九州大学学術情報リポジトリ
Kyushu University Institutional Repository

GIS-BASED SUITABILITY ANALYSIS FOR SOLAR ENERGY POTENTIAL SITES IN ZAMBOANGA CITY USING WEIGHTED DECISION SUPPORT

Adrian Melana
Department of Mining Engineering, Caraga State University

Veronica Capin
University of the Philippines - Diliman

Jhon Lester Arellaga
University of the Philippines - Diliman

Ayin Tamondong
University of the Philippines - Diliman

https://doi.org/10.5109/7395704

出版情報：Proceedings of International Exchange and Innovation Conference on Engineering & Sciences (IEICES). 11, pp.1477-1484, 2025-10-30. International Exchange and Innovation Conference on Engineering & Sciences
バージョン：
権利関係：Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International

KYUSHU UNIVERSITY

GIS-BASED SUITABILITY ANALYSIS FOR SOLAR ENERGY POTENTIAL SITES IN ZAMBOANGA CITY USING WEIGHTED DECISION SUPPORT

Adrian Melana[1,2], Veronica Capin[2] , Jhon Lester Arellaga[2], Ayin Tamondong[2]
[1]Department of Mining Engineering, Caraga State University, [2]University of the Philippines - Diliman
Corresponding author email: almelana@carsu.edu.ph

Abstract: *Increasing climate change awareness has led many countries to focus on renewable energy for its lower environmental impact. Several cities have experienced power supply shortages, particularly Zamboanga City, which has led to scheduled power interruptions. This study focuses on the potential solar energy production in Zamboanga City, leveraging the city's abundant solar energy source. The researchers considered nine parameters: solar irradiance, temperature, cloud cover/relative humidity, precipitation, slope, aspect, elevation, road network, and land use/cover. Weighted Overlay was employed to identify the potential site map for this study. The final potential sites were created after overlaying the criteria weights assigned to each map. Of the 38, 665.85 hectares of the studied area, only 3,773.698 hectares (9.76% of the total) are suitable under the criteria. Based on the map's findings, the majority of the areas were less suitable with 90.18%, suitable with only 9.81%, and unsuitable with the least percentage of 0.01%.*

Keywords: Geographic Information System, Solar Energy, Zamboanga City, Renewable Energy

1. INTRODUCTION

The Renewable Energy Act of 2008, more commonly known as Republic Act No. 9513, was a law that was approved to expedite the exploration and commercial development of renewable energy resources in the country. Furthermore, an economic investment with a feed-in tariff (FIT) encouraged companies to engage in renewable source business ventures. Specifically, the FIT system provides renewable energy generators with a feed-in payment based on the electricity provider from the energy source that they feed into the grid over a minimum 12-year duration [1].

The total installed renewable energy capacity as of May 31, 2021, is 5468.91 MW, a significant distance from the 2030 target of 15,304.3 MW set by the NREP. According to the 2020 energy supply mix, which comes from 66.5% natural gas, ethanol, coal, and oil, and 33.5% renewable energy sources, the US is still primarily dependent on fossil fuels for energy production [2]. With increasing awareness regarding the risks of climate change, many countries have undertaken strategies for transitioning to low-carbon economies. This has led to a focus on using renewable energy sources, as they are generally considered "clean", with a considerably lower environmental impact than other energy sources [3]. By 2050, 70% of the global population is expected to live in cities, leading to a projected 75% share of global energy consumption by urban areas by 2030 [4].

Solar energy is an unlimited and clean renewable energy source [5], which is gradually replacing non-renewable energy sources. Reliance on the electric grid must be reduced by promoting renewable energy research and policies that support innovation toward energy-independent communities [6]. Solar power generation has become one of the fastest-growing renewable energy sources. As the price of solar panels is steadily declining and various stimulus policies are being implemented, the growth rate of photovoltaic (PV) energy is increasing. PV energy is considered one of the most promising alternatives due to its ubiquitous and sustainable nature [7].

1.1 Statement of the Problem

Zamboanga City is a 1, 403 square kilometer city in southern west Philippines with a population of 977,234 people, as of 2020 according to PSA. The almost 1 million inhabitants of the city rely on power sources from adjacent and far provinces through a grid system, which results in inconsistencies in the power supply. The inhabitants face energy shortages, leading to scheduled power interruptions that disrupt daily operations. To ensure stable commercial and residential power supply, the city must explore and consider alternative energy sources.

1.2 Significance of the Study

The Energy Department of the country is pushing towards clean energy giving incentives and prioritization for such projects. The selection of potential sites for solar panel installation in Zamboanga is particularly relevant to decision-makers, including government officials involved in urban planning. It ensures that solutions are strategically planned and executed. This study represents an initial milestone in creating smart and sustainable cities, encouraging researchers interested in Zamboanga City to develop innovative solutions and contribute to building a more resilient community.

1.3 Objective

The primary objective of this study is to determine optimal locations for solar panel installation in Zamboanga City by utilizing the criteria and weights established by Loquias *et al*. [8] and integrating them with a Geographic Information System (GIS)-based on a weighted decision support approach. Specifically, the study aims to identify potential barangays for solar energy development and estimate the potential energy output from these suitable areas.

1.4 Scope and Limitations

This study focuses on the two districts: Curuan and Manicahan. Data were collected from various available sources, as outlined in Table 3. Consequently, the research was constrained by the availability and reliability of these online resources. Despite these constraints, the study aims to provide valuable insights in identifying potential sites for solar panel installation in Zamboanga City. The weights assigned to parameters in the suitability analysis were cited from the literature, ensuring alignment with established methodologies and practices.

2. LITERATURE REVIEW

Solar power is a variable energy source dependent on the sun's cycle. The Philippines, situated near the equator, has many potential sites for harnessing solar energy. As of 2018, the country has an installed generating capacity of 896 MW. Solar power technology may not generate energy at night but can supply electricity to the grid in the daytime [9].

Baquiran et al. [10] analyzed structures' rooftop suitability for solar PV systems installation in the Centro barangays of Tuguegarao City, Cagayan, Philippines. The study uses Geographical Information Systems (GIS) generated by overlaying all map layers and applying criteria. Meanwhile, the same study was also conducted by Galvan [11]. The study also used the same tool and technique to identify renewable energy.

On the other hand, Levosada et al. [13] mapped suitable sites of Concentrated Solar Power Plants (CSP) in the Philippines using GIS and AHP, respectively while Garcia et al. [12] conducted Solar PV Farm Installation in Simara Island, Romblon, Philippines.

A suitable site has three criteria to consider [9]: technical aspect (solar insolation), environmental aspect (land-use-land cover and protection buffers), and economic aspect (slope, elevation, and road proximity). Therefore, site selection is complex. All these factors need to be considered.

Table 1. Summary of previous studies for solar energy

Author	Plant Type	MCDA Method	Study Area
Baquiran, A. *et al. [10]*	PV	AHP	Tuguegarao City, Cagayan
Galvan, J.P.D. [11]	PV	AHP	Cagayan Province
Garcia, J., Gacu, J., and Lawrence, M. [12]	PV	AHP	Simara Island, Romblon
Levosada, A.T.A, *et al.* [13]	CSP	AHP	Whole Philippines
Loquias, R.T., *et al*. [8]	PV	AHP	5th Congressional District of Camarines Sur

The criteria for selecting potential sites for solar production vary by region and depend on the relative importance of each parameter. This study used nine distinct criteria established by Loquias *et al*. [8]. Each of these is elaborated in this section, providing insights into their role in the site selection process.

2.1 Average Annual Solar Irradiance

Solar irradiance refers to the quantity of light energy emitted by the sun and received on the Earth's surface. It's quantified by the volume of sunlight falling on a square meter area within a second [15]. It's regarded as the primary factor in selecting sites for photovoltaic (PV) systems [7]. Increased solar insolation directly correlates with a more significant potential for generating electricity [16].

2.2 Temperature

Temperature directly impacts both the voltage and current output of solar panels. As temperature rises, the energy output of a panel decreases because of heightened resistance, which slows down the flow of electrical current. Conversely, when temperature drops, resistance decreases, leading to increased energy production [17].

2.3 Precipitation

Precipitation data is essential due to its direct impact on the efficiency and sustainability of solar power generation. Rainfall aids in naturally cleaning solar panels, ensuring maximum sunlight absorption and optimal energy production. This cleaning effect helps mitigate the dust, dirt, and debris buildup on the panels, which can otherwise hinder their performance over time [18].

2.4 Cloud Cover/Relative Humidity

Low clouds can obstruct sunlight, resulting in decreased solar energy reaching solar panels. However, under specific cloudy conditions, such as thin or scattered clouds, the diffused light can enhance the amount of light reaching the solar panels (National Oceanic and Atmospheric Administration, 2024).

2.5 Slope

Flat terrain or gently sloping areas are preferred for large-scale PV farm projects to avoid the high building costs associated with steep slopes. Elevated locations are rarely chosen because they necessitate flat topography, which is more cost-effective [19]. Flat areas are ideal for solar power plants because they receive the most solar radiation, leading to higher production from solar photovoltaic (PV) systems [20].

2.6 Proximity to Road Network

Roads are a crucial factor in selecting construction sites for PV energy facilities. Proximity to transport routes is economically beneficial, as it reduces costs related to site access, material transportation, and ongoing maintenance [21].

2.7 Aspect

Aspect is measured in degrees clockwise from north, indicating the direction a slope faces. It is vital for determining an area’s solar potential and efficiency in reflecting sunlight [21]. The Philippines, located in the Northern Hemisphere and has an inclined topography, is preferred to the south direction. Areas oriented towards the south, southeast, and southwest generate the most electricity from solar panels, making them highly suitable for solar energy production [8].

2.8 Elevation

Lower elevation means a thicker atmosphere, reducing solar yield due to increased absorption and scattering. Solar farms at higher elevations are preferred in humid areas for clearer air and higher sunlight capture [22]. However, higher elevations require higher installation, transportation, and maintenance costs. The researchers used the suitable elevation set by Loquias *et. al.*, [8] which is 10-50 meters.

2.9 Land Use and Land Cover

Bare and non-agricultural vacant lands are deemed appropriate for setting up solar farms, while agricultural lands, residential areas, water bodies, protected regions, and forested areas are considered unsuitable for such installations [22].

3. METHODOLOGY

The methods and criteria employed in this study were based on the analysis of Loquias *et. al.* [8] in identifying the suitable sites for solar panel installations in Zamboanga City. Weights are also assigned to each parameter, ensuring precise evaluation.

3.1 Methodological Flowchart

Based on the suggested criteria from related literature, the study area's top possible candidate location for a solar energy plant was assessed using the GIS and its spatial analysis tools coupled with MCDA. Figure 1 illustrates the overall methods used in this study.

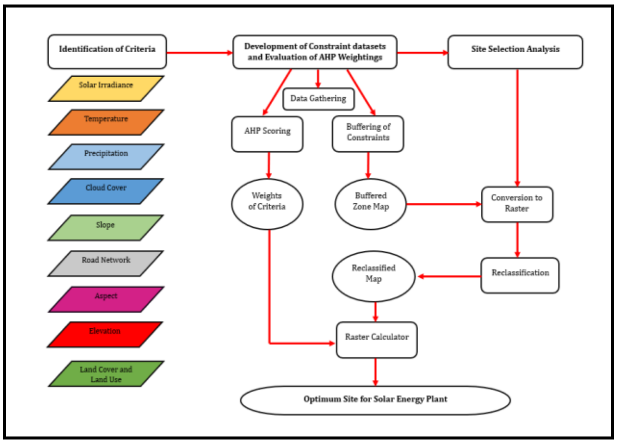

Fig. 1. Methodological Flowchart

3.2 Study Area

Zamboanga City, part of Zamboanga Peninsula in the Philippines and administratively grouped with Zamboanga del Sur province. For this study, only two districts were considered: Curuan and Manicahan, as depicted in Table 2, comprising ten barangays in Curuan District and six barangays in Manicahan District. The total land area of the study area is 38, 665.85 hectares (or approximately 386.66 square kilometres). The study area within these two districts represents about 27.44% of Zamboanga City's total area, which spans 1,414.70 square kilometers. Figure 2 depicts the map of the study area highlighting the barangays within the Curuan and Manicahan Districts.

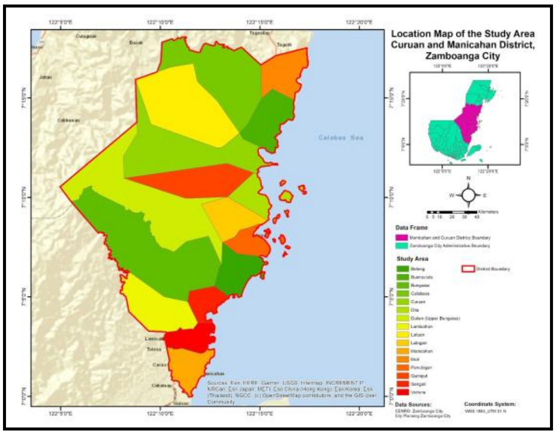

Fig. 2. Location Map of the Study Area

Table 2. Barangays of Zamboanga City (PSA, 2020)

Geographic Location	Barangay	Area (ha)	Population
Curuan	Buenavista	1,003.5189	6,485
Curuan	Calabasa	1,849.9353	3,222
Curuan	Curuan	7,216.0695	8,796
Curuan	Dita	133.7222	2,085
Curuan	Dulian (Upper Bunguiao)	1,542.3299	2,570
Curuan	Latuan (Curuan)	98.0766	2,457
Curuan	Lubigan	1,416.7021	2,945
Curuan	Muti	1,233.2268	2,983
Curuan	Panubigan	431.0032	1,610
Curuan	Quiniput	1,031.6762	3,329
Manicahan	Bolong	1,574.0594	6,460
Manicahan	Bunguiao	2,562.0727	7,287
Manicahan	Lamisahan	2,125.8888	2,289
Manicahan	Manicahan	1,801.7465	10,081
Manicahan	Sangali	1,259.3212	20,766
Manicahan	Victoria	334.6	2,802

3.3 Criteria Selection

Developing relevant spatial criteria and factors is essential for determining suitable locations for installing solar power plants [12, 8]. The initial data collection and factor identification stage involved gathering essential information from relevant literature and previous research initiatives. After thoroughly reviewing the relevant literature on GIS-based suitability assessments and carefully considering the characteristics of each category, the selections were made. Table 3 details the criteria, types, units, and sources utilized for criteria selection. Table 4 details the suitability ranking for each criterion with its corresponding weighting factors adapted from Loquias *et al*. [8].

Table 3. Data Criteria and Gathering

Criteria	Sub-Criteria	Data Type	Source
Solar Irradiance	Minimum is 1300 kWh/m^2/year or 3.56 kWh/m^2/day	Raster	solargis.com
Temperature	15-45°C	Raster	solargis.com
Ave. Annual Precipitation	<15 mm	Raster	DOST PAG-ASA
Ave. Annual Cloud Cover	<50%	Raster	DOST PAG-ASA
Slope	5-15 degrees	Raster	USGS
Road Network	<1000 m	Shapefile	CENRO-IX
Aspect	112.5 – 247.5° (southeast, south, southwest)	Raster	USGS Earth Explorer
Elevation	10 – 50 m	Raster	USGS Earth Explorer
Land Cover and Land Use	Free from mountains, forests, water bodies, buildings, wetlands, floodplains, low and medium grassy vegetation, shrublands, and barren lands	Shapefile	CENRO-IX

Table 4 displays the suitability level ranking for nine parameters, adapted from Loquias *et al*. [8]. Each parameter is assigned a ranking from 1 to 3, with 1 indicating unsuitability, 2 less suitability, and 3 signifying suitability. Weights have been assigned to each parameter, representing the relative importance of each parameter in determining overall site suitability.

Table 4. Suitability Level (Loquias et al., 2022)

Criteria	Unit of Measure	Suitability Level Ranking			Weights
		Unsuit-able	Less Suitable	Suit-able	
		1	2	3	
Solar Irradiance (GHI)	kWh/m^2/year	<1,583.723	1,583.724 – 1,685.493	1,685.492 – 1,890.493	0.30
Temperature	°C	-	25.65 – 25.8	25.8 – 25.94	0.12
Precipitation	mm	-	<4.35	4.35 – 4.51	0.12
Cloud Cover	percent	>50	-	-	0.12
Slope	degree	>5, >20	15 - 20	5-15	0.10
Road Network	m	>4000	1000-4000	<1000	0.07
Aspect	direction	Flat, N, NW	NE, W, E	SE, S, SW	0.06
Elevation	m	<10, >150	50 -150	10 - 50	0.06
Land Cover and Land Use		Open Forest, Built-up, Closed Forest, Fishpond, Inland Water, Mangrove Forest	Brush and Shrubs	Annual Crops, Grassland, Perennial Crops, Open/Barren	0.05

3.4 Geographic Information System Analysis

ArcGIS was used for spatial data analysis in this study because it provides a flexible environment for assigning weight to each criterion and overlaying all to produce the suitable location needed for analysis.

3.5 Data Preparation

The study began with the preparation of geospatial data, which involves the process of clipping and conversion. Clipping entails overlaying the area of interest onto the input maps to a larger extent and extracting only the relevant feature data within the outline area defined by the clip polygon.

3.6 Data Analysis

Four types of spatial analyses were were conducted to produce the data requirements of the suitability model, with all output cells defined at a resolution of 30 meters. First, the Euclidean distance for the road network layer (ArcGIS Toolbox > Spatial Analyst Tools > Distance > Euclidean Distance). Each cell's distance from the nearest source was calculated using the Euclidean distance. Between the centroid of the source cell and each neighboring cell, the Euclidean distance was determined.

Second, local cell statistics were used to compute the annual averages of the parameters of temperature, precipitation, humidity, and solar irradiance (ArcGIS Toolbox > Spatial Analyst Tools > Local > Cell Statistics). These averaged values were then converted into points for applying interpolation methods (ArcGIS Toolbox > Spatial Analyst Tools > Interpolation > IDW). This process created continuous surface data from discrete points for the four parameters.

Third, the Surface tool was employed to derive aspect and slope parameters from the digital elevation model of the study area (ArcGIS Toolbox > Spatial Analyst Tools > Surface > Aspect/Slope).

Lastly, the reclassification tool. Each map layer was evaluated according to its level of suitability and closeness to the site, and the reclass tool set in the Spatial Analyst tool offers numerous options for reclassifying cell input values to a different value. These layers include solar irradiance, temperature, precipitation, cloud cover, slope, road network, aspect and land use, and land cover. Using the grading scale of 1-3, all of the values on the original raster values were modified following the literature and decision-makers. Where 1 denotes unsuitable sites, 2 is less suitable, and 3 denotes suitable sites. This process (ArcGIS Toolbox > Spatial Analysis > Reclass >Reclassify) changes the values based on the defined or operationally set classification of zones.

3.7 Suitability Modelling

Suitability modeling was conducted using the weighted overlay analysis tool available in the ArcGIS toolbox (Spatial Analysis > Overlay > Weighted Overlay). This tool overlays several rasters on a standard measurement scale and assigns weights to each according to its importance (ArcGIS Help).

4. RESULTS AND DISCUSSION

The generated reclassified maps clearly visualize the suitable and unsuitable sites for each parameter. This section covered each of the nine parameters and how they relate to the overall site selection process. The reclassified maps include a unique symbol for each acceptable site.

4.1 Global Horizontal Irradiance (GHI)

Figure 3(left) shows the reclassified solar irradiance map. This was classified into three categories with the following ranges: below 1,583.723 kWh/m²/year is not suitable, while from range 1,583.723-1,695.492 kWh/m²/year is less suitable, and from range 1,695.493-1,807.260 kWh/m²/year is suitable. Following these suitability level ranking of Loquias et al., (2022), most of the locations in Curuan and Manicahan Districts are suitable under this parameter.

4.2 Temperature

Figure 3(right) shows the reclassified temperature of the study location. The requirement must range from 15-45°C. Since the computed data value falls within the range, the values were equally classified to identify the location with the highest temperature. A reclassified temperature map revealed that the southern part of the Curuan and Manicahan Districts were suitable under this parameter.

4.3 Precipitation

Figure 4(left) shows the reclassified precipitation map. Initially, all sites were deemed suitable; however, for the purpose of this study, the researchers redefined suitability criteria: sites with precipitation values below <4.65 mm were considered less suitable, while those with values above 4.65> were classified as suitable.

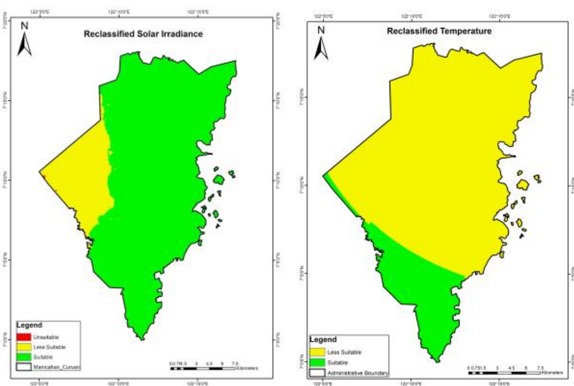

Fig. 3. (Left) Reclassified Solar Irradiance Map and (Right) Reclassified Temperature Map

4.4 Relative Humidity / Cloud Cover

Figure 4(right) shows the reclassified relative humidity/cloud cover. Under this requirement, the suitable area was less than 50%, and the less suitable area was 63.1%. However, the map revealed that the location was unsuitable under this parameter.

4.5 Slope

The slope data were reclassified into three categories: suitable, less suitable, and unsuitable. Areas with a slope angle of 5-15 degrees are considered suitable. Less suitable areas have a slope angle of 15-20 degrees, while unsuitable areas have a slope angle of less than 5 degrees or greater than 20 degrees. Figure 5(left) indicates that most of the study area falls within the category, with slopes of 5-15 degrees highlighted in green.

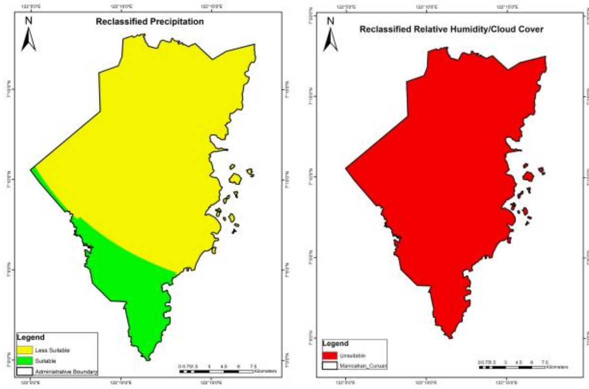

Fig. 4 (Left) Reclassified Precipitation Map and (Right) Reclassified Relative Humidity/Cloud Cover Map

4.6 Proximity to Road Network

Road networks of Curuan District and Manicahan District were analyzed to calculate a euclidean distance of 4500 meters. These distances were subsequently reclassified into three categories: areas less than 1000m from the road were deemed suitable (shown in green in Figure 5(right)), areas between 1000m and 4000m were considered less suitable (shown in yellow), and areas greater than 4000m from the road were classified as unsuitable (shown in red). These classifications indicate that locations within 1000m of the road are more suitable due to their accessibility, which reduces costs compared to more distant locations.

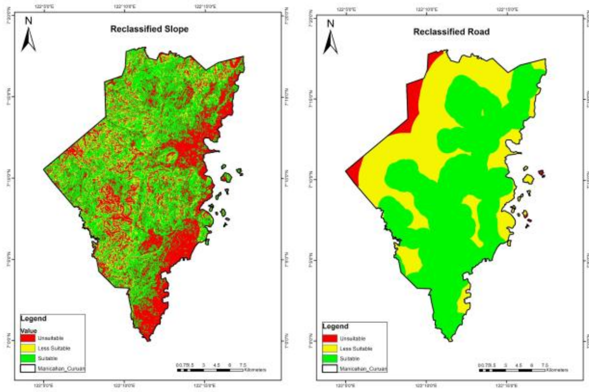

Fig. 5. (Left) Reclassified Slope Map and (Right) Reclassified Road Map

4.7 Aspect

Aspect is a relevant factor in maximizing solar energy production. Slopes oriented towards the South, Southeast, and Southwest received the most prolonged solar radiation and were marked in green in Figure 6(left), indicating their high suitability. In contrast, slopes facing Northeast, West, and East were less suitable, shown in yellow. Slopes facing North, Northwest, and flat areas were considered unsuitable for solar energy production and were depicted in red.

4.8 Elevation

Most locations in the Curuan and Manicahan Districts were classified as unsuitable for solar panel installation due to having elevations less than 10 meters or more than 150 meters, as shown in red in Figure 6(right). Areas marked in green were suitable for solar panel installation, while those in yellow were less suitable. The vast red regions indicated the mountainous terrain of these districts, emphasizing the impracticality of these areas for solar production. Only 16.5% of the total land area in these districts was deemed suitable for solar energy production.

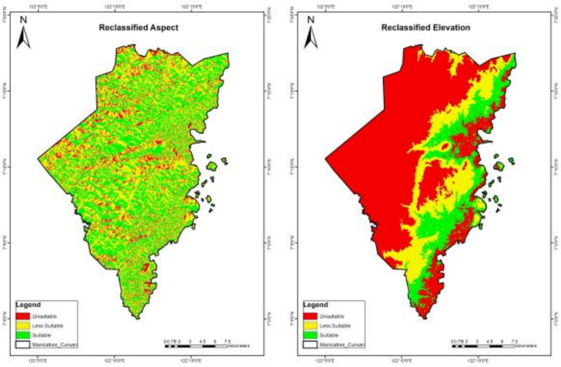

Fig. 6. (Left) Reclassified Aspect Map and (Right) Reclassified Elevation Map

4.9 Land Use and Land Cover

Suitable areas under land use/land cover are marked in green in Figure 7. These areas mainly consist of grassland, crops, barren land, and open areas. Less suitable areas include regions with shrubs and bare ground. In contrast, unsuitable areas were flooded vegetation, waterbodies, forestland, and built areas. As shown in Figure 7, 9.36% of the total land area was classified as unsuitable, 30.44% as less suitable, and 60.19% as suitable.

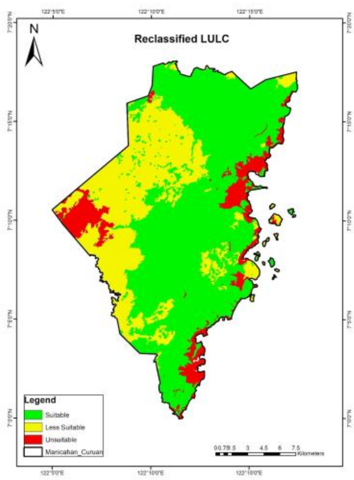

Fig. 7. Reclassified LULC Map

4.10 Identification of the Potential Sites

A Weighted Overlay was employed to identify the potential site map for this study. After overlaying the criteria weights that were assigned to each of the maps, the final potential sites were created. Figure 8 shows a map of the potential sites for solar energy.

The selected sites were distributed on the map, with the most suitable sites receiving the highest priority. Of the total 38, 665.85 hectares of the studied area, only 3,773.698 hectares (9.76% of the total) are suitable under the criteria. In the Curuan District, seven barangays were classified as suitable: Buenavista, Calabasa, Curuan, Dita, Lubigan, Muti, Panubigan, and Quiniput. In the Manicahan District, all barangays were deemed suitable, including Bolong, Bunguiao, Lamisahan, Manicahan, Sangali, and Victoria. Based on the map's findings as shown in Figure 8, the majority of the areas were less suitable with 90.18%, suitable with only 9.81%, and unsuitable with the least percentage of 0.01%. These locations meet the criteria for solar power plant installations.

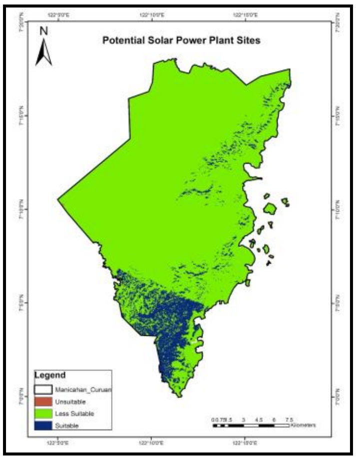

Fig. 8. Potential Solar Energy Sites

4.11 Best Potential Sites

A general guideline is that a 10 square meter area is needed for a 1 kW solar system capacity [8]. The annual solar energy production is influenced by factors such as the total available area, the expected area factor of panel coverage, the type of solar PV technology used, and the module efficiency [8]. The output layer's raster format was converted to vector format as seen in Figure 9, selecting only the areas meeting the 10-hectare requirement to generate 10 megawatts in Zamboanga City to meet its peak demand of 60.27 megawatts.

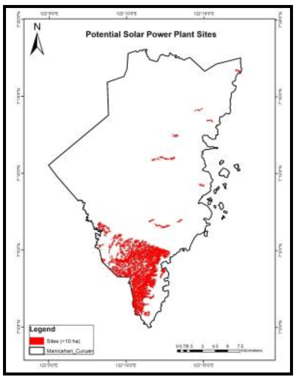

Fig. 9. Selected Solar Power Sites with Areas of 10-ha

4.12 Validation of the Potential Sites Map

This study found 1,196 potential sites for deploying solar energy facilities, with only 20 selected sites that met the 10-hectare land requirement. Table 5 shows the land area ranges of the identified suitable locations.

The identified locations meet the criteria for solar power plant installations. The solar suitability map, created using ArcMap, was converted into a Keyhole Markup Language (KML) file and viewed as a satellite image in Google Earth Pro. Figure 10 displays this suitability map in Google Earth Pro for the Curuan and Manicahan districts in the city of Zamboanga. The red lines represent the administrative boundaries of the districts, while the areas highlighted in yellow are the suitable sites for solar energy installations.

Table 5. Land Area of the Selected Sites

Sites	Barangay	Land Area (ha)	Long	Lat
1	Lamisahan	2,474.66	122.181460°	7.064174°
2	Lamisahan	65.474	122.154025°	7.093717°
3	Bunguiao	55.5024	122.139994°	7.108778°
4	Victoria	33.96	122.205938°	7.059434°
5	Quiniput	32.0785	122.210891°	7.183073°
6	Bunguiao	27.6571	122.146013°	7.103621°
7	Manicahan	24.2705	122.189053°	7.014550°
8	Bunguiao	18.7203	122.208790°	7.109064°
9	Curuan	13.6404	122.219428°	7.207565°
10	Quiniput	13.5464	122.197638°	7.181618°
11	Lamisahan	13.5464	122.142040°	7.072327°
12	Muti	12.8878	122.286864°	7.277811°
13	Lamisahan	12.7938	122.138970°	7.088115°
14	Bunguiao	12.6997	122.200764°	7.110297°
15	Dita	11.4768	122.247713°	7.153930°
16	Buenavista	11.0064	122.256524°	7.223924°
17	Bunguiao	10.9123	122.160724°	7.094783°
18	Calabasa	10.3479	122.244329°	7.235538°
19	Bolong	10.3479	122.224165°	7.115198°
20	Bunguiao	10.0657	122.193583°	7.115535°

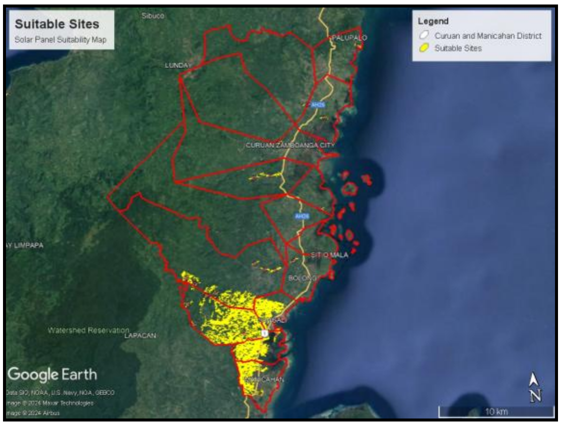

Fig. 10. Solar Energy Suitability Map in Google Earth Pro

5. CONCLUSION AND RECOMMENDATION

This suitability analysis for Solar Energy Potential Sites in Zamboanga City, conducted using Geographic Information System (GIS) and weighted decision support methodology, offers significant insights into identifying optimal locations for solar energy installations. The study assessed the suitability of various sites by integrating spatial data layers representing solar irradiance, temperature, precipitation, cloud cover, slope, road network proximity, aspect, elevation, and land use/land cover.

The result indicated that the districts of Curuan and Manicahan exhibit considerable potential for solar energy development, with specific areas meeting the established criteria for optimal site selection. The study found that there were 11 barangays that are suitable: Lamisahan, Bunguiao, Victoria, Quiniput, Manicahan, Curuan, Muti, Dita, Buenavista, Calabasa, and Bolong which Barangay Lamisahan has the most land for solar power suitable sites.

It is recommended to validate and refine the identified sites through stakeholders' engagement and additional data validation as this needs more aspects and considerations like environmental and technical, such as existing structures, protected areas, and flood risks.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the Engineering Research and Development for Technology (ERDT) Program of the Department of Science and Technology – Science Education Institute (DOST-SEI) for the support in providing the funding assistance that made this study possible.

6. REFERENCES

[1] Suarez, B., and Wada, M (2017). The role of solar photovoltaic power plants in Philippine energy production. *Doshisha University Leading Graduate School Global Resource Management Journal*. Volume **3**, 51–62.

[2] Department of Energy 2024. Executive Summary. URL: https://www.doe.gov.ph/executive-summary?withshield=1. Date Accessed: April 18, 2024.

[3] Tahri, M., Hakdaoui, M., and Maanan, M. (2015). The evaluation of solar farm locations applying Geographic Information System and Multi-Criteria Decision-Making methods: Case study in southern Morocco. *Renewable Sustainable Energy Review*, Volume **51**, 1354–1362.

[4] Lamien, M. H. Y., & Farzaneh, H. (2024, October). Mapping suitable solar farm sites in suez governorate via remote sensing and GIS Techniques. International Exchange and Innovation Conference on Engineering & Sciences.

[5] Lukac, N. et al., (2013). Rating of roofs surfaces regarding their solar potential and suitability for PV systems, based on LiDAR data. *Applied Energy*, Volume **102**, 803–812.

[6] Rumbayan, M., Pasiowan, C., & Sambul, A. (2024, October). Towards Becoming Energy-Independent Village: A Case Study of Solar Rural Electrification in Lalumpe Village, Indonesia. International Exchange and Innovation Conference on Engineering & Sciences.

[7] Al Garni, H.Z., & Awasthi, A. (2017). Solar PV power plant site selection using a GIS AHP based approach with application in Saudi Arabia. Applied Energy, 206, 1225 1240. https://doi.org/10.1016/j.apenergy.2017.10.024

[8] Loquias, R. T., Palima, N. A. P., Juanillas, M. V. B., Magno, L. N., Compuesto, K. S., Zagada, A. M., ... & Terano, H. J. (2022). Suitability mapping of solar energy potential of selected areas in camarines Sur using ArcGIS. *Journal of Engineering and Emerging Technologies*, *1*(1), 37-49.

[9] Renewable Energy Management Bureau 2019. Empowered: Renewable Energy Decade Report 2008-2018, 2F PNOC Building V., Energy Center, Rizal Drive, 34th St. Taguig 1632, Metro Manila, Philippines.

[10] Baquiran, A., Javier, T. B., Dalit, R. J., Manuel, J. J., Pacis, D. J., Palchan, D. L., ... & Daliuag, J. (2020). Mapping of Solar Power Potential Structures Using Geographic Information System. *Engineering Research Bulletin*, *8*, 5-9.

[11] Galvan, J.P.D. (2021). Suitability Analysis for Solar Energy System Development using GIS and AHP in Cagayan Province, Philippines. *Mindanao Journal of Science and Technology*, Volume **19 (2)**, 107-125.

[12] Garcia, J., Gacu, J. and Lawrence, M. (2024). Suitability Analysis for Solar PV Farm Installation using GIS and Analytical Hierarchy Process (AHP) in Simara Island, Province of Romblon, Philippines. *E3S Web of Conference*, 473, 01013.

[13] Levosada, A. T. A., Ogena, R. P. T., Santos, J. R. V., & Danao, L. A. M. (2022). Mapping of suitable sites for concentrated solar power plants in the Philippines using geographic information system and analytic hierarchy process. *Sustainability*, *14*(19), 12260.

[14] Garcia, J., Gacu, J., & Lawrence, M. (2024). Suitability Analysis for Solar PV Farm Installation using GIS and Analytical Hierarchy Process (AHP) in Simara Island, Province of Romblon, Philippines. In *E3S Web of Conferences* (Vol. 473, p. 01013). EDP Sciences.

[15] Opie, N. 2022. The importance of solar irradiance and meteorological data for PV design. URL: https://ratedpower.com/blog/solar-irradiance-meteorological-data/. Date accessed: May 27, 2024.

[16] Arnette, A.N., & Zobel, C.W. (2011). Spatial analysis of renewable energy potential in the greater southern Appalachian mountains. Renewable Energy, 36(11), 2785 2798. https://doi.org/10.1016/j.renene.2011.04.024

[17] Ilum Energy Solutions 2024. How does temperature affect solar panel energy production?. URL:https://ilumsolar.com/how-does-temperature-affect-solar-panel-energy production/#:~:text=On%20a%20cool%20and%20sunny,rated%20at%2077%C2%B0F. Date accessed: May 27, 2024.

[18] Lewis, N. (2016). Solar Energy: How it works and how it can work for you. Rosen Publishing.

[19] Islam, M. R., Aziz, M. T., Alauddin, M., Kader, Z., & Islam, M. R. (2024). Site suitability assessment for solar power plants in Bangladesh: A GIS-based analytical hierarchy process (AHP) and multi-criteria decision analysis (MCDA) approach. Renewable Energy, 220, 119595.

[20] Nebey, A. H., Taye, B. Z., & Workineh, T. G. (2020). Site suitability analysis of solar PV power generation in South Gondar, Amhara Region. *Journal of Energy*, *2020*(1), 3519257.

[21] Kamati, K.; Smit, J.; Hull, S. Multicriteria Decision Method for Siting Wind and Solar Power Plants in Central North Namibia. Geomatics 2023, 3, 47-67. https://doi.org/10.3390/geomatics3010002

[22] Kırcalı, Ş., Selim, S. Site suitability analysis for solar farms using the geographic information system and multi-criteria decision analysis: the case of Antalya, Turkey. Clean Techn Environ Policy 23, 1233–1250 (2021). https://doi.org/10.1007/s10098-020-02018-3