Available online at sjuoz.uoz.edu.krd

journals.uoz.edu.krd

Science Journal of University of Zakho

Vol. 10, No. 3, pp. 93 –97, July-September 2022

p-ISSN: 2663-628X
e-ISSN: 2663-6298

STUDY OF GLOBAL SOLAR RADIATION IN DUHOK PROVINCE

Farhan Keti Kabao [a,*], Omar Salih Omar [a]

[a] Dept. of Physics, College of Science, University of Duhok, Duhok, Kurdistan Region of Iraq.
(farhan.kabao@uod.ac; Omar_Dosky@uod.ac)

Received: *20 May., 2022 /* ***Accepted:*** *29 Jun., 2022 /* ***Published:*** *15 Jul., 2022* *https://doi.org/10.25271/sjuoz.2022.10.3.934*

ABSTRACT:

This paper studies and analyzes the ground-based global solar radiation (GSR) data in the Duhok governorate. The data is collected from the Meteorological Directorate in Duhok for six stations: Kani Masi, Bamarni, Amedi, Mangesh, Akre, and Semel. The highest monthly average values of global solar radiation in Duhok are in June and July, and the lowest values are in December and January. Among all stations, Amedi has the highest value of the monthly mean of GSR 8.704 kWh/m^2/day followed by Kani Masi at 8.527, Mangesh at 8.325, Bamarni at 8.072, Semel at 7.051, and finally Akre 6.117 kWh/m^2/day, while the lowest values of GSR are in December 2018 mostly, except for Semel is in December 2016. The annual mean of global solar radiation in kWh/m^2/day for these stations are 5.017, 4.831, 4.817, 4.755, 4.316, and 3.618 for Amedi, Kani Masi, Mangesh, Bamarni, Semel, and Akre respectively. The monthly mean of the daily clearness index (K_T) of the study area peaks is in the mid months of the year (May, June, July, August, and September). K_T values experience a dramatic decrease in March in all stations except Mangesh shows a slight increase. Among all the stations, Akre shows the lowest values in K_T ranging from 0.330 to 0.507 with an annual average of 0.424.

KEYWORDS: Solar Energy, Climate Change, Global Solar Radiation, Air Pollution, Metrological Data in Kurdistan.

1. INTRODUCTION

Solar irradiance that reaches our planet (earth) is the most basic source of renewable energy in nature (Sen, 2009). The sun provides 3.8 x 10^{23} kW/Sec. of energy, of which about 1.8 x 10^{14} kW/Sec. enters the earth's surface as electromagnetic radiation (Duffie et al., 1994). The sun's annual energy input to the Earth is moreover 10,000 times the world's industrial energy consumption (Mousazadeh et al., 2009). The energy from the sun could play a key role in decarbonizing the global economy alongside improvements in energy efficiency and imposing costs on greenhouse gas emitters (Besharat et al., 2013).

For the designing of any effective solar energy system, detailed information about the availability of solar radiation at the desired site is required. Installing measuring tools such as pyrometers at several locations around a region is the best approach to determining the amount of global solar radiation (GSR) at any location (Katiyar & Pandey, 2010).

Air pollution in the Duhok governorate is one of the major issues the local authorities are facing and it is increasing year after year, this phenomenon has adverse effects on the lives of citizens, especially in terms of health. Some studies conducted in the region showed that transportation and the large number of commercial electric generators that run on diesel are among the factors that reduce air quality in the city. A study conducted (the results showed that the average content of carbon monoxide in the air was 116 ppm, which is higher than the local and international standards (Hassan, 2012). A significant increase in No_3^-, So_4^{-2}, and Co_2 concentrations was also observed during the chemical analysis of rain in 2015 compared to 2014 (Meena & Omar, 2015). Duhok air is also found to contain many toxic heavy metals such as lead, copper, and cadmium (Yousif, 2016).

Recently, Iraq has joined the Paris Agreement, which aims to strengthen the global response to the danger of climate change by limiting global average temperature increase this century to well below 2 ˚C above pre-industrial levels and pursuing attempts to minimize temperature rise even further to 1.5 ˚C. (UN). Besides that Iraq is one of the top countries that started suffering from drought as in Mosul and Anbar provinces (IOM) (Vojáčková-Sollorano, 2022).

For the reasons mentioned above, the significance of studying and investing in renewable energies appears such as solar energy since it is clean, abundant, and inexhaustible dislike fossil fuels. In addition, Duhok is located in a sunny position, it has an average of 2778 sunshine hours per year (Omar, 2010).

Due to the broad application area, many studies on GSR have been conducted in neighboring countries. In Saudi Arabia, data from 30 stations around the country were evaluated, and the results are well suited for PV technology performance due to the high GSR values in all locations (Zell et al., 2015). In Jordan, the measured monthly GSR data for the period (1998 to 2007) has been analyzed and the results were excellent for the production of solar energy (Al Tarabsheh and M. Ababne, 2010). In Syria, also the high potential of solar radiation is considerable (Elistratov & Ramadan, 2018). In Turkey, Van province, the calculated and analyzed data of GSR, surface temperature, and sunshine duration showed that the region has a high potential for solar radiation and clearness index (Uçkan, 2018). Iran as well receives between 1800 and 2200 kWh/m^2 per year of solar radiation, which is more than the global average, in addition, more than 90 percent of Iran's territory has an annual average of more than 280 sunshine days, implying a substantial potential energy source (Alamdari et al., 2013).

For Iraq, meteorological data has been used to develop a multi-linear correlation to estimate GSR. The data was collected by the

* Corresponding author

Iraqi Meteorological Office in three sites: Baghdad, Mosul, and Rutba spanning five years from 2004 to 2008. The model had been put to the test and compared to actual measurements (AL-Salihi et al., 2010). In another study, GSR data was taken from 14 meteorological stations at different sites in Iraq, Angström-Prescott equation was used for the estimation of these data based on the sunshine duration values of these 14 stations (Abd & Al-Hassany, 2019).

Providing electric power is still one of the most important challenges facing the governorate of Duhok, due to its dependence on fossil fuels as the only source for generating this energy until writing this paper.

This study aims to clarify the importance of solar energy in the region and the diversification of energy sources as a solution to the problem of daily power outages, especially during the summer and winter seasons.

2. MATERIALS AND METHOD

The monthly mean of daily ground-based data of global solar radiation (GSR) of six automatic meteorological stations in Duhok province was collected. The data for Akre station is for the period of five years (2013-2017), while for Amedi and Bamarni stations for the period of six years (2015-2020) and the other three stations through seven years' period (2015-2021). Figure (1) shows the location map of the study area (Duhok province) (Ibrahim, 2021). To measure the GSR in these stations, a QMS101 pyranometer manufactured by Vaisala Company has been utilized. Table (1) includes the specifications of the QMS101 Pyranometer.

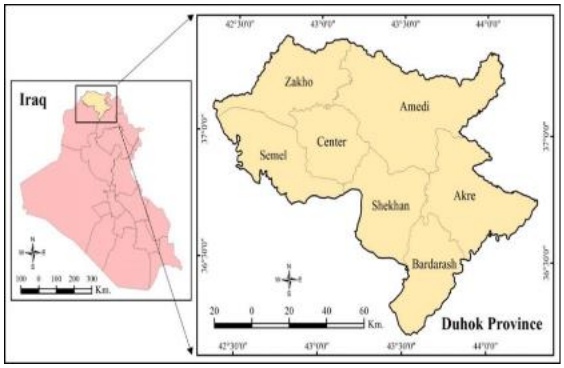

Figure 1. Map location of Duhok province

Table 1. Specifications of QMS 101 pyranometer

Sensitivity	100 µV/W/m^2
Spectral Range	0.4-1.1 µm
Response time	< 1 sec.
Range	0 - 2000 W/m^2
Operating Temperature	-30 to +70 ºC

The monthly mean extraterrestrial radiation (H_o) in kWh/m^2/day can be calculated from the equations (1) (Duffie et al., 1994).

$$H_o = F_o \times \frac{24}{\pi}\left(1 + 0.033\cos\left(\frac{360^{\circ}D}{365}\right) \times \left((cos\phi cos\delta cos\omega_S)\left(\frac{\pi\omega_S}{180}\right) sin\phi sin\delta\right)\right) \quad (1)$$

Here Fo is solar constant and equals 1.367 kW/m^2. The sunset hour angle ω_s is in degree and can be calculated from the following equation:

$$\omega_s = -cos^{-1}(-tan\delta tan\phi). \quad (2)$$

Where ϕ is the local latitude in meter (m), its value can be taken from the table (2) for each station, and δ is the declination angle which can be calculated from the below equation:

$$\delta = 23.45\sin\left(\frac{360^{\circ}(D+284)}{365}\right) \quad (3)$$

Where D is the characteristic day for each month in the year. The monthly mean daily clearness index (K_T) is obtained as in the following equation:

$$K_T = \frac{H}{H_o} \quad (4)$$

Where H is the global solar radiation on a horizontal surface and H_o is the extraterrestrial solar radiation

Table 2. Geographic coordinates of the meteorological stations

Station	Lat. N°	Long. E°	Alt.(m)
Kani Masi	37.1349	43.2610	1340
Bamarni	37.0702	43.1597	1220
Amedi	37.0535	43.2903	1190
Mangesh	37.0215	43.0484	948
Akre	36.4441	43.5347	636
Semel	36.5129	42.5201	456

Table 3. Extraterrestrial solar radiation (Ho) of the study area

Month	Kani Masi	Bamarni	Amedi	Mangesh	Akre	Semel
Jan.	4.717	4.728	4.731	4.736	4.834	4.822
Feb.	6.145	6.155	6.158	6.163	6.252	6.241
Mar.	7.980	7.987	7.989	7.993	8.062	8.054
Apr.	9.819	9.823	9.825	9.827	9.865	9.860
May	11.080	11.081	11.081	11.082	11.090	11.089
Jun.	11.576	11.576	11.575	11.575	11.567	11.568
Jul.	11.309	11.309	11.309	11.309	11.308	11.308
Aug.	10.295	10.298	10.298	10.300	10.325	10.322
Sep.	8.626	8.633	8.634	8.637	8.695	8.688
Oct.	6.678	6.687	6.690	6.694	6.777	6.767
Nov.	5.047	5.058	5.061	5.066	5.162	5.150
Dec.	4.323	4.334	4.337	4.343	4.442	4.430

The values of the extraterrestrial solar radiation (H_o) for all stations are shown in table (3). These values for all sites during the whole year are almost identical, this is due to the fact that all sites are geographically close together. Here H_o varies from 4.323 in Dec. at Kani Masi to 11.576 kWh/m^2/day in June at the same region

3. RESULTS AND DISCUSSION

To analyze the global solar radiation data in this paper, the Origin Lab2019b software was used (OriginLab Corp., 2019). It is well known that the geographical location of the region has a significant impact on the amount of solar radiation that reaches the region, as the sunshine duration and solar radiation reach their peak in Duhok Governorate during the summer months and vice versa in the winter. Figure (2) shows the monthly mean of GSR variation for the

six stations. As it's seen in Kani Masi through the seven years (2015-2021), figure 2(a), the highest value of GSR was 8.527 kWh/m^2 /day in June 2021. This might be due to the clarity of the sky in this region since it is located in the mountains region close to the Turkish border, during the summer period the sky is very clear and the chance of having dust in the air is very rare. The GSR lowest value in this station was 1.363 kWh/m^2/day in December 2018. It has observed a crucial drop in GSR during the 2018 months, maybe the reason behind that is the high number of cloudy days in the region.

For the Bamarni station figure 2(b), it's clear from the graph that the monthly average of GSR ranges from 1.646 kWh/m^2/day in Dec 2018 to 8.073 kWh/m^2/day in July 2019, the maximum annual average of GSR was 4.865 kWh/m^2/day in 2017, while the minimum yearly average was 4.690 kWh/m^2/day in 2018. The wide fluctuations occurred in October at this station, probably due to the changes in weather conditions in this region throughout this month from one year to another.

In the Amedi district, as shown in figure 2(c), the GSR values in kWh/m^2/day started to rise with an average of 2.138 in January and reached 8.363 as a mean of GSR in June, then dropped to 1.893 in December. Overall no big differences are seen in GSR data from one year to another in Amedi, this means that the weather has not changed much from year to year in this area, in contrast to the Kani Masi region.

Figure 2(d), depicts the distribution of monthly average GSR data at Mangesh Station in the period between 2015 and 2021. The highest and lowest values of GSR were 8.625 and 0.925 kWh/m^2/day in June 2021 and December 2018 respectively.

In Akre station, figure 3(e), the monthly mean of GSR surged from 1.039 kWh/m^2/day in December 2018 to 6.117 kWh/m^2/day in June 2017. The overall GSR data in this station is less than the GSR data of the other five stations, which is because of the low clearness index in Akre compared to other stations, and this may be due to the weather conditions such as clouds and dust in the Akre's atmosphere.

Figure 2(f) shows the monthly mean of daily GSR measurements in the Semel station, as the highest value of GSR, was 7.051 kWh/m^2/day in July 2013, and the lowest value was 1.053 kWh/m^2/day in December 2016. Although Semel enjoys abundant hours of sunshine duration, the GSR is less compared to Amedi, Kani Masi, and Bamarni, and the reason for this is believed to be the polluted area's atmosphere with dust and gasses emitted from the factories that have a direct impact on the air quality in the region and the cloudiness is another reason as well.

From the results we obtained, we found that Duhok Governorate, at an annual mean of GSR 4.559 kWh/m^2/day, is characterized by the abundance of solar energy, as in the rest of Iraq, where this feature has not been exploited well so far.

By comparing the GSR data for Duhok governorate with other governorates of Iraq, we find that Duhok has an annual average of GSR higher than Mosul 4.097, and lower than both Anbar (Rutba) 5.140 and Baghdad 5.159 (AL-Salihi et al., 2010). Another study, has found that Tikrit has 4.813 as an annual average GSR (Abed Al-Dulaimy & Mohammed, 2013), and the city of Nasiriyah, has an annual average of GSR 4.241 (Mahmood & Al-Hassany, 2014).

The monthly mean of the daily clearness index of the study area is illustrated in figure (3). It is obvious from the graph that the clearness index peaks are in the mid months of the year (May, June, July, August, and September), while the lowest values are in the winter season. This may happen due to the weather conditions since the relationship between the clearness and cloudiness indices is reversed. K_T values experienced a dramatic decrease in March in all stations except Mangesh which showed a slight increase. Among all the stations, Akre saw the lowest values in K_T ranging from 0.330 to 0.507 with an annual average of 0.424.

Since Semel is not a mountainous area, it is exposed to sandstorms and its atmosphere is affected by aerosols and dust, in addition, a large number of factories and industries in the area have a great impact on the pollution of the area's atmosphere. These factors are thought to be contributed to lowering the clearness index in Semel which ranges from 0.408 in December to 0.581 in June. The remaining four regions have a relatively higher K_T than Semel and Akre, as the annual average of K_T in Amedi, Kani Masi, Bamarni, and Mangesh was 0.588, 0.576, 0.568, and 0.539 respectively.

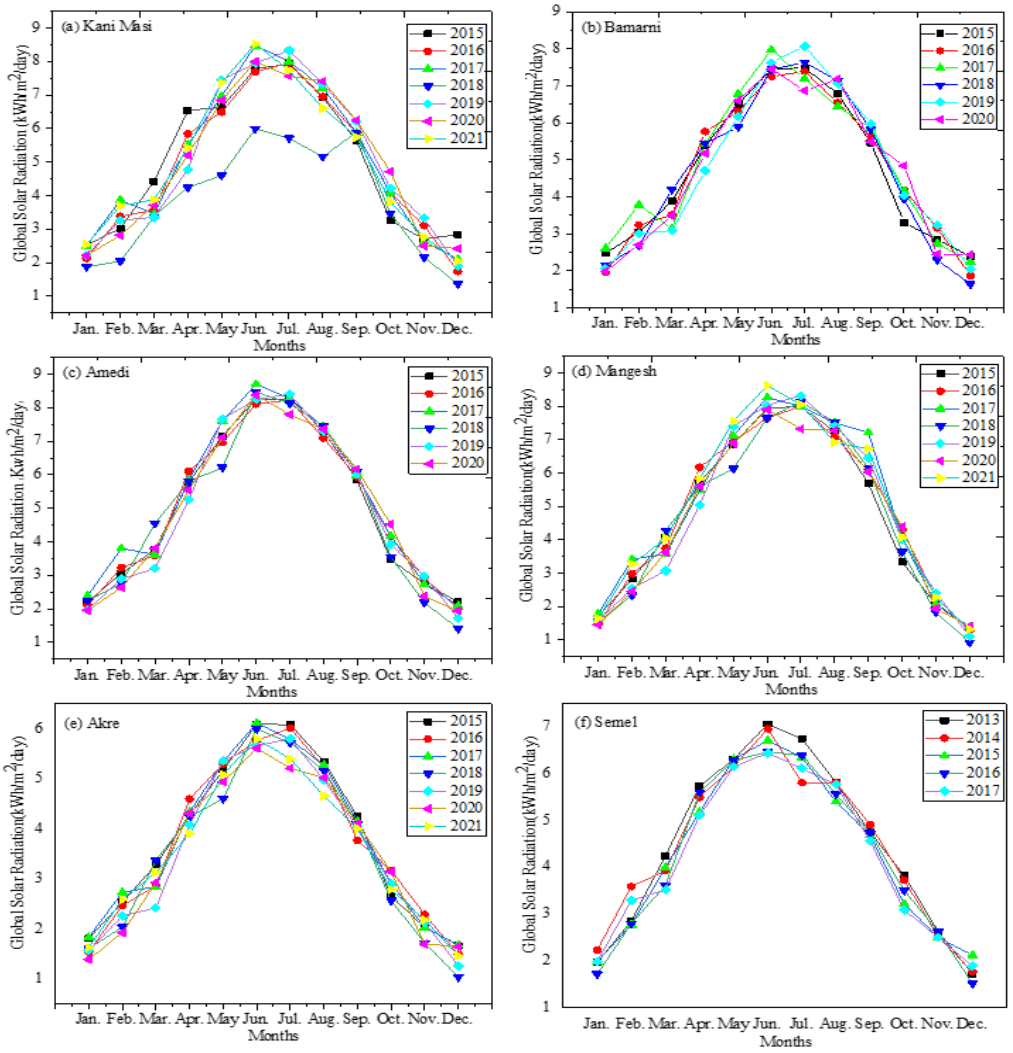

Figure 2. Variation of the monthly mean of daily global solar radiation (H) in the study area

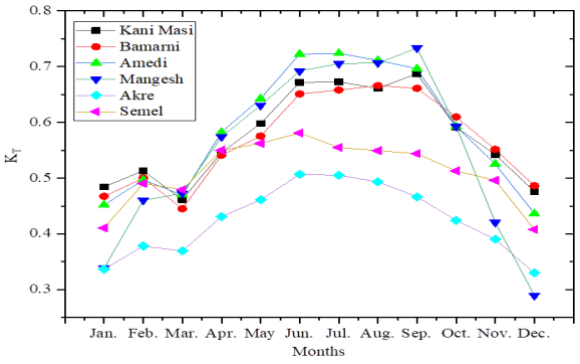

Figure 3.Clearness Index (K_T) of the studied area

4. CONCLUSION

This paper aimed to study global solar radiation availability using actual measured data in different sites in Duhok province. The results were promising, as Duhok is characterized by an abundance of solar energy, this can be seen from the annual average values of (H) in kWh/m^2/day and (K_T) of Kani Masi, Amedi, Bamarni, Mangesh, Akre, and Semel are (4.831, 0.576), (5.017, 0.588), (4.755, 0.568), (4.82, 0.551), (3.618, 0.424), and (4.316, 0.512) respectively.

From these results, we conclude that exploiting this advantage and investing in solar energy to produce electricity has become a necessity because of its economic feasibility, especially its eco-friendly, as it will benefit all communities in Duhok, in addition to several thousand urban homes, schools, companies, and government offices, among others. It's a massive private sector industry.

ACKNOWLEDGMENT

The authors extend their thanks and appreciation to the Directorate of Meteorology and Seismology in Duhok for their cooperation and efforts in providing the required data for this study.

REFERENCES

Abd, M. N., & Al-Hassany, G. S. (2019). Estimation of an average of global solar radiation depending on sunshine duration hours for Iraqi metrological stations. *Iraqi Journal of Science*, 2742–2752.

Abed Al-Dulaimy, F. M., & Mohammed, G.-Y.-. (2013). A Correlative Measurement of an Hourly Record of Solar Radiation and Climatological Parameters. *Tikrit Journal of Engineer Ing Sciences/, 20.*

Al Tarabsheh and M. Ababne, A. (2010). Analysis of solar radiation in Jordan. *Jordan J Mech Ind Eng*, *6*(4), 733–737.

Alamdari, P., Nematollahi, O., & Alemrajabi, A. A. (2013). Solar energy potentials in Iran: A review. *Renewable and Sustainable Energy Reviews*, *21*, 778–788.

Al-Salihi, A. M., M. Kadum, M., & Mohammed, A. J. (2010). Estimation of global solar radiation on the horizontal surface using routine meteorological measurements for different cities in Iraq. *Asian Journal of Scientific Research*, *3*(4), 240–248.

Besharat, F., Dehghan, A. A., & Faghih, A. R. (2013). Empirical models for estimating global solar radiation: A review and case study. *Renewable and Sustainable Energy Reviews*, *21*, 798–821.

Duffie, J. A., Beckman, W. A., & Worek, W. M. (1994). Solar Engineering of Thermal Processes, 2nd ed. *Journal of Solar Energy Engineering*, *116*(1), 67–68.

Elistratov, V., & Ramadan, A. (2018). Energy potential assessment of solar and wind resources in Syria. *Istrazivanja i Projektovanja Za Privredu*, *16*(2), 208–216.

Hassan, R. A. (2012). *Evaluation of the Effect of Vehicle Exhaust Emission on the Ambient Air Quality in Duhok City* [Ph.D.]. Duhok.

Ibrahim, G. R. (2021). Multi-Criteria Decision Analysis Technique for Solar Power Sites Selection in Duhok Governorate–Iraq.

Katiyar, A. K., & Pandey, C. K. (2010). Simple correlation for estimating the global solar radiation on horizontal surfaces in India. *Energy (Oxford, England)*, *35*(12), 5043–5048.

Mahmood, F. H., & Al-Hassany, G. S. (2014). Study Global Solar Radiation Based on Sunshine Hours in Iraq. *Iraqi Journal of Science*, *55*(44), 1663–1674.

Meena, B., & Omar, K. (2015). Chemical analysis of rainwater and study effect of vehicle emissions on human health in Kurdistan region. *Oriental Journal of Chemistry*, *31*(2), 689–695.

Mousazadeh, H., Keyhani, A., Javadi, A., Mobli, H., Abrinia, K., & Sharifi, A. (2009). A review of principle and sun-tracking methods for maximizing solar systems output. *Renewable and Sustainable Energy Reviews*, *13*(8), 1800–1818.

OriginLab Corp., N. M. (2019). *Origin lab*. Retrieved from https://www.originlab.com/

Omar, O. S. (2010). *Estimation Of Global Solar Radiation In Duhok City And Characterization Of Two Types Of Silicon Solar Cells* [MSc]. Dohok.

Sen, Z. (2009). *Solar energy fundamentals and modeling techniques: atmosphere, environment, climate change and renewable*

energy (Vol. 46, pp. 46-2687-46–2687). Springer Science & Business Media.

Uçkan, İ. (2018). Analysis of solar radiation data in van, turkey. *Celal Bayar Üniversitesi Fen Bilimleri Dergisi*, 421–427.

Vojáčková-Sollorano, I. (2022). *As Iraq joins Paris Agreement, the UN calls for further support to help the country adapt*. Https://Iraq.Un.Org/.

Yousif, K. M. (2016). Preliminary assessment of heavy metal in selected sites within Duhok city, Iraq. *Am. Acad. Sci. Res. J. Eng. Technol. Sci.*, *26*(2), 316–325.

Zell, E., Gasim, S., Wilcox, S., Katamoura, S., Stoffel, T., Shibli, H., Engel-Cox, J., & Subie, M. A. (2015). Assessment of solar radiation resources in Saudi Arabia. *Solar Energy (Phoenix, Ariz.)*, *119*, 422–438.