Spatial Analysis and Site Allocation for Solar Energy Systems in KarbalaUsing GIS-Fuzzy AHP

Sinan Sameer Mahmood Al-Dabbagh

University of Baghdad

senan.samir@sc.uobaghdad.edu.iq

Ahmed A.Ali

Islamic azad university science & research branch

Enas Kh .Hassan

University of Baghdad,

Mohammed M. Wadod

University of Baghdad,

Raghda A .Ali

University of Baghdad,

Majid A .Albakr

University of Baghdad

Hassan j .Alatta

University of Baghdad,

Najah A .Abd

University of Baghdad

Abstract

Solar panel systems installation is critical for increasing energy production and advancing sustainable development ,especially in locations where there are millions of people converging for the Ziyarat Al-Arbaeen .In this work ,we use the GIS-Fuzzy Analytical Hierarchy Process) AHP (approach to pinpoint the ideal locations in Karbala ,Iraq, for solar panel installation and to reduce the difficulties encountered by Visitors during the Ziyarat Al-Arbaeen and provide a reliable electricity supply to the governorate of holy Karbala throughout the year .In order to assist decision-makers in choosing solar panel sites, our thorough analysis considers a variety of traits and factors ,including land cover ,solar radiation ,slope ,water bodies ,road infrastructure, and buildings .We classify land cover and examine changes using GIS techniques to present a thorough picture of the present land use patterns and infrastructure layout in Karbala .Fuzzy logic is used to choose the best places for installing solar panels based on these parameters. In order to assure optimal energy generation ,solar radiation analysis helps locate areas with greater sun irradiance levels .Finding the best sites for panel alignment and placement is aided by slope analysis. To comprehend possible shading or cooling impacts on photovoltaic)PV (performance ,the link between land cover and water bodies is assessed .In order to enable quick access and reduce shadowing, building presence and road infrastructure are also taken into account. The results of our analysis are aimed at reducing the difficulties that the numerous Visitors encountered during the Ziyarat Al-Arbaeen in Karbala .We can significantly improve the services and facilities available to the pilgrims ,easing their burdens and improving their overall experience ,by identifying areas with favorable land cover, increased solar radiation levels ,moderate slopes ,safe distance from water bodies ,easy access to roads ,and minimal building shading. This study offers a systematic and thorough way to help guide the site selection process by utilizing the GIS-Fuzzy AHP technology, with an emphasis on specifically enhancing the circumstances for the Ziyarat Al-Arbaeen .The findings encourage the effective use of solar energy sources ,furthering environmental and renewable energy projects while also increasing the Visitor experience for millions of visitors.

Keywords: Solar panel siting ,GIS ,Fuzzy AHP ,Ziyarat Al-Arbaeen, land cover ,solar radiation ,slope ,water bodies ,road infrastructure, buildings ,Karbala ,Iraq.

1. Introduction

The choice of the best location for the installation of solar panels is an important choice that may have a big impact on the system's efficacy and efficiency. Solar irradiation, temperature, and other environmental elements all have a significant impact on a solar panel's performance [1]. To guarantee the selection of an appropriate site that optimizes solar energy output while reducing potential barriers and inefficiencies to the system, significant thought and study must be put into it sun panel energy production is greatly influenced by sun radiation.

So, in order to optimize energy production, it's crucial to pick a site with lots of solar radiation. Additionally, a suitable site must be chosen in order to conduct feasibility studies like technical and economic feasibility in order to make the most of the solar panels' performance [2]. A number of earlier academics have looked at the best ways to use slope angle relationships and take installation location into account while choosing a site for solar panels. Researchers have put out a number of theoretical models that account for variables like latitude and solar energy generation to determine the best slope angles. For photovoltaic panels to produce the most solar energy, the best slope angle must be chosen. However, because multiple techniques and empirical models were employed to determine the ideal slope, there is a large discrepancy between the optimal tilt angles values published in the literature. The fuzzy Analytical Hierarchy Process is one method that has been utilized to tackle this site selection issue.

In order to deal with the inherent uncertainty and ambiguity in site selection decision-making, the fuzzy Analytical Hierarchy Process (fuzzy-AHP) combines the concepts of fuzzy logic and the Analytical Hierarchy Process. By considering a number of factors and their respective weights, the fuzzy-AHP methodology helps to get beyond the drawbacks of conventional site selection techniques.

With this approach, it is possible to take into account both quantitative and qualitative elements, such as solar radiation levels, accessible land area, geography, proximity to infrastructure and transmission lines, environmental effects, and societal acceptance.

Using fuzzy-AHP, decision-makers may rank these criteria in terms of priority and evaluate them accordingly. They can then choose the best location for the installation of solar panels based on a thorough and impartial analysis of all pertinent elements. The fuzzy-AHP method also enables decision-makers to take into account the opinions of experts and their own personal preferences. The fuzzy-AHP technique enables decision-makers to more precisely convey their subjective judgments by utilizing linguistic factors and fuzzy membership functions. This lessens the chance of prejudice and guarantees a fair and impartial decision-making process while enabling a more accurate and thorough study of site choices [2].

Several research on solar panel site selection have successfully used the fuzzy-AHP technique. For instance, a research carried out in Belgium examined the effectiveness of photovoltaic solar systems using climatological variables, panel orientation, and density [3]. The best location for these installations was chosen using the fuzzy-AHP approach, which took into account factors including solar radiation levels, shading effects, and the amount of space that was available at each candidate location.

Another Taiwanese research that employed the fuzzy-AHP technique to choose appropriate sites for the installation of solar panels did so by taking into account variables including available land cover space, solar radiation levels, and proximity to the infrastructure that provides power [4]. In order to efficiently analyze and prioritize these criteria, the fuzzy-AHP approach was also employed to include the preferences and expert views of the experts. These illustrations show how the fuzzy-AHP method may effectively overcome some of the drawbacks of conventional site selection techniques.

The AHP technique now includes fuzzy set theory, enabling a more reliable and adaptable method of site selection. The decision-making process is made more adaptable and able to handle the ambiguities and uncertainties related to site selection criteria by using fuzzy logic.

This is especially true when choosing a location for solar panels because variables like weather and regional variance may create a lot of uncertainty. Additionally, the fuzzy-AHP method gives decision-makers the ability to handle several criteria and their interactions at once. This is essential when choosing a location for solar panels since there are so many factors to take into account, including solar radiation levels, shading effects, available space, the distance to power infrastructure, and environmental consequences. The fuzzy-AHP approach may be used to evaluate both physical and intangible criteria since it can incorporate both qualitative and quantitative data. The fuzzy-AHP technique also takes into account the preferences and viewpoints of the experts who are participating in the decision-making process.

This is significant when choosing a solar panel installation location since professionals may offer insightful information about the precise conditions needed for installation success. The fuzzy-AHP technique offers a thorough and adaptable framework for choosing a solar panel site.

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It considers the complexity and unpredictability involved in the decision-making process, enabling a more precise and informed choice of suitable places.

The fuzzy-AHP method combines the advantages of fuzzy set theory and the Analytic Hierarchy Process to address the challenges faced in solar panel site selection [5]. It integrates fuzzy set theory into the AHP method, allowing decision-makers to assign weights and perform pairwise comparisons based on their expert opinions. The decision-making process may be made more flexible to the ambiguities and uncertainties connected with site selection criteria by employing fuzzy set theory.

2. Solar Power Panel Installation Systems in Karbala to Serve the Masses of Visitors

The installation of solar energy systems in Karbala, Iraq, is a critical step towards reaching renewable energy targets and lowering reliance on fossil fuels. Iraq has the potential to lead the area in solar power production due to its good weather for solar applications. Numerous studies have been done on the impact of weather conditions on solar energy applications, according to academics in Iraq, and these studies have given important insights into the viability and efficiency of solar power panels in Karbala and other parts of Iraq [6].

Furthermore, Karbala's latitude of 32.61°N, which receives plenty of sunshine all year round, makes it a great position for the production of solar electricity. The performance of solar collectors under transitory circumstances has been examined in experimental tests carried out in Karbala. These research' findings suggest that the tilt angle of solar collectors has a big impact on how well they work. Increased effectiveness and energy production may be obtained by adjusting the tilt angle in accordance with the latitude and the weather. Additionally, Karbala enjoys a year-round sunshine duration of about 3,000 hours and daily average solar radiation of up to 6.5-7 kWh/m2.

Karbala is a desirable location for the installation of solar panels due to its high solar radiation potential, plenty of sunlight, and agreeable weather. Iraq has made tremendous progress in developing renewable energy in addition to its good weather. But it's crucial to recognize the difficulties Iraq will confront in utilizing its solar energy potential. The country's hot environment makes it difficult to successfully use photovoltaic technology to harness solar energy. The performance and efficiency of solar panels may be impacted by the high temperatures, thereby creating thermal management problems. Additionally, Iraq's history of war and political instability, together with issues with planning and execution, have made it difficult to use solar energy resources effectively [7].

Despite these obstacles, installing solar energy systems in Karbala, Iraq, has enormous potential for the nation and its people. In Iraq's Karbala, purchasing solar energy systems can offer a number of advantages and prospects. Reducing reliance on fossil fuels, supporting energy security, minimizing the consequences of climate change, and boosting economic growth by creating jobs in the renewable energy industry are a few of these objectives. Iraq's ambition to become into a producer and exporter of solar energy can be furthered by the installation of solar power plants there. Additionally, Iraq's geographical distribution of solar irradiance suggests that the whole nation has a wealth of solar energy resources [8].

This means that solar power panels may be installed in numerous areas around Iraq, increasing the nation's capacity to produce solar energy [8]. Solar energy provides services through solar power systems that can meet the demands of the many millions of Visitors that visit Holy Karbala during the Ziyarat Al-Arbaeen, in addition to offering the governorate a dependable energy supply all year long. In addition to powering electric refrigerators, these services also include providing energy for restrooms, kitchens, lighting, cooling, and irrigation systems. In conclusion, Iraq's vast solar energy potential makes it an attractive place for the deployment of solar power panels, especially in Karbala, despite the difficulties posed by the environment and political unrest.

3. Methodology

3.1. Fuzzy-AHP Method for Solar Panel Site Selection

The choice of a solar panel installation site involves making a number of difficult decisions and managing many variables. A strong foundation for addressing these issues and assisting in sensible site selection is provided by the Fuzzy Analytic Hierarchy Process (Fuzzy-AHP) technique. The Analytic Hierarchy Process (AHP) and fuzzy logic are combined to create the Fuzzy-AHP technique, which gives decision-makers a systematic way to manage ambiguous information and include subjective judgements [9].

The Fuzzy-AHP technique starts by identifying pertinent standards for choosing solar panel locations. Solar radiation, land availability, shading analysis, geography, accessibility to infrastructure, and environmental restrictions are a few examples of these criteria. The relevance of each criterion is expressed by verbal values or fuzzily defined figures, which represent the subjective assessments of decision-makers. This accommodates the amorphous character of decision-making and enables a more flexible depiction of preferences [9].

The relative relevance of the criteria is then assessed using pairwise comparisons. Using language phrases or fuzzily defined figures, decision-makers rank the relevance of each criterion in relation to the others. These conclusions are transformed into fuzzy numbers using the Fuzzy-AHP approach, which captures the fuzziness and imprecision present in subjective evaluations. To make sure the pairwise comparisons are coherent and to correct any errors, consistency checks are carried out [10].

Following the completion of the pairwise comparisons, the Fuzzy-AHP approach determines the priority weights for the criterion. To acquire precise numerical values, the pairwise comparison results' fuzzy numbers are combined and defuzzified. The fuzzy numbers are defuzzed using techniques like the centroid or alpha-cut approach to provide useful priority weights. The relative weights of the factors in the site selection process are represented by these weights.

The Fuzzy-AHP approach examines and ranks prospective locations for solar panel installation after prioritizing the criteria. Each site is evaluated in relation to the predetermined standards, and decision-makers give each option verbal values or fuzzy numbers to represent how suitable it is. Defuzzification is used to convert the ratings into clear numerical values, enabling a quantitative comparison of the options. Decision-makers can choose the best places for installing solar panels by sorting the sites based on their total ratings [10].

Sensitivity analysis is done to determine how reliable the decision model is. Decision-makers can comprehend the effects of uncertainty on the site selection process by modifying the judgements and monitoring the variations in rankings that occur. By identifying and fixing any discrepancies in the pairwise comparisons, consistency checks are also carried out to guarantee the trustworthiness of the decision model.

The Fuzzy-AHP approach for choosing solar panel sites has a number of benefits. It provides a systematic framework for decision support and enables decision-makers to take into account both quantitative and qualitative criteria as well as to include subjective judgements. The presentation and analysis of geographical data, criterion layers, and alternative site locations are made easier by the integration of the Fuzzy-AHP approach with Geographic Information Systems (GIS). This improves the site selection procedure's effectiveness and accuracy.

A useful way for choosing a solar panel site is the Fuzzy-AHP method. Decision-makers may successfully manage uncertainties and subjective judgements by integrating fuzzy logic and the AHP, resulting in better informed and ideal site selection decisions. The Fuzzy-AHP technique encourages the effective usage of solar resources and advances sustainable energy planning [10].

3.2. Data acquisition

Landsat 8 satellite imagery was used to collect the data for this paper on land use categorization and solar panel siting. The required data for analysis were collected using the Thermal Infrared Sensor and the Landsat 8 Operational Land Imager sensor. In order to improve the quality of the data, the Landsat 8 imagery was processed, which included scene mosaicking and atmospheric correction [11]. Without supervision, categorization an unsupervised classification method utilizing ISO Cluster was used to categorize the land use surrounding each research location. A data analysis tool called the ISO Cluster methodology locates geographical groupings in satellite images. This method automatically groups comparable pixels based on their spectral similarity, therefore it does not require previous information or training sets for classification. The ideal pixel grouping is calculated using the ISO Cluster approach by measuring the distance between cluster centers and the standard deviation within each cluster. The ISO Cluster methodology was selected for this research because it offers a reliable and impartial method of classifying land use [12].

Additionally, the ISO Cluster approach is suitable for remote sensing analysis and enables for the fast processing of massive datasets. To detect and categorize various land use types, the Landsat 8 images was subjected to the ISO Cluster algorithm [13].

3.3. Determination of Research Parameters

Effective solar panel placement is essential for maximizing the use of solar energy in certain areas. This study intends to pinpoint important research criteria for choosing appropriate locations for the installation of solar panels in the setting of Karbala, Iraq. This study offers important insights for the effective location of solar panels in Karbala by analyzing the slope, solar radiation, water bodies, road infrastructure, and structures.

An extensive examination was carried out in Karbala, Iraq, to establish the research criteria for choosing the location for solar panels. The results of the investigation into the parameters are listed in Table 1:

Slope:

The performance of solar panels is significantly influenced by the inclination and orientation of the land surface. Using topographic information and Geographic Information System (GIS) methods, the slope of probable locations in Karbala was examined [14].

Solar Radiation:

The capability of solar panels to produce electricity is significantly influenced by the availability of sun radiation. Weather stations and satellite sources were used to gather information on solar radiation, including direct, diffuse, and total radiation [14]. This study looked at the solar radiation levels in several Karbala neighborhoods to pinpoint those with high sun irradiance, which indicates the best locations for solar panel placement.

Water Bodies:

The effectiveness of solar panel installations may be affected by the presence of nearby bodies of water [15]. In order to determine the proximity of water bodies, such as rivers, lakes or reservoirs, to potential solar panel locations in Karbala, GIS techniques were used. This research helps in identifying the locations where the water bodies are far away because they may present potential safety risks.

Road Infrastructure:

For the building, use, and upkeep of solar panel systems, accessible road infrastructure is crucial for the transit of supplies and machinery [15]. Using GIS data and satellite images, this study looked at the accessibility and closeness of road networks to possible solar panel installations. The effective design and execution of solar energy projects in Karbala are aided by the identification of locations with easy access to road infrastructure.

Buildings:

The effectiveness of solar panels can be impacted by nearby buildings and structures due to shade and sunlight interference. This research evaluated the presence and height of surrounding structures near prospective locations for solar panel installations. Suitable sites with little influence from shade were found for the placement of solar panels by taking into account the orientation and shadowing effects of the structures [15].

For the effective use of solar energy resources, it is essential to establish the research parameters for choosing the location of solar panels in Karbala, Iraq. This research offers important insights for decision-makers and stakeholders involved in solar energy projects in Karbala by evaluating the factors of slope, solar radiation, water bodies, road infrastructure, and structures. The research parameter with its type, which is shown in Table 1, aids in the successful selection of ideal locations for solar panel installation, fostering the production of sustainable and effective solar energy in the area.

Table 1: Research Parameters.

Parameter	Type of Parameter
Slope	Geomorphological
Solar Radiation	Climatic
Water Bodies	Hydrological
Road Infrastructure	Infrastructure
Buildings	Urban

3.4. Analysis method

Euclidean distance and reclassify are two methods frequently employed in spatial analysis.

Reclassifying entails assigning new values or categories to a raster or vector dataset in accordance with predetermined standards. For various analytical purposes, it enables the transformation of data into various classes or categories. For instance, reclassifying elevation data into slope categories or reclassifying land cover data into various vegetation types.

The distance in a straight line between two points in a Euclidean space is known as the Euclidean distance. It is frequently used in spatial analysis to determine the distance between objects or locations. When analyzing proximity or accessibility, such as locating the closest neighbor or identifying areas within a certain distance of a location, this distance metric is especially helpful.

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4. Study Area

The study area is concentrates on the city of Karbala, which is located in the center of Iraq and about 110 kilometers southwest of Baghdad, the country's capital. Karbala, which spans a region of around 5,034 square kilometers, is physically situated between latitudes 32°N and 33°N and longitudes 43°E and 44°E. The three provinces that make up the city Karbala, Hindiyah, and Eantamer each contribute to the regions overall growth and scenery.

Karbala has significantly urbanized over the past two decades as a result of both population expansion and increased migration to the city. New residential, commercial, and industrial projects have changed the neighborhood and shaped the urban fabric as a result of the urban growth. The development of industrial facilities and educational institutions has coincided with the increase in urbanization, thus enhancing Karbala's economic and social dynamics [16].

Figure (1), which shows an Iraqi map with a window selected to indicate the research's particular emphasis, shows the region within Karbala that is the subject of the study. The selected region captures the essential traits and traits of Karbala, enabling a thorough investigation of the urban and rural environments [16].

The aim of this study is to choose appropriate locations for the installation of solar panels in Karbala, Iraq. Both urban and rural land uses may be found in the Karbala region. The area is mostly utilized for the cultivation of crops including date palms, barley, wheat, fruit trees, and different summer crops in terms of agriculture. The local economy and food production depend on these agricultural operations. A lively urban environment with cutting-edge infrastructure and historical landmarks that draw tourists from all over the world is created by the urban areas, which also include residential buildings, commercial hubs, industrial facilities, and educational institutions.

Finding the best places to put solar panels requires an understanding of the dynamics and features of the study area in Karbala. Researchers want to examine elements including sunshine exposure, land availability, and potential shading difficulties to find the best locations for solar panel deployment by looking at how agricultural and urban regions interact. This study will aid in the creation of practical plans for capturing solar energy in Karbala and advancing clean and sustainable energy production.

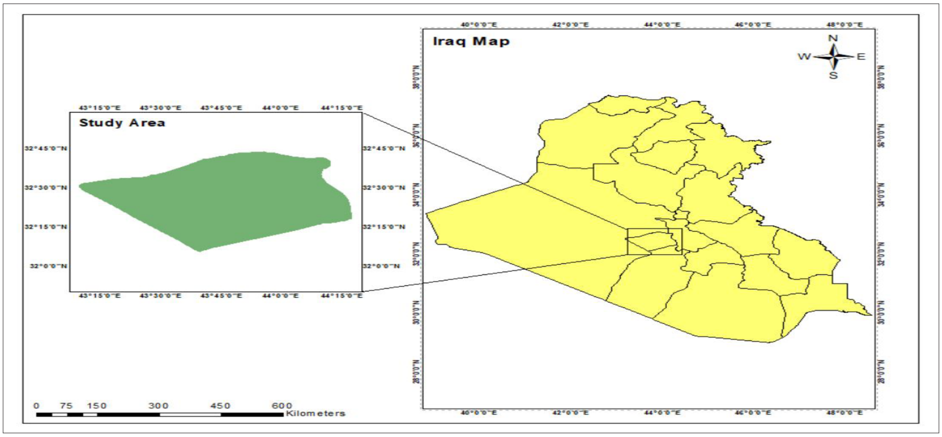

Figure 1: Study Area/ Karbala city, Iraq.

4.1. Land Use in Karbala City

Several variables affect how land usage in Karbala City affects natural ecosystems. The topography of the landscape is an important element that affects how suitable a piece of land is for various uses. Figure (2) depicts the patterns of land use and cover in Karbala City and offers important details on the placement of electricity lines and roadways.

The particular features of the terrain become important when installing photovoltaic (PV) systems. The extent of the land area the PV system occupies, the kind of terrain, its closeness to vulnerable ecosystems or scenic regions, and its biodiversity status are all taken into consideration. These elements aid in assessing the possible effects and alterations that could occur during the building phase, such as earth movements and transportation operations.

The conversion of arable land for the installation of PV systems, which might affect soil production, is one possible worry. Conflicts and unhappiness among farmers who have sentimental attachments to their arable land may result from this.

It is crucial to take into account the possible environmental and social effects of installing PV systems in order to maintain sustainable land use practices. By using the results of this study to inform site selection decisions, land use changes may be addressed socially and with less negative effects on natural ecosystems [17].

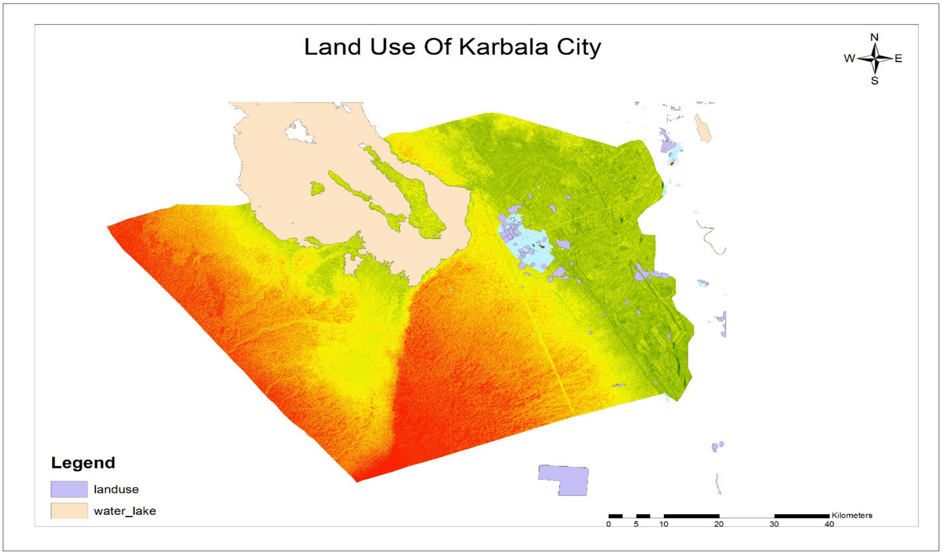

Figure 2: Land cover and land use patterns in Karbala City.

5. Results and Discussion

The results gathered from the use of GIS-Fuzzy Analytical Hierarchy Process (AHP) for solar panel placement selection in Karbala, Iraq, are given and discussed in this section. The use of GIS with the fuzzy AHP approach together enables a thorough and systematic assessment of many factors and their corresponding weights in the decision-making process.

Figures (3–9) illustrate the classification process and change detection outcomes and Table 2 contains data on the weights that were used to determine the results. Figure (3) illustrates the various forms of land cover and the distribution of roads and power lines throughout the region, offering insights into the land cover and roads/ power lines in Karbala. Understanding the current land use patterns and infrastructure is essential for influencing the PV system placement decision.

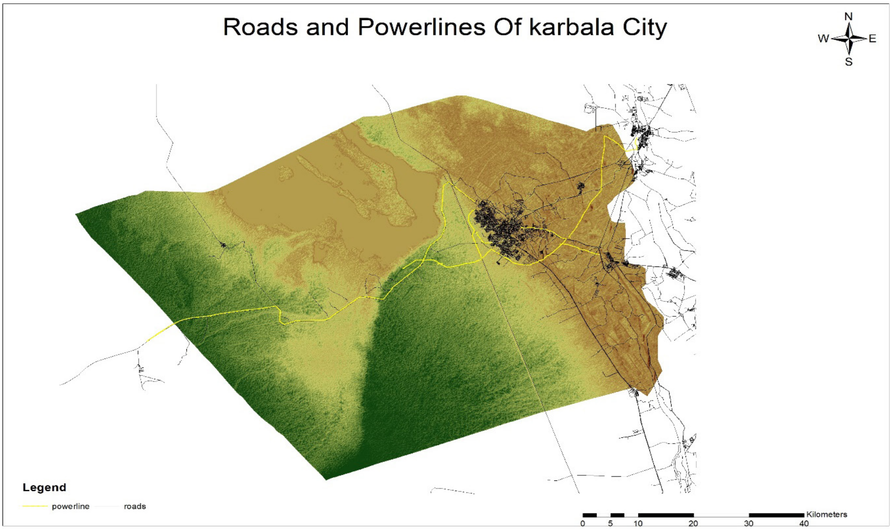

Figure 3: Land Cover and Roads/Power Lines in Karbala, Iraq

The Reclassify of roads, are shown in Figure (4). This map includes reclassification of roads in Karbala Governorate

Reclassification involves assigning new values or categories to a vector or raster data set according to predefined criteria. For various analysis purposes, in order to facilitate decision-making and fuzzy analysis.

Figure (5) depicts the analysis and visualization of solar radiation, a crucial component in the production of PV energy. This map shows how the amount of solar radiation is distributed around Karbala, highlighting areas with higher sun irradiance. This knowledge is crucial for increasing PV system energy output and choosing the best locations to install solar panels.

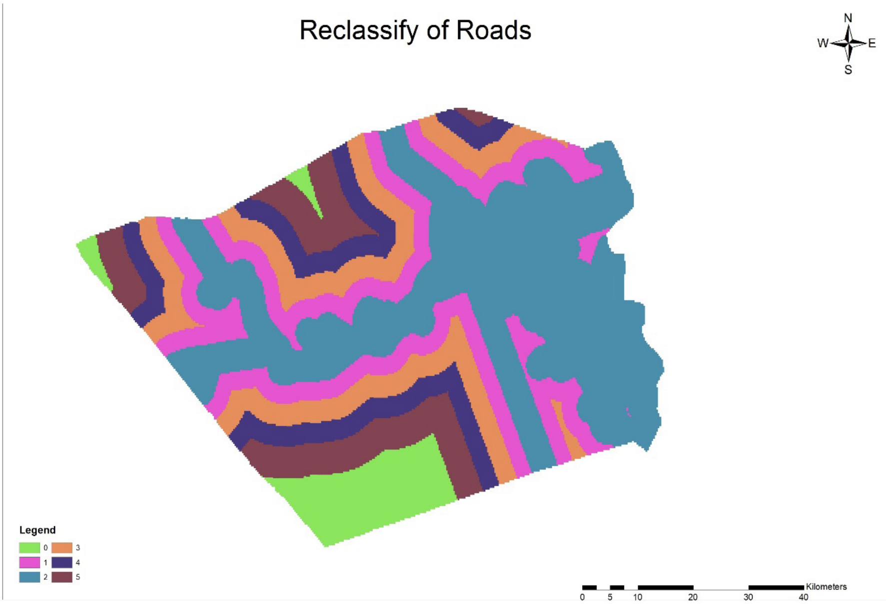

Figure 4: Reclassify Of Roads in Karbala, Iraq

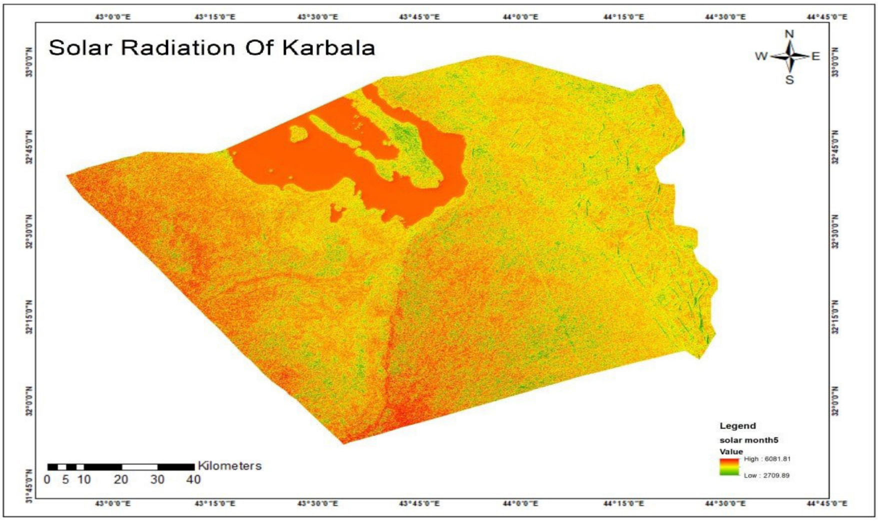

Figure 5: Solar Radiation Distribution in Karbala, Iraq

Figure (6) shows the slope analysis of the city of Karbala and highlights locations with various slope inclinations. In order to choose acceptable locations for solar panel alignment and positioning that ensure optimal energy generation, it is essential to take slope information into account.

Figure (7) shows the assessment of the association between Karbala lakes and land cover using fuzzy logic. This map illustrates the relationship between the different types of land cover and the local occurrence of lakes. Assessing possible shading or cooling impacts from surrounding water bodies and their impact on PV performance is made easier with an understanding of this connection.

Finally, Figure (8) displays the digital elevation model (DEM) data-derived map of Karbala's land cover. An overview of the distribution of land uses, including metropolitan regions, agricultural areas, and other land use types, is shown on this map. It is a resource for examining present land cover patterns and locating locations that might be ideal for installing solar panels.

Figure No. (9) shows the fuzzy hierarchical analysis of the slope in Karbala and highlights the sites with different slopes classified by linear classification. In order to select acceptable sites for solar panel alignment and to locate sites that ensure optimal power generation, it is necessary to take gradient information into account.

Figure (10) shows a fuzzy hierarchical analysis of the roads in Karbala. Classified by fuzzy linear classification. to determine the best results

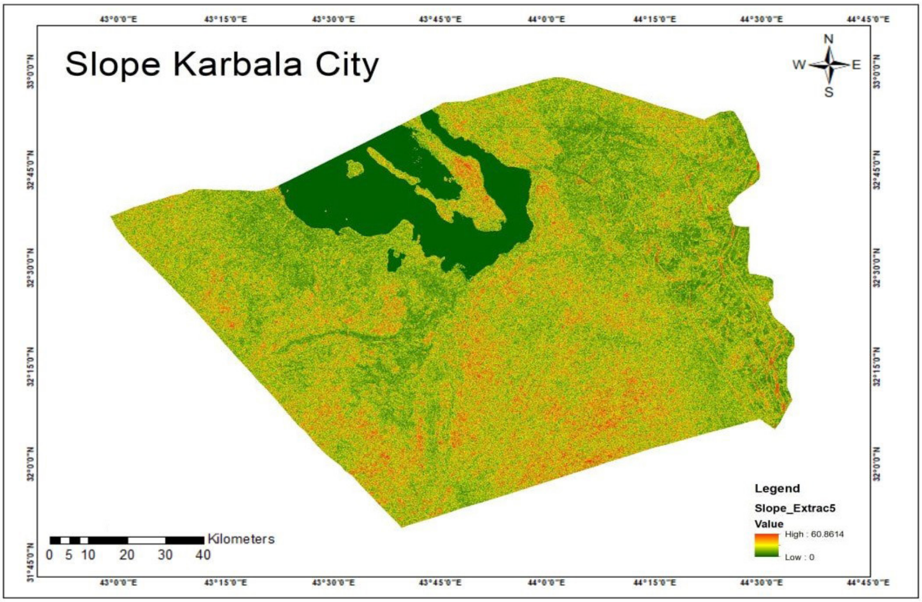

Figure 6: Slope Analysis of Karbala City for Solar Panel Siting Selection

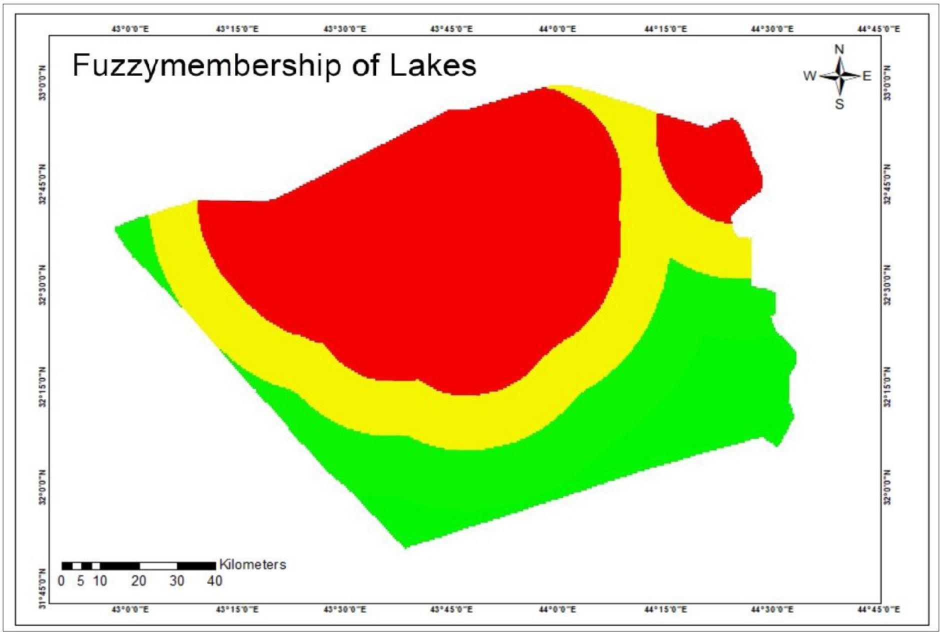

Figure 7: Relationship between Land Cover and Lakes in Karbala, Iraq

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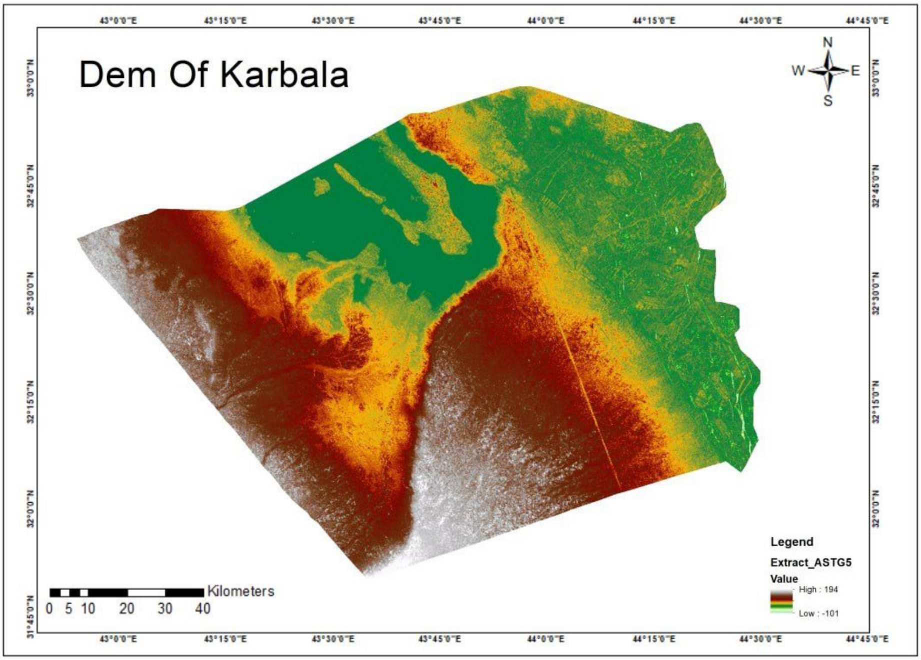

Figure 8: Land Cover Map of Karbala City Derived from DEM Data

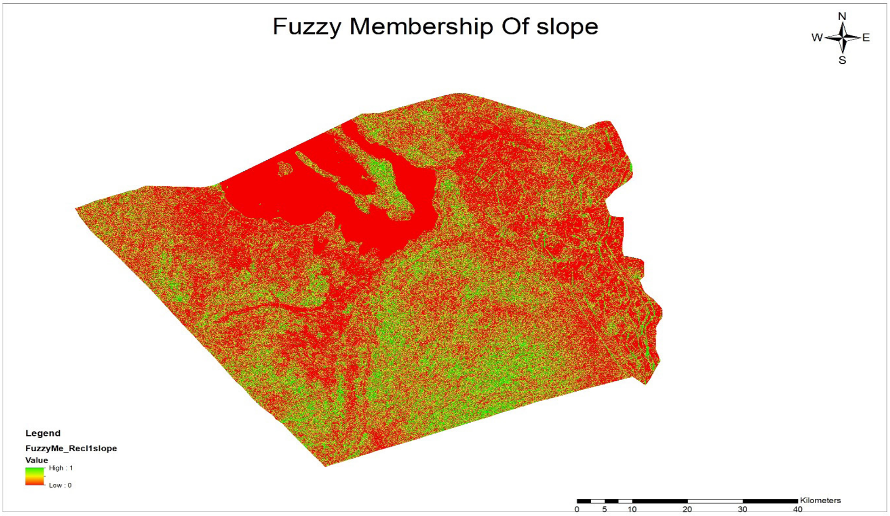

Figure :9 Fuzzy membership of Slope of Karbala City

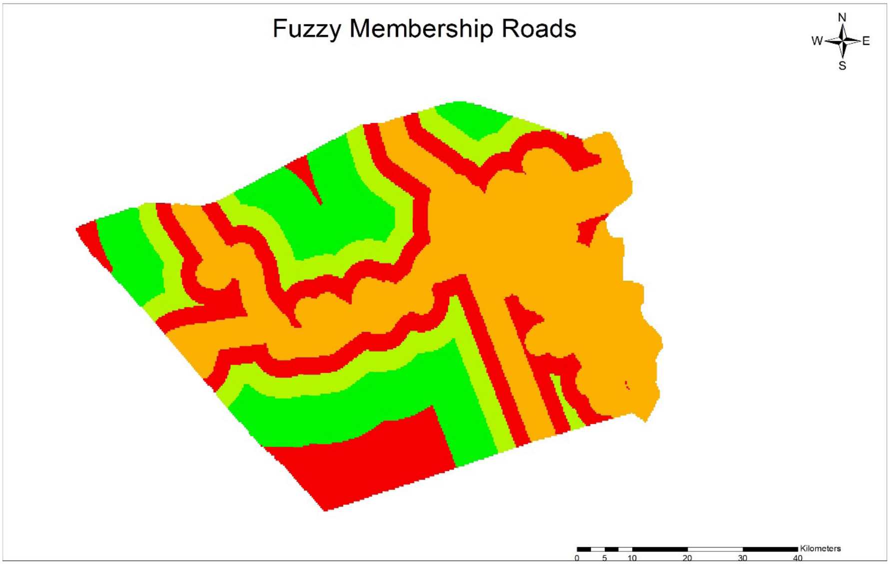

Figure :10 Fuzzy membership of Roads of Karbala City

The classification process ,change detection ,and application of the GIS-Fuzzy AHP technique produced useful data that may be used to choose the best location for solar panels in Karbala ,Iraq. The study of land cover ,suitability mapping ,evaluation of solar radiation ,analysis of slope ,interaction with lakes ,and map of land cover obtained from DEM provide insights into the spatial features and parameters influencing the choice of the best locations for PV installations .These findings support the effective use of solar energy resources in Karbala by fostering informed decision-making.

Table :2 Weighting Factors for Classification and Change Detection Outcomes

Land cover	Dis.city	Dis.road	Dis.power	Slope	Solar.rad	Criteria
(1/8,1/7,1/6)	(11/6,1/5,1/4)	(1/5,1/4,1/3)	(1/3,2/2,1/2)	(1/4,1/3,1/2)	(1,1,1)	Solar.Rad
(3/8,3/7,3/6)	(3/6,3/5,3/4)	(3/5,3/4,3/3)	(3/3,3/2,3,1)	(1,1,1)	(2,3,4)	Slope
(2/8,2/7,2/6)	(2/6,2/5,2/4)	(1/3,2/2,1/2)	(1,1,1)	(2/4,2/3,2/2)	(1,2,3)	Dis.Power
(4/8,4/7,4/6)	(4/6,4/5,4/4)	(1,1,1)	(1,2,3)	(4/4,4/3,4/2)	(3,4,5)	Dis.Road
(5/8,5/7,5/6)	(1,1,1)	(5/5,5/4,5/3)	(5/3,5/2,5/1)	(5/4,5/3,5/2)	(4,5,6)	Dis.City
(1,1,1)	(7/6,7/5,7/4)	(7/5,7/4,7/3)	(7/3,7/2,7/1)	(7/4,7/3,7/2)	(6,7,8)	LandCover
0.03	0.05	0.07	0.23	0.11	0.51	Weight

The optimal places for PV installation in Karbala ,as identified by fuzzy logic ,are shown in Figure .(11) The fuzzy logic technique assists in identifying sites that are highly suitable for PV installation by integrating several variables such as slope ,solar radiation ,and distance from water bodies .The best locations for establishing solar energy villages are in the southern part of Karbala province .The decision-makers and stakeholders engaged in the process of choosing a location for solar panels might use this map as a reference.

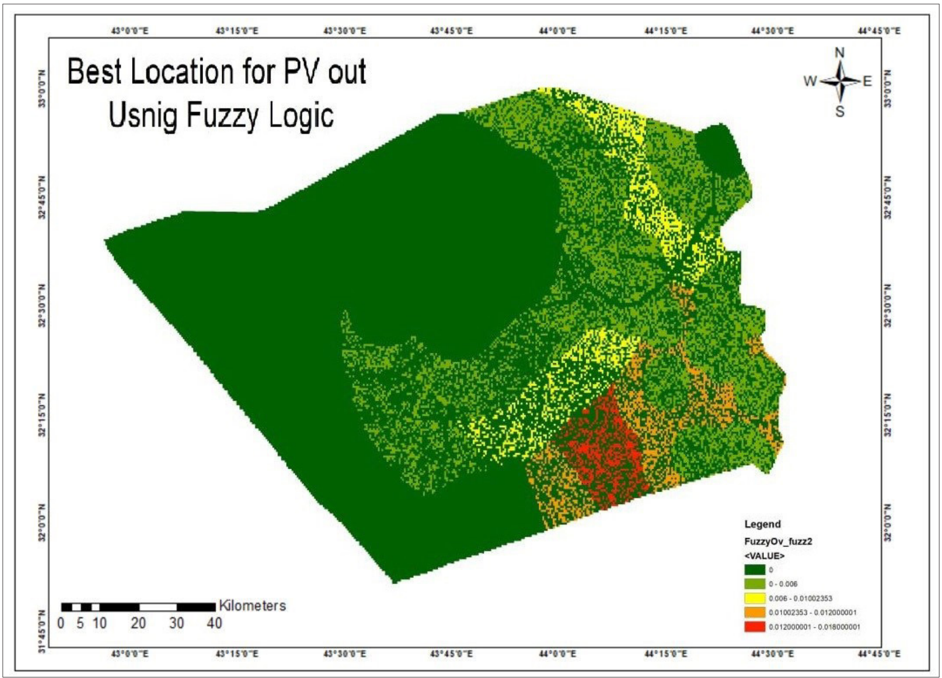

Figure :11 Land Cover and Best Locations for PV Installation in Karbala ,Iraq

8. Conclusion

For the location of the solar panels in Karbala, Iraq, we used a GIS-Fuzzy Analytical Hierarchy Process (AHP) technique in this study. We gained important insights into the ideal places for PV installation in the area by examining a number of metrics and criteria, including land cover, solar radiation, slope, water bodies, road infrastructure, and buildings. We detected the land cover and roads/power lines in Karbala using the classification method and change detection, which offered a thorough grasp of the current land use patterns and infrastructure architecture. Based on the following criteria, we used fuzzy logic to identify the ideal sites for installing solar panels, Land cover taking into account elements like plant covering, built-up areas, and agricultural land, we evaluated various land cover types and their potential for PV installation. Sun radiation to locate places with higher sun irradiance, which indicate areas with better potential for PV energy generation, we evaluated the geographical distribution of solar radiation levels. Slope taking into account elements like the steepness of the terrain and its direction towards the sun, we found potential locations for the installation of solar panels by analyzing the slope characteristics of the city of Karbala. Water bodies in order to evaluate the possible shading or cooling impacts of surrounding lakes or rivers on PV performance, we looked at the link between land cover and water bodies. Road infrastructure to determine locations with better accessibility for the installation and maintenance of solar panels, the road network was taken into consideration. Buildings to ensure that PV panels receive the most sunlight possible and produce the most energy, we took buildings' existence into account. According to the results of our analysis, the best places in Karbala for installing solar panels are those that have a favorable combination of suitable land cover, higher solar radiation levels, gentle slopes, distance from water bodies, easy access to roads, and little building shading. These areas have the best potential for producing PV energy effectively and efficiently. This research focuses on using renewable and environmentally friendly energy sources to enhance the electrical situation in the holy province of Karbala and give the finest services to the millions of Visitors during the Ziyarat Al-Arbaeen of Imam Hussein (peace be upon him) Additionally, the province as a whole will have access to clean electricity all year round because of these solar energy systems. The goal of the study was to locate the best location to install solar power systems. Through spatial suitability analysis, this study determined the best locations for establishing solar energy villages in the southern part of Karbala province.

The GIS-Fuzzy AHP algorithm used to arrive at this result depended on weighting factors such as slope, closeness to electricity transmission lines, road access, solar radiation intensity, and the distance from buildings and water bodies.

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