Geospatial Analysis of Photovoltaic Plants Potential in Palestine Using a GIS-AHP-Based Technique

Amer Braik*, Kamaruzzaman Sopian*, Hasila Jarimi*, Ahmad Fazlizan*, Ag Sufiyan Abd Hamid **, Adnan Ibrahim*‡

* Solar Energy Research Institute, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia

** Faculty of Science and Natural Resources, Universiti Malaysia Sabah, 88400 Kota Kinabalu, Sabah, Malaysia

(P110230@siswa.ukm.edu.my , ksopian@ukm.edu.my , hasila.jarimi@ukm.edu.my , a.fazlizan@ukm.edu.my , pian@ums.edu.my , iadnan@ukm.edu.my)

‡ Corresponding Author; Adnan Ibrahim, 43600 Bangi Selangor, Tel: +60 389 11 8581, Fax: +60 389 11 8574, iadnan@ukm.edu.my

Received: 27.01.2022 Accepted: 17.03.2022

Abstract- Geographical multi-criteria decision analysis (MCDA) has been applied to various spatial challenges in recent years, including solar energy site appropriateness. MCDA may be used to aid in selecting potential solar energy project locations. The study on the solar photovoltaic PV system site appraisal in Palestine is new; therefore, a geographical MCDA framework is provided for conducting a geospatial analysis of solar energy in Nablus, Palestine. This framework comprises data collection, spatial analysis, a spatial decision support system, and visualization. The process for resolving the site appropriateness issue is discussed. It utilized a Geographical Information System (GIS) in conjunction with the Analytic Hierarchy Process (GIS-AHP). The results indicate that the ideal areas are north and northwest of Nablus. The PV plants in this location can achieve more than 1700 kWh/kWp/year as electricity production, cool temperatures, averaging 22°C, and flatlands with a slope of less than 5. These lands can be obtained from all engineers and designers to install the highest efficient electricity generation plant using Solar Energy in Nablus, Palestine.

Keywords PV Solar Plants; GIS; AHP; Palestine

1. Introduction

The World Bank report emphasized that the energy sector is essential to the economic growth and development of Palestine [1]. The overall West Bank electrical supply is projected at 850 MW. Currently, roughly 65 MW comes from renewable sources, 35 MW from Jordan, and 750 MW from Israel. The West Bank has five electricity distribution companies: JDECO, which serves Jerusalem, Jericho, Ramallah, and Bethlehem; NEDCO and TEDCO, which serve the northern West Bank; and HEPCO and SELCO, which serve the southern West Bank [2].

Like other Middle Eastern countries, Palestine has a booming energy market. Solar power was used to meet energy demands [3]. However, Nablus in Palestine seems like an excellent fit for solar energy initiatives because of its unique geographical disposition [4]. So, creating efficient land selection strategies will ensure the land selected for PV solar plants meets optimal requirements. Given environmental concerns about air pollution generated by burning fossil fuels to produce electrical power, it is becoming of great interest to use solar energy as a renewable and sustainable energy source. Solar energy is of great interest in arid and semi-arid regions as a renewable, inexpensive, and sustainable source for electrical power generation. Photovoltaic systems that generate electricity from the sun are a simple, sustainable source to handle and directly generate energy from the sun [5].

However, it is a significant challenge to find the best locations to gain from the full potential of solar energy. In this paper, we introduced a geographical MCDA framework to conduct a geospatial analysis of solar energy in Nablus, Palestine. The proposed framework is new for this country and it comprises of the following key components; data collection, spatial analysis, a spatial decision support system, and visualization. This research was aimed at showing the vast amount of available land for the installation of photovoltaic energy systems to improve the electrical capacity of Palestinian communities, which in turn will improve the economy through increased use of electricity, and what better form of electricity to use than clean and environmentally friendly one without taking into consideration any land value nor any type of financial costs. Also, assist those in Palestine who are seeking for a certain technique to locate these possibilities.

2. Literature Review

An overview of previous research studies conducted in the fields of AHP and GIS processing is provided in this section. Combining these two technologies, which is regarded a geospatial analytic tool, is described as the discovery and selection of optimal locations for solar energy projects in order to maximize the likelihood of project success in terms of maximization of power output.

The forecast of the output power of solar cells in a given location has always been a significant aspect in the planning of solar cell panels installations, as well as in assisting electrical businesses in the proper control, management, and distribution of energy into their electricity networks [6]. for example, the usage of Artificial Neural Networks (ANNs) has been increasing in recent years in solar radiation modelling for places at various latitudes and with varying climates [7]. A related body of study has been carried out in countries such as Saudi Arabia and Oman; Spain and Turkey; China; Egypt; Cyprus and Greece; India; Algeria; and the United Kingdom. ANN networks may be more accurate in forecasting solar radiation [7]. Although a different approach was employed in this study to estimate solar radiation, the selection feature was utilized, and geographical maps were displayed in a smooth and understandable fashion. The analytic hierarchy process (AHP) is a technique that has been widely utilized for evaluating site suitability for solar energy projects. Utilizing geographic information systems (GIS) and the AHP, Uyan [8] evaluated site suitability for PV solar farms in Karapinar, Turkey [9]. The AHP has also been used to determine the most favourable areas for PV system installations in southern England [10], Tanzania [11], and Saudi Arabia [12], using a mix of geographic information systems and acoustic measurements [9]. In Palestine, however, no research has assessed site suitability for PV systems using GIS and the AHP, as has been done in other parts of the world.

2.1. Analytical Hierarchy Process

A tool for organizing and evaluating complex decisions, using math and psychology, is Analytical Hierarchy Process AHP. It was created in the 1970s by Thomas L. Saaty [13]. It has three components namely; the ultimate purpose or dilemma to be solved, all potential alternative solutions to the problem, and the criteria to determine the alternatives [13]. By quantifying the parameters and alternative alternatives, AHP offers a logical basis for a necessary decision and connects those elements to the overall objective [14]. Understanding the structure of a problem and the real hindrance managers face when solving it is the real motivation behind the AHP method [14]. The AHP method acknowledges that the significance of each criterion might not be equal, as there are many criteria [14]. Therefore, weights must be added to the criterion when assessing alternative solutions to ensure the correct outcome [15]. However, management scientists have faced problems with assigning weights in AHP. The assignments become more and more random as the number of parameters multiplies [15]. One important use of the AHP model is in decision models. The AHP method starts by specifying the options that need to be evaluated. Such alternatives may be the various parameters by which solutions must be evaluated [16]. They may also be the distinct attributes of a commodity that need to be weighted to understand consumers' understanding better [17]. A detailed list of all the alternatives available must be ready at the end of phase 1 [18]. The next step consists of modelling the problem [18].

According to AHP methodology, one of the problems is a connected group of sub problems [19]. Therefore, the AHP strategy splits the problem into a hierarchy of more minor issues [20]. Criteria to test the solutions arise in breaking down the sub problem [21]. However, an individual can go on and on to deeper levels within the problem, including root cause analysis [20]. A subjective decision is when to avoid splitting the problem into smaller sub problems. The next phase is to use pairwise comparison to set priority among parameters. The AHP approach utilizes pairwise comparison to construct a matrix [22]. The organization would be asked to weigh the relative value of security from decline vs liquidity, and there would be a pairwise contrast of liquidity and the likelihood of appreciation in the following matrix [22]. Managers are supposed to fill out this information in compliance with the end user's preferences or the individuals who will use the process [23]. Testing consistency is the next step. This phase is integrated into most software tools that help solve problems with AHP [23]. Finally, obtaining the relative weights was the next step. Based on the results, the software tool will run the mathematical calculation and assign the relative criteria weights [24]. Once the equation is ready with weighted parameters, the alternatives can be evaluated to get the best solution that fits their requirements.

2.2. Geographic Information System (GIS) Processing

Geographic Information Systems (GIS) Processing is a knowledge collection, management, and review system. GIS, rooted in geographical science, incorporates several data types, analyses spatial positions, and organizes information layers using maps and 3D scenes into visualizations [25]. GIS reveals more profound insights into knowledge such as trends, relationships, and circumstances with this specific capability, helping users make better decisions [25].

GIS technology uses geographic science with understanding and communication methods and helps people achieve the shared aim of gathering actionable information from all data forms. Geographical Information System (GIS) techniques can assess the optimum spatial location for solar PV farms to achieve this objective. Using geographical, topographical, and soil data, potential locations for constructing a power plant is one way that the energy industry utilizes GIS-based approaches [26]. The spatial variability of solar energy uses GIS-based techniques to evaluate the best location for constructing a power plant by using satellite images with different spatial resolutions [26]. Whereas spatial data such as topography and climate parameters are required to achieve more precise results, it is easier to use a combination of the fuzzy and the Analytical Hierarchy Process (AHP) methods to determine a suitable location for solar PV farms [27]. Climatic parameters are also often considered in addition to topography maps to assess the optimum position of PV farms more accurately [27].

3. Methodology

The proposed framework for the decision model is shown in Figure 1 below. It is also possible to follow along as this study was carried out, as well as the data that was collected and evaluated at each stage of the procedure. Using any programming technique of their choice, any Palestinian community may use this strategy to filter out inappropriate territory.

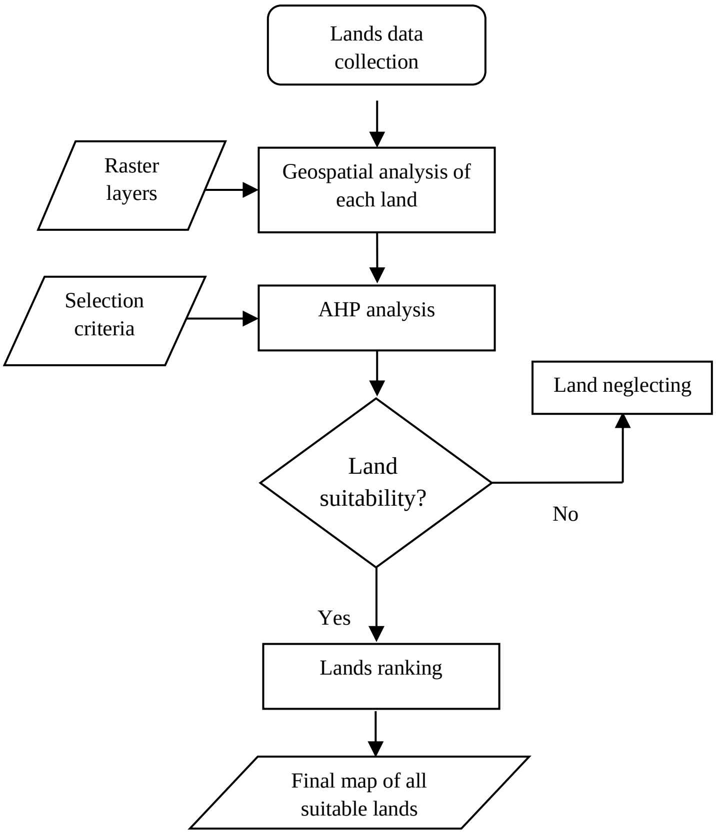

Fig. 1. The proposed research GIS decision Model

However, Arcmap 10.7 software was utilized in GIS processing and spatial analysis computation, taking into account all available raster layers utilizing MySQL code to analyze and process each lands data with extracting their attributes to be saved in an individual database. Furthermore, criteria were employed to meet the author's requirements for the places where the pv plants should be installed. To determine whether or not a particular land meets all of these criteria, a decision technique was employed once the AHP analysis and weighting was completed. Not doing so means that the land was left to deteriorate and wasn't included in the database. otherwise, it was put to a database of the most effective land-oppurtiation methods. It was therefore possible for anybody to locate any of the specified territories by looking at a single map.

3.1. Lands Data Collection

The areas included in this analysis were picked from open-source data published by the Palestinian ministry of local government [28], which included more than 400,000 lands in total. Following the application of many decision equations and analysis for the lands, the sample was selected using geographic information system software called ArcMap. The most suitable locations are those with the least amount of rainfall, the shortest distance between the Land Centroid and the nearest Point of Common Coupling (PCC), the existence of a road within the land, the calculation of the annual average temperature, the south façade of the land, the calculation of the annual average solar energy, and the lowest land slope. By selecting the most suitable locations, the cost of constructing the PV plants is reduced while the amount of energy produced is increased. The identification of suitable sites for the development of solar PV plants represents a significant problem. The development of land-use plans is vital for the equitable and sustainable use of non-renewable natural resources, such as property, because they allow the resource to be used in a planned, sustainable, and suitable manner [29]. Raster and vector models are two types of data models that are ideal for data land gathering and are represented by a pixel grid, with each storing data, including the location of the data collection site, in a different way. Geographical objects are represented in vector data models by vector features, which preserve the geometric properties of the objects. Vector features are more suitable for representing boundaries and other geometric spatial objects [30]. They take the form of points, lines, and polygons that store information about their properties [31]. While raster data represents square areas, vector data represents interiors rather than limits [32]. While vector data is excellent for capturing and storing spatial information, the raster data is more suitable for capturing, storing, and analysing data that differ continuously from place to place, such as elevation and temperature [32]. Aerial and satellite imagery are also stored using Raster data formats. Raster graphics of the underlying data structure also often have relative simplicity [33]. Each grid position depicted in the raster image corresponds to a single value, and it is relatively easy to perform overlay analyses on raster data with this simple data structure [33]. Compared to its vector equivalent, this simplicity also allowed simple understanding and maintenance of the graphics. One downside of the raster technique was that files are generally extensive in the case of raster images constructed from the technique of cell-by-cell encoding the sheer number of values stored for given dataset results in potentially huge files [34]. The output images were often less in quality than their vector counterparts, and this was especially noticeable when the raster images are enlarged or zoomed [34]. The geometric changes that occurred during map projection attempts can cause raster graphics problems, and this is their other drawback, combined with the fact that it is not sufficient for certain kinds of spatial analysis. In the vector model, the data structure appeared to be much more complex than the basic raster data model. Since the position of each vertex must be stored explicitly in the model, there are no data storage shortcuts like there are for raster models [35]. Due to small variations in precision and accuracy between the input datasets, spatial analysis can also be relatively complex [35].

As previously said, selection criteria were devised in this research to rank the most ideal possibilities by adding a weight to each land based on a variety of factors, as represented in the table 1 below, in order to rank the most suitable opportunities.

Table 1. Research Selection Criteria values

No.	Criteria	Unit	Condition
1	Lands Area	M^2	x >= 12000
2	Land South Orientation		Yes
3	Land slope	°	x <= 10
4	Road existence		Yes
5	Distance from land centroid to nearest PCC	KM	x =< 5
6	Energy Yield from a PV System	KWH/KWP	x >= 1500
7	Annual Monthly Average Ambient temperature	C°	15 <= x <= 30
8	Rainfall amount		No restrictions since there is a slightly varies in the study area

3.2. Geospatial Analysis of each land

The model has processed several critical data types of Nablus which was illustrating as Raster layers, namely, the rainfall amount, road existence inside the land, annual average temperature calculation, annual average solar energy calculations, south façade of land, and land slope, which generated several maps to describe each data set as explained in the following sections.

3.2.1. Determination of Rainfall Amount

The city of Nablus is situated in the northern part of the West Bank, about 52 km east of the Mediterranean Sea and 60 km north of Jerusalem, at an altitude of 570 m above sea level. As shown in Figure 2, with an average annual rainfall of 658 mm, the city has semi-arid characteristics [36]. Due to good insolation, the evaporation rate is exceptionally high in the summer, and it significantly exceeds the rainfall in the period from April to October.

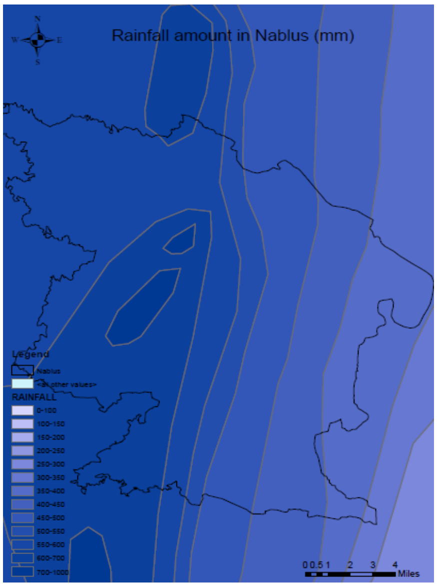

Fig. 2. Annual Average Rainfall Amount in Nablus

3.2.2. Road Existence Nearby the land

In selecting suitable areas for establishing PV plants, roads play a crucial role. The preferred economic consideration is proximity to roads because it prevents extra expenses for building facilities. The sub-criteria of the main road criterion are local roads, primary roads, and express roads. For greater accessibility, PV plants should be located near express roads. Nablus has an extensive road network that is ideal for setting up solar PV plants, according to Figure 3 showing the main roads network in Nablus.

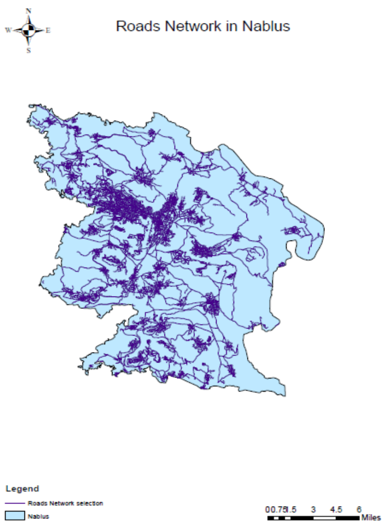

Fig. 3. Roads Network in Nablus

3.2.3. Annual Average Temperature Analysis

As shown in Figure 4, temperature significantly affects solar energy generation. The summers are long, humid, arid, and clear in Nablus, and the winters are cold and often clear [37].

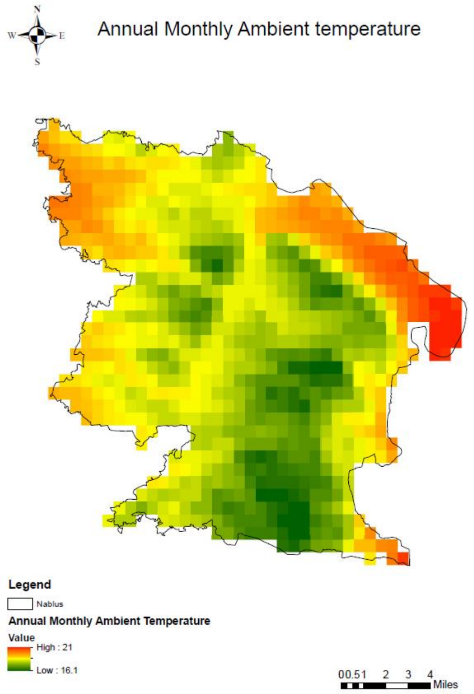

Fig. 4. Annual Monthly Ambient Temperature in Nablus

The average daily mean temperature varies from 24.4°C in summer to around 9.6°C in winter and the average relative humidity per month ranges from 51% to 67 % [37]; [38]. The average daily mean temperature is optimal because, with higher insolation, these temperatures offer a higher generation [38]. Higher module temperatures will lead to a lower solar energy generation than expected [39].

3.2.4. PV System Energy Yield Assessment

Solar radiation calculations have significant applications and include estimating solar power plant energy generation, building heating and cooling loads, and climate modelling and weather forecasting [40]. These calculations would help determine sun radiation at Nablus as the solar PV plants are being installed. However, Figure 5 shows the Annual average global tilted irradiation in Nablus. Moreover, average monthly daily energy output values from a PV system were illustrated in the following figures by showing the distribution of energy generation through the year. These data were driven from the Global Solar Atlas of Westbank and Gaza in 2018.

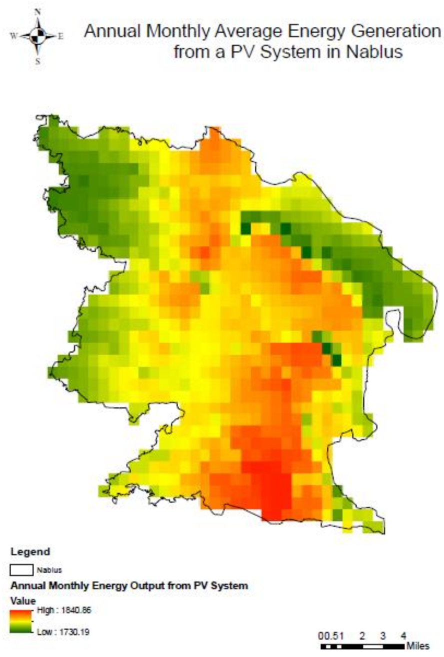

Fig. 5. Monthly Daily Averages of Energy Output from 1kWp PV System

3.2.5. Determination of Lands South Façade

Horizontal blades are built into the south façade to shade the summer sun while allowing low-angled winter sun into space. Using the SOL algorithm, the solar power potential of facades is best calculated [41]. The algorithm begins with a re-sampled geo-referenced LiDAR data cloud for a 1×1m2 raster [41]. On tilted surfaces, the hourly global irradiance, G, is defined by its two main components, as presented in Equation 1.

$$G = \left(Gbh\ x\ \left(\frac{cos\ cos\ \theta}{\cos \cos \theta z}\right) x\ SC\right) + (Gdh\ x\ Fd\ x\ SVF) \quad (1)$$

Where Gbh and Gdh are the hourly direct and diffuse horizontal components of irradiance, respectively, SC is the isotropic diffuse radiation transposition factor, SVF denotes the Sky View Factor, θz is the zenith angle of the sun, and θ is the angle of incidence of sun rays on the tilted plane [42]. This algorithm will determine the most efficient way to set up panels at the solar PV plants in Nablus.

3.2.6. Determination of Lands Slope

Site characteristics, such as ground slope, should be considered when building solar plants. Sites with a steep gradient where solar panels are difficult to mount should be removed [43]. Using Equation 2, flat terrain or gentle slopes facing south with less than a 5% graded slope for large-scale PV power plants was found suitable [43]. To ensure that all PV modules can be mounted at an appropriate tilt angle, fields flatter than 10° are a technical necessity.

$$\%slope = \left(\frac{Rise}{Run}\right) x\ 100\% \qquad (2)$$

3.3. Analytical Hierarchy Process Analysis

Saaty’s scale was used in the pair-wise comparison between the above selection criteria according to the table 2 below:

Table 2. Saaty's scale in the pair-wise comparison process

Definition	Importance
Equal importance	1
Weak importance of one over another	3
Essential or strong importance	5
Demonstrated importance	7
Absolute importance	9
Intermediate values between two adjacent judgments	2,4,6,8

As a result of applying pairwise comparison repeatedly, we got a complete picture of the relationship between the selection criteria for each land and each other, which would have allowed us to determine the weights of each of these attributes in order to accurately adopt the weights of the land and obtain the required arrangement for the best possible opportunities from these lands, as well as a complete illustration of the relationship between each of these attributes and each other.

Table 3. Selection Criteria Weight based on AHP Analysis

Item Description	Weight
Lands Area	33.20%
South Façade for Majority of land	19.40%
Land Slope	20.30%
Road existence	8.50%
Distance from land centroid to nearest PCC	9.70%
Annual Monthly Average Energy generation per kWp	3.50%
Annual Monthly Average Ambient temperature	3.50%
Rainfall amount	1.90%

4. Results and Discussion

The land suitability analysis methods include assessing and grouping areas of land on their suitability for specified use [44], such as electricity generation using PV panels in our case. Due to the consideration of distinct criteria, the concepts of sustainable development make land-use suitability analysis increasingly complex [44]. This includes not only the intrinsic ability of the land unit to maintain the land use for an extended period of time without depreciation, but also the socioeconomic and environmental costs. [45]. It is extremely advantageous to identify land areas for the development of solar PV power for the sustainable development of a region where transmission planning is optimized [46]. Because, Photovoltaic (PV) energy is one of the potential solutions to today's energy and environmental concerns. PV modules employed photoelectric converters known as solar cells, which convert directly absorbed sunlight into electrical energy, Further advancements in PV conversion efficiency and cost reduction are required to move PV implementation forward. Considering its drawbacks, one way for meeting peak load needs is to integrate renewable energy sources, which has far less negative effects [47]. So, connecting photovoltaic (PV) energy to the power grid can assist boost local economy. However, its integrating into the grid necessitates a study of the inverter and grid factors (frequency, voltage, etc.) [48]. It is anticipated that this integration of PV Plants would significantly increase the potential of the national grid, since it will close the supply-demand gap that has been formed due to a lack of investment in current plants, antiquated grid distribution systems, power theft, and line losses [49]. This will aid in the transformation of the present national grid into a smart grid through the integration of communication and smart metering technologies. Because the goal of a smart grid is to increase the dependability of the energy network by encouraging the use of alternative energy sources. Furthermore, it ensures a stable system that is not affected by grid failures [50]. Also, the most important element in determining the most advantageous site for the three PV plants is to construct numerous plants and inject them into the grid in order to lower peak power use under the above circumstances. The installation of these PV stations will, in the end, aid in the reduction of peak demand throughout the day, the reduction of dependency on the electric grid, the reduction of carbon emissions, and the improvement of the overall stability of electrical systems [51].

4.1. Data Normalization

Area, slope, expected electrical energy, and ambient temperature were all calculated using a certain logarithm to determine the highest possible value for each attribute, which was then divided by the value of each piece of land to determine its standard weight, and the product was multiplied by the total weight of the attribute to arrive at a final value for each attribute. Calculate the usual weight for each piece of land independently in order to carry out the classification and arrangement procedure according to the land with the highest weight. For example, Equation 3 shows the calculation formula of lands area normalization, and this information was repeated for the slope, energy yield and ambient temperate respectively.

$$Land\ Normalized\ Area\ = \frac{Land\ Area}{Largest\ Land\ Area} \qquad (3)$$

The map modelling characteristics were arranged according to the classification below to show the importance of each option. As shown in Table 3, the land area was chosen with the highest degree, and the rainfall option was chosen with the lowest degree. Selected lands of Area, Slope, Energy

Yield and Ambient Temperature data were normalized to calculate the overall weight of each land for the ranking process according to Equation 4, since the value of south façade was analysed to have (0,1) and can't be normalized.

$$\begin{aligned} \mathit{Normalized\ Weight} &= \mathit{Normalized\ Area} * 0.332 \\ &+ \mathit{Normalized\ Slope} * 0.203 \\ &+ \mathit{Normalized\ Energy\ Yield} * 0.035 \\ &+ \mathit{Normalized\ Ambient\ Temperature} \\ &* 0.035 \qquad (4) \end{aligned}$$

4.2. Lands Ranking

Table 4 shows the top ten lands that have been identified through this research; each has a unique identification number, as well as a unique rank, area, south-facing orientation for a majority of the land, degree of inclination, expected electrical energy per kilowatt peak produced by the solar power plant, ambient temperature in the area, and a standard weight assigned to each piece. The total number of lands identified as appropriate for the development and construction of solar power plants is 263 according to the findings of the study.

Table 4. Top ten optimal lands for PV plants in Nablus

Land ID	Rank	Area (Dunam)	South Orientation	Slope (Degrees)	Mean Energy Yield	Mean Ambient Temperature	Total Weight
109	1	453.28	1	8.71	1820	19	0.59
113	2	183.25	1	4.93	1758	21	0.39
241	3	161.08	1	7.10	1803	19	0.37
221	4	122.98	1	4.50	1798	21	0.35
175	5	122.98	1	4.50	1778	21	0.35
167	6	119.40	1	9.01	1740	18	0.34
76	7	86.44	1	0	1767	20	0.33
71	8	106.37	1	7.95	1752	20	0.33
59	9	94.46	1	9.10	1743	21	0.32
237	10	60.30	1	0	1735	18	0.32

4.3. Final Optimal Lands Map

The following lands in Figure 6 illustrate the final optimal lands selection for installing PV plants in Nablus regarding the methodology described above. researchers and engineers in the solar energy sector in the country can use it as a reference to make searching for suitable areas that can be found through this study, as well as building solar energy plants in those areas to generate electricity, faster and more efficiently. Further research into the amount to which these power plants' electrical networks are absorbing this energy will be required in the future, and this will be done in subsequent studies.

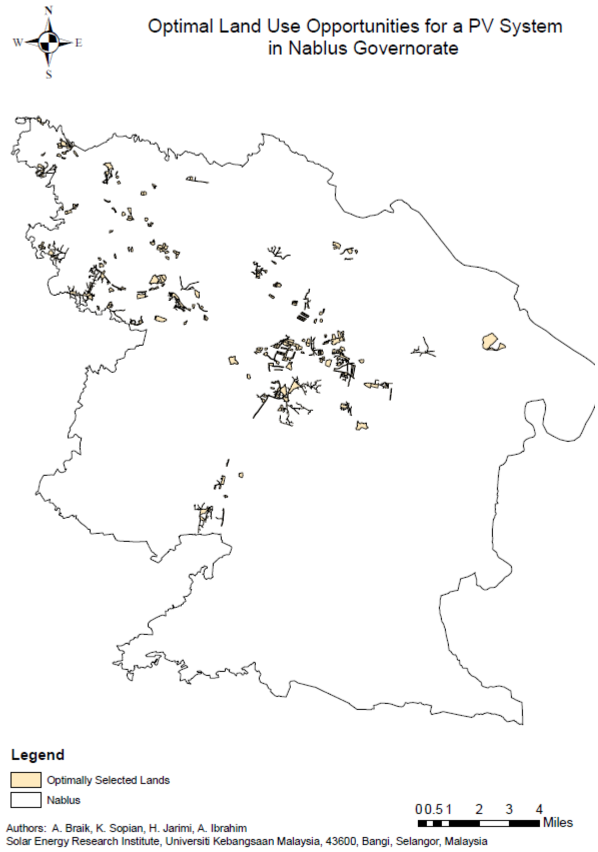

Fig. 6. Optimal Land use opportunities for PV Systems in Nablus, Palestine.

5. Conclusion

Geographic multi-criteria decision analysis (MCDA) has been used to address a variety of geographical difficulties, including the suitability of solar energy sites for production. The MCDA can be used to assist in the selection of potential solar energy project locations, among other things. In order to conduct a geospatial analysis of solar energy resources in Nablus, Palestine, a geographical MCDA framework is offered for conducting a study on the site appraisal of solar photovoltaic PV systems in Palestine for the first time. In this framework, data gathering, geographic analysis, a spatial decision support system, and visualization are all included. The approach for resolving the issue of site appropriateness is explored in detail. This project used the Analytic Hierarchy Process in conjunction with a Geographical Information System (GIS) to gather data (GIS-AHP). According to the findings, the best locations are located north and northwest of Nablus. Solar photovoltaic (PV) plants in this location have the potential to produce more than 1700 kWh/kWp/year of power. The area has cool temperatures on average of 22°C and flatlands with a slope of less than 5. Lands in Nablus, Palestine, can be obtained from any and all engineers and designers that are interested in constructing the most energy-efficient electricity-generation plant possible using solar energy. Finally, several bullet points were illustrated below to wrap up the process efficiency.

- The number of lands that processed and analysed using this mythology was more than 400,000 available lands.
- The number of selected lands was 263.
- The first ten ranked lands area was 1,510,000 m^2, which showing the huge accessible lands to install high efficient PV Plants.
- Most important factors to be taken into consideration were: Land Area, Land Slope, Energy yield and Ambient temperature.

Acknowledgements

The authors are pleased to thank Universiti Kebangsaan Malaysia (UKM) and Solar Energy Research Institute (SERI) for their research funding MRUN-RAKAN RU-2019-001/4.

References

[1] World Bank (2007). West Bank and Gaza energy sector review. [Online] Available at: http://hdl.handle.net/10986/19226 [Accessed 3 Feb. 2021].

[2] Barsoum, A. (2019). West Bank and Gaza - Energy. [Online] www.trade.gov. Available at: https://www.trade.gov/knowledge-product/west-bank-energy [Accessed 4 Feb. 2021].

[3] E. Ajlouni and H. Alsamamra, “A review of solar energy prospects in Palestine”, American Journal of Modern Energy, 5(3), 49-62, 2019.

[4] S. Hamada and A. Ghodieh, “Mapping of solar energy potential in the west bank, Palestine using Geographic Information Systems”, Applied Geography, 1-14, 2021.

[5] A. Ibrahim, M. Y. Othman, M. H. Ruslan, S. Mat, A. Zaharim, and K. Sopian, “A Pilot Study of the Building Integrated Photovoltaic Thermal (BIPVT) Collector for Commercial Applications in Malaysia”, Proceedings of the 4th WSEAS international conference on Energy and development, p.139-142, 2011.

[6] I. Qasrawi and M. Awad, “Prediction of the Power Output of Solar Cells Using Neural Networks:Solar Cells Energy Sector in Palestine”, International Journal of Computer Science and Security (IJCSS), Volume 9, Issue 6, 2015.

[7] T. Khatib, A. Mohamed, K. Sopian, and M. Mahmoud, “Assessment of Artificial Neural Networks for Hourly Solar Radiation Prediction”, International Journal of Photoenergy, Vol. 2012, pp. 1–7, 2012.

[8] S. Ziuku, L. Seyitini, B. Mapurisa, D. Chikodzi, and K. Van Kuijk, “Potential of Concentrated Solar Power (CSP) in Zimbabwe”, Energy for Sustainable Development, Vol. 23, pp. 220–227, 2014.

[9] U. Munkhbat and Y. Choi, “GIS-Based Site Suitability Analysis for Solar Power Systems in Mongolia”, Applied Sciences, 11(9), 3748, 2021.

[10] J. J. W. Watson and M. D. Hudson, “Regional Scale wind farm and solar farm suitability assessment using GIS-assisted multi-criteria evaluation”, Landscape and Urban Planning, vol. 138, pp. 20–31, 2015.

[11] A. Aly, S. S. Jensen, and A. B. Pedersen, “Solar power potential of Tanzania: Identifying CSP and PV hot spots through a GIS multicriteria decision making analysis”, Renewable Energy, vol. 113, pp. 159–175, 2017.

[12] H. Z. Al Garni and A. Awasthi, “Solar PV power plant site selection using a GIS-AHP based approach with application in Saudi Arabia”, Applied Energy, vol. 206, pp. 1225–1240, 2017.

[13] C. Kocabaldir and M. A. Yücel, “GIS-based multi-criteria decision analysis of site selection for photovoltaic power plants in Çanakkale Province”, International Journal of Environment and Geoinformatics, 7(3), 347-355, 2020.

[14] M. Sedrati, M. Maanan, and H. Rhinane, “PV power plants sites selection using GIS-FAHP based approach in North-Western Morocco”, International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, 42, 385-392, 2019.

[15] B. Settou, N. Settou, A. Gouareh, B. Negrou, C. Mokhtara, and D. Messaoudi, “A high-resolution geographic information system-analytical hierarchy process-based method for solar PV power plant site selection: a case study Algeria”, Clean Technologies and Environmental Policy, 1-16, 2020.

[16] S. S. Wigati, B. M. Sopha, A. M. S. Asih, and H. Sutanta, “Bibliometric analysis for site selection problems using geographic information systems, multi-criteria decision analysis and fuzzy method”, Journal of Physics: Conference Series, vol. 1351, no. 1, p. 012051, 2019.

[17] H. A. Effat and A. El-Zeiny, “Modeling potential zones for solar energy in Fayoum, Egypt, using satellite and spatial data”, Modeling Earth Systems and Environment, 3(4), 1529-1542, 2017.

[18] T. C. Wang and S. Y. Tsai, “Solar panel supplier selection for the photovoltaic system design by using fuzzy multi-criteria decision making (MCDM) approaches”, Energies, 11(8), p.1989, 2018.

[19] I. Guaita-Pradas, I. Marques-Perez, A. Gallego, and B. Segura, “Analyzing territory for the sustainable development of solar photovoltaic power using GIS databases”, Environmental monitoring and assessment, 191(12), 1-17, 2019.

[20] A. H. Nebey, B. Z. Taye, and T. G. Workineh, “Site Suitability Analysis of Solar PV Power Generation in South Gondar Amhara Region”, Journal of Energy, v.2020, p. 15, 2020.

[21] T. Salihoğlu, E. C. Seyrek, and M. Kaymakçioğlu, “Alternatives to solar power plant location through GIS and AHP: Case of Karaman, Turkey”, Kent Akademisi, 13(4), 651-667, 2020.
[22] D. A. Q. Badang, C. F. Sarip, and A. P. Tahud, “Geographic information system (GIS) and multi-criteria decision making (MCDM) for optimal selection of hydropower location in Rogongon, Iligan City”, 2018 IEEE 10th International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment and Management (HNICEM), pp. 1-5, 2018.
[23] H. Ammar, S. E. Boukebbous, and N, Benbaha, “Photovoltaic water pumping system site suitability analysis using AHP GIS method in Southern Algeria”, 2018 4th International Conference on Renewable Energies for Developing Countries (REDEC), pp. 1-5, IEEE, 2018.
[24] W. Khemiri, R. Yaagoubi, and Y. Miky, “Optimal placement of solar photovoltaic farms using analytical hierarchical process and geographic information system in Mekkah, Saudi Arabia”, 1st International Congress on Solar Energy Research, Technology and Applications (ICSERTA 2018), 2018.
[25] S. Iqbal, S. M. Ali, A. Islam, S. N. F. Zaidi, and I. Ali, “Alternate energy source selection in Gilgit Baltistan Pakistan using geographical information system and analytical hierarchy process”, International Journal of Energy and Water Resources, v.4, pp.257-270, 2020.
[26] C. Erdin and H. E. Akbaş, “A comparative analysis of fuzzy topsis and geographic information systems (gis) for the location selection of shopping malls: A case study from turkey”, Sustainability, 11(14), 3837, 2019.
[27] T. R. Ayodele, A. S. O. Ogunjuyigbe, O. Odigie, and J. L. Munda, “A multi-criteria GIS-based model for wind farm site selection using interval type-2 fuzzy analytic hierarchy process: The case study of Nigeria”, Applied Energy, 228, 1853-1869, 2018.
[28] Geomolg [Online] Available at: https://geomolg.ps/L5/index.html?viewer=A3.V1 [Accessed 3 Feb.2021]
[29] H. Z. Al Garni and A. Awasthi, “Solar PV power plant site selection using a GIS-AHP based approach with application in Saudi Arabia”, Applied Energy, 206, pp.1225–1240, 2017.
[30] J. R. Doorga, S. D. Rughooputh, and R. Boojhawon, “Multi-criteria GIS-based modelling technique for identifying potential solar farm sites: A case study in Mauritius”, Renewable energy, 133, 1201-1219, 2019.
[31] D. Guler and T Yomralioglu, “Optimal location selection for electric vehicle charging stations using GIS”, 7th International Conference on Cartography and GIS, pp. 340-345, 2018.
[32] H. Z. Al Garni and A. Awasthi, “A fuzzy AHP and GIS-based approach to prioritize utility-scale solar PV sites in Saudi Arabia”, 2017 IEEE International Conference on Systems, Man, and Cybernetics (SMC), pp. 1244-1249, 2017b.
[33] H. Z. Al Garni and A. Awasthi, “Solar PV power plants site selection: A review”, Advances in Renewable Energies and Power Technologies, 57-75, 2018.
[34] S. M. Habib, A. E. R. E. Suliman, A. H. Al Nahry, and E. N. Abd El Rahman, “Spatial modelling for the optimum site selection of solar photovoltaics power plant in the northwest coast of Egypt”, Remote Sensing Applications: Society and Environment, 18, 100313, 2020.
[35] A. Koc, S. Turk, and G. Şahin, “Multi-criteria of wind-solar site selection problem using a GIS-AHP-based approach with an application in Igdir Province/Turkey”, Environmental Science and Pollution Research, 26(31), 32298-32310, 2019.
[36] P. Díaz-Cuevas, J. M. Camarillo-Naranjo, and J. P. Pérez-Alcántara, “Relational spatial database and multi-criteria decision methods for selecting optimum locations for photovoltaic power plants in the province of Seville (southern Spain)”, Clean Technologies and Environmental Policy, 20(8), 1889-1902, 2018.
[37] M. K. Anser, M. Mohsin, Q. Abbas, and I. S. Chaudhry, “Assessing the integration of solar power projects: SWOT-based AHP–F-TOPSIS case study of Turkey”, Environmental Science and Pollution Research, 27(25), 31737-31749, 2020.
[38] D. Ronak, A. Ibrahim, J. Goh Li, H. Mohd, and K. Sopian, “Predicting the performance of amorphous and crystalline silicon based photovoltaic solar thermal collectors”, Energy Conversion and Management, Volume 52, Issue 3, Pages 1741-1747, 2011.
[39] I. Marques-Perez, I. Guaita-Pradas, A. Gallego, and B. Segura, “Territorial planning for photovoltaic power plants using an outranking approach and GIS”, Journal of Cleaner Production, 257, 120602, 2020.
[40] H. Yousefi, H. Hafeznia, and A. Yousefi-Sahzabi, “Spatial site selection for solar power plants using a gis-based boolean-fuzzy logic model: A case study of Markazi Province, Iran”, Energies, 11(7), 1648, 2018.
[41] A. Tunc, G. Tuncay, Z. Alacakanat, and F. S. Sevimli, “GIS Based Solar Power Plants Site Selection Using Analytic Hierarchy Process (AHP) in Istanbul, Turkey”, The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. XLII-2/W13, pp. 1353–1360, 2019.
[42] D. Kereush and I. Perovych, “Determining criteria for optimal site selection for solar power plants”, Geomatics, Landmanagement and Landscape, No. 4, 39–54, 2017.
[43] R. P. Tarife, Y. Nakanishi, J. V. S. Bondaug, R. V. Irosido, A. P. Tahud, and N. R. Estoperez, “Optimization of Electric Transmission Line Routing for a Renewable Energy Based Micro-Grid System using Geographic Information System (GIS) Spatial Analysis”, 9th International Conference on

Renewable Energy Research and Application (ICRERA), pp. 215-220, IEEE, 2020.

[44] R. Azmi, H. Amar, and I. Kacimi, “Photovoltaic site suitability analysis using analytical hierarchy process and sensitivity analysis methods with GIS and remote sensing in Southern Morocco: case of Draa-Tafilatet Region”, International Renewable and Sustainable Energy Conference (IRSEC), pp. 1-5, IEEE, 2017.

[45] D. Simón-Martín, A. M. Diez-Suárez, L. Álvarez-de Prado, A. González-Martínez, D. la Puente-Gil, and J. Blanes-Peiró, “Development of a GIS tool for high precision PV degradation monitoring and supervision: Feasibility analysis in large and small PV plants”, Sustainability, 9(6), 965, 2017.

[46] A. Suuronen, A. Lensu, M. Kuitunen, R. Andrade-Alvear, N. G. Celis, M. Miranda, and J. Kukkonen, “Optimization of photovoltaic solar power plant locations in northern Chile”, Environmental Earth Sciences, 76(24),1-14, 2017.

[47] M. T. Elsir, M. A. Abdulgalil, A. T. Al-Awami, and M. Khalid, “Sizing and Allocation for Solar Energy Storage System Considering the Cost Optimization”, 8th International Conference on Renewable Energy Research and Applications (ICRERA), IEEE, 2019.

[48] T. T. Guingane, D. Bonkoungou, E. Korsaga, E. Simonguy, Z. Koalaga, and F. Zougmore, “Modeling and Simulation of a Photovoltaic System Connected to The Electricity Grid with MALTAB/Simulink/Simpower Software”, 8th International Conference on Smart Grid (icSmartGrid), IEEE, 2020.

[49] S. Ilyas, A. Hassan, and H. Mufti, “Review of the renewable energy status and prospects in Pakistan”, International Journal of Smart Grid – ijSmartGrid, Vol 5, No 4, 2021.

[50] A. Harrouz, M. Abbes, I. Colak, and K. Kayisli, “Smart grid and renewable energy in Algeria”, 6th International Conference on Renewable Energy Research and Applications (ICRERA), IEEE, pp.1166-1171, 2017.

[51] I. Keskin and G. Soykan, “Reduction of peak power consumption by using photovoltaic panels in Turkey”, 6th International Conference on Renewable Energy Research and Applications (ICRERA), pp. 886-890, IEEE, 2017.