DETERMINATION OPTIMUM SITES FOR SOLAR ENERGY HARVESTING IN IRAQ USING MULTI-CRITERIA

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ABSTRACT

This study was aimed to investigate the multi-criteria Analysis based on the geographic information systems (GIS) to determine the most suitable spatial locations for harvesting solar energy in Iraq. 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 defined criteria, including solar radiation, distance from power transmission lines, distance from major roads, distance from residential area, elevation, slope, and land use, are identified. The final map of priority of different locations of Iraq for solar energy harvesting is then created by stacking these criteria layers. It has been found that the entire region is almost suitable for solar energy harvesting with varying suitability index. Moreover, areas of high suitability index cover 14% of the all-area, which is a significant indicator of the potential of solar energy harvesting in Iraq. the area with a moderate suitability index covers 60%, and the low suitability index was 21%, while 5% of unsuitable have been identified. The results indicated that the optimal locations of suitable harvesting solar energy located almost in the south of Iraq.

Keyword: suitability index, environmental, economic, technical, renewable, energy, harvesting, remote sensing.

تحديد المواقع المثلى لحصاد الطاقة الشمسية في العراق باستخدام معايير متعددة

رسل ابراهيم العاني ياسين كاظم التميمي
باحث استاذ
قسم علوم الجو – كلية العلوم – الجامعة المستنصرية

المستخلص

تهدف الدراسة على استعمال التحليل متعدد المعايير القائم على نظم المعلومات الجغرافية (GIS) لتحديد افضل المواقع المكانية لحصاد الطاقة الشمسية في العراق باستخدام بعض المعايير والشروط المطلوبة سواء كانت تقنية أو بيئية أو اقتصادية من أجل تحديد مدى ملاءمة المناطق المختلفة، تم تحديد 6 معايير محددة، والتي تشمل الإشعاع الشمسي، والمسافة من خطوط نقل الطاقة، والمسافة من الطرق الرئيسية، والمسافة من المنطقة السكنية، والارتفاع، والمنحدر، واستخدام الأراضي. بعد ذلك من خلال تراكب طبقات المعايير المختلفة، يتم تطوير الخريطة النهائية لتحديد افضل المناطق في العراق لحصاد الطاقة الشمسية. وقد وجد أن المنطقة بأكملها مناسبة تقريبًا لحصاد الطاقة الشمسية مع مؤشر ملاءمة متفاوت. علاوة على ذلك، تغطي المناطق ذات مؤشر الملاءمة المرتفع 14٪ من المساحة الإجمالية، وهو مؤشر مهم على إمكانات حصاد الطاقة الشمسية في العراق. تغطي المنطقة ذات مؤشر الملاءمة المعتدل 60٪، ومؤشر الملاءمة المنخفض 21٪، بينما تم تحديد 5٪ من المناطق غير الملائمة. أشارت النتائج إلى أن المواقع المثلى لحصاد الطاقة الشمسية المناسبة تقع تقريباً في جنوب العراق.

كلمات مفتاحية: مؤشر ملائمة، بيئي، اقتصادي، تقني، متجددة، طاقة، حصاد، الاستشعار عن بعد.

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INTRODUCTION

Solar energy is one of the more promising renewable energy sources because it is considered a stable source of energy and is not significantly affected by changes in seasonal weather patterns (17). In addition, the production efficiency of solar energy technologies has increased in recent years and the ability to use it in a variety of locations is very favorable (11).The demand for solar energy is increasing worldwide as countries follow steps for sustainable development and reduction of carbon dioxide emissions (12). The world's population continues to grow. Increasing population growth and industrialization of countries leads to the need to increase the use of energy sources(19). Evidence indicates that global energy demand in recent years, demand for energy from nonrenewable energy sources has skyrocketed, especially wind and solar energy, which have become the focus of interest in many countries (15). The usage of nonrenewable fossil fuels on a worldwide scale has a negative influence on the environment (19). The consumption of fossil fuels leads to global problems, including environmental degradation and climate change. furthermore, due to the significant increase in the use of non-renewable fossil fuels, interest in using renewable energy sources has increased (8, 20). Extendible energy is becoming increasingly important now, but fossil fuels also need time to be output naturally. With reduced precautions, prices of fossil fuels become higher renewables are a good substitue for fossil fuels because they are non-renewable (7). Solar energy is the best example of renewable energy, where the sun is used to generate energy without emitting CO2 atmospheric emissions (16). Solar electricity is one of the sustainable energy sources that never runs out. The use of photovoltaic (PV) instruments to directly gather solar energy is becoming more popular as an integral part of the world's energy nutrients of the future. Iraq is one of the governments in the Midst Eastern that has little electro and, yearly, there are troubles with produce and participation. Land administration, and the optimum use, because of the importance of ecological resources and their appropriate use, it is a crucial topic that governments and masters are considering nowdays. To set the right site for solar PV some technical, economic and environmental criteria are studied, for their importance (3). In 2021, the Solar Energy Farms using Analytic Hierarchy Process (AHP) in GIS Environment has been studied.Numerous climatic, geomorphological, economic, and environmental criteria and some exceptional limitations have been adopted in the modeling process supported by expert knowledge and a comprehensive literature review. The results showed that approximately 19% of the study area is the optimal area for installing solar farms (14) . In 2017, the multi-criteria analysis and GIS model and the site suitability approach to select the most suitable location for locating the solar PV and wind farms across the Sinai Peninsula. The results of analysis of the spatial GIS model suitability model were displayed in two main maps for the Sinai Peninsula showed respectively the optimal sites for both types of renewable energy power plants; solar PV and wind power. as the main result of this study, the obtained two main results show that there is a very high potential of solar power generation in extensive areas of Sinai across the north-west, south-west and middle areas of Sinai respectively (1). Multi-criteria to locate appropriate sites for solar energy harvesting in Egypt have been studied. This study focuses on utilizing the Multi-Criteria Analysis (MCA) within a Geographic Information System (GIS) environment to locate optimum locations for solar energy projects. It has been found that almost all the Egyptian lands are promising in solar energy harvesting with a variable suitability index. High suitability locations have been identified with a total area of more than 25 thousand square kilometers (9) . In 2017, studied Optimum sites for solar energy harvesting in Makkah metropolitan area based on multi-criteria GIS. Several physical and environmental spatial databases have been built up and an integrated GIS system has been developed. The results of the final adequacy model indicate that each Makkah region is suitable for solar energy collection projects with an average suitable of 80% (10). The study was aimed to use Geographic Information System (GIS) by

multi-criteria suitability analysis to determine the most suitable spatial locations for harvesting solar energy in Iraq.

MATERIALS AND METHODS

Iraq is a large Mesopotamian alluvial plain,Consisting of the Tigris and the Euphrates rivers (6).The Study area "Iraq" which located in Southwest of Asia, the total area (437072 km^2), where the land area is (432162 km^2) while the area of water bodies is (4910 km^2)(2). Iraq is located in the range of semi-tropical latitude in the Northern Hemisphere between longitudes (38.45°-48.45°) east of Greenwich line and between latitudes (29.5°-37.5°) north of the equator (13).The average monthly temperatures range between 6°C in January to 34°C in July, but the temperatures decrease toward north regions of Iraq. The annual average of wind speed in the northern regions was low about 2.7 m/s compared to the middle and southern regions (2). Iraq can be divided into three climatic zones according to the rainfall factor, the study area in Arid and Semi-Arid Zone where the annual rainfall above 400 mm. In April and May (5).Most of the rainfall occurs between December and April and the annual rainfall rate is "100-180 mm" (4). See (Figure 1). The current analysis is based on a vareity of effective spatial creteria and elements that influence solar power plant feasibility.

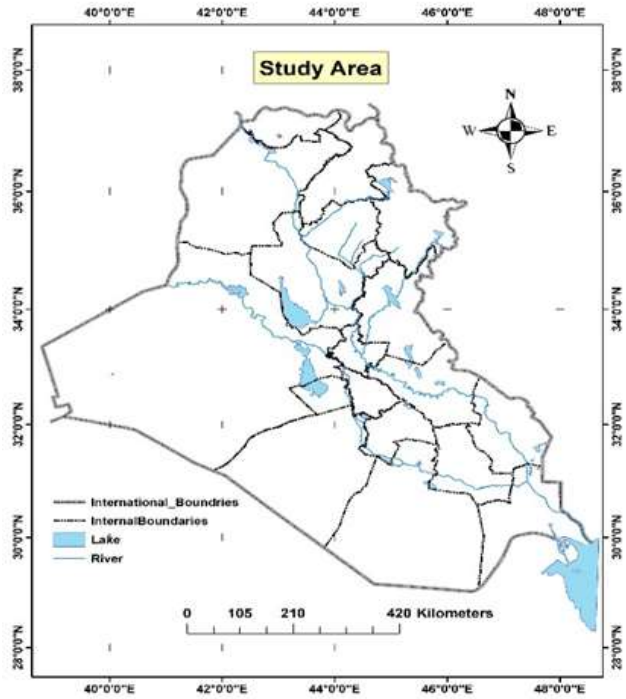

Figure 1. location map of study area, Iraq

Expert comments and past research studies were used to develop the study's creteria. In the current study, the criteria and factors have been classified into three groups: technical, economic, and environmental. The criteria and factors used in this study include meteorological data for annual average solar radiation for the period 1980-2020 getting from Iraqi Meteorological organization and seismology, Digital Elevation Model ASTER satellite picture (DEM), and statistical data and shapefiles of the major cities, major roads, and power lines in Iraq from the Ministry of Planning, Iraqi Ministry of Electricity and sustainable energy. we have conducted all of our analysis using the ArcGIS10.7.1 in order to perform a site-suitability analysis. after initially checking that data sets, then converting all to raster format when we used the Euclidean distance tool to convert the formats of those layers to a raster format for the power line, roads and cities criteria. Subsequently, the outputs of the previous step will be reclassified into four main categories and finally we were conducted the weight overly analysis to depict our result, we have excluded the non-suitable areas such as water bodies.

Evaluation criteria

In general, site selection creteria are usually studied in groupings, such as environmental, economic, hydrological, technical, etc. Based on several kinds of literature and case studies concerning solar energy harvesting, six criteria have been selected to be processed in the current research. The criteria used in this study can be divided generally into three groups: technical criteria (potential of solar radiation, terrain slopes, and distance from power line distribution network); economical criteria (distance from roads and cities), and environmental criteria (land use) . For each criterion, a reclassification has been performed in order to evaluate its particular suitability for solar energy harvesting. A specific weight strategy has been applied in treating the utilized criteria while processing the final suitability model. (Figure 2).

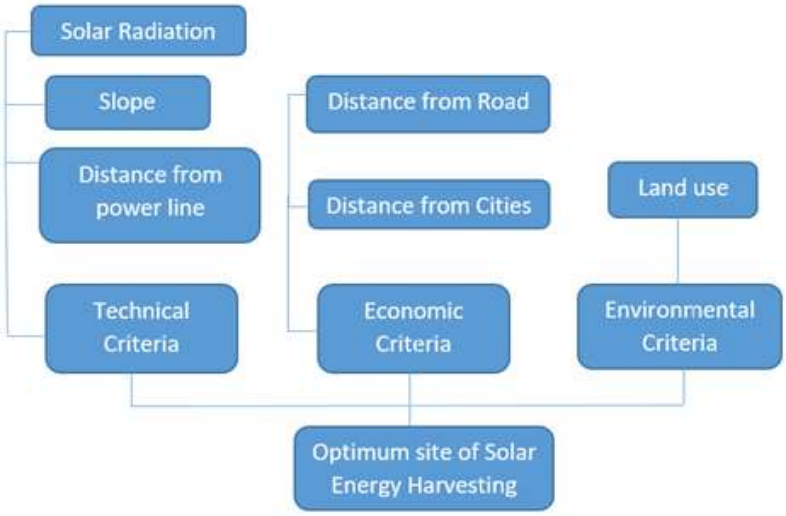

Figure 2. Evaluation criteria of solar energy harvesting

The Arc GIS software has been applied to extract criteria maps. One of the most essential factors in determining whether selected areas will receive enough sunlight throughout the year is solar radiation. (Figure 3) showes the result of interpolation and reclassify map of solar radation it can be seen that the annual average of solar radiation range between 3.86357 kwh/m^2/year to 4.53988 kwh/m^2/year. A number of processing procedures for the Digital Elevation Model (DEM) have been performed in order to get the slope map. One of the most critical considerations in solar energy site selection is slope, which is found to vary from 0 to 82 degrees. (Figure 4).

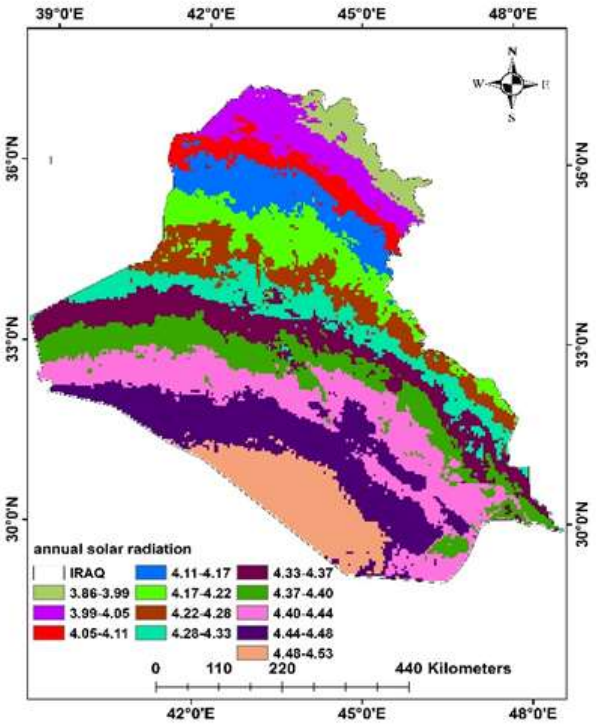

Figure 3. Criteria range of solar radiation

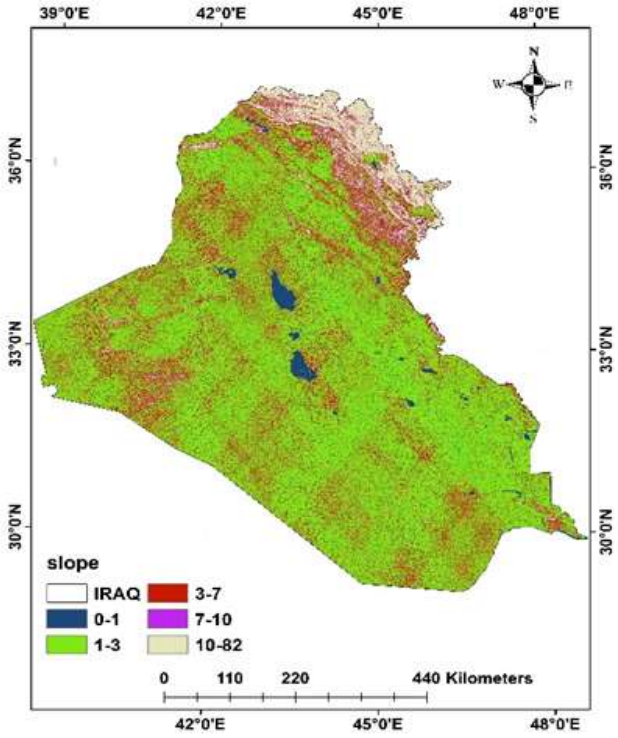

Figure 4. Criteria range of slope

The distance from power lines and highways is a significant consideration when locating solar energy. Overall, the positioning of solar energy is influenced by electric power lines and roads in term of safety, network security and easy accessibility (Figure 5), and (Figure 6) shows the roads in the study area.

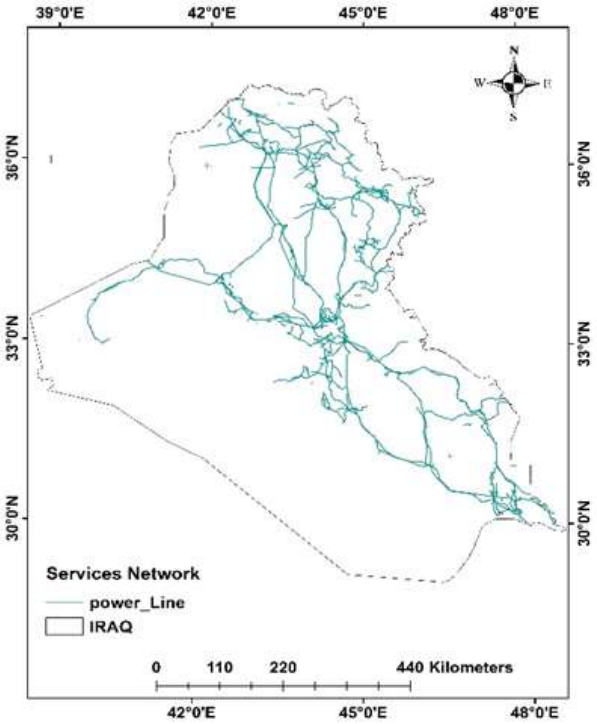

Figure 5. Power line networks of Iraq

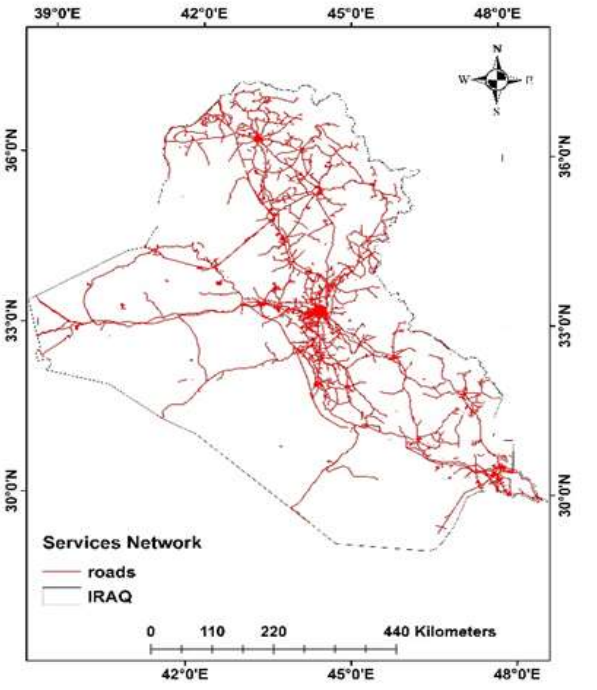

Figure. 6 Roads networks of Iraq

One key environmental issue in site selection is land usage. Land use was assessed for eight different forms of land use in this paper water, trees, grass, flooded vegetation, crops, shrub, built area, and bare ground. Barren areas were considered as the best areas and irrigated areas have the lowest priority for exploitation solar energy harvesting. (Figure 7).

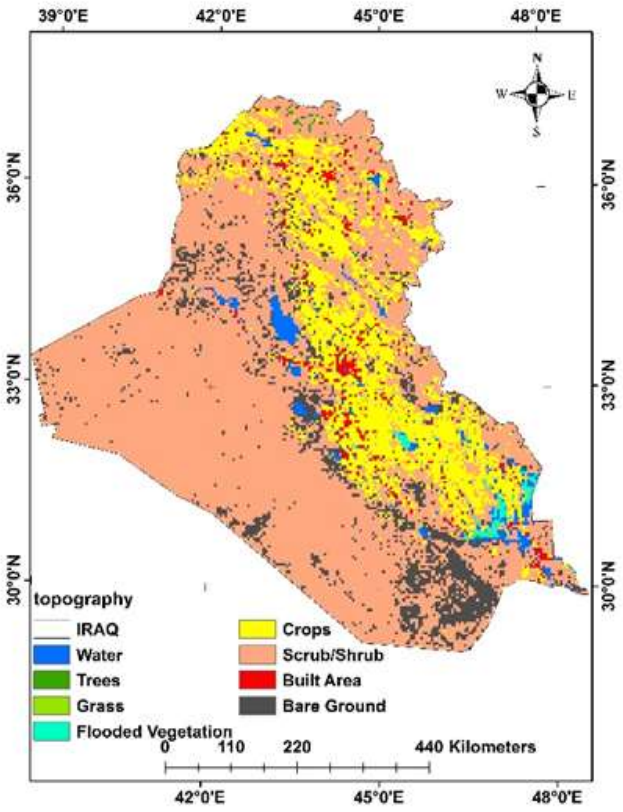

Figure 7. Topography of Iraq

RESULTS AND DISCUSSION

The value of solar radiation reaching the earth is the first criterion in harvesting solar energy, then comes the criterion of the slope of the earth's surface. (Figure 8), shows the slope of the Earth's surface, it can be seen that most parts of the study area have good fitting scores, except for the northern and northeastern regions, which have large slopes, and therefore it can be classified as an unsuitable area for harvesting. Also, the distance from the power line network is an important factor, as the greater this distance, the greater the amount of energy lost during the transmission process, and also the higher the cost of energy transmission. From an environmental point of view, The layers of the values of each of the criteria were transformed into layers that represent the spatial suitability of each criterion individually.

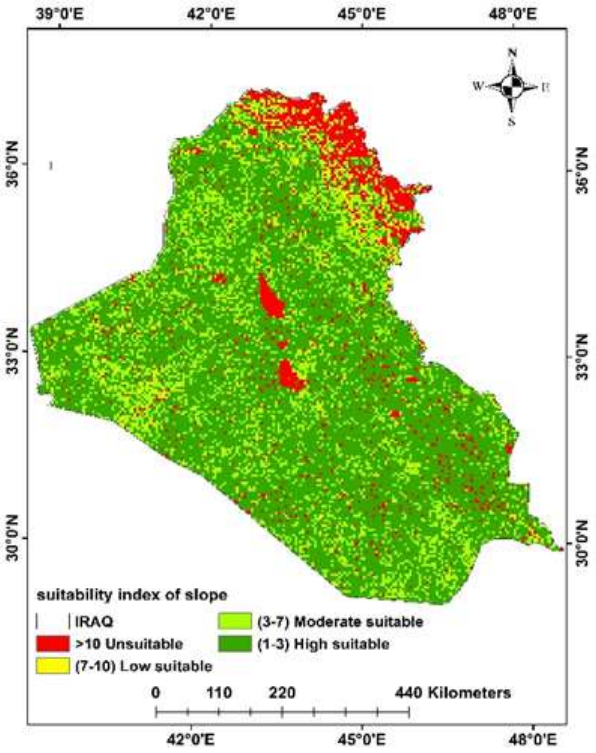

Figure 8. Suitability of terrain slope

(Figure 9), shows the criterion of distance from the electricity distribution network, as it is noted that the highly suitable sites are those that are not more than 5 km away from the distribution lines of this network.distance from the main cities, and roads are also important factors in choosing the most appropriate sites for energy harvesting solar. As for the appropriateness model for the criterion of distance from the main roads, it is shown in (Figure 10), which shows that the road network extends almost throughout the entire study area.Raster layer was obtained for each of the specified criteria, which represents the classification of the criteria's values into categories and then re-classification into degrees on a scale ranging from 1 to 4 for ease of presentation and analysis, then applying the specified weights to reach the final suitable model. Table (1) shows the six criteria that were used in the study. also, the relative weights of each of these criteria were determined as shown in the last column of the table. The adopted criteria, can be divided generally into three groups: technical criteria (potential of solar radiation, terrain slopes, and distances from the electrical distribution network), economical criteria (distances from roads, and cities), and environmental which include the protected areas' types have been imposed as constraints in the processing multi-criteria stage.

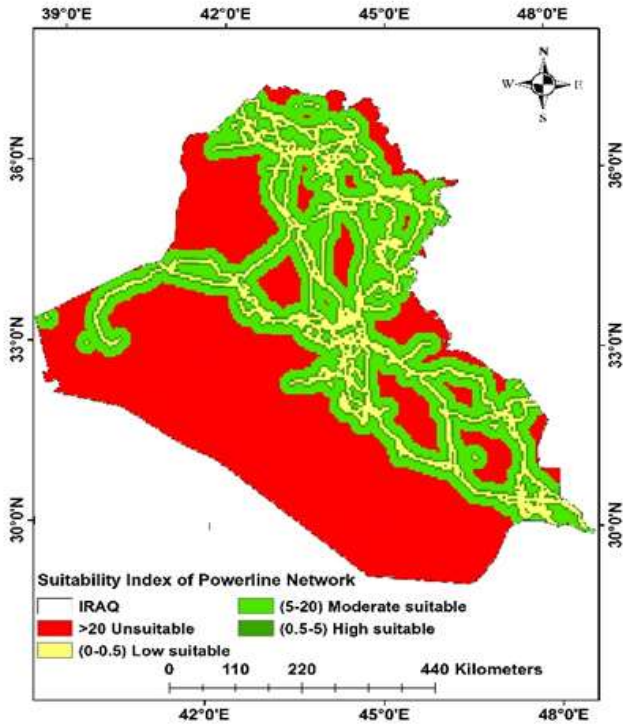

Figure 9. Suitability of distance from power line network

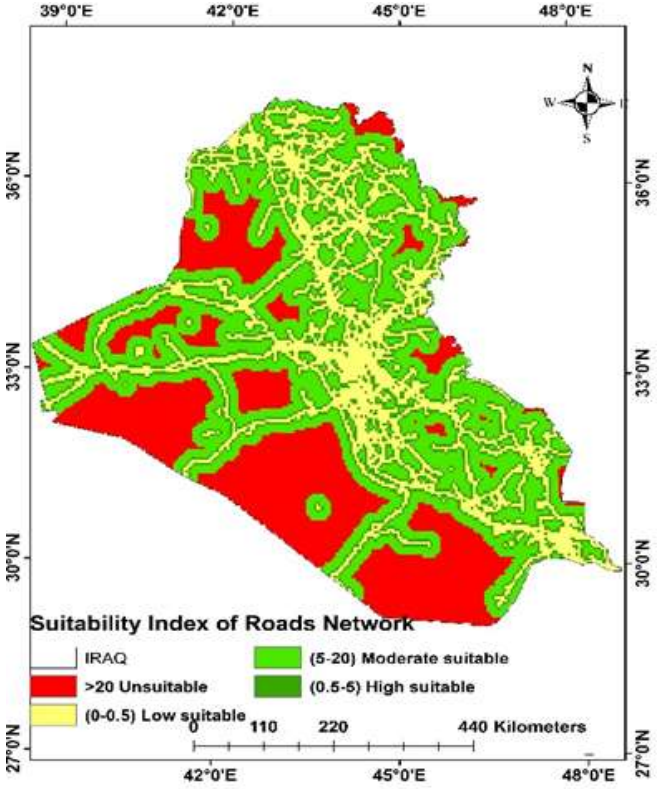

Figure 10. Suitability of distance from roads network

TABLE 1. Utilized criteria and weights

Criteria Type	Criterion	Categories	Suitability	Weight
	Solar Radiation (kwh/m2/day)	>4.53	High	0.38
		4.27-4.40	Medium	
		4.11-4.27	Low	
		<3.86	NA	
Technical	Slope(degree)	1-3	High	0.20
		3-7	Medium	
		7-10	Low	
		>10	NA	
	Distance from power line Network(km)	0-0.5	Low	0.09
		0.5-5	High	
		5-20	Medium	
		>20	NA	
	Distance from Road(km)	0-0.5	Low	0.09
		0.5-5	High	
		5-20	Medium	
		>20	NA	
Economical	Distance from cities(km)	0-2	NA	0.09
		2-5	Low	
		5-20	Medium	
		>20	High	
Environmental	Land use	water	NA	0.15
			Suitable	

Lastly, the raster of the suitability index has been calculated using a weighted overlay function in GIS, this function allows you to overlay several rasters using a common measurement scale and weight each according to its importance. (Figure 11, 12) shows the final suitability model and percentage of each class of suitability index. The results of the final suitability model indicate that the study area varies in terms of solar energy harvesting, with percentages ranging between 14% for areas of high suitability, 60% for medium suitability, 21% for low suitability, and 5% for unsuitable areas. The high suitability areas which cover 14 % of the total area have been identified. It has been concluded that these high-suitability sites have a total area of 61364 square kilometers, which is a good indicator of the potential of solar energy harvesting in Iraq.

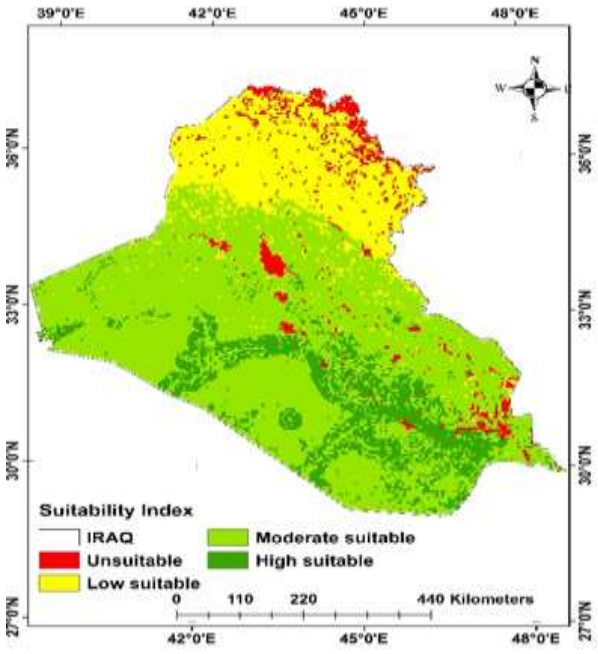

Figure 11. Final suitability model

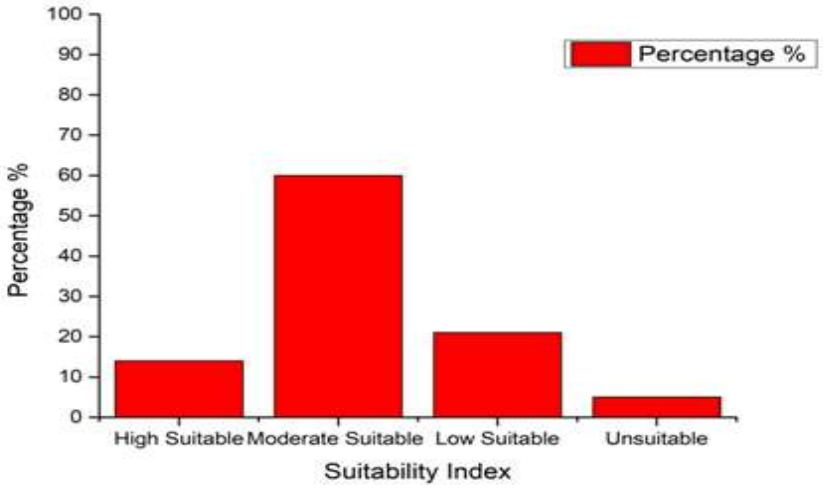

Figure 12. Percentage each class of suitability model

Conclusion

1.The adoption of solar energy can effectively contribute to solve the problem of scare energy supplies in Iraq due to Iraq's unique location, which allows receiving large amounts of annual solar radiation. Moving to solar energy will also diversify the country's energy mix, invest local energy resources, reduce environmental consequences, and aboost long-term growth.

2. This paper focused on the utilization of multi-criteria GIS approach for locating optimum sites for solar energy harvesting in Iraq.

3. The results of the criteria importunacy questionnaire revealed that solar radiation, slope, and distance to power lines all had a significant impact on solar farm location decisions.

4. The results indicated that 14% of the total lands of the study area are of a high suitable of suitability, 60% of the moderate suitable, 21% of the low suitable, and 5% of the lands are unsuitable for estalishing solar farms. The areas with a high suitable of suitability were concentrated in the southern and southwestern regions and a few parts of the western region of Iraq.

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