T R e k R i T e l
(Teknologi Rekayasa Jaringan Telekomunikasi) : Jurnal Teknik Elektro
Volume 6, Nomor 2, Oktober 2026, ISSN 2776 – 5946
DOI: https://doi.org/10.51510/trekritel.v6i2.002

GIS-Based Multi-Criteria Decision Framework for Spatial Planning of Solar Power Plant Sites in West Kalimantan Province

Aprima Anugerah Matondang[1], M. Syahruddin[2], Z Zumhari[3], S Suparmono[4], Nobert Sitorus[5]
[1*,4]Program Studi Teknik Listrik, Jurusan Teknik Elektro, Politeknik Negeri Medan, Indonesia
[2,5]Program Studi Teknologi Rekayasa Instalasi Listrik, Jurusan Teknik Elektro, Politeknik Negeri Medan,
[3]Program Studi Teknik Elektronika, Jurusan Teknik Elektro, Politeknik Negeri Medan, Indonesia
e-mail: aprimaamatondang@polmed.ac.id

Abstrak— Transisi energi global menuntut perencanaan spasial pembangkit listrik tenaga surya (PLTS) yang efisien, terutama di wilayah ekuator seperti Provinsi Kalimantan Barat (Kalbar), Indonesia, yang memiliki potensi surya melimpah. Penelitian ini mengembangkan kerangka pengambilan keputusan multi-kriteria berbasis sistem informasi geografis (GIS-MCDM) untuk pemilihan lokasi PLTS di Kalbar dengan membandingkan metode *Analytical Hierarchy Process* (AHP) dan *Weighted Overlay Analysis* (WOA). Delapan kriteria dikelompokkan ke dalam faktor iklim (radiasi surya, suhu permukaan tanah), topografi (kemiringan, aspek, ketinggian), infrastruktur (kedekatan saluran listrik dan jalan raya), serta lingkungan (tata guna lahan/tutupan lahan, kedekatan badan air). Matriks perbandingan berpasangan AHP menghasilkan rasio konsistensi 0,087 (<0,10), dengan radiasi surya (25,8%) dan kedekatan saluran listrik (18,4%) sebagai kriteria paling berpengaruh. Setelah eksklusi kawasan lindung, hanya 33,05% (~48.500 km²) wilayah provinsi yang dapat dimanfaatkan, di mana sekitar 30,3% tergolong sangat sesuai hingga sangat tinggi kesesuaiannya. Kedua metode menghasilkan pola spasial konsisten dengan tingkat kesepakatan sekitar 78%, dengan wilayah tenggara di sekitar Ketapang menunjukkan kesesuaian tertinggi. AHP menawarkan transparansi metodologis lebih baik, sedangkan WOA menyediakan efisiensi komputasi. Kerangka ini mendukung target energi terbarukan Indonesia, termasuk kapasitas PLTS 366,4 MW untuk Kalbar pada 2025.

Kata kunci : AHP, GIS, MDCM, PLTS, Kalimantan Barat

Abstract—*The global energy transition requires efficient spatial planning for solar photovoltaic (PV) power plants, particularly in equatorial regions such as West Kalimantan Province (WKP), Indonesia, which possesses abundant solar resources. This study develops a GIS-based multi-criteria decision-making (GIS-MCDM) framework for solar power plant site selection in WKP by comparing the Analytical Hierarchy Process (AHP) and Weighted Overlay Analysis (WOA). Eight criteria were organized into climatic (solar radiation, land surface temperature), topographic (slope, aspect, altitude), infrastructural (proximity to power lines and highways), and environmental (land use/land cover, proximity to water bodies) factors. The AHP pairwise comparison matrix produced a consistency ratio of 0.087 (<0.10), with solar radiation (25.8%) and proximity to power lines (18.4%) as the most influential criteria. After protected-area exclusion, only 33.05% (~48,500 km²) of the province remains exploitable, of which approximately 30.3% is classified as highly to very highly suitable. Both methods produced consistent spatial patterns with approximately 78% agreement, with the southeastern region around Ketapang exhibiting the highest suitability. AHP offers greater methodological transparency, while WOA provides computational efficiency. The framework supports Indonesia's renewable energy targets, including 366.4 MW of solar PV capacity for WKP by 2025.*

Keywords : AHP, GIS, MDCM, solar power plant, west kalimantan

Copyright© 2021 TRekRiTel (Teknologi Rekayasa Jaringan Telekomunikasi) : Jurnal Teknik Elektro.
This is an open acces article under the CC-BY-SA lisence (https://creativecommons.org/licenses/by-sa/4.0/).

I. INTRODUCTION

A. Global Energy Transistion and the Role of Solar PV

The global transition toward renewable energy sources has intensified the need for efficient planning strategies for photovoltaic (PV) power generation. Fossil fuels contribute significantly to environmental degradation and global warming, meeting approximately 81% of global energy demand in 2023 and contributing roughly 80% of energy-related CO_2 emissions. The dwindling reserves of non-renewable energy sources drive the urgent need for renewable alternatives, with the International Energy Agency (IEA) projecting that solar energy can account for 11% of global energy needs in the next three decades. Recent advancements in machine learning are reshaping spatial decision-making systems, though AHP-based GIS-MCDM frameworks remain dominant due to their interpretability and structured expert judgment incorporation (Algawbery et al., 2025).

B. Indonesia's Solar Potential and Energy Challanges

In Indonesia, high solar irradiation provides significant potential for PV adoption. The country imports approximately 200 million barrels of oil annually, costing 150 trillion IDR (US$11.5 billion) per year. The theoretical solar power potential is estimated at 500 GW with average insolation of 4.80 kWh/m²/day. West Kalimantan Province (WKP), the second largest province on Borneo Island covering 146,807 km², experiences uniform climate conditions with a daily average of sunlight of 12 hours and 7 minutes, making it ideal for solar energy development. However, current PV development in WKP is nearly stagnant, with less than 0.01% (0.18 MW) solar installed capacity, far below the RUEN target of 366.4 MW by 2025 (Algawbery et al., 2025), (Babatunde & Olanrewaju, 2025)

C. GIS-MCDM for Site Selection

The identification of optimal locations for solar power plants requires integration of diverse spatial, environmental, and infrastructural factors. GIS combined with MCDM methods has become the dominant approach for PV site suitability analysis. Techniques such as AHP, TOPSIS, and WOA are widely used to integrate heterogeneous criteria. The AHP method, developed by (Christina et al., 2026), (Astarani et al., 2026), enables systematic weighting of criteria through pairwise comparison matrices. Recent studies demonstrate the effectiveness of integrating AHP with machine learning techniques. However, few studies have systematically compared AHP and WOA within a single integrated framework, particularly in regions with complex protected-area constraints such as WKP

D. Novelty and Objectives

The novelty of this study lies in its systematic comparative analysis of AHP and WOA methods within an integrated GIS-MCDM framework for solar power plant site selection in West Kalimantan, a region with significant challenges due to protected areas. The objectives are: (1) to develop a GIS-based MCDM framework for WKP; (2) to apply AHP and WOA methods; (3) to compare both methods in terms of spatial agreement, suitability distribution, and methodological transparency; and (4) to provide recommendations for renewable energy planning in Indonesia.

II. LITERATURE REVIEW

A. AHP in Renewable Energy Site Selection

AHP, developed by (Gacu et al., 2023), enables systematic weighting of criteria through pairwise comparison matrices using a 1–9 scale. The method has been proven effective in various renewable energy site suitability studies due to its ability to accommodate expert judgment in a structured manner. The consistency ratio (CR) is used to validate the judgments, with a threshold of 0.10 generally accepted. Ruiz et al. (2020) applied GIS-AHP for solar plant location analysis in Indonesia and found that after conservation area exclusion, optimal locations reduced to 0.03%–0.07% of the total area. The study also noted that temperature and relative humidity variance across WKP is negligible (<2%), making them low-priority criteria. (S Suparmono et al., 2025) assessed the technical and economic feasibility of utility-scale solar PV plants in West Kalimantan and emphasized the importance of proximity to grid infrastructure.

B. WOA and Comparative MCDM Studies (Al-Awadhi et al., 2025).

Volume 6, Nomor 2, Oktober 2026
ISSN 2776 – 5946 (online), Hal 8 – 15,

WOA offers computational efficiency through weighted overlay operations on raster layers, although the weights used still require justification. Shehab et al. (2024) demonstrated the effectiveness of MCDM approaches for identifying optimal solar farm locations through multi-technique comparative analysis. (Djunaedi & Widaningrum, 2025), (Z Zumhari et al., 2025) assessed GIS-based MCDM techniques for solar PV power plant site suitability, confirming the reliability of AHP-based approaches. However, systematic comparisons between AHP and WOA remain limited, particularly in equatorial regions with complex land-use constraints.

C. Research Gap

While AHP-based GIS-MCDM frameworks dominate the literature, few studies have systematically compared AHP and WOA within a single integrated framework for solar power plant site selection in regions with significant protected-area challenges. This study addresses this gap by applying both methods to WKP and comparing their results in terms of spatial agreement, suitability distribution, and methodological characteristics.

Table 1. Data Sources and Evaluation Criteria

Tabel 1. Data Sources and Evaluation Criteria for Solar Power Plant Site Selection in West Kalimantan Province

No	Criteria	Thematic Group	Source	Resolution	Measurement Unit
1	Solar Radiation (GHI)	Climatic	Solargis / BMKG	0.5° × 0.5°	kWh/m²/day
2	Land Surface Temperature (LST)	Climatic	Landsat Band 10–11	30 m	°C
3	Slope	Topographic	USGS/SRTM	30 m	Degrees (%)
4	Aspect	Topographic	USGS/SRTM	30 m	Degrees (0–360°)
5	Altitude	Topographic	USGS/SRTM	30 m	Meters (m a.s.l.)
6	Proximity to Power Lines	Infrastructural	PLN	Vector	Meters (m)
7	Proximity to Highways	Infrastructural	BAPPEDA / OpenStreetMap	Vector	Meters (m)
8	Land Use / Land Cover	Environmental	MENLHK / PERTANIAN	30 m	Class (categorical)

Source: Data processed by author (2026)

C. Analytical Hierarchy Process (AHP)

AHP was implemented following Saaty (1980). Expert judgments were solicited using a 1–9 Saaty scale. The pairwise comparison matrix was constructed for the eight criteria. The matrix was normalized, and criteria weights were derived from the principal eigenvector. The consistency ratio (CR) was calculated to validate the judgments, with CR < 0.10 considered acceptable. The pairwise comparison matrix yielded a CR of 0.087, below the acceptable threshold of 0.10, indicating consistent judgments. The AHP weights were then used to generate the final suitability map through weighted overlay operations.

D. Weighted Overlay Analysis (WOA)

WOA was performed using the same reclassification scheme as AHP but with standard weights. Each criterion layer was reclassified into a common suitability scale, and weighted overlay operations were performed to generate the final suitability map. The WOA method provides computational efficiency and reduces subjectivity in weight assignment.

E. Protected Areas Exclusion

Following Ruiz et al. (2020), protected areas, conservation zones, water bodies, and urban areas were excluded from the analysis. This exclusion is critical in WKP due to the province's widely diversified protected areas, which cover approximately 66.95% (~98,000 km²) of the total area. The exclusion process ensured that only legally and environmentally feasible areas were considered for solar power plant development as shown in Figure 1 below

Copyright© 2021 TRekRiTel (Teknologi Rekayasa Jaringan Telekomunikasi) : Jurnal Teknik Elektro.
This is an open acces article under the CC-BY-SA lisence (https://creativecommons.org/licenses/by-sa/4.0/).

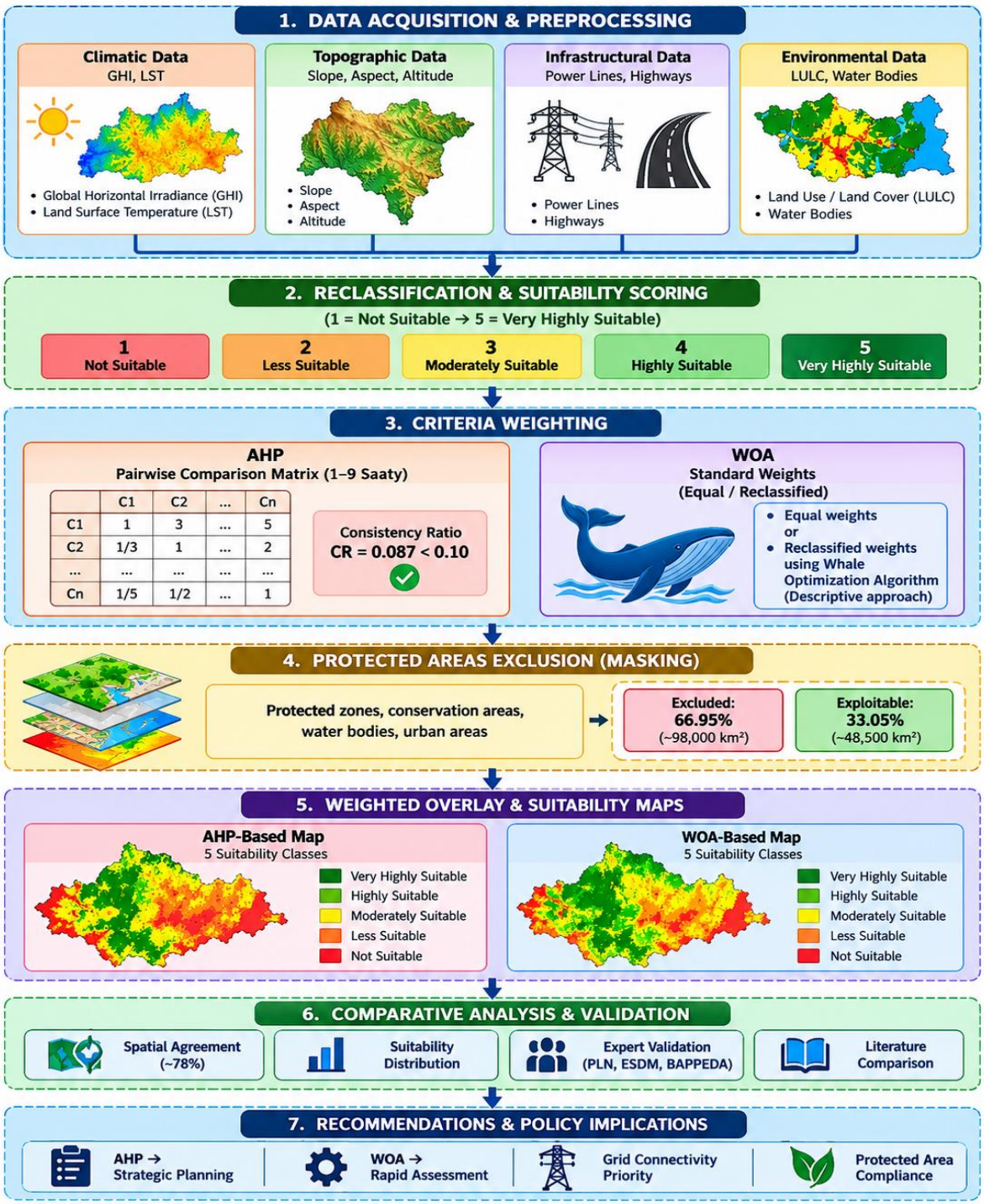


Figure 1. Research Framework Flowchart
Source: Data processed by author (2026)

F. Comparative Analysis and Validation

Comparative analysis used consistency analysis, suitability distribution comparison, and sensitivity analysis. Validation used literature comparison with Ruiz et al. (2020) and expert validation from PLN, ESDM, and BAPPEDA. The spatial agreement between AHP and WOA was quantified using overlay comparison, with approximately 78% agreement between the two methods.

Copyright© 2021 TRekRiTel (Teknologi Rekayasa Jaringan Telekomunikasi) : Jurnal Teknik Elektro.
This is an open acces article under the CC-BY-SA lisence (https://creativecommons.org/licenses/by-sa/4.0/).

Volume 6, Nomor 2, Oktober 2026
ISSN 2776 – 5946 (online), Hal 8 – 15,

III. RESULT AND DISCUSSION

A. AHP Weight Calculation Result

The pairwise comparison matrix yielded criteria weights with a CR of 0.087, below the acceptable threshold of 0.10. Solar radiation (GHI) was the most significant factor (25.8%), followed by proximity to power lines (18.4%), land surface temperature (13.2%), land use/land cover (12.1%), altitude (9.8%), aspect (7.5%), proximity to roads (7.0%), and slope (6.2%). The dominance of solar radiation and proximity to power lines reflects the specific conditions of WKP, where uniform climate and low slope topography reduce the relative importance of temperature and slope criteria. The high weight of proximity to power lines (18.4%) underscores the critical role of grid connectivity in a province with limited transmission infrastructure. The relatively low weight of slope (6.2%) is consistent with WKP's low slope topology, which makes slope a less discriminating criterion compared to regions with more varied terrain.

B. Protected Areas Exclusion

After exclusion, only 33.05% (~48,500 km²) of the total WKP area (146,807 km²) remains exploitable, while 66.95% (~98,000 km²) is excluded. This significant reduction highlights the challenges posed by protected areas in WKP and the importance of explicit spatial exclusion in site selection. The exclusion process is particularly critical in WKP due to the province's widely diversified protected areas, which include conservation zones, water bodies, and urban areas. Without this exclusion, suitability maps would overestimate the available land for solar power plant development.

Tabel 2. AHP Pairwise Comparison Matrix, Criteria Weights, and Consistency Ratio

Criteria	GHI	LST	SL	AS	AL	PL	RH	LU	Weight (%)	Rank
GHI	1	3	5	4	3	2	3	2	**25.8**	1
LST	1/3	1	3	2	2	1/2	2	1/2	**13.2**	3
SL	1/5	1/3	1	1/2	1/2	1/3	1/2	1/3	**6.2**	8
AS	1/4	1/2	2	1	1/2	1/3	1/2	1/3	**7.5**	6
AL	1/3	1/2	2	2	1	1/3	1/2	1/2	**9.8**	5
PL	1/2	2	3	3	3	1	3	2	**18.4**	2
RH	1/3	1/2	2	2	2	1/3	1	1/2	**7.0**	7
LU	1/2	2	3	3	2	1/2	2	1	**12.1**	4

Source: Data processed by author (2026)

C. AHP-Based Suitability Map

The AHP weighted overlay produced suitability classifications across five categories. Approximately 37.8% (18,334.5 km²) of the exploitable area is classified as "Not Suitable," while 21.4% (10,376 km²) is "Less Suitable." The "Moderately Suitable" category covers 35.8% (17,363 km²). Importantly, 21.5% (10,426 km²) is classified as "Highly Suitable," and 8.8% (4,270 km²) as "Very Highly Suitable." This means that approximately 30.3% of the exploitable area in WKP is considered highly or very highly suitable for solar power plant development. The southeastern region, particularly around Ketapang, exhibits the highest suitability due to favorable solar radiation, low slope topography, and proximity to existing power infrastructure. In contrast, the northern and central regions show lower suitability due to protected areas, steeper slopes, and limited grid connectivity (Gökler, 2025), (Suprianto, Hardi & Matondang, n.d.).

D. WOA-Based Suitability Map

The WOA method, using the same reclassification scheme but standard weights, produced slightly different results. The WOA method classified 36.3% (17,588 km²) as "Not Suitable," 21.4% (10,400 km²) as "Less Suitable," and 36.9% (17,896 km²) as "Moderately Suitable." The "Highly Suitable" category covers 21.9% (10,608 km²), while "Very Highly Suitable" accounts for 8.3% (4,008 km²). The spatial pattern is largely consistent with the AHP results, with the southeastern region around Ketapang remaining the most suitable area. Additional pockets of high suitability were identified in the central region near Pontianak and along the coast. Overall, the WOA method tends to classify slightly more areas as moderately suitable compared to the AHP method (Lestari & Anugrahwaty, 2026).

Copyright© 2021 TRekRiTel (Teknologi Rekayasa Jaringan Telekomunikasi) : Jurnal Teknik Elektro.
This is an open acces article under the CC-BY-SA lisence (https://creativecommons.org/licenses/by-sa/4.0/).

E. Comparative Analysis

The comparative analysis reveals that both AHP and WOA methods produce generally consistent spatial patterns, with approximately 78% agreement between the two methods. The AHP method classifies 8.8% of the exploitable area as "Very Highly Suitable," compared to 8.3% for WOA, a difference of only 0.5%. For "Highly Suitable," AHP gives 21.5% while WOA gives 21.9% (difference of 0.4%). The "Moderately Suitable" category shows the largest difference, with AHP at 35.8% and WOA at 36.9% (difference of 1.1%). (Mohd Nor et al., 2025), (Nainggolan et al., 2026). The "Less Suitable" category is identical at 21.4% for both methods, while "Not Suitable" shows a 0.5% difference. Areas of disagreement between the two methods are primarily concentrated in transition zones between suitability classes, where criteria thresholds are less distinct. The AHP method offers greater methodological transparency and allows for structured incorporation of expert judgment, while the WOA method provides computational efficiency and reduces subjectivity in weight assignment. Both methods are considered acceptable for solar power plant site selection, consistent with findings from previous studies in similar contexts.

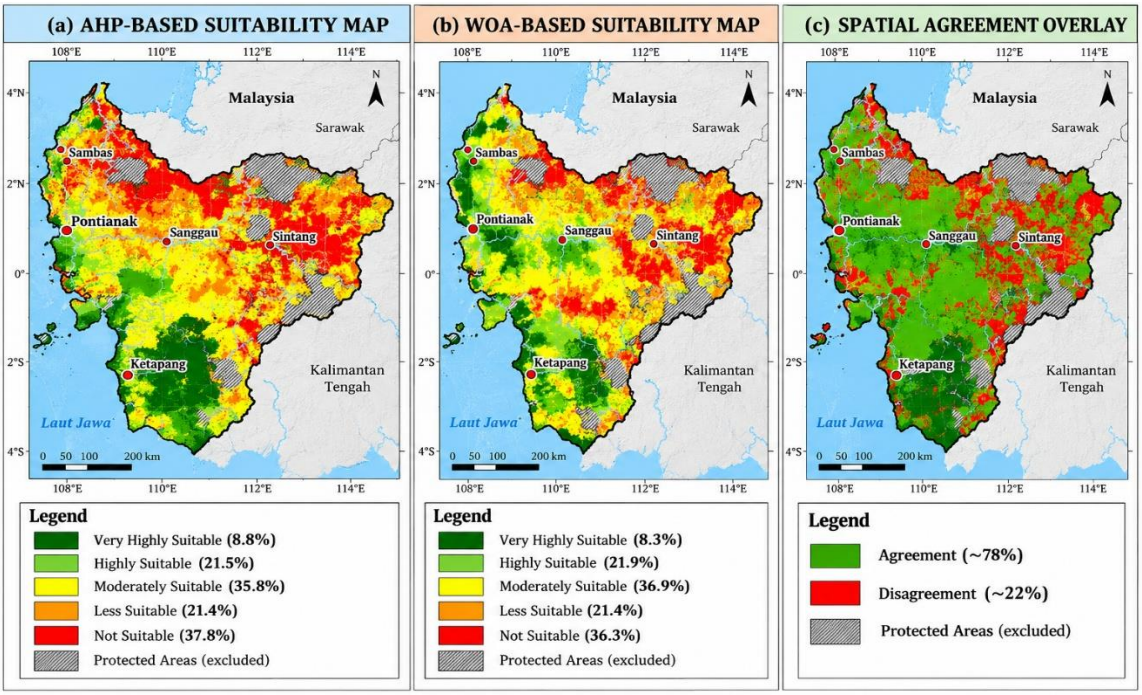


Figure 2. Research Framework Flowchart
Source: Data processed by author (2026)

F. Discussion

The comparative analysis reveals both methods produce consistent patterns with approximately 78% agreement. AHP offers greater methodological transparency and allows incorporation of expert judgment, while WOA provides computational efficiency and reduces subjectivity. This aligns with literature confirming AHP-based GIS-MCDM dominance in PV site suitability analysis.

The specific conditions of WKP influenced criteria weights. As noted by (Ruiz et al., 2020), (Sitorus et al., 2025), temperature and relative humidity variance across WKP is negligible (<2%), making them low-priority criteria. WKP's low slope topology makes slope a low weighting criterion. Approximately 30.3% of exploitable area was classified as highly or very highly suitable, aligning with Ruiz et al. (2020), who identified optimal locations reduced to 0.03%–0.07% of WKP after conservation area exclusion. Estimated annual generation of 8.91–20.96 TWh/year indicates WKP's resources could meet national targets.

The findings complement research on hybrid renewable energy systems. (Nainggolan et al., 2026) optimized axial wind turbine blades for hybrid systems integrating solar PV and micro-hydro. (Purba et al., 2026) analyzed energy consumption for electric bus deployment, while (Lestari & Anugrahwaty,

Copyright© 2021 TRekRiTel (Teknologi Rekayasa Jaringan Telekomunikasi) : Jurnal Teknik Elektro.
This is an open acces article under the CC-BY-SA lisence (https://creativecommons.org/licenses/by-sa/4.0/).

2026) examined charging demand for electric two-wheelers. These studies emphasize the need for holistic renewable energy planning.

Practical recommendations include: (1) use AHP for large-scale strategic planning and WOA for rapid assessment; (2) explicitly address protected areas in site selection; (3) prioritize grid connectivity; and (4) ensure robust grid integration including protection against transient disturbances.

IV. CONCLUSION

This study presents a GIS-based MCDM framework for solar power plant site selection in West Kalimantan Province, comparing AHP and WOA methods. Key findings are as follows. First, solar radiation (25.8%) and proximity to power lines (18.4%) were the most influential criteria. Second, only 33.05% of WKP is available after protected area exclusion, with optimal locations reducing to 0.03%–0.07% of WKP (46.60–108.58 km²) and estimated capacity of 2,034–4,785 MW. Third, approximately 30.3% of exploitable areas were highly or very highly suitable. Fourth, both methods produced consistent results (~78% agreement), with AHP offering transparency and WOA providing efficiency. Fifth, the GIS-MCDM framework supports Indonesia's renewable energy targets, including 366.4 MW for WKP by 2025.

The novelty lies in the systematic comparison of AHP and WOA within West Kalimantan, a region with protected area challenges. Results demonstrate that GIS-based MCDM approaches support sustainable energy planning and SDG 7. Successful deployment requires optimal site selection and robust grid integration, including protection against transient disturbances. The framework can be enhanced by integrating machine learning techniques achieving accuracy rates as high as 96%.

ACKNOWLEDGEMENTS

The authors gratefully express their sincere appreciation to the Department of Electrical Engineering, Politeknik Negeri Medan, Indonesia, for providing academic support, research facilities, and a collaborative environment that contributed to the successful completion of this study. We also gratefully acknowledge the data from BMKG and the insightful comments and constructive suggestions from the editor and anonymous reviewers. Additional thanks are extended to colleagues and researchers whose contributions, although not individually listed, have been invaluable to this work.

REFERENCES

Al-Awadhi, T., Al Ramimi, W., Al Jabri, K., & Abulibdeh, A. (2025). Solar farms suitability analysis using GIS-Based Analytic Hierarchy Process (AHP) multi-criteria: A case study of Al Duqm – Oman. *Renewable Energy*, *241*, 122295. https://doi.org/10.1016/j.renene.2024.122295

Algawbery, A. N., Shukri, M. A., & AL-Moutawakel, M. K. (2025). Suitability Analysis of Solar Energy Plant Sites in Yemen Using AHP, BWM, and GIS Methods. *لا لعلوم صنعاء جامعة مجلة والا تكنولوجيا التطبيقية*, *3*(4), 999–1007. https://doi.org/10.59628/jast.v3i4.2068

Astarani, T. F., Christina, S., Pardede, Y., & Matondang, A. A. (2026). *Expert System for Electric Vehicle Charging Infrastructure Planning : A Scenario-Based Decision Support Framework for Two-Wheeler and Bus Fleets*. *5*(4), 1601–1613. https://doi.org/10.55123/insologi.v5i4.9209

Babatunde, O. M., & Olanrewaju, O. (2025). A Review of Multi-Criteria Decision-Making Techniques for Spatial Optimization of Hybrid Renewable Energy Systems. *2025 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM)*, 0781–0787. https://doi.org/10.1109/IEEM63636.2025.11357721

Christina, S., Pardede, Y., Astarani, T. F., Hardi, S., & Anugerah, A. (2026). *Sistem Pendukung Keputusan Berbasis IoT untuk Monitoring Kinerja Panel Surya dan Pemeliharaan Prediktif*. *5*(4), 1527–1537. https://doi.org/10.55123/insologi.v5i4.9169

Copyright© 2021 TRekRiTel (Teknologi Rekayasa Jaringan Telekomunikasi) : Jurnal Teknik Elektro.
This is an open acces article under the CC-BY-SA lisence (https://creativecommons.org/licenses/by-sa/4.0/).

Djunaedi, A. C., & Widaningrum, D. L. (2025). Geospatial and AHP Analysis for Solar-Powered Aerator Site Selection Based on Socio-Economic Factors in Freshwater Aquaculture: A Case Study in Purworejo Regency. *IOP Conference Series: Earth and Environmental Science*, *1564*(1), 012109. https://doi.org/10.1088/1755-1315/1564/1/012109

Gacu, J. G., Garcia, J. D., Fetalvero, E. G., Catajay-Mani, M. P., & Monjardin, C. E. F. (2023). Suitability Analysis Using GIS-Based Analytic Hierarchy Process (AHP) for Solar Power Exploration. *Energies*, *16*(18), 6724. https://doi.org/10.3390/en16186724

Gökler, S. H. (2025). Enhanced site selection for solar power plants utilizing the geographic information system and pythagorean fuzzy analytical hierarchy process method. *Sustainable Energy, Grids and Networks*, *44*, 101929. https://doi.org/10.1016/j.segan.2025.101929

Lestari, M. W., & Anugrahwaty, R. (2026). *Scenario - Based Charging Demand and Load Characterization for Electric Two - Wheeler Systems*. *5*(2), 391–401.

Mohd Nor, T. N. A. T., Samsudin, S. H., Ismail, M. N., Yusop, H., & Elias, M. A. (2025). Assessment of GIS-Based Multi-Criteria Decision Making (MCDM) Techniques for Solar PV Power Plant Site Suitability. *IOP Conference Series: Earth and Environmental Science*, *1560*(1), 012042. https://doi.org/10.1088/1755-1315/1560/1/012042

Nainggolan, R., Kamil, I., Matondang, A. A., Sitorus, N., Suadi, S., Sibarani, B., & Hestukoro, S. (2026). Parametric optimization of an axial wind turbine blade for a hybrid renewable energy system integrating solar PV and micro-hydro. *Science, Technology, and Communication Journal*, *6*(3), 385–392. https://doi.org/10.59190/stc.v6i3.395

Purba, A. M., Napitu, D. H. S., Lestari, M. W., Simangunsong, J., Hutajulu, E., Hutabarat, N. F., & Matondang, A. A. (2026). Energy Consumption and Charging Infrastructure Analysis for Electric Bus Deployment in Urban Transportation Systems. *Jurnal Penelitian Pendidikan IPA*, *12*(4), 639–648. https://doi.org/10.29303/jppipa.v12i4.11221

Ruiz, H. S., Sunarso, A., Ibrahim-Bathis, K., Murti, S. A., & Budiarto, I. (2020). GIS-AHP Multi Criteria Decision Analysis for the optimal location of solar energy plants at Indonesia. *Energy Reports*, *6*, 3249–3263. https://doi.org/10.1016/j.egyr.2020.11.198

S Suparmono, C Cholish, A Abdullah, Sinambela, H., Alda, T., Matondang, A. A., & Simanjuntak, A. V. (2025). Quantitative Assessment of Passive Load Balancing for a Designed HVAC Installation: Case study in Magnificent Hall, Deli Park. *Journal of Geoscience, Engineering, Environment, and Technology*, *10*(3), 397–401. https://doi.org/10.25299/jgeet.2025.10.3.24696

Sitorus, N., Ginting, B. B., Panjaitan, B. P., Simanjuntak, B. E., Naibaho, P. R. P., Matondang, A. A., & Simanjuntak, A. V. H. (2025). Design and Performance Evaluation of a 200 Wp Off-Grid Solar Photovoltaic Module for Renewable Energy in Indonesia. *Journal of Geoscience, Engineering, Environment, and Technology*, *10*(3), 408–412. https://doi.org/10.25299/jgeet.2025.10.3.24981

Suprianto, Hardi, S., & Matondang, A. A. (n.d.). *SISTEM PENDUKUNG KEPUTUSAN CERDAS UNTUK MENGINTEGRASIKAN PV SURYA DAN PENGISIAN*. *7*(1), 64–72.

Z Zumhari, Hutajulu, E., Sibarani, B., Sirait, R., Anggriani, T., & Matondang, A. A. (2025). Advancing Environmental and Health Pollution Monitoring in Medan, Indonesia: A Mechatronics-Based Meta-Analysis. *Journal of Geoscience, Engineering, Environment, and Technology*, *10*(3), 402–407. https://doi.org/10.25299/jgeet.2025.10.3.24694

Copyright© 2021 TRekRiTel (Teknologi Rekayasa Jaringan Telekomunikasi) : Jurnal Teknik Elektro.
This is an open acces article under the CC-BY-SA lisence (https://creativecommons.org/licenses/by-sa/4.0/).