TOPOGRAPHIC MODEL ANALYSIS AS A TOOL FOR SUSTAINABLE LAND INVENTORY AND MANAGEMENT

Keyword; Topographic Model, Sustainable development, land inventory, Management, etc.

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EXECUTIVE SUMMARY

Achieving sustainable development in Sub-Sahara Africa depends largely on the prudent utilization of land resources. Topographic modelling analysis is very important process through which we can minimize the adverse anthropogenic effect on the environment, its ecology and landscape. Land, which is one of the most useful natural resources is shrinking day- by- day due, to unending demand for it. These include, industrialization, urbanization, haphazard waste and infrastructural facilities, needed for uncontrolled and unchecked population growth. This paper is aimed at using Earths Satellite observational dataset to map and analyse the topographic nature of Old Aba Metropolis, Abia state Nigeria. Sentinel-2 Satellite imagery (10m resolution), SRTM (Resolution 30 arc seconds) and Tersus GNSS Rover data were entered into ArcGIS software for analysis, manipulation and extraction of the terrain features for the project area and inventory management. The data so extracted was used for digital terrain model, aspect, slope, contour, 3D model, land used /land cover, road network maping of the study area. These digital dataset/infrastructural are vital for good understanding of the topographic nature of Old Aba metropolis, Abia state, Nigeria, for efficient land use/land cover planning and policy making. The results show that Old Aba metropolis Abia state Nigeria, has a nearly flat surface terrain and bird-view shape which make it possible to have a good gradient for drainage network Planning, development and sustainable engineering construction. This paper concentrates on concept, definitions, datasets, modelling techniques/algorithms, classifications of land use/ land cover of the study area to generate current statistics or land resource inventory management.

1.0 INTRODUCTION

Topographic modelling (analysis) and land use inventory management algorithm are two important tools for promoting sustainable development. Topographic modelling is the process of creating digital representations of the terrain, including its elevation, slope, aspect, and other physical features. This information is then used to support decision making in different areas such as environmental protection, urban planning, and infrastructure development. Land use management involves the planning and regulation of the use of land in a particular area. When use together, topographic modelling analysis and land use management algorithm can provide a comprehensive understanding of the physical and social characteristics of a region, which can help to support sustainable development of the study area. Therefore, understanding the configuration of its topography is essential for proper management and prudent utilization of the natural resources on or beneath the earth. Analysing the physical structure of our environment at a particular time helps to improve safety and well-being of the populace.

Old Aba metropolis is a low-lying land that is almost a flat terrain. This condition predisposes it to flooding during the raining season. Thus, Absence of proper topographic model leading to a poorly developed inadequate channel/water drainage network had cause flooding within the study area. Also, lack of up-to-date topographic maps of the study area makes it difficult for planners, land use managers, to properly utilize the available land space.

Despite the importance of topographic modelling analysis and land use management in promoting sustainable development, there is need for a comprehensive evaluation of the effectiveness of these tools. This is particularly important in light of the rapid pace of development and increasing pressure on the environment, which makes it increasingly important to promote sustainable development practices.

This study is trying to evaluate the effectiveness of topographic modelling (analysis) and the resultant land use management data in promoting sustainable development. The study investigates the place of topographic modelling in identifying areas of high ecological value and also assessing the potential impacts of development projects on the environment, as well as the use of land use data in promoting compact, sustainable development patterns and minimizing the negative impacts of development on the environment.

1.1 RESEARCH MOTIVATION

In contemporary times, the use of Remote sensing and Geographic Information systems (GIS) techniques have become the state-of-the-art innovation in map making. GIS is an innovative technology beginning with automated modelling of landscape captured by cameras, digitizers, and scanners (Ajami et al. 2016). Calogero Schillaci (2015) argued that Geographic Information Systems (GIS) allowed the detailed analysis of land surface, whereas the development in Remote Sensing (RS) offered increasingly detailed Digital Elevation Models (DEMs) and multispectral imagery. Remote sensing datasets in combination with GIS have increased the confidence ascribed to outputs in the field of terrain and other environmental analyses. Sandeep et al. 2013 noted that researchers use GIS and DEM for increasing the quality of landform mapping because it includes 3-D relief features and elevation information. Geospatial researchers have used terrain analysis for visualization of the land surface features. These include drainage pattern, land use, Landforms, etc. The power of visualization cannot be omitted in spatial pattern assessment and this merit is one of the fundamental characters of GIS. Owais et al. (2019), reported that Spatial information pattern assessment and visualization are some of the fundamental characters of GIS.

According to J. Smith,2002, B. Johntual (2007), M. Davis (2008), Brown (2010), S.Chen (2011) etc, topographic modelling and land use management analysis tools reveal that topographic features such as slope, aspect, elevation, etc play a crucial role in shaping land use patterns and can impact the usability of land resources and ecosystems. Therefore, Remote sensing platforms or derivatives such as satellite imagery and aerial photography can be used to create accurate land use maps and detect changes on landscape over time.

1.2 DESCRIPTION OF THE STUDY AREA

The study area is old Aba, metropolis Abia state Nigeria, that comprises of Osisioma-Ngwa, Isiala-Ngwa North L.GA, Isiala-Ngwa South L.G.A, Obingwa L.G.A, Aba South L.G.A, Aba North L.G.A, Ukwa East L.G.A, Ukwa West L.G.A, and Ugwunabgo L.G.A with a total land mass of 1,116km^2.

Aba is a low-lying coastal state in south-Eastern Nigeria located between longitudes 5°07'00N-5°15'41''E and latitudes 7°22'00''N - 7°25'10''N. The state has a relatively flat terrain with negligible terrain undulations. Aba is bounded in the north and east by Umuahia town, the Abia state Capital. Akwa Ibom state, in the west by the Imo State and in the south by the Rivers state. About 70% of Aba metropolis total land area is flat. Aba is the major commercial city of Abia state and the commercial hub of the state, eastern geopolitical zone. It has a population of 2,534,265 (NPC2016).

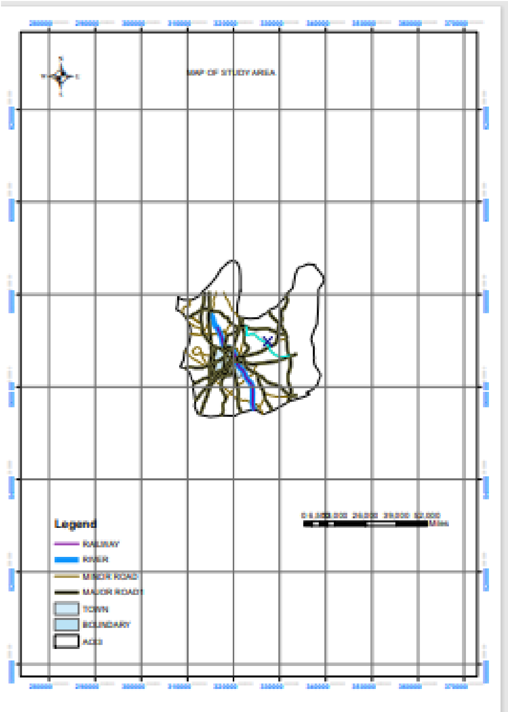

Fig 1.0 Map showing the study Area. (Source. Okezie et al. 2023)

2.0 MATERIAL AND METHODS

The data use in this study includes Schulte Radar Topographic Mission (SRTM) with 30m resolution, The data was used to generate topographic feature, such as contour lines, aspect, slope, flow accumulation. Google earth elevation dataset (20239) was extracted and converted into X, Y, Z dataset and used to create the digital elevation model 3-D wireframe, 3-D surface, and flow direction vector, Sentinel 2 satellites image with 10m resolution were used for the land use land cover map of the study area. This was obtained from Earthexplora USGS website. The data were download and processes using ArcGIS 10.5 version. The areas of interest (AOI) were extracted from the shapefile of the administrative Map of Abia state, obtained from the ministry of land survey and urban planning. Software used includes, ARCGIS 10.5, surfer 11, Microsoft excel and GPS visualizer. These software suites used for topographic analysis, terrain analysis and various features extraction and manipulation exercises, respectively in the GIS environment.

2.1 TOPOGRAPHIC ANALYSIS MODEL

To analyse the topographic configuration of the study area, the SRTM raster file was added to ARGIS 10.5 software progressively. The dataset was manipulated using spatial analysis tool. From the spatial analysis tool, contour lines, aspects, flow accumulations, slopes and digital terrain model were created. The google earth data were converted to GPS dataset visualizer which is an online utility that creates maps and profiles. From geographic data. The GPS dataset were converted to X, Y, Z dataset and have exported to surfer-11 software data worksheet where DAT file was created and gridded. The data was grided using kriging interpolation, method. The grided data was subsequently processed to create wireframe and elevation profile. This topographical dataset is very important to understand the configuration of the study area for decision making and landscape planning.

2.2 HYDROLOGICAL NETWORK ANALYSIS

Hydrological features are physical characteristics of a watershed or river basin that are important for understanding the movement and storage of water. These features were extracted using ArcMap 10.5 version from sentinel 2 image which provide valuable information for managing water resources, predicting floods, droughts, and understanding the impacts of land use and climate change on water availability. The major River within the study area is Aba bule River which passes through the centre of Aba metropolis and all the major tributaries were extracted from sentinel-2 imagery while other networks were also extracted from the SRTM dataset. The DTM dataset were Imported into ArcMap software, Using the "Add Data" button to import the DTM and stream network data into ArcMap. The data were later Pre-processed and the hydrological data needed was checked to ensure that it is in the correct format and projection for image analysis in ArcMap. These involved converting the data to a specific file format or projection, such as the UTM projection, etc. Progressively, we Used the "Fill" tool to fill sinks in the DTM, and then use the "Flow Direction" and "Flow Accumulation" tools to generate flow direction and accumulation grids. These grids were used to calculate other hydrological features. The hydrological analysis tools in

ArcMap10.5 software was use to extract the desired hydrologic cycle or flow network of the study area (fig 1.6).

2.3 LAND USED /LAND COVER (LULC) ANALYSIS

A land use/land cover (LULC) map is a thematic map that represents the different types of land use and land cover in a particular area. It shows the distribution and extent of various land uses such as agriculture, urban areas, forest, water bodies, wetlands, barren land, and other types of land cover in a specific region. By understanding the distribution and extent of various land use/land cover types in a region, policy makers and planners can make informed decisions about how to allocate resources and manage the landscape for different purposes. In other to create the land used /land cover of the study area, the sentinel 2 image with 10m resolution were downloaded from Earthexplora USGS website. Progressively, the dataset was added into ArcMap environment and the area of interest (AOI)was also displayed. Shapefile was added. The Maximum Likelihood (MLH) method was adopted as the classification algorithm, and a total of 20 trained samples were used for each classification. The land use/ land cover themes were bare land, vegetation. Built-up areas and water bodies.

3.0 RESULTS AND ANALYSIS OF DATA

The results obtained showed that the configuration of the landscape and undulation nature of the study area from figure 1-figure to 9, using contour, aspect, digital terrain model, hill shade, slope, land use / land cover and 3D wireframe. These digital derivatives are vital for good understanding, policy making and management of the physical environmental of the area under investigation.

3.1 CONTOUR MAP OF THE STUDY AREA

The results in Figure 1.1 depict the topography of the study area with reference to height and relief. The northern part showed high spatial cluster in the density of contour lines and generally represents the upland while the southern part and the central area represents loa cluster the low cluster density,

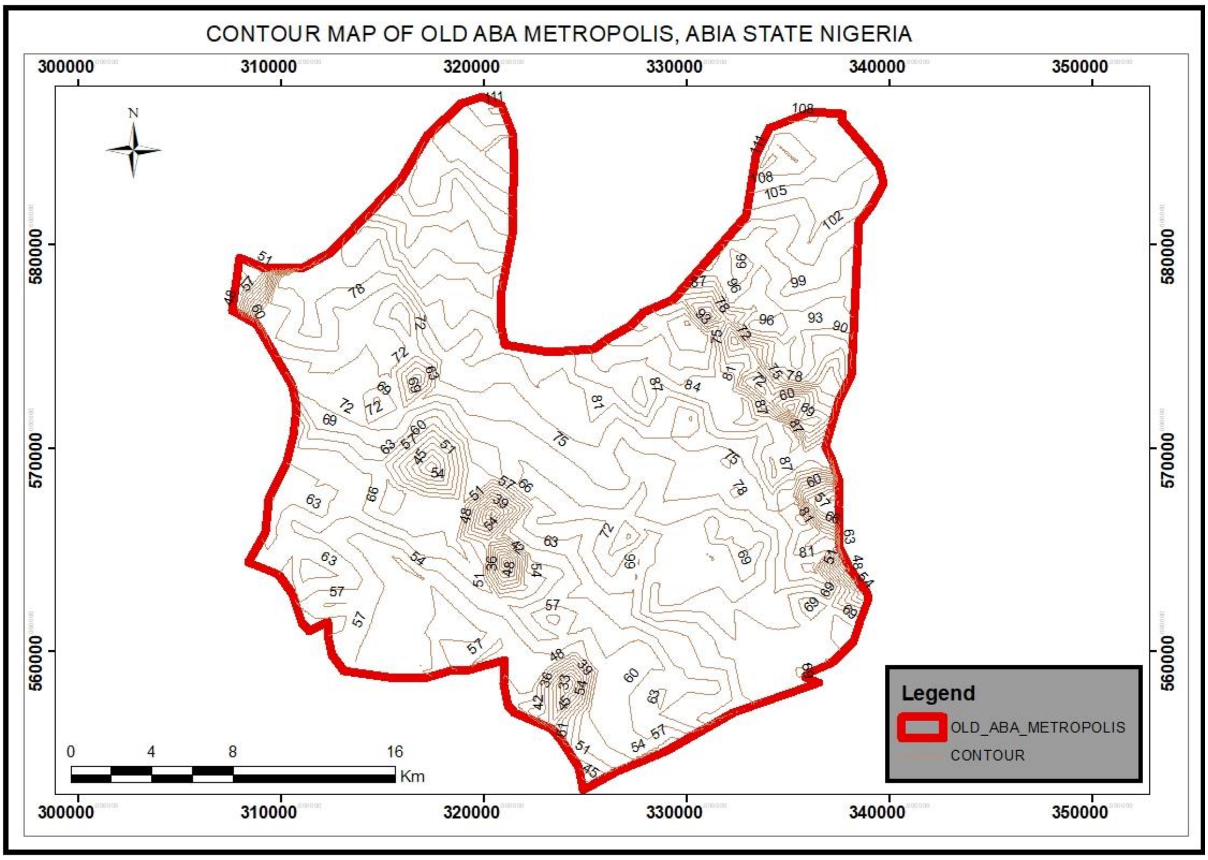

Fig 1.1 contour map of the old Aba Metropolis. (Source. Okezie et al. 2023)

3.2 DIGITAL TERRAIN ANALYSIS (DTM).

The digital terrain model uses colour variation to show elevation differences. Each cell within the DTM, when proper manipulated, has an exclusive colour which signifies a unique symbol representing the height within the cell. These heights, within the cells correspond to the positions they occupied in space. This approach of terrain analysis is currently gaining popularity due to its unique characteristics of assigning unique colour representing elevation value to every pixel or cell. Figure 1.2 shows the digital terrain model of the study area. A careful investigation shows that the study area is situated within elevation range of 10 m to 110 m above mean sea level (MLS).

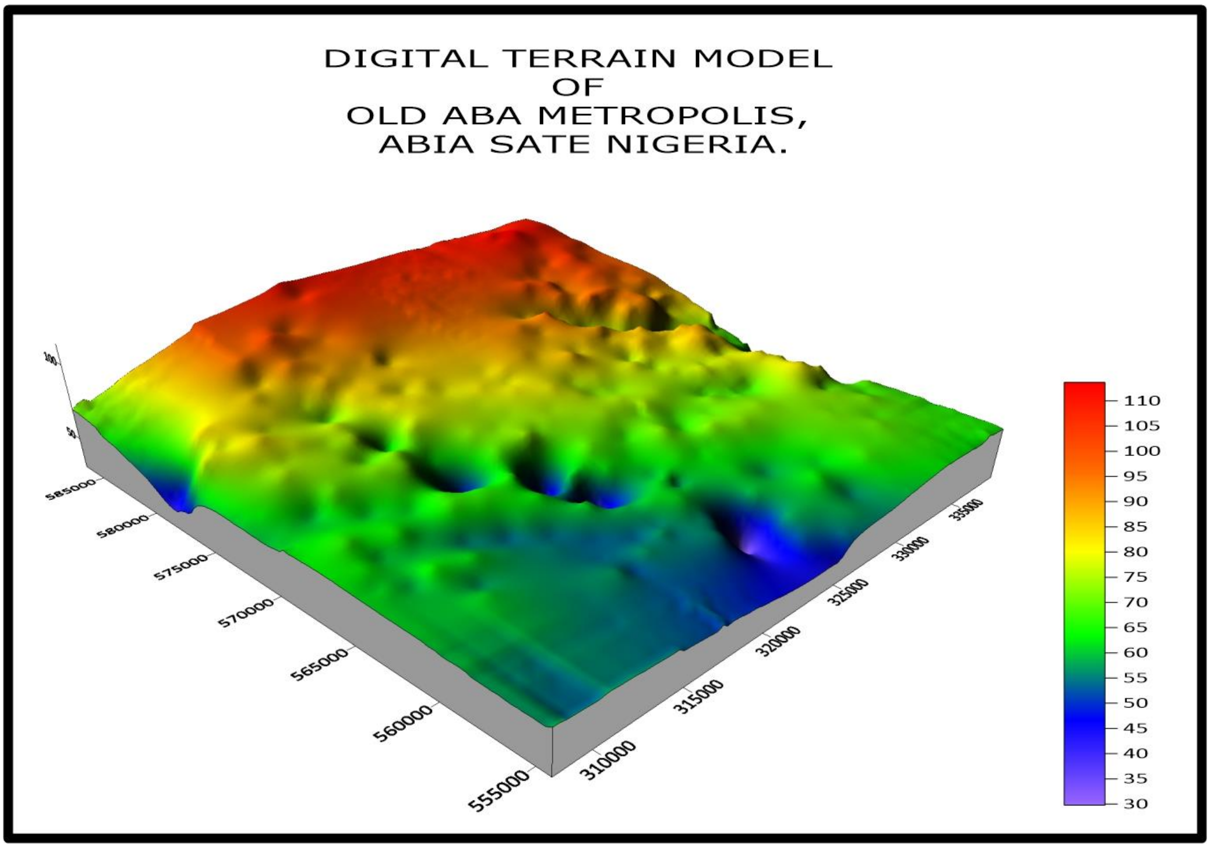

Fig 1.2 Digital terrain model of old Aba Metropolis. (Source. Okezie etal. 2023)

3.3 SLOPE AND ASPECT

Figure 1.7 shows the slope of the study area, the maximum point is above 100 m while the lowest point shows zero (0) value which points to total flatness. Slope at a point is calculated as the ramp of the plane formed by the vector connecting the left and right path and the vector connecting the upper and lower neighbours of the pixel (rise). The degree of steepness or the value of surface structure inclination is displayed by the slope of that area. The slope values in an elevation grid of an area range from 00mm that is flat surface to 900mm that is perfect vertical slope. However, Aspect (Figure 1.3) depicts the slope direction and is measured clockwise from 0˚ to 360˚. It shows the direction of surface water flow. The aspect and slope are invaluable tools for erosion and flood modelling. They can also be applied in advance topographical modelling such as estimating the portion of land that will receive high and low solar illumination for agricultural research purposes (John P. Wilson 2022).

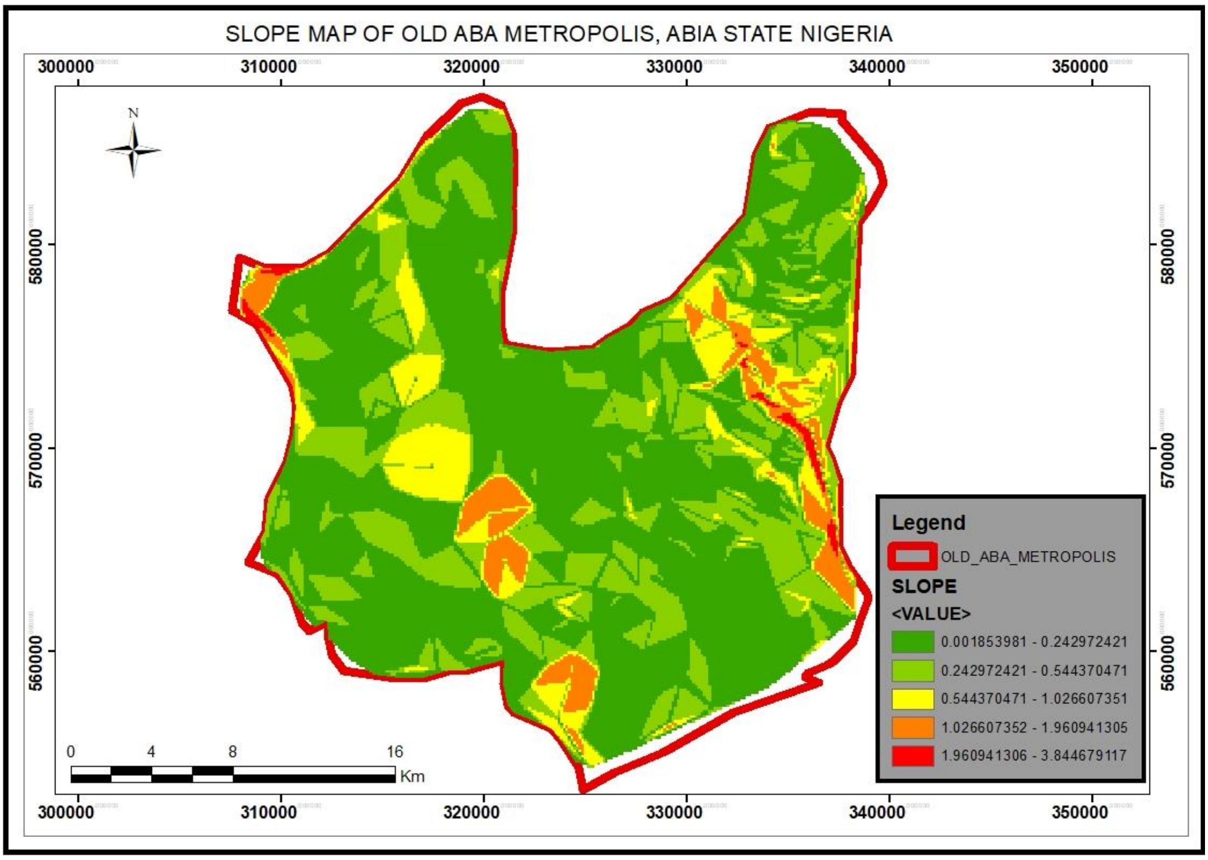

Fig 1.3 Slope map of old Aba Metropolis. (Source. Okezie etal. 2023)

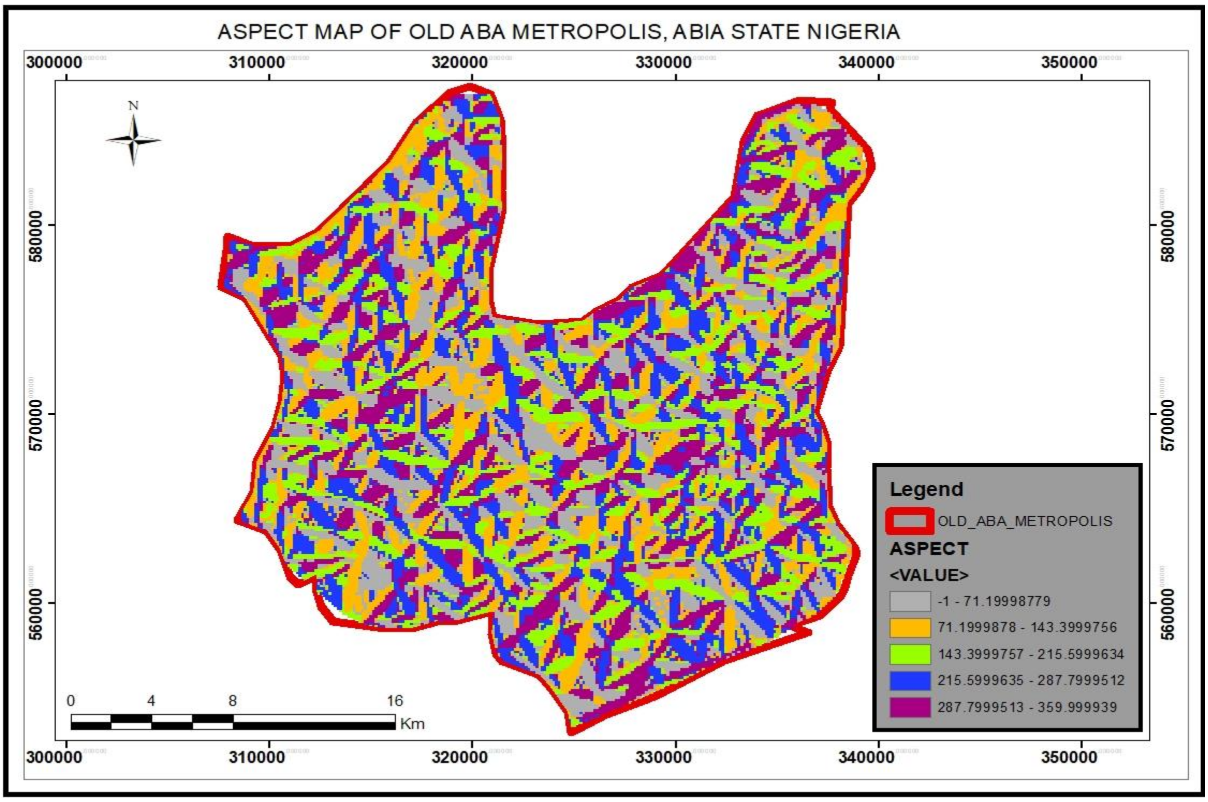

Fig 1.4 aspect map of old Aba Metropolis. (Source. Okezie et al. 2023)

3.4 HILLSHADE MAP

Hill shade is a commonly used technique in cartography and geospatial analysis to create a three-dimensional representation of terrain. It is a way of representing the varying topography of a landscape through the use of shadows and highlights. Essentially, hill shade creates the effect of sunlight shining on a landscape, highlighting the peaks and ridges and casting shadows in the valleys and depressions. The hill shade procedure involves using digital elevation data, such as a digital terrain model (DTM) or a digital elevation model (DEM), to calculate the slope and aspect of each point on the terrain. The slope is the steepness of the terrain at that point, while the aspect is the direction that the terrain is facing. By combining this information with a hypothetical light source, the technique simulates the way that light would interact with the terrain, creating a realistic representation of the landscape which give the planners and developers insight in taking good decisions.

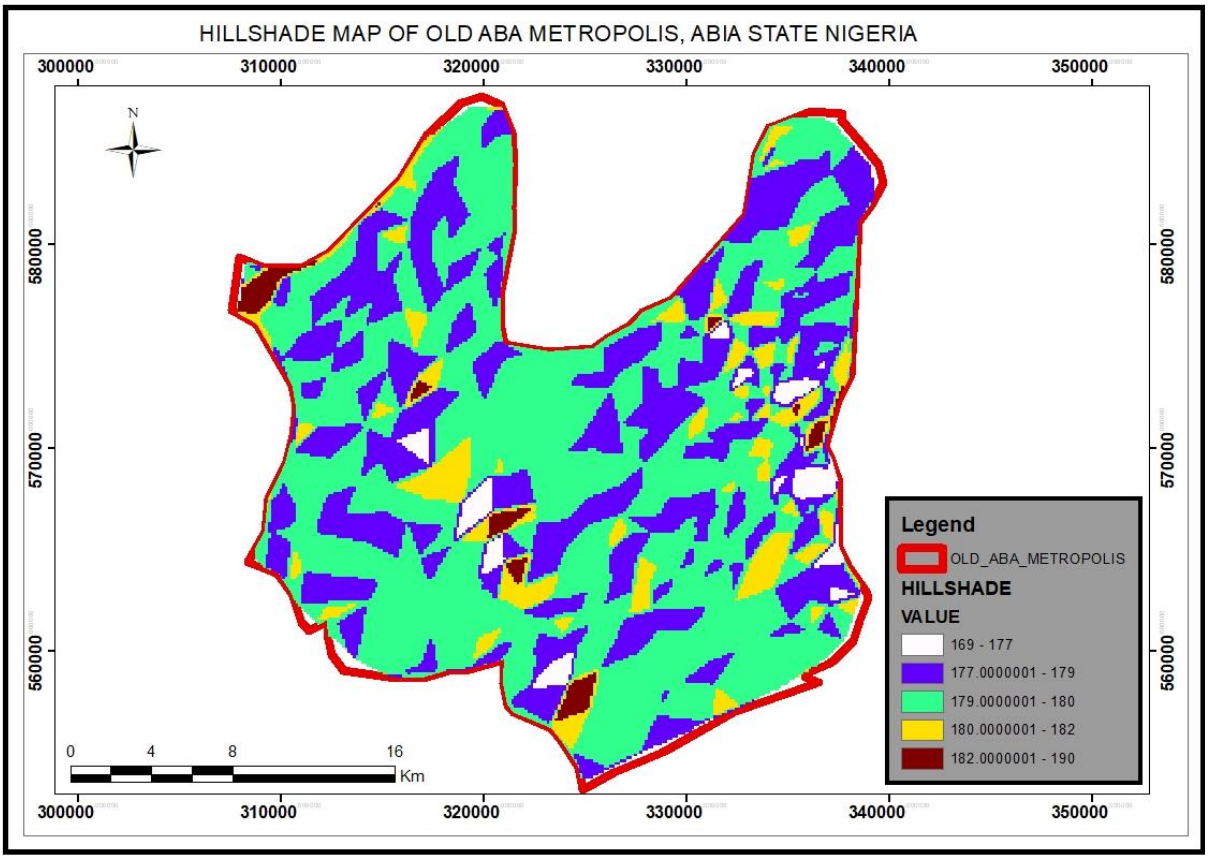

Fig 1.5 Hill shade map of old Aba Metropolis. (Source. Okezie et al. 2023)

3.5 STREAM NETWORK ANALYSIS

The result reveals that there is a number of streams within old Aba metropolis and all of them are connected to Aba blue River (water side). This is good indication that the topographic nature of the study area slopes down to Aba Rive and it shows that storm water and runoff water cannot retain on the surface, that every drainage system should be link to water side, Also the flow accumulation points toward the deepest path of the river.

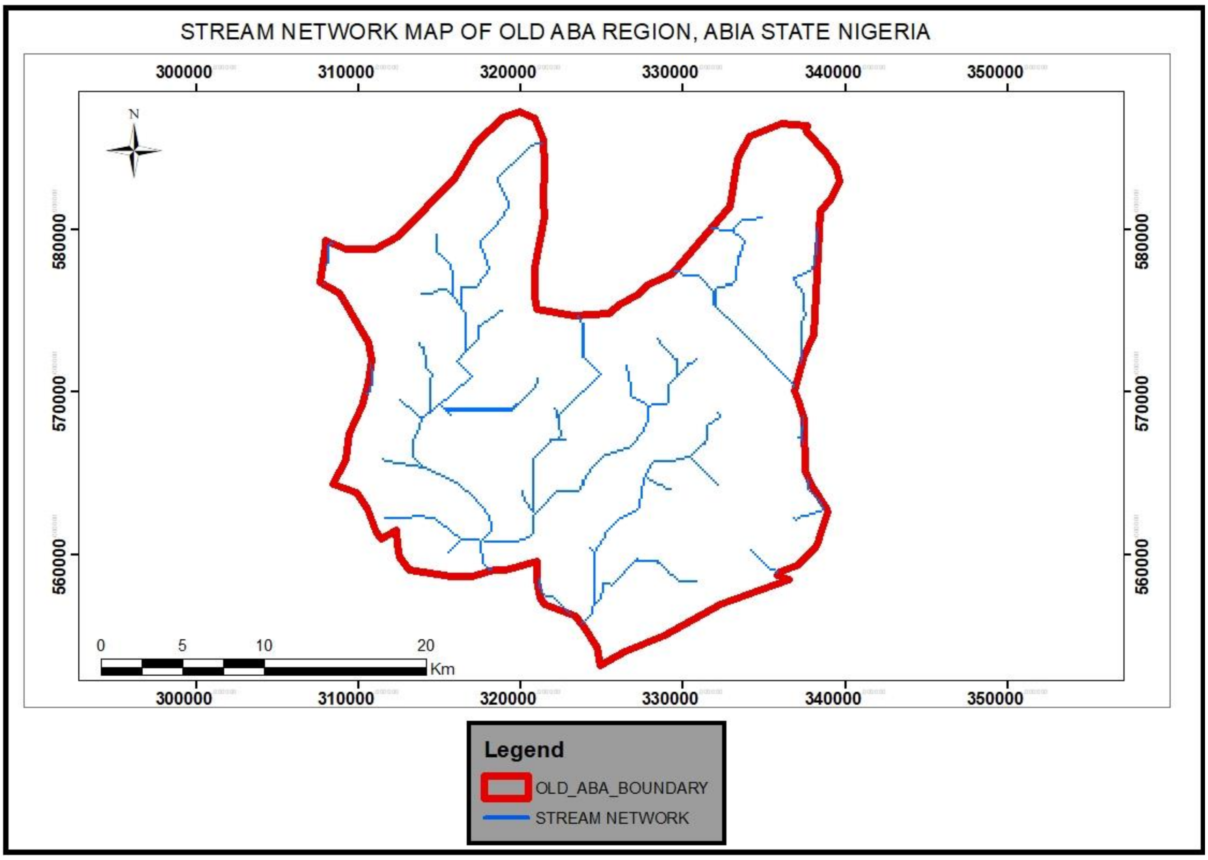

Fig 1.6 Stream network map of the study area. (Source. Okezie etal. 2023)

3.6 LAND USE/LAND COVER ANALYSIS

Figure 1.7 revealed a total of four land use classes identified within the study area. These are Built up areas, vegetation areas, bare land and water bodies. Further analysis revealed that Built up areas covers 187.833 km2 (16%), vegetation areas cover 732.700 km2 (60%), bare land covers 241.411sqkms (20%), water bodies cover 43.658km2. (4%). These quantitative attributes are shown in Table 1. A cursory examination revealed that Aba metropolis which is the economic nerve of the state is located close to Aba River and this shows that the topographer gradually slopes down and form a gutter shape at the centre. The result also reveals that there is enough uncultivated land which gives room for further development, if properly manage and utilize it will bring for economic prosperity thereby provide opportunity for sustainable development.

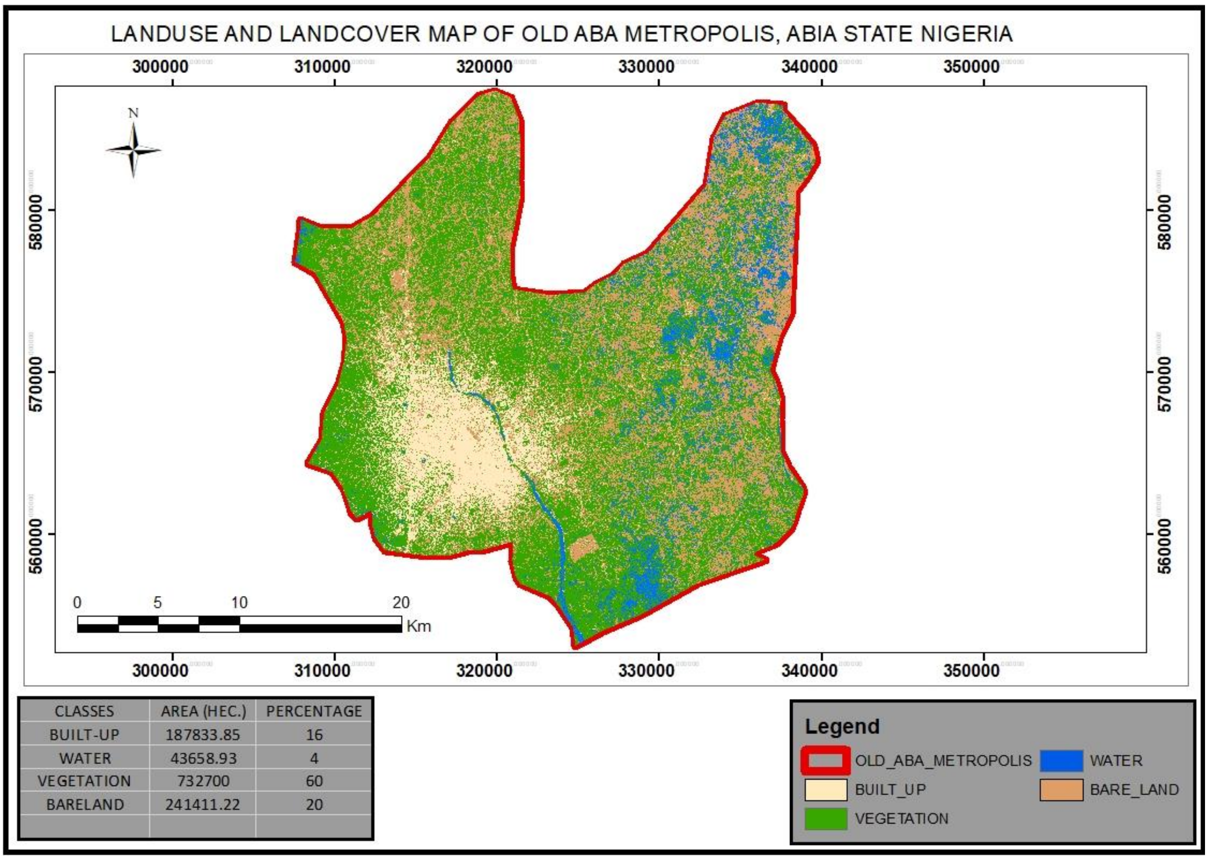

Fig 1.7 land use land cover of old Aba Metropolis. (Source. Okezie et al. 2023)

Table 1 shows land use land cover analysis of old Aba Metropolis

Land use /Land cover classes	Areas (Hectares)	Percentage
Built-up areas	187833.850	16
Water bodies	43658.931	4
Vegetation	732700.080	60
Bare land	241411.220	20

(Source. Okezie et al. 2023)

4.1 SUMMARY

Topographic modelling analysis and land use management algorithms are two important tools for promoting sustainable development and this is fundamental for good selfless and management of the physical milieu. It is needed for proper terrain analysis investigation and improved safety terrain features and usage. In the past environmental analysis relied heavily on analogue methods for modelling and analysis of the topography and this approach can no longer satisfy the modern-day planning needs. Based on this, robust method that produces reliable result must be adopted to ensure that the right decision is made during planning. The use of earth observation system (EOS) technology, Remote Sensing (RS) and GIS platforms have become an integrated, well developed and dependable method in terrain analysis. The result of this study revealed the various and multi-dimensional proficiencies of integrating remote sensing data and GIS in terrain modelling and analysis. The dynamic procedure developed in the study being indication by the efficacy of the results. This can be seen in the series of thematic maps produced, which establish a geospatial database for informed decision making. With this technique it was possible to map and analyse the landscape and other terrain features and recognise a suitable location for storm water deposit within the study area. This study is highly recommended for planning agencies and Institutions of government in prior construction work before approval are made for development of some areas for settlements.

4.2 CONCLUSION

Achieving sustainable development in sub-Sahara Africa depends largely on the prudent utilization of land resources. Topographic modelling is the process of creating digital representations of the terrain, including its elevation, slope, aspect, and other physical features. This information is then used to support decision making in areas such as environmental protection, urban planning, and infrastructure development. The use of earth observation system (EOS) Technology, Remote sensing and GIS platform has become an integrated, well developed and dependable method into topographical analysis. The result of this study revealed the various and multi-dimensional proficiencies of integrating remote sensing data and GIS in terrain modelling and analysis.

4.3 RECOMMENDATION

This work is recommended for those in the bult industry, planners, developers, policy makers and academia. It is also served as a contribution to the body of work in terrain modelling analysis and required further investigations in other to achieved substantiable development within Sub-Sharan Africa.

As a novel exercise, the gains of scientific study like this, cannot be over-emphasised, owing to the importance of land use/ Land cover study in the overall land inventory and planning for sustainability. It is necessary to recommend the incorporation of terrain analysis models of slope, aspect, DTM/DEM etc, for proper revelation of the character of the terrain or configuration the topography, which could hamper good planning and development. Therefor, it is of a primacies' importance, that planers and government agencies shall incorporate this geospatial study in land use/land cover inventories.

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