INVESTIGATING SOLAR ENERGY POTENTIAL OF DIYARBAKIR PROVINCE

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Abstract

Nowadays, a large ration its energy needs are changed by fossil fuels. Research into the use of these fuels with limited reserves to be, and renewable energy sources because of the damage they have on the environment are focused. Solar energy, compared to other renewable energy resources in addition to the potential and ease of use has an easier way, you can spread opportunity. In this study, renewable energy sources include solar energy potential of Diyarbakir both existing potential to have both different and important places in the solar based energy production systems in terms of production technology and the degree of use of this potential and the method was investigated. The findings of the survey results indicate that H/H_0=-1.0308$(S/S_0)^2$+1.8082(S/S_0)–0.2235 and R^2 0.9481 among all statistical mathematical model.

Key words: Solar energy, solar models, statistical parameters, renewable energy sources, Diyarbakır solar energy potential, Diyarbakır solar energy utilization.

1. Introduction

Recently, that energy sources being spent are at the brink of depletion and that they are up to come to an end has increased the number of studies carried about on new and renewable energy sources due to environmental pollution these sources have caused. Of all energy sources, solar energy has most advantages. Initially, it is abundant, clean and convenient for local applications. The fact that oil prices are high increases the interest in solar energy, accordingly, the number of solar based systems.

Solar energy is one of the primary renewable energy sources in nature; therefore, it deserves a significant place among alternative energy sources. Solar energy applications, in order to design the system and project it, it is necessary to know the solar radiation data and their components belonging to the region.

Since the solar radiation measurement devices cannot be conducted wherever wanted, and are costly, they need to be calibrated at regular intervals. In places where solar radiation is not measured, it is possible to compute solar radiation values according to places establishing suitable correlations with acceptable error margin.

In order to measure the solar radiation, a number of empirical methods have been developed. These methods have been obtained by employing various parameters such as sunshine duration, cloudiness and environmental temperature. On this subject, studies have been

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conducted by many researchers and empirical formulas related to the different parameters were attained [1-25]. Among all energy sources, solar energy has a number of advantages. Initially, it is plentiful and clean; and also it is convenient for local applications. The fact that oil prices are high increases the demand for solar energy; accordingly, it raises the number of solar energy based systems.

In this study, global solar radiation in Diyarbakır region has been calculated by means of a simple computing method and the measured and calculated values have been compared to one another.

2. Materials and Method

In this study, Diyarbakır province has been chosen as the material. Diyarbakır is located in the north of Mesopotamia in the central part of Southeastern Part of Anatolia. Diyarbakır is surrounded by provinces such as Batman and Muş in the east; Şanlıurfa, Adıyaman and Malatya in the west; Elazığ and Bingöl in the east and Mardin in the south. In terms of geological formations, it is surrounded by mountains of Southeastern Tarsus mountains, branches in general; therefore, it appears to be on a land whose middle part seems to be hollow. The highest mountain of the province is Anduk Mountain (2830 m) on the border of Muş (Fig. 1).

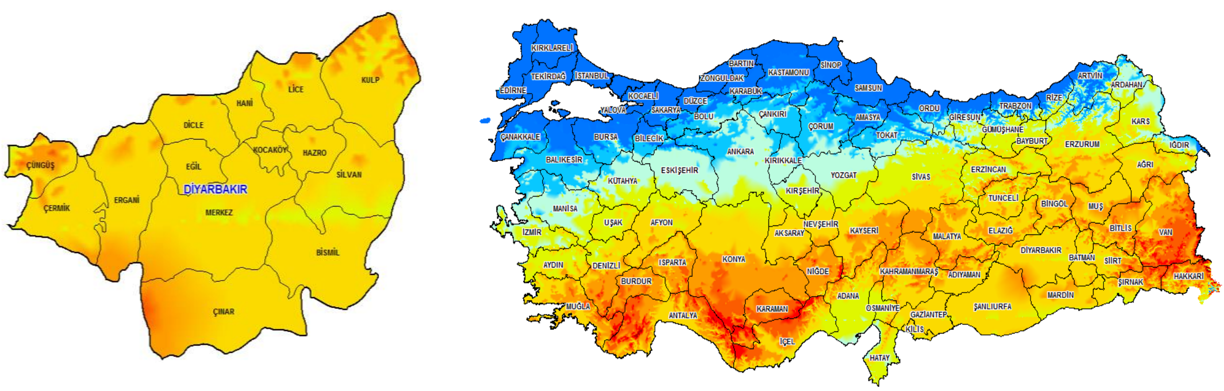


Figure 1. Diyarbakir Province Solar Energy Potential Map and Solar Power Map of Turkey (GEPA) [26]

Diyarbakır is dominated by a severe climate. Summers are very hot; while winters are not as cold as Eastern Part of Anatolia. The fundamental reason for this is that Southeastern Taurus Mountain crescent cuts the cold winds blowing from the north. The hottest temperature mean is 40.2 °C, while the coldest month mean is -10.1 °C. The highest temperature measured till today is 48.4 °C which is recorded on 29th July 1946; on the other hand, the lowest temperature measured until now is -25.7 °C which is recorded on 11th January 1933. July and August are the hottest months of the year. It is usual that the thermometers show 46 °C. However the average temperature is 22.5 °C. Diyarbakır displays high values with respect to clear days. The number of monthly clear days exceeds 25 days in August, yet, it is 5 days in March. Diyarbakır enjoys 154 cloudy days of a year in average. The number of the overcast weather days is determined as 68 days in a year.

Table 1. Distribution of Annual Total Solar Power Potential to Regions in Turkey Reference: EIE General Directorate [27]

Region	*Total Solar Energy (Kwh/m^2-Year)*	*Hours of Sunshine (Hour/Year)*
Southeastern Anatolia	1460	2993
Mediterranean	1390	2956
East Anatolia	1365	2664
Central Anatolia	1314	2628
Aegean	1304	2738
Marmara	1168	2409
The Black Sea	1120	1971

The annual precipitation mean is 496 mm in the province. Only 2% of this precipitation fall in summer months. As advanced to the skirts of the mountains in the north, the rainfall amount rises. Steppes, a natural plant cover of Southeastern Part of Anatolia, dominate the landscape of Diyarbakır. The herbaceous plants are more than that of the other kids in the steppes. These plants bush out in spring in a very short time, then blossom; and they dry out at the beginning of summer when precipitations stop. The mountains around are covered with oak tree forests partly. The 33% landscape of Diyarbakir is covered with forest and heathland, 40% is covered with planted areas and 22% is covered with meadow. In spring everywhere is green. In summer months, all grass dries out and everywhere are steppe except for the river and brooks banks. In valleys, willow, walnut and poplar trees; and at the higher altitudes oak, juniper and wild fruit trees take place. Although forest area seems to be about 33%, neat forest area has diminished a great deal. Some models available in the literature were investigated in order to determine daily mean global solar radiation in monthly basis coming to the horizontal surface in Diyarbakır.

2.1. Theory/calculation

Utilizing data of the sun-shining duration and solar radiation intensity prepared by the Renewable Energy General Directorate, it is retained that annual sun-shining duration is 2.737 hours (daily total 7.5 hours) and annual solar energy is 1527 kWh/m^2 (daily total 4.2 kWh/m^2) according to Solar Energy Potential Atlas of Turkey. The most sun receiving region of Turkey is South-eastern Part of Anatolia with an annual average 2.993 hours of sunshine duration and 1.460 kWh/m^2.

Daily total sun-shining calculation idea firstly was put forward by Angstrom. Angstrom equation was for the first time developed by Angstrom (1924). Angstrom used sunshine duration and clear weather data. For specific regions, a wide variety of equations encapsulating measured meteorological parameters such as weather temperature, soil temperature, relative humidity, precipitation, cloudiness, sun-shining duration were developed for the purpose to determine the amount of solar energy. The most widely used ones are the equations given as sun-shining duration function. (H) is the total solar radiation coming to horizontal unit surface; and (H_o) is solar radiation coming to out of atmosphere; and (S) is the sun-shining duration; and (S_o) is the day length. The equation known as 'Angstrom Equation' is expressed as follows:

$$\frac{H}{H_o} = a + b\left(\frac{S}{S_o}\right) \quad (2.1)$$

Here, (a) and (b) values called as Angstrom coefficient are regression constants.

Day length in hours (S_o) changes according to different time periods in the year related to hour angle (ω_s).

$$H_o = \left(\frac{24}{\pi}\right).Gsc\,.f.\left[\cos\emptyset.\cos\delta.\sin\omega_s + \left(\frac{\pi}{180}\right).\sin\emptyset.\sin\delta.\omega_s\right] \quad (2.2)$$

$$S_o = \left(\frac{2}{15}\right).\omega_s = \left(\frac{2}{15}\right).\arccos(-\tan\delta.\tan\emptyset) \quad (2.3)$$

So as to find monthly mean daily total solar radiation (H) value, various estimation models in many parts of Turkey and the world were developed. Many of the models developed were of a specific position since they possessed parameters of the region the calculation of which is desired to be carried out. Below, it is possible to find twenty authentic calculation models about different geographies of Turkey and the world in general.

Table 2. Input parameters for the estimation of monthly average daily global solar radiation in Diyarbakır, Turkey (W/m^2) [26]

Month	H_m	H_0	***S***	S_0	W_s	H_m/H_0	S/S_0
January	1690	5201.303	3.73	9.690327	72.67745	0.324918564	0.384919927
February	2470	6537.556	4.89	10.62354	79.67652	0.377817048	0.460298746
March	3750	8220.433	6.16	11.74867	88.11503	0.456180356	0.524314636
April	4740	9933.776	7.21	12.98961	97.42205	0.477159942	0.55505915
May	6010	11119.29	8.76	14.04959	105.3719	0.540502378	0.623505605
June	6350	11592.48	10.21	14.58586	109.394	0.547769069	0.699992778
July	6320	11333.33	11.06	14.34302	107.5726	0.557647394	0.771106946
August	5710	10364.67	10.45	13.43224	100.7418	0.550909959	0.777979027
September	4700	8814.574	8.83	12.23042	91.72817	0.533207823	0.721970168
October	3260	7012.658	6.48	10.99052	82.42891	0.464873658	0.589598969
November	1970	5504.688	4.73	9.935965	74.51973	0.357876778	0.476048396
December	1470	4825.505	3.35	9.418855	70.64141	0.304631327	0.355669562

The above models are the ones used as the basis for this study. Total Solar Radiation Calculation models (sun-shining duration, length of day, cloudiness, heat, relative humidity, precipitation, altitude, latitude, declination angle) displayed above were generated with regard to climatic properties of different areas of the world. Within an area of 200-300 km^2, climatic parameters change and models related to the climatic properties were made up since there were not sufficient numbers of meteorological stations. In order to calculate Complete Solar Radiation Meteorological in the regions where there are not meteorological stat.

Table 3. List of All Models Compare

Model	*a*	*b*	*References*
1	0.23	0.48	Page (1961)
2	0.2281	0.5093	Katiyar (2010)
3	0.215	0.5270	Said (1998)
4	0.3647	0.3505	El Sabaii and Trabea (2009)
5	0.1332	0.6471	Jin (2003)

2.2. Statistical Analysis

In these statistical studies, to examine the relation between these variables has always been one of the exertions of science. It is necessary to face this situation natural in order that the case can be explained. Because, in our daily life, whether in our daily lives or in scientific studies, most of the problems we come across are related to if there is a relation between two or more parameters. Whether there are any relations between two variables and if there is, finding out the level of this relation is a matter encountered intensively in statistical amylases.

In literature, there are a number of statistical test methods so as to evaluate the performance of solar radiation estimation models. The most common ones among these are as follows: the calculations of relative error percentage (e), specificity coefficient (R^2), mean bias error (MBE), and t-statistics (t-sat).

2.2.1 Relative error percentage (e %)

Relative error is expressed as follows:

$$e = \left(\frac{mi - ci}{mi}\right) \times 100 \qquad (2.4)$$

Percentile bias between calculated and measured data is expressed with (e), and its ideal value is equal to zero. While *ci* (calculated) in equation shows the calculated value, *mi* (measured) demonstrates the measured value.

2.2.2 Determination coefficient (R^2)

Determination coefficient shows at what rate a variable is relative to the other. It is used to determine the linear relation between calculated and measured values. The value of this coefficient change between 0 and 1 ($0 < R^2 < 1$) and the ideal value is the one that is close to 1.

$$R^2 = \frac{\sum_{i=1}^{n}(ci - ca)x(mi - ma)}{\left[\sqrt{\sum_{i=1}^{n}(ci - ca)^2}\right]x\left[\sum_{i=1}^{n}(mi - ma)^2\right]} \qquad (2.5)$$

Here (ca) and (ma) are the mean of calculated and measured values respectively.

2.2.3 Mean percentile error (MPE %)

Monthly mean radiation value predicted out of models suggested and measured value bias are calculated with the help of equation below.

$$MPE = \frac{\sum_{i=1}^{n}\left(\frac{mi-ci}{mi}\right)}{n} \; x \; 100 \qquad (2.6)$$

Here, (n) value is number of calculated and measured values.

2.2.4 Mean absolute error percentage (MAPE%)

The mean percentage error value is calculated by means of the following equation as absolute mean value of the difference between measured values.

$$MAPE = \frac{\sum_{i=1}^{n}\left|\left(\frac{mi-ci}{mi}\right)\right|}{n} \; x \; 100 \qquad (2.7)$$

2.2.5 Mean Bias Error (MBE)

It gives information about long term value of the correlation. Its lowest value is the desired value. Ideal value is the one which is close to zero. It is calculated via following equations.

$$MBE = \frac{1}{n}\sum_{i=1}^{n}(mi - ci) \qquad (2.8)$$

2.2.6 Mean error squares root (RMSE)

This statistical data has importance in comparing model performance measured and predicted in the short term. Though it receives a positive value all the time, its ideal value is the one which is close to zero.

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(ci-mi)^2} \qquad (2.9)$$

2.2.7 t-test method (t-stat)

Comparing t-test one of the most extensively used hypothesis tests and means of two groups, the difference between the two is decided logically whether the difference is coincidental or statistical. It becomes a crucial factor in determining the statistical significance between measured solar radiation values and predicted solar radiation values [27].

$$t - stat = \sqrt{\frac{(n-1)MBE^2}{RMSE^2 - MBE^2}} \qquad (2.10)$$

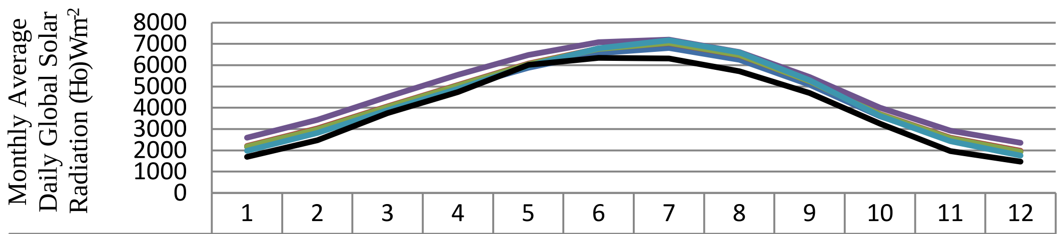
3.Results

The statistics of convenience of solar radiation values are calculated by means of the equation above. Solar radiation is estimated to Diyarbakır selected models province of radiation data with the closest value model literature Saudi last in 2009 by 4 as indicated al-Sabai, and

Traba Arabia-specific empirical correlations to the results of measurement when compared statistically. The R^2 of the model is fairly balanced in terms of compatibility with the radiation data of Diyarbakir, taking the value 0.9481. The highest monthly values harmony May showed the worst is analysed on the basis of December. Monthly relative percentage error value varies according to the month between 7.90 and -60.64 value. This model respectively identified as Model 1 Page Developed by specific global relations, Model 2 as specified by adding India equation developed specific to the general, the Model 3 with defined Said developed for the Libyan model and the model specified as 5 by Jin [14] for China to specific models followed.

Table 4. Statistical Analysis of the Total Value of Solar Radiation

Statistical Analysis of the Total Value Solar Radiation					
	Model 1 % e	***Model 2 % e***	***Model 3 % e***	***Model 4 % e***	***Model 5 % e***
January	-27.65092899	-30.53723799	-28.6023171	-53.76604793	-17.65461485
February	-19.35496304	-22.42172599	-21.1108502	-39.23000911	-14.09207729
March	-5.587848907	-8.538966507	-7.701659307	-20.23145504	-3.573947093
April	-4.038153376	-7.04830403	-6.361856414	-17.20351671	-3.189461857
May	2.075788852	-0.952637088	-0.570779235	-7.906780399	0.70895183
June	-3.327581827	-6.724960299	-6.595320283	-11.36946257	-7.009570157
July	-7.618423576	-11.32926913	-11.42764544	-13.86639513	-13.36613639
August	-9.53331359	-13.32609046	-13.44774895	-15.6961566	-15.55976035
September	-8.127761085	-11.73868447	-11.67845879	-15.85549153	-12.59904115
October	-10.35417825	-13.66158224	-13.08850218	-22.90531607	-10.72459887
November	-28.11762558	-31.48420838	-30.17818807	-48.5301634	-23.29688447
December	-31.5430666	-34.34025694	-32.10652449	-60.64079347	-19.27656184
R^2	0.990163	0.989498	0.988559	0.995899	0.981673
MPE %	-12.7648	-16.0087	-15.2392	-27.2668	-11.6361
MAPE	13.1108	16.00866	15.23915	27.2668	11.7543
MBE	-349.655	-483.962	-465.036	-813.409	-395.953
RMSE	397.6509	516.9441	502.2644	823.8619	475.8933
t-stat	6.123263	8.834264	8.127633	20.62147	4.974349



	1	2	3	4	5	6	7	8	9	10	11	12
Model 1	2157	2948	3960	4931	5885	6561	6801	6254	5082	3598	2524	1934
Model 2	2206	3024	4070	5074	6067	6777	7036	6471	5252	3705	2590	1975
Model 3	2173	2991	4039	5042	6044	6769	7042	6478	5249	3687	2565	1942
Model 4	2599	3439	4509	5555	6485	7072	7196	6606	5445	4007	2926	2361
Model 5	1988	2818	3884	4891	5967	6795	7165	6598	5292	3610	2429	1753
H measured	1690	2470	3750	4740	6010	6350	6320	5710	4700	3260	1970	1470

Figure 2. Average daily total radiation values of Diyarbakır model 1-5.

4. Conclusions

When the results of analyses are examined, it can easily be seen that the most appropriate model for Diyarbakır province Quadratic model. This model is followed by Logarithmic, Exponential, Linear and Exponential Power models, respectively.

Table 5. List of the Developing Models for Diyarbakır

References	***a***	***b***	***c***	R^2	
Lineer	0.6212	0.0985	-	0.911	$H/Ho = 0.6212\, S/So + 0.0985$
Quadratic	-1.0308	1.8082	-0.2235	0.9481	$H/Ho = -1.0308\left(\frac{S}{So}\right)^2 + 1.8082\left(\frac{S}{So}\right) - 0.2235$
Logaritmic	0.3474	0.6586	-	0.9374	$H/Ho = 0.3474 \ln\frac{S}{So} + 0.6586$
Exponential	0.7165	0.812	-	0.9322	$H/Ho = 0.7165\,(S/So)^{0.812}$
Exponential Power	0.1948	1.4403	-	0.8919	$H/Ho = 0.1948\, exp^{1.4403(S/So)}$

When examined in detail, Quadratic model is seen to be a second degree equation. When this model is observed from the angle of measurement results and compliance, its R^2 is 0.9481. It is accepted by everybody from general perspectives in present literature since this rate is very close to the other.

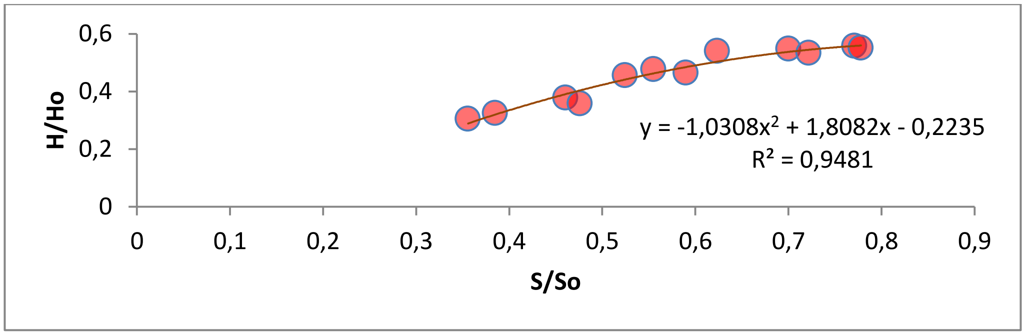
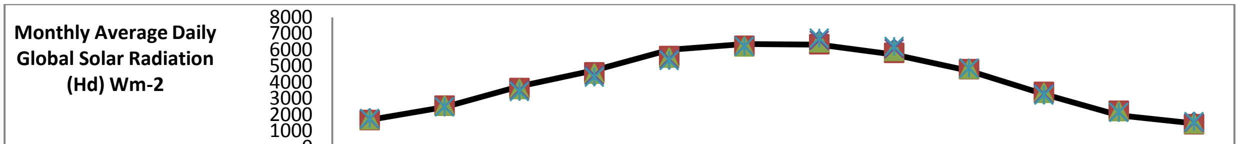


Figure 3. Correlation curve of quadratic model development.



	Oca	Şub	Mar	Nis	May	Haz	Tem	Ağu	Eyl	Eki	Kas	Ara
◆ Lineer Model	1756	2513	3487	4404	5402	6183	6545	6030	4821	3259	2170	1541
■ Quadratic Model	1663	2552	3627	4595	5595	6227	6323	5797	4801	3396	2222	1396
▲ Logaritmic Model	1700	2543	3570	4511	5498	6198	6441	5922	4808	3331	2206	1445
× Exponential Model	1717	2495	3487	4413	5429	6217	6575	6057	4848	3272	2159	1494
⁎ Exponential Power Model	1764	2471	3408	4304	5317	6189	6703	6191	4857	3194	2129	1569
━ H Measured	1690	2470	3750	4740	6010	6350	6320	5710	4700	3260	1970	1470

Figure 4. Total radiation values of models developed for Diyarbakır province.

This statistical data relative error percentage taking place among the other examined statistical data of the model's results and percentile MPE, MAPE, MBE, RMSE and t-stat values were figured out to be quite reasonable. When the monthly change compliance of Quadratic model was examined, while July provided the highest compliance, August, January, June, September, April, March, February, October, December, May and November followed this month, respectively. It is understood that the Mathematical model being able to meet appropriate solar radiation estimation in the best way in Diyarbakır climate geography was Quadratic equation.

It has become a must to utilize renewable energy sources due to the energy crisis experienced in the world and global climate change. Diyarbakır province chosen as material possesses a significant potential, especially in terms of solar energy. In our country, many solar energy plants have been established by public institutions. These plants generally meet small energy needs. Photovoltaic solar electric systems used for research have reached an energy capacity of 3.5 MW. In our country, solar energy is not sufficiently utilized. Researches carried out in this field have not come to the required level. Data analysis of monthly average daily total solar radiation models for Diyarbakır province has been performed and the values to be used for the new model related to average sun-shining duration and day length climate parameters have been given.

Table 6. Analysis of Models Developed for Diyarbakır Province

Statistical Analysis of the Global Solar Radiation Values of the Developing Models					
	Lineer Model % e	*Quadratic Model % e*	*Logaritmic Model % e*	*Exponential Model % e*	*Exponential Power Model % e*
January	-3.906745562	1.579822485	-0.619171598	-1.569289941	-4.372781065
February	-1.752307692	-3.333481781	-2.97562753	-1.000364372	-0.053157895
March	7.00952	3.28544	4.797173333	7.020266667	9.130373333
April	7.09556962	3.055970464	4.834345992	6.89871308	9.192341772
May	10.11663894	6.903311148	8.513061564	9.67063228	11.52856905
June	2.634976378	1.939448819	2.388141732	2.088283465	2.535385827
July	-3.562151899	-0.044541139	-1.910443038	-4.038386076	-6.063939873
August	-5.60357268	-1.531751313	-3.716269702	-6.072189142	-8.428984238
September	-2.584361702	-2.149914894	-2.291638298	-3.142425532	-3.346340426
October	0.024693252	-4.174325153	-2.192116564	-0.36291411	2.038220859
November	-10.15558376	-12.80101523	-11.97913706	-9.581015228	-8.05142132
December	-4.861836735	5.057482993	1.69292517	-1.59952381	-6.731088435
R^2	0.979354	0.992158	0.987273	0.979591	0.966913
MPE %	-0.4621	-0.18446	-0.28823	-0.14068	-0.21857
MAPE	4.94233	3.821375	3.992504	4.420334	5.95605
MBE	27.32717	20.43508	22.09583	23.259	28.65242
RMSE	258.0479	167.4471	205.7048	254.3651	324.1843
t-stat	0.353215	0.407806	0.358329	0.304546	0.294285

References

[1] Akinoglu BG, Ecevit A. Construction of a quadratic model using modified Angstrom coefficients to estimate global solar radiation. Solar Energy 1990;45:85-92.

[2] Aksoy B. Estimated monthly average global radiation for Turkey and its comparison with observations. Renewable Energy 1997;10;625-33.

[3] Almorox J, Benito M, Hontoria C. Estimation of monthly Angstrom-Prescott equation coefficients from measured daily data in Toledo, Spain. Renewable Energy 2005;30:931-6.

[4] Aras H, Balli O, Hepbasli A. Global solar radiation potential, Part 1: Model development. Energy Sources Part B 2006;1:303-15.

[5] Badescu V. Verification of some very simple, clear and cloudy sky models to evaluate global solar irradiance. Solar Energy 1997;61:251-64.

[6] Bahel V, Bakhsh H, Srinivasan R. A correlation for estimation of global solar radiation. Energy 1987;12:131-5.

[7] Bakırcı K. Estimation of global solar radiation on horizontal surface (Yatay yüzeye gelen global güneş ışınımınım tahmini). Isı Bilimi ve Tekniği Dergisi 2007;27:7-11.

[8] Bakırcı, .K., A Simple calculation method for estimation of instantaneous global solar radiation on horizontal surface (Yatay yüzeye gelen anlık global güneş işınımın tahmini için basit bir hesaplama metodu). Isı Bilimi ve Tekniği Dergisi, 2009;29(2):53-8.

[9] Bulut H, Buyukalaca O. Simple model for the generation of daily global solar-radiation data in Turkey. Appl Energy 2007;84:477-91.

[10] Dincer I, Dilmac S, Ture IE, Edin M. A simple technique for estimating solar radiation parameters and its application for Gebze. Energy Convers Manage 1996;37:183-98.

[11] Elagib NA, Mansell MG. New approaches for estimating global solar radiation across Sudan. Energy Convers Manage 2000;41:419-34.

[12] Ertekin C, Yaldiz O. Comparison of some existing models for estimating global solar radiation for Antalya (Turkey). Energy Convers Manage 2000;41:311-30.

[13] Gopinathan KK, Soler A. A sunshine dependent global insolation model for latitudes between 60°N and 70°N. Renewable Energy 1992;2:401-4.

[14] Jin Z, Yezheng W, Gang Y. General formula for estimation of monthly average daily global solar radiation in China. Energy Convers Manage 2005;46:257-68.

[15] Kaygusuz K. The comparison of measured and calculated solar radiations in Trabzon, Turkey. Energy Sources 1999;21:347-53.

[16] Klein SA. Calculation of monthly average insolation on titled surfaces. Solar Energy 1977;19:325-9.

[17] Newland FJ. A study of solar radiation models for the coastal region of South China. Solar Energy 1988;31:227-35.

[18] Ogelman H, Ecevit A, Tasdemiroglu E. A new method for estimating solar radiation from bright sunshine data. Solar Energy 1984;33:619-25.

[19] Samuel TDMA. Estimation of global radiation for Sri Lanka. Solar Energy 1991;47:333-7.

[20] Rehman S. Empirical model development and comparison with existing correlations. Appl Energy 1999;64:369-78.

[21] Rietveld MR. A new method for estimating the regression coefficients in the formula relating solar radiation to sunshine. Agricultural Meteorology 1978;19:243-52.

[22] Tahran S, Sarı A. Model selection for global and diffuse radiation over the Central Black Sea (CBS) region of Turkey. Energy Convers Manage 2005;46:605-13.

[23] Tasdemiroglu E, Sever R. An improved correlation for estimating solar radiation from bright sunshine data for Turkey. Energy Convers Manage 1991;31:599-600.

[24] Tiris M, Tiris C, Ture IE. Correlations of monthly-average daily, global, diffuse and beam radiations with hours of bright sunshine in Gebze, Turkey. Energy Convers Manage 1996;37:1417-21.

[25] Togrul IT, Togrul H. Global solar radiation over Turkey: comparison of predicted and measured data. Renew Energy 2002;25:55–67.

[26] http: //www.eie.gov.tr/ last access: 01.02.2015.

[27] Kallioğlu MA. Niğde ili için yatay düzenleme gelen günlük tüm, yayılı ve direkt güneş ışınımını hesaplama modeli geliştirilmesi. Msc Thesis, Niğde Üniversitesi, 2014.