Optimal site selection for establishing solar power plant based on solar radiation using GIS

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Abstract. Although many nations employ solar energy as a backup energy source, not every site is equally conducive to the production of solar power. This is caused by the unequal dispersion of solar energy as well as a number of environmental conditions. The framework incorporates a number of Geographic Information Systems (GIS) features, including model builder and area classification. The framework used to derive the five sub-criteria weights determines the ideal locations for plant in the area based on the quantum of potential photovoltaic electricity production (PVOUT) that could possibly produce from Slope, exposure to sunlight, near to highways and closeness to a residential area. Finding the best locations for solar plant side identification in the "Anantapur" district using multicriteria decision analysis (MCDA).

1 Introduction

The most important renewable energy is solar energy, due to more positive impact rather than negatives lie purification of raw materials, reduction of oil, coal and gas imports. It is environmentally friendly, renewable and never-ending resource of energy. Numerous factors influence where to select the location of site for establishing the plant, which is critical to its installation. Increasing energy production while lowering startup and continuing operating costs can be achieved by optimizing these variables. During installation these are the steps should be considered in order to properly position the plant.

2 Objectives

Selecting an ideal location to establish a solar power plant in the district of Anantapur using GIS with sun radiation data.

3 Literature Survey

The GIS application determines the site selection for solar power plants and the data was provided to see more unoccupied lands in the specific locations known. In the current study, the site selection for a solar power plant is determined using Analytic Hierarchy Process (AHP) approach used in Geographic Information System (GIS) and Multi-criteria Decision

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Analysis (MCDA). After creating a map to locate the suitable areas, such as undeveloped land, vegetation, highways, etc. [1]

Nine crucial factors, including soil map, roadways, solar radiation, LST, aspect, slope, and Euclidean distance, were taken into account. Each and every variable was given a characteristic. The multi-influence factor method was employed to compute the outcomes. zoning for solar system site selection. Because of the characteristics that were used to determine which sites would be excellent for power plantations and where there is more available vacant land, we need to know which area on that map is best suited for power plantations [9].

Digital elevation model is used; the elevation, slope, morphology, road data, and site appropriate analysis were obtained. (DEM; resolution of 30 m). With the use of the road map data and the "Weighted sum" overlay analysis, the Euclidean distance was utilized to categorized the lands like vegetation and vacant land, which were subsequently overlaid in the geographic information system (GIS) domain. This study's main objective is to identify the areas that are ideal for power plant placement on undeveloped land.

Various factors like accessibility to facilities, environmentally protected areas, and weather conditions influence the site selection for utility projects. The main objective of this work is to identify an ideal location to place an utility scale project using GID and MCDM method. The model takes into account a variety of criteria, including economic and technical ones, in order to ensure that maximum power is achieved while keeping project costs to a minimum. Five categories like least suitable, marginally suitable, moderately suitable, highly suitable, most suitable are used by LSI model to classify the locations. In order to achieve the suitability analytical hierarchy process is used and land suitability index and weigh criteria are adopted a case study in Saudi Arabia. [2],[5]. The model is based on actual meteorological and legal data, such as road, mountain, and protected area information. The solar analyst tool in ArcGIS software analyses sun insolation across the full research region using actual atmospheric conditions. According to the map overlay, 16% of the research area is promising and appropriate for the installation of utility scale PV power plants. [3],[4] with the best locations being in Saudi Arabia's north and northwest [8].It has been discovered that appropriate land follows a pattern that roughly corresponds to the distance from major highways, power lines, and metropolitan centers. A moderate to high LSI was present in more than 80% of the appropriate regions. The combination of GIS and MCDM techniques has proven to be a highly effective strategy for dealing with rich geographic information data, large areas, and manipulating variables important for establishing the best locations for solar power facilities.

4 Selection Criteria

In order to select the ideal locations, it is critical to design effectual spatial criterion that take into account elements such as the feasibility of plant in the area. We used three categories: economic, environmental, and climatic. In decision making to help infrastructure various data analysis tools and criterions has been used. Multiple decision making versions are compared after collection of data and applying mathematical tool to compare their feasibility.
4.1 Economic criteria

The economic parameters chosen for this study were the separation from roads, the location of power lines, and the slope. For instance, the proximity to a transportation network lowers the installation costs of a power plant while increasing its operational efficiency. Road accessibility is crucial for lowering the cost of PV installation [7]. To minimize potential energy waste, it is also important to build new power cables close to an electrical station.

4.2 Environmental criteria

To avoid any possible detrimental effects on nearby residents and native environment, the distance from protected area data was collected from NDVI satellite pictures considering environmental criterion. [10]. In order to minimize any environmental harm, environmental resource preservation should be considered when choosing the preeminent location.

4.3 Climate criteria

When choosing a location for a solar plant, climatic considerations should be examined. Temperature, precipitation, humidity, and sunshine hours are examples of climatic parameters since they have an impact on the amount of radiation received. This study concentrated on one key factor, solar irradiance, to choose locations for the power plant that would get enough solar radiation.

4.4 Proximity of roads

As there is much importance for roads and accessibility to plant, this criterion was used to based on the distance from the roads. For the shipping and installation of the many pieces of equipment needed to produce solar energy, roads serve as a vital means of connection [6]. To eliminate all the problems that could arise from putting these facilities on the side of roadways, it is required and unavoidable to maintain a safe distance from them.

5 Methodology

![Flowchart Diagram]

Fig. 1. site suitability analysis Flowchart.
5.1 Study Area

One of the eight districts in the Rayalaseema area of Andhra Pradesh, Anantapur district is often referred to as "Anantapuramu district." Anantapur city serves as the home of the district administration. It is one of South India's driest regions. With a population of 2,241,105, it is the largest district in the state by area according to the Indian census. Anantapur has a total area of 10,205 square kilometers. The location of Anantapur is at 14° 41' 8.0304" N and 77° 35' 43.4616" E. Fig2 represents the Study area map.

Fig. 2 Study area map “Anantapur district”.

5.2 Data Collection

The DEM data for SRTM is gathered from USGS Earth Explorer in order to build specific maps, such as drainage maps and drainage buffer maps. To combine the raw SRTM DEM data which are collected from earth explorer into a single file the mosaic tool is used and uploaded to content panel. Using the analysis tools clip tool available under the Geo processing tab, the raster is clipped to the desired area of interest in order to retrieve DEM data for the required area.

Fig.3. DEM data clipped from study area.
5.3 Digitalization

In order to locate empty or barren land for a solar power plant, digitalization is done. Four acres of unoccupied land are required in total.

1. To add a FCC picture for digitalization, select the clip's boundary image by left-clicking it in the top open image categorization.

2. If the tool bar for picture classification is not highlighted, select Customize and check off all extensions. You can locate the draw polygon tool under the image classification tool bar.

3. Select seven classifications you can identify, then present example sets to each of them.

4. Using the draw polygon tool, choose a water body and make sure all of its color ranges are included. Then, go to the training sample and combine all of the water classes into one, naming it a water body.

5. In the same manner, create training sets for agricultural, dense vegetation, built-up vegetation, and the ocean.

6. Access the classification with the highest likelihood. Enter your address for the input and the output, which will be saved there.

7. Add the layers of the classified output to the attribute data, alter the symbology, add the layout, legend, title, scale, arrow, author, and date, and then save it.

Fig.4. Land use and land cover map for Anantapur district.

5.4 Slope Map

A multitude of factors, including slope, influence the location. The selection is based on the inclination percentage, as the slope increases the site is not suitable. Instead of steep slopes, flat places are preferable for establishing a station. The slope % was computed in this study utilising the slope tools in ArcGIS and the DEM model of the terrain for the analysed area. This gadget, which resembles a mirror that reflects the land's surface, aided in determining
the slopes in each cell of the raster surfacer. The slope value defines the steepness of the terrain; the lower the slope value, the flatter the landscape. The slope cannot be greater than 5%.

![Slope Map](image1)

**Fig. 5.** Layout of slope map for Anantapur district.

![Aspect Map](image2)

**Fig. 6.** Layout of aspect map for Anantapur district.

### 5.5 Aspect Map

Aspect values show which directions the real slopes face. To create an aspect map, you will require a digital elevation model (DEM). The output raster symbolizes based on the direction slope after the Aspect tool has been run. A range of slope angles will be represented by each slope direction. By altering the symbology and adjusting the number of classes, you can reclassify the aspect map. Fig6 Represents the Aspect map.
5.6 Soil Map

The required area of research must be extracted from the maps of India that contain the type of soil that is present in the area that we choose, and a map must be made. Fig7 Represents the Soil map.

Fig.7. Layout of soil map for Anantapur district.

5.7 Road Network Map

Good road networks are necessary to get solar panels to such areas at an affordable price because they are the lifeblood of any nation. Roads so play a significant role. make a shape file for the Anantapur district, then gather Indian road data and select the Anantapur district area for clipping: tools for data management, raster, raster processing, and clip. Fig8 Represents the Road Network Map.

Fig. 8. Layout of road map for Anantapur district.
5.8 Distance from Road Map

The map shows the shortest distance from each pixel in the objects (or background) of the original binary image to the closest pixel in the backdrop. (or the objects). Two photo scans, with each line moving both forward and backward, can yield a map with minimal mistakes. Fig. 9 Represents the Distance from Road map.

![Distance from Road Map](image)

Fig. 9. Layout of distance from road map for Anantapur district.

5.9 Solar Radiation Map

Solar plants generate electricity by using energy exerted from sun to heat a fluid to a high temperature. This fluid's heat is then transferred to water, which boils into extremely hot steam. This steam is then utilised to turn turbines in a power plant, where it is converted into electricity by a generator. This technique of production is similar to that of burning fossil fuels to generate electricity, however instead of utilising fossil fuels to heat steam, sunlight is employed. Solar collectors are used in these systems to focus the Sun's rays on a single spot and generate high enough temperatures.

![Solar Radiation Map](image)

Fig. 10. Layout of radiation map for Anantapur district.
5.10 Land Surface Temperature Map

The Landsat 8 thermal bands can be used to compute or estimate LST. All that is required is to run a series of equations using a raster image calculator. The initial step in this method is to get a Landsat 8 image from a given location, unzip it, and examine the metadata for essential information. Landsat 8 bands can be used to calculate Land Surface Temperature (LST). The Normal Difference Vegetation Index (NVDI) is calculated using bands 4 and 5, with band 10 serving as the thermal band. To calculate the LST, use the USGS techniques (additional information are provided in the paper Algorithm for Automated Mapping of Land Surface Temperature Using LANDSAT 8 Satellite Data).

![Land Surface Temperature Map](image1)

**Fig. 11.** Layout of land surface temperature map for Anantapur district.

5.11 Weighted Overlay Map

Using a similar measurement scale overlays a number of rasters, based on the significance a weight is assigned. Each raster layer is assigned a weight in the suitability analysis. A common suitability scale is used to categorise the data in the rasters. A suitability value is obtained by overlapping raster layers, dividing each raster cell's suitability value by its layer weight, and adding the results. These values are written to new cells in a layer of output. These data serve as the foundation for the output layer's symbology. You may control the influence of various factors in the appropriateness model by assigning a weight to each

![Weighted Overlay Map](image2)

**Fig. 12.** Layout of weighted overlay map for Anantapur district.
raster during the overlay process. In the Spero model, you might give slope greater weight than aspect.

6. Results and Conclusion

The LULC map, the slope map, the aspect map, the soil map, the road map, the distance from the road, and the land surface temperature map are all examples of the maps mentioned above.

Of the total area of the three categories, it has been established that 3265.6 Km² is appropriate for the erection of a solar power plant. And only 4796.35 Km² region is somewhat suitable. And the area of 2143.05Km² is wholly unsuited for solar power plant.

![Pie chart representing the suitable area for the establishment of solar power plant for Anantapur district.](image)

The objective of the work is to develop a GIS AHP based model to perform spatial analysis and discover suitable sites for solar energy projects. To locate the best suitable site to construct the plant, starting with the most suitable and progressing to constrained sites by weighing the various factors. The calculation of the amount of solar radiation required for each area’s appropriateness is also done. To achieve these objectives, three essential aspects, are considered which includes climatic conditions, environmental conditions and economy. By taking the weight values in to consideration all the above criterions were integrated. Using Multi Criteria Decision Making- Analytical Hierarchical Process these weight values were determined.

**References**