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Geographical information systems based site selection methodology for renewable energy systems in Palestinian territories

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ABSTRACT

Renewable energy is the key term for the energy industry sector in the world recently. Palestinian territories (PT) have good potential for multiple renewable energy applications. The purpose of this study was to evaluate the potential sites for solar photovoltaic systems, concentrated solar power systems, and wind farms in the West Bank (WB). The study was derived from geographical information systems (GIS) and multi-criteria decision making (MCDM). The criteria for each application were identified and weighted according to the analytical hierarchy process (AHP). All the resulting layers were multiplied to produce the final suitability map for each application. The results of the study depend on two scenarios, In the first scenario, where area C is included, the areas classified as highly suitable for photovoltaic (PV), concentrated solar power (CSP), and wind turbines are between 14.27 and 7.56 km^2. The second scenario is excluding area C, the highly suitable areas were between 4.1 to 2.47 km^2

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1. INTRODUCTION

Regional and international attempts were boosted during the last years to lessen the damaging effects of these gases. Palestinian territories (PT) are trying to have secure, reliable, and resilient energy. PT seems to be volatile and critical due to its semi-complete dependence on imported energy, nearly all of which comes from Israel for political reasons and Palestine’s undeveloped domestic resources [1]. PT is a developing occupied country, split into two geographical areas: West Bank (WB) (including East Jerusalem) and Gaza Strip. The research is focused on WB. Administrative divisions had been declared by Oslo II in 1995, which divided WB into three administrative divisions: areas A, B, and C. Only 18% of the total area is area A, which indicates that full civil and security control is under the Palestinian authorities (PA), and represents the major cities.

The United Nations Office of Coordination of Humanitarian Affairs (OCHA) has stated that Palestinians would have an estimated 35% of the gross domestic product (GDP) if they had been able to enter and develop area C without the present limitations on the area [1]. The lack of conventional energy resources has created energy price control and energy shortage which consequently lead to an energy crisis. PT depends on Israel to import its need for petroleum products, and around 92% of its electrical energy from the Israeli Electric Corporation (IEC) [2], and the expenses of energy are considered the most pricey in the region. To overcome the hurdles in the Palestinian energy sector the Palestinian energy and natural resources authority (PENRA) is adopting renewable energy (RE) and energy efficiency (EE). The reliance on domestic renewables can reach a maximum of 19% in the production of areas A and B and up to 30% in area C [3]. In 2015 the Palestinian authorities declared a decision related to renewable energy (RE) and energy efficiency (EE), which aimed to encourage the utilization and development of RE resources, to achieve a secure supply of energy [3]. PENRA has prepared a strategic plan for RE with clear goals for 2020, by gradually getting 240-gigawatt hours (GWh) at least, which is equal to 10% of the total local power production, and another 500 megawatts (MW) plan to be installed by 2030 of renewable energy. To facilitate the achievement of these goals, this study was conducted.

Selecting the potential sites for RE applications is one of the primary technical issues since the selection of the site is related to future demand, and environmental impacts at local levels [4]. It is not a fully inclusive approach to take into account only the viability of the resource since several other important factors affect the site selection decision. As a response, we must investigate the suitability of the sites as per the environmental, technical, social, and economic factors [5]. With all of these spatially dependent factors, it ought to be evident to adopt a multi-criterion decision-making (MCDM) method. The MCDM method is a vital tool for site selection as it gives adequate solutions. The evaluation of the method is by comparing different factors according to their characteristics properties to select a suitable location for RE application. Many studies conducted the MCDM method in RE site selection.

Literature has shown successful efforts to employ geographical information systems (GIS) in the selection of wind turbine sites and a multitude of attempts have been developed to integrate GIS with various multi-criteria decision-making apps. Al-Garni and Awasthi [6], [7] used using GIS and an MCDM technique to locate the ideal spot for utility-scale solar photovoltaic (PV) projects in Saudi Arabia. The model took into account several economic and technical considerations, to ensure optimal efficiency while lowering project expenses. Haaren and Fthenakis [8] performed according to spatial cost-revenue optimization a site selection strategy for wind turbine farms in New York State. Silva *et al.* [9] evolved a multicriteria decision-making support system to determine the far more relevant locations for biogas plants which involved different environmental, economic, safety, and social factors. They used GIS to handle and interpret spatial data in a flexible manner.

Piirisaar [10] conducted a study GIS and MCDM-based for the locating of Irish utility-scale photovoltaic solar plants, using different datasets to indicate different suitability classes according to analytical hierarchy process (AHP). Daim *et al.* [11] did a study to introduce tools used for evaluating energy alternatives, it is stated that MCDM delivers a flexible tool and a reliable methodology that can handle a variety of variables to provide beneficial support to the decision-maker to rank alternative RE sources, noting that there is no superior or worse manner, merely a strategy that is better suited to a certain scenario. While Wang *et al.* [12] examined the associated procedures in several levels of MCDM for renewable energy, such as criterion selection, the weighting of criteria, appraisal, and ultimate aggregate. They observed that as far as criteria selection and weights are adequate and suited to the individual decision concerns, the method will assist and can be a powerful mechanism for sustainable energy system decision-making.

This study focuses to investigate, assess and highlight the RE potential in the WB by preparing a database for three applications: PV-mounted systems, concentrated solar power (CSP), and wind farms. This will be set by applying a specific criterion for each application relying on previous studies in the same area, taking into consideration the unique condition of the WB. Thereafter, the data was procced and analyzed using MCDM, and the AHP method to be shaped into maps using GIS illustrating the land suitability for each application and estimating the productivity of the application depending on the data. The resulting maps will yield significant advantages for the benefit of the PENRA and anyone interested to invest in RE, as it can be considered a decision support system and a pre-feasibility study, as we hypothesize. As the market of RE in Palestine is growing and with little experience in the field, this study is important to conduct to fill the void.

2. METHOD

The method developed for the present study encompasses three phases: intelligence, design, and choice. In the intelligence phase, data is collected, analyzed, as well as an inferential statical analysis is performed. This phase is concerned with framing the problem, followed by the goals to be pursued are investigated, and the grading criteria or qualities chosen. The design phase entails data gathering, sorting, and the formulation of multicriteria analysis through the linkage between the decision maker’s objectives and preferences, and precise decision procedures, which are employed in the assessment and classification of alternatives. The final phase comprises formal MCDM-GIS engagement to produce a set of spatial decision variants as a solution that incorporates decision analytical method and GIS functions. Alternatives are weighted and reviewed to make the best guidance [9]. A criterion has been decided for each application; photovoltaic (PV)-mounted systems, CSP systems, and wind farms.

The AHP method was applied to each application depending on the criteria by comparing pairs of criteria which is developed by Saaty as shown in Table 1, to weigh the criteria and evaluate the suitable sites [13]. For example, comparing solar resources with the slope for PV mounted systems, depending on the face-to-face interviews with experts; Mr. N. Abu Baker (Palestinian Energy Transmission Company Ltd, April 2021), Mr. Basel Yaseen (Palestinian Energy and Natural Resources), and Dr. A. Yasin and Dr. M. Al Sayed (An-Najah National University). The experts agreed that the slope of the land is essential or of strong importance compared to solar resources regarding the site selection process for the application, stating that the variance in solar radiation in the WB is not that much of a difference so the slope of the land takes the priority in choosing the suitable site, as explained all the other pairwise comparisons were done for each application. The pairwise comparisons were translated into a matrix to estimate the weight of each factor.

Table 1. Saaty`s scale in the pair-wise comparison process

Constraints	Source
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

2.1. Input data

GIS can be used for different applications geared to store, gather, dissect, and trace spatial data. GIS has two coverage representations: raster and vector. A raster is defined by a rectangular grid called pixels that holds particular data relevant to a relevant geographic area. Vectors contain geometric figures (polygons, lines, and points) that classify limitations in a reference system [14]. In this research data was processed in both ways depending on the data used and the final data were represented in Raster. The set of criteria and weights is based on experts' opinions and literature reviews that comply with national and international guidelines.

Freely available data from Geomolg [15] prepared by the Ministry of Local Governate, Palestinian Electricity Transmission Ltd (PETL) [16], Global Solar Atlas [17], and Global Wind Atlas [18] were used in this study. The data for PV, CSP, and Wind farms applications were prepared before getting the final output. First, the following layers have been excluded from the study area as none of these applications can be sited there, noting that all data have been projected using the Palestinian 1923 Grid coordinate system including Forests, Medium agricultural value lands, and High agricultural value lands, Natural Reserve, Colonies borders, Military base, Occupation Industrial areas, and Built-up areas.

2.2. Site selection

Generally, all the RE sites should be economically feasible and have no substantial impact on the surrounding environment. The set of criteria and weights based on experts' opinions and literature reviews that comply with national and international guidelines. Each RE application has its criteria described as follows:

2.2.1. Site selection criteria for solar photovoltaic-mounted systems

The siting of PV systems is vital to support decision-making to reduce the time, cost, and environmental impacts. There are no clearly defined guidelines for choosing the site for the systems. Based on literature reviews and experts' personal judgments, the key constraints that needed to be addressed when selecting sites for PV systems are shown in Table 2 [19]. Avoiding Israeli military areas and settlements is another important constraint that should be considered in the Palestinian case. The constraints mainly focused on solar resources, availability of lands for 0.5 MWp projects, the climate at the location, topography of the lands, grid connection proximity, availability and capacity, and finally water accessibility.

2.2.2. Site selection criteria for concentrated solar thermal power

The selected CSP systems sites must meet strict specifications. The key constraints that are needed in siting CSP system from mega scale projects are decided and set according to experts' opinions and related studies. These requirements can be split into five groups [19]–[24] described in Table 3, including the direct normal irradiance (DNI), land availability, the topography of locations, land accessibility, local climate, and grid availability. The key constraints that are needed to be addressed in siting CSP systems from 1 MWp in an open area of 25,000 m^2.

Table 2. Site selections constraints for solar photovoltaic-mounted systems

Constraints	Source
Solar resource	Global horizontal irradiance (GHI) with values varies from m 2.63 kW h/m^2/day in December up to 8.4 kW h/m^2/day in June.
Available area	Studies show that a 1 MWp plant requires between 10,000 to 20,000 m^2. In this study, the minimum area should be above 5,000 m^2 to be considered,
Local climate	Palestinian weather is acceptable but varies slightly between the locations in the WB depending on the elevation and the location which will increase the risk of damage or downtime in some sites in the WB.
Topography	South-facing lands are preferable for PV systems, followed by south-western and then south-eastern lands
Grid connection proximity, Availability and capacity	The proximity of the grid is important. The capacity of the grid should be far enough to absorb the power generated from the solar PV system.

Table 3. Site selections constraints for CSP systems

Constraints	Source
Solar radiation potential	The DNI potential is ranging from 1,900 to 2,100 kWh/m^2/y.
Land cover, use, and slope	The average surface area is around 25,000 m^2/MW. The slope should be varying from around 1-2% for linear focus and up to 3-4% for point focus technologies.
Water availability	Except for Dish-Stirling, all CSP methods for wet cooling systems require approximately 3 m^3 of water per megawatt-hour (MWh) generated. For dry cooling systems, all CSP technology except Dish-Stirling requires about 0.3 m^3 of deionized water for each MWh generated, whereas Dish-Stirling needs about 0.075 m^3 of deionized water for each MWh produced.
Transportation	The plant should be close to populated areas.
Power transmission lines	The spacing between the transmission lines and the power plant is desirable to be short.
Meteorological conditions	The solar field is designed to handle wind speeds from 120 to 130 km/h (33.3 to 36.1 m/s). The efficiency depends on ambient temperature, and changes in relative humidity levels affect the overall energy production of CSP plants.

2.2.3. Site selection criteria for wind farms

In general, the wind farm's location ought to be economically feasible and got no sizable influence on the nearby ecosystem in terms of optical and aural intrusion, electromagnetic disturbance, and potential wildlife collisions [8]. To have the best decision making in siting wind farms experts' opinions were taken taking into consideration different constraints. The following are the considered parameters for wind farms site selection relying on data availability and economic and environmental worth [4], [5], [25] which are detailed in Table 4.

Table 4. Site selections constraints for wind farms

Constraints	Source
Wind speed	Areas with a wind speed of 4.4 m/s (elevation 10 m) are suitable for wind farm investments. Areas with less than 4.4 m/s are not suitable for siting wind farms according to National Renewable Energy Laboratory (NREL) classification [25].
Distance from residential areas	It is preferable to consider areas away from urban areas for wind farms. According to the literature review, the suitable threshold sites distance from residential areas to neglect the visual impacts range from 500 to 2,500 [4], a 500 m buffer zone was obscured in this study.
Land use and land cover	It is preferable to have shorter vegetation over higher vegetation. In this study, we are considering all types of land since there is little variety in land cover across the West Bank, and the design of the wind turbines will consider the nature of the location with minimum costs and best efficiency.
Distance to roads	A 100 m buffer zone from roads was taken in this study for safety considerations [26] and to reduce visual disturbance and ensure electrical safety.
Proximity to gridlines	It is preferable to be placed close to the grid lines to reduce the initial cost of the project by reducing the construction cost of new grid lines [14].
Slope	The recommended value for slope ranges from 10% to 45% [27], [28]

2.3. Criteria decision making

As mentioned before MCDM and AHP have been undertaken in this study for each application. Because of the lack of planning policies and national guidelines in the West Bank for the development of Renewable energies, the criteria employed in this study rely on related research and Palestinian experts' opinions in the field of renewable energy in Palestine. A set of rules for the specified criteria has been applied to each application according to the literature and experts' opinions including a maximum slope of 15%, 4%, 20% for photovoltaic systems, CSP systems, and wind farms respectively, and south facing, south-west facing and south-east facing sites were given the highest values for photovoltaic systems and CSP systems as shown in Table 5.

Table 5. GIS used model for PV systems, CSP systems, and wind farms site selection

PV Systems		CSP Systems		Wind Farms	
Criteria	Condition	Criteria	Condition	Criteria	Condition
Solar resource	No limitation since there is a minor variation in the radiation in the study area	Solar resource	No limitation since there is a minor variation in the radiation in the study area	Wind speed	Values from 4 to 7.6 m/s were given the highest values at 10 m.
Slope	Up to 15%	Slope	Up to 4%	Slope	Up to 20%
Aspect	South-facing, south-west facing, and south-east facing sites were given the highest values	Aspect	South-facing, south-west facing, and south-east facing sites were given the highest values	Grid connection point proximity	Different scales were given up to 2,000 m
Grid connection point proximity	Different scales were given, up to 2,000 m	Grid connection point proximity	Different scales were given, up to 2,000 m	Road accessibility	Different scales were given up to 1,500 m
Road accessibility	Different scales were given, up to 1,500 m	Road accessibility	Different scales were given, up to 1,500 m		

2.4. Simulation

Enhancing the quality of the output results by using MCDM and GIS was one of the main objectives for this study. To ameliorate and obtain advanced results of the models and to make it easier for feasibility study, we calculated the energy potential of each suitable location for each application by using different equation for each RE application. Having the estimated annual production for each suitable land in each application makes it easier for decision makers to have a quick overview for the estimated projects costs.

To find the annual energy output potential for PV systems, we used (1):

$$EPV = GHI \times APV \times \eta PV \qquad (1)$$

where, GHI is the yearly average of daily global irradiation in kWh/m^2, the data were taken for the solar atlas as mentioned before. APV is the surface area of the PV modules in m^2, we assumed that 0.7 of the 1 m^2 of the area is for the PV surface area [29]. ηPV is the PV module efficiency, assumed 12%. All the energy losses involving wire losses, connection losses, and other losses were assumed to be zero, also the effect of temperature on the PV cells is ignored. Regarding CSP systems, to find the annual electricity generation, we used (2):

$$AEG_{CSP} = (365 \times 25) \times CF_{CSP} \times P_{CSP} \qquad (2)$$

where, PCSP represents the capacity of the CSP system, CF_{CSP} represents the capacity factor, which is assumed to be 0.36 [19]. Each CSP plant capacity in the project is 1 MW with about 25,000 m^2 of area.

For wind systems, the proportion of wind energy that a specific location can generate is proportional to the speed of wind at the specific location and can be found in (3) and (4) [30].

$$P_{in} = \frac{1}{2}\rho A v_m^3 \qquad (3)$$

$$Annual\ energy\ production = P_{in} \times C_p \times 8760 \qquad (4)$$

where, C_p is assumed to be 25%, ρ is the air density in kg/m^3=1.225, A is the swept area in m^2 of the rotor blades, and V_m is the average wind speed in m/s. The energy potential for the wind was calculated per m^2 of the swept area.

A matrix of each GIS model was filled according to Saaty's scale values based on different experts' opinions who are professional and enrolled in multiple energy-related jobs, then the weights were calculated using the AHP online system-AHP-OS, and adjusted based on experts' recommendations. The greater the weight, the more essential the relevant criterion. The weights are presented in Table 6.

Table 6. The three applications criteria weights

PV Systems		CSP Systems		Wind Farms	
Factor	Weight	Factor	Weight	Factor	Weight
Grid Connection Point Proximity	36%	Slope	60%	Wind speed	68%
Aspect	26%	Grid Connection Point Proximity	24%	Grid Connection Point Proximity	21%
Slope	22%	Road Accessibility	9%	Road Accessibility	7%
Solar Resource	9%	Solar Resource	7%	Slope	4%
Road Accessibility	7%				

3. RESULTS AND DISCUSSION

Weighted layers for each application resulted from applying the MCDM AHP in GIS. The excluded layer mentioned before were multiplied by the weighted layers to generate the overall suitability map. Two main scenarios were assumed: one including area C in the study area and the other excluding area C. Resulted maps and data for each application is as follows:

3.1. Solar PV mounted systems suitability maps

In this application, we were targeting empty lands with an area above 5,000 m^2, after excluding all the mentioned layers before and applying the weights in Table 6. This process was applied twice one while including area C in the study area, and the other excluding area C. The data were ranked on a scale of 1 to 4 considering 4 as the most suitable and 1 as the least suitable, each governorate was analyzed on its own for better-detailed results in locations, and the equations mentioned before were applied to calculate the potential for each area. As shown in Figure 1(a), the total high and moderately suitable areas for PV systems including area C is 444 km^2 with an approximate production of 76,825 GWh per year while excluding area C will result in a 90 km^2 with an approximate production of 15,632 GWh annually. The resulting data including area C shows that Qalqiliya has the lowest potential with only 13 km^2 available for good investments in PV systems, and Hebron has the highest potential with about 110 km^2 of available area for PV systems investments with an annual potential of 19,508 GWh, while resulted data for each governorate excluding area C shows that Tubas has the lowest potential for PV systems with only a 0.1 km^2 available for solar investments, and Hebron as the highest potential with about 33 km^2 and an annual potential of 5,851 GWh.

3.2. CSP systems suitability maps

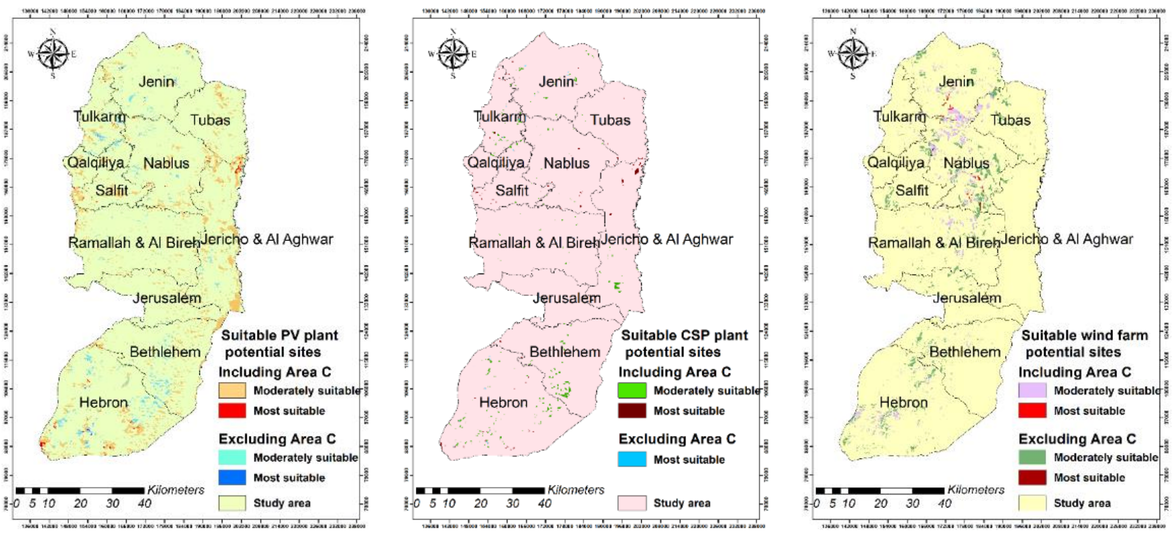
In this application, we are targeting empty lands with an area above 25,000 m^2, after excluding all the mentioned layers before and applying the weights in Table 6. This process was applied twice one while including area C in the study area, and the other excluding area C. The data were ranked on a scale of 1 to 4 considering 4 being the most suitable and 1 being the least suitable, each governorate was analyzed on its own for better-detailed resulted locations and the equations mentioned before were applied to calculate the potential for each area. The total high suitable available areas for CSP systems as shown in Figure 1(b) including area C is 13.63 km^2 with an approximate production of 1,719 GWh per year while excluding area C will result in a 2.81 km^2 of available area with an approximate production of 319 GWh annually. The data that was generated including area C illustrated that Jerusalem, Ramallah and Al-Bireh have zero potential for CSP systems investments, and Hebron has the highest potential with about 3.65 km^2 of available area for CSP systems investments with an annual potential of 460 GWh, with the exclusion of area C resulted from data demonstrate that Jerusalem, Ramallah and Al-Bireh, there is also Tubas, Salfit and Bethlehem have zero potential of CSP systems, and Hebron has the highest potential with about 1.26 km^2 and an annual potential of 159 GWh.

3.3. Wind farms suitability maps

For this application, we did not target specific areas of empty land, since the spacing area between each wind turbine differs from one type to another depending on many factors, we are not interested to discuss it in this study now. After excluding all the mentioned layers except the agricultural land classification before and applying the weights in Table 6. This process was applied twice one while including area C in the study area, and the other excluding area C. The data were ranked on a scale of 1 to 4 considering 4 as the most suitable and 1 as the least suitable, each governorate was analyzed on its own for better-detailed results in locations, and the equations mentioned before were applied to calculate the potential for each area. The total high and moderately suitable available areas for Wind systems are illustrated in Figure 1(c) including area C is 276 km^2 with an approximate production of 0.13 GWh/m^2 per year, the data shows that Jericho and Al-Aghwar have the lowest potential with only 2.43 km^2 available for good investments for wind systems, and Nablus as the highest potential with about 83.84 km^2 of available area for wind systems investments with an annual potential of 0.029 GWh/m^2. While excluding area C will result in

121 km^2 of total available area with an approximate production of 0.0719 GWh/m^2 annually. Jericho and Al-Aghwar have zero potential for wind systems investments and Nablus has the highest potential with about 43 km^2 and an annual potential of 0.0202 GWh/m^2.

Aside from analyzing the available areas and the potential energy production for each governorate, electricity company concession area, and municipalities including and excluding area C, an analysis was done to compare the annual potential production for each electricity company and municipality and the energy purchase per year using three scenarios 50%, 30%, and 10% of the estimated annual potential in GWh for PV systems and CSP systems. Demonstrating the Companies' energy purchases (GWh) vs. PV annual potential (GWh) for PV systems including area C can be noticed that the 10% scenario can cover the energy purchase for all of the governorates and more, which opens a lot of potential options and investments to reduce the energy bill in each governorate and electricity company while excluding area C affect the percentage coverage so the 30% scenario can cover the energy purchase for some of the governorates. Furthermore, comparing the companies' energy purchases (GWh) vs. CSP annual potential (GWh) for CSP systems including area C, it is easily noticeable that none of the scenarios can cover the energy purchase which also leads us to realize that excluding area C will dramatically decline the opportunities of investing in CSP systems. For further analysis, we located the highest-ranked lands according to the used scale with high potential and excluded area C from this analysis. For the PV system, the most suitable area in the West Bank is located in Tulkarem, in Ramin with an area of 0.28652 km^2 and a total annual output of 47.87 GWh. For CSP systems, the most suitable location is in Hebron, at As-Samu' village in the south with an area of 0.20658 km^2 and an overall production of 26.92 GWh per year. Lastly, for wind systems, the most suitable location is in Nablus, at Aqraba village with an area of 0.20658 km^2 and a total production of 0.00039 GWh/m^2 per year.



(a) (b) (c)

Figure 1. Suitable sites for (a) PV systems, (b) CSP systems, and (c) wind farms in the West Bank

4. CONCLUSION

The suitable sites are located in Hebron, Bethlehem, Jenin Nablus, and Tulkarem mainly, which is about 20% only from the area including area C. CSP systems potential sites have the highest available area according to the criteria applied potential is located in all of the governorates if we included area C except Jerusalem and Ramallah and Al-Bireh, and excluding area C will exclude Tubas, Salfit, and Tulkarem also with almost 21% only of the high suitability area with area C. Regarding Wind farms, at 10 m wind speeds, the highest potential sites including area C are located in Nablus, Hebron, and Jenin. But excluding area C will result in fully neglecting Jericho and Al-Aghwar from this investment, the available area is about 45% of the total area for the highest potential sites including area C.

The study area after removing all the restricted areas mentioned before equals 32% of the West Bank area, excluding area C will result in only 7% of the total area for PV and CSP systems investments, while 58% of the West Bank area for wind farms investments, and only 19% of the total area excluding area C. Suitable areas for PV systems investments with an area >5,000 m^2 cover 8% of the West Bank with area

C, and 2% of the West Bank area if we excluded area C. For CSP systems investments with an area >25,000 m^2 cover 0.24% of the West Bank area with area C, and 0.05% without area C included. While suitable areas for wind systems investments cover 5% of the West Bank area including area C in the calculations. Excluding area, C from the study area will lead to only 2% of the West Bank area available for Wind investments.

The availability of the missing data will improve the accuracy of the study. Many criteria were not considered in the current analysis. No site visits were conducted during this study due to coronavirus disease (COVID-19), the potential sites could be located using Google Earth. The usage of GIS-based MCDM for site selection was found to be very effective for classifying the suitability of the lands for each RE application. This study used the AHP method as it is easy to understand and modify for any future adjustments, and the results depend on the factors mentioned earlier in the study. The findings lead to the following conclusions: i) the suitable areas for the three applications are scattered in the governorates. Hebron is lucky to have the highest suitable locations for the two applications (PV, CSP) including and excluding area C, and Nablus is the highest for Wind systems including and excluding area C; ii) available areas for PV systems are scattered between the governorates, for CSP systems, Ramallah and Al-Bireh, and Jerusalem has zero available areas including area C, adding to that Tubas, Tulkarem, Salfit, and Jenin with zero available areas when we exclude area C; iii) small investing in these locations will achieve PENRA's goal for RE investments as mentioned before and will cover a good percentage of the annual electricity bills, and reduce the shortage of electricity.

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