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APPLICATION OF GEOGRAPHIC INFORMATION SYSTEM AND REMOTE SENSING IN THE DEVELOPMENT OF DRAINAGE PATTERN OF OLUYOLE LOCAL GOVERNMENT AREA, NIGERIA

*Lasisi, M. O., Akinola, F. F., & Awe, B. S.

Department of Agricultural and Bio-Environmental Engineering
The Federal Polytechnic Ado-Ekiti, Ekiti State, Nigeria
*Corresponding author email: lasisimukaila72@gmail.com

ABSTRACT

Remote Sensing (RS) and Geographical Information System (GIS) have become effective and efficient tools in identification of drainage pattern of any 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, geo-referenced and exported into ArcGIS 10.0 software. The digitized map was edited, and saved as line coverage in ArcGIS Software. This paper aimed at applying GIS and RS for the development of drainage system for Oluyole catchment area in order to prevent or reduce the persistent occurrence of flooding. 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, watershed, slope, flow direction, flow length and flow accumulation maps of the study area were generated by using the Digital Elevation Model. Results obtained indicated that the studied basins exhibited high, medium and low spatial variations in their morphometric properties. The results revealed that the use of remotely sensed data and ArcGIS 10.0 software provided an effective approach to develop accurate drainage pattern with a minimum amount of time, effort, and cost. This approach created easy to read and accessible charts and maps that facilitate the identification of drainage pattern of the study area. This study would help the local people to utilize the resources for sustainable development of the basin area.

KEYWORDS: Geographic information system; Drainage pattern; Development; Remote sensing

INTRODUCTION

Drainage basin area has been identified as the most important of all the morphometric parameters controlling catchment runoff pattern (Nabegu, 2005). This is because, the bigger the basin, the greater the volume of rainfall it intercepts, and the higher the peak discharge that result (Jain & Sinha, 2000). The occurrence of flood and has been on the increase all over the world especially in developing countries like Nigeria, as a result of poor drainage system. However, various control measures have come up over the years, but most of these have not focused on the identification of areas that are prone to high risk of flood in Oluyole catchment area. This oversight had led to loss of lives and properties worth billions of Naira in the recent past. The historical update showed that flood management have become the major issues to contend with in this catchment area, especially whenever there is an intense rainfall. This underscores the need for this study because it will facilitate a good flood management in the catchment area. The application of Geographic information system in the development of drainage pattern will reduce the persistent occurrence of flood in Oluyole catchment area.

Over the years, the response of government and relief agencies to floods in the Oluyole catchment area has been in the area of rescue and supply of relief materials to victims. Little has been done to ensure that the hazard is prevented and its associated risk reduced to the nearest minimum (Jeb & Aggarwal, 2008). Reduction of risk depends on the development drainage system in the areas that are at risk during flood events (Ishaya et al., 2009). The use of modern techniques in developing measures will help government in identifying the areas that are at risk and in planning against their reoccurrence in the future.

Flood control play an important role in the determination of the quality of metropolitan environment. The disposal of a city's floodwater poses one of the most critical environmental problems of urban living. Oluyole area is already built up, occupied with people and economic resources. The perennial menace of flood is critical along Ogunpa river as a result of inadequate drainage system, improper land use pattern, poor waste management, conscription of river channel and over flooding during heavy rainfall in Oluyole catchment area. This situation urgently calls for necessary control measure to forestall the persistent loss of lives, properties, social and health hazards that result in the huge socio- economic hardship on the people.

Drainage, watershed, aspect, flow direction, flow length, flow accumulation and slope maps are very essential tools in the identification and control of flood vulnerable areas (Orok, 2011). Remote sensing (RS) and Geographic Information Systems (GIS) have been used in generating drainage and watershed maps for identification of areas that are prone to flooding in the developed countries (Demessie, 2007). In developed countries, production of drainage map has become important criteria for carrying out some major development interventions (Orok, 2011). The results of this research will create easily read and accessible maps that can facilitate the identification of areas that are prone to flooding and also help to prioritize their mitigation and response efforts. The results will also focus on determining the drainage pattern which can be used by government for policy making and addressing current problems and future occurrence.

MATERIALS AND METHOD

Description of the Study Area

The study area is Oluyole Local Government Area, Oyo State, Nigeria. Its capital is Idi- Ayunre and it is located between latitude $7^{o}\ 30^{1}\ 00^{\ 11}$ N, longitude $3^{o}43^{1}00^{11}$ E, and latitude $7^{o}\ 20^{1}\ 00^{11}$ N, longitude $4^{o}28^{1}\ 00^{11}$ E, in the south western political zone of Nigeria. It has a tropical wet and dry climate, with a lengthy wet season and relatively constant temperatures throughout the course of the year. 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. There are pockets of grass land which are suitable for animal rearing, vast forest reserves and rivers.

Data Collection

For the research, satellite images of LANDSAT 7 sensor of 2006 ETM+, path 191 and row 55 of VHS with Latitude $7^{o}\ 30^{1}\ 00^{\ 11}$ N, Longitude

3º43¹00¹¹ E and Latitude 7º 20¹ 00¹¹ N, Longitude 4º28¹ 00¹¹ E 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 Oluyole Local Government Area was obtained from the office of the Surveyor General, Oyo State was used. The map was scanned and geo-referenced before it was imported into ArcGIS 10.0 software.

Data Analysis

Data were analyzed in Surfer 8 and ArcGIS 10.0 software to generate Digital Elevation Model, Triangulated Irregular Network, slope map, land use map, flow accumulation, flow length, and flood risk map for this research.

Digital Elevation Model (DEM)

The Oluyole catchment area was delineated in Google Earth and several points within the study area were marked within Google Earth and their coordinates and elevations were recorded in a Microsoft Excel spreadsheet. The X, Y and Z point data was exported to Surfer 8 software where the data were re-sampled to a grid interval of 10 m. The re-sampled data was blanked from the blank file and then the digital elevation model of the study area was generated. High resolution imagery was required for a clear depiction of the extent of vulnerability (Muhammad, 2013).

Drainage, watershed, slope, flow direction, flow accumulation and flow length maps

Drainage, watershed, slope and flow direction maps were developed by using the appropriate tools in the hydrological tool box. The flow accumulation which represents the cell within the study area where water accumulates as it flows downwards was developed by using the flow accumulation function in the spatial analyst tool box and flow length which represents the distance at which water flows in the study area was generated by using the flow length function in the spatial analyst tool box (Noha, 2009).

RESULTS AND DISCUSSION

The following results were obtained from the field and desk work of this study;

Digital Elevation Model (DEM)

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

Aspect Map of the Study Area

The aspect map represents the degree direction of the topographic slope and physical landscape characteristic ranges from -1º to 360º (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 0º – 337.5º which indicates a North to Northwest direction. Figure 3 is the predominantly 67.5º – 112.5º (East direction), 157.5º – 202.5º (South direction) to 292.5º – 337.5º (Northwest direction). The aspect map was also used to explain 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.

Slope of the Study Area

The slope map of Oluyole catchment area 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 direction 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. In Figure 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.

Drainage 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 as shown in Figure 5. 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 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 rate 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.

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 6 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.

Flow Length of the Study Area

Figure 7 shows that the flow length varies between 0 – 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.

Flow Accumulation of the Study Area

Figure 8 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 have 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 and erosion while the areas with medium accumulation are moderately susceptible to flooding and erosion and areas with low flow accumulation are less susceptible to flooding and erosion. The areas with high flow accumulation in Oluyole catchment area are suitable for the cultivation of rice, sugar cane and vegetables

Watershed of the Study Area

Watershed which refers to the collection of rainwater and drains to a single outlet within the catchment area varies between 0 – 13428 m, 134281-27426 m and 27461-43309 m. The watershed of Oluyole catchment area represents the flow accumulation which gives a cumulative count of the number of pixels that naturally drain into outlet within the area. As input, the operation used the output map of the flow direction operation. The output map contains cumulative hydrologic flow values that represented the number of input pixels that contribute any water to any outlet (or sinks if these have not been removed). The outlets of the largest streams and rivers will have the largest values. The operation was used to determine the drainage pattern of a terrain of the catchment area. In Figure 9, the area in dark red represents the area with high watershed while the area in deep red shows the area with medium watershed and area in light red indicates the area with low watershed. The area with low values range between 0 - 13428 m represents the areas with low watershed while areas with the average values range between 134281 – 27426 m represents the areas with moderate watershed and the areas with 27461 – 43309 m represents the areas with high watershed.

CONCLUSIONS AND RECOMMENDATIONS

This study was carried out with the aim of applying Geographic information system and remote sensing to develop a drainage system for controlling or reducing the persistent occurrence of flood in Oluyole Local Government Area, Ibadan, Nigeria. The remotely sensed imageries were acquired from LANDSAT sensor 7 of 2006 ETM+ and Google Earth, and the analysis was carried out with ArcGIS 10.0 and Surfer 8. The Digital Elevation Model (DEM) was generated, reclassified and integrated with imageries of the area to show areas of different vulnerability to flood risk. The results indicated that the used of remotely sensed data and ArcGIS 10.0 software provide an effective approach to apply accurate watershed analysis in generating drainage and watershed maps to prevent or reduce the persistent occurrence of flood with a minimum amount of time, effort, and cost. The DEM was used to analyze the terrain of the study area. The slope map revealed that the areas with low, medium and high slope are less, moderately and highly vulnerable to erosion. The map showed that the areas of high, medium and low elevation are low in vulnerability, moderately vulnerable and highly vulnerable to erosion. Drainage map can be used to design a model for early identification of flood prone properties during emergencies which allow public safety organizations to establish warning and evacuation properties; government agencies can initiate corrective and remedial efforts before disaster strikes. Finally, residential buildings should not be erected in the high risk zones and riparian vegetation should be planted to act as flood breaks, reducing the velocity of flow.

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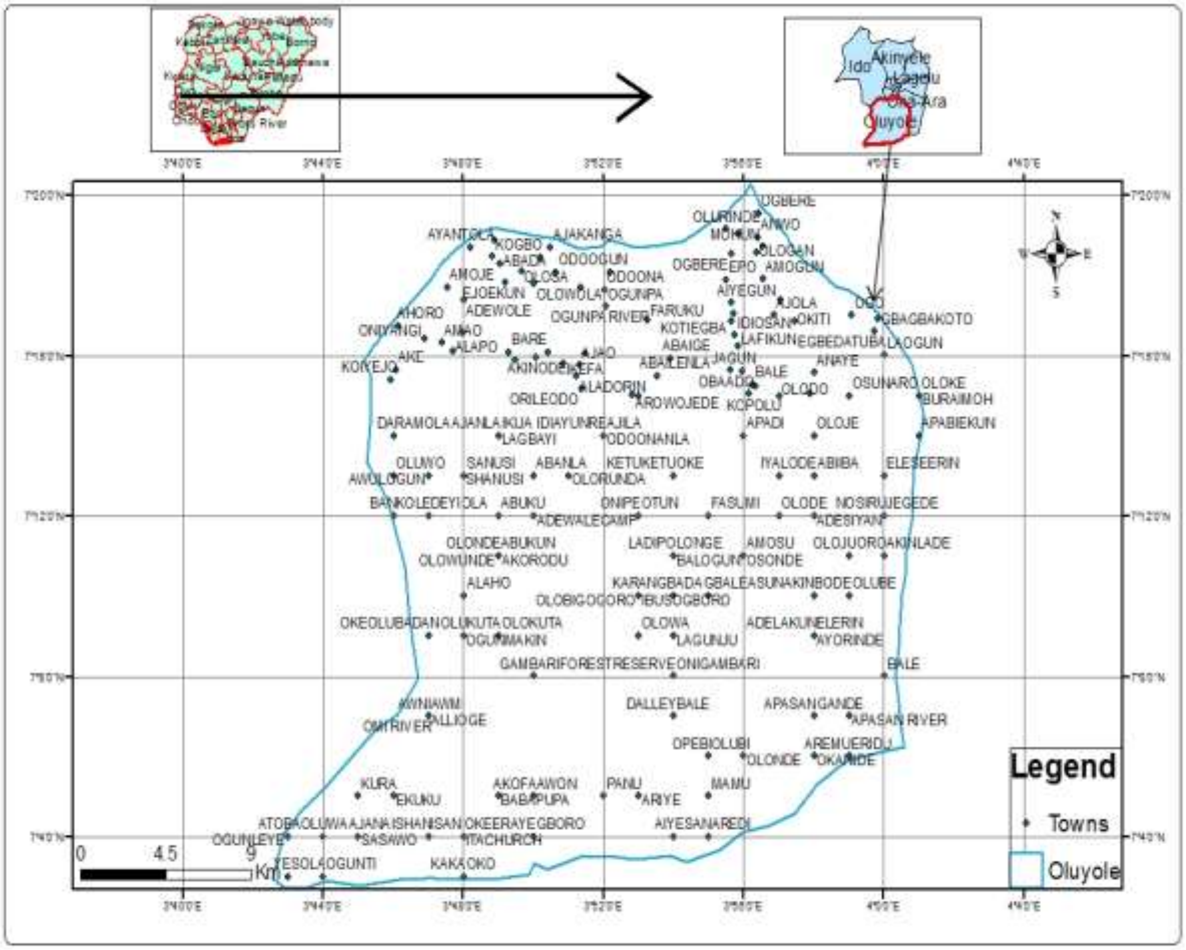

Figure 1. Map of Oluyole Local Government Area

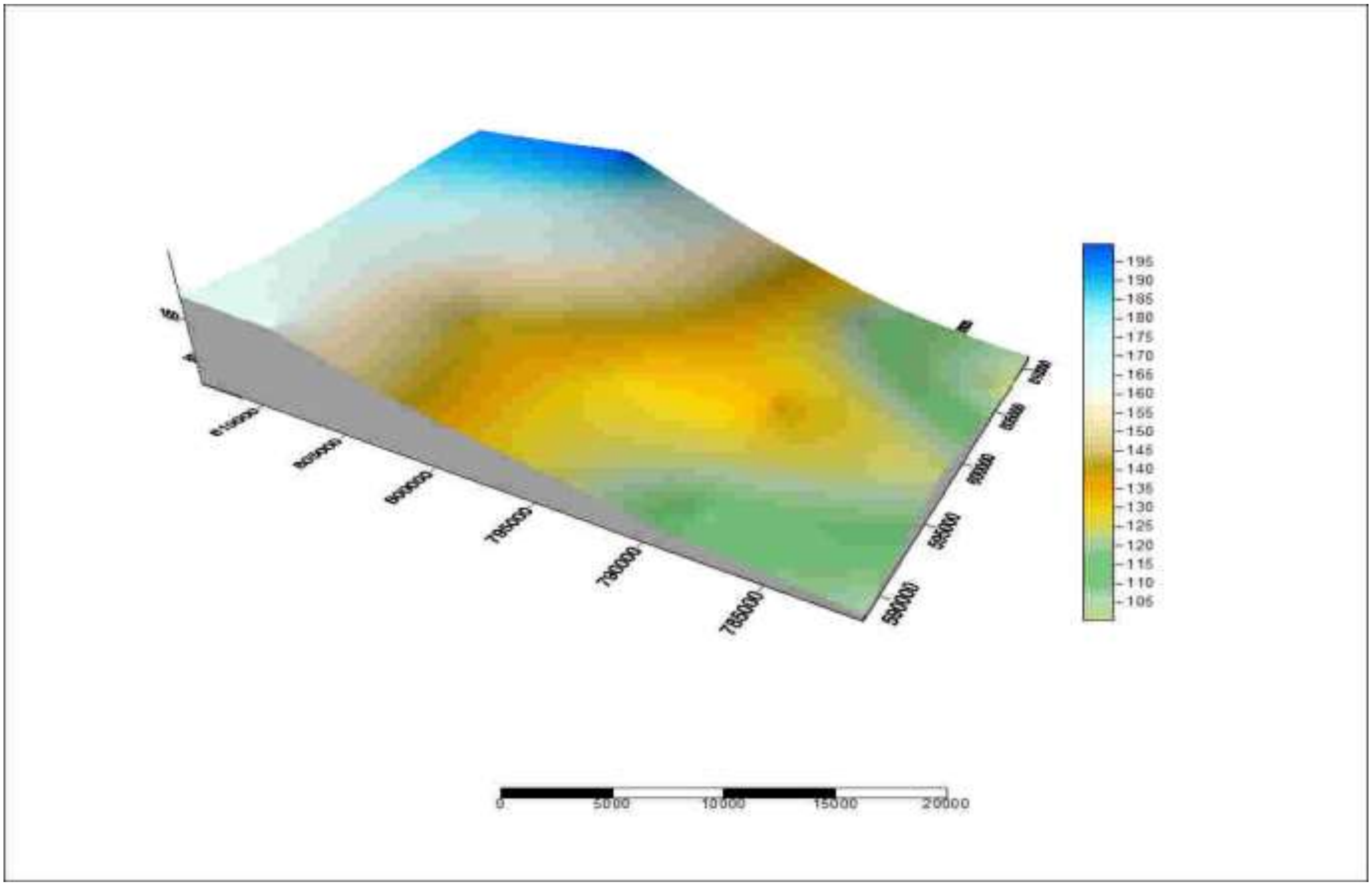

Figure 2. DEM showing a 3D view Developed from Surfer 8

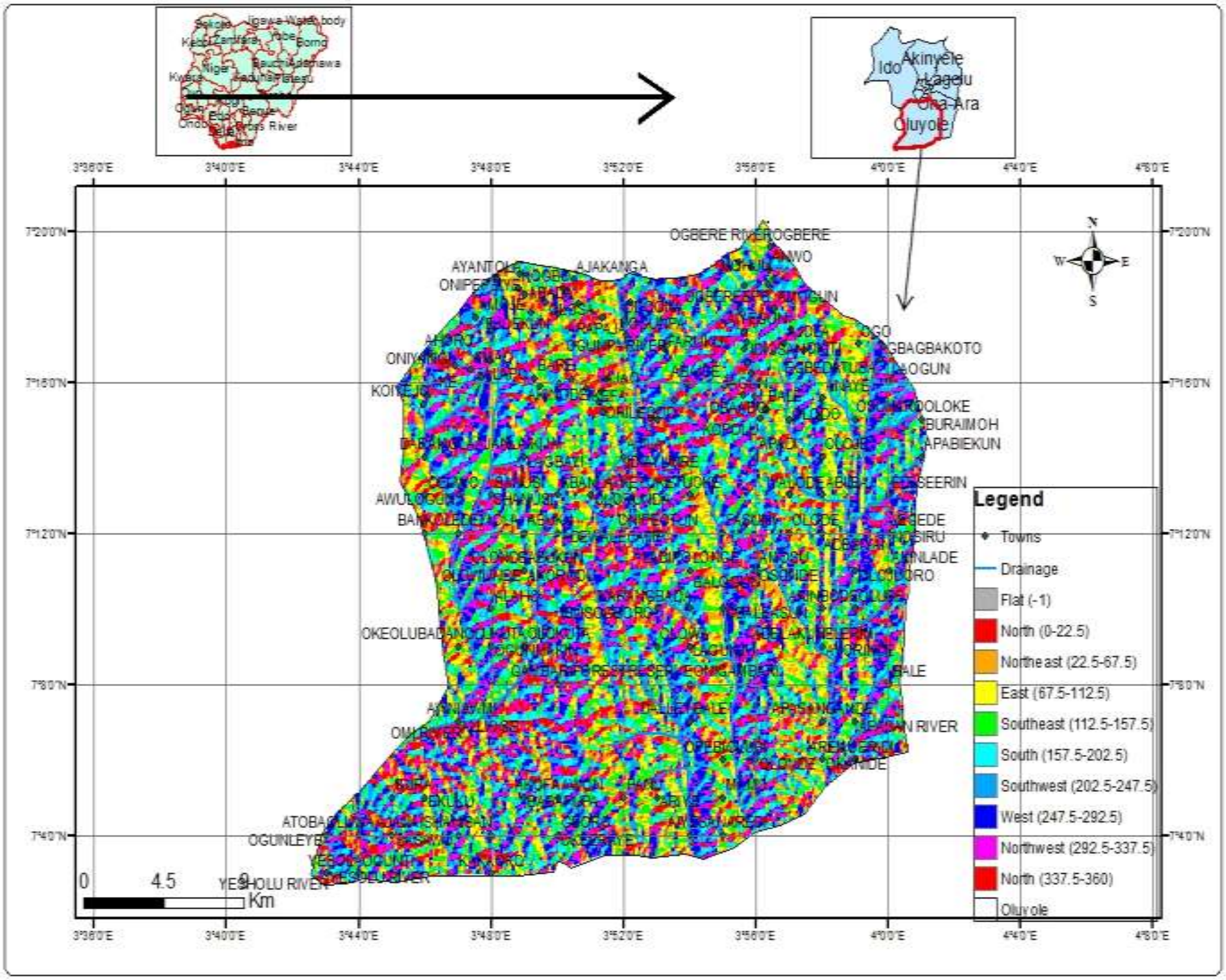

Figure 3. Aspect Map of the Study Area

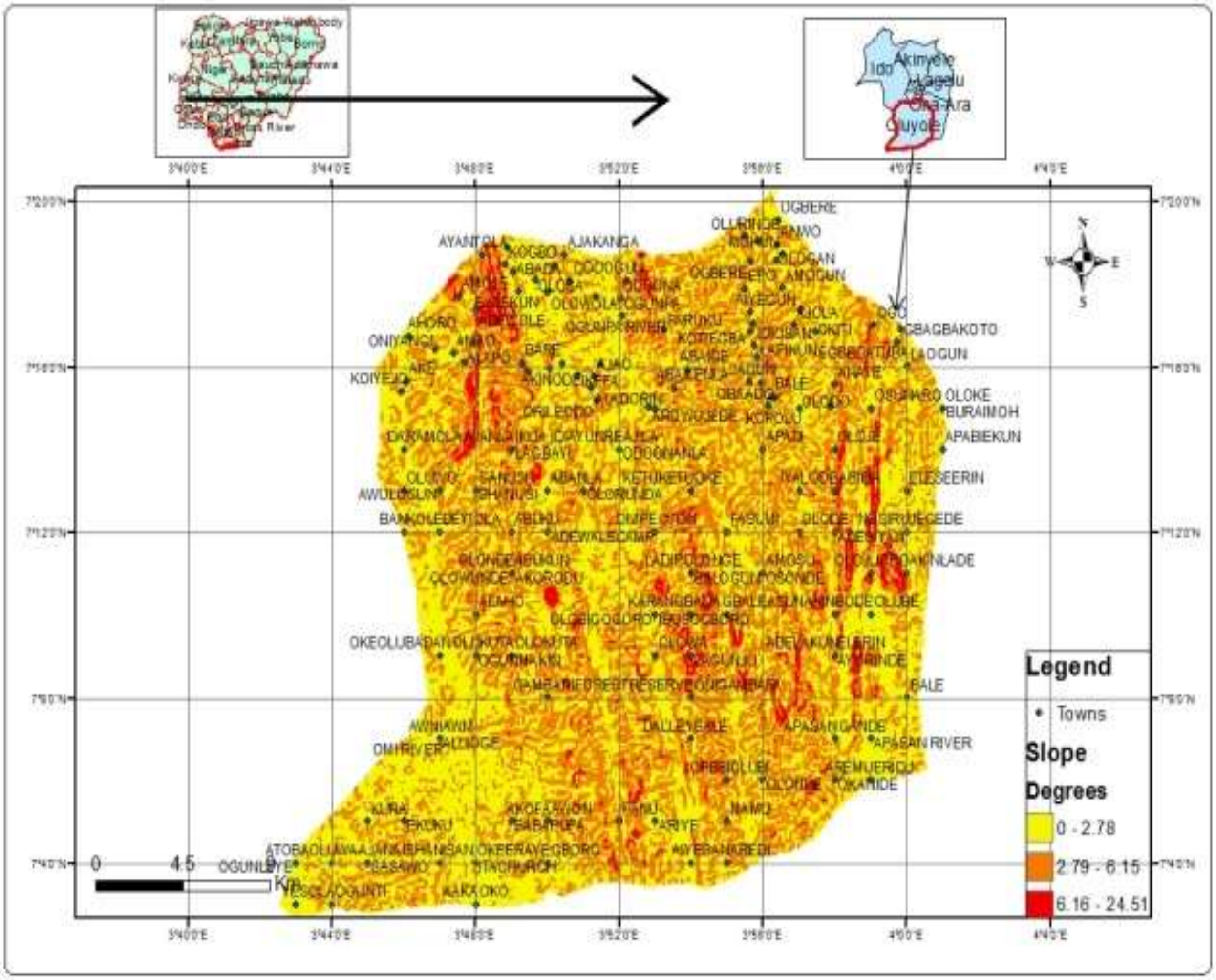

Figure 4. Slope Map

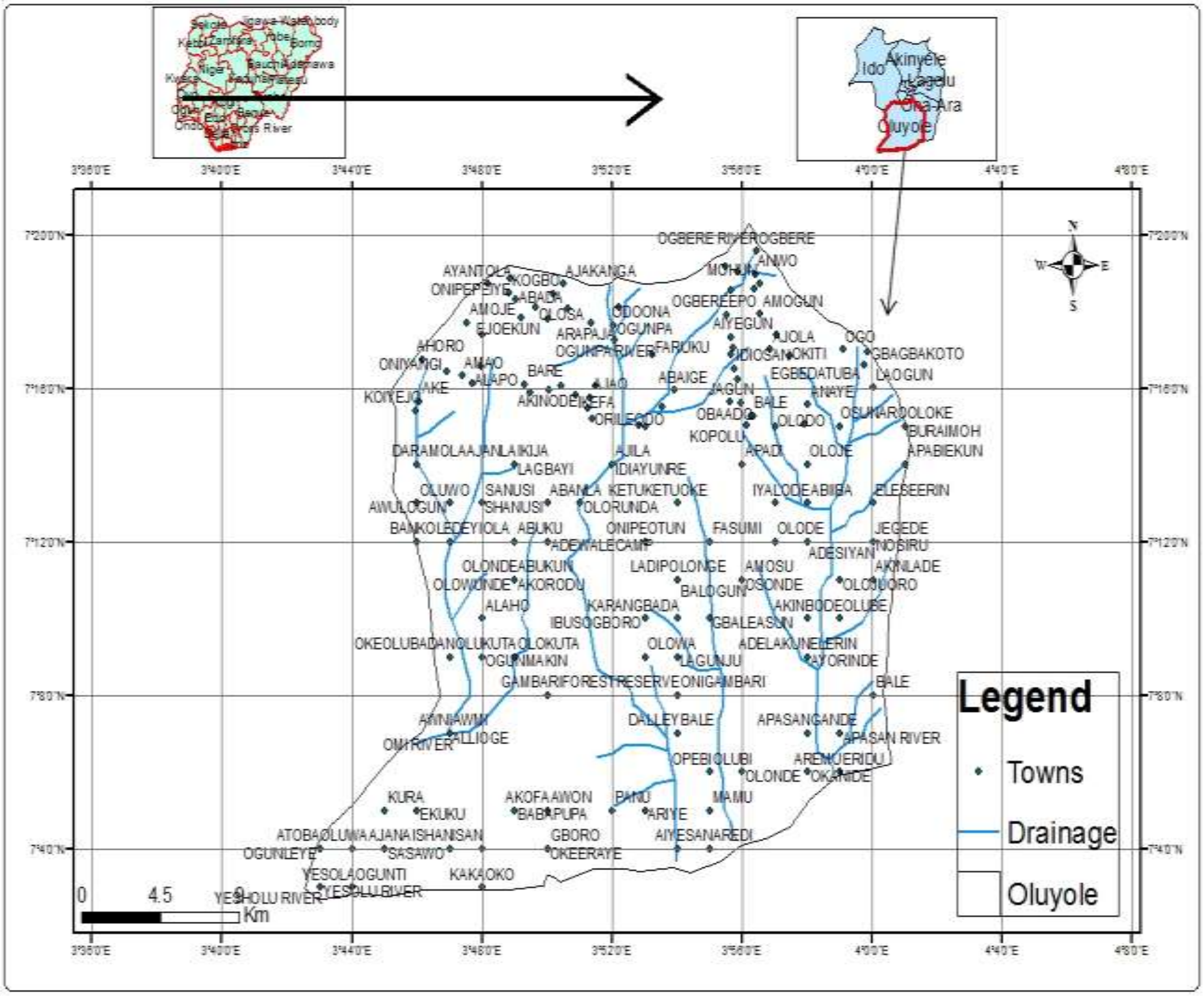

Figure 5. Drainage Map of the Study Area

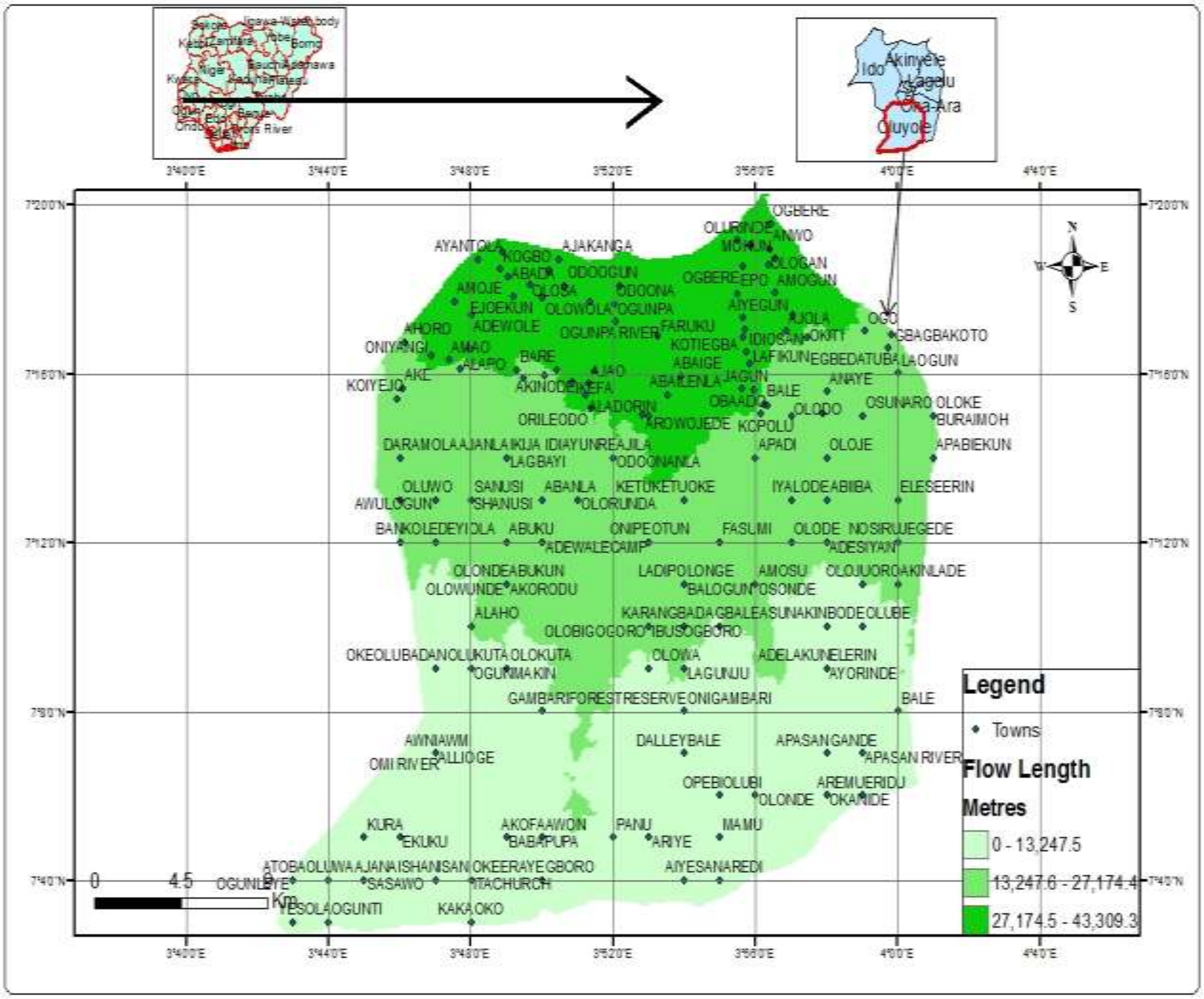

Figure 6: Flow Direction

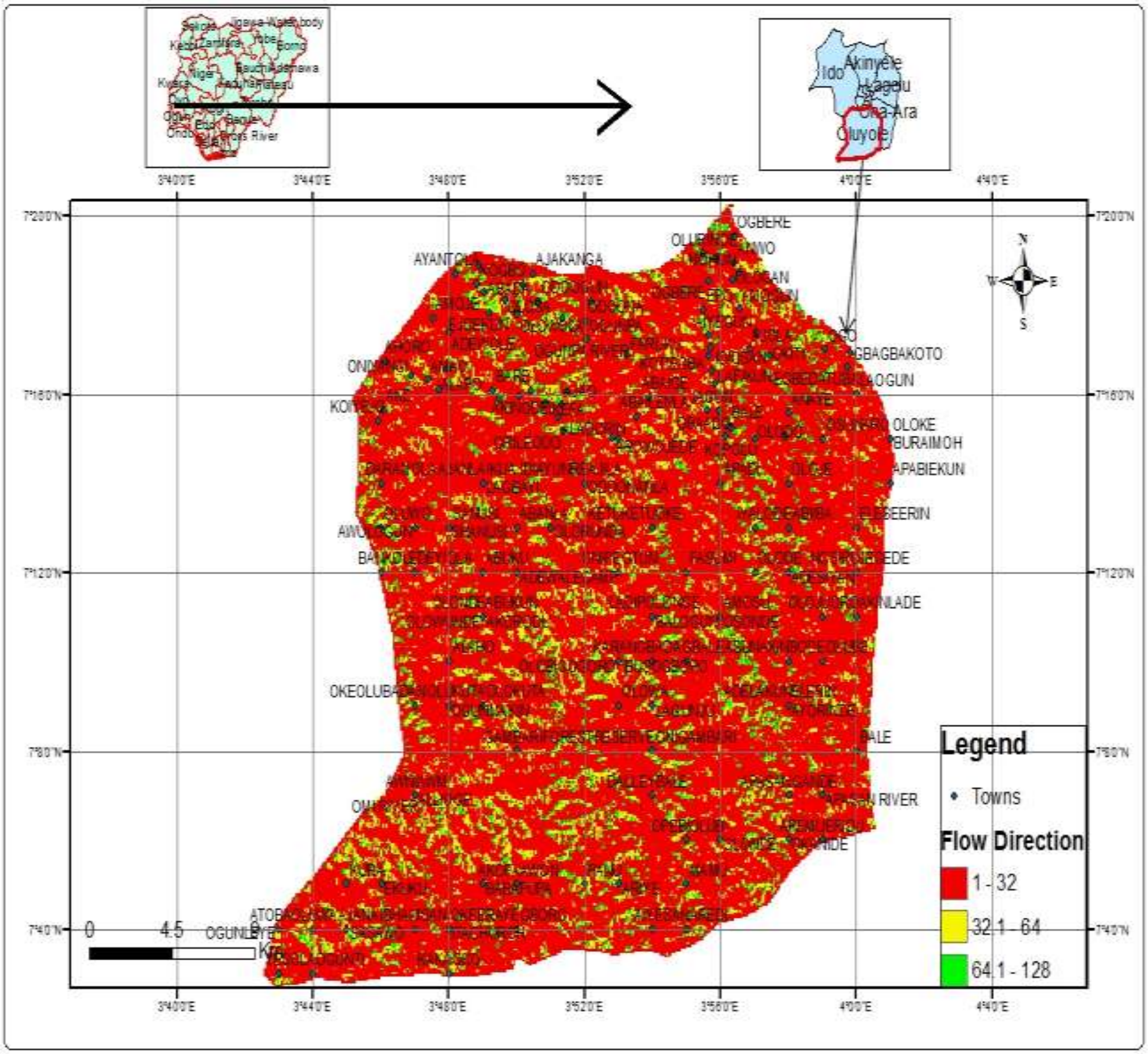

Figure 7. Flow Length of the Study Area

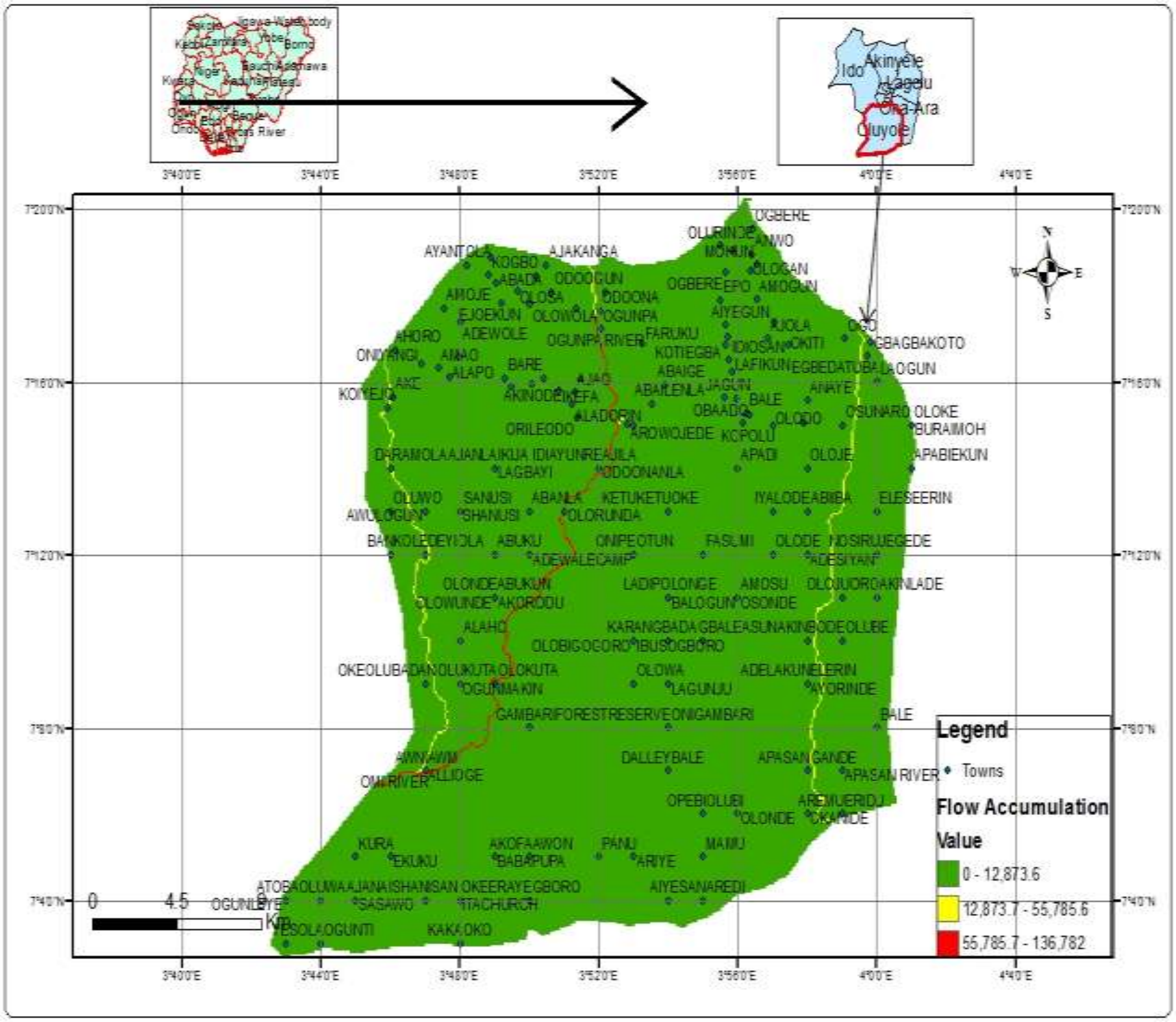

Figure 8. Flow Accumulation of the Study Area

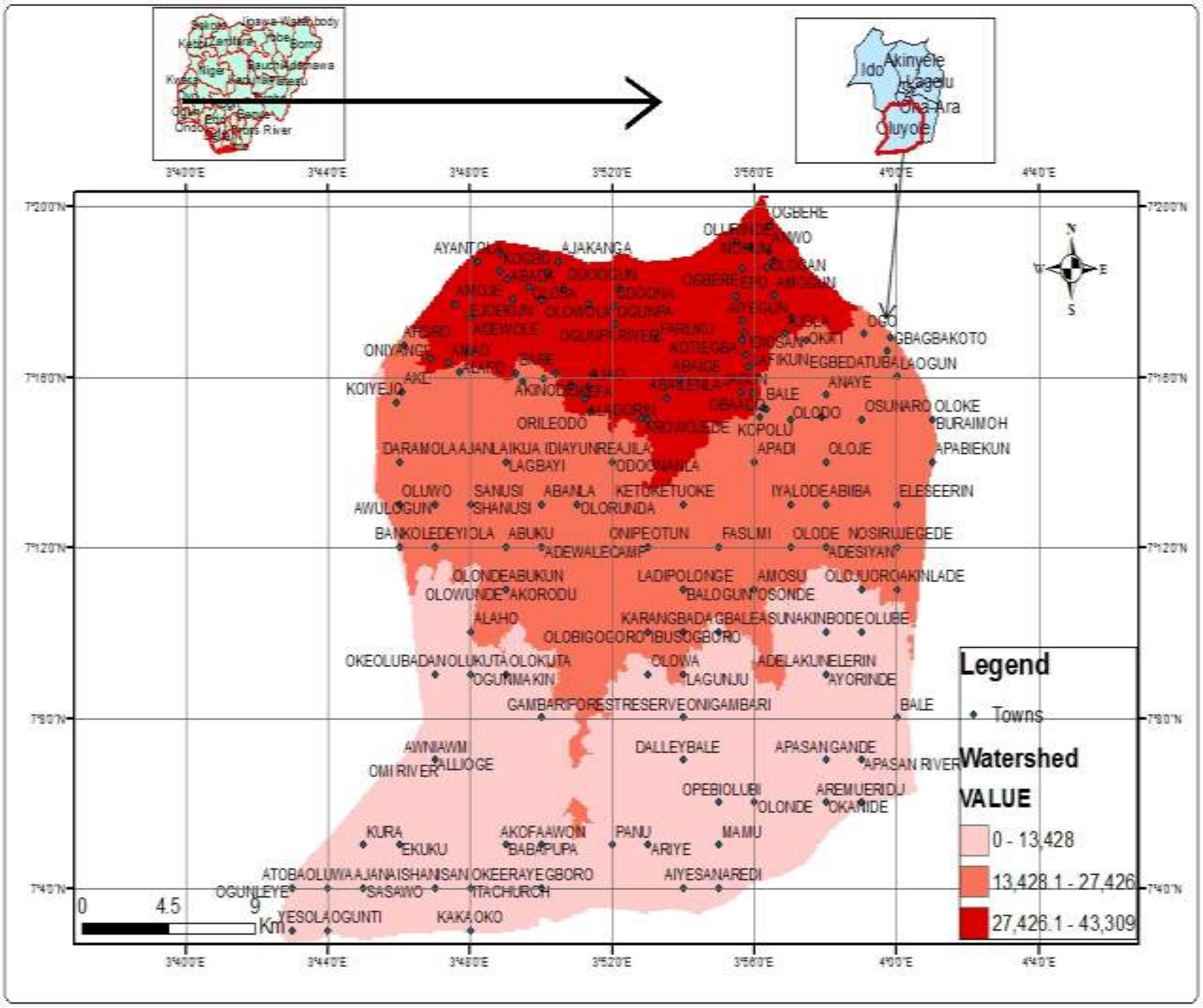

Figure 9. Watershed Map of the Study Area