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Site Suitability Analysis for Wind Power Plant in Maysan Governorate, Iraq Using GIS-AHP Technique

Hamsa H. Abbas[1], Faleh H. Mahmood[1], Ali K. Resen[2*]

[1]*University of Baghdad, College of Science, Department of Remote Sensing and GIS, Baghdad, Iraq*
[2]*Scientific Research Commission, Research and Technology Center of Environment, Water and Renewable Energy, Baghdad, Iraq*

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Abstract

This paper presents a comprehensive methodology for enhancing land suitability analysis for wind power plants using the Analytic Hierarchy Process (AHP) and Geographic Information System (GIS) techniques. This study evaluates Maysan governorate in Iraq, concentrating on identifying sustainable strategies to enhance and promote renewable energy as a viable alternative to meet energy demands. The integrated methodology involving AHP and GIS encompasses several stages, including the structuring of the AHP hierarchy, the description of appraisal criteria, the execution of pairwise comparisons, and the preparation of criterion maps and land appropriateness maps. This approach was used to identify locations suitable for the installation of wind power plants. The results revealed that 28.35% of the total land (16,683.1 km²) is classified as having low land suitability, 67.58% as moderate land suitability, and 4.06% as having high land suitability for installing wind power plants.

Keywords: GIS, AHP, Wind Energy, MCDM, Weight overlay

تحليل مدى ملاءمة الموقع لمحطة طاقة الرياح في محافظة ميسان، العراق باستخدام تقنية GIS–AHP

همسة حيدر عباس[1]، فالح حسن محمود[1]، علي كاظم رسن[2*]

[1]*جامعة بغداد، كلية العلوم، قسم التحسس النائي ونظم المعلومات الجغرافية، بغداد، العراق*
[2]*هيئة البحث العلمي، مركز بحوث وتكنولوجيا البيئة والمياه والطاقات المتجددة، بغداد، العراق*

الخلاصة:

تقدم هذه الورقة منهجية شاملة تهدف إلى تعزيز تحليل مدى ملاءمة الأراضي لمحطات طاقة الرياح من خلال تقنيات عملية التسلسل الهرمي التحليلي (AHP) ونظام المعلومات الجغرافية (GIS). تقوم هذه الدراسة

*Email: alialbadry80@gmail.com

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بتقييم محافظة ميسان في العراق، مع التركيز على تحديد الاستراتيجيات المستدامة لتعزيز وتشجيع الطاقة المتجددة كبديل قابل للتطبيق لتلبية متطلبات الطاقة. تشمل المنهجية المتكاملة التي تتضمن AHP وGIS عدة مراحل، بما في ذلك هيكلة التسلسل الهرمي لـ AHP، ووصف معايير التقييم، وتنفيذ المقارنات الزوجية، وإعداد خرائط المعايير وخرائط ملاءمة الأراضي. وقد تم استخدام هذا النهج لتحديد الموقع المناسب لتركيب محطات طاقة الرياح. وكشفت النتائج أن 28.35% من إجمالي الأراضي (16,683.1 كم2) تصنف على أنها أراضي منخفضة الملائمة، و67.58% على أنها أراضي متوسطة، و4.06% على أنها أراضي مرتفعة ملاءمة لتركيب محطات طاقة الرياح.

1. Introduction

Energy is the primary factor driving economic growth worldwide, as it is essential for a country's long-term prosperity. Fossil fuels are at the heart of the climate crisis. Reduce the massive production and use of fossil fuels by at least 12% annually. It is essential to avoid the most catastrophic climate warming scenarios [2].

Wind energy plays a crucial role in fulfilling the United Nations Sustainable Development Goals (SDGs) by providing a clean, renewable, and progressively economical energy source. It immediately advances SDG 7 (Affordable and Clean Energy) by enhancing access to sustainable energy, SDG 13 (Climate Action) by mitigating greenhouse gas emissions, and SDG 9 (Industry, Innovation, and Infrastructure) by fostering the development of resilient energy systems. Moreover, wind energy promotes SDG 8 (Decent Work and Economic Growth) by creating employment opportunities in manufacturing, installation, and maintenance. Consequently, incorporating wind energy into national energy policies is essential for promoting long-term, sustainable growth [3].

Employment sources of renewable energy, especially wind energy, require greater attention to address this issue, as they offer an appropriate solution for generating electricity, are environmentally friendly, and contribute to pollution reduction [4]. Due to current concerns and conditions, wind energy has effectively met power demand [5,6]. Several factors influence the installation of wind turbines in a specific location, including economic and environmental considerations, the availability of suitable land, physical constraints, and sites with high wind quality [7]. Multi-criteria decision-making MCDM is used to evaluate many criteria in decision-making problems [8] to locate and build wind farms. MCDM can be applied to various purposes and is a suitable approach for addressing multiple potentially conflicting criteria in determining optimal locations for wind turbine installations [9,10]. Analytic Hierarchy Process AHP is one of the ways to weigh MCDM, and it is very likely to provide a ranking of options that would not be acceptable to a rational person [11]. AHP is the most inclusive system for making decisions with multiple criteria because it develops a hierarchical problem and considers a combination of qualitative and quantitative criteria [12]. In 1980, Saaty proposed the AHP and defined it as an integrated scheme that combines objective and subjective criteria through pairwise comparisons based on a relative scale [13]. It adopts matrices (n×n) to obtain relative weights between criteria and alternatives, while each criterion will be compared with the other in terms of the extent of its contribution to achieving the goal[14].

GIS is one of the important tools for analyzing information and data with high accuracy, helping to make decisions that require choosing the appropriate locations for various projects, including wind energy projects. [15,16]. Particularly, the application of GIS-based MCDM evaluation for erecting wind farms gained importance in the early 2000s and is utilized in various countries, such as Turkey [17] and Greece [18]. On the other hand, some research has shown that a GIS-based AHP approach is a sophisticated multi-constraint decision-making

method for exploring land suitability [19-21]. Geovanna Villacreses et al. [22] implemented a GIS with an MCDM procedure to determine the highly feasible location for the erection of wind power plants in continental Ecuador. Elissavet Feloni and Evgenia Karandinaki [23] implemented a GIS-based process to determine the most suitable wind farm locations using a multi-criteria decision-making (MCDM) procedure. Mustafa Serdar Genç et al. [24] assessed the comprehensive feasibility of a desired offshore wind power plant by applying GIS and (MCDM) guidance for the coastal area of Turkey. Ali, et al.[25] Utilized the AHP for selecting the optimum sites for a wind farm in Pakistan, while Xu, Y. et al. [26] used it in China, integrating it with VIKOR and GIS. Nagababu, G. et al. [27] used a two-stage GIS-MCDM-based approach to select suitable sites for a wind farm.

In this study, the spatial analysis approach available in GIS was utilized to conduct the AHP process and perform the weighted overlay analysis to identify suitable locations for wind power plant installation in Maysan Governorate. Unlike conventional approaches, this study leverages MCDM within a GIS framework to enhance the precision of site selection. Combining expert-driven AHP weighting with spatial analysis ensures a more objective, data-driven, and geographically informed decision-making process.

2. Study Area

Maysan governorate is located in southeastern Iraq, bordering Iran and sharing internal boundaries with Basra, Wasit, and Dhi Qar (Figure 1). It is located between longitudes (46°20' - 48°05' east) and latitudes (31°10' - 32°50' north). It is located 400 km^2 away from Baghdad, the capital of Iraq. Maysan governorate covers 3.7% of Iraq's total area, approximately 16,683 km² [28]. The study area's environment is hot, dry summers and frigid, damp winters. Usually, the seasons of fall and spring cover only a few weeks [29]. Table 1 presents the monthly and annual wind speeds for the study area over a 24-year period.

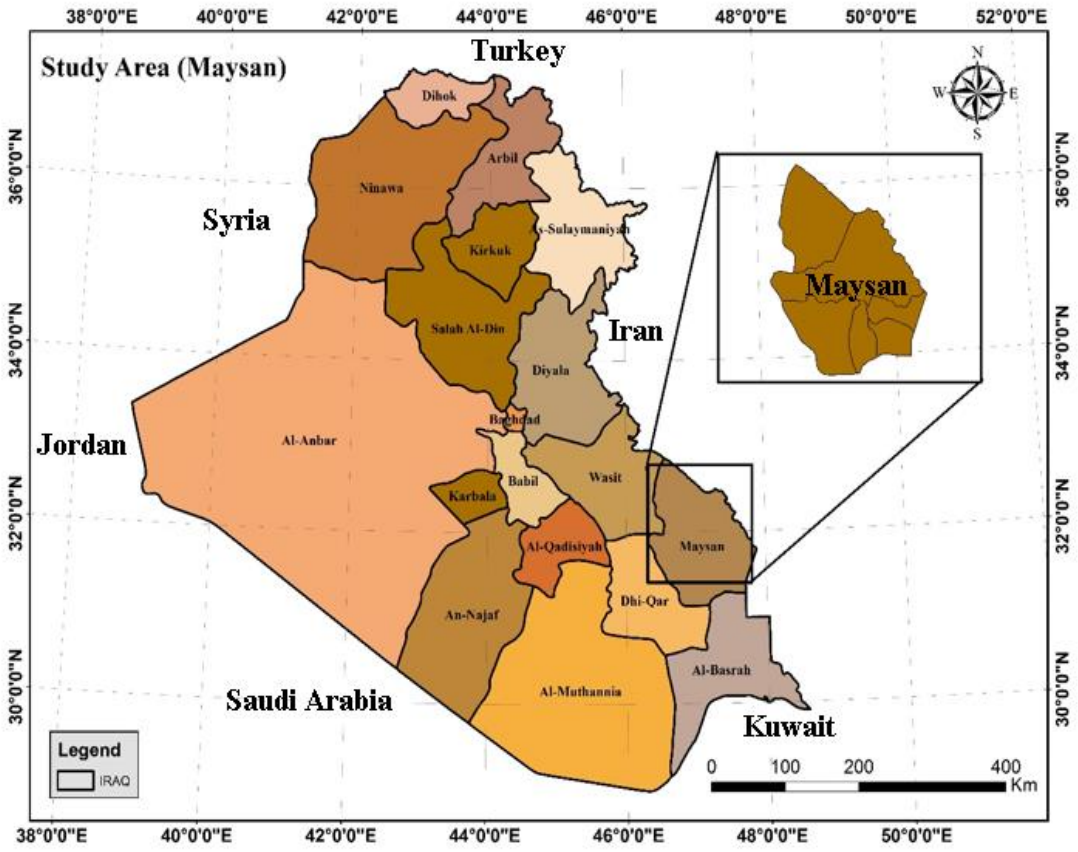


Figure 1: Map of Iraq showing the study area, Maysan

Table 1: Monthly and annual wind speed at 50m for Maysan governorate

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
2000	5.3	5.7	6.3	6.1	7.5	8.1	5.8	6.5	6.4	5.5	4.2	5.1	6.0
2001	4.1	5.2	5.2	6.3	7.8	8.4	7.6	6.8	6.5	5.0	5.3	5.2	6.1
2002	5.1	5.6	5.5	5.7	6.6	7.0	7.5	8.7	7.4	4.5	4.3	5.0	6.1
2003	5.3	5.8	6.2	6.4	5.6	8.0	9.3	7.7	8.1	5.2	6.1	5.6	6.6
2004	5.0	5.7	5.4	5.8	6.5	8.9	6.3	8.9	5.8	5.3	5.4	5.0	6.2
2005	5.0	4.7	6.0	5.9	6.2	8.8	8.2	7.2	7.7	5.9	5.2	4.9	6.3
2006	5.6	5.3	6.2	5.3	6.6	8.4	9.5	6.6	6.8	5.9	4.9	5.0	6.4
2007	4.6	5.6	5.9	5.9	5.4	8.6	7.3	7.1	6.9	4.7	5.7	5.7	6.1
2008	4.3	6.3	6.3	6.0	6.6	9.2	8.0	6.7	6.5	6.1	4.8	5.5	6.4
2009	5.3	6.2	6.1	5.2	5.9	6.8	9.5	8.3	7.1	5.8	4.6	4.3	6.3
2010	6.1	5.6	5.5	5.4	6.7	7.6	7.8	4.7	5.8	6.6	4.5	5.1	6.0
2011	5.4	5.5	6.7	6.4	6.8	8.7	7.8	8.0	7.8	6.2	5.4	5.4	6.7
2012	5.6	6.0	6.3	5.7	6.3	8.6	7.6	8.6	7.5	5.6	4.9	5.1	6.5
2013	5.6	5.7	6.3	5.7	5.6	10.0	9.8	7.9	6.8	5.9	4.5	5.6	6.6
2014	4.4	5.6	5.1	5.4	6.0	8.5	8.8	7.6	7.5	6.3	5.1	5.0	6.3
2015	5.0	5.4	5.3	6.7	6.2	9.7	8.0	7.1	5.4	5.6	4.6	4.9	6.1
2016	5.6	5.9	6.0	4.8	6.7	7.2	8.5	6.7	7.7	5.5	5.7	5.5	6.3
2017	6.0	5.6	5.7	6.2	7.0	9.2	7.2	6.3	6.7	6.3	5.4	6.1	6.5
2018	5.5	5.6	6.0	5.1	5.7	9.4	9.3	8.5	6.8	4.6	4.9	4.9	6.4
2019	5.6	6.1	6.0	5.5	5.8	8.0	11.0	8.4	7.5	5.0	4.9	4.6	6.5
2020	5.1	5.6	5.4	5.6	6.4	9.0	6.8	8.2	6.2	4.9	5.2	5.3	6.1
2021	4.9	5.7	6.3	6.9	6.1	10.4	8.8	7.1	8.6	7.1	5.1	5.7	6.9
2022	5.3	6.2	6.1	5.8	7.7	8.2	9.0	7.1	6.6	4.7	5.1	5.6	6.5
2023	4.5	5.6	5.3	6.0	6.5	10.1	9.7	6.6	7.6	6.0	5.2	4.8	6.5
2024	6.0	5.6	5.7	5.3	6.4	7.9	9.8	8.8	8.0	5.8	5.7	5.3	6.7

The prevailing wind direction in Maysan Governorate is from the northwest, according to long-term wind statistics.

3. Methodology

Figure 2 illustrates the flowchart outlining a systematic approach for identifying suitable wind farm locations by integrating GIS with AHP.

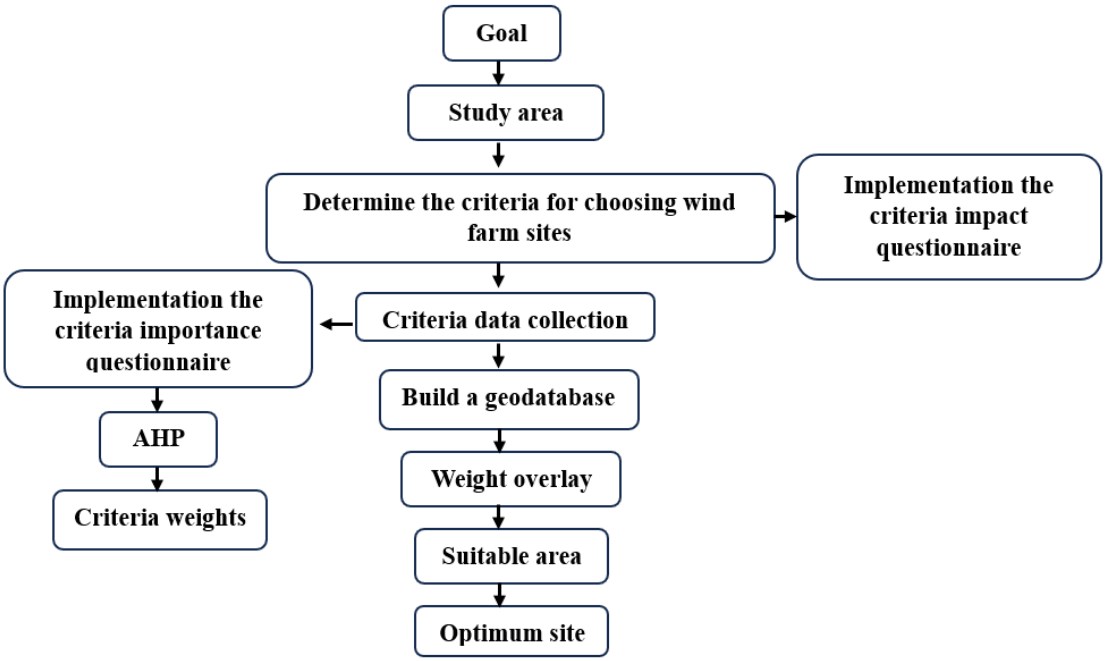


Figure 2: Flowchart of the adopted methodology

The methodology begins by defining the research objective and identifying the study area to establish the geographical focus. Subsequently, pertinent criteria for site selection were established based on aspects such as wind velocity, land utilization, environmental consequences, and proximity to infrastructure. A criteria impact questionnaire was subsequently employed to evaluate the effect of these parameters. Subsequently, data collection occurs, acquiring essential geographical and environmental information. A comprehensive questionnaire is administered to facilitate a weighted decision-making process, enabling specialists to assess the corresponding relevance of each criterion. The inputs are analyzed using the AHP method, which assigns weights to criteria based on expert evaluations. The collected data were subsequently organized into a geo-database, facilitating GIS-based spatial analysis. A suitability map was generated by integrating numerous criteria using a weight overlay technique. The analysis identifies appropriate locations for wind farm development, from which the most optimal site is chosen. This methodology guarantees a methodical, data-driven approach, improving the precision and viability of wind farm site selection.

3.1 Definition of criteria and weights

The function of hierarchical analysis is to derive the weights for the criteria. The procedure involves establishing a hierarchical framework for the interrelation and order of all decision components inside the hierarchy, from the highest to the lowest level. Upon establishing the hierarchical structure, the relative significance of all decision elements was documented and elucidated through pairwise comparisons, which were utilized to construct a ratio matrix. Subsequently, pairwise comparisons among criteria within the same hierarchical level were conducted, employing a numerical scale as proposed by Saaty, ranging from 1 to 9, in the pairwise comparison matrices. The scale of pairwise comparisons is presented in Table 2 [14,15].

Table 2: SAATY 1-9 degree of pairwise comparison [15]

Intensity of importance	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
2	Weak or Slight	
3	Moderate Importance	Experience and judgment slightly favor one activity over another
4	Moderate Plus	
5	Strong Importance	Experience and judgment strongly favor one activity over another
6	Strong Plus	
7	Very Strong	An activity is favored very strongly over another
8	Very, very Strong	
9	Extreme Importance	The evidence favoring one activity over another is of the highest possible order of affirmation

The criteria received from the experts were classified into four main groups (Table 3.

Table 3: Main criteria of the adopted methodology

Climatical Criteria	Geomorphological Criteria	Economic Criteria	Environmental Criteria
Wind speed	Slope	Distance to road	Land Cover
Air temperature	Elevation	Distance to power	
Solar radiation	Terrain Ruggedness Index (TRI)	Distance to Settlement	

The AHP program was used to determine the relative importance of each criterion within the matrix, while extracting the consistency ratio index, which is the ratio resulting from dividing the consistency index by the randomness index, as described in equation (1) [30].

$$CR = \frac{CI}{RI} \quad (1)$$

CR is the consistency ratio, CI is the consistency index, 10% or less is acceptable, and RI is the Randomness Index [26].

The consistency index (CI) was calculated using Equation (2).

$$CI = \frac{\lambda_{max} - n}{n-1} \quad (2)$$

Where λmax is the latent root of the pairwise comparison matrix, and n is the number of criteria being compared. [30].

3.2 Data collection and management

Table 4 illustrates the sources of the data used in this study. All datasets used in this study were obtained from globally recognized and validated sources. The DEM of the Shuttle Radar Topography Mission (SRTM), 30m spatial resolution, was adopted to describe terrain elevation data sets in a digital raster form and sourced from the United States Geological Survey (USGS), known for its high-resolution and consistent elevation data. Slope, elevation, and Terrain Ruggedness Index TRI were derived from the DEM by using GIS tools. The Global Wind Atlas, based on long-term mesoscale modeling and validated using ground measurements, and the Global Solar Atlas provide spatially consistent and quality-assured data. GLCNMO and national authorities, ensuring compatibility and standardization. These high-quality datasets contribute significantly to the accuracy and robustness of the GIS-AHP-based site suitability assessment.

The Maysan Governorate, located in southern Iraq, features a semi-arid to arid climate characterized by high solar radiation and significant seasonal temperature fluctuations. The yearly average wind speed in the region, according to the Global Wind Atlas, varies from 4.5 to 6.5 m/s at an elevation of 100 meters, suggesting significant potential for wind energy production. Solar radiation is plentiful. The air temperature generally fluctuates from 10°C in winter to over 45°C in summer, affecting the technical performance and cooling needs of energy infrastructure. The climatic conditions, based on extensive global databases, offer a dependable foundation for evaluating the viability of wind power development in Maysan.

Table 4: Data types and sources used in this study.

Data	Data Source
DEM	United States Geological Survey (USGS)
Wind speed	Global Wind Atlas
Air temperature	Global Solar Radiation
Solar radiation	Global Solar Radiation
Slope	Digital Elevation Model (DEM)
Elevation	Digital Elevation Model (DEM)
Terrain Ruggedness Index (TRI)	Digital Elevation Model (DEM)
Distance to road	General Authority of Survey, Ministry of Water Reservoirs.
Distance to power	Ministry of Electricity of Iraq
Distance to settlement	GLCNMO(Global Land Cover by National Mapping Organization
Land cover	GLCNMO(Global Land Cover by National Mapping Organization https://globalmaps.github.io/glcnmo.html

3.3 Site selection algorithm

The process of developing an approach for selecting the best possible location for a site included the following steps:

1. Create raster models:

In ArcGIS, a weighted overlay is used as a component to determine the optimal location for wind turbines. Since the data should be in the Raster format, 3D analyst tools were used to convert the various standard categories in the geographical database into Raster data. According to DEM, the resulting cell size is 30 m. In addition, the MCDA decision-making approach was applied using a weight-overlooked tool, which combined multiple balanced layers in a single-layer Raster. Since each standard assigns a weight according to its relative importance, it is possible to identify highly suitable sites for erecting the wind farm. Additionally, the Euclidean distance tool was used to generate raster data corresponding to the three economic criteria.

2. Reclassify:

The raster data was reclassified using the reclassify tool within the Spatial Analyst Tools. The newly reclassified raster data has three classes, the weight values of which will be subsequently disclosed.

3. Weighted Overlay:

The Weighted Overlay approach pertains to overlay analysis used to discuss multi-criteria matters, such as location-choice adequacy models. The weighted overlay method enables the execution of many stages of the overarching overlay analysis within a singular instrument.

Following re-classification, this article utilized raster data for the selected criteria as input for the Weighted Overlay tool. The Weighted Overlay tool provided criteria weights and class weights determined by the AHP method. The overlay tool subsequently generated a raster map to delineate the suitability area. Figure 4 shows the optimum site selection procedure.

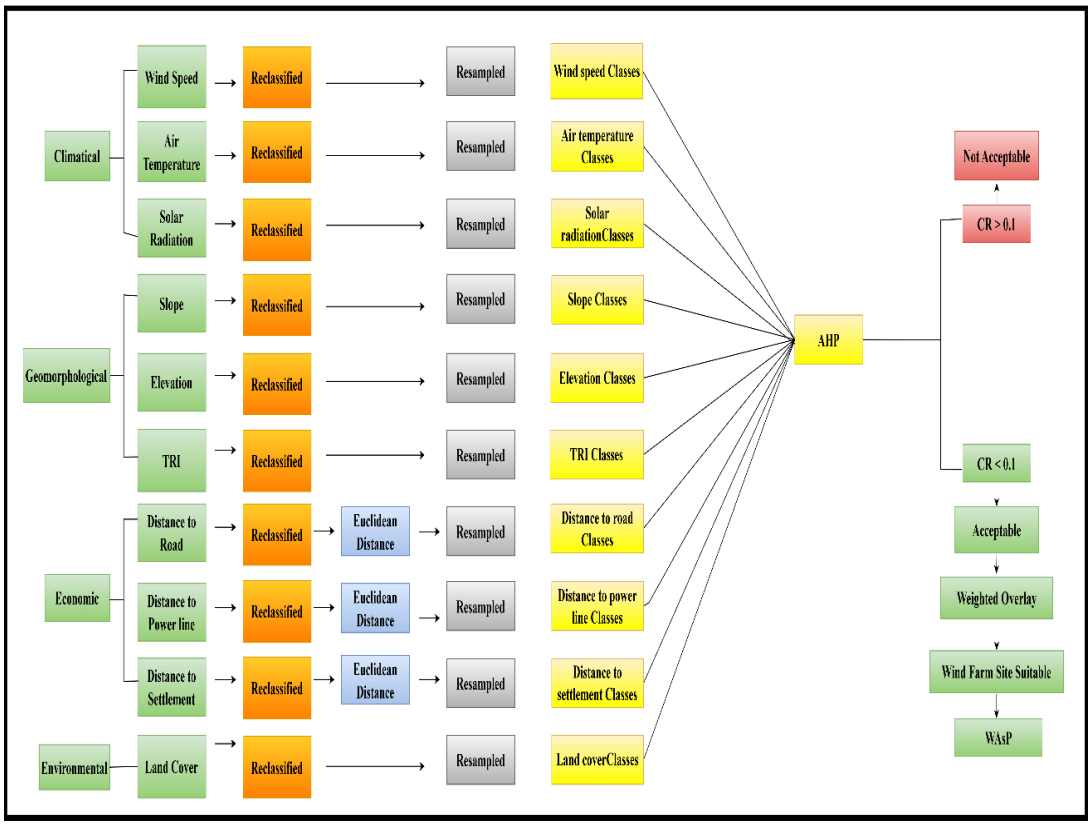


Figure 4: Shows the optimum site selection procedure

4. Result and Discussion

4.1 Weights of Criteria

The criterion weights used in the AHP analysis were derived from the opinions of 20 experts in the fields of renewable energy, environmental science, and GIS. Their evaluations were collected through structured questionnaires designed according to the AHP methodology. The collected responses were then used to construct pairwise comparison matrices, and the final weights were calculated using the AHP technique, ensuring a consistent and expert-informed weighting process.

Table 5 assesses the criteria using relative weights for each main and sub-criterion, with the partial weight determined by multiplying the weight of each sub-criterion by the weight of its corresponding main criterion. The GIS class encompasses the classes utilized in ArcGIS to depict the applicability of each spatial category. Each class is assigned a class weight based on its appropriateness score, with the most suitable class receiving a weight of 0.30 and the least suitable class receiving a weight of 0.10, arranged in descending order. The Final Weight is determined by multiplying the class weight by the partial weight, resulting in a final score for each class according to its significance in the analysis.

Table 5: Synopsis of the criteria main weight and sub-weight.

Main Criteria	Main Weight	Sub-Criteria	Sub Weight	Partial Weight= Sub weight * main weight	GIS Class		Class Weight	Final Weight= Class Weight * Partial Weight
Climatical	0.562	Wind speed	0.764	0.429	less	6.5	0.10	0.043
					6.5	7	0.15	0.064
					7	7.5	0.20	0.086
					7.5	8.05	0.25	0.107
					8.05	more	0.30	0.129
		Air Temperature	0.122	0.069	less	25	0.30	0.021
					25	26	0.25	0.017
					26	26.72	0.20	0.014
					26.72	27	0.15	0.010
					27	more	0.10	0.007
		Solar radiation	0.114	0.064	less	1914	0.10	0.006
					1914	1960	0.15	0.01
					1960	1971	0.20	0.013
					1971	2003	0.25	0.016
					2003	more	0.30	0.019
Geomorphological	0.174	Slop	0.749	0.130	less	6.5	0.30	0.039
					6.5	7	0.25	0.033
					7	7.5	0.20	0.026
					7.5	8.05	0.15	0.011
					8.05	more	0.10	0.013
		Elevation	0.126	0.022	less	19	0.10	0.002
					19	49	0.15	0.003
					49	50	0.20	0.004
					50	103	0.25	0.006
					103	more	0.30	0.007
		TRI	0.126	0.022	less	0.3	0.30	0.007
					0.3	0.4	0.25	0.006
					0.4	0.5	0.20	0.004
					0.5	0.7	0.15	0.003
					0.7	more	0.10	0.002
Economic	0.183	Distance to road	0.241	0.044	less	9	0.10	0.004
					9	18	0.20	0.009
					18	28	0.30	0.013
					28	37	0.25	0.011
					37	more	0.15	0.007
		Distance to power network	0.210	0.038	less	16	0.30	0.011
					16	32	0.25	0.001
					32	48	0.20	0.008
					48	64	0.15	0.006
					64	more	0.10	0.004
		Distance to settlement	0.549	0.100	Less	5	0.15	0.015
					5	10	0.25	0.025
					10	15	0.30	0.03
					15	25	0.20	0.02
					25	more	0.10	0.01
Environmental	0.081	Land cover	1	0.081	Bare land + Dry land Crops		0.671	0.054
					Shallow Land (Wetlands)		0.173	0.014
					Trees (Forested Areas)		0.086	0.007
					Water		0.070	0.006
	∑=1			∑=1				∑=1

4.2 Reclassifying results of the criteria

The reclassification tool and spatial analysis in ArcGIS 10.8 software were utilized to simplify the classification of raster data based on the specified criteria. The reclassification outcome in new raster models, each comprising only four classes. The legend accompanying each graphic delineates the four categories and their respective values. Figure 5 illustrates the reclassification results based on climatic, geomorphological, economic, and environmental criteria.

The sub-main criteria utilized in this investigation are reclassified in Figure 5. Three climatic criteria were incorporated into this study: wind speed, air temperature, and solar radiation, which were designated as A, B, and C. The spatial distribution of this characteristic in Maysan Governorate was represented by a wind speed raster layer (Figure 5-A). The maximum and minimum wind speed values represented the climatic variations across the region. The data suggests that the western and northwestern regions of Maysan Governorate are the locations of the highest wind speed values. Figure (5-B) illustrates the outcomes of the raster model for air temperature. As is customary, temperatures in Maysan Governorate increase during the summer. The findings indicate that the study area's lowest temperatures are situated in the northeast, while the maximum temperatures are found in the south, southwest, east, west, and northwest. The results of the solar radiation raster model are illustrated in Figure 5-C.

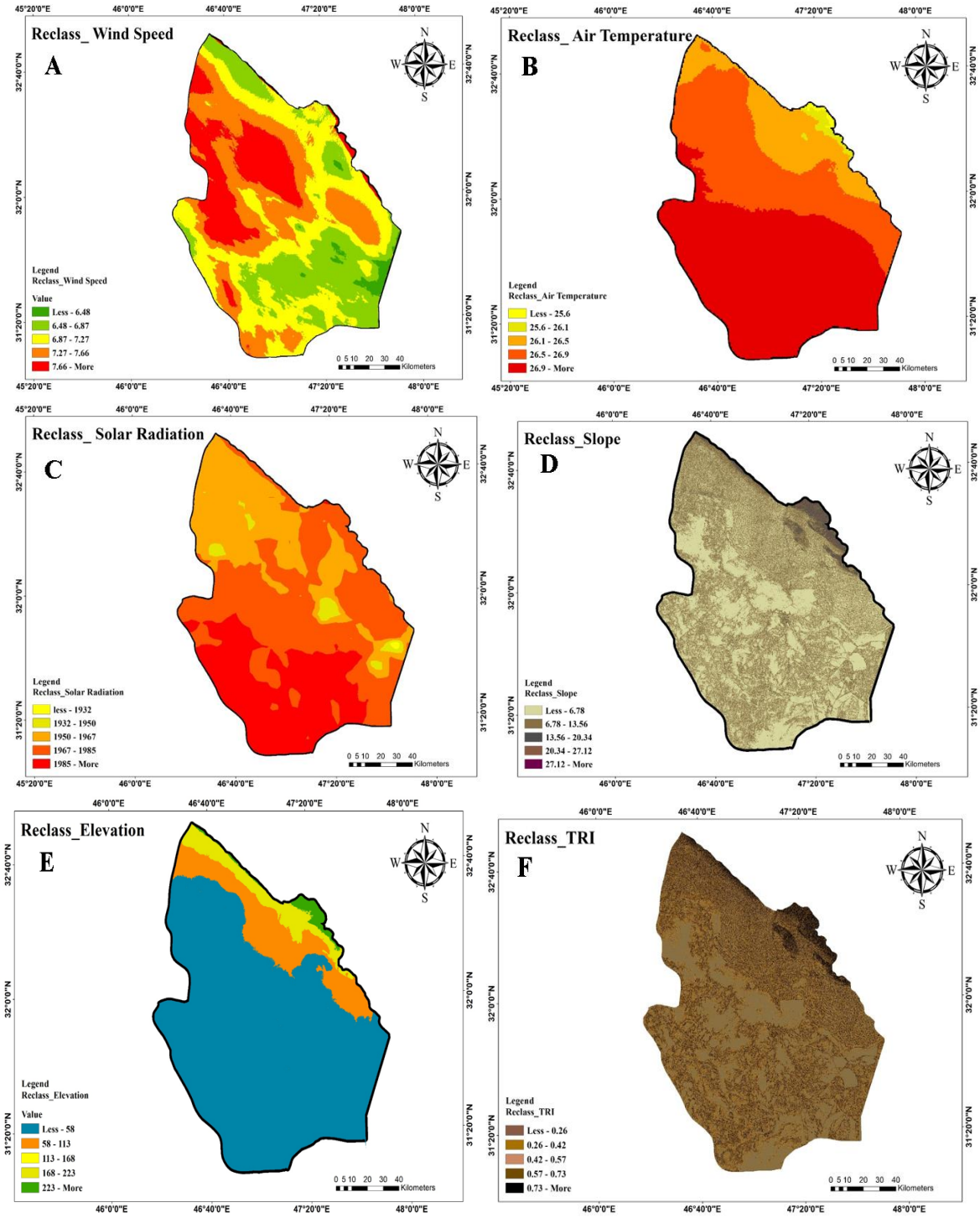
The data suggests that the western and southwestern regions of the study area experience high levels of solar radiation, while the north, northwest, and southeast regions experience low levels of solar radiation. This Figure was labelled as D, E, and F and contained three geomorphological criteria: slope, elevation, and terrain roughness index. The digital elevation model was used to determine the slope criterion (Figure 5-D). The slope raster model data depicted in this Figure indicates that the majority of the research area is primarily level with a minimal incline. Conversely, the elevation criterion that is derived from the classification of the digital elevation model is illustrated in Figure 5-E. The findings indicate that elevated altitudes characterise the northern and northeastern regions, while lower elevations characterise the northwestern, southwestern, and southeastern regions. The terrain roughness index, illustrated in Figure 5-F, is employed to evaluate the complexity or regularity of the land surface. The construction of wind turbines is impeded by the increasingly harsh terrain, which also complicates the maintenance process. The study area exhibits a random distribution of low terrain roughness values, whereas medium terrain roughness values are substantially concentrated in the outskirts of the northern and northeastern regions, as indicated by the map data. In the northern and northeastern regions, high terrain roughness index values are sporadic and dispersed.

Figure 5 was labelled as G, H, and I and contained three economic criteria: distance to roads, distance to electricity lines, and distance to settlements, respectively. To ensure compatibility with other criteria formats, the Euclidean distance utility was implemented to convert the data for the three economic criteria from vector to raster format.

In general, areas close to settlements, roads, or power lines appear in a color gradient ranging from yellow to light green, while distant areas appear in red. These areas are considered suitable for the distance to settlement criterion due to visual and noise pollution, so they should be further away. Meanwhile, nearby areas, shown in light green and yellow, are considered suitable for the distance to roads and power lines criterion due to their ease of

access for wind turbine transportation and maintenance. Their proximity also facilitates direct power delivery, preventing energy losses.

Land cover is the sole environmental criterion represented in this figure. The data in Figure 5-J illustrates the land cover classifications on the map, which include (water, trees, arid lands, crops, shallow water, and barren areas). The weighted overlay tool was used to determine the most suitable locations for wind turbine installation by integrating all layers.



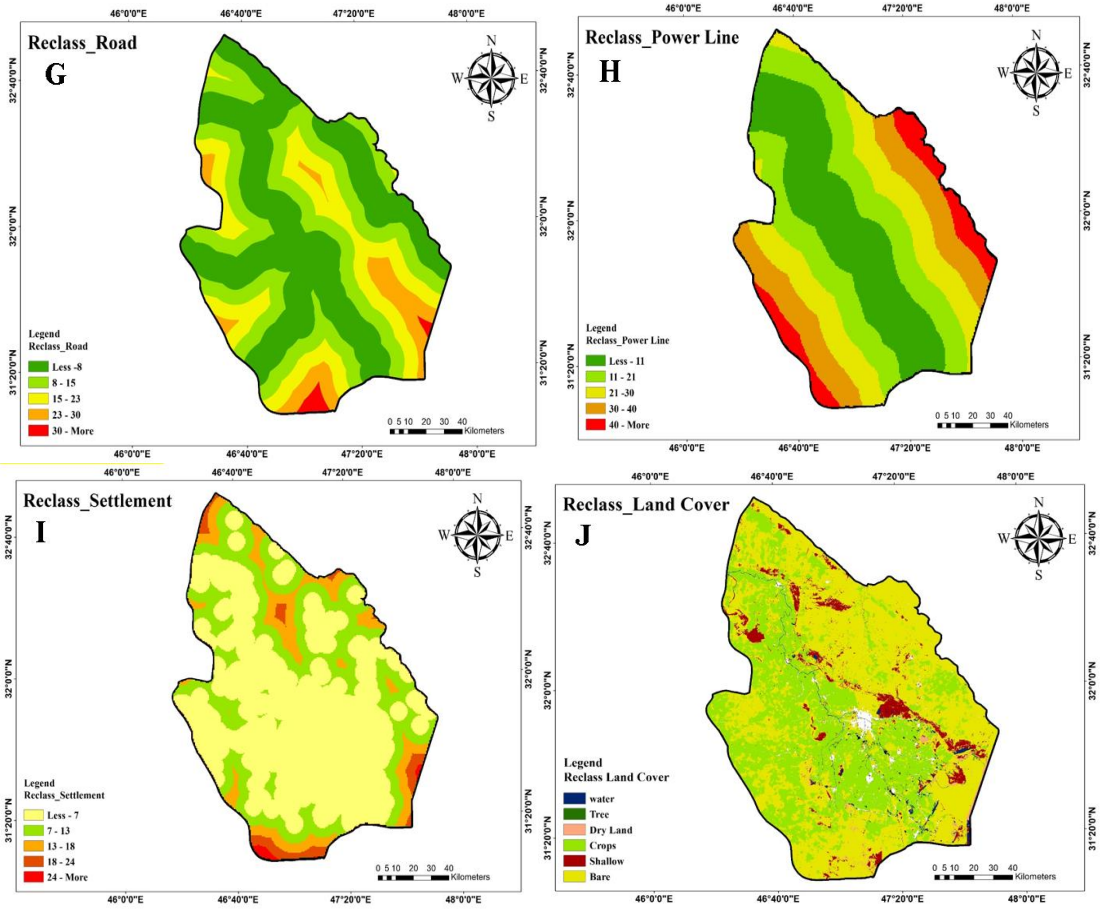


Figure 5: Maps the re-classification of sub-criteria

4.3 Suitable areas

A suitable location for a wind power plant was selected using the weighted overlay method. The results produced a raster model categorized into three classifications according to appropriateness, as depicted in Figure 6. The starting category is indicated by the green color class, representing a low level of suitability, while the final category is represented by the red color class, signifying a high level of suitability. The results indicated that 28.35% of the total land in the research region, 16,683.1 km², was classified as unsuitable, 67.58% as moderately suitable, and 4.06% as highly suitable for wind farm installation. These percentages are primarily due to the combined influence of multiple spatial and environmental factors considered in the GIS-AHP analysis. These factors include wind speed, land slope, land use, distance to infrastructure, and environmental constraints, each weighted according to its relative importance. The moderate suitability class dominates because much of the region meets several but not all ideal criteria simultaneously. Areas classified as highly suitable exhibit optimal conditions such as consistent high wind speeds, gentle slopes, and minimal environmental or infrastructural restrictions, which are limited in extent. Conversely, unsuitable zones are those with unfavorable conditions, such as low wind speeds or protected land uses. A wind speed of 6.5 m/s at 50 meters height, as recorded in the study area, is considered suitable for utility-scale wind power generation. According to international standards and literature, wind speeds above 6 m/s are generally favorable for the economic operation of modern wind turbines.

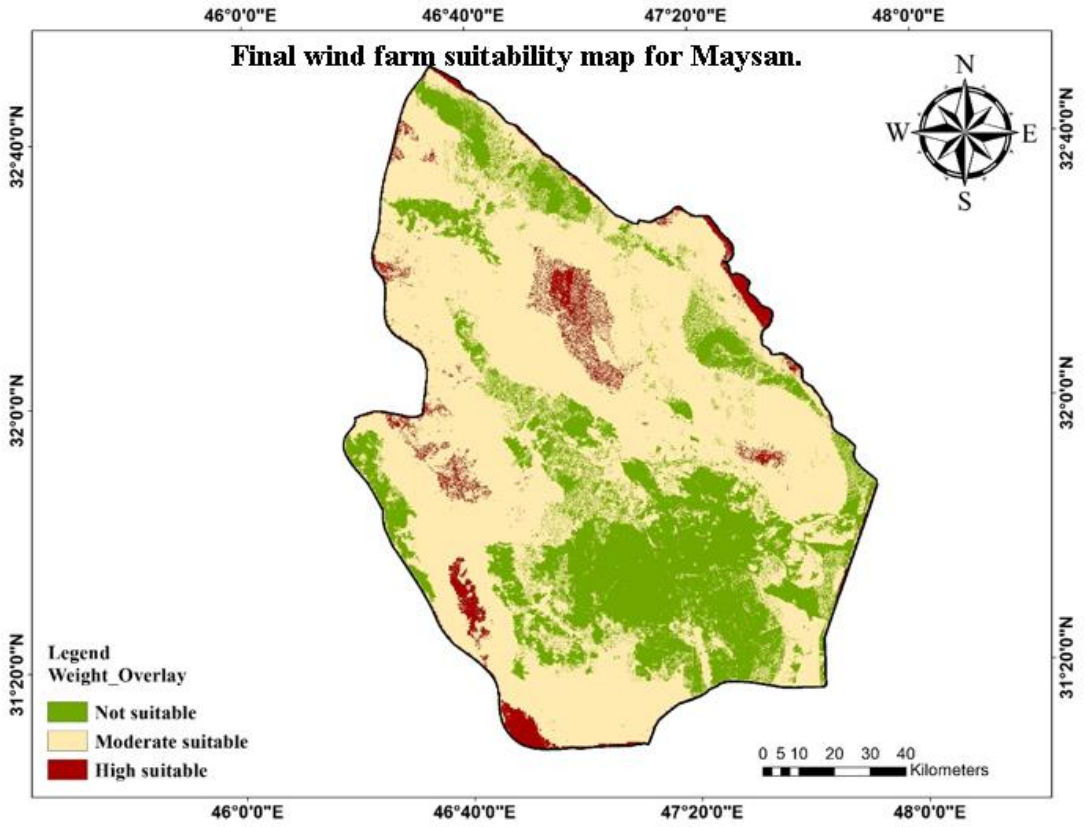


Figure 6: Final wind farm suitability map for Maysan.

Conclusion

This research examined a multi-criteria decision-making procedure for the selection of wind farm sites in Maysan, Iraq, incorporating the AHP and GIS-based weighted overlay analysis. Four primary criteria were identified by experts: climatic, geomorphologic, economic, and environmental, each accompanied by sub-criteria to enhance site suitability assessment. To select suitable locations for wind farms, a framework for evaluation and exclusion was developed, taking into account a comprehensive literature review, data availability, regional characteristics, and insights from national experts. The assessment reveals that 4.06% of the study area is suitable for wind farms, while 28.35% is unsuitable due to environmental and socioeconomic constraints. The central and southeastern regions of Maysan represent the most advantageous locations for wind energy development, demonstrating significant potential for future renewable energy initiatives. The study's findings indicate that the region has significant potential for wind farm installations through the effective utilization of sites deemed highly and moderately suitable for wind energy development. The land suitability model presented in this study demonstrates potential applications for planning wind farms across various regions.

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