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# A Systematic Review of integrated GIS and MCDM methodology for Wind Farm Site Selection: Trends, Methods, and Criteria

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**ABSTRACT**

Wind energy has emerged as one of the most promising renewable energy sources and a sustainable alternative to conventional fossil fuels. However, selecting suitable locations for wind farms is a complex process that depends on several factors, including social, technological, economic, and environmental aspects. Over the past decade, academics have increasingly employed combinations of Geographic Information Systems (GIS) and Multi-Criteria Decision-Making (MCDM) techniques to address the challenges of wind farm location selection. This tendency is reflected in the significant number of scholarly papers on the subject. To give researchers a state-of-the-art perspective and a thorough understanding of current approaches, a comprehensive review of 147 studies published between 2015 and 2025 was carried out. A constructed taxonomy that encompasses GIS software, application fields, uncertainty treatment, MCDM techniques, spatial resolution in GIS, and site selection criteria was used to classify the examined studies. The most popular MCDM techniques for criterion weighting and ranking of alternatives are the Analytical Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) methods. An examination of the criteria reveals that wind speed, slope, land use, distance from transmission lines, road proximity, environmental restrictions, and social acceptance are the most frequently considered factors during wind farm site selection. Identifying research gaps, improving modelling techniques, and facilitating well-informed decision-making in future wind energy development initiatives are all made possible by these classifications and insights.

## 1. Introduction

The importance of wind energy in reducing greenhouse gas emissions and mitigating the consequences of climate change is increasingly being recognized, making it one of the most promising renewable energy sources [1]. By providing a clean, reliable, and sustainable energy source, it increases energy security and reduces dependency on fossil fuels [2]. As nations strive to achieve

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sustainable development goals, wind power projects are becoming an essential part of overall clean energy initiatives. However, the careful selection of ideal locations is vital to wind farm success. Site selection is inherently complex and necessitates striking a balance between technological, economic, environmental, and social variables [3]. Environmental considerations include biodiversity, ecosystems, and land use, while technical factors include wind resource potential, grid connectivity, and turbine availability. Social factors deal with property ownership, community acceptability, and possible societal repercussions, while economic considerations are related to the costs of land and infrastructure. Therefore, a thorough and objective assessment of these variables is necessary to guarantee the long-term viability and effectiveness of wind-powered initiatives [4].

Multi-Criteria Decision-Making (MCDM) and Geographic Information Systems (GIS) techniques have become effective tools for choosing wind farm sites in response to these challenges, Diverse variables, including topography, land use, and wind speed, can be integrated and spatially analyzed within a single framework through GIS. Meanwhile, MCDM offers structured methods for evaluating and prioritizing various criteria, enabling decision-makers to handle trade-offs in a systematic manner. When combined, these techniques offer a robust framework for identifying potential wind farm locations.

This study reviews 150 publications published between 2015 and 2025 to identify important trends, methodological developments, and persistent challenges in wind farm site selection. The findings are categorized based on elements such as the use of GIS technology, uncertainty management, and regional applicability. In addition to highlighting the need for social acceptance and community involvement as crucial factors for project success, the study also identifies best practices, typical limitations, and research gaps. Ultimately, this assessment provides researchers and policymakers with valuable data that guide the development of improved frameworks for decision support, maximizing wind energy’s contribution to the creation of a sustainable energy future.

## 2. Methodology for selecting research papers

A systematic and structured methodology was used to locate, evaluate, and analyze the most relevant research articles on wind farm site selection using Geographic Information Systems (GIS) and MCDM approaches. This approach aimed to ensure a comprehensive and reproducible review of the literature that considers the evolving research patterns and methodological developments in the field. Peer-reviewed journal articles, conference proceedings, and systematic reviews published between 2015 and 2025; which include significant advancements in renewable energy planning and decision-support technology; were the only publications included in the review. Clear study objectives and guiding questions on the primary standards, methodological difficulties, and decision-making instruments utilized in GIS–MCDM-based wind farm site selection marked the start of the procedure. Boolean operators and a well-defined search string were used to find pertinent studies, combining key terms as follows: "wind farm site selection" AND ("Geographic Information System" OR "GIS") AND ("MCDM" OR "multi-criteria decision making") Included were only English-language studies that directly addressed GIS–MCDM applications in wind farm site selection and were published between 2015 and 2025. Articles without methodological rigor, those unrelated to site appropriateness assessment, and those published prior to 2015 were not included.

The selected papers underwent a comprehensive full-text examination following the first screening of titles and abstracts. Each paper was thoroughly examined, with particular attention paid to the analytical methods, geographical datasets, evaluation systems, and criteria for making decisions. After the data was extracted, it was categorized into subject groups that aligned with the objectives of the review. This allowed for a thorough synthesis of methodological approaches, research trends, knowledge gaps, and future research possibilities.

## 3. Statistical analysis of research publications on selection of wind farm sites

The selection of suitable sites for wind farms is an important field of renewable energy research that reflects the growing interest in sustainable energy solutions globally. The patterns, technique, and target areas found by a statistical analysis of research publications in this topic may serve as a guide for future studies and applications. The quantity of academic articles pertaining to the selection of wind farm sites has significantly increased over the last ten years. Numerous factors, such as technological breakthroughs, increased awareness of climate change, and the global push for renewable energy sources, are responsible for this rise. A thorough analysis of the literature reveals that 147 research in all were released between 2015 and 2025, demonstrating a strong body of work covering a range of site-related topics. Publication trends indicate a consistent rise in publications, with a notable surge in recent years, indicating increased scholarly interest and funding for wind energy research. A lot of research comes from areas like Europe and North America that have a lot of wind potential, but new markets in Asia and Africa are also starting to add to the body of knowledge. The approaches used in these investigations differ greatly, and a number of patterns are discernible. GIS are used in a significant number of studies to analyze spatial data, which enables researchers to properly evaluate numerous criteria and display possible places. To assess and rank potential locations based on a variety of factors, MCDM techniques are frequently employed. The intricate process of selecting a wind energy location is reflected in these studies, which usually include variables including wind speed, distance to transmission lines, land use, slope, accessibility to roads, environmental constraints, and societal acceptance. Despite significant advancements in the sector, some gaps still exist. Since many studies concentrate mostly on technical and environmental criteria, the integration of social variables is frequently limited. More thorough integration of social factors should be the goal of future studies. Furthermore, managing uncertainty in data and decision-making procedures, further research is necessary. The robustness of site selection results can be increased with better approaches to dealing with uncertainty. Additional comparative studies between various locations and methodology may provide insightful information about cutting-edge strategies and best practices. A dynamic and developing field that is essential to the advancement of renewable energy solutions is shown through this statistical examination of studies on the selection of wind farm locations. Through the identification of trends, methods, and gaps, this analysis demonstrates the present state of research and makes recommendations for future approaches that may increase the effectiveness of wind energy deployment. Continued study and development in this area will be necessary to meet the world's energy demands in a sustainable manner.

The temporal distribution of the 147 scientific publications released since 2015 is displayed in Figure 1. Due to the date of the database search, based on appearance frequency, research publications rose dramatically between 2015 and 2021. Each reviewed paper's authors conduct their research using a case study and offer a method for wind farm deployment.

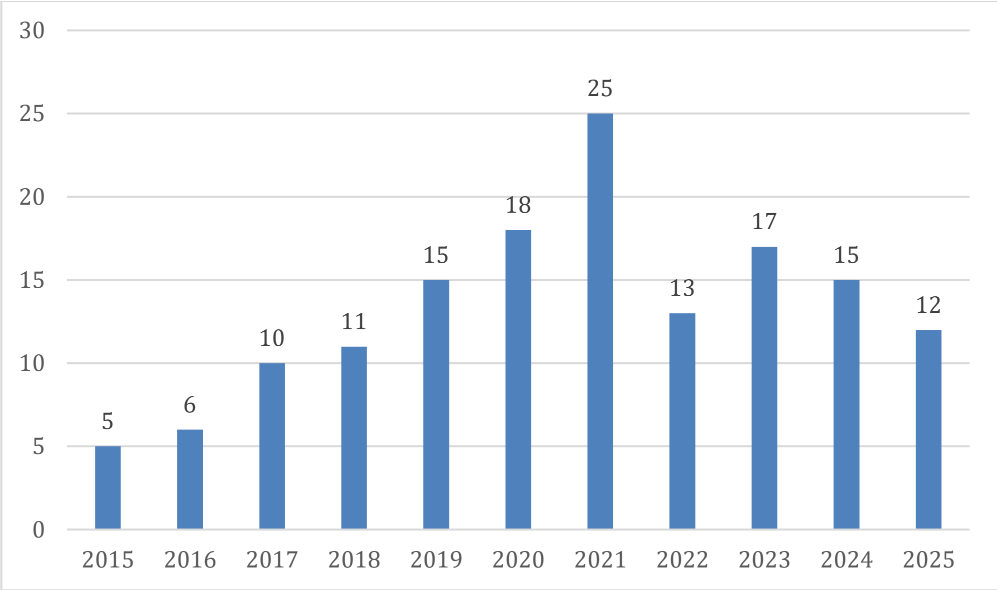


**Fig. 1**. Annual distribution of published papers

Table 1 displays the frequency and total number of publications for each of the 48 case study countries and global studies. The following four countries represent a substantial share of the research output, highlighting their importance in the context of the studies conducted: Turkey (23 articles), Iran (19 articles), Greece (9 articles), and China (7 articles).

**Table 1**
Countries in which the studies were conducted, along with the number of papers published from each country

| No | Country | Total articles | Ref. No. | No | Country | Total articles | Ref. No. |
|---|---|---|---|---|---|---|---|
| 1 | Algeria | 3 | [5] [6] [7] | 2 | Malaysia | 2 | [8] [9] |
| 3 | Global | 6 | [10] [11] [12] [13] [14] [15] | 4 | Mauritius | 2 | [16] [17] |
| 5 | Bangladesh | 1 | [18] | 6 | Mexico | 1 | [19] |
| 7 | Brazil | 1 | [20] | 8 | Morocco | 3 | [21] [22] [23] |
| 9 | Burundi | 2 | [24] [25] | 10 | Nigeria | 1 | [26] |
| 11 | Cameroon | 1 | [27] | 12 | Afghanistan | 1 | [28] |
| 13 | China | 7 | [29] [30] [31] [32] [33] [34] [35] | 14 | Middle-East | 1 | [36] |
| 15 | Kuwait | 1 | [37] | 16 | Qatar | 1 | [38] |
| 17 | Croatia | 1 | [39] | 18 | Saudi Arabia | 6 | [40] [41] [42] [43] [44] [45] |
| 19 | India | 1 | [46] | 20 | Serbia | 1 | [47] |
| 21 | Ecuador | 3 | [48] [49] [50] | 22 | South Africa | 2 | [51] [52] |
| 23 | Egypt | 1 | [53] | 24 | South Korea | 1 | [54] |
| 25 | Ethiopia | 1 | [55] | 26 | Spain | 3 | [56] [57] [58] |
| 27 | Poland | 2 | [59] [60] | 28 | Switzerland | 1 | [61] |
| 29 | Greece | 9 | [62] [63] [64] [65] [66] [67] [68] [69] [70] | 30 | Taiwan | 1 | [71] |
| 31 | Kenya | 1 | [72] | 32 | Vietnam | 4 | [73] [74] [75] [76] |
| 33 | Mozambique | 1 | [77] | 34 | Tunisia | 4 | [78] [79] [80] [81] |

**Table 1**
Continued

| No | Country | Total articles | Ref. No. | No | Country | Total articles | Ref. No. |
|---|---|---|---|---|---|---|---|
| 35 | Iran | 19 | [3] [82] [83] [84] [85] [86] [87] [88] [89] [90] [91] [92] [93] [94] [95] [96] [97] [98] [99] | 36 | Turkey | 23 | [100] [101] [102] [103] [104] [105] [106] [107] [108] [109] [110] [111] [112] [113] [114] [115] [116] [117] [118] [119] [120] [121] [122] |
| 37 | Iraq | 5 | [123] [124] [125] [126] [127] | 38 | United Kingdom | 4 | [128] [129] [131] [132] |
| 39 | Libya | 6 | [133] [134] [135] [136] [137] [138] | 40 | Azerbaijan | 2 | [139] [140] |
| 41 | Pakistan | 1 | [141] | 42 | USA | 1 | [130] |
| 43 | Colombia | 1 | [142] | 44 | Thailand | 2 | [143] [144] |
| 45 | Philippines | 2 | [145] [146] | 46 | Ghana | 1 | [147] |
| 47 | Sudan | 1 | [148] | 48 | Red Sea | 1 | [149] |
| 49 | Hong Kong | 1 | [150] | | | | |

To help practitioners and academics navigate complicated data and make well-informed decisions, a variety of methodologies have been developed in the subject of decision-making. GIS are the most often used method, with 125 research articles employing this technique, underscoring its importance in spatial analysis and decision support. GIS is particularly pertinent for site selection in a variety of applications since it offers crucial insights into geographical and environmental factors.

MCDM is helpful for prioritizing by evaluating potential solutions based on a range of environmental, social, and economic considerations it is covered in 97 articles following GIS in 125 articles. Furthermore, the Analytic Hierarchy Process (AHP) is well-known for its hierarchical framework, which has been applied in 95 studies to facilitate challenging decision-making circumstances. Additional approaches like TOPSIS, fuzzy logic, and different optimization techniques like BWM and PROMETHEE further highlight the variety of approaches that can be used to address the complex problems of decision-making. This variety emphasizes how crucial it is to use the right approach in order to guarantee long-lasting and efficient results. The analytical techniques used in the examined research are compiled in Table 2 along with the number of articles that used by each technique.

**Table 2**
Analytical techniques used in the reviewed studies and the number of publications for each technique

| No | Methods Used | Total articles | No | Methods Used | Total articles |
|---|---|---|---|---|---|
| 1 | GIS | 125 | 13 | FAHP | 4 |
| 2 | PSO | 2 | 14 | DEA | 3 |
| 3 | Fuzzy | 21 | 15 | PROMETHEE | 5 |
| 4 | AHP | 95 | 16 | Entropy | 3 |
| 5 | BWM | 7 | 17 | Integer Programming | 1 |
| 6 | TODIM | 2 | 18 | MOORA | 1 |
| 7 | MATLAB | 1 | 19 | Machine Learning | 1 |
| 8 | T2NN-CRITIC | 1 | 20 | DEA | 3 |

**Table 2**
Continued

| No | Methods Used | Total articles | No | Methods Used | Total articles |
|---|---|---|---|---|---|
| 9 | WLC | 4 | 21 | DSS | 1 |
| 10 | VIKOR | 4 | 22 | SWOT Analysis | 1 |
| 11 | TOPSIS | 17 | 23 | TODIM | 2 |
| 12 | FWASPAS | 1 | | | |

Wind farms have drawn increasing attention from researchers in recent years, indicating the sector's significance in the realm of renewable energy. Based on an examination of the data in the table, the number of published articles on this topic has been rising continuously since 2015. Only two publications were published in 2015; however, by 2023, that number had dramatically increased to twenty-four, suggesting that wind energy technologies are becoming more widely known and the subject of more research. According to the data, the number of publications has significantly increased annually, indicating that wind farms are now a major subject of scholarly research and debate. Forecasts suggest that this tendency will persist in the upcoming years. It is projected that wind farm research will continue to grow, advancing environmental sustainability and helping to create new technologies. Scientific publications published since 2015 are displayed in Table 3.

**Table 3**
Analytical methods used in the studies and the total number of articles applying each method

| No | Publication Year | Total articles | Reference No. |
|---|---|---|---|
| 1 | 2015 | 5 | [23] [65] [114] [116] [132] |
| 2 | 2016 | 6 | [12] [36] [92] [94] [122] [147] |
| 3 | 2017 | 10 | [45] [50] [54] [61] [69] [91] [95] [97] [99] [117] |
| 4 | 2018 | 11 | [35] [57] [64] [74] [75] [90] [103] [106] [131] [141] [146] |
| 5 | 2019 | 15 | [5] [7] [17] [30] [58] [62] [63] [68] [76] [119] [121] [139] [143] [144] [150] |
| 6 | 2020 | 18 | [14] [16] [22] [32] [33] [38] [41] [43] [49] [52] [83] [88] [96] [104] [107] [108] [110] [115] |
| 7 | 2021 | 25 | [6] [19] [21] [27] [34] [51] [56] [66] [70] [71] [72] [73] [87] [100] [105] [111] [120] [123] [126] [130] [135] [136] [140] [142] [148] |
| 8 | 2022 | 13 | [3] [8] [9] [10] [15] [18] [46] [48] [89] [93] [98] [109] [112] |
| 9 | 2023 | 17 | [13] [25] [29] [37] [39] [40] [44] [55] [102] [47] [77] [79] [113] [134] [137] [138] [145] |
| 10 | 2024 | 15 | [11] [20] [24] [42] [59] [60] [80] [82] [84] [86] [101] [124] [129] [133] [149] |
| 11 | 2025 | 12 | [26] [28] [31] [53] [67] [78] [81] [85] [118] [125] [127] [128] |

## 4. Research methodology

Finding appropriate wind farm sites entails a number of crucial steps, including gathering pertinent spatial and non-spatial data, assessing local environmental conditions, analyzing federal, state, and local laws, making thorough maps, locating possible wind farm sites, and performing initial site investigations. Planning and management procedures are increasingly using GIS techniques due to their transdisciplinary character. Because of its benefits, which include sophisticated spatial analytics and modeling, several academics are using GIS in the process of choosing wind farm sites. 125 out of 147 reviewed research publications (85.0%) use GIS tools in conjunction with other solution methodologies during the site selection process. Furthermore, some studies have employed GIS as a stand-alone technique for wind farm suitability study.

In alternative selection research, the literature looks at the trends and advantages of combining GIS methodologies with MCDM tools. By fulfilling predetermined requirements or using exclusive restrictions or criteria (Boolean constraints), this combination produces an outstanding analytical tool that enables the identification of viable alternatives. The excluding criteria are based from physical impacts (such steep slopes or protected areas) or legal limitations on wind farm location (like the separation from residential areas, airports, and cultural heritage sites). To effectively apply these constraints, olein logic and GIS overlay methods are employed. Finding appropriate alternatives usually involves using unions (OR conditions) when at least one precondition is satisfied or logical intersections (AND conditions) when all prerequisites are satisfied.

**5. Wind farm site selection criteria**

When selecting a location for wind farm areas, a variety of criteria are often taken into consideration throughout the site evaluation process. The role that exclusionary and non-exclusionary criteria play in the decision-making process frequently determines how they are used. Excluding criteria, which are considered essential, are used in an initial screening procedure to exclude topics that are not appropriate for further research. Wind farms cannot be placed in areas that are not permitted by legislation, including as adjacent to residential areas, airports, cultural landmarks, or protected natural regions. Furthermore, it may not be physically possible to erect wind farms in some places, such as steep hills, surface water bodies, and areas with high ecological sensitivity. The remaining feasible locations are ranked using non-exclusionary criteria to determine the possible wind farm location candidates. Some studies determine the optimal choice by weighing the non-exclusionary criteria. Non-exclusionary characteristics that are incommensurable or may be challenging to measure should be taken into account because they may be evaluated using various scales. The criteria employed in the reviewed studies is shown in Figure 2 and Table 4.


**Fig. 2.** Main criteria used in most studies

The most often utilized key criteria in the analyzed studies are shown in Table 4.

**Table 4**
Main criteria employed in the reviewed studies

| No | Criterion | Frequency (%) |
|---|---|---|
| 1 | Slope | 42.18% |
| 2 | Proximity to Roads | 12.24% |
| 3 | Wind Speed | 40.14% |
| 4 | Land Use | 29.93% |
| 5 | Solar Radiation | 12.93% |
| 6 | Environmental Impact | 8.84% |
| 7 | Environmental | 39.46% |
| 8 | Water Depth | 8.84% |
| 9 | Elevation | 9.52% |
| 10 | Economic | 21.09% |
| 11 | Water Bodies | 6.12% |
| 12 | Protected Areas | 8.16 % |

## 6. Detailed analyses of literature

The challenge of selecting wind farm locations is highlighted by several important topics in the literature, especially in circumstances such as Libya. There is a lot of emphasis on integrating GIS with MCDM techniques since it makes spatial analysis easier and enhances the precision and efficacy of site selection. Decision-makers can assess the social, environmental, and accessibility impacts of potential wind-farm locations using GIS–MCDM. Factors such as terrain and land cover (elevation, slope, surface roughness), environmental protection (protected areas, surface waters, ecologically sensitive zones, bird-migration corridors), social/planning constraints (setbacks from residential areas, airports, and cultural heritage), and wind resource quality (hub-height wind speed, Weibull parameters, power density) are all taken into account. Economic viability (connection and building costs) and grid and logistics factors (distance to highways, substations, and transmission corridors) are also common factors in site selection. Evaluating these several aspects aids in the process of making informed choices. A formal framework for carefully examining these many elements is provided by MCDM approaches such as fuzzy logic and the AHP. These techniques are frequently used in conjunction with weighted linear combination algorithms for ranking and sensitivity testing, TOPSIS, PROMETHEE, VIKOR, and BWM. This makes it easier to make wise decisions.

Our study of datasets from 2015 to 2025 highlights these trends. Out of 147 publications, 125 research (~85%) employ GIS, 97 use MCDM, and 95 use AHP (often to derive weights). In addition to single-study tools (e.g., MOORA, integer programming, machine learning, DSS, SWOT), other techniques include fuzzy (21), TOPSIS (17), BWM (7), PROMETHEE (5), VIKOR (4), WLC (4), DEA (3), Entropy (3), TODIM (2), and PSO (2). From 2018 onward, publication activity significantly increases (because to search timing, 2025 is under-represented). 38 countries are covered by case studies, with Turkey (25), Iran (18), and China (11), leading the way. Libya offers 7 instances, demonstrating both regional and worldwide relevance.

We have used a range of GIS–MCDM models to examine and evaluate a selection of studies on wind-farm site selection. The paper provides a detailed analysis of the examined studies, including their primary goals, methodologies, and conclusions. Furthermore, it situates these findings within the broader context of national trends and provides specific Libyan examples discussed in the literature.

### *6.1 Used GIS software*

One of the most important tools for assessing the viability of onshore wind farm locations is GIS. GIS enables decision-makers to find the best locations by integrating geographic information with technological, environmental, and infrastructure-related aspects. GIS creates high-resolution suitability maps that improve planning and location analysis by examining several geographical layers, such as wind speed, elevation, slope, proximity to highways and power lines, and ecologically sensitive regions.

Numerous worldwide studies have demonstrated the effective use of GIS in wind farm site selection. For example, Garbellini *et al.,* [20] integrated wind resource, land use, and infrastructure proximity using a GIS framework. Here, we conducted the first countrywide onshore wind farm site selection for Brazil, one of the top nations in the world for wind resources and renewable energy, using a Geographic Information System-based Multi-Criteria Decision-Making technique. Baseer *et al.,* [45] used a GIS-based MCDM technique to assess the suitability of sites for wind farms. Karipoğlu *et al.,* [105] integrated GIS with MCDM methodology to generate rapid, visually-supported findings. Eight common parameters, including wind speed, sea depth, and bird migratory routes, are used in this scope and thoroughly examined utilizing a Geographic Information System.

In contrast to Yousefi *et al.,* [82] used a combination of GIS and MCDM approach to identify a suitable area for wind farms in Western Iran. The research conducted a thorough analysis and weighing of the electrical, techno-economic, environmental, and geo-infrastructure factors as well as their corresponding sub-criteria. This outcome was obtained by applying the AHP method. Koc al., [119] used GIS and AHP, to evaluate four districts in Igdir; Tuzluca, Igdir Central, Karakoyunlu, and Aralik; for hybrid solar-wind energy potential.

Nassif *et al.,* [124] employed a GIS-based multi-criteria analysis to identify optimal sites for wind energy development in Iraq and to help meet future renewable energy demand. Villacreses *et al.,* [48] used GIS and MCDM approaches to identify suitable locations for photovoltaic solar farm installations based on Ecuadorian energy regulations. Rekik and El Alimi [79] suggested utilizing GIS and MCDM to conduct an initial evaluation of Tunisia's most likely locations for large-scale WPPs and SPVPs. Lastly, Badang *et al.,* [146] utilized high-resolution Digital Elevation Models (DEM) and field data within a GIS framework to identify potential hydropower sites.

### 6.2 Multi-criteria decision-making (MCDM)

MCDM is a systematic approach to evaluating and prioritizing a number of competing criteria in complex circumstances. It excels at solving issues involving a wide range of sometimes incompatible technological, social, economic, and environmental factors. By converting qualitative and quantitative inputs into comparable measurements, MCDM enables decision-makers to do trade-off analyses and make well-informed strategic choices. Additionally, this approach is highly helpful in determining the optimum locations for wind farms since it can integrate and assess technical, environmental, and geographical data to identify areas that maximize energy production while minimizing environmental damage.

The AHP is by far the most used MCDM approach, being employed in 95 research, or 64.63% of cases, according to a comprehensive study of 147 relevant articles. Fuzzy-based methods come in second with 14.29% of research (21), followed by TOPSIS with 11.56% (17). 3.40% (5) utilize PROMETHEE, whereas 4.76% (7) employ the Best–Worst Method (BWM). Less often used than 1% include DEA (2.04%), FAHP (2.72%), WLC (2.72%), VIKOR (2.72%), TODIM (1.36%), and more complex methods like Machine Learning, MOORA, PSO, and SWOT Analysis.

In order to create a visualization framework that combines GIS and MCDM, Genç *et al.,* [111] used Kayseri–Develi in Turkey as a case study. In order to assist sustainable coastal and inland energy investments, the authors combined disparate onshore geographical information using CORINE CLC 2000 data and other data sources. In order to determine useful criteria for choosing solar power plant locations and suitable solar technologies. Adedeji *et al.,* [52] carried out an extensive study in South Africa that reviewed a wide range of MCDM methodologies put forth by different scholars. A research by Díaz-Cuevas et al *et al.,* [58] suggested an integrated GIS–MCDM system for spatial planning of renewable energy. The framework was used to find high-potential locations for wind, solar, and biomass energy plants in the southern Spanish province of Málaga by defining, weighting, and combining criteria and limitations. The findings showed that the best option for the area is a single or combination wind-solar system.

Bandırma Bay, which offers substantial potential for offshore wind energy installations, was the subject of a research by Karipoğlu *et al.,* [105]. The authors assessed eight important factors, including as wind speed, ocean depth, and bird migration paths, by combining GIS with MCDM algorithms. They found two extremely appropriate offshore locations with projected capacities of 72 MW and 48 MW.

In order to find appropriate sites for a 9.5 MW biomass power plant in southern Thailand, Ali and Waewsak [143] carried out a study using a GIS–AHP-based technique. About 35% of the research region was moderately to very favorable for biomass-based energy plants, according to the analysis which evaluated eleven regions. Environmental and socioeconomic parameters were used in a study by Noorollahi et al,[94] to assess wind energy potential in western Iran using GIS framework. Equal weight was given to technical, environmental, economic, and geographic factors. According to the results, about 28% of the research region is suitable for largescale wind farm projects that satisfy international criteria for energy generation.

A study by Li *et al.,* [33] suggested a two-stage GIS–CDM decision framework to find viable islands for the construction of wave power plants in Shandong Province, China. To decrease subjectivity and increase decision robustness, the framework combined fuzzy group decision-making, AHP, entropy weighting, and TOPSIS–GRA techniques. In order to examine various factors influencing wind farm siting, Khanlari *et al.,*[15] integrated GIS with an MCDM framework. The authors created suitability layers based on geography, wind resources, and infrastructural proximity and used the AHP approach to weight nine evaluation factors. A fuzzy multiple attribute decision-making (MADM) framework for offshore wind farm site selection was proposed. The methodology proposed by Wu *et al.,* [35] was applied to a real-world case in the East China Sea. It combined installation feasibility and maritime safety considerations, with particular emphasis on maritime safety as a decisive criterion.

In order to find appropriate wind energy sites in the Qassim region of Saudi Arabia Ahmed *et al.,* [42] integrated GIS with MCDA methodologies. The northern portion of the region has the greatest potential for wind farm construction, according to a land suitability score that was created by analyzing and weighting several spatial variables.

In order to determine the best sites for solar farms in the UK Hosouli *et al.,* [129] carried out a study using a thorough MCDM framework based on the Fuzzy Analytic Hierarchy Process (FAHP). To systematically rank possible locations, characteristics linked to demand, infrastructure, and clima te were assessed.

## 7. Discussion of results

Significant methodological and geographic trends that offer deeper insights into the development of wind farm site selection research are revealed by the study of 147 studies published between 2015 and 2025. The scientific community's preference for organized, transparent, and computationally efficient methods is reflected in AHP's supremacy as the main MCDM technique. This points to a larger methodological trend toward instruments that strike a compromise between analytical precision and real-world usefulness. Geographically, the concentration of studies in countries such as Turkey, Iran, and China illustrates the critical importance of policy frameworks, government incentives, and data availability in defining research priorities. In the meantime, the growing acceptance of uncertainty as a crucial component of decision-making models is indicated by the growing incorporation of fuzzy logic and hybrid approaches, suggesting a move toward more reliable and adaptive evaluation frameworks.

Additionally, the increasing use of socioeconomic and environmental criteria, which go beyond strictly technical ones, indicates a shift in site selection methodologies toward comprehensive sustainability evaluations. This trend mirrors the goals of the global energy transition, where long-term economic feasibility, ecological effect, and social acceptance are becoming just as significant as the potential of wind resources. All things considered, these results show that the area is progressing from straightforward technical evaluations to more extensive, multifaceted decision-support systems. In order for engineers, planners, and legislators to make more informed choices that support sustainable development plans, community needs, and climate goals, this progression is crucial.

## 8. Future studies

Although this analysis provides a comprehensive overview of GIS MCDM applications in wind farm site selection, it has some flaws that highlight important areas that require more research. First, most existing research relies on static environmental and geographical data, which is inadequate to capture temporal variables such as seasonal variations in wind or the effects of climate change. Future studies should include dynamic and time-dependent data to increase the reliability and robustness of site selection models. Second, stakeholder participation and public approval are still underrepresented by existing methods. To guarantee long term project success, more interdisciplinary approaches that take into account socioeconomic dynamics, legislative frameworks, and public perception are required. Third, there aren't many studies that use actual project results to validate their models. In order to close the gap between theory and reality, future research should prioritize empirical validation and field testing. Furthermore, the use of cutting-edge tools for decision support technologies like machine learning, big data analytics, and artificial intelligence provide promising opportunities for handling complex information and improving decision accuracy. Last but not least, future research should focus on developing internationally relevant frameworks and consistent criterion weighting to enhance comparability across case studies and geographic regions.

## 9. Conclusions

The methodologies and criteria used to identify wind farm sites, as reported in academic articles from 2015 to 2025, are thoroughly reviewed in this study. It compiles published case studies' geographic patterns, methodological preferences, and trends in GIS–MCDM integration in an organized manner. Statistical analysis shows a notable rise in publications after 2018, indicating the growing worldwide emphasis on renewable energy siting, with China, Greece, Iran, and Turkey leading the way in case study frequency.

GIS was found to be the most often used tool, with 85% of the studies under review utilizing it either by itself or in combination with other methods of decision-making. The most popular MCDM method (64.63%) was the AHP, which is primarily used to establish criterion weights. Fuzzy-based approaches (14.29%) and TOPSIS (11.56%) were next in line. Other strategies, such as BWM, PROMETHEE, and VIKOR, were less common, while solutions based on optimization and artificial intelligence very sometimes surfaced.

Technical (wind speed, topography, and distance to grid infrastructure), environmental (protected areas, biodiversity, and ecological constraints), socio-economic and planning constraints (closeness to settlements, airports, and cultural sites), and economic/logistical factors (land cost, accessibility, and maintenance feasibility) were the four primary categories into which the most frequently thought-of evaluation criteria were divided. Most studies initially applied exclusionary constraints, including prohibited zones or improper slopes, and then ranked the viable sites using weighted non-exclusionary factors.

In conclusion, integrating GIS and MCDM provides a robust and transparent framework for selecting wind farm sites, allowing decision-makers to balance technical performance, environmental sustainability, and socioeconomic considerations. This review offers researchers, engineers, and policymakers a helpful resource for renewable energy planning in addition to suggesting future research directions such as incorporating public acceptance factors into decision-making models, enhancing spatial-temporal wind data analysis, and incorporating sophisticated optimization algorithms.

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**Conflicts of Interest**
The authors declare no conflict of interest.

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