Equip Ziyarte Al-Arba'een service points with clean energy through solar radiation Using remote sensing techniques: a case study along the path from northern Baghdad to the holy Karbala

Mostafa S.S
University of Baghdad- Collage of Science- Department of Remote sensing and GIS
Mostafa.sabah@sc.uobaghdad.edu.iq

Hassan. J. M. Alatta
University of Baghdad- Collage of Science- Department of Remote sensing and GIS

Ebtesam F. khanjer
University of Baghdad- Collage of Science- Department of Remote sensing and GIS

Ban abul Al-Razak
University of Baghdad- Collage of Science- Department of Remote sensing and GIS

Abstract

Millions head on foot every Hijri year in the month of Safar from various provinces of Iraq, as well as pilgrims from different countries of the world to commemorate the day of Zeyart AL-Arbaeen of Imam Hussein, as millions head towards the Holy Karbala. During the course of the visit, a large number of organizations or stations (processions) are erected on both sides of the visitors' path to provide service to pilgrims. In this study, we will highlight the possibility of providing electric energy using renewable energy to these bodies on the side of the Baghdad-Karbala road. Photovoltaic cells are one of the most important and most common renewable energy sources, especially in sites with high solar radiation such as Iraq. To determine the best sites location for the installation of solar cell stations using sensing applications and geographic information systems through the analysis of satellite images (Sentinel 2 and ALOS PALSAR) to calculate a set of necessary criteria to determine the best location as well as using the hierarchical analysis process to determine the best location for the installation of photovoltaic cells in addition to estimate the rate of energy produced by photovoltaic cells using simulation in MATLAB

The results of this research provide 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 effective approach to ensure sustainable energy supply for the processions and the results can guide decision-making and development of energy infrastructure in the future and work on similar initiatives in other regions

Semi-Annual Scientific Journal w w w . a r b n j . c o m Shaaban 1445 A.H, March 2024 A.D

Keywords: Zeyart AL-Arbaeen; Remote Sensing; Multi Criteria Decision Making; GIS; AHP; Pv Array; Simulink

1. Introduction

Zeyart AL-Arbaeen 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, who is 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 10th of Muharram (the first month of the Hijri year) in the year 61 Ah (68 AD) [2]. About 20 million pilgrims are heading to Holy Karbala from various Islamic countries to commemorate the Zeyart AL-Arbaeen anniversary two weeks before the Arbaeen, millions of pilgrims begin their journey on foot from various regions of Iraq (mostly from Central and southern Iraq) to the city of 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 that fossil fuels face a 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 the installation of photovoltaic plants are determined based on a set of criteria such as solar radiation, slope, type of ground cover and others, to decide the best location the analytical hierarchy process (AHP) was used 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 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 study in this research focuses on the provision of electrical

Semi-Annual Scientific Journal
www.arbnj.com
Shaaban 1445 A.H, March 2024 A.D

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. Literature review

The most suitable sites for the installation of solar photovoltaic power plants in Azerbaijan have been identified through a comprehensive assessment of the meteorological and environmental parameters of the potential areas Using an analytical hierarchical process method based on a multi-criteria decision-making technique for large-scale solar energy projects In this study (N. S. Imamverdiyev 2021), By converting the digital elevation model's data using the geographic information system's "Area solar radiation" tool, the solar radiation values for study area were calculated. The site suitability index was calculated using the ArcGIS weighted overlay tool, and it was found that 1.17% (1016.8 km2) of the country had the best locations for solar PV system installation[9].

B. Halder In 2022, Remote sensing and Geographic information system Technologies were used in this study to determine the possible location selection of solar power plants in Kolkata, India, as well as the sequencing and multi-criteria decision-making process was used to calculate the weights. A total of 1438.15 km2 (32.43%) of the total area was calculated as highly suitable for solar power plants[10].

In2021The main goal of this article is to identify and evaluate the

best locations around Tunisia for constructing massive solar PV power facilities. For this reason, we use geographic information systems (GIS) and multi-criteria decision-making analysis (MCDM) to analyze the land suitability of the research area. The results showed that the most practical places covered 1571 km2 and accounted for 1.11% of the total surface area. Additionally, it was noted that the administrative regions of Tataouine, Gabès, Gafsa, and Kassérine have demonstrated the greatest potential for solar PV system construction-friendly sites. Additionally, it was calculated that the annual solar energy yield would be close to 328 TWh. Consequently, it was determined that the accepted model was a highly helpful [11].

The suitability of Moroccan land for hosting solar power plants was studied using the combination of the Geographic Information System (GIS) and the Analytical Hierarchy Process (AHP) by (Meryem Taoufik in 2021), the results presented that 53.88% of the occupation area have high suitability land for solar plant[12].

In 2021, a study to select the optimum site for solar energy farms in Iraq, In order to determine if land is suitable for the construction of solar farms, this study combines the Geographic Information System (GIS) with Analytic Hierarchy Process, one of the multi-criteria decision-making methodologies. The findings indicated that 19% of the research area would make excellent locations for solar farms. The majority of the eligible areas were acquired by the southern, southeastern, and a few western regions. Additionally, this method is easily adaptable to include various criteria and weights to help planners choose the best

Semi-Annual Scientific Journal
www.arbnj.com
Shaaban 1445 A.H, March 2024 A.D

places for solar farms[13].

Experimental measurements were made to study the characteristics of voltages-current and power-and current for two types of photovoltaic cell model. Using MATLAB, a solar cell simulation model was created with variable solar radiation values and values for Energy, current and voltage were obtained for each of the solar radiation values[14].

3. 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[15]. The length of the road (139.683 Km), which starts from the north of Baghdad (from a city called Rashidieh) and passes through the province of Babylon, to reaches the Holy Shrines in Karbala. The route of the road for pilgrims was selected by the Iraqi security forces for the purpose of providing protection and securing the way for pilgrims towards Karbala. Camps (processions) are erected on the side of the specified road for the purpose of providing free services to pilgrims[16].

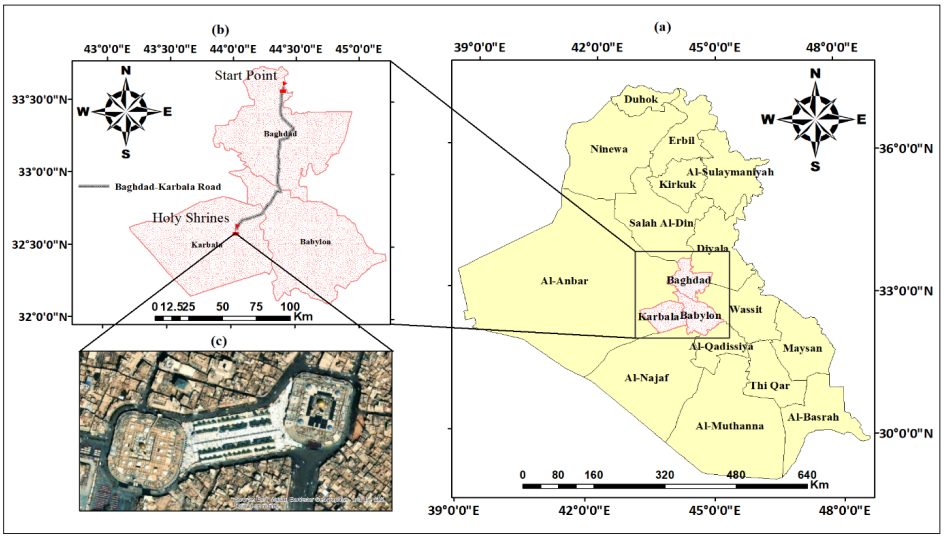


Figure 1. (a) Study area location, (b) Baghdad-Karbala Road, (c) Holy Shrines

4.Methodology

4.1. 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, the 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[17]. In this research, seven criteria were selected to analyze the suitability of the study area (Solar radiation, Slope, Aspects, Elevation, Land cover, Proximate from highway and proximate from Power transmission lines).

Semi-Annual Scientific Journal
www.arbnj.com
Shaaban 1445 A.H, March 2024 A.D

Table 1.The criteria adopted in previous studies to analyze the site suitability of photovoltaic system [17].

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.

4.2. 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), 6 scenes obtained to represent the study area. Vector data is represented by the data of the road network and the power transmission network as shapefile. Table2 show the data reference and properties.

Table: 2.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	×

Semi-Annual Scientific Journal
www.arbnj.com
Shaaban 1445 A.H, March 2024 A.D

These data were processed using the program ArcGIS from ESRI, which contains many tools suitable for analyzing the criteria to determine the land suitability. A set of processors is performed on raster data, the geometric correction of the satellite images was performed using GIS 10.5 to convert them to geospatial coordinates of UTM, also o get rid of No Data value and extract the study area from the overall scenes

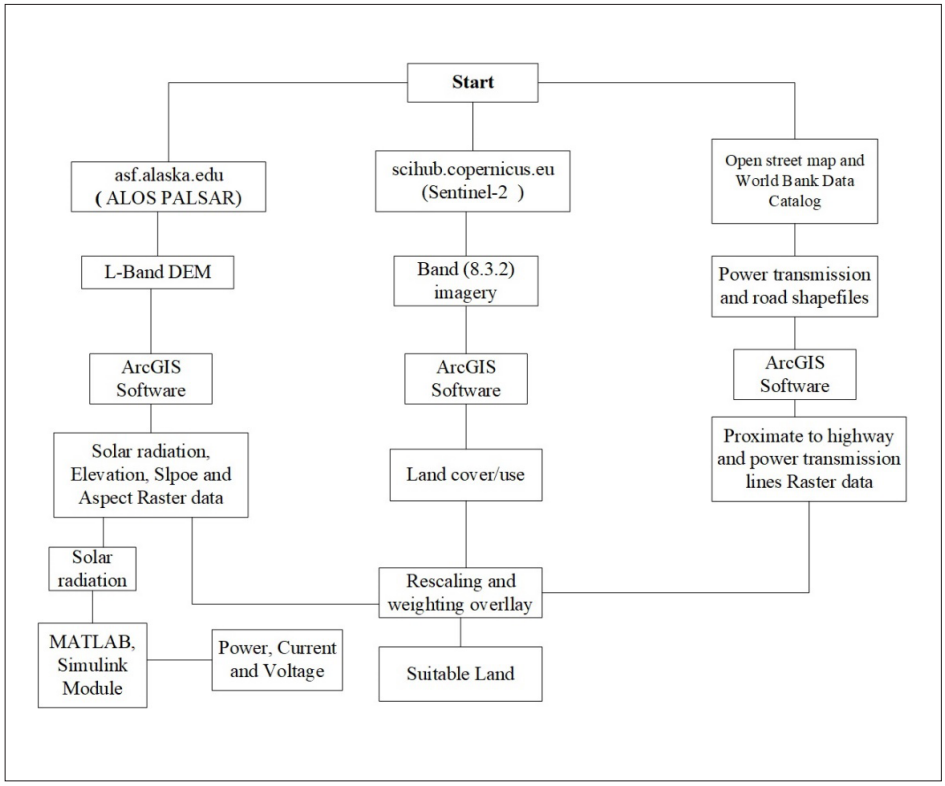


Figure 2.Methodology flowchart for Land suitability of solar cell site selection

4.3. 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 referred to as the solar irradiance, which is typically stated in W/m2 (Watts per square meter). There are two types of solar radiation: diffuse (diffuse irradiance) and direct (direct irradiance), both of which are received from the direction of the sun. Since the atmosphere scatters it, diffuse radiation is emitted in all directions. [18] , by using (Area solar radiation) in ArcGIS which using the Digital Elevation Model (DEM) as input data, set the (Area solar radiation) tool at specific day (2022-8-21)

- **Elevation, Slope and Aspect:** The DEM represent the altitude of the area, the value Z in DEM represent the Elevation value from the sea in meter. Where the highlands received solar radiation greater than lowlands. The slope, which is measured in degrees and ranges from zero (flat) to 90 (vertical), represents the elevation change associated with a change in horizontal position, its indicate the steepness of the landscape. Aspect is yet another important terrain feature that is commonly retrieved from digital elevation data. The aspect indicates a downward slope. The direction is frequently expressed using an azimuth angle[19]. The surface analysis tools used DEM raster data to calculate Slope and Aspect[20].

Semi-Annual Scientific Journal
www.arbnj.com
Shaaban 1445 A.H, March 2024 A.D

- **Proximate to highway and power transmission lines:** Because of the enhanced distribution efficiency across the study region due to distance from highway, the potential locations for solar power plants were most affected by the distance from highway criterion. Roads were frequently utilized by researchers to define the solar power plant area, also, 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 lines zones based on the actual circumstances and the literature assessment [21]. The multi-buffer tool in ArcGIS enables us to draw a set of areas with certain areas surrounding the lines, in this study, Baghdad-Babylon-Karbala Road represent 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, the process of 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[22].

Depending Criteria raster data values rating into five categories (value 1 mean unsuitable categories and 5 mean most suitable categories), because of the land suitability was analyzed by comparison. The table (2) show the criteria rating depending of previous studies [23-26].

Table:3.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

Semi-Annual Scientific Journal
w w w . a r b n j . c o m
Shaaban 1445 A.H, March 2024 A.D

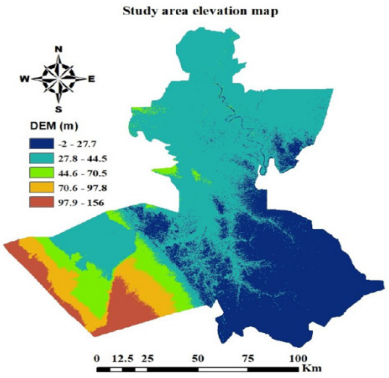


Figure 4. Elevation map

4.3.

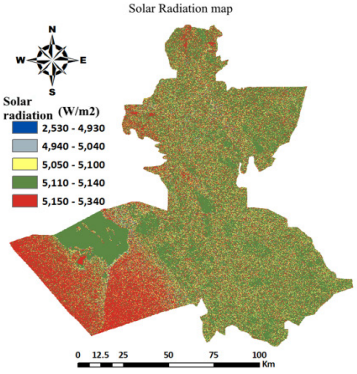


Figure 3. Solar radiation map

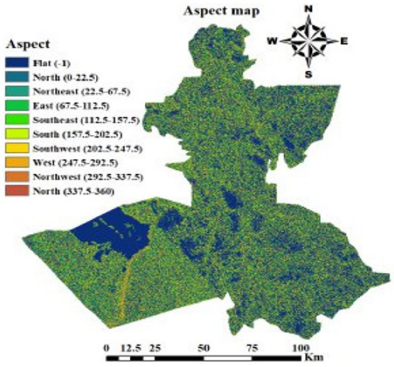


Figure 5. Aspect map

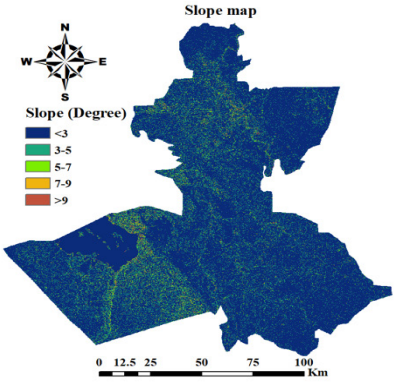


Figure 6. Slope map

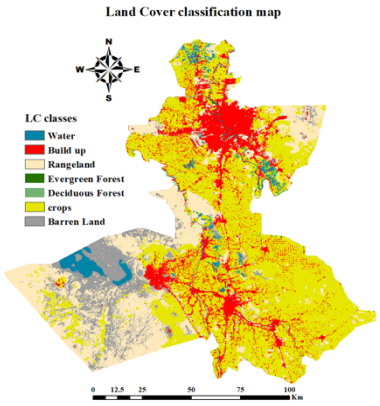


Figure 7. Land Cover/ Use map

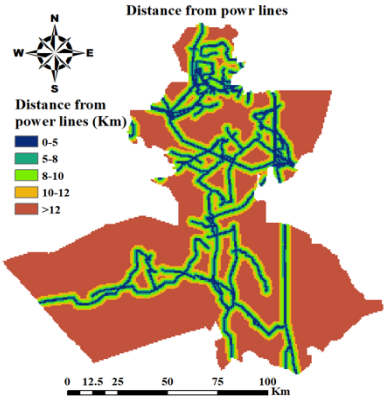


Figure 8. Proximate to Power transmission lines

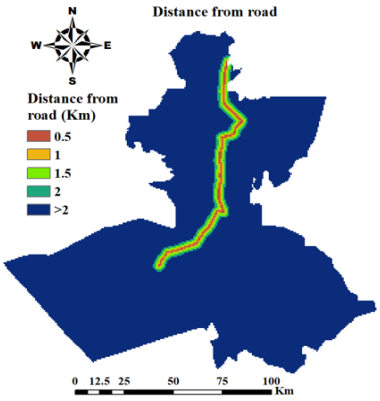


Figure 9. Proximate to Baghdad-Babylon-Karbala road

4.4. Weighting Criteria

Saaty created the AHP approach, which has been applied to decision-making, particularly when weighting numerous variables. It offers the benefit of reducing pairwise comparisons of difficult judgments. This approach is also a crucial tool for ensuring choice consistency and minimizing decision analysis bias [27]. 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)

$$A = \begin{bmatrix} 1 & p & q \\ 1/p & 1 & r \\ 1/q & 1/r & 1 \end{bmatrix} \quad (1)$$

Using a numerical scale from 1 to 9, each component of M shows the relative weight of the two criteria as determined by experts [28]. As shown in table 4.

Semi-Annual Scientific Journal
w w w . a r b n j . c o m
Shaaban 1445 A.H, March 2024 A.D

Table:4. Pairwise Comparison scale[28, 29]

Importance Degree	Definition	Description
1	Equally preferred	Both the activities have equal contributions towards 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)

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

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

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

A matrix that has had the judgments entered randomly is called a random matrix. It is therefore very inconsistent. Saaty delivers RI values that have been broadly estimated depending on the sizes of various criteria. Recalculating the pair comparison values would be necessary if CR ≤10% [30] , as shown in table below

Table:5.Random Consistency Index[30]

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

Semi-Annual Scientific Journal www.arbnj.com Shaaban 1445 A.H, March 2024 A.D

4.5. Solar PV cell modeling

Solar PV cells are the fundamental building block of a solar PV array or panel; to obtain the necessary voltage and current levels, they are coupled in series and parallel. 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.

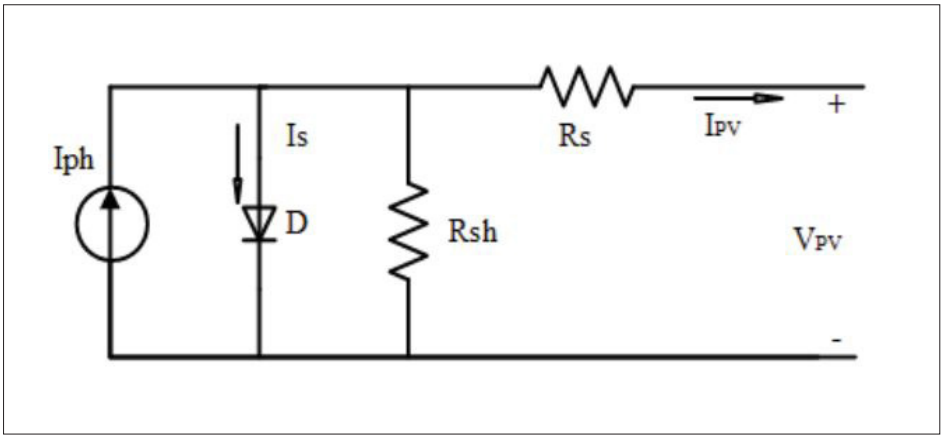


Figure:10 PV cell Equivalent circuit

Cell photocurrent (Iph), exponential diode (D), and shunt resistance (Rsh) are linked in parallel and in series, respectively, with series resistance (Rs). The PV cell's current and voltage are expressed as Ipv and Vpv, respectively [31].

The 200W PV array system and PV panel designed using MATLAB Simulink[32], as shown in figure (11)

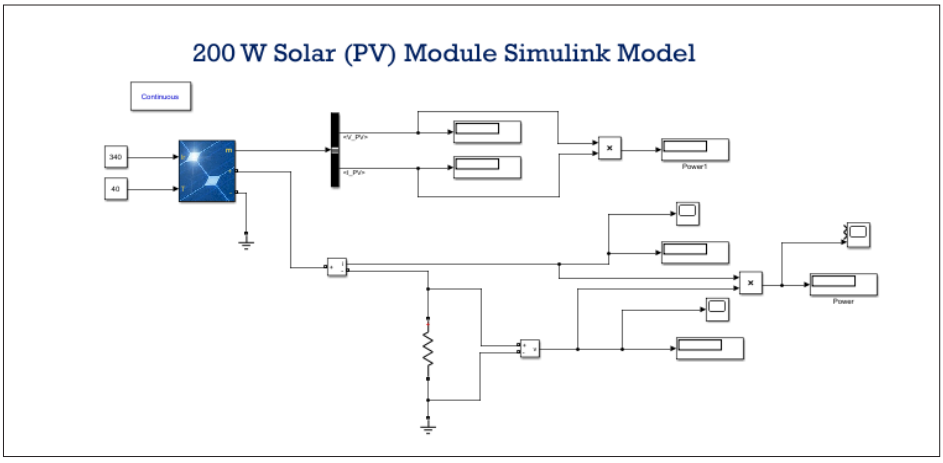


Figure 11. MATLAB Simulink model of Solar Cell

Table:6. PV panel parameters[32]

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 inParallel (Np)	1

5. 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 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 6. Pairwise comparison, weight for each criteria and consistency ratio (CR).

Criteria	C1	C2	C3	C4	C5	C6	C7	Weight	CR
C1	1	2	4	7	6	5	3	35.428	0.025
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	
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 used as input data in Weighted Overlay tool table (weighted Overlay its ArcGIS software tool) to create a Map for Land suitability for study area as shown if figure 10, The appropriate map is classified into 5 categories (Unsuitable, Low suitability, Moderate suitability, Suitable and Most suitable)

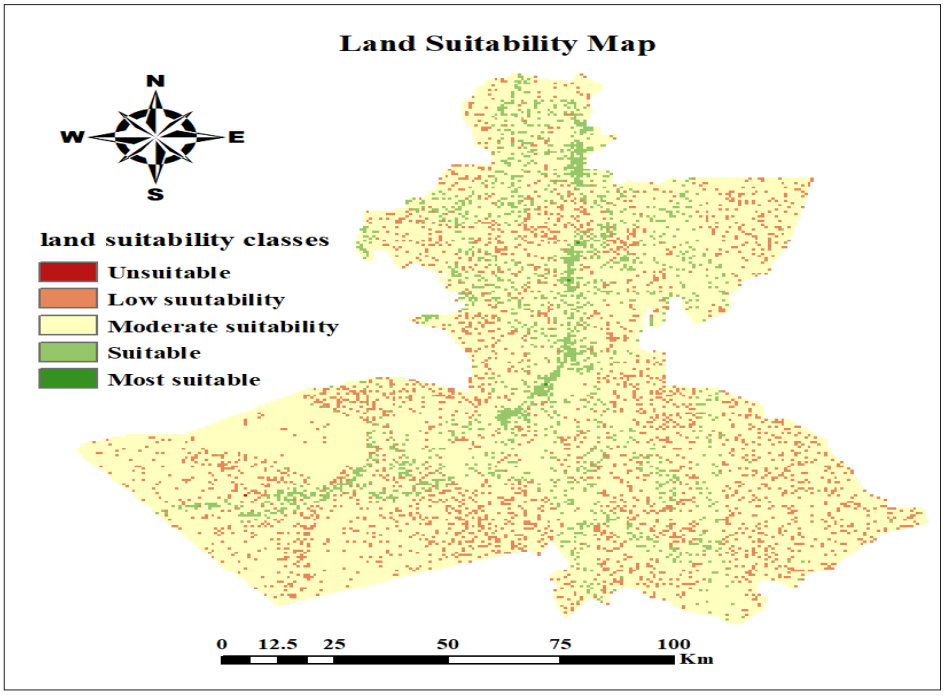


Figure 12. Map classification of suitable lands for the installation of solar photovoltaic power plants

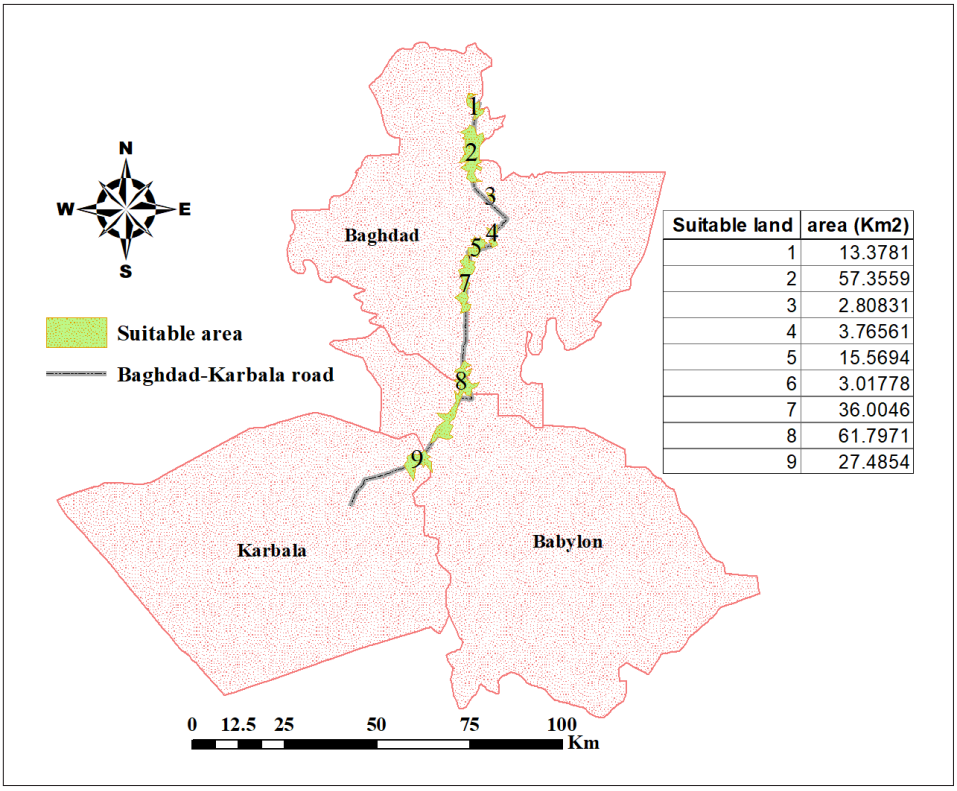
The results showed that the Moderate suitability areas represent (82.3%) of the total area, Low suitability areas (10.6%), Suitable areas (7%), Most suitable areas (0.01%) and the Unsuitable areas (0.003%). The table (7) shows the geometric information of land suitability classes

Semi-Annual Scientific Journal
www.arbnj.com
Shaaban 1445 A.H, March 2024 A.D

Table 7. 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 month, the sun rises at 5.30 am and sets at 18.40 pm. The value of solar radiation during this period for the sites indicated in the figure (13) was calculated using ArcGIS (Point Solar Radiation tool). The results showed that the values of solar radiation during the same period of time 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 the 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 were obtained as shown in the two figures (14,15)

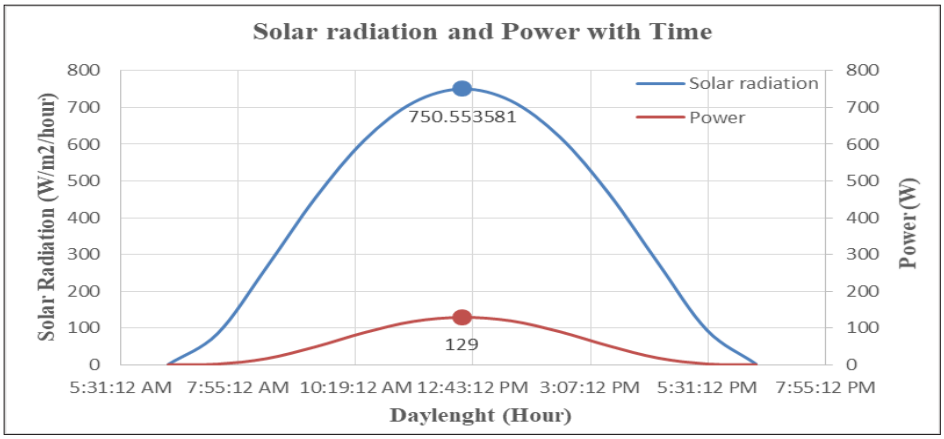


Figure 14. Solar radiation and Power with Time for single PB panel

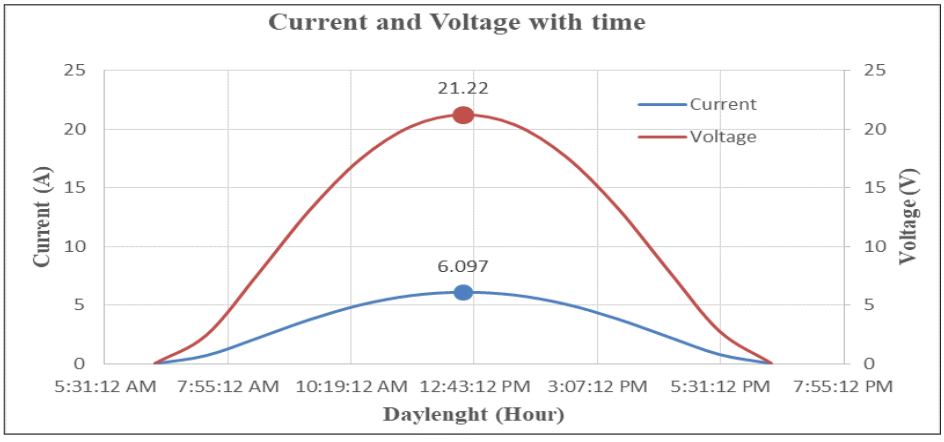


Figure 15. Current and Voltage with time for single PV panel

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 single PV panel.

The standard size of PV panel about 25 square feet (2.3 m2) [33], 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.

6. Conclusion

Solar radiation is the most important criterion for determining the suitability of sites for the installation of photovoltaic solar cells

The study area is exposed to a high amount of solar radiation during the long daylight period in the summer, so solar panels are the best ways to obtain renewable energy

The values of seasonal radiation reach their highest levels during the afternoon, so the pilgrims of the forty should not walk during this period in order to avoid exposure to solar radiation

The specifications of solar panels can be changed by specialists for the purpose of obtaining higher efficiency and greater electrical energy

Semi-Annual Scientific Journal www.arbnj.com Shaaban 1445 A.H, March 2024 A.D

References

1. A. Soltani, "The necessity of health-centered research in arbaeen mass gathering," Iran Red Crescent Med J, vol. 22, p. e101174, 2020.
2. Z. G. Tari and E. Kadkhodaee, "Pilgrimage and Conflict Resolution: The Case of Interpersonal Contact between Iranians and Iraqis in the Arbaeen Walk," Journal of World Sociopolitical Studies| Vol, vol. 6, pp. 539,565-2022.
3. A. Nikjoo, M. Sharifi-Tehrani, M. Karoubi, and A. Siyamiyan, "From attachment to a sacred figure to loyalty to a sacred route: the walking pilgrimage of Arbaeen," Religions, vol. 11, p. 145, 2020.
4. A. A. Shalbafian and N. Zarandian, "A New Look at the Arba'een Mega-event from the Perspective of Iraqis as the Host Community," International Journal of Religious Tourism and Pilgrimage, vol. 9, p. 8, 2021.
5. K. R. Abbasi, M. Shahbaz, J. Zhang, M. Irfan, and R. Alvarado, "Analyze the environmental sustainability factors of China: The role of fossil fuel energy and renewable energy," Renewable Energy, vol. 187, pp. 3902022 ,402-.
6. H.-R. Seo, G.-H. Kim, S.-Y. Kim, N. Kim, H.-G. Lee, C. Hwang, et al., "Power quality control strategy for grid-connected renewable energy sources using PV array and supercapacitor," in 2010 International Conference on Electrical Machines and Systems, 2010, pp. 437441-.
7. N. S. Imamverdiyev, "Site selection for solar photovoltaic system installation using analytical hierarchy process model in Azerbaijan," Журнал Белорусского государственного университета. География. Геология, pp. 752021 ,92-.
8. S. M. Ahmed and F. K. M. Al-Ramahi, "Evaluate the Effect of Relative Humidity in the Atmosphere of Baghdad City urban expansion Using Remote Sensing Data," Iraqi Journal of Science, pp. 18482022 ,1859-.
9. N. S. Imamverdiyev, "Site selection for solar photovoltaic system installation using analytical hierarchy process model in Azerbaijan," Journal of the Belarusian State University. Geography and Geology, pp. 752021 ,92-.

10. B. Halder, P. Banik, H. Almohamad, A. A. Al Dughairi, M. Al-Mutiry, H. F. Al Shahrani, et al., "Land Suitability Investigation for Solar Power Plant Using GIS, AHP and Multi-Criteria Decision Approach: A Case of Megacity Kolkata, West Bengal, India," Sustainability, vol. 14, p. 11276, 2022.

11. S. Rekik and S. El Alimi, "Land Suitability Mapping For Large-scale Solar PV Farms In Tunisia Using GIS-Based MCDM Approach," EasyChair, 2023.

12. M. Taoufik, L. Meriem, and F. Ahmed, "Land suitability analysis for solar farms exploitation using the GIS and Analytic Hierarchy Process (AHP) – a case study of Morocco," Polityka Energetyczna – Energy Policy Journal, vol. 24, pp. 792021 ,96-.

13. S. M. Khazael and M. Al-Bakri, "The Optimum Site Selection for Solar Energy Farms using AHP in GIS Environment, A Case Study of Iraq," Iraqi Journal of Science, pp. 45712021 ,4587-.

14. N. S. Katee, O. I. Abdullah, and E. T. Hashim, "Extracting Four Solar Model Electrical Parameters of Mono-Crystalline Silicon (mc-Si) and Thin Film (CIGS) Solar Modules using Different Methods," Journal of Engineering, vol. 27, pp. 162021 ,32-.

15. S. N. JASIM and H. N. HUSSAIN, "Roadside landscape of Baghdad–Babylon-Karbala road," GLOBAL RESEARCH REVIEW, vol. 1, pp. 55-2021 ,68.

16. Q. N. Jaleel and N. K. Ghazal, "The best school site choosing for rural areas of the Husseiniya district in Karbala province using GIS (Model Builder) Techniques," Iraqi Journal of Science, pp. 24732017 ,2485-.

17. U. Munkhbat and Y. Choi, "GIS-Based Site Suitability Analysis for Solar Power Systems in Mongolia," Applied Sciences, vol. 11, p. 3748, 2021.

18. R. Müller and U. Pfeifroth, "Remote sensing of solar surface radiation–a reflection of concepts, applications and input data based on experience with the effective cloud albedo," Atmospheric Measurement Techniques, vol. 15, pp. 15372022 ,1561-.

Semi-Annual Scientific Journal
www.arbnj.com
Shaaban 1445 A.H, March 2024 A.D

19. G. D. Malaperdas and V. V. Panagiotidis, "The aspects of Aspect: Understanding land exposure and its part in geographic information systems analysis," Energy & Environment, vol. 29, pp. 10222018 ,1037-.

20. S. Saha, P. D. Kunte, and K. Mahender, "Application of the remote sensing and geo-spatial technology in terrain analysis and terrain classification in context of creation of SDI for marine and coastal regions," 2016.

21. N. Muhsin, T. Ahamed, and R. Noguchi, "GIS-based multi-criteria analysis modeling used to locate suitable sites for industries in suburban areas in Bangladesh to ensure the sustainability of agricultural lands," Asia-Pacific Journal of Regional Science, vol. 2, pp. 352018 ,64-.

22. K. Abida, M. Barbouchi, K. Boudabbous, W. Toukabri, K. Saad, H. Bousnina, et al., "Sentinel-2 data for land use mapping: Comparing different supervised classifications in semi-arid areas," Agriculture, vol. 12, p. 1429, 2022.

23. M. Uyan, "GIS-based solar farms site selection using analytic hierarchy process (AHP) in Karapinar region, Konya/Turkey," Renewable and Sustainable Energy Reviews, vol. 28, pp. 112013 ,17-.

24. A. Asakereh, M. Omid, R. Alimardani, and F. Sarmadian, "Developing a GIS-based fuzzy AHP model for selecting solar energy sites in Shodirwan region in Iran," International Journal of Advanced Science and Technology, vol. 68, pp. 372014 ,48-.

25. J. M. Sánchez-Lozano, J. Teruel-Solano, P. L. Soto-Elvira, and M. S. García-Cascales, "Geographical Information Systems (GIS) and Multi-Criteria Decision Making (MCDM) methods for the evaluation of solar farms locations: Case study in south-eastern Spain," Renewable and sustainable energy reviews, vol. 24, pp. 5442013 ,556-.

26. M. Taoufik, M. Laghlimi, and A. Fekri, "Land suitability analysis for solar farms exploitation using the GIS and Analytic Hierarchy Process (AHP)–a case study of Morocco," Polityka Energetyczna, vol. 24, pp. 792021 ,96-.

27. K. Kulakowski, Understanding the analytic hierarchy process: CRC Press, 2020.

28. I. Gašparović and M. Gašparović, "Determining optimal solar power plant locations based on remote sensing and GIS methods: A case study from Croatia," Remote Sensing, vol. 11, p. 1481, 2019.

29. T. L. Saaty, "The analytic hierarchy process: planning, priority setting, resource allocation," ed: McGraw-Hill, New York London, 1980.

30. T. L. Saaty, "Decision making with the analytic hierarchy process," International journal of services sciences, vol. 1, pp. 832008 ,98-.

31. O. Ibrahim, N. Z. Yahaya, N. Saad, and M. W. Umar, "Matlab/Simulink model of solar PV array with perturb and observe MPPT for maximising PV array efficiency," in 2015 IEEE conference on energy conversion (CENCON), 2015, pp. 254258-.

32. M. S. Tolia, K. Wangchuk, H. Raj, and D. J. P. Kesari, "Design And Analysis of 200 W Solar Cell Using MATLAB and ANSYS," INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS, vol. 10, 2022.

33. A. Bhatia, "Design and Sizing of Solar Photovoltaic Systems," Contin. Educ. Dev. Inc, pp. 22005 ,125-.