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Global Solar Radiation Analysis and Possible Linked to Sunspots Number over Gaza, Palestine

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Abstract
An investigation of the global solar radiation analysis in Gaza, Palestine was explored for the period from 2002 to 2006. Analyses are based on weather data comprise, Monthly mean daily sunshine duration and monthly mean daily global solar radiation obtained from the Palestinian meteorological department. In this study, the maximum and minimum calculated values of monthly average daily global solar radiation are found 337 W m^{-2} and 71 W m^{-2} in July and January respectively. The mean annual solar radiation is about 1943.6 KWh m^{-2} $year^{-1}$ (222 W m^{-2}). Net longwave radiation (Rnl) was smallest in winter due to reduced reflection and variety between 32 W m^{-2} in February and about 59 W m^{-2} in June over the study period. This study shows that, Gaza receives abundant solar energy that can be usefully harnessed to generation of electric power. Linear regression analysis revealed a strong relationship between the variables, estimated solar radiation, and sunspots number in some months.

1. Introduction

Solar energy occupies one of the most important alternative energy sources and necessary factor for human life. Solar radiation has been recognized as the biggest and the main source of renewable energy on earth [1, 2, 3]. The solar radiation amount varies according to season, geographical location, and position of the collector [4]. Solar radiation become an important issue for renewable energy, thus increasing the need of reliable measurements of surface solar radiation [5]. It is considered an environmentally friendly source of energy because it comes directly from the sun [6]. Design of a solar energy conversion system requires precise knowledge regarding the availability of global solar radiation at the location of interest [7, 8, 9]. Unfortunately, for many developing countries solar radiation measurements are not easily available due to the deficiency of measurement equipment.

The geographical position of Palestine in the solar belt, compared with other neighboring countries distinguishes by a high potential of solar energy falling out during the year. The mean daily solar radiation in Palestinian is measured at 5.54 kWh/ m²/day [10]. The mean daily of solar radiation during winter is around (3.5 kWh/m²/day), and it reaches (6.2 KWh/m²/day) in the rest of the year (Palestinian Energy & Environment Research Center).

The Global horizontal radiation for Gaza Strip is more than 1900 Kwh/m2/year [11]. In one year, Gaza Strip shines about 2861 hours per year [12]. [12] encouraged local authorities to put rules and policies concerning the usage of renewable energy. [13] examined the challenges facing the Palestinian energy sector, and evaluated the renewable energy potential in meeting part of the energy demand. The study exhibited that the main renewable energy sources in Palestine are solar, wind biomass and geothermal.

Intermittent power supply is one of the most important problems in Gaza Strip. Environmentally friendly and economically acceptable alternative source of energy is required in Gaza Strip.

The solar magnetic field are found to increase and decrease along with the sunspot number. The increased UV radiation during sunspot maxima leads directly to an ozone increase and associated heating in the upper stratosphere [14] [15] [16] .

The 1 Wm 2 variation in total solar irradiance over an 11-year sunspot cycle corresponds to a change in the radiation forcing of about 0.17 Wm2 [17, 18]. This variety in radiation is measured to cause a change in Earth's surface temperature of approximately 0.07 K [18] [19] [20].

The author's first goal is to discussing and analysis the solar radiation to help engineers and designers to study the implementation of solar systems as alternative sources of energy, their benefit and the possibility to apply them in our region. Second, studying the possible linked between Sunspots Number and estimated Solar Radiation over Gaza, Palestine.

2. Material and Methods

In this present study, data of the monthly mean of daily global solar radiation and sunshine duration from Palestinian Meteorological Department were collected and utilized. Considering the limitation of meteorological observation, the longest and continuity data obtained cover a period of five years (2002-2006) for Gaza (Latitude 31°25′N Longitude 34°20′E and Altitude 14 meters). The global solar radiation was measured with a Spherical Pyranometer, while the sunshine-hours data was measured using the Camp-Bell Stokes Sunshine Recorder.

[21] suggested first theoretical methods for calculating global solar radiation based on sunshine duration. [22] are presented the relevant equations and calculation procedures in detail. Among the many empirical equations, the most widely used one is Angstrom empirical equation modified by FAO Penman–Monteith method [22].

Microsoft Excel was used for the calculating of the monthly mean daily values of the data gathered from Palestinian Meteorological Department. Calculated values of global solar radiation were compared with the ground estimated data to determine their level of accuracy using relative percentage errors ($e = \frac{R_{S,E}-R_{S,C}}{R_{S,E}} \times 100$). Measured radiation includes: R_a Extraterrestrial solar radiation, R_s Global solar radiation, Rso Clear-sky shortwave radiation, R_{ns} net shortwave radiation and R_{nl} Net outgoing longwave radiation [MJ m^{-2} day^{-1}] for the period from 2002 to 2006 over Gaza weather station.

Monthly mean sunspots number obtained by NOAA (National centres for Environmental Information - Solar Data Services). Regression analysis is used to understand the relationship between solar radiation and sunspots number.

3. Study Areas

Palestine is situated between 29°and 33° north latitude and between 35° and 39°east longitude in the Middle East at the eastern south ends of the Mediterranean Sea in south west of Asia (see Figure 1). It is bordered to the north by Lebanon, the northeast by Syria, the east by Jordan, and to the southwest by Egypt. The Gaza Strip is an exclave region and a part of the Palestinian National Authority, which also includes the West Bank and are claimed by the State of Palestine. The Gaza strip is 41 kilometers (25 mi) long, and from 6 to 12 kilometers (3.7 to 7.5 mi) wide, with a total area of 365 square kilometers (141 sq. mi), with around 1.9 million. Gaza is among the areas with the highest population density around the world. The Gaza Strip is located at 31°50′N 34°41′E. Gaza weather station has a Mediterranean climate with dry hot summers and mild winters (Köppen climate classification Csa), located on the country's Mediterranean coastal plain at the distance of nearly 200m from the shoreline, 14m above sea level.

Figure 1: The location of study area.

4. Results and Discussion

4.1. Solar Radiation Analysis

The extraterrestrial solar radiation Ra (MJ m^{-2} day^{-1}), the global solar radiation $R_{S,C}$ (MJ m^{-2} day^{-1}), daylight hours and relative percentage of errors were computed for each month as shown in the Table 1. It is observed that sunshine duration is above 55 percent throughout the year with exception of the months of December, January and February (Table 1). The value of n/N (= 0.42) corresponding to the lowest value of Ra (= 14.99 MJ m^{-2} day^{-1}) and $R_{S,C}$ (6.18 MJ m^{-2} day^{-1}) in the month of January is an indication of cloudy sky condition. These conditions correspond to the rainy season (December – February) observed in Gaza, during which there is much cloud cover.

The mean annual estimated solar radiation is about 1943.6 KWh m^{-2} year^{-1} (19.17 MJ m^{-2} day^{-1}). Both the values of the relative sunshine duration and calculated solar radiation in July reached peaks at 0.97 and 29.05 MJ m^{-2} day^{-1} respectively. This involves that a clear sky within the dry season and hence a high solar radiation is experienced. Noticeably, this is the dry season period in Gaza. The maximum error is found during winter months. It is observed that the error relatively increases with the increase of cloud cover and vice versa.

Figure 2 above clearly shows that the highest estimated solar radiation of 336.98 W/m2 was recorded in the month of July which may probably be as a result of end of rain in that month when the particles in the atmosphere were cleaned after rains and the sun intensities were high. The atmospheric particle (cloud and dust) reflect a few of incoming solar radiation back to space, thus reducing the amount of radiation reaches the earth surface. [23] found that, the average annual global horizontal radiation for Gaza is 2017 KWh m^{-2} year^{-1} (19.89 MJ m^{-2} day^{-1}).

The highest values of R_{so}(=29.56 MJ m^{-2} day^{-1}) and R_{ns}(=23.40 MJ m^{-2} day^{-1}) was recorded in July (as seen in Table 2).

Table 1: The solar radiation data include: extraterrestrial solar radiation, estimated and calculated global solar radiation (MJ m^{-2} day^{-1}), daylight hours, actual duration of sunshine and relative percentage errors for Gaza station (2002 - 2006).

Months	R_a	$R_{S,E}$	$R_{S,C}$	N	n	n/N	e
Jan	14.99	10.27	6.18	14.52	6.10	0.42	39%
Feb	18.15	13.15	7.94	15.89	8.50	0.53	39%
Mar	29.28	18.98	15.08	14.06	9.90	0.70	20%
Apr	30.73	22.85	14.38	17.57	10.00	0.56	37%
May	39.14	26.39	26.04	11.77	9.78	0.83	1%
Jun	37.66	28.58	28.28	10.16	9.70	0.95	1%
Jul	39.40	30.40	29.05	11.20	10.92	0.97	4%
Aug	37.68	24.1	23.69	13.91	10.54	0.75	1%
Sep	32.77	21.44	21.30	12.07	9.66	0.80	6%
Oct	24.30	14.77	13.29	14.14	8.40	0.59	10%
Nov	18.79	9.89	8.91	13.22	7.67	0.58	9%
Dec	18.30	9.22	7.70	11.00	3.67	0.33	16%

As seen in Figure 3, the net longwave radiation flux received at the surface is considerably modified in the cloudy-sky conditions. The water droplet and ice crystal absorb and emit longwave radiation more effectively than water in the vapor phase. So the clouds play important role in emit and absorb longwave solar radiation. The highest values of R_{so} and $R_{ns}$was recorded in July and the lowest in January.

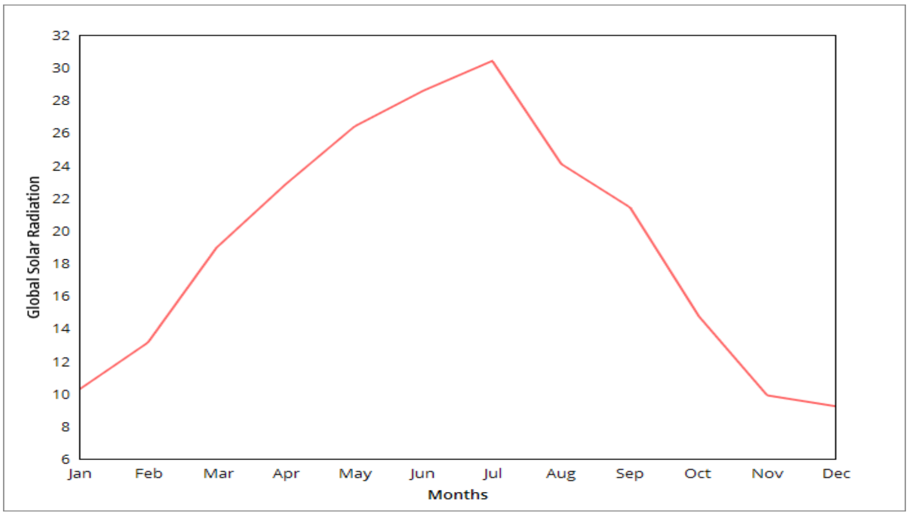

Figure 2: Monthly mean daily global solar radiation ($R_{S,E}$) during the study periods for Gaza station.

Rso was the biggest and Rnl was the smallest component of the radiation analysis. In general, Rso and Rns were largest in July and decreased toward the winter. Rnl was smallest in the winter due to reduced reflection of radiation from the surface during partial cloud cover. Rnl increased toward the midseason as the canopy developed, increasing reflection. Rnl ranged between 2.59 MJ m^{-2} day^{-1} in January and about 5.15 MJ m^{-2} day^{-1} in June over the study period.

Table 2: Calculated monthly mean Clear-sky shortwave radiation (Rso), net longwave radiation (R_{nl}) and net shortwave radiation (R_{ns}) (in MJ m^{-2} day^{-1}) for Gaza station (2002 - 2006).

Months	R_{SO}	R_{nl}	R_{ns}
Jan	11.24	2.59	7.9
Feb	13.61	2.79	10.12
Mar	21.96	3.59	14.61
Apr	23.05	3.00	17.59
May	29.36	4.69	20.32
Jun	28.25	5.15	22.00
Jul	29.56	4.74	23.40
Aug	28.27	3.74	18.55
Sep	24.58	3.79	16.50
Oct	18.23	3.91	11.37
Nov	14.09	3.91	7.61
Dec	13.73	3.65	7.09

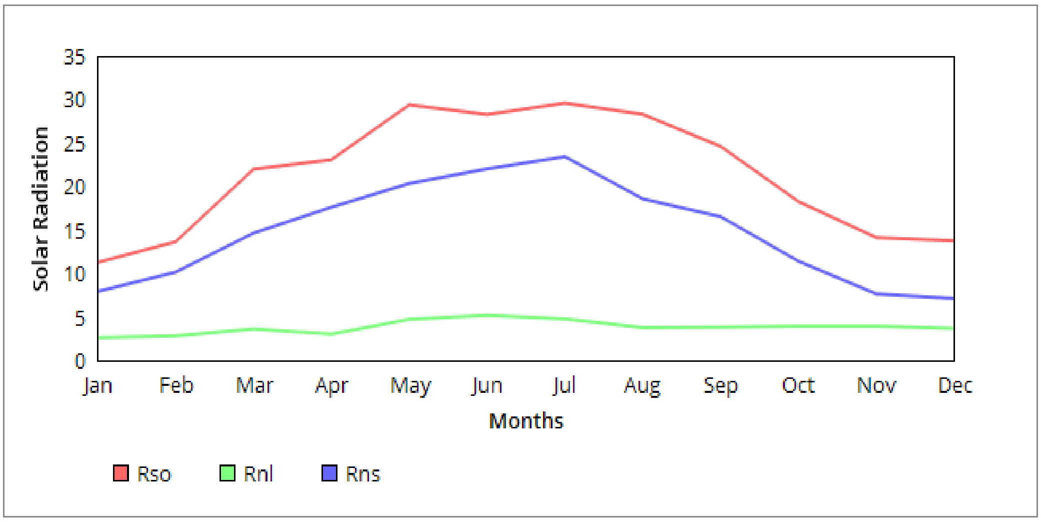

Figure 3: Correlation of clear sky solar radiation (R_{so}), net longwave radiation (R_{nl}) and net shortwave radiation (R_{ns}) for Gaza station during (2002-2006).

Figure 4 gives a comparison between estimated and calculated values of global solar radiation. The Figure 4 showed that, there is a good agreement between the estimated and calculated values of global solar radiation in Gaza. However, there is small variation during the time of rainy and cloudy season. The estimated values of global solar radiation of Gaza station is comparatively higher than the calculated values.

Figure 4: Comparison of estimated with calculated solar radiation for Gaza weather station during the study periods (2002 – 2006).

4.2. Relationship between Sunspots Number and Solar Radiation

The equation of linear regression line is founder by $Y=a+bX$, where X is the independent variable (annual mean sunspot number) and Y is the dependent variable (solar radiation). The value of R-square ($R2$) or the square of the correlation from the regression analysis was applied to exhibit how strong the correlation and relationship between the variables X and Y are. probability value (Pvalue) from the analysis is the test for the significant level $\alpha = 0.05$.

Since the probability value (Pvalue) from the regression analysis for the slopes of the monthly trend lines was greater than the significant level $\alpha= 0.05$, the null hypothesis (Ho: there is no trend in the data, fail to reject) except the summer months. Additionally, the$R$-square statistic also indicated a strong relationship between the variables, solar radiation, and sunspots number during summer months. The linear trend lines of the monthly rainfall indicated a downward trend in the month of February and upward trend for other months.

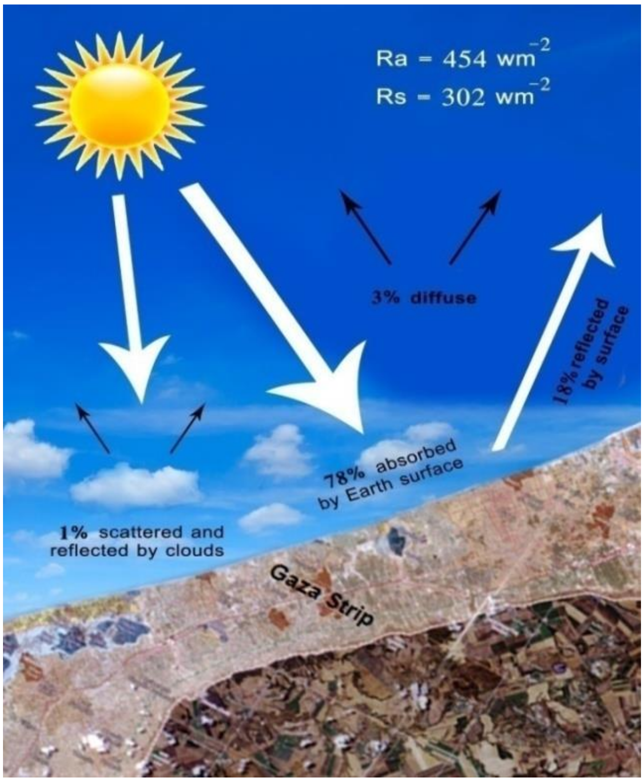

Figure 5: Global solar radiation analysis in May over Gaza during (2002-2006).

Table 3: Statistically output regression data from 2002-2006.

Months	Regression Equation	*R*-square	r- correlation	*P*value
Jan	Y= 0.002x+10.03	0.1012	0.31	0.601
Feb	Y= -0.005x+13.52	0.0813	0.28	0.641
Mar	Y= 0.000x+18.94	0.0005	0.02	0.969
Apr	Y= 0.015x+21.51	0.4142	0.64	0.241
May	Y= 0.030x+23.67	0.7577	0.87	0.056
Jun	Y= 0.026x+25.59	0.3662	0.60	0.279
Jul	Y= 0.028x+22.70	0.8839	0.94	0.017
Aug	Y= 0.025x+20.05	0.7920	0.88	0.043
Sep	Y= 0.015x+17.54	0.5169	0.71	0.171
Oct	Y= 0.010x+13.62	0.2885	0.53	0.350
Nov	Y= 0.012x+9.988	0.3672	0.60	0.278
Dec	Y= 0.004x+9.259	0.0360	0.18	0.759
Annual	Y= 0.742x+65.42	0.3794	0.61	0.032

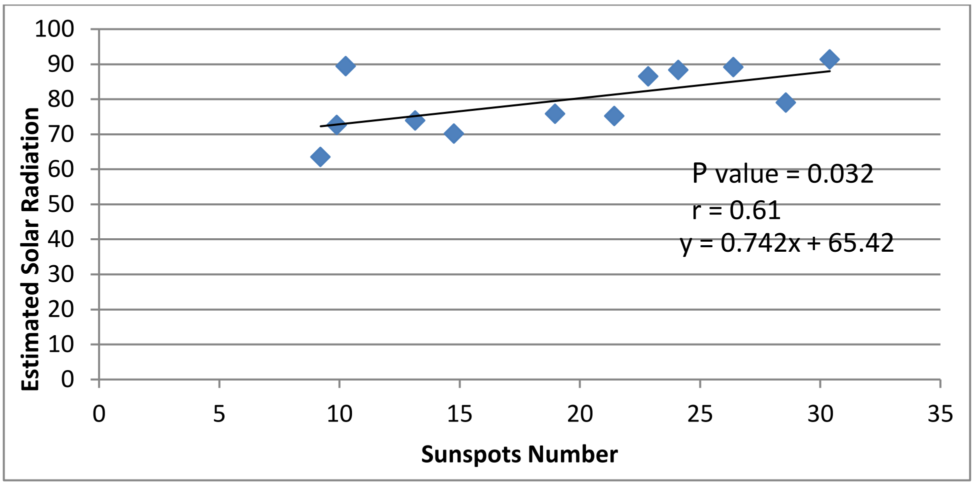

Figure 6: Average annual correlation between Sunspots Number and $R_{S,E}$.

Conclusion

In conclusion, It can be deduced from the results that, a good agreement has been found between the observed and calculated values of global solar radiation for the study locations except in winter months. The error variation domain between the estimated and calculated solar radiation is slight. The study has shown that, the maximum irradiation values found in the dry season linked with long duration of sunshine hours (above 10 hours/day) and less cloudy cover which take place in July. Minimum irradiation values are in the rainy and cloudy season linked with the slightest sunshine hour (less than 4 hours/day) which take place in December.

The mean monthly of daily solar radiation over Gaza is 5.3 KWh m^{-2} day^{-1} (1943.6 KWh m^{-2} $year^{-1}$), comparing with 5.54 KWh m^{-2} day^{-1} (2022.1 KWh m^{-2} $year^{-1}$) found by Global Solar Atlas. The seasonal variation of mean daily solar radiation is 7.2 KWh m^{-2} day^{-1} and 3.5 KWh m^{-2} day^{-1}(2628 and 1277.5 KWh m^{-2} $year^{-1}$) during summer and winter months respectively. According to these result, a high potential of solar energy falling out during the year. By using these alternative energy sources may significantly reduce the energy dependence on neighboring countries and improve the Palestinian population's access to energy. The optimal solution of irregular and intermittent electricity is using of solar energy systems as an alternative source of energy in Gaza Strip.

It is evident from the results of the linear regression analysis, that there is a strong relationship between the solar radiation and sunspots number during summer months.

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