SITE SELECTION OF SOLAR POWER PLANT BY USING OPEN SOURCE GIS FOR ESKİSEHİR PROVINCE-TURKEY

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ABSTRACT: Sun, which has the largest energy in the renewable energy sources. Solar energy which was not popular in the past, gained importance nowadays due to population growth, increasing importance of energy requirements and development of technology. Solar energy resources are also addressed in the most harmless effect when environmental impacts are taking into account. The most advantages of using solar energy compared to other types of energy are having inexhaustible source of energy, having clean energy, the lack of sophisticated technology, the lack of external dependency, to the low operating costs and can be considered to be suitable for local applications. In addition to these benefits, it has some disadvantages. It is known that sunlight is not continuous, so it requires storage facility. Solar power plant needs large spaces for installation and high initial installation costs. Electric production amount changes in winter-summer, even day and night. Considering all these cases, it's seen that site selection of Solar Power Plant is an important phase. The sun is an inexhaustible source of energy, but it does not come to a constant value everywhere. In this case, certain conditions must be provided for the installation of solar power plant. Solar Energy Potential Atlas gives a certain idea for places according to solar plant installation in Turkey. This atlas use the values based on the solar radiation and sunshine duration. The more realistic and detailed studies for the site determination slope of the land, land properties, geology and soil conditions, adjacency to the electricity distribution network is required. Geographic Information Systems (GIS) should be used for this type of spatial analysis. In this study, the Open Source GIS software QGIS is used for potential power plant installation site for the districts in the Eskisehir province. The most suitable district for solar power plant site has been determined. The most suitable location in this district were selected by considering the land properties and electricity network distribution of the region.

1. INTRODUCTION

Sun, which has the largest energy in the renewable energy sources. Solar energy which was not popular in the past, gained importance nowadays due to population growth, increasing importance of energy requirements and development of technology. Solar energy resources are also addressed in the most harmless effect when environmental impacts are taking into account.

The energy which comes from the sun to the Earth for each year, is equal to the 160 times of the determined fossil fuel reserves on the earth (AÖF, 2013). It is clean and inexhaustible source of energy. Foreign dependence will decline if its technology is learned.

Besides being so much of the return, installation of Solar Power Plant and to determine the location of the plant will be installed is the most important part of the work on this issue. Due to the high investment cost of the Solar Power Plant, site selection phase is very important. Solar Energy Potential Atlas for Turkey gives some specific idea about appropriate installation site. But this map is a general map prepared all across Turkey. Using this map will not sufficient for this kind of expensive Solar Power Plant investment. GES considered as an expensive investment will be sufficient to use the map. Many variables are effective for the site selection of Solar Power Plant (Effat, H.A., 2013). It is necessary to determine these variables, reveal the relationship with each other and make interpretation about favorable site. Most of the variables is composed of spatial data. It is necessary to use Geographic Information Systems (GIS) for the interpretation of these variables (Khan, G., Rathi, S., 2014). Open Source GIS software were chosen in this study. The main reason is the lack of software usage fees and it provides great opportunities for the users.

Open Source GIS software were used where appropriate Solar Power Plant installation site is found into the district borders of Eskisehir during analyzing. The interested area was descended from all cities of Turkey to only Eskisehir. Then favorable districts of Eskisehir were determined for the most appropriate installation site for the Solar Power Plant. Favorable installation sites of the districts were identified according to terrain analysis, proximity to electricity distribution network and residential areas. At the end of the study, it is understood that Solar Energy Potential Atlas

(GEPA, 2015) for Turkey is not enough for the determination of site selection and in addition to that, more detailed studies should be made. When the importance of spatial data is known in this study, it is understood that the accuracy of the work done will increase and favorable site selection phase time for Solar Power Plant will be reduced by the GIS.

2. GEOGRAPHIC LOCATION OF THE STUDIED REGION

The area in the border of Eskisehir province have been selected as the studied area (Figure 1). Eskisehir province consists of 14 districts. Eskisehir has an area of 13.925 km^2 and 830.000 people live within the borders of the province according to the census 2015 (Wikipedia, 2016).

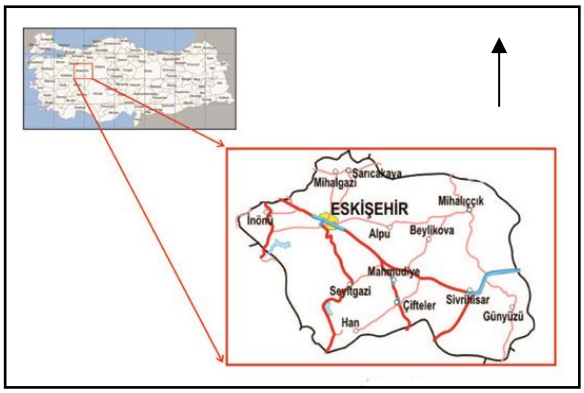

Figure 1. Geographic location of the studied area.

Primarily 14 districts in the province where take into account for suitable terrain. Selection of the appropriate district is made. In the second stage, suitable areas have been identified in accordance with district boundaries.

3. METHODOLOGY

Open Source software is used in this study. The main feature of this kind of software is no license fee. The software codes are open to everyone and the desired changes can be made. The software can be downloaded from the Internet and installation can be done easily. QGIS and GRASS software are used for this study (QGIS, 2016). Three different data types are used in finding suitable locations for solar power plant mentioned in the study. These data types are;

a. The terrain parameters of the area,
b. Solar duration parameter of the area,
c. Proximity analysis of the interested objects,

GIS methodology is used to create a different type of data and to interpret them. Digital Terrain Modelling (DEM) was used for obtain terrain parameters like slope and aspect. Grid Analysis was used to determine the appropriate meteorological conditions around the study area. The proximity to residential areas, to power lines, to roads of the suitable site areas has also been analyzed by using GIS.

4. SITE SELECTION FOR THE SOLAR POWER PLANT

4.1. Suitable Areas according to Terrain

Topography is a major factor determining the amount of solar energy at a location on the Earth's surface (Dubayah and Rich, 1995). Slope and aspect maps of the Eskisehir Province which have 90x90 m resolution were obtained from the Shuttle Radar Topography Mission (SRTM) satellite data (Figure 2). Raster Terrain Analysis was used for obtaining terrain parameters like slope and aspect for the province (Figure 3, 4). Regular grid data structure is used in this study. New raster layers were obtained from the calculation of existing raster pixel values. Solar power plants require as flat as possible area of land (Eurus Energy, 2012). The $\leq 10^0$ pixel values were obtained and these places were defined as suitable map of the province according to slope condition (Figure 5). It's known that, this situation is convenient for site selection. The same methodology were applied for the aspect of the terrain. The aspect values between 135^0-225^0 correspond to the south looking terrain surface (Figure 6). This situation is obtained from the aspect map and defined as suitable site for the solar power plant for the Eskisehir province.

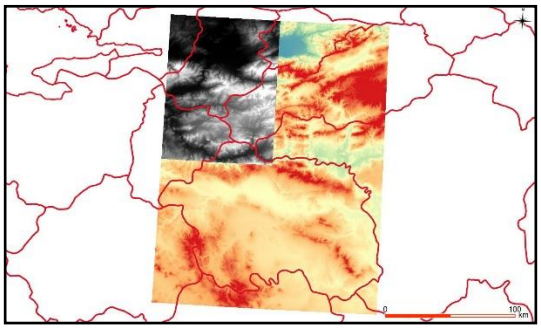

Figure 2. SRTM satellite images of the Eskisehir Province.

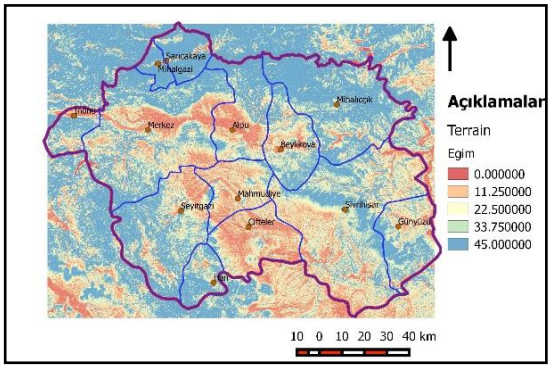

Figure 3. Slope map of the Eskisehir province.

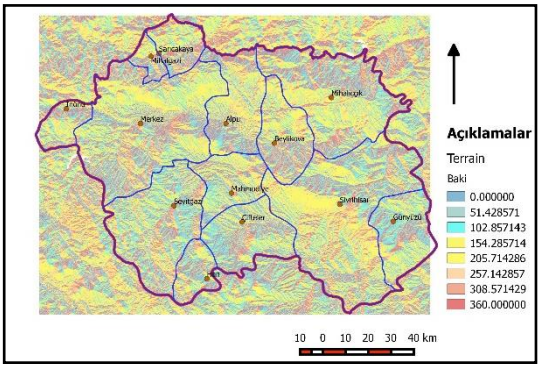

Figure 4. Aspect map of the Eskisehir province.

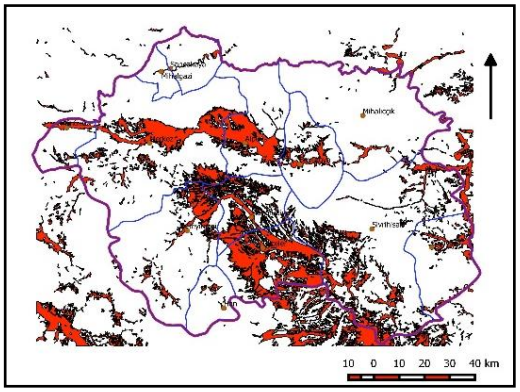

Figure 5 Suitable areas according to slope ($\leq 10^0$)

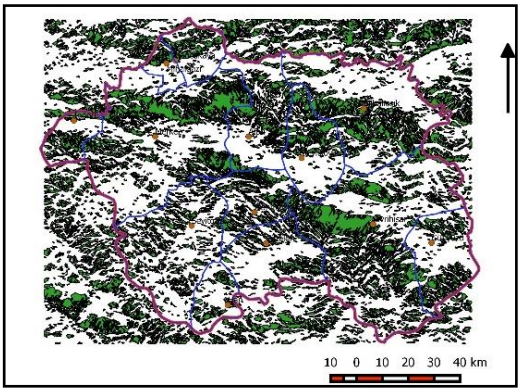

Figure 6 Suitable areas according to aspect (bearing between 135^0-225^0)

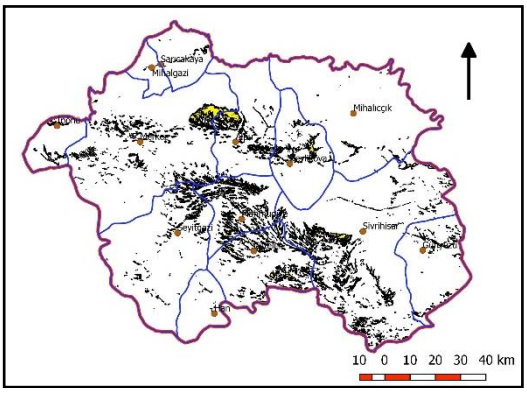

Figure 7 Results of suitable slope and aspect areas for the solar power plant installation.

4.2. Suitable Areas According to Solar Duration

One of the most important parameters to be taken into account for the design of solar power plant is the amount of solar energy in the region. This value must be used in conjunction with other parameters.

It is known that two data need to determine the energy from the area which the solar power plant will be install. These are radiation intensity and solar duration of the region. Solar duration is used in this study. Solar duration is defined as the time to receive the amount of sun light of this area in one day (EİE, 2012). Usually this time is calculated in one year. According to certain values above the threshold value of solar duration is determined as an appropriate place for solar power plant. In Turkey, the facilities of the solar power plant will be, to have at least 2000 hours of annual solar duration and solar energy value of 1500 kWh per square meter per year is required. In addition to that, number of days with sunshine duration is at least 4 hours is above 150. Any other work necessary for solar power plant design must be done in a region satisfying the above conditions.

Solar duration values of each districts of Eskişehir were used as an input for suitable area selection analysis. These values were given in the Table 1 (GEPA, 2012). These solar duration values of Eskişehir districts were used for the GIS analysis.

Table 1. Solar duration values of Eskişehir districts (solar duration/year)

District	Duration/Year	District	Duration/Year
Alpu	2454	Merkez	2357
Beylikova	2506	Mihalgazi	2374
Çifteler	2553	Mihalıççık	2502
Günyüzü	2640	Sarıcakaya	2391
Han	2540	Seyitgazi	2376
İnönü	2454	Sivrihisar	2594
Mahmudiye	2499		

Inverse Distance Weighted (IDW) methodology is used and the grid interval is taken as 500X500 m. Solar duration value distribution of Eskişehir districts is seen on the map after GIS analysis (Figure 8). It is understood that the east side of the line which joins the Mihallicik and Han districts is suitable for this situation (Figure 9).

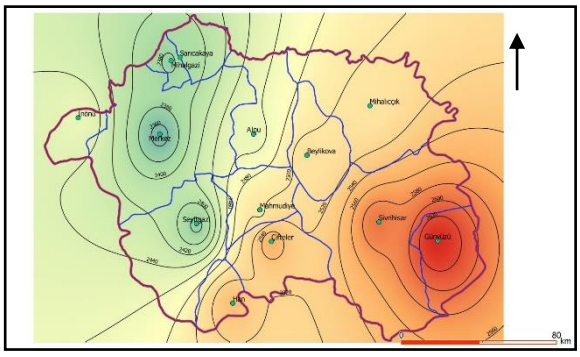

Figure 8. Solar duration value distribution map of Eskişehir districts.

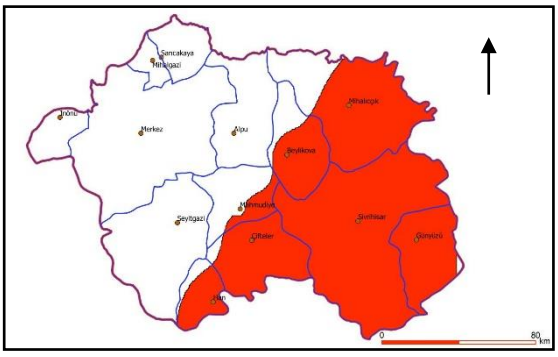

Figure 9. Suitable area according to solar duration (red colored areas).

4.3. Proximity Analysis of the interested objects

Spatial GIS analysis must be used during working on spatial situations about the project. It's known that many spatial variables are required for the suitable solar power plant site selection study. The number of the variable is reduce or increase according to the size of the project under consideration. In this study, only the distance to the residential areas and proximity to the power lines are used in the analysis (Figure 10). Proximity to the residential areas is selected as 20 km and to the power lines as 5 km which is designated as suitable areas for the solar power plant installation (Figure 11).

At the end the final suitable solar power plant sites are obtained by the intersection of suitable terrain analysis, solar duration analysis and proximity to power lines and residential areas. Sivrihisar and Günyüzü districts are selected as the most suitable districts of Eskişehir Province. The suitable places for the installation of solar power plant are seen

on the result map (Figure 12). It is also possible to see these suitable areas on the Google Earth (2016) distinctively (Figure 13).

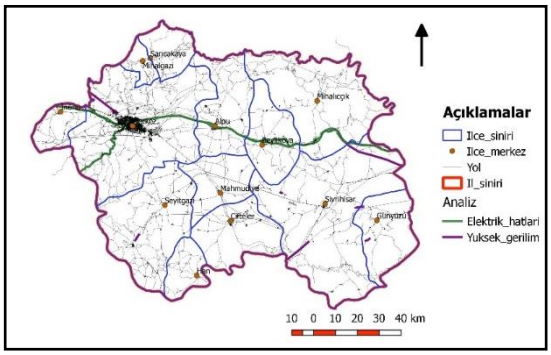

Figure 10. Power lines and residential places of Eskişehir Province.

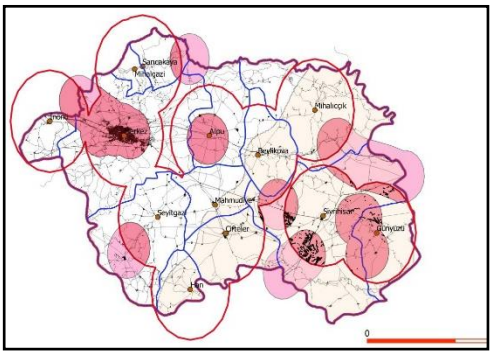

Figure 11. Results of proximity analysis of power lines and residential areas.

Figure 12. Final suitable solar power plant sites for Eskişehir Province.

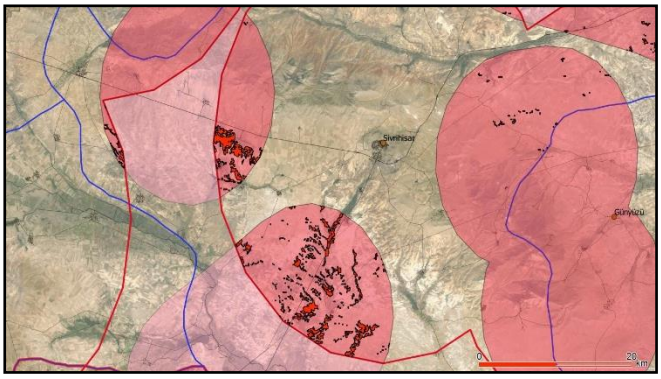

Figure 13. Suitable sites for solar power plant on the Google Earth view.

It is also understood that the suitable power plant installation area for Sivrihisar is 55 km^2 and 4 km^2 for Günyüzü district (Table 2).

Table 2. The number of suitable and total areas for the Sivrihisar and Günyüzü districts

District	Number	Area (km^2)
Sivrihisar	281	55.86
Günyüzü	38	4.38

5. RESULTS and RECOMMENDATIONS

The following results were obtained at the end of the study;

- Primarily Sivrihisar district is selected as the most suitable district for the solar power plant installation according to terrain analyses. Çifteler, Mahmudiye and Seyitgazi districts have secondary choice.
- It is understood that the annual solar duration is above 2500 hours for Günyüzü, Sivrihisar, Çifteler and Han districts.
- Intersection of suitable terrain analysis, solar duration analysis and proximity to power lines and residential areas have mentioned approximately 55 km^2 and 4 km^2 areas are suitable for the solar power plant installation.
- It's seen that, Solar Energy Potential Atlas for Turkey which was prepared only by meteorological parameters gives some clues about the site selection but terrain analysis and proximity analysis must be used for more detailed studies.

The following recommendations are made at the end;

- A lots of spatial data is needed for the site selection analysis of solar power plant. Therefore it is absolutely GIS software should be used.
- The use of Open Source GIS software should be advised to use during analysis. This is a task for the benefit of the country.
- The maps prepared from the terrain analyses must be used for this kind of study.
- The parameters which were used in this study changes from one place to another. The weighted parameter values must be used for different places. It is recommended to use Analytical Hierarchy Process (AHP) for these kind of works.
- Sivrihisar is a district where industrial development is growing during the last years. Many marble quarries and marble cutting factories have opened in the Günyüzü district. If the electricity requirements of these quarries and factories were supplied from the suggested solar power plants from the same districts will provide economic benefits to the region.

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