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Research Paper

MORPHOMETRIC ANALYSIS AND TERRAIN EVALUATION OF THE LOWER NIGER RIVER BASIN, NIGERIA

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The quantitative geomorphological analysis of the lower Niger River basin in Nigeria was carried out in other to evaluate the drainage morphology, the stream order, drainage density, and the slope analysis on the basis of acquired satellite imagery. The study indicates that analysis of morphometric parameters with the aid of Geographic Information System (GIS) would prove a viable method of characterizing the hydrological response behaviour of the watershed. It is also well observed that remote sensing satellite data is emerging as the most effective, time saving and accurate technique for morphometric analysis of a basin. This technique is found relevant for the extraction of river basin and its stream networks through Nigeria (DEM) in conjunction with remote sensing satellite data. In this study, lower Niger River basin and its tributaries have been selected for detailed geomorphological analysis using ArcGIS software. There are six different stream orders within the drainage basin, the first, second, third, and fourth flow into the fifth stream order. This is affected by the slope of the river basin. The fifth order flows in the northeast direction as it flows outside the river basin. The slope also dictates the flow pattern and direction of smaller streams that are tributaries of larger streams and they determine the volume of water in the larger streams and the drainage basin.

Keywords: Geomorphology, Morphology, Watershed, GIS, Remote sensing, River basin

INTRODUCTION

Geomorphology is the study of the features that make up the earth surface and their relationship to the underlying geology. A geomorphological study will provide conceptual features of coastal processes and the potential behaviour of the coastal system. These includes taking into account changes in the bedrock composition that could affect potential rate of future coastal evolution. The result tends to be qualitative, rather than quantitative. The geomorphological analysis of the lower Niger basin is aimed at identifying the drainage morphology, the stream order, drainage density, and the slope analysis. A widely acknowledged principle of geomorphology is that drainage basin morphology reflects various

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geological and geomorphological processes over time. It is well established that the influence of drainage morphology is very significant in understanding the landform processes, soil physical properties and erosional characteristics. The analysis of the drainage does not appear to be complete if it lacks the systematic approach towards the development of drainage basin in the area. Drainage lines of an area do not only explain the existing three dimensional geometry of the region but also help to narrate its evolutional process. Besides, the quantitative analysis of drainage system is an important aspect of characteristics of watershed. It is important in any hydrological investigation like assessment of groundwater potential, groundwater management, basin management and environmental assessment. Hydrologic and geomorphic processes occur within the watershed and morphology characterization at the watershed scale reveals information regarding formation and development of land surface processes.

The remote sensing technique is the convenient method for geomorphological analysis as the satellite images provide a synoptic view of a large area and is very useful in the analysis of drainage basin morphology. The fast emerging spatial information technology, remote sensing, GIS, and GPS have effective tools to overcome most of the problems of land and water resources planning and management rather than conventional methods of data process. GIS-based evaluation using Shuttle Radar Topographic Mission (SRTM) and Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) data has given a precise, fast, and an inexpensive way for geomorphological analysis of the lower Niger River basin, as well as for other analysis. The processed DEM was used successfully for generating the stream network and other supporting layers. The digital elevation model (DEM) of the area was generated to deduce the morphometric parameters like drainage basin area, drainage density, drainage order, relief and network diameter in GIS environment. Combination of the remote sensing satellite data and hydrological and spatial analysis in GIS environment is made easy to identify and discriminate the drainage area. The geographic and geomorphic characteristics of a drainage basin are important for hydrological investigationsinvolving the assessment of groundwater potential, etc. The present study aims at using the remote sensing andGIS technology to compute various morphometric characteristics of the lower Niger River basin in Nigeria.

Scientists have been involved in river basin research for a long time, and many models for soil erosion loss estimation as it affects river basin morphology have been developed notable among such researches are Wischmeier and Smith (1978), Nearing *et al.* (1989), Adinarayana *et al.* (1999) and D'Ambrosio *et al.* (2001). Fullen (2003) summarized some keynote papers about soil erosion in northern Europe, and Lal (2001) highlighted major empirical models for predicting soil erosion loss and its effects on the geomorphology of river basins. The use of remote sensing and Geographical Information System (GIS) techniques makes soil erosion estimation and its spatial distribution feasible with reasonable costs and better accuracy in larger areas (Millward and Mersey, 1999). For example, a combination of remote sensing, GIS, and RUSLE provides the potential to estimate soil erosion loss on a cell-by-cell basis (Millward and Mersey, 1999).

In general, remote-sensing data were primarily used to develop the cover-management factor image through land-cover classifications (Millward and Mersey, 1999). while GIS tools were used for derivation of the topographic factor from DEM data, data interpolation of sample plots, and calculation of soil erosion loss (Cerri *et al*., 2001; and Bartsch *et al*., 2002).

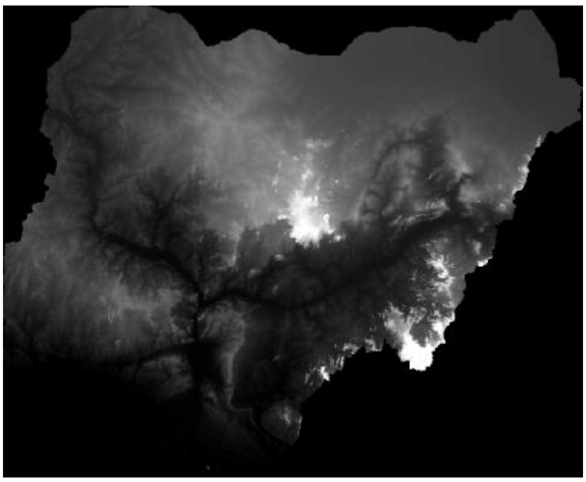
STUDY AREA

The study area is located in the northwestern (NW) part of Nigeria having a coordinate of Longitude (maximum 8^{0}00''0E W and minimum 2^{0}00''0'E) and Latitude (maximum 10^{0}30''0'N and minimum 4^{0}00''0'N). The most important tributary of the lower NigerRiver is the Benuewhich merges with the river at Lokoja in Nigeria. The lower NigerRiver basin heads southwards and empties in the gulf of guinea through a network of outlet that constitutes its maritime delta.

MATERIALS AND METHODS

Nigeria DEM

Figure 1: SRTM Image of Nigeria



Methods

The scanned map showing the area was loaded into Arc MAP environment for further processes, also the Nigerian DEM was used in the analysis. The scanned map of Nigeria was geo-referenced to define its location using map coordinates and assign the coordinate system to each pixel of the scanned map. The map was digitized to show the Lower Niger Basin from the already geo-referenced map.

For the DEM to be effectively used for hydrological analysis, it should be projected so that the calculation would be as accurate as possible. The digitized basin was laid on the Nigerian DEM for masking.

RESULT AND DISCUSSION

Flow Accumulation

The Flow Accumulation calculates accumulated flow as the accumulated weight of all cells flowing into each downslope cell in the output raster.

Flow Direction

One of the keys to deriving hydrologic characteristics of a surface is the ability to determine the direction of flow. The flow direction of the basin as shown in Figure 3 is majorly to the south and to the east direction. Which shows that the volume of water in these areas will be more than other areas in the basin. The underground recharge will be faster in these regions and water will be higher.

Drainage Pattern

The area upon which waterfalls and the network through which it travels to an outlet are referred to as a drainage system. The flow of water through a drainage system is only a subset of what is commonly referred to as the hydrologic

Figure 2: Flow Accumulation of the Lower Niger River Basin

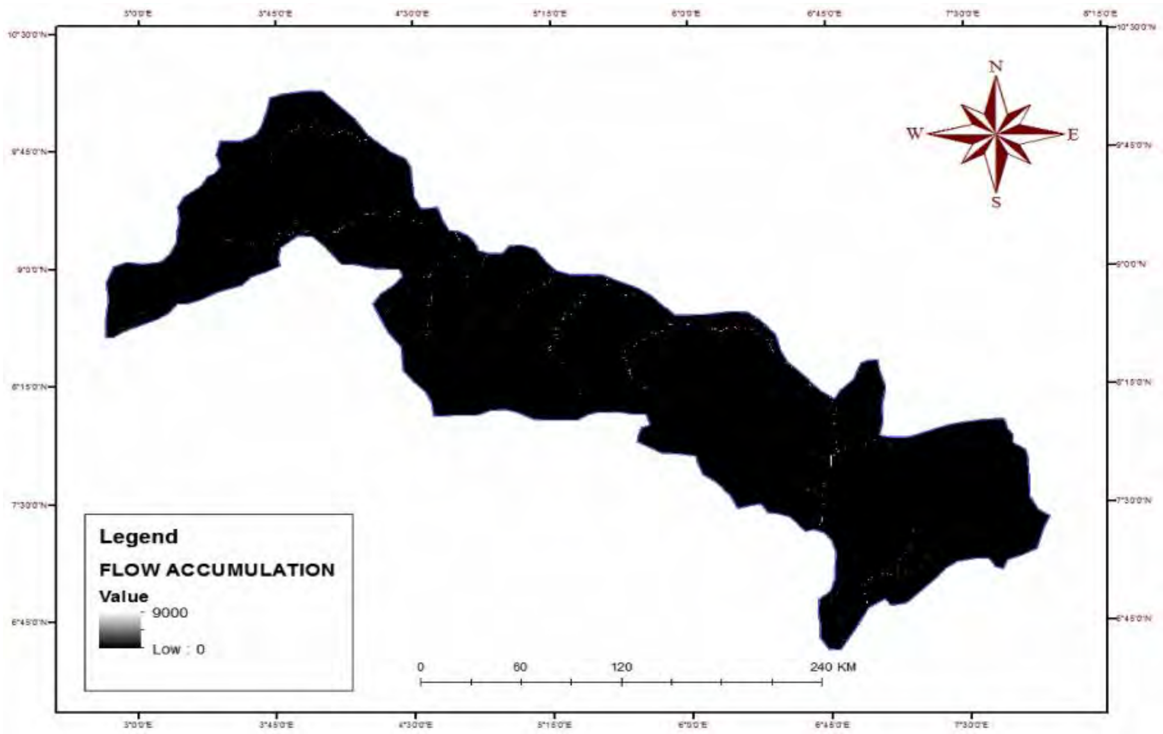


Figure 3: Flow Direction of the Lower Niger Basin

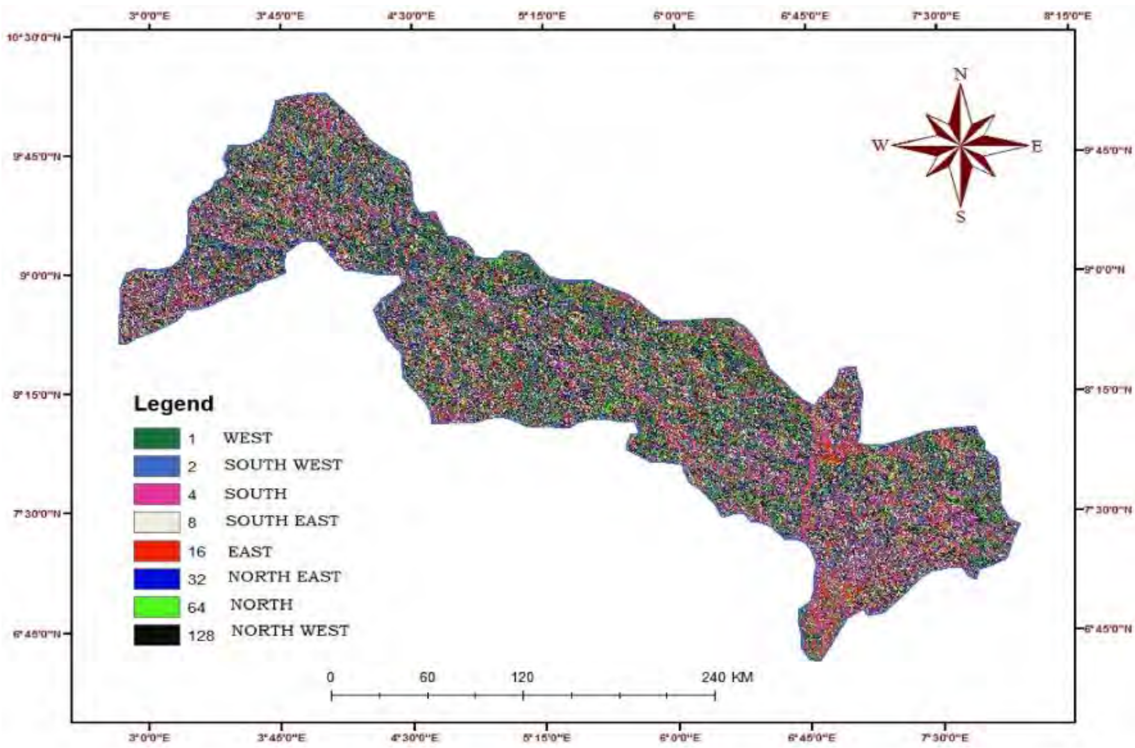


Figure 4: Drainage Pattern of the Lower Niger River Basin

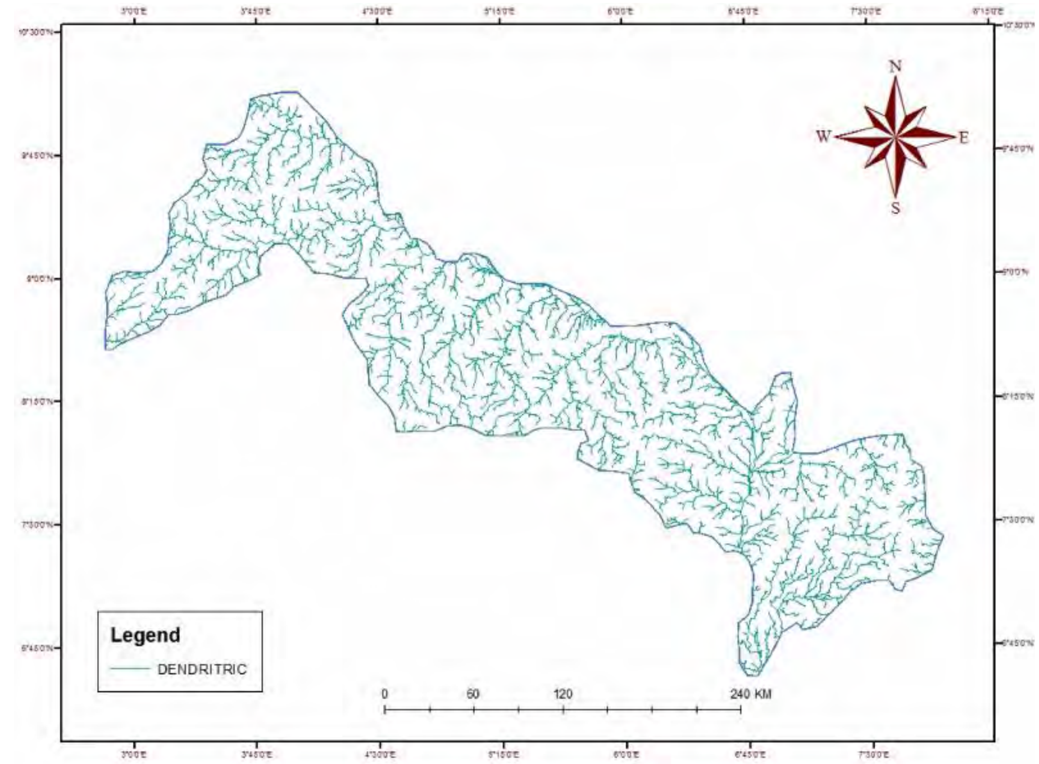
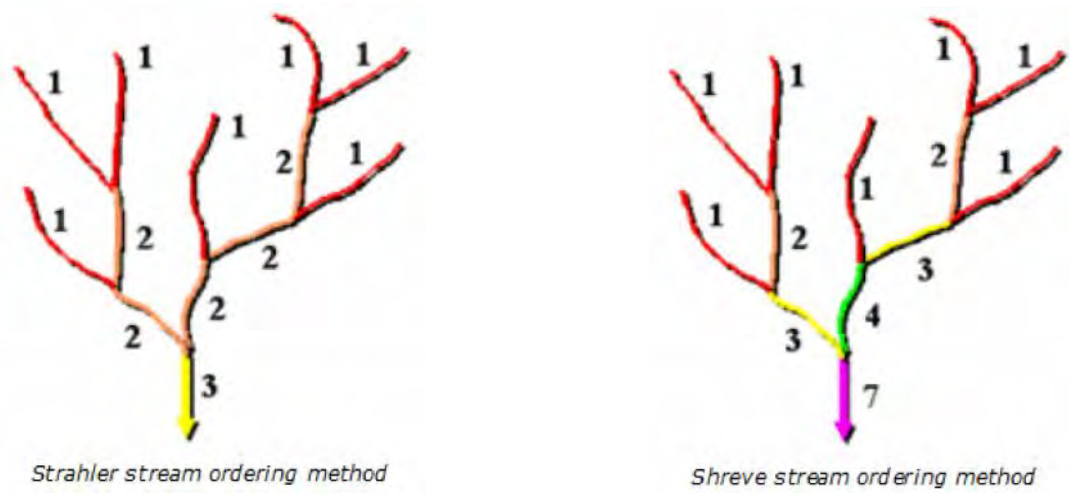
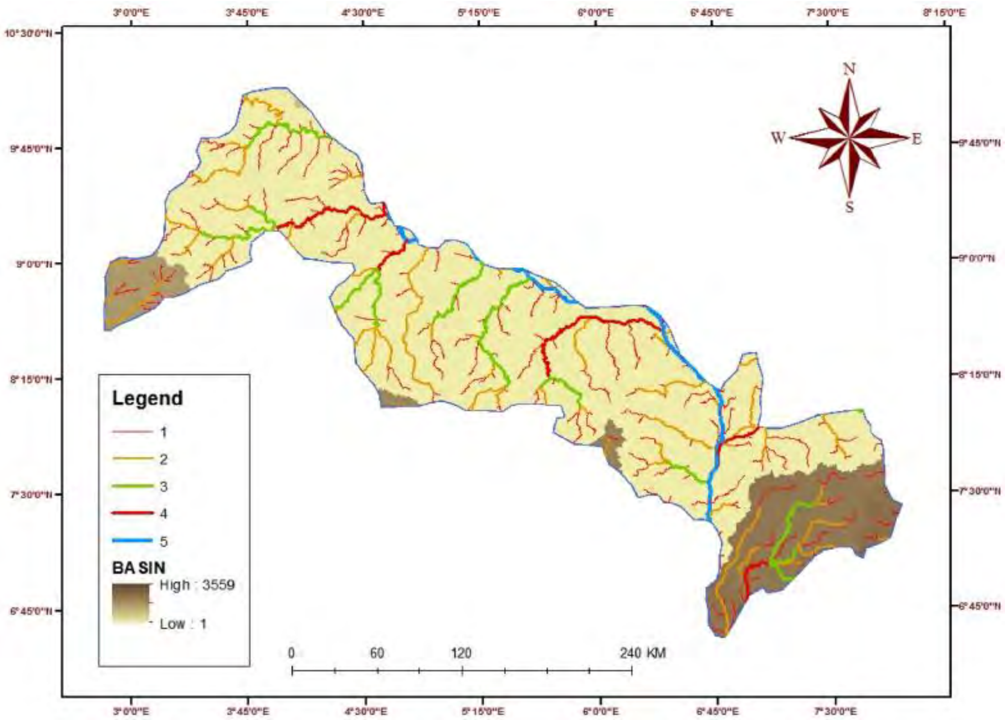


Figure 5: Stream Order According to Strahler and Shreve



cycle, which also includes precipitation, evapo transpiration, and groundwater flow. A drainage basin is an area that drains water and other substances to a common outlet. Other common terms for a drainage basin are watershed, basin, catchment, or contributing area. This area is normally defined as the total area flowing to a given outlet, or pour point. A pour point is the point at which water flows out of an area. The boundary between two basins is referred to as a drainage

Figure 6: Stream Order of the Lower Niger River Basin



divide or watershed boundary. The predominant drainage pattern from the map is the dendritic drainage pattern.

Stream Order

Stream order is a method of assigning a numeric order to links in a stream network. This order is a method for identifying and classifying types of streams based on their numbers of tributaries. Some characteristics of streams can be inferred by simply knowing their order.

The stream order tool has two methods you can use to assign orders. These are the methods proposed by Strahler (1957) and Shreve (1966).

In both methods, the upstream stream segments, or exterior links, are always assigned an order of 1. There are five different stream orders in the drainage basin according to Horton and Strahler's classification. Figure 6 gives a vivid description of the stream orders in The Lower Niger River Basin.

Slope

Slope identifies the steepest downhill slope for a location on a surface. The lower the slope value, the flatter the terrain; the higher the slope value, the steeper the terrain. Figure 7 shows the variation in the slope level of the basin, a large percentage of the basin has a gentle slope while a small percentage is steep.

Aspect of the Terrain

Aspect identifies the down slope direction of the maximum rate of change in value from each cell to its neighbours. Aspect can be thought of as the slope direction. The values of the output will be the compass direction of the aspect. Like the slope the aspect of the terrain gives the slope direction but also relates the slope to the other subsets of the basin. The slope is angled in

Figure 7: Slope of Lower Niger River Basin

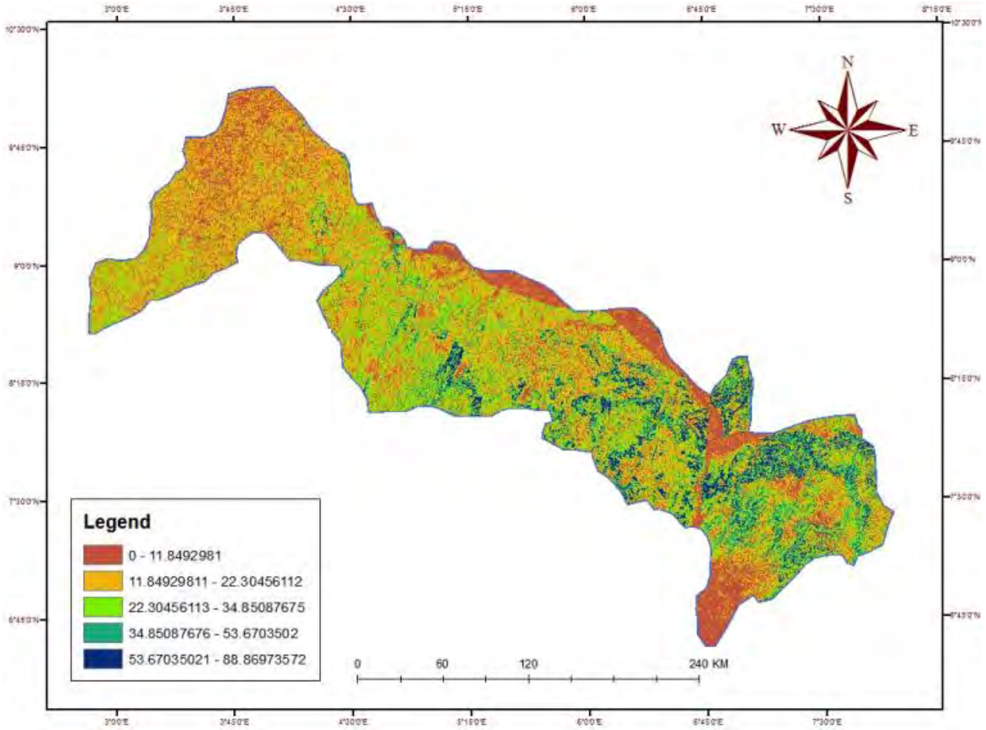
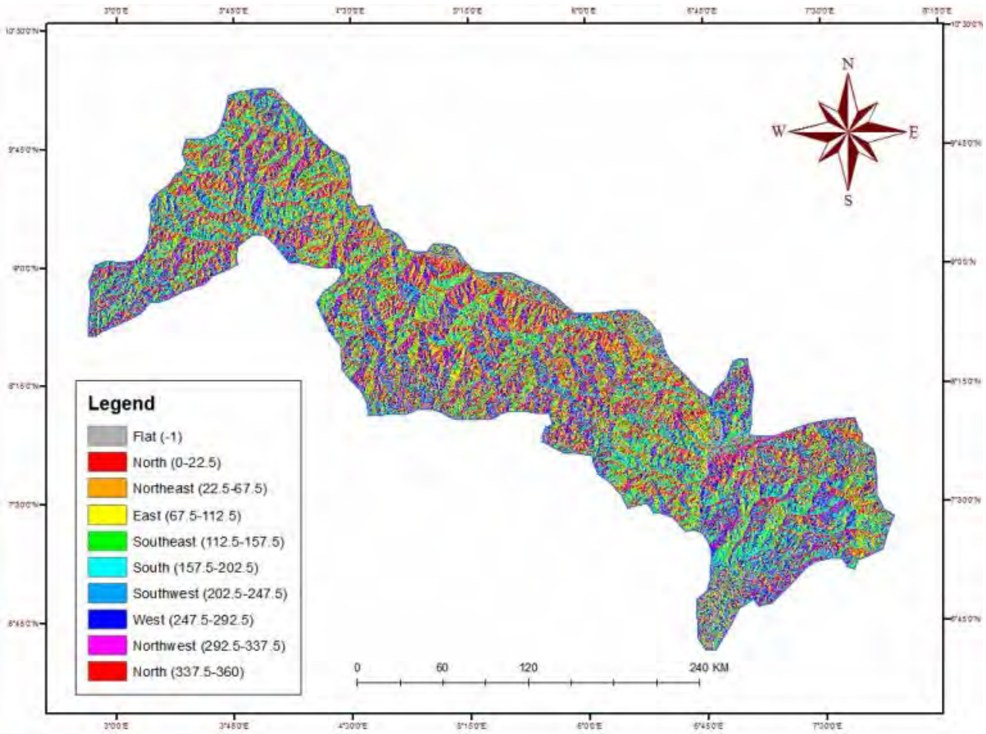


Figure 8: Aspect of Lower Niger River Basin



different directions which has a significant effect on the flow pattern of surface and underground water. This goes further to determine the quantity of water in the basin and the sub-basin with the highest volume of water.

Drainage Density

$$Drainage\ density = \frac{Total\ stream\ length}{Basin\ area}$$

Drainage density = 0.681755 km^{-1}

CONCLUSION

Geomorphological analysis of drainage system is prerequisite to any hydrological study. Thus, determination of stream networks behaviour and their interrelation with each other is of great importance in many water resources studies. Remote sensing satellite data and GIS techniqueshave been proved to be an effective tool in drainage delineation. Their updates in conjunction with old datasets bring a bright picture enabling geomorphologists to infer concrete conclusion about the drainage basin. In this geomorphological study, the analysis of the lower Niger Riverbasin, based on several drainage parameters using remotesensing satellite data and latest GIS tools for drainage analysis has been delineated.

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