Selecting Suitable Sites for Wind Energy harvesting in Iraq using GIS Techniques

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Abstract

Wind energy is energy extracted from the kinetic energy of the wind by using wind turbines to produce electric energy. Wind energy is one of the most important types of renewable energy that has been widely used as an alternative to fossil fuels. It is abundant and renewable energy, but its availability varies from one location to another. The study aims to identify the best sites for wind energy in Iraq in order to produce the needed future energy from renewable sources. Multi-criteria analysis was used to determine the most suitable sites for harvesting wind energy using Geographic Information System (GIS). The most important data collected was climatic data and which includes a RASTER file of annual wind speed, temperatures, precipitation. soil moisture and NDVI (Normalized Difference Vegetation Index), covering the study area over the past forty years.~~,~~ In addition, the shape file was used for each (distance from power lines, roads, Cities, slopes, and land use), where an appropriate model based on geographic information systems was produced when a set of raster data sets were classified and overlayed by the weighted overlay tool in Spatial Analysis Tools in ArcGIS 10.7.1. The results indicated that the best suitable sites for harvesting wind energy are located in the southeastern regions of Iraq. It is characterized by wind activity with a speed of more than 6.2 m / s. On the other hand, these areas are close to power transmission lines, roads, and slopes are moderate. Therefore, these areas were considered suitable for wind farms. Moreover, areas with a high suitability index cover 1% of the total area, which is an important indicator of wind energy harvesting potential in Iraq. The area with a moderate suitability index covers 71%, and the low suitability index was 15%, while 13% of unsuitable have been identified.

Key words: Wind Energy (WE), Multi-criteria, GIS, Iraq.

1. Introduction

Renewable energy or alternative energy is in contrast to other traditional energy sources because it is permanent, inexhaustible and non-polluting Atmosphere, and environment compared to other energy sources, as wind energy is one of the fastest growing renewable energy sources in recent decades. Along with faster growth wind energy has become a large part of the energy consumed globally[1]. The aim of the study is to find the best wind power production sites for

utility-scale wind power plants using geographic information systems, spatial analysis tools, and multi-criteria decision-making techniques. GIS tools provide the full functionality and capabilities to articulate, analyze and visualize valuable results for decision-makers. Many researchers interested in the field of clean energy have presented several studies to find the optimal siting of wind farms by using a number of different criteria in the economic, technical and environmental fields, including average wind speed, to obtain the cost of building wind turbines [2]. Other researchers use GIS to identify areas with high wind speeds to build wind turbines to reduce pollution and global warming [3]. In a different study on renewable energy and finding the best way to maintain an emissions-free environment, researchers developed a hybrid technique that uses GIS models to integrate solar and wind energy. They found this approach to be one of the best and most rigorous for multi-criteria decision making [4].The suitability of sites for building wind turbines to release annual energy at rates that can be used in everyday life depends on the wind speed in the area. Other criteria depend on planning at the time of formulation and decision making, including the distance of areas, roads or transport lines [5]. A study in Diyala province has shown that by establishing and improving wind farm projects, economic conditions can be improved and the increase in energy consumption dependent on fossil fuels can be Reduced [6]Many works in different countries have used multiple GIS standards to determine the most appropriate location for wind power plants using multi-criteria decision analysis - Analytical Hierarchy Process (AHP), where the results of the studies showed that GIS has an important role in the decision support system in building a station Electricity generation[7,8] .Due to the increasing demand for renewable energy, energy experts in many countries have conducted field studies by analyzing the impact generated by the environment, considering that wind speed is a sustainable and stable source of wind energy and the impact of these changes in determining the most suitable locations. [9,10]. Scientific studies in several researches from different countries that include the process of integrating AHP and GIS as a decision-making tool for the optimal allocation of the wind farm. Where the study focused on knowing the main factors affecting the development of wind energy and presenting the suitability of the land based on an analytical model (GIS) to determine the optimal allocation of the wind farm[11.12]
The purpose of this study is to select suitable wind farm sites based on several climatic, economic and environmental criteria in Iraq by analyzing 40-year GIS data.

2. Material and Methods

2.1. Source of data

A set of data was collected to influence the criteria for selecting wind power farms from various sources. The most important collected data, were climatic data. It Includes a RASTER file of annual wind speed, temperatures, precipitation. soil moisture and NDVI, covering the study area for the past 40 years. The Digital elevation model (DEM) is one of the most required data to carry out the study. using DEM, Typical morphological parameters of height and slope can be generated). In addition, GIS layers of economic parameters and GIS layers were obtained for the economic parameters and protected area restrictions, which were merged with the approved geographic database after the implementation of the structure. LULC (Land Use/Land Cover) data as the server was used to download and extract the Iraq map.

The last step of these processes was the collection of the above reclassified raster data. The Weighted Overlay tool works by grouping all raster layers based on their weights. Table 1, determines the suitable area for wind harvesting, which is calculated on the basis of merging the exclusion zone and the classified area into one map based on the calculated values to determine the suitable areas for wind farms.

Table 1: Criteria used in wind speed suitability of weight overly

No	Criteria	Weight%	factors	Suitability
1	**Annual Wind Speed (50 m) high[5]**	0.28	<4.2 m/s 4.2-5.2 5.2-6.2 >6.2	Unsuitable Low Suitable Moderate Suitable High Suitable
2	**Slope,degree**	0.18	1-3 % 3-7 7-10 10-82	High Suitable Moderate Suitable Low Suitable Unsuitable
3	**Land cover/use**	0.24	Water Bodies Other	Restructure Suitable
4	**Distance from Cities**	0.1	0-2 km 2-5 5-20 >20	Unsuitable Low Suitable Moderate Suitable High Suitable
5	**Distance from Roads**	0.1	0-0.5 km 0.5-5 5-20 >20	Low Suitable High Suitable Moderate Suitable Unsuitable
6	**Distance from power line**	0.1	0-0.5 km 0.5-5 5-20 >20	Low Suitable High Suitable Moderate Suitable Unsuitable

2.2. Statistical analysis

GIS is defined as a system of computer programs, hardware and data, through which data and information can be entered, processed, analyzed and presented linked to a location on the Earth's surface. It can be dealt with by inputting, processing, analyzing, and presenting the bound information to a location on the Earth's surface [13,14], Geographic information systems (GIS) were used to perform suitability analysis and select optimal sites for wind farms and exclude unsuitable sites such as water bodies, trees and forests through weight overlay analysis tool [15]. The weighted suitability model was developed using geographic information systems for appropriate site suggestion techniques, based on a number of objective layers and based on the principle of multi-criteria evaluation, where this model is used to apply a common measurement of values on various and dissimilar inputs in order to create an integrated analysis, the analysis factors may not be equal. Each point cell is reclassified into appropriate units and multiplied by weight to assign the importance of a proportion to each individual, and finally they are combined together in the final weight to obtain an appropriate value [16] for each location on the map, as in the equation :

$$SI_i = \sum_{j=1}^{n} w_i x_{i,j}$$

where,
w_i is the weight assigned to the criterion i
$x_{i,j}$ is the score of cell i under criterion j
n is the number of criterion

SI_i is the suitability index for cell

In this study, all thematic layers were merged in order to prepare a map showing the most suitable areas [15] as in Figure 1 :

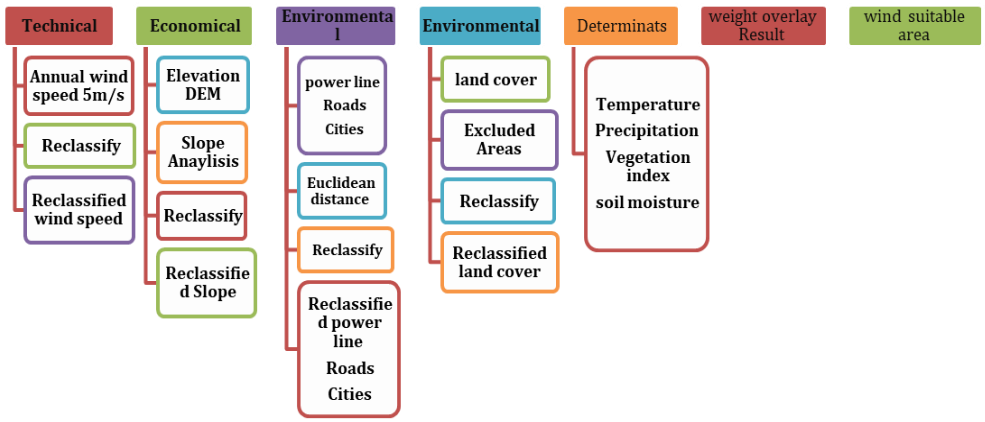


Fig 1 :Overview of wind power site suitability

3. Results and Discussion

Figure 2, shows the average wind speed at a height of 50 m above the ground, adjusted based on the surface roughness and the measured data. As the wind speed that is less than 4.2 m/s is no longer feasible from an economic point of view, the areas where the wind speed is lesser than 3 m/s were excluded (figure 2a). Figure 2b shows the average wind speed reclassified in accordance with the requirements of wind energy projects and the nature of the study area (figure 2b). Therefore, the point layer of the mean wind speed was reclassified into four main categories, as shown in Table 2, which starts from a region of high suitability where the wind speed is greater than 6.2 m/s to medium (5.2-6.2 m/s) and then low suitability (4.2-5.2 m/s) to the exclusion zone, where the wind speed is less than 4.2 m/s.

Table2: Reclassified wind speed in Iraq

Old Values Average wind speed in m/s	New values
<4.2	1
4.2-5.2	2
5.2-6.2	3
>6.2	4

a) b)

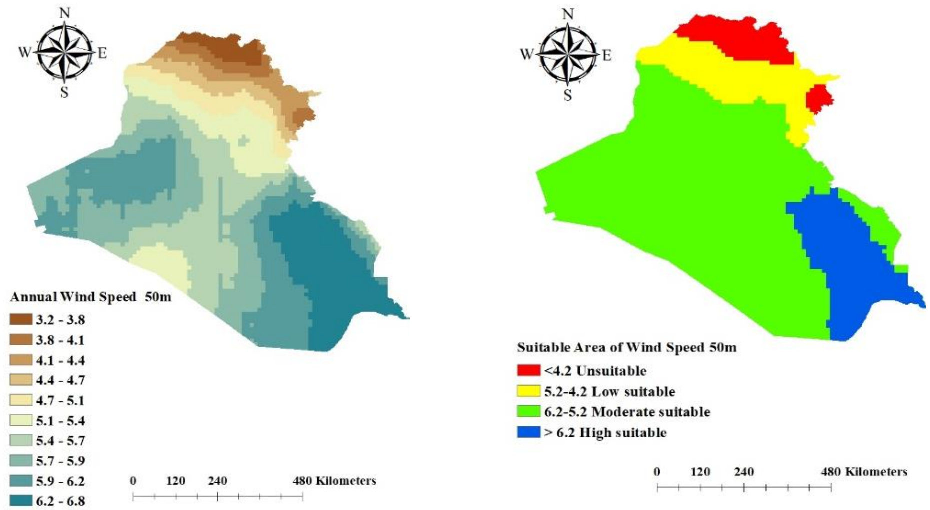


Fig 2: The average wind speed at 50 m over Iraq

a)Annual wind speed b) Reclassified wind speed

The second analyze criterion is the terrain slope which is plotted on Figure 3. The slope layer was obtained from the Digital Elevation Model after using slope management until this map was obtained. Our aim purpose is to look at the areas whose slope value is in the range (0-10) degrees, as shown in Figure 3a, where the areas with slopes less than 10 degrees are considered suitable for wind power plants while the value of the slope greater than 5 degrees will produce more turbulent wind patterns, causing disturbances in the stability of the turbine. From an economic point of view, building on high slopes leads to an increase in project costs, so the terrain must be flat because it is exposed to more winds of constant speed. The slope was classified into four categories: high degrees suitable (1-3 degrees), medium, low degrees (3 -10 degrees) and unsuitable degrees (> 10 degrees).

Table3: Reclassified Slope in Iraq

Old Values Slope	New values
1-3	4
3-7	3
7-10	2
10-82	1

a) b)

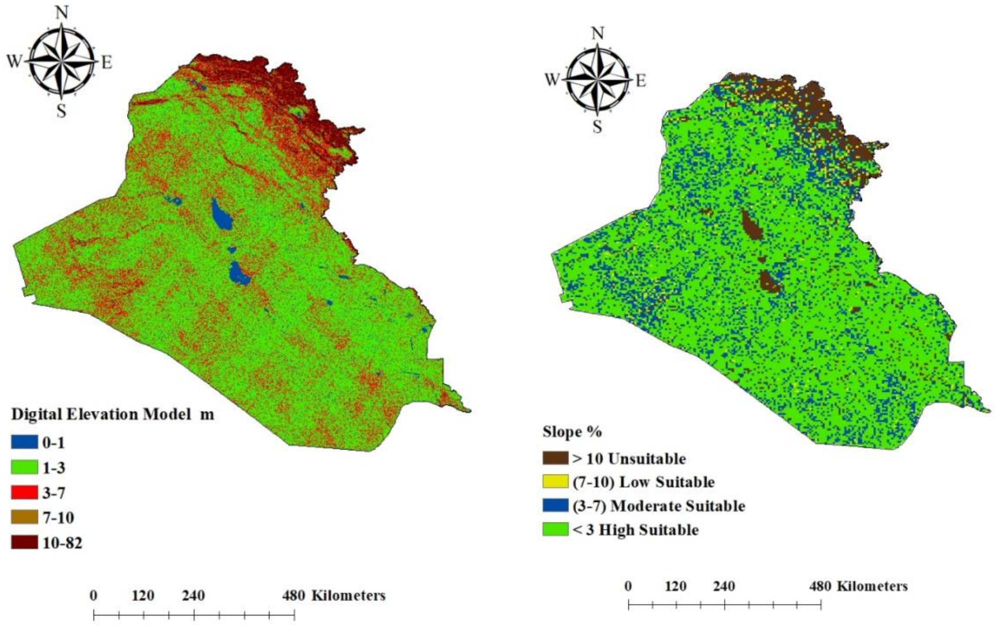


Fig3: Suitability of Slope of Iraq

a) Elevation after used slope tool , b) Reclassified of Slope

Figure 4 shows the distance between the transmission lines where the pattern was changed from a vector to a raster, using spatial analysis, which reclassifies the tool for these layers using the Euclidean distance tool to convert from a vector to a raster, as in Figure 4a. In order to evaluate the available areas that are considered an important economic factor at the time of increasing the cost or decreasing the cost of production, therefore, the proximity to power stations must be taken into consideration when choosing suitable sites for building renewable energy stations to reduce production costs. Then, the distance between the transmission lines was reclassified as shown in Figure 4b, where the distance is necessary to transfer the energy generated from wind energy and at the same time reduce construction and maintenance costs. Therefore, the most appropriate locations are close to the power lines and away from wind energy. Areas as appropriate for power stations as shown in Table 4 between the proposed distance of power lines, where the standards are set, and the distance of 0.5-20 km, respectively, and finally, areas of less than 0.5 km from low-power lines are considered appropriate.

Table4: Reclassified distance power line in Iraq

Old values distance power line(km)	New values
0-0.5	2
0.5-5	4
5-20	3
20-21.9375	1

a) b)

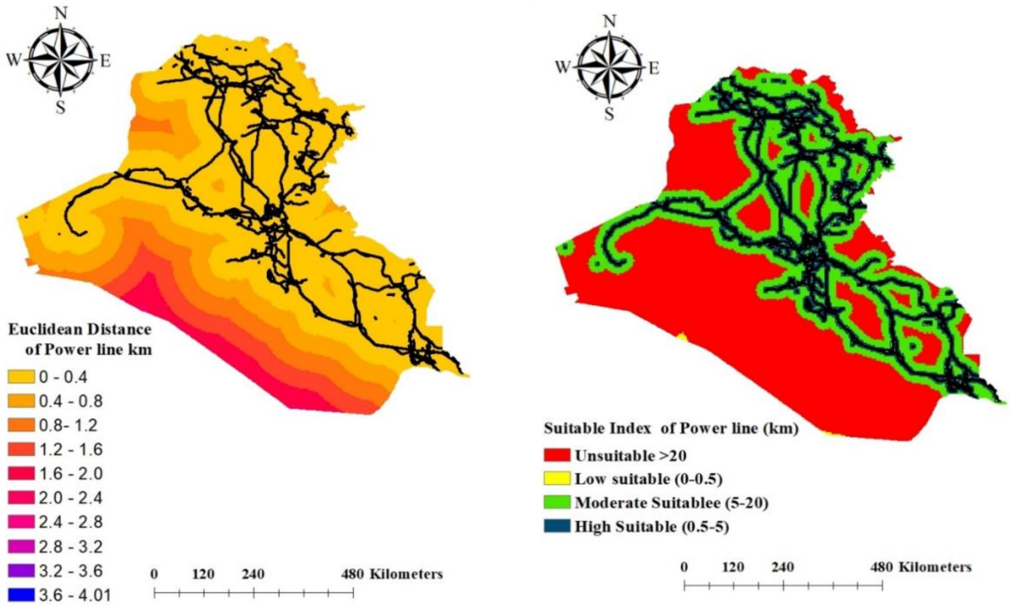


Fig 4 :Suitability of distances from Power lines

a)Euclidean distance of power line, b) Reclassified power lines

For cities, we also use the Euclidean distance tool as in (5a). The insulating layer has been reclassified into four classes as in Table (5) with a suitable high score greater than 5 km and not suitable when the distance is less than 2 km and marginally Fit, moderate suitable to values between (5-20), and can be seen in Figure (5b).

Table5: Reclassified Cities in Iraq

Old values distance of Cities (km)	New values
0-2	1
2-5	2
5-20	3
>20	4

a) b)

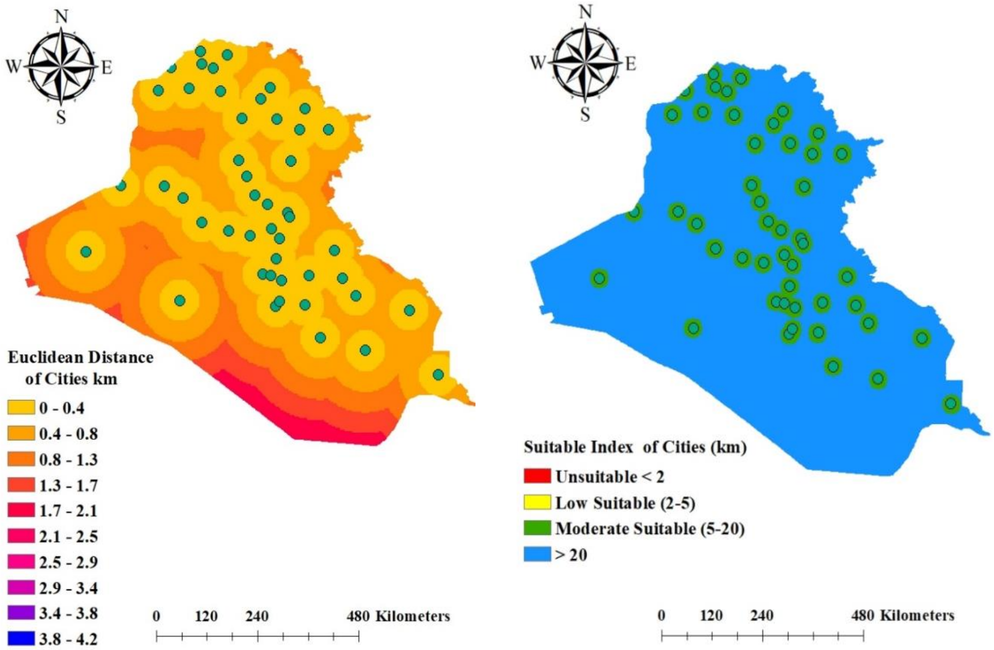


Fig 5 : Suitability of distances from cities of Iraq

a)Euclidean distance of Cities, b) Reclassified Cities

Since Euclidean distances were previously adopted by power lines, the distances between Iraqi roads and proposed areas were reclassified according to Table (6) and Figures (6a-6b).

Table6: Reclassified distance roads in Iraq

Old values distance of roads (km)	New values
0-0.5	2
0.5-5	4
5-20	3
20-120.346	1

(a) (b)

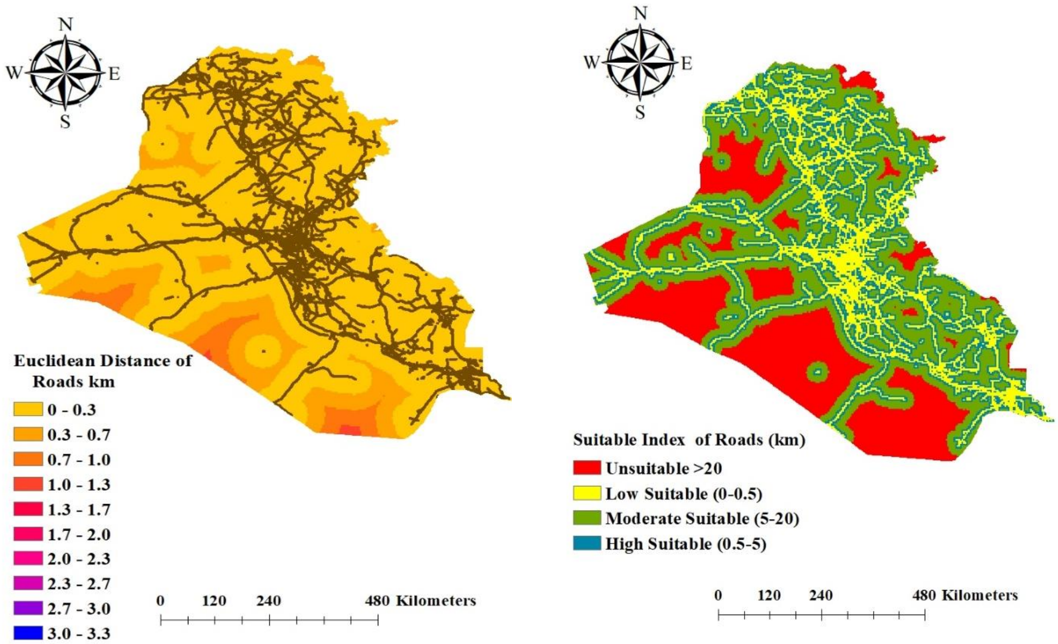


Fig 6: Suitability of distances from road of Iraq

a)Euclidean distance of Roads, b) Reclassified of Road

The classification of the raster layer of the land cover is shown on figure 7. To choose the optimal locations for wind farms, the agricultural areas were excluded in his analysis. It is considered that dry areas and soils are the best areas for wind activities, in which the wind speed is high and important for wind turbines within the permissible rate. As for the unsuitable sites, they are represented in the mountains, as they are considered unsuitable sites for the establishment of wind energy projects. Not only that, but water bodies, wetlands, and forests within the classification of areas are considered unsuitable and this is what has been done in excluding and removing water bodies and trees when using the weight overlay tool, because they are considered unsuitable areas.

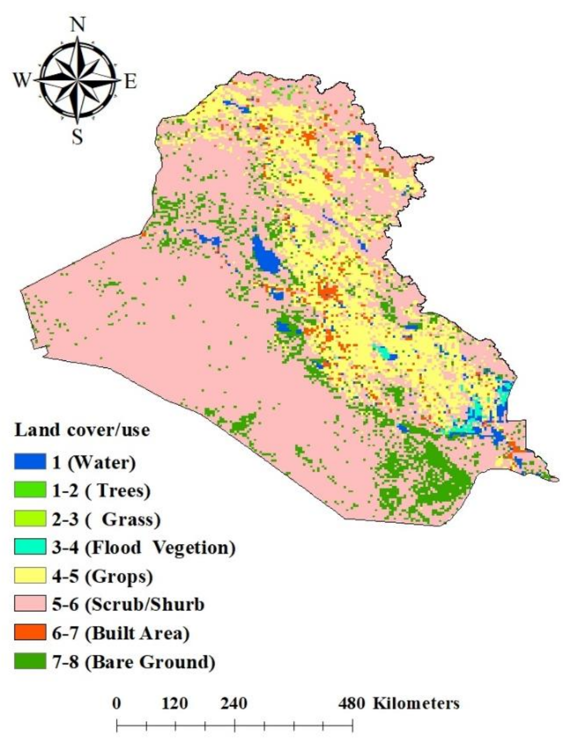


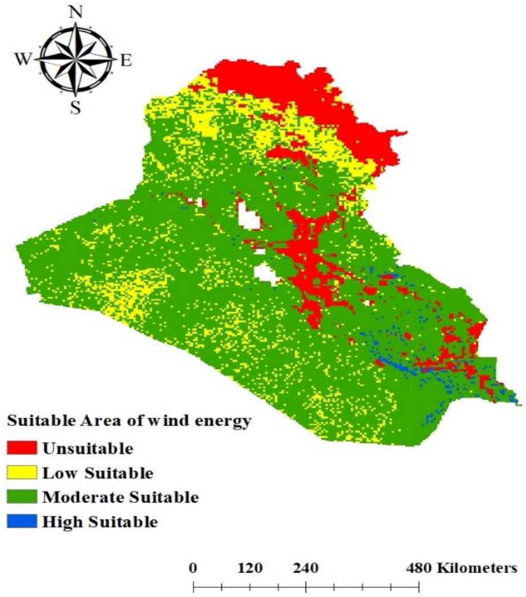
Fig 7 : Classification of the Land cover

To obtain the final site fit map, all datasets were combined and The final results are calculated based on the raster format so that the result can be specified per pixel. The final result (Figure 8) show that the southeastern region of Iraq was considered more suitable for wind harvesting (figure 8a), mainly due to its high wind speed, moderate slope, proximity to main roads and grid lines, and its distance from cities. After excluding the areas of water bodies and forests, four regions were obtained, ranging from the most suitable to the unsuitable regions for wind harvesting. Figure 8b (Table 7) shows the percentage and area of each region and we have 1% for suitable high regions, 71% for the moderate Suitable, 15% for the low Suitable and 13% for the unsuitable regions.

Table7: Percentage of wind harvested areas

Area classification	Percentage %
Unsuitable	13%
Low Suitable	15%
Moderate Suitable	71%
High Suitable	1%

a) b)



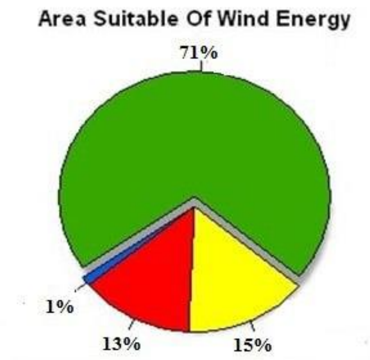


Fig 8 : Suitable for wind harvesting

a) Suitable Area of wind energy, b)Percentage of fit areas

4. Conclusion

In this study we have identified suitable sites for wind farms based on several climatic, economic and environmental criteria in Iraq by analyzing the data for 40 years data geographic information systems by using six criteria through a weight overlay tool, knowing that water bodies and trees are excluded. We can conclude that the southeastern regions are the most suitable locations for wind energy projects because they have several advantages that make the wind turbine work with high efficiency. In the southern regions wind speed is greater than 6.2 m/s which is required to operate the wind turbine. Moreover, these regions are characterized by low terrain slope and population density and are close to electricity transmission lines and roads which reduce transportation costs and have better access for construction and maintenance of wind farms.

This analyze is a preliminary work and will be consolidated in the future.

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