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Floating Photovoltaic Potential Assessment of Angat Reservoir, Philippines using Remote Sensing and Geographic Information Systems

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Abstract

The Philippines faces a continuous energy dilemma as population growth increases electricity demand from nonrenewable resources, which consequently raises electricity prices and contributes to environmental degradation. While solar energy offers a cleaner alternative, its potential remains underutilized due to land scarcity and performance issues related to land-based installations. Therefore, this study explored the potential of floating photovoltaic (FPV) systems on the Angat Reservoir in the Philippines as a sustainable alternative for solar energy production. This study utilized remote sensing (RS) and geographic information systems (GIS) to systematically assess both the theoretical and technical solar potential of the Angat Reservoir based on solar yield, highly usable area, and the specifications of the selected photovoltaic (PV) modules. Fuzzy analytic hierarchy process (AHP) was specifically employed to determine the weights per criterion to select highly usable areas for FPV installation. The results revealed an annual theoretical potential of approximately 1,609.85 kWh/m². Moreover, with a 4.26 km² highly usable area, the reservoir demonstrated an electricity generation potential of around 909.42 GWh and an overall technical potential of approximately 1,295 kWh/kWp. These findings confirm the significant potential of Angat Reservoir for solar energy production through FPV deployment.

1. Introduction

The Philippine population is expected to grow over the next 35 years, regardless of the total fertility rate declining to 1.7 children by 2055 (Philippine Statistics Authority, 2024). Over the past decade, the country's electricity consumption has steadily increased, and in 2023, it reached 118,004 GWh, marking a 5.82% growth compared to the previous year (Department of Energy, 2024a). This trend suggests that the projected population increase will likely correspond with a rise in electricity consumption, particularly from nonrenewable resources.

Nonrenewable resources account for 77.73% of the gross power generation of the Philippines in 2023, with coal having a 62.50% share, whereas renewable resources contribute only 22.27%. (Department of Energy, 2024a). The growing demand for nonrenewable resources is gradually depleting the supply of coal and other fossil fuels while substantially degrading the environment and causing volatile and rising electricity prices. For instance, the average residential electricity cost in the Philippines for 2023 is 180 USD/MWh, the second highest among Southeast Asian countries following Singapore (Organisation for Economic Co-operation and Development, 2024). The extent of the environmental and economic impacts of nonrenewable consumption therefore necessitates the move toward cleaner energy production.

Currently, there are a total of 1,460 renewable energy projects in the Philippines, of which solar resources have the second highest potential capacity (Department of Energy, 2024b). However, the solar potential of the country remains underutilized due to land scarcity and reduced performance of PV modules installed on land (Al-bashir et al., 2020; Department of Energy, 2024b). These issues call for alternative solutions, such as installing solar modules to areas where competition with other land uses such as agriculture can be addressed and temperature rise can be better mitigated. Water bodies are examples of such areas because water, compared to land, provides a cooler environment, and consequently higher efficiency rate, for PV modules (Dörenkämper et al., 2021). Moreover, installing PV on waterbodies can potentially prevent the accelerating evaporation, caused by climate change, from vital water sources such as Angat Reservoir (Lee et al., 2020). Thus, this study explored the use of floating photovoltaics or FPV specifically in Angat Reservoir and was able to assess its theoretical and technical potential for solar energy generation.

2. Methodology

2.1 Flowchart

Figure 1 shows the methodology flowchart for assessing the FPV potential of the Angat Reservoir.

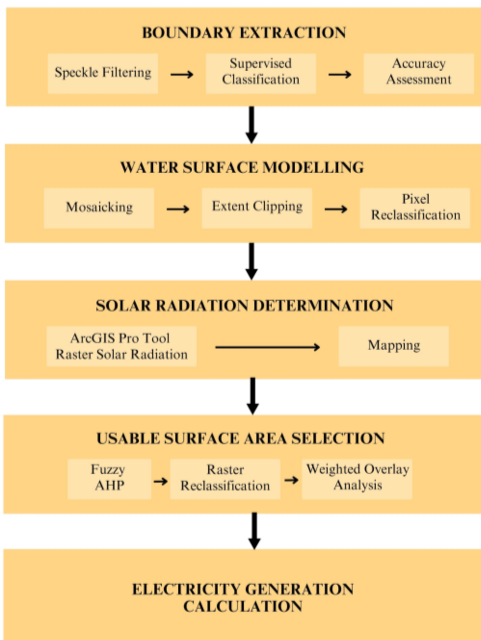

Figure 1. Methodology Flowchart.

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2.2 Study Area

The study was conducted in Angat Reservoir, as illustrated in Figure 2, which is 38 km north of the Philippines' capital region, Metro Manila. The reservoir has a surface area of about 23 km^2 and a water storage capacity sufficient to supply a city for up to 30 days (Jaranilla-Sanchez et al., 2014). It plays a critical role in providing water, as well as energy through the Angat Dam, to both its home province and Metro Manila. However, it is also susceptible to evaporation during drought seasons, affecting the water supply for its beneficiaries (Lee et al., 2020).

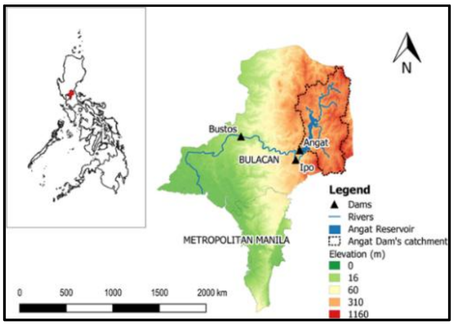

Figure 2. Angat Reservoir (Libisch-Lehner et al., 2019).

2.3 Data Collection

Sentinel-1 C-Band Synthetic Aperture Radar Ground Range Detected (SAR GRD) images were used to delineate the Angat Reservoir boundary. All images containing the study area from the collection for 2023 were obtained.

The ALOS World 3D Digital Surface Model (DSM) provided by the Japan Aerospace Exploration Agency (2024) was used to model the reservoir surface and vicinity. It has a horizontal resolution of 30 meters and a vertical accuracy of around 5 meters RMS, referenced from mean sea level (MSL). Version 4.1 of this dataset was recently released in April 2024, with enhanced overall quality and corrections (Japan Aerospace Exploration Agency, 2024).

The Angat Reservoir water levels for 2023 were obtained from the National Power Corporation. These data are recorded daily in meters above sea level units, which ensures compatibility with the ALOS World 3D DSM. The bathymetry of the Angat Reservoir, needed for the water depth criterion, was sourced from the same agency, while the locations of the electrical grid for the distance from the electrical grid were acquired from the National Grid Corporation of the Philippines.

2.4 Reservoir Boundary Extraction

The changes in the reservoir boundaries over 2023 were determined and analyzed using the Google Earth Engine (GEE) platform with Sentinel-1 SAR data. The data was pre-processed through the Refined Lee Filtering method before classification was performed using random forest (RF) supervised classification. For this study, the RF algorithm implemented in GEE took the backscatter information of the despeckled SAR data from its VH band as input and processed it using 10 decision trees. The classifier's performance in distinguishing water and non-water areas was assessed by randomly splitting the 100 training samples, which were manually selected within the reservoir and around its vicinity, into 80% for the training set and 20% for the validation set.

After classification, the accuracy of the classified images was assessed using four metrics: producer's accuracy (PA), consumer's accuracy (CA), overall accuracy (OA), and kappa coefficient (κ).

2.5 Water Surface Modeling

Due to the large surface area of the Angat Reservoir, it spans two ALOS World 3D DSM grid squares. These two datasets were mosaicked to obtain a composite DSM of the whole reservoir. Afterward, the mosaicked DSM was clipped using a 100-m buffer from the extracted water boundaries to consider surface elements like mountains and trees that surround the reservoir. The pixels within the extracted water boundaries were then reclassified using the water level data on the same day when the satellite image was captured. This process was repeated for all extracted water boundaries and corresponding water level data.

The outputs were the Water Surface Models (WSMs) of the Angat Reservoir and its vicinity, which are referenced to MSL through the year 2023. The WSMs are critical representations of the topography of the area, used to account for potential impacts of topography-induced shading (Yilmaz et al., 2023).

2.6 Solar Radiation Determination

The ArcGIS Pro Raster Solar Radiation tool was used to determine the total amount of solar radiation received by the study area. For this study, the WSMs and reservoir boundaries were used as the input rasters and masks, respectively, while the range of analysis was set to monthly. The process produced solar radiation rasters with monthly values in kilowatt-hours per square meter (kWh/m²), which were subsequently averaged to generate a monthly mean solar radiation raster for the entire area. Yilmaz et al. (2023) revealed the similarities of results between the tool's output and the measurements in the HelioClim-3 solar radiation database, illustrating its integrity and accuracy for use.

2.7 Usable Area Selection

A weighted overlay analysis was conducted to identify the most suitable sites within the Angat Reservoir for FPV installations. The criteria considered for the study included the water depth, distance from land, and distance from the electrical grid. The weight of each criterion for spatial analysis was determined using the multi-criteria decision-making approach Fuzzy AHP.

2.7.1 Fuzzy AHP: Fuzzy AHP integrates fuzzy logic to address the uncertainties in the response of experts on the relative importance of one factor over another. For this study, the triangular fuzzy number design, together with the geometric mean method of Buckley (1985), was utilized. For each pair of criteria, the importance of one over the other was determined from the judgment of 10 experts from the fields of solar installation, dam management, solar research, and the academe. Prior to weight calculation, the consistency of the judgments was first evaluated through the crisp consistency test. When the consistency ratio is less than 0.1, the judgments are considered consistent and usable for processing (Chan et al., 2019; Saaty, 1987). Otherwise, judgments require revision.

2.7.2 Water Depth: Water depth influences the stability of the floating panels and the efficiency of their mooring or anchoring mechanisms. As such, it is pertinent to consider water depth when planning FPV installations. Generally, water depths

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greater than 5 meters but less than 100 meters are preferred for FPVs, since the water needs to be neither too deep to prevent FPVs from colliding with the bottom of the water nor too shallow to avoid uneconomical mooring or anchoring processes (Kim et al., 2019; Nebey et al., 2020; Prateek & Sika, 2024). Table 1 below shows the values for water depth used. In this study, water depth was calculated by subtracting the bathymetric data of the Angat Reservoir from the water level. The water level was a single numerical value representing the lowest water level in 2023, which occurred on July 16. Both datasets, i.e., bathymetric data and water level, have spatial extent constrained to the extracted minimum boundary of the reservoir. This was done to eliminate areas that intermittently lose water and ensure consistency in spatial analysis.

Water Depth	Classification	Reclassification Value
<5 m	Minimally Usable	1
5-25 m	Moderately Usable	2
25-100 m	Highly Usable	3

Table 1. Criteria for water depth.

2.7.3 Distance from Land: Installing FPV systems near the land increases the risk of vandalism from people and interference from nearshore objects (Nebey et al., 2020). Hence, FPV systems should be installed at a safe and secure distance from land such that destructive actions toward the technologies can be avoided or minimized. Table 2 below shows the values for the distance from land criteria used. In this study, the distance from land was referenced from the shoreline of the reservoir, which was delineated using the extracted minimum boundary to ensure that only areas of the reservoir that consistently hold water, regardless of fluctuations in water level, were included.

Distance From Land	Classification	Reclassification Value
<20 m	Minimally Usable	1
20-50 m	Moderately Usable	2
>50 m	Highly Usable	3

Table 2. Criteria for distance from land.

2.7.4 Distance from Electrical Grid: Electrical grids provide connectivity for the practical application and deployment of FPV outputs. Building FPVs in areas near such networks makes building additional infrastructure unnecessary while simultaneously minimizing electrical losses during transmission (Islam et al., 2024). Table 3 below shows the values for the distance from electrical grid criteria used. In this study, electrical grid lines obtained from NGCP were also buffered to account for their proximity to FPV installations, and the resulting distances were reclassified for succeeding analyses.

Distance From Electrical Grid	Classification	Reclassification Value
>5000 m	Minimally Usable	1
1000-5000 m	Moderately Usable	2
< 1000 m	Highly Usable	3

Table 3. Criteria for distance from electrical grid.

2.8 Electricity Generation Calculation

The electricity generation potential of FPV systems on the Angat Reservoir depends on the solar radiation received by the location, the usable area for surface installation, and the characteristics of the PV system installed on the site. Quantitatively, it can be determined using the following equation (Yilmaz et al., 2023),

$$EPG = R_{GHI} \times A_u \times e \times PR, \quad (1)$$

where EPG = monthly electricity generation potential (kWh),
R_{GHI} = the monthly mean solar radiation received by the highly usable area of the reservoir (kWh/m^2),
A_u = total highly usable area for installing FPV (m^2),
e = module efficiency, and
PR = performance ratio.

Subsequently, the overall technical potential of the reservoir can be calculated using the equation shown below,

$$TP = \frac{EPG}{IPC}, \quad (2)$$

where TP = overall technical potential in kWh/kWp, and
IPC = installed peak capacity in kWp

IPC can be obtained using the following equation.

$$IPC = \frac{A_u}{PS} * RP, \quad (3)$$

where PS = approximate panel size of PV module, and
RP = rated power of PV module.

In this study, monocrystalline silicon was selected as the PV module since it generates the highest average efficiency, with 16% to 21%, among other photovoltaic cell technologies (Nguyen et al., 2023). Moreover, they are abundant and can be produced at low cost, so numerous studies on the solar potential of FPV systems focus on utilizing them (Kim et al., 2019; Nebey et al., 2020). To avoid overestimation, this study assumed the minimum average efficiency, i.e., 16%. The performance ratio will be set to 80% based on the conservative assumption of the World Bank for the estimation of the potential electricity generation of FPV systems (World Bank Group et al., 2019). Moreover, the study considered 2 m^2 for the average size and 330 Wp for the rated power of a PV module (Kim et al., 2019; Nguyen et al., 2023; Padilha Campos Lopes et al., 2022).

3. Results and Discussion

3.1 Reservoir Boundary Extraction

Using the Sentinel-1 SAR data and the RF algorithm on the GEE platform, 30 images covering the entire year of 2023 were processed. For each image, water and non-water areas were successfully classified across the vicinity of the Angat Reservoir. The water areas represent the approximate surface extent of the reservoir at the time the satellite image was captured and would serve as the spatial boundary for subsequent analyses, whereas non-water areas indicate all other land covers within the specified region of interest.

The accuracy of the classification approach resulting in the classified images was assessed on the same platform, and the results revealed that PA, CA, and OA of all classified images exceeded 90%, with 94.23% being the lowest and 99.75% being the highest. Additionally, the kappa coefficient ranged from 0.94 to 0.99, indicating high probabilities of correct classification. These accuracy figures surpassed the required threshold of more than 85% generally required for land use and land cover (LULC) reservoir mapping for planning purposes (Anderson et al., 1976). Similar results were identified from various studies, where RF classification on Sentinel-1 SAR data has demonstrated high performance, with an over 90% accuracy level, in water and flood mapping (Gui et al., 2025). Therefore, the reservoir boundaries extracted from the classification process are considered acceptable.

Moreover, the analysis of these boundaries has successfully revealed the changes in the surface area of the Angat Reservoir. Maximum areas were exhibited during the wet season of the country, around December to January, while minimum areas occurred during the dry season, around June to July, where water levels are at their highest and lowest points, respectively. The corresponding maximum and minimum extracted boundaries at these points are illustrated in Figure 3.

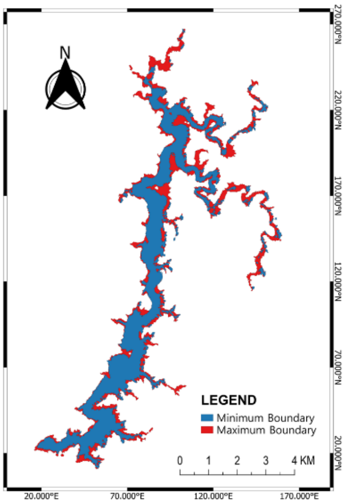

Figure 3. Extracted boundaries of the Angat Reservoir.

3.2 Solar Radiation Analysis

Using the generated WSMs and reservoir boundaries as input layers, the theoretical solar potential of the Angat Reservoir was determined. The results are presented in Table 4, where the monthly average solar yield is 134.15 kWh/m², and the minimum and maximum values range from 95.47 kWh/m² in December to 160.43 kWh/m² in May. Consequently, the annual sum for solar yield is 1609.85 kWh/m². This value exceeds the ideal 1550 kWh/m² recommended by Karipoğlu et al. (2024) for FPV installations and the 1300 kWh/m² recommended by Noorollahi et al. (2022) for ground-mounted solar systems. Ultimately, the findings indicate that the reservoir has a sufficiently abundant solar energy resource for large-scale operations.

Month	Solar Yield (kWh/m²)		
	Minimum	Maximum	Mean
January	0.73	127.07	100.94
February	0.22	125.68	108.49
March	0.33	153.02	141.84
April	2.37	157.39	151.53
May	3.14	168.05	160.43
June	0.44	164.16	154.37
July	1.86	169.28	158.30
August	4.05	165.78	159.82
September	1.30	152.67	144.54
October	0.81	145.74	130.16
November	0.57	126.95	103.95
December	1.27	122.99	95.47
Annual Sum			1609.85

Table 4. Theoretical solar potential of the reservoir.

In terms of trends, the Philippines experiences three broad seasons per year: cool dry (December to February), hot dry (March to May), and wet (June to November) (DOST-PAGASA, n.d.). The average monthly solar radiation increases from January and February, where it reaches a higher level in March and April before peaking in May. The values then slightly decrease until August, after which they decrease rapidly to hit the lowest values in December. This trend is different from expected patterns in the Philippines, where solar yield would already be trending downwards starting in June (Teves et al., n.d.). The uptick in the solar yield values for July and August might be an indirect manifestation of the 2023-2024 El Niño in the country, which PAG-ASA announced on July 4 of that year (Arceo, 2023). The El Niño phenomenon is tied to periods of reduced rainfall that are atypical of expected conditions, which increases the risk of drought in affected areas (Tejada et al., 2023).

On the other hand, the annual solar yield of 1609.85 kWh/m² in this study was found to be about 10.40% less than the estimate of PVGIS at 1777.25 kWh/m² for 2023 (European Commission & Joint Research Centre, 2025). This might be because of general differences in methodology, and it is possible that the specific emphasis on topography-induced shading caused the result of this study to be smaller. Moreover, the more local scope of this study is expected to have impacts on the findings as well, as compared to the more global scope of the PVGIS database. In contrast to other areas in the Philippines, the potential of Central Luzon, where Angat Reservoir is located, for solar PV installations is pointedly recognized, along with Central Visayas and Central Mindanao (Sotto et al., 2022).

Based on the overall findings, it can be concluded that the solar energy resource in Angat Reservoir, particularly in the areas farther away from land, is economically feasible to explore.

3.3 Fuzzy AHP

In this study, three criteria for selecting areas within the Angat Reservoir suitable for FPV installation were evaluated by 10 experts from the fields of solar installation, dam management, solar research, and the academe. The evaluation process involved identifying the importance of one criterion over the other. The geometric mean method and fuzzy AHP were utilized to aggregate the expert's judgment and determine the weights of the criteria. Table 5 shows the corresponding consistency matrix derived from the aggregation and defuzzification of judgments for the determination of the consistency ratio (CR).

Criteria	Water Depth	Distance from Land	Distance From Electrical Grid
Water Depth	0.20	0.19	0.22
Distance from Land	0.23	0.21	0.20
Distance From Electrical Grid	0.54	0.64	0.58

Table 5. Consistency matrix for FPV usable area determination.

Based on Table 5, the consistency index (CI) was calculated to be 0.00339, and the random index (RI) was identified as 0.58, given that n=3, which corresponds to the number of criteria. Using the formula for CR, the resulting value was 0.00586. This value falls within the threshold of less than 0.1, which indicates acceptable consistency (Saaty, 1987). Therefore, the fuzzy matrix was consistent, the expert's judgements were justified, and the calculation of the weights proceeded.

Using Buckley's geometric mean method, the fuzzy weights were obtained and are presented in Table 6 (Buckley, 1985). However, since spatial analysis requires crisp weights for more meaningful interpretation, the fuzzy weights were defuzzified and normalized. The final weights are shown in Table 7.

Criteria	Fuzzy Weight		
Water Depth	0.21	0.20	0.20
Distance from Land	0.22	0.21	0.21
Distance From Electrical Grid	0.57	0.58	0.60

Table 6. Fuzzy weight of each criterion.

Criteria	Weight (%)
Water Depth	20
Distance from Land	22
Distance From Electrical Grid	58

Table 7. Final weights of FPV installation criteria

Based on the results, distance from the electrical grid had the highest weight of 58%, followed by distance from land with 22% and water depth with 20%. This suggests that, in FPV installation, significant importance is placed on proximity to the electrical grid, likely due to the need to minimize energy losses for efficient power transmission. Similar findings were reported by Karipoğlu et al. (2024), where, excluding irradiance, distance from the electrical grid was identified as the most critical criterion for selecting areas on water bodies for FPV installation. Similarly, Gökmener et al. (2023), using a fuzzy sine trigonometry approach, found that proximity to the grid was the most important criterion after solar-related variables such as irradiance, sunshine duration, and temperature. This study also agrees with Nebey et al. (2020) and Gökmener et al. (2023), where distance from land ranked higher than water depth.

3.4 Usable Area for FPV Installation

Three considerations were used to determine the usable areas for FPV installations in the Angat reservoir, including distance from the electrical grid, distance from land, and water depth criteria. Figure 4 shows the usability classes per criteria, divided into areas of low, moderate, and high usability for FPV installations. Only a few areas were classified as highly usable for the distance from the electrical grid criterion. The closest electrical grid to the reservoir is at the southernmost part, where the main infrastructure of the hydropower plant is situated. The other surrounding areas of the reservoir do not have a connection due to challenging terrain and thick forest cover. Since the Angat Reservoir is shaped more prominently in the vertical direction, the northern parts of the water body are farther from the electrical grid and more economically stressful to connect. Moreover, the results for the distance from land criterion are more uniform. The most usable areas for this criterion are concentrated in the middle of the reservoir and are the largest suitability class among the three. This is because the minimum value to be classified as highly usable is only 50 meters. A staggering 53% of the surface area satisfies this requirement, in part due to the large size of the reservoir itself. On the other hand, a large portion of the low usable sites for this criterion include the small pockets of water outside the main water body. Lastly, the highly usable areas for the water depth criteria are mostly in the southern and middle parts of the reservoir. After interpolating the bathymetric survey, it was found that the terrain of the north section has higher bottom elevations than the southern portions. At a constant water level throughout the reservoir, this means that the water is shallower in the northern part.

It is important to note that the distance from land and water depth criteria were based on the minimum water boundary extracted. This ensures that the scope of the assessment is limited to areas that actually hold water for the whole year, regardless of the month or season, and serves as an additional exclusion parameter to make sure the analysis is logically and economically sound.

Using weighted overlay analysis for the three criteria, the usable areas for FPV installation in Angat Dam are illustrated in Figure 5. The total area of highly usable areas was found to be approximately 4.26 km^2 Moreover, 4.53 km^2 and 2.95 km^2 were classified as moderately and minimally usable, respectively. The entire western area of the southernmost part is classified as highly usable, along with the southeast and middle parts that are not immediately adjacent to land. In contrast, the northern region only has moderately and minimally usable classes.

Based on Figure 5, the distance from the electrical grid criteria is highly significant. Furthermore, except for the western area of the southernmost part, the classes seem to be differentiated mostly by the distance from land criteria. This could be due to many results for both criteria coinciding since the farther water areas from land tend to be deeper and vice versa.

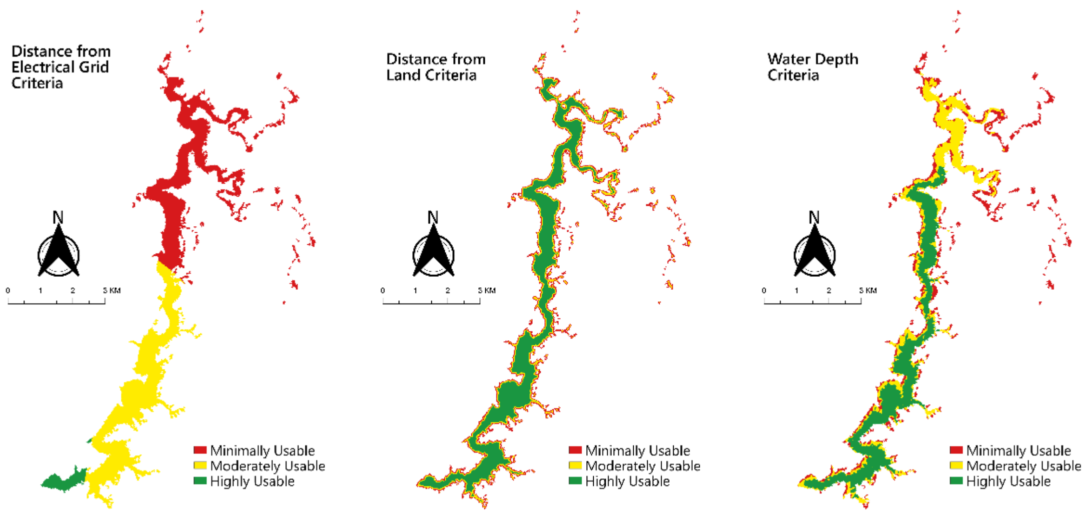

Figure 4. Classification of each usability criterion.

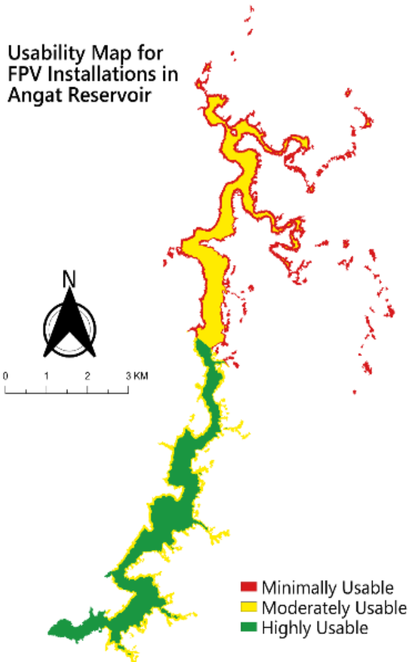

Figure 5. Final usability map.

3.5 Electricity Generation Potential

Using the solar energy yield and the spatial usability of the Angat Reservoir covering 4.26 km^2, the electricity generation potential of the area is presented in Table 8. It can be observed that there is a seasonal pattern in the electricity generation estimate, with the highest output occurring in May at approximately 90.69 GWh, and the lowest in December at around 53.88 GWh. This fluctuation shows that accounting for the month-to-month variations in the available solar resource is important when assessing the potential of FPV systems in reservoirs. For instance, since the installation area is constrained, selecting appropriate PV modules and an inverter setup based on the lowest-generation month would help optimize the annual electricity production of the reservoir.

Month	Electricity Generation Estimate (GWh)
January	57.10
February	61.13
March	80.05
April	85.24
May	90.69
June	87.45
July	90.32
August	89.88
September	81.54
October	73.32
November	58.81
December	53.88
Annual Sum	909.42

Table 8. Electricity generation potential of the reservoir.

Cumulatively, the Angat Reservoir resulted in an annual electricity generation potential of around 909.42 GWh, which closely aligns with the 868.06 GWh potential estimated by the PVGIS tool of the European Commission & Joint Research Centre (2025). The approximately 4.55% higher estimate from this study can be attributed primarily to its methodological differences with the tool. Specifically, this study utilized localized parameters such as the spatial extent and surface model of the reservoir, as well as the appropriate time zone that accurately models the position of the sun with respect to the local area. In contrast, PVGIS used a more generalized and global model that relies on a single-point location for analysis and a resolution of approximately 25 km. These figures might have led to conservative tendencies in yield calculations and consequently dismissed the advantages of localized estimation (European Commission & Joint Research Centre, n.d.).

Nonetheless, the large-scale output from this study, supported by the PVGIS tool, represents a meaningful contribution to the energy supply of the region. For example, with an average monthly consumption of 200 kWh per household in the Philippines, approximately 378,925 households can be powered for one year (Meralco, 2023). Moreover, considering the total residential electricity consumption of the Philippines in 2023 of 36,968 GWh, the reservoir alone could supply about 2.46% of that demand (Department of Energy, 2024a). This output is also equivalent to around 35.75% of the total electricity generated by solar power plants in the same year. The significant potential of reservoirs for FPV installation, when considering the topographic characteristics of the area and incorporating PV module characteristics, is also observed in the study of Yilmaz et al. (2023), which revealed that a reservoir with around 4.8 km² of suitable surface area can generate over 1,000 GWh of electricity annually. Similarly, the study by Ateş (2022), which incorporated reservoir extent and PV module capacity, showed that their reservoir of interest could produce over 1,600 kWh of electricity annually per kilowatt-peak of installed capacity.

In terms of overall technical potential, the Angat Reservoir demonstrates an annual specific yield of approximately 1,295 kWh/kWp, which means that for every kilowatt-peak (kWp) of installed solar capacity, the FPV system in the area can produce over 1,200 kWh annually. This figure is consistent with the Global Solar Atlas estimation for the region, which ranges from 1,255 to 1,398 kWh/kWp (World Bank Group, 2025). These results confirm that the Angat Reservoir has high potential in solar energy production through FPV deployment.

3.6 Implementation Challenges

The study aimed to focus on quantifying the theoretical and technical solar potential of the Angat Dam. The social acceptability, environmental performance, and economic impact of implementing the FPV system were not included in the analyses. Realistically, however, challenges and limitations related to such sectors are expected while installing FPVs in the vicinity due to the physical nature of Angat Dam. The logistics of transporting equipment and materials, connecting to the electrical grid, and maintenance could be difficult due to the limited access points present in the reservoir, which is mainly in its southernmost part near the hydroelectric power plant. Consequently, the effect of water level fluctuations and environmental forces like typhoons also need to be studied thoroughly. With this, rigorous and science-based multi-sectoral planning and support from all stakeholders are required to successfully operate an FPV system in Angat Dam. Collaboration between government agencies, private entities, NGOs, and the local communities would be essential in such pursuits. Official standards and guidelines regarding FPV installation also needs to be studied, especially as the Philippines is need in water bodies that may be appropriate for such systems.

4. Conclusion

This study aimed to systematically assess the solar energy generation potential of the Angat Reservoir using RS and GIS methods. Through random forest image classification, the temporal variation of the water body extent was delineated successfully, with all accuracies, including PA, CA, OA, and κ, greater than 90%. The subsequent theoretical potential assessment used this variation, along with the WSMs, to calculate a more precise estimate of available solar energy resources in the area. From this, the total average solar yield in the Angat Reservoir was found to be 1609.85 kWh/m^2 for the whole year, which indicates its potential to be tapped for solar energy generation to cater to community needs.

Optimal sites for panel installation within the reservoir were selected considering three criteria: distance from the electrical grid, distance from land, and water depth. Expert consensus established that distance from the electrical grid was the most important criterion of the three, and water depth was the least. Through weighted overlay analysis, 4.26 km² was found to be highly usable for FPV installations. Subsequently, 4.53 km² were classified as moderately usable, and 2.95 km² were minimally usable. The highly usable areas are concentrated in the southern portion, where the closest electrical grid is situated.

From these, the annual electricity generation potential of the Angat Reservoir was found to be around 909.42 GWh. This value accounts for nearly 2.46% of the total electricity demand and around 35.75% of the total electricity generated by solar power plants in 2023 in the Philippines. This illustrates the potential for developing solar infrastructure in the Angat Reservoir to support the electricity demands in the country.

Overall, integrating GIS and RS into the workflow of this study proves their capability to assess solar theoretical and technical potential systematically. This work presents objective findings that contribute to the understanding of FPV deployment in inland water bodies in the Philippines, which will lay the foundation for further research on innovative renewable energy sources in the country. However, it is important to note that this study is limited to assessing only the theoretical and technical potential of the Angat Reservoir. This study recommends that future studies incorporate the assessment of aspects as Levelized Cost of Electricity and evaporation reduction.

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