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**APPLICATION OF GEOSPATIAL TECHNIQUES DAM SITE SELECTION IN ONDO  
AND EKITI STATES, NIGERIA**

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**ABSTRACT**

Application of remote sensing (RS) and geographic information system (GIS) techniques in hydrology is today one of the most effective approaches for possible dam site selection. Digital elevation models (DEMs) as well as layers produced by RS and GIS provide a solid geospatial data foundation, which is suitable for selecting the possible dam sites for hydro power stations. The study aimed to demonstrate the use of remote sensing and geographic information system in dam site selection within the context of a catchment scale. Google Earth and Enhanced Thematic Mapper Plus (ETM+) from LANDSAT 7 were used to acquire the satellite imageries of the possible areas. Using high resolution imageries from the Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER 30m), a Digital Elevation Model (DEM) was developed with Surfer 8 to characterise the catchment area. ArcGIS 10.0 was used to develop the flow direction, flow length and flow accumulation maps. The flow direction, flow accumulation and flow length maps were combined with land use map to produce the major and mini hydro power dam maps with the use of map algebra in ArcGIS 10.0 software. The results shows that the areas with main hydro-power stations are areas that are closest to the main prominent rivers with their several tributaries and are located on low relief while areas with mini hydro-power stations are far away from the main rivers. The study area has three prominent rivers (Rivers Ogbese, Owena and Ose) and their several tributaries (Rivers Ala, Elegbin and Ureje). The results also shows that the areas in red colour represents the areas that are suitable for major hydro-power stations while the areas in yellow colour represent the areas that are suitable for mini hydro-power stations. The used of remotely sensed data and ArcGIS 10.0 software provide an effective approach to develop accurate possible dam sites with a minimum amount of time, effort, and cost. This approach creates easily read and accessible charts and maps that facilitate the identification of possible areas and also can be used effectively in planning.

**Keywords:** Geographic information system, remote sensing and dam selection

**1. INTRODUCTION**

Application of remote sensing and GIS techniques in dam site selection is today one of the most effective approaches. Remote sensing has provided valuable datasets to examine hydrological variables and morphological changes over large regions at different spatial and temporal scales. GIS and remote sensing can provide a huge amount of valuable data in spatial and temporal

resolutions for areas where ground data are not easily available. In 2008, GIS and remote sensing techniques were applied by Forzieri *et al.* (2008) to assess the suitability of sites for the installation of small dams for the purpose of water harvesting in arid areas. In a similar study, Singh *et al.*, (2009) used the slope, soil infiltration rate, land use and soil type.

Shafapour (2015) described in detail a workflow for the Digital Elevation Model (DEM) pre-processing and extraction from ASTER images including accuracy estimation. In addition to the low spatial and temporal resolutions in the majority of remote sensing imagery, data accuracy in most related research is still a dilemma. A review by Sanyal and Lu (2004) on the application of Remote Sensing in flood management noted that DEM model is the main part of dam site mapping. In particular, slopes data from DEM are useful for many hydrological studies and can be employed for dam location selection. Furthermore, a limited effort has been devoted in recent years to determine the capability of these techniques in assisting engineering dam design by allowing efficient, quick and economic data collection (Salih, 2012).

Kumar (2009) used remote sensing and GIS techniques to assign the location of small water harvesting structures across streams/watersheds. Various thematic layers such as Land use/Land cover, geomorphology and lineaments were used. These layers along with geology and drainage were integrated using GIS techniques to derive suitable possible dam sites. In addition to the suitable site selection of the dams, they calculated the storage and transmittance of groundwater in the study area. Youssef *et al.* (2014) furthermore, proposed three dam site locations for Jeddah City in Saudi Arabia based on topographical analysis using different data sets such as topographic maps, remote sensing images, a digital elevation model with 90-m resolution (STRM 2000) and geological map. In addition, these selected locations were in the outlet areas where large tracts of land could be temporarily inundated by water as a result of water being held back by the proposed dam.

Salih *et al.*, (2012) applied most recently satellite data (Synthetic Aperture Radar (SAR)) for the precise monitoring of earth dams ground deformation. They found high agreement between final SAR and in-situ instrumental data, which demonstrated the reliability of such a technique for future use.

## **2.MATERIALS AND METHODS**

Google Earth and LANDSAT Thematic Mapper (TM) were used to acquire the satellite imageries of Rivers Owena, Ogbese and Ose in Ondo and Ekiti States, Nigeria. A topographic map (scale: 1:200,000) of Ondo and Ekiti States was obtained from the office of the Surveyor General, Ondo State. Figure 4.1 shows the map of Rivers Ogbese, Osse and Owena in Ondo and Ekiti States. The map was scanned and geo-referenced before it was imported into ArcGIS 10.0 software. Pre-processing of the data was done to eliminate any discrepancies of mismatching during overlaying of the image. This was done with the aid of topographic map and images. And image enhancement was carried out in order to improve the visual quality and to characterize the image. Band combination was also done through the analyses of reflectance properties of features. By using different TM 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 high, medium and low differentiation. The filling of sinks was carried out to regulate the elevation or depression value

to solve these problems (Olaniyan, 2015). The Rivers Ogbese, Owena and Osse as shown in Figures 4.2, 4.5 and 4.6 were 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). The slope map which is the degree of steepness of a surface was generated by using the slope function in the 3D analyst 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).

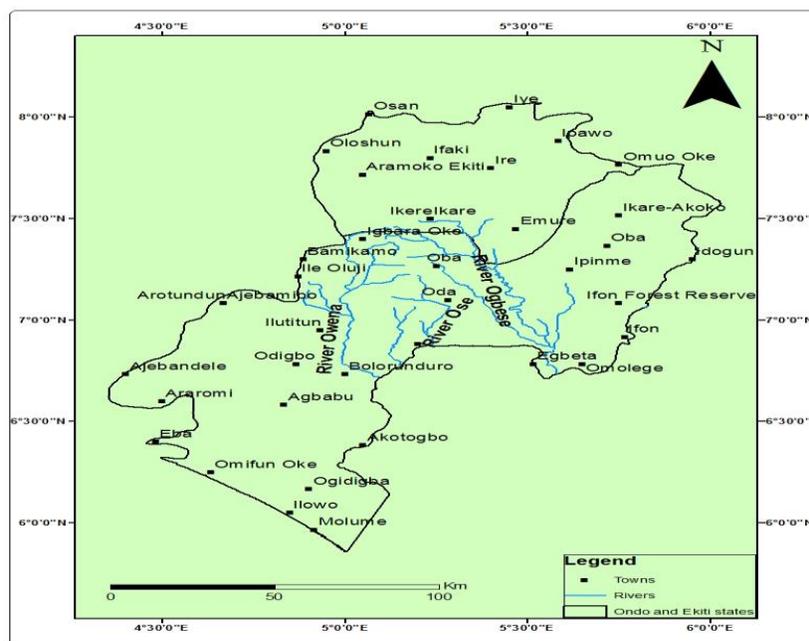


Figure 4.1: Map showing Ogbese, Owena and Ose rivers in Ondo and Ekiti States

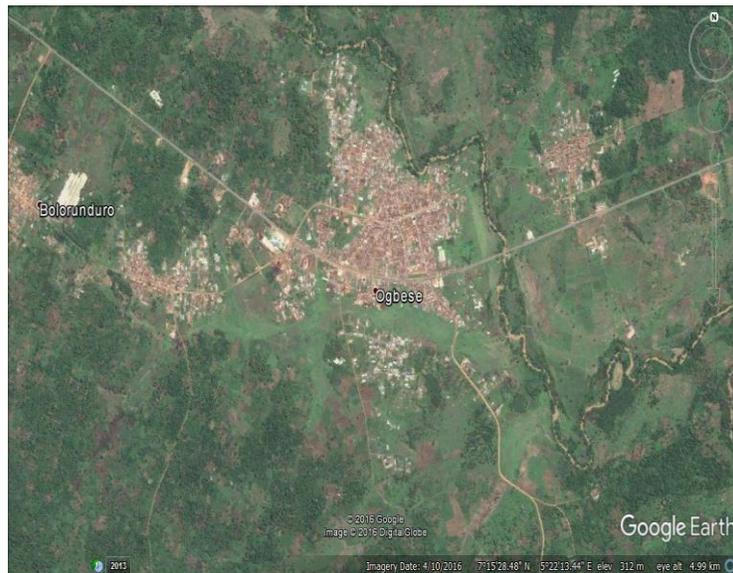


Figure 4.2: Satellite Imagery of Ogbese River, Ondo State  
Source: Google Earth of 2015

### 3.RESULTS AND DISCUSSION

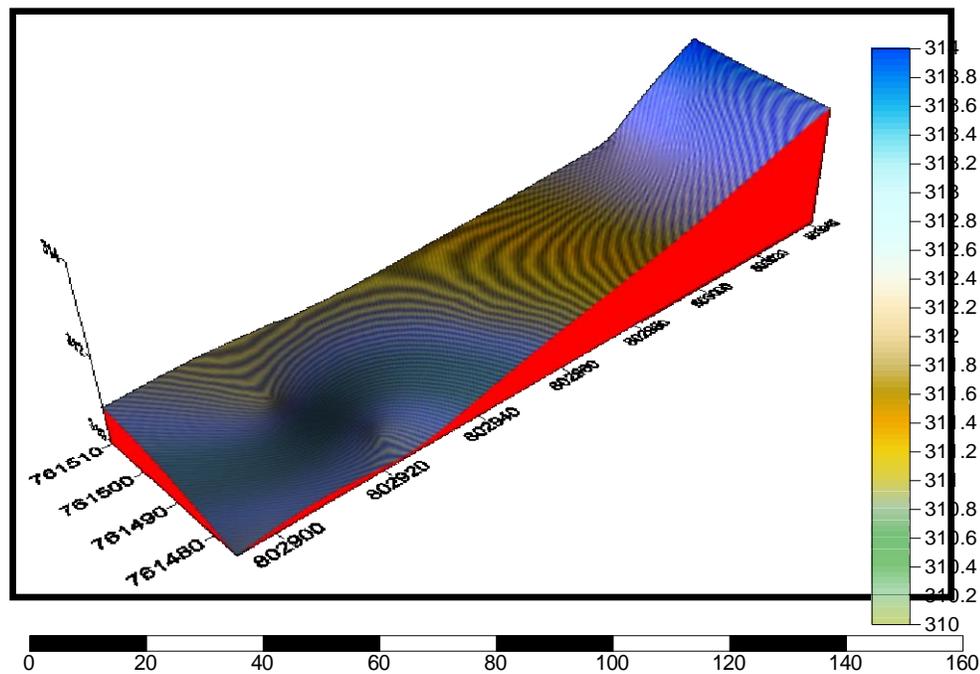
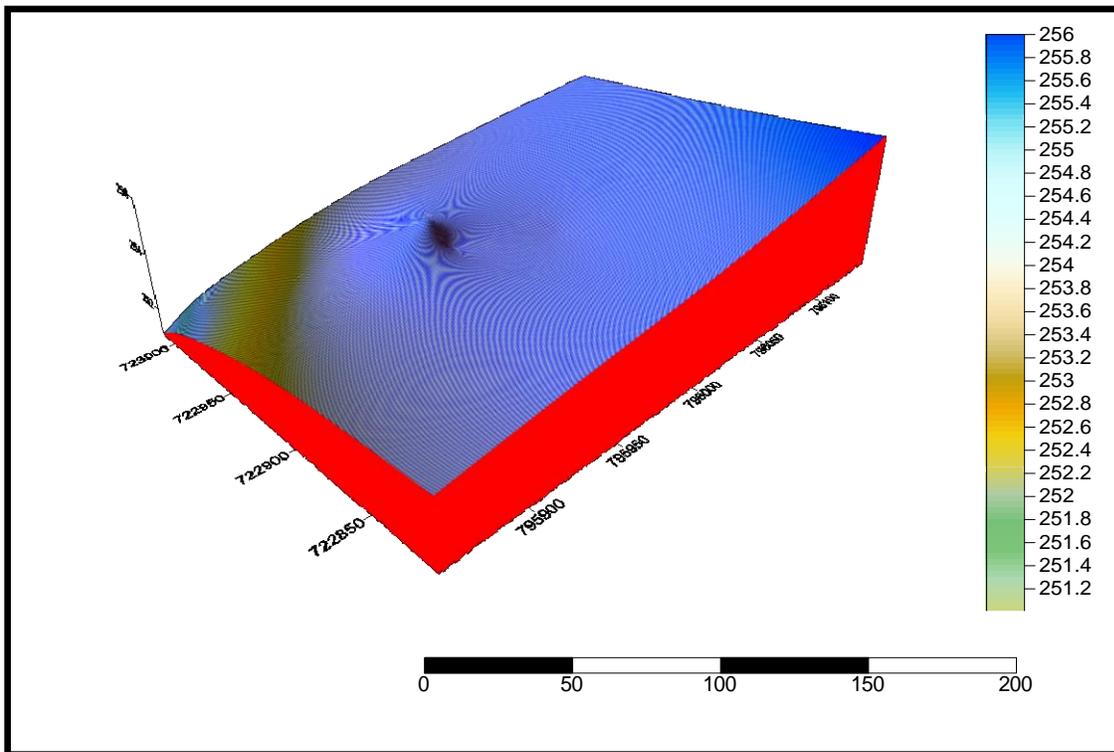


Figure 4.3: Digital Elevation Model (DEM) showing a 3D view developed from Surfer 8

Digital Elevation Model (DEM)

The coordinates and elevations of the study area were recorded as X, Y and Z in Table 4.1. The digital elevation model in Figure 4.1 revealed that Ogbese river in Ondo State consists of areas with high, medium and low elevation within the catchment area. Figure 4.3 represents the DEM of the study area which ranges between 310 – 314 m. The values within 310 m indicate the lowest point on the map while the areas with values within 314 m represent the peak of the study area. Values from 314 – 313 m show areas of high elevation which are likely suitable for hydro-power station while the values from 312.8 - 311 m show areas of medium elevation which are moderately suitable for hydro-power station while values ranging from 310.8 - 310 m represent areas of very low elevation which are suitable for mini hydro-power station.



**Figure 4.4: Digital Elevation Model (DEM) showing a 3D view developed from Surfer 8**

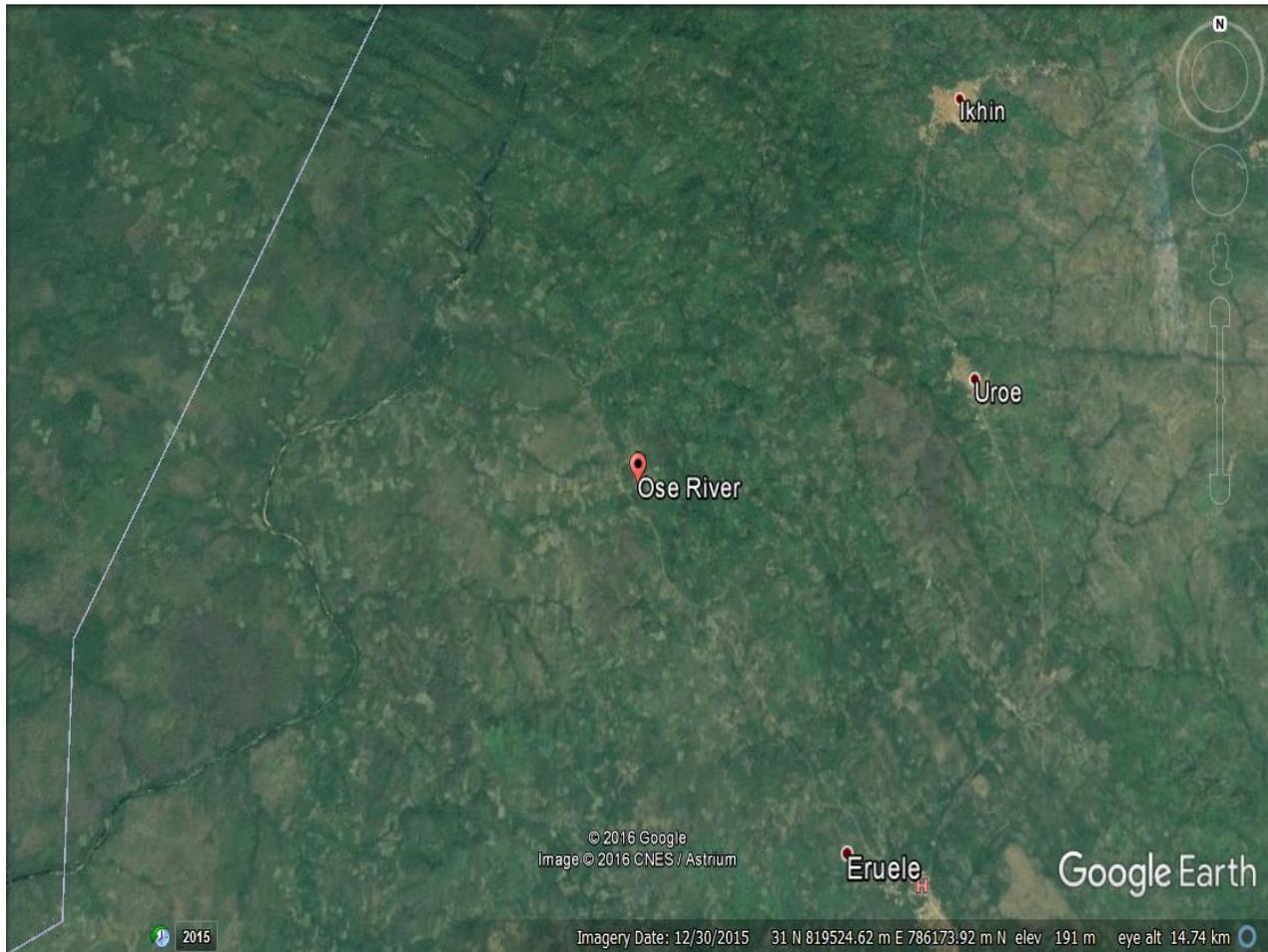


**Figure 4.5: Satellite Imagery of Owena river, Ondo State**

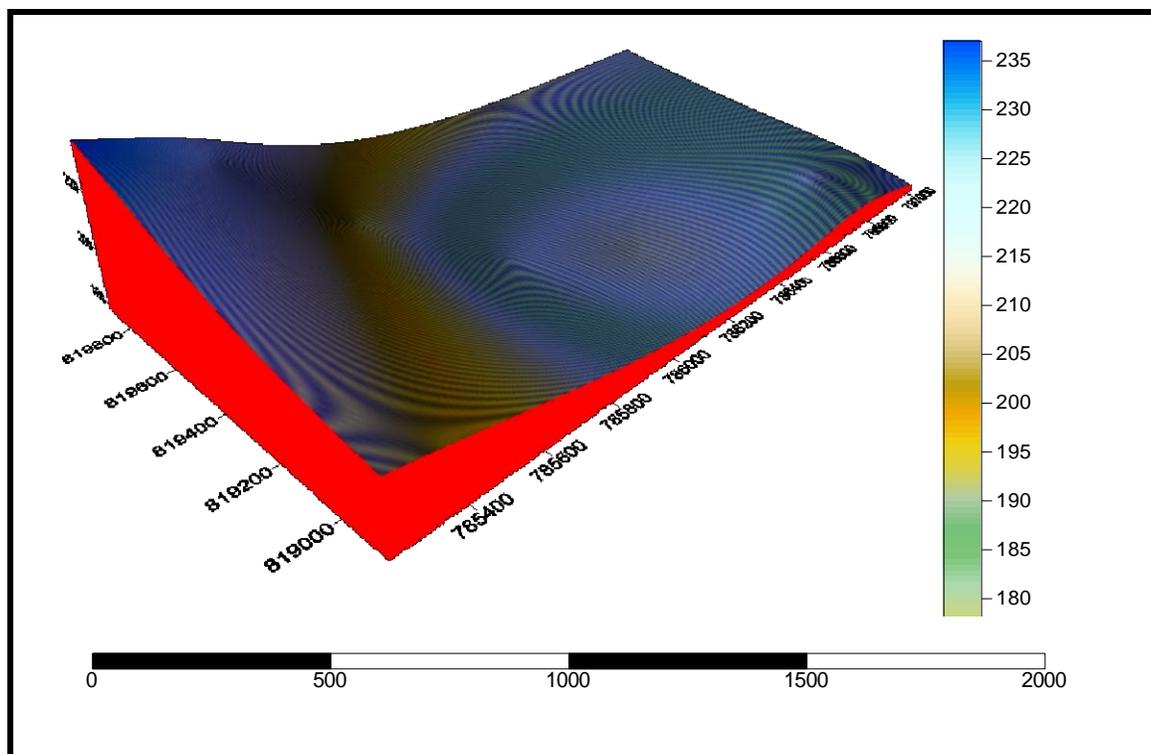
**Source: Google Earth of 2016**

### **Digital Elevation Model (DEM)**

The coordinates and elevations of the study area were recorded as X, Y and Z in Table 4.2. The digital elevation model in Figure 4.2 revealed that Owena river in Ondo State consists of areas with high, medium and low elevation within the catchment area. Figure 4.4 represents the DEM of the study area which ranges between 251.2 – 256 m. The values within 251.2 m indicate the lowest point on the map while the areas with values within 256 m represent the peak of the study area. Values from 256 – 254.2 m show areas of high elevation which are likely suitable for hydro-power station while the values from 254.8 – 252.2 m show areas of medium elevation which are moderately suitable for hydro-power station while values ranging from 252 – 251.2 m represent areas of very low elevation which are suitable for mini hydro-power station.



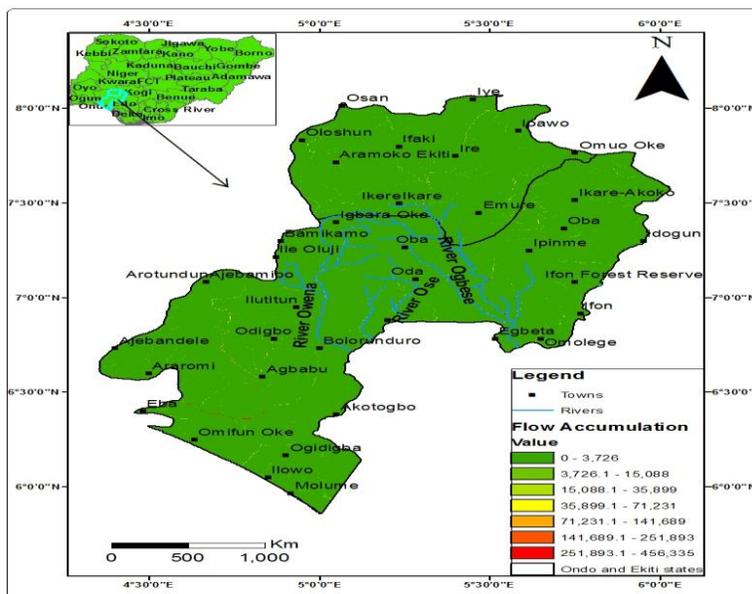
**Figure 4.6: Satellite Imagery of Osse river, Ondo State**  
**Source: Google Earth of 2016**



**Figure 4.7: Digital Elevation Model (DEM) showing a 3D view developed from Surfer 8**

#### **Digital Elevation Model (DEM)**

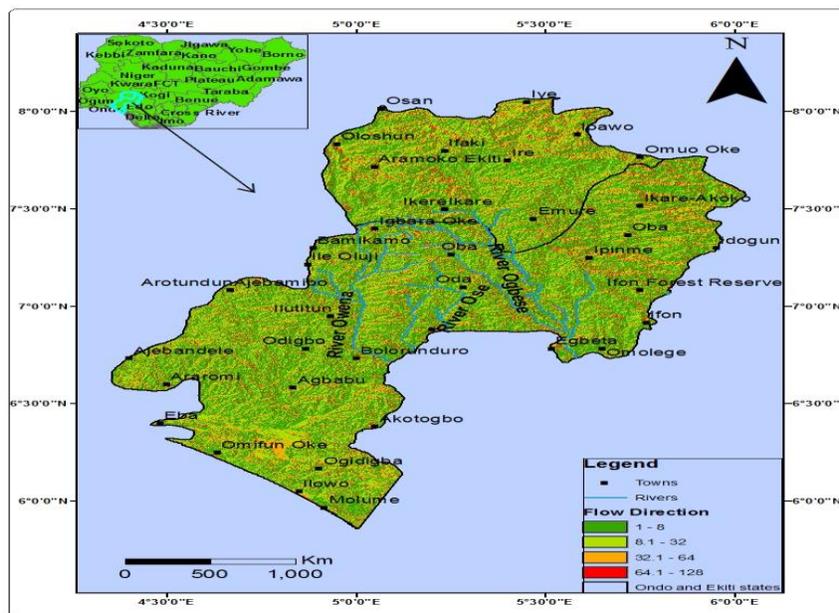
The coordinates and elevations of the study area were recorded as X, Y and Z in Table 4.3. The digital elevation model in Figure 4.7 revealed that Ose river in Ondo State consists of areas with high, medium and low elevation within the catchment area. Figure 4.1 represents the DEM of the study area which ranges between 180 – 235 m. The values within 180 m indicate the lowest point on the map while the areas with values within 235 m represent the peak of the study area. Values from 235 – 220 m show areas of high elevation which are likely suitable for small or mini hydro-power station while the values from 215 - 195 m show areas of medium elevation which are moderately suitable for hydro-power station while values ranging from 190 - 180 m represent areas of very low elevation which are suitable for irrigation and flood prone commercial Agriculture. The land area around the low plain will sustain commercial cultivation of rice, maize, yam, other cereal crops and plantain.



**Figure 4.8: Flow Accumulation of Rivers in Ondo and Ekiti States**

**Flow Accumulation of the Study Area**

Flow accumulation which represents the cell within the catchment area where water accumulates as it flows downwards varies between 0 and 456,335 m. Figure 4.8 represents the cells that have the greatest accumulation of water flowing on the surface of the elevation model and it also reveals a downward path for all water flowing on the surface of the area. Output cells with a high flow accumulation are areas of high concentration of flow and can be used to identify stream channels while the output cells with a flow accumulation of zero are areas of low concentrated flow and can be used to identify uplands. Figure 4.8 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 are stream channels or concentrated flow. The area with the values range between 251893.1 – 456335 m represents the areas with the highest flow or accumulation of water while the areas with 12873.6 – 55785.6 m represents or indicates the areas of average concentration of river or stream channels and areas with 0 – 12873.6 m represents areas that are ridges or the uplands of the surrounding river or stream channels. The green colour represents the areas with low flow accumulation while the areas in yellow colour shows the areas with medium flow accumulation and areas in red colour indicates the areas with high flow accumulation. The areas with high flow accumulation are likely to be more suitable for hydro- power station while the areas with medium accumulation are likely to be moderately suitable for hydro- power station and areas with low flow accumulation are likely to be suitable for mini hydro- station. The areas with high flow accumulation in Ondo and Ekiti catchment areas are likely to be suitable for construction of dam.



**Figure 4.9: Flow Direction of Rivers in Ondo and Ekiti States**

**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 – 8, 8.1 – 32, 32.1 - 64 and 64.1 – 128. The map of flow direction in Ondo and Ekiti catchment areas represent 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 areas were used to determine the flow accumulation in different cells within the areas. Figure 4.9 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 likely to be more suitable for hydro-power station while the areas with medium flow direction (32.1-64) are likely to be moderately suitable and the areas with low flow direction (1-32) are likely to be suitable for mini hydro-power station.

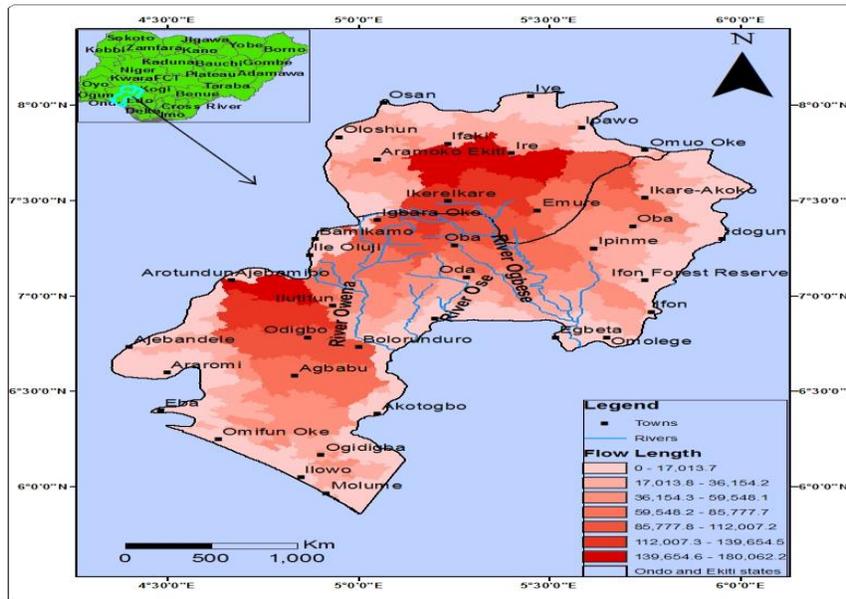


Figure 4.10: Flow Length of Rivers in Ondo and Ekiti States

### 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 suitability of dam site. The flow length in Ondo and Ekiti catchment areas vary between 0 and 180062.2 m. The lowest flow distance is between 0 – 59548.1 m while 59548.2 – 112007.2 m is the average flow length and the highest flow distance is between 112007.3 – 180062.2 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 10 shows that the areas with long flow length are likely to be more suitable for hydro-power station while the areas with medium flow length are likely to be moderately suitable for hydro-power station and areas with low flow length are likely to be suitable for mini hydro-power station. Therefore these areas are more suitable than the others.

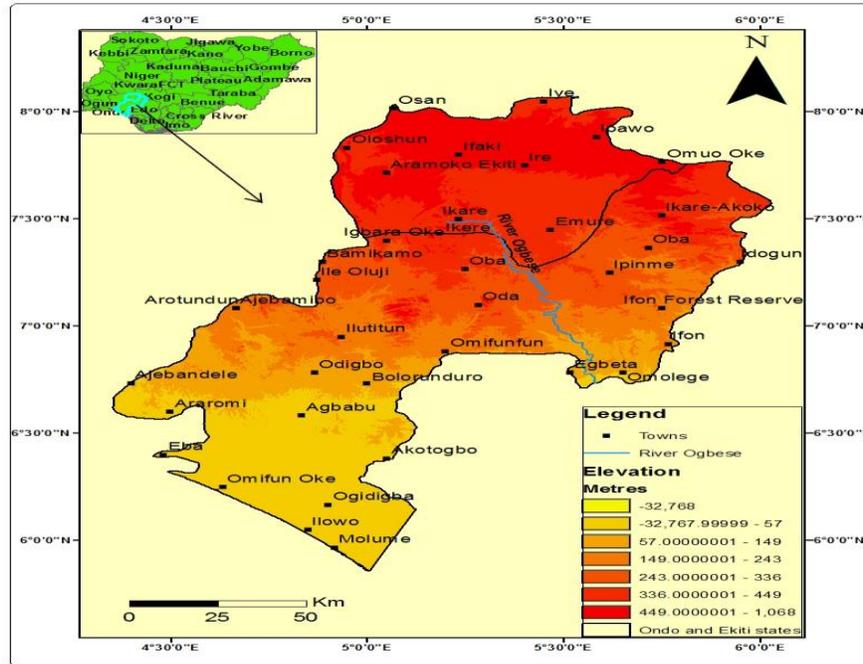


Figure 4.11: Elevation Map of Rivers in Ondo and Ekiti States

### Elevation of the Study Area

The elevation of the study area which represents the degree of depression and change in slope varies between -32768 m and 1068 m. The elevation map of Ondo and Ekiti catchment areas show that the break lines represent significant terrain features like streams or roads that are indicative change in slope. The lateral coordinates of the channel centre was calculated by averaging the lateral coordinates of all points possessing the same minimum elevation. The value represents the altitude of the study area where -32768 m indicates the points of lowest elevation in the area and 1068 m represents the point of highest elevation in the area. The elevation value of 3360000001 – 1068 m from the legend shows areas that are likely suitable for hydro-power station while the value 14900000001 m – 336 m from the legend showing areas that are moderately suitable for hydro-power station and the value -32768 m – 149 m from the legend showing areas that are suitable for mini hydro-power station.

Figure 4.11 shows that the area in light orange colour represents the area with moderate elevation while the area in deep orange colour represents the area with the highest elevation and the area in lighter orange colour represents the area with the lowest elevation.

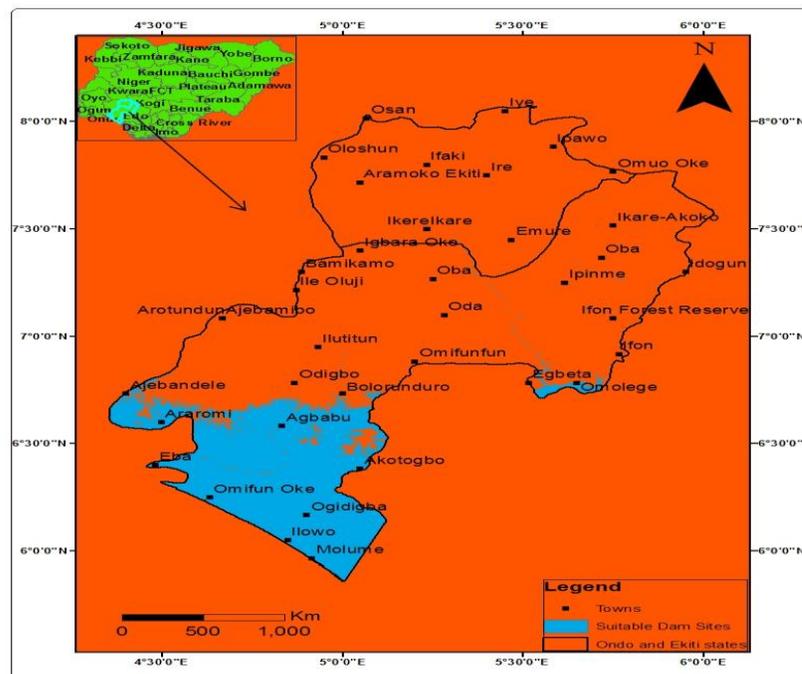


Figure 4.12: Map showing the Suitable Hydro-power Stations

### Map showing the Suitable Hydro-power Stations

The areas suitable for hydro-power stations were classified into three: high, medium and low areas. The areas with main hydro-power stations are areas that are closest to the main prominent rivers with their several tributaries and are located on low relief while areas with moderate hydro-power stations are far away from the main rivers and areas with mini hydro-power stations are far from the main rivers. The study area has three prominent rivers (Rivers Ogbese, Owena and Ose) and their several tributaries (Rivers Ala, Elegbin and Ureje). Figure 4.12 shows that the areas in blue colour represent the areas that are suitable for hydro-power stations.

### 3.CONCLUSION AND RECOMMENDATIONS

This study was carried out with the aim of selecting the possible dam location in Ondo and Ekiti States, Nigeria using Remote Sensing (RS) and Geographic Information System (GIS). The Digital Elevation Model (DEM) was generated, reclassified and integrated with imageries of the area to show areas of possible dam location. The results indicated that the used of remotely sensed data and ArcGIS 10.0 software provide an effective approach to generate possible hydro power station map with a minimum amount of time, effort, and cost. The areas suitable for hydro-power stations were classified into three: high, medium and low areas. The areas with main hydro-power stations are areas that are closest to the main prominent rivers with their several tributaries and are located on low relief while areas with moderate hydro-power stations are far away from the main rivers and areas with mini hydro-power stations are far from the main

rivers. The study area has three prominent rivers (Rivers Ogbese, Owena and Ose) and their several tributaries (Rivers Ala, Elegbin and Ureje). The areas in blue colour represent the areas that are suitable for hydro-power stations.

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