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RESEARCH ARTICLE

SPATIAL MONITORING OF THE EXTENT GULLY EROSION IN AGULU-NANKA AND ITS ENVIRONS IN ANAMBRA STATE USING GEO-INFORMATION TECHNOLOGIES

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ABSTRACT

Soil erosion by water is one of the most important global land degradation problems mainly because of its negative onsite landscape effects such as loss of soil quality and offsite effects such as sedimentation of rivers, lakes and estuaries. This study tends to investigate and monitor the spatial extent of gullies in Agulu – Nanka of Anoacha and Orumba North LGA using Geo-Information Technology. In order to determine the land use and cover change of the gully erosion area, a 27 years change detection analysis was performed through the use of Landsat 4 TM of 1986, Landsat 7 ETM+ of 2000, and Landsat 7 ETM+ of 2013. A supervised classification of the MLC algorithm was performed through the aid of ERDAS 9.3 and the analysis was classified into 5 classes. The result indicates severe variation in all the three eroded/bare soil in the area throughout the study period. However, Eroded/Bare area land cover witnessed a decrease from 5.2% in 1986 to 2.87% in 2000 and increase from 2.87% in 2000 to 3.9% in 2013. This result indicates that man's awareness to preserve the environment by applying mitigation and preventive measures especially in the areas prone to erosion might be encouraging.

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INTRODUCTION

Soil is the earth's fragile skin that anchors all life on earth (Ofomata, 2002). It is comprised of countless species that create dynamic and complex ecosystem and is among the most precious resources to humans. Soil erosion is the systematic removal of soil and organic materials from the surfaced of the earth through denudational processes, which include wind, water and ice and then transported and deposited in order location (Igbokwe *et al*., 2008). Soil erosion by water is one of the most important global land degradation problems mainly because of its negative onsite landscape effects such as loss of soil quality and offsite effects such as sedimentation of rivers, lakes and estuaries (Dwivedi *et al*., 1997) Water and wind are the two major causes of soil erosion.

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They are responsible for 84% of degraded acreage of land in the world therefore making soil erosion one of the significant environmental problems we face today (Blanco *et al*., 2010). China faces one of the most serious soil erosion problems in the world the latest survey carried out shows that the country has some 3.56 million square kilometres of soil erosion areas. This accounts for about 38% of China total territory (Beijing Time, 2002). In Nigerian gullies occupy less than 1% of the land area, yet the number of gully erosion sites is dauntingly large and the size of some individual gullies is astonishingly enormous (Ofomata, 1985). In spite of technological advancement, erosion menace still remains a major problem in Nigeria (especially in South Eastern Nigeria). The yearly heavy rainfall has very adverse impacts altering existing landscape and forms (Nwilo *et al*., 2011). Such landforms create deep gullies that cut into the soil. The gullies spread and grow until the soil is removed from the sloping ground. Gullies when formed expand rapidly coupled with exceptional storm or torrential rain down the stream by head-ward erosion gulping up arable lands, economic trees, homes, lives, sacking of families and valuable properties that are worth millions of Naira (Umudu, 2008). Gully erosion as defined by the Soil Science Society of America (2011), is a channel resulting from erosion and caused by the concentration but intermittent flow of water during and immediately following heavy rains. It was proposed to be deep enough (usually less than half a meter) to interfere with and not be obliterated by normal tillage operations (Hudson, 1981). Gully is also a land form created by running water, eroding sharply into the soil. However GIS provides the sects of tools and techniques for taking these interrelationships. These techniques also provide a basis for monitoring the natural environment because the analysis of GIS data at regular time interval reveals trends and changes (Ayeniyi, 1998). Furthermore, due to the devastation caused by the gully erosion in Anoacha and Orumba North LGA, this study tends to investigate and monitor the spatial extent of gullies in Anoacha and Orumba North LGA using Geo-Information Technology.

Problem Statement

It is widely recognized that accelerated erosion is one of the most factors responsible for soil degradation, Erosion usually transports rocky materials or soil particles after the process of weathering have broken them down into smaller particles which are moveable. Erosion is facilitated by numerous factors and process such as land use, topography, climate, rainfall and soil. The most devastating gully erosions in Nigeria are found in South Eastern Nigeria in the densely populated Anambra, Imo, Enugu and Abia State. The other lesser area is in Auchi in Edo State of Nigeria, The origin of the present erosion menace in Agulu-Nanka started in 1850 (about 160 years ago) as narrow channel of rill erosion and metamorphosed into gully erosion (Nwajide, 1979; Egboka *et al*., 1984) . In 1983, the gully had covered an area of about 1100 km^2 and was estimated to grow at a rate of 20-50m per year. In Agulu-Nanka the genesis is surfaced flood that was left unabated which later resulted or created gullies and the development rate of gully is 150 metres every 3-5 years (Ajaero, 2011). Heavy rainfall and slides events have devastating effects on the environment (Okoye, 2009). The causes of gully advancement in Agulu-Nanka and its environs is the fragile geological formations, high tropical rainfall, the action of man such as encroachment of agricultural activities on forest areas, deforestation for commercial and industrial purposes, urbanization, inadequate drainage system, excavation of sands and misuse of land (Igbokwe *et al*., 2008). The impact of these devastation on the communities are creation of badlands, loss of forests, loss of pasture, loss of houses, loss of soil fertility, displacement of populations, loss of human lives. This study assessed the spatial extent of gullies periodically in relation to other land use types through the use of Geo-information technology in Agulu-Nanka. However the menace of gully erosion deserves being attended to urgently to investigate the direction of gully development and spatial coverage of its development.

Study Site

The study area is Agulu -Nanka and its environs in Anoacha and Orumba North LGA of Anambra State, Nigeria. It is lies between latitude 5°45N and 6°45N and longitude 7°15E and 7°45E (Figure 1). Climate in the study area is characterized by two main seasons-the rainy (wet) season and dry season. The study area records average maximum and minimum temperatures of about 320C rainfall of about 2000mm (Onyegbule, 2010). The study area is drained with the Anambra river rises on the Gala Plateau near Ankpa in Kogi State and flows through the northern low plain where it, as well as its right bank tributaries, meander heavily, developing ox-bow lakes and abandoned meander channels.

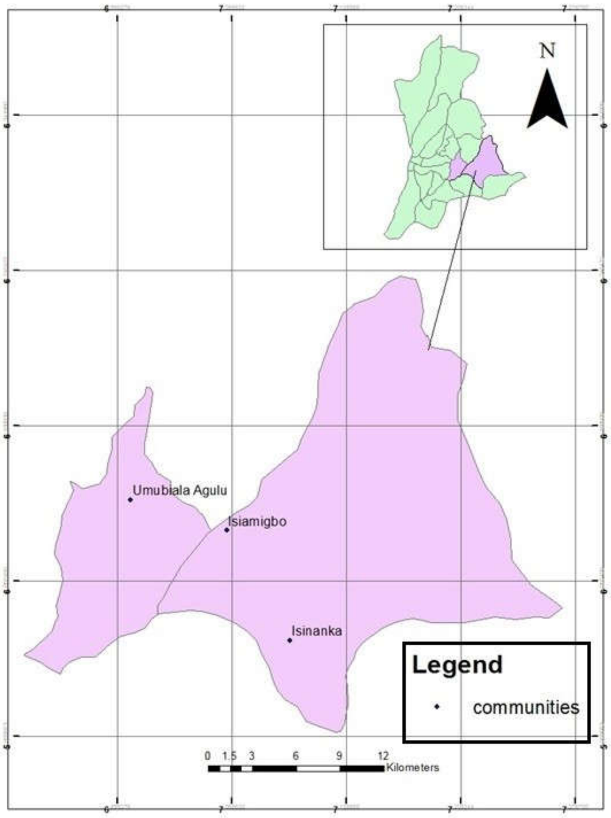

Figure 1. Map of Anambra state showing the study area

Agulu-Nanka falls within the Anambra basin which comprise of ancient cretaceous deltas, similar to the Niger Delta, with the Nkporo Shale, the Mamu formation, the Ajali sandtone and the Nsukka formation as the main deposits. The soil types recognized in Anaocha and Orumba LGA are hydromorphic ferallitic soils. Hydromorphic soils are developed on the Mamu plain east of the cuesta, extending northward into the eastern part of Anambra river flood plain where the underlying impervious clayed shale cause water logging of the soil during rainy season (Oraefo, 2010). The soils are deeply red to reddish brown loamy sand, often referred to as red earth or acid sand because of low fertility (Onyegbule, 2010) which is easily eroded into gullies. Due to heavy rainfall in the area the natural vegetation is tropical dry ordeciduous forest, which, in its original form, comprised tall trees with thick under growth especially climbers; The typical trees (Silk Cotton, Iroko and Oil bean) are deciduous, shedding their leaves in the dry season. In the southern part where rainfall is higher have tropical rainforest type of vegetation, because of the high population density in the state most of the forest have been cleared for settlement and cultivation. What exists now is secondary regrowth, or a forest savannah mosaic, where the oil palm is predominant together with selectively reserved economic trees.

MATERIAL AND METHODS

Satellite imageries and Digital Elevation Model (DEM)

Considering the problem associated to gully erosion in Agulu-Nanka and its environs.

A field inventory was carried out in the study area to ascertain the extent of gully erosion in the area. A handheld global position system (*Garmin GPSmap62)* with accuracy level of 2 – 5 m was used to ground truth data for the land use feature of the erosion area.

Satellite imageries and Digital Elevation Model (DEM)

This study depended vigorously on satellite datasets for the land use and land cover analyses. Table 1 show details of Landsat imageries and Digital Elevation Model (DEM) used. The datasets of 1987, 2000 and 2013 were obtained from the archive of United States Geological Survey (USGS) (http://earthexplorer.usgs.gov/)

Image pre-processing

Image Layer Stacking, and Area of Interest (AOI)

Spectral Band combination for 4, 3, 2 of 1986, 2000 and 2013 were layer stacked respectively through the aid of ERDAS Imagine 9.3 software to form a singer layer spectrum for analysis. The Area of Interest was clipped out from the full satellite sense image through the process of overlaying digitized spatially referenced vector polygon on each of the spectral band combination in ERDAS Imagine 9.3 software.

The MLC assumes that the distribution of the spectral data within a given class ι observes a multivariate Gaussian distribution (Ahmad, 2012; Ochege *et al*., 2017)

Cartographic Model

The systematic graphical representation or presentation of data and analytical procedures below was used in a study.

RESULTS

Land use Land Cover (LULC) Change

Land use and land cover of 1986 (Table 2, Figure 3) shows that Vegetation land cover was 51.9% of the study. This result indicates the presence of abundant Vegetation resources that was untapped by human. Rock/cleared Land occupied 23.6% in the study area which was as a result of change in land form, agricultural activities and other human activities. Built area covers 18.7% of the study area as a result of building development of critical infrastructure and other man made structure while Eroded/Bare soil covers about 5.2% of the study. This result was due to undulating nature of the environment and other natural phenomenon coupled with human encroachment.

Table 1. Data Characteristics and Source

Satellite Sensor	Path	Row	Image Spatial Resolution	Date of Acquisition	Source	Product Format
Landsat TM	188	56	30m	1986	USGS	GeoTIFF
Landsat ETM+	188	56	30m	2000	USGS	GeoTIFF
Landsat ETM+	188	56	30m	2013	USGS	GeoTIFF
ASTER Global DEM (ADEM)			1 Arc–Second	2011	USGS	GeoTIFF

Multispectral Analysis

The study adopted Maximum Likelihood Classifier (MLC) of the supervised Classification algorithm through the aid of ERDAS 9.3 Imagine Software. The MLC classifies estimates pixel signature in relative to the maximum probability of a set of observed classes. This algorithm was performed on the three spectral band combination of the three different years 1986, 2000 and 2013. The algorithm of the MLC is derived from the Bayes Theorem which states that the a posteriori distribution (Ahmad, 2012; Ochege *et al*., 2017). The MLC function of the linear normal distribution is given as:

$$P(\omega) = (P("\omega/\iota)\, P(\iota)")/(P(\omega)) \quad (1)$$

Where:

$P(\omega/\iota)$ = likelihood function,
$P(i)$ = the a priori information (the probability that the class in occurs in the study area)
$P(\omega)$ = the probability that x is observed, which can be written

$$P(\omega) = n\sum\_(1-\iota)\^m \left[P(\omega/\iota)P(\iota)\right] \quad (2)$$

Where:

m = the number of classes.

$P(\omega)$ = normalization constant to ensure $\sum(.) = m\ \iota\ 1\ P\ \iota|\omega$ sums to 1.
Pixel x is assigned to class i by the rule:

$x \in \iota\ \ P(\iota/\omega) > (Pj/\omega)$ for all $j \neq 1$

The last was water body which covers 0.5% of the study area which significantly shows the presence of rivers and lake in the study area. Land use and land cover of 2000 (Table 2, Figure 3) shows that Built Area land cover is 43.3% of the study area.

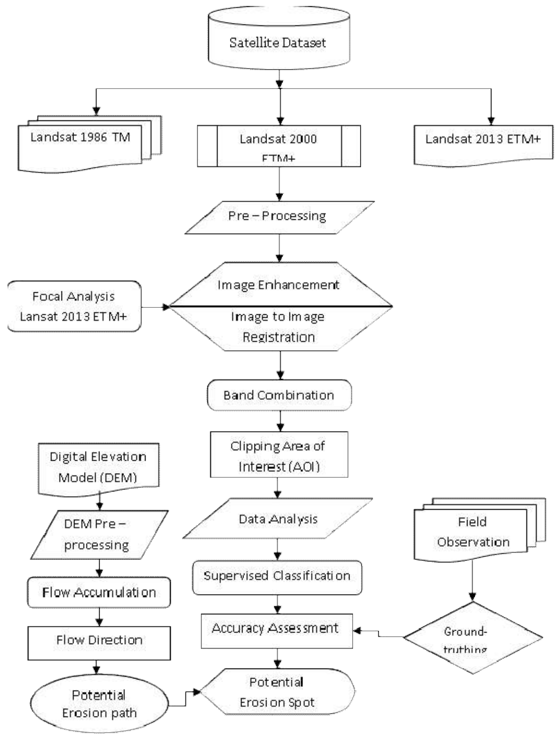

Figure 2. Cartographical model of the study area

Table 2. Land Use Land Cover of the Study Area

LULC Attributes	1986		2000		2013	
	Area (Km^2)	%	Area (Km^2)	%	Area (Km^2)	%
Built Area	27.3	18.7	69.1	47.3	59.2	40.5
Rock/Cleared Area	34.4	23.6	13.1	8.97	19.8	13.6
Eroded/Bare Soil	7.6	5.2	4.2	2.87	5.8	3.9
Vegetation	75.9	51.9	58.6	40.1	60.1	41.1
Water Body	0.7	0.5	0.9	0.6	1.1	0.8

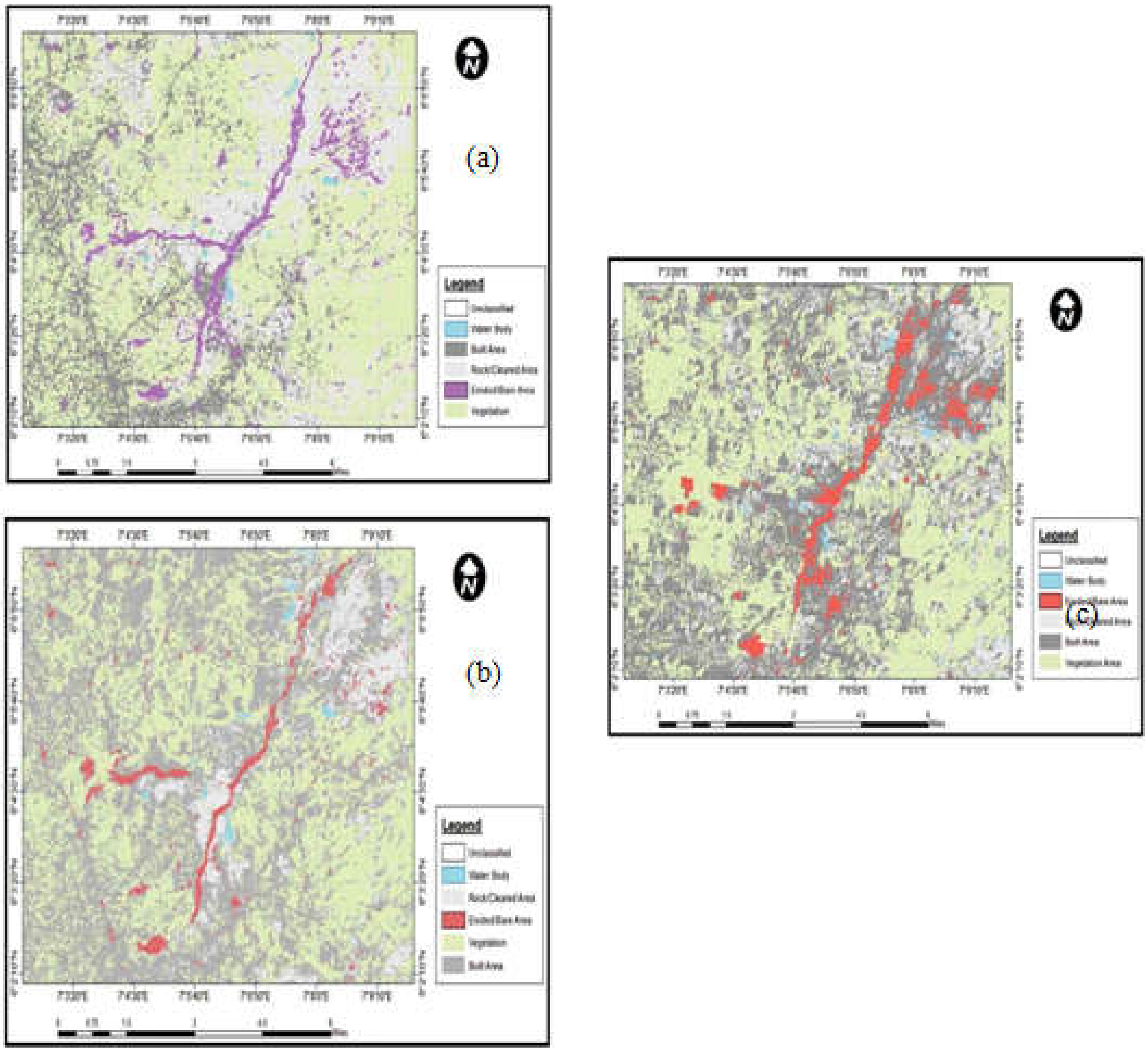

Figure 3. LULC Change of Agulu-Nanka and its Environs (a) 1986 (b) 2000 (c) 2013

LULC Attributes	User Accuracy (%)			Producer Accuracy (%)		
	1986	2000	2013	1986	2000	2013
Built Area	100.0	99.94	90.1	99.99	100.0	100.0
Rock/Cleared Area	100.0	100.0	100.0	100.0	100.0	100.0
Eroded/Bare Soil	100.0	98.38	100.0	100.0	99.99	100.0
Vegetation	92.75	99.65	95.66	100.0	100.0	100.0
Water Body	100.0	98.33	99.85	100.0	99.99	100.0
Overall Classification Accuracy (%)	98.55	99.26	97.12	99.998	99.996	100.0

This result indicates increase in Urbanization, socioeconomic activities, modernization. Vegetation land cover shows 40.1% of the study area which indicates continual action of deforestation by man. Eroded/Bare soil land cover shows 2.87% of the total land mass of the study area. This result was due to mitigation measures applied by man in the study area. Rock/Cleared Area land cover shows 8.97% of the study. This result indicates a reduction in mans action like destruction/clearing of bushes for developmental projects and other activities and Water body covered 0.6% of the study which implies an increase in the presence of rivers, streams lakes and variation in climatic conditions of the area. Land use and land cover of 2013 which shows that Vegetation land cover shows 41.1% of the study.

This result indicates the realization or consciousness in man of the impact of deforestation and other actions on the study area. Built Area land cover shows 40.5% of the study which signifiers a reduction in development and urbanization in the study. Rock/Cleared land cover shows 13.6% of the study. This result indicates a decrease in mans actions that exposes the earth surface like bush burning, excavation, clearing of vegetation, in the study area. Eroded/Bare soil land cover shows 3.9% of the study. This result indicates a little increase in eroded areas and bare soil due to reduction in preventive action by man in the study area. The last attributes is Water body which covers 0.8% of the study which significantly shows the increase in rivers, lakes and streams in the study area.

Trend and Rate of Change in Land use and Land cover

The rate of change in Land use and Land cover for the study area and for the periods 1986-2000 and 2000-2013 as shown in the table was calculated using the following formula:

$\%\Delta\text{rate} = ((A - B))/B$

Where:

%Δrate= Percentage Change rate
A = Recent area Land use and Landover in km^2
B = Previous area of land use and land cover in km^2
While the annual rate of change = Observed Area of change/number of study

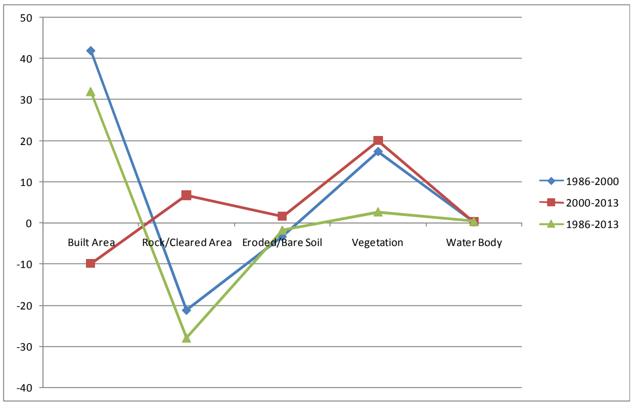

Figure 4. Trend and Rate of Change in LULC change

The trend in rate of change of land use/land covers of 1986 to 2013. Rock/Cleared area land cover (Figure 4) shows negative change and positive change, negative change implies low exposed surface to erosion (1986-2000) and positive change signifiers' high exposed surface to erosion (2000-2013). The built area showed positive change indicating decrease in human activities (1986-2000) and negative indicates increase in activities like urbanization, constructions, and buildings. Also there is a negative and positive change in eroded/bare soil, negative change shows the highest period of erosion (1986-2000) while 2000-2013 witnessed low rate of eroded area as a result of some trees, channelization of water, awareness or sensitization of the inhabitance, building of embankments.

Drainage Pattern of Agulu - Nanka and its Environs

In the study, 30m spatial resolution DEM and filled DEM (Figure 4a), it is observed that drainage resulting from rainfall originates from the southwest part of the state towards the northeast. This was evident in the distributed capillaries which previous studies such as (Lindsay, 2013) attributed divergent flow on hill slopes and convergent flows in lower areas. This proves that a natural drainage pattern of Anambra exists. A flow direction analysis of the filled DEM as showing (Figure 4a) further confirmed this drainage pattern. Further analysis of the drainage network delineation using flow accumulation highlighted the existence of the natural drainage pattern in the study area. The resulting drainage pattern from the flow accumulation of the contributing area is depicted in (Figure 4c).It also shows that drainage originates from the finest parts of the slopes. Drainage networks are not very stable (Williams, 2011) resulting in critical contributing areas in certain areas. The realistic drainage network generated shows clearly that water drains from the drainage channels in blue to the main drainage channels in red which empty into the surrounding water bodies. Also the flow accumulation is a divergent flow as a result of the runoff areas.

Classification accuracy

The accuracy assessment created from the supervised classification of the MLC uncovered overall accuracy for Kappa coefficient of 0.99, which demonstrates a good greement between thematic maps produced from processed satellite image and the reference data. This amount of agreement is generally considered a good statistical return. This shows that 98.55%, 99.6% and 99.50% of the land use and land cover classes are correctly classified in the years 1986, 2000, and 2013 respectively.

DISCUSSION

The changes in the spatial extent of the land use identified in Agulu-Nanka and its environs between 1986 and 2013. It is revealed that vegetation reduced from 51.9% in 1986 to 41.1% in 2013. This reduction must have increased the spatial extent of gully erosion in the area because deforestation supports increase in runoff which can eventually increase rate of soil erosion as seen in (Table 2, and Table 3) respectively. However, vegetation acts in a variety of ways by intercepting raindrops through encouraging greater infiltration of water and through increasing surface soil organic matter and thereby reducing soil erodibility (Stocking, 1987). This result indicates that man's actions might have increased in the environment through deforestation, construction and urbanization which might have resulted to the increase weathered areas. Built area land cover increased from 18.7% in 1986 to 47.3% in 2000 and decreased to 40.5% in 2013. There was no pattern in the spatial coverage by the built up area and this shows that at a particular time increase in population may bring about a tremendous increase in built area and decrease again due to man's awareness of the impact of urbanization and low developmental projects. Eroded/Bare area land cover witnessed a decrease from 5.2% in1986 to 2.87% in 2000 and increase from 2.87% in 2000 to 3.9% in 2013. This result indicates that man's awareness to preserve the environment by applying mitigation and preventive measures especially in the areas prone to erosion might be encouraging. Meanwhile, some mitigation measures to reduce erosion were put in place by governments in Agulu-Nanka which included planting of trees. The trend in the rate of change of land use/land cover of 1986 to 2013 reveals that rock/cleared area land cover reduced between 1986 and 2000 while it increased between 2000 and 2013 as seen in Table 3 respectively.

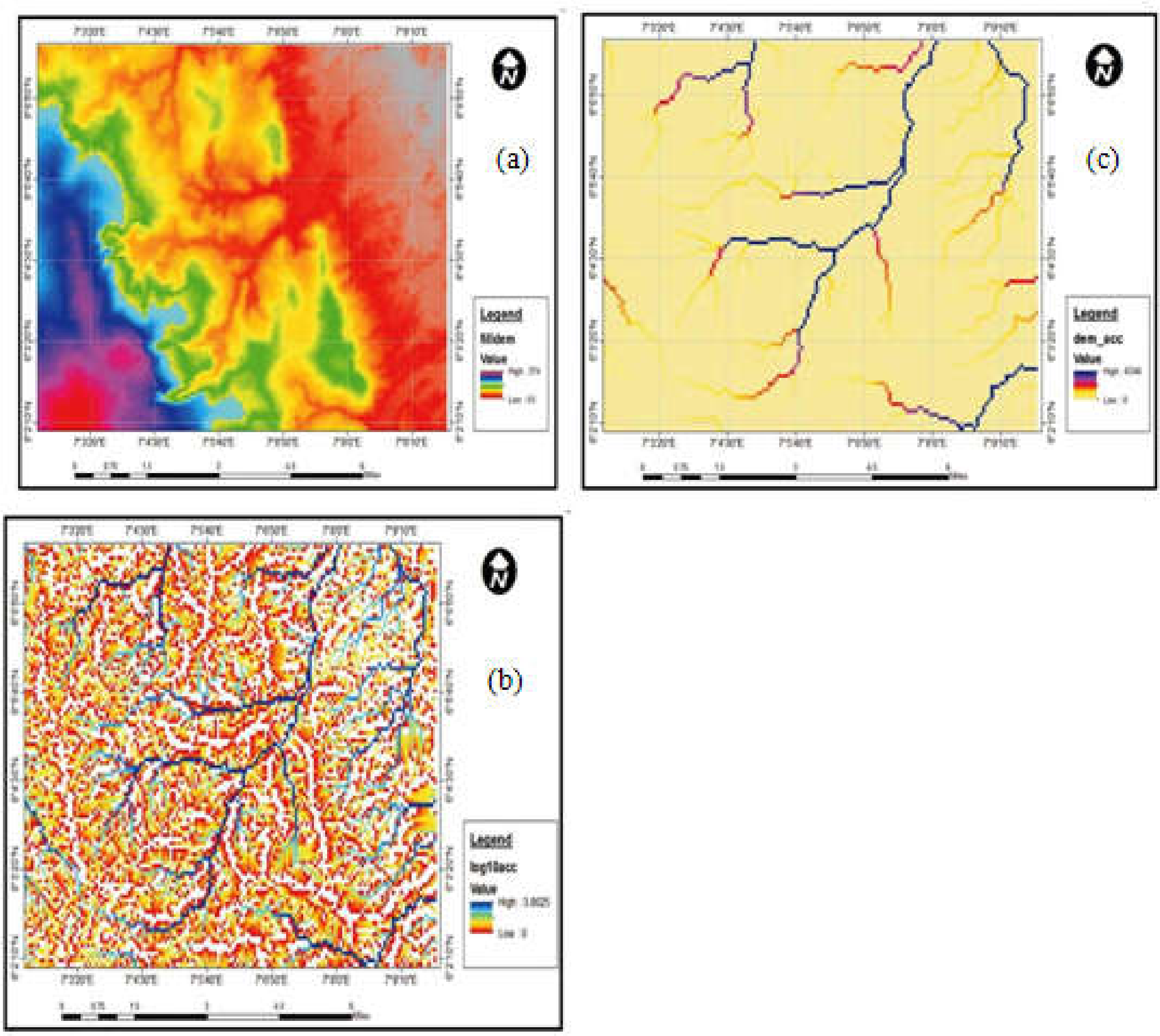

Figure 5. Map showing (a) Digital Elevation Model (b) Flow Accumulation (c) Drainage pattern of Agulu-Nanka and its environs

Similarly, the built area showed positive change between 1986 and 2000 while between 2000 and 2013, the built up area decreased. The decrease shows that human activities might have been restricted by gully erosion in Agulu-Nanka. Eroded area decreased between 1986 and 2000 but an increase was observed between 2000 and 2013. The decrease might be related to some measures adopted during that period which included trees planting, channelization of water, awareness or sensitization of the inhabitance and building of embankments while the increase may be due to climatic and edaphic factors which may not be easily controlled by man. Findings from (table 2) also showed that the impacts of gully erosion on the land use type varied between 1986 and 2013. Gully erosion captured 62.38% in vegetation land use in between 1986 and 2000 while 38.46% was captured between 2000 and 2013. The reduction in the capture may be due to mans actions like deforestation, lumbering, bush burning might have been controlled due to man's consciousness and awareness of the environment. Similarly, the spatial extent captured in built up area and water bodies also reduced with time. The reduction in built up may also be linked with the awareness of the environment as regards gully erosion. The impacts of gully erosion on the cleared area showed an increase from 8.66% to 31.48% within the periods of 1986-2000 and 2000-2013 respectively. The reason may be due to shortage of vegetation which may reduce the rate of runoff.

As clear lands increases, there is tendency for erosion to increase. More so, it shows that the encroachment into the high forest is increasing in the study area due to urbanization. Also in (Figure 3b) Digital Elevation Model showed that the directional flow of water in Agulu-Nanka is from southwest to northeast as a result of undulating nature of the area and (Figure 4c) show the drainage pattern as dentritic (multi flow direction). This study has assessed gully erosion in Agulu-Nanka and its environs of Anambra State, Nigeria. The result indicates that there was a significant increase and decrease in trend in rock/cleared area, built area and eroded/bare soil. Also water body indicates increase while vegetation or forest indicates decrease. The causes of changes in erosion assessment of Agulu-Nanka and its environs are mainly anthropogenic and natural phenomenon and mitigation activities on going for instance self help projects, embankments, drainage channels, awareness, resettlements, planting of trees.

Conclusion

The assessment of gully erosion in Agulu-Nanka and its environs using geo-information technologies is a difficult task to perform accurately. The erosion changes shown in this study may not provide the ultimate explanation for all problems related to erosion changes, but will serve as a base line to understand the spatial pattern of changes in the study area. This research made use of geo-information technologies to analyze the rate of changes of the spatial extent of gullies in Orumba West and Anoacha LGA between 1986 and 2013. The classification achieved in this study produced an overall accuracy level that fulfils the minimum accuracy. Furthermore, this study will go a long way on raising awareness on the need to use geo-information technology in assessing erosion prone areas and other research work. Gully erosion is a complex and relatively frequent process. The genesis and development of the process is sometimes related to human activities. Negative consequences are well-known including those affecting flow and those happening in depositional areas. In spite of this, some aspects of the process are still unknown, mainly, the consequences of future climate fluctuations.

Recommendation

To address the issue of gully erosion assessment in Agulu-Nanka and its environment using Geo-spatial technology, the following recommendations are made:-

- Gully information data base should be created to enhance future analysis.
- The government should make fund available each year to reduce and combat the challenges resulting from effect of the gully erosion.
- Structure and non structural measures of mitigation should be implemented.
- Government, nongovernmental organizations, co-operate organizations, federal emergency relief agency and spirited individuals should get closer to the affected settings and assist the victims.
- There should be regular and improvement in the resolution of dataset that will be used as Light Detection and Range (LIDAR) and Remote Sensing application should be adopted.
- Researchers and Institutions should predict and prevent the consequences of climatic transformations in land use and gullying process.

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