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Full Length Research Article

DRAINAGE BASIN MORPHOLOGY AND TERRAIN ANALYSIS OF THE LOWER BENUE RIVER BASIN, NIGERIA

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ABSTRACT
The Lower Benue Trough is part of the Benue Trough of Nigeria and it consists of a series of rift basins which form a part of the Central West African Rift System of the Niger, Chad, Cameroon and Sudan Basement fragmentations. This research attempts to evaluate the geomorphological changes on the drainage basin interpreted using several techniques including the use of Remote Sensing and GIS. Several digital image enhancement techniques such as general contrast stretching and edge enhancement were applied to the Landsat image in ARCGIS, after which structures were mapped out on-screen using ArcGIS. The Digital Elevation Model (DEM) of the Trough was also generated from Shuttle RADAR Topographic Mission and used to enhance geomorphic features. The analysis carried out on the images revealed that the slope tool calculates the maximum rate of changes between each cell and its neighbors. The drainage density calculated shows that the drainage area = 86282.1km^2, while the drainage density is 0.39872 km/$^{km-2}$. The result from the modeling concludes by revealing four sub-basins in the Lower Benue Trough with maximum thickness of 7-10km.

Keywords: Benue, Remote Sensing, GIS, Geomorphology, River Basin.

INTRODUCTION
The Benue Trough is one of the most important rift features in Africa and is believed to be formed by the rifting of the central West African basement during the Cretaceous. The trough is subdivided into Lower, Middle and Upper Benue with its Southern limit towards the northern boundary of Niger Delta and its northern sector include the easterly Yola/Garoua Flank extending across the Cameroon border and the northerly Gongola Flank. Careful re-examination of geophysical evidence makes it quite clear that there are only three interconnected rifts in West Africa; the Lower Benue Rift which extends from the Gulf of Guinea to a triple junction near Chum and the Gongola and Yola Rifts which extend to the north and east, respectively from the Chum triple junction (Nkeki, et al., 2013).
One of the attempts at checking the menace of flood, erosion and watershed management and its attendant consequences was the establishment of the River Basin and Rural Development Authorities (RBRDAs). These were created by Decree No. 25 and 31 of the 1976 and 1977 respectively, and amended by decree No. 87 of 1979. As an agency, LBRBRDA (Lower Benue River Basin and Rural Development Agency) has a cardinal aim of raising the income of the rural people through optimization of land and water resources potentials within the country for multi-purpose use ranging from irrigation to household use. Specifically, the agency (LBRBRDA), just like the other RBRDAs have the following as their functions: the development of both surface and underground water resources for multi-purpose use, control of floods and erosion, and for water-shed management, construct and maintain dams, dykes, polders, wells, boreholes, irrigation and drainage system, develop irrigation schemes for the production of crops and livestock and to lease the irrigated land to farmers or recognized associations in the locality of the area concerned, to resettle persons affected by the works in paragraphs 'c' and 'd' above and to control pollution in rivers and lakes etc. (FGN, 1976).
Studies on river and stream ordering systems abound all over the world as a result of the relevance of water to the sustenance of life. Depending on the outflow point; all of the land that drains water to the outflow point is the watershed for that outflow location and watersheds are important because the stream flow, and the water quality of a river are affected by things, human-induced or not, happening in the land area 'above' the river-outflow" which defines the lower and upper basins of a river (Adekeye and Akande, 2002). In this subsection, we present a succinct conceptual overview of a river and stream order pattern in addition to some relevant studies that had been carried out in the subject area.
An understanding of the concept of a "stream", "a river", "stream order" and "stream segment"; its delineation, morphology, classification and quantification, functionality and usages is a fundamental requirement in appraising drainage system and the water resources of an area. Akinmosun, et al., (2005) remarked that "there are some ambiguity concerning the terms 'stream' and 'river'. It is however generally accepted that all natural flowing water channel segments of 'order 1' to 'order 4' should be designated as streams while channel segments of higher orders are rivers." This principle hold true in this study. Thus, the method of classifying stream size (including length and order) is important to geographers, geologists, hydrologists and other scientists because it gives them an idea of the size and strength of specific waterways within stream networks, an important component to water management (Akinmosun, et. al., 2005; Philips, et.al. 2009).
Geomorphologists rank the relative importance of stream segments in the network by assigning a numerical order value to each segment using one to four ordering systems. (Benkhelil, 1989). Stream order, that is, a measure of the relative size of streams and the smallest tributaries, usually perennial are referred to as first-order (1st) streams, followed by a second order beginning where two 1st orders meets to form the second order, in that Similarly, a "stream order" according to Obaje (2009) is defined as "the designation by a dimensionless integer series (1, 2, 3 ...) of the relative position of stream segments in the network of a watershed. The stream order hierarchy was officially proposed in 1952 by Arthur

Newell Strahler, a geoscience professor at Columbia University in New York City, in his article "Hypsometric (Area Altitude) Analysis of Erosion Topology". The article, which appeared in the Geological Society of America Bulletin outlined the order of streams as a way to define the size of perennial (a stream with water in its bed continuously throughout the year) and recurring (a stream with water in its bed only part of the year) streams" (Bejide, 2000; Philip, *et al*., 2009).

The Benue Trough in Nigeria consists of a series of rift basins which form a part of the Central West African Rift System of the Niger, Chad , Cameroon and Sudan Basement fragmentation, block faulting, subsidence and rifting accompanying the opening of the South Atlantic Ocean led to the deposition and accumulation of sediments ranging between 4000 to 6000m in the greater Benue Trough along the 800km axis over a width of 120km from the northern parts of the Niger Delta Basin in the south west to the fringes of the Chad Basin on the north east. The trough is divisible geographically into the Lower, Middle and Upper Benue basins with the Lower Benue consisting of the Abakaliki and Anambra Basins and the Middle Benue Basin occupying the region north of the Gboko regional fracture system i.e. the Gboko. Localized geological factors controlled the basins development and are reflected in the lithostratigraphy and ages of the facies associations. The Benue trough is a major geological formation underlying a large part of Nigeria and extending about 1,000km north east from the Bight of Benin to Lake Chad. It is part of the broader central African rift system.

The trough has its southern limit at the northern boundary of the Niger delta, where it tips down and is overlaid with tertiary and more recent to the sediments. It extends in a northern easterly direction to the chad basin, and is about 150kmwide. The trough is arbitrarily divided into lower, middle and upper region, and the upper region is further divided into Gongola and Yola arms. The Anambra basin in the west of the lower regionis more recent than the rest of the trough, being formed during a later period of compression, but is considered part of the formation. Previous accounts of the stratigraphy of the Lower Benue TroughThe Benue Trough is one of the most important rift features in Africa and is believed to be formed by the rifting of the central West African basement during the Cretaceous. The trough is subdivided into Lower, Middle and Upper Benue with its Southern limit towards the northern boundary of Niger Delta and its northern sector include the easterly Yola/Garoua Flank extending across the Cameroon border and the northerly Gongola Flank. Careful re-examination of geophysical evidence makes it quite clear that there are only three interconnected rifts in West Africa; the Lower Benue Rift which extends from the Gulf of Guinea to a triple junction near Chum and the Gongola and Yola Rifts which extend to the north and east, respectively from the Chum triple junction (Nkeki, et al., 2013).

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METHODS AND MATERIALS

Methods

The primary data used for this study is the Google earth image 2016 of the Lower Benue basin, Shuttle Radar Topographic Mission (SRTM) image of the Nigeria, Catchment map of Nigeria, and political map of the catchment area. The projection used in Nigeria is (UTM) projected coordinate system and WGS84 datum in zone 31N. The spatial resolution of the image gotten from the Google earth depends on the satellite that took the image in the time of extraction. The resolution of the image used is very high so as to be able to have a better interpretation. The Lower Benue catchment area was extracted from the drainage basin/catchment map of Nigeria in ArcMAP environment. The map was first geo-referenced by means of image to image registration using the geo-referenced administrative map of Nigeria states to geo-reference image of the drainage basin map of Nigeria. The extraction is in form of digitizing and shape-files creation for the catchment area and the river systems in the area. The extracted upper basin shape file is overlaid on the SRTM data of Nigeria to clip out the digital elevation model (DEM) data of the Upper Benue basin area. The shuttle radar topographic mission (SRTM) image of the Lower Benue catchment areas was used to generate the flow direction, flow accumulation, stream order, catchment basins and the interpretation of the terrain by using the SRTM image to generate the Triangular Irregular Network (TIN) image for the perception of the relief of the area. The drainage density of the river was also calculated and used to generate the total stream length and the area of the catchment. The drainage density is given by the formula stream length divided by drainage area. The slope of the area was also generated by using the SRTM image extracted on the ArcMAP with a series of process involved. The processes used in the study are described in the flow chart in Figure 1.

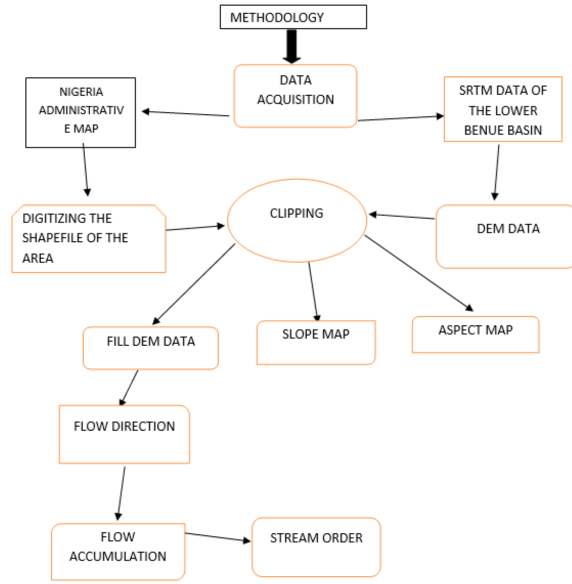

Figure 1: Flow chart of methods used

RESULTS AND DISCUSSION

Geomorphological Changes That Has Occurred In Lower Benue Basin

There are lots of geomorphologic changes that has taken place in the Lower Benue Basin. Flood is one of the causes of the changes that have taken place. Floods are devastating natural disasters with a significant impact on human life and the surrounding environment. This paper analyses the historical and recent flood peak flow at strategic locations, land use activities and Floodplain Vulnerability Index analyses of the Niger–Benue River Floodplain. The 2012 peak flow at Jederbode on the Niger River was about 50% above the long term average. At Jebba (Niger), the 2012 peak flow of 1567m^3/s was also far higher than the long term mean annual peak flow of 1159m^3/s. The 2012 peak flow at Lokoja was also about 50% above the historical average.

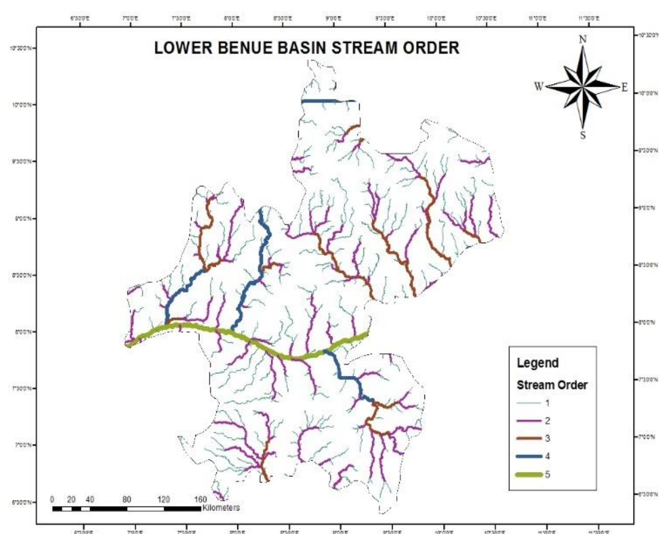

Figure 2: Map Showing the Stream Order of Lower Benue Basin

The stream order of the Lower Benue River Basin is determined by the underlying rocks, in the basin. These rocks have controlled the flow direction of the rivers and have impacted on the size and volume of water in each of the tributaries.

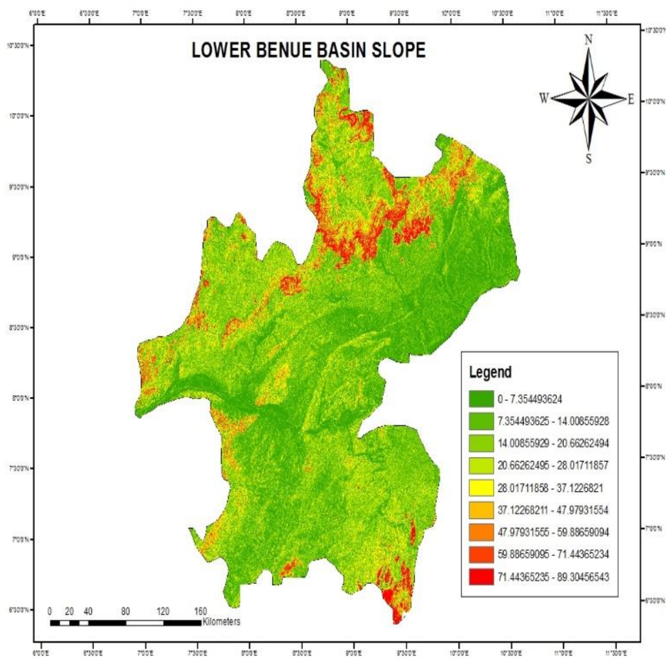

Figure 3: Map Showing the Slope of Lower Benue Basin

Figure 3 shows the slope of the river basin, the highest point is above 89m while the lowest point is below 7m as extracted from the DEM.

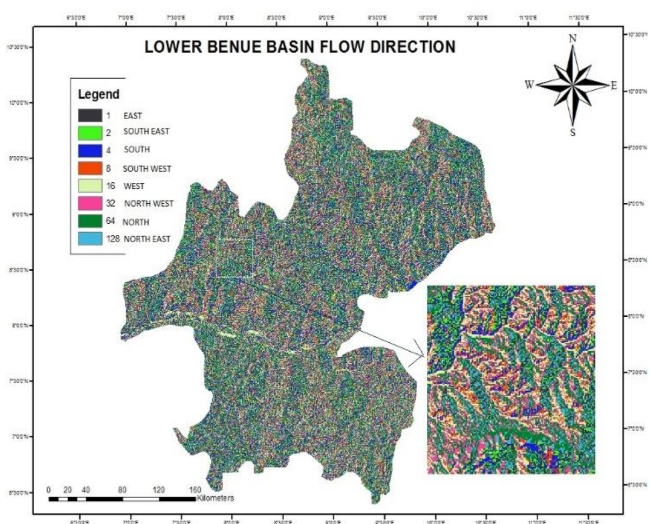

Figure 4: Flow direction of the River Basin.

The flow direction of the River Basin is explained by cardinal points, as shown in Figure 4 some flow in the Northeast direction and others in the west direction. The flow direction of each drainage is differentiated by colour, and affects the drainage pattern of the basin

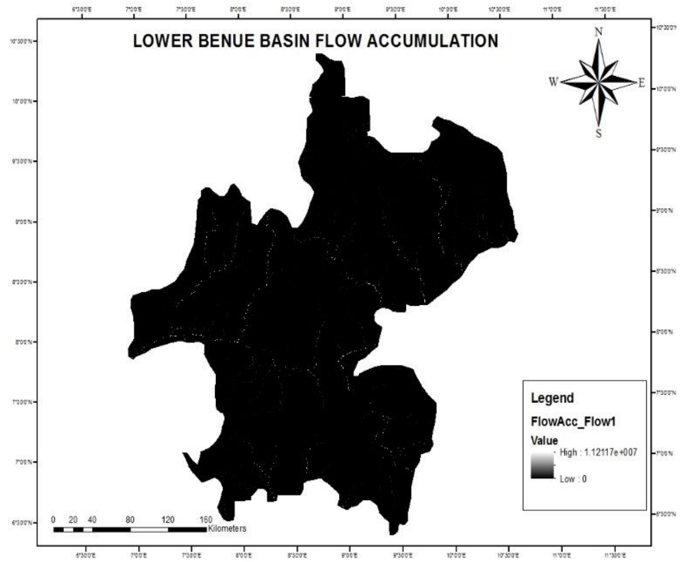

Figure 5: Map Showing the Flow Accumulation of Lower Benue Basin

Drainage Density

Drainage density is the total length of all the streams and rivers in a drainage basin divided by the total area of the drainage basin. Soil permeability and underlying rock type affect the run off in a water shed; impermeable ground or exposed bedrock will lead to an increase in surface water runoff and therefore to more frequent stream.

It is a measure of how well or poorly water shed is drained by stream channels. It is equal to the reciprocal of the constant of the maintenance and equal to the reciprocal of two times the length of overland flow.

Drainage density depends upon both climate and physical characteristics of the drainage basin. Drainage density can affect the shape of a river hydrograph during a rain storm. Rivers that have high drainage density will often have a more 'flashy' hydrograph with a steep falling limb. High density can also mean a high bifurcation ratio.

Drainage density

The total length of the stream = 34402.38412 km

Drainage area = 86282km^2

Drainage density = stream length/drainage area

34402.38km/86282km^2

= 0.398km^{-1}

Conclusion

There are a lot of changes that have taken place over time in the drainage basin; one of the factors that affect the flow direction of rivers is the underlying rocks and these has impacted the size and volume of water in each tributary. The highest point in the basin is 89m while the lowest point in 7m. The 1st, 2nd, 3rd and 4th order streams flow in different directions. Some flow towards the Northwest and others flow in the west direction of the basin.

The study established that drainage density depends on both climate and physical characteristics of the drainage basin, the drainage density was calculated to be 0.398km^{-1}

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