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GIS-integrated multi-criteria decision-making for sustainable energy facility site selection: A systematic review and bibliometric mapping

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Abstract: GIS-integrated multi-criteria decision-making (GIS-MCDM) is used to assess sites for energy-generation facilities and related infrastructure. This systematic review examines 87 studies published from 2023 to 2025, selected from 554 Scopus-indexed records. MCDM methods, publication years, study locations, facility types, and siting criteria were coded at the study level; a VOSviewer overlay was used to describe keyword co-occurrence. The included studies numbered 22 in 2023 (25.29%), 36 in 2024 (41.38%), and 29 in 2025 (33.33%). Turkey was the most frequently examined setting (n = 22), followed by China (n = 15), India (n = 7), and Iran (n = 6), after subnational location labels were harmonised. AHP was coded in 60 studies (68.97%), TOPSIS in 14 (16.09%), and fuzzy AHP in 10 (11.49%); a study could use more than one method. Solar (n = 31; 35.63%), wind (n = 22; 25.29%), and hybrid renewable applications (n = 15; 17.24%) were the most common facility types. Slope (n = 56), proximity to electrical networks (n = 52), road access (n = 49), and proximity to residential areas (n = 47) were the most frequently coded criteria. The concentration of study locations and variation in reported criteria limit direct comparison across studies. Future GIS-MCDM applications should state their spatial criteria, decision rules, and sensitivity analyses clearly.

Keywords: energy facility site selection; GIS; MCDM; systematic literature review; bibliometric mapping; renewable energy planning

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1. Introduction

Decisions the spatial allocation of power generation facilities exerts a significant influence on technical performance, economic feasibility, environmental compatibility, and societal acceptance of energy systems. Site selection is a strategic planning decision that shapes the entire lifecycle of power generation projects (Islam et al., 2024). Inappropriate siting leads to reduced energy yield, land use conflicts, environmental degradation, and prolonged regulatory processes (Wati & Meukam, 2024), making systematic and methodologically defensible approaches essential (Rekik & El Alimi, 2024a). The spatial allocation of power generation facilities exerts a significant influence on technical performance, economic feasibility, environmental compatibility, and societal acceptance of energy systems. Site selection is a strategic planning decision that shapes the entire lifecycle of power generation projects (Islam et al., 2024). Inappropriate siting leads to reduced energy yield, land use conflicts, environmental degradation, and prolonged regulatory processes, making systematic and methodologically defensible approaches essential (Rekik & El Alimi, 2024a; Wati & Meukam, 2024). Under the global energy transition, accelerated renewable energy deployment driven by international commitments to decarbonization and energy security has made effective siting more critical than ever

(Hasti et al., 2023). Unlike fossil fuel plants, renewable energy systems depend on spatially heterogeneous natural resources, where solar PV installations rely on solar irradiance, land availability, and grid proximity, while wind energy development is governed by wind speed distribution, topography, and environmental exclusion zones (Kocabaldır & Yücel, 2023; Saeidi et al., 2023). Suboptimal siting in densely populated or environmentally sensitive landscapes can undermine technical performance and generate social and regulatory resistance (Yildiz, 2024). Beyond conventional technologies, emerging systems including offshore wind, hybrid configurations, and marine-based renewables introduce additional spatial complexity that demands integration of resource evaluation, spatial optimization, and multi-criteria evaluation frameworks (Chisale & Lee, 2024; Yousefi et al., 2024). As a result, power plant site selection has evolved from a technical optimization task into a multidimensional challenge that must reconcile technical, environmental, economic, and sociopolitical criteria within a unified analytical framework (Romero-Ramos et al., 2023; Uyan & Ertunç, 2023).

Geographic Information Systems (GIS) have become increasingly central to spatial planning in the energy sector, with a growing body of research demonstrating their value in supporting site selection decisions for power generation facilities (Cook & Pétursson, 2025). Studies consistently show that GIS-based approaches allow planners to evaluate large geographic areas under multiple spatial constraints, making them a widely adopted tool in energy infrastructure planning (Shao et al., 2024). Research has increasingly combined GIS with Multi-Criteria Decision-Making (MCDM) methods to strengthen the analytical basis of site selection. This integration has gained traction because single-method spatial approaches are often insufficient for addressing the complexity of real-world planning decisions. By incorporating expert judgment and multiple competing criteria, GIS-MCDM studies produce more transparent and reproducible siting outcomes across diverse planning contexts (Flora, 2025; R. Kumar & Pamucar, 2025; Zandi et al., 2025).

The methodological orientation of GIS-MCDM research has shifted considerably over the past two decades, moving from deterministic and rule-based approaches toward fuzzy and hybrid models that better handle uncertainty and complexity in spatial data and expert judgment (Shao et al., 2023; Shehab et al., 2024; Yousefi et al., 2022). Sectorally, this line of research has expanded well beyond its origins in solar and wind energy. While these two sectors continue to dominate the literature due to their rapid global deployment and strong spatial resource dependence (Wang et al., 2023; Yaman, 2024), more recent studies have extended GIS-MCDM applications into offshore wind, hybrid renewable configurations, wave and tidal energy, and biogas production, each introducing distinct spatial and environmental planning considerations (Karipoğlu et al., 2023; Shao et al., 2024).

Geographically, GIS-MCDM research remains concentrated in a small number of regions, particularly parts of Asia and the Middle East where renewable energy investment and spatial data availability are relatively high (Hasti et al., 2023; Islam et al., 2024). Many other regions remain underrepresented, which limits the generalizability of existing findings (Zandi & Lotfata, 2025). Studies published after 2020 reflect a growing emphasis on hybrid and fuzzy approaches and the incorporation of emerging technologies such as hydrogen systems (Flora, 2025; R. Kumar & Pamucar, 2025). Despite this growth, the literature remains fragmented across technology-specific and region-specific case studies with varied criteria and methods, making broader comparisons difficult and constraining the development of generalizable insights regarding dominant approaches, geographic coverage, and sectoral evolution (Cook & Pétursson, 2025).

Although several reviews have examined GIS and MCDM applications in renewable energy planning, most focus on specific sectors or limited time periods, leaving important dimensions insufficiently explored (Shao et al., 2020). Many do not include studies published after 2023, and only a few consider

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methodological, geographic, and sectoral patterns within a single integrated framework. At the same time, the growing use of hybrid energy systems, offshore renewable technologies, and hydrogen related applications has introduced new spatial planning challenges that earlier reviews have not fully captured, while recent advances in fuzzy logic and hybrid MCDM models have further expanded methodological diversity (R. Kumar & Pamucar, 2025). These gaps highlight the need for a more comprehensive and up to date synthesis of GIS and MCDM applications in power plant site selection.

This review examines GIS-MCDM studies of energy-facility site selection published between 2023 and 2025. It identifies the MCDM methods used, the years and settings of the included studies, the types of facilities examined, and the site selection criteria reported (Figure 1). The review addresses four research questions:

RQ1: Which MCDM methods are most commonly used in GIS-based energy facility site selection?
RQ2: How are the included energy-facility siting studies distributed by publication year and study location?
RQ3: Which energy facility types are examined most often, and how are they distributed by publication year?
RQ4: Which site selection criteria are reported most often across the included studies?

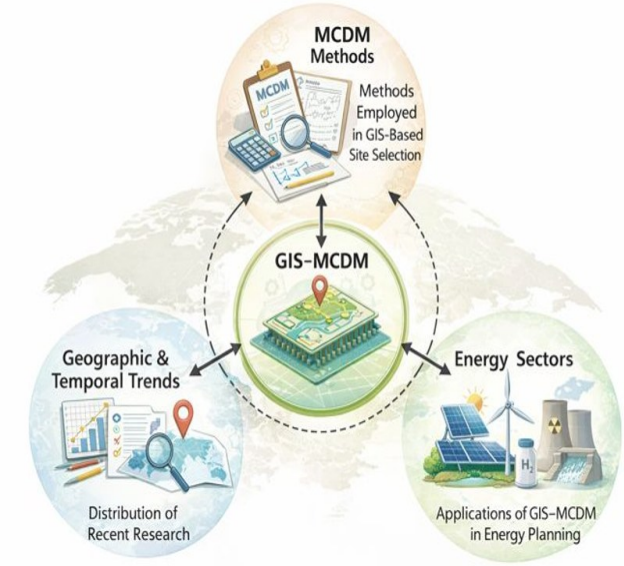


Figure 1. Conceptual framework for GIS-MCDM energy facility site selection

2. Material and methods

This study adopts a Systematic Literature Review (SLR) to examine, evaluate, and synthesize empirical evidence on the application of Geographic Information Systems (GIS) integrated with Multi-Criteria Decision-Making (MCDM) approaches in energy facility site selection (Amjad et al., 2025; Hafida et al., 2025; W. Li et al., 2025). The review follows PRISMA guidelines (Page et al., 2021) and applies a four-stage workflow consisting of identification, screening, eligibility, and inclusion to systematically filter relevant studies. The Scopus search combined site-selection, GIS-MCDM, and energy-technology terms, as detailed in Table 1, backward reference checking was also used to identify additional eligible studies. The selected articles were then analysed using qualitative thematic narrative synthesis to identify recurring patterns in GIS techniques, dominant MCDM methods, and spatial criteria used in decision making, while bibliometric mapping with VOSviewer was employed to reveal the intellectual structure and temporal evolution of this research stream. This mapping illustrates the

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progression of GIS MCDM applications over time and highlights the energy sectors that most frequently adopt these approaches, including wind, solar, thermal, and geothermal systems (Aziz et al., 2025; Demir et al., 2024). Although the use of PRISMA improves methodological transparency, predefined inclusion and exclusion criteria may unintentionally omit relevant evidence that falls outside conventional quality thresholds (Shamseer et al., 2015), and the emphasis on established GIS MCDM techniques may also limit attention to emerging or less conventional decision-making frameworks that could provide additional insights for energy facility site selection.

2.1 Data and search strategy

The bibliographic search was conducted using the Scopus database. Publisher information was extracted solely for descriptive reporting based on Scopus metadata. The complete search strings, filter settings, and search date are provided in Table 1.

Table 1. Database search configuration for systematic review

Data Source	Description
Scopus	Journal articles indexed in Scopus, with publisher metadata including Elsevier, MDPI, Springer, Wiley, IEEE, Taylor and Francis, and SAGE
Initial keyword search	(TITLE-ABS-KEY ("site selection" OR "site suitability" OR "suitability analysis" OR "location selection" OR siting) AND ("power plant" OR "power station" OR "electricity generation" OR "renewable energy" OR "solar farm" OR "photovoltaic plant" OR "wind farm" OR hydropower OR "hydro power" OR "biomass plant" OR geothermal) AND ("GIS" OR "geographic information system*" OR geospatial OR "spatial analysis" OR "spatial decision support") AND ("multi-criteria" OR "multi criteria" OR MCDM OR MCDA OR "multi-criteria decision" OR AHP OR ANP OR TOPSIS OR VIKOR))
Keyword search (with restrictions)	(TITLE-ABS-KEY ("site selection" OR "site suitability" OR "suitability analysis" OR "location selection" OR siting) AND ("power plant" OR "power station" OR "electricity generation" OR "renewable energy" OR "solar farm" OR "photovoltaic plant" OR "wind farm" OR hydropower OR "hydro power" OR "biomass plant" OR geothermal) AND ("GIS" OR "geographic information system*" OR geospatial OR "spatial analysis" OR "spatial decision support") AND ("multi-criteria" OR "multi criteria" OR MCDM OR MCDA OR "multi-criteria decision" OR AHP OR ANP OR TOPSIS OR VIKOR) AND PUBYEAR >= 2023 AND PUBYEAR <= 2025 AND (LIMIT-TO (DOCTYPE , "OR")) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (SRCTYPE , "j")) AND (LIMIT-TO (PUBSTAGE , "final"))
Timeframe and Language	2023 – 2025, English articles

2.2 Inclusion and exclusion criterion

The bibliographic search focused on English-language journal articles indexed in Scopus from 2023 to 2025. Studies were eligible when GIS-MCDM supported a spatial siting decision for an energy facility. For this review, energy facilities include generation, conversion, storage, distribution, and energy-coupled end-use applications in which energy-related criteria form part of the location analysis. Table 2 states the inclusion and exclusion rules used for the 87-study list.

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Table 2. Inclusion and exclusion criteria for article screening

Criteria	Inclusion (accepted articles)	Exclusion (rejected articles)
Publication Type and Stage	Original research articles published in scientific journals that have gone through the final publication stage.	Editorials, conference proceedings, book series, trade journals, and articles still in press.
Language	Articles published in English.	Articles published in languages other than English.
Time Frame	Articles published between 2023 and 2025.	Articles published before 2023.
Keywords and Scope	GIS-MCDM studies of site selection for generation, conversion, storage, distribution, or energy-coupled end-use facilities.	Studies without a spatial siting decision for an energy facility or without GIS-MCDM analysis.
Research Method	Empirical studies (quantitative, qualitative, or mixed-methods).	Conceptual papers or articles without empirical data, such as review articles.
Relevance of Research Focus	Articles that evaluate energy-related criteria in selecting an energy facility location.	Studies whose primary decision does not concern an energy facility location
Data Quality	Clearly defined objectives, detailed methodology, and measurable outcomes.	Unclear research design, low data quality, or insufficient reporting.

Following the application of these criteria, the retrieved records were refined by removing duplicates and subsequently screened and selected using the PRISMA flow process, as summarized in Figure 2. This process ensures that only studies that meet the predefined inclusion criteria are included for further analysis.

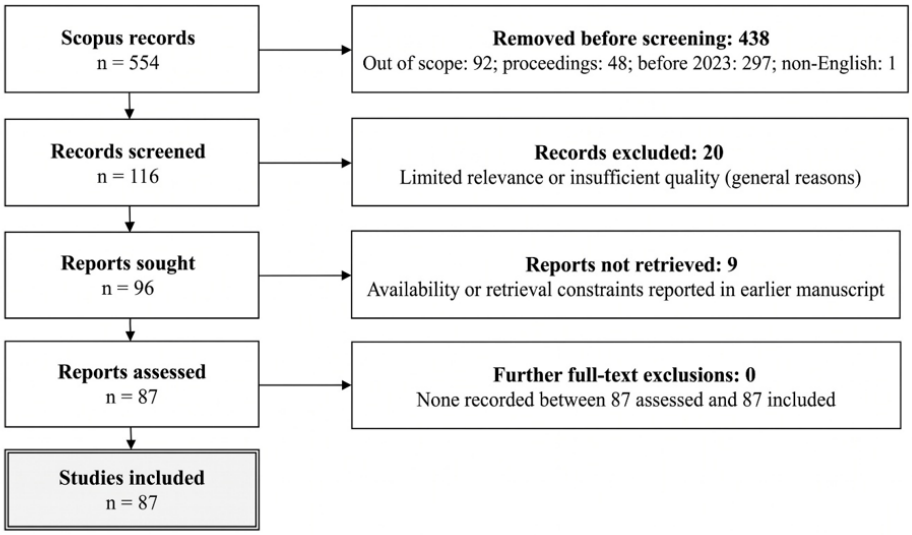


Figure 2. PRISMA flowchart for GIS-MCDM energy facility site selection

Figure 2 reports 554 Scopus records, 438 records removed before screening, 116 screened records, and 20 screening exclusions. Of 96 reports sought, nine were recorded as not retrieved; 87 reports were assessed and included. The original figure repeated the nine as full-text exclusions, which would incorrectly reduce the final total to 78. Reasons for the nine unretrieved reports were not available in the supplied records. The original publisher totals sum to 87: Elsevier 52, MDPI 16, Springer 13, Wiley three, and IEEE, Taylor & Francis, and SAGE one each.

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2.3 Quality assurance

The available material includes eligibility questions and a final 87-record recap but no archived study-level appraisal scores or assessor-agreement results. Table 3 is therefore treated as a reporting checklist. No numerical quality threshold, independent dual screening, or quality-based exclusion is inferred from the material supplied for this revision.

Table 3. Reporting-quality criteria for evaluating studies

Reporting domain	Operational description
Decision problem	The facility, location, and siting objective can be identified.
GIS and MCDM integration	The spatial workflow and the role of each named decision method are described.
Criterion reporting	The spatial criteria and any exclusions are named clearly enough for coding.
Method reporting	Weight derivation, ranking, and uncertainty procedures are described where used.
Output reporting	The suitability map, selected sites, or other location outcome is reported.

The checklist in Table 3 describes what should be reported for a study to be coded. It does not establish risk of bias or a comparative quality score. The descriptive synthesis below uses the author-supplied study list, the original citation-linked method table, and the numbered criterion references. Coding and eligibility decisions that cannot be reconstructed from these sources remain identified as limitations.

2.4 Data analysis technique

For RQ1, the unit was a unique study matched from each Mendeley citation in the original method table to one of the 87 listed records; a study could use several methods. RQ2 used publication year and study setting, with Tibet harmonised to China and Kurdistan Province to Iran. RQ3 assigned one primary facility type per record using the labels in the supplied recap. RQ4 counted each criterion once per referenced study, allowing several criteria per study. Percentages for every category use 87 as the denominator; method and criterion percentages need not sum to 100%. The retained sources are examples of GIS-MCDM research, not evidence for this review's coded (Benti et al., 2023; Chai et al., 2024; Feloni & Karandinaki, 2021).

A VOSviewer keyword overlay was available in the reviewed manuscript. The raster image shows a colour scale for average publication year, but the supplied files do not include the VOSviewer project, keyword threshold, counting settings, or normalisation record. The map is therefore used as a descriptive illustration only. The retained references concern GIS-based applications and bibliometric context (Abdi et al., 2025; Zandi & Lotfata, 2025). Results were summarised with counts and percentages by publication year. We did not estimate pooled effects or rank the effectiveness of MCDM methods because the records describe different decision problems and outcomes. The keyword map is interpreted separately from the study-level sector and method counts.

3. Results and discussion

The descriptive analysis covers 87 included studies. Figure 3 groups them by publisher: Elsevier (52 studies), MDPI (16), Springer (13), Wiley (3), and IEEE, Taylor & Francis, and SAGE (1 each). These counts account for all 87 studies. Sections 3.1 to 3.4 then address RQ1 (MCDM methods), RQ2

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(publication years and study locations), RQ3 (energy sectors), and RQ4 (site selection criteria), respectively.

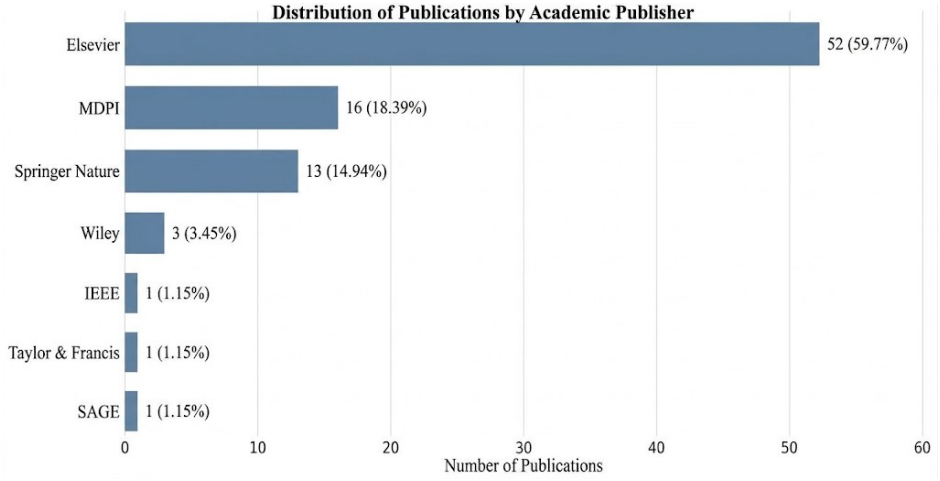


Figure 3. Publisher distribution of the selected power plant site selection studies

3.1 RQ1. MCDM methods

The original Table 4 contains active Mendeley citations for the studies assigned to each method. Matching those citation records to the 87-item list yields 60 studies using AHP (68.97%), 14 using TOPSIS (16.09%), and ten using fuzzy AHP (11.49%). These are frequencies of reported method use, not evidence that one method produces better sites. The original discussion cited broader reviews and method examples (Mahmudah et al., 2024; Sánchez-Lozano et al., 2022).

Methods were reported in different roles. AHP and related pairwise-comparison variants commonly derived weights; TOPSIS and other compromise methods ordered candidate locations. Some studies combined weighting and ranking methods. The references retained in this paragraph provide background context; the frequencies above come from the study identities linked in Table 4 (Khanlari & Alhuyi Nazari, 2022; A. Kumar et al., 2017; Nzotcha et al., 2019; Pohekar & Ramachandran, 2004).

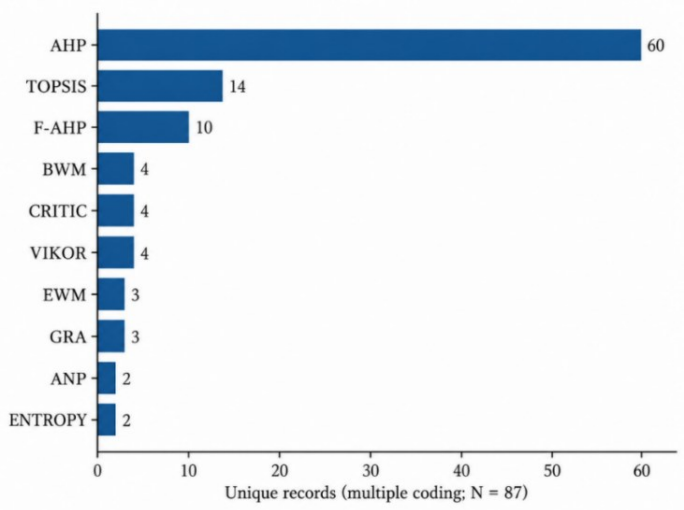


Figure 4. Publication trend of the selected power plant site selection studies by year

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GIS overlays spatial data and exclusion zones, while MCDM assigns priorities or compares candidate locations. The 34 labels in Table 4 include distinct methods and variants; related variants were kept separate to match the citation-linked rows. The percentage denominator is 87 even though a paper may contribute to more than one row (Shao et al., 2020; Tarife et al., 2023).

Table 4. MCDM methods, unique study counts, and source citations (N = 87)

Method, n (% of 87)	Reference
AHP 60 (68.97%)	(Akay, 2025; Amsharuk & Łaska, 2023, 2024; Asadi, Pourhossein, & Mohammadi-Ivatloo, 2023; Asadi, Pourhossein, Noorollahi, et al., 2023; Asadi, Ramezanzade, et al., 2023; Başeğmez, 2025; Bawazir et al., 2023; Bertsiou et al., 2025; Bimenyimana et al., 2024; Boonman et al., 2025; Can et al., 2024; Chai et al., 2024; Chouhan et al., 2024; Demir et al., 2023, 2024; Dinçer et al., 2024, 2025; Eslami et al., 2023; Ghiyas et al., 2025; Ghosh et al., 2024; Girma et al., 2025; Hafida et al., 2025; Hasti et al., 2023; Hauger et al., 2025; Imam et al., 2024; Islam et al., 2024; Jbaihi et al., 2024; Kocabaldır & Yücel, 2023; Y. Li et al., 2025; Liao et al., 2025; Mbufua et al., 2025; Nassar et al., 2025; Rane et al., 2024; Raza et al., 2023; Reher et al., 2025; Rekik & El Alimi, 2023, 2024b; Romero-Ramos et al., 2023; Salih et al., 2024; Saraswat et al., 2024; Shao et al., 2023, 2024; Shehab et al., 2024; Shi et al., 2025; Sun et al., 2025; Tarife et al., 2023; Tian et al., 2024; Vasudevan et al., 2024; Wati & Meukam, 2024; Yaman, 2024; Yang et al., 2025; Yegizaw & Mengistu, 2023; Yildiz, 2024; Yousefi et al., 2024; Yu et al., 2025; Yum & Das Adhikari, 2023)
ANP 2 (2.30%)	(Uyan & Dogmus, 2023)
BWM 4 (4.60%)	(Amjad et al., 2025; Gumussoy et al., 2024; Shafii et al., 2025; Uyan & Ertunç, 2023)
CRITIC 4 (4.60%)	(Abdi et al., 2025; S. Kumar et al., 2024; Luhaniwal et al., 2025; Shao et al., 2023)
DEA 1 (1.15%)	(Shafii et al., 2025)
EDAS 1 (1.15%)	(Rekik & El Alimi, 2024a)
ENTROPY 2 (2.30%)	(S. Kumar et al., 2024; Liu et al., 2024)
EWM 3 (3.45%)	(Başeğmez, 2025; Sun et al., 2025; Yu et al., 2025)
F-AHP 10 (11.49%)	(Arca et al., 2023; Aziz et al., 2025; Chisale & Lee, 2024; Jbaihi et al., 2024; Karipoğlu et al., 2023, 2024; Kaynak & Gümüş, 2025; Rekik & El Alimi, 2024a; Tang et al., 2024; Yilmaz et al., 2024)
F-MARCOS 1 (1.15%)	(G. Demir et al., 2024)
F-SWARA 1 (1.15%)	(G. Demir et al., 2024)
F-TOPSIS 2 (2.30%)	(Karipoğlu et al., 2023; Saeidi et al., 2023; Tang et al., 2024)
G-AHP 1 (1.15%)	(Shao et al., 2023)
G-CRITIC 1 (1.15%)	(Zhao et al., 2024)
GIAHP 1 (1.15%)	(Shao et al., 2025)
GRA 3 (3.45%)	(Luhaniwal et al., 2024; Shafii et al., 2025; Zhao et al., 2024)
GTMA 1 (1.15%)	(Luhaniwal et al., 2024)
IF 1 (1.15%)	(Luhaniwal et al., 2024; Şahin et al., 2024)
IF-AHP 1 (1.15%)	(Gökler, 2025)
MAIRCA 1 (1.15%)	(Abdi et al., 2025)
MARCOS 1 (1.15%)	(S. Kumar et al., 2024)
MAUT 1 (1.15%)	(Saraswat et al., 2024)
MEREC 2 (2.30%)	(R. Kumar & Pamucar, 2025; Shao et al., 2025)
MULTIMOORA 1 (1.15%)	(Malinić et al., 2025)
PF-AHP 1 (1.15%)	(Gökler, 2025)
PROMETHEE 1 (1.15%)	(Mbufua et al., 2025)
SAW 2 (2.30%)	(Nwaiwu et al., 2023; Shehab et al., 2024)
SWARA 1 (1.15%)	(Liu et al., 2024)
TODIM 1 (1.15%)	(Liu et al., 2024)
TOPSIS 14 (16.09%)	(Amsharuk & Łaska, 2023, 2024; Gumussoy et al., 2024; Hasti et al., 2023; Kaynak & Gümüş, 2025; Luhaniwal et al., 2025; Malinić et al., 2025; Saraswat et al., 2024; Shafii et al., 2025; Shi et al., 2025; Sun et al., 2025; Tian et al., 2024)
VIKOR 4 (4.60%)	(Luhaniwal et al., 2024; Shao et al., 2023; Sun et al., 2025; Yu et al., 2025)
WASPAS 1 (1.15%)	(Saraswat et al., 2024)

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AHP accounted for 60 unique studies, followed by TOPSIS (14) and fuzzy AHP (10). The citation-linked Table 4 differs from the shorter method list in the separate recap, which lists 54, 11, and nine, respectively. This revision uses the manuscript's active citations because all cited method entries could be linked to the 87-study list. Method combinations are counted in each applicable row (Ayough et al., 2022; Boonmee & Tanpruttianunt, 2026; Dehe & Bamford, 2015; Höfer et al., 2016; Malinić et al., 2025; Opricovic & Tzeng, 2004; Pohekar & Ramachandran, 2004; Prieto-Amparán et al., 2021; Rezaei, 2015).

The distribution is descriptive. Frequent use of AHP shows what the authors chose in this set of articles; it cannot establish accuracy, stability, or superiority. Comparisons would require common alternatives, criteria, and validation data across studies. The retained sources discuss GIS-MCDM and decision support more generally (Shao et al., 2020; Sotiropoulou & Vavatsikos, 2021).

Weighting methods assign relative importance to criteria. Ranking methods compare candidate sites after performance values and weights are combined. Fuzzy extensions represent imprecise preferences or inputs and can be applied at either stage. These functions should be reported separately when one study combines several techniques. In an AHP-based analysis, pairwise comparisons produce a set of criterion weights. Those weights express the decision maker's priorities for factors such as resource potential, slope, road access, and grid connection. They do not by themselves show that the final map is insensitive to changes in judgement (Farsi et al., 2024). A ranking procedure orders discrete alternatives or suitable zones after criterion values have been assembled. TOPSIS, VIKOR, PROMETHEE, and other methods use different comparison rules, so a paper should state both how it weighted criteria and how it ranked sites. AHP can supply weights to a later ranking step, as the retained citation discusses in its application.

Handling uncertainty in MCDM-based siting decisions involves several recurring challenges reported across the reviewed literature. One major difficulty is the inherent ambiguity and subjectivity embedded in both the criteria framework and the importance assigned to each criterion. Because weights are frequently derived from expert judgment, the process can introduce bias and vagueness that propagate into the final suitability outcomes (Chen Jong & Mohamud Ahmed, 2024) . To address this, some studies apply fuzzy set theory to represent imprecise inputs and subjective preferences more flexibly, allowing decision-makers to express evaluations in a way that better reflects real-world uncertainty (Dheena & Mohanraj, 2011).

A second challenge concerns model sensitivity and stability. MCDM outputs can change substantially under small perturbations in assumptions, which may undermine confidence in the resulting site ranking. This issue has motivated the integration of simulation-based strategies, such as Monte Carlo methods, to quantify uncertainty and improve the reliability of decision outcomes (Cui et al., 2023). Relatedly, uncertainty often exists simultaneously in both criteria performance values and the associated weights. Stochastic frameworks such as SMAA–TOPSIS have been proposed to explicitly model this dual uncertainty and to produce rankings that are more risk-informed and statistically robust (F. Zhu et al., 2018).

Beyond technical uncertainty, the literature also highlights human and temporal factors. Experts operate under bounded rationality, and the relevance or credibility of evidence may shift over time as new information becomes available. Time-aware approaches, including time-series-based evidential reasoning, have therefore been used to update expert evidence dynamically and reduce subjectivity as the decision context evolves (Fang & Liao, 2021). Collectively, these challenges support the broader need for uncertainty-aware MCDM designs that not only quantify imprecision, but also enhance robustness, transparency, and decision defensibility in siting applications.

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3.2 RQ2. Publication year and study setting

Turkey is the most common study setting (22 records), followed by China (15), India (seven), and Iran (six). The raw recap lists China as 14 and Tibet as one; those were combined for country reporting. It also lists Iran as five and Kurdistan as one. The Kurdistan article identifies Kurdistan Province, Iran, so the country total is six. Table 5 gives year-specific counts. The other 37 studies cover 27 settings after those country labels and "Marocco" are harmonised. Table 5 combines those settings in one row; the complete location coding remains in the extraction recap. These are study locations, not author affiliations. One publication can address a location without representing national research output, so the pattern should be interpreted as case-study coverage only.

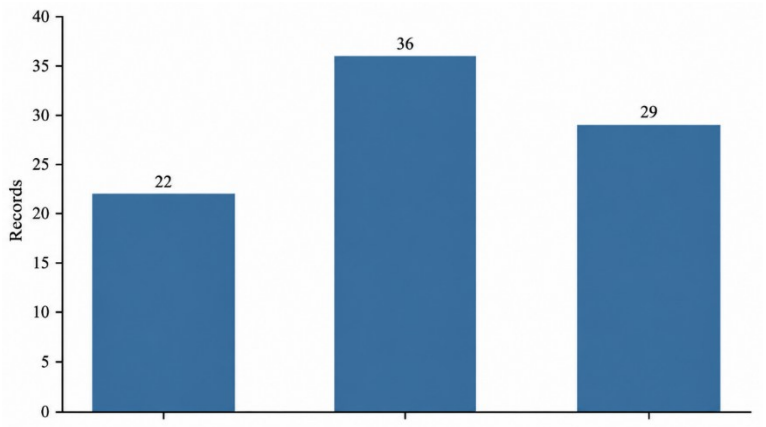


Figure 5. Publication years in the author-supplied 87 included studies

Publication counts for the 87 included studies were 22 in 2023 (25.29%), 36 in 2024 (41.38%), and 29 in 2025 (33.33%). The count was highest in 2024 (Figure 5). These figures describe the studies captured by the stated search limits and do not establish a long-term growth trend in the field.

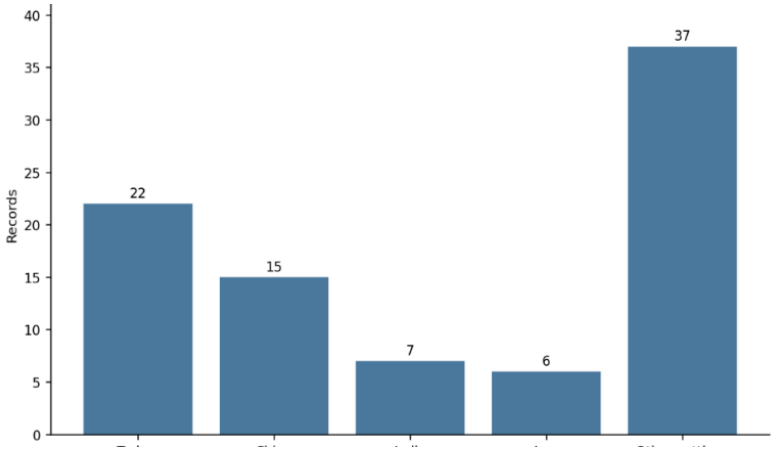


Figure 6. Study locations of the 87 included studies (2023–2025)

Across the 87 included studies, Turkey was the most frequently examined setting (n = 22), followed by China (n = 15), India (n = 7), and Iran (n = 6; Figure 6). For country-level reporting, the record labelled Tibet was counted under China and the Kurdistan Province record under Iran. Table 5 reports study locations by publication year. The remaining 37 studies cover 27 settings after spelling and country labels were standardised. These counts describe the locations examined in the studies, not the authors' institutional affiliations or national research output.

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Table 5. Leading study settings and other locations by publication year (N = 87)

Setting	2023	2024	2025	Total
Turkey	8	8	6	22
China	1	7	7	15
India	0	6	1	7
Iran	4	1	1	6
Other settings	9	14	14	37

3.3 RQ3. Energy sectors

Using one primary sector per study, solar accounted for 31 records (35.63%), wind for 22 (25.29%), and hybrid renewable systems for 15 (17.24%). Concentrated solar power was coded as solar, and the source label "Windy Energy" was standardised as wind. Table 6 reports sector counts by publication year, and Figure 7 shows the sector totals.

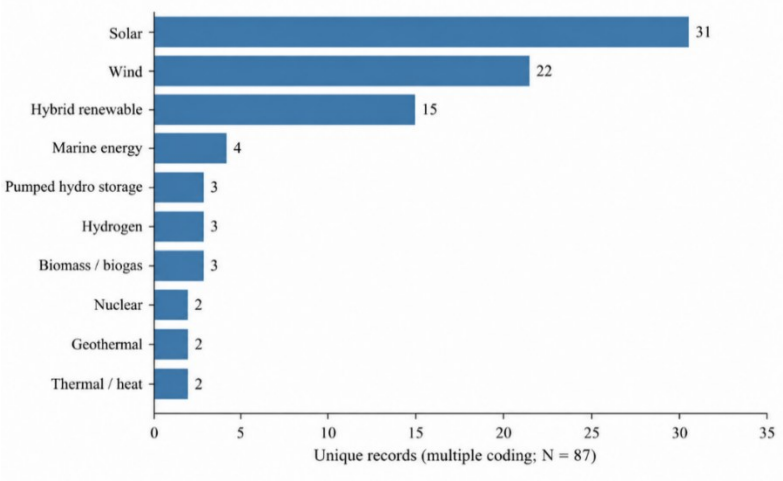


Figure 7. Primary energy-sector labels in the supplied 87 included studies

The other sectors were marine energy (n = 4), hydrogen (n = 3), pumped hydro storage (n = 3), biomass or biogas (n = 3), geothermal (n = 2), nuclear (n = 2), and thermal or heat systems (n = 2). The hybrid category includes a solar/wind-powered desalination facility.

Table 6. Primary energy sector labels in the supplied list (classification pending; N = 87)

Sector	2023	2024	2025	Total
Solar	8	13	10	31
Wind	4	12	6	22
Hybrid renewable	5	5	5	15
Marine energy	1	3	0	4
Pumped hydro storage	0	0	3	3
Hydrogen	0	2	1	3
Biomass / biogas	1	0	2	3
Nuclear	0	0	2	2
Geothermal	1	1	0	2
Thermal / heat	2	0	0	2

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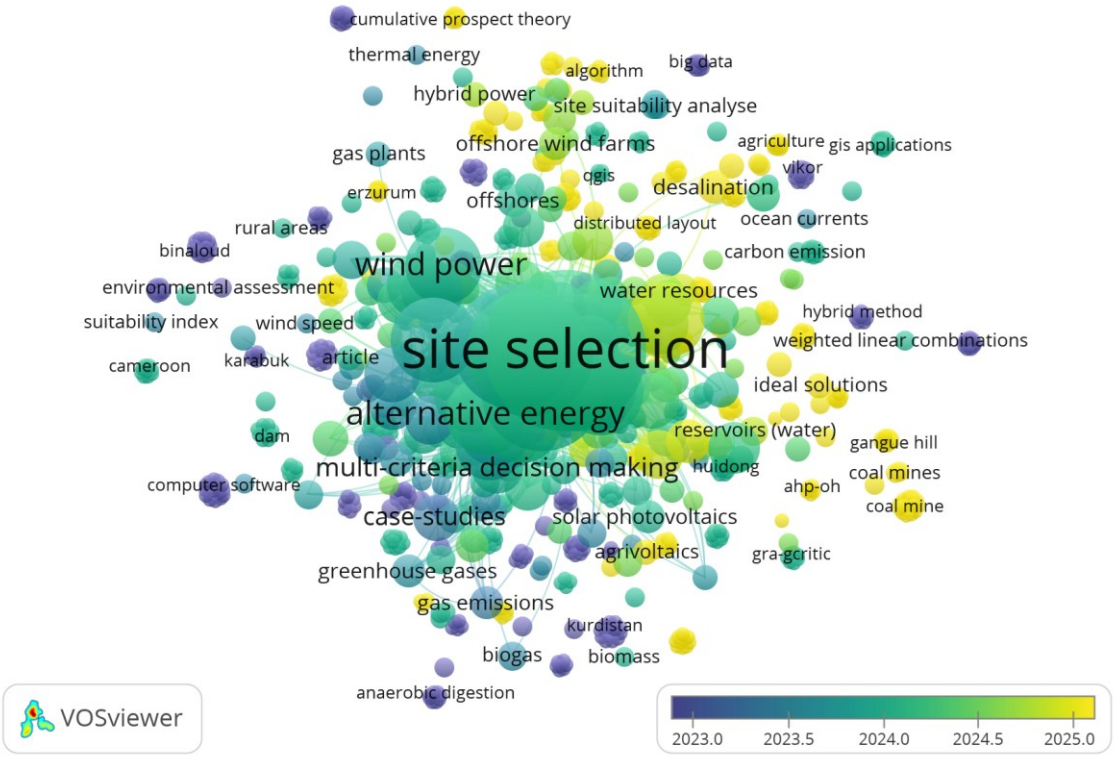


Figure 8. Keyword co-occurrence overlay

Figure 8 shows a VOSviewer keyword co-occurrence overlay. Larger nodes represent more frequent keywords, links indicate co-occurrence, and colour represents average publication year. Yellow terms have a later average publication year than purple terms on the displayed scale. Keywords such as "desalination" and "coal mine" appear in the map, but keyword labels alone cannot determine study eligibility or establish a research trend.

Solar and wind are the largest primary sector groups, comprising 31 and 22 studies, respectively. Together, they account for 53 of the 87 included studies (60.92%). This proportion describes the composition of this review's 2023–2025 study set. Recent studies have examined the application of GIS-based multi-criteria decision analysis to renewable-energy planning, including a systematic review of location and design criteria for renewable-energy projects (Cook & Pétursson, 2025) and an integrated GIS-MCDA-AHP framework for solar and wind energy site selection (Nassar et al., 2025).

The smaller groups include marine energy (n = 4), hydrogen (n = 3), pumped hydro storage (n = 3), and nuclear energy (n = 2). Siting requirements differ by energy technology. Decision-making for marine energy has been reviewed in the context of multi-criteria decision-making applications, while solar–hydrogen production has been examined in related research (Flora, 2025). Nuclear power plant siting has also been investigated using multi-criteria decision-making and GIS-based approaches (Shafii et al., 2025; Susiati et al., 2025). Under the eligibility rule in Table 2, the solar/wind-powered desalination facility and district-heating application remain in the 87-study set as energy-coupled facilities, rather than being described as electricity-generation plants.

Related GIS-MCDM applications extend to electric-vehicle charging (W. Li et al., 2025). Other examples concern hydrogen infrastructure (Gül & Akyüz, 2026), power-to-gas conversion (Soha & Hartmann, 2022) , and pumped-storage siting (C. Zhu et al., 2026) . These examples provide context; the frequencies in Table 6 were calculated from the 87 included studies.

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3.4 RQ4. Site-selection criteria

The numbered criterion list in the recap was linked to the 87 study identities, with repeat references to the same paper counted once per criterion. Slope appears in 56 studies (64.37%), electrical-network proximity in 52 (59.77%), highway or road access in 49 (56.32%), residential areas in 47 (54.02%), and land use in 36 (41.38%). Table 7 reports the ten most frequent coded labels by year; the complete 27-label list remains in the extraction recap. Figure 9 groups selected labels conceptually and is not a frequency plot. The retained citations provide context for criterion selection.

Table 7. Ten most frequent siting criteria by publication year (multiple coding; N = 87)

Criterion	2023	2024	2025	Total	%
Slope	12	20	24	56	64.37
Proximity to Electrical Network	12	20	20	52	59.77
Highway and Road	11	21	17	49	56.32
Residental Area	8	20	19	47	54.02
Land Use	8	15	13	36	41.38
Elevation	4	12	12	28	32.18
Proximity to Protected Areas	4	10	13	27	31.03
Aspect	6	9	9	24	27.59
Source of water (waterbodies)	4	8	4	16	18.39
Proximity to Faults	3	5	7	15	17.24

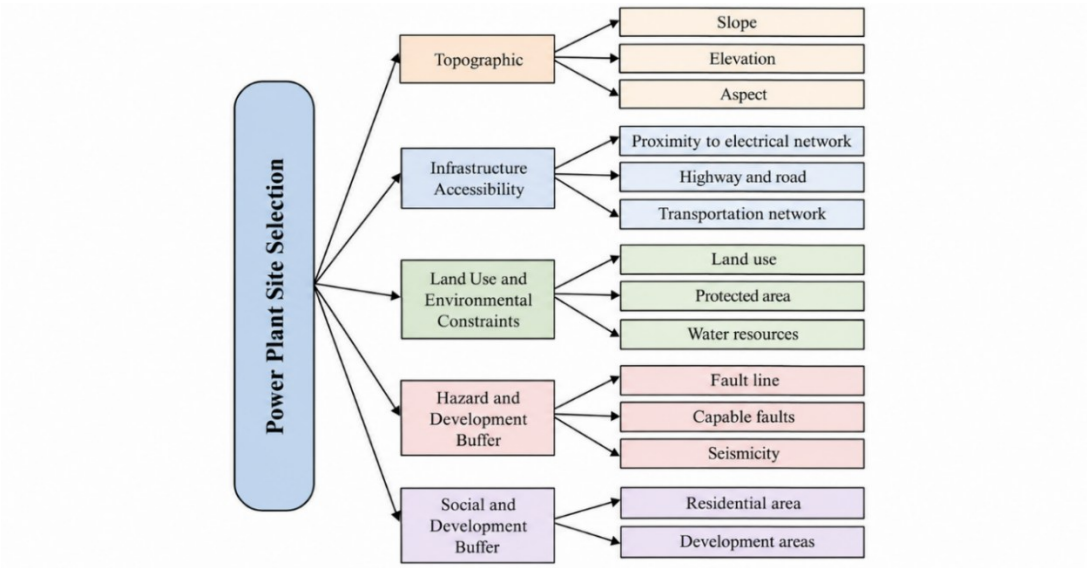


Figure 9. Conceptual grouping of selected siting criteria

Land use is consistently applied because power plant siting must avoid conflict with existing land functions and fit broader spatial planning and environmental conservation objectives (Tercan et al., 2021). Proximity to the electrical network and roads is repeatedly favored because suitability declines as facilities become more remote from substations and transport access, which increases interconnection and logistics burdens (Chen et al., 2026). Distance from residential areas is regularly incorporated because support for renewable and other power projects is strongly shaped by location, size, visual effects, and other place-based perceptions that influence local acceptance (Enserink et al., 2022). Protected areas are frequently screened or buffered because biodiversity related siting criteria are used to reduce ecological conflict and satisfy legal requirements in project development (Levin et

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al., 2025). Water related criteria become important where cooling or process water is operationally decisive, since adequate freshwater availability remains a key condition for reliable plant performance in water intensive technologies (Erdem et al., 2025). Taken together, these findings indicate that power plant siting through GIS and MCDM now relies on a recognizable common planning core, while still requiring contextual adjustment in response to local geography, regulation, and technology specific risk exposure (Wimhurst et al., 2023).

4. Conclusion

This review synthesised 87 GIS-MCDM studies of energy facility site selection published between 2023 and 2025. AHP appeared in 60 studies, TOPSIS in 14, and fuzzy AHP in ten; some studies used more than one method. The number of included studies was highest in 2024 (36), while Turkey was the most frequently examined setting (22). Solar (31), wind (22), and hybrid renewable applications (15) accounted for 68 of the 87 studies. Slope (56), proximity to electrical networks (52), road access (49), and proximity to residential areas (47) were the most frequently coded siting criteria.

These frequencies describe the methods and criteria reported in the included studies. They do not show which method produces better sites or which criterion should receive the greatest weight. The review also covers generation, storage, conversion, and energy-coupled facilities. Their technical requirements differ, so a criterion or decision rule used for one facility type cannot be transferred to another without examining its relevance and measurement.

The findings are bounded by the English-language Scopus search for 2023 to 2025 and the available coding of the 87 studies. Annual publication counts cannot establish long-term growth. In addition, the absence of archived study-level quality scores prevents the synthesis from weighting findings by methodological quality. Future reviews should retain screening decisions and study-level coding records. Primary GIS-MCDM studies should report criterion definitions, exclusion thresholds, weighting procedures, and sensitivity results so that their site rankings can be examined and compared.

Author's declaration

Author contribution

Reza Nugraha: Conceptualization, methodology, formal analysis, data curation, investigation, visualization, and writing - original draft. **Ade Gafar Abdullah**: Supervision, validation, project administration, and writing - review and editing. **Ade Karim**: Methodology, formal analysis, validation, and writing - review and editing. **Dimas Aulia Saputra**: Data extraction, bibliometric analysis, visualization, and writing - review and editing. **Navia Rahmalia Zahra**: Data extraction, literature screening, validation, and writing - review and editing. **Ida Hamidah**: Supervision, validation, resources, and writing - review and editing. **Nina Widiawati**: Validation, resources, and writing - review and editing.

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Data availability

The bibliographic data used in this study were obtained from the Scopus database. The search strategies, coding templates, extracted data, and decision logs supporting the findings of this systematic review are available from the corresponding author upon reasonable request.

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Conflict of interest

The authors declare that they have no conflicts of interest regarding the publication of this manuscript.

Ethical clearance

This research does not involve humans as subjects. The study is a systematic literature review based on previously published scientific literature and bibliographic data; therefore, ethical clearance and informed consent were not required.

AI statements

ChatGPT (OpenAI) was used only to assist with language refinement, including grammar, coherence, cohesiveness, and readability. All AI-assisted suggestions were manually reviewed and verified by the authors for accuracy and consistency with the original data, references, and intended scientific meaning. The authors remain fully responsible for the accuracy, integrity, and content of the manuscript. No AI tool was used to generate or analyse the research data.

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