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Evaluation of the Energy Potential of Solar Radiation in the Rural Centers of Chaharmahal va Bakhtiari Province, Iran

ABSTRACT

Solar energy plays an effective role in human's life. This study aims to determine the energy potential of solar radiation in Chaharmahal va Bakhtiari Province. The radiation and climate survey data gathered in a daily scale were used to determine the radiation estimate model and find the amount of radiation in Chaharmahal va Bakhtiari Province. The amount of radiation at 13 stations was estimated using experimental models and statistical relationships of radiation with other elements of climate. The reliability of models and the accuracy of the estimated values were confirmed by using the mean bias error and root mean square errors and the correlation between the predicted and observed values. Radiation estimates that used Angstrom models based on the lighting coefficient had more credibility in estimating the amount of radiation in the no-radiometer station. The study of the correlation coefficient between estimated radiation and radiation measurement also showed that in stations which lighting coefficient is used to estimate the amount of radiation, the correlation coefficient was stronger and more meaningful than that of other stations used, based on other climatic parameters such as cloudiness, humidity and temperature.

Key words: *Chaharmahal va Bakhtiari Province, Solar Radiation, Estimation Model, Lighting Coefficient*

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INTRODUCTION

Solar energy, as a clean source of energy with little environmental impact, has long been used in various ways by human. Now, with the use of solar collectors, this source of energy can be increasingly used to save fossil fuels. Iran is in the Sun Belt, receiving a very high annual amount of solar energy. Estimates indicate that solar energy is 1,600 times more than Iran's exports in 1990, equivalent to 5.952 million barrels of oil (*Jafarpoor and Karshenas 2001*). The Shiraz Solar Power Plant, with a capacity of 250 KWh, had a good start to get further knowledge and develop the industry. Chaharmahal va Bakhtiari Province, due to its mountainous areas, has regions with different amounts of solar energy. Therefore, determination of the solar radiation potential can help to take advantage of solar energy in different ways. The results can be used to estimate the effect of solar radiation on human health. Therefore, electricity distribution network in this province can impose high costs on governments, especially in remote and rural areas. On the other hand, problems caused by unfavorable weather conditions, especially during cold and long winters, should be considered, as well as rain, snow and strong winds. Thus, determining the potential of solar radiation can guide any plans aiming to exploit solar energy and create a sustainable environment. The aim of this study was to determine the amount of radiation in Chaharmahal va Bakhtiari Province and identify the potential areas for the exploitation of solar energy. Further, it aims to estimate the effect of radiation on human health. Although the use of solar energy has a very long history as a systematic research, it has been noted in some studies to benefit from solar energy. For example, *Samimi* (*1985*) developed a clasification in Iran in terms of annual solar radiation into the radiation zone of less than 350 Cal cm^{-2} d , the zone with the average radiation between 350 to 390 Cal cm^{-2} d, the zone with high radiation, between 390 and 430 Cal cm^{-2} d, and very high radiation areas with more than 430 Cal cm^{-2} d. Sunshine, cloudiness and relative humidity of 85 synoptic stations in a period from 1996 to 1991 have been used by *Khalili and RezaSadr* (*1995*) and they recommended the Angstrom model and the relative humidity exponential model for the estimation of the radiation in Iran. *Byrne et al.* (*2007*) studied the potential of small-scale renewable energy systems in 531 villages of three provinces in western China. The methodology was based on the life cycle cost assessment method using the GIS techniques. The study revealed that off-grid renewable energy technologies could be a very cost-effective and reliable alternative to conventional generator sets in catering for the energy needs of the villagers. This study confirmed the findings of *Byrne et al.* (*1998*). *Kanase-Patil et al.* (*2010*) which integrated renewable energy systems for some off-grid rural electrification plan designed to satisfy the electrical needs of seven villages without electricity in Uttarakhand state, India. They compared four different renewable energy scenarios using the LINGO software, version 10. Finally, the fourth scenario including micro hydropower (MHP), Biomass, Biogas, and solar energy along with the additional resources of wind and cultivation energy was proposed; this scenario was proved to be the most reliable and cost effective among all the scenarios considered.

Hoesen and Letendre (*2010*) studied the potential of renewable energies in Poultney, Vermont, to make the required plans supporting the economy of the rural community. *Hoesen and Letendre* (*2010*) proposed a possible model for supporting the rural community energy projects by using the Geographic Information System (GIS). Due to the mountainous rural areas, the use of renewable biomass energy, wind energy and solar energy could be assumed to be the best and most cost-effective method of providing energy.

Economic conditions related to the development of Renewable Energy in rural areas neighboring Sub-Saharan Africa were considered and studied by *Deichmann et al.* (*2010*) under the support of the World Bank. The study showed decentralization of renewable energies could have a significant effect on meeting the energy needs of the villagers in this area. Regardless of the technological maturity, the use of renewable energies seems to be the most economical solution, especially if the cost is considered during a period of 20 years. *Saberifar* (*2010*) launched a survey examining the potential of solar radiation in photovoltaic systems and solar water heaters in South Khorasan Province. *Saberifar* (*2010*) divided South Khorasan province into five irradiative zones. *Moeini et al.* (*2010*) used various meteorological parameters such as temperature, precipitation, humidity, sunshine and cloudiness to estimate the amount of radiation used in Yazd station by Angstrom equation and tested the predicted values with the error indicator. The study showed high accuracy for estimating radiation model. *Mousavi Bayegi and Ashraf* (*2011*) determined radiation areas of Iran on the basis of areas of low cloud and the calculation of the correlations between cloudiness and the amount of radiation received in 120 synoptic stations. The lowest amount of cloud was in accordance with that in the southeast and south areas and cloudiness was added to the north and North West. *Jafarkazemi and Mardi* (*2011*) compared radiation measured based on the amount of radiation estimated by the model Beckman Duffy in synoptic stations of Tehran Azad University, in the south, at a period from August 9th to October 11th, 2011; the results were confirmed based on the decrease in the prediction errors. *El-Sebaii and Trabea* (*2005*) developed the Angstrom model to estimate the amount of radiation at five stations in Egypt and the results obtained by using Mean Square Error (MBE), Root Mean Square Error (RMSE), Mean Percentage Error (MPE) were evaluated. Climate data used in the models factor included the brightness and cloudiness. Their results showed that this model could be used to calculate the radiation in all parts of Egypt. *Shyam and Aggarwal* (*2011*), on the other hand, employed the elements of temperature and sunshine hours in order to calculate the amount of radiation in the horizontal and inclined surfaces in Delhi, using a modified version of Orgill and Hollands, and the slope factor was calculated by Klein. The proposed method could be used to calculate the total and diffused radiation on horizontal and inclined surfaces. *Souza and Escobedo* (*2013*) used 20 models to measure the amount of scattered radiation on the slopes in South East Brazil. The study showed that with the increase in atmospheric irradiative transfer coefficient and the slope value, the amount of scattered radiation was increased too. The best estimator models anisotropies were models of Ma and Iqba, Hey, Reindl et al., and Wilmot and the best isotropic models were models of Badescu and Koronakis and Circumsolar. *Umoh et al.* (*2014*) applied the multiple regression model to estimate the solar radiation based on sunshine hours on the horizontal surfaces in Port Harcourt, Nigeria. The results were evaluated using the square root error of estimation and the estimation error. *Datta et al.* (*2014*) calculated radiation on horizontal and inclined surfaces using regression models for 6 regions of Bangladesh and detected areas with high potential solar radiation.

MATERIALS AND METHOD

In this study, radiation measurement data was gathered daily in Shahrekord Station. The initial survey of data indicated the outlier data in the data set as mentioned, possibly due to machine error and inaccuracies in data entry. The average error in the measurement time was up to 30%, which was the major cause of the lack of calibration devices, and there was dust on it too. To identify outliers, the semi-quartile range was used. In this method, which is called outliers in the data, as compared to 1.5 times, the average semi-quartile range was more or less. (Semi-quartile range is the distance between the first and second quarters). High and low outliers were calculated from the following equations (*Emamhadi and Moradi 2008*).

(first quarter - third quarter) × 1/5 - first quartile
= low limit outliers (1)

(first quarter - third quarter) × 1/5 + first quarter
= upper limit outliers (2)

In many outliers, data3.5 could be replaced with 1.5.

After the quality control of the data, the missing data related to the amount of radiation received by relevance sunshine was restored and the homogeneity of the data was confirmed by the Run Test.

The first quarter of radiation data or data of 25% was 1472.75 W m^2 d , such that in the Equation of 1472 W m^2 d, it was used and/ or for the data of 75%, the third quarter was 2713. Therefore, based on the following formula, data lower boundary was 390 = 389.5 W m^2 d and the upper boundary data was 3333.5= 3334 W m^2 d, respectively.

Low Bank=1472-1.5(2713-1472)

High Bank=1472+1.5(2713-1472)

The best way to measure solar energy is installing a Pyrometer in stations and reading information recorded by them. In the absence of measuring devices, we could employ useful experimental models. This model, which is based on climatic factors, predicts and estimates the amount of solar energy available. We used climatic elements including sun hours, air temperature, relative humidity and cloudiness to estimate the amount of radiation in Chaharmahal va Bakhtiari Province in this research. Since solar radiation at ground surface has a close relationship with solar lighting or direct sunlight (daylight hours) at the ground level, we used the Angstrom model to estimate the amount of radiation.

RESULTS AND DISCUSSION

The angstrom model could be used with little error to estimate the amount of radiation. So the correlation coefficient between the brightness ratio and the ratio of radiation in the ground horizontal level, as compared to radiation in the upper atmosphere in Shahrekord Station, was R=+0.83, as confirmed at 99% confidence level. The estimated amount of radiation is compared with that measured at Shahrekord Station (**Figure 1**). According to the overlap near the two lines, the accuracy of the model used to estimate the radiation was very high.

The amount of radiation in the atmosphere above Shahrekord Station was calculated in the unit J m^2 by the following formula (3) (*Duffie and Beckamn, 1980*):

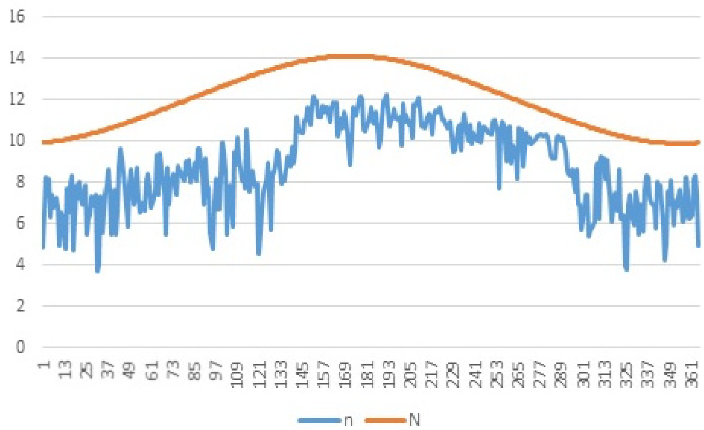

Figure 1. Comparison of the number of actual sunshine hours (n) and the number of sunshine hours in astronomical days (N) in Shahrekord Station.

$$H_0 = \frac{24\times3600G_{sc}}{\pi}\left(1+0.033\cos\frac{360n}{365}\right)\times\left(\cos\varphi\cos\delta\sin\omega_s+\frac{\pi\omega_s}{180}\sin\varphi\sin\delta\right) \quad (3)$$

Where:
H0: The amount of solar radiation in the upper atmosphere
Gsc: The constant sun in w m^2; in this equation, it was assumed to be 1367 w m^2
n: The number of days could be calculated from the first of January in throughput.
ωs: Hour angle of the sun was calculated from the following equation:

$$\cos\omega_s = -\tan\varphi\tan\delta \quad (4)$$

It is clear that hour angle is the inverse cosine ωs.

Where:
Φ: latitude location
δ: Angle of declination of the sun is calculated by the following equation:

$$\delta = 23.45^{\circ}\sin\left[\frac{360}{365}(d-81)\right] \quad (5)$$

Where:
d: Number of days from the beginning of the year (January)

Angstrom model, using the linear regression equation, was developed for Shahrekord Station and the amount of radiation received on the earth's surface was calculated based on the amount of sun lighting coefficient and cloudiness. The correlation between the ratio of ground surface radiation and the above atmosphere radiation) (H/H°) (with sun lighting coefficient (n/N) was R=0.83, such that with the coefficient of determination of R^2= 0.689, the significance was confirmed at 99% confidence level. The regression model for estimating radiation in Shahrekord

Station has been brought in equation 6.

$$\frac{H}{H_\circ} = 0.277 + 0.519\frac{n}{N} \quad (6)$$

Where:
H: the amount of radiation received at the earth's surface.
H0: the amount of radiation received at the top of the atmosphere.
n: is the number of hours of actual sunshine hours.
N: is the number of hours of astronomy days

The number of sunshine hours in astronomical days (N) has been compared with that of actual sunshine hours (n) in Shahrekord Sation (**Figure 1**). Angstrom formula is based on the ratio of the length of the actual day to astronomical days length (n/N) or solar brightness factor for the estimation of radiation (**Figure 1**).

The measured radiation and radiation estimated by the model have been compared in Shahrekord Station (**Figure 2**). As can be seen, radiation was very close to the amount of the estimated value, thereby providing further evidence showing the validity of the model for estimating radiation (**Figure 2**).

Analysis of prediction error was calculated by using the equation of the MBE (7).

$$\mathrm{MBE} = \frac{1}{n}\sum_{i=1}^{n}\left(H_{i,c} - H_{i,m}\right) \quad (7)$$

Where Hi,c i-th refers to the amount estimated by the model and Hi,m i-th shows the measured value by the Radiometer. Based on the estimated mean error analysis, the amount estimated by the model was +0.48, thereby indicating that the amount estimated by the model was slightly higher than that recorded by the Radiometer. The RMSE also was

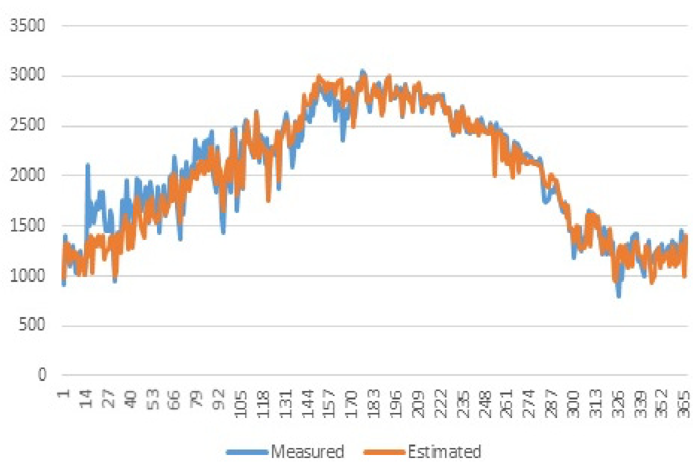

Figure 2. Comparison of the measured and estimated values of radiation in Shahrekord Station

error (RMSE) also was calculated by using equation (8).

$$\mathrm{RMSE} = \left[\frac{1}{n}\sum_{i=1}^{n}\left(H_{i,c} - H_{i,m}\right)^2\right]^{0.5} \quad (8)$$

The root mean square error RMSE for the estimated values of the observed values was equal to 16.9, and the MPE was equal to 0.292%.

$$\mathrm{MPE} = \left[\sum_{i=1}^{n}\frac{(H_{i,m} - H_{i,c})}{n.H_{i,m}} \times 100\right] \quad (9)$$

Also, by using Equation 10 (*Datta et al. 2014*), the correlation between the observed and estimated values was calculated.

$$r = \frac{\sum(H_{estimated} - \bar{H}_e)(H_{measured} - \bar{H}_m)}{\sqrt{\sum(H_{estimated} - \bar{H}_e)^2 \sum(H_{measured} - \bar{H}_m)^2}} \quad (10)$$

$\bar{H}_e$: The average of the estimated value

$\bar{H}_m$: The average of the measured value

The correlation coefficient between the measured value and the estimated value at Shahrekord Station was R=0.971, which was significant at 99% confidence level. This showed the accuracy of model in estimating the amount of radiation at the earth's horizontal surface.

To estimate radiation in stations with no radiometers and no sunshine house data, other parameters including daily mean and maximum temperature, daily average and minimum relative humidity, and daily average cloudiness were considered, showing the highest correlation with the amount of radiation received in Shahrekord Station. The correlation coefficient between each parameter, including temperature, relative humidity and cloudiness and radiation intensity were, respectively, R=0.692, R=-0.689 and R=-0.442, which was significant at 99% confidence level.

The amount of radiation was detected by the following formula (11).

R=1943.2+(28.98T)-(9.9R)-(39.8Cl) (11)

The correlation coefficient between the estimated amount of radiation and the radiation measurement stations in Shahrekord station is shown for every station (**Table. 1**). However, the correlation coefficient between the estimated radiation at all stations and the amount of radiation measured at Shahrekord Station was high and significant at a confidence level of 99%, but the values in stations containing brightness coefficient (stations 1-10) were

Table 1. View of the weather stations in Chaharmahal va Bakhtiari Province and the correlation between the amount of radiation estimated at each station and the amount of radiation measured in Shahrekord Station.

Row	Name	Function Estimation	Correlation Coefficient
1	Ardal	lighting coefficient	.961**
2	Brojen	lighting coefficient	.963**
3	Farsan	lighting coefficient	.966**
4	Kohrang	lighting coefficient	.950**
5	Lordegan	lighting coefficient	.959**
6	Saman	lighting coefficient	.965**
7	Shahrekord	Radiometer Station	.971**
8	Farokhshahr	lighting coefficient	.969**
9	Overgan	lighting coefficient	.956**
10	Dezak	lighting coefficient	.956**

higher, implying the validity of Angstrom model in estimating the solar radiation.

To study the radiation in all parts of the province, the radiation map of Chaharmahal va Bakhtiari province was plotted using the IDW interpolation method, (**Figure 3**). Accordingly, most of the province showed some irradiance between 1990 -1960 W m^2 d. Areas above 2000 W m^2 d were limited to small regions in the South and East. Areas receiving the minimum radiation were at rainy stations including Koohrang, Dezak, Oregon and other adjacent areas.

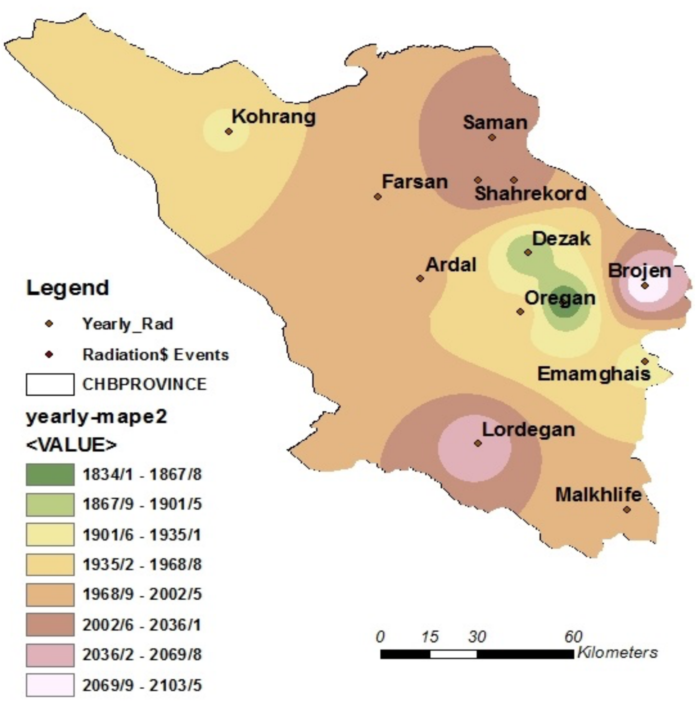

Figure 2. Zoning radiation of Chaharmahal va Bakhtiari Province (W m^2 d).

The amount of radiation in 57 sample rural points of the province was measured using a map (**Figure 3**). Therefore, the villages of Kaj, Khardan and Sarmor, with the annual values of 2108, 2098 and 2088 W m^2 d, respectively, received the highest radiation; also villages of Oregon, Imam Qais and Shahid Behesht, with the annual values of 1757, 1925 and 1959 W m^2 d, respectively, received the least amount of radiation. The amount of radiation in the horizontal plane for some days of the year when the Sun was in the sky at the zenith or perigee (**Table 2**). This could be used to design solar system collectors.

CONCLUSION AND RECOMMENDATION

The aim of this study was to estimate the amount of solar radiation in Chaharmahal va Bakhtiari Province. The results could be used to investigate the effects of solar energy and radiation on diseases such as cataracts. As solar radiation values are only recorded in the synoptic station of Sahrekord, mapping could check scattered radiation levels at 14 sites across the province, using the experimental models and the relationships between radiation and other climatic elements, respectively. Thus, the amount of radiation at 14 stations was estimated using the experimental models and the statistical relationships of radiation with other elements of climate. The potential solar radiation map was plotted using the IDW interpolation method for the horizontal surface. Many researches used sun hours, cloudiness, humidity, altitude and temperature in their experimental models to estimate solar energy (*Khalil and RezaSadr 1995; Samimi 1985; Moeini et al. 2010; El-Sebaii and Trabea; Safaripour and Mehrabian 2011; Datta et al. 2014; Umoh et al. 2013*). Radiation estimates using Angstrom models based on the lighting coefficient had more credibility in estimating the amount of radiation in the no-radiometer station. The study of the correlation coefficient between the estimated radiation and the radiation measurement also showed that in stations using the lighting coefficient to estimate the amount of radiation, the correlation coefficient was stronger and more meaningful than that of other stations used, based on other climatic parameters. Also, the iso-radiation map showed that in areas where the cloudiness was higher, such as Koohrang, Dezak, Oregon and Imam Qais station, the received radiation was lower. But in places like shahrekord, Farokhshahr, Borujen, Saman and Lordegan stations, it was found that the greater the sunny factor, the more the radiation received. The use of solar energy in the rural areas of Chaharmahal va Bakhtiari Province seems to be the best and most cost-effective solution because of mountainous areas, snow and strong winds in this province, the power transmission network is constantly facing outages, and this costs much to the government. The present study outcome

Table 2. Estimated amount of radiation in some villages of the province (W m^2 day).

	21-Jan	22-March	22-Jun	23-Jul	23-Sep	6-Nov	22-Dec	Yearly
Sheikh Ali Khan	1272.8	1778.2	2349.2	2558.5	2359.7	1616.4	1221.8	1962.7
Samsamie	1309.7	1858.0	2421.1	2625.6	2385.4	1648.2	1258.5	2017.9
Beheshti	1269.6	1771.0	2344.0	2553.9	2359.6	1613.7	1218.4	1959.0
Ab-Bidak	1309.8	1924.4	2470.8	2686.2	2373.2	1655.0	1306.4	2039.6
Kahidan	1308.6	1910.7	2447.1	2668.6	2371.2	1653.8	1300.8	2031.0
Mashkdozan	1310.7	1925.8	2473.7	2688.3	2374.3	1655.5	1307.2	2041.0
Toledan	1313.2	1912.0	2450.7	2671.5	2383.9	1660.5	1301.6	2037.6
Mashkdozn	1309.4	1925.1	2471.5	2686.7	2373.4	1655.1	1306.5	2040.0
Dime	1279.0	1791.9	2360.0	2567.6	2360.6	1621.5	1227.7	1970.2
Deh-Kohne	1313.2	1912.0	2450.7	2671.5	2383.9	1660.5	1301.6	2037.6
Ab-Sarde	1343.5	1902.6	2469.8	2677.6	2432.3	1682.9	1299.6	2060.1
Rostam-Abad	1344.3	1901.6	2485.8	2689.5	2459.8	1686.9	1294.4	2074.8
Sare-Zard	1314.0	1912.3	2451.8	2672.3	2386.2	1661.7	1301.8	2038.9
Mishan-Sofla	1112.2	1972.4	2383.4	2635.9	2262.6	1556.8	1347.4	1975.9
Jozestan	1352.0	1916.0	2485.2	2697.4	2451.3	1694.6	1319.0	2073.3
SarAghaSayed	1294.6	1826.2	2381.2	2586.8	2354.9	1633.7	1244.9	1984.4
Malekshir	1313.2	1912.3	2451.2	2671.9	2384.5	1660.8	1301.5	2038.0
Khair-Abad	1398.5	1911.4	2339.8	2527.5	2162.0	1735.1	1300.3	1996.1
Asad-Abad	1307.6	1869.3	2440.6	2635.6	2395.3	1647.8	1247.8	2029.6
Ghale-Rashid	1328.5	1883.2	2466.3	2669.5	2438.4	1668.2	1274.6	2058.3
Mishan-Olia	1114.7	1971.2	2384.1	2636.4	2263.8	1558.1	1346.3	1976.3
Tang-Kalore	1112.3	1972.3	2383.3	2635.9	2262.6	1556.9	1347.3	1975.9
Sarmoor	1361.7	1919.4	2501.2	2707.8	2476.7	1704.2	1318.0	2088.3
Sarkhon	1320.4	1906.6	2452.3	2671.2	2393.2	1665.4	1298.3	2040.5
Gharah	1115.7	1970.9	2384.3	2636.5	2264.2	1558.7	1346.0	1976.6
Karan	1297.9	1835.7	2445.2	2647.6	2438.4	1628.4	1227.5	2046.1
Isa-Abad	1296.5	1831.1	2442.5	2645.1	2438.5	1625.5	1225.0	2044.6
Margh-Malek	1311.1	1863.6	2421.4	2616.0	2371.3	1648.4	1254.5	2012.3
Eshkaftak	1318.5	1959.6	2484.0	2665.7	2386.9	1686.7	1267.7	2045.0
Sarchah	1359.4	1917.1	2500.5	2706.1	2476.6	1702.6	1314.3	2087.7
Fil-Abad	1300.3	1841.1	2440.4	2642.0	2425.8	1632.2	1233.2	2039.7
Khoy	1308.2	1891.7	2450.8	2642.7	2386.8	1657.9	1252.7	2031.0
Pardenjan	1296.8	1834.1	2444.5	2646.7	2438.3	1627.0	1225.8	2045.5
Deh-Cheshme	1295.8	1828.5	2443.8	2646.9	2443.4	1623.9	1223.1	2046.8
Dezak	1468.2	1912.9	2304.2	2481.4	2094.0	1778.7	1315.7	2002.3
Vanan	1306.6	1873.8	2445.2	2640.0	2397.4	1649.3	1247.3	2032.3
Haroni	1308.0	1865.3	2436.5	2632.1	2393.4	1646.4	1248.1	2027.1
Kharaji	1331.8	1904.4	2397.4	2601.5	2284.7	1681.9	1286.1	2005.0
Dashtak	1313.6	1863.7	2447.2	2650.1	2420.1	1650.2	1255.5	2042.6
Mostafa-Abad	1304.6	1878.7	2451.9	2647.8	2402.0	1651.2	1246.5	2037.2
Vardenjan	1347.4	1889.9	2418.9	2595.1	2358.4	1666.3	1276.3	2006.7
Rast-Ab	1306.2	1861.9	2451.1	2651.5	2422.4	1645.2	1244.4	2044.6
Kaj	1371.3	1928.4	2524.0	2727.7	2509.6	1717.4	1325.4	2108.4
Gojan	1293.8	1823.6	2443.1	2646.4	2446.6	1620.5	1219.3	2047.3
Sarteshniz	1369.7	1905.2	2354.3	2550.1	2200.0	1710.2	1292.3	1993.4
Boger	1304.6	1907.5	2444.5	2666.3	2354.2	1643.1	1300.8	2021.9
Oregan	1222.3	1665.7	2111.6	2382.6	2089.1	1416.7	1269.7	1757.2
Khardan	1359.3	1968.7	2577.0	2762.3	2435.3	1688.9	1334.3	2098.8
Emam-Ghais	1000.1	1870.4	2410.9	2655.9	2278.3	1596.5	1267.7	1925.2
Yan-Cheshme	1328.2	1840.2	2378.9	2554.8	2305.8	1644.7	1263.2	1965.5
Harchegan	1327.7	1889.8	2425.4	2606.5	2354.5	1662.8	1267.8	2007.3
Bardbar	1277.8	1926.9	2461.3	2683.5	2350.5	1637.8	1307.5	2025.5
Deh-Sahra	1214.4	1916.5	2410.1	2651.3	2307.6	1609.2	1299.7	1989.9
Chalshtor	1317.7	1956.4	2481.7	2663.4	2384.2	1685.3	1266.8	2042.8
Chelice	1303.1	1856.1	2448.9	2649.3	2423.5	1640.6	1239.2	2043.5
Dastena	1339.9	1909.5	2443.9	2652.5	2375.8	1686.7	1301.5	2040.3

is in agreement with the findings of the previous research carried out by *Byrne et al.* (*2007*), *KanasePatil et al.* (*2010*), *Hoesen and Letendre* (*2010*), and *Deichmann at al.* (*2010*). In these areas, owing to the greater transparency of the sky and the suitable slope, the intensity of solar radiation is the maximum.

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