Synopsis

On

SITE SUITABILITY ANALYSIS FOR INSTALLATION OF SOLAR PANELS USING RS & GIS

Submitted

By

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**Introduction**

Energy plays a vital role in nations' sustainable development and well-being worldwide. According to the International Energy Agency (IEA), fossil fuels currently account for most energy generation globally(IEA, Policy Review, 2020). Fossil fuels, which include crude oil, coal, and natural gas, collectively account for approximately 80% of the world's energy production. To break this down further, crude oil contributes 31%, coal 28%, and natural gas 22% to the overall energy capacity (Uyan et al., 2013). This heavy reliance on fossil fuels presents a pressing issue, primarily due to their finite and unevenly distributed nature. This imbalance is anticipated to give rise to significant economic and political conflicts in the foreseeable future. Depleting reserves of fossil fuels, coupled with escalating fuel prices and growing environmental concerns, have catalyzed a growing emphasis on harnessing renewable energy sources (RES). These renewable sources have already gained substantial capacity on a global scale, offering a sustainable alternative to address our energy needs while mitigating the associated challenges.

Solar energy, for instance, stands out as a noteworthy contender in this regard. It possesses the capability to convert direct sunlight into usable energy for a multitude of applications. Solar energy is characterized by its accessibility, abundance, environmental friendliness, and cost-effectiveness. An additional advantage is its ability to function even when the weather is cloudy during the day, addressing energy demands at their peak. In recent times, the attention of investors and policymakers has gravitated towards nations endowed with substantial solar energy potential, such as India. Projections indicate that solar energy is poised to substantially impact the global energy landscape by 2040, with expectations of contributing to 35% of capacity expansion and attracting 30% of global energy investments (Neo et al, 2015). Another research source even suggests that solar energy will become the world's leading source of electricity generation by 2050 (IEA, 2014). Solar photovoltaic (PV) systems have gained prominence over concentrated solar energy systems that employ reflective materials. This preference arises from their lower installation costs and ability to convert solar energy into electricity through semiconductor materials directly. However, a critical consideration in deploying solar PV farms is the selection of optimal locations, as these installations require substantial space and incur significant initial construction expenses while delivering relatively low-intensity electricity (Choi et al., 2019).

The strategic decision regarding site selection is pivotal in overall efficiency, impacting procurement, manufacturing, and distribution costs. Poorly chosen locations can lead to additional costs and limited capacity. Although research on site selection for solar PV farms has been conducted, many proposed solutions are too specific and unsuitable for diverse locations. To address this challenge, a comprehensive approach is needed, which involves considering various data and descriptors, including criteria, sub-criteria, and restrictions in the construction of solar PV farms. Geographic Information System (GIS) has become valuable tools for integrating different data types and facilitating spatial energy planning. GIS provides sophisticated capabilities for data analysis, editing, mapping, and spatial queries. Integrating GIS with multiple criteria decision-making (MCDM) methods enables the selection of the optimal location for solar PV farms, thus increasing energy production potential while reducing investment costs. MCDM methods assist in assessing the significance of diverse criteria that influence site selection, accounting for factors such as expert opinion, data characteristics, and requirements. This integration of GIS and MCDM methods empowers decision-makers to make informed choices among potentially conflicting alternatives, ensuring the selection of the best-suited location for solar PV farm installations (Colak et al., 2020).

**Motivation of the Research**

In this project, the GIS-based Analytic Hierarchy Process-Multiple Criteria Decision-Making (AHP-MCDM) methodology will be used to identify suitable and unsuitable sites for installation of PV farms in Dhanbad District, located in the Indian state of Jharkhand. The choice of GIS as a tool is grounded in its ability to swiftly, efficiently, and adaptably process, analyze, and visualize data that exhibit diverse properties and content. The utilization of the Analytic Hierarchy Process (AHP) serves to streamline and structure the decision-making process. AHP offers several advantages, including the simplification of problem understanding, presenting complex problems in a more manageable format, and enabling the joint evaluation of quantitative and qualitative criteria. Additionally, AHP facilitates the assessment of the consistency of decision-makers' judgments through sensitivity analysis. Moreover, AHP can be employed to standardize planning criteria for land-use suitability, employing straightforward mathematical calculations and organizing them systematically based on available data. By incorporating a comprehensive array of exception and evaluation criteria, the proposed framework will offer valuable support to stakeholders involved in deploying solar PV farms in Dhanbad.

**Literature Review**

Being economically viable and environment friendly, PV technology has been the focus of numerous studies. Tahri et al. (2015) assessed the suitability for PV power plants in Ouarzazate, Morocco by considering criteria related to location, orography, land-use as well as climate by employing an MCDM approach. The final results indicated that most of the study area is highly suitable for PV plant installations.

Several spatial variables generally determine the efficiency of solar PV energy-generating systems. For example, the electric power generated from solar PV systems positively correlates with the amount of solar irradiation (Garni et al., 2017) and sunshine duration. Meanwhile, the generated electric power reduced noticeably with increasing temperature and relative humidity. Usually, increasing air temperature leads to increasing PV module temperature, which reduces the efficiency of PV systems (Yelmen et al, 2016). Similarly, increasing relative humidity reduces sun rays' general absorption and penetration (Doljak et al., 2017). Thus, it can be argued that areas with lower average temperatures, lower average relative humidity, and higher sunshine duration are more favorable for siting solar PV systems. Also, land topography, particularly slope and aspect, may influence solar radiation distribution on the Earth's surface (Cioban et al., 2013) and determine the potential for electric energy production. In this respect, it was reported that local shadowing effects of the terrain due to land slope and aspect play a crucial role in modifying the distribution of solar irradiation (Malgorzata et al, 2017).

Accordingly, it was argued that the performance of solar PV systems generally increases in the case of flat or gentle slopes less than 5 degrees (Garni et al., 2017) and southward slopes in the northern hemisphere. Meanwhile, cost-effectiveness and low operational costs can be attained by a high level of accessibility, minimizing the construction costs of solar PV systems, minimizing the loss of electricity during transmission, and avoiding costs associated with extending new transmission power lines (Calka et al, 2017). For these purposes, solar PV systems are recommended to be sited near existing road networks, power transmission lines, and human settlements (Garni et al., 2017, Nagasaka et al., 2017). The above criteria are the primary criteria considered in most of the literature. Apart from this, several criteria are taken into consideration by some of the researchers. Zoghi et al., 2017 considered humidity, dust, snow, rain, and cloud cover in Isfahan, Iran, to perform a solar site selection by a combination of techniques like fuzzy logic, Weighted Linear Combination (WLC), and MCDM. Findings demonstrated the reliability of the combination of selection methods in identifying solar sites with 76.8% and 3.12% of the validated area as favorable and excellent, respectively. Ouchani et al., 2020 used wind speed as an additional criterion to find suitable sites for large-scale PV power plants in Morocco. Results show that 74% of the study area was considered suitable for PV power plants, of which 24.3% was highly suitable. Aly et al., 2017 used proximity to mines as an additional criterion in Tanzania to find suitable sites using AHP-GIS techniques. Saraswat et al., 2021 used distance from water bodies and airports as additional criteria for assessment of solar farm locations in India.

This project will focus on site suitability analysis based on 14 criteria and they are solar iPrevious studies have overlooked some important parameters, such as temperature, humidity, and aspect, while incorporating new parameters like proximity to mines, wind speed, and water bodies. Precipitation, a key parameter, is considered in very few studies. Although modern PV panels are designed to handle precipitation, it can affect their efficiency in the long run. Thus, it should be considered when making strategic decisions.

The novelty of this project lies in its comprehensive site suitability analysis based on 14 criteria, including solar irradiance, temperature, humidity, precipitation, dust, slope, aspect, elevation, distance from roads, distance power lines, distance water bodies, and distance from protected areas, Land-use Land cover (LULC), and proximity to mines. The methodology of this project will be the use of AHP-GIS techniques. This project is one of the first kinds of assessments carried out in Dhanbad to identify potential sites for the installation of solar power plants with the consideration of regional criteria as well as primary criteria. It will help stakeholders make novel decisions for installing solar panels in suitable sites.

**Table 1: Overview of adapted criteria in previous studies**

| Year | 2015 | 2017 | 2017 | 2017 | 2017 |
| --- | --- | --- | --- | --- | --- |
| Author | Tahri et al. | Aly et al. | Zoghi et al. | Doljak et al. | AI Garni et al. |
| Study area | Ouarzazate(Morocco) | Tanzania | Isfahan-IRAN | Serbia | Saudi Arabia |
| Methodology | AHP-GIS | AHP-GIS | AHP-FUZZY and WLC methods-GIS | AHP-GIS | FUZZY, AHP-GIS |
| System | PV | PV and CSP | PV | PV | PV |
| Solar Irradiance | x | x | x | x | x |
| Temperature |  |  |  | x | x |
| Humidity |  |  | x | x |  |
| Snow & Rain |  |  | x |  |  |
| Cloud cover |  |  | x |  |  |
| Dust |  |  | x |  |  |
| Slope | x |  | x | x | x |
| Aspect | x |  | x | x | x |
| Elevation |  |  | x |  |  |
| Distance to roads | x | x |  | x | x |
| Distance to waterbodies/dams |  | x |  |  |  |
| Distance to transmission lines/grid | x | x | x |  | x |
| Distance to residence area/urban areas |  | x | x | x | x |
| Land use/Land cover | x |  |  | x | x |
| Proximity to mines |  | x |  |  |  |
| Windspeed |  |  |  |  |  |

| Year | 2020 | 2020 | 2020 | 2021 | 2021 | 2022 |
| --- | --- | --- | --- | --- | --- | --- |
| Author | Ouchani et al. | Hassan et al. | Ruiz et al. | Saraswat et al. | Gunen et al. | Noorollahi et al. |
| Study area | Marrakesh-Safi region, Morocco | Kuwait | Indonesia | India | Kahramanmaras,Turkey | Khuzestan, IRAN |
| Methodology | AHP-GIS | AHP-GIS | AHP-GIS | AHP-GIS | AHP-GIS | FUZZY-Boolean logic and AHP-GIS |
| System | PV | PV | PV | Solar plants | PV | PV |
| Solar Irradiance | x | x | x | x | x | x |
| Temperature | x | x | x |  | x | x |
| Humidity |  | x | x |  | x | x |
| Snow & Rain |  |  |  |  | x |  |
| Cloud cover |  |  |  |  |  |  |
| Dust |  |  |  |  |  |  |
| Slope | x | x | x | x | x | x |
| Aspect |  | x | x | x | x | x |
| Elevation |  |  | x | x |  | x |
| Distance to roads | x | x | x | x | x | x |
| Distance to waterbodies/dams | x |  |  | x | x |  |
| Distance to transmission lines/grid | x | x | x | x | x | x |
| Distance to residence area/urban areas | x | x | x | x | x | x |
| Land use/Land cover |  | x |  | x | x | x |
| Proximity to mines |  |  |  |  |  |  |
| Windspeed | x |  |  |  |  | x |

**Study Area**

Dhanbad is a city in the Indian state of Jharkhand, with latitude range 23.63° – 24.0595° N and Longitude range 86.1101° – 86.8298° E. It has a population of over 1.1 million people and is India's 32nd most populous city. Dhanbad is known for its coal mines and is one of the largest coal-producing regions in the country. The major coal mines in Dhanbad include the Jharia Coalfield, Bharat Coking Coal Limited (BCCL) Mines, Eastern Coalfields Limited (ECL) mines, Tata Steel Mines and Moonidih Coal Mine. The city also has several other industries, including steel, cement, and engineering.

Dhanbad is suitable for a solar PV project due to its high solar radiation potential. The city has an average global horizontal irradiance (GHI) of 5.5 kWh/m2/day. The temperature in Dhanbad ranges from 10°C to 35°C, with an average temperature of 25 °C. The precipitation in Dhanbad is moderate, with an average annual rainfall of 1,200 millimeters. The humidity in Dhanbad is high, with an average humidity of 70%. The dust and wind conditions are generally favorable for solar PV projects. The slope of the land in Dhanbad is generally gentle, with an average slope of 5%. The aspect of the land in Dhanbad is generally south-facing. The elevation of Dhanbad is 200 meters above sea level.

It is well-connected by roads and railways. The city is located on the National Highway 2 and the Grand Trunk Road. Dhanbad is also connected to the Indian Railways network. The nearest airport is at Ranchi, which is located 130 kilometers from Dhanbad. There are many power transmission lines in Dhanbad. The city is connected to the Eastern Grid of the Power Grid Corporation of India. Dhanbad is also close to many coal mines. Since the city falls within a seismic zone, our analysis requires careful consideration of environmental constraints and safety measures.

**Objectives**

Based on a thorough review of pertinent literature and research, the objective of this project is summarized as follows:

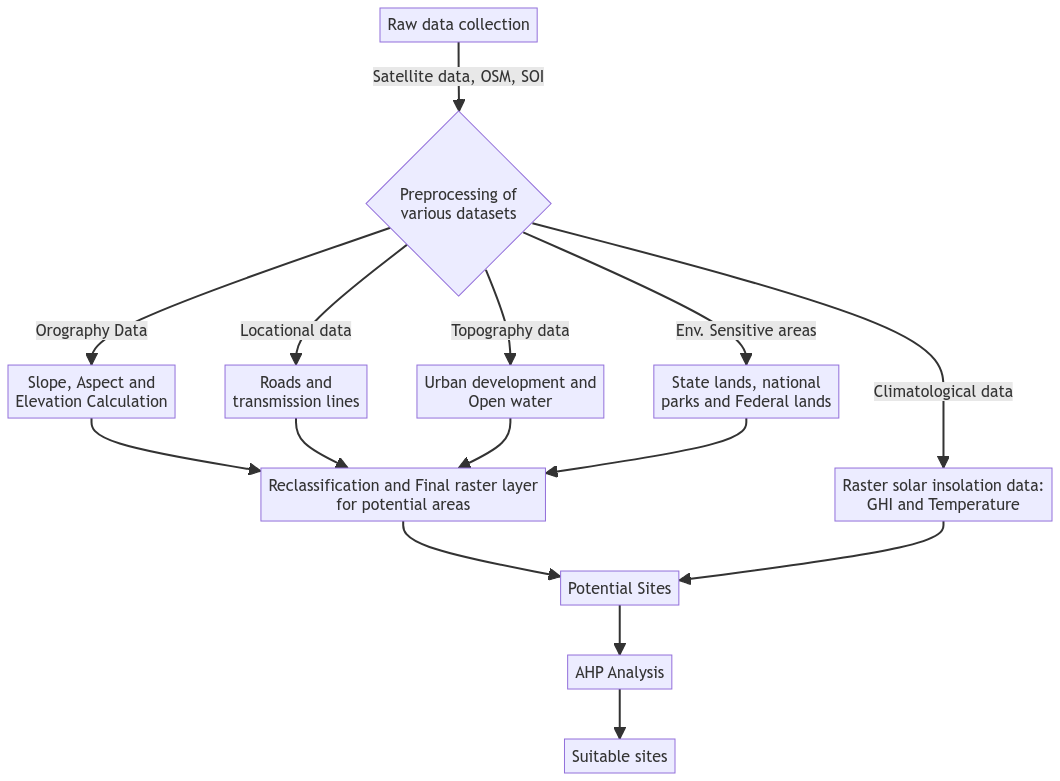
* Conduct a comprehensive site suitability analysis for the installation of solar panels in Dhanbad, utilizing GIS and AHP techniques,
* Identify and assess potential solar installation sites, considering key regional factors such as proximity to mines, precipitation levels, and humidity.
* Analysis based on 4 primary criteria: Climatology, Orography, Location, and Socio-economic criteria.

**Methodology**

The methodology can be summarized in the following steps:

1. Raw data collection: Satellite data, OpenStreetMap (OSM) data, and Survey of India (SOI) data are collected.
2. Preprocessing of various datasets: The satellite data is preprocessed to generate datasets on orography (slope, aspect, and elevation), locational data (roads and transmission lines), topography (urban development and open water), and environmental sensitivity (state lands, national parks, and federal lands).
3. Reclassification and final raster layer for potential areas: The preprocessed datasets are reclassified and combined to create a final raster layer of potential areas for solar PV development.
4. Climatological data: Climatological data on solar insolation (GHI) and temperature are collected.
5. Potential sites: The final raster layer of potential areas is combined with the climatological data to identify potential sites for solar PV development.
6. Analytic hierarchy process (AHP) analysis: An AHP analysis is conducted to prioritize the potential sites based on a set of criteria, such as solar insolation, land availability, and proximity to transmission lines.
7. Suitable sites: The AHP analysis is used to identify the most suitable sites for solar PV development.

Flowchart for above methodology:

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**Brief Description of Criteria:**

1. **Solar Irradiance:** Solar irradiance represents the amount of sunlight a location receives, and it directly affects the energy production potential of a solar panel system.For CSP technology, the Direct Normal Irradiation (DNI) is the significant factor to be appraised since it is the solar component that is concentrated. Whereas, for PV technology the amount of the Global Horizontal Irradiation (GHI) is the factor that should be considered for PV site assessment.
2. **Temperature:** The efficiency of solar panels decreases as the temperature increases. The temperature in Dhanbad rarely goes above 35°C, so it is generally a suitable location for solar installations.However, it is important to consider the specific temperature conditions of the solar site. For example, if the site is exposed to direct sunlight for most of the day, the temperature of the solar panels may be higher than the ambient temperature.
3. **Humidity:** In general, high humidity can have a negative impact on the performance of solar panels. This is because water vapor in the air can absorb sunlight, reducing the amount of sunlight that reaches the solar panels. Additionally, high humidity can promote the growth of dust and dirt on the solar panels, which can also reduce their efficiency.However, the impact of humidity on solar panel performance is relatively small. For example, a study by the National Renewable Energy Laboratory found that a 10% increase in humidity can reduce solar panel efficiency by about 1%. Therefore, while high humidity is not ideal for solar panel installation, it is still possible to have a successful solar installation in Dhanbad. It is important to take steps to mitigate the effects of humidity, such as choosing solar panels that are designed to operate in humid environments and regularly cleaning the solar panels.
4. **Precipitation:** In general, moderate precipitation is not a major concern for solar panel installation. However, it is important to consider the specific precipitation patterns of the solar site. For example, if the site is prone to flooding, special measures may need to be taken to protect the solar panels.Additionally, it is important to note that the impact of precipitation on solar panel performance can vary depending on the type of solar panels used. For example, some solar panels are designed to operate in wet environments, while others are more susceptible to damage from moisture.
5. **Dust:** Dust is an important factor to consider when selecting a site for solar panel installation. Dust can accumulate on solar panels and reduce their efficiency. Additionally, dust can cause damage to solar panels, such as scratching and corrosion. The severity of the impact of dust on solar panel performance depends on a number of factors, including the type of dust, the amount of dust, and the frequency with which the solar panels are cleaned.
6. **Slope:** Slope is an important criteria for site suitability analysis when considering the installation of solar panels. Sloped terrain can create shading issues, with taller objects or natural features casting shadows on the solar panels. Proper site analysis should assess potential shading to ensure panels receive maximum sunlight exposure. Also, proper water drainage is essential to prevent soil erosion and water damage to solar equipment. The slope of the land should facilitate efficient drainage to protect the solar array.
7. **Aspect:** This factor has a direct and significant impact on the overall efficiency and performance of a solar energy system. Proper aspect orientation can result in a substantial increase in energy production over the life of the solar panels. Solar panels should ideally face south (in the northern hemisphere) or north (in the southern hemisphere) to receive the most sunlight throughout the day. Panels facing east or west may still produce energy but at reduced efficiency.
8. **Elevation:** Elevation affects the angle at which sunlight strikes the solar panels and can influence shading, snow accumulation, and temperature. Elevation can influence temperature, which in turn affects the efficiency of solar panels. Generally, higher elevations may experience cooler temperatures, which can be beneficial for panel performance. But sometimes, higher elevations may be more susceptible to shading from nearby structures or natural features. Elevation also impacts the likelihood of snow accumulation on solar panels, which can reduce energy production.
9. **Distance from Roads:** It is an important criterion in site suitability analysis for solar panel installation is crucial for assessing the practicality, cost-efficiency, and overall feasibility of a project. It ensures that the selected site not only meets the technical and environmental requirements but also allows for efficient construction, operation, and maintenance while minimizing environmental impact and costs.
10. **Distance from Power Lines:** This criteria is instrumental in identifying sites that not only meet technical and environmental criteria but also offer practicality, cost-efficiency, and a smoother path to grid connection. It plays a crucial role in the overall feasibility and success of solar panel installations, ensuring that the energy generated can be efficiently delivered to consumers.
11. **Distance from Water Bodies:** Proximity to water bodies, such as rivers, lakes, or ponds, can have environmental implications. Analyzing the distance to water bodies helps in minimizing environmental disruption and safeguarding aquatic ecosystems. It ensures that the installation of solar panels does not harm nearby water resources. But sites near water bodies may benefit from natural cooling effects too. The availability of water for panel cooling systems can help maintain optimal operating temperatures and improve energy production. Also, analyzing the distance to water bodies helps in assessing and mitigating flood risks, especially during periods of heavy rainfall or extreme weather events, ensuring the safety and reliability of the solar installation.
12. **Land use/ Land Cover:** Evaluating land use and land cover as criteria in site suitability analysis for the installation of solar panels is essential for several reasons, especially concerning various land types like barren land, mixed shrubland/grassland, irrigated cropland, herbaceous wetlands, and mixed forest. Properly managed solar installations can provide clean energy benefits while preserving the natural and agricultural landscapes.
13. **Proximity to mines:** Sites very close to coal mines may have easy access to resources and infrastructure. The closer the solar site is to a mine, the greater the risk of mining activities causing ground vibrations and other disturbances that could damage the solar panels. However, it is important to note that the impact of proximity to mines on solar panel performance will vary depending on the specific location of the solar site and the type of mining activities being conducted. For example, a solar site that is located near a coal mine that is actively being mined may be more susceptible to dust and other pollutants than a solar site that is located near a coal mine that is no longer being mined.
14. **Protected areas:** Preserving protected areas ensures the long-term sustainability of natural resources and ecosystems.Planning solar installations away from these areas aligns with responsible and sustainable development practices, supporting both environmental and energy goals.

**Table 2: Ranking of the proposed criteria parameters**

| Factors | Suitability Ranking | | | | |
| --- | --- | --- | --- | --- | --- |
|  | Highly Suitable | Suitable | Moderately Suitable | Less Suitable | Not Suitable |
|  | 1 | 2 | 3 | 4 | 5 |
| Solar Irradiance (KWh/m2/day) | >5.5 | 5.0-5.5 | 4.4-5.0 | 3.8-4.4 | <3.8 |
| Temperature (°C) | 10-15 | 15-25 | 25-30 | 30-35 | >35 |
| Humidity (%) | 50-55 | 55-57 | 57-59 | 59-65 | >65 |
| Annual Precipitation (mm) | 436-550 | 550-675 | 675-800 | 800-1000 | >1000 |
| Dust (days) | <40 | 40-45 | 45-50 | 50-55 | >55 |
| Slope (degree) | <2 | 2-3 | 3-4 | 4-5 | >5 |
| Aspect | South, Flat | SE and SW | East and West | NE and NW | North |
| Elevation (m) | <300 | 300-700 | 700-1100 | 1100-1500 | >1500 |
| Distance from Roads (km) | <10 | 10-20 | 20-30 | 30-40 | >40 |
| Distance from Power lines (km) | <10 | 10-20 | 20-30 | 30-40 | >40 |
| Distance from Water bodies (km) | >28 | 21-28 | 14-21 | 7-14 | <7 |
| Protected Areas (km) | >40 | 30-40 | 20-30 | 10-20 | <10 |
| Land use/ Land cover | Barren/ Sparsely Vegetated | Mixed Shrub-land/Grassland | Irrigated Cropland and Pasture | Herbaceous Wetlands | Mixed Forest |
| Proximity to mines (km) | 5-10 | 10-15 | 15-20 | 20-25 | >30 |

**Work Plan:**

**Table 3: Sequence of proposed work**

| **Work distribution during different months** | Aug - Sep | Oct - Nov | Dec - Jan | Feb - Mar | Apr - May |
| --- | --- | --- | --- | --- | --- |
| Literature Review |  |  |  |  |  |
| Data Collection |  |  |  |  |  |
| Preprocessing Data and Modelling |  |  |  |  |  |
| Statistical Analysis |  |  |  |  |  |
| Final Thesis Preparation & Submission |  |  |  |  |  |

**References:**

IEA, India, Energy Policy Review, 2020, p. 2020. [https://niti.gov.in/sites/ default/files/2020-01/IEA-India 2020-In-depth-EnergyPolicy\_0.pdf](https://niti.gov.in/sites/).

M. Uyan, GIS-based solar farms site selection using analytic hierarchy process (AHP) in Karapinar region , Konya/Turkey, Renew. Sustain. Energy Rev. 28 (2013) 11e17, https://doi.org/10.1016/j.rser.2013.07.042.

Neo, Bloomberg New Energy Finance, The new energy outlook. [https://data.bloomberglp.com/bnef/sites/4/2015/06/BNEF-NEO2015\_Executive-summary. pdf](https://data.bloomberglp.com/bnef/sites/4/2015/06/BNEF-NEO2015_Executive-summary.), 2015. (Accessed 22 February 2021).

IEA, International Energy Agency, How solar energy could be the largest source of electricity by mid-century.[https://www.iea.org/news/how-solarenergy-could-be-the-largest-source-of-electricity-by-mid-century, 2014](https://www.iea.org/news/how-solarenergy-could-be-the-largest-source-of-electricity-by-mid-century,). (Accessed 20 February 2021)

Y. Choi, J. Suh, S.-M. Kim, GIS-based solar radiation mapping, site evaluation, and potential assessment: a review, Appl. Sci. 9 (9) (2019) 1960

H.E. Colak, T. Memisoglu, Y. Gercek, Optimal site selection for solar photovoltaic (PV) power plants using GIS and AHP: a case study of Malatya Province, Turkey, Renew. Energy 149 (2020) 565e576

W. Khemiri, R. Yaagoubi, Y. Miky; Optimal placement of solar photovoltaic farms using analytical hierarchical process and geographic information system in Mekkah, Saudi Arabia. *AIP Conf. Proc.* 20 December 2018; 2056 (1): 020025. <https://doi.org/10.1063/1.5084998>

Yelmen, Bekir, Tarik Çakir, M., 2016. Influence of temperature changes in various regions of Turkey on powers of photovoltaic solar panels. Energy Sources Part A 38, 542–550. [https://doi.org/10.1080/15567036.2011.551925.](https://doi.org/10.1080/15567036.2011.551925)

Doljak, Dejan, Stanojevic´, Gorica, 2017. Evaluation of natural conditions for site selection of ground-mounted photovoltaic power plants in Serbia. Energy 127, 291–300. [https://doi.org/10.1016/j.energy.2017.03.140.](https://doi.org/10.1016/j.energy.2017.03.140)

Cioban, Alina, Criveanu, Horia, Matei, Florica, Pop, Ioana, Rotaru, Ancuta, 2013. Aspects of solar radiation analysis using ArcGis. Bull. UASVM Horticulture 70, 437–440.

Al Garni, Hassan & Awasthi, Anjali. (2017). A fuzzy AHP and GIS-based approach to prioritize utility-scale solar PV sites in Saudi Arabia. <https://doi.org/10.1109/SMC.2017.8122783.>

Noorollahi, Younes & Ghenaatpisheh Senani, Ali & Fadaei, Ahmad & Simaee, Mobina & Moltames, Rahim. (2022). A framework for GIS-based site selection and technical potential evaluation of PV solar farm using Fuzzy-Boolean logic and AHP multi-criteria decision-making approach. Renewable Energy. 186.<https://doi.org/10.1016/j.renene.2021.12.124>

Zoghi, M., Houshang Ehsani, A., Sadat, M., javad Amiri, M., Karimi, S., 2017. Optimization solar site selection by fuzzy logic model and weighted linear combination method in arid and semi-arid region: a case study Isfahan-Iran. Renew. Sustain. Energy Rev. [https://doi.org/10.1016/j.rser.2015.07.014.](https://doi.org/10.1016/j.rser.2015.07.014)

Ouchani, F., Jbaihi, O., Maaroufi, M., Ghennioui, A., 2020. Identification of suitable sites for large-scale photovoltaic installations through a geographic information system and analytical hierarchy process combination: a case study in Marrakesh-Safi region, Morocco. Prog. Photovoltaics Res. Appl. 3357 [https://doi.org/10.1002/pip.3357](https://doi.org/10.1002/pip.3357%20) pip.

Hassaan, Mahmoud & Hassan, Ahmed & Aldashti, Hasan. (2020). GIS-based suitability analysis for siting solar power plants in Kuwait. The Egyptian Journal of Remote Sensing and Space Science. 24. [https://doi.org/10.1016/j.ejrs.2020.11.004.](https://doi.org/10.1016/j.ejrs.2020.11.004)

Ruiz, H.S., Sunarso, A., Ibrahim-Bathis, K., Murti, S.A., Budiarto, I., 2020. GIS-AHP Multi Criteria Decision Analysis for the optimal location of solar energy plants at Indonesia. Energy Rep. 6, 3249–3263. [https://doi.org/10.1016/j.egyr.2020.11.198.](https://doi.org/10.1016/j.egyr.2020.11.198)

S.K. Saraswat, Abhijeet K. Digalwar, S.S. Yadav, Gaurav Kumar, MCDM and GIS based modelling technique for assessment of solar and wind farm locations in India,Renewable Energy,Volume 169, 2021, [https://doi.org/10.1016/j.renene.2021.01.056.](https://doi.org/10.1016/j.renene.2021.01.056)

Günen, M.A., 2021. A comprehensive framework based on GIS-AHP for the installation of solar PV farms in Kahramanmaras¸, Turkey. Renew. Energy 178, 212–225. [https://doi.org/10.1016/j.renene.2021.06.078.](https://doi.org/10.1016/j.renene.2021.06.078)

Al Garni, H.Z., Awasthi, A., 2017. Solar PV power plant site selection using a GIS-AHP based approach with application in Saudi Arabia. Appl. Energy 206, 1225–1240. [https://doi.org/10.1016/j.apenergy.2017.10.024.](https://doi.org/10.1016/j.apenergy.2017.10.024)

Aly, A., Jensen, S.S., Pedersen, A.B., 2017. Solar power potential of Tanzania: identifying CSP and PV hot spots through a GIS multicriteria decision making analysis. Renew. Energy 113, 159–175. [https://doi.org/10.1016/j.renene.2017.05.077.](https://doi.org/10.1016/j.renene.2017.05.077)

Pietras-Szewczyk, Małgorzata, 2017. Generate real total radiation spatial distribution of solar radiation using cloud mask algorithm. Geomatics Environ. Eng. 11, 41. [https://doi.org/10.7494/geom.2017.11.2.41.](https://doi.org/10.7494/geom.2017.11.2.41)

Pragya Gupta Dr. S.R. Samadder

(20JE0695) (Professor/ESE)