



## Geographical Information System Based Remote Sensing Integration to Monitor and Evaluate Electric Power Plant

<sup>1</sup>Abdulkadir Hamidu Alkali, <sup>1</sup>Muhammed Zaharadeen Ahmed, <sup>1</sup>Muhammad Rabiu Usman, <sup>2</sup>Abdulsalam Ya'u Gital, <sup>3</sup>Hajara Musa, <sup>2</sup>Abubakar Umar

<sup>1</sup>Department of Computer Engineering, University of Maiduguri, Maiduguri, Nigeria

<sup>2</sup>Department of Mathematical Sciences, Abubakar Tafawa Balewa University Bauchi, Nigeria

<sup>3</sup>Department of Mathematical Sciences, Gombe State University, Gombe, Gombe State, Nigeria.

### ABSTRACT

Remote sensing and GIS are essential fundamental to each other. The advancement of Remote Sensing is capitalized on the development of GIS. Remote Sensing provides large amount of data for the entire universe frequently. GIS analyses enormous amount of data in short time interval. The Manual manipulation of one-time remote sensing data consume long time, and this does not enable easy data analysis. This paper conducted analytical and experimental manipulation of remotely sensed data using Multiple-Criteria Decision-Making (MCDM) and solar irradiation. Based on the method used in this analysis, Irradiance Horizontal Global (GHI) is proposed in the power plant. Data are represented as Direct Normal Irradiation (DNI), Diffuse Horizontal Irradiation (DHI), and Global Horizontal Irradiation (GHI) in the datasets and respective digital or poster. Error analysis is conducted whereby slope and elevation condition of the regions is critically assessed. In the results, we considered Geometric Correction algorithm to manipulate the remotely sensed images and the technique of correcting geometric distortion. Polynomial mapping function is assessed to identify a master and slave relationship during data representation.

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### INTRODUCTION

To ensure long-term socioeconomic development, cheap and reliable sources of energy are preferred. In the present day and age, fossil fuels are the primary energy source. As a result, numerous costly and serious negative environmental impacts were being identified all over the world. It is obvious that the both short- and long-term negative effects of these issues will have negative repercussions for civilizations and ecosystems. Renewable Energy (RE) sources represent the most viable option in this circumstance for addressing environmental and social issues. Therefore, the application of renewable energy resources is projected to rise by 73% between 2012 and 2035, while non-renewable energy sources are predicted to run out in the future [1]. Power generation from solar photovoltaic (PV) technology is becoming increasingly common in recent decades because of scientific and technological advances such as enhancing the efficiencies of PV systems

(cells, modules, systems) while lowering their costs. By developing Very Large Photovoltaic Power Plants (VLPVPP), costs can be reduced by taking economies of scale into account. Due to its high solar insolation values and energy potential, Turkey is among the advantaged countries in terms of solar power plant investments. Turkey is one of several countries attempting to create some renewable energy models. A Geographic Information System (GIS) is a useful tool for processing and analyzing many spatial data from various sources relating to political, financial, social, technical, technical, legal, environmental, ethical, demographic, ecological, and comparable criteria [2] [3].

A very well-organized set of computer hardware, software, and people for entering, storing, updating, displaying, manipulating, analyzing, and combining all types of spatially referenced data. A GIS is a system for capturing, storing, manipulating, analyzing, managing, and displaying all types

\*Corresponding author: Muhammed Z. A. ✉ [zahradeen22@unimaid.edu.ng](mailto:zahradeen22@unimaid.edu.ng) ✉ Department of Computer Engineering, University of Maiduguri, Maiduguri, Borno State. © 2022 Faculty of Technology Education, ATBU Bauchi. All rights reserved

of geographically referenced data [4]. GIS can evaluate, collect, and store data by presenting pointers like location (longitude and latitude). The development of new and more effective techniques and tools for storing and evaluating geographic and non-geographic data is required to meet environmental engineering problems. One of the most substantial difficulties to the use of GIS is currently the cost of software, which is relatively expensive when compared to other methodologies [5].

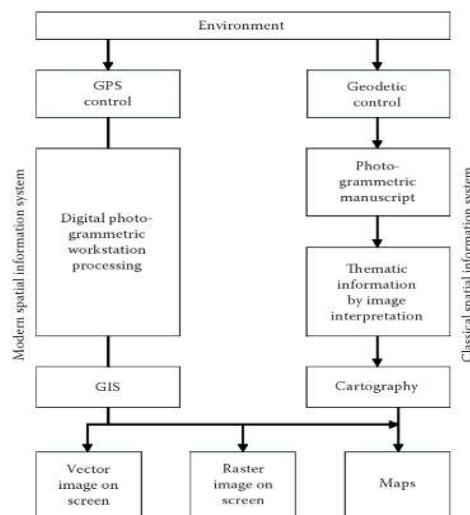


Figure 1. Spatial Information System [6]

Figure 1 above presents the differences that exist between classical approach of spatial information systems and the novel geospatial information concept. Over the years, similar disciplines such as geodesy, photogrammetry and cartography conduct their operation approach autonomously when providing printable maps. Based on the novel concept, GPS, remote sensing, photometry, and GIS cannot generate their printable maps but can generate raster and vector images using a computer screen presentation. This can enable analysis in an interdisciplinary approach for the public consumption [6].

### LITERATURE REVIEW

This research considers reviewing various related works conducted on geographical information systems, remote

sensing, Multiple-Criteria Decision-Making for Site Selection (i.e six regions of Nigeria) and Solar Irradiation for an electric power plant.

### GIS Foundations and Theoretical Framework

First, definitions related to the dust topic that is frequently mentioned in various articles will be provided [7].

- i. **Remote Sensing:** Remote sensing science is the technology and art of gathering information about distant phenomena or gathering data from areas that are inaccessible due to danger, high cost, or distance.
- ii. **Geographical Information System:** This program enables you to save current Earth information and combine it with other data. This information is useful in a variety of fields, including urban and regional planning, environmental planning, geology and mining studies, agriculture, and natural resources, and so on.

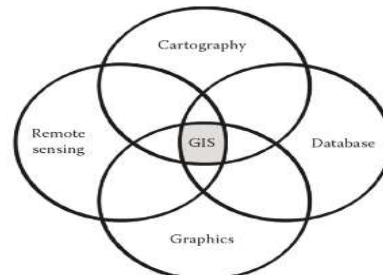


Figure 2. GIS disciplines [6]

Based on the interrelationship of GIS disciplines in figure 2, Enormous digital data is generated in remote sensing that require geocoded rectification and analysis.

- iii. **Electric Power Plant:** Heavy elements, such as zinc, cadmium, cobalt, copper, lead, nickel, arsenic, vanadium, and chromium, have a greater atomic mass than iron and are highly absorbed into living tissues; accumulating in them and exhausting them from the

\*Corresponding author: Muhammed Z. A. ✉ [zahradeen22@unimaid.edu.ng](mailto:zahradeen22@unimaid.edu.ng) ✉ Department of Computer Engineering, University of Maiduguri, Maiduguri, Borno State. © 2022 Faculty of Technology Education, ATBU Bauchi. All rights reserved

- tissue occurs rarely.
- iv. **Dust Falling:** Dust falling is defined as dust that falls from the atmosphere onto the earth's surface and studying it can lead to an indirect investigation of all suspended particle contamination.

#### **MCDM for Site Selection**

Multiple-Criteria Decision-Making (MCDM), also identified as Multiple-Criteria Decision Analysis (MCDA), is a subsidiary of data science in which multiple competing decision-making criteria are evaluated. Conflicting criteria are common in the cost estimation or value options, which is generally one of the key aspects, as well as some quality computation is usually another criterion, easily in conflict with cost. MCDM tools and applications have been used in previous studies to solve field issues such as electricity, climate, and sustainability. MCDM methods have been developed to define a preferred option, classify alternatives into a small number of categories and/or classify alternatives in qualitative order of preference. When there is more than one competing criterion, MCDM is a catch-all term for all approaches that exist to assist people in making decisions based on their preferences. Modern MCDM methods enable decision-makers to address all of the information types mentioned above. One of the issues encountered during the MCDM process is the selection of the aggregation method for solving the decision problem [8].

#### **Solar Irradiation**

The amount of light energy emitted by the entire sun disc as measured on Earth is known as solar irradiance. According to the National Aeronautics and Space Administration, irradiance is defined as the amount of light energy from one item impacting a square meter of another per second (NASA). The power per unit of the sun measured as electromagnetic radiation in the wavelength range of the measuring equipment is referred to as sunlight. Spectral solar radiance is a measurement of the brightness of a wavelength of light across the Sun. In kW/m<sup>2</sup>,

solar radiance is a measure of instantaneous power density. When designing a photovoltaic system, it is critical to know the amount of sunlight available at a given location at a given time. Solar irradiance can be measured in several ways. Total Solar Irradiance (TSI) is a measurement of the amount of solar power incident on the Earth's stratosphere at all wavelengths. It is measured parallel to the incoming sunlight direction. The solar constant is a conventional measure of mean TSI at one astronomical unit distance (AU). Direct Normal Irradiance (DNI), also identified as beam radiation, is measured at the Earth's surface at a specific location using a surface element perpendicular to the Sun [9] [10].

#### **METHODOLOGY**

There are different approaches of hierarchical methodology to computer the rooftop. These are the physical, geographic, and technical solar photovoltaic potential which was identified after extensive literature review. The use of satellite images is exploited to determine the potential rooftops for solar photovoltaic installation and electricity generation at all three levels.

A general decision-making procedure is specifically designed for transforming a spatially defined data set into a common digital decision-making map for power plant experimentation. An Assessment policy is required. Therefore, A few requirements are chosen as policy. However, the policy does not require excessive mathematical computation. It is also a requirement to set up maps for each evaluation policy such that the values can ranges between 0 – 8 thereby isolating unsuitable zones and deploying suitable zones. Based on the method used, expert weight computation is generated. This means that Expert evaluations is needed to be as an input for subjective weighting approaches until sufficient probabilistic or possibilistic approaches are modelled in accordance with the proposed autonomous IDSM. This study exploits 5 single experts along with 1 expert group. Single experts evaluate and assess themselves with no tutoring. However, expert groups evaluate themselves as a group with the mentorship of a single expert among five

\*Corresponding author: Muhammed Z. A. ✉ [zahradeen22@unimaid.edu.ng](mailto:zahradeen22@unimaid.edu.ng) ✉ Department of Computer Engineering, University of Maiduguri, Maiduguri, Borno State. © 2022 Faculty of Technology Education, ATBU Bauchi. All rights reserved



single experts. By using an MCDM, the current experimental MCDM model for power plants has 5 main criteria, 14 criteria, and 79 value ranges. In term of simulation the proposed study used QGIS 3.10 A Coruna.

At the power plant, compute the Photovoltaic Solar Suitability Index (PVSSI) by creating a digital map of Photovoltaic land suitability. All PV land suitability digital maps in five suitability classes - low suitability, medium suitability, high suitability - are produced in this research in digital formats using four weighting approaches. These digital maps are intended to depict all stages of PV power operation, investment, and planning. Hence, we conduct a comparison of the outcomes of four weighting approaches by given suitable remarks to validate, verify, and improve the proposed system. Also, a forward-backward-looking analysis is conducted.

#### **Experiment and Study Region**

The Afam Power Plc, Sapele Power Plc, Egbin Power Plc, Ughelli Power Plc, Kainji Power Plant, Jebba Power Plant and Shiroro Power Plc in are located across the six regions of Nigeria. And are to be covered in experiment of this research due to their access to up-to-date information and data availability. The climatic region of the study area consists of all the seasons of hot summers and warm/rainy winters. Due to the geographical area, climate, and natural conditions and properties of the region, the opportunities and activities of the agricultural and tourism industries are high. This means it is ideal to expect a long-term increase in power demand. Also, built-ups rooftops are chosen in the six geographical regions of the power plants spread geographically in a stretch of 53,483 km<sup>2</sup> between Latitude: 9° 04' 39.90" N and Longitude: 8° 40' 38.84" E. Between the regions, some are mostly plain topography and others are hilly in nature.

#### **Irradiance Horizontal Global (GHI)**

In the proposed power plant, solar powered device is sectioned appropriately. Any solar power device's instantaneous peak power output performance is measured using solar irradiance. For solar power subjects,

there are three major components of solar radiation: direct, diffused and ground reflected. They are represented as Direct Normal Irradiation (DNI), Diffuse Horizontal Irradiation (DHI), and Global Horizontal Irradiation (GHI) in the datasets and respective digital or poster. We take GHI into account using Photovoltaic power plant technology. i.e., the overall amount of sunlight that falls on the PV module (panel) surface. GHI is beneficial in may power plant policies and is measured in kWh/m<sup>2</sup>. In most advanced countries, smart maps, data, and information are generated using Global Solar Atlas as it is among the most efficient solar sources. More information and downloads can be found on their official website such as GIS raster (grid) data with a resolution (pixel size) of 30 arcsec (nominally 1 km) in GeoTIFF and AAIGRID (Esri ASCII Grid) formats.

#### **Slope**

To select a suitable location for the proposed photovoltaic power plant, some requirements are needed to ensure proper slope. These are ease of organizing, design, engineering, logistics, construction, operation, and maintenance costs. Some Elevated slope areas, like valleys and steep lands are not the target location and is always discouraged. However, changes in topography needs to be considered when determining a slope threshold value to achieve reasonable results. The slope is demonstrated as an objective cost criterion.

#### **Elevation and Ground Conditions (geology/lithology)**

Elevation is a challenging factor when selecting site for Photovoltaic Power Plants. This is in terms of electric power/energy generation and cost. Lithologic information of the ground also play an important role for Photovoltaic Power Plant formation. Challenges may occur and can lead to affecting foundation conditions such as geology, hydrology, and soil.

#### **Error Analysis**

The precision in GIS used in this research is considered to present understanding of errors impeded while using remote sensing. However, other GIS users centre their concern on the types and how

\*Corresponding author: Muhammed Z. A. ✉ [zahradeen22@unimaid.edu.ng](mailto:zahradeen22@unimaid.edu.ng) ✉ Department of Computer Engineering, University of Maiduguri, Maiduguri, Borno State. © 2022 Faculty of Technology Education, ATBU Bauchi. All rights reserved

large the errors in data products generated from remotely sensed data. Therefore, the proposed research considers the basic generated data better than uncertain generated data and associating it with remote sensing and GIS. This is satisfactorily quantified and interpreted into the process of decision making. This research recommends proposing error classification and a comprehensive approach of producing error report such that data can be transferred using spatial data transfer standard (SDTS) approach. This means that data users can gain access to an extended approach of information dissemination. However, other researchers proposed different approaches of remote sensing error assessment such that their procedures do not support the use of spatial data analysis.

**Data Structures and Data Accessibility**

The results of spatial data representation conversion present some errors. However, the error presentation is reader unfriendly and are not documented with better precision. The approach of data accessibility and data structure used in this analysis does not give the user a better tool and sufficient information required to compute data suitability based on user need. Field base framework for space is exploited in remote sensing and is systematically sampled by the system used for sensing. The analysis used in this research use GIS from object-oriented viewpoint. This present various abstraction level and precision during this data representation and accessibility.

**GIS integration of remote sensing data**

Remotely sensed image is differentiated based on the sensing algorithm and its recording platform. Recording platform involves a device to conduct the process using the following

- i. **Central perspective.** Image recording is conducted for an insignificant time interval. This process of recording involves the use of camera where film is exposed as an analog device. However, digitised camera using two-dimensional array of charge-coupled devices (CCDs) slightly gain some grounds because of their low resolution in the range of 4000 x 4000 pixels.

- ii. **Along-track scanner:** this device takes record of a single line of an image per each recording step having nearly a thousand CCD sensors attached in a linear array. The image is then generated in form of a series of line leading to a forward motion of a recording device. This kind of a device technology is referred to as High Resolution Visible (HRV) sensor.
- iii. **Cross-track scanner.** This scanner device uses a single sensor to generate a complete image. This is with the aid of a rotating mirror (oscillation). The oscillation process of the mirror record only a single line on the image whereas the forward motion of the device is reused as a second dimension. Such examples of device for efficient usage are the Landsat Multispectral scanner (MSS) and the Thermal Mapper (TM) sensor.
- iv. **Active Sensor:** this kind of sensor sends electromagnetic energy by recording the information to the sensor. To generate an image, time difference and intensity of the backscattered signal must be used. Image is also formed using sensors with pointing sideways and to generate some number of geometric issues.

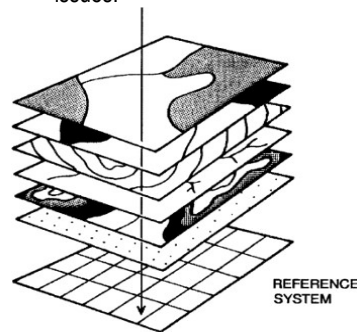


Figure 3: IGIS Database [7]

Figure 3. above present the layers of an IGIS database with data precision registered to enable interpretive processing.

\*Corresponding author: Muhammed Z. A. ✉ [zahradeen22@unimaid.edu.ng](mailto:zahradeen22@unimaid.edu.ng) ✉ Department of Computer Engineering, University of Maiduguri, Maiduguri, Borno State. © 2022 Faculty of Technology Education, ATBU Bauchi. All rights reserved



## RESULTS

Results of this analysis is achieved in two approaches. These are the geometric correction algorithm and polynomial mapping function.

### Geometric Correction Algorithm

The remote sensing of image used in this research exploits two techniques of correcting geometric distortion.

- i. **Deterministic Technique:** this involve correcting the generated data using one of the models type and size of distortion. The technique is well utilised if the distortion in the image generated is well known such as the sensor type, earth rotation on its axis, or curvature of the earth. However, this analysis did not cover an actual flight path model because of its requirement to extreme precision of ancillary data such as position or value of altitude. This research present computation of SPOT imagery displacement as a function of terrain and angle of camara visibility. The table below present the challenges of terrain on pixel location.

**Table 1:** SPOT Imagery Displacement Based on Viewing Angle

Angle visibility	Terrain Relief (meters)				
	0	100	200	500	1000
0	0	0	0	0	0
5	0	10	20	49	98
10	0	20	40	100	200
15	0	31	62	153	305
20	0	42	84	209	418
25	0	54	108	271	542

Based on the result of table 1. Above, the terrain information at 200m generated angle displacement of 3 pixel for 10<sup>0</sup> viewing angles. However, if data is generated based on Landsat TM, these challenges is normally negligible due to near nadir viewing geometry of the system.

- ii. **Statistical Technique:** this technique involves introducing an assumption of mathematical relationship between pixel location on a remotely sensed image and its

location in the original image. Additionally, the coordinate can also be used for the points on the ground. Therefore, the statistical technique has no dependence on physical relationship as the deterministic technique used in this research. This technique exploits mathematical function and parameters to be driven using basic procedures of statistics. Using this technique in the proposed research, the data set of master – slave relationship is used to correct the image geometry regardless of how bad distortion affect it. This procedure enables the use of any of the relevant mathematical function to apply on during error correction. In this analysis, mapping function F, is assumed existing and the pixel coordinates (x, y) of a slave data set can easily be mapped into the system of coordinate (X, Y) as master data set. This can be represented as in equation 1 below

$$F(x, y) = (X, Y) \dots \dots \dots (1)$$

The relationship between master and slave holds true for all image pixel (x, y). Similarly, if the function of the slave F is clearly known, the exact pixel location can be computed to register and create an identified data set. Concluding remark of this result identifies that the explicit form of the mathematical mapping function is not vividly known. Also, because of assumption, a function such as the mater might not exist if not adequately identified. Therefore, each individual image needs a distinctive mapping function declaration.

**Table 2:** Variance Analysis Test

Sources change	df	Sum of Square	Mean of Square	F	Signal
Month	4	1.78	0.954	1.544	ns0.22
Error	75	55.32	0.775		
Total	79	57.1	1.729	1.544	0.22
Month	10	16.454	0.656	0.955	ns0.563
Error	62	33.543	0.764		
Total	72	49.997	1.42	0.955	0.563

\*Corresponding author: Muhammed Z. A. ✉ [zahradeen22@unimaid.edu.ng](mailto:zahradeen22@unimaid.edu.ng) ✉ Department of Computer Engineering, University of Maiduguri, Maiduguri, Borno State. © 2022 Faculty of Technology Education, ATBU Bauchi. All rights reserved

Based on information in table 2 above, the spatial analysis of this experiment presented that between some of the regions of the geographical region are deserts. Some areas of the north-eastern region consist of sand dunes being devastated by humans' negligence. Experimental power plant result generated based on sampling and analysis electric power which has noise interference such as dust data in northeast indicate that the variance analysis test based on months during spring season is insignificant. The approach of zoning our generated data is distributed using Geoaccumulation. This is to introduce a mitigation approach of the dust interference. Afterward, analyzing and normalizing the generated data was conducted using Kriging approach based on zoning.

### Polynomial Mapping Function

Practically, the mapping function is selected as a simple polynomial of 1st to 5th degree polynomial. In this analysis, the general polynomial form of the mapping function is given by  $(X, Y) = F(x, y)$  of  $n$ th degree is presented in equation 2 below as follows

$$X = \sum_{i=0}^n \sum_{j=0}^i c_{ij} x^{i-j} y^j ; Y = \sum_{i=0}^n \sum_{j=0}^i d_{ij} x^{i-j} y^j \dots \dots \dots (2)$$

An explicit polynomial of second-degree order is given in equation 3 below as follows.

$$X = c_{00} + c_{10}x + c_{11}y + c_{20}x^2 + c_{21}xy + c_{22}y^2;$$

$$Y = d_{00} + d_{10}x + d_{11}y + d_{20}x^2 + d_{21}xy + d_{22}y^2 \dots \dots \dots (3)$$

In equation 2, if parameters  $c_{ij}$  and  $d_{ij}$  are identified and known, all pixels can be used for polynomial mapping and relate it to slave data set to an exact location in the master dataset. This enables data values of the mathematical parameters be computed by selecting some features to be identified in both the master and slave data set. The features are known as a Control Point (CP). However, the feature is known as Ground Control Points (GCPs) in geodetic or geographic reference coordinate system. This analysis substitute CP coordinates into equations (2) and (3) to generate more equations for the coefficients of the unknown polynomial. Therefore, more CPs enables the computation of more set of equations to achieve solution of other unknown parameters. An efficient approach of computing residual positional error immediately

after identification is to generate an autonomous assumption using withheld test and check points. This can be presented in figure (4) below.

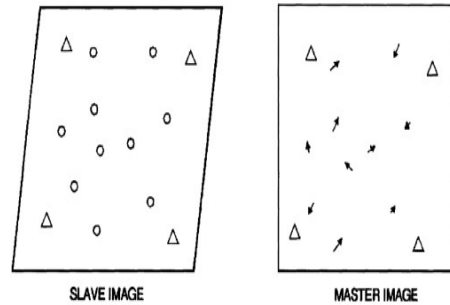


Figure 4: Data Representation in Polynomial Graph

Figure (4) above present's graphical representation of data registration using polynomials generated from CPs. The image can be able to transform image data to a reference base. Error vector at test points also known as circles after rectification processes are utilized to compute the proposed approach.

### CONCLUSION

Based on the study results, it is feasible to achieve enhanced energy rates demand by deploying a PV module system in all the power plants regions. It is also feasible to achieve energy surplus in regions where there is less density of people. Within the 6 regions, the remote sensed PV systems can generate 57% of the electricity consumption. Area Topography and absence of flat land is recorded as a major challenge to deploy large scale solar PV modules in a hill regions. It is identified that Decentralized electrification in hilly regions is conducted using flat rooftop of buildings for solar PV module.

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\*Corresponding author: Muhammed Z. A. ✉ [zahradeen22@unimaid.edu.ng](mailto:zahradeen22@unimaid.edu.ng) ✉ Department of Computer Engineering, University of Maiduguri, Maiduguri, Borno State. © 2022 Faculty of Technology Education, ATBU Bauchi. All rights reserved



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