

Figure 5. Classification of Aspect for the Nabatieh District.

Elevation

Elevation holds significance in the selection of photovoltaic (PV) sites, especially considering its relationship with cloudiness, particularly in mountainous areas. In elevated regions, the condensation of water vapor is higher, leading to the formation of cloud layers that can obstruct the sun's rays

[11]. Consequently, this results in reduced solar energy availability. Lower areas are generally better suited for solar energy production due to the reduced impact of cloud. The value has been classified in meters regarding the study area categories. We have different levels of elevation, and this criterion plays a big role in determining the final results (Error! Reference source not found.).

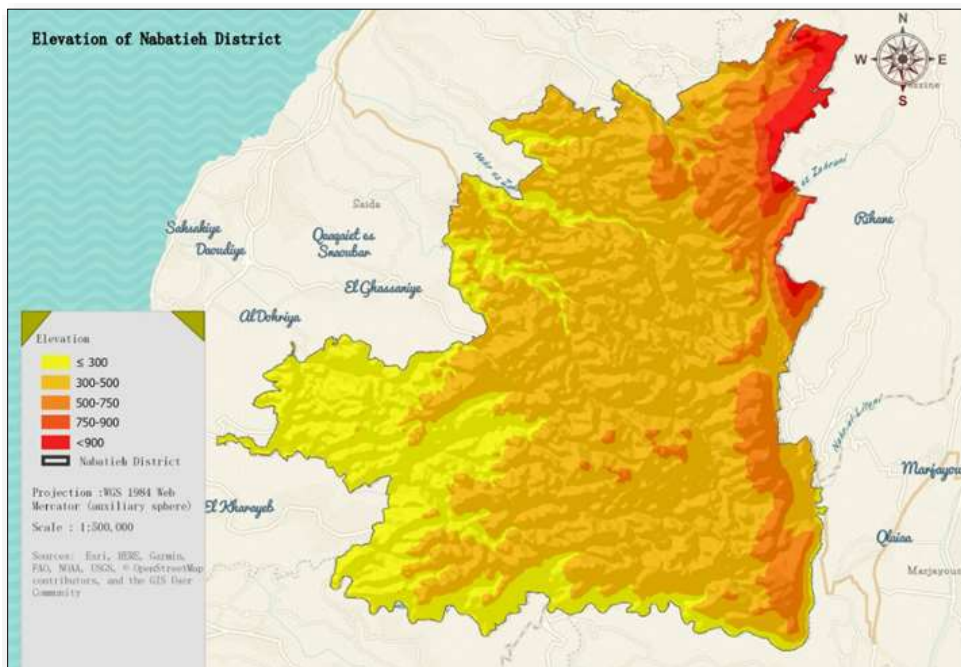


Figure 6. Elevation map of the Nabatieh District.

Slope

The classified values regarding the study area categories, influenced by different levels of elevation, play a significant role in determining the final results. The slope value classifications were determined due to the importance of this criterion and the study area location. In the context of photovoltaic (PV) installations, the slope, measured as the decline from a horizontal surface, plays a crucial role. A steep slope can impact construction costs, particularly when

adjusting the panel's direction toward the sun, leading to higher expenses for construction and maintenance on steeper slopes. Moreover, the optimal orientation and inclination of PV systems are influenced by the slope. The classification of slope values in degree was particularly crucial due to the significance of this criterion and the specific characteristics of the study area location. In cases where the slope is low, the orientation becomes less critical, making such areas more suitable for PV (Figure 7) [12].



Figure 7. Slope map of the Nabatieh District.

Soil

Soil types must be taken into consideration while installing PVs. This is in order to avoid erosion and its effects. When

there is permeability, it prevents flooding, while when there is non-permeability, it becomes heavy, which leads to the drifting of the soil. According to Colunga [13] this data has been processed accordingly (Figure 8).



Figure 8. Classification of Soil map of the Nabatieh District.

Soil type is also affecting the solar cells in that soil dust can make a seal and prevent solar radiation from completely reaching the cell. Therefore, in friable and unconsolidated soil material areas, PV will be under such a problem.

Roads network

The proximity of roads to photovoltaic (PV) sites is a significant factor to consider. The closer the site is to

existing roads, the less expensive and environmentally damaging it is to construct new roads for access. However, it is advisable to maintain a distance of not less than 50 meters from the road to prevent issues related on the arrival of solar irradiation to the panels, which can be caused by dust generated by passing vehicles (**Figure 9**).



Figure 9. Road Network of the Nabatieh District.

Land cover

In the context of land cover, a suitable area for photovoltaic installations should be free of natural obstructions such as forests, high buildings, water bodies, or any constructions

that could potentially block sunlight from reaching the panels. It is preferable to avoid proximity to human settlements to minimize the risk of shading. The maps are typically classified into three categories, which are **Figures 10-12**.



Figure 10. Classified Forest Map of the Nabatieh District.



Figure 11. Classified Bare Soil Map of the Nabatieh District.

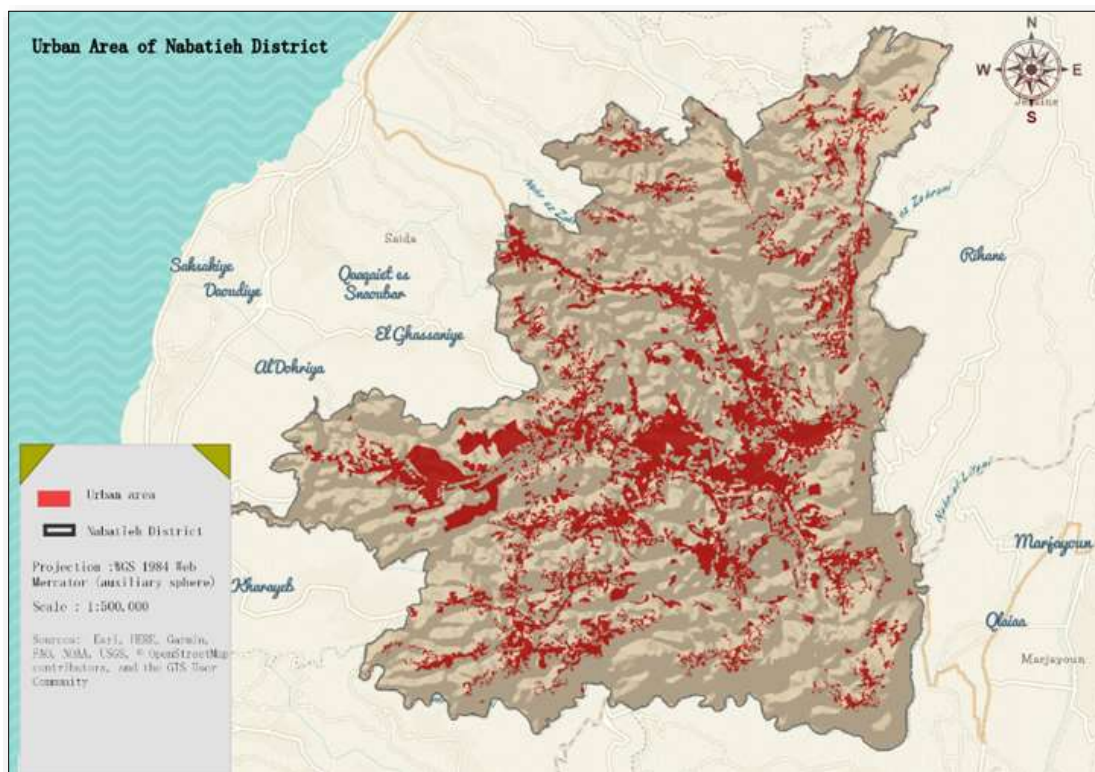


Figure 12. Classified Urban Area Map of the Nabatieh District.

Finally, faults were considered to let the PV away from it a distance to avoid the impact of the earthquake (Figure 13).



Figure 13. Faults Line Map of Nabatieh District.

In the final step, the tools under the CGES method were applied based on the sub-factor values to achieve the optimal location for solar power (OLSP) stations. The influencing factors mapped under CGES exhibit a diverse range of

classes, which are either represented by numerical values (e.g., slope and elevation) or in descriptive forms (e.g., soil type, aspect, etc.) (Table 2).

Table 2. Sub Factors Description for Solar PV siting.

Sub Factors	Description	Impact Level
Elevation	< 300 m	2
	300m-500m	4
	500m-750m	3
	750m-900m	2
	900m <	1
Slope	0°-10°	3
	10°-20°	2
	20° <	1
Aspect	Flat	10
	SE, E	7
	S	5
	SW	4
	W	3
	NW	2
	N	1
Soil Type	Permeability	3
	Semi-permeability	2
	Non-permeability	1
Land Cover Land Use	Urban	1
	forest	0
	Bare	10
Faults	>100 m	0
Distance of Human Settlement	50m<Distance <100m	1
Distance of Transportation	50m<Distance <100m	0

Using ArcGIS Pro 2.5, the classifications of each point are determined, establishing the main value for each sub-factor. Data management tools and overlay tools are employed to

overlay all the map layers. Subsequently, these layers are weighted and ranked based on their importance and their

respective effects on solar power (SP) to generate the final result map.

RESULT AND DISCUSSION

The results were obtained in two major phases in accordance with the method of the study and the eleven sub-factors mentioned (Error! Reference source not found.). The result

map, which was deduced from the CGES method, was prepared and classified into three classes based on manual interval classification, which works by defining the different classes that we have, manually adding class breaks, and setting class ranges that are appropriate for the data, which ranged from low, moderate, and high classes (Error! Reference source not found.).

Table 3. Manual Interval Classification for method result.

Range	Value
Low	4-12
Moderate	12-22
High	22-34

The result has been determined according to a two-phase process. First, the overall main result, which determines all the optimal locations for installing SP stations that consider low, moderate, and high classes; then, by making a visual analysis to determine the second step, which determines the final map of the study, which considers just the acceptable zones for the installation of SP stations. Considering the classes of moderate and high and the area of more than 50 hectares, to be able to generate electricity for a district or a city, we estimate that we need about 25 megawatts, which is an estimated area of 50 hectares according to tip [14] each 1 MW needs 2 hectares of area.

Through this analysis, it was determined that there are four clusters of ideal locations within this area suitable for establishing a solar power plant. are considered to install SP stations in the Nabatieh District.

The suitable zones for SP: In **Figure 14**, the shown result was categorized into four zones, each represented by a distinctive hatching in the colors Olive, Green, Orange, and Bronze they are determined due to the areas and the location of it.

- **Zone one (Green Hatches):** Which is located in the north of Nabatieh District, with an approximate area of 402 hectares. It is located between six municipalities: Masqat-el-Khreibe, Houmine El-Tahta, Sarba, Hmaila, Izze, Houmine-el-Faouka, Habbouche, and Bfarwee. In addition, these areas can be considered the primary beneficiaries of this zone. It turns out that the moderate class is more prevalent in this zone.

- **Zone two (Orange Hatches):** Which is located in the north of Nabatieh District, with an approximate area of 861 hectares. And it is located between eight Municipalities Houmine-el-Faouka, Mazraet El-Bayad, Deir El-Zehrani, Nmeriye, El-Charkiye, and El-Kfour. In addition, these areas can be considered as primary beneficiaries of this zone. It turns out that high class is more prevalent in this zone.
- **Zone three (Olive Hatches):** Which is located in the south East of Nabatieh District, with an approximate area of 312 hectares and it is the smallest zone in our result. And it is located between two Municipalities Kafr Tebnite and Arnoune. In addition, these areas can be considered the primary beneficiaries of this zone. It turns out that high class is more prevalent in this zone.
- **Zone four (Bronze Hatches):** Which is located in the South of Nabatieh District, with an approximate area of 1073 hectares which is the highest zone in our study. And it is located between eleven municipalities Jobchite, Choukine, Maifadoune, Kakiat-El Jisr, Zaoutar El-Gharbiye, Zaoutar El-Charkiye, El-Hamra, Yohmor, Zebdine, Harouf and Kafr Dajjal. In addition, these areas can be considered the primary beneficiaries of this zone. It turns out that high class is more prevalent in this zone.

If we present the area of each zone and the number of municipalities that they pass, the electricity that may be generated is enough to cover all these Municipalities, and may the surrounding Municipalities benefit from it (Error! Reference source not found.).

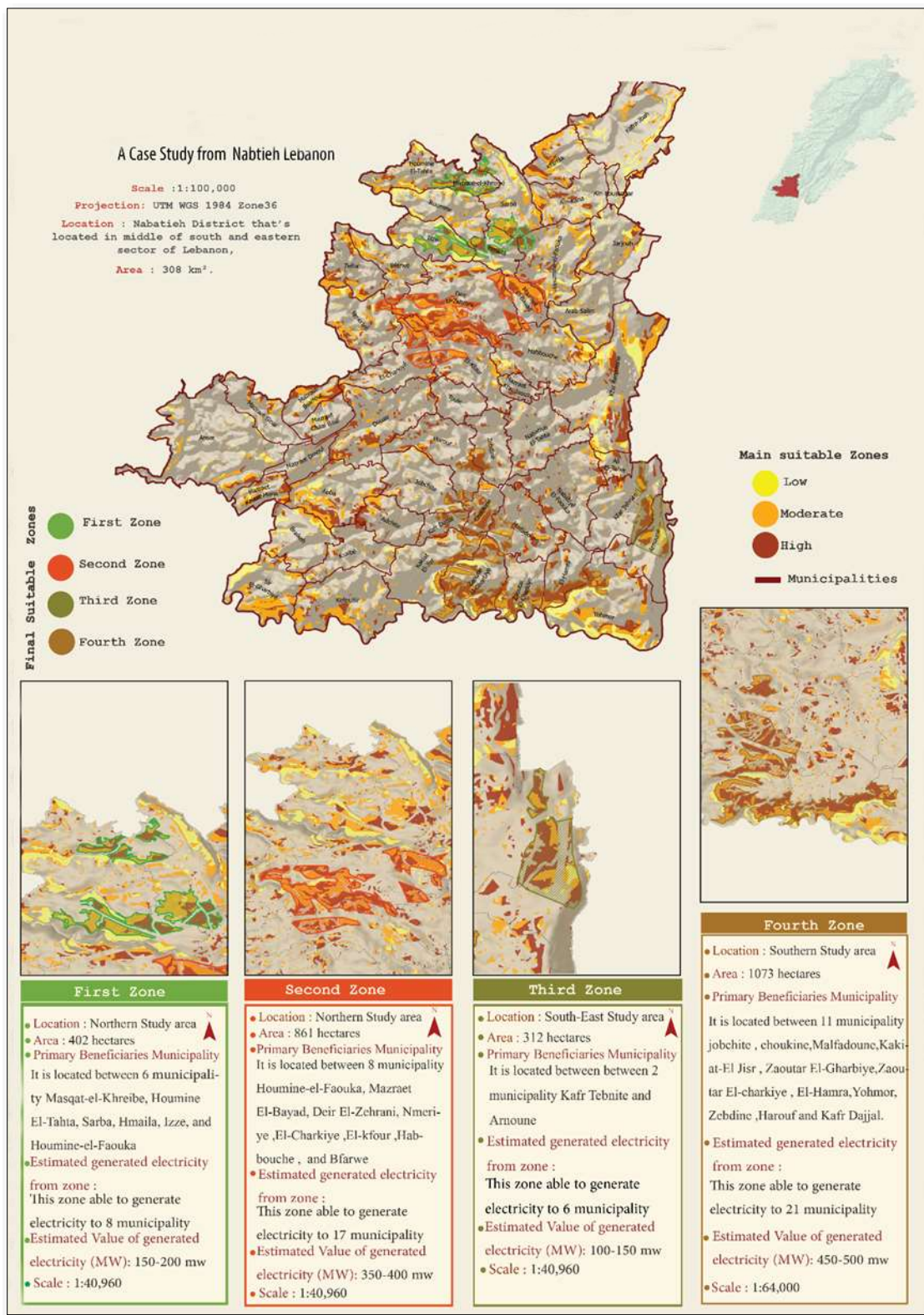


Figure 14. Final Result Map Suitable sites for PVs in the Nabatieh District.

Table 4. Estimation of electricity generated from each zone.

Zones	Number of Municipality Zone Included	Estimate Number of Municipality can Zone Generate	Estimated Value of generated electricity (MW)
1	6 Municipality	8 Municipality	150-200
2	8 Municipality	17 Municipality	350-400
3	2 Municipality	6 Municipality	100-150
4	11 Municipality	21 Municipality	450-500

The second phase of the result was determines presented as distributed zones where SPs can be built with small-scale solar power stations. These stations can be used in many

small projects that need electricity, like car recharging stations.

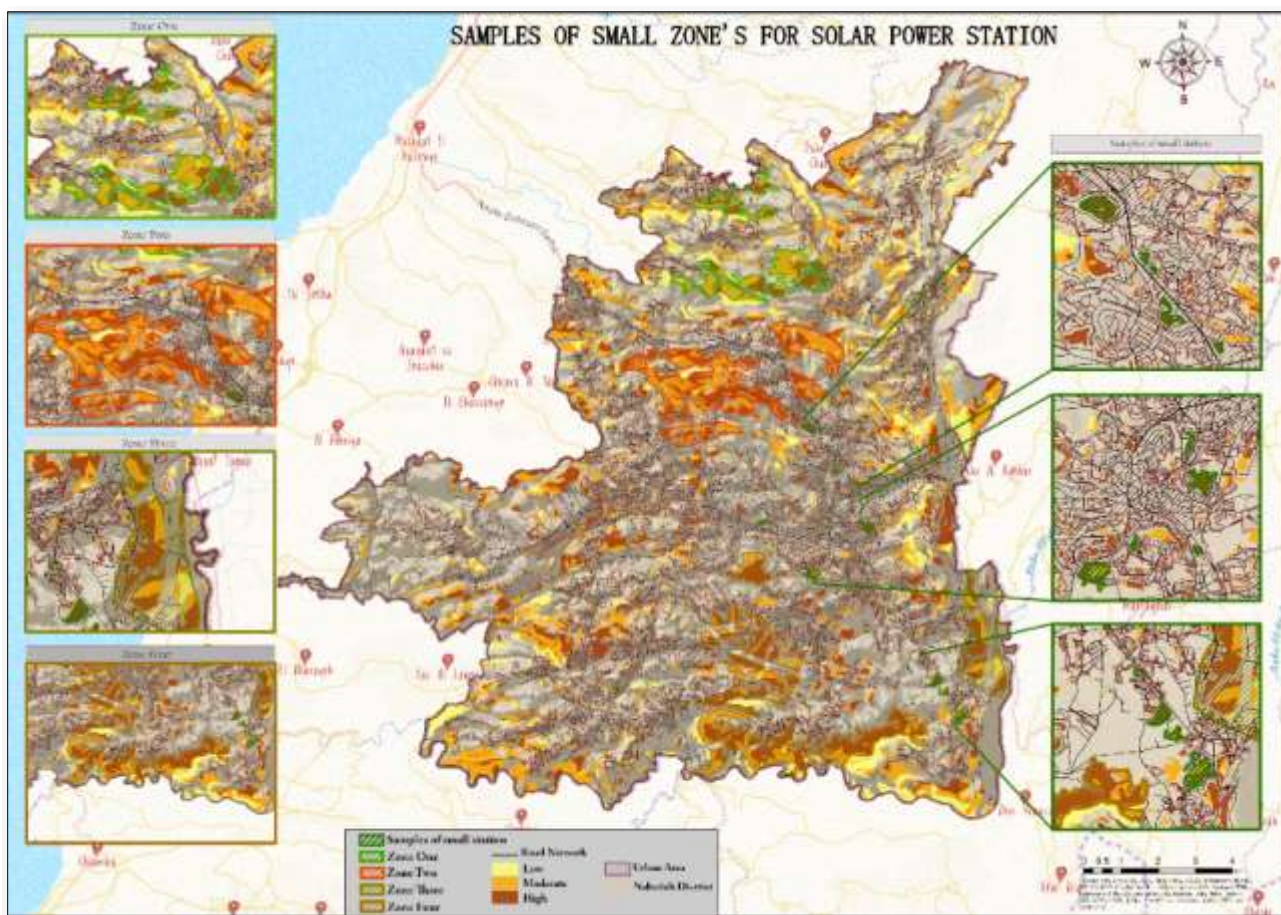


Figure 15. Small distributed Stations in Nabatieh District.

In Figure 15, the small zones depicted on the right side of the map, marked with green hatching, represent the suitable areas for the small stations in the study area. On the left side, the primary results of the study regarding the four main zones have also been arranged to visualize the location of all suitable areas.

CONCLUSION

The application of the CGES Method in determining the locations of solar power plants has proven to be a precise and effective method. Based on the analysis conducted, the study area demonstrated significant potential for the development of these technologies, considering various

criteria and sub-criteria factors. This study focused on selecting the most suitable zones for solar power plants using spatial analysis, geographic, and climate data in different layers. The examination revealed that the most influential factors affecting the results were cloudiness and elevation. In mountainous regions, clouds tend to accumulate at the peaks, resulting in an additional two hours of sunlight blockage compared to lower elevations during the summer. Additionally, in winter, it is possible for clouds to obscure the entire day. Therefore, it became evident that the higher the elevation, the weaker the production of solar panels, especially when situated at the feet of high mountains.

This approach will enable the mountain areas to contribute significantly to identifying the challenges faced by the solar power station projects and contributing to creating a healthier environment.

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