

Siting of Photovoltaic (P.V.) Potential Station in the Borno State of Nigeria, Using Satellite Images

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Abstract: In large quantities, solar energy is released from the sun's surface. However, we can convert only some part of its reaching the earth's surface into valuable forms of energy for utilization such as thermal, electrical, or mechanical. As proposed in this research to determine the most suitable site for the installation of Photovoltaic power solar station in Borno state, Nigeria using satellite images. Annual global solar irradiance for satellite images was obtained and validated with annual global irradiance calculated from meteorological data. It can also determine Slope, Aspect, Road, Grid network, and temperature. We used an analytical hierarchy process to determine the percentage weight of each factor. We have also applied the Weighted Overlay tool to multiply the input raster, producing a final constraints layer of the most suitable area. The Annual global solar irradiance was obtained as 2240.10 Kilo-Watt-hour/meter²/year for meteorological station data and 2244.98 Kilo-Watt-hour/meter²/year for satellite images data with the validation difference of 0.88 Kilo-Watt-hour/meter²/year. The coefficient of determination $R^2=0.778$. For Slope = 0 to 89.18-degree rise, Aspect = -1 to 359 degrees, Road & Grid network = 0 to 1.31km and Temperature = 22.20 to 29.80 degrees Celsius. The weight of each factor was determined as: Slope=13%, Aspect=13% Road & Grid =5%, Temperature=5% and Global solar irradiance =64%. The most suitable area for installing a solar station was an estimated 39,426 square kilometers, mostly in the northern and some central parts of the study area, which is about 54.5% of the total land mass of Borno state. The annual global solar irradiance obtained from satellite images was converted into electric energy by different solar cell technologies: Single crystalline Silicone=1101Mega Watt, Multi crystalline Silicone=1019 Mega Watt, amorphous Silicone=440.5 Megawatt and Cadmium Tellurium=798.5 Megawatt. It found that the main factors for installing the solar station were global solar irradiance, temperature, topographical Slope and aspect, and nearest to the road and grid network. The global solar irradiance estimated in the study area is adequate to generate sufficient electrical energy for the Borno state. We found the satellite imagery data method to effectively identify suitable sites for the solar station to install a Photovoltaic power plant.

Keywords: Electrical Energy, Global Solar Irradiance, Meteorological Station, Photovoltaic Cell, Satellite Image

1. Introduction

Nigeria is enriched with an annual daily sunshine hour of an average of 6.25 hours. It also has an annual average daily solar radiation of about 3500 Wm²/ day in the southern region and 7000 Wm²/ day in the northern part [1]. The quantity of solar energy reaching the earth is approximately 1.5×10^{18} kWh/year [2]. The energy rate released by the sun is 1373

W/m², known as the solar constant [3].

Electron pairs are created when sunlight hits the semiconductor surface and moves through the N-type semiconductor material. This will generate more negatives in the n-type and positives in the P-type semiconductors, leading to a high flow of electricity. It is known as the Photovoltaic effect [4].

Related studies were conducted in different parts of the world, using different approaches to determine solar radiation potential

and select the most suitable sites for photovoltaic (PV) installations, where incoming solar radiation is estimated in a relatively large country such as Nigeria despite the vast range of applications demanding solar radiation data, other meteorological parameters, and satellite images are mathematically exploited to estimate the global solar irradiance reaching the earth surface. Below are some of the research on solar radiation measurement in various parts of the world.

Wenjun *et al.* [5] estimated global solar radiation using a hybrid method for estimating solar irradiance and evaluated it against the controlled data; Alkasim *et al.* [6] Estimated the land surface temperature of Yola, Using Landsat-7 ETM+ Satellite Image, Falayi and Rabi [7] estimated solar irradiance using surface temperature. Isikwue *et al.* [8] used the empirical model to estimate total solar irradiance. Adhikari *et al.* [9] estimated total solar irradiance using a regression model based on sunshine hours, temperature, and relative humidity; Auwal and Darma [4] estimated global solar radiation based on meteorological data, Kalthiya *et al.* [10] predicted global solar radiation using Angstrom-page equation model for Makurdi Benue state, Nigeria. Garba *et al.* [11] estimated the total solar irradiance of Maiduguri, northeast Nigeria. Ado *et al.* [12] evaluated empirical formulae for calculating the global irradiance of Jos, and Salihu *et al.* [13] mapped the spectral radiance over Mubi town using satellite images Landsat 7 ETM. Alkasim *et al.* [14] used an empirical model to estimate global and diffuse solar radiation over Yola, northeastern Nigeria, based on air temperature.

A photovoltaic electric energy generation system is measured in kilowatts (kWh) which is the amount of electrical energy that a plane is assumed to give when the sun is directly overhead on a day. Researchers have developed a different approach for calculating a photovoltaic electric energy system. A brief review of these methods is presented as follows;

Chokmaviraj *et al.*, [15] Photovoltaic Conversion System In solar energy studies, data on solar radiation and its components at a given location are a fundamental input for solar energy applications such as PV design. So *et al.* [16] evaluated the performance of a large-scale PV system and monitoring system installed in Daegu City to observe the effect of meteorological conditions on their operation characteristics for the monitoring period. Pacca *et al.* [17] assessed the modelling areas that affect the performance of photovoltaic electricity generation technologies. Alazraki and Haselip [18] determined the impact of PV systems installed. Rehman *et al.* [19] evaluated the installation of 5MW capacity photovoltaic-based grid electricity generation. Denholm and Margolis [20] estimated some of the limits in electric power system installation of photovoltaic (PV). Osram and Chapman [21] compared the available P.V. and MPPT methods. German and Hepbasli [22] explained the photovoltaic (PV) areas and described them using their tilt angle. Xiao *et al.* [23] studied the spatial relations and geometric properties of the Photovoltaic (PV) system to optimize the operation of the

maximum power point tracker (MPPT). The research proposed an individual power interface for each PV module and suggested a suitable structure for the PV system. Stoppato [24] estimated the outcomes of electric energy generation utilizing photovoltaic. Gules *et al.* [25] implemented a standalone photovoltaic (PV) power generation. The researchers constructed a prototype board that showed a maximum of 45 W power and was found during photovoltaic power generation. Mills *et al.* [26] examined the importance of electric energy design on the economic value of PV systems. Hocaoglu *et al.* [27] studied the effect of temperature on PV generator efficiency. Apeh [28] focused on alleviating acute electrical power generation in Nigeria using a solar power system. Zhou *et al.* [29] determined how temperatures affect PV cells and solar irradiance on PV cells. Jalilzadeh *et al.* [30] applied the energy balance methodology to deduce PV generator efficiency regarding solar irradiance and surface temperature Parida *et al.* [31] reviewed major solar photovoltaic technologies. The study focused on PV system performance. Gaurav *et al.* [32] studied the transmission of Electric energy through the Satellite method.

Most recently, Nigerian societies have faced the main challenges of energy generation and sustainable utilization. Most of the available energy resources currently relied on in Nigeria are exhaustible and will be depleted because of the increasing demand.

Nigerian electric energy sector depends solemnly on hydroelectric and thermal electric generation companies, which increase demand in some regions such as Borno state. Electrical energy consumption in Nigeria's Territories is the lowest per capita in the northeastern part, and the consumption tariff is higher than anywhere else in the country.

This research figures out a lasting solution for electrical energy for the entire Borno state of Nigeria, aiming to determine the most suitable site for installing Photovoltaic (PV) In the Borno State Nigeria Using Satellite image.

2. Method

2.1. Study Areas

The map of Borno state of Nigeria is shown in Figure 1, and it has situated at latitude 11°30'N and longitude 13°15'E. Sharing a border with Yobe state toward the west, Gombe state toward the southwest, and Adamawa state in the southern areas; on the eastern side, it forms a border with part of Cameroon, the northern part of Niger Republic. The northeastern region creates a boundary with Chad, the only State bordered by three countries in Nigeria. In 2016 it had a determined population of 5.86 million, and it has a land mass of 70,321 km²; the State has been categorized geographically into semi-desert Sahelian savanna in the north and central part and Mandara plateau in the southern region. As an agriculturally-based state, the rural area of Borno State's economy relied heavily on livestock and crop farming before

the Boko haram insurgency. The state capital Maiduguri is a major regional trade and service centre that needs electrical energy to burst back the economy of the State.

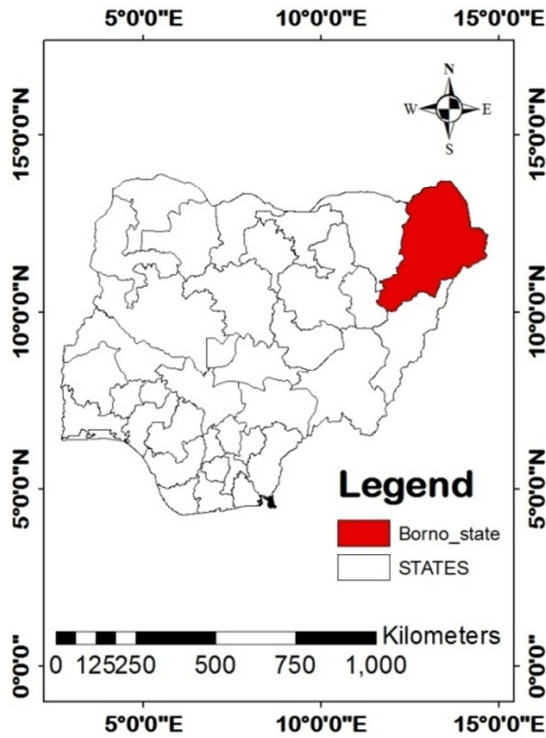


Figure 1. Map of Nigeria Showing Borno State as a Study Area.

2.2. Data Sources

a) Have been collected meteorological data from state meteorological stations for 2008-2018.

b) We downloaded satellite imagery data from Solargis global solar model. It has been delivered for the Global Solar Atlas (<https://globalsolaratlas.info/>). Long-term yearly average, covering the period 2008-2018.

2.3. Data Processing

The data was processed in the following manner.

2.3.1. Estimation of Global Annual Solar Irradiance (GASI) of Meteorological Data

The estimating GASI was formulated by Angstroms and modified by Prescott. As given in equation 1

$$\frac{\bar{G}}{G_o} = a + b \frac{\bar{S}}{S_o} \quad (1)$$

Where

\bar{G} = The monthly mean global solar radiation on a horizontal surface (kWh/m²/day),

G_o = the monthly mean extra-terrestrial solar radiation on a flat surface (kWh/m²/day)

\bar{S} = The monthly mean daily bright sunshine hours (Hours),

S_o =, the maximum possible monthly mean daily sunshine hours (Hours),

a and b are regression constants depending on on-site location.

2.3.2. Estimation of GASI Using Satellite Image

Satellite images have to undergo processing techniques such as denoising and geometrical correction. Several Wavelet techniques for denoising satellite images include the Coiflet wavelet transform, Haar wavelet transform, Daubechies wavelet transform, etc. [33], but we chose Haar wavelet techniques for this research. Wavelet denoising was performed using Matlab (R2010a) Image Processing Toolbox and Wavelet toolbox [34] by decomposing the noising image into wavelet coefficients and modifying it based on the soft thresholding function, as shown in Figure 2. Furthermore, the inverse wavelet transform was also utilized on modified coefficients before the reconstructed satellite image, as presented in Figure 3.

i. Haar wavelet transform was applied to the noise satellite image. The wavelet transform decomposes the image information into the wavelet coefficients as follows.

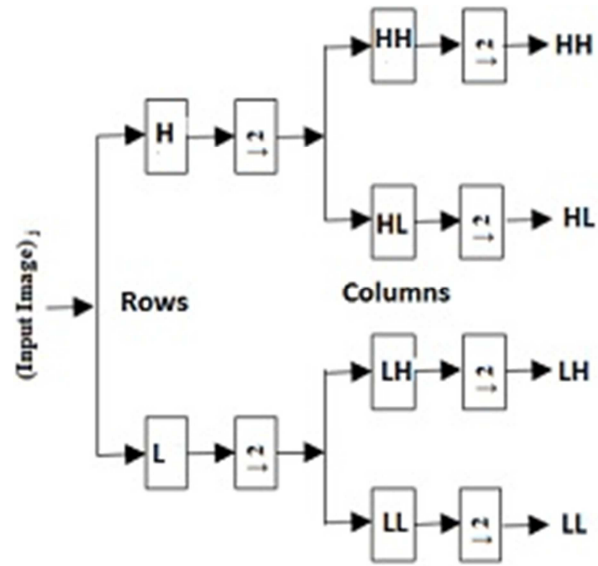


Figure 2. Level 2 Wavelet Decomposition [35, 36, 37].

We used a soft threshold function to filter unwanted wavelet coefficient components. The smaller than 0 will be removed, and the more significant coefficients will be retained [38].

$$\phi(i, j) = \begin{cases} \text{sgn}(\phi(i, j))(|\phi(i, j)| - t), & |\phi(i, j)| \geq t \\ 0, & |\phi(i, j)| \leq t \end{cases} \quad (2)$$

Where $\text{sgn}(\phi(i, j))$ is the sgn scaling function defined as

$$\text{sgn} = \begin{cases} 1 & \phi(i, j) > 0 \\ 0 & \phi(i, j) = 0 \\ -1 & \phi(i, j) < 0 \end{cases} \quad (3)$$

't' is the threshold value, and (i and j) represent the wavelet coefficients before and after thresholding.

ii. Inverse Haar wavelet transformation was then applied to reconstruct the satellite images, as depicted in Figure 3.

After denoising, ArcGIS 10.4.1 solar radiation tool was used to calculate GASI in KWh/m²/year.

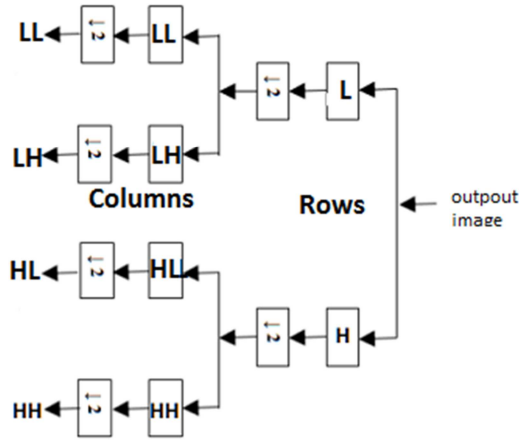


Figure 3. Level 2 Wavelet Reconstructed Image [35-37].

2.3.3. Qualitatively Evaluation

A cartographic map was generated using ArcGIS 10.4.1. Those mapping revealed the temperature, Slope, aspect, accessibility to the grid network, and road adjacent to the study area.

2.3.4. Analytical Hierarchy Process

(AHP) was chosen for this study as one of the preferred methods for site selection. AHP is a systematic pair-wise comparison concerning each criterion for a given criterion. Alternative i is preferred to alternative j with the strength of preference given by $A_{ij}=N$, $1 \leq N \leq 9$, correspondingly, $A_{ji}=1/N$. [39] A weight for each criterion by comparing the pairs of criteria, as shown in Table 1.

Table 1. Systematic Pair-Wise Criterion.

| 1/9 | 1/7 | 1/5 | 1/3 | 1 | 3 | 5 | 7 | 9 |
|-----|-----|-----|-----|----|----|----|----|----|
| Ex | Ve | St | Md | Eq | Md | St | Ve | Ex |

Where: Ex=extreme, Ve = very, St=strong, Md = moderate and Eq=equal

According to [40], to draw out pair-wise comparisons performed at a given level, a reciprocal matrix M is created by putting the result of the pair-wise comparison of element i and element j into the position a_{ij} as shown in Equation 2]:

$$M = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1j} \\ \vdots & \vdots & \dots & \vdots \\ \dots & \dots & \dots & \dots \\ a_{ij} & \dots & \dots & a_{ij} \end{bmatrix} \quad (4)$$

Subsequently, a priority vector (eigenvector) was computed to establish weights (w_j). The procedure consists of two steps: raising the matrix to power and sum and normalizing the row. This process must be iterated until the eigenvector solution does not change from the previous iteration. These weights are a quantitative measure of the consistency of the value judgments between pairs of factors [41]. A consistency index (CI) is calculated using Equation 2.5.

Where λ_{\max} is the largest eigenvalue and n is the number of rows or columns of the matrix:

$$CI = \frac{\lambda_{\max} - n}{n - 1} \quad (5)$$

ArcGIS Weighted Overlay tool was used to determine the suitability modeling. Slope, aspect, GASI, temperature, distance from roads, and grid network were input rasters. The input criteria were reclassified into the desired preference scale indicated as unsuitable, reasonably suitable, and most suitable. The more favourable the criteria range, the higher the value. The constraints layers slope, aspect, distance from roads and grid network, temperature, and GASI were multiplied and produced the final constraints layer, as shown in Figure 11.

2.3.5. Conversion of Solar Irradiance to Electrical Energy

The electric power generation potential per year for the selected area was estimated based on the calculated GASI per unit surface area per year using Equation 2.6.[36]:

$$E.P. = GASI.T_A.A_F.\eta \quad (6)$$

Where,

E.E. = Electric power generation potential per year (kWh/year)

GASI = Annual solar radiation received per unit horizontal area (kWh/m²/year)

T.A. = Calculated total area of suitable land (m²)

A.F. = the area factor indicates what fraction of the calculated areas can be covered by solar panels

η = PV system efficiency

The efficiency (η) of different P.V. technologies used for this research is shown in Table 2.

Table 2. Typical Efficiency of Solar Panels (source: [46]).

| Solar cell technology | Efficiency (%) |
|-----------------------|----------------|
| Sc-Si | 20.0 |
| Mc-Si | 18.5 |
| A-Si | 8.00 |
| CdTe | 14.5 |

Where: Sc-Si=Single-crystalline Silicon, Mc-Si=Multi-crystalline Silicon, A-Si=Amorphous Silicon and CdTe= Cadmium-Telluride

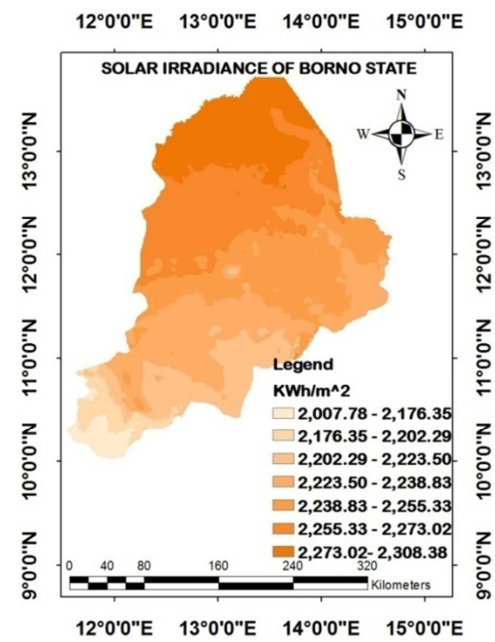


Figure 4. GASI (KWh/m²/Yr) of Borno State.

3. Result

Table 3 shows the result of meteorological GASI, and Figure 4 presents the satellite image processed GASI of Borno State. Figures 5 & 6 show satellite and meteorological GASIs graphs, respectively. Figures 7 to 13

depict the results of the Slope, aspect, road and grid network, temperature, most suitable area, the graph of suitability area, and graph of determining potential electrical energy of Borno state, respectively. Table 3 shows the selected electric power of the Borno state with different solar cell technologies.

Table 3. The amount of GASI (KWh/m²/Yr) in Borno State Is Determined by Meteorological Data.

| m/Y | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|-----|------|------|------|------|------|------|------|------|------|------|
| Ja | 194 | 197 | 197 | 197 | 190 | 192 | 196 | 223 | 197 | 190 |
| Fb | 191 | 190 | 179 | 197 | 191 | 192 | 190 | 199 | 192 | 201 |
| M | 225 | 222 | 228 | 226 | 220 | 207 | 220 | 210 | 228 | 228 |
| Ap | 204 | 214 | 215 | 214 | 201 | 209 | 225 | 213 | 210 | 207 |
| My | 193 | 213 | 212 | 198 | 207 | 202 | 215 | 208 | 215 | 206 |
| Ju | 189 | 187 | 184 | 181 | 180 | 194 | 195 | 186 | 189 | 178 |
| Jl | 181 | 159 | 183 | 175 | 184 | 180 | 180 | 181 | 184 | 179 |
| Au | 177 | 171 | 164 | 162 | 152 | 172 | 174 | 165 | 147 | 164 |
| Sp | 190 | 177 | 179 | 188 | 179 | 180 | 181 | 185 | 181 | 173 |
| Oc | 183 | 193 | 198 | 194 | 200 | 194 | 202 | 205 | 211 | 201 |
| Nv | 188 | 191 | 196 | 189 | 191 | 190 | 193 | 190 | 190 | 194 |
| Dc | 191 | 191 | 192 | 191 | 187 | 188 | 186 | 184 | 189 | 188 |
| Tot | 2306 | 2307 | 2327 | 2312 | 2282 | 2299 | 2357 | 2350 | 2332 | 2307 |

Where: m=monthly, Y=year, Ja=January, Fb=February, M=march, Ap=April, My=May, Ju=June, Jl=July, Au=August, Sp=September, Oc=October, Nv=November and Dc=December.

While 09=2009, 10=2010, 11=2011, 12=2012, 13=2013, 14=2014, 15=2015, 16=2016, 17=2017 and 18=2018

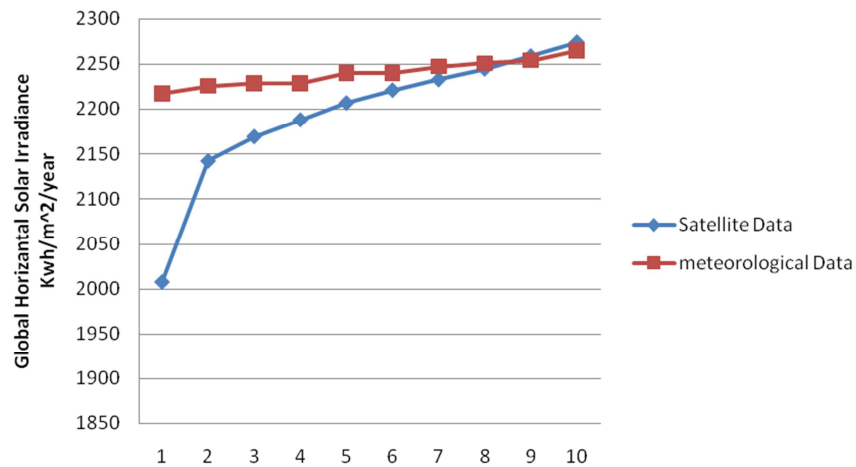


Figure 5. Show the Graph of Satellite and Meteorological Determined GASI.

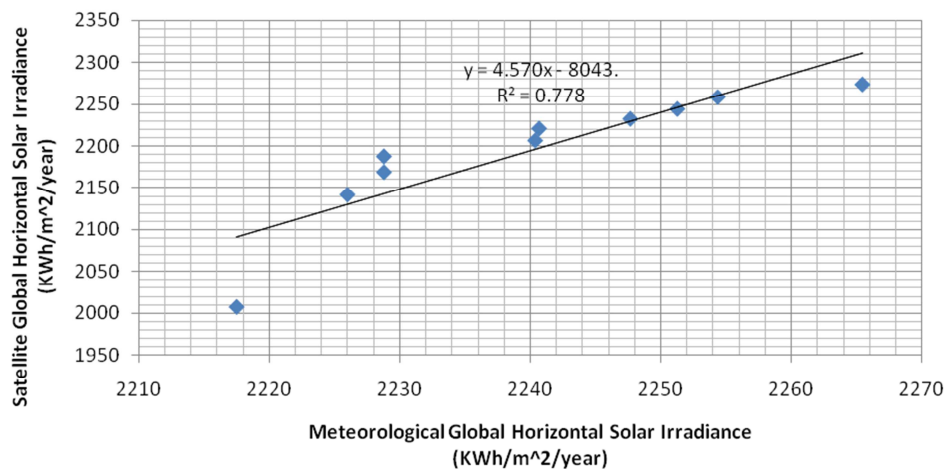


Figure 6. The Graph of Validation of Satellite and Meteorological GAS.

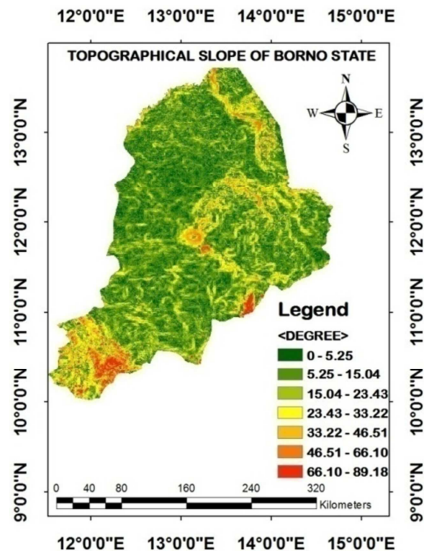


Figure 7. The Topographical Slope of BornoState.

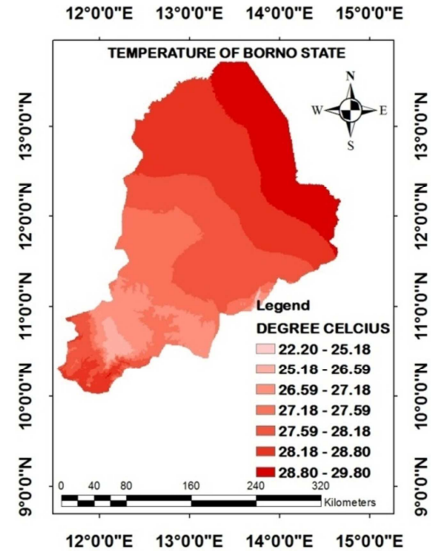


Figure 10. The Temperature of BornoState.

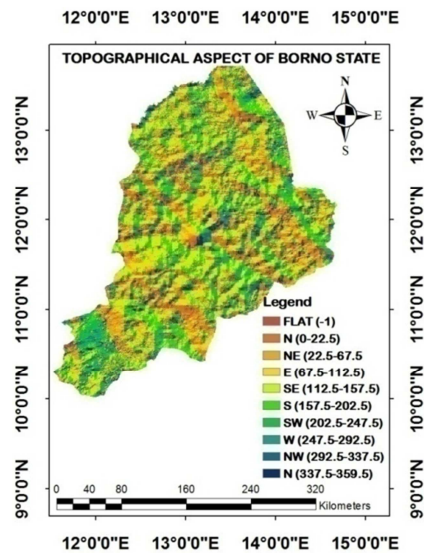


Figure 8. Topographical Aspect of BornoState.

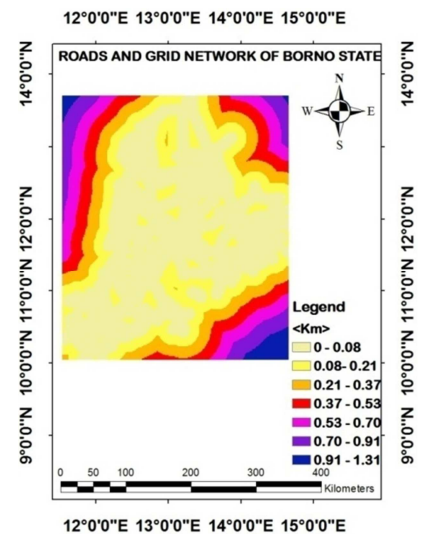


Figure 9. The Road and Grid Network of BornoState.

Table 4. Pair-Wise Matrix of Criterion.

| | Sp | As | R.G. | Te | SI | Wt |
|----|-----|-----|------|----|-----|-----|
| Sp | 1 | 1 | 3 | 3 | 1/7 | 13% |
| As | 1 | 1 | 3 | 3 | 1/7 | 13% |
| RG | 1/3 | 1/3 | 1 | 1 | 1/9 | 5% |
| Te | 1/3 | 1/3 | 1 | 1 | 1/9 | 5% |
| SI | 7 | 7 | 9 | 9 | 1 | 64% |

Where Sp=Slope, As=Aspect, RG=Road & Grid, Te=Temperature, SI=Solar Irradiance and Wt=weight.

Table 5. The Determined Electric Energy of Borno State with Different Solar Cell Technology.

| Solar cell | η | CA | AF | GASI | EE |
|------------|--------|----------|-------|---------|-------|
| sc-Si | 0.200 | 39426300 | 0.545 | 2244.94 | 1101 |
| mc-Si | 0.185 | | | | 1019 |
| a-Si | 0.080 | | | | 440.5 |
| CdTe | 0.145 | | | | 798.5 |

Where there unit are: η = (%), CA = (m^2), AF = (%) GASI = ($kWh/m^2/year$) and EE=MW

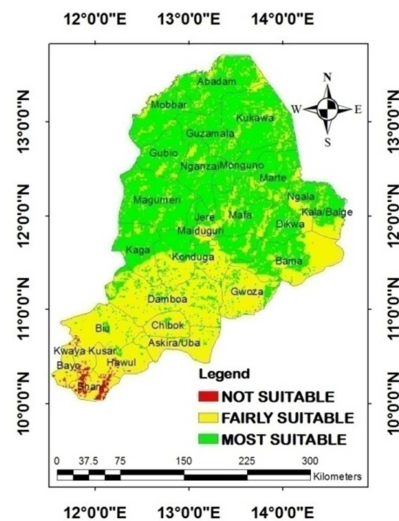


Figure 11. Showing Map of the Determined Suitable Site of BornoState.

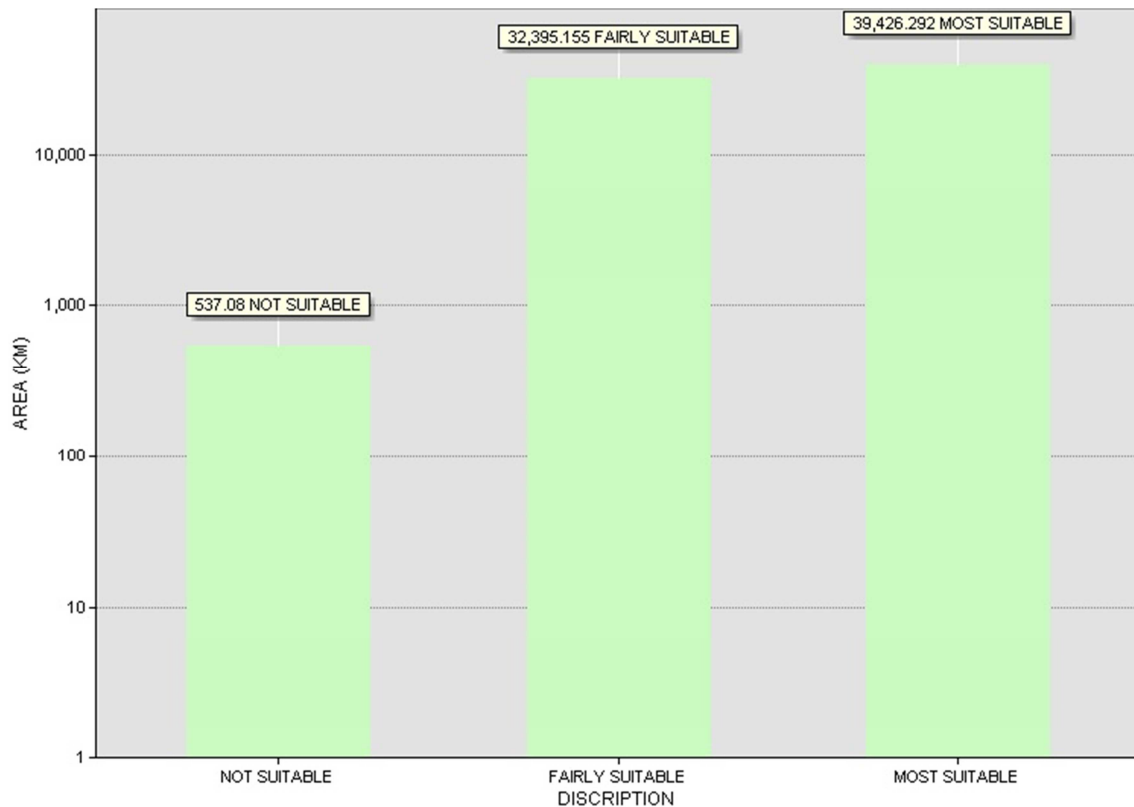


Figure 12. Graph Showing Suitability Area of Borno state.

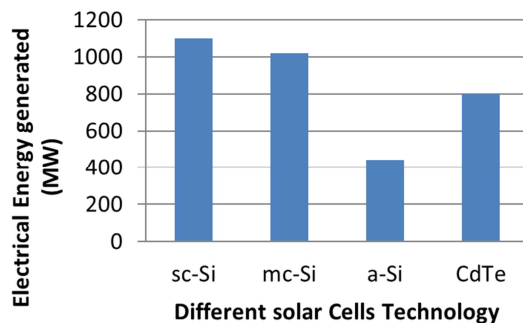


Figure 13. Graph of Determining Electrical Energy Generated from Different Solar Cell Technologies of BornoState.

4. Discussions

The amount of GASI was calculated for both satellite and meteorological data. Meteorological data ranged from 2217.51 to 2265.51 kWh/m²/year, with the Mean Annual Value (MAV) of 2240.10 kWh/m²/year, as presented in Table 2. Satellite image data was obtained from 2007.78 to 2308.40 kWh/m²/year with a MAV of 2244.95 kWh/m²/year, as shown in Figure 4. GASI obtained from meteorological data was used to validate that obtained from satellite image data, with a difference of 0.88 kWh/m²/year. With a coefficient of determination $R^2 = 0.778$, as shown in Figure 6.

The slopes (Degree) were obtained as; 0-5.25, 5.25-23.43, 23.43-33.22, 33.22-46.51, 46.51- 66.10, and 66.10- 89.18, as presented in Figure 7. A Slope > 5 degrees was chosen as a

suitable solar station site for this work. [42]

Aspect (Degree), as depicted in Figure 8, it gives nine different directions that the slopes were facing, such as North (N), Northeast (N.E.), Northwest (N.W.), East (E), Southeast (S.E.), South (S), Southwest (S.W.), West (W), and flat areas. Flat (-1) and south-facing slopes were considered the best for suitable installation of the solar station, such as S.E. (102.14-153.71), S (153.71- 205.29), and S.W. (205.29 – 256.91) [43].

Distance to Road and Grid network (Km) was obtained as: 0.08, 0.21, 0.37, 0.53, 0.70, 0.91 and 1.31, as presented in Figure 9. For suitable installation S.S., less than 1km was selected based on a criterion used in [44].

The Temperature (°C) was obtained as 22.20, 25.18, 26.59, 27.59, 28.80 and 29.80, as depicted in Figure 10. It is recommended that 25°C is the standard temperature test condition [45]. Therefore 22.20- 25.18°C is the best temperature for installing a Solar Station (S.S.).

The criteria were weighted according to the Analytical hierarchy process presented in Table 4. GASI is the most crucial criterion, weighted 64%, while the topographical Slope is 13%, the topographical aspect is 13%, the nearest to the road & grid network is 5%, and the temperature is 5%.

The preferable Installation Area was obtained as follows; the most suitable area is 39,462km², the reasonably suitable area is 32,395.16km², and the unsuitable area is 537.08km², as depicted in Figure 11. Furthermore, the most appropriate area primarily lies in the study areas in the northern and some central parts.

To further ascertain the validity of the GASI obtained, MAV

was converted to electric energy in megawatts (M.W.) with different solar cell technologies as Sc-Si = 1101, Mc-Si = 1019, a-Si = 440.5, and CdTe = 798.5 as presented in Table 5. However, the electric energy given to Borno state by the national power Grid is less than what was obtained by GASI by 1075.04 MW.

5. Conclusions

The main factor for S.S. installations in the study area was GASI, temperature, topographical Slope, and aspect nearest to the road and grid network. Energy generation from solar station installation is possible in Borno state. It has a high potential for renewable energy in the northern area of the central district part of the State due to its terrain and a good amount of GASI and other factors in that area, while in the southern region, due to the high plateau terrain, reasonably suitable or not suitable for the installation of S.S. As S.S. can be installed, this advantage can enable Borno State to meet renewable energy targets for 2022.

The chosen satellite imagery data methodology effectively identified suitable sites for S.S. installation. It can be recommended for future studies in some areas, other parts of the country, or the world.

List of Abbreviations

SS: Solar Station
 GASI: Global Annual Solar Irradiance
 AHP: Analytic Hierarchy Process
 W/m²/day: Watt per meter square per day
 W/h: Watt per hour
 KWh/year: Kilo-Watt-hour per year
 KW/m²: Kilowatt per meter square
 DC: Direct current
 SPV: Solar Photovoltaic
 N-type semiconductor: Negative-type semiconductor
 P-type semiconductor: Positive-type semiconductor
 sc-Si: Single-crystalline Silicon
 mc-Si: multi-crystalline Silicon
 a-Si: Amorphous Silicon
 CdTe: Cadmium-Telluride
 PV: photovoltaic
 MPPT: Maximum power point tracker
 LCA: life cycle assessment
 \bar{G} : The monthly mean global solar radiation on a horizontal surface (kWh/m²/day),
 G_o : the monthly mean extra-terrestrial solar radiation on a horizontal surface (kWh/m²/day)
 \bar{S} : The monthly mean daily bright sunshine hours (Hours),
 S_o : the maximum possible monthly mean daily sunshine hours (Hours),
 and b are regression constants depending on on-site location
 KWh/m²/year: Kilo-Watt-hour per meter square per year
 Ep: Electric power generation potential per year (kWh/year)
 A.R.: Annual solar radiation received per unit horizontal area (kWh/m²/year)
 T.A.: Calculated total area of suitable land (m²)

A.F.: the area factor,
 η : P.V. system efficiency
 N: North
 NE: Northeast
 NW: Northwest
 E: East
 SE: Southeast
 S: South
 SW: southwest
 W: West
 Km: kilo-meter
 MATLAB: Matrix Laboratory
 ArcGIS: Aeronautical reconnaissance coverage geographical information system

Declarations

Ethics Approval and Consent to Participate

Not applicable.

Consent for Publication

Not Applicable.

Availability of Data and Material

1. The data used for this research are of two types: Meteorological data was collected from Borno state of Nigeria meteorological station, and Satellite imagery data was downloaded freely from Solargis global solar model (<https://globalsolaratlas.info/>).
2. University of Maiduguri Meteorological Data Station, Borno State of Nigeria.

Competing Interests

The research has no competing interests.

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Authors' Contributions

Both Authors have read and approved the manuscript.

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