International Journal of Mechanics and Energy (IJME)
Vol. 11, Issue 1, 2024, ISSN: 2286-5845

Assessment of the suitability of the land for solar energy farms in Iraq using GIS techniques

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Abstract: Solar energy is one of the components of renewable energy, which is a significant source of clean energy in many industries, particularly electricity generation and water desalination is solar energy. This work aims to apply a multi-criteria GIS method to identify the most suitable spatial locations for solar energy collection in Iraq in order to produce the energy required to generate electricity. Some of the required criteria and conditions, whether technical, environmental, or economic criteria, have been used. In order to identify the suitability of different regions, 6 criteria, including solar radiation, distance from power transmission lines, distance from major roads, distance from the residential area, elevation, slope, and land use, are identified. The final findings showed that the southern parts of Iraq, which are distinguished by high radiation (5.6 kWh/m2), moderate slope, closeness to major roads and network lines, and distance from cities, are the ideal sites for gathering solar energy. In addition, the study area was divided into regions, with a high suitability index covering 6.2% of the total area, which is a significant indicator of the potential for harvesting solar energy. This was followed by a moderate suitability index of 79.8%, a low suitability index of 8.4%, and unsuitable areas were identified at 5.3%.

Key words: solar power (SP), Multi-criteria, GIS, renewable energy, Iraq

1. Introduction

There are several factors that need to be taken into account when constructing a power plant, including the characteristics of the local and regional environment. Remote sensing, geographic information systems, and multi-criteria spatial data analysis are used to identify a place optimal for developing or utilizing renewable energy sources. Since "green power stations" must be developed, spatial studies based on Geographic Information Systems (GIS) are also essential [1]. Energy is a crucial global indicator of the level of development. Globally, the need for energy is rising daily due to population growth, scientific and technological advancements, and other factors [2]. The exploration of alternative energy sources other than fossil fuels has increased significantly due to the demand for a safe, dependable energy supply and the desire to minimize greenhouse gas emissions [3]. Recent studies have combined GIS and Multi-criteria Decision Analysis (MCDA) approaches to choose the best locations for renewable energy facilities. Solar power is among them [4]. Expanding and enhancing the capabilities of GIS and related technologies to support decision-makers in their decisions is the main objective of merging GIS and MCDA [5]. The researcher used the Analytical Hierarchy Process (AHP) as a multi-criteria decision analysis approach to estimate and develop the weight of each parameter to locate and map the ideal solar PV locations using GIS technology. The goal was to identify the significant contributing parameters in determining the location of PV plants within each region [6]. By conducting technical and theoretical assessments to ascertain the quantity of solar energy

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that can be used in the development of electric power, a research team conducted a scientific study for the prospective theoretical and technical evaluation of solar power generation [7]. An integrated geographic information system and the best methods for site selection for photovoltaic power plant projects were the subjects of earlier studies. The model ensures the selection of the optimal site from an implementation and technical standpoint by considering several measures in three areas, namely climate, location, and geography [8]. Researchers in renewable energy presented a study using topography, land use/land cover factors, and a Digital Elevation Model (DEM) in a geographic information systems context to create a site suitability map for capturing solar energy [9]. By using the mapping technique, GIS, and then applying AHP to the issue, the researcher provided a different study to investigate probable places for constructing a solar power station in order to identify the best locations for solar energy [10]. Numerous studies conducted recently have found potential locations for photovoltaic power facilities. The best placement for the solar installation depends on a variety of technical, economic, environmental, and social considerations in addition to the solar radiation received [11]. Choosing a good site is crucial when establishing solar energy projects since the first stage is to deliver a project that is both cost-effective and high performing [12]. Using solar radiation and the digital elevation model in comparison to each other, an accredited study in the field of renewable energy sought to determine the best locations for establishing large-scale solar farms in order to produce the best outcomes for solar energy projects [13]. Other scholars have used the Earth's height, the sun's direction, the Earth's slope, and the radiation's maximum. They viewed these criteria as viable ones to use with the weight overlay GIS application. A final map that can be used as a reference for final decision-making is created by superimposing all of the data and criteria maps [14]. This study aims to select suitable locations for solar power plants in Iraq based on numerous climatic, economic, and environmental criteria using an analysis of 40 years' worth of GIS data.

1.1 Study area

The study area was Iraq. It is in the southwest of the Asian continent, bordered to the north by Turkey, to the east by Iran, to the south by Kuwait and Saudi Arabia, and to the west by Saudi Arabia, Syria, and Jordan. The area of Iraq is about 438,320 km^2. Iraq enjoys a transitional climate between the desert climate and the Mediterranean climate. It is a continental climate characterized by dryness, high temperatures in summer, and low temperatures with little rain in winter [15,16].

2. Material and Methods

2.1 Data source

To adopt the selection criteria for Solar power projects from multiple sources, a set of data was gathered. Climate data were the most significant data that were gathered for the past 40 years, the research region has been covered by a RASTER file of annual Solar Radiation, temperature, precipitation, soil moisture, and NDVI (Normalized Difference Vegetation Index). One of the most essential pieces of information for conducting the investigation is the Digital Elevation Model (DEM). Common morphological parameters, such as height and slope, can be created using DEM. Additionally, GIS layers for economic parameters, protected area limits, and GIS.

Layers for economic parameters were acquired and combined with the approved geographic database following the installation of the structure. The server's LULC (Land Use/Land Cover) projects from multiple sources, a set of data was gathered. Climate data were the most significant data that were gathered For the past 40 years, a RASTER file of annual Solar

Radiation, temperature, precipitation, soil moisture, and NDVI has covered the research region. One of the most essential pieces of information for conducting the investigation is the digital elevation model (DEM). Common morphological parameters, such as height and slope, can be created using DEM. Additionally, GIS layers for economic parameters and protected area limits were acquired and combined with the approved geographic database following the installation of the structure. The server's LULC (Land Use/Land Cover) data was used to download and extract data to download and extract the map of Iraq.

The acquisition of the classed raster data was the final stage of these processes. The Weighted Overlay tool groups all raster layers according to their weights in order to function by combining the exclusion zone and the classed region into one map based on the computed values to identify the suitable areas for solar PV plants.

2.2 Statistical analysis

Remotely sensed data can be used to process objects or occurrences in distant (remote) locations to extract topics and measurement information and prepare it for inclusion in GIS [17,18]. The GIS facilitates data collecting, geospatial data processing, visualization, scientific communication, and collaborative research [19]. The weighted suitability model was designed for suitable site suggestion procedures employing geographic information systems based on various objective layers, and based on the multi-criteria evaluation concept, the disaggregated datasets should be integrated to locate the best solar sites [20,21]. To develop an integrative analysis of distinct and dissimilar input values (the proper cell has a more excellent value), all data sets were classed into the same descriptive statistic. The weight of each criterion is assigned to the input layer based on its importance and degree of influence, and the total weight is calculated as a sum to assign an important degree to each of them. The Suitability Index (SI) can also be used to determine the appropriateness of the selection in the equation below [22, 23].

where,

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

SI_i is the suitability index for cell i

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 criteria

All the layers were blended in this study to create a map displaying the best-suited places [24], as shown in Figure 1.

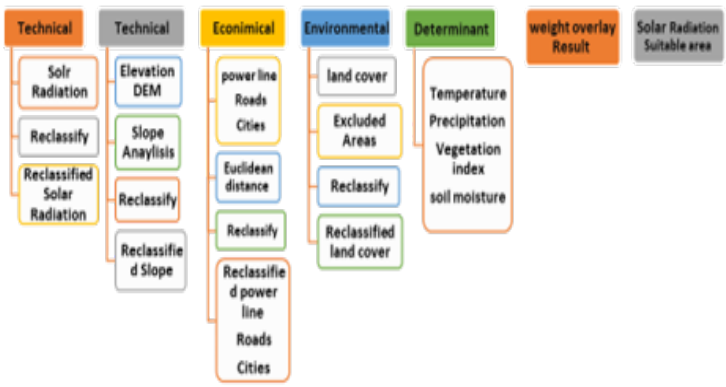


Fig 1 Overview of Solar power site suitability

3. Results and Discussion

3.1 Solar Radiation

Fig (2a) represents the long-term annual average of global solar radiation for the years (1980-2022) in kWh / m2 to conduct an analysis of the suitability of solar electric energy, The average solar radiation was reclassified into four raster data categories from high suitability (5.4-5.6), medium suitability (5.1-5.4), low suitability (5.1-4.9), to unsuitable (4.7-4.9) as in Table 1 and Fig (2b).

Table 1 Reclassified Solar Radiation in Iraq

Old Values Average Solar radiation in kWh / m2	New values
4.7-4.9	1
4.9-5.1	2
5.1-5.4	3
5.4-5.6	4

Table 2 Reclassified Slope in Iraq

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

(a) (b)

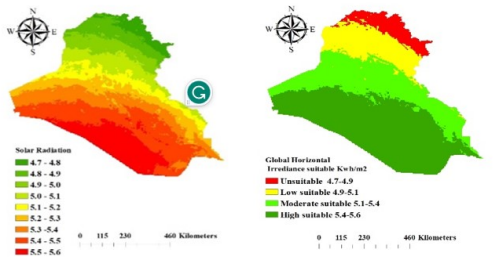


Fig 2 a) Annual Solar radiation (1979-2020) , b) Suitability of global solar radiation

3.2 Topographic Criteria

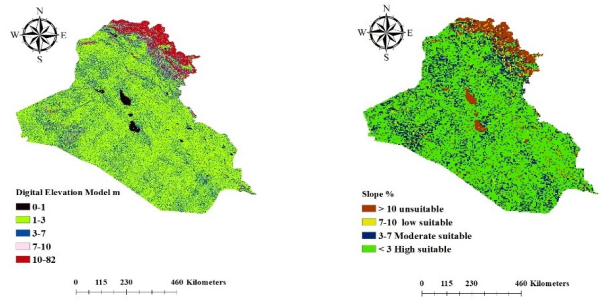
The slope is one of the important criteria in this study as it is the main reason for receiving solar radiation and is logically affected by the gradient of the earth, where the flat areas are considered one of the most important areas in receiving the largest percentage of solar radiation.

Figure (3a) shows the digital elevation model that was created from a data set that was downloaded from several snapshots to obtain the slope shown in Figure (3b).

In this figure we note that the lakes in blue are classified as exclusion zones in addition to the northern regions that are considered with high slopes.

It is difficult to build solar cells, which is viewed as an exclusion zone when designing energy projects, as for the southern regions, it is considered one of the best and highly suitable regions, as it enjoys flat lands and is regarded as a good recipient of solar radiation. Therefore, these regions are chosen when designing solar energy projects.

(a) (b)



(c)

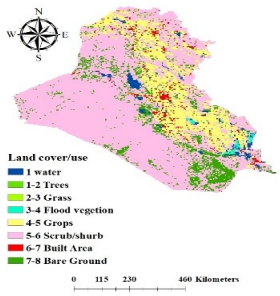


Fig 3 a) The elevation of Iraq after using slope tool, b) Suitability of slope, c) Land Cover classification of Iraq

3.3. Economic criteria

The economic factors represented by the distance between (power transmission lines, roads, cities) are considered essential factors when choosing the most suitable sites for building renewable energy projects.

The distance to the power transmission lines is necessary to transfer the energy generated from the

solar energy and to reduce construction and maintenance costs. Therefore, the sites close to the power transmission lines are considered the most appropriate locations as shown in Figure (4a), where the criteria were determined. The distance is from 0.5 to 20 km when choosing the suitability index, figure (4b), represents the distance between the roads, where the sites close to the roads are considered the most suitable sites because they reduce the cost of transportation and enhance rapid access, as the areas can be divided into highly suitable (0.5-5) km. In comparison, the unsuitable areas are larger than 20 km due to their distance about solar power plants.

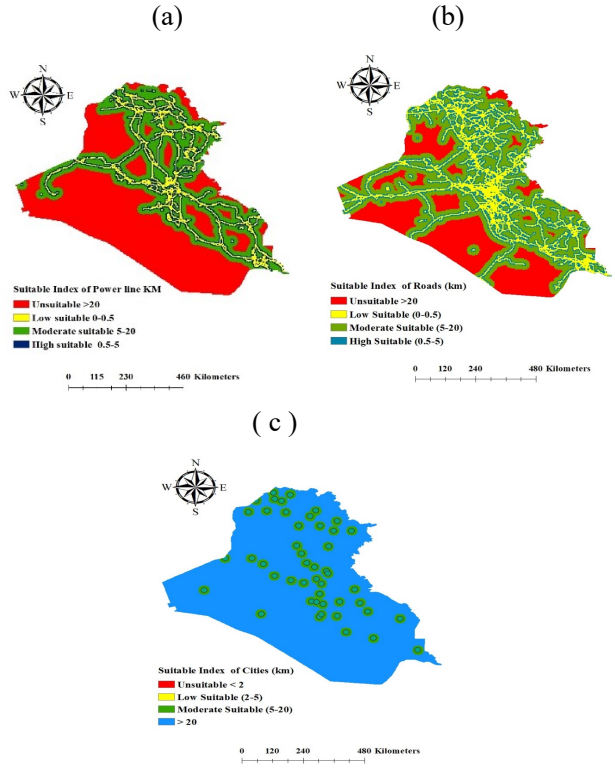


Fig 4 Suitability of distances from , a) Power lines , b) Roads c)Cities of Iraq

Regarding the distance between cities, as shown in Figure (4c); the buffer zone was reclassified into four main categories with high altitude <5 km and inappropriate when the distance is less than 2 km, as the farther away the design of solar energy projects from cities, the more appropriate, Where the regions were divided and reclassified into four main categories from a highly suitable area to an unsuitable area, as in Table 3

Table 3 Reclassified distance (power line, Cities, Roads) in Iraq

Criteria	Old values				New values			
power line	0-0.5	0.5-5	20-May	20-21.9375	2	4	3	1
Cities	0-2	5-Feb	20-May	>20	1	2	3	4
Roads	0-0.5	0.5-5	20-May	20-21.9375	2	4	3	1

3.4 Determinants that reduce the efficiency of solar cells

There are many climatic determinants that are important to study when determining the appropriate sites for building solar cells, including (temperature, rainfall, soil moisture).

The temperatures in Figure (5a) are considered an important factor for photovoltaic systems, as a rise in temperatures above 40 m can have a significant impact on the efficiency of photovoltaic units, as high temperatures significantly reduce the performance of the system as well as its components. Therefore, areas with higher temperatures are chosen. The temperature is moderate, between 20-25 degrees Celsius to ensure the performance of the solar cells, so the existing temperatures are considered a good evaluation for the construction of photovoltaic cells; figure (5b) shows precipitation, which is considered one of the factors for evaluating the most suitable areas for solar cells in terms of its impact on the performance of solar systems, as we note that the northern regions are the most precipitation, so they were excluded in addition to the nature of the surface. In addition, an important factor is considered when choosing the appropriate location for solar energy projects: soil moisture in Figure(5c), where lands with increased soil moisture are excluded because it could. Reduce the efficiency

of cell work by reducing the life of the transformers and the system's performance.

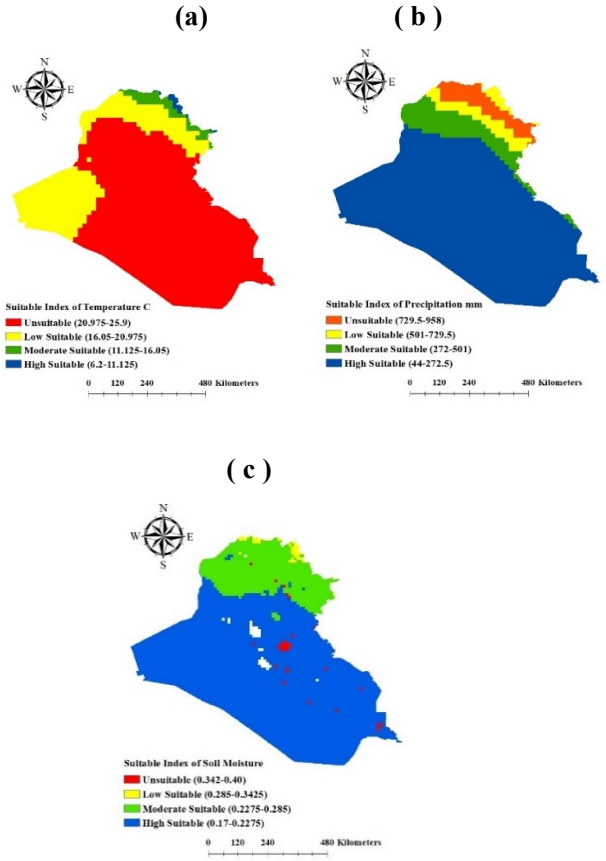
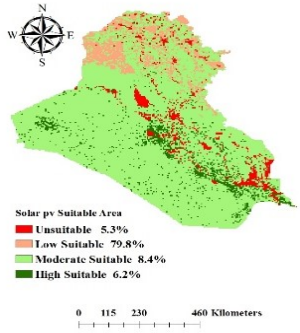


Fig 5 Climatic determinants: a) temperature [C], b) Precipitation mm, c) Soil moisture

3.5 Suitable Area of Solar PV

An overlay analysis of weights was performed as in (Fig 6) to obtain the best suitable sites for collecting solar energy, where all the reclassified layers were collected from the raster data set that includes (solar radiation, slope, distance between roads, power transmission lines and cities, land cover). By overlaying the weights tool and then reclassifying them manually to clarify the data more clearly. The result shows that it has been identified that the southern region of Iraq is the most suitable for solar photovoltaic power plants. The reason for choosing this region is due to high solar radiation, moderate slope, its proximity to roads and power transmission lines, and away from cities. It has been noticed that there is a moderate percentage in the center, and the harvest of solar energy gradually decreases when heading north until it becomes



unsuitable for the installation of photovoltaic cells.

Fig 6 Suitability of the solar

4. Conclusion

In this study, we selected the potential areas for solar energy harvesting based on various climatic, economic, and environmental factors in Iraq by evaluating 40 years of GIS data using six criteria using the weight overlay method, knowing that water bodies, trees, forests, and crops were excluded. We can conclude that the southern regions are the most suitable locations for solar photovoltaic projects because they have many advantages that make solar cells operate with high efficiency. In the southern regions, solar radiation is greater than 5.6 kWh/ $m^{2,}$ which is required to operate solar cells. Moreover, these areas are characterized by low terrain slope and low population density and are close-to-power transmission lines and roads, which reduce transportation costs and have better access to the construction and maintenance of solar energy projects. This analysis is preliminary work and will be standardized in the future.

Acknowledgments

I would like to express my appreciation to NASA for making the process of obtaining the data used in this research more accessible by making it clear that it will be included in a doctoral dissertation that will be submitted in the future. I also want to thank the dissertation supervisors for the guidance and observations they provided me with to obtain these preliminary results.

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