monitoring and calculation of gully erosion rates. GIS is a faster and better technological tool for geographical data manipulation and for spatial modelling whereas remote sensing techniques have several advantages over other mapping techniques in mapping land cover changes and large areas due to its large coverage, available archive data and volume of thematic information that can be obtained in a single image. The study demonstrates the usefulness of GIS and remote sensing for the Analysis of Risk and temporal dynamics of gully erosion in EFAB area. The process of Risk analysis and data capture has been automated by the use of ArcGIS software and satellite remote sensing. Further, the remote sensing techniques have been found to be suitable for the preparation of updated land use/ land cover map in a timely and cost-effective manner and should be preferred in soil erosion studies for deriving input data layers.

The study revealed that a total 16.881km² was affected by severe gullies with the Queens and Verizon gully having an area of 65.480km² for queens and 19,922km² for Verizon and of the rate of gully expansion in the area. The Queens and Verizon gully erosion has a Y-shape and flows into the river. The method to estimate the rate of gully expansion material losses was not validated with factors affecting gully developments, and analysis. The implemented analysis technique, based on the comparison of satellite image data and non-regression analysis, only showed significant changes in the spatial extent of gully areas. Compared with the other morphological characteristic parameters, gully length and width, especially gully length, proved to be the best indicators for predicting gully volume. To improve our prediction model for gully volume, more influencing factors will be considered in the future, and machine learning models, including random forest and the support vector machine model will be a priority.

V. RECOMMENDATIONS

From the results, knowledge and experiences gained while carrying out the research study, the following recommendations was made

1. GIS and remote sensing technique are recommended for use in analysing the risk and temporal dynamics of gully erosion in F.C.T state in particular and the whole northern region of Nigeria in general.
2. That detailed investigations of the pedological, geological, hydro- geological, geotechnical, and hydro-geochemical characteristics of the region and of the socio-psychological conditions of the area should also be done before any control measures are applied to the gully since the improper control measures can worsen the gully condition and is a waste of resources.
3. The strengthening of the erosion control and monitoring activities and the control measures should be carried out quickly as the rate of gully expansion is increasing.
4. The ministry of urban planning and housing department should also spread their tentacles to the rural areas for proper land use planning of the areas and strict adherence to the planned land use. Good drainage network should also be constructed in the area.
5. Public awareness campaign should be intensified to educate the communities in the area where gully erosion predominates on land use techniques that will help preserve the soil

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