Determination of Suitable Sites for Solar Power Plants by Using Weighted Overlay Analysis: Sivrihisar Case

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Abstract- Turkey spends around 50 billion dollars for oil and natural gas import products each year to meet the increasing energy demand. In fact, Turkey has rich renewable energy resources. Recently, serious efforts have been made to increase the utilization of solar energy. The annual sunshine duration and annual solar energy potential of the country are respectively 2737 hours (7,2 hours/day) and 1527 kWh/m² (4,2 kWh/m²-day). Sivrihisar district of Eskişehir province, located in the central Anatolia, is also reported have remarkable potential for solar energy generation in terms of solar radiation, sunshine duration, topography and climatic conditions. There are currently 3 solar power plants in the region with a total generation capacity of 5MW. From this point, this study focuses on the determination of the suitable sites for the installation of solar power plants using weighted overlay analysis method via the utilization of geographical information systems (GIS). A variety of natural and cultural characteristics, such as solar energy potential, topography, transportation and infrastructure, fault lines, protected areas, bird migration routes etc. were included in the analysis. The weighted overlay results showed that 2,2% of the study area had 1st degree suitability, while 42,3% of Sivrihisar had 2nd degree suitable lands for solar power plant installation, according to the criteria adopted during the determination process. It was also concluded that 15%-efficient polycrystalline solar power plants, which would be installed on an area of 505000 m^2, could generate electricity of 79489181 kWh/year (7,95 GWh/year), which would totally meet the annual electric demand in the district. The methodology and the results are supposed to encourage and guide the further solar power plant installation plans within the study area, as well as providing a sample framework in the country focusing on the consideration of a wide range of factors.

Keywords Renewable energy, solar energy, solar power plant, geographical information systems, suitable land determination.

1. Introduction

Global energy demand is increasing due to the increase in population, needs and expectations to use energy for a high number of different activities and advancements in the technology [1-3]. According to the World Energy Outlook-2017 Report published by International Energy Agency (IEA), the global energy demand will have already increased by 30% by 2040, and renewable energy resources are estimated to become the least-cost source of new generation for many countries [4]. Today, most of the total energy generation and electricity production are provided from fossil fuels [5]. However, it is reported by a good number of scientific studies and researches that the amount of fossil fuel reserves, which meets most of the energy demand worldwide, is getting exploited [6] and actually should remain unexploited for the benefit of the globe and the mankind [7-12]. This is why the fossil fuel based energy production and utilization is reported to be responsible for 80% of carbon dioxide [13] and, therefore, the increase in the global warming and related disasters such as storms, droughts, wildfires and hunger [14, 15]. From this point, implementation of renewable energy resources, such as wind, solar, biomass, hydropower, geothermal, marine and hydrogen becomes inevitable [16-18], since they lower the negative environmental impacts resulting from the use of fossil fuels, decrease dependency on foreign resources, provide employment and local development opportunities [19]. As a result, the governments worldwide have increased their supports for the renewable energy systems [20] and most of the countries have started implementing renewable energy policies and investing on efficient and clean energy technologies [21]. Reference [22] highlights Denmark's investments of wind energy. Germany's innovative energy policies, as well as Portugal's energy generation from renewable resources in 2018 are the remarkable cases. With its estimated solar addition of 53GW, China was reported to be the biggest renewable energy investor in 2017, while Mexico, the United Arab Emirates and Egypt were amongst the eye-catching new countries in the same field [23].

Among the renewable energy resources, the share of solar energy is increasing. The net amount of solar energy reaching Earth's surface is 10^4 times higher than the fossil fuel and nuclear energy resources. Hence, only 0,003% of the annual radiation is remarked to be sufficient to meet the global electricity demand.

Solar energy is free, inexhaustible, clean and convertible into electricity, heat and fuel [24, 25]. The amortization period of the solar energy facilities is approximately 5-6 years; installation, operation and maintenance costs are considerably low and, therefore, solar energy is preferable in terms of financial issues as well as the environmental ones. Especially after the 1970s, the researches on the utilization of solar energy potential gained speed [26] and new technologies have been developed to harvest solar energy to increase the efficiency. Especially, photovoltaic systems have become widespread due to their availability and capability to produce electric energy [27]. Consequently, the share of solar energy used for energy generation continuously increases. Solar energy is currently used in a variety of activities such as cooling, cooking, heating of the greenhouses and swimming pools, agricultural product drying, transportation, communication and signalization [28]. However, some negativities of solar energy generation are also informed. Amongst those are the variable efficiency resulting from factors such as climate, time, geographical/topographical conditions and incident angle, necessity to have large surface areas to generate energy and difficulties in solar energy accumulation. The negative environmental effects such as hazardous material emissions, accidental chemical releases and albedo effects endangering the species and the landscape, threats on the ecosystems, water resources and land uses, visual impacts, work safety and hygiene problems etc. are also reported [29-31].

From this perspective, the design, planning and installation of solar energy facilities becomes a significant issue not only in terms solar energy potential/efficiency of the geographical context but also the natural and cultural characteristics of the land, so as to provide sustainability in all aspects. In fact, ignoring the natural characteristics during the installation of solar facilities would directly degrade its reputation of being clean and environmentally friendly. Therefore, it becomes critically important to adopt a holistic approach evaluating different criteria for the determination of suitable lands for solar energy facilities. Accordingly, a variety of studies are observed in the literature on the determination of suitable lands for solar energy facilities [32-36]. Some of these criteria adopted during the analyses for the determination of suitable sites for solar power plants (SPP) are as follows;

- *Solar energy potential:* The major factor affecting the efficiency of the SPPs is the solar energy potential. The amount of solar radiation in the region has a direct relation with the electricity generated by the SPPs. Consequently, it is of great significance to properly and accurately determine the solar energy potential of the geographical context, so that a feasible investment can be planned. Reference [37] expresses that the amount of solar radiation received by the photovoltaic panels is the most important factor for the determination of the electrical energy production capacity. Besides solar radiation temperature plays a significant role in the amount of power generated by photovoltaic panels [38].

- *Topography:* Slope rates of the topography which are higher than 20^0 increases the shading and installation costs for the SPPs. Therefore, for productive results the potential areas should preferably have less than 10^0 inclines. Besides, regions facing south aspects (135^0-225^0) are usually protected against the negative impacts of seasonal changes and have higher sunshine durations, and thus, are more suitable for SPP installations [39]. In this respect, Turkey's southern latitudes, are the most efficient in terms of solar energy potential. As it moves towards the research area (as it approaches the northern latitudes), the solar energy potential decreases.

- *Infrastructure and transportation:* The existence of necessary and proper infrastructures and transportation opportunities are important both to lower the installation costs and transmit the generated electricity into the system. According to Reference [40], distance to and quality of the existing electrical infrastructure and the preferred type of solar stations are critical issues. For example, photovoltaic stations are difficult to combine with the poor electrical infrastructure units.

- *Land use/cover:* Different land use types may have either restrictive or encouraging characteristics. Proximity to settlement areas, military zones and fault lines should be evaluated in accordance with the project strategies. Proximity to settlement areas are necessary in terms of efficiency and operation life of the SPPs, while they are expected to be distant from the military zones and fault lines in order to respectively avoid the mutual negative interactions resulting from the military activities and the earthquake risks. Agricultural areas and pastures should be avoided so that they can be reserved for related activities and are not exploited.

➢ *Natural resources:* Natural resources such as hydrological resources, protected areas, forests, habitats, migration routes etc. are amongst the other factors affecting the site selection for SPPs. Wild life and habitats should be protected from the negative impacts that SPPs may cause. However, SPPs are preferred to be at an accessible distance to water resources to facilitate maintenance and operation activities of the facilities.

Considering the situation in Turkey, the statistics show that the government spent $9x10^9$ USD for energy importation for the first three months in 2017, which is 39% higher than the same period in 2016. Turkey provides 70% of its energy from foreign sources [41]. This reveals the necessity to develop a national roadmap to use alternative and clean energy resources both to protect the environment and decrease the dependency on the foreign resources to meet the increasing energy demand in the country. Actually, Turkey is located in an advantageous geographical location in terms of potential renewable energy resources. Current total installed power of the facilities in the country, which generate electricity from renewable energy resources is 38907,9 MW. Table 1 summarizes the installed capacity in Turkey.

Table 1. Installed capacity (MW) of Turkey-2019 [42].

Type of Resource	Installed Capacity (MW) by 31st February 2019
Fuel+Oil+Naphtha+Diesel Fuel	294
Domestic coal	10403,50
Imported coal	879390
Natural gas+LNG	22437,80
Geothermal	1302,50
Hydropower (dam)	20567,50
Hydropower (river)	7783,70
Wind	6946,80
Solar	81,70
Thermic (unlicensed)	319,30
Wind (unlicensed)	63,10
Hydropower (unlicensed)	7,60
Solar (unlicensed)	5098,50

According to the calculator provided by General Directorate of Renewable Energy (GDRE), Ministry of Energy and Natural Resources of Turkey (http://www.yegm.gov.tr/MyCalculator/Default.aspx), the annual sunshine duration and annual solar energy potential of the country are respectively 2737 hours (7,2 hours/day) and 1527 kWh/m² (4,2 kWh/m²-day). Reference [43] notifies that Turkey has $380x10^9$ kWh/year solar energy potential, however the county could get a place within the installed capacity lists only in 2014.

To sum up, it is necessary to increase the investments amounts on renewable energy resources in Turkey, so that the dependency on foreign resources can be reduced and financial, social and environmental benefits are utilized. Within this point, a multi-criteria analysis method was performed to determine the suitable lands for SPP installation in Sivrihisar district, which is amongst the most proper regions in Eskişehir province in terms of current solar energy potential as well as existence of large and flat surfaces.

2. Materials and Methods

The main material of this study consists of the graphical data of Sivrihisar district. Academic findings and standards based on the literature and legislation review, as well as consultations with academics from different disciplines, have also been of great significance for the determination of the method, data layers, classification criteria and influence weights. The ArcMap software was used for the digitization and spatial analyses. The main data of the study are as follows;

➢ 1/25.000-scale Digital Elevation Model (DEM) of Sivrihisar was obtained from Alaska Satellite Facility (ASF) and used to perform slope, aspect and solar potential analyses.

➢ Energy transmission lines and energy power units' data were taken from Turkish Electricity Transmission Corporation (TEİAŞ).

➢ 1/25.000-scale Turkey Active Fault Map was obtained from General Directorate of Mineral Research and Exploration (MTA) and used as a base-map to digitize the fault lines within the study area.

➢ Data related to rivers, military zones, roads and railways were obtained in shape file format from Open Street Map, 2018.

➢ Bird migration route data were obtained from Birdmap website and digitized ((https://www.birdguides.com/sightings/birdmap/).

The method of the study is based on the weighted overlay analysis, which is commonly utilized during spatial multi-criteria decision making processes. Weighted overlay is quite a useful method when a number of inputs with differing units, ranges and influences on the output product are evaluated, as it facilitates analysis of all the varying layers in one common environment. Thus, the data groups, either primary or secondary, are weighted and overlaid in different suitability classes to produce a composite map showing the desirable lands for specific purposes [44].

Besides weighted overlay analysis, the following methods were also performed to produce some of the necessary data groups;

➢ *Digitization:* Some of the data such as fault lines, settlement areas, protection sites and bird migration routes were digitized from various base-maps.

➢ *Topographic analysis:* DEM data was cut in accordance with the borders of the study area and used to produce slope and aspect maps. DEM was also used to calculate the solar energy potential of the study area using Area Solar Radiation tool.

➢ *Buffer analysis:* Multiple Ring Buffer tool was utilized to produce multiple buffer areas around rivers, roads, railways, military zones, energy transmission lines and power distribution units in accordance with the criteria given in Table 2.

For the weighted overlay process, 5 main and 12 sub-data groups, 4 different suitability classes ranging from "restricted" to "3rd degree suitable", where the latter refers to the avoidable lands unless there is a necessity, and influence weights were determined, regarding the results of the literature review, related legislation and the consultations with a group of academics. All the data were converted into raster format with a grid size of 12,5 meters for each layer of data. After all data layers were classified with respect to the criteria determined, all the classes were then assigned a suitability point and reclassified into their suitability classes. Table 2 summarizes the weighted overlay data groups, suitability classes and influence weights.

Table 2. Weighted overlay data groups, suitability classes and influence weights.

Data Groups		**Criteria/Attributes**	**Points**	**Suitability Class**	**Influence Weight**	
SOLAR ENERGY POTENTIAL (kWh/m^2)		<1300	1	3rd degree suitable	0,22	
		1300-1400	2	2nd degree suitable		
		>1400	3	1st degree suitable		
TOPOGRAPHY	***Slope (Degree)***	0-5	3	1st degree suitable	0,40	0,22
		5-10	2	2nd degree suitable		
		10-20	1	3rd degree suitable		
		>20	0	Restricted		
	Aspect	135°-225°	3	1st degree suitable	0,60	
		Others	0	Restricted		
INFRASTRUCTURE AND TRANSPORTATION	***Proximity to energy lines (meter)***	<3000	3	1st degree suitable	0,35	0,20
		3000-5000	2	2nd degree suitable		
		5000-10000	1	3rd degree suitable		
		>10000	0	Restricted		
	Proximity to energy power units (meter)	<3000	3	1st degree suitable	0,25	
		3000-5000	2	2nd degree suitable		
		5000-10000	1	3rd degree suitable		
		>10000	0	Restricted		
	Proximity to roads (meter)	<1000	3	1st degree suitable	0,25	
		1000-3000	2	2nd degree suitable		
		3000-5000	1	3rd degree suitable		
		>5000	0	Restricted		
	Proximity to railways (meter)	<1000	3	1st degree suitable	0,15	
		1000-3000	2	2nd degree suitable		
		>3000	1	3rd degree suitable		
LAND USE	***Proximity to settlement areas (meter)***	<1000	0	Restricted	0,40	0,18
		1000-2000	1	3rd degree suitable		
		2000-5000	2	2nd degree suitable		
		>5000	3	1st degree suitable		
	Proximity to fault lines (meter)	0-1500	0	Restricted	0,30	
		1500-3000	1	3rd degree suitable		
		3000-4500	2	2nd degree suitable		
		>4500	3	1st degree suitable		
	Proximity to military zones (meter)	<3000	0	Restricted	0,30	
		>3000	3	1st degree suitable		
URA L RES	***Proximity to rivers (meter)***	<500	3	1st degree suitable	0,30	0,18
		500-2000	2	2nd degree suitable		

		2000-4500	1	3rd degree suitable		
		>4500	0	Restricted		
	Proximity to protection sites (meter)	<500	0	Restricted	0,35	
		>500	3	1st degree suitable		
	Proximity to bird migration routes (meter)	<500	0	Restricted	0,35	
		>500	3	1st degree suitable		

As a part of the weighted overlay method, each sub-data layers were overlaid in the first place to produce primary suitability maps followed by the weighted overlay of the primary suitability maps to obtain the final suitability map of the study area.

3. Study Area

The study area is the Sivrihisar district, which is located on the south of Eskişehir province, Turkey, between the geographic coordinates of 3901’59”-39044’51” northern latitudes and 31010’21”-31057’55” eastern longitudes, comprising an area of 2987 km^2 and 78 neighborhoods. The population of the district is 20.886 according to the 2016 official records of Turkish Statistical Institute (TUIK). However, the population in 2000 was recorded 31583, which underlines the existence of an emigration tendency among the inhabitants. Figure 1 illustrates the location of the study area.

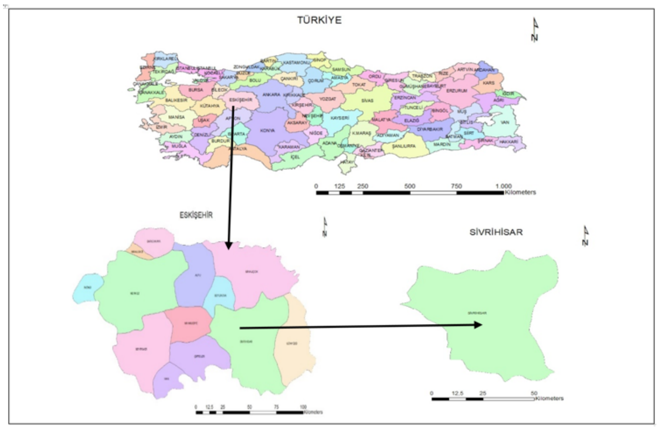

Fig. 1. Location of Sivrihisar.

Topography of Sivrihisar is mostly flat or slightly sloped, still there are mountainous regions in the central and northern parts with the highest elevation of 1700 m from the sea level. Thus, a maximum of 55^0 slope rate is reached especially on the hilly lands. The south aspects between the range of 135° – 225° comprise the 26% of the area. Figure 2 illustrates the slope map and Fig. 3 gives the aspect map of the study area.

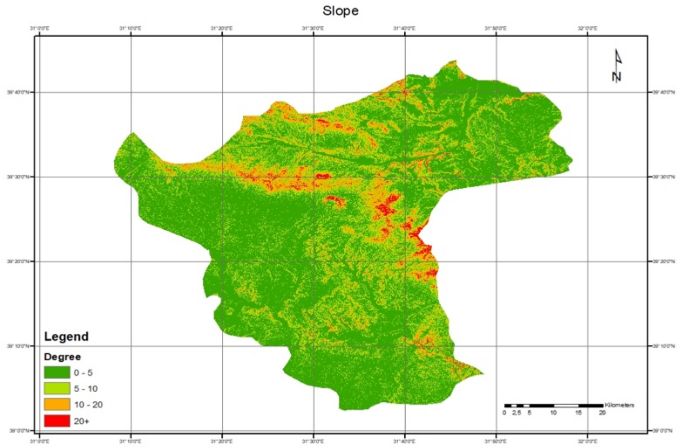

Fig. 2. Slope map of Sivrihisar.

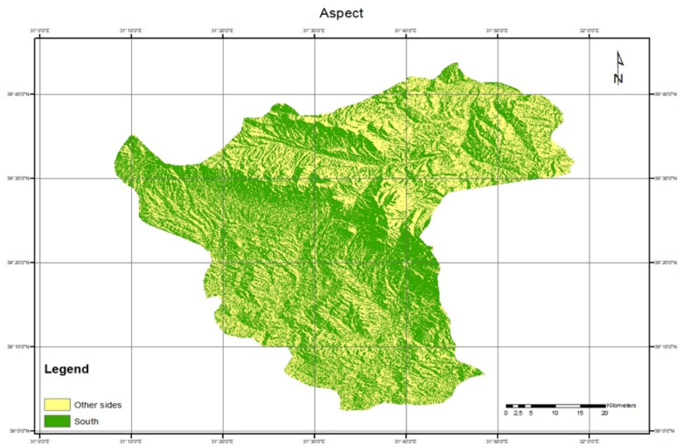

Fig. 3. Aspect map of Sivrihisar.

The study area reserves a significant wetland made up of a number of small ponds and marshes, namely Balıkdamı Wetland, which is one of the largest in Turkey and spreads over an area of 30.000 m^2, on the southern part of the district. Balıkdamı Wetland is a significant bird conservation area [45] and was declared as a wild life protection site in 1994 by the Ministry of Culture and Tourism, since it hosts significant habitats for various plant, fish and bird species. Besides Balıkdamı Wetland, Sakarya and Porsuk rivers, as well as other small streams, are the major hydrological resources of the study area. Sakarya River flows through the southern territories, while Porsuk River is on the northern part of the region. There is an active fault in the area, which lies between Kaymaz and Paşakadın neighborhoods. Figure 4 shows the land use map of the study area.

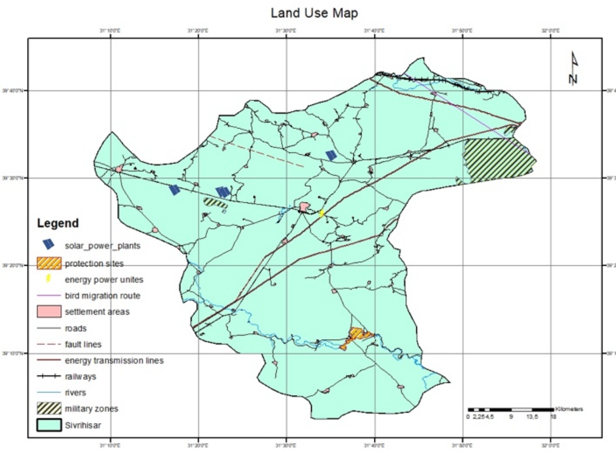

Fig. 4. Land use map.

When compared to the other 12 districts of Eskişehir, Sivrihisar is amongst the ones with considerably higher solar energy potential according to the Solar Energy Potential Atlas (GEPA) produced by GDRE, Ministry of Energy and Natural Resources. This fact, along with the study area's mostly flat topography and large surface area, have been the major characteristics for selecting Sivrihisar as the study area to investigate the suitable lands for the establishment of SPPs. Reference [39] also explain that both in terms of topography and annual sunshine duration value, which is greater than 2500 hour/year, Sivrihisar and Günyüzü are the two districts in Eskişehir suitable for SPP installation. Figure 5 shows the global radiation value of the study area.

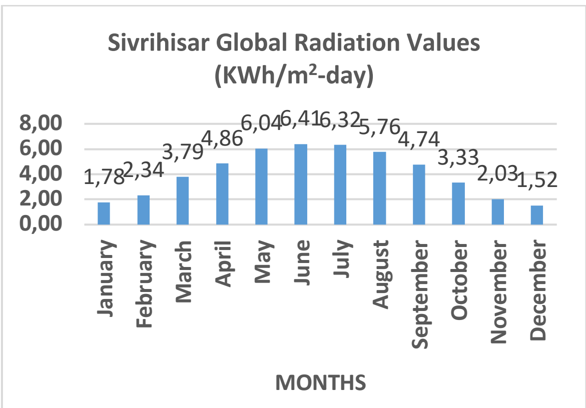

Fig. 5. Global radiation values of Sivrihisar [46].

4. Results

The results were obtained in two major phases in accordance with the method of the study and the information given in Table 2. During the first phase, the primary suitability maps of the study area were produced in terms of solar energy potential, topography, infrastructure and transportation, land use and natural resources. Table 3 summarizes the results for each primary suitability map.

Table 3. Results for primary suitability maps.

Suitability Map	Suitability Class	Covered Area	
		%	km²
Solar Energy Potential	1st Degree	11,311	337,86
	2nd Degree	88,634	2647,50
	3rd Degree	0,055	1,65
	Restricted	-	-
Topography	1st Degree	24,520	732,40
	2nd Degree	20,017	597,91
	3rd Degree	13,566	405,23
	Restricted	41,897	1251,46
Infrastructure and Transportation	1st Degree	1,793	53,575
	2nd Degree	39,172	1170,073
	3rd Degree	59,034	1763,352
	Restricted	-	-
Land Use	1st Degree	82,10	2452,13
	2nd Degree	5,75	171,76
	3rd Degree	-	-
	Restricted	12,15	363,11
Natural Resources	1st Degree	10,327	308,47
	2nd Degree	86,115	2572,25
	3rd Degree	-	-
	Restricted	3,558	106,27

According to the primary suitability maps, 1st degree suitable lands in the solar energy potential map, which have a potential of 1500 kWh/m², are mostly located on the central and northwest territories, while 2nd degree suitable lands (1300-1400 kWh/m²) make the most of the study area. Topography suitability map, which was developed after the weighted overlay of the slope and aspect suitability maps, presents that 24% of the total study area is 1st degree suitable for the installation of SPPs.

In terms of infrastructure and transportation, the suitability map shows that 59% of Sivrihisar's lands have a suitability of 3rd degree, followed with 39% 2nd degree and 1,7% 1st degree suitability for the installation of SPPs. The land use suitability map reveals that 82% of the study area is made up of 1st degree suitable lands while the rest is 2nd degree suitable areas for SPP installation.

The last primary suitability map is the natural resources suitability map. Natural resources are of significance both for sustainability and protection of the environment and the efficient sustainable use of SPPs.

According to the natural resources suitability map, 10% of the study area is 1st degree suitable for SPP installation.

Figures 6 illustrates the primary suitability maps of Sivrihisar.

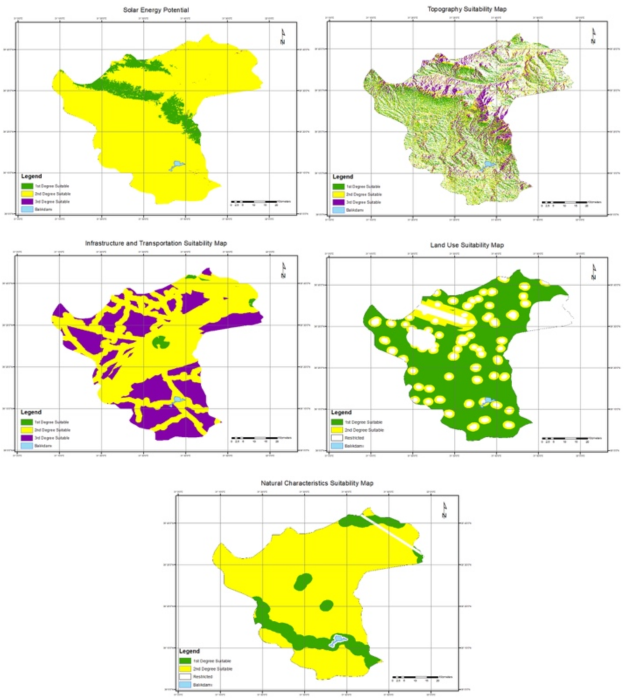

Fig. 6. Primary suitability maps.

During the second phase, all the primary suitability maps were weighted overlaid according to the criteria given in Table 2 to produce the final suitability map, which included the evaluation of a different range of factors affecting social, economic and natural sustainability. According to the primary suitability map, 2,2% of the total study area (65,7 km^2), which are mostly spread on the central parts, as well as the south-western and northern territories of Sivrihisar district, is 1st degree suitable for the installation of SPPs. The rate of the 2nd degree suitable lands is 42,3% (1263,5 km^2). The ratio of the 3rd degree suitable areas is nearly ignorable, while the restricted lands cover the 55,4% of Sivrihisar. The final suitability map is illustrated in Fig. 7. Table 4 summarizes the results for final suitability map.

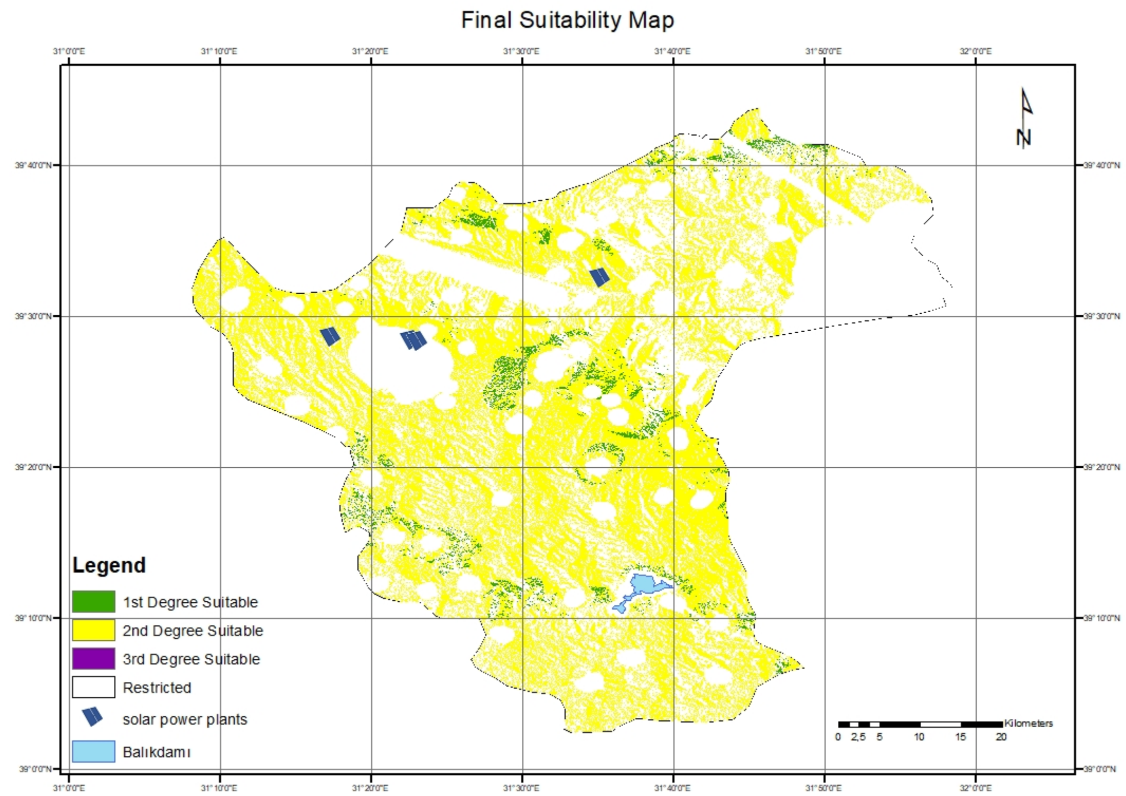

Fig. 7. Final suitability map.

Table 4. Results for final suitability map.

Suitability Map	Suitability Class	Covered Area	
		%	km^2
Final Suitability Map	1st Degree	2,2	65,714
	2nd Degree	42,3	1263,501
	3rd Degree	0,1	2,987
	Restricted	55,4	1654,798

Figure 7 shows that one of the installed SPPs is within the restricted zone, due to its proximity to the military zone. Besides, 1st degree suitable areas are mostly scattered around the settlement areas and the hydrological features (rivers and Balıkdamı).

5. Conclusions

Turkey's energy need continuously increases. The use of fossil fuels as the primary source of energy has negative impacts both on the environment and the country's economy, since most of the resources are imported. Therefore, alternative energy resources, mostly the solar energy, have lately become one of the most significant issues not only for Turkey's energy agenda but also the World's. From this point, this study was aimed at the determination of the suitable lands for SPP installation within our study area, Sivrihisar district, Eskişehir, Turkey, with an approach adopting the evaluation of a wide range of different criteria (solar energy potential, topography, infrastructure, transportation, fault lines, natural resources, land use etc.) rather than just focusing on the solar potential of the geographical context, so that sustainability both for the natural, cultural and social resources, and the SPPs themselves is provided.

Though there are some other studies presenting different calculation methods and results, the results obtained in this study revealed that the average annual solar energy potential of Sivrihisar is 1400 kWh/m^2. The final suitability map produced in this study presents that according to the weighted overlay criteria and the influence weights, 42,3% of the total area reserves 2nd degree suitable lands for the installation of SPPs. The 1st degree suitable lands comprise 90,2 km^2, which is approximately 2,2% of the total study area. Currently, there are 3 installed SPPs in the district, two of them with 2 MW and one of them with 1 MW energy generation capacity. However, 1 of the existing SPPs in the study is located in the restricted area (Fig. 7), as it is within the buffer area of the military zone. Nevertheless, it is significant to make further investigations and cost-benefit analysis prior to decision-making to compare all variations. In this case, legal restrictions and apprehensions of military authorities are vital inputs for the determination of restricted zone limits surrounding military facilities.

According to the data at the Ministry of Energy and Natural Resources, the annual average electric consumption per person is 3800 kWh/year. Considering the population of the study area, which is 20886, the average electric consumption in the district can be estimated approximately as 79366800 kWh/year. In case the annual average solar energy potential of Sivrihisar is accepted 1400 kWh/year, and losses in efficiency resulting from various factors such as cable transmission (3%), energy conversion (7%), shading (3%) and dust (2%) are deducted, the generation capacity of a 15%-efficient polycrystalline SPP on an area of 505000 m^2 can be calculated as 79489181 kWh/year, which would meet the total energy demand in the district.

These results reveal that, although central Anatolia is not the luckiest region in the country in terms of solar energy potential compared to the southern territories, still, the potential in the study area is even higher than most of the European countries that have adopted environmental friendly national energy policies and long been investing on and benefiting from the research, development and installation of solar energy facilities to generate their own energy. For example, Germany has an average annual solar energy potential of 900 kWh/m^2, and is amongst the leading countries in the field of SPP installation and solar energy utilization. Therefore, ignorance of such advantageous potential and resources would be quite harmful for the future of the environment and the country.

In this study, it was particularly highlighted that the determination of suitable lands for any specific purposes should be realized through a holistic approach, which helps consider a range of different factors and perspectives. No doubt, GIS is amongst the unique tools today to facilitate the multi criteria decision-making processes. Therefore, the focus of determination in this study was not only the solar energy potential of the region, but necessary other factors as well, which are believed to affect the environment, social resources, economic sustainability and efficiency of the SPPs. Nevertheless, it is not possible to claim that the criteria covered in this study are sufficient to make the optimum decision. Reference [47] remarks that common criteria and meaningful weights are often difficult to define. However, information related to land use capability classes, agricultural lands, forests, land cover, erosion, meadows, lithology, disaster risk zones, ownership, protection sites, development plans, land costs, population, human labor etc. should be included in the determination process (weighted overlay in this case) to obtain more accurate and precise results. Especially, irrigated agricultural lands should be protected and only reserved for agricultural activities to sustain the productivity in the region. Besides the variety of the data, other study steps might be performed differently. For example, the assignment of the suitability classes and the influence weights may also differ depending on the local characteristics of the project area, local/regional/national strategies, priorities, legislation and policies. Another example can be given regarding the topographic characteristics of the lands. The results of a research by [48] presented a model for the utilization of digital elevation models and indicated that in case ground level receivers were used, higher elevations would increase the efficiency. However, hillside heliostat fields did not require flat lands. Therefore, the analysis frameworks should also be planned in accordance with the advancements in solar technologies and site selection methodologies. Reference [40] focuses on the quality of the electrical infrastructure, the grid capacity and the necessity to use higher spatial resolution to better determine the solar radiation.

Consequently, this study highlights the importance of the utilization of advanced technologies, especially GIS, for the determination of proper locations for SPP installation and adoption of a holistic approach to provide sustainability in all ways.

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