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# APPLICATION OF REMOTE SENSING AND GEOGRAPHYSIC INFORMATION SYSTEM IN HYDROPOWER STATIONS SELECTION IN ONDO STATE, NIGERIA

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## ABSTRACT
*The growing demand for renewable energy sources in Ondo State, Nigeria, necessitates the integration of remote sensing and geographic information systems for selecting hydropower station sites. This study explores the application of Geographic Information Systems (GIS) and remote sensing in the selection process. The objective is to utilize remote sensing and GIS to identify optimal sites for hydropower development in Ondo State. Satellite imageries of the study area were obtained using Google Earth and LANDSAT 7's Thematic Mapper Plus (ETM+), which provides a high resolution of 30 meters. ArcGIS 10.0 and Surfer 8 were used to generate the digital elevation model (DEM) and maps for flow direction, flow length, flow accumulation, slope, and land use. The results indicate that potential sites for hydropower stations are located in areas with steep slopes, high flow accumulation, low relief, and short flow lengths. The most suitable locations are highlighted in red and yellow. The use of ArcGIS 10.0 and remote sensing proved to be an efficient and cost-effective method for accurately identifying potential sites for hydropower stations. This approach reduces time and effort while producing easily interpretable maps and charts that facilitate planning and decision-making processes for mini hydropower station development.*

**KEYWORDS:** Application; remote sensing; geographic information system; hydropower station; selection

## INTRODUCTION
Hydroelectric power is energy generated from the release of falling water. The waterfalls produce kinetic energy that is converted into mechanical energy, which is later transformed into a usable form of electrical energy (Rabi, 2005). Dams have been created by men to store water at a higher and more convenient location to acquire maximal power capacity (Duane et al., 2003**).** Recently, there has been interest from several quarters for the acquisition of advanced hydro technologies (Sergergren, 2005). Hydropower plants are in micro, mini, small, and large sizes. A Micro-sized plant generates less than 100 kW, the Mini plant can power a community via a small factory for the production of 100 kW – 1 MW of electricity. A Small plant generates 1 MW – 30 MW and can serve as a regional grid, while a large plant produces more than 30 MW of power (Nnaemeka & Kyung-Jin, 2015). Hydroelectric power is responsible for 13.1% of energy produced in Nigeria as of 2008 (Francis, 2008). Ozoro (2007) highlighted that electrical energy is highly demanded in comparison with the minute supply by the National grid. Makoju (2003) posited that only about 10% of rural households have access to electricity. Awosope and Okoye (2003) stated that the development of a nation is directly to the availability of Rural electrification. Access to electricity in developed countries' rural areas is high while in developing nations such as ours is as low as 8.6% (Adebayo and Yusuf, 2011: Ejiko et al., 2020). The supply and generation of electricity are major predicaments that remain unsolved by the government (Awosope & Okoye, 2003; Erinle et al., 2020). There is an urgent need for the multiplication of hydropower stations

due to the increase in energy consumption and rapid growth in population as experienced within the country, our population increased from 88.5 million in 1991 to 140 million in 2005 and now probably more than 200 million (Francis, 2008; Emmanuel & Ejiko, 2013; Nnaemeka & Kyung-Jin, 2015). To establish reliable hydropower stations with a projection of their relative power capacity generation techniques such as Remote Sensing (RS) and Geographic Information Systems (GIS) are used in hydrology to carry out feasibility studies in several locations (ACRoRS, 1999).

Ondo state, located in southwestern Nigeria, is known for its abundant water resources, making it conducive for hydropower generation. However, the conventional method of site selection for hydropower projects is often time-consuming and resource-intensive (Sanyal & Lu, 2004). The primary aim of this research is to develop a comprehensive framework for the application of remote sensing and GIS in the selection of mini hydropower stations in Ondo state.

The application of remote sensing and geographic information systems (GIS) in the selection of hydropower stations in Ondo state presents a significant opportunity to harness the state's renewable energy potential (Liu et al., 2003). This study aims to explore the use of advanced technologies to identify suitable locations for setting up hydropower stations efficiently and sustainably.

The current challenge faced in the selection of hydropower sites in Ondo state is the lack of a systematic and data-driven approach. Traditional methods rely heavily on manual inspections and feasibility studies, which can be subjective and inefficient (Clark, 1998). This study aims to address these limitations by integrating remote sensing data and GIS analysis to improve the accuracy and efficiency of site selection. The utilization of renewable energy sources such as hydropower is crucial for sustainable development and energy security (Salih & Al-Tarif, 2012). The application of remote sensing and GIS technologies provides valuable insights for policymakers, energy planners, and investors involved in the development of hydropower stations in the study area (Kumar et al., 2009).

There is a significant gap in the literature regarding the application of remote sensing and GIS in the selection of mini hydropower stations, particularly in the context of Ondo state. This study aims to fill this gap by providing a systematic and data-driven approach that can enhance the efficiency and sustainability of hydropower development in the region.

## MATERIALS AND METHODS

### *Description of the study area*

Rivers Owena and Ogbese in Ondo State, Nigeria shown in Figure 1, are significant watercourses that play vital roles in the region's hydrology. The Owena River, a major tributary of the Osse River, supports agriculture and water supply, while the Ogbese River is crucial for irrigation and local livelihoods. Both rivers contribute to the region's potential for sustainable hydropower development.

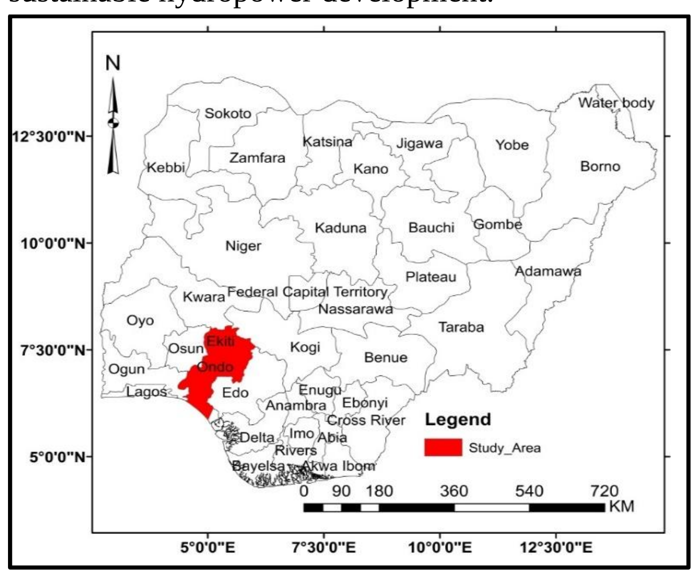


Figure 1: Map of Nigeria with the study area as an inset

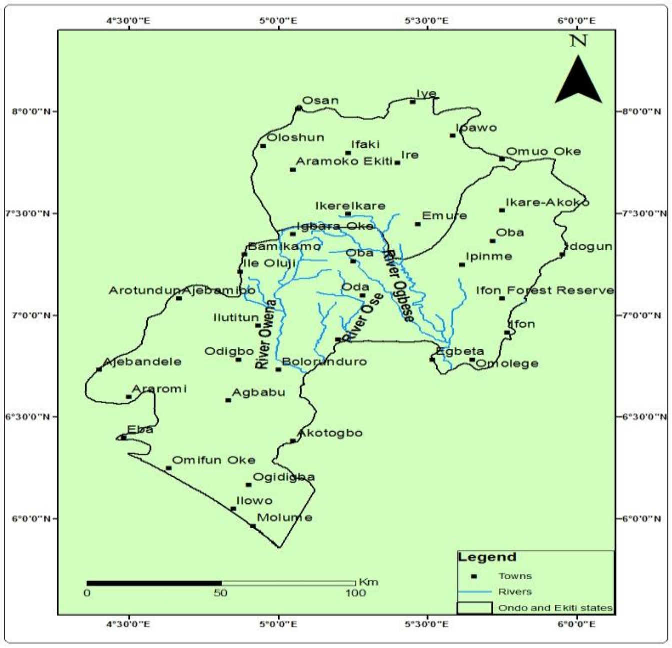


Figure 2: Map of the study area

***Data acquisition***

For the research, satellite images of LANDSAT8/9 OLIfor2024 with path 191 and rows 54 and 55 were downloaded from the Earth Explorer website. An administrative map of the study area was downloaded from the DIVAGIS website. Open Topography plugin in QGIS was used to download the Digital Elevation Model (DEM) for the study area.

***Data analysis***

Data were analyzed using ArcGIS 10.8 and QGIS 3,38.1 software to generate slope maps, hydrological maps (River Channels), flow accumulation, flow length, and flow direction maps for this research.

***Flow accumulation, flow direction, flow length, hydrological map, and slope map***

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 toolbox (Muhammad & Iyortim, 2012), flow direction which represents the direction of water flows in the study area was generated by using the flow direction function in the spatial analyst toolbox 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 toolbox (Noha, 2009). The slope map which is the degree of steepness of a surface was generated by using the slope function in the 3D analyst toolbox. A hydrological map was generated by using the hydrology function in the 3D analyst toolbox (Forzieni et al., 2008).

**RESULTS AND DISCUSSION**

***Digital elevation model***

The Digital Elevation Model (DEM) was employed to identify areas with significant elevation changes, which are indicative of potential energy generation from flowing water (Deng et al., 2007). This tool is vital in selecting suitable locations for a hydropower station for the study area, as it provides essential information about the terrain's elevation. The terrain is crucial for analyzing water flow patterns and determining potential sites for dam construction. Slope maps derived from the DEM can further pinpoint regions with ideal slopes for water flow, which is necessary for effective hydropower generation.

The DEM, illustrated in Figure 2, revealed that the Owena River in Ondo State encompasses areas of high, medium, and low elevation within the catchment area. The elevation in the study area ranges between 251.2 and 256 meters. The lowest points, indicated by values around 251.2 meters, and the highest points, around 256 meters, help to delineate the terrain's suitability for hydropower stations. Areas with elevations between 256 and 254.2 meters are identified as highly suitable for hydropower stations, while those between 254.8 and 252.2 meters are moderately suitable. Regions with elevations ranging from 252 to 251.2 meters are considered appropriate for hydropower stations due to their lower elevation.

DEM depicted in Figure 9 reveals that the Ose River in Ondo State encompasses areas of high, medium, and low elevation within its catchment area. Figure 3, which represents the DEM of the study area, shows elevation values ranging from 180 to 235 meters. The lowest points, at 180 meters, indicate the lowest elevation on the map, while the highest points, at 235 meters, represent the peak elevation. Areas with elevations between 235 and 220 meters are likely suitable for small or mini-hydropower stations due to their high elevation. Regions with elevations between 215 and 195 meters are moderately suitable for hydropower stations, while areas ranging from 190 to 180 meters, characterized by very low elevation, are more suitable for irrigation and flood-prone commercial agriculture as reflected in Figure 4.

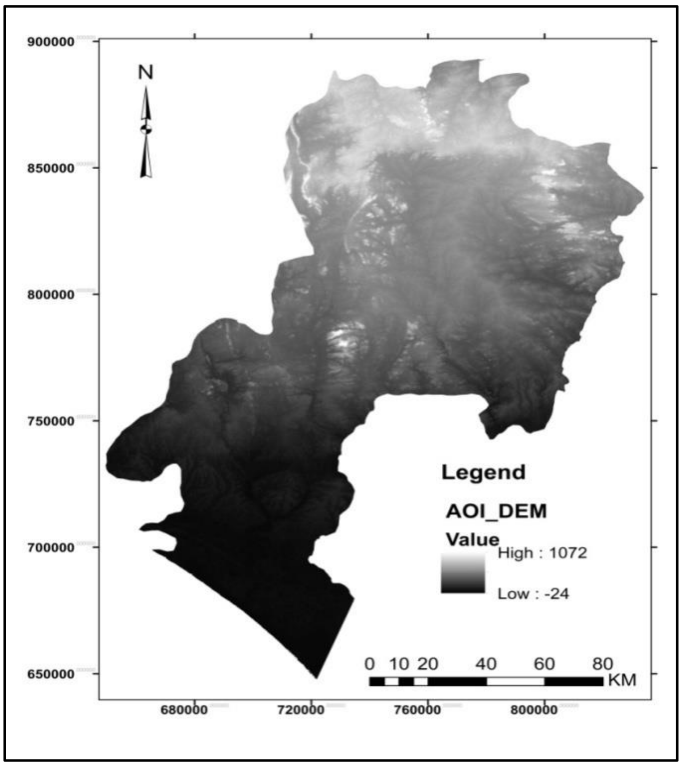


Figure 3: Digital Elevation Model (DEM) of the study area (AOI)

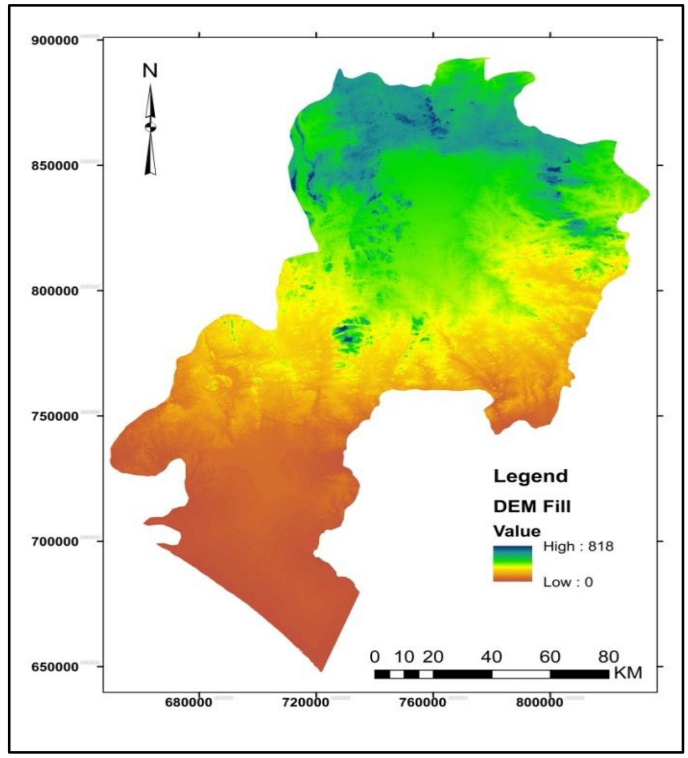


Figure 4: Digital Elevation Model (DEM) fill of the study area

***Slope map***

Developed from the DEM, was used in identifying areas with sufficient slope gradients that can facilitate water flow and provide the necessary pressure for efficient hydropower generation as shown in Figure 5.

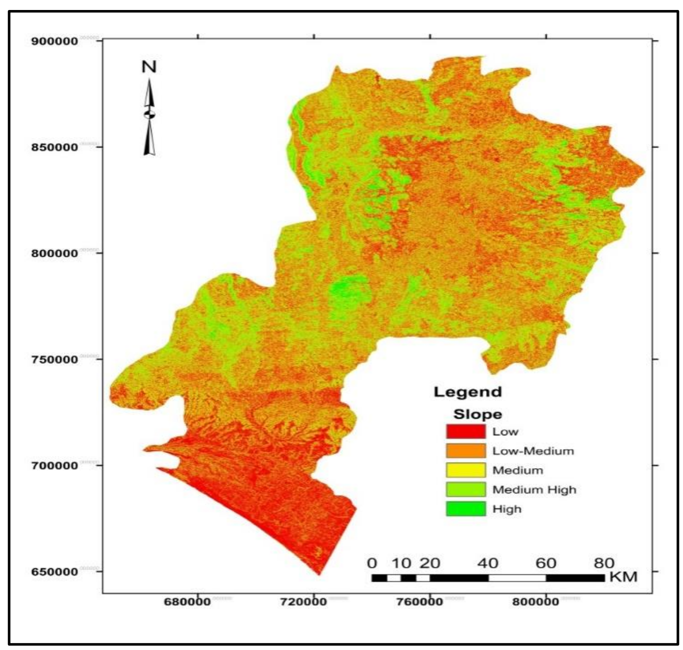


Figure 5: Slope map of the study area

***Flow direction of the study area***

Flow direction maps help identify the natural pathways of water runoff, crucial for selecting sites with adequate water flow rates for hydropower generation. This map in Figure 6 displays water flow directions across the surface, with values ranging from 1 to 128. In the Ondo and Ekiti catchment areas, the flow direction map reveals the downward paths of surface water. Areas with high flow direction values (64.1-128), shown in green, are most suitable for main hydropower stations, while areas with medium values (32.1-64), shown in yellow, are moderately suitable. Low flow direction areas (1-32), shown in red, are better suited for mini hydropower stations. These maps also assist in determining flow accumulation and stream networks, essential for hydropower site selection.

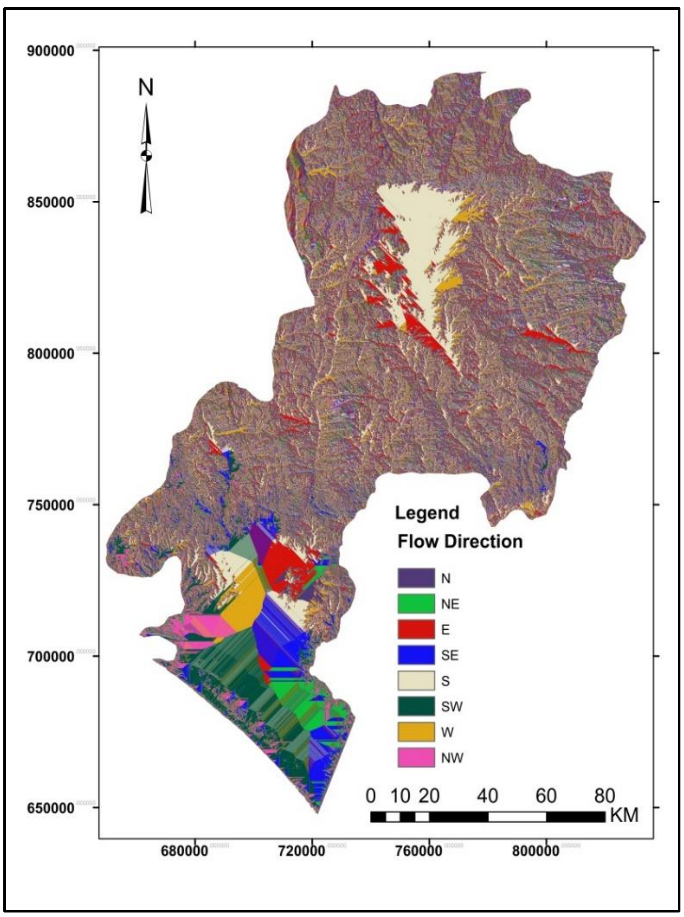


Figure 6: Flow direction for the study area

***Flow accumulation***

Flow accumulation maps highlight areas with potential for reservoirs by identifying regions of high water concentration as shown in Figure 7. These maps, derived from flow direction data, range from 0 to 456,335 meters in the study area. High-flow accumulation areas, shown in red, indicate stream channels and are prime sites for hydropower stations, while medium accumulation areas, shown in yellow, are moderately suitable. Low accumulation areas, shown in green, represent ridges or uplands and are more appropriate for mini hydropower stations. The study suggests that areas with high flow accumulation in Ondo and Ekiti are particularly suitable for main hydropower development.

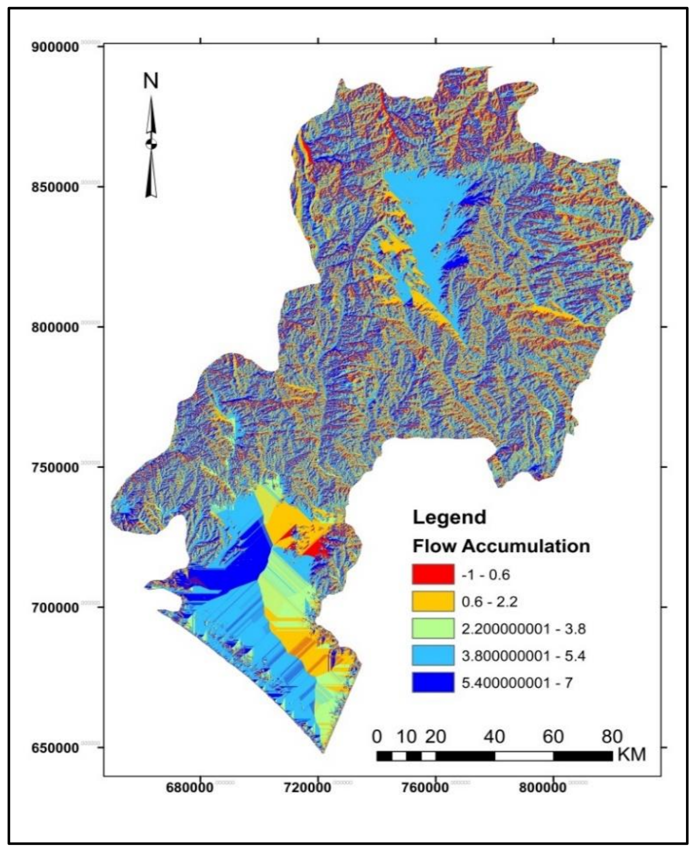


Figure 7: Flow accumulation of Rivers in Ondo state

***Flow length of the study area***

Flow length in Figure 8 indicates the distance water travels within a catchment, which is crucial in assessing dam site suitability. In the Ondo and Ekiti catchment areas, flow lengths range from 0 to

180,062.2 meters. The shortest flow distances (0–59,548.1 meters) are represented by lighter green, average distances (59,548.2–112,007.2 meters) by light green, and the longest distances (112,007.3–180,062.2 meters) by dark green on the map. Areas with the longest flow lengths are most suitable for main hydropower stations, while those with average lengths are moderately suitable, and regions with short flow lengths are better suited for mini hydropower stations. Figure 9 illustrates the suitability of these areas based on their flow length.

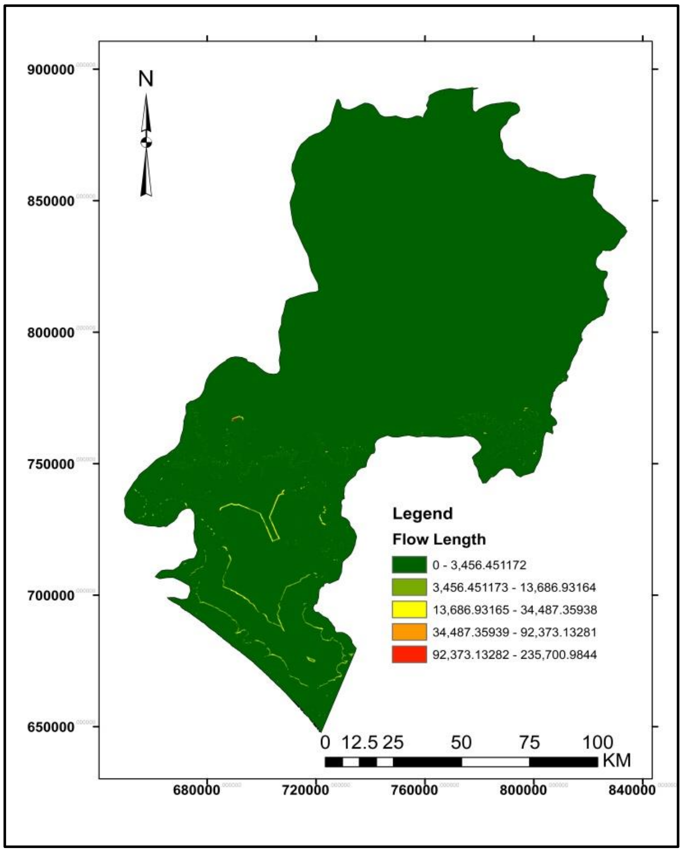


Figure 8: Flow length of rivers of the study area

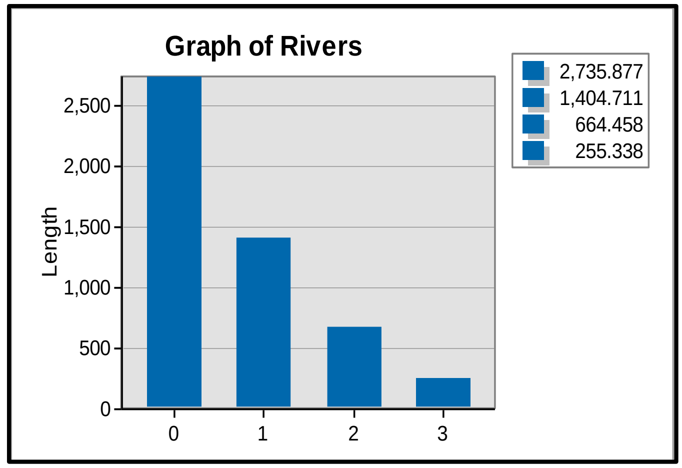


Figure 9: Length of rivers of the study area

***Elevation of the study area***

The elevation in the study area varies from -32,768 meters to 1,068 meters, reflecting the degree of depression and slope changes. The elevation map of the Ondo and Ekiti catchment areas highlights key terrain features like streams or roads that indicate changes in slope. The lowest elevation (-32,768 meters) and the highest elevation (1,068 meters) are critical for determining main hydropower station suitability. Areas with the highest elevations are most suitable, while moderately elevated regions are moderately suitable, and the lowest elevations are best suited for mini hydropower stations. Figure 10 uses color coding to represent these elevation levels, aiding in site selection.

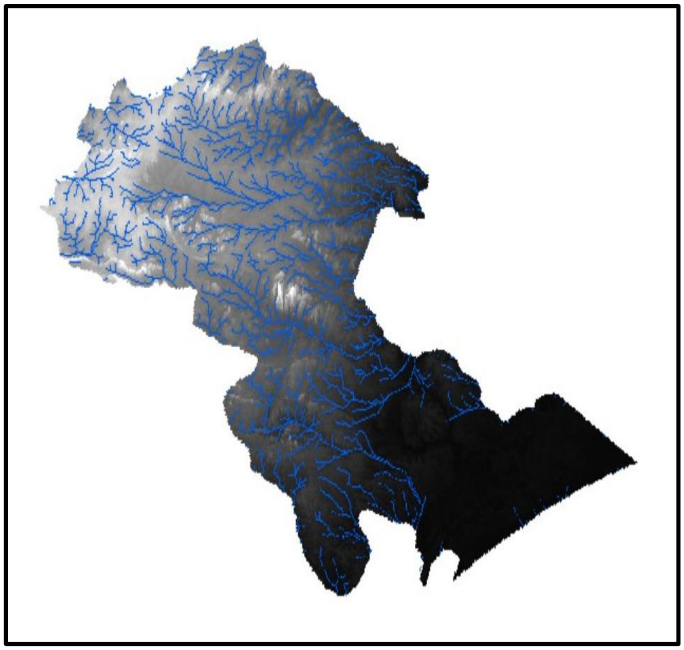

Figure 10: Elevation map of rivers in Ondo state

***Hydrological map***

Figure 11 provides detailed information about the distribution and availability of water resources, considering factors like rainfall patterns, river networks, and groundwater levels (Kite & Pietroniro, 1996). Access to a reliable and consistent water supply is vital for the efficient operation of a hydropower station (Jakeman et al., 1990). By analyzing hydrological maps, locations with sustainable water resources can be identified, ensuring the long-term viability of the hydropower project.

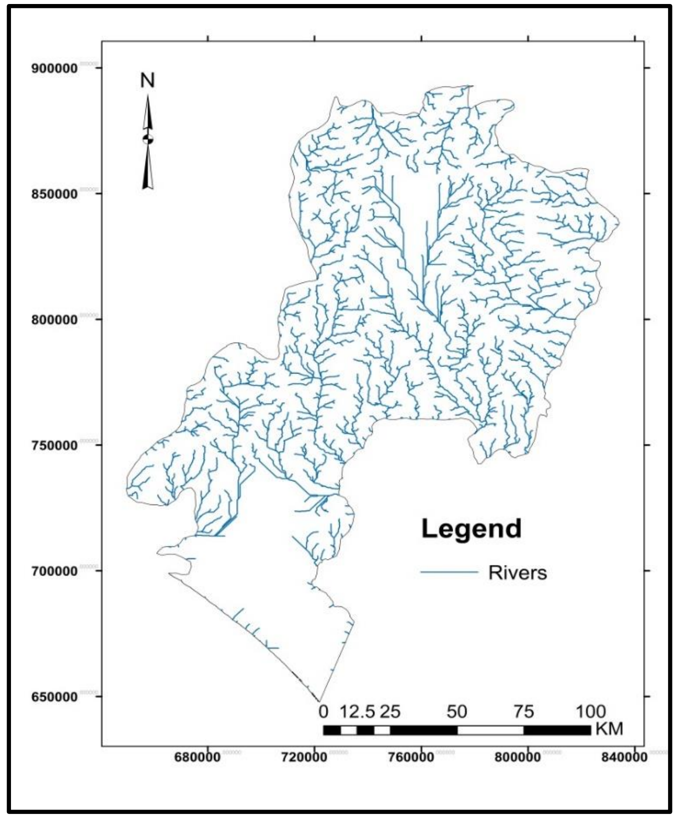


Figure 11: Map showing the hydrological map of the study area

***Map showing the suitable Hydro-power stations***

The study classified areas suitable for hydropower stations into three categories: high, medium, and low suitability. Areas with the highest suitability for main hydropower stations are those closest to the prominent rivers and their numerous tributaries, typically located on low-relief terrain. Medium suitability areas, where moderate hydropower stations are feasible, are farther from the main rivers. Low suitability areas, where only mini hydropower stations are viable, are the most distant from the main rivers.

The study area is characterized by three prominent rivers as captured in Figure 12 - Ogbese, Owena, and Ose along with several tributaries, including Rivers Ala. The areas marked in red indicate regions most suitable for the development of hydropower stations.

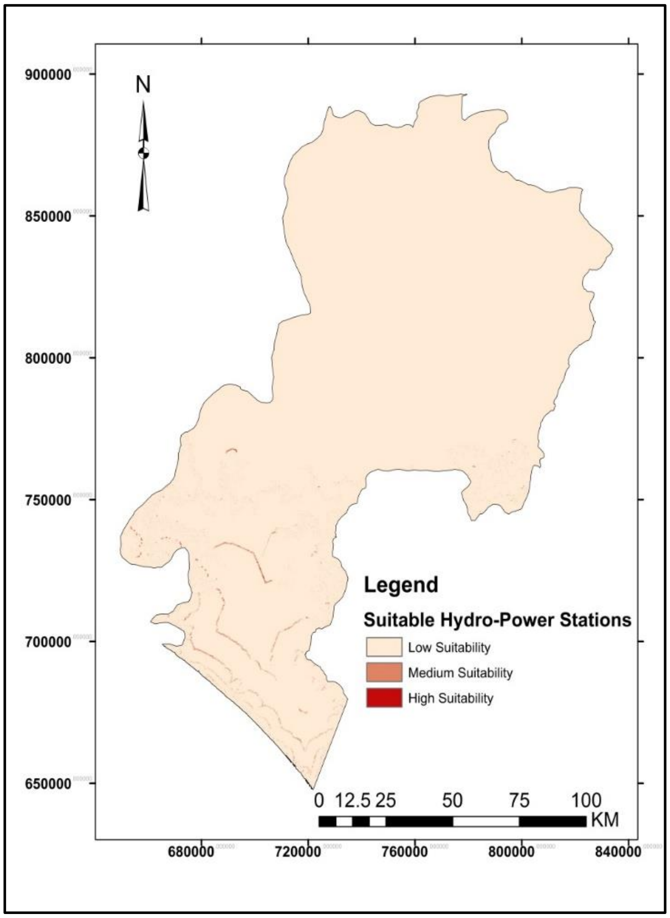


Figure 12: Map showing the suitable hydro-power stations of the study area

## CONCLUSIONS AND RECOMMENDATIONS

This study focused on identifying potential locations for mini hydropower stations in Ondo State, Nigeria, utilizing Remote Sensing (RS) and Geographic Information System (GIS) technologies. By generating and reclassifying a Digital Elevation Model (DEM) and integrating it with satellite imagery, the study effectively highlighted areas suitable for mini hydropower stations. The results demonstrated that the use of GIS software is an efficient approach for creating a map of potential mini hydropower station sites, minimizing the time, effort, and costs involved.

The study classified the suitable areas for hydropower stations into three categories: high, medium, and low suitability. High-suitability areas, ideal for main hydropower stations, are located closest to the prominent rivers and their tributaries, typically on low-relief terrain. Medium-suitability areas, suited for moderate hydropower stations, are farther from the main rivers, while low-suitability areas, where only mini hydropower stations are viable, are the most distant. The study area includes three prominent Rivers Ogbese, Owena, and Ose. The areas indicated in blue on the study map are those most suitable for mini hydropower stations. The abundant water resources, favorable terrain, and the need for reliable, sustainable, and low-cost electricity, particularly for irrigation and other purposes in rural and urban areas, the study recommends the development of mini hydropower stations in Ondo State. The integration of the digital elevation model, slope map, flow direction map, flow accumulation map, land use map, and hydrological map is essential in selecting suitable locations for hydropower stations. These tools provide critical information on terrain, water flow patterns, land use, and water availability, enabling informed decision-making that ensures the successful and sustainable generation of hydropower in the region.

**REFERENCES**

ACRoRS. (1999). *Instruction of remote sensing notes and GIS workbook CD-ROM version 1.0*. Asian Center for Research on Remote Sensing (ACRoRS) in Asian Institute of Technology (AIT). Retrieved from http://ksrs.Or.kr /library/index.htm.

Adebayo, A. A., & Yusuf, B. M. (2011). Perennial power problem in Nigeria: Small hydropower option. *7th Engineering Forum the Federal Polytechnic, Ado Ekiti, Ekiti state,* 188 - 192.

Awosope, C. O., & Okoye, C. U. (2003). Rural electrification: emerging technical considerations for suitability in a developing economy. *Proceeding of the Nineteenth Annual Conference of Nigerian Society of Engineers (Electrical Division), Lagos, October 2 - 3*, 25 - 30.

Clark, J. (1998). Putting water in its place: A perspective on GIS in hydrology and water. *Hydrological Process, 12,* 823 - 834.

Deng, Y., Wilson, J. J., & Bauer, O. (2007). DEM resolution dependencies of terrain attributes across a landscape. *International Journal of Geographical Information Science, 2*1, 187 - 213.

Duane, C., Eric, C., Morgan, W., & Lauren, P. (2003). A study of hydroelectric power: From a global perspective to a local application. *Center for Advanced Undergraduate Studies and Experience from Industrial Revolution to Industrial Ecology: Energy and Society, College of Earth and Mineral Sciences. The Pennsylvania State University*

Ejiko, S. O., Adubi, E. G., & Adewuyi, R. A. (2020). Hydroelectric power plant design: A case study of Agric livestock investigation centre dam in Erinfun, Ekiti State. *Adeleke University Journal of Engineering and Technology AUJET* 3 (2), 61 - 79.

Erinle, T. J., Ejiko, S. O., & Oladebeye, D. H. (2020). Design of micro hydro turbine for domestic energy generation. *International Advanced Research Journal in Science, Engineering and Technology,* 7(4), 85 – 93.

Emmanuel, A. A., & Ejiko, S. O. (2013). Innovation of a plant for generating electricity from waste material. *Nigerian Association of Technologists in Engineering, Book of Proceedings 30th Conference of Technologists in Engineering and Annual General Meeting, CONFOTECH LAGOS,* 13th -15th November, 98 - 100.

Francis, S. I. (2008). *Status of renewable energy in Nigeria* (Online). Retrieved from http://www.renewablenigeria.org/status of renewable energy in Nigeria.pdf

Forzienii, G., Gardenti, M., Caparrini, F., Castelli, F. (2008). A methodology for the pre-selection of suitable sites for surface and underground small dams in arid areas: A case study in the region of Kidal. *Physics and Chemistry of the Earth, 33,* 74 - 85.

Jakeman, J., Littlewood, G., & Whitehead, G. (1990). Computation of the instantaneous unit hydrograph and identifiable component flows with application to two small upland catchments. *Journal of Hydrology, 117,* 275 - 300.

Kite, W., & Pietroniro, A. (1996). Remote sensing applications in hydrological modelling. *Hydrological Science, 41,* 563 - 591.

Kumar, M., Agarwal, A., & Bali, R. (2009). Delineation of potential sites for water harvesting structures using remote sensing and GIS. *Journal of the Indian Society of Remote Sensing, 36,* 323 - 334.

Liu, J., Chen, J. M., & Cihlar, J. (2003). Mapping evapotranspiration based on remote sensing: An application to Canada's landmass. *Water Resources Research, 39* (7), 1 - 15.

Makoju, J. O. (2003). Quantifying the electrical supply gas a simplistic treatment. *Proceeding of the Nineteenth Annual National Conference of Nigerian Society of Engineers (Electrical Division), Lagos. October 2 - 3,* 1 – 5.

Muhammad, I., & Iyortim, O. S. (2012). Application of remote sensing (RS) and geographic information systems (GIS) in flood vulnerability mapping: Case study of River Kaduna. *International Journal of Geomatics and Geosciences, 3* (3), 1 -15.

Noha, D. (2009). Application of remotely sensed imagery to watershed analysis: A case study of Lake Karoun Catchment, Egypt. *Thirteenth International Water Technology Conference, IWTC 13 2009, Hurghada, Egypt.*

Nnaemeka, V. E., & Kyung-Jin, B. (2015). Sustainable energy development in Nigeria: Overcoming energy poverty. *International Journal of Energy Economics and Policy, 5* (2), 580 - 597.

Ozoro, J. I. (2007). The national electric power authority (NEPA) and the challenges of privatization. *Proceedings of the Nineteenth Annual National Conference of Nigerian Society of Engineers (Electrical Division), Lagos. October 2 - 3,* 25 – 30.

Rabi, A. (2005). Final technical report, version 2 externalities of energy extension of accounting framework and policy applications. European Commissioning

Salih, S. A., & Al-Tarif, A. S. M. (2012). Using of GIS spatial analyses to study the selected location for dam reservoir on Wadi Al-Jirnaf, West of Shirqat area, Iraq. *Journal of Geographical Information System,* 4 (2), 117 - 127.

Sanyal, J., & Lu, X. (2004). Application of remote sensing in flood management with special reference to monsoon Asia: A review. *Natural Hazard, 33,* 283 - 301.

Segergren, E. (2005). *Direct drive generator for renewable power conversion from water Currents.* Acta Universitatis Upsaliensis. Digital comprehensive summaries of Uppsala Dissertations from the faculty of Science and Technology 100, 1 - 44.