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Identifying the most suitable sites for solar energy projects using GIS in Owerri, Imo state, Nigeria

Onyedikachi C. Ukachukwu*, **Benedicta U. Dike, Martin C. Okeke**

Civil Engineering Dept., Federal University of Technology Owerri, Imo State Nigeria.
*Corresponding author Email: collinsukachukwu93@gmail.com

HIGHLIGHTS

- Due to low slopes, south-facing aspects, and optimal temperatures, about 15% of the area is ideal for solar farms.
- Factors include slope for efficiency, temperature for suitability, and road proximity for better accessibility.
- Findings provide a framework for planning sustainable energy projects while reducing environmental and social impacts.

Keywords:
Geographic Information System (GIS)
Renewable Energy Projects
Suitability mapping
Owerri Municipal

ABSTRACT

This study explores the potential of renewable energy in Owerri Municipal, Nigeria, using Geographic Information Systems (GIS) to identify optimal locations for renewable energy projects. The objective is to contribute to sustainable energy development by assessing the spatial distribution of renewable energy resources, evaluating environmental and socio-economic factors, and generating suitability maps for various renewable energy technologies. This was achieved by integrating GIS-based analysis with comprehensive data on solar radiation and Land Use Land Cover (LULC) types. Classifying LULC was a critical step in remote sensing, offering insights into various land cover classes' spatial distribution and dynamics. An aspect model was employed to determine slope orientation with maximum solar exposure. Proximity to road networks and grid stations in Owerri Municipal was also analyzed to identify the most accessible and motorable locations. Land surface temperature (LST), a measure of the earth's surface temperature, was also examined using data from the thermal Band-10 of the Landsat 8 OLI satellite. Combining these datasets and applying the weighted overlay tool, this research identified locations with the highest potential for renewable energy generation while minimizing negative environmental and socio-economic impacts. The results aim to assist policymakers, investors, and project developers in making informed decisions regarding renewable energy projects in Owerri Municipal and serve as a valuable reference for similar initiatives in other regions.

1. Introduction

Energy is fundamental to life on Earth and will continue to be the cornerstone of global economic and human development and world peace. The energy demand has been rising exponentially, and it is predicted that there will be 8 billion people on the planet by 2020 [1]. However, conventional energy sources are finite, and the rapid depletion of fossil fuel reserves, coupled with their unstable global prices, has made the search for alternative energy very necessary, spurring interest in renewable energy sources. As a result, renewable energy sources must be utilized to allow current and future generations to thrive without harming their support system.

Among the several options, solar and wind energy are the most promising for supplying the steadily rising energy demand. Concerns about the environment have grown worldwide since the 1990 and greenhouse gas-induced global warming has drawn attention from all corners of the globe. These days, wind and solar generators serve telecommunication, lighting, electricity in rural places, water pumping, and other uses [2]. The International Energy Agency (IEA) has conducted significant studies to determine the amount of solar energy available and the best strategies to take advantage of it. The IEA study estimated that, within this scenario, sunlight would reach the Earth in ninety minutes. The outcomes line up with global energy consumption levels. According to the IEA, solar energy will provide 11% of the world's energy needs in the next thirty years. Nonetheless, a considerable rise in renewable energy sources is anticipated by 2030, with an annual growth rate of 7.6% [3]. Nigeria also has vast reserves of fossil fuel energy resources, which it exports to other nations. However, this is not a sustainable clean energy method, and the earnings are insufficient to meet the high national consumption quota. Nigeria's energy and electricity usage

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will quadruple over the next ten years. The yearly growth rate of electricity consumption is also expected to be 20%. Nigeria has established goals for its use of renewable energy sources. One of the most promising substitutes is solar energy.

Vast land regions with high annual solar radiation have attractive opportunities for applying solar technology. However, the inconsistency and variability of solar radiation, which can vary geographically from one location to another, is one of the obstacles to the growth of solar power. Certain elements must be considered before choosing a location for such an installation. This is where Geographic Information Systems (GIS) come into play, as they can aid in choosing a site by considering important criteria. Geographic Information Systems is initialized as GIS [4]. Roger Tomlinson [5] developed the first computerized GIS and coined the word GIS. GIS is a computer system that combines hardware and software to link non-spatial features with Geographically linked data, allowing users to layer multiple data types together to manipulate and analyze at a base to create new maps and tabular data [6]. Selecting sites for renewable energy project development goes beyond finding convenient locations. The systemic evaluation of project sites can be done using GIS, which provides an integrated technology that combines geospatial information with analytical resources. Thematic maps are an important output of spatial analysis in GIS (Geographic Information Systems). They are maps that represent specific themes or topics, such as population density, land use, or vegetation cover, and are used to display patterns and trends in the data visually. Spatial analysis in GIS involves manipulating and analyzing geographic data, including spatial relationships, distances, and patterns [7]. The Geographic Information System (GIS) has become increasingly popular for various site selection studies, especially energy planning. Computer software studies and shows data in a geographical context, utilizing information associated with an area of study. Renewable energy projects, particularly solar energy, are used to assess the availability of sources and plan and develop solar energy projects [8]. Geographic information systems (GIS) have become increasingly popular as a valuable tool for geospatial management and planning. The main rationale behind this is that it may be used in the planning procedure to include several factors in land-use decisions [9]. As a result, their application can be very useful for data visualization and management and for evaluating choices based on spatially connected criteria. GIS data mixes digital information with real-world objects such as highways, land usage, and elevation [7]. In assessing optimal for solar and wind energy developments, it operates as a decision support tool, recognizing economically viable and environmentally attainable sites by using an enormous amount of spatial data linked to numerous technical, economic, social, and environmental criteria [10].

In 2017, Dariah and Igor [11] talked about slopes and aspects. In terms of slope, a level surface is ideal for solar energy projects. Construction on sloping terrain is more difficult and costly [12]. As the slope rises, so too does the intricate nature of the design, and it typically leads to a proportional increase in cost. Setting up solar panels on steep slopes may cause erosion, drainage problems, and foundation stability issues. The slope of the earth's surface affects both the optimal alignment and angle of photovoltaic modules and the technicalities of any solar energy facility installation. The maximum slope at which the setting up is theoretically possible is anticipated to be 15%. If the slope is small, the angle of tilt is negligible because it may be easily overcome via building supports for photovoltaic modules; nevertheless, on a more inclined slope, the angle of tilt is a barrier, and solar energy stations can only be created in south-facing locations.

A study by Kumar et al., [13] explores the use of Land Surface Temperature (LST) as a key parameter in the site selection process for solar farms in India. The researchers employed GIS to analyze spatial data, integrating LST with other critical factors such as solar irradiance, land availability, and proximity to infrastructure. The analysis revealed that regions with higher LST levels corresponded to areas with lower cloud cover and higher solar irradiance, making them ideal for solar farm installations. The higher efficiency of solar panels in high LST areas was confirmed, as the panels performed better with reduced energy losses. The study's recommendations led to the development of pilot solar farm projects in the identified areas. A 50 MW solar farm was established in Rajasthan's identified high LST zone, showcasing improved efficiency due to optimal climatic conditions.

A research paper by Shaikh and Ramkumar [14] assessed the suitability of sites for solar PV farms in India using GIS-based AHP and weighted overlay analysis. Proximity to road networks was one criterion for ensuring logistical convenience.

The selected sites showed a good balance of solar potential, minimal environmental impact, and accessibility. The proximity to road networks facilitated easier transportation and maintenance, improving project feasibility and execution.

The study's primary objective is to determine how GIS can be applied for site selection in renewable energy projects, particularly on solar energy in Nigeria. This paper analyzes several spatial parameters to determine which places have the most energy potential and the fewest logistical and environmental issues. Additionally, the research tends to support sustainable energy development by attempting to provide data-driven methodologies for site selection that will improve the design and implementation of renewable energy projects.

2. Materials and methods

Owerri Municipal, located in Imo State, Nigeria, is one of the state's 27 Local Government Areas (LGAs). It covers an area of approximately 73 square kilometers and is situated in the heart of Owerri, the capital city of Imo State. Owerri Municipal is a key commercial hub known for its trade in palm products, maize, yams, and cassava. Historically, the area has been central to trade and transport, connecting to other major cities via roads leading to Port Harcourt, Aba, Onitsha, Orlu, and Okigwe. The tools or materials in Table 1 were used to identify suitable sites.

Table 1: Materials and tools used for site identification

Data	Sensor/Tool	Description
Digital Elevation Model (DEM)	Remote sensing, GIS (ArcMap)	3D representation of terrain; essential for topography and slope analysis
Land Use Land Cover (LULC)	ESRI Landcover, Sentinel-2 Explorer	Data to classify various land types, providing insight into land distribution
Land Surface Temperature (LST)	Thermal Band-10 (Landsat 8 OLI satellite)	Temperature data from the earth's surface is critical for solar energy assessments.
Road Network Data	GIS (Euclidean distance tool)	Used to assess proximity to road networks, ensuring access and motorability
Slope and Aspect Analysis	GIS (ArcMap)	Slope and aspect calculations to determine optimal solar exposure

2.1 Digital elevation model (DEM):

A model is an artificial abstraction that captures the key features of a complicated system or idea while omitting unimportant details that hinder the analysis or problem [15]

- The DEM used in the study was sourced from high-quality digital elevation data, providing the elevation distribution for Owerri Municipal. DEMs are commonly obtained from remote sensing technologies like LiDAR, satellite-based sensors, or topographic surveys. In this case, they were obtained from topographic surveys.
- DEMs provide a 3D representation of terrain with high accuracy, depending on the resolution of the data source. The reliability of a DEM depends on its resolution and how well it captures fine details like terrain irregularities. The data obtained for Owerri Municipal is suitable for environmental modeling and topographic analysis.

2.2 ESRI Landcover sentinel 2:

- The ESRI Landcover data used in this study comes from Sentinel-2, a satellite-based mission from the European Space Agency (ESA) that provides multi-spectral images with a resolution of 10 meters. Sentinel-2's Land Cover Explorer offers up-to-date land cover classification, making it ideal for environmental monitoring and land use assessment.
- Sentinel-2 statistics are exceptionally reliable, featuring regular updates and comprehensive global information coverage. Therefore, land cover classification accuracy depends on cloud cover and satellite picture resolution. In turn, this was crucial to this study's identification of land use patterns and their spatial distribution.

3. Methods

3.1 Processing input data by calculating the slope and aspect

Slope and aspect are critical terrain characteristics for various applications, including solar farm suitability analysis. Accurate estimation of these parameters requires careful processing and cleaning of the input data. This report outlines the steps in preparing data for slope and aspect estimation in a GIS environment.

3.1.1 Slope Calculation

The Slope tool determines the steepness of each cell in a raster surface. The slope value indicates whether the ground is flat or steep [16]

Use GIS tools to calculate slope based on the elevation data. The slope (S) is commonly expressed in degrees and can be computed using the formula as shown in Equation (1):

$$S = \arctan\left(\sqrt{(\partial x \partial z)^2 + (\partial y \partial z)^2}\right) \quad (1)$$

3.1.2 Aspect Calculation

The Aspect tool depicts the face of a descending slope. The values of each cell in the output raster show the compass direction the surface faces at that location. It is gauged in degrees clockwise, from 0 (due north) to 360. Regions that are level and cannot slope downward receive a grade of -1 [16].

The slope's compass direction is represented by aspect (A), which is computed using Equation (2):

$$A = \arctan\left(\frac{\partial y}{\partial z}, \frac{\partial x}{\partial z}\right) \quad (2)$$

3.2 Extraction of LST from a thermal band of satellite imageries

Land Surface Temperature (LST) analysis plays a crucial role in suitability modeling for siting a solar farm in Owerri Municipal. Owerri, being a region with significant solar energy potential, requires a thorough understanding of LST to optimize the performance and efficiency of a solar farm.

The single thermal band is mainly required for obtaining LST data; in this research, we will obtain the LST data from the thermal (Band-10) Landsat 8 OLI [17].

Five distinct operations must be performed using ArcGIS 10.8 software to extract LST data from Landsat thermal bands. The following techniques are used to acquire land surface temperature from thermal bands in LANDSAT photos.

3.2.1 Converting to TOA radiance

All things in the globe radiate some thermal electromagnetic radiation because it has a greater degree of heat than 0 (zero) K, also known as absolute zero. Using this concept, the thermal sensor (ETM+) detects signals that can be transformed into at-sensor radiance. The spectral radiance (Lλ) has been determined using Equation (3) [18]:

$$L\lambda = ML * QCAL + AL \quad (3)$$

where, $L\lambda$ = the TOA Spectral Radiance, Radiance Multiband (ML) = 0.0003342, AL represents Radiance Add Band, QCAL denotes Quantified and Calibrated Standardized Product Pixel Value, (Band 10).

3.2.2 Converting spectral radiation to satellite brightness temperatures

Emissivity (e) changes modify glowing temperatures depending on the vegetation type. Its average value is 0.95 for vegetated land and 0.92 for non-vegetated covered land [19]. Its adjusted emissivity of the surface temperature was calculated using Artis and Carnahan's [20] method as shown in Equation (4):

$$T = \frac{K2}{ln\,(\frac{K1}{L}+1)} - 273.15 \quad (4)$$

where T = Satellite Brightness Temperature, L= TOA Spectral Radiance, K1 = Constant Band, K2 = Constant Band

For LANDSAT 8 OLI value of K1 for band 10 is 774.8853 and K2 is 1321.0789.

3.2.3 The Proportion of Vegetation (PV) Is Capable of Being Calculated

Understanding and quantifying the proportion of vegetation cover in a given area is crucial to understanding the intricate nature of land surface temperature.

Vegetation exerts a profound influence on land surface temperatures through processes such as transpiration, evaporation, and shading. As a result, the amount and health of vegetation can significantly impact a region's overall thermal characteristics. In LST analysis, considering the proportion of vegetation becomes imperative as it directly influences the energy balance and heat fluxes at the land surface.

High vegetation cover tends to cool the surface by absorbing solar radiation during photosynthesis and releasing it through transpiration. On the contrary, areas with sparse or no vegetation are prone to higher temperatures due to increased absorption and reduced evaporative cooling [21]. This can be calculated using Equations (5) and (6):

$$v = (\frac{(NDVI - NDVImn)}{NDVImax + NDVImin})^2 \quad (5)$$

where PV = Proportion of vegetation

Normalized Difference Vegetation Index (NDVI) = (Near Infrared) band 5 and (Red) band 4 [22].

$$NDVI = (\frac{Band\ 5 + Band\ 4}{Band\ 5 - Band\ 4}) \quad (6)$$

where NDVI min = 0.0202589, and NDVI max = 0.273034.

The proportion of vegetation is often expressed as a numerical measure of the quantity of plant cover in a given region. Several indices are commonly used to quantify vegetation cover, each incorporating different parameters to capture various aspects of the interaction between vegetation and electromagnetic radiation. One widely used index is the Normalized Difference Vegetation Index (NDVI). The NVDI is calculated using the formula presented in Equation 7.

$$NDVI = (NIR + Red) / (NIR - Red) \quad (7)$$

3.2.4 Land surface emissivity (ε)

Land surface emissivity (ε) measures how a surface emits heat radiation. It is a value devoid of dimensions ranging from 0 to 1, with 0 being a perfect reflector (no emissivity) and 1 representing a perfect emitter (black body) [23]

Land surface emissivity was calculated by using Equation (8):

$$e = 0.004 * Pv + 0.986 \quad (8)$$

3.2.5 Land surface temperature (LST)

Land Surface Temperature (LST) measures the ambient temperature of the Earth's surface as detected by satellites or various remote sensing sensors. It is an essential metric in several domains, including climate research, environmental surveillance, and agriculture. The formula for LST can vary depending on the method and data sources used, but a commonly used formula, presented in Equation (9), is derived from the Stefan-Boltzmann Law [23]:

$$LST = \left(\frac{BT}{1}\right) + W * \left(\frac{BT}{14380}\right) * In(e) \quad (9)$$

where BT = At-satellite Brightness Temperatures, W = Wavelength of emitted radiance = 10.8, The land surface temperature is commonly expressed in degrees Celsius**.**

3.3 Proximity Analysis of Road Network Layers in ArcGIS 10.8

This flowchart below illustrates a step-by-step workflow for proximity analysis using GIS software as shown in Figure 1, crucial for tasks requiring distance-based spatial insights.

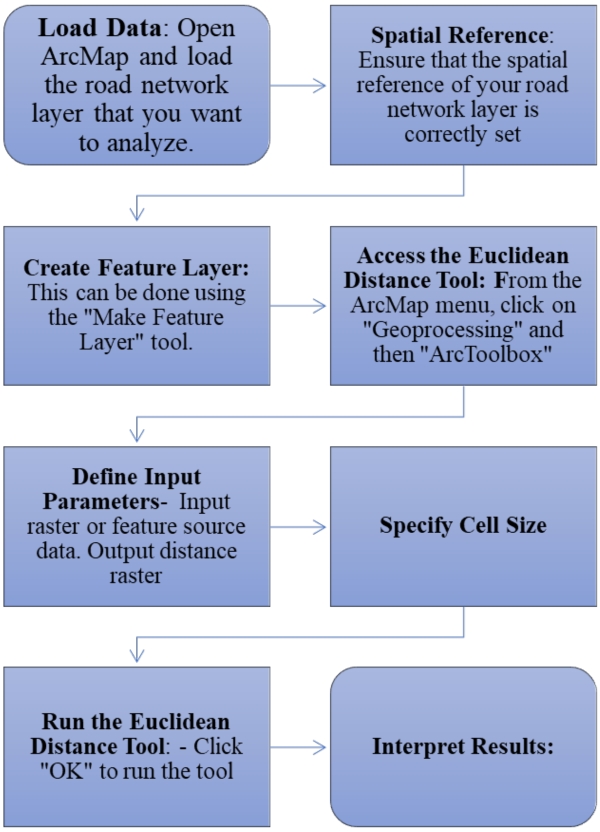

Figure 1: Flowchart illustrates a step-by-step workflow for proximity analysis using GIS software

4. Results and discussion

4.1 The Slope and Aspect

After calculating the slope and aspect of the supplied research area, the data was entered into the GIS tool, and the necessary spatial models for the slope and aspect of our given area were obtained, as shown in Figures 2 and 3. Slopes pointing east and west gain more insolation than slopes pointing north but less than slopes pointing south. They also receive it at various intervals throughout the day. East- or southeast-facing slopes receive the sun first in the early morning when temperatures are often the coolest. South-facing slopes see their highest insolation levels around noon when temperatures are higher. West- and southwest-pointing slopes gain the highest insolation in the afternoon when temperatures are usually warm. This is exactly what Daria and Igor [11] discussed in their research on slopes and aspects. Regarding terrain slope, they say flat land is best suited for solar projects, as we previously indicated. Sloping terrain makes construction more difficult and costly. As the slope expands, so does the intricate nature of the design, which frequently results in a proportionate increase in expense. They also said that installing photovoltaic panels on sloping terrain can pose problems with erosion, systems for drainage, and foundation stability. That is how to obtain the right place to set up the solar farms, and as seen in Figure 2, the places marked green were the best places to site the solar farms because they have no slope. Slope and aspect analyses are indispensable in understanding the topographic suitability of Owerri Municipality for solar projects. Our analysis observed that about 65% of the area falls within slopes less than 5%, which is highly suitable for solar farm installation. These areas, largely situated within the central and eastern parts of the municipality, provide ideal conditions for installing solar panels with minimum need for intensive land preparation.

The aspect analysis indicates that about 40% of the land area faces south, southeast, or southwest, providing ideal orientation for maximum solar exposure throughout the day. Particularly noteworthy is a large contiguous area in the northeastern section of the municipality that combines a favorable slope (<3%) with a southern aspect, making it a prime candidate for large-scale solar installations. In fact, we identified challenges in the western region where slopes exceed 10% over about 15% of the total area. As one might expect, areas with a slope over 10% are less suited for large-scale solar farms. They may still be considered for smaller, distributed solar projects with appropriate engineering solutions.

The combined slope and aspect findings suggest that Owerri Municipal has significant potential for solar energy development. The prevalence of flat to gently sloping terrain facing optimal directions indicates that large-scale solar farms could be constructed with minimal earthwork, potentially reducing initial investment costs and environmental impact.

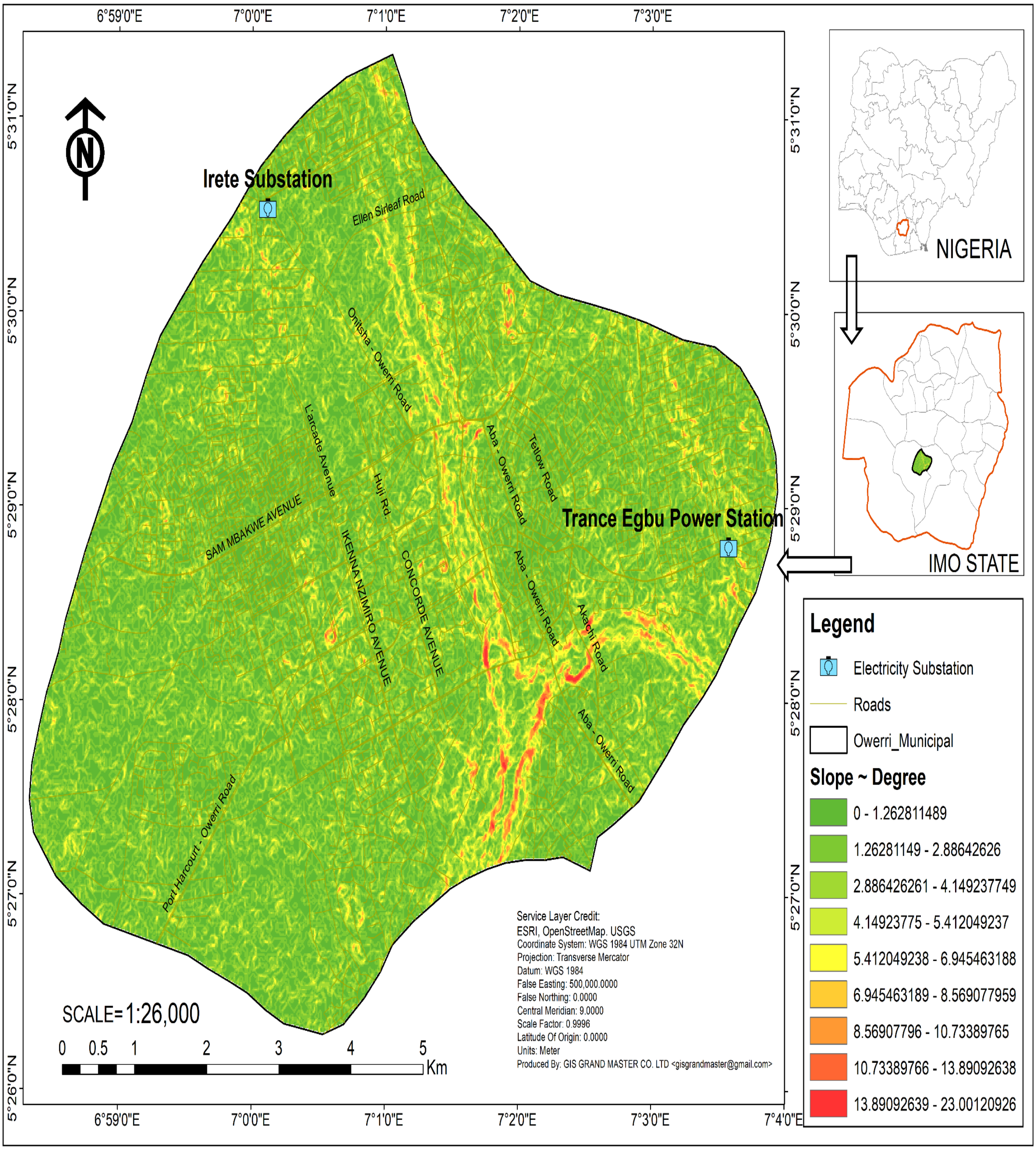

Figure 2: Slope map of research zone

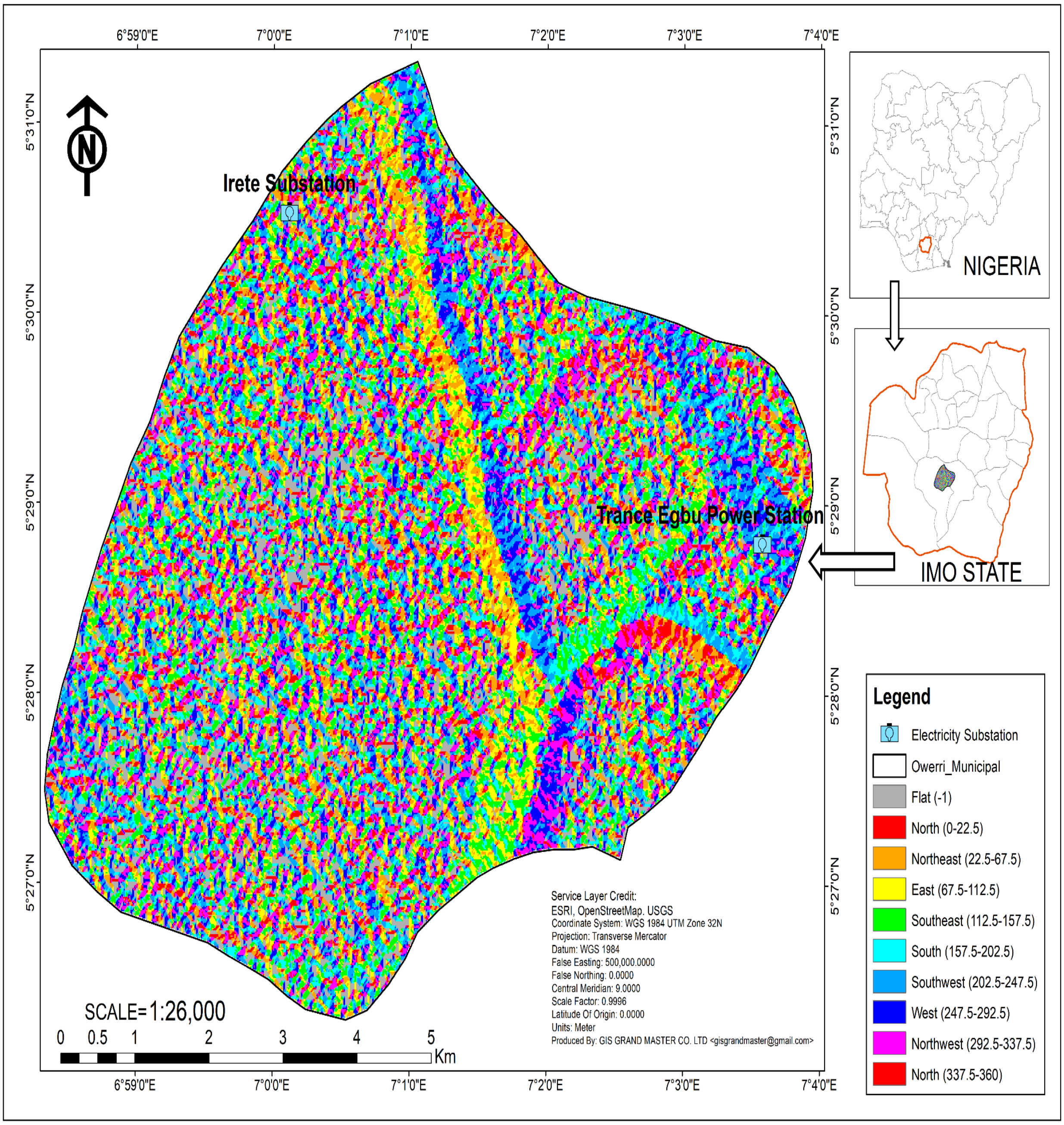

Figure 3: Aspect of the research zone

4.2 Land Surface Temperature (LST)

The land use and land cover (LULC), as shown in Figure 4, were processed to generate Figure 5 as the output file, representing the region's land surface temperature (LST) derived from thermal satellite imagery. The LST diagram shows what the heat map of the area looks like. Here, we can see which land is more exposed to increased temperature. Land Surface Temperature (LST) is a measurement of the ambient temperature of the Earth's surface, as detected by satellites or various remote sensing sensors. In the context of siting, analyzing LST involves studying the temperature variations across the land surface. This analysis was conducted using satellite imagery and remote sensing techniques.

The single thermal band is mainly required for obtaining LST data; in this research, we will obtain the LST data from the thermal (Band-10) Landsat 8 OLI [17]

The Land Surface Temperature analysis gives us a basic understanding of the area's thermal characteristics, which directly affect the efficiency and longevity of solar panels. We find the municipality's mean LST to be 32°C, with a minimum of 26°C and a maximum of 39°C. The statistical analysis shows that LST is not normally distributed. The study area affirms the following: 20% of the area falls in the range 26-30 °C, 45% falls in the range 30-34 °C,30% falls in the range 34-37 °C, 5% is over 37 °C.

This can be correlated with the land use/land cover data where it can be observed that temperature above 37°C corresponds only to the land-use type of built-up urban and bare soil, likely due to the urban heat island effect and lack of vegetation. On the other hand, the coolest areas of 26-30 °C are matched by the forested regions and water bodies.

In turn, these LST patterns have great implications for solar farm siting. Although higher temperatures can reduce photovoltaic efficiency, most of the study area is within an acceptable range for the proper operation of solar panels. Sites in the urban core may need additional cooling systems or high-temperature-resistant panels to operate within their optimal specifications.

Where seasonal analysis is available, it has been shown that the variation of LST is most marked during the dry season months of November to March, peaking in February. Consequently, this seasonal extreme should be considered in the design of solar farms to ensure efficiency throughout the year.

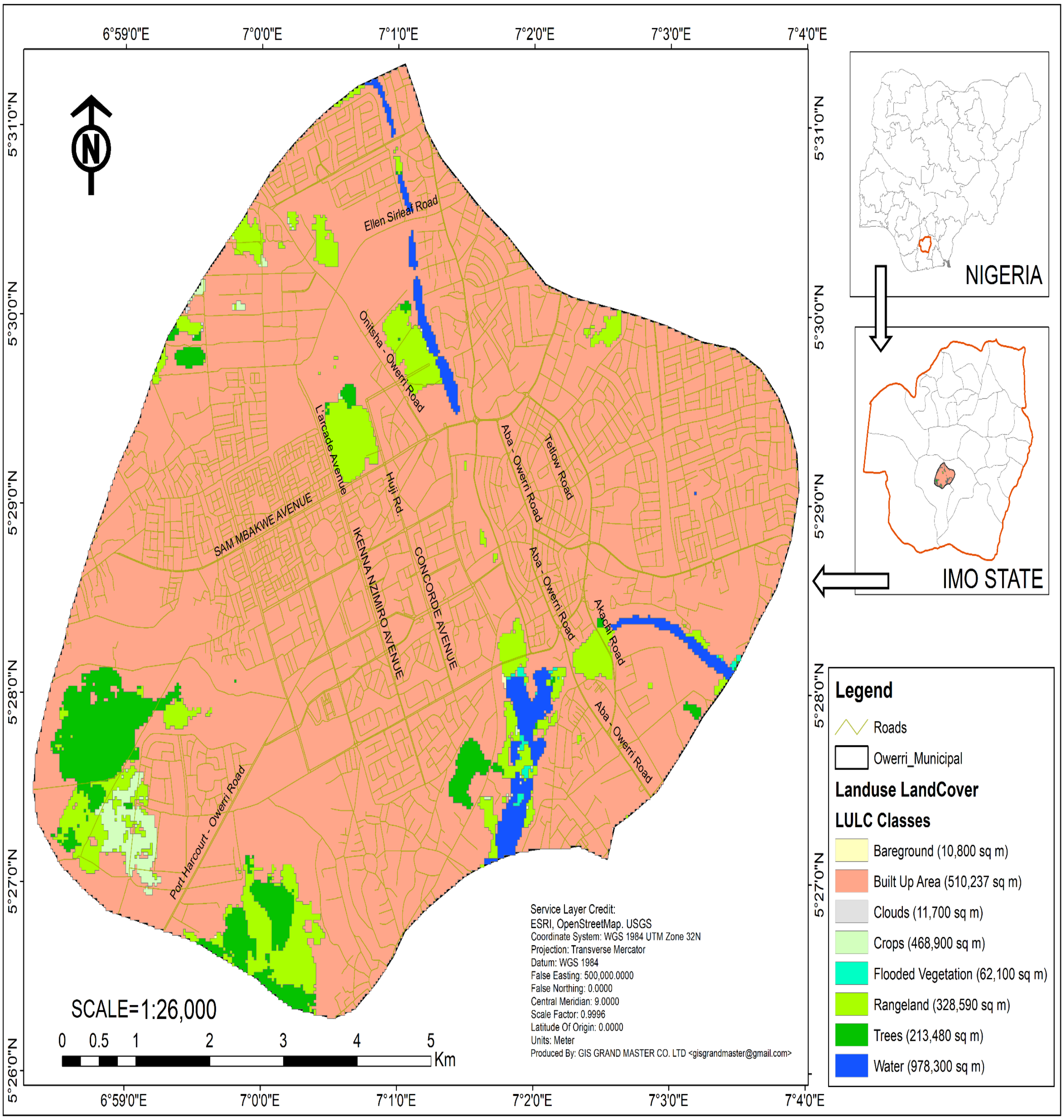

Figure 4: Land Use and Land Cover Map of the Research Zone

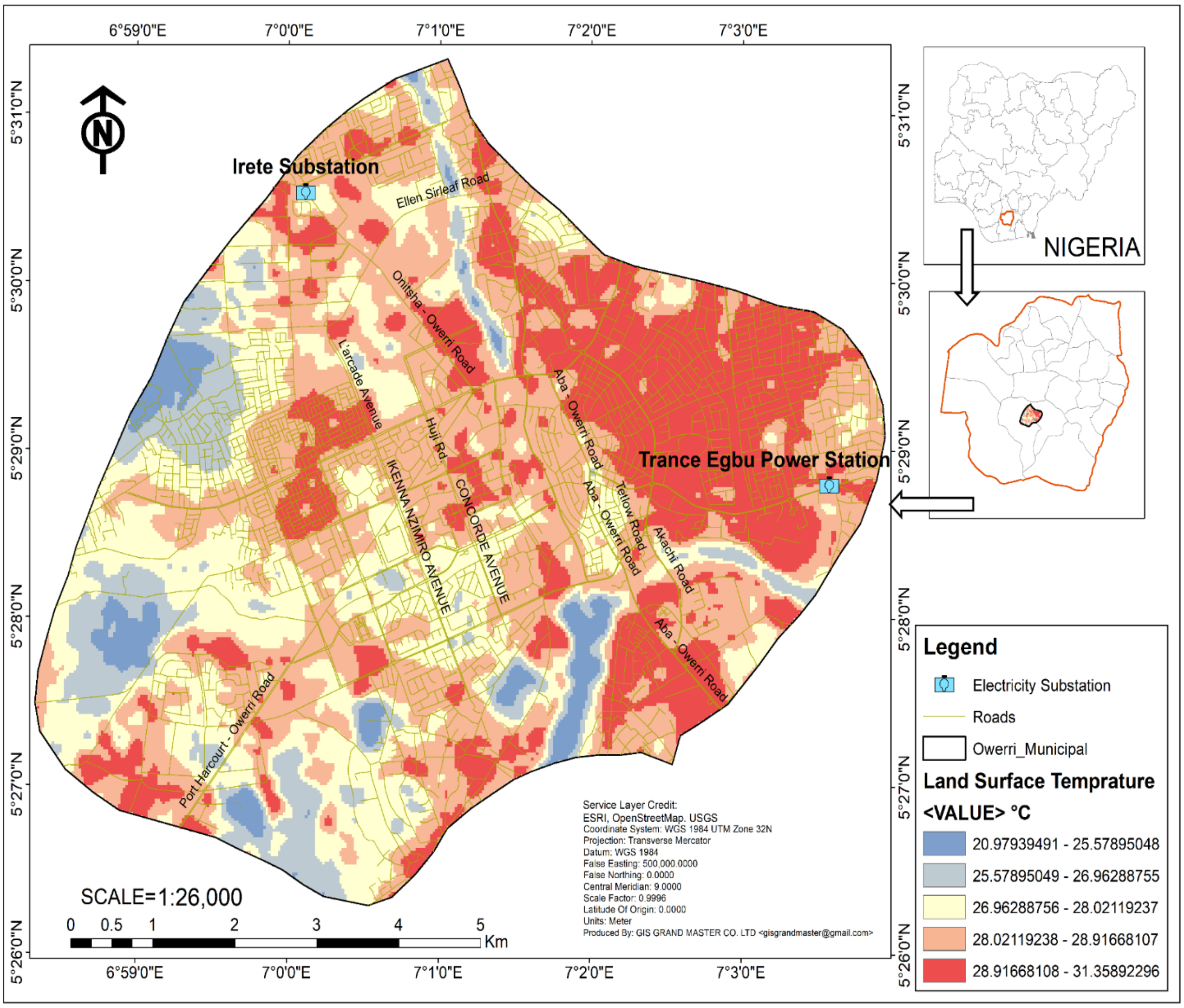

Figure 5: Land Surface Temperature Map of the study area

4.3 The Proximity to Road Network:

After getting the land surface temperature, the proximity analysis of road networks, showing the different road networks and routes within the area, was obtained, as shown in Figure 6. Proximity to the road network was a crucial factor influencing this project's feasibility and success. While working to get an accurate model showing the proximity analysis of road networks, the following factors were considered factor:

Distance Considerations: Proximity to major roads poses potential risks, including accidents and security concerns. Therefore, establishing a buffer zone between the project site and the road was necessary.

Impact on Local Roads: The proximity analysis of the road network provided valuable insights into the logistical feasibility of potential solar farm sites. The findings are as follows:

- 25% of suitable areas (determined based on slope and land surface temperature [LST]) are within 1 km of major roads.
- 40% are within a 1–3 km range.
- 25% are within 3–5 km of major roads.
- 10% are located more than 5 km away from major roads.

A positive correlation was observed between road proximity and favorable LST conditions, with areas closer to roads generally exhibiting slightly higher temperatures. This trend may be attributed to the heat-absorbing properties of road surfaces and surrounding infrastructure.

Sites within 1 km of major roads offer advantages such as ease of construction and strong grid connectivity. However, these areas may also face higher land acquisition costs and potential visual impact concerns.

The substantial proportion of suitable land within the 1–3 km range presents an optimal balance between accessibility and cost-effectiveness. These areas may serve as the best compromise, ensuring logistical efficiency while minimizing disruption to existing infrastructure and communities.

Sites beyond 5 km from major roads would be considerably more challenging from a logistics perspective but could enable larger facilities that are less disturbed. The added cost of connection to a road and the grid would have to be carefully weighed against other benefits.

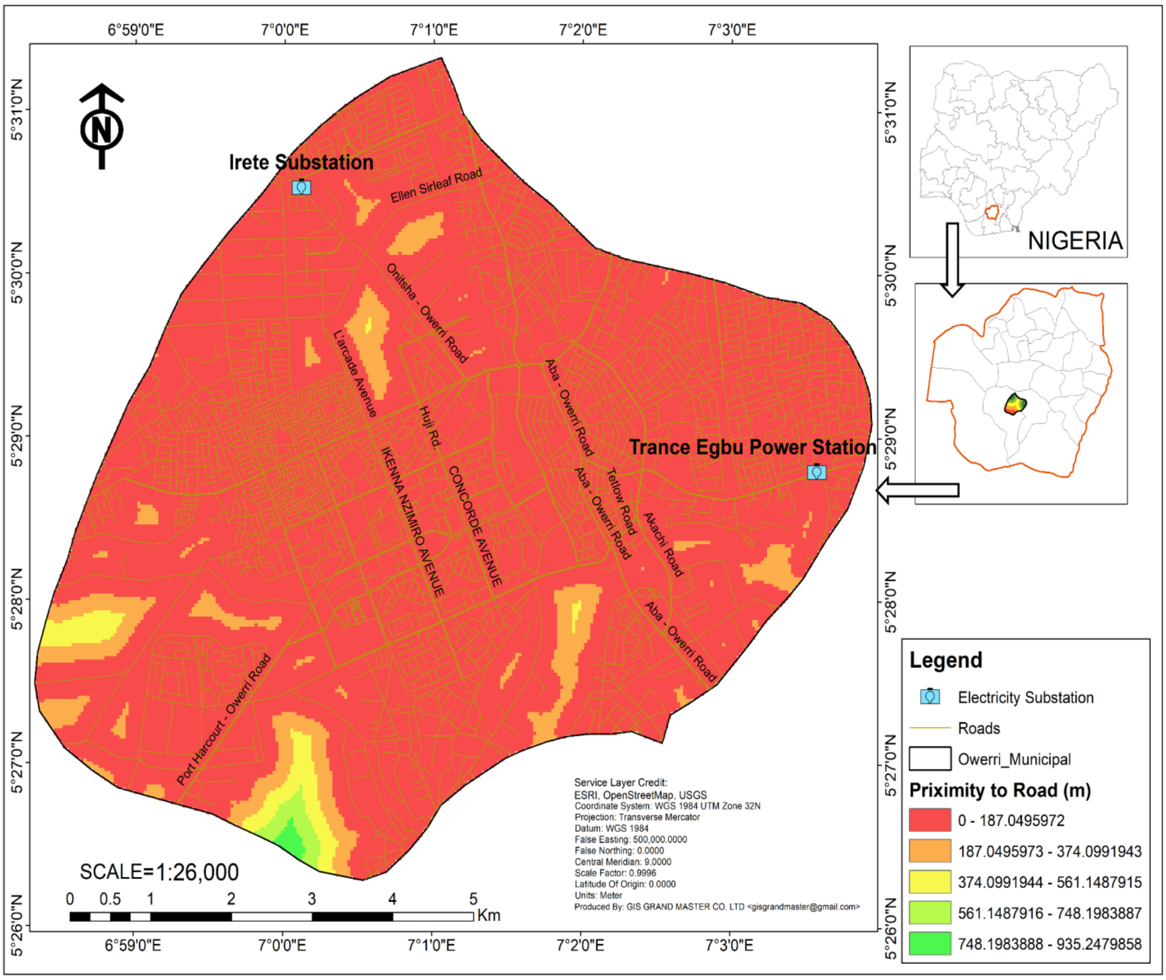

Figure 6: Proximity to Road Network model

4.4 The Suitable Sites Selected for Siting the Projects

Final Suitability Analysis

The final suitability analysis was conducted using the weighted overlay approach, integrating all considered factors. The weighting scheme applied to each factor is as follows:

- Slope: 30%
- Aspect: 20%
- Land Surface Temperature (LST): 25%
- Road Proximity: 25%

This weighting scheme prioritizes critical physical requirements—slope and LST—while also giving significant consideration to logistical factors.

The classification of the study area based on suitability is as follows:

- Highly Suitable: 15% of the total area
- Moderately Suitable: 35%
- Marginally Suitable: 30%
- Unsuitable: 20%

As illustrated in the suitability map (Figure 7), all six identified sites fall within the "Highly Suitable" category. These sites share the following common characteristics:

- Slopes of less than 3%
- Southern or southeastern aspect
- LST ranging between 30–34 °C
- Located within 3 km of major roads

Site 1 and Site 2 at Umuojala, New Owerri, are the most promising areas since both present the most optimal combination of the factors considered herein. However, being close to urban areas, land-use conflicts could arise, which will need careful attention. Site 3, located in Umuechata, Imo state, shares similar favorable topographical features with Sites 1 and 2, given its proximity to them. It offers a balance of favorable physical conditions and potentially lower development costs than Sites 1 and 2. Its slightly greater distance from the urban center of New Owerri could provide advantages in terms of land availability and cost while still maintaining good accessibility. The proximity to Sites 1 and 2 also opens up possibilities for integrated, large-scale solar development in this area of Owerri Municipal.

Sites 4, 5, and 6, located around the Osuji Beach in Nekede, offer an interesting alternative. Their quality is somewhat less optimal because of the distance of the road from the sites. Still, they provide larger contiguous areas that could be used for larger installations, possibly offsetting the greater costs for the necessary infrastructure.

Seeing the full satellite imagery of the suitable sites in Figure 8 alone is not enough to pinpoint the exact locations of the different sites. Table 2 shows the coordinates of the different points suitable for siting the projects.

Table 2: Coordinates of the different points suitable for siting the projects

Name	Latitude	Longitude	Name of Location
Site 1	5.450951975	6.978489882	Umuojala, New Owerri, Imo State
Site 2	5.451645833	6.9785353	Umuojala, New Owerri, Imo State
Site 3	5.452355395	6.98325922	Umuecheta, Imo State
Site 4	5.449002676	6.998604616	Osuji Beach, Nekede, Imo State.
Site 5	5.448314834	6.998931529	Osuji Beach, Nekede, Imo State.
Site 6	5.447627119	6.999296634	Osuji Beach, Nekede, Imo State.

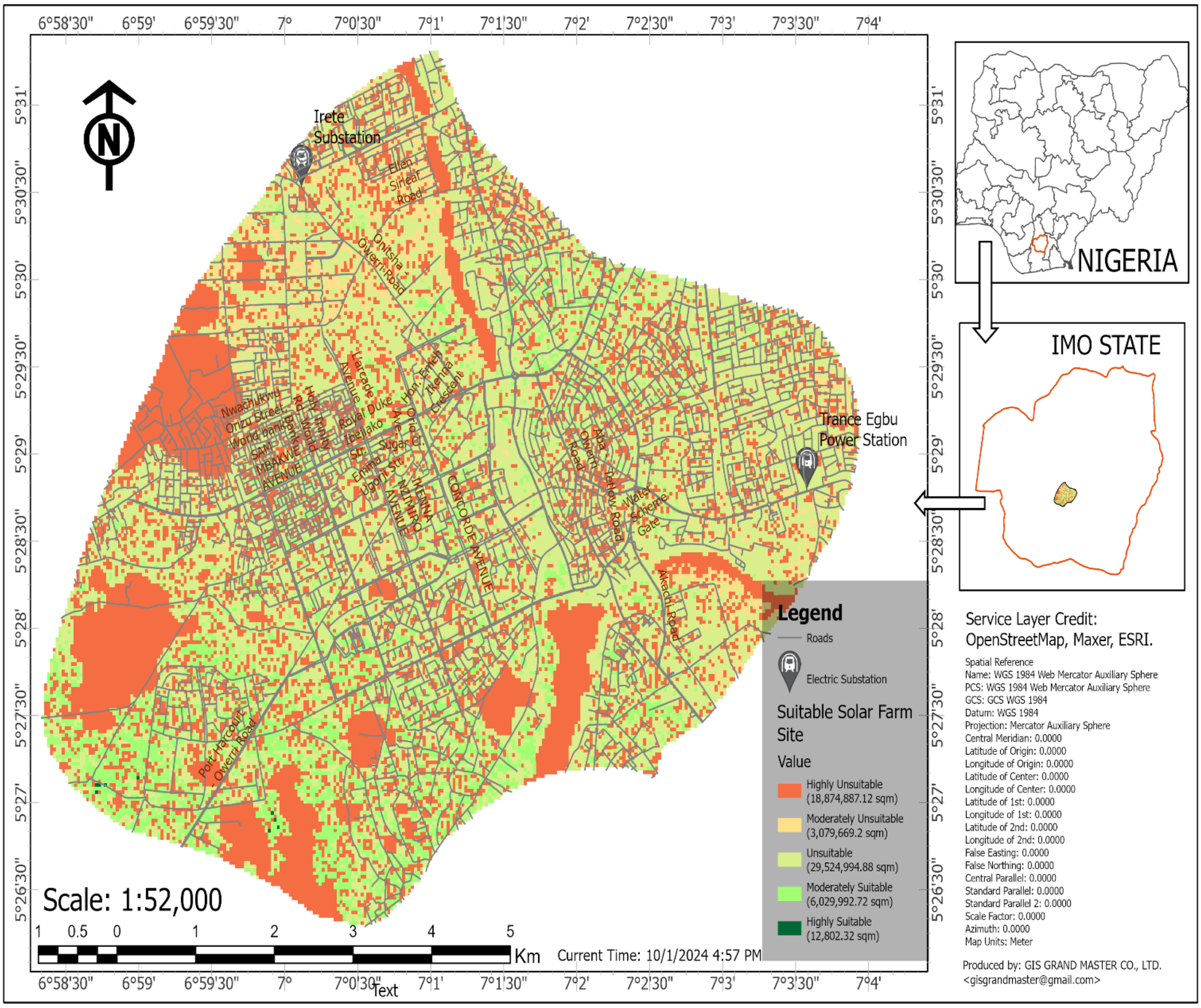

Figure 7: Suitable Site Map

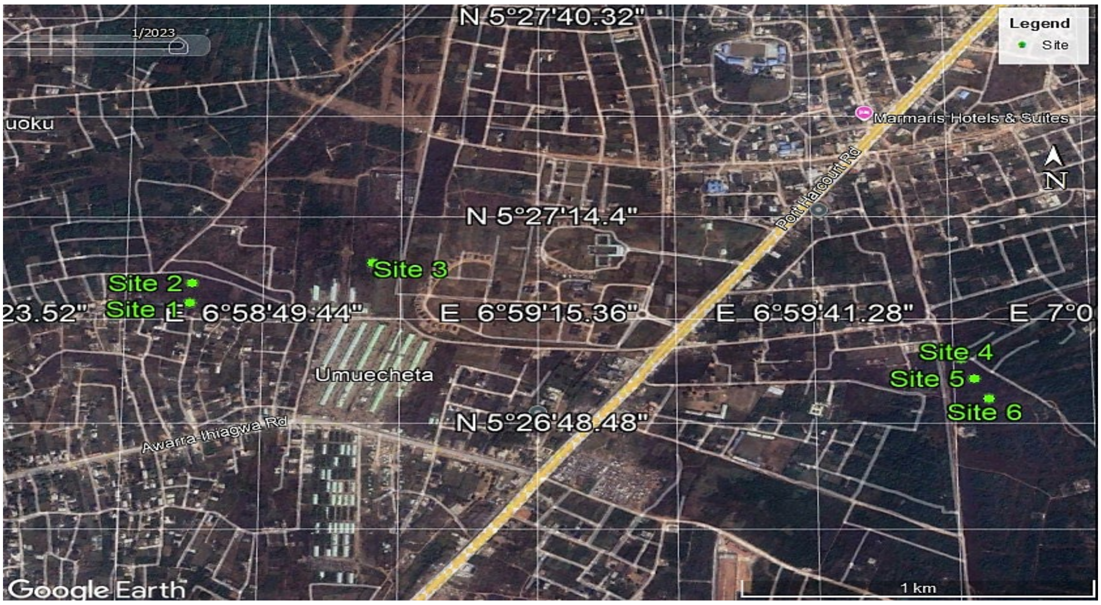

Figure 8: Full satellite imagery of the suitable sites

5. Conclusion

This study emphasizes the essential function of Geographic Information Systems (GIS) in enhancing the site selection process for solar energy initiatives in Owerri Municipal. The analysis using ArcMap 10.8 allowed for a comprehensive evaluation of essential factors such as slope and aspect, land surface temperature (LST), and proximity to road networks.

The slope and aspect analysis results revealed the terrain's steepness and orientation, which are key factors in determining the viability of renewable energy installations. Areas with favorable slopes and aspects were identified as potential sites for renewable energy deployment.

The Land Surface Temperature (LST) analysis, based on Band-10 of the Landsat 8 OLI, provided crucial insights for siting solar farms. The data were processed through five stages: top-of-atmosphere (TOA) radiance, spectral radiance, satellite brightness temperatures, Proportion of Vegetation (PV), and land surface emissivity (ε). The study identified areas with optimal temperature conditions for solar energy production. Moreover, the proximity to road networks was analyzed using the Euclidean distance tool in ArcGIS 10.8. This enabled the identification of easily accessible locations crucial for transporting materials and maintaining renewable energy infrastructure.

In conclusion, this study demonstrates the effectiveness of GIS in renewable energy project planning, providing policymakers, investors, and developers with essential tools for making informed decisions. The findings contribute to Nigeria's broader goal of sustainable energy development by pinpointing the most suitable sites for renewable energy projects while minimizing environmental and socio-economic impacts.

Author contributions

Conceptualization, **O. Ukachukwu, B. Dike,** and **M. Okeke**; data curation, **M. Okeke**; formal analysis, **O. Ukachukwu, B. Dike,** and **M. Okeke**; investigation, **O. Ukachukwu, B. Dike,** and **M. Okeke**; methodology, **O. Ukachukwu**; project administration, **O. Ukachukwu, B. Dike,** and **M. Okeke**; resources, **O. Ukachukwu, B. Dike,** and **M. Okeke**; software, **O. Ukachukwu, B. Dike,** and **M. Okeke**; supervision, **O. Ukachukwu**; validation, **O. Ukachukwu, B. Dike**, and **M. Okeke; visualization, O. Ukachukwu**; writing—original draft preparation, **O. Ukachukwu**; writing—review and editing, **O. Ukachukwu, B. Dike** and **M. Okeke**. All authors have read and agreed to the published version of the manuscript.

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Data availability statement

The data that support the findings of this study are available on request from the corresponding author.

Conflicts of interest

The authors declare that there is no conflict of interest.

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