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GIS-Based Land Suitability and Wind Resource Analysis for Assessing Potential Wind Power Sites in Camiguin Island

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Abstract

The increasing energy demand in Mindanao, alongside Camiguin Island's slow urbanization, underscores the need for sustainable energy solutions. The Philippines' reliance on fossil fuels has led to rising carbon emissions, highlighting the urgency of transitioning to renewable energy. Wind energy offers a viable alternative, but its deployment is constrained by geographical and logistical challenges. This study employs a Geographic Information System (GIS)-based methodology to assess wind energy potential in Camiguin Island. Wind speed data from the Global Wind Atlas, integrated with theoretical modeling on a GIS platform, were used to identify optimal wind farm locations. The analysis revealed two highly suitable sites in Guinsiliban, specifically in Barangay Cabuan, that align with the operational parameters of wind turbines such as Gamesa G114-2.0 and Sany SE11520. The identified land area covers approximately 270,000 m2, with an estimated wind energy yield of 17.9 GWh/year. These findings highlight the feasibility of wind power development in Camiguin and provide a replicable framework for wind resource assessment in geographically constrained regions.

Keywords: Camiguin, geographic information system (GIS), site selection, wind energy, wind farm

1. Introduction

The growing energy demand in Mindanao, coupled with the gradual urbanization of Camiguin Island, highlights the need for sustainable and locally sourced energy solutions. The Camiguin Electric Cooperative, Inc. (CAMELCO) currently sources electricity from the National Power Corporation (NPC) hydroelectric plant in Mindanao via a 10.6 km submarine cable, which connects to a 69 kV transmission line from Kinoguitan, Misamis Oriental. This infrastructure supplies electricity to all 58 barangays in the province (Department of Energy [DOE], n.d.). However, to meet growing energy demands, CAMELCO has entered into power supply agreements with various providers, including FDC Misamis Power, a coal-fired plant in Villanueva, Misamis Oriental (4 MW); King Energy Generation Inc., a diesel power plant in Cagayan de Oro (2 MW); and GN Power, another coal-fired plant in Lanao del Norte (1 MW) (Jerusalem, 2019).

Despite these diversified power sources, CAMELCO continues to experience substantial system losses, a common issue for island provinces reliant on external electricity. In 2019, its system loss reached 16.21%, with a peak of 17.19%, exceeding the Energy Regulatory Commission's (ERC) 12% cap (Lagsa, 2019). This inefficiency is primarily due to transmission distance, dependence on a submarine cable, and reliance on fossil-fuel-based energy. While submarine cables are robust and designed for long-term use, they are costly, vulnerable to undersea disturbances, and require expensive maintenance and repairs (Labis *et al*., 2011). Furthermore, as energy demand rises with economic development, this dependence on external power sources not only increases system losses but also places a financial burden on consumers.

The province's reliance on fossil fuels also contributes to its carbon footprint, as coal remains the dominant energy source in the region. The Philippine government has emphasized the need to transition to low-carbon energy solutions to mitigate climate change. One key policy measure is the promotion of renewable energy integration into the country's energy infrastructure (DOE, 2021). In line with this, Camiguin has begun exploring alternative energy sources, particularly solar and wind. The Camiguin Solar Power Project by Camigreen Inc. is in the pre-development stage and has been submitted to the Department of Energy (DOE). The project, proposed for installation in Guinsiliban, Mahinog, and Sagay, is expected to generate 5 MW of electricity (DOE, 2024). However, solar energy's intermittency necessitates exploring other renewable energy sources to ensure a stable and reliable energy supply.

Wind energy is another viable alternative. According to the Philippines Wind Energy Resource Atlas, locations with an annual average wind speed of 6.5–7.0 m/s are optimal for grid-connected wind farms, while rural applications remain viable at speeds as low as 4.5–6.0 m/s (Elliott, 2000). Based on the wind resource atlas, Camiguin has an average wind speed of 5.65 m/s, indicating its potential suitability for wind energy development. However, a major challenge in wind farm installation is identifying optimal locations, as geographical constraints, land-use policies, and accessibility issues may hinder large-scale implementation.

Previous studies have demonstrated the effectiveness of Geographic Information System (GIS) technology in renewable energy site selection. GIS-based Decision Support Systems (DSS) have been widely used to evaluate wind energy feasibility by integrating wind resource data, topographic factors, and land-use assessments (Abdi *et al*., 2024; Rehman *et al*., 2020). Similar GIS-based sustainability analyses have also been conducted for other renewable sources in the Philippines, such as solar power suitability assessments on the Sibuyan and Simara Islands using the Analytic Hierarchy Process (AHP) (Gacu *et al*., 2024; Garcia *et al*., 2024). These studies highlight the versatility of GIS for renewable energy planning, but most remain focused on large-scale or mainland contexts. There remains a research gap in applying high-resolution GIS assessments to small island provinces like Camiguin, which face distinct topographic and infrastructural constraints.

Beyond energy demand, several site-specific factors justify focusing this study on Camiguin Island. The island is geographically isolated and heavily dependent on a single submarine cable, leaving it vulnerable to disruptions and supply issues (DOE, n.d). Camiguin is also a major eco-tourism destination, and its economy relies on reliable power to support hotels, resorts, and tourism services. Integrating wind energy not only enhances energy resilience but also aligns with the island’s commitment to sustainable tourism and environmental protection. These factors make Camiguin an ideal candidate for a localized, GIS-based wind energy assessment.

This study aims to address these gaps by using a GIS-based approach to assess wind energy potential and identify suitable wind farm locations in Camiguin. By integrating wind speed data, topographic constraints, and land-use factors, the study seeks to determine optimal sites for wind power generation. Additionally, the research evaluates the compatibility of identified sites with existing wind turbine models to estimate potential power output. The results will inform the strategic planning of renewable energy projects in Camiguin and serve as a framework for wind energy assessment in other island provinces.

2. Methodology

2.1 Study Area

Camiguin is a mountainous island in the Bohol (Mindanao) Sea, located about 10 km off the northern coast of Mindanao (Figure 1). It covers 230 km² and has a population of 92,808 as of the 2020 census (Britannica Editors, 2018). The province comprises several small towns, with Catarman and Mahinog among the less densely populated areas. Due to its geographic isolation, Camiguin relies on the Camiguin Electric Cooperative (CAMELCO) for electricity, which is sourced from mainland Mindanao through power agreements with FDC Misamis Power (4 MW), King Energy Generation Inc. (2 MW), and GN Power (1 MW) (Lagsa, 2019). Despite these agreements, system losses remain a critical issue, and the gap between contracted power and actual consumption drives high electricity costs for consumers. Given these challenges, developing a localized renewable energy source, such as wind power, is essential for energy security and cost reduction.

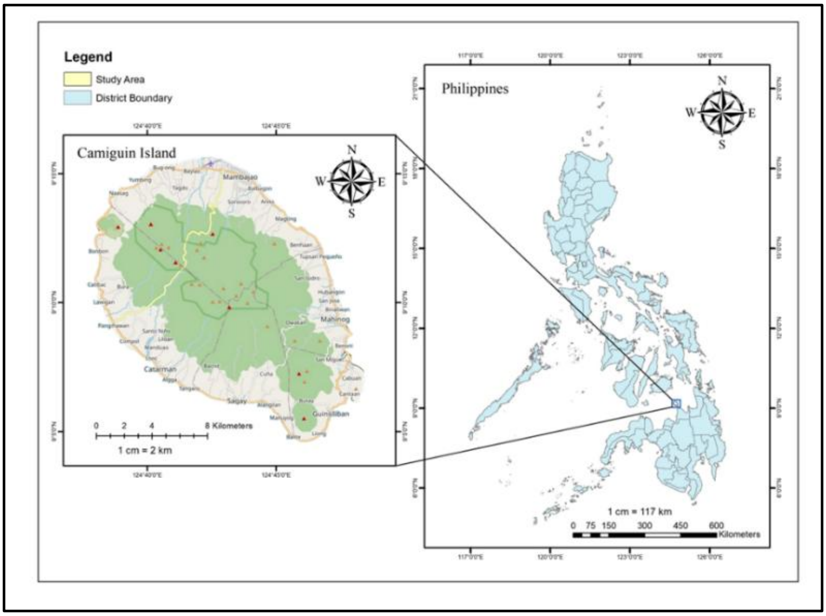

Figure 1. Map of study area

2.2 Wind Resource Data and Processing

Wind speed and wind power density data for the study area were obtained directly from the Global Wind Atlas, a high-resolution dataset developed by the Technical University of Denmark [DTU] & World Bank (n.d.). The dataset is based on ERA-Interim reanalysis data, with mesoscale modeling performed at 9 km resolution by Vortex and microscale modeling at 1 km resolution by DTU. These data were processed in ArcGIS to generate spatial distributions of wind speed and wind power density at a hub height of 100 m, following established procedures for wind resource mapping (Zhang, 2015).

The wind data were imported as raster files and resampled to a 1 km × 1 km resolution using the Data Management Tool in ArcGIS. Spatial interpolation was performed to generate continuous wind speed and power density maps. The Raster to Polygon conversion tool was used to extract vector-based wind resource layers, ensuring an accurate representation of wind variability across the study area. Wind speed values were classified into three categories, and wind power density into five, to facilitate analysis of suitable locations for wind energy development. Unless otherwise stated, all rasters and overlays were analyzed on the 1 km × 1 km grid. Outputs represent patterns at this resolution. Conditions can vary within a 1-km cell, so the value shown for a cell may not apply uniformly across that cell, and features smaller than the grid cell may not be fully resolved (Elliott, 2000).

Note that the wind power density used in this study represents long-term mean conditions and does not capture diurnal or seasonal variability; results are therefore screening-level and should be validated with time-resolved, on-site measurements.

2.3 Land Suitability Analysis

Potential wind farm sites were identified based on land use constraints and infrastructure accessibility, following Venoya (2019). Areas unsuitable for wind energy development, including protected zones, urban areas, water bodies, and steep slopes, were excluded using predefined buffer zones: 500 m for forests, urban areas, and water bodies; 2,500 m for airports; and slopes exceeding 10% (Baban & Parry, 2001; Zhang, 2015). Wind farms were also sited at least 500 m from residential areas to mitigate noise concerns (Miller, 2008). A limitation of the overlay approach is that ridge-induced obstruction of the prevailing wind may not be captured by the screening, and intersecting spacing buffers can reduce or eliminate feasible turbine placements within candidate areas. Final siting should be confirmed with higher-resolution layout and wind flow assessment.

Because the objective was to identify where wind farms can be developed rather than to rank potential sites by preference, MCDA was not used in this study. Unlike MCDA, which weights competing factors, this study used a binary GIS overlay approach that systematically eliminates unsuitable areas according to predefined exclusion criteria. This method ensures objective, transparent, and reproducible site selection. In this paper, areas described in the results as highly suitable refer to grid cells that meet all screening thresholds, including buffers, slope, and resource requirements. The analysis therefore uses a binary classification (suitable or unsuitable), and no intermediate suitability levels were defined.

2.4 Technical Analysis

The technical wind energy potential was assessed based on wind resource availability and turbine specifications. Unlike conventional methodologies that employ the Weibull probability distribution function to characterize wind speed variability and compute expected energy output (Shu & Jesson, 2021), this study used pre-computed wind power density values from the Global Wind Atlas. This approach simplifies estimation and enables a direct GIS-based spatial assessment of wind energy potential.

The annual wind energy output per grid cell (E_i) was estimated using Equation 1:

$$E_i = P_{d,i} \times A \times C_p \times T \quad (1)$$

where E_i is the annual energy output (Wh) for grid cell i; $P_{d,i}$ is the mean wind power density (W/m^2); A is the swept area of the turbine rotor *(m^2);* C_p is the turbine power coefficient; and T represents the annual full-load hours (FLH).

Since $P_{d,i}$ was obtained directly from the Global Wind Atlas, which assumes standard air density under neutral atmospheric conditions, no site-specific recalculation from wind speed and air density was required. A uniform representative power coefficient of $C_p = 0.40$ was applied, with a sensitivity range of 0.35–0.45 to reflect modern horizontal-axis wind turbine performance. This simplification was adopted for coarse screening, as $C_p$varies among turbine models, wind speeds, and control strategies (Kamal & Ali, 2025; Schallenberg-Rodriguez, 2013). Annual FLH values of 2,000–

2,300 h were adopted (Morthorst & Kitzing, 2016), consistent with typical onshore turbine operation.
The number of turbines that can be micro-sited within the available area of grid cell *i* was estimated following standard turbine-spacing practices used in wind farm layout design. The number of turbines per grid cell (N_i) was calculated in Equation 2 (Maandal *et al*., 2021):

$$N_i = A_i/(k_x k_y D^2) \quad (2)$$

where, A_i is the suitable land area within the 1 km × 1 km grid cell (i.e., after GIS exclusions for buffers and slope/elevation), *D* is the rotor diameter of the turbine, and k_x and k_y are the downwind and crosswind spacing factors, respectively.

Values of 10 and 5 were applied to the downwind and crosswind spacing factors (Maandal *et al*., 2021), respectively, to reduce inter-turbine wake losses and to reflect typical industry spacing practices for onshore wind farms.

The total annual wind energy generation potential was obtained by summing the estimated outputs across all feasible grid cells. Since this study focuses on onshore wind energy, offshore-specific constraints such as sea depth, marine ecology, and grid connection challenges were not considered. Grid access in this screening is represented only by proximity to existing lines. Transmission and substation capacity, voltage-class compatibility, interconnection cost and queue status, protection constraints, and curtailment risk were not modeled.

The analytical workflow for wind farm site selection is shown in Figure 2 and outlines the integration of wind data analysis, land suitability assessment, and technical evaluation.

Although the GIS-based methods used in this study have been applied in other renewable energy assessments, their use for Camiguin Island is novel. To our knowledge, this is the first comprehensive wind energy suitability assessment for the island, which faces unique geographic and infrastructural constraints that warrant localized analysis.

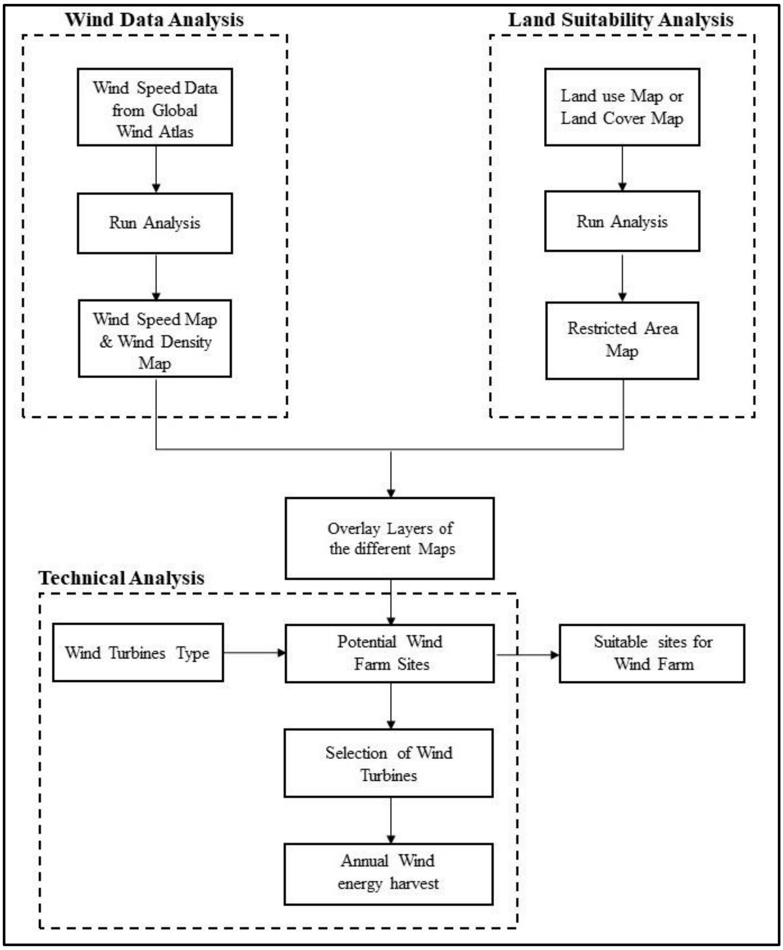

Figure 2. Methodological framework for wind farm site selection

3. Results and Discussions

3.1 Wind Data Analysis

Figure 3 shows the Annual Wind Speed Map of the study area at 100 m, derived from Global Wind Atlas data and processed in ArcGIS. Wind speeds across the region range from 2.91 m/s to 11.5 m/s, with significant spatial variation. Wind speed is a critical factor in assessing the feasibility of wind energy generation.

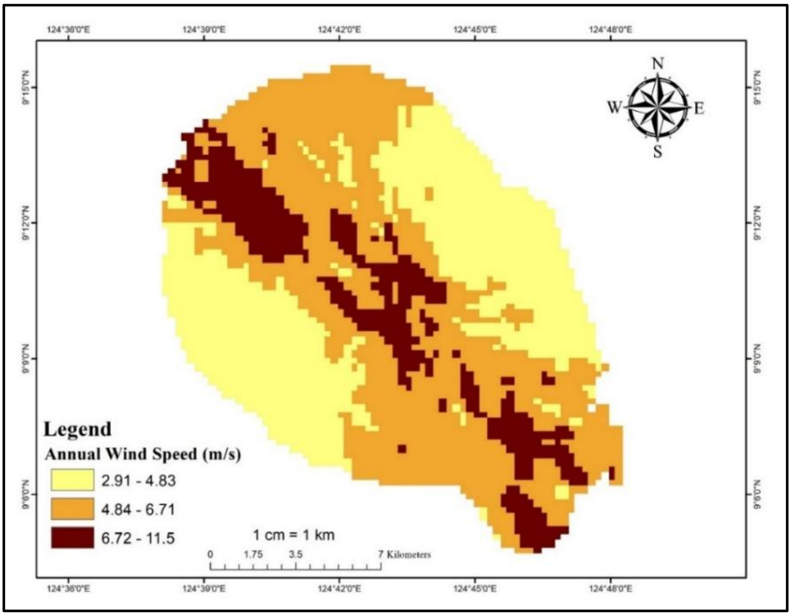

Figure 3. Annual mean wind speed map of Camiguin Island

The northwestern, central, and southern regions of the province have the highest wind speeds, making them ideal for wind energy development. These areas meet or exceed the 6.5–7.0 m/s cut-in speed, which is essential for utility-scale, grid-connected wind turbines (Elliott, 2000). Furthermore, a subset of the study area has annual mean wind speeds between 6.72 m/s and 11.5 m/s, reinforcing its potential for sustainable wind energy generation.

Figure 4 shows the Wind Power Density Map at 100 m, illustrating the distribution of extractable wind energy across the study area. Wind power density (W/m²) quantifies the energy available in the wind and serves as a crucial indicator of wind farm viability.

Most of the province has wind power densities between 43.64 W/m² and 183.69 W/m², with some areas reaching 183.7 W/m² to 350.42 W/m². However, only a few locations have significantly higher power densities, ranging from 1070.8 W/m² to 1744.3 W/m², which are optimal for large-scale wind energy projects.

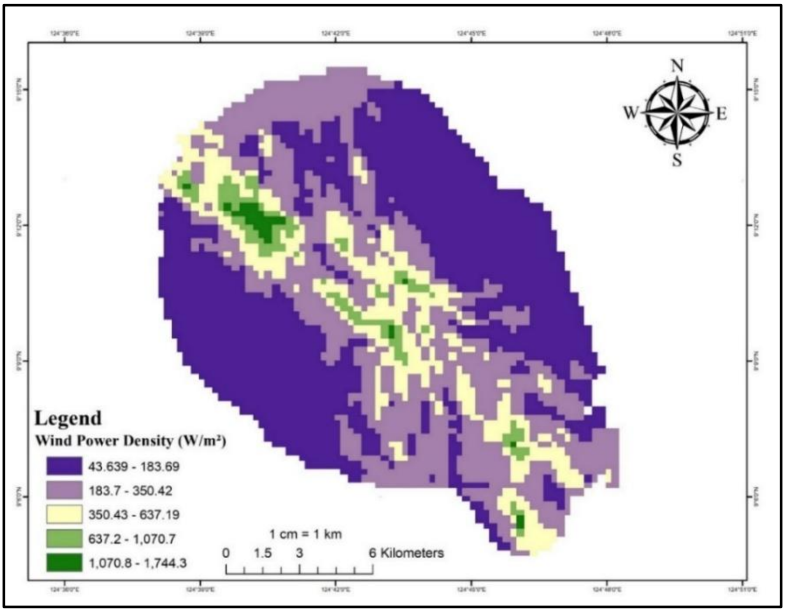

Figure 4. Wind power density map of Camiguin Island

Like wind speed distribution, the northwestern, central, and southern regions exhibit moderate to high wind power densities, making them promising sites for future wind energy development. While most provinces do not reach the highest power density thresholds required for large-scale wind farms, several locations still offer sufficient wind energy resources for medium-sized wind applications.

3.2 Land Suitability Analysis

The land use or land cover map was analyzed alongside OpenStreetMap data (OpenStreetMap contributors, n.d.) to classify land features according to the Land Cover Classification of the Philippines. The classification process identified restricted areas using predefined criteria, including urban settlements, wetlands, forests, water bodies, and transportation infrastructure. The buffer tool was used to create exclusion zones, and the union tool was used to generate a comprehensive restricted area map.

The classification of land features and their corresponding buffer distances is presented in Table 1. Urban areas, power plants, roads, and other infrastructure were assigned buffer zones ranging from 500 m to 2,500 m to ensure that wind farm sites were located away from areas with potential land-use conflicts.

Table 1. Layer classification of the land cover data

Layer Feature	Land Classification base on Land Cover Classification of the Philippines	Land Classification base on Restriction criteria	Buffer Distance
Places	Settlements	Urban Area	500 m
Airport Runway	Settlements	Airport	2500 m
Airport Terminal	Settlements	Airport	2500 m
Power Plant	Settlements	Urban Area	500 m
Water Ways	Wetland	Waterbody/Wetland	500 m
Roads	Settlements	Urban Area	500 m
Nature Wetland	Wetland	Wetland	500 m
Lagoon	Wetland	Waterbody	500 m
Natural	Forest	Forest	500 m
Land use	Alienable and Disposable lands	Urban Area	500 m
Buildings	Settlements	Urban Area	500 m

Figure 5 shows the restricted area layers used in the land suitability analysis for wind farm siting. Because Camiguin Island is dominated by natural landscapes, dense forests, and mountainous terrain, areas with slopes greater than 10% and elevations above 1,500 m were excluded. These restrictions were applied to ensure that the selected sites were both topographically suitable and structurally stable for wind farm development.

The exclusion of steep slopes and high elevations was necessary due to the technical challenges associated with turbine installation, accessibility, and maintenance. Areas with slopes greater than 10% pose difficulties in transporting and assembling wind turbine components and increase the risk of foundation instability and erosion. Furthermore, elevations above 1,500 m were excluded due to potential air density variations, which can affect turbine performance, as well as increased logistical constraints in high-altitude regions.

Figure 6 presents the final restricted area map, highlighting forestlands, urban areas, protected reserves, water bodies, airports, and steep slopes as unsuitable for wind farm development. Locations within designated buffer zones are classified as restricted areas and have been excluded from consideration as potential wind farm sites. These restrictions were applied to ensure compliance with land-use policies, environmental conservation regulations, and infrastructure safety standards.

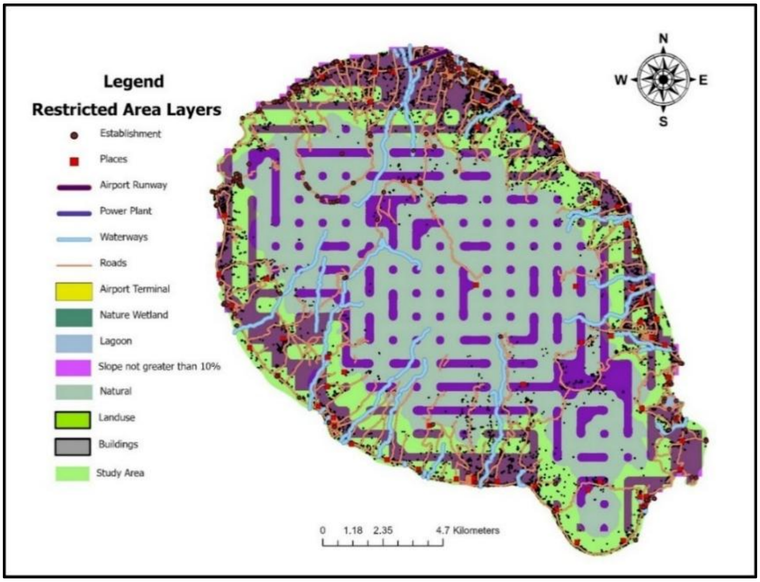

Figure 5. Restricted area map layers

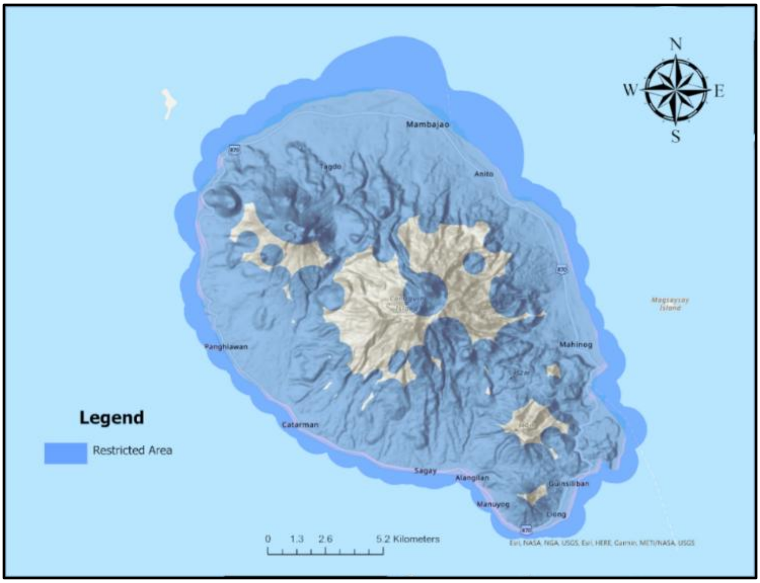

Figure 6. Final restricted area map

The exclusion of restricted areas was a crucial step in refining potential wind farm sites in Camiguin. Urban settlements, roads, and airport facilities were assigned buffer distances ranging from 500 m to 2,500 m, following standard zoning regulations to prevent conflicts related to noise pollution, visual impact, and safety concerns. Similarly, forestlands and wetlands were excluded due to conservation efforts and ecological sensitivities, ensuring that wind energy development does not interfere with protected ecosystems.

Although a significant portion of the island falls within these restricted zones, several areas remain viable for wind energy projects. The analysis identified locations outside the buffer zones with favorable terrain and sufficient wind resources, making them suitable candidates for wind farm development. These areas were further evaluated based on slope and elevation criteria, leading to the identification of the most optimal wind farm sites for the province.

3.3 Identification of Suitable Sites

The land suitability analysis identified locations that do not overlap with restricted zones, as shown in Figure 7. These areas were further refined by overlaying slope and elevation constraints with the restricted area map shown in Figure 8 to determine the optimal wind farm sites. The integration of these factors ensures that the selected locations are both geophysically suitable and free from land-use conflicts, making them viable candidates for wind energy development.

The spatial distribution of optimal sites across the province reveals that Catarman contains the largest number of optimal sites, comprising 44.4% (20 sites). Mambajao follows with 20% (9 sites), Mahinog with 17.8% (8 sites), Guinsiliban with 13.3% (6 sites), and Sagay with 4.4% (2 sites). The higher concentration of suitable locations in Catarman may be attributed to its relatively lower urban density and greater availability of open land, particularly in areas with moderate slopes and minimal environmental restrictions.

Mambajao, the commercial and administrative center of Camiguin, ranks second in terms of site availability, despite its more developed infrastructure. The presence of urban settlements and critical infrastructure likely limited the number of available locations. However, its proximity to existing roads and power infrastructure may offer logistical advantages for wind farm development.

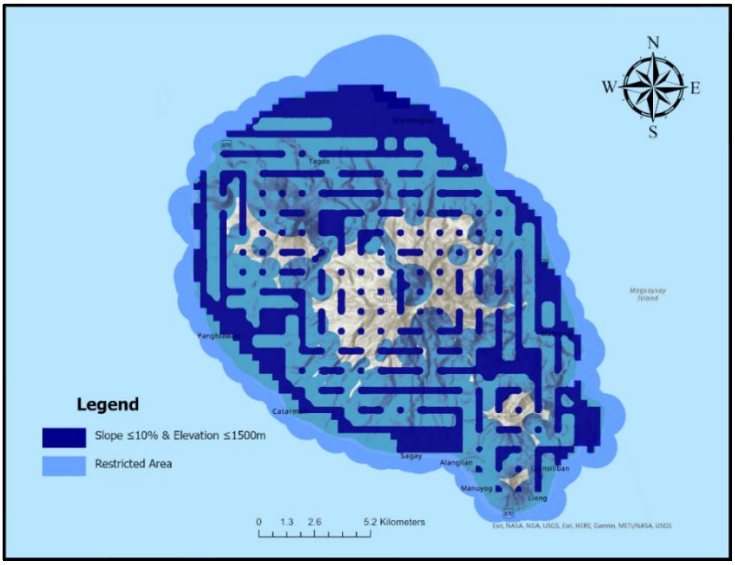

Figure 7. Layer feature for land suitability analysis

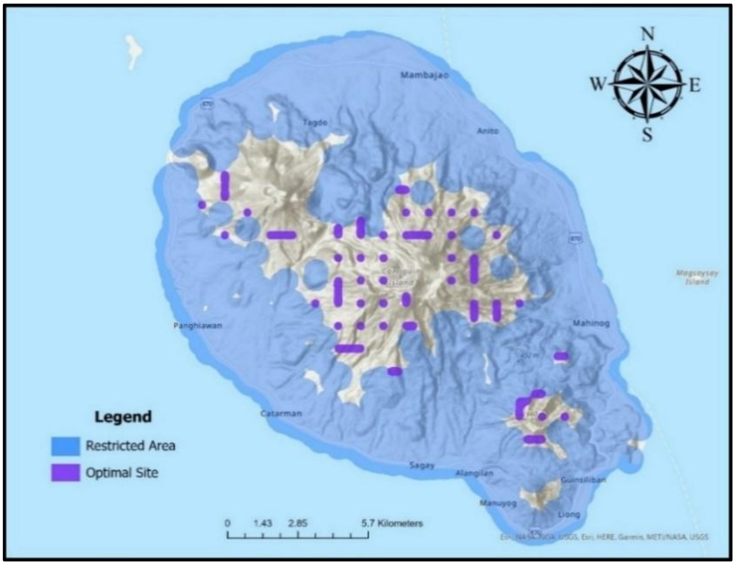

Figure 8. Optimal site from land suitability analysis

Mahinog, Guinsiliban, and Sagay have fewer optimal sites, reflecting greater land-use constraints and topographical challenges. Mahinog and Guinsiliban, while having some open areas suitable for wind farms, contain coastal and ecologically sensitive zones that reduced the number of feasible sites. Sagay, the smallest municipality, has the least number of identified optimal sites, indicating limited available land that meets all suitability criteria.

The Raster Calculator tool was applied to analyze the raster data of mean wind speed and wind power density across Camiguin Island. The results, presented in Figure 9, show that the minimum wind speed in the identified suitable areas is 6 m/s, with a minimum wind power density of 620 W/m². These values were used as thresholds for determining sites that have sufficient wind energy potential for power generation.

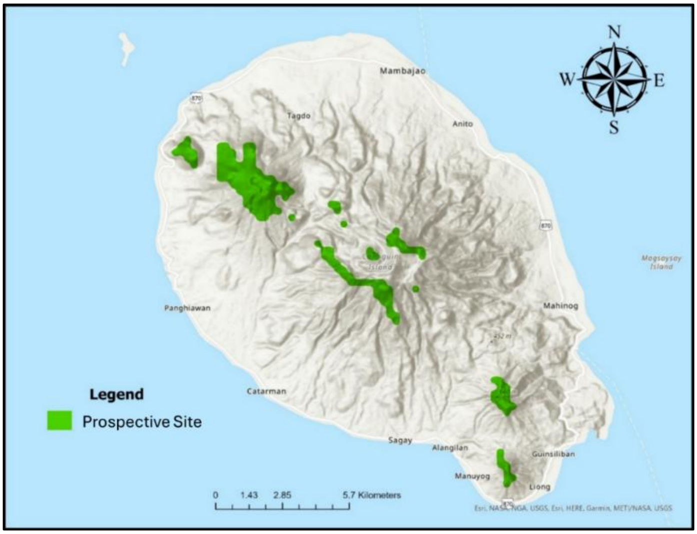

Figure 9. Prospective sites from wind data analysis

The spatial distribution of prospective wind farm sites indicates that Catarman has the highest concentration, accounting for 42.1% (31 sites). Mambajao and Guinsiliban follow with 23.1% (22 sites) each, while Sagay and Mahinog contribute 6.3% (6 sites) and 5.3% (5 sites), respectively. The dominance of Catarman and Mambajao in the results suggests that these municipalities experience relatively favorable wind conditions and have land areas that meet the exclusion criteria for wind farm development.

To determine the final potential wind farm sites, the Raster Calculator tool was further applied to overlay optimal and prospective sites, filtering locations based on both land suitability and wind resource availability. The results identified seven potential wind farm sites, as shown in Figure 10, with four located in Catarman, two in Guinsiliban, and one in Sagay. The specific coordinates, total land area, and key site characteristics of these locations are summarized in Table 2.

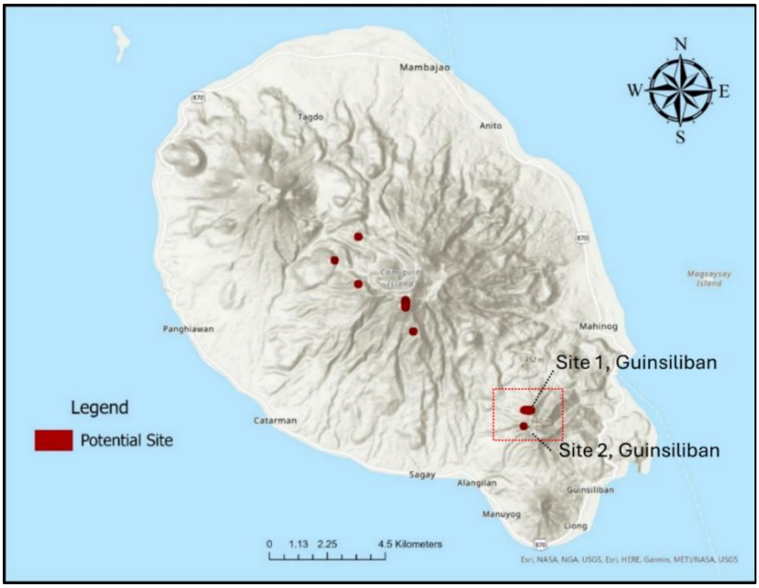

Figure 10. Potential site for wind farm installation in Camiguin

The results indicate that while Catarman offers the most viable sites, Guinsiliban emerges as the most suitable location due to its balance of wind speed, land availability, minimal land-use restrictions, and road access. Sotto *et al*. (2023) used MCDA for offshore wind site selection in the Philippines, emphasizing exclusion zones based on slope, land use, and proximity to infrastructure—criteria that closely align with our study's land-suitability method. Their emphasis on balancing wind resource availability with grid access supports the selection of Guinsiliban, which combines good wind speeds with access to feeder lines. Unlike other municipalities, which exhibited greater land-use constraints and topographical challenges, Guinsiliban’s coastal location and moderate slopes provide an advantage in turbine accessibility and wind resource availability. The presence of road networks near the identified sites further enhances their feasibility, as ease of transportation is a critical factor for wind farm construction and long-term maintenance.

Table 2. Identified suitable wind farm sites with coordinates, land area, and key site characteristics

Municipality	No. of Suitable Sites	Coordinates	Total Area of Suitable Location (m^2)	Remarks
Catarman	4	124.704891°E, 9.186598°N; 124.696585°E, 9.178638°N; 124.70489°E, 9.171024°N; 124.720983°E, 9.165487°N	360,000	Distant from feeder line, limited road access
Guinsiliban	2	124.76359°E, 9.1265617°N; 124.762678°E, 9.1209567°N	270,000	Close to feeder lines, road accessible, stable wind conditions, low population density.
Sagay	1	124.72375°E, 9.15372°N	90,000	Distant from feeder line, limited road access, near Mount Mambajao.

Meanwhile, certain sites in Catarman and Sagay were deemed unsuitable for wind farm development due to various constraints. As highlighted by Janke (2010), based on public and private sector surveys, wind farms should avoid mountain summits, steep slopes, woodlands, and densely populated areas. Proximity to roads and the existing power grid is essential for feasibility, as supported by Yousefi *et al*. (2022) in a case study of Semnan Province, Iran, and by Lee *et al*. (2008). Moreover, the Department of Public Works and Highways (DPWH) classifies volcanic mountains and landslide-prone areas as zona non aedificandi (no-build zones) due to their hazardous nature. These factors contributed to the rejection of sites in Catarman and Sagay, reinforcing Guinsiliban as the most suitable wind farm location due to its more favorable geographic and infrastructural conditions. Recent studies in Philippine island settings similarly highlight the challenges posed by land and environmental constraints in renewable energy development. Gacu *et al*. (2024) conducted a wind resource assessment for Sibuyan Island and reported that only a small fraction of land was classified as highly suitable, primarily due to terrain limitations and protected areas, similar to the findings for Camiguin.

3.4 Technical Wind Power Analysis

After identifying potential sites in ArcGIS, two locations were selected for their suitability for wind farm installation. These sites, located in Barangay Cabuan, Municipality of Guinsiliban, were chosen for their favorable wind conditions and geographical characteristics. The evaluation of wind turbines at each site focused on annual wind energy yield and the impact of swept area on energy generation.

The selection of wind turbine models was based on their compatibility with the wind conditions at each site. Key considerations included operational efficiency across the expected wind speed range, energy generation potential, and land use requirements. Additionally, turbines with different swept areas were selected to assess the relationship between rotor size and power output. The selected models provide a representative analysis of wind turbine performance across varying site conditions. The number of turbines per site was determined using Equation 2 to ensure an optimal balance between energy generation capacity and land use efficiency.

The energy generation potential of the three selected wind turbine models—Sany SE11520, General Electric GE 2.3-107, and Gamesa G114-2.0—was evaluated at Site 1, as illustrated in Figure 11. All power-curve and performance data for these models cited in this paper were obtained from The Wind Power (n.d.). Their specifications, detailed further by Bauer & Matysik (2022), highlight differences in rotor diameter, rated power, and hub height, which influence their performance under varying wind conditions. Among them, the Sany SE11520 produced the highest annual wind energy yield, primarily due to its larger swept area. However, this advantage comes with the trade-off of increased land requirements, which may pose constraints depending on site availability and spatial considerations.

Despite having the smallest swept area among the models, the General Electric GE 2.3-107 delivered competitive energy output. This suggests that turbine efficiency, wind conditions, and power coefficient contribute significantly to overall performance beyond rotor size alone. The GE 2.3-107's ability to generate substantial energy while requiring a smaller footprint makes it a practical choice where land availability is limited.

Meanwhile, the Gamesa G114-2.0 also demonstrated strong energy yield despite its moderate swept area, making it a viable option for this site. As shown in Figure 11, this model balances energy production with spatial requirements, making it a promising alternative for optimizing land-use efficiency.

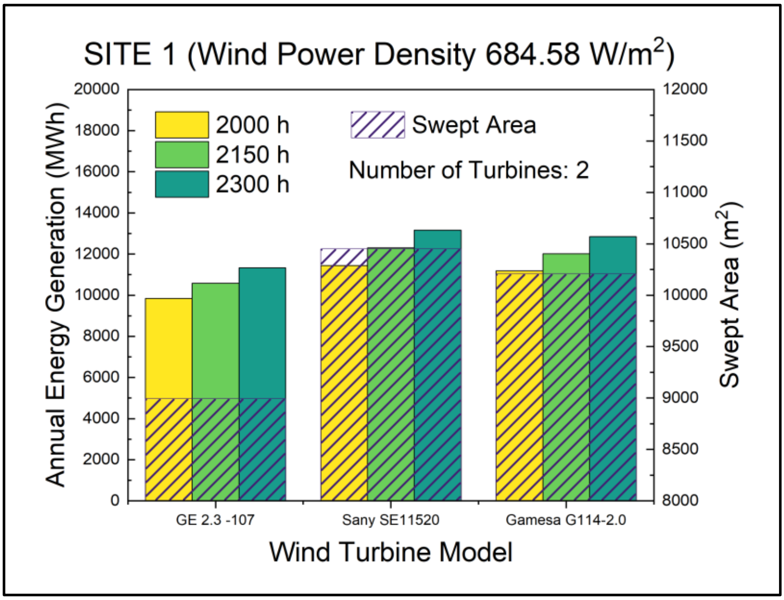

Figure 11. Annual energy generation and swept area of selected wind turbines at Site 1. Average hub-height wind speed is 8.5 m/s. Full-load hours (FLH) are 2000, 2150, and 2300 h

A similar assessment was conducted at site 2, where the wind conditions warranted evaluating Sany SE11520, General Electric GE 2.0-2.7 - 116, and General Electric GE 3.2-103. As shown in Figure 12, the results reaffirm the correlation between larger swept areas and higher energy yields. However, at this location, the General Electric GE 2.0-2.7 - 116 exhibited the highest energy generation potential, though it also required more land for installation.

Despite this, the Sany SE11520 proved the most favorable choice for Site 2, achieving an energy yield comparable to the GE 2.0-2.7 - 116 while requiring less land area. This finding indicates that the Sany SE11520 remains a reliable option across diverse wind conditions, offering both high energy output and reasonable land-use efficiency. Abella *et al*. (2024) conducted a techno-economic analysis of floating offshore wind energy in the Philippines, using GIS-based modeling to assess wind resource potential and turbine compatibility. Their research underscored the need to match turbine specifications to site-specific wind conditions and infrastructure requirements. This approach aligns with our selection of the Sany SE11520 and Gamesa G114-2.0 turbines for Guinsiliban, where characteristics such as swept area, wind power density, and proximity to existing feeder lines were crucial to maximizing energy yield within spatial limits. Proximity to feeder lines does not imply available hosting capacity. Confirmation requires utility interconnection and hosting capacity studies, including load flow and protection analysis.

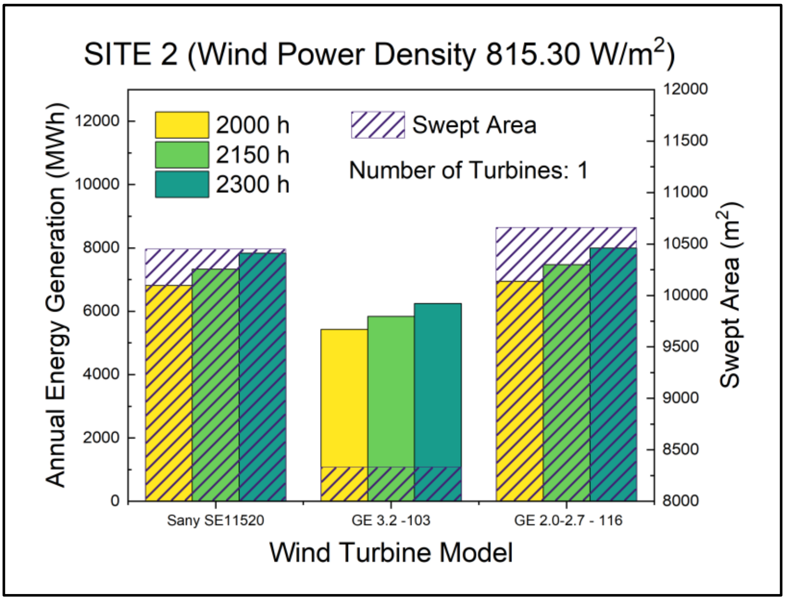

Figure 12. Annual energy generation and swept area of selected wind turbines at Site 2. Average hub-height wind speed is 9.1 m/s. Full-load hours (FLH) are 2000, 2150, and 2300 h

While these results offer a performance-based assessment of wind turbine suitability, a comprehensive cost-benefit analysis would provide deeper insight into the economic feasibility of each model. Considerations such as installation costs, maintenance expenses, and long-term operational efficiency could influence the overall viability of turbine deployment. Tarife *et al*. (2023)

employed an integrated GIS-Fuzzy AHP framework for hybrid renewable energy system planning in the Southern Philippines, underscoring the importance of combining spatial, technical, and socio-environmental factors in suitability evaluations. These recent studies support the methodology and results presented for Camiguin Island. However, such economic analysis falls beyond the scope of this study and is recommended for future investigation.

The wind resource layers used here are based on long-term climatology from the Global Wind Atlas rather than site measurements. In complex coastal–volcanic terrain such as Camiguin, mesoscale-to-microscale downscaling can smooth local speed-ups/deficits and misrepresent hub-height shear/veer; absolute energy-yield values are therefore indicative. We recommend staged validation comprising 12–24 months of on-site measurements (met mast or LiDAR), Measure–Correlate–Predict (MCP) to anchor short records to long-term climate, and checks of turbulence intensity and extreme winds/typhoon exposure. These data will calibrate the GIS screen, inform micro-siting and turbine class selection, and support bankable feasibility.

3.5 Discussion

The spatial patterns indicate that suitability in Camiguin is driven more by constraints than by resource magnitude alone. Areas that combine gentle slopes, adequate setbacks from settlements and protected zones, and practical access to roads and existing lines form the main suitability clusters. This explains why the most contiguous opportunity appears in Guinsiliban, while the other municipalities mostly contain smaller, fragmented patches. In an island setting with complex terrain and multiple protected areas, integrating constraints is the primary driver that converts broad wind resource potential into realistic siting options.

The binary overlay used here is transparent and reproducible, making it well suited for early screening and communication. Its trade-off is sensitivity: treating all rules as equally decisive means small changes to slope limits or buffer distances can expand or contract the suitable footprint. The 1-km raster grid also generalizes sub-kilometer terrain breaks and parcel boundaries, so polygon edges should be interpreted at that resolution and expected to shift with finer inputs.

Future work can strengthen the analysis by expanding the rule-based screen into a calibrated multi-criteria or optimization workflow that incorporates grid hosting capacity, interconnection costs, terrain constructability, and route-to-site road-building effort to produce an LCOE-style suitability surface. It should also add Camiguin-specific environmental risk layers, including typhoon gust exceedance, landslide and flood corridors, and avian or bat sensitivity, to de-risk siting and prioritize feasible zones.

4. Conclusions and Recommendation

This study used a GIS-based approach to assess land suitability for wind farms on Camiguin Island, Philippines, integrating environmental and technical factors. The methodology provides a systematic, quantitative tool for identifying potential sites and guiding decision-makers. Applied to Camiguin, it identifies two highly suitable sites in Barangay Cabuan, Guinsiliban, totaling ~270,000 m^2, with an indicative wind-energy yield of ~17.9 GWh/year under turbine parameters representative of Gamesa G114-2.0 and Sany SE11520. The final suitability map helps narrow down locations, but the identified sites remain provisional and require further investigation before final selection.

While GIS provides a strong preliminary assessment, field validation is essential. On-site wind speed measurements and ecological evaluations should confirm feasibility. Future research should incorporate high-resolution meteorological data and more advanced multi-criteria decision-making techniques to improve the accuracy of wind farm site selection. Stakeholder engagement, including environmental and community assessments, is crucial to sustainable wind energy development.

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