DOI: 10.24996/ijs.2025.66.12.46

ISSN: 0067-2904

Harnessing Renewable Energy for Special Events Using Image processing, Remote Sensing and GIS techniques

Mustafa S. Srayyih[1*], Hassan. J. M. Alatta[2], Ebtesam F. khanjer[2], Ban abul Al-Razak[2], Sundus A.Abdullah Albakry[2]

[1]*Department of Astronomy and Space, Collage of Science, University of Baghdad, Baghdad, Iraq*

[2]*Department of Remote sensing and GIS, Collage of Science, University of Baghdad, Baghdad, Iraq*

Received: 31/5/2024 Accepted: 31/**12**/2024 Published: 30/12/2025

Abstract

Photovoltaic cells are among the most important and common renewable energy sources, especially in areas with high solar radiation, like Iraq, millions of pilgrims travel on foot every Hijri year in the month of Safar from various provinces of Iraq and from different countries to commemorate the Arbaeen anniversary of Imam Hussein by heading towards the Holy Karbala. During the pilgrimage, numerous organizations or stations (processions) are set up on both sides of the pilgrim's path to provide service to pilgrims. This study highlights the possibility of providing electric energy using renewable energy to these processions along the Baghdad-Karbala Road. The study aims to provide electric energy using renewable sources to these processions along the Baghdad-Karbala Road. Photovoltaic cells are among the most important and common renewable energy sources, especially in areas with high solar radiation, like Iraq. The best sites for solar cell stations will be determined using remote sensing applications and Geographic Information Systems (GIS) by analyzing satellite images (Sentinel 2 and ALOS PALSAR) to calculate the necessary criteria. The hierarchical analysis process is used to determine the optimal locations for photovoltaic cells and to estimate the energy production rate using MATLAB simulations. This research provides valuable insights into the possibility of providing Husseini Camps (processions) with clean energy along the Baghdad-Karbala Road by taking advantage of solar radiation. This study provides a comprehensive and practical approach to ensure sustainable energy supply for the processions, and the results can guide decision-making and development of energy infrastructure in the future, as well as work on similar initiatives in other regions. The results showed that the study area receives high solar radiation, that a low slope characterizes the area's nature, and that the percentage of land suitable for constructing photovoltaic stations is more than 80%. Thus, it is possible to establish more than one photovoltaic station to supply the main electricity grid with renewable energy.

Keywords: Arbaeen anniversary. Remote Sensing and GIS. Multi-Criteria Decision Making. Pv Array. Simulink

Email: * Mostafa.sabah@sc.uobaghdad.edu.iq

تسخير الطاقة المتجددة للمناسبات الخاصة باستخدام تقنيات معالجة الصور والاستشعار عن بعد ونظم المعلومات الجغرافية

مصطفى صباح سريح*[1], حسن جابر محمد[2] , ابتسام فاضل خنجر [2], بان عبدالرزاق عباس[2] , سندس عبد العباس البكري[2]

[1]قسم الفلك و الفضاء , كلية العلوم, جامعة بغدداد, بغداد, العراق

[2]قسم التحسس النائي ونظم المعلومات الجغرافيه, كلية العلوم, جامعة بغدداد, بغداد, العراق

الخلاصة

تعد الخلايا الكهروضوئية واحدة من أهم مصادر الطاقة المتجدده وأكثرها شيوعا و خاصه في المناطق ذات الاشعاع الشمسي العالي مثل العراق. يتوجه ملايين الزوار سيرا على الأقدام كل عام هجري في شهر صفر من مختلف محافظات العراق ، وكذلك الزوار من مختلف دول العالم لإحياء ذكرى اربعينيه للإمام الحسين ، حيث يتوجه الزوار نحو كربلاء المقدسة.خلال مسيره الزياره، يتم نصب عدد كبير من المنظمات أو المحطات (مواكب) على جانبي مسار الزوار لتقديم الخدمة للزوار. الغرض من هذه الدراسة هو توفير الطاقة الكهربائية باستخدام الطاقة المتجددة لهذه الهيئات على جانب طريق بغداد– كربلاء. لتحديد افضل المناطق لنصب محطات الخلايات الشمسيه باستخدام تطبيقات التحسس ونظم المعلومات الجغرافيه من خلال تحليل صور الاقمار الصناعيه (Sentinel 2 and ALOS PALSAR) لحساب مجموعه من المعايير الضروريه لتحديد افضل موقع وكذلك الاستعانه بعمليه التحليل الهرمي لتحديد افضل موقع لنصب الخلايا الضوئيه اضافه الى حساب معدل الطاقة التي تنتجها الخلايا الضوئيه في المناطق الملائمه باستخدام المحاكاه في برنامج MATLAB

توفر نتائج هذا البحث رؤى قيمه حول امكانيه تزويد المواكب الحسينيه بالطاقه النظيفه على طول طريق بغداد – كربلاء من خلال الاستفاده من الاشعاع الشمسي. تقدم هذه الدراسه نهجا شاملا وفعالا لضمان امدادات الطاقه المستدامه للمواكب كما يمكن للنتائج ان تسترشد بها العاملين على اتخاذ القرار وتطوير البنى التحتيه للطاقه في المستقبل والعمل على مبادرات مماثله في مناطق اخرى. اضهرت النتائج ان منطقة الدراسة تستقبل كمية كبيره من الاشعاع الشمسي وكذلك يتميز سطح منطقة الدراسة بانه قليل الانحدار وان نسبة المساحات المناسبة لنصب المحطات الكهروضوئية تتجاوز ال 80% من مساحة منطقة الدراسة الكلية مما تجعل امكانية نصب اكثر من محطة كهروضوئية لانتاج الطاقة المتجدده لرفد منظومة الطاقة الرئيسية بالطاقة.

1. Introduction

The Arbaeen pilgrimage represents the largest religious gathering in the world, according to the World Health Organization, and the public health of mass gatherings, which marks the 40th day after the martyrdom of Imam Hussein (peace be upon him), the third Imam of the Shia [1]. Imam Hussein, the son of Imam Ali, the grandson of the Prophet Muhammad, and the third Imam of the twelve Shia imams, Imam Hussein was martyred in a battle that took place in the Karbala region of Iraq, which was called (the Battle of Karbala), which took place between Imam Hussein and 72 of his companions with the Umayyad State on the 10^{th} of Muharram (the first month of the Hijri year) in the year 61 Ah (680 AD) [2]. About 20 million pilgrims from various Islamic countries are heading to Holy Karbala to commemorate the Arbaeen anniversary. Two weeks before the Arbaeen, millions of pilgrims begin their journey on foot from various regions of Iraq (mainly from Central and southern Iraq) to Karbala, where the Holy Shrines are located [3]. The camps (processions) are set up on the pilgrims ' road towards Holy Karbala by donors from various religious communities to provide services to pilgrims, including free food and drink, as well as a place for pilgrims to

sleep and rest, and to provide them with the necessary health supplies and aid. These camps need electric power sources to continue providing comfortable services for pilgrims[4].
Electricity can be provided using renewable energy, especially since fossil fuels face the problem of depletion of their resources, in addition to the climatic effects that accompany the use of fossil fuels; so renewable energy is the best alternative because sources are flowing, renewable, and not stored. Solar energy is one of the best renewable energy sources, especially in Iraq due to the intensity of solar radiation[5]; photovoltaic stations convert solar energy into electrical energy, which is characterized by being less expensive and does not affect the environment, as well as these stations can be developed and increase energy production by adding photovoltaic panels and also characterized by easy connection with the energy transmission network and easy maintenance [6]. The most suitable sites for installing photovoltaic plants are determined based on criteria such as solar radiation, slope, type of ground cover, and others. The analytical hierarchy process (AHP) was used to decide the best location, depending on the criteria [7]. Remote sensing techniques and geographic information systems (GIS) were used to calculate the parameters through satellite images (Sentinel 2 and ALOS PALSAR) and analyze them using the ArcGIS software. For optimum site selection studies, a combination of GIS and AHP was used[8].
To calculate the amount of energy produced by photovoltaic plants based on the amount of solar radiation, a simulation model of a photovoltaic plant system was designed using MATLAB software
The aim of the study is focused on the provision of electrical energy using renewable energy, determining the appropriate locations for the installation of photovoltaic stations, and calculating the amount of energy produced, which feeds the camps (processions) installed on the road north of Baghdad-Karbala

2. Study area

The Baghdad-Babylon-Karbala Road is a major route that links Baghdad to the central and southern governorates. It is also significant for religious tourism to Karbala and Najaf, for its commercial significance in that owners of heavy and medium load vehicles frequently use it to transport goods between the governorates and for the industrial businesses that are located next to the road, such as the Alexandrian automobile industry and the mechanical company[9]. The length of the road (139.683 Km) starts from the north of Baghdad (from a city called Rashidieh) and passes through the province of Babylon to reach the Holy Shrines in Karbala. The Iraqi security forces selected the road route for pilgrims to provide protection and secure the way for pilgrims toward Karbala. Camps (processions) are erected on the side of the specified road to provide free services to pilgrims[10].

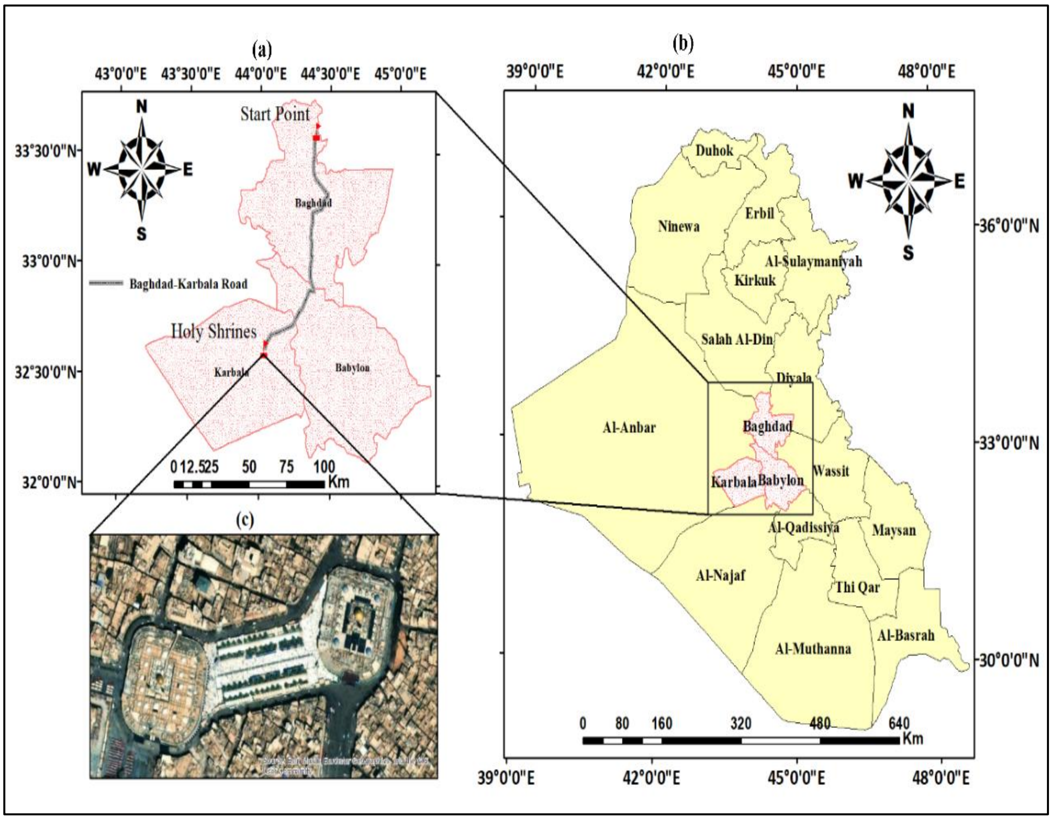


Figure 1: (a) Study area (Baghdad-Karbala Road), (b) Study area location Baghdad-Karbala Road, (c) Pilgrims gathering area between the Holy Shrines.

3. Material and Methodology

3.1. Weighting Criteria

Saaty created the AHP approach, which was applied to decision-making, particularly when weighing numerous variables. It offers the benefit of reducing pairwise comparisons of complex judgments. This approach ensures choice consistency and minimizes decision analysis bias [11]. The creation of a pairwise comparison matrix (A), if the number of criteria is n, then the A=n×n, as shown in equation (1)

$$A = \begin{bmatrix} 1 & p & q \\ 1/p & 1 & r \\ 1/q & 1/r & 1 \end{bmatrix} \tag{1}$$

Using a numerical scale from 1 to 9, each component of M shows the relative weight of the two criteria as determined by experts [12]. As shown in table 4.

Table 1: Pairwise Comparison scale[12, 13]

Importance Degree	Definition	Description
1	Equally preferred	Both activities have equal contributions toward achieving the objective
3	Moderately preferred	One of the activities is slightly favored over the other.
5	Strongly preferred	One of the activities is strongly favored over the other.
7	Very strongly preferred	One of the activities is very strongly favored over the other
9	Extremely preferred	One of the activities is favored over the other of the highest possible degree.
2,4,6,8	Intermediate values	Between the degrees of importance

The elements of the column must be divided by the sum of the elements of the same column to determine the weight of each criterion, Hence normalizing A.
The AHP method enables us to calculate the consistency of a weight by using the following equation: (2)

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

Where:
CI= the consistency index
λmax = is the comparison matrix's biggest eigenvalue.
By comparing the consistency index value (CI) with the consistency index of a random-like matrix (RI), the consistency ratio (CR) was determined as shown in Equation 3

$$CR = \frac{CI}{RI} \quad (3)$$

A matrix that has had the judgments entered randomly is called a random matrix. It is, therefore, very inconsistent. Saaty delivers RI values that were broadly estimated depending on the sizes of various criteria. Recalculating the pair comparison values would be necessary if CR ≤10% [14], as shown in the table below

Table 2: Random Consistency Index[14].

Number of Criteria	**1**	**2**	**3**	**4**	**5**	**6**	**7**
RI	**0**	**0**	**0.58**	**0.90**	**1.12**	**1.24**	**1.32**

3.2. Data Acquisition and Software

Two types of data were used in this research: (raster data and vector data). The raster data represents multispectral images taken from the Sentinel 2 satellite with a resolution of 20m in (2022-8-21) from (https://scihub.copernicus.eu); 5 scenes were used to cover the study area, in addition to the digital elevation models (DEM) provided by the ALOS PALSAR satellite, which represent the elevation of the area with an accuracy of 12.5 m in (2007-6-21) from (https://asf.alaska.edu), six scenes obtained to represent the study area. Vector data is represented by the data of the road network and the power transmission network as a shapefile. Table 2 shows the data reference and properties.

Table 3: Data references and properties.

Reference	*Data type*	*Band*	*Sensing time*	*Resolution (m)*
Sentinel-2 Instrument: MSI	*Raster*	*8.3.2*	*2022-8-21*	*20*
ALOS PALSAR	*Raster*	*L-band*	*2007-6-21*	*12.5*
Open street map	*Shapefile*		*Up-to-date*	
World Bank Data Catalog	*Shapefile*	✗	*Up-to-date*	✗

These data were processed using the ArcGIS program from ESRI, which contains many tools for analyzing the criteria to determine land suitability. A set of processors is performed on raster data, and the geometric correction of the satellite images was performed using GIS 10.5 to convert them to geospatial coordinates of UTM, also to get rid of NoData value and extract the study area from the overall scenes.

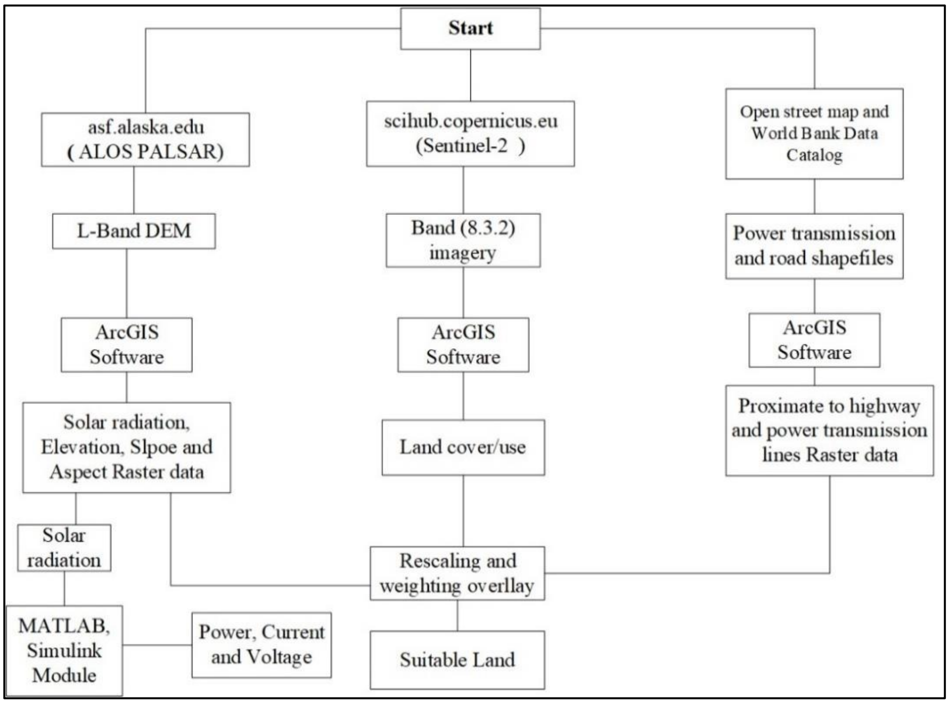


Figure 2: Methodology Diagram for Land suitability of solar cell site selection.

3.3. Criteria selection

The selection of criteria is the most important step in the process of assessing the suitability of the site for the installation of photovoltaic solar cells; table (1) shows the criteria that were used in previous studies that analyzed the suitability of the site for the installation of photovoltaic solar cells[15]. In this research, seven criteria were selected to analyze the suitability of the study area (Solar radiation, slope, aspects, elevation, land cover, Proximity from highway, and proximity from power transmission lines).

Table 4: The criteria adopted in previous studies to analyze the site suitability of photovoltaic systems [15].

References	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Uyan			✔			✔	✔	✔	✔	
Watson and Hudson			✔	✔		✔			✔	
Aly et al.	✔					✔	✔	✔		✔
Al Garni and Awasthi	✔	✔	✔	✔		✔		✔		
Yushchenko et al.	✔					✔	✔	✔		
Tahri et al.	✔	✔	✔			✔	✔		✔	
Merrouni et al.	✔		✔			✔	✔	✔		✔
Asakereh et al.			✔	✔	✔		✔	✔	✔	
Noorollahi et al.	✔	✔	✔		✔	✔	✔	✔	✔	
Suh and Brownson	✔	✔	✔				✔	✔	✔	
Sánchez-Lozano et al.	✔	✔	✔			✔	✔	✔		

C1: Solar radiation, C2: temperature, C3: Slope, C4: Aspect, C5: Elevation, C6: distance from a residential area, C7: distance from a road, C8: distance from a power line, C9: land use, C10: waterbody.

3.4. Criteria calculation

➢ **Solar Radiation**: The incoming solar radiation at the surface in the 0.2–4.0 m wavelength range on a specific surface area is called solar irradiance, typically stated in W/m2 (Watts per square meter). There are two types of solar radiation: diffuse (diffuse irradiance) and direct (direct irradiance), both received from the sun's direction. Since the atmosphere scatters it, diffuse radiation is emitted in all directions.[16] , by using (Area solar radiation) in ArcGIS, which uses the Digital Elevation Model (DEM) as input data, set the (Area solar radiation) tool at a specific day (2022-8-21)

➢ **Elevation, Slope, and Aspect**

The DEM represents the area's altitude, and the value Z in DEM represents the sea's Elevation value in meters. Where the highlands received solar radiation greater than the lowlands. The slope, measured in degrees and ranges from zero (flat) to 90 (vertical), represents the elevation change associated with a change in horizontal position, indicating the steepness of the landscape. Aspect is another important terrain feature commonly retrieved from digital elevation data. The aspect indicates a downward slope. The direction is frequently expressed using an azimuth angle[17]. The surface analysis tools used DEM raster data to calculate Slope and Aspect[18].

➢ **Proximate to highway and power transmission lines**

Because of the enhanced distribution efficiency across the study region due to distance from the highway, the potential locations for solar power plants were most affected by the distance from highway criterion. Researchers frequently utilized roads to define the solar power plant area, and proximate to power transmission lines is an important criterion for facilitating the transfer of energy produced by solar cells and connecting it with the distribution network. Five buffer zones were created for roads and power line zones based on the actual circumstances and the literature assessment [19]. The multi-buffer tool in ArcGIS enables us to draw areas with certain areas surrounding the lines. In this study, the Baghdad-Babylon-Karbala Road represents the main highway.

➢ **Land cover/use**

One of the most common uses of remote sensing is the classification of land cover and use. Different methods are used to extract data about the various categories of Land Cover from optical imagery (Sentinel-2) using the pixel values. Classifying pixels under user supervision is referred to as supervised classification. The user defines the numerous spectral signatures or pixel values that may be connected to the particular class[20].

Depending on Criteria, raster data values were rated into five categories (value one means unsuitable and five means most suitable categories) because the land suitability was analyzed by comparison. Table (2) shows the criteria rating depending on previous studies [21-24].

Table 5: Criteria Values Rating

C1	C2	C3	C4	C5	C6	C7	Value Rate
5150-5340	<3	S	Barren land	0.5	0-5	97.9-156	5
5110-5140	3-5	SE, SW	Rangeland	1.0	5-8	70.6-97.8	4
5050-5100	5-7	E, W	Crops	1.5	8-10	44.6-70.5	3
4940-5040	7-9	N, NE, NW	Deciduous forest	2	10-12	27.8-44.5	2
2530-4930	>9	Flat	Water/ Build area / Evergreen forest	>2	>12	-2-27.2	1

C1: Solar radiation, C2: Slope, C3: Aspect, C4: land use, C5: Proximate to highway, C6: Proximate to power transmission lines, C7: Elevation.

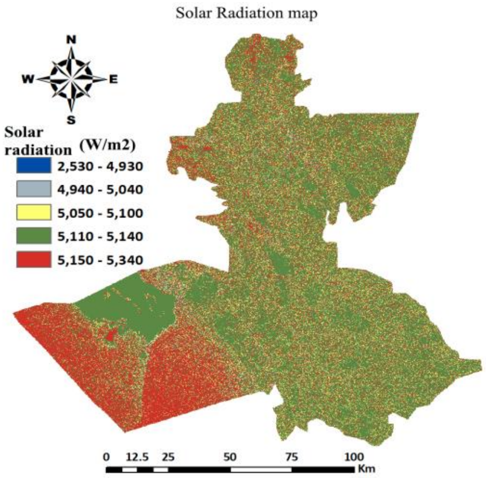


Figure 3: Solar radiation map.

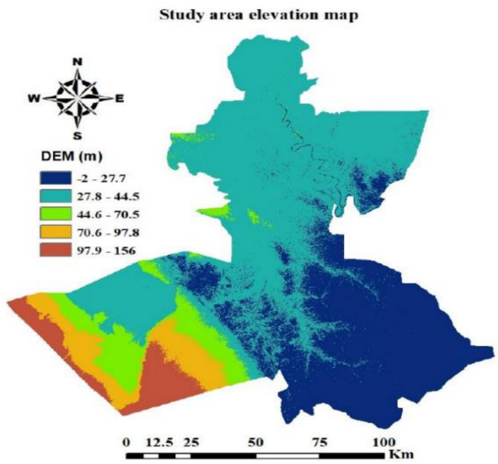


Figure 4: Elevation map.

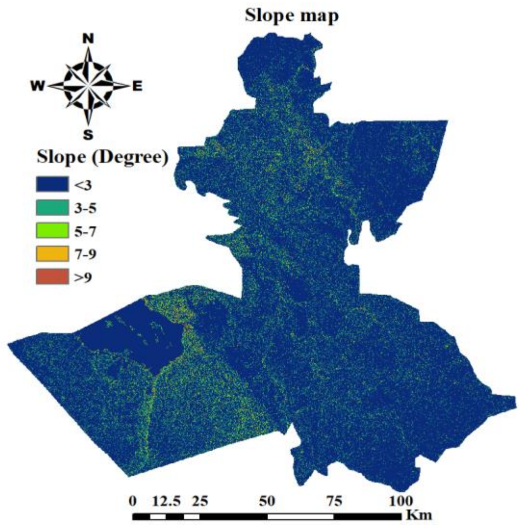


Figure 6: Slope map.

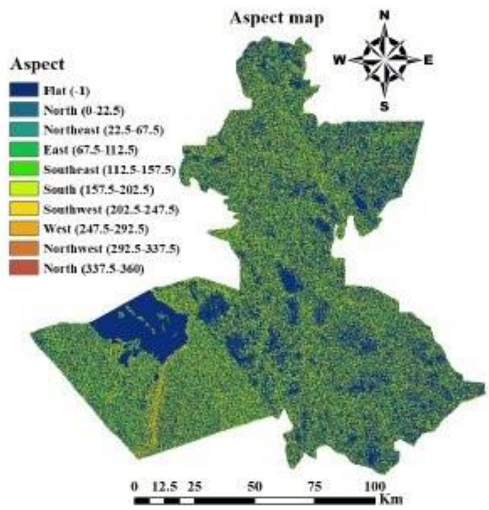


Figure 5: Aspect map**.**

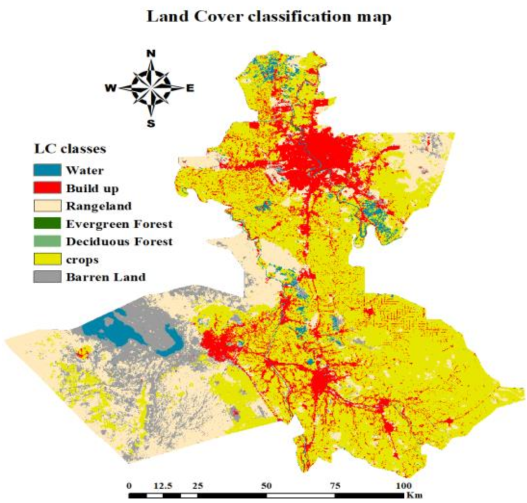


Figure 7: Land Cover/ Use map.

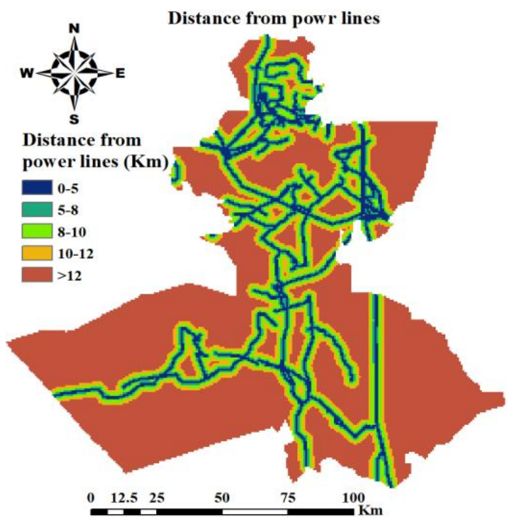


Figure 8: Proximate to Power transmission lines.

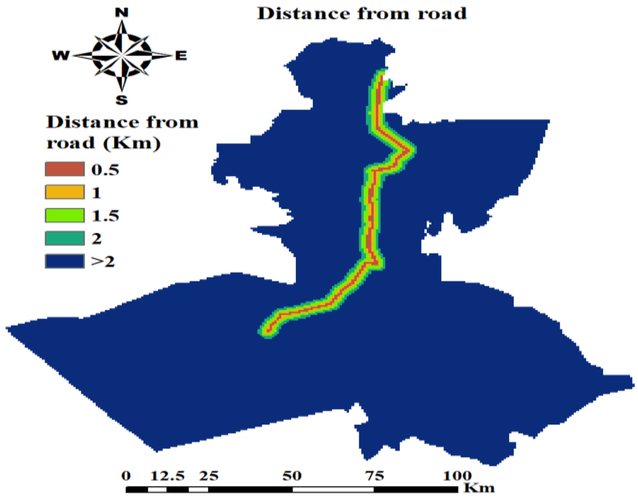


Figure 9: Proximate to Baghdad-Babylon-Karbala Road.

3.5. Solar PV cell modeling

Solar PV cells are the fundamental building block of a solar PV array or panel; they are coupled in series and parallel to obtain the necessary voltage and current levels. A PV cell is a semiconductor with a p-n junction that produces electricity when exposed to light. The PV cell mathematical model can be used for simulation to show how voltage, current, and power behave under various operating situations. Fig. 1 displays a simplified equivalent PV cell circuit with five parameters.

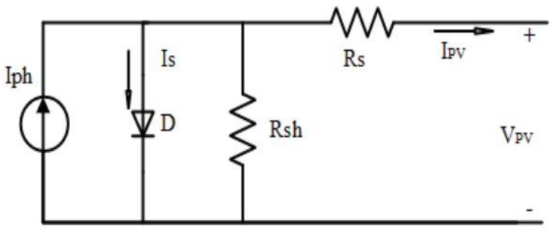


Figure 10: PV cell Equivalent circuit

Cell photocurrent (I_{ph}), exponential diode (D), and shunt resistance (R_{sh}) are linked in parallel and series, respectively, with series resistance (R_s). The PV cell's current and voltage are expressed as I_{pv} and V_{pv}, respectively [25].

The 200W PV array system and PV panel designed using MATLAB Simulink[26], as shown in figure (11)

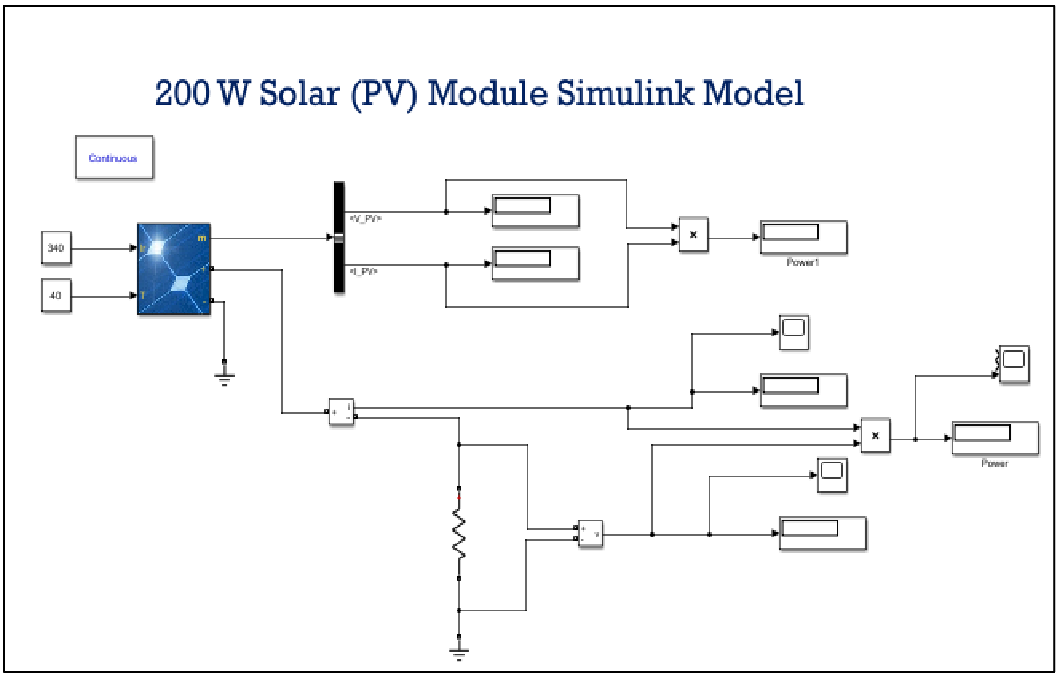


Figure 11: MATLAB Simulink model of Solar Cell

Table 6: PV panel parameters[26]

PARAMETER	RATED VALUE
Rated Power(Pmp)	200W
Voltage at Maximum Power(Vmp)	26.4V
Current at Maximum Power(Imp)	7.58A
Open Circuit Voltage(Voc)	32.9V
ShortCircuit Current (Isc)	8.21A
TotalNumberofcellsinSeries(Ns)	55
Total Number of cells in parallel (Np)	1

4. Results and Discussion

According to Table (6). AHP results indicate that the Solar radiation factor has the most weight (35.428%), Slope (23.993%), Elevation (15.865%), Aspect (10.362%), proximate to power transmission lines (6.756%), proximate to the highway (4.477%) and Land Cover/Use (3.17%). The pairwise comparison results for this investigation were acceptable because the CR was 2.5%, and the values were thought to be stable.

Table 1: Pairwise comparison, weight for each criterion, and consistency ratio (CR).

Criteria	C1	C2	C3	C4	C5	C6	C7	Weight	CR
C1	1	2	4	7	6	5	3	35.428	
C2	0.5	1	3	6	5	4	2	23.993	
C3	0.25	0.333	1	4	3	2	0.5	10.362	
C4	0.143	0.167	0.25	1	0.5	0.333	0.2	3.17	0.025
C5	0.167	0.2	0.333	2	1	0.5	0.25	4.477	
C6	0.2	0.25	0.5	3	2	1	0.333	6.756	
C7	0.333	0.5	2	5	4	3	1	15.865	

The rating raster data for each Criteria and its weights are used as input data in the Weighted Overlay tool table (weighted Overlay is an ArcGIS software tool) to create a Map for Land suitability for the study area is shown in Figure 10; the appropriate map is classified into five categories (Unsuitable, Low suitability, Moderate suitability, Suitable and Most suitable)

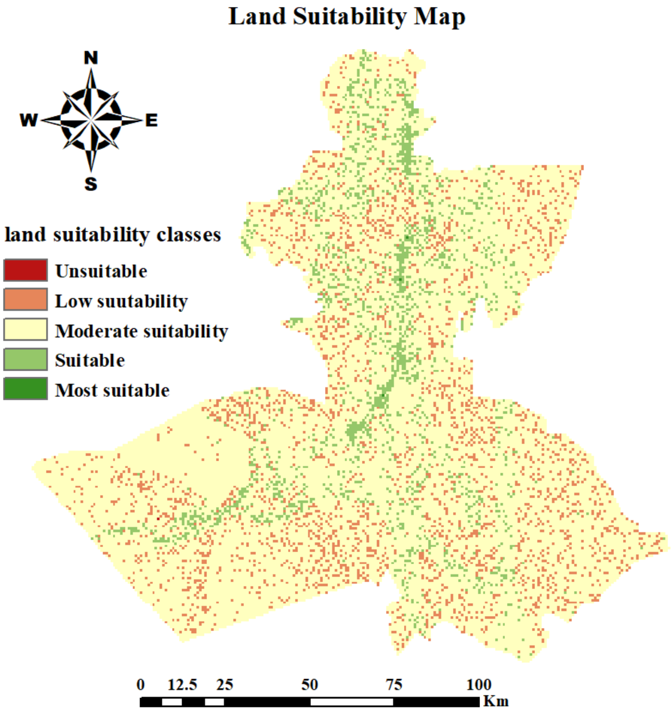


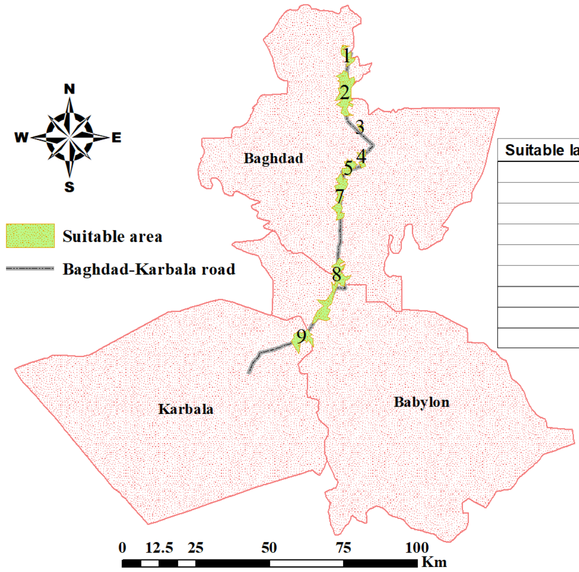
Figure 12: Map classification of suitable lands for the installation of solar photovoltaic power plants

The results showed that the Moderate suitability areas represent (82.3%) of the total area, Low suitability areas (10.6%), Suitable areas (7%), Most suitable areas (0.01%), and Unsuitable areas (0.003%). The table (7) shows the geometric information of land suitability classes

Table 2: Area and percentage of land suitability categories

Categories	Area (Km^2)	Percentage %
Unsuitable	0.5329	0.003
Low suitability	1632.273	10.62
Moderate suitability	12663.84	82.36
Suitable	1078.59	7.01
Most suitable	1.5987	0.01
Total area	15376.82972	100

After determining the appropriate sites for the installation of solar power stations, the appropriate sites near the Pilgrims ' Road (The Baghdad-Babylon-Karbala) were identified in order to facilitate the process of transferring the electrical energy produced from the solar power stations that will be installed on the specified sites to the camps (processions) located on both sides of the Pilgrims' Road (The Baghdad-Babylon-Karbala). The results showed the existence of nine sites at different sites as shown in the figure (11)



Suitable land	area (Km2)
1	13.3781
2	57.3559
3	2.80831
4	3.76561
5	15.5694
6	3.01778
7	36.0046
8	61.7971
9	27.4854

Figure 13: Suitable land close to The Baghdad-Babylon-Karbala Road

The amount of solar radiation depends on the length of the day. The daytime period for the study area averages 13 hours. During August, the sun rises at 5.30 am and sets at 6.40 pm. The solar radiation value during this period for the sites indicated in Figure (13) was calculated using ArcGIS (Point Solar Radiation tool). The results showed that the values of solar radiation during the same period for these sites were close due to the convergence of the height values of the study area.

Finally. A simulation of the PV array system model shown in Figure (11) was performed with the values of solar radiation and the average temperature of the sites (40C°, https://power.larc.nasa.gov/) using MATLAB Simulink, the values of both energy, current and voltage was obtained as shown in the two figures (14,15)

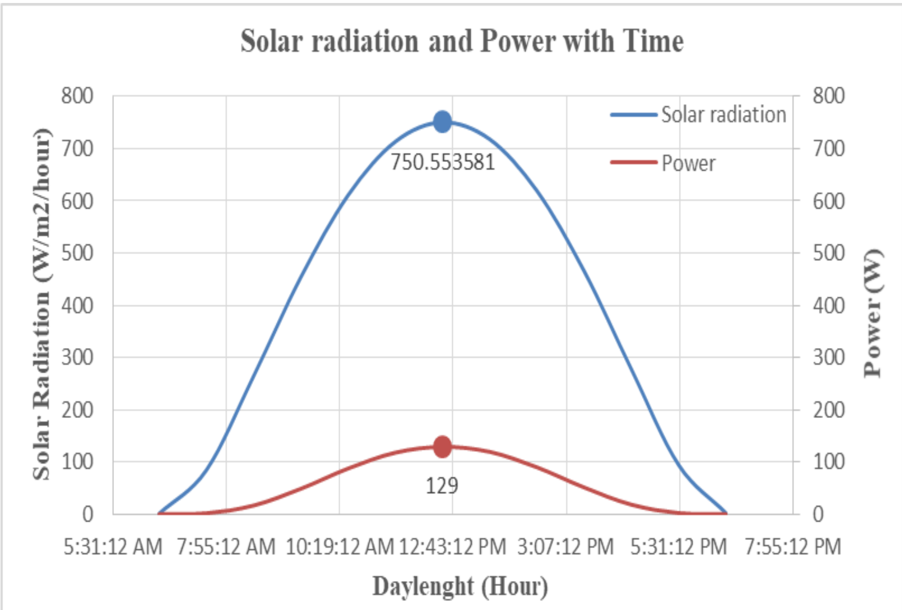


Figure 14: Solar radiation and Power with Time for a single PB panel

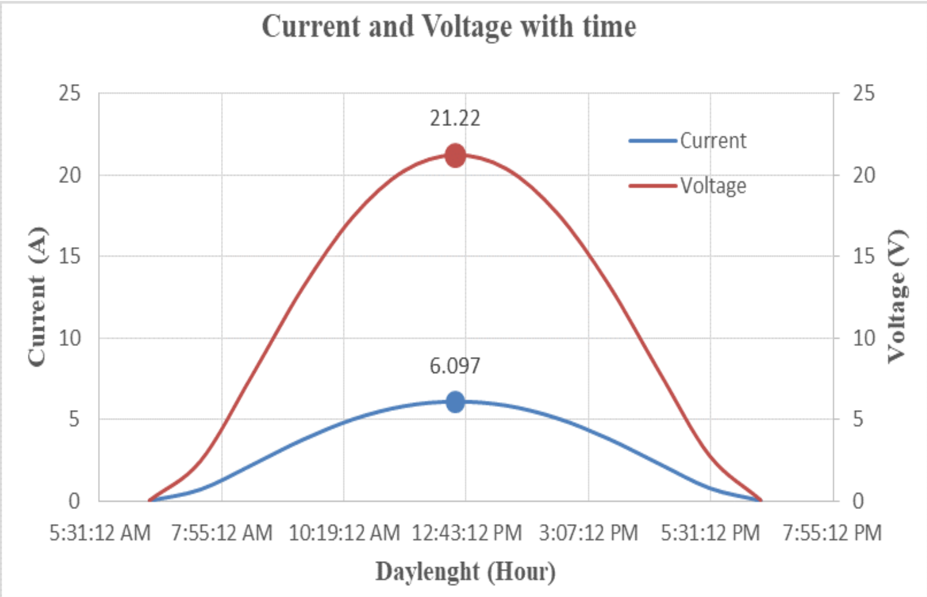


Figure 15: Current and Voltage with time for single PV panel

The values of Power, Voltage, and Current increase with the increase in the value of solar radiation, where the maximum Power values were recorded (129W), maximum Current (6.97A), and maximum Voltage (21.22V) for a single PV panel.

The standard size of a PV panel is about 25 square feet (2.3 m^2) [27], so many PV panels can be added due to the vast areas of the selected sites to increase the amount of electric energy output that feeds the camps (processions) along the Baghdad-Babylon-Karbala highway.

5. Conclusion

The surface of the study area is characterized by an average height of 44 meters above sea level, as it is considered one of the Central low-lying areas, in addition to being flat and with few undulations, which makes it suitable for the construction of projects and construction.

The Aspect map showed that the direction of the slope in the region is towards the East, which is facing the sun's rays, which makes it an ideal area to receive the largest amount of sunlight.

Barren and Rangeland areas constitute a significant portion of the study area's surface, as they are considered suitable for constructing photovoltaic stations because they are uninhabited and are not used for agricultural or residential activities. Moreover, these regions' skys are transparent, allowing the largest amount of solar radiation to be received.

According to the results, over 80% of the study area is suitable for solar power plant construction because of the abundance of solar radiation and the surface's characteristics. As a result, camps along the pilgrims' road from Baghdad to Karbala can be supplied with renewable energy by constructing more than eight photovoltaic power plants, which will greatly reduce environmental pollution and the demand for electric energy; it was demonstrated that each photovoltaic panel could produce electrical energy at a rate of (4A) over 10 hours by simulating the operation of virtual photovoltaic plants based on the duration of the day and the amount of incoming radiation.

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