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Research article

ON THE USE OF SUNSHINE BASED MODELS TO ESTIMATE GLOBAL SOLAR RADIATION IN HEBRON CITY, PALESTINE

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Abstract

In this study, the daily sunshine duration is used to estimate average global solar radiation for Hebron city, Palestine. The daily sunshine data were measured for four years (2007 to 2010) from which the monthly mean values were determined. In this work, several equations were employed to estimate global solar radiation from sunshine hours. These equations included the original Angstrom-Prescott linear regression and modified functions (quadratic, logarithmic and exponential functions). Estimated values were compared with measured values in terms of the coefficient of determination (R^2), root mean square error (RMSE) and mean absolute percentage error (MAPE). The four models fitted the data adequately and can be used to estimate global solar radiation from sunshine hours. This study finds that the linear models performed better than the other models and it is preferred due its greater simplicity and wider application.

Keywords: solar radiation, Angstrom model, sunshine hours, correlation models.

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1. Introduction

Global solar radiation data are necessary at various steps of the design, simulation, engineers, agricultural scientists and performance evaluation of any project involving solar energy. Solar radiation provides the energy for photosynthesis and transpiration of crops and is one of the meteorological factors determining potential yields [1]. To evaluate the solar energy potential of an area, it is essential to calculate the local solar radiation. One way of a good approximation is through continuous, long-term measurements of data at the site of interest.

Compared to measurements of other meteorological variables, the measurement of solar radiation is more prone to errors and often encounters more problems such as technical failure and operation related problems. These problems could be one of many: calibration problems, problems with dirt on the sensors, accumulated water, shading of sensor by masts, etc [2]

Nevertheless, for many developing countries solar radiation measurements are not easily available due to the incapability to afford the measuring equipments and techniques involved [3]. It is therefore important to consider methods of estimating the solar radiation based on the readily available meteorological parameters.

Several empirical models have been used to calculate solar radiation, using available meteorological, climatological, and geographical parameters such as sunshine duration, ir temperature, latitude, precipitation, and relative humidity. The most commonly used parameter for estimating global solar radiation is sunshine hours [4-9]. Sunshine hours can be easily and reliably measured, and data are widely available. The most widely used method is that of Angstrom, who proposed a linear relationship between the ratio of average daily global solar radiation to the corresponding value on a completely clear day and the ratio of the average daily sunshine duration to the maximum possible sunshine duration [10].

The objective of this study was to validate several expression models for the prediction of monthly average global solar radiation on a horizontal surface from sunshine duration in Hebron city, Palestine, and to select the most adequate model.

2. Methodology

The most convenient and widely used correlation for predicting solar radiation was developed by Angstrom. Angstrom [6] proposed the first theoretical model for estimating global solar radiation based on sunshine duration. Page [7] and Prescott [8] reconsidered this model in order to make it possible to calculate monthly average of daily global radiation $\overline{H}$ (MJ/m^2 day) on a horizontal surface from monthly average daily total insolation on an extraterrestrial horizontal surface as the following relation:

$$\frac{H}{H_0} = a + b\left(\frac{S}{S_0}\right), \qquad (1)$$

where H is the monthly average global radiation on horizontal surface, S is the monthly average daily bright sunshine hours, S_0 is the maximum possible monthly average daily sunshine hours or the day length, a and b are constants, and H_0 is the monthly average daily extraterrestrial radiation (MJ/m^2 day) which can be expressed as [11]

$$H_0 = \frac{24}{\pi} I_{sc} \left[1 + 0.33 cos\left(\frac{360 D_n}{365}\right)\right]$$

$$\times \left[\cos L \cos\delta \, sin w_s + \frac{2\pi w_s}{360} \sin L \sin\delta\right], \qquad (2)$$

where w_s is sunset hour angle in degree and defined as:

$$w_s = \ cos^{-1} \qquad (3)$$

The value of 1367 W/m^2 has been recommended for the solar constant I_{sc}. L is the latitude of location under consideration; D_n is the day of the year starting from January 1 to December 31 and δ is the declination angle as given below:

$$\delta = 23.45 \, sin\left[\frac{360(284 + D_n)}{365}\right]. \qquad (4)$$

For a given month, the maximum possible sunshine duration can be computed by the following equation [12]:

$$S_0 = \frac{2}{15} cos^{-1}(-\tan L \tan\delta). \qquad (5)$$

The regression models proposed in the literature and developed in this study are listed in Table 1. In order to evaluate the performance of the equations proposed to estimate the global solar radiation in Hebron city for the period (2007-2010) a statistical comparison is performed using the indicators Root Mean Square Error (RMSE) and Mean Absolute Percentage Error (MAPE) [12]. The test on RMSE provides information on the short-term performance of the model as it follows a term-by term comparison of the actual deviation between calculated and measured value [13]. The test of MAPE provides information on the long term performance of the models studied. Also, the correlation coefficient (R^2) was used to measure the relation between measured and estimated global solar radiation.

Table 1: Regression models proposed in the literature.

Model No.	Model Type	Regression equation	Source
1	**Linear**	$\frac{H}{H_0} = a + b\left(\frac{S}{S_0}\right)$	Angstrom [6] and Prescott [8]
2	**Exponential**	$\frac{H}{H_0} = a + b\exp\left(\frac{S}{S_0}\right)$	Akinoglu and Ecevit [4]
3	**Logarithmic**	$\frac{H}{H_0} = a + b\log\left(\frac{S}{S_0}\right)$	Almorox and Hontoria [5]
4	**Quadratic**	$\frac{H}{H_0} = a + b\left(\frac{S}{S_0}\right) + c\left(\frac{S}{S_0}\right)^2$	Bakirci [9]

3. Results and discussion

The global solar radiation and sunshine duration data employed in this work were supplied by the Palestinian meteorological office. A radiometric station was established at the Hebron city (1000 m above sea level). During the (48-month) period from January (2007) to December (2010). Measurements including horizontal solar irradiance and sunshine duration were made on the rooftop in a position relatively free from any external obstructions. Data collection started before sunrise and finished after sunset. All measurements were referred to true solar-time. This facilitates the computations involving solar altitude for the extraterrestrial irradiance on unit horizontal surface and the subsequent comparison of data for different locations.

The regression constants a, b and c are reported for the four models in Table 2. The regression coefficient provides a valuable value for the four models with higher values for linear and quadratic models. The monthly values of RMSE and MAPE between measures and estimated global solar radiation data for the four models are calculated and presented in Table 3.

Table 2: Regression constants for Hebron city in the period of 2007-2010.

Model Type	R^2	a	b	c
Linear	0.9525	0.4612	0.3442	
Exponential	0.9492	0.4836	0.4722	
Logarithmic	0.9374	0.7462	0.1953	
Quadratic	0.9523	0.4782	0.2457	0.0521

Table 3: Statistical Validation of the four models.

Month	RMSE				MAPE			
	Linear	Exponential	Logarithmic	Quadratic	Linear	Exponential	Logarithmic	Quadratic
JAN	0.7421	0.7531	0.7632	0.7132	0.2560	0.9180	1.3342	0.5235
FEB	0.8061	0.8141	0.8542	0.8411	0.8221	0.7441	0.9954	0.7356
MAR	0.8113	0.8213	0.8365	0.8541	2.5621	2.1231	1.9726	2.0553
APR	0.7028	0.7215	0.6882	0.7032	1.6630	1.7640	1.4483	1.5642
MAY	0.9104	0.9243	0.9113	0.9253	0.7764	0.9443	1.7342	0.7067
JUN	1.0233	0.9835	1.1225	1.0156	1.0347	0.9726	0.6988	0.9945
JUL	1.0370	1.1264	1.1092	1.1045	1.6021	1.1241	0.9872	1.1150
AUG	0.9553	0.9621	0.9034	0.9482	1.3324	1.4534	1.1136	1.1783
SEP	0.7781	0.7814	0.8187	0.7703	1.1187	1.0837	1.1568	1.0092
OCT	0.7995	0.8105	0.8210	0.8034	0.9626	0.9165	1.0973	1.1554
NOV	0.6464	0.6884	0.6723	0.6992	1.2781	1.0851	1.2920	1.2045
DEC	0.5451	0.5821	0.6154	0.5773	1.2553	1.4163	1.2934	1.1330

Higher values of RMSE for exponential and logarithmic, however, the four models provides higher values of RMSE in summer months (May to August) and lower values in winter months (November to February), the lowest values of RMSE were obtained for January. In general, the MAPE values of the four models are low with lower values for linear and quadratic models.

Table 4 presents the measures and calculated values of the monthly average of daily global solar radiation on a horizontal surface for Hebron city. It can be concluded that the calculated values from the four models are in a good agreement with the measured data. However, the four models provide an overestimation in summer months and lower estimation in winter months. Overall, the linear model estimated values are very close to that of the measured data.

Table 4: The comparison between measured and estimated values of the monthly average daily global solar radiation (MJ/m^2) for the models.

Month	Measured	Models			
		Linear	Exponential	Logarithmic	Quadratic
JAN	12.2287	12.2036	12.1204	12.1933	12.1374
FEB	15.2516	15.1143	15.1447	15.2110	15.2306
MAR	19.5389	19.2665	19.4089	19.2943	19.1238
APR	24.4923	24.1874	24.2991	24.2119	24.1159
MAY	28.2219	28.0113	28.3421	28.1338	28.3476
JUN	30.2431	30.4478	30.3938	30.3267	30.4813
JUL	29.7603	30.5291	30.1190	29.9665	30.2512
AUG	27.3566	28.2371	28.3367	28.0457	28.1337
SEP	23.6811	23.8224	23.4998	23.2283	23.3790
OCT	18.4909	18.2038	18.1965	18.1988	18.3078
NOV	13.9922	13.4803	13.6948	13.8265	13.7731
DEC	11.3490	11.1976	11.0967	11.2038	11.1745

Comparing the results, we can see that all the regression equations gave very good results. The linear and quadratic models equations provided the best estimate and have the smallest errors for the monthly values. Also, the logarithmic and exponential regression equations provide good and very similar accuracy.

Given the small differences between the variance explained by linear regression and the most accurate equation, the quadratic and the simplicity and wider application of the linear equation, the simple linear regression, is in practice, sufficient, and the use of logarithmic and exponential equations is not sufficiently justified.

4. Conclusions

The results of this work clearly indicate the main significance of developing empirical models for estimating global solar radiation on horizontal surfaces reaching the earth for a particular geographical location. Several sunshine based models have been employed for estimating global solar radiation for Hebron city. The differences between the results of the different models are negligible. The linear equation is best overall, according to R^2, RMSE and MAPE, and has the best performance based on the measured data at one station in Hebron. It can be recommended to use the linear equation, however, due to the small differences between the exponential regression and quadratic regression and the greater simplicity of the linear equation. The linear equation can be used to estimate the global solar radiation in Hebron, Palestine.

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References

[1] J.L Bosch, G. Lopez, F.J Batlles, Daily solar irradiation estimation over a mountainous area using artificial neural network, Renewable Energy 33 (2008) 1622-1628.

[2] Alsamamra H, Ruiz-Arias J, Pozo-Vazquez D, Tovar-Pescador J. A comparative study of ordinary and residual kriging for mapping solar radiation over southern Spain, Agriculture and Forest Meteorology 3 (2009) 1343-1357.

[3] M. Mahmoud, I. Ibrik, Field experience on solar electric power systems and their potential in Palestine. Renewable and Sustainable Energy Review 7 (2003) 531-543.

[4] B.G Akinoglu, A Ecevit, Construction of a quadratic model using modified Angstrom coefficients to estimate global solar radiation, Solar Energy 45 (1990) 85-92.

[5] J. Almorox, C. Hontoria, Global solar radiation estimation using sunshine duration in Spain, Energy Conversion and Management 45 (2004) 1529-1535.

[6] A. Angstrom, Solar and terrestrial radiation, Quarterly Journal of Royal Meteorological Society 50 (1924) 121-125.

[7] J.K Page, The estimation of monthly mean values of daily total short wave radiation on vertical and inclined surface from sunshine records. Proceedings of UN Conference on New Sources of Energy 4(1961) 378-390.

[8] J.A Prescott, Evaporation from a water surface in relation to solar radiation, Transactions of the Royal Society of Australia (1940) 64 114-125.

[9] K. Bakirci, Correlations for estimation of daily global solar radiation with hours of bright sunshine in Turkey, Energy 34 (2009) 485-501.

[10] A.K Katiyar and C. Pandey, A review of solar radiation Models-Part I, Journal of Renewable Energy 2 (2013) 1-11.

[11] D.W Medugu, A. Adisa, F. Burari, M. Azeez, Solar radiation correlation between measured and predicted values in Mubi, Nigeria, International Journal of Science and Technology Education Research 4 (2011) 11-17.

[12] E. Isaaks, R. Srivastava, An Introduction to Applied Geostatistics. Oxford University: New York 1989; p. 561.

[13] R. Kittaneh, H. Alsamamra, A. Aljunaidi, Modeling of wind energy in some areas of Palestine, Energy Conversion and Management 5 (2012) 64-69.