REMOTE SENSING, A TOOL FOR EROSION STUDY: A CASE STUDY OF NEKEDE AND ITS ENVIRONS

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Abstract: This study adopts Remote Sensing as a tool to identify and study erosion especially gully erosion in the study area, Old Nekede Road and its environs in Owerri, Imo State, South Eastern Nigeria which is located between latitude 5.18° – 5.39° N and longitude 6.51° - 7.08° E. Remotely sensed data consisting of the Landsat Thermatic Mapper (TM) imagery of NigeriaSat-2 2012 satellite and Digital elevation model of study area were studied with the objective of identifying the drainage and structures associated with the area and to infer their influence on gully erosion initiation and propagation. The Landsat TM data was analysed and processed using ILWIS 3.3 Academic, Multispec 3.3 and Landserf 2.3. Results obtained from the structural analysis revealed numerous lineaments at several parts of the satellite image. On the whole, this study has demonstrated the usefulness of Satellite (Remote Sensing) technology in studying erosion.

Keywords: Erosion, Nekede, Remote Sensing, Landsat, DEM.

1. Introduction

The task of managing natural resources of the earth is daily growing in complexities. This is due partly to increasing uncertainties in the natural-physical systems, as well as increasing interference of man with these systems. Natural resources development and management is of tremendous concern to mankind. The utility derivable from resource use and the deleterious effects and consequences of resource abuse are important for continued existence of man and survival of the natural ecosystems. Degradation sets in when the capacity of a natural eco-system to renew itself is constrained by frequent disturbance and/or perturbations and this is a big threat to human survival and livelihood. Maps and measurements of degraded land can be derived directly from remotely sensed data by a variety of analytical procedures, including statistical methods and human interpretation.

Conventional maps are categorical, dividing land into categories of land use and land cover (thematic mapping; land classification), while recent techniques allow the mapping of land degradation and other properties of land as continuous variables or as fraction of the land by different land use- land cover categories, such as tree canopy, herbaceous vegetation, and barren (continuous fields mapping). These types of datasets may be compared between time periods using Geographic Information Systems (GIS) to map and measure their extent and change at local, regional, and global scales. South eastern Nigeria is a typical erosion region in the country. The presence of gully sites is one of the hazardous features that characterize Imo State and several other eastern states adjoining it (Okereke et al., 2012).

Remote Sensing is the acquisition of information about an object of phenomenon without making physical contact with the object. Remote sensing makes it possible to collect data on dangerous or inaccessible areas. In most cases remote sensing techniques have been applied simply to identify the characteristics (or the absence) of the vegetation cover, largely because of limited visibility of the soil surface in humid and sub-humid environments. Other studies have demonstrated the usefulness of remote sensing techniques in determining temporal and spatial erosion patterns. Calculation of the percentage of bare ground has also been used to estimate erosion risk. Other methodologies applied to inventories and monitoring of erosion processes include band ratios vegetation indices, combinations of reflective and microwave data, and combinations of remote sensing data and other ancillary data (Vrieling, 2006).

Remote sensing has been used for geologic interpretations with remarkable success. Remote sensing techniques are used because of their cost effectiveness, their ability to access areas that are difficult to access and because the data can be collected frequently and rapidly on a large scale. Remote sensing also replaces costly and slow data collection on the ground, ensuring in the processes that areas or objects are not disturbed. These data sets allow earth-based phenomena such as land use and land cover characteristics to be rapidly mapped, if needed repetitively and at relatively low costs. With increasing capacity to rapidly generate maps of large areas, planners in the rural and urban areas are getting more empowered to address issues associated with land use analysis.

Several studies have estimated erosion in the south eastern Nigeria using remote sensing at regional and catchment scales. These studies have revealed that Anambra, Abia, Imo, Enugu and Ebonyi States have over 750, 650, 500, 400 and 250 major erosion sites respectively. This gully census is conservative and incomplete since smaller and younger gullies were not enumerated. These younger gullies shall ultimately mature within a few years and pose as serious a hazard as older ones. They must also be included in any control programmes (Boniface, 2011). Imo State has the fifth highest concentration of active gully sites in Nigeria. Gully erosion has remained the most prominent feature in the landscape of Imo State and every community in the State has a tale of woe as a result of ever increasing gullies that affect soil productivity, restricts land use and can threaten roads, fences and buildings (Okereke et al., 2012). Albert (2006) stated that soil erosion in the South-eastern part of Nigeria has been identified as the most threatening environmental hazard in the country.

Soil erosion remains the world's biggest environmental problem, threatening sustainability of both plant and animal in the world. Over 65% of the soil on earth is said to have been displaced by degradation phenomena as a result of soil erosion, salinity and desertification (Okin, 2002).

2. Scope and objectives

The scope of the project is to map out erosion risk zones for the study area using remote sensing. A more comprehensive erosion risk analysis would however involve higher spatial and spectral resolution of the Landsat scenes and higher DEM resolution (higher than 90m).

The objective is that this study will further demonstrate the usefulness and enhance appreciation for the techniques of Remote Sensing in land degradation assessment and proffer possible control measures to tackle the erosion problem, recommend the use of the remote sensing technique in monitoring against development of erosion process in general and gullies in particular and to provide useful spatial information of the study area for future references.

3. Study Area

The study area is situated in Owerri West Local Government Area, Imo State, south-eastern Nigeria, and is located approximately between latitude 5.18° – 5.39° North of the Equator and longitude 6.51° - 7.08° East of the Greenwich with an average altitude of about 300m and above covering about 1,200 square km and has a humid tropical climate, having a mean annual rainfall varying from 1,500mm to 2,200mm (60 to 80 inches) and a mean annual temperature range of 27^0-28^0C. Orographic rainfall is common in the area. The Otamiri River is a major tributary of the Imo River traversing the site.

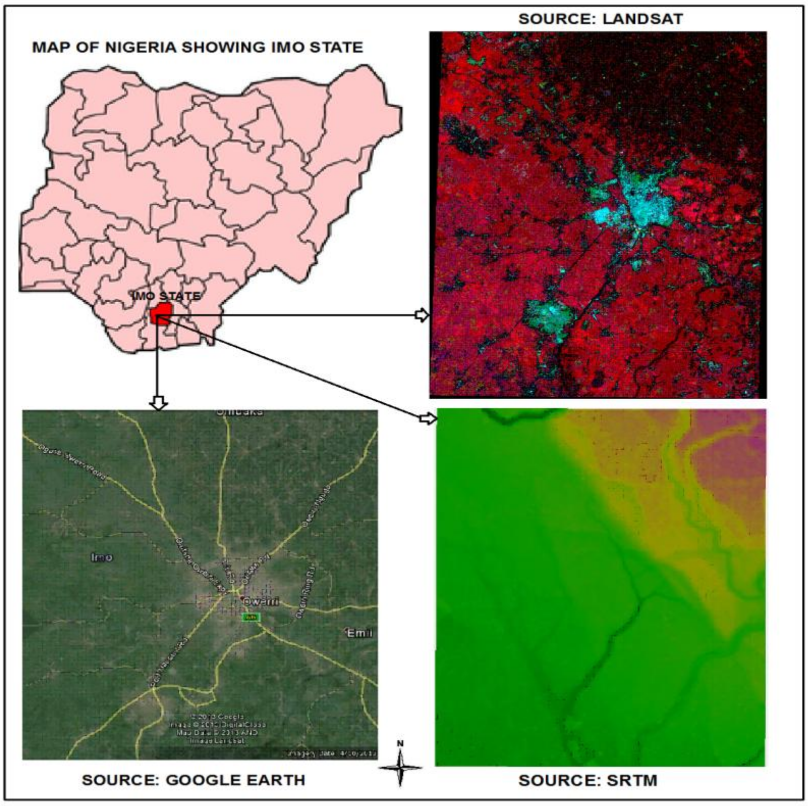

FIGURE 1: MAP OF NIGERIA; IMO STATE SHOWING LOCATION OF STUDY AREA

FIG 1: MAP OF NIGERIA SHOWING IMO STATE AND STUDY AREA.

FIG 2: GULLY EROSION THREATENING TO COLLAPSE A HOME

FIG 3: ONE SIDED STEEP V SHAPED GULLY BY OLD NEKEDE ROAD, UMUMBAZU

4. **Methodology**

The reconnaissance survey of the selected gully erosion site was carried out on 16th of March, 2013. This survey involved physically checking out the gully sites, making observations, visual analysis of outcrops, topography, slope, gullies and vegetation cover. The Global Positioning System (GPS) device was used to measure the coordinates of the study area to give a range of latitude 5.18° – 5.39° N and longitude 6.51° - 7.08° E.

Two types of data were used for this study. One of them is the Landsat data which were the NigeriaSat-2 images acquired in May 2013 from the National Space Research and Development Agency (NASRDA). The images were obtained using Landsat ETM sensor with a resolution of 30m. Landsat TM and ETM data acquired had cloud cover of less than 20%. The images were Geo-referenced to a universal transverse Mercator (UTM) grid using the softwares to allow compatibility and comparison with other data sets (Ibeneme, 2013).

SRTM 90m DEM of the study area was downloaded from the CIAT-CSI SRTM website (http://srtm.csi.cgiar.org) and was in datum WGS84 on the 30th April 2013. The data was projected to the UTM coordinate system and clipped to the extent of the study area.

The softwares used in data processing have the capacity of carrying out various data enhancement techniques and analysis such as linear enhancement, statistical analysis, principal component analysis and normalized difference vegetation index and are listed below.

1. Purdue Research Foundation’s Multispec 3.3: for Landsat NDVI processing.
2. 52North’s Ilwis 3.31 Academic: used for image enhancement and falsecolour Composite image generation of Landsat data.
3. Landserf 2.3: Used for image clipping and geo-referencing of Landsat data and generation of contour, drainage, terrain, slope and relief maps of DEM.

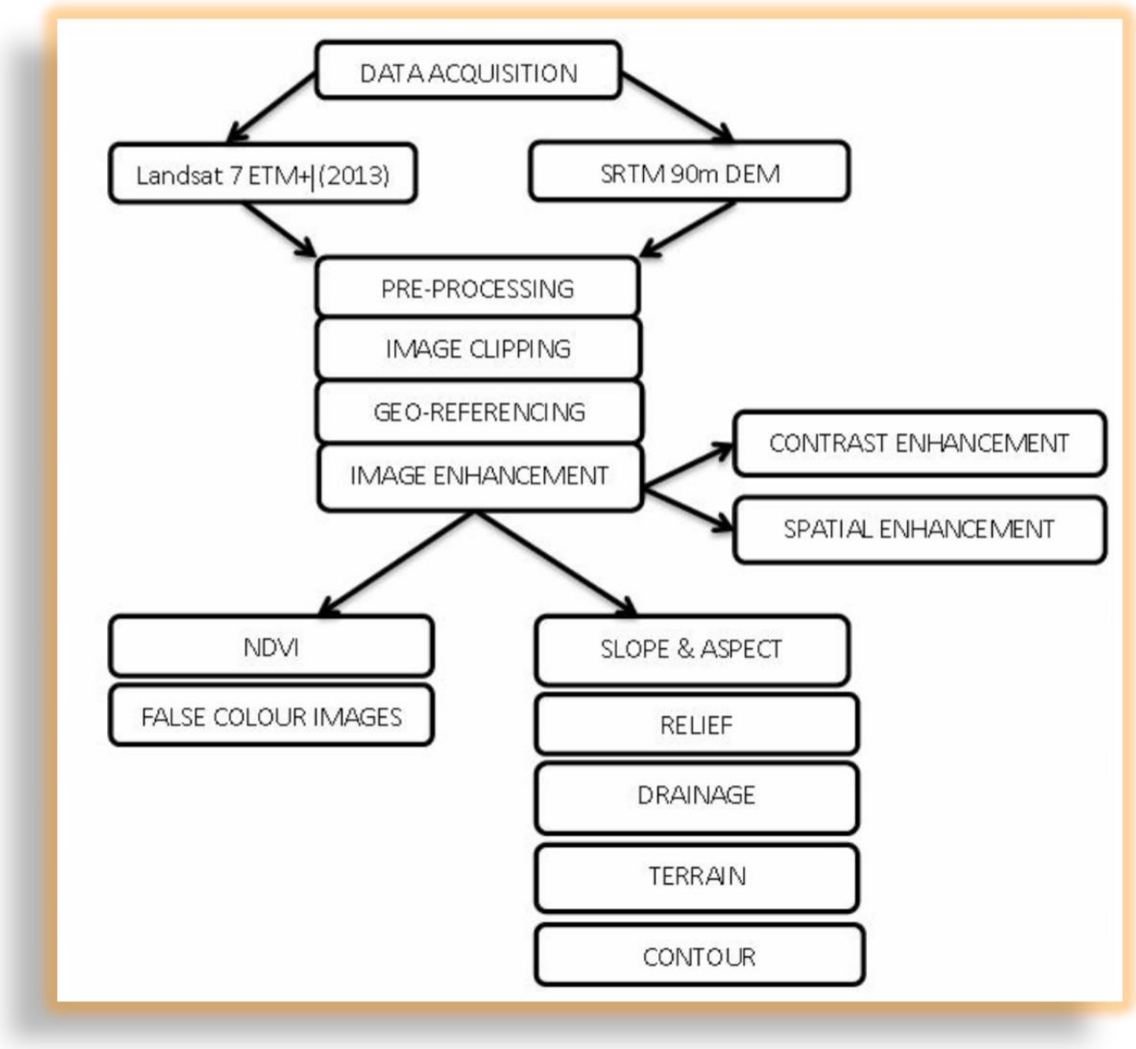

FIG 4: METHODOLOGY FLOW DIAGRAM

5.1 RESULTS FROM LANDSAT 7 ETM+

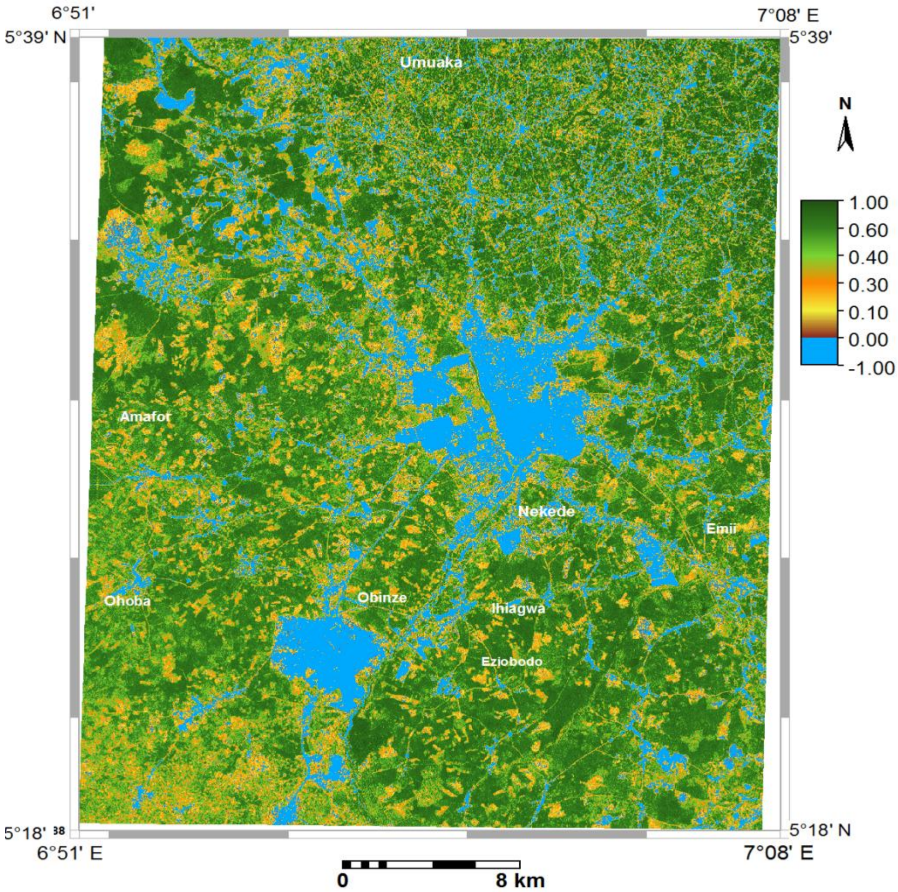

FIG 5: NDVI MAP OF STUDY AREA

It is clearly shown on the NDVI map that the discrimination between the 3 land cover types is greatly enhanced by the creation of a vegetation index. Green vegetation yields high values for the index. In contrast, water yield negative values and bare soil gives indices near zero.

As we can see in Fig. 5, The Central region can be visibly spotted as areas represented by the blue colour with NDVI of -1.00 – 0.00. This colour can also be noticed in a large part of the south west area indicating built up areas. The area were much earlier in time protected by dense forest cover which the inhabitants removed in the process of urbanization and agricultural activities leading to an exposure of the fragile soil to the heavy downpour and concentrated runoff of the area. The high speed of the surface runoff culminates in rapid washing away of the soil surface and weakening the soil strata which can cause gullies in the area. This fact is attested to by the findings of Igbokwe (2003). The regions represented by the colour green have the highest vegetation with an NDVI of 0.35 up to 1.00.

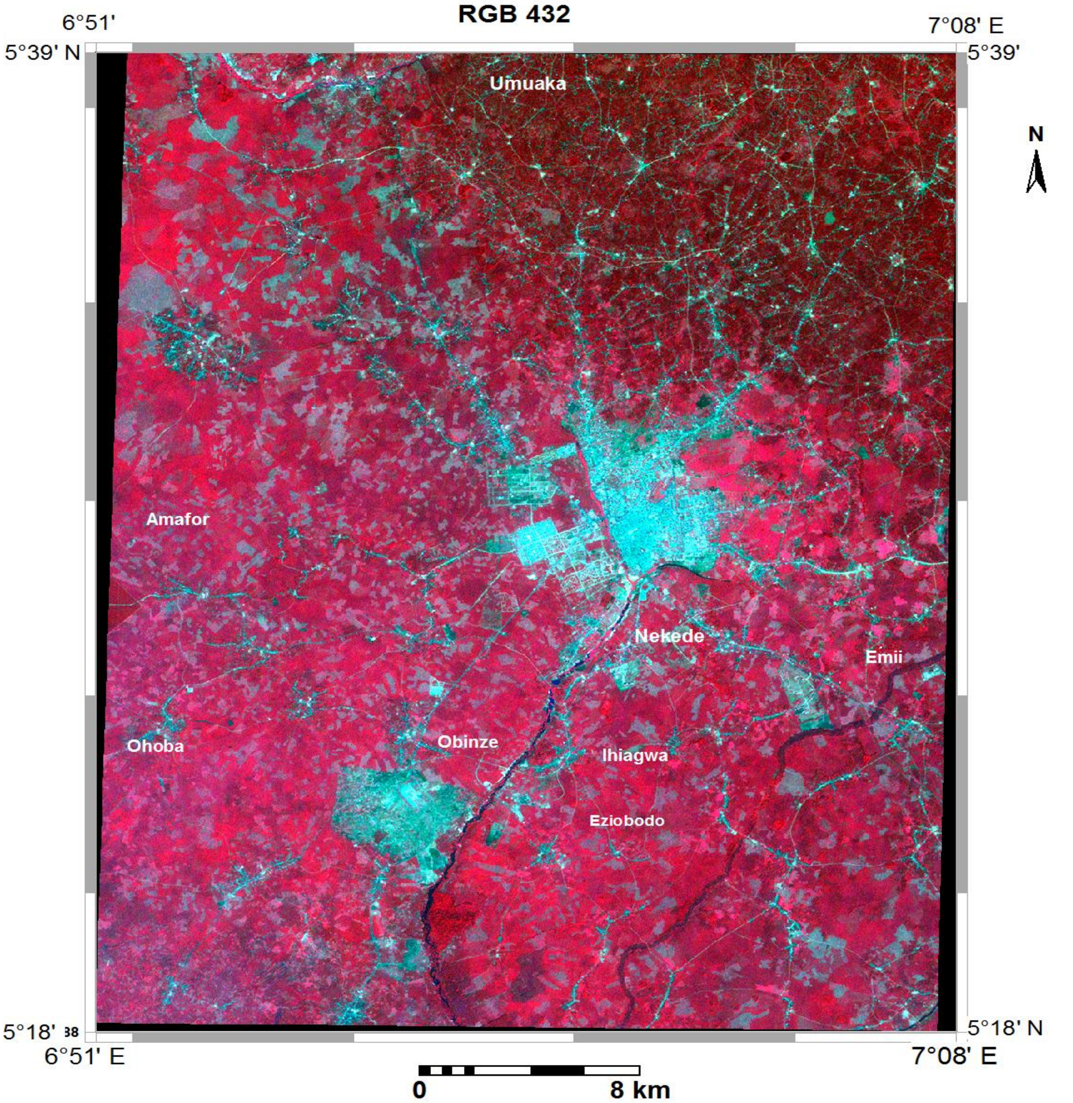

FIG 6: RGB 432; Standard False Colour Composite

This is a very popular band combination and is useful for vegetation studies, monitoring drainage and soil patterns and various stages of crop growth. Vegetation appears in shades of red, urban areas are cyan blue, and soils vary from dark to light browns. Clouds are white or light cyan. Coniferous trees will appear darker red than hardwoods. Generally, deep red hues indicate broad leaf and/or healthier vegetation while lighter reds signify grasslands or sparsely vegetated areas. Densely populated urban areas are shown in light blue and blue represents water bodies.

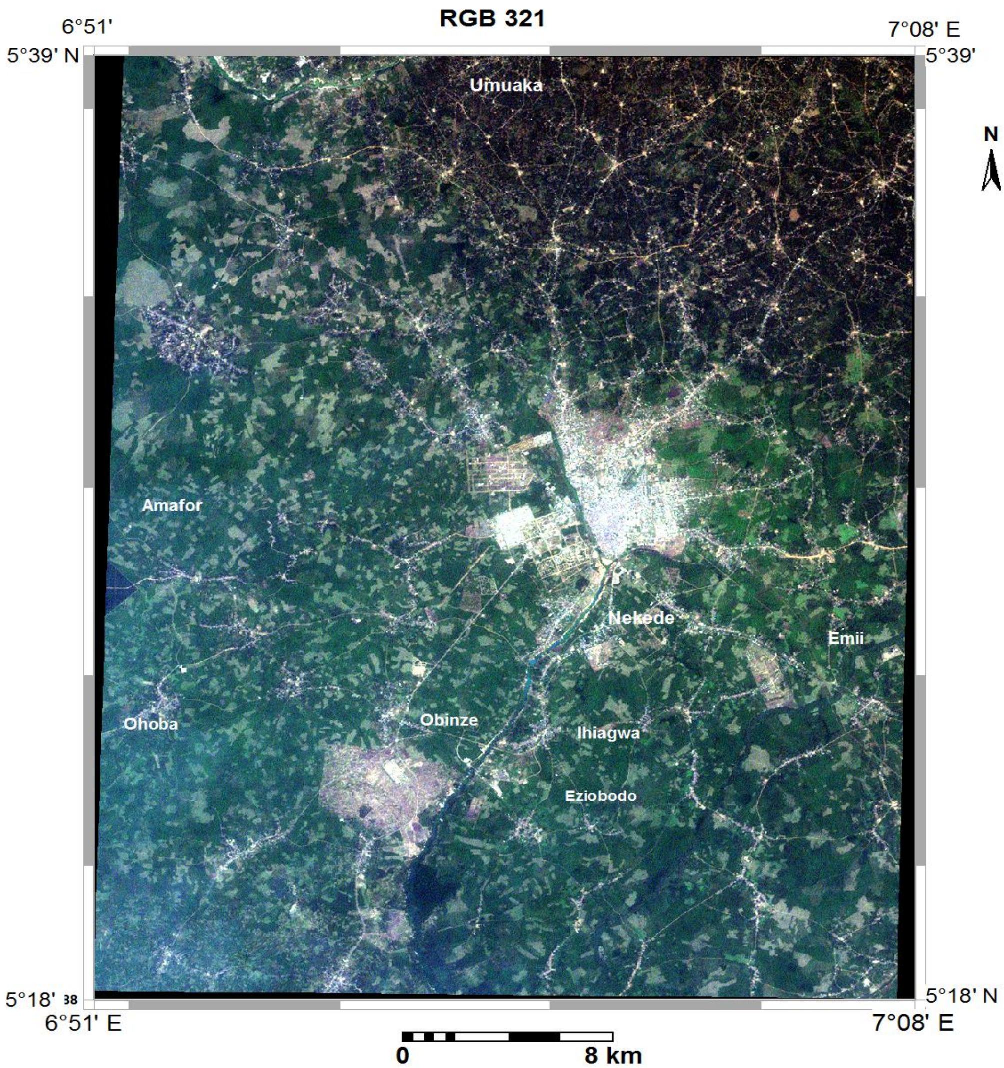

FIG 7: RGB 321 (TRUE NATURAL COLOUR IMAGE)

Fig. 7 is the "natural colour" band combination because the visible bands are used in this combination, ground features appear in colours similar to their appearance to the human visual system, healthy vegetation is green, recently cleared fields are very light, unhealthy vegetation is brown and yellow, roads are grey, and shorelines are white. Light blue regions show the urban areas and bare soil, while the shades of blue represent the drainage channels. This band combination provides the most water penetration information. It is also used for urban studies. Cleared and sparsely vegetated areas are not as easily detected here as in RGB 432. Clouds appear white and are difficult to distinguish. Also note that vegetation types are not as easily distinguished as the RGB 451. The RGB 321 combination does not distinguish shallow water from soil as well as RGB 753 does.

5.2 RESULTS FROM SRTM 90M DEM

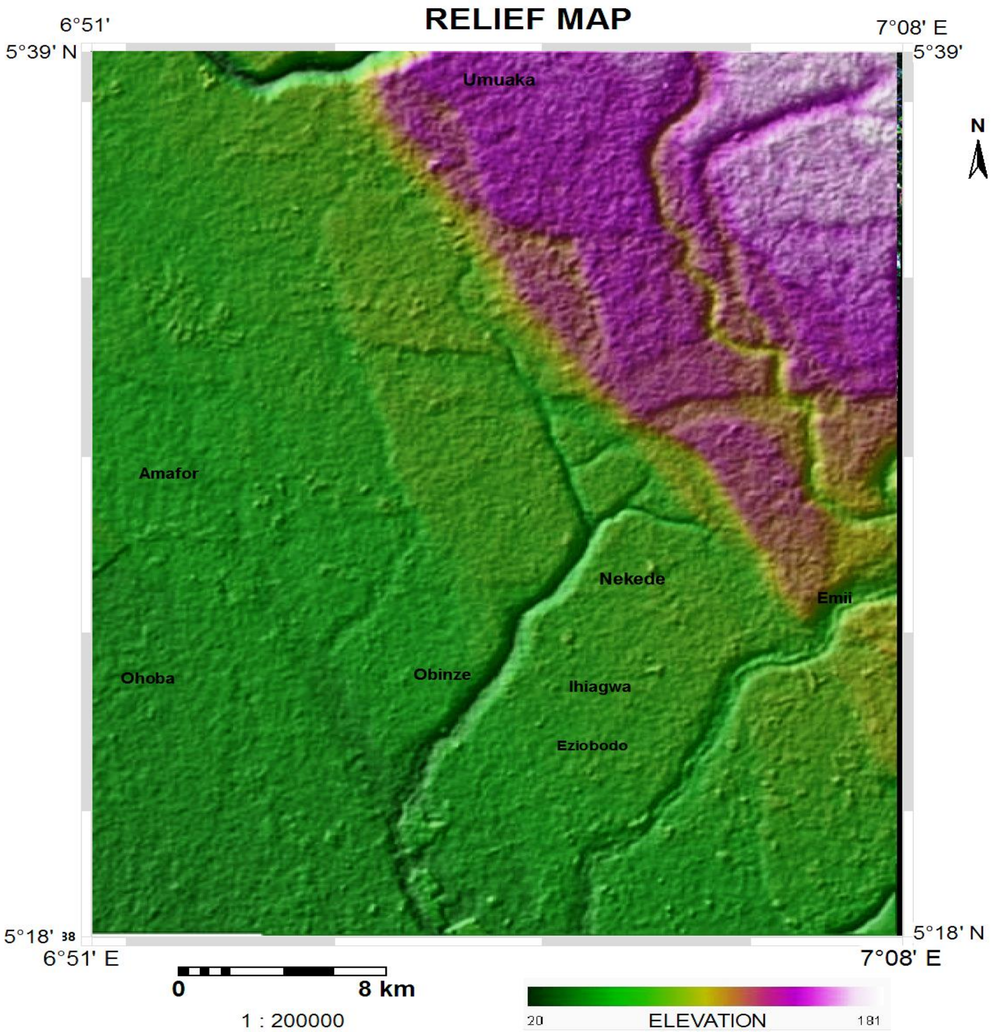

FIG 8: DIGITAL ELEVATION MODEL (DEM) OF STUDY AREA SHOWING RELIEF

Relief represents the elevation of an area from the mean sea level. As far as the study area is concerned, the relief ranges from 20m to 181m from the mean sea level. Using Landserf 2.3, the relief map was prepared for the study area. From the Figure, The South-West region records a low elevations and large coverage with low lands ranging from 48 - 90 meters above sea level. As we travel North-east we notice higher elevations ranging from 90 – 140 meters trending North-east and the highest elevations are found at the North-east corner with a peak of 140 - 180 meters. While the South-West region has the lowest elevation records, the elevation of the area is increasing as you move from the south-western part to the north-eastern part of the study area and it is characterized by low hills with steep slopes which when correlated with the intense rainfall can be a causative factor for gully erosion in the area.

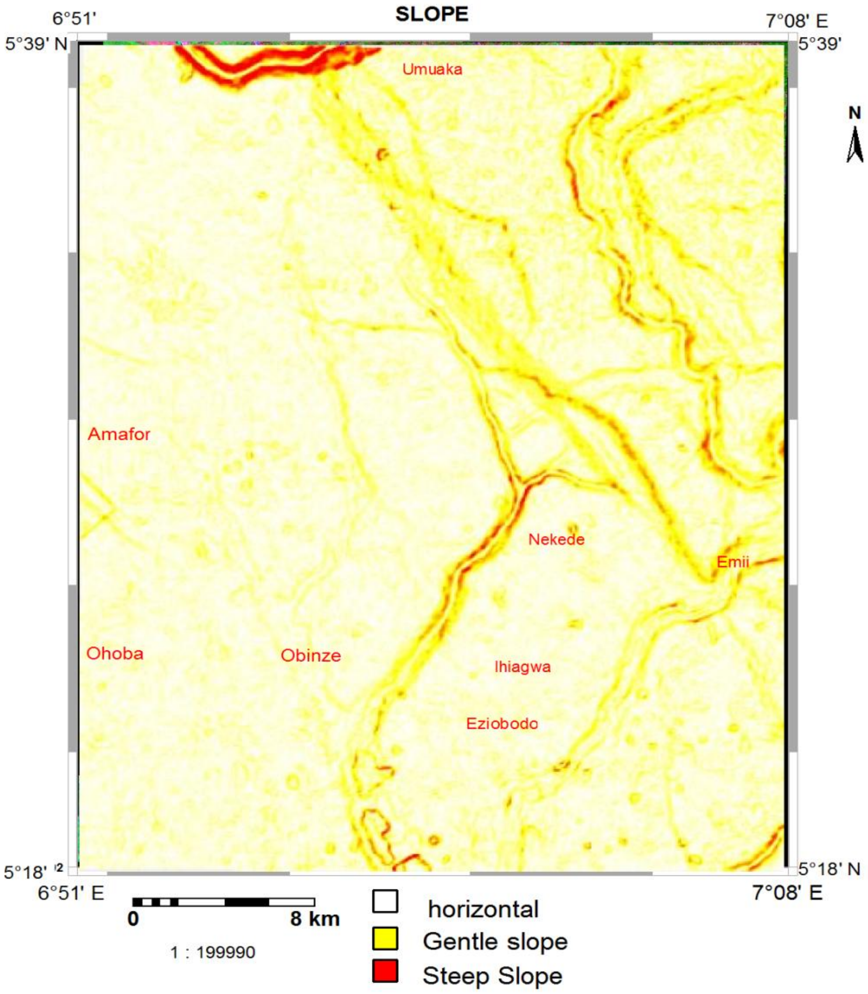

FIG 9: SLOPE MAP

We can get a better idea of the ’roughness’ of the terrain by calculating a slope map using quadratic regression. Slope represents plane of tangent to the surface. Slope is coloured from white (horizontal) through yellow to red (steepest slope). This new image shows the steepest slope at the north of the map. Steep slopes can also be observed in areas bordering Otamiri River and its tributaries. Slope is an important controlling factor for development and formation of soil erosion. Some of the best transport equations are based on stream power, which is the product of slope and discharge (Hessel and Jetten, 2007). Since discharge itself is also determined by slope, the relation between erosion and slope is a power function and therefore it is very sensitive.

Slope represents one of the four surface parameters that are often used to characterise surface behaviour. The other three are aspect which represents the direction to which the terrain slopes, profile curvature, which describes the rate of change of slope in profile, and plan curvature, which describes the rate of change of aspect in plan. Maps can be generated for each of these parameters.

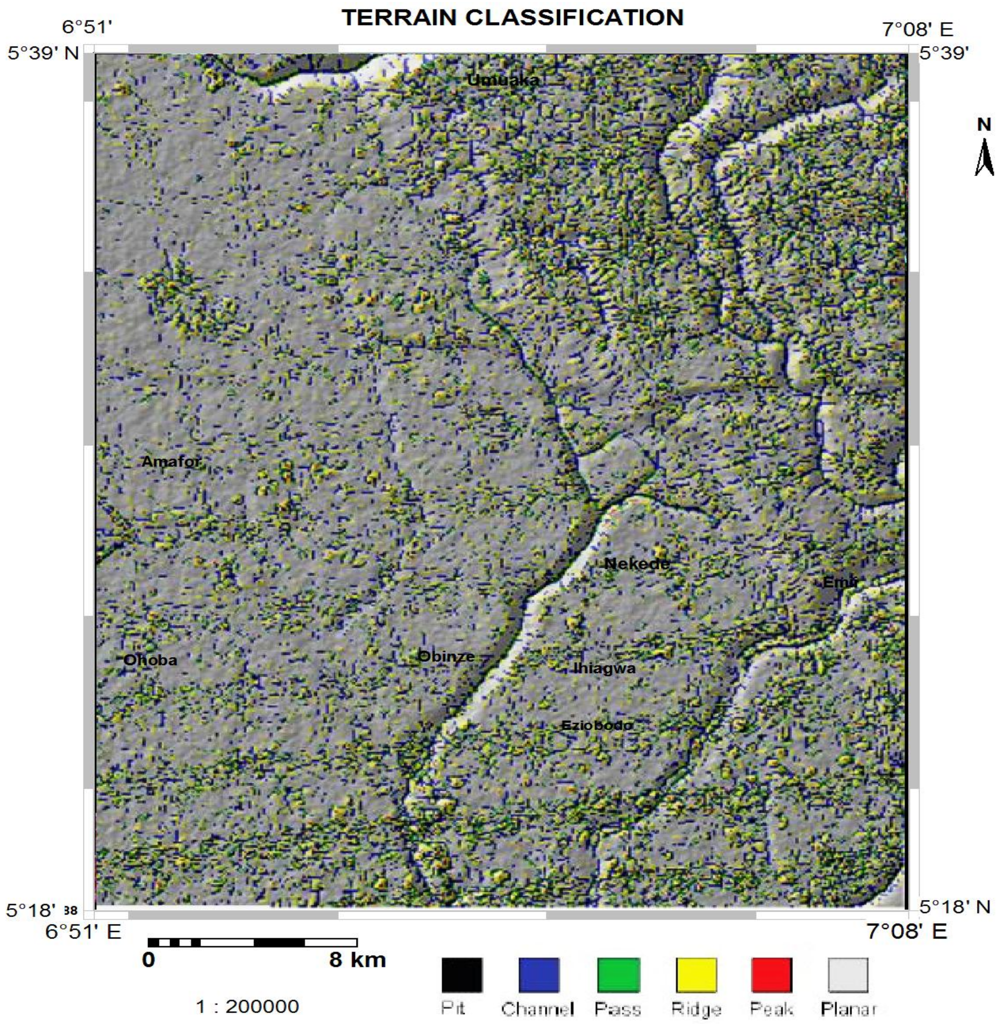

FIG 10: TERRAIN CLASSIFICATION OF STUDY AREA

Finally, we shall examine one further characterisation of the surface. We classify the terrain into surface features by grouping all points on a terrain into one of the following: channels, passes, ridges, peaks and planar regions.

On the Terrain Classification map, we see a predominantly grey, blue and yellow image appear. The grey areas represent planar regions, blue areas represent channels and yellow ridges and looking carefully, we can also see occasional red cells that represent local peaks and green cells that represent passes in the landscape. Feature classifications like this are useful for several reasons. The pattern of channels appears somewhat similar to a drainage network, thus giving us an idea of where water would flow over the surface. Perhaps less obviously the pattern of yellow cells gives us an equivalent ridge network, identifying portions of the landscape where water is likely to flow from.

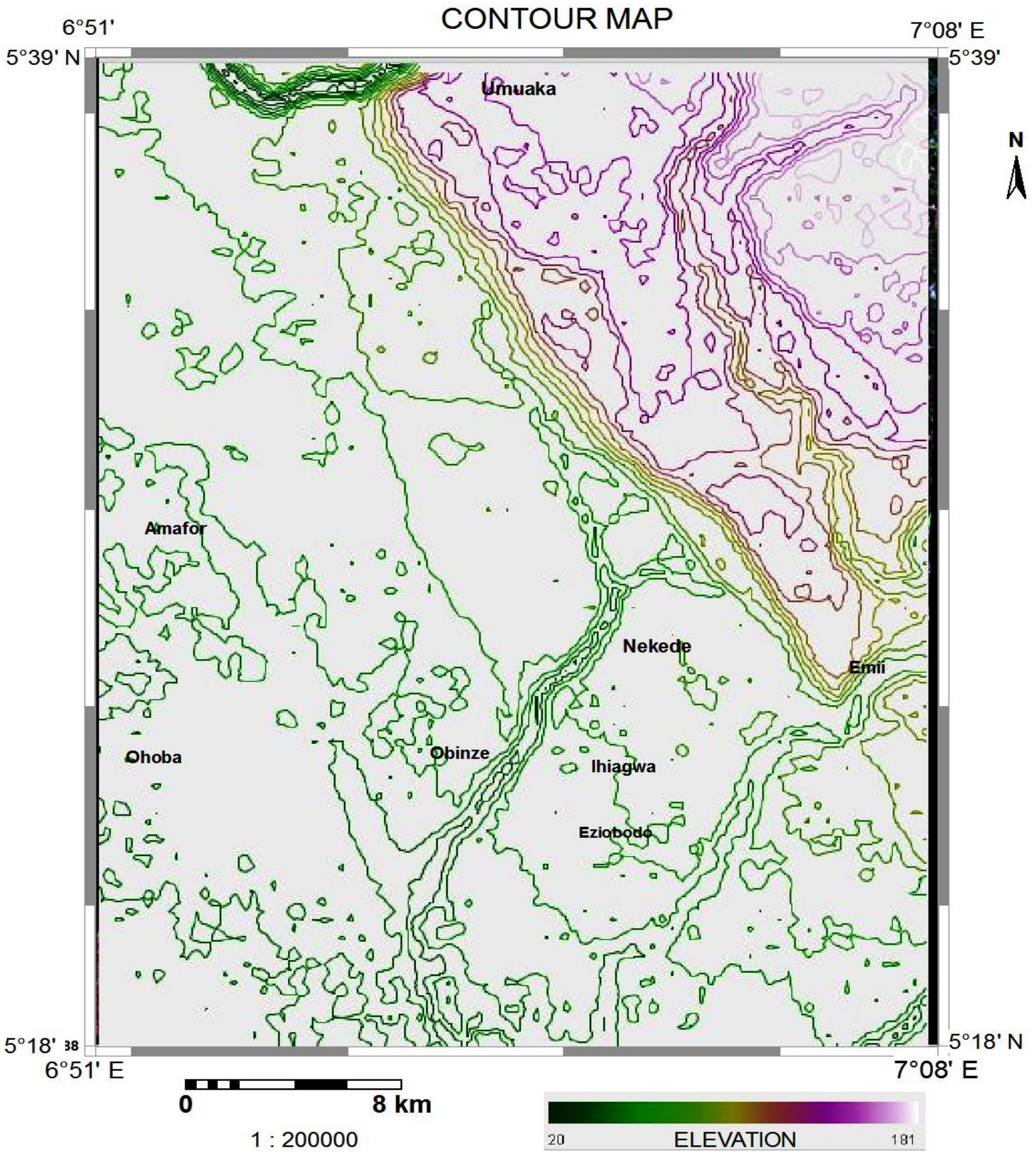

FIG 11: CONTOUR MAP GENERATED FROM THE DEM OF THE STUDY AREA

A contour representation of a DEM is obtained using contour interval of 8m and the elevation of the lowest contour as 20m and grid width of 4m. All these variables can be varied as desired.

The patterns produced by drainage networks are a useful guide to underlying soils and geology. Dendritic drainage patterns are typical of relatively uniform, moderately well-drained soils and rocks and forms in easily-erodible silt deposits (Okereke et al., 2012). The dendritic drainage pattern observed in the study area in terrain classification map is associated with trench branching tributaries joining the main stream at acute angle and this pattern shows up on homogeneous, uniform soil and rock materials mostly in soft sedimentary rocks and old dissected coastal plains (Omutoand Shrestha, 2007).

6.1 CONCLUSION

This study has demonstrated the beauty and utility of remote sensing data in erosion study at a local scale.

All the parameters associated with soil erosion estimated from imagery including assessments of vegetation cover, calculation of vegetation index, changes in topography as outlined by Alatorre and Begueria (2009) were all explored and it was also determined that inherited susceptibility of the study area to gully erosion is derived from the effects of activities on the geologic formations of the area which is characterized by poor geotechnical properties based on previous studies in south eastern Nigeria as a whole (Nwajide and Hogue, 1999; Egboka and Okpoka, 1994; Ehirim and Ebeniro, 2006).

The Landsat Images of the study area obtained is cost effective and easy to edit for various scenarios, while the Applications used to analyse them are user friendly and provide spatial analysis of multiple data layers, technical professionals can reap the benefits of GIS without having to be a proficient GIS specialist.

6.2 RECOMMENDATIONS

- The government should release fund each year to reduce and combat the challenges resulting from effects of the gully erosions.
- Application of measures such as channelization of floodwater, tree planting and erection of concrete breakers etc. in protecting and preserving the environment and making available more land for agriculture and other human activities and at the same time create a functional, attractive, liveable and beautiful environment.
- To achieve the above, the following landscape elements are required; trees, shrubs, grasses, walls, buffers, rocks, and gravels. Economic and non-economic tree should be used, which can be hewn and replaced at intervals. For shrubs, approved seeds and fast growing leguminous grasses that can restore worn out soil nutrients as a result of erosion should be used. Structural and non-structural landscaping measures are recommended as good control and management techniques to check continuous gully erosion problems and its impacts. A more practical approach at the local level, with respect to control of farming practice, enhanced afforestation, prevention of bush burning and overgrazing would go a long way in reducing the problems and consequences of erosion in the study area, Imo State and Nigeria in general.

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