Assessment of Solar Power Potential Mapping in Telangana State Using GIS

Manish S. Dharek, Prashant C. Sunagar, Manjunath V. Kadalli, K. S. Sreekeshava, and Anant G. Pujar

Abstract Solar energy replacing conservative non-renewable energy is being witnessed in often around the world. Solar energy has a massive prospective in a humid country like India. Most parts of the country get around 300 sunshiny days in a year with 8 h of daily sunlight. Presently, one of the most interesting problems is how to mend the effectiveness of generating solar energy. Before installing solar panels, evaluating where solar panels should be positioned can considerably benefit panel performance. The present study is aimed at carrying out site selection analysis for setting up of solar panel using geographic information system (GIS). Telangana is a state which ranks fourth in terms of capacity to harness and utilize solar energy. The project is aimed at mapping the areas with high solar energy potential at both macro- and micro-levels. The solar irradiation data (GHI and DNI), land use data and digital elevation model (DEM) have been used in GIS environment while retaining land use criteria and topography to omit unsuitable sites for harnessing solar energy. The study carried out concludes total suitable area of 11,520.60 km^2 at macro-analysis for economical and effective harnessing of solar power.

Keyword Geographic information systems · Solar energy potential · Site selection analysis

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1 Introduction

The daily energy requirement is increasing at faster rate by all the populace across world. The necessity for energy has seen a sharp increase and its linked facilities to gratify human social and economic development, as well as welfare. Above events have led to over-exploitation and extreme use of non-renewable resources, as seen through fossil fuel-based power generation, for example, the ever-growing demand for petrol production. In addition, depletion of non-renewable sources has elevated the energy crisis. Serious impacts can still be evaded if efforts are made to transform current energy systems.

Solar energy is genesis for all forms of energy. This energy is used in two ways, first, in thermal route where heat medium is used to generate power in different forms, and, second, photovoltaic route which converts solar energy into electricity. Switching to solar energy helps to cut down the major ill effects on earth, for instance, the pollution caused from CO_2 [1]. Majority of energy consumption is associated with solar sources, and hence, the focus is increasing on extracting this efficient source of energy through improved technology. In our project, we have found easier ways to transform energy content on a large scale to meet consumer demands. Incorporating geographic information systems with data collected, we have depicted results by working through objectives of plan for Telangana state. This paper includes the methodology of analyzing potential energy using GIS and illustrates this for Telangana state of India.

2 Literature Review

Joshi et al. [2] demonstrated monthly solar mapping developed in GIS environment by input of the location and solar irradiation value in polygon format for Uttarakhand state. Solar mapping was developed using MapInfo and linking information about RE with the databases for individual district. SQL queries were used to retrieve the data from database. They also concluded that entire state receives solar radiation of about 3–6.5 kWh/m^2/day and this map can be helpful in formulating new facilities to utilize the solar energy. Moreover, they suggests that GIS can be used to exploit the advantages of terrain and topographic features of Uttarakhand with the help of government leaders by initiating new facilities to be instated. Wang et al. [3] explained spatial planning for renewable energy using pre-planned procedure at the regional level utilizing concept of GIS. Potential sites are selected according to geographic characteristics. Energy density mapping was executed to find out the potential areas having self-sufficiency in terms of renewable energy. The criteria to select sites are non-urbanized areas in urbanized areas and having minimum land area of 1.5 Ha and excluding built-up areas, agricultural lands, commercial and public spaces. The terrain slope considered is up to 2.5% and aspect of 2.5–15% to face south. They concluded that among available renewable energy potential sources, solar power has the maximum theoretic potential among all the five RES. Ramachandra et al. [4, 5] discussed the application of geographic information system (GIS) to map the renewable energy potential in Karnataka. Global solar radiation was calculated by compiled data from stations which were used unswervingly and for locations where the data was not obtainable, indirect methods were used. Their study concluded that global solar radiation during monsoon is less compared to summer and winter because of the dense cloud cover. The study identifies that coastal parts of Karnataka with the higher global solar radiation are ideally suited for harvesting solar energy.

3 Objectives

- To prepare the solar radiation map with interpretation of solar irradiance data
- To prepare the mapping for optimum site selection using geographic information system (GIS).

Furthermore, there are few specific reasons why Telangana is our study area, as it is fourth highest producer of solar energy in India with a figure of reaching 1287 kw of capacity. Second, Telangana has a vast solar potential with average solar insolation of nearly 5.5 kWh/m^2 for more than 300 sunny days. Government of Telangana state intends to substantially use this potential energy for major power generation.

4 Data Collected

Datasets collected include solar radiation data, Land Use and Land Cover information and digital elevation model (DEM) for macro-analysis. Aerial imagery of good resolution from Google Earth Pro software has been derived. Other datasets include Telangana State Boundary, etc. Data used in study is summarized in Table 1.

Table 1 Datasets collected to model the solar maps

Sl. No.	Data	Source	Format
1.	Global Horizontal Irradiation (GHI)	Global Weather Data	Excel Sheet File (.xls)
2.	Terrain Slope And Aspect	Bhuvan, India (Geo-Platform of ISRO)	GeoTIFF
3.	Land Use and Land Cover	Bhuvan, India (Geo-Platform of ISRO)	GeoTIFF
4.	Telangana State Boundary	DataMeet Web site	Shapefile
5.	Malepally Ward Boundary	DataMeet Web site	Shapefile
6.	Aerial Satellite Image	Google Earth Pro	–

Solar irradiance data was derived from National Centers for Environmental Prediction (NCEP) online data repository for the period of July 2013 to June 2014. Land Use and Land Cover data is collected from Oak Ridge National Laboratory (ORNL) Distributed Active Archive Centre (DAAC) managed by NASA. The data is at 100-m resolution for India at decadal period from 1985-01-01 to 2005-12-31. Land Use and Land Cover map describes the vegetation, water, natural surface and cultural features on land surface.

5 Features Considered for Analysis of Solar Panels

5.1 Amount of Incoming Solar Radiation

The average level of sun exposure determines solar radiation striking a specific location on Earth's surface. Solar radiation greater than 5kWh/m^2 is considered to be economical for the project.

5.2 Shadow Impacts

Ideal performance of PV panels is easily affected by physical factors, such as surface orientation, land surface gradient, adjacent obstacles which can have significant impact by causing shadow effects. The relative angular position of sun throughout the day and year should be considered to decide the appropriate orientation. Summer in northern hemisphere coincides with the northern hemisphere being more oriented toward the sun, which causes solar rays to strike the ground more directly. Therefore, a southern exposure is generally optimal for obtaining the strongest intensity of sunlight in northern hemisphere.

5.3 Land Restricting Factor

Identification of land cover establishes the baseline information for activities like thematic mapping of solar power potential analysis. Installations of solar panel should be situated away from aquatic sources and coastline zones to reduce risk of water pollution from PV construction contamination. Similarly, classification of land use helps us to determine different available and optimum sites. Barren land, waste land, fallow land and shrub land are incorporated as suitable land.

5.4 Other Factors

Losses due to transmission and distance of solar installation to substations have to consider to improve PV system performance. Factors affecting site selection are given in Table 2.

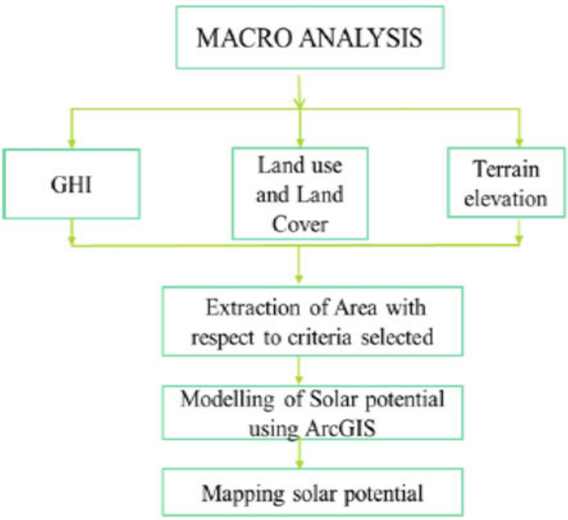
6 Methodology

To develop a process for solar panel placement site selection, diverse methods were used for macro-scale levels of study. First, monthly and yearly accumulated solar radiation maps, slope map and Land Use and Land Cover (LULC) map [6] were generated to assist site selection for macro-scales. A multi-criteria analysis (MCA) approach has been adopted at macro-scale level. The general methodology for analysis of solar energy framework using GIS approach is summarized in flowchart in Fig. 1.

Table 2 Factors affecting optimum site selection

Sl. No.	Criteria	Standard and restriction
1.	Slope	Slope limit is less than 4%
2.	Aspect	Southeast to southwest facing orientation only
3.	GHI	Equal to or greater than 5 KWh/m^2/year
4.	Land suitability	Shrub land, barren land, waste land, fallow land and grassland

Fig. 1 Flowchart explaining the methodology adopted



6.1 Analysis

As discussed above about macro-analysis, the following are brief steps for solar power potential mapping.

- STEP 1: Creating a solar irradiation map, slope map, Land Use and Land Cover map
- STEP 2: Extracting unsuitability factor for each map according to criteria selected
- STEP 3: Modeling and overlaying all extracted maps to obtain optimum site for solar PV system.

6.2 Solar Irradiation Map

Using Inverse Weighted Distance Tool in ArcMap 10.3, we form solar heat maps of both monthly and yearly mean. Figures 2, 3 and 4 show the monthly solar heat maps, and Fig. 5 displays the mean annual solar heat map.

6.3 Slope Map

Digital elevation model (DEM) [7] is used to create slope map. Mosaic tool, fill tool and slope tools are used to get the figurative slope map of Telangana as seen in Fig. 6.

6.4 LULC Map

LULC map is needed to identify the sites to install the solar panels, so it is necessary to classify the land and identify built-up land, cropland, forest land, water bodies, etc., to exclude them. Extraction by mask is used to remove the Telangana state characteristics from India's LULC map. Figure 7 shows LULC map of Telangana as per year 2005.

6.5 Extraction of Solar Irradiation Map

Using Less Than tool and Set Null tool, we erase sites having solar radiation less than 5 kWh/m^2. Figure 8 displays areas having radiation more than 5 kWh/m^2.

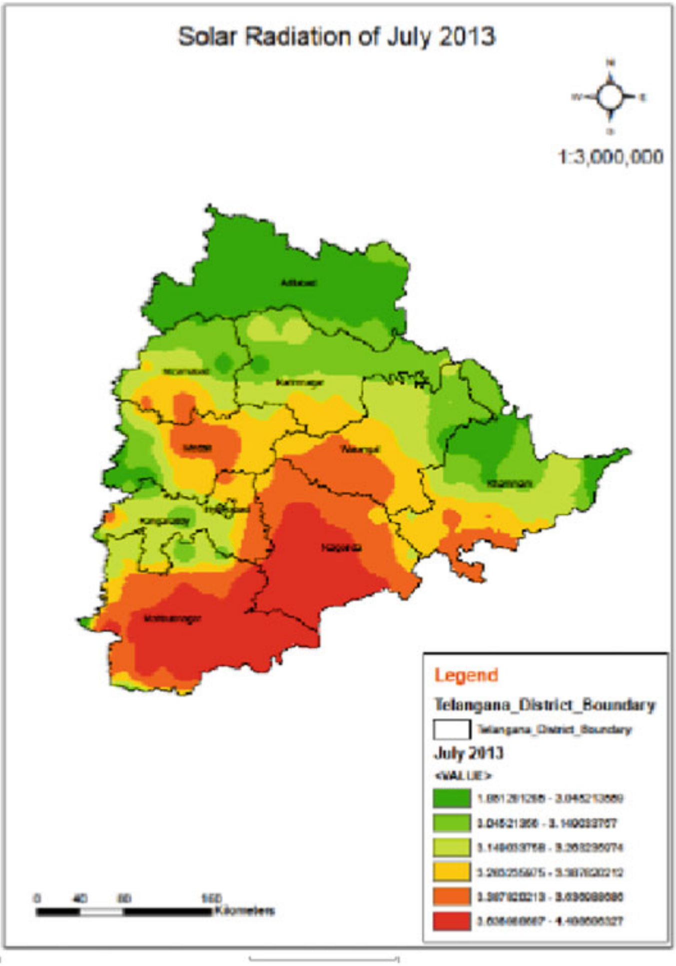


Fig. 2 Monthly radiation maps, July 2003

6.6 Extraction of Slope Map

Flat terrain is vital for solar exposure and constructability, while a high daily annual solar irradiance is needed for plant efficiency and stability. For economical site selection, slope should be less than 4% (2.29°). By using Greater Than tool and Set Null tool, we erase unsuitable areas from map. Figure 9 shows us that most of land is available for panel installation.

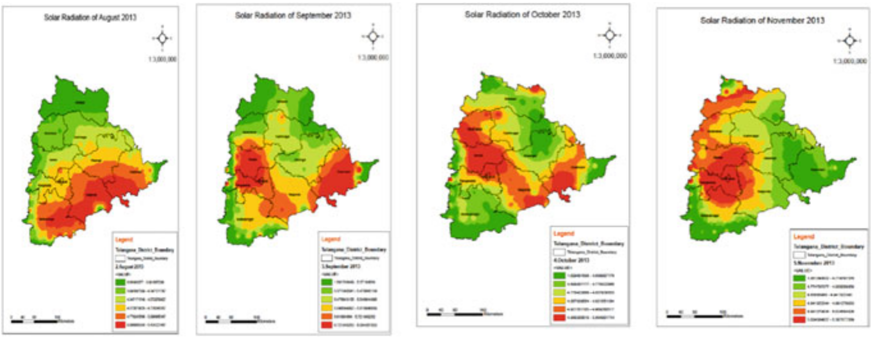


Fig. 3 Monthly radiation maps, August 2003, September, October, November 2013 (left, middle, right)

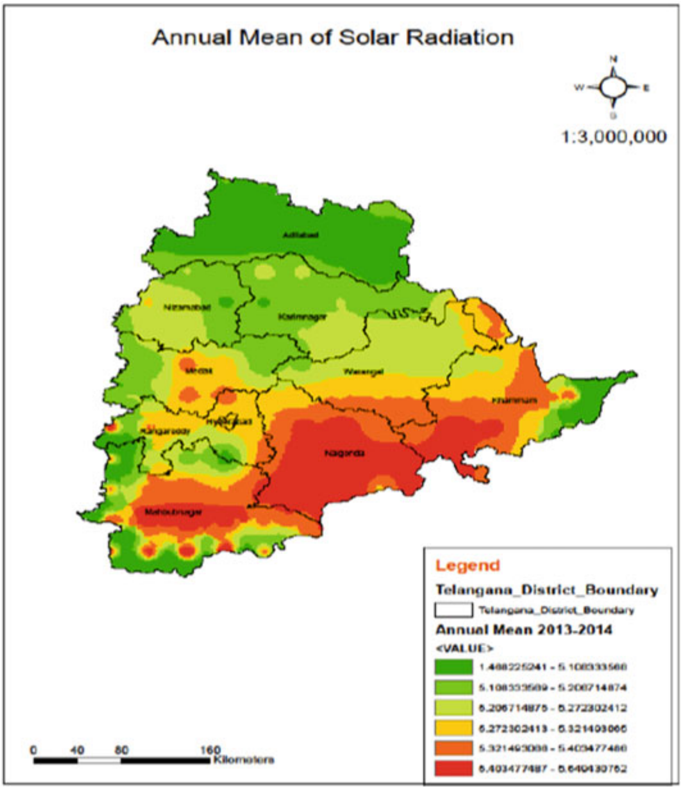


Fig. 4 Mean annual solar heat map

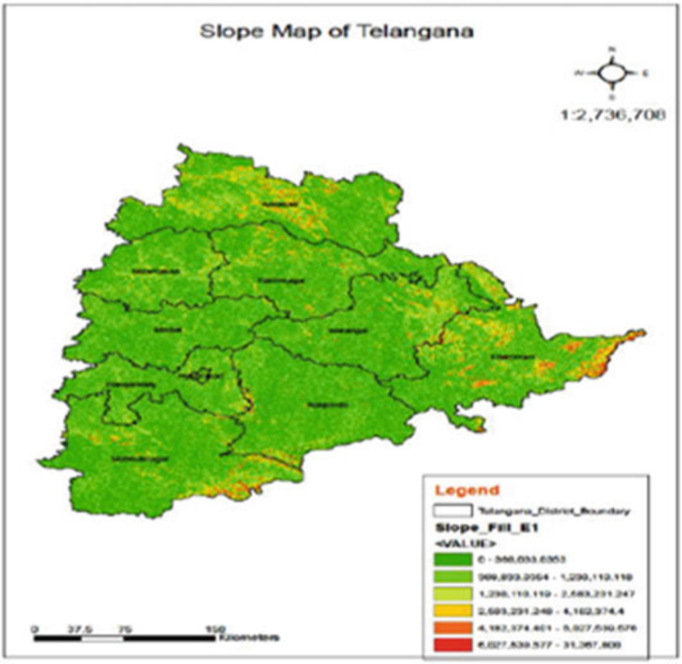


Fig. 5 Slope map of Telangana state

6.7 Extraction of LULC Map

Equal To tool and Set Null tool help to remove areas where there are built-up structures, water bodies, croplands, forest land, etc. Figure 10 displays feasible distributed areas around the state.

6.8 Extraction of LULC Map

Combining all three extracted maps helps to find the most feasible and optimum site for ground mount panels or retrofitted panels, based on financial viability. Fuzzy overlay tool is used to overlay all three maps to obtain an optimum site map as seen in Fig. 11.

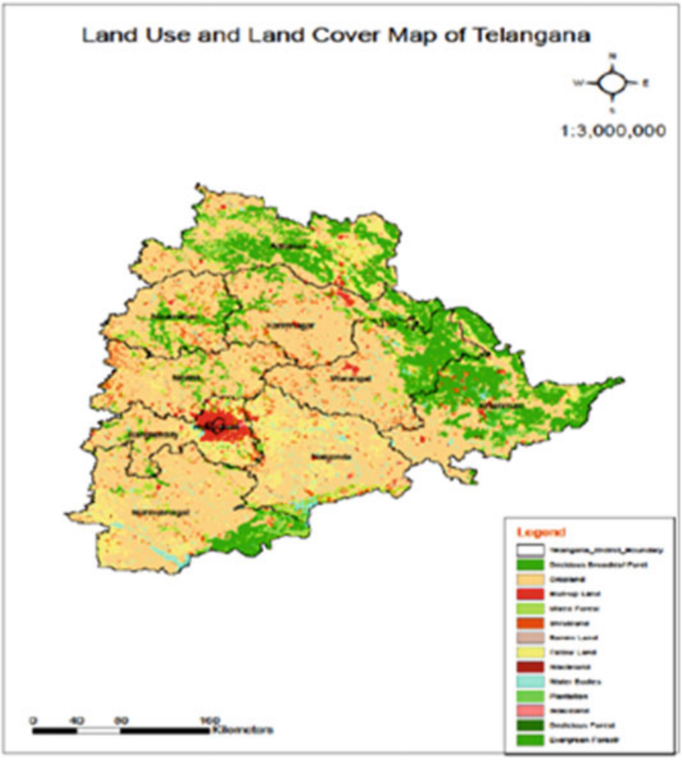


Fig. 6 Land use and land cover map of Telangana

7 Results and Discussion

The PV site suitability model and map product define the areas that satisfy the technical, economical and environmental goals of this study. The study shows Telangana received Global Horizontal Irradiance (GHI) in the range as displayed in Table 3.

The dark red-colored areas represent high intensity of solar radiation in Fig. 11, whereas green-colored areas indicate least intensity of solar radiation. Total area of Telangana state is 112,077 km^2, out of which suitable area to be found out was 11,520.6 km^2. Nalgonda District has more annual solar power potential.

8 Conclusion

Based on the following results, conclusions are as follows.

- Feasible area available for solar energy is harvested on waste, barren and un-utilized lands of Telangana state.

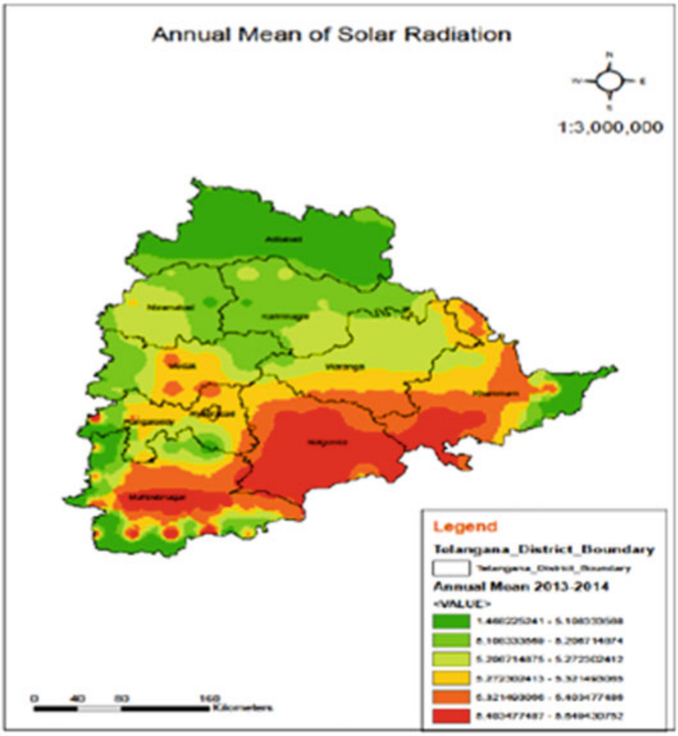


Fig. 7 Map of solar radiation more than 5 kWh/m^2 in Telangana

- The total feasible area found at macro-level is 11,520 km^2, where we can install solar panels to generate electricity profitably. This area is distributed all around in Telangana state, while the installation of a solar park has to be done in concentrated area. Nalgonda region has met the requirements, and the area can be used for maximum advantage to build solar parks.
- This project can be undertaken by Government of Telangana to further advance the decision making and provide the area with maximum solar exposure.

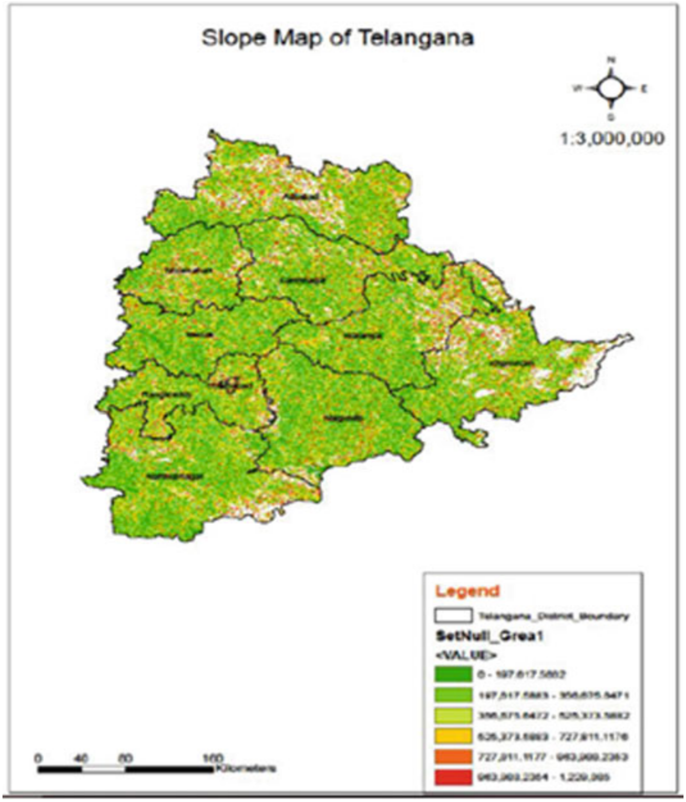


Fig. 8 Map of Telangana having slope less than 4% (2.29°)

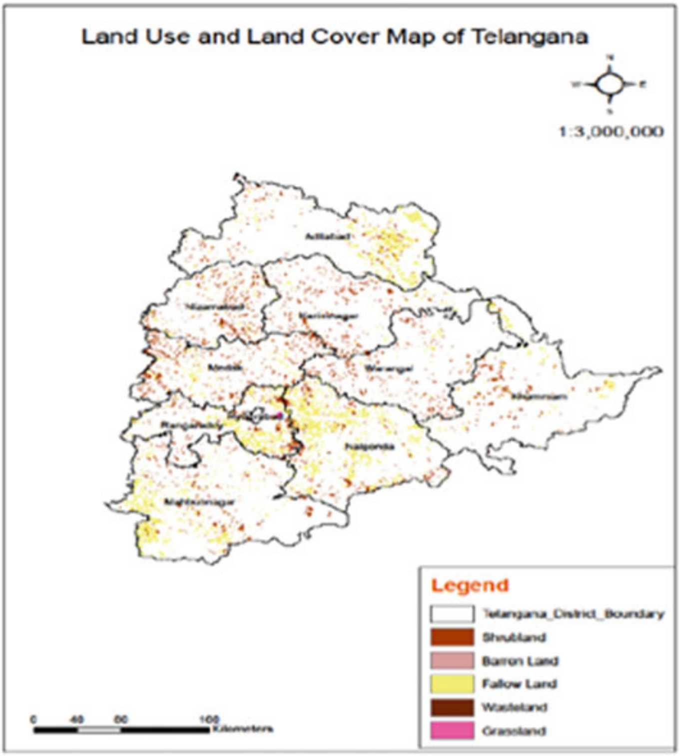


Fig. 9 Map indicating areas where solar panels can be installed in Telangana for maximum output

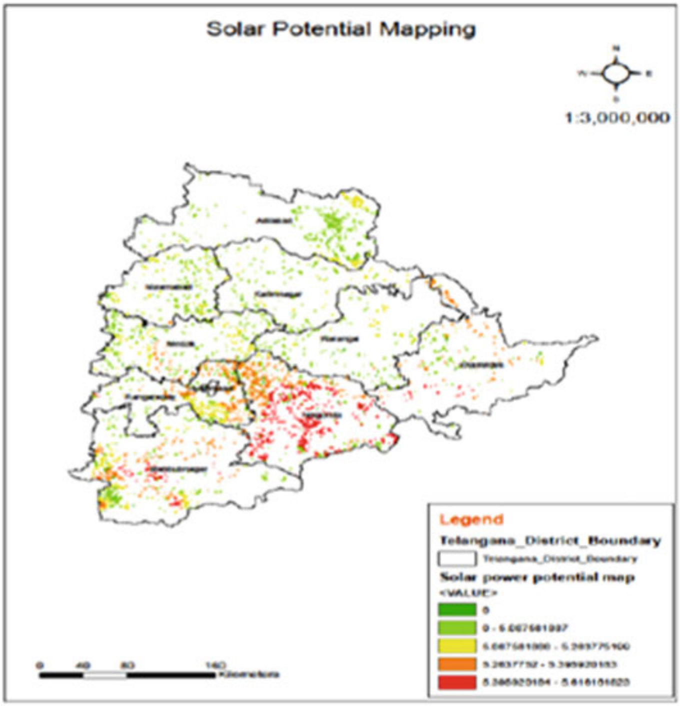


Fig. 10 Overlay map of the annual solar heat map, extracted slope map and extracted LULC map

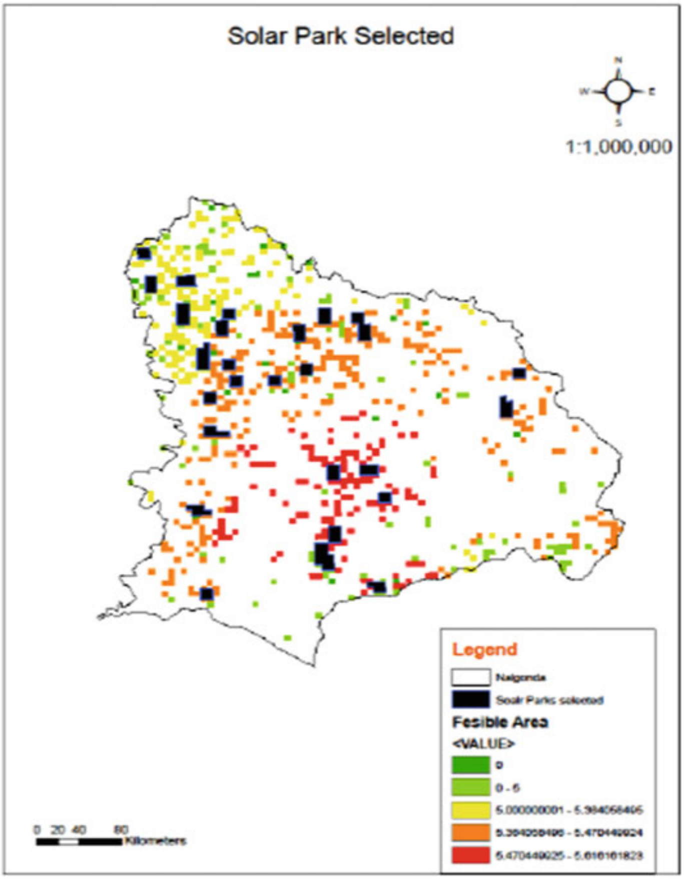


Fig. 11 Map showing areas where solar parks can be set up

Table 3 Monthly irradiance values (kWH/m^2)

Month	Irradiation values
January	5.1
February	5.68
March	5.9
April	6.57
May	6.18
June	5.56
July	3.21
August	4.47
September	5.53
October	4.84
November	4.92
December	5.08

References

1. Singh A, Madhava C, Kapoor K, Kadali M (2018) Assessment of solar power potential mapping of Telangana state using GIS. UG Thesis, Department of Civil Engineering, BMSIT&M, Bengaluru
2. Joshi J (2013) A research study on developing solar potential map using GIS 2(3). www.ijettcs
3. Wang Q, M'Ikiugu MM, Kinoshita I (2014) A GIS-based approach in support of spatial planning for renewable energy: a case study of Fukushima, Japan. Sustainability 6:2087–2117
4. Ramachandra TV (2007) Solar energy potential assessment using GIS. Energy Educ Sci Technol 18(2):101–114
5. Ramachandra TV, Jha RK, Krishna SV, Shruthi BV (2005) Solar energy decision support system. Int J Sust Energy 24:207–224
6. Reddy Anji (2014) Text book on remote sensing and GIS, III edn. B S Publications, Hyderabad
7. Manugula SS (2017) Photogrammetry, GIS & remote sensing, I edn. ebooks2go publications, Hyderabad