Locating Biomass Collection Points (BCP) For Optimal Siting of Coconut Biomass Energy Facilities in Palawan Province Using GIS*

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Abstract:

Power distribution inefficiencies and heavy reliance on diesel generators remain key challenges in Palawan. As one of the major coconut producers in the Philippines, Palawan's coconut residues present significant biomass energy potential to address energy issues while promoting clean energy production. This study evaluates the theoretical and available energy potential of coconut residues in Palawan and identifies biomass collection points (BCPs) based on their biomass collection capacity within a 0.7-km radius and proximity to the road network. These points are used as supply sources, with candidate sites as demand points, and the road network is incorporated to optimally locate biomass conversion facilities using Geographic Information System (GIS) and spatial analysis. Results indicate an estimated theoretical potential of 15465.919 metric tons and an available potential of 85.173 MJ/ha, sufficient to supply one biomass energy facility with an approximate capacity of 1.5 MW. Twelve BCPs were identified in Southern Palawan: two in Sofronio Espanola, three in Rizal and Brooke's Point, and four in Quezon. Additionally, eight BCPs were identified in Cuyo Island: three in Cuyo and five in Magsaysay. There are 96 candidate sites determined as potential locations for biomass conversion facilities. The optimal site for a biomass conversion facility was identified in Quezon, Palawan. In conclusion, this research effectively employed GIS and the BCP framework to locate biomass collection points and strategically determine the optimal site for a biomass conversion facility.

1. Introduction

In the Philippines, many off-grid communities continue to experience inadequate access to sustainable energy and suffer from inefficient power distribution systems (Pacaldo et al., 2022). This problem is particularly observed in Palawan, where one of the most pressing issues is the frequent occurrence of rotational power outages. These outages have persisted for years. Palawan has faced years of rotational power outages (Fabro, 2019). In 2022, the province nearly faced a power crisis when one of its major electricity providers was at risk of closure (Cordero, 2022).

The island's energy supply heavily depends on diesel, with 24 SPUG (Small Power Utilities Group) plants operated by the National Power Corporation. Despite its widespread use, diesel is both non-renewable and environmentally damaging, significantly contributing to air pollution (Castro et al., 2022).

Biomass presents a renewable alternative that could offset diesel use and improve the national energy mix. The Philippines has an abundant biomass resource base (De Guia, 2023), but its energy potential remains largely underutilized (PSA, 2021). Although installation proposals have been made, Palawan had no operational biomass power plants as of December 2022 (DOE, 2022).

As one of the country's leading coconut producers (PSA, 2022), Palawan possesses considerable potential in biomass energy generation through coconut residues. However, practical challenges, such as high transport costs and the need for secure storage to ensure steady plant operation, limit the viability of biomass energy systems (Abbasi and Zeeshan, 2023). Poor infrastructure in rural areas further hampers the efficient transport of biomass, which is often reliant on manual labor and substandard roads (Samson et al., 2001).

Researchers frequently apply Multi-Criteria Decision Analysis (MCDA) in combination with Geographic Information Systems (GIS) to improve site selection for biomass facilities (Fatima and Zeeshan, 2024). These methods incorporate environmental, economic, and social indicators to identify optimal sites. Among them, the Analytical Hierarchy Process (AHP) stands out as the most widely adopted due to its simplicity and flexibility, appearing in over half of the 85 studies reviewed (Shao et al., 2020). However, conventional models typically assume that biomass is collected from centralized locations with consistent yields and uniform transport distances. These assumptions often do not reflect real-world conditions, as rural areas commonly experience uneven biomass distribution and limited access to road networks.

Morato et al. (2019) addressed this issue by introducing a Biomass Collection Point (BCP) locating framework tailored for areas like Bolivia, where agricultural fields are dispersed and access to well-structured road networks is limited. This study applies a similar model to the Philippine context, where biomass yield is highly variable (Galang et al., 2022), and road infrastructure is frequently irregular and unpaved (Palarca et al., 2014).

By implementing the BCP locating framework alongside site suitability and optimal location analyses, this research aims to identify optimal sites of BCPs and biomass energy facilities in Palawan. This integrated approach addresses the logistical and infrastructural constraints that currently limit biomass energy development in the region.

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1.1 Limitations

Due to time constraints, the biomass resource assessment utilized spatial data on coconut cultivation derived from the global coconut layer developed by Descals et al. (2023). The 2023 provincial crop production data were the latest available for the study area, obtained from the Philippine Statistics Authority (PSA, 2023). The research did not assess the economic or technical potential of biomass energy in the region, nor perform field validation due to limited resources.

The optimal location analysis assumed that biomass transportation occurs only on paved roads to improve collection efficiency, which may not always reflect real-world conditions, as not all agricultural fields have direct access to paved roads. The analysis also assumed that biomass availability is unevenly distributed and does not follow a homogeneous spatial pattern, which may affect the accuracy of the site selection process. Furthermore, the study did not account for future developments such as urban expansion or new industrial projects, which could alter the optimal location of BCPs over time.

The study did not consider the energy potential for succeeding years, as the assessment is limited to the current state of biomass availability. Additionally, the analysis did not address the fluctuating trends in coconut production for succeeding years, which could influence biomass availability and energy potential in the long term. In conclusion, while this study provided valuable insights into the biomass energy potential in Palawan and the implementation of a BCP locating framework, it was constrained by several limitations related to data accuracy, temporal scope, and the exclusion of broader economic factors. The findings should be viewed within these constraints, and further validation and analysis are needed to refine the results and assess the long-term feasibility of biomass energy in the region.

2. Locating Biomass Collection Points

The environmental impact of biomass energy goes beyond energy generation, encompassing emissions from feedstock collection, processing, and transportation (Boonman et al., 2025). Early research on biomass energy systems often assumed centralized collection from regions with uniform biomass yields and averaged transportation distances.

Morato et al. (2019) recognized these problems and proposed a BCP locating framework, which considers areas where biomass availability is geographically varied and road networks are irregular. They applied this framework to a case study in Bolivia, a country characterized by agricultural fields lacking access to well-structured, paved roads and an irregular approach to biomass collection, as it emphasizes the need for location-specific strategies that account for both the spatial distribution of biomass and the infrastructure limitations in rural areas.

The BCP locating framework introduced by Morato et al. (2019) provides an important contribution to the field by addressing the challenges of biomass collection in regions where traditional models fail to capture the difficulties of local conditions. This approach integrates spatial analysis techniques to identify areas with the highest potential for biomass collection and minimum distance to the road network. By incorporating these considerations, the framework offers a more modern understanding of biomass logistics, which prioritizes the importance of adapting collection systems to the specific characteristics of each region. This approach is crucial for improving the efficiency and sustainability of biomass energy systems in areas with variable biomass resources and infrastructure.

In this study, the framework is adjusted to consider the conditions within the study area. The iteration process applied is shown in Figure 1.

3. Methodology

3.1 Study Area

Palawan is situated in Region IV-B (MIMAROPA) in the western Philippines. Palawan is an archipelago that has about 2000 kilometers of irregular coastline, providing favorable conditions for coconut cultivation (PCSDS, 2015).

3.2 Data Collection

Spatial data on coconut cropland were obtained from the Global Coconut Palm Layer produced by Descals et al. (2023), using Sentinel-1 and Sentinel-2 annual composites from 2020. The Palawan crop yield for 2023 was sourced from the Philippine Statistics Authority. On the other hand, the values of the remaining parameters for estimating biomass energy potential within the study area were retrieved from Phil-LiDAR 2 REMap by Blanco et al. (2015), except for the area of the region of interest, which was calculated using the GADM shapefile of Palawan.

Site suitability analysis incorporated geospatial data on roads, rivers, land cover, and boundaries. Criteria for exclusion included protected areas, water bodies, transmission lines, industrial and mining areas, road networks, airports, substations, power plants, pipelines, and urban areas. The preference analysis included proximity to water, roads, transmission lines, and urban areas, as well as biomass sources, slope, agrarian reform communities, and land cover type. These criteria were derived from literature (Khan, 2015; Sultana and Kumar, 2012; Eskandari et al., 2012; Ma et al., 2005) and adjusted to fit national contexts.

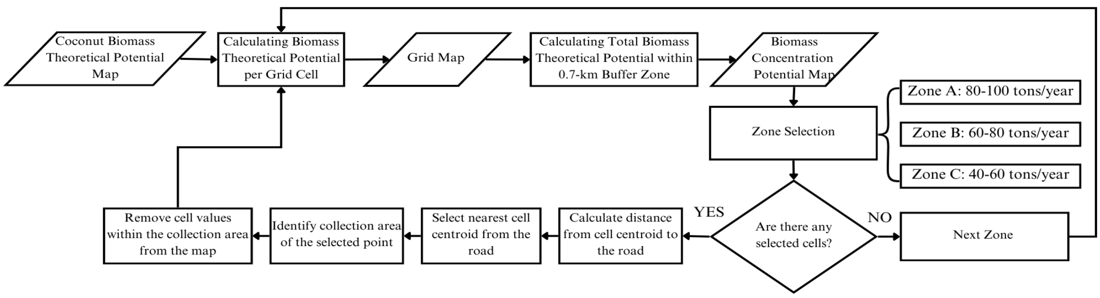

Figure 1. Flowchart for locating biomass collection points.

3.2.1 AHP Survey. An Analytical Hierarchy Process (AHP) template (Goepel, 2013) was used to process expert feedback, which contributed to the calculation of weights and consistency ratios for the suitability factors. A total of sixteen responses were collected from individuals holding various roles, including power managers, compliance officers, and engineers, representing organizations such as the Department of Energy and other prominent biomass energy companies. A list of biomass power plant professionals and project heads, along with their contact information, was provided by the Department of Energy (DOE) for this study. These experts, with experience ranging from 1 to 21 years, provided valuable insights into biomass power and conversion facilities.

However, it is important to acknowledge the inherent limitations of the AHP method, which relies on subjective weight assignments that may vary between experts. To mitigate this, the procedure involved thorough discussions with each participant to ensure a consistent understanding of the criteria and their relevance in selecting biomass plant sites. Precautions were taken to ensure that the consistency ratio of all responses remained below 10%, and respondents were informed of this requirement before participation. A consistency ratio of less than 10% ensured that the experts' judgments were logically consistent, thus enhancing the reliability of the final decision. However, the AHP method did not account for changes over time or unexpected external factors that may affect site suitability in the future.

3.3 Methods

The methodology is divided into four sections as shown in Figure 2: (1) assessment of available biomass, (2) identification of BCPs, (3) site suitability analysis using exclusion and preference criteria through the Analytical Hierarchy Process (AHP), and (4) optimal location analysis using location-allocation to determine the best biomass collection sites.

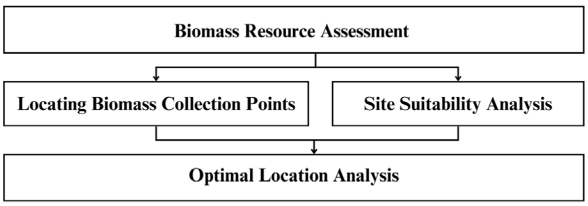

Figure 2. Overview of the methodology.

3.3.1 Biomass Resource Assessment. In this study, the biomass theoretical potential refers to the maximum quantity of coconut husk and shell produced in the province, while the biomass available potential estimates the portion of coconut biomass within the study area that is usable for energy purposes, accounting for factors such as collection efficiency, availability, and lower heating value.

The theoretical potential of coconut biomass in Palawan was estimated by multiplying the coconut cropland area by the residue yield. The cropland area was derived from field calculations using the Global Coconut Palm Layer, while the aggregated residue yield of coconut husk and shell was based on the province's 2023 coconut crop yield and residue-to-product ratio (RPR). The theoretical yield was then adjusted based on collection efficiency, availability for energy production, and lower heating value. This adjusted value was divided by the area of the region of interest to estimate the available potential. All parameter values are provided in Table 1.

The calculated coconut biomass energy potentials were used to estimate the number of conversion facilities. Also, municipal-level maps were produced to provide insight into the potential locations for BCPs and biomass conversion facilities.

Parameters	Crop Residue	
	Coconut Husk	Coconut Shell
Crop Yield (metric tons/ha)	75.376	75.376
RPR	1/3	0.15
Efficiency of Collection %	100	100
Availability for Energy Production %	43.400	19.530
Lower Heating Value (MJ/ton)	21.750	25.320

Table 1. Parameters Derived from Literature.

3.3.2 Locating Biomass Collection Points. In this study, an iteration model was developed using ArcGIS Pro to take advantage of the ModelBuilder tool to locate the BCPs in Palawan. Several data management and analysis tools were employed to construct the iterative process from the ModelBuilder.

The process begins by calculating the theoretical potential for each 200-m grid cell to generate the biomass theoretical potential grid map. Figure 3 shows a portion of this map, illustrating the variation in theoretical potential per cell as a result of differences in cropland area.

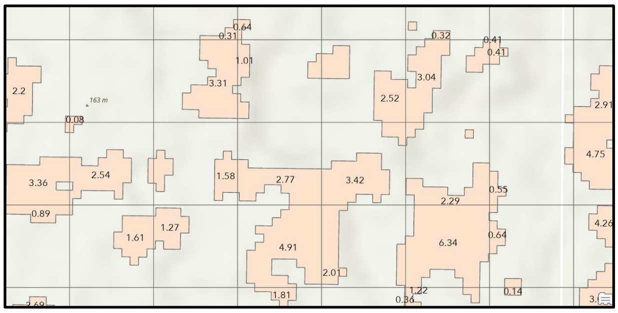

Figure 3. Biomass theoretical potential per grid cell (metric tons per year). The colored polygons represent coconut cropland, while the numbers indicate the theoretical biomass potential in every cell.

Each grid cell generates a 0.7-km circular buffer around its centroid to define its collection area. The theoretical potential values of all cells within each buffer are aggregated and assigned to the central cell, resulting in a biomass concentration potential for each cell. This step produces the biomass concentration potential map (Figure 4) and illustrates the capacity of each cell to collect biomass within a 0.7-km radius.

The cell size and buffer distance used in this study align with the dimensions established by Morato et al. (2019). Their framework assumes that each buffer zone should encompass at least 20 agricultural farms. Given that the average coconut farm size in the Philippines is approximately 2.4 hectares (PSA, 2002), a 0.7-km buffer is expected to cover around 20 coconut farms.

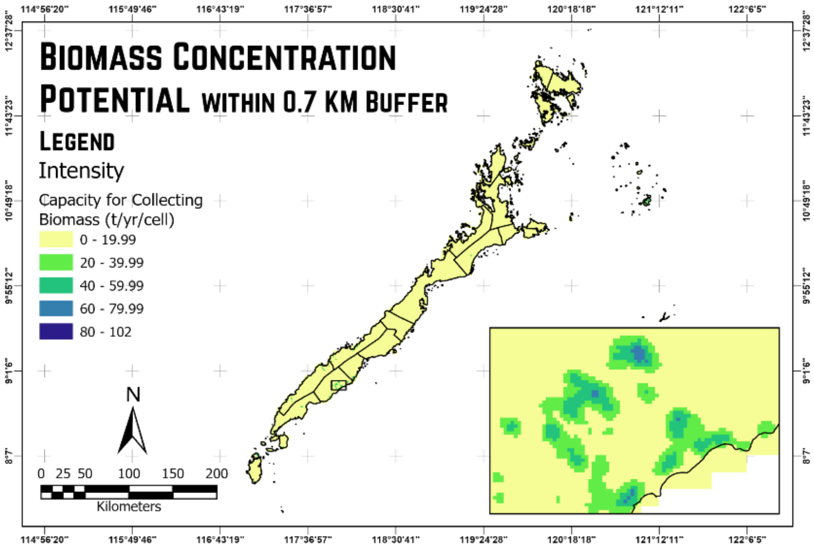

Figure 4. Intensity Map of Biomass Concentration Potential within a 0.7 km buffer zone. The inset map shows the biomass concentration potential in Brooke's Point, Palawan.

Based on the biomass concentration potential map, zones were classified as follows: Zone A contains 80–100 tons, Zone B contains 60–80 tons, and Zone C contains 40–60 tons of coconut biomass. The model prioritizes the selection of Zone A due to its high concentration potential. It then checks for the presence of selected cells, indicating whether biomass is still available within the collection area. If no Zone A cells are selected, the model proceeds to Zone B or Zone C, or stops if no zones remain. If there are selected cells, the process continues to the next step. These classification thresholds were defined by the researchers based on the methodology of Morato et al. (2019).

Following zone classification, the framework intended to iterate Zone A selection and assess the potential to collect biomass. If biomass collection is possible, the distance from the centroids of the selected cells to the road network was then calculated to identify the nearest point. The nearest point was designated as a BCP.

After selecting the nearest cell, the biomass-collection simulation begins by adding a buffer around its centroid. All other cells within this buffer have their theoretical potential values set to zero, indicating that their biomass has been collected. The process repeats, where the potential to concentrate biomass of the remaining cells is recalculated, and then it reflects the change in neighbouring values. The next cell is identified and buffered.

At the end of each iteration, a tool was used to simulate biomass collection by updating the theoretical potential of the intersected cells to zero (Figure 5). The model continues to prioritize and select cells that are calculated and classified as Zone A until no such cells remain.

Once no further biomass collection was possible under Zone A, the iteration advanced to Zone B, followed by Zone C, applying the same process and algorithm described by Morato et al. (2019). The model was configured to overwrite the biomass concentration map, resulting in updated biomass concentration values for the next iteration.

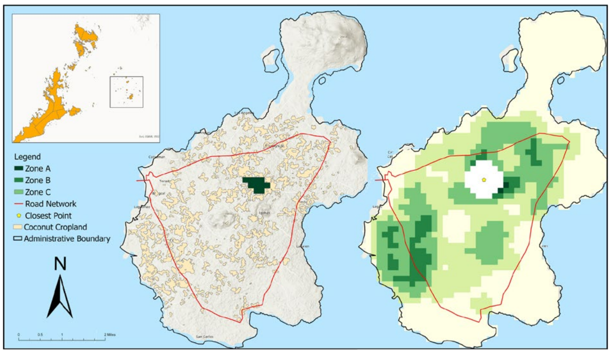

Figure 5. Selection of Zone A (left), and simulation process for biomass collection (right) in Cuyo Island, Palawan, when the energy potential of grid cells within the buffer is set to zero.

3.3.3 Site Suitability Analysis. A Site Suitability Analysis was conducted using geospatial data to identify candidate sites for biomass facilities. This analysis consists of both Exclusion and Preference Analysis, as it utilizes geospatial information to evaluate and select the most appropriate sites for development.

3.3.3.1 Exclusion Analysis. The exclusion analysis identified regions unsuitable for biomass facility development within the study area based on various constraints. Buffer zones were created for each constraint, with distances adapted from previous studies to avoid sensitive areas. The exclusion constraints and their corresponding buffer zones are as follows: Protected areas (5,000 m) (Knorn et al., 2012), rivers, lakes, lagoons, and wetlands (150 m) (Woo et al., 2018; Silva et al., 2014, as cited in Bingol et al., 2023), transmission lines, industrial and mining areas, airports, and natural gas and oil pipelines (100 m) (Sultana and Kumar, 2012), road network, substations, and power generation facilities (50 m) (Sultana and Kumar, 2012; Morato et al., 2019), and urban areas (300 m) (Nantasaksiri et al., 2021).

The buffer zones were combined into a single dataset, eliminating redundant areas and refining the exclusion layer. The resulting layer was processed to remove unsuitable regions. The final exclusion areas were delineated and prepared for the subsequent evaluation of biomass facility suitability.

3.3.3.2 Preference Analysis. The preference analysis identified priority areas for biomass facility development by considering geographic and socio-economic features. Higher priority was given to areas closer to biomass sources, road networks, water sources, and transmission lines, as proximity to these features enhances logistical efficiency and reduces infrastructure costs (Khan, 2015). For urban areas, lower priority was assigned to locations nearer to dense populations due to environmental and health risks associated with pollutant emissions (Morato et al., 2019). Areas with slopes less than 15 degrees were assigned higher priority due to easier development and stability (Sultana & Kumar, 2012). Priority values for agrarian reform communities and land cover types were adapted from prior studies, emphasizing agricultural productivity and land-use suitability for biomass projects (Morato et al., 2019).

Buffer zones were created for key features, and for the remaining factors, priority values were assigned according to predefined criteria in the literature. Data were converted to raster format, with priority values incorporated into each layer for subsequent weighted overlay analysis.

The Analytical Hierarchy Process (AHP), a multi-criteria decision-making method (Saaty, 1987), was employed to calculate the weight of each feature. An AHP Excel template (Goepel, 2013, revised 2022) facilitated the calculations. Sixteen experts with experience in biomass facilities completed the pairwise comparisons, providing the basis for determining the relative weights of the factors. The template calculated weight values, consistency ratios, and other parameters. The eight rasters were combined, each multiplied by its corresponding weight (summing to 100), to generate the final preference map.

3.3.3.3 Determination of Candidate Sites. To develop the site suitability map, the exclusion and preference maps were combined using a raster calculator, multiplying corresponding values at the cell level. The exclusion map, with binary values (1 or 0), was combined with the preference map, which has values ranging from 0 to 10. The multiplication resulted in a suitability map, where values of 9 and 10 indicated the most favorable locations for biomass conversion facilities.

Values of 9 and 10 were extracted using the Extract by Attributes tool. The Raster to Polygon tool then converted the suitability raster to polygons, and the Geometry Attributes tool calculated the area of each polygon in hectares. Polygons smaller than 10 hectares, the minimum required for facility construction (Sultana and Kumar, 2012), were removed, though none were identified. The Feature to Point tool extracted the centroid of each polygon, representing the candidate sites for facility placement.

3.3.4 Optimal Location Analysis. The optimal location analysis identified biomass facility sites that minimize transportation distances between BCPs and candidate sites. BCPs were used as supply points, and candidate sites as demand points, with the same road network data from previous processes. A network dataset was created from the road network, with transportation cost defined as physical distance. The location-allocation layer was created, assigning a weight to each supply point based on its biomass concentration (Bn_sum). The process for this analysis is shown in Figure 6.

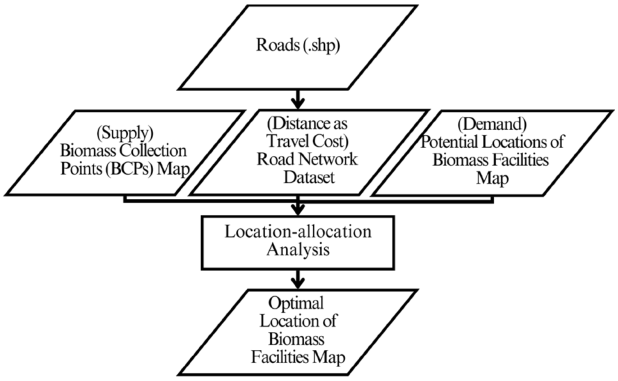

Figure 6. Optimal Location Analysis Process.

4. Results and Discussion

4.1 Biomass Resource Assessment

The coconut cropland area in Palawan was estimated at 8,148.54 hectares. With husk and shell residue yields of 1.31 metric tons/ha and 0.59 metric tons per hectare, respectively, the combined theoretical biomass potential is 15,465.92 metric tons per year.

Based on the estimated theoretical energy potential and the GIS-derived land area of Palawan, spanning 1,460,787.68 hectares, the available energy potential was calculated to be 85.17 megajoules per hectare. A summary of the biomass energy potentials is provided below (Table 2).

Crop	Energy Potential	
	Theoretical	Available
	metric tons	MJ/ha
Coconut Husk	10666.432	68.926
Coconut Shell	4799.487	16.247
Coconut	15465.919	85.173

Table 2. Summary of the Theoretical and Available Energy Potential of Coconut Biomass in 2023.

Operating biomass power plants in the Philippines requires approximately 10,000 to 19,600 tons of biomass per megawatt annually. For example, the 12 MW San Jose City iPower plant uses about 120,450 t/yr (10,037 t/yr/MW) (Roque, 2015), while a 2 MW proposal in Isabela estimated 39,270 t/yr (Japan Engineering Consultants Co., Ltd., 2008). Using the lower range of 10,000 t/yr/MW as a design benchmark, the available biomass supply of 15,465.92 tons supports one 1.5-MW power plant.

Figure 7 shows that municipalities shaded in darker green have higher energy potential. Southern Palawan has the highest biomass energy potential, followed by Cuyo Island. These areas are identified as optimal locations for BCPs and conversion facilities.

4.2 Locating Biomass Collection Points

A total of 20 biomass collection points were identified based on their potential to concentrate biomass within a 0.7 km-radius buffer zone and their proximity to road networks. Presented in the maps (Figure 8) are the locations of BCPs in Palawan.

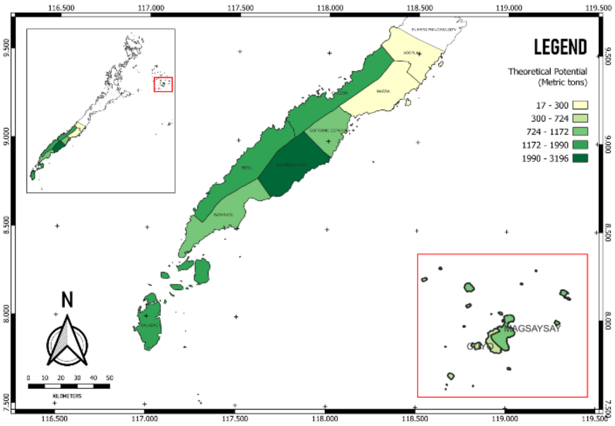

Figure 7. Biomass theoretical potential map showing high-potential areas in Cuyo Island (inset map), and southern Palawan.

The majority of BCPs are clustered in southern Palawan, with the remainder in Cuyo Island. Using the iteration model, the researchers have identified 12 BCPs in the southern Palawan: two in Sofronio Española, three in Brooke's Point and Rizal, and four in Quezon. The eight remaining BCPs lie in Cuyo Island: three on Cuyo and five in the municipality of Magsaysay.

The BCP framework combines resource availability and road access to identify optimal BCPs. This approach goes beyond basic site mapping by refining facility locations to balance biomass potential with logistical efficiency. It supports better decision-making and enhances the effectiveness of biomass collection and transport.

4.3 Site Suitability Analysis

4.3.1 Exclusion Analysis. The exclusion analysis removed 4,503 km² (30.74%) of the study area, leaving 69.26% suitable for development. A detailed representation is shown in Figure 9.

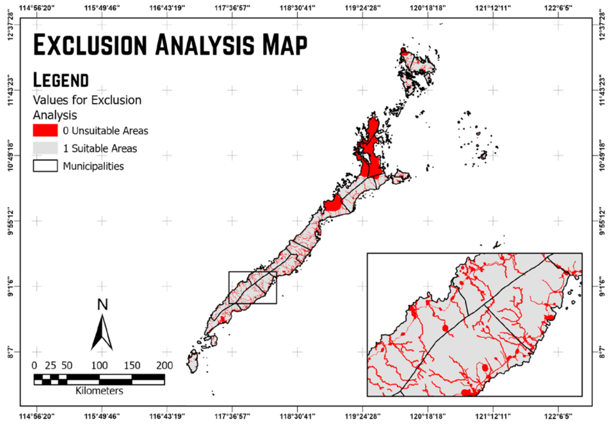

Figure 9. Exclusion Analysis Map.

4.3.2 Preference Analysis. The Analytical Hierarchy Process (AHP) quantified the relative significance of the eight preference factors, producing corresponding weights. AHP identified proximity to biomass sources (22.89%), water availability (20.66%), proximity to transmission lines (18.64%), and proximity to the road network (11.93%) as the most influential factors, while agrarian property type (7.86%), slope (6.31%), land cover type (6.48%), and proximity to urban areas (5.23%) were considered secondary. The AHP consistency ratio of 0.4% indicated high reliability in expert evaluations.

The Preference Analysis Map, derived from these weighted criteria, featured high-suitability areas near biomass resources, water sources, transmission lines, and roads, with scores ranging from 7 to 9.

These sites were predominantly located along the study area's edges, offering favorable logistical and environmental conditions. No location received the lowest (1) or highest (10) suitability scores. A total of 390 cells received a suitability score of 9, as shown in Figure 10.

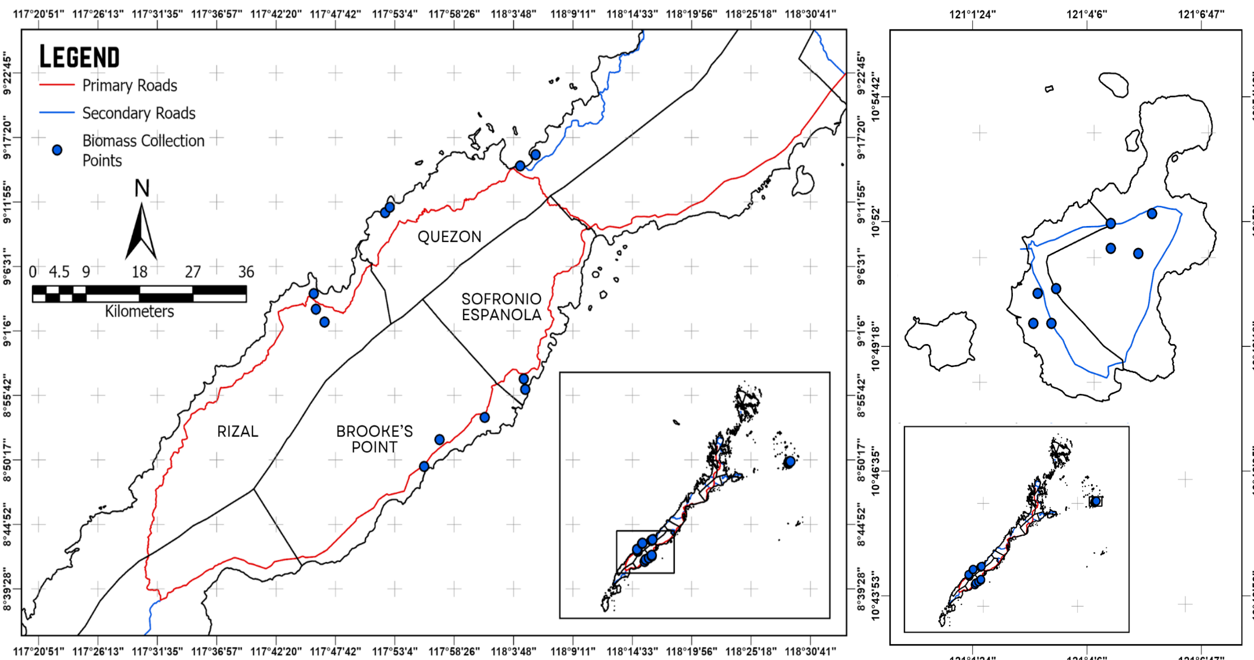

Figure 8. BCPs in Southern Palawan (left) and Cuyo Island (right). Scale-based sizing was applied for a closer view of the BCPs on the map.

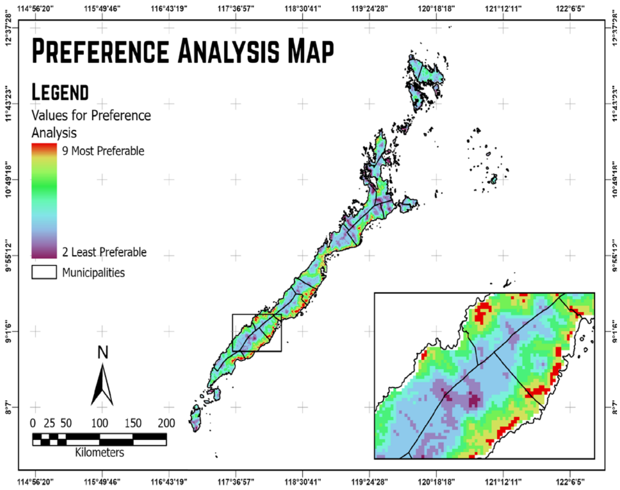

Figure 10. Preference Analysis Map.

4.3.3 Determination of Candidate Sites. The exclusion and preference maps were multiplied at the cell level, assigning a value of zero to all excluded areas. Any cell that intersects an exclusion criterion becomes unsuitable. Only cells with a score of nine in the preference analysis that did not intersect with unsuitable areas were considered potential sites. This reduced the number of suitable cells from 390 to 248 and effectively narrowed the study area to potential sites for biomass energy facilities. The Site Suitability Map is shown in Figure 11.

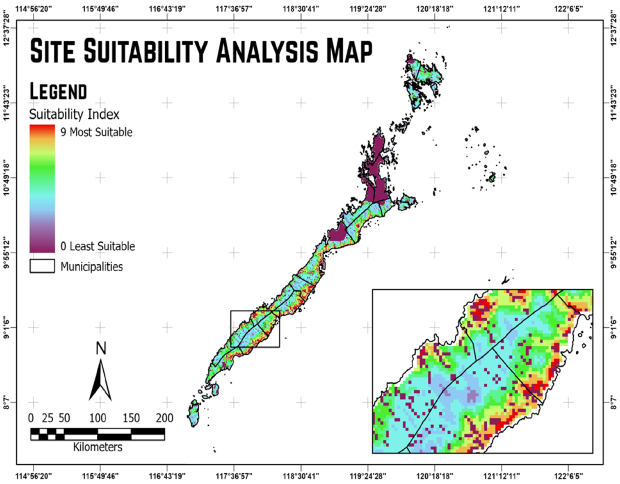

Figure 11. Site Suitability Analysis Map.

These 248 cells formed spatial clusters, which were merged into polygons when converted to vectors. After applying centroids to each polygon, it was determined that the number of candidate sites had been reduced to 96. These are shown in Figure 12 as potential biomass facility locations.

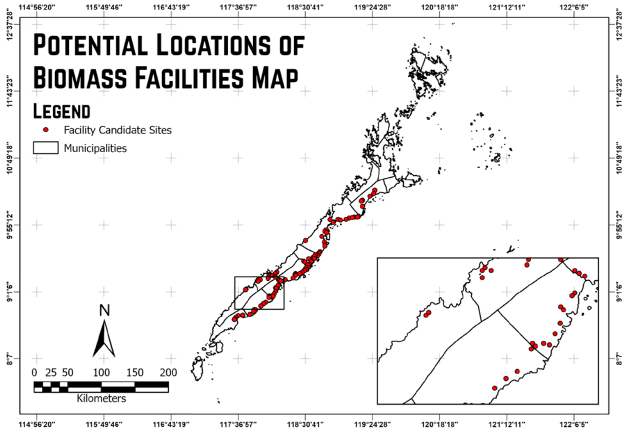

Figure 12. Potential Locations of Biomass Facilities Map.

4.4 Optimal Location Analysis

The optimal location for a biomass facility was identified using facility candidate sites, BCPs, and the road network. The chosen site, located in Quezon municipality, is at the center of the largest cluster of weighted BCPs, minimizing road-based travel distances weighted by biomass potential. The site is adjacent to primary roads as it aligns with the preference criteria for biomass transportation. BCPs on isolated islands remain unlinked, indicating the limits of the road system. This configuration reflects proximity to high biomass sources and the road network, as it considers capacity and impedance constraints. The Optimal Location of Biomass Facilities Map is shown in Figure 13.

5. Conclusion

This study assessed the biomass energy potential of coconut residues in Palawan, aiming to harness renewable energy for provincial electrification and sustainable energy production. Palawan, a leading coconut-producing province, has high biomass energy potential, with a theoretical energy capacity of 15,465.92 metric tons from coconut husk and shell, yielding 85.17 MJ/ha. This supports one power plant with a 1.5 MW capacity.

Twenty BCPs were identified based on biomass concentration and road proximity, primarily in southern Palawan and Cuyo Island. This analysis facilitates efficient biomass collection and supports site selection, ensuring a reliable supply chain between farms and conversion facilities for sustainable energy.

Exclusion analysis removed 30.74% of the study area. Meanwhile, preference analysis, using the Analytical Hierarchy Process (AHP), prioritized areas based on eight geographic and socio-economic criteria. High-suitability areas were mainly located along the study area's edges, aligning with biomass sources and infrastructure. 96 candidate sites for biomass facilities were identified.

Through location-allocation analysis, the optimal site was found in Quezon municipality, minimizing transport distances and aligning with high-biomass BCP clusters and road access. This site, located near a primary road, is the most efficient and sustainable option.

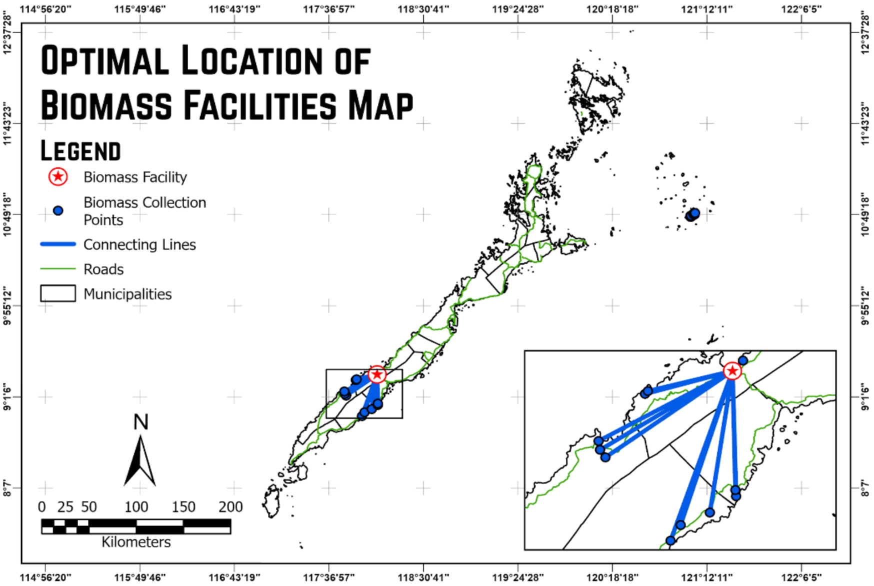

Figure 13. Optimal Location of Biomass Facilities Map.

6. Recommendations

Based on the findings and limitations identified in this study, several recommendations are proposed for future research.

First, it is recommended that future studies utilize locally acquired spatial data to improve the accuracy of coconut biomass mapping. The global coconut cultivation dataset used in this study, derived from Descals et al. (2023), provides a broad and generalized representation of coconut cultivation patterns. However, due to potential variations in cultivation practices and biomass distribution at the local level, incorporating regional surveys, high-resolution satellite imagery, or local agricultural records would yield more accurate and representative data specific to the study area.

Second, future research may focus on optimizing closely situated biomass collection points (BCPs). Exploring different cell sizes and buffer distances is suggested to enhance the efficiency of biomass collection. This approach would consider changes in the spatial extent of coconut farms and plantations, enabling the collection of a greater amount of biomass. Additionally, conducting a cost-benefit analysis on various buffer radii for each biomass collection point could further extend and enrich this study.

Lastly, it is also recommended to include validation of both the methodology, specifically the locations of the identified BCPs and biomass conversion facilities, to ensure the reliability and practicality of the results.

References

Argonza, Y. B., Argueza, J.R.L., 2025. Locating Biomass Collection Points (BCP) For Optimal Siting of Coconut Biomass Energy Facilities in Palawan Province Using GIS [Unpublished B.S. thesis]. University of the Philippines Diliman.

Blanco, A. C., Tamondong, A. M., Perez, A. M. C., Ang, M. R. C. O., Paringit, E. C. 2015. The Phil-LiDAR 2 Program: National Resource Inventory of the Philippines Using LiDAR and Other Remotely Sensed Data. *the International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences/International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XL-7/W3, 1123–1127. doi.org/10.5194/isprsarchives-xl-7-w3-1123-2015.

Boonman, A., Fukuda, S., Tiwari, S., Kraxner, F. 2025. Two-Phase approach for designing sustainable biomass supply chains for Community-Scale biomass power plants in Thailand. *Energies*, 18(3), 520. doi.org/10.3390/en18030520.

Descals, A., Wich, S., Szantoi, Z., Struebig, M. J., Dennis, R., Hatton, Z., Ariffin, T., Unus, N., Gaveau, D. L. A., Meijaard, E. 2023. High-resolution global map of closed-canopy coconut palm. *Earth System Science Data*, 15(9), 3991–4010. doi.org/10.5194/essd-15-3991-2023.

Galang, W. N., Tabañag, I. D. F., Loretero, M. E. 2022. RS-GIS Approach on Biomass Energy Potential Estimation of sugarcane residues in Medellin, Cebu. *Applied Environmental Research*, 67–79. doi.org/10.35762/aer.2021.44.1.6.

Morato, T., Vaezi, M., Kumar, A. 2019. Developing a framework to optimally locate biomass collection points to improve the biomass-based energy facilities locating procedure – A case study for Bolivia. *Renewable and Sustainable Energy Reviews*, 107, 183–199. doi.org/10.1016/j.rser.2019.03.004.

Pacaldo, J. C., Bilgera, P. H. T., Abundo, M. L. S., 2022. Nearshore Wave Energy Resource Assessment for Off-Grid Islands: A case study in Cuyo Island, Palawan, Philippines. *Energies*, 15(22), 8637. doi.org/10.3390/en15228637.

Philippine Statistics Authority. 2022. Commodity Fact Sheets (CFS). psa.gov.ph/system/files/main-publication/Commodity%20Fact%20Sheets%202022%20%28signed%29.pdf (8 May 2025).

Palarca, N. T., Daiwey, E. P., Ferreras, T. E. F. 2014. Local resource-based road maintenance in the Philippines: A guide. International Labour Organization, ILO Country Office for the Philippines. ilo.org/sites/default/files/wcmsp5/groups/public/@asia/@ro-bangkok/@ilo-manila/documents/publication/wcms_327021.pdf (9 May 2025).