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Research Paper

Morphological Characterization of Anambra River Niger Basin in Nigeria

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ABSTRACT
*Good understanding of mophormetric attributes is inestimable in watershed management. It is invaluable for interpretation of topographical, hydrological and geological processes within a watershed.Despite the hydrological importance of Anambra river basin to the community, its morphometry and hydrology are not well known. This study aimed to characterize hydro-geomorphology of the basin through basin morphometry analysis. Basic terrain and hydrological parameters such as slope aspect, 3-D Land scape, flow direction,stream order, stream number, stream length, mean stream length, Bifurcation ratio, drainage density, stream frequency, circulatory ratio, form factor, elongation ratio etc, have been calculated by applying series of processing techniques on SRTM DEM data in GIS environment. The river basin is designated as 4th order basin, and 1st order streams are mostly dominating. Strahler's method of stream ordering adopted, revealed that the basins have one (1) four order streams, two (2) third order streams, eleven (11) second order streams and fortyone(41) first order streams. This study further recorded a drainage density of 0.1153 km^{-1}, stream frequency of 9.945*10^{-3}, bifurcation ratio of between 2 and 6, circulatory ratio of 0.489 with a value of 0.449 for the form factor. These values indicate that the basin is elongated less structural control Low discharge and erosion potential.*

KEY WORDS*; SRTM, Mophormetry, Watershed, Drainage, Hydrology*

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I. INTRODUCTION

Conservation of natural resources is of prime importance for sustainable development and to mitigate the demand and supply gap between resources(Sangeetha et.al 2019). In recent years, there has been a marked increase in the levelof interest towards watershed management for which we have to understand the morphology of the catchment for proper management of land and water resources therein. Watershed management is inestimable for conservation and management of resources within a river basin. Watershed management is the process of formulating and carrying out a course of action involving manipulation of the natural system of watershed to achieve specified objectives. It implies the proper use of all land and water resources of a watershed for optimum production with minimum hazard to natural resources (Amulya e tal 2018). Other terms use to refer to watershed are catchment areas and drainage basin.A drainagebasin is the developmental unit used to effectively manage resources sustainably. As per Chopra et'al (2005), It is a natural hydrological feature within which runoff is directed into collecting channels, streams, or rivers.María (2017) appraised that well-delineated drainage basin boundary is a critical factor in numerous natural resources studies such as flood assessment, water-usage, basin protection,preservation, planning, and resources management. Watershed Management is a method to protect and improve the quality of water and also control erosion in the catchment area in a broad manner. Morphometric characterization of the river basin is invaluable for its proper management. The study of the river basin morphometry analysis provides the useful parameter for the assessment of the groundwater potential, surface and groundwater resource management, runoff and geographic characteristics of the drainage system (Subhash2011).Morphometry is the measurementand mathematical analysis of the configuration of the earth's surface, shape, anddimension of its landforms(Clarke, 1996).Morphometric parameters define the topographical, geological and hydrological condition of a basin

(Angillieri 2012; Kabite and Gessesse 2018; Madavi2019). The study on drainage system morphometry enhances the understanding of landform formation, soil physical properties, erosion characteristics and runoff discharge (Ameri et al. 2018; Madavi 2019). Morphometric analysis is categorized into three major aspects. These are linear aspect , area aspect and relief aspect. Evaluation of morphometric parameters requires the analysis of various drainage parameters such as ordering of the various streams, measurement of basin area and perimeter, length of drainage channels, drainage density (Dd), bifurcation ratio (Rb), stream length ratio (RL), and relief ratio (Rh). Notwithstanding the numerous advantages of morphometric characterization to watershed management it has been rarely applied in the study area and this underscores the need for this study

1.1. Study Area

Anambra river Niger basin is located in south eastern part of Nigeria. Geographically it is located between latitudes 5°.40`N and 6°.50`N, then longitudes 6°.35`E and 7°.25`E and measures approximately 5530.Sqkm. The basin is rich in natural gas, crude oil, bauxite, and ceramics and has 100 percent arable soil. The most important hydro-geological features are River Niger and the confluence of river Niger and omambala river.

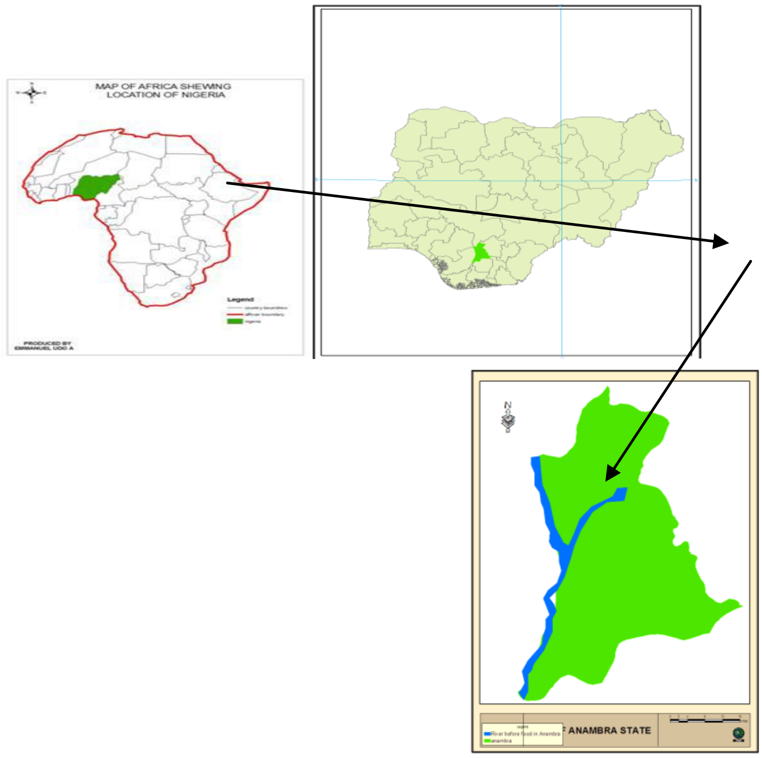


Fig1 Location map of the study area

II. MATERIALS AND METHODS

The Shuttle Radar Topography Mission (SRTM) DEM of one arc secondcovering the study area was acquired through the U.S.Geological Survey Earth Resources Observation and Science Center (EROS) http://earthexplorer.usgs.gov/. Data processingwas carried out as per the methodology shown in (Fig. 2).The ArcGIS 10.5(ArcMap 10.5) has been employed to extract the /watershed boundary,and other analysis. The tiles of the elevation raster (DEM) were mosaicked and the shape file of the study area was digitized from the administrative map of the study area.The digitized shape-file was used to clipped out the study area to the actual boundary limit. The hydrological, and surface extensions of the spatial analysis tool of ArcGIS 10.5 have been employed for hydrological and surface analysis. Progressively, the calculate geometry module was also used to calculate the stream length, stream number, watershed area etc.The Strahler's and Horton's method ofstream ordering has been utilized for streamall stream related calculations in the basins and Bifurcation ratio (Rb) was used todetermine the ratio number of stream segments of given order to the number of segments of the next higher order in the watershed.

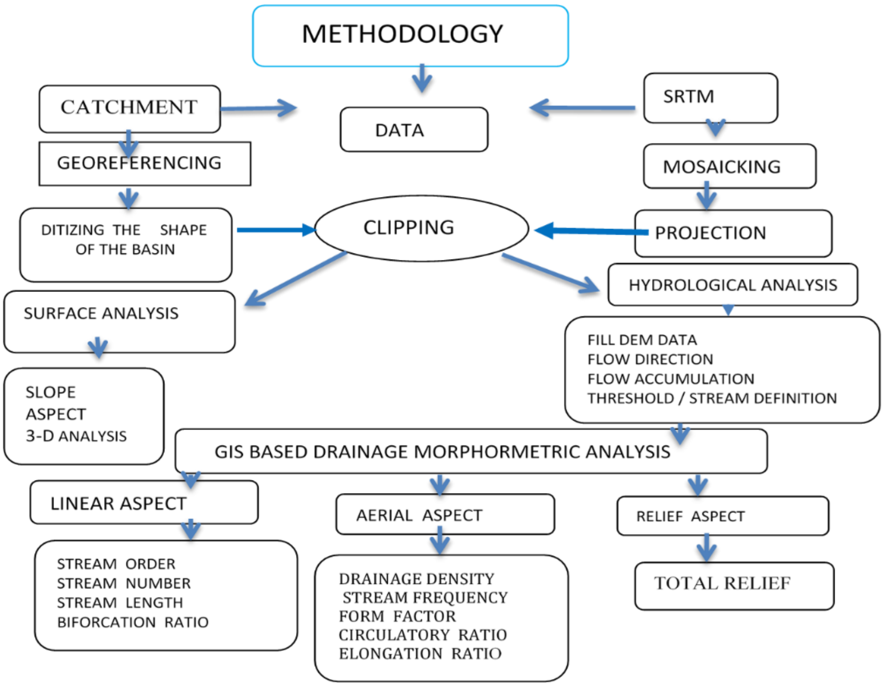
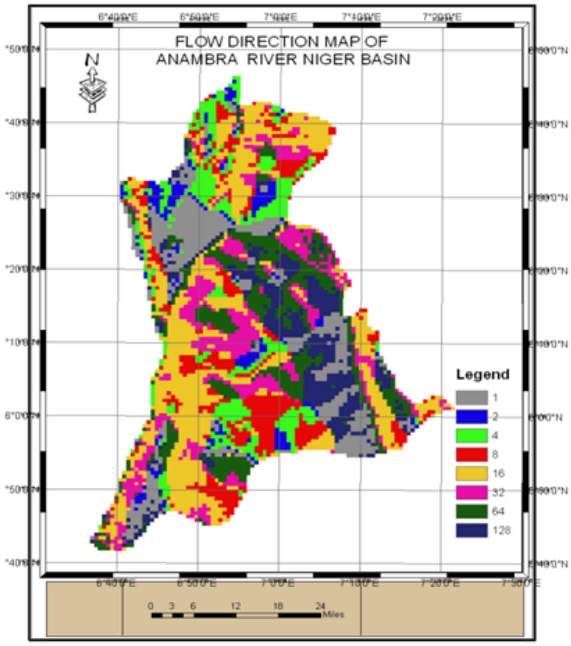


Figure 2 Methodological flow chart

III. REULTS AND DISCUSSIONS

The Digital elevation model is the first input given for morphometric analysis. Digital Elevation Models are a type of raster Geographical information system layer. In a Digital elevation model, each cell of raster GIS layer has elevation value corresponding to the position it occupies in space. As per chukwuocha (2014) The DEM is a grid of elevation cells where each cell holds the elevation value of the terrain space the cell covers. It is widely accepted that hydrological behavior of a given area is a function of the surface in which it flows. The generation of depressionless DEM is always the preparatory step in hydrological analysis. The fill sink tool has been used to remove all imperfection in the elevation raster. A sink is a cell that does not have associated drainage value. Drainage value indicates the direction of water flow out of the cell and are assigned during the process of creatingthe flow direction grid of the landscape. Fig2a is the flow direction grid. The Flow Direction function takes a DEM grid and computes the corresponding flow direction grid. this grid holds values in its cells that indicate the direction of the steepest descent from each cell. The areas of each value represent areas of similar aspect. The cells flow to their nearest neighbor along 1 of 8 compass directions labeled East =1, SE =2, S =4, SW=8,W=16, NW= 32, N=64, NE=128. A cursory study of fig2a (flow direction map) revealed that majority of the grids hold value that indicates Southwest, west and Northwest direction of flow where river Niger channel is located.



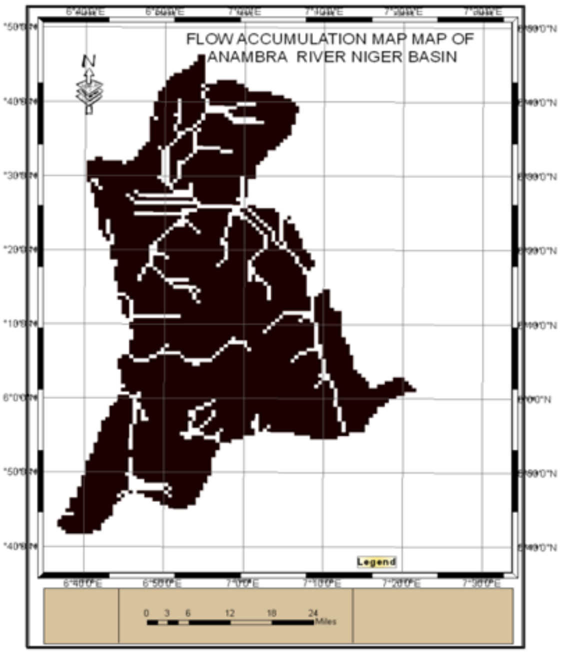


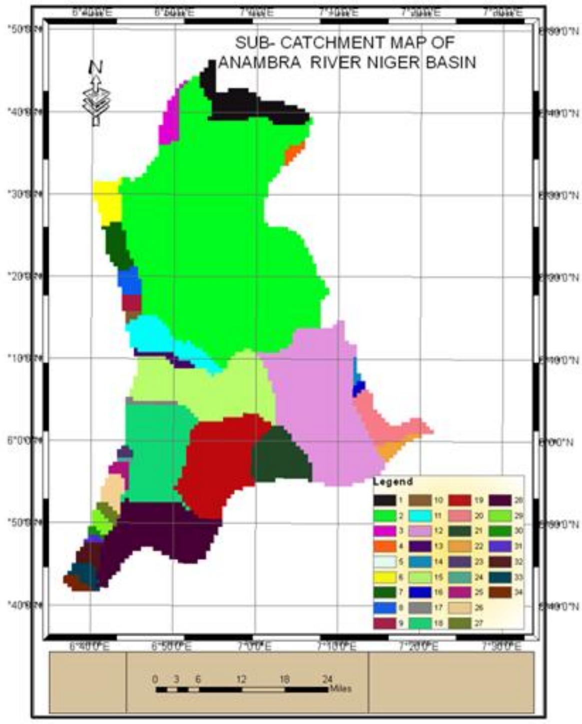
Fig2a flow direction grid of the study area fig2b stream networkflow direction grid of the study area

3.1 Flow Accumulation and Stream Definition

Fig2a and fig2b are flow direction grid and drainage network of the basin. The Flow Direction Grid was the input data to compute the associated Flow Accumulation Grid.The flow accumulation calculate flow into each cell by identifying upstream cells that flow into Each downstream cell. In other wards each cell in the flow accumulation grid contain a value that is determined by the number of upstream cells flowing into it based on landscape topography. The flow accumulation grid is important in the sense that it enables identification of cells of high flow where streams and channels are to be expected. For better visualization and further calculation, the flow accumulation grid was subjected to stream definition(visualization) and segmentation algorithms. The stream definition is based on a specified threshold that isusually applied to reveal the stream length.It tries to determine the number of accumulating cells that define a stream cell

3.2 Sub-Catchment Mapping

Figure3a is the sub-catchment map of the study area and Figure 3b is an overlay of the stream lines vector and the watershed polygons. This map will be helpful whenthere is need to study the hydrographic terrain of the study area. In most cases, it is utilized for planningagricultural activities and more importantly, it is an indispensable tool for monitoring and tracking down sourcesof stream pollution. The catchment measures 5530 square kilometers and a total of34 sub-catchment were identified within the basin . The largest and smallest sub-catchments measures approximately 2206square kilometers and 5square kilometers respectively. The largest catchment is spatially located in the northern part of the basin. It has 26 streams located on it with a flat topography and higher exposure to flood compared to other areas within the basin.



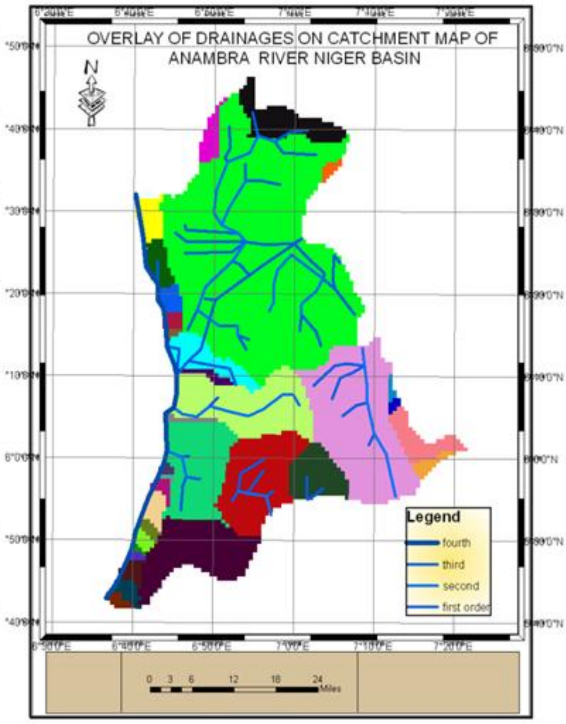


Figure 3a sub catchment map of the basin **fig3b overlay of the subcatchment and drainage of the basin**

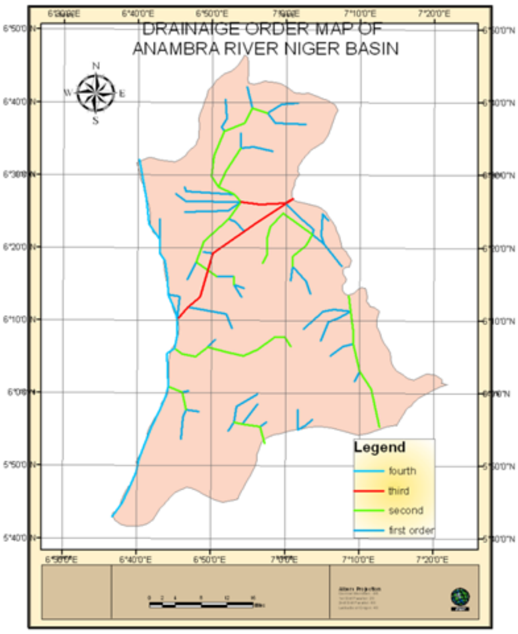
Figure4 is the drainage order map of the basin and table1 is the metric attributes of the catchment. The Strahler's method of stream order has been used to categorize the streams into order in the basin. The study revealed that there are three stream order excluding river Niger Benue which occupies the highest rank in the basins. It revealed that the basins have one (1) four order streams, two (2) third order streams, eleven (11) second order streams and forty one (41) first order streams Within the basin. T\he length of the 1^{st}, 2^{nd}, 3^{rd} and 4^{th}orders when added together measures 293 km, 194 km, 54 km and 97 km respectively. These values corresponds to mean stream length of 7.15 km, 17.64km, and 27.00km for 1^{st}, 2^{nd} and 3^{rd} orders respectively. Drainage density and stream frequencies are factor that indicate the topographical condition of a basin. they are also inestimable for predicting runoff potential of a river basin. The drainage density has been calculated by dividing the total length of the stream and rivers by the area of the basin and the stream frequency was calculated by dividing the total stream numbers of all the orders by the surface area of the basin. Drainage density and stream frequency of the basin are $0.115371km^{-1}$ and $9.945*10^{-3}$respectively. These characteristicsindicate coarse drainage texture,high permeability of subsurface materials with low flood and erosion potential within the basin.

3.3 Elongation ratio, Circulatory Ratio, Form factor and Relief

Elongation ratio is defined as the ratio of diameter of a circle of the same area as the basin to the maximum basin length. Sumantra et al (2016)reported that it is a meaningful index for classifying drainage basins into varying shapes. The value of elongation ratio varies from 0 to 1 i.e. circular (0.9- 1.0), oval (0.8-0.9), less elongated (0.7-0.8), elongated (0.5-0.7),and more elongated (<0.5) (Schumms1956). A circular basin is more efficient in runoff discharge than an elongated basin (Singh and Singh 1997;Praveen et'al 2014). In this study elongation was computed using the formular;$Re = D/L = 1.128HA/L$. As per Miller (1953) circularity ratio is the ratio of the area of the basins to the area of circle having the same circumference as the perimeter of the basin. It is a dimensionless parameter which provides a quantitative index of the shapeof the basin. In this studyCirculatory ratiowas computed using the formula; $Rc = 4\pi A/P^{2}$. Form factor is defined as the ratio of the basin area to the square of the basin length. It is dimensionless quantity which is used to describe the different shape of basin. The basins with high form factors portrays high peak flows of shorter duration, whereas, elongated drainage basin with low form factors depicts lower peak flow of longer duration. Values of 0.7559, 0.480, and 0.449 recorded for elongation ratio, circulatory ratio and form factor respectively indicates that the basin is elongated in shape and of low discharge potential.

Relief ratio is an index for predicting runoff potential of a basin.Total relief (Z –z) of a basin is the difference between the highest and lowest point on the basin. Sayeed et al (2017) appraised that relief ratio is the ratio between the totalrelief of a basin and the longest dimension of the basin parallelto the main drainage line. In the present study, relief ratio has been calculated using the formular; Rh=H/Lb and this recorded a value of 0.003 which signifies low discharge potential.

Table Mophormetric Attributes of Anambra River Niger Basin

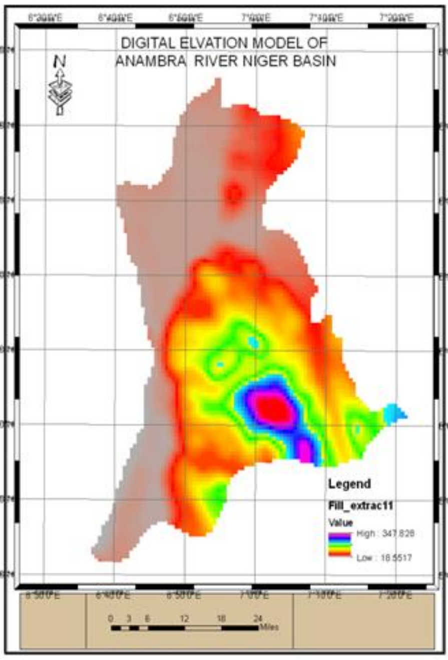


Order	Stream number	Stream length(m)	Mean stream. Length (m)	Bifurcation Ratio	Stream Length Ratio
1	41	293000	7146.341	3.727273	
2	11	194000	17636.36	5.5	0.662116
3	2	54000	27000	2	0.278351
4	1	97000	97000		1.796296
Basin Area				$5530km^2$	
Basin Length				111km	
Circulatory Ratio (Rc)				0.480	
Elongation Ratio (Re)				0.7559	
Perimeter of Basin				378km	
Form Factor (Ff)				0.449	
Stream Frequency				$9.945*10^{-3}$	
Highest Relief of The Basin				380m	
Lowest Relief of The Basin				20m	
Total relief				360m	
Relief ratio				0.003m	
Drainage Density				$0.115371km^{-1}$	
Sum of Lengths of Drainages				638	
Total Number of Streams				55	

Figure4 Drainage order map

3.4 Surface Analysis

Fig5a, 5b and 5c a revealed digital terrain model , 3-D surface model and the over lay analysis of 3-D and flow models the basin.A cursory examination of the digital terrain model of the surface models shows that generally, there is hierarchy in the topography with reference to height and ruggedness of the relief. Easter part of the basin is undulating high land while the western part is flat. The surfaceanalysis shows that the elevation decreases towards the river Niger channel. The over lay analysis of surface flow vectors and the 3-D model reveals the direction of surface flow. This is invaluable for determination of ground water potential and can asso be used to determine areasexposed to flood and errosion. Basin relief (H) is defined as the difference in height between the highest and the lowest points on the basin. Relative relief is an important morphometric variable used for the assessment of morphological characteristics of anytopography (Gayen et al. 2013). In this study, the highest and the lowest relief value are 380 m and 20 m respectively. Z is used to represent highest relief while z represents the lowest relief on the basin. The parameter; Z- z is known as the total relief. In the present study, the total relief of the basin has been calculated as 360m.Relief Ratio (Rh) isdefined as the ratio between the totalrelief of a basin and the longest dimension of the basin parallelto the main drainage line (Schumms 1956;Sayeed et al 2017) . High value of Rh indicates steep slope which shows high surface run-off and high discharge potential from the basin and vice versa. In the present study, relief ratio has been calculated using the formular; Rh=H/Lb and this recorded a value of 0.003m which value indicate low runoff potential of the basin.



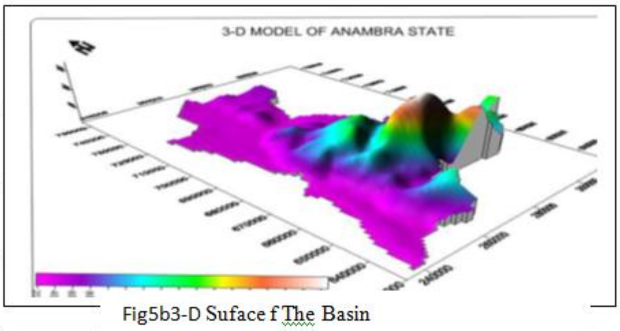


Fig5b3-D Suface f The Basin

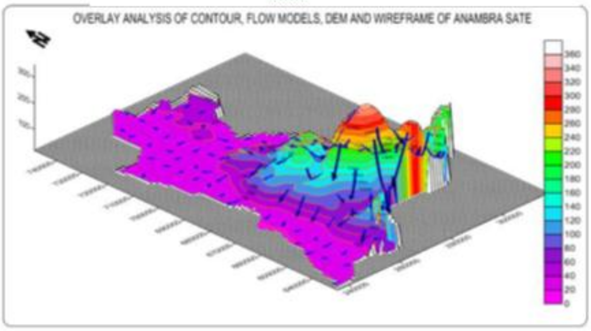
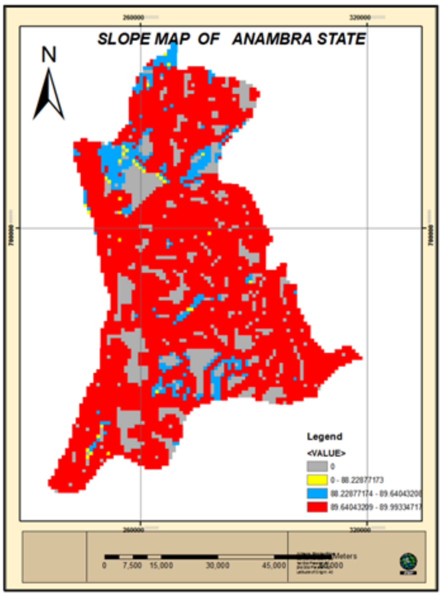


Figure5a digital elevation model of the basinFigure5c 3-D Suface Of The Basin showing flow vectors

3.5 Aspect and slope

Slope is defined as the maximum rate of change in value from each cell to its neighbors. Slope (fig6a) at a point is calculated as the gradient of the plane formed by the vector connecting the left and right neighbors (run) and the vector connecting the upper and lower neighbors' of the pixel (rise) (Ganas et al., 2005). The DEM data has beenprocessed to slope map of the study area using spatial analysis tool. Higher slope degree results in rapid runoff and increased erosion rate (potential soil loss) with less ground water recharge Potential. The degree of slope in Anambra river Niger basin basin varies from $< 1.0^0$ to $> 89^0$

Aspect (Fig6b) depicts the slope direction and is measured clockwise from 0° to 360°. It shows the direction of surface water flow. The aspect of a slope can make very significant influences on its local climate because the sun's rays are in the west at the hottest time of day in the afternoon, and so in most cases a west-facing slope will be warmer than sheltered east-facing slope. This can have major effects on the distribution of vegetation in the watershed (Praveen et'al). The slope direction grid can be used effectively for advance topographical modeling such as identifying and characterizing areas of high water runoff and landslide and for drainage design.



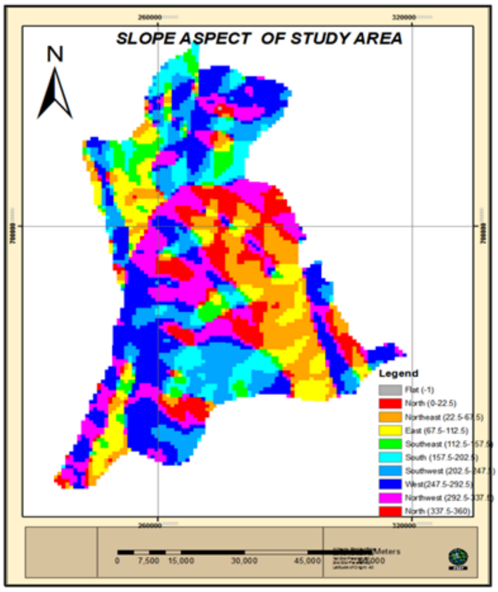


Fig6aslope map of the basin Fig6bAspect map of the basin

IV. CONCLUSION

Drainage morphology analysis is essential to any hydrological study and indispensable in watershed management. Hence, the determination of stream networks behavior and their inter-relation with each other is of great importance in many water resources studies.The use of ground based data capture for such investigation is cumbersome and uneconomical therefore in this study, remote sensing data (SRTM) and GIS tools has been employed to evaluate geophysical and metric attributes of Anambra river Niger basin in Nigeria. This investigation revealed that the basins have one (1) four order streams, two (2) third order streams, eleven (11) second order streams and forty one(41) first order streams. This study further recorded a drainage density of 0.1153 km^{-1}, stream frequency of $9.945*10^{-3,}$ bifurcation ratio of between 2 and 6, circulatory ratio of 0.489 with a value of 0.449 for the form factor. These values indicate that the basin is elongated less structural control Low discharge and erosion potentialand coarse drainage texture.

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