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DATA-DRIVEN OPTIMAL SITE SELECTION FOR SOLAR POWER PLANTS BASED ON SOLAR IRRADIANCE ANALYSIS

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Highlights

- Monthly GHI maps were generated using DNI, DIF, and solar incidence angles
- A GIS-based GHI approach was developed for solar power plant suitability
- High and very high suitability areas cover 28% of Elmalı
- Highest GHI values were concentrated in central and southwestern Elmalı
- Priority areas for solar power plant investments were identified
- The results support data-driven solar energy planning and investment

Graphical Abstract

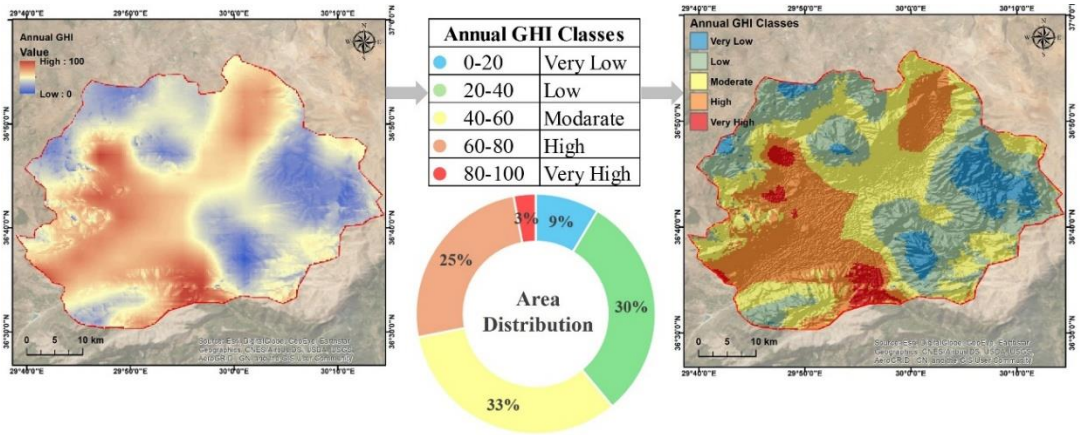


Figure Graphical abstract of the paper

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ABSTRACT: Solar power plants play a critical role in meeting global energy demands in a sustainable and environmentally friendly manner. The efficiency and long-term sustainability of clean energy production largely depend on the optimal siting of these plants, making solar irradiation data a crucial factor for ensuring maximum energy yield. This study focuses on Global Horizontal Irradiance (GHI), one of the most significant and widely used indicators in the literature for identifying suitable solar power plant locations, by performing monthly analyses through remote sensing (RS) and geographic information systems (GIS). Regions with higher irradiation levels were classified accordingly. Technical, environmental, and economic factors, which may vary across countries or regions, were intentionally excluded to highlight the primary influence of solar irradiance on site suitability. The study was conducted specifically for the Elmalı district in Antalya, Türkiye. Results show that 28% of the area is highly suitable for solar power plant installation, 33% is moderately suitable, and 39% is less suitable based on GHI. In absolute terms, 4,969 hectares are classified as "very high suitability" and 43,038 hectares as "high suitability," indicating areas with strong investment potential. This study provides a clear, data-driven assessment of irradiance-based suitability and is expected to support and guide strategic solar energy investment and planning decisions in the region.

Keywords: *Solar power plants, solar radiation, suitable site selection, Global Horizontal Irradiance, Remote sensing and GIS.*

1. INTRODUCTION

The global demand for energy continues to grow steadily due to increasing population, industrialization, and technological advancements [1]. According to reports by the International Energy Agency (IEA), a significant rise in energy demand is expected in the coming years, particularly in developing countries [2]. This increasing demand intensifies the pressure on fossil fuels, which have limited reserves and cause environmental harm. Consequently, this situation presents serious challenges in terms of energy security and sustainability [3]. With environmental threats such as global warming and climate change becoming more apparent, the need for sustainable and environmentally friendly energy sources has become more crucial than ever [4].

In this context, solar energy stands out among renewable energy sources as a prominent alternative due to its considerable advantages over traditional energy sources [5]. Compared to other renewables such as wind, hydroelectric, and geothermal energy, solar energy holds great potential due to its accessibility, continuity, and environmentally benign nature [6]. It is estimated that the Sun delivers more energy to the Earth in one hour than the entire world consumes in a year [7]. This immense potential can be converted into electrical energy through photovoltaic (PV) systems and solar thermal technologies, serving as an effective tool in reducing dependence on fossil fuels in energy production [8].

Türkiye is one of the countries with a high solar energy potential due to its geographical location [5].

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With an average annual total sunshine duration of 2,741.07 hours, an average daily sunshine duration of 7.50 hours, an average annual total solar irradiation of 1,527.46 kWh/m², and an average daily total irradiation of 4.18 kWh/m², Türkiye is in an advantageous position for solar energy production [9]. Despite this potential, a significant portion of the country's energy demand is still met through imported fossil fuels. In 2024, the distribution of electricity generation in Türkiye was as follows: 35.2% from coal, 18.9% from natural gas, 21.5% from hydropower, 10.5% from wind, 7.5% from solar, 3.2% from geothermal energy, and 3.2% from other sources [10]. This situation increases economic dependency on foreign energy sources and poses challenges to environmental sustainability. In recent years, however, Türkiye has taken significant steps in the field of renewable energy, leading to a rise in solar energy investments. As of the end of March 2025, the total number of electricity generation facilities in Türkiye reached 35,160, including unlicensed power plants. Of these, 768 are hydroelectric, 72 are coal-based, 376 are wind, 66 are geothermal, 333 are natural gas, 33,086 are solar, and 459 operate with other sources [10]. Thanks to governmental incentives, regulatory policies, and private sector initiatives, solar power plants have become increasingly widespread in electricity generation.

Among the most effective strategies for large-scale solar energy utilization is the development of solar power plants [11]. Therefore, site selection for solar power plants is of critical importance for the success of such projects. These solar power plants convert sunlight directly into electrical energy through photovoltaic panels spread across large areas, feeding the electricity into the grid [12]. However, the efficiency and economic viability of solar power plants depend heavily on proper site selection [13]. A well-selected site maximizes energy production, minimizes operational costs, and ensures long-term sustainability. Conversely, poorly chosen locations may result in low energy yields, high maintenance costs, and various environmental or social challenges [14]. Identifying suitable areas for solar power plants requires a complex decision-making process that takes into account a wide range of technical, economic, environmental, and social factors [15, 16]. These factors include sunshine duration, solar radiation intensity and distribution, air temperature, wind direction, humidity, land slope and aspect, land use status, proximity to the power grid and transformers, accessibility, and environmental protection statuses [16]. Traditional site selection methods primarily rely on field surveys and expert opinions, which can be time-consuming and prone to subjectivity. In contrast, modern approaches employ Geographic Information Systems (GIS), Multi-Criteria Decision Making (MCDM) techniques, and remote sensing technologies to provide more objective and data-driven analyses [17].

Global Horizontal Irradiance (GHI) data is among the most critical factors used in solar power plants site selection [18]. GHI refers to the amount of solar energy received on a given surface over a specific time period and directly influences the capacity for electricity generation from solar power [19]. Therefore, analyses conducted using high-accuracy GHI data can more reliably predict potential energy output [20]. Considering that solar irradiance exhibits seasonal and geographical variability, the use of detailed and localized solar data is of great importance in the site selection process.

While previous studies have incorporated GHI within multi-criteria frameworks, few have prioritized it as the sole determinant in site selection, highlighting a gap in the literature that this study aims to address. The innovation of this study lies in placing GHI data at the core of the solar power plants site selection process and producing decision-supporting outcomes by analyzing the annual variations in GHI based on the sun's angle of incidence throughout the year. While many studies incorporate GHI as part of multi-criteria analyses [21, 22, 23], studies that calculate GHI by accounting for the local angle of solar incidence are limited. This research approaches GHI—the most important and prioritized factor in solar power plants site selection—as the primary determining criterion, analyzing and mapping its variation over the course of a year. Through this approach, it is aimed to first identify the adequacy of solar irradiance levels by month for any region where a solar power plant are planned, thereby accelerating the decision-making process and directing investments more effectively. Accordingly, basic solar radiation components such as Global Horizontal Irradiance (GHI), Direct Normal Irradiance (DNI), and Diffuse Horizontal Irradiance (DIF), which are essential for the effective management of solar energy harvesting, were used in the study [24].

The study was conducted in Antalya province, located in southwestern Türkiye, specifically focusing on the Elmalı district. Antalya is a significant region in terms of both tourism and agriculture, and it is one of the areas with high solar potential [5]. With predominantly sunny weather throughout much of the year, Antalya presents a highly suitable geography for solar energy investments [25]. Elmalı, located in the northwestern part of Antalya, features relatively flat terrain, low building density, and consistent solar exposure [26]. However, the mountainous surroundings and locally variable climate conditions increase the importance of micro-regional analyses. Therefore, analyses conducted specifically for Elmalı are expected to accelerate solar power plants site selection decisions and guide investors. In this context, the study aims to determine the most suitable areas for solar power plants in Elmalı solely based on solar irradiance data. Through spatial analyses conducted in a GIS environment, concrete maps and reliable information will be generated for investors and planners. It is anticipated that the methodology used and the results produced will serve as a model not only for Elmalı and Antalya but also for all other regions where solar power plants are planned—especially in determining the sufficiency of solar irradiance and facilitating rapid decision-making in the early stages of investment. In conclusion, this study aims to contribute to the field of sustainable energy planning and to enhance the efficiency of energy investments by supporting rapid decision-making processes through a solar irradiance-based site selection methodology. The approach developed through the Antalya-Elmalı case study highlights the significance of scientific data and geographic analyses in the transition to clean energy.

2. MATERIAL AND METHODS

2.1. Study area

Located in the south of Türkiye, within the administrative boundaries of Antalya Province, Elmalı district is situated on a plateau that extends through the Western Mediterranean Region of the Taurus Mountains, which cover Southern Anatolia. The district lies on the southern foothills of Mount Elmalı, which reaches an elevation of 2,503 meters [27]. The study area encompasses the entire district, covering approximately 168,000 hectares [28]. According to the address-based population registration system, the total population of the district in 2024 was 41,853 [29]. The district is located at coordinates 36°43'49.70"N and 29°52'53.48"E (Figure 1).

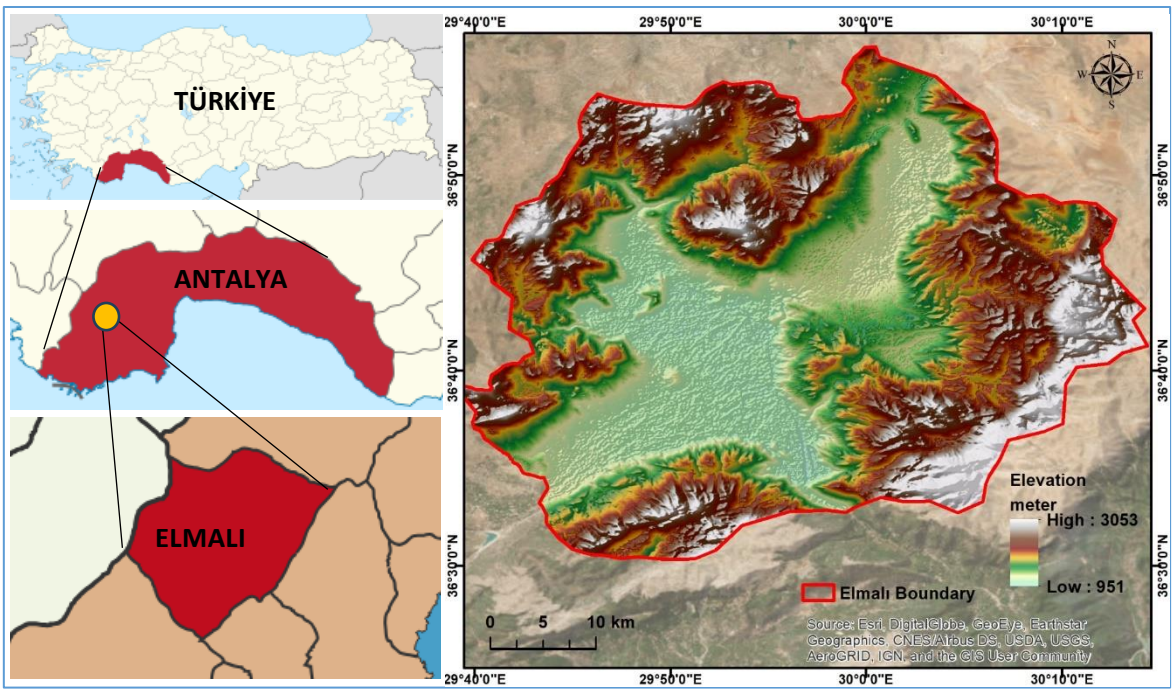


Figure 1. Geographical location of the study area

According to the Köppen climate classification, the district falls under the Csa Mediterranean climate category [30]. In the Elmalı region, summers are warm, dry, and clear, while winters are long, very cold, wet, and partly cloudy. Throughout the year, temperatures typically range between -2°C and 30°C, and rarely fall below -7°C or rise above 32°C. The warm season lasts for approximately 3.2 months, from June 14 to September 20, with average daily high temperatures exceeding 25°C. July is the hottest month in Elmalı, with an average high of 29°C and a low of 16°C. The cold season lasts for about 3.8 months, from November 27 to March 21, with average daily high temperatures below 11°C. January is the coldest month, with average low and high temperatures of -2°C and 6°C, respectively. The average daily incident shortwave solar energy exhibits seasonal variation throughout the year. The sunnier period of the year lasts for approximately 3.5 months, from May 11 to August 25, during which the average daily incident shortwave energy exceeds 7.3 kWh per square meter (Figure 2). June is the sunniest month in Elmalı, with an average of 8.3 kWh, while December is the darkest month, with an average of 2.4 kWh [31].

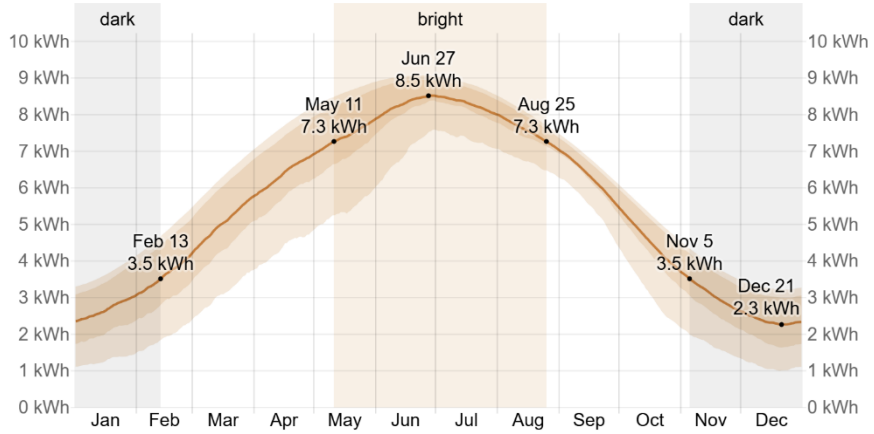


Figure 2. Average daily incident shortwave solar energy in Elmalı district [31]

2.2. Methods

The core dataset of this study consists of solar irradiance data (DNI and DIF) and the sun's angle of incidence by month throughout the year. In the study methodology, the sun's angles of incidence were first calculated specifically for the region, and these angles were then used together with DNI and DIF data to compute GHI. Monthly GHI maps were generated for the Elmalı district, and these maps were subsequently combined to determine GHI suitability classes for the year 2024.

The spatial analysis of solar irradiance for the Elmalı district was performed using ArcGIS Pro 3.1, integrating multiple data layers to generate precise suitability maps. Monthly GHI maps were created as raster layers, and solar incidence angles were incorporated to ensure accuracy in energy potential estimation. Subsequently, overlay analysis and raster algebra were applied to combine the monthly layers into an annual suitability map, which was then normalized to a 0–100 scale. The classification of suitability levels was based on standardized thresholds, allowing consistent identification of areas with very high, high, moderate, low and very low potential. The workflow included creating the following GIS layers: (i) monthly GHI rasters, (ii) solar incidence angle rasters, and (iii) composite suitability maps.

Solar irradiance data: Solar irradiance refers to the instantaneous power per unit area received from the sun on a given surface. It comprises different components: direct irradiance, which is the portion of solar power that arrives at the surface in a straight line from the sun; diffuse irradiance, which results from solar radiation scattered by atmospheric particles; and global irradiance, which is the total of both direct and diffuse components incident on the surface. In contrast, solar irradiation denotes the total solar energy received per unit area over a defined time interval, typically expressed in joules per square meter or kilowatt-hours per square meter [32]. The Global Solar Atlas (https://globalsolaratlas.info/map) provides

three main solar radiation indicators. Global Horizontal Irradiance (GHI) and Diffuse Horizontal Irradiance (DIF) are measured with respect to a surface oriented horizontally to the ground, while Direct Normal Irradiance (DNI) is measured on a surface that remains perpendicular to the sun's direct rays [24, 33]. The relationship between GHI, DNI, and DIF is illustrated in Figure 3, and the calculation of GHI is given in Equation 1 [34]. The primary dataset of this study consists of solar irradiance data (DNI and DIF) and the monthly variation in the sun's angle of incidence throughout the year. As part of the study methodology, solar angles were first calculated specifically for the region, and these angles were then integrated with DNI and DIF data to calculate GHI. Monthly GHI maps were generated for the Elmalı district, and these were subsequently compiled to define GHI suitability classes for the year 2024.

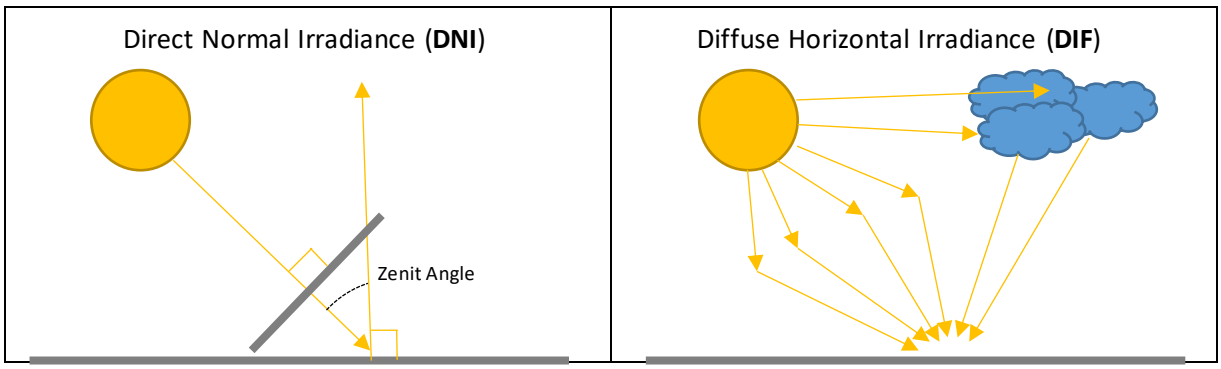


Figure 3. Schematic representation of DNI and DIF

$$GHI = DIF + DNI * cos_{(zenit)} \quad (1).$$

In this study, the DNI and DIF data were obtained from the official website of the Global Solar Atlas (https://globalsolaratlas.info/map) which is open-access and easily accessible. The units of the data are in W/m², and the datasets were subset according to the boundaries of the Elmalı district and then transferred into the GIS environment.

Solar incidence angle data: The solar incidence angle refers to the angle at which solar rays strike the Earth's surface, directly influencing the intensity of solar energy received. As the sun's rays become more perpendicular to the surface (i.e., the incidence angle increases and the zenith angle decreases), the amount of energy reaching the surface also increases. This angle varies depending on the time of day, time of year, geographical location, and surface slope [35, 36]. Therefore, the solar incidence angle is considered one of the most critical factors in maximizing solar energy yield in solar power plants. The calculation of the solar incidence angle is presented in Equation 2.

$$\cos\theta_s = \sin\alpha_s = \sin\Phi \sin\delta + \cos\Phi \cos\delta \cos h \quad (2)$$

αs: Solar altitude angle (in degrees
θ_s: Solar zenith angle (in degrees)
δ: Solar declination, calculated based on the day of the year
ϕ: Latitude of the location
h: Local hour angle, calculated using local solar time
Solar Declination (δ)

$$\delta = -23.45° \times \cos\left(\frac{360°}{365} \times (d + 10)\right)$$

Where, d represents the day of the year (for example, d = 5 for January 5).
Local Hour Angle (h):
$h = 15° \times (T - 12)$ (3)

Where, T is the local solar time expressed in hours (when T = 12, $h = 0$, which corresponds to the time when the sun's rays strike the surface at the most perpendicular angle).

Using the formula mentioned above, the monthly solar incidence angles were calculated separately for each of the 12 months specific to the Elmalı district (Table 1).

Table 1. Monthly solar incidence angles for Elmalı district for 2024

Date/Month	Angle	Date/Month	Angle	Date/Month	Angle	Date/Month	Angle
01 September	28.92°	01 December	58.81°	30 March	33.22°	21 June	13.29°
01 October	40.85°	31 January	54.59°	30 April	22.23°	01 July	13.60°
01 November	52.02°	29 February	45.50°	31 May	14.87°	01 August	18.76°

In determining the most suitable areas for solar energy fields within the scope of solar radiation data of Elmalı district, the data produced after determining the sun's incidence angles were used in the calculation of GHI and 12-month suitability maps were created. Then, these maps were normalized to the range of 0-100, combined by performing overlay analysis and the most suitable areas were classified within the scope of GHI.

3. RESULTS

In this study, conducted to determine the most suitable locations for the installation of solar power plants in Elmalı District of Antalya Province based on Global Horizontal Irradiance (GHI), Direct Normal Irradiance (DNI) and Diffuse Horizontal Irradiance (DIF) maps were generated to create the GHI maps (Figure 4).

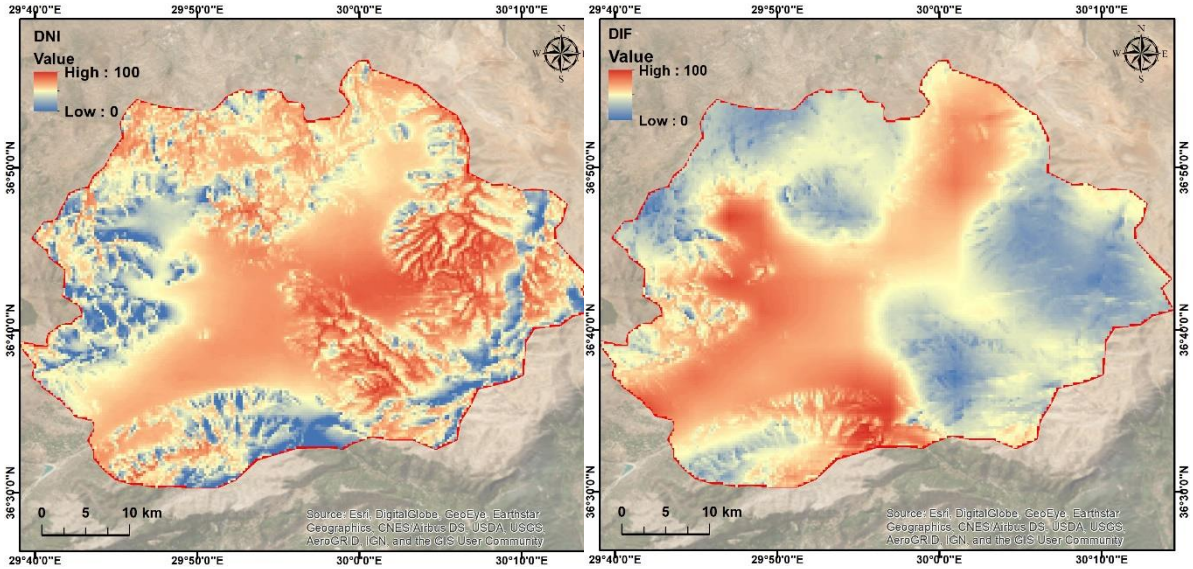


Figure 4. DNI and DIF maps of Elmalı District

In the DNI map, the central parts of the city, which are relatively flat or nearly flat, along with the northeastern regions, exhibit high potential in terms of direct solar irradiance. In contrast, the DIF map indicates that the southwestern parts of the city are more affected by irradiance due to diffuse radiation reaching the Earth's surface. Although both maps provide information on radiation intensity, considering the monthly variations in the solar incidence angle, the GHI maps—generated by integrating these two

maps with the sun's angle of incidence—offer a more comprehensive understanding of the region's monthly total irradiance (Figure 5).

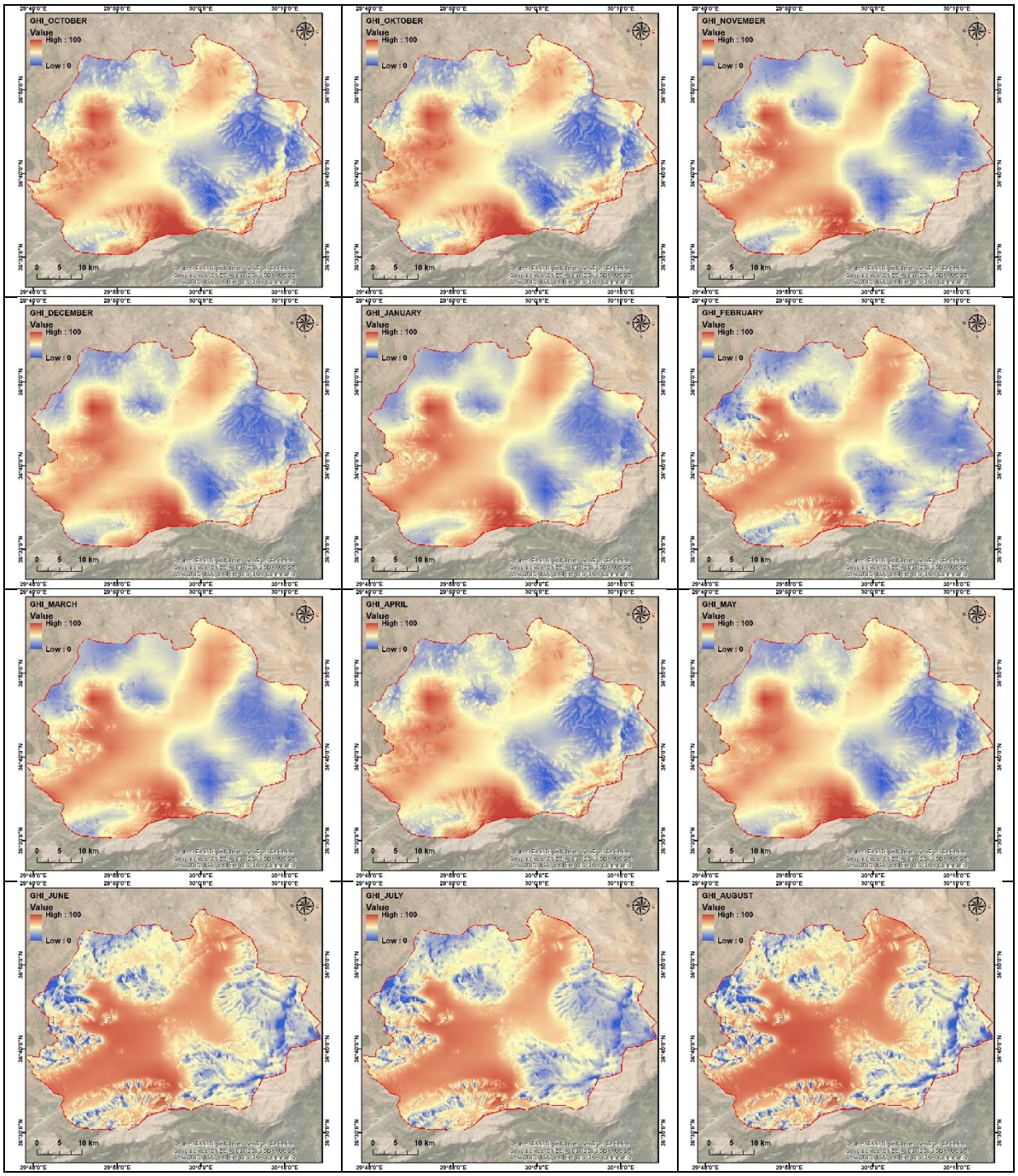


Figure 5. GHI maps produced for each month

In the maps above, the normalized GHI values range from blue (0) to brown (100), representing low to high solar irradiance, respectively. These values illustrate the spatial distribution of solar radiation received at the surface. During the summer months, extensive brown and orange areas observed in the central and southwestern parts of the study area indicate high solar irradiance potential. These regions typically correspond to relatively flat terrain and south-facing slopes, making them highly suitable for photovoltaic (PV) system installations. Conversely, the dominant blue tones along the northeastern and

eastern edges of the region indicate lower GHI values, likely due to mountainous terrain, shadowing effects, or north-facing slopes, which reduce solar energy utilization potential. The summer distribution of GHI is directly influenced by the topographic diversity of Elmalı. Mountainous areas create significant variability in GHI due to shadowing and slope effects. This variation is particularly evident in valleys and ridge lines, where mixed color patterns appear on the maps. In winter, due to the region's continental climate, temperature drops and cloudiness increases. The maps for winter months reveal a significant reduction in GHI values compared to the summer period. During these months, GHI values are closely linked to cloud cover, atmospheric humidity, and the angle of solar incidence. In December, January, and February, the duration of sunshine shortens and the solar altitude decreases. As the sun's rays reach the Earth at lower angles, they travel a longer atmospheric path, leading to greater scattering and refraction, which in turn reduces GHI levels. January is particularly characterized by a high number of cloudy days, making diffuse radiation more dominant than direct irradiance. Low winter GHI values decrease the efficiency of solar energy systems; therefore, optimizing the tilt angle of solar panels is essential for maximizing energy capture during this season. In spring (March, April, May) and autumn (September, October, November), the monthly total GHI values in Elmalı exhibit a balanced distribution, aligned with seasonal transitions and influenced by solar incidence angle, day length, and topographic effects. In spring, the solar angle gradually increases starting in March, when monthly total GHI in Elmalı typically ranges between 120–140 kWh/m². As sunshine duration increases and cloudiness decreases in April, the solar angle becomes steeper, raising GHI values to approximately 160–180 kWh/m². In May, this upward trend peaks, with monthly GHI generally reaching 200–220 kWh/m². In autumn, GHI values follow a reverse trend. Due to the lingering effects of summer, September values remain high at around 180–200 kWh/m². These values decrease to 140–160 kWh/m² in October and drop further to 90–110 kWh/m² in November. As the solar incidence angle declines, the atmospheric path lengthens, leading to increased scattering and reduced GHI. In mountainous regions and valleys, topography can cause shading during morning and evening hours, resulting in locally lower GHI values. Due to Elmalı's high elevation, the thinner atmosphere leads to relatively lower radiation losses, allowing for more effective GHI reception on clear days. The regular monthly increase and decrease in GHI plays a significant role in the seasonal efficiency analysis of solar energy systems. By optimizing panel tilt angles according to the seasons, maximum benefit can be derived during these transitional periods.

Considering Elmalı District's land use characteristics, topography, and monthly GHI values, the area shows significant potential for the development of large-scale solar power plants. Given their ability to generate energy year-round, monthly GHI maps were combined to produce an annual GHI map. This map was categorized into five equally spaced classes (0–20 Very Low, 20–40 Low, 40–60 Moderate, 60–80 High, 80–100 Very High) (Figure 6).

In the resulting maps, high GHI values are observed in the southwestern and central parts of the district. These areas are advantageous in terms of annual total sunshine duration and solar irradiance intensity and should be prioritized as potential locations for solar power plant installations. High GHI levels are a key factor that directly increases the annual energy output of photovoltaic systems. In contrast, the eastern and northeastern parts of the region exhibit lower annual GHI values, which is most likely due to topographical barriers such as mountainous terrain, north-facing slopes, and valleys. These areas, where the solar incidence angle is less favorable and shading effects are more prominent, are therefore less suitable for solar energy investments. The topographical structure of Elmalı significantly affects the distribution of GHI. Located at an elevation of approximately 1100 meters in the interior parts of the Western Taurus Mountains, the district features rugged terrain. The areas with high GHI values are predominantly concentrated on south- or southwest-facing sloped terrains, as observed in the maps. These orientations allow solar radiation to strike the surface at steeper angles throughout the year, thereby increasing irradiance intensity. As a result, south-facing slopes are more suitable for solar power plant installations, both technically and economically. Conversely, areas with low GHI values are generally located on topographically enclosed, shaded, or high-altitude north-facing slopes. These locations, due to

their shorter sunshine durations and higher shading potential, should be considered secondary priorities in terms of solar energy investment.

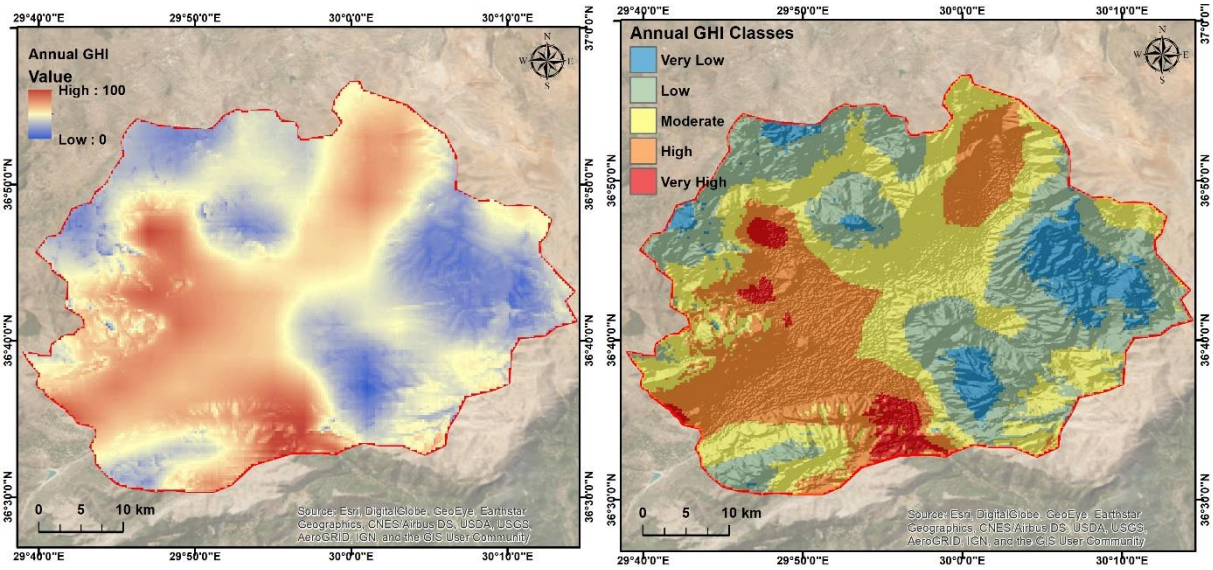


Figure 6. The Annual GHI map generated from monthly data (left), and the Suitable Sites for Solar Power Plants map based on annual GHI (right).

In conclusion, the GHI maps generated by integrating DNI and DIF data with region-specific monthly solar incidence angles demonstrate that the Elmalı district offers favorable conditions for solar power plant investments. According to the solar suitability map created using normalized GHI values, within the study area, 14,431 ha fall into the "very low" class, 50,912 ha into the "low" class, 55,219 ha into the "moderate" class, 43,038 ha into the "high" class, and 4,969 ha into the "very high" class. Accordingly, the areas with high and very high GHI values—suitable for solar power plant development—constitute 28% of the entire study area. Approximately 33% of the area falls into the moderate GHI class, while 39%, influenced by topography and solar incidence angle, belongs to the low GHI class.

4. DISCUSSION AND CONCLUSIONS

This study focuses on identifying the most suitable locations for the installation of solar power plants based on Global Horizontal Irradiance (GHI), with solar irradiance values calculated and classified specifically for the study area. GHI plays a fundamental role in determining optimal sites for solar power plant, as it incorporates components such as direct solar radiation, atmospheric scattering, and surface reflections, making it a direct indicator of solar energy production potential [37, 38]. In solar power plant projects, the return on investment, system efficiency, and energy production capacity are highly dependent on GHI levels [39]. Areas with high GHI values enable solar panels to generate more electricity, leading to faster investment recovery and more cost-effective operation [24]. Conversely, in areas with low GHI values, factors such as shading, cloud cover, or topographic barriers can reduce system efficiency, potentially rendering projects economically unviable. Therefore, GHI data is recommended to be considered among the primary criteria during site selection, as it plays a critical role in determining the efficiency of photovoltaic systems. In this study, Global Horizontal Irradiance was used as the basis for evaluating solar energy potential at a regional scale. However, since photovoltaic panels are practically installed at specific tilt angles and orientations, the irradiance they actually receive is defined as Global Tilted Irradiance, which can differ considerably from GHI, especially in areas with complex and rugged topography due to slope orientation and topographic shading [40]. In this context, while GHI-based analyses provide a strong indicator for preliminary regional assessments and accelerating investment

decisions, GTI-based analyses should be considered in future micro-siting and detailed system design studies to achieve more accurate predictions of energy production potential [41].

In the literature, while the relative importance of GHI compared to other criteria varies across studies, it is generally assigned a weight between 30% and 60% [22, 42, 43]. For instance, GHI was assigned a weight of 31% in a study conducted in Morocco [43], 35% in Saudi Arabia [22], and 59% in southwestern Iran [14]. Even slight increases in this weight were found to significantly influence the results of site suitability analyses. Other criteria include land slope, orientation, proximity to infrastructure, land use, and distance from environmentally protected areas [44, 45]. However, due to its direct representation of solar energy production potential, GHI's relatively high weight ensures that it remains a top priority in decision-making processes.

The mountainous topography of the Elmalı district and the persistent snow cover observed during winter months make the role of surface albedo particularly significant in solar energy potential. Snow-covered surfaces have higher reflectance coefficients compared to bare soil or vegetation, reflecting a substantial portion of incoming shortwave solar radiation and thereby increasing ambient irradiance levels [46]. This increase can provide additional gains in total energy output, especially in bifacial photovoltaic panels, due to enhanced rear-side irradiance [47]. However, the current study primarily presents a macro-scale site selection analysis, and the albedo effect is not directly quantified. Evaluating this effect requires a combined consideration of parameters such as panel type, installation geometry (panel tilt and orientation, elevation above ground), and micro-scale radiation measurements [48]. In this context, considering the potential contributions of seasonal albedo variations to energy production in snow-covered regions like Elmalı, future studies based on detailed field measurements and micro-scale modeling are expected to significantly improve the accuracy and applicability of energy yield predictions. In addition, the Global Solar Atlas datasets used in this study represent an appropriate and widely accepted data source for assessing solar energy potential at the regional scale. Nevertheless, the use of higher spatial resolution satellite data (e.g., Sentinel-2) would enable more detailed, pixel-level analyses of topographic shading, land cover heterogeneity, and micro-scale irradiance variations. Integrating such high-resolution datasets would contribute to more precise determination of solar energy potential in future micro-siting and detailed system design studies.

In conclusion, GHI is one of the most decisive factors in SPP site selection and is advised to be prioritized in the planning of solar energy investments. To achieve high efficiency and maximize benefits during the planning and investment stages of solar power plants, it is recommended that GHI be assessed alongside environmental, technical, economic, and topographic criteria. Ultimately, optimal site selection for solar power plants based on GHI analysis is considered appropriate for successful and sustainable solar energy investments.

Declaration of Ethical Standards

The authors declare that all ethical guidelines including authorship, citation, data reporting, and publishing original research are followed.

Credit Authorship Contribution Statement

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Author 1 and Author 2. The first draft of the manuscript was written by Author 1 and all authors commented on previous versions of the manuscript. All authors read and approved of the final manuscript.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data Availability

The data presented in this study are available on request from the corresponding author due to their reuse in future studies planned to be conducted in the same region using different models.

Use of Artificial Intelligence

Generative AI tools were used only for language editing and improving readability. The authors are fully responsible for the scientific content, accuracy, and originality of the manuscript.

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