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Investigating solar radiation (case study: Shemiranat city)

Sobhanian Sodabeh ✉

Department of Geography, Firouzabad Institute of Higher Education, Firouzabad, Fars, Iran

✉ sodabesobhani3@gmail.com

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Abstract:

Solar energy is one of the most important and cleanest types of renewable energy in the world. Suitable climatic conditions in Iran due to being in a special geographical position and the high potential of receiving solar energy, is a factor to make the most of this huge source of clean energy production. Information related to global solar radiation is needed in many fields such as agriculture, hydrology, solar energy systems, and studies related to water, soil, and plant relationships. In stations where there is no solar radiation measuring device, using common estimation models, the value of this parameter can be estimated with appropriate accuracy. Meanwhile, the use of mathematical methods as one of the methods of calculating solar radiation is very common. Based on this, the aim of this study is to calculate the amount of solar radiation (pure, in clear sky, short wavelength radiation, etc.) for the synoptic station in the north of Tehran. Using computational methods, we will calculate all the parameters involved in radiation estimation and reach the final goal. Therefore, the average net outgoing long wave radiation is 13.38 MJ/m2/day, solar radiation in a clear sky is 12.89 MJ/m2/day, specific incoming short wave radiation is 7.33 MJ/m2/day, daily extraterrestrial radiation is 16.53 MJ/m2/day and long wave radiation Short wave is 9.77 MJ/m2/day.

Key words: solar radiation, north of Tehran, renewable energy.

1.Introduction

The tremendous development of science and technology in today's world has apparently brought about the comfort and well-being of human life, but this development has also caused new problems for humans, including environmental pollution, extensive changes in the climate on earth, especially heat and he pointed out the decrease in precipitation (Dimitrios et al., 2015). Most of the energy consumed in the world is provided by fossil fuels. Combustion of fossil fuels causes a huge amount of sulfur and nitrogen oxides, carbon monoxide and carbon dioxide to enter the atmosphere (Esfandiari, 2019). The continuous increase in the level of greenhouse gas emissions and the rise in the price of fuel materials are the main driving forces behind more effective efforts to use different sources of renewable energy (Kinsarin, 2007). These problems have led the world to use alternative energies that have less destructive effects and are also renewable. Alternative energy refers to energy that is produced from carbon-free sources; such as solar energy, wind energy, marine energy, geothermal, hydropower plants, etc. Meanwhile, solar energy is one of the most important and cleanest types of renewable energy in the world (Haidari, 2008). Continuous monitoring of solar radiation reaching the earth's surface is of particular importance due to its effect on the earth's heat balance, effect on air and soil heat, evaporation and transpiration, photosynthesis and snow melting. Investigating changes in radiation is used in branches such as hydrology, meteorology, biological processes, thermal systems and agriculture (Adicost et al., 1987:141). Solar radiation is one of the safest, most effective and economical sources of energy, which has the potential to become the main source of energy in the near future (Dinser, 2000). Estimation of solar radiation reaching the earth's surface has many applications in architectural sciences, energy engineering, agriculture and hydrology. The correct estimation of the amount of solar radiation is one of the basic and important principles of network design and irrigation planning (Elmoreux and Hontoria, 2004). Also, accurate knowledge of the amount and intensity of solar radiation in a place is necessary for the expansion of solar sites and in the long term, estimating the change in efficiency of solar systems. Such information is used in the design, cost estimation and efficiency calculation of projects (Hotel and Willier, 1958). Due to its location in low latitudes, Iran has a greater ability to receive radiant energy (Battles et al., 2008). Also, due to the presence of many windy areas, it has a high potential in the field of using wind energy. Exploitation of wind energy in Iran has practically started since 2013 in Manjil and Rudbar regions and so far the wind energy in this region has reached about 34 megawatts. A 10-year survey of the wind in the country's synoptic stations showed that many areas of Iran, including the coastal areas of the Oman Sea, the Persian Gulf islands, the coastal areas of Khuzestan province and the eastern regions of the country, with a few scattered spots such as Manjil, Rafsanjan, Ardabil and Bijar are windy. and they have the ability to produce wind power, especially in the summer season. Of course, in many other parts of the country, there is wind power generation capacity at limited times of the year (Gandemkar, 2018). Hoshangi et al., in a research titled "Regional investigation of solar radiation potential by evaluation and optimization of interpolation methods in the country of Iran" (2013), selected the parameters of altitude and temperature model for the zoning of solar energy potential in Iran. Valizadeh Kamrani (2013) calculated the amount of radiation reaching the earth's surface to estimate potential evaporation and transpiration using DEMSRTM and with the help of Solar Analyst function in Arc GIS software environment in East Azarbaijan province.

Etziri et al. (2012) assessed wind energy in Sabzevar city using wind direction and hour data. The results showed that the average annual wind speed in this station is 2.53 m/s and the prevailing wind is east in all months.

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Ghastli and Cherabi (2010) used the radiation analysis method in GIS software to measure solar radiation in Oman. Their results showed the high power of solar energy in most areas of Oman during a year.

Martins et al. (2009) used digital earth model and Meteosat satellite images to estimate daily solar radiation in areas with different topography, their results showed low values of RMSE and MBE error statistics for the estimated values.

In his 2015 study, Holstein analyzed the potential of photovoltaic systems using geographic information systems for a city in Virginia. In this study, radiation maps were obtained using geographic information system. In order to calculate the global incoming solar radiation, atmospheric parameters were included in the modeling. The results of this research showed the ability of the Solar Analyst tool to model solar radiation for a complex topography. The purpose of the present research is to investigate the potential measurement of solar radiation energy in Shemiranat city.

2. materials and methods

Estimation of total radiation by analytical method (GIS)

Topography is the main factor in determining the spatial distribution of radiation. The change in height, slope, direction of slope and shadows, which is caused by the difference in topography in various places, leads to a change in the intensity of radiation that reaches the ground. The amount of radiation changes from day to day throughout the year. The radiation analysis method is able to analyze and depict the effect of the sun on a geographical area during a certain period of time. This tool estimates the radiation during the day by taking into account the atmospheric effects, latitude, location altitude, slope amount, slope direction and sun entry angle. The sun's rays undergo changes in passing through the atmosphere, and the biggest change in radiation is caused by topography and particles in the atmosphere, and causes the creation of components of direct radiation, diffused and reflected radiation. The aforementioned items constitute the main components of total radiation, respectively. The radiation analysis method does not consider the reflected radiation components. Therefore, total radiation is estimated from the sum of direct radiation and diffuse radiation. Also, this tool is able to estimate radiation for a point or a geographical area (Memon and Spencer, 1942). Figure 1 shows the six steps of radiation estimation in this tool.

The process of estimating direct radiation and diffused radiation with an analytical method requires the estimation of Viewshed, Sunmap and Sun-Track. In the following, the details of total daily radiation estimation with this tool will be described. The term "shadow" at a point of angular distribution means the ability to see the sky in front of the obstacles in the way of radiation to reach the desired point. The silhouette is produced by considering the length of the radiation at a point and determining the obstacles on the path of the radiation along the object (Figure 2).

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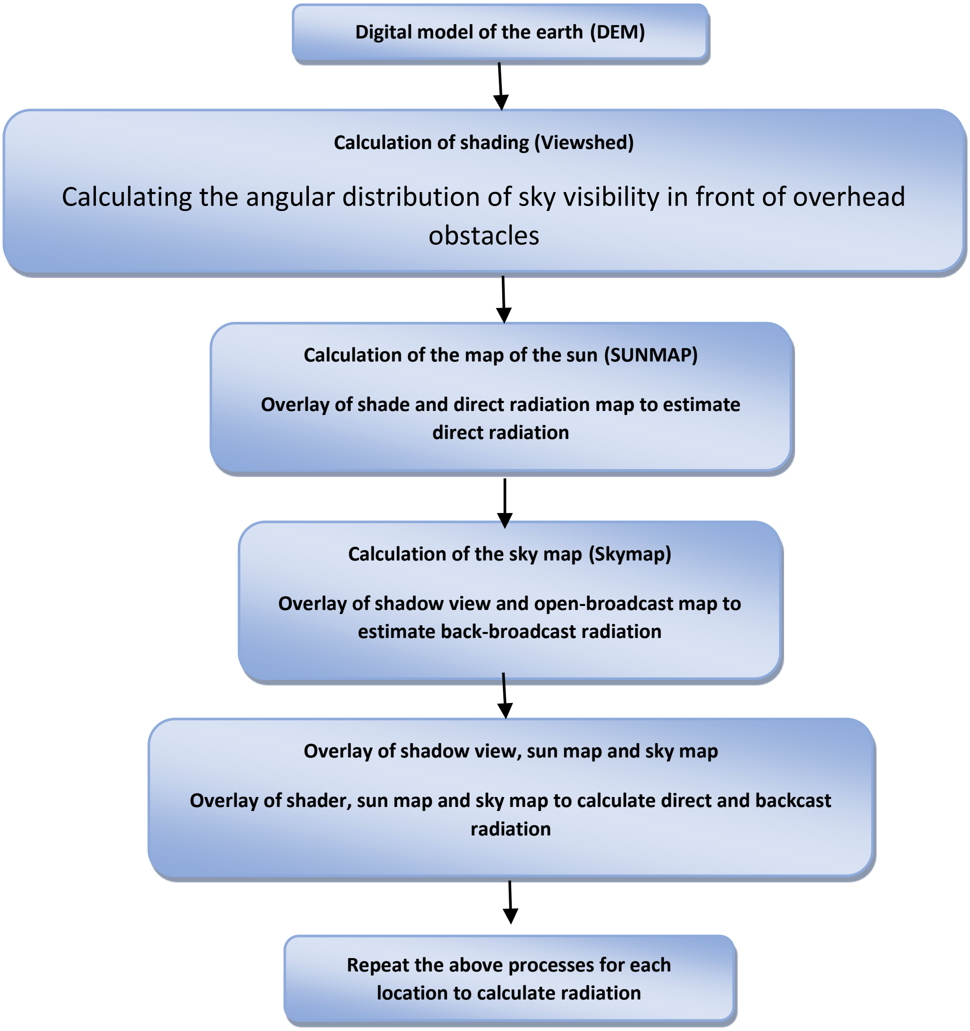

Figure 1- The six stages of radiation estimation by the radiation analysis method

Figure 2- Shadow view (Martinez et al., 2009)

The map of the path of the sun is a digital map that shows the location of the sun at different times. A map of the sky is a digital map that is made by dividing the sky into smaller parts and taking into account the angles of the solar vertex. The solar zenith angles at the center of each pixel are estimated pointwise with astronomical relations.

Estimation of the direct component of solar radiation

Solar irradiance is estimated for each part of the sun map that is not completely blocked by obstacles. The solar radiation analysis method uses a simple model for estimation. This model starts with a solar constant and estimates atmospheric effects based on traxilation and optical depth. Relations (1) to (3) show how to calculate daily direct radiation (Hb):

(1) $'\psi Hb=\sum B\Theta z,$

(2) $B\Theta Z,\psi= ISC\ \tau m\Theta\ S\Theta Z,\psi\ \xi\Theta Z,\psi\ COS\Theta$

(3) $\Theta= acos[cos(\Theta Z)+sin(\Theta z)sin(\Theta s)cos(\psi-\psi s)$

where $B\Theta Z,\psi$: momentary direct solar radiation from a part of the solar map in terms of (MJ.m-2.Day-1), ISC: solar constant (1367 W/m2), τ: daily traxilation of the atmosphere, $m\Theta$: optical mass The atmosphere (Optical Air Mass) is in the path of solar rays and is a function of the angle of the solar vertex, $S\Theta Z,\psi$: the ratio of scattered radiation to the total radiation, $\xi\Theta Z,\psi$: the gap fraction available for a part of the solar map, Θ: the angle between the center of mass of a part of The sky and the axis perpendicular to the surface are $cos(\Theta Z)$ and $sin(\Theta z)$: the cosine and sine of the solar vertical angle, and ψs: the azimuth angle.

Estimation of the diffuse solar radiation component

To estimate diffuse radiation, two models of uniform diffuse radiation and standard overcast diffuse radiation are used. In the model of uniform diffuse radiation, which is used in clear sky conditions, the assumption is based on the assumption that the incoming diffuse radiation is the same in all stretches of the sky. In the standard all-cloud diffuse radiation model, the diffuse radiation varies according to the vertical angle and has an empirical relationship with it. Both models are used in solar radiation analysis. First, the diffuse radiation in the center of each part (DϴZ,ψ) is calculated (Relation 4) and then the total daily diffuse radiation (Hd) in each area is obtained from the sum of the estimated values (Relation 5) (Martinez et al., 2009):(

(4) DϴZ,ψ= RnKΔVϴZ,ψ COS(ϴ)

(5) Hd= ∑ DϴZ,ψ

where DϴZ,ψ: diffused radiation from the sky MJ.m-2.Day-1, Rn: direct solar radiation at the surface, k: diffuse fraction of daily radiation, Δ: time period, VϴZ,ψ: sky shadow ratio for sky diffusion , SϴZ,ψ: is the duration of radiation in the sky.

Total solar radiation

Total radiation (Hg) (MJ.m-2. Day-1) is obtained from the sum of direct radiation and diffuse radiation (Relation 6). These steps are repeated for each point of the area separately and finally the radiation map is estimated for the entire area.

(6) Hg=HB+Hd,

In the GIS radiation analysis method, the amount of radiation is estimated in terms of Wh.m-2. To convert the unit MJ.m-2 to Wh.m-2, the number obtained from equation (6) must be multiplied by 277/77.

Estimation of required input parameters of each station

The solar analysis model needs two parameters of scattered fraction (k) and atmospheric traxilation (Ѣ) to estimate the total radiation, which are not measured in synoptic and radiometric stations. In order to enter these two parameters in the GIS software package, these two parameters must be estimated first. Using the measured values of total radiation and atmospheric radiation (radiation in the roof of the atmosphere) in the investigated stations, first, the atmospheric transparency coefficient (Kt) which is compared to the radiation measured at the horizon level in the stations to the atmospheric radiation was calculated and then using this the coefficient of spread fraction (k) should be calculated. The transmissivity coefficient was also obtained from equation (8), where Ѣ is the emissivity coefficient and n/N is the percentage of sunny hours (Gastali and Qarabi, 2010):

(7) K= 0/99-0/356kt+ 2/783kt2-10/67k3t+7/63k4t

(8) Ѣ=02505+101468(n/N) – 0.3974(n/N)2

3. Discussion and results

This research has been done based on satellite data (altitude digital model map) and geographic information system software and the combination of processing models for the purpose of zoning and calculating solar radiation in Shemiranat city. Is.

Digital model of the earth

Digital elevation model or DEM is a digital model or three-dimensional representation of the earth's surface, which is usually prepared to show the unevenness of the earth and using elevation data from the sea level. In fact, the digital model displays the elevation and height of the earth by a cellular network. Each cell (pixel) of this grid is identified with a numeric code that indicates the average height of the surface inside that pixel. In other words, the surface of the earth is considered as digital areas and the height of each cell is stored in the cell itself, and depending on the source from which the DEM is prepared, its accuracy is different. Accuracy can be named for each cell with height accuracy and spatial accuracy. The spatial accuracy is related to the size of the side of each cell, the smaller it is, the higher the accuracy, and the height accuracy is the detection of the minimum height in each cell that can be measured and identified by the satellite. In measuring spatial accuracy, each second is actually equal to 30 meters. (Figure 3).

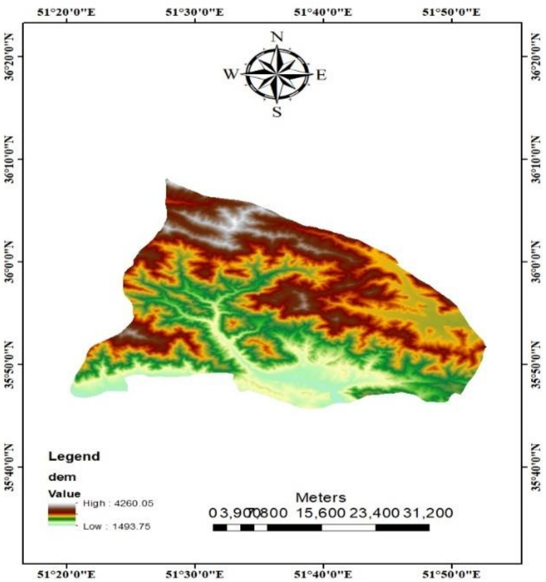

Figure 3- Digital height model

Estimation of total radiation by analytical method (GIS)

The area solar radiation tool is a spatial analysis tool that extracts the incoming solar radiation from a raster surface. Input raster refers to an input elevation surface raster, a DEM layer. The rest of the entries are optional and can be changed if needed. For example: "Latitude" is the latitude for the site area. If not changed manually, the average latitude will be calculated automatically if the input raster contains a spatial reference, otherwise the latitude will default to 45 degrees. Sky size is the resolution or sky size for raster view, sky map and sun map. The units are cells. By default, it creates a 200 x 200 cell raster. The time configuration specifies the time period used for calculations. z-factor is used to convert z units to x,y units to correct calculations. If the data is not in a predicted coordinate system with units of meters (or other units used for x,y), it must be specified, since the units of Z must be the same as the ground units of x,y to give accurate results. The next step after preparing the map is direct solar energy (Figure 4).

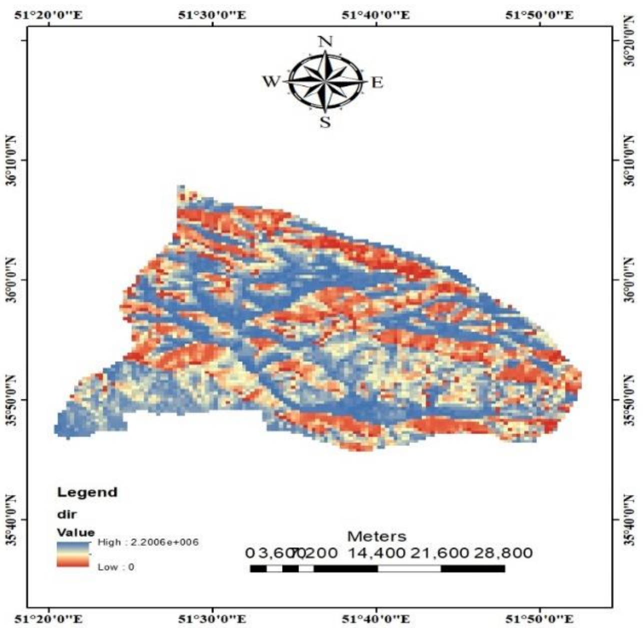

Figure 4- Direct solar energy

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Then a map of indirect solar energy was prepared (Figure 5).

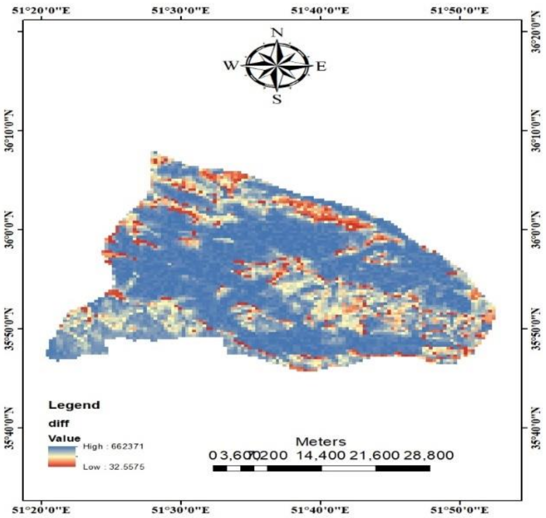

Figure 5- Indirect solar energy

Finally, the total solar energy map of the studied area was prepared (Figure 6).

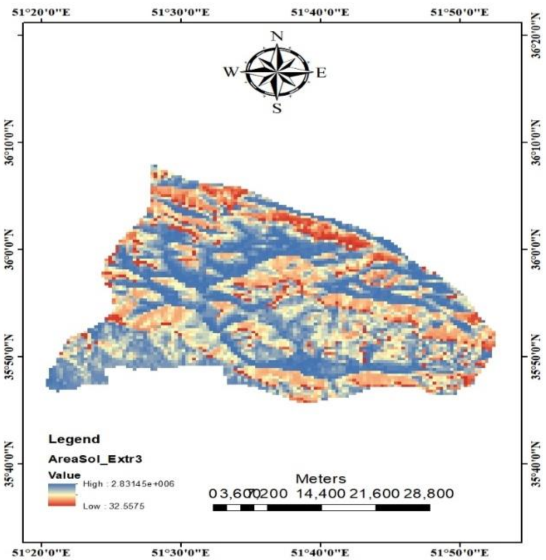

Figure 6- Map of total solar energy

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According to the solar radiation map, we found that the areas with blue color, which spread over the entire area, have high solar radiation and energy. These areas are mostly in the highlands and these areas do not include the low altitude areas. Regarding the potential of the region in the use of solar energy, because this factor has an opposite relationship with the population of the region, that is, the higher the population of the region, the lower the potential of using solar energy, and the higher the population, the average amount of each person undergoes changes, so it should be He stated that the higher areas of these areas, which are villages, have more potential from the point of view of using solar energy and building a solar power plant. Because these areas have less population than cities and their energy consumption is higher.

In addition, for such researches, it is better to include more stations in the study, and by calculating the radiation in each of the stations, a map of this parameter based on the spatial distribution of radiation should be prepared first. Because numerical calculations will not give a good insight to the reader who does not live in these areas; because he is unfamiliar with the behavior of radiation in these areas.

4. **Conclusion**

Based on what was said, the amount of solar radiation outside the atmosphere increases with decreasing latitude (areas near the equator) and decreases with increasing latitude and approaching the poles. In addition to latitude, the radiation that reaches the earth's surface is affected by various factors. These factors include:

A- Height

In a certain latitude, the intensity of radiation is higher in high places. The reason for this is the decrease in the thickness of the atmosphere with the increase in altitude. Also, the suspended particles in the air also decrease with the increase in height and increase the received radiation.

B- Abernaki

At a given latitude, areas with more clouds will receive less radiation.

C- Sunbathing direction

At a certain latitude, the amount of radiation in the areas located on the northern slopes of the mountains will be lower than the southern slopes. Also, the amount of radiation to the sunny slopes of the mountains is more than the neighboring lowlands.

D- The angle of radiation and the duration of radiation

The angle of radiation is a function of latitude and the duration of radiation is affected by longitude. The amount of radiation received is directly related to the angle of radiation and the duration of radiation. According to the mentioned materials, it is necessary to examine and consider these factors in any area where solar radiation reaching the earth's surface is studied.

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