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Morphometric Analysis of A Drainage Basin: Case Study of Oluyole Catchement Area, Ibadan, Nigeria

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Abstract: Remote sensing (RS) and Geographical information system (GIS) have become effective and efficient tools in identification of drainage pattern of the study area. GIS and RS techniques can be used for the identification of morphological features and analyzing properties of basin. The topographic map of Oluyole catchment area was scanned and geo-referenced before it was exported into ArcGIS 10.0 software. The digitized map is edited, and saved as line coverage in ArcGIS Software. This paper aimed at analysing the morphometric parameters of Oluyole drainage basins located on basement steep rock in South Western Nigeria. Geographical Information System (GIS) and Remote Sensing (RS) techniques were used for morphometric analyzes of drainage basins of Oluyole catchment area. Google Earth and LANDSAT 7 sensor of 2016 ETM+, path 191 and row 55 of VHS were used to acquire the satellite imageries of Oluyole catchment area. Using high resolution imageries, a Digital Elevation Model (DEM) was developed with Surfer 8 and ArcGIS 10.0. The drainage, elevation, land use, slope, flow direction, flow length and flow accumulation maps of the study area were generated by using the Digital Elevation Model. Result obtained indicated that studied basins exhibits high, medium and low spatial variations in their morphometric properties. The study further revealed that morphometric properties of Oluyole drainage basin induced high, medium and low magnitude flood. The results revealed that the used of remotely sensed data and ArcGIS 10.0 software provide an effective approach to develop accurate morphometric analysis of drainage basin with a minimum amount of time, effort, and cost. This approach creates easily read and accessible charts and maps that facilitate the identification of drainage pattern of the study area. The GIS based Morphometric analysis of this drainage basin revealed that the Oluyole catchment is homogeneity in texture. This study would help the local people to utilize the resources for sustainable development of the basin area.

Keyword: *Morphometric Analysis, Drainage Basin, Gis And Rs.*

I. INTRODUCTION

Remote Sensing and GIS techniques are efficient and effective tools in the assessment, identification and delineation of drainage basins. The drainage basin analysis plays a vital role in the control of floods and erosion, assessment of groundwater potential, groundwater quality and groundwater exploration. Size, shape, slope of drainage area, drainage density, size and length of the tributaries are some of the physiographic characteristics of drainage basins (Rastogi *et al.*, 2014). Remote sensing and geographic information system data can be used for the identification of soil salinity, assessment of groundwater potentials and quality, identification of flood and erosion prone areas, evolving water and soil conservation strategies, selection of sites for dams (Dutta *et al.*, 2002). The remote sensing technique is a simple method for morphometric analysis as the satellite images which provides the coordinates of a large area and is very useful in the analysis of drainage basin morphometric. The advancement of RS and GIS are effective tools to provide solution to most of the problems of land and water resources planning and management rather than conventional methods of data collection, processing and analysis (Rao *et al.*, 2010). Application of Shuttle Radar Topographic Mission (SRTM) and Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) data in GIS- based evaluation has given a correct, fast, and cheap way for analysing hydrological systems (Smith and Sandwell 2003; Grohmann 2004). The DEM was used for generating the slope, flow length, flow direction and flow accumulation maps of the study area (Mesa 2006; Magesh *et al.*, 2011). The digital elevation model (DEM) of the area was generated to reveal the drainage basin area in GIS environment. The application of remote sensing and GIS can be used to identify and delineate the drainage pattern of the study area (Pirasteh *et al.*, 2010). The morphometric characteristics of a drainage basin are important for hydrological investigations and assessment of groundwater potential, etc. The present study aims at using the remote sensing and GIS technology to compute various parameters of morphometric characteristics of the Oluyole catchment area watershed.

Hydrological response of a drainage basin is the production of runoff against a given rainfall, which in turn is characterized by basin morphometric properties, soil characteristics and land use pattern (Okoko and Olujinmi, 2003). While the soil characteristics and land use pattern control the infiltration loss, the distribution of the remaining excess rainfall is corrected by basin morphometric properties. Drainage basin area stands out to be one of the most important of all the morphometric parameters controlling catchment runoff pattern (Nabegu, 2005). This is because, the larger the basin, the greater the volume of rainfall it intercepts, and the higher the peak discharge (Jain and Sinha, 2000). Another reason for the high positive correlation between basin area and discharge is the fact that basin area is also highly correlated with some of the other catchment morphometric characteristics which influence runoff, such as, basin length and stream length (Ebisemiju, 2002 and Ifabiyi, 2004). However, other catchment morphometric parameters such as relief, shape and length also influence basin discharge pattern strongly. This is through their varying effects on lag time (Gregory and Walling, 1973). These morphometric factors have proved very important when a rate of flooding is being compared between the two basins being investigated in this study. The longer the length of a basins, the lower the chances that such a basin will be flooded when compared with a more compact basin. This is because, the longer the basin, the lower its slope. Not only this, time of concentration (lag time) in such a basin will be higher than a more compact basin which produces sharp hydrographic peak due to high bifurcation ratio (Faniran and Ojo, 1980). This led to rapid withdrawal of water from such a basin (Knapp, 1999). High concentration time thus exposes the water drainage basin to longer duration of infiltration and evaporation process, hence reduction in runoff volume. Relief ratio is an indicator of rates of erosion operating along the slope of a basin (Schumm, 2001). The higher erosive capacity and sediment yields which disposes the basin to higher flood peaks (Okoko and Olujimi, 2003). The shorter the basin length, the closer to the circulatory ratio.

II. MATERIALS AND METHODS

A. Description of the Study Area

The Oluyole catchment area is located between latitude 7^o 30' 00'' N, longitude 3^o43'00'' E, and latitude 7^o 20' 00'' N, longitude 4^o28' 00'' E, in the south western zone of Nigeria. It has a tropical wet and dry climate. It has total area coverage of 629 km^2 and a population of 202,725. River Ogunpa, River Ogbeere, River Omi and River Apasan are some of the prominent rivers in the catchment area. On account of extensive fertile soil which is suitable for agriculture, the basic occupation of the people is farming.

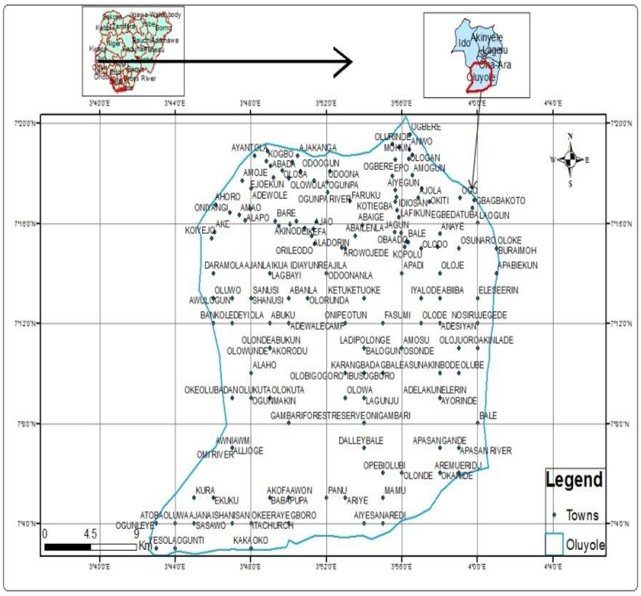

Figure 1: Map of the Study Area

B. Data Collection and Processing

The satellite images of LANDSAT 7 sensor of 2006 ETM+, path 191 and row 55 of VHS was obtained from Global Land Cover Facility (GLCF) an Earth Science Data Interface hosted by University of Maryland, USA and was acquired in November, 2015. A topographic map (scale: 1:200,000) of Oluyle catchment area was obtained from the office of the Surveyor General, Oyo State, Nigeria. The scanned and geo-referenced topographic map was imported into ArcGIS 10.0 software. Pre-processing was done to eliminate any discrepancies of mismatching during overlaying of the images while image enhancement was done in order to increase the details of the image by assigning maximum and minimum brightness values to maximum and minimum display values. However, image classification was done to convert image data into thematic data and to improve the visual quality and to classify the image into different land use type. Spectral profile was generated from the image and the different band combinations were made for the analysis. By using different ETM+ bands for (Red, Green and Blue), different colour composite were created for the catchment, each with its own characteristics. By comparing the different colour composites, a selection was made, which was used for vegetation, mixed and settlement differentiation. Filling of sink was carried out in order to regulate the elevation or depression value (Olaniyan, 2015).

C. Data Analysis

Data were analysed in ArcGIS 10.0 and Surfer 8 softwares to generate the DEM, elevation map, watershed map, drainage map, slope map, land use map, flow accumulation and flow length for this research.

III. RESULTS AND DISCUSSION

A. Digital Elevation Model (DEM)

The Digital Elevation Model in Figure 2 revealed that Oluyole catchment area consists of areas with high, medium and low elevation within the terrain. Figure 2 represents the DEM of the study area which ranges between 105 – 195 m. The values within 105 m indicate the lowest point on the map while the areas with values within 195 m represent the peak of the study area. Values from 195 – 170 m, 165 – 140 m and 135 – 105 m show areas of high, medium and low elevation which are less, moderately and highly vulnerable.

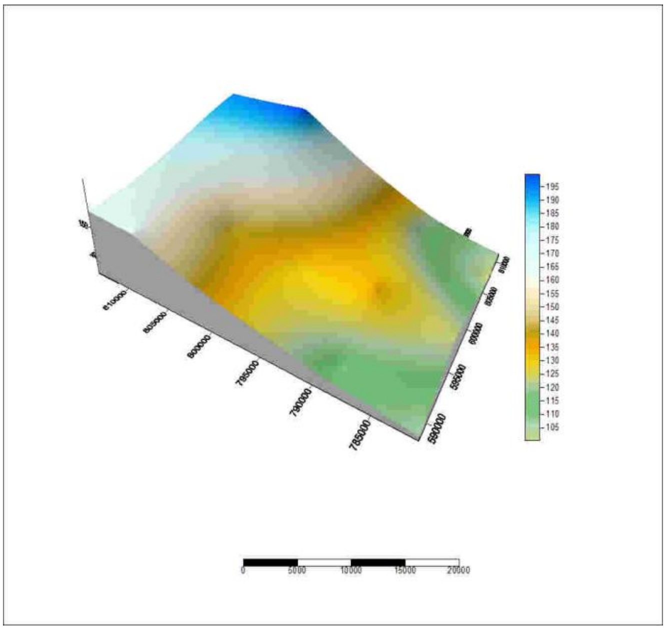

Figure 2: DEM showing a 3D view Developed from Surfer 8

A. Aspect Map of the Study Area

The aspect map which represents the degree direction of the topographic slope and physical landscape characteristic ranges from -1^o to 360^o (North direction). The aspect map of Oluyole catchment area which was generated from surface raster of the area with an Azimuth angle of light source was measured clockwise from north and altitude directly overhead. Oluyole catchment area is generally between 0^o – 337.5^o which indicates a North to Northwest direction. It is predominantly 67.5^o – 112.5^o (East direction), 157.5^o – 202.5^o (South direction) to 292.5^o – 337.5^o (Northwest direction). The catchment area is occupied by vegetation, settlement and mixed (combination of vegetation and settlement) going by the result from the legend of the map in Figure 4.3. The areas covered by vegetation, settlement and mixed (vegetation and settlement) are not, highly and moderately vulnerable to flooding and erosion. The aspect map was also used to determine the down slope direction of the maximum rate in value from each cell to its neighbours. The complexity of a terrain surface may be described by the concept of its roughness and irregularity which are characterized by different numerical parameters such as roughness vector relief.

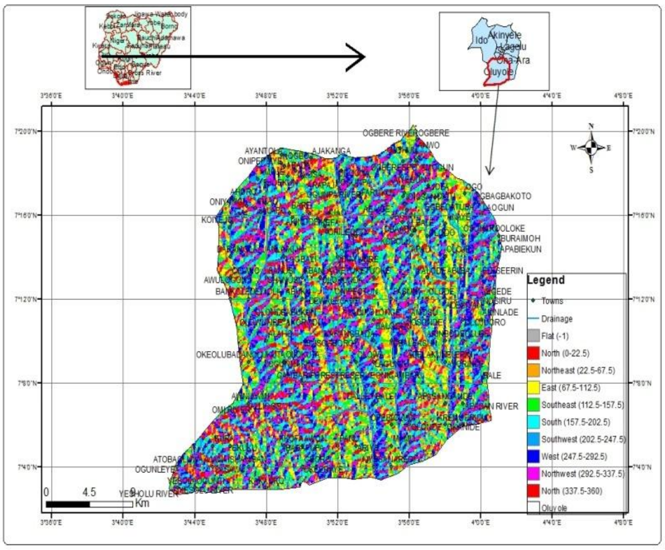

Figure 3: Aspect Map of the Study Area

B. Slope of the Study Area

The slope map of Oluyole catchment area which represents the degree of steepness of a surface ranges between 0^o – 2.78^o, 2.79^o – 6.15^o and 6.16^o – 24.51^o. It represents the steepness and direction of slope of study area in the descending order of the percentage showing the directing of flow of water. The river channels and the flood plains are characterized by very low gradients (0^o- 2.78^o) while the areas with moderate and high relief have surface gradients of 2.79^o- 6.15^o and 6.16^o- 24.51^o, respectively. Surface gradient influences runoff and precipitates erosion. The knowledge base ranking of the risk values of slope steepness map to soil erosion was based on the ascending order of slope degree as shown in the slope map of Oluyole catchment area.

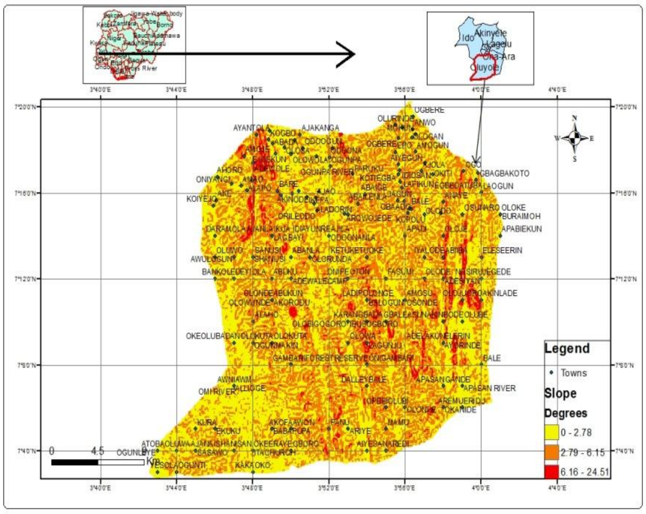

Figure 4: Slope Map of the Catchment Area

In Figure 4.4, the first level with yellow colour indicates the low degree of hazard or instability while the second level with brown colour indicates the high degree of hazard or instability which can result into loss of arable land and the third level with red colour indicates the higher degree of hazard or instability which can endanger human life and property. This type of hazard is indicated on the map by corresponding erosion. Generally, the study of the slope of the area measured in degree shows values range between 0^o – 24.51^o, where 0^o represents areas with the lowest slope and 24.51^o represents areas with the highest slope. However, the areas with low slope (0^o - 2.78^o) show the lowland region while the areas with medium slope (2.79^o - 6.15^o) represent the plain region and the areas with high slope (6.16^o - 24.51^o) indicate the highland region.

C. Flow Direction of the Study Area

The flow direction which represents the direction of movement of water across the surface shows the flow of the cells from the values range between 1 – 32, 32.1 - 64 and 64.1 – 128. The map of flow direction in Oluyole catchment area represents the downward path for all water flowing on the surface of the area. The creation of flow direction which was also the first step in producing the stream networks in the study area was used to determine the flow accumulation in different cells within the area. Figure 4.10 shows that the area in red colour represents the area with low flow direction while the area in yellow colour represents the area with medium flow direction and the area in green colour represents the area with high flow direction. The areas with high flow direction (64.1-128) are more vulnerable to flooding and erosion while the areas with medium flow direction (32.1-64) are moderately susceptible to flooding and erosion and the areas with low flow direction (1-32) are less vulnerable to flooding and erosion.

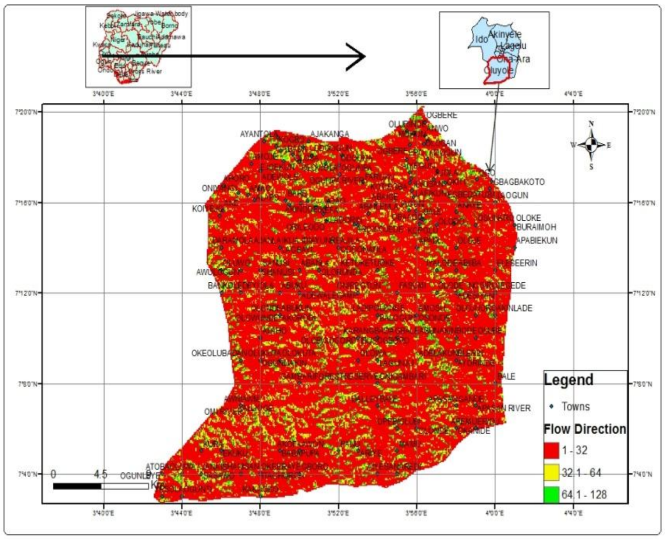

Figure 5: Flow Direction of the Catchment Area

D. Flow Length of the Study Area

The flow length which represents the distance at which water flows in the catchment is one of the factors used to determine the flood and erosion risk areas. The flow length in Oluyole catchment area varies between 0 and 43309.3 m. The lowest flow distance is between 0 – 13247.5 m while 13247.6 – 27174.4 m is the average flow length and the highest flow distance is between 27174.5 – 43309.3 m. However, the area in olive lighter green colour represents the area with the shortest flow distance while the area in olive light green colour represents the area with the moderate flow distance and the area in olive dark green colour represents the area with the longest flow distance. Figure 4.11shows that the areas with long flow length (27174.5 - 43309.3 m) are more vulnerable to flooding and erosion while the areas with medium flow length (13247.6 - 27174.4 m) are moderately vulnerable to flooding and erosion and areas with low flow length (0 - 13247.5 m) are less susceptible to flooding and erosion. Therefore these areas pose more threat of flood and erosion the others.

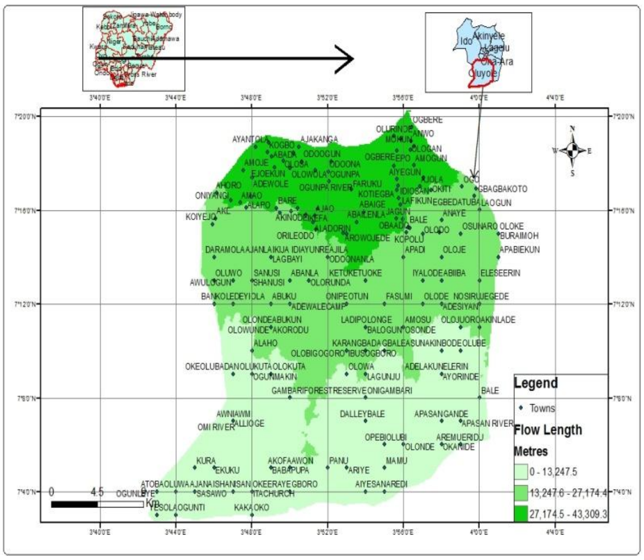

Figure 6: Flow Length of the Study Area

E. Flow Accumulation of the Study Area

Figure 6 shows the flow accumulation of the study areas which vary between 0 – 136782 m with the areas with low values representing areas that are ridges and areas with high values representing areas that are stream channels or concentrated flow. The area with the values range between 55785.7 – 136782 m represents the areas with the highest flow or accumulation of water while the areas with 12873.6 – 55785.6 m represents the areas of average concentration of river or stream channels and areas with 0 – 12873.6 m represents areas that are ridges or colour represent the areas with low flow accumulation while the areas in yellow colour show the areas with medium flow accumulation and areas in red colour indicate the areas with high flow accumulation. The areas with high flow accumulation are more vulnerable to flooding while the areas with medium accumulation are moderately susceptible to flooding and areas with low flow accumulation are less susceptible to flooding.

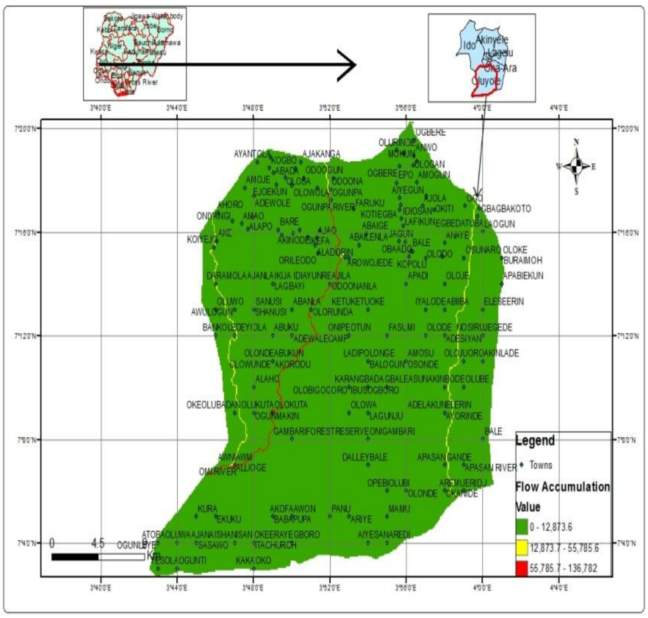

Figure 7: Flow Accumulation of the Study Area

F. Drainage Map of the Study Area

Drainage basins which represent the areas where all surface water flowing on the terrain flow out from a common or s single outlet. Drainage of the catchment area indicates watershed boundaries and represents the main river and its attributes assisting in seeing the direction of flow of water. The areas with high drainage have dense vegetation, low relief region and high resistance while the areas with low drainage have sparse vegetation and mountainous relief. The reason for this is because of sufficient aeration is available in the area of high drainage whereas little aeration is available in the area of low drainage. Figure 4.5 shows that the streams are deflected from their original (straight) path and follow transitional course. Steep rocky catchments with less vegetation produce more runoff while flat areas with more vegetation produce less or no runoff. Reasons for more frequent flood in Ogunpa when compared with Ogbere drainage basin are not far- fetched. Ogbere drainage basin is larger in size, a factor which affect its length (the larger the basin, the longer its length). The longer the length of a basin, the lower the chances that such a basin will be flooded when compared with a more compact basin like Ogunpa river. This is because, the longer the basin, the lower its slope. Not only this, time of concentration (lag time) in such a basin will be higher than a more compact basin which produces sharp hydro graphic peak due to high bifurcation ratio. This led to rapid withdrawal of water from such a basin. High concentration time thus exposes the water intercepted by Ogbere river drainage basin to longer duration of infiltration and evaporation process, hence reduction in runoff volume. Other reasons which might have promoted higher incidences of flooding in Ogunpa river when compared with Ogbere river include higher drainage density, higher relief and circulatory ratio. Relief ratio is an indicator of rates of erosion operating along the slope of a basin. Ogunpa river basin has higher relief ratio when compared with Ogbere river basin hence, the higher erosive capacity and sediment yields which disposes the basin to higher flood peaks. Higher circulatory ratio recorded by Ogunpa river drainage basin is in conformity with proposition. Ogunpa river have shorter time lag, shorter time of rise and higher hydro graphic peak; hence the frequency of flood in the basin.

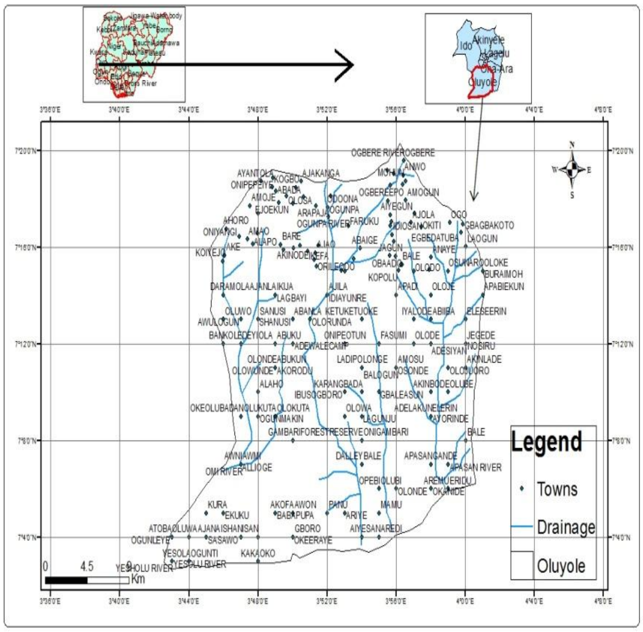

Figure 8: Drainage Map of the Catchment Area

CONCLUSION

GIS and Remote sensing techniques have proved to be accurate, effective and efficient tool in drainage delineation. Flow length, direction and accumulation of basin indicate that the basin is fourth order basin with dendritic type of drainage pattern with homogeneous nature and there is no structural or tectonic control. The visual interpretation of DEM of study area indicates low, moderate and high relief, low, moderate and high run off with low, medium and high infiltrations with early flood and erosion development. The morphometric analysis of drainage basin indicates that the study area has low, medium and high groundwater potential. Drainage works are very vital instruments in controlling flood and erosion which are great threat to the developing countries like Nigeria, especially the south eastern and western parts of the country. These parts of the country are characterized by loose soils which have been devastated by flood and erosion as a result of poor drainage system. Care should be taken to avoid the destruction of infrastructural, health and other amenities by floods and erosion as a result of poor drainage system. The results show that the larger the basin, the greater the volume of rainfall it intercepts, and the higher the peak discharge. The deterioration drainage system has negative impact on the environment and health of the people around the study area and should be corrected as a matter of urgency. The longer the length of a basin, the lower the chances of flood and the longer the basin, the lower its slope. The time of concentration (lag time) in such a basin will be higher than a more compact basin which produces sharp hydrographic peak due to high bifurcation ratio. High concentration time thus exposes the water drainage basin to longer duration of infiltration and evaporation process, hence reduction in runoff volume. The higher erosive capacity and sediment yields which disposes the basin to higher flood peaks. The shorter the basin length, the closer to the circulatory ratio. Routine inspection and monitoring of the drainage system should be carried out to avoid distort or break of the system. The government should provide a suitable drainage network and the optimal drainage network for future developments of the area, so standard drainages have to be built-up.

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