Performance Evaluation of Different Radiation Models for Sub Humid Region

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Abstract— This study aimed to Performance of six radiation models. The objective was to determine the most accurate model for estimating solar radiation. Performance Evaluation of all the models on the same basis is prerequisite for selecting an alternative approach in accordance with available data such as air temperature (Tmax, Tmin, Tmean), actual sunshine hours (n) and potential sunshine hours (N). Therefore, recommended Angstrom-Prescott (A-P) model, locally calibrated A-P model, Chen et al. (2004), Ertekin and Yaldiz (1999), Togrul-Onat (1999), Almorox - Hontoria (2004) and Ogelman et al. (1984) radiation based model were used to estimate monthly solar radiation (Rs) at Pantnagar (Uttarakhand), India. Further, the performance of all these methods were evaluated by regression and error analysis between standard Rs derived using FAO recommended Angstrom-Prescott (A-P) model and Rs values estimated using all the five models, on monthly basis. On monthly basis, Almorox - Hontoria (2004) model performed best with lowest Root mean square error (0.1178) MJ m−2 day−1 and high coefficient of determination (0.997). Based on overall results it was concluded that the radiation based model provides average monthly accurate estimate of solar radiation compared to other models.

Key words: Radiation Models, Solar Radiation

I. INTRODUCTION

Almost all of the energy that drives the various systems (climate systems, ecosystems, hydrologic systems, etc.) found on the Earth originates from the sun. Solar energy is created at the core of the sun when hydrogen atoms are fused into helium by nuclear fusion. The core occupies an area from the sun's centre to about a quarter of the star's radius. At the core, gravity pulls all of the mass of the sun inward and creates intense pressure. This pressure is high enough to force the fusion of atomic masses. For each second of the solar nuclear fusion process, 700 million tons of hydrogen is converted into the heavier atom helium. Since its formation 4.5 billion years ago, the sun has used up about half of the hydrogen found in its core. The solar nuclear process also creates immense heat that causes atoms to discharge photons. Temperatures at the core are about 15 million degrees Kelvin (27 million degrees F). Each photon that is created travels about one micrometer before being absorbed by an adjacent gas molecule. This absorption then causes the heating of the neigh boring atom and it re-emits another photon that again travels a short distance before being absorbed by another atom. This process then repeats itself many times over before the photon can finally be emitted to outer space at the sun's surface. The last 20% of the journey to the surface the energy is transported more by convection than by radiation. It takes a photon approximately 100,000 years or about 1025 absorptions and re-emissions to make the journey from the core to the sun's surface. The trip from the sun's surface to the Earth takes about 8 minutes.

The irradiative surface of the sun, or photosphere, has an average temperature of about 5,800 Kelvin. Most of the electromagnetic emitted from the sun's surface lies in the visible band cantered at 500 nm (1 nm = 10^{-9}meters), although the sun also emits significant energy in the ultraviolet and infrared bands, and small amounts of energy in the radio, microwave, X-ray and gamma ray bands. The total quantity of energy emitted from the sun's surface is approximately 63,000,000 Watts per square meter (W/m^2 or Wm^{-2}). The energy emitted by the sun passes through space until it is intercepted by planets, other celestial objects, or interstellar gas and dust. The intensity of solar radiation striking these objects is determined by a physical law known as the Inverse Square Law. This law merely states that the intensity of the radiation emitted from the sun varies with the squared distance from the source. As a result of this law, if the intensity of radiation at a given distance is one unit, at twice the distance the intensity will become only one-quarter. At three times the distance, the intensity will become only one-ninth of its original intensity at a distance of one unit, and so on.

II. SOLAR RADIATION

Solar radiation is radiant energy emitted by the sun, particularly electromagnetic energy. About half of the radiation is in the visible short-wave part of the electromagnetic spectrum. The other half is mostly in the near-infrared part, with some in the ultraviolet part of the spectrum. The amount of energy radiated by the sun and the average Earth-sun distance of 149.5 million kilometres, the amount of radiation intercepted by the outer limits of the atmosphere can be calculated to be around 1,367 W/m2. Only about 40% of the solar energy intercepted at the top of Earth's atmosphere passes through to the surface. The atmosphere reflects and scatters some of the received visible radiation. Gamma rays, X-rays, and ultraviolet radiation less than 200 nanometres in wavelength are selectively absorbed in the atmosphere by oxygen and nitrogen and turned into heat energy. Most of the solar ultraviolet radiation with a range of wavelengths from 200 to 300 nm is absorbed by the concentration of ozone (O3) gas found in the stratosphere. Infrared solar radiation with wavelengths greater than 700 nm is partially absorbed by carbon dioxide, ozone, and water present in the atmosphere in liquid and vapour forms. Roughly 30% of the sun's visible radiation (wavelengths from 400 nm to 700 nm) is reflected back to space by the atmosphere or the Earth's surface. The reflectivity of the Earth or and body is referred to as its albedo, defined as the ratio of light reflected to the light received from a source, expressed as a number between zero (total absorption) and one (total reflectance).

Knowledge of the local global solar radiation is required by most models that simulate crop growth, and is also essential for many applications, including evapotranspiration estimates, architectural design, and solar energy systems. Design of a solar energy conversion system requires precise knowledge regarding the availability of global solar radiation at the location of interest. Since the global solar radiation reaching the earth's surface depends upon the local meteorological conditions, a study of solar radiation under local climatic conditions is Essential. Solar irradiance can be estimated using empirical models (Almorox, 2011).

Therefore, various methods have been explored by many researchers to estimate, with reasonable accuracy, the solar radiation from other available meteorological data. Parameters used as inputs in the relationships include astronomical factors (solar constant, world-sun distance, solar declination and hour angle); geographical factors (latitude, longitude and altitude); geometrical factors (surface azimuth, surface tilt angle, solar altitude, solar azimuth); physical factors (albedo, scattering of air molecules, water vapour content, scattering of dust and other atmospheric constituents); and meteorological factors (atmospheric pressure, cloudiness, temperature, sunshine duration, air temperature, soil temperature, relative humidity, evaporation, precipitation, number of rainy days, total perceptible water, etc).

Total daily solar radiation is considered as the most important parameter in the performance prediction of renewable energy systems, particularly in sizing photovoltaic (PV) power systems, agriculture and building design applications (Sabziparvar and Shetaee, 2007).

Solar radiation arriving on earth is the most fundamental renewable energy source in nature. a reasonably accurate knowledge of the availability of the solar resource at any place is required by solar engineers, architects, agriculturists, and hydrologists for many applications of solar energy such as solar furnaces, concentrating collectors, and interior illumination of buildings. In spite of the importance of solar radiation measurements, this information is not readily available due to cost, maintenance, and calibration requirements of the measuring equipment (Bakirci, 2009).

A good knowledge of solar radiation is essential for many applications, including agricultural, ecological, hydrological and soil–vegetation–atmosphere transfer models (Liu *et al.*, 2009). Despite its significance, accurate long-term records of solar radiation are not widely available due to the cost of measuring equipment and its difficult maintenance and calibration (Hunt *et al*., 1998).

Solar energy is the most abundant renewable and sustainable energy source on earth. Due to the nature of solar energy which is inexhaustible and ubiquitous, it can be utilized extensively as an appropriate option to supply the worldwide energy demand and diminish the existing environmental problems such as climate change. Thus, the growth of solar energy technology industry has been significant recently (Gani *et al*., 2015).

A. *Objectives:*

Keeping in view the relevance of precise calculation of solar radiation (Rs) values for monthly average, present study was taken up with following major objectives:

1) To determine monthly average solar radiation: and
2) To compare Rs values obtained from different model with standard model.

III. MATERIALS AND METHODS

This chapter encompasses description of study area, collection and analysis of metrologicol data and comparison of solar radiation by using five different models with Angstrom-Prescott (A-P) method.

A. *General description of the study area*

The study was conducted at G.B. Pant University of Agriculture and Technology, Pantnagar (29°N latitude, 79.3°E longitude, and 243.8 m above m.s.l.) in Uttarakhand state of india which lies in Tarai belt, located in foothills of the great Himalayas. The area has a sub-humid sub tropical climate with three distinct seasons namely, summer (March-June), monsoon (July- October) and winter season (November- February).

B. *Data Collection and Analysis of Metologicol Data*

The study was undertaken to estimated solar radiation by using five different models and Angstrom-Prescott (A-P) method. The metrological data on daily basis for the period of 17 year (1999-2015), consisting of air temperature (maximum and minimum); relative humidity (maximum and minimum); wind speed; duration of actual sunshine hours, were collected from meteorological observatory situated in the premises of Crop Research Centre of the G.B Pant University of Agriculture and Technology, Pantnagar.

C. *Estimation of solar radiation*

1) *Angstrom-Prescott (A-P) model*

The A-P model was first proposed by Angstrom in 1924 and further modified by Prescott in 1940. The A-P formula was developed based on the linear relationship between monthly mean daily Rs and sunshine hours as follows:

$$R_s=\left[0.25 + 0.50\left(\frac{n}{N}\right)\right] R_a \text{.........}(1)$$

Where, Rs is solar radiation (MJ m^{-2} day^{-1}), R_a is extraterrestrial solar radiation (MJ m^{-2} day^{-1}), n is actual sunshine hours (hs), and N is potential sunshine hours (hs), and a (0.25) and b (0.50) are the empirical A-P coefficients.

2) *Chen model*

Chen *et al*. (2004) proposed the following model

$$R_s=[0.28\ln(Tmax - Tmin) + 0.15]R_a \text{.........} (2)$$

Where Rs is solar radiation (MJ m−2 day−1), Ra is extraterrestrial solar radiation (MJ m−2 day−1), Tmax is maximum temperature and Tmin is minimum temperature(°C).

3) *Ertekin-Yaldiz model*

Ertekin and Yaldiz (1999) reported that RS can be calculated by the following equation:

$$R_s = - 4.46 + 0.477\ R_a - 0.226T \text{.........} (3)$$

Where Rs is solar radiation (MJ m^{-2} day^{-1}), R_a is extraterrestrial solar radiation (MJ m^{-2} day^{-1}), T is mean air temperature (°C).

4) Togrul-Onat model

Togrul-Onat (1999) estimated RS for Elazig, Turkey by a multiple linear Regression as follows:

$$Rs = -1.3876 + 0.518Ra + 2.3064\left(\frac{n}{N}\right) \ldots\ldots\ldots(4)$$

Where Rs is solar radiation (MJ m−2 day−1), Ra is extraterrestrial solar radiation (MJ m−2 day−1), n is actual sunshine hours (hs) and N is potential sunshine hours (hs).

5) Almorox- Hontoria model

Almorox and Hontoria (2004) have suggested an exponential type model.

$$R_s = \left[-0.0271 + 0.3096\, exp\left(\frac{n}{N}\right)\right]R_a \ldots\ldots\ldots (5)$$

Where Rs is solar radiation (MJ m^{-2} day^{-1}), R_a is extraterrestrial solar radiation (MJ m^{-2} day^{-1}), n is actual sunshine hours (hs) and N is potential sunshine hours (hs).

6) Ogelman model

Ogelman et al. (1984) suggested a second order polynomial equation for estimating $Rs=\left[0.195 + 0.676\left(\frac{n}{N}\right) - 0.142\left(\frac{n}{N}\right)2\right]Ra \ldots\ldots\ldots(6)$

Where Rs is solar radiation (MJ m^{-2} day^{-1}), R_a is extraterrestrial solar radiation (MJ 'm^{-2} day^{-1}), n and N are respectively the actual and potential sunshine hours (hs).

7) Statistical Analysis

Observed and estimated Rs values were compared by the following parameters: root mean square error (RMSE) and coefficient of determination (R^2) as:

8) Root Mean Square Error (RMSE)

RMSE is a quadratic scoring rule which measures average magnitude of error. The difference between forecast predicted and corresponding observed values are each squared and then averaged over the sample. Finally, square root of this average value is taken. Since errors are squared before they are averaged, RMSE given a relatively high weight to large errors which means that RMSE in negative – oriented score and in most useful when large error are particularly undesirable. It is expressed mathematically as:

$$RMSE = \frac{1}{\sqrt{n}}\sqrt{\sum_{i}^{n} = 1\,(P-O)^2} \ldots\ldots\ldots (7)$$

9) The coefficient of determination

(R^2) of a linear regression model is the quotient of the variances of the fitted values and observed values of the dependent variable. If we denote $\hat{y}_i$ as the observed values of the dependent variable, $\overline{y}$ as its mean, and y_i as the fitted value, then the coefficient of determination is:

$$R^2 = \frac{\sum_{i=1}^{n}(\hat{y}_i-\overline{y})^2}{\sum_{i=1}^{n}(y_i-\overline{y})^2} \ldots\ldots\ldots (8)$$

IV. Results and Discussion

The present study was carried out to determine solar radiation value for Pantnagar situated in Udham Singh Nagar district of Uttarakhand state by using value of Rs obtained with Angstrom-Prescott (A-P) model and different model to assess performance of different models for determining the Rs value.

Comparison of Rs value determined by different model with Angstrom-Prescott (A-P) method model on average monthly basis.

The data related to comparison between Observed values and estimated values monthly average daily solar radiation (MJm−2 day−1) for five Models is presented in

Month	Observed	model				
		Togrul	Ogelman	Almorox	Ertekin-Xaldiz	Chen
Jan	10.3188	11.0906	8.7262	10.0150	8.9857	12.0220
Feb	15.4743	14.1438	13.9618	15.2556	12.2422	16.2502
Mar	19.7001	17.1421	18.0751	19.6393	15.9054	20.6591
Apr	22.9977	19.7298	21.1871	23.0056	19.5493	24.3997
May	23.3914	21.0193	21.2116	23.1005	21.5644	23.6306
Jun	20.4362	21.0028	17.6768	19.8290	21.9176	20.2953
Jul	17.3827	20.2448	14.3238	16.8571	21.2386	15.3426
Aug	17.1557	18.9493	14.4311	16.6172	19.8410	14.3264
Sept	17.3849	16.7809	15.3802	16.9797	17.2215	14.5569
Oct	16.6112	14.1287	15.3818	16.6996	13.5046	15.7030
Nov	13.3682	11.7806	12.2387	13.3070	10.4500	13.9358
Dec	10.8463	10.5026	9.5690	10.5729	8.6508	12.2719

Table 1: The comparison between observed values and estimated values monthly average daily solar radiation (MJm−2 day−1) for 5 Models

Models	R^2	RMSE (MJm^{-2} day^{-1})
Almorox	0.997	0.2818
Ogelman	0.978	1.9087
Chen	0.854	1.3182
Togrul	0.796	1.7117
Ertekin-Xaldiz	0.737	2.5035

Table 2: Statistical comparison between observed Rs values and those estimated by the five models.

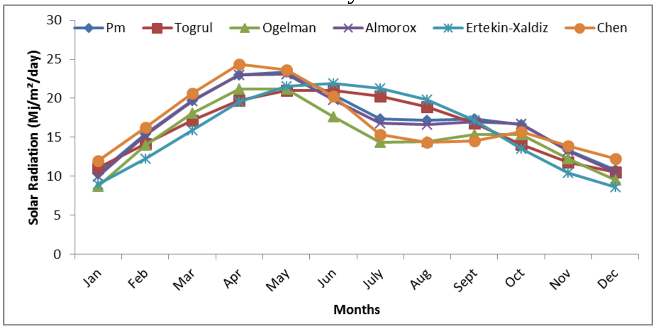

Fig. 1: Comparison between the Observed and estimated values by different models of solar radiation.

Daily solar radiation by various equations was estimated and compared with observed radiation at the weather station. Figure 1 showed that the values of solar radiation for Togrul-Onat (1999) model were overestimated from Angstrom-Prescott (A-P) model for January, June, July and August by 7.4, 2.7, 16.7 and 10.4 % respectively and underestimated for remaining months. The values of solar radiation for Ogelman et al. (1984) model were underestimated from Angstrom-Prescott (A-P) model in all months. the Almorox-Hontoria (2004) model were overestimated from Angstrom-Prescott (A-P) model for April by 0.03% respectively and underestimated for remaining months .the value of solar radiation for Ertekin and Yaldiz (1999) model were overestimated with observed model in the three months (June, July and August) by 7.2, 22.15 and 15.65 % respectively and underestimated in all months. the Chen et al. (2004) model were overestimated from Angstrom-Prescott (A-P) model for February, march, April, May, November and December by 5 %, 4.8 %, 6%, 1%, 4% and 13.1% respectively and underestimated for remaining months.

A. Statistics comparison

The statistical analyses for different models are presented Table 2. A linear regression between the Rs values estimated by five models and the values observed in weather station is presented for Angstrom-Prescott (A-P) model. In each section of figure 2 to 6 the equation of regression line and coefficient of determination (R2) are represented. Characteristics of regression line and the amounts of statistical indices resulting from comparison are represented also in Table 2. Table 2 showed that the values of coefficient of determination and root mean square error for different model.

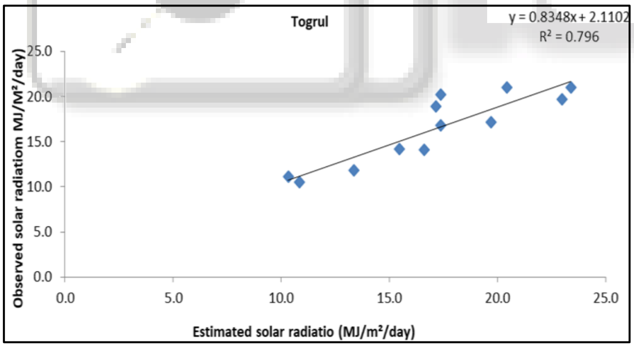

Fig 2. Estimated radiation from Togrul model against measured radiation.

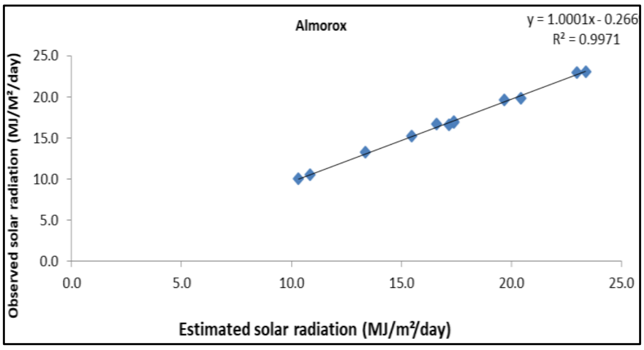

Fig 3. Estimated radiation from Almorox model against measured radiation.

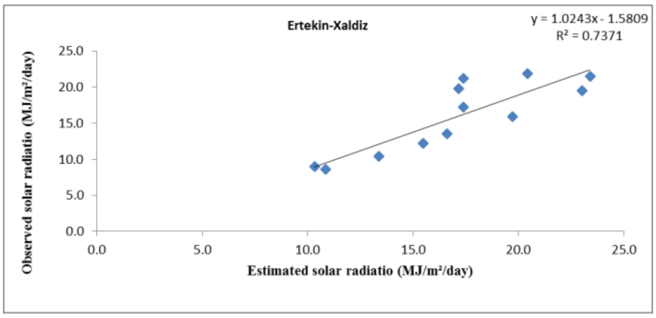

Fig 4. Estimated radiation from Ertekin- Xaldiz model against measured radiation.

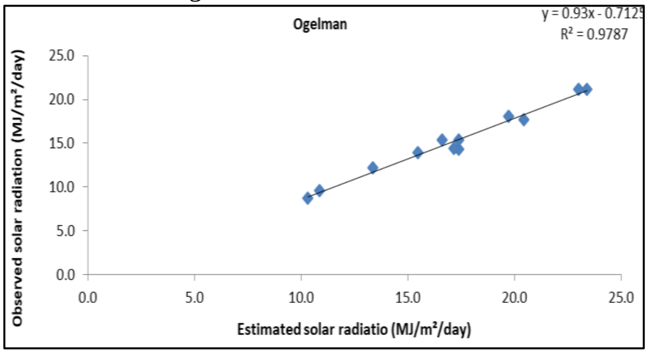

Fig 5. Estimated radiation from Ogelman model against measured radiation.

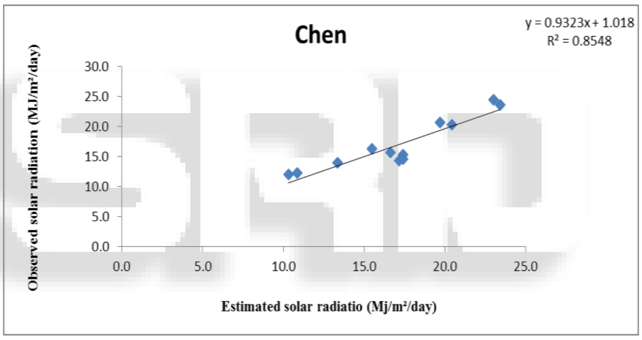

Fig 6. Estimated radiation from Chen model against measured radiation

The highest R^2 values was found for Almorox - Hontoria (2004) model with a value of 0.997 and lowest for Ertekin - Yaldiz (1999) model with a value of 0.737. Similarly the highest RMSE value was found for Ertekin and Yaldiz (1999) model with a value of 7.4282 and lowest for Almorox - Hontoria (2004) model with a value of 0.1178.

The result revealed that Almorox - Hontoria (2004) model was more accurate method for calculating solar radiation.

V. SUMMARY AND CONCLUSIONS

The main objective of this study was to determine value of solar radiation by various models as suggested by Chen et al. (2004), Ertekin and Yaldiz (1999), Togrul-Onat (1999), Almorox and Hontoria (2004) and Ogelman et al. (1984) in comparison to that observed by Angstrom-Prescott (A-P) model on the basis of long term daily meteorological dataset of 17 year (1999-2015) recorded at Pantnagar (29°N latitude, 79.3°E longitude, and 243.8 m above m.s.l.) in Uttarakhand state of india. The other objective in this study includes, compareson analysis of monthly average of Rs values calculated by A-P model and different models.

The study was carried out at the G.B. Pant University of Agriculture and Technology, Pantnagar situated in Tarai region having a sub-humid sub tropical climate.

- On monthly basis, average value of Rs determined by differenet model analysis varied from 24.6591 to 8.6508 with maximum value for the month of April and minimum for the month of December.
- The good correlation was observed between Rs estimated by models proposed by Almorox- Hontoria (2004) and Ogelman et al. (1984). Model.
- The Almorox - Hontoria (2004) model was more accurate method for calculating solar radiation compared to other different models.

References

[1] Ahmed, F.; Aqil, Burney. S. M. and Husain, S. A., 1991. Monthly average daily global beam and diffuse solar radiation and its correlation with hours of bright sunshine for Karachi, Pakistan. Renewable Energy., 1(1): 115–118.

[2] Aksoy, B. U.; Rusen, S. E. and Akinoglu, B. G., 2011. A simple correlation to estimate global solar irradiation on a horizontal surface using METEOSAT satellite images Turkish. J. Eng. Env.

a. Sci., 35: 125 –137.

[3] Álvarez, J.; Mitasova, H. and Allen, H. Lee., 2011. Estimating monthly solar radiation in south- central chile. Chilean Journal of Agricultural Research. 71(4).

[4] Almorox, J.; 2009. Estimating global solar radiation from common meteorological data in Aranjuez. Spain. Turk. J. Phys., 35: 53 – 64.

[5] Aladenola, O. O. and Madramootoo, C. A., 2014. Evaluation of solar radiation estimation methods for reference evapotranspiration estimation in Canada. Theory Apply Climatol., 118: 377–385.

[6] Badescu, V and Dumitrescu, A., 2015. Simple solar radiation modelling for different cloud types and climatology. Throe. Appl. Climatol., 124: 141–160.

[7] Benghanem, M. and Mellit., 2013. A simplified calibrated model for estimating daily global solar radiation in Madinah, Saudi Arabia. Theor. Appl. Climatol., 115: 197–205

[8] Bakirci, Kadir., 2009. Correlations for estimation of daily global solar radiation with hours of bright sunshine in Turkey. Energy., 34: 485–501.

[9] Bannani, F. K, S. T. and A, Ben-Khalifa. A., 2006. Estimation of monthly average solar radiation in Libya. Theor. Apply Climatol., 83: 211–215.

[10] Chen, J. Long. And Li, Guo-Sheng., 2013. Evaluation of support vector machine for estimation of solar radiation from measured meteorological variables. Theor. Appl. Climatol., 115: 627–638.

[11] Gadiwala, S. M.; Usman, A.; Akhtar, M. and Jamil, K., 2.013. Empirical models for the estimation of global solar radiation with sunshine hours on horizontal surface in various cities of pakistan., 18(9).

[12] Gani, A.; Mohammadi, K. and Shamshirband, S., 2015. Day of the year-based prediction of horizontal global solar radiation by a neural network auto-regressive model. Theor. Appl. Climatol., DOI 10.1007/s00704-015-1533-8.

[13] Gana, N. N. and Akpootu, D. O., 2013. Angstrom type empirical correlation for estimating global solar radiation in north-eastern Nigeria. ISSN(e): 2319-1813 ISSN(p): 2319-1805.Lke, C. U., 2013. Climatological Effects of total solar radiation in awake, Nigeria. IOSR Journal of Applied Physics., 5(2): 51-54.

[14] Irmak, S.; Irmak, A.; Allen, R. G. and Jones, J.W., 2003. Solar and net radiation-based equations to estimate reference evapotranspiration in humid climates. Journal of Irrigation and Drainage Engineering., (97): 0733-9437.

[15] I, U. A. and U, U. J., 2011. Performance assessment of Hargreaves model in estimating solar radiation in Abuja using minimum climatological data. International Journal of the Physical Sciences., 31(6): 7285 – 7290.

[16] Jacobs, J. M.; Anderson, M. C.; Friess, L. C. and Diak, G. R., 2004. Solar radiation, long wave radiation and emergent wetland evapotranspiration estimates from satellite data in Florida, USA.Hydrological Sciences–Journal–desSciences Hydrologiques., 49(3).

[17] Li, H.; Cao, F.; Bu, X. And Zhao, l., 2014. Models for calculating daily global solar radiation from air temperature in humid regions a case study. DOI 10.1002/ep.12018.

[18] Lyra, G.B.; Zanetti, S. S. and Santos, A. R., 2015. Estimation of monthly global solar irradiation using the hargreaves–samani model and an artificial neural network for the state of Alagoas in north eastern Brazil. 10.1007/s00704-015-1541-8.

[19] Mubiru, J.; B, E.; D, U. and F, Senyonga. T., 2007. Assessing the performance of global solar radiation empirical formulations in Kampala, Uganda. Theor. Appl. Climatol., 87: 179–184.

[20] Muzathik, A. M.; Ibrahim, M. Z.; Samo, K. B. and Wan, N. W. B., 2011 Estimation of global solar irradiation on horizontal and inclined surfaces based on the horizontal measurements. Energy., 36: 812–818.

[21] Myers, D. R., 2003. Solar Radiation modelling and measurements for renewable energy applications. Data and Model Quality., CP-560-33620.

[22] Mubiru, J.; Karume, K.; Majaliwa, M.; Banda, E. J. K. B. and Otiti, T., 2007. Interpolating methods for solar radiation in Uganda. Theor. Appl. Climatol., 88: 259–263.

[23] Mghouchi, Y. El.; Bouardi, A. El.; Choulli, Z. and Ajzoul, T., 2014. New model to estimate and evaluate the solar radiation. International Journal of Sustainable Built Environment., (3): 225–234

[24] Moradi, I.; Mueller, R. and Perez, R., 2014. Retrieving daily global solar radiation from routine climate variables. Theor. Appl. Climatol., 116: 661–669.

[25] Muzathik, M. A.; Nik, W. M. B. W.; Samo, K. B. and Ibrahim, M. Z., 2010. Reference solar radiation year and some climatology aspects of east coast of west malaysia. American J. of Engineering and Applied Sciences., 3(2): 293-299.

[26] Namrata, K.; Sharma, S. P. and Saksena, S. B. L., 2013. Comparison of different models for estimation of global

solar radiation in Jharkhand (India) Region. Smart Grid and Renewable Energy., 4: 348-352.
[27] Olmo, F. J.; Vida, J.; Morons, F.; Tovar, J. and Alados-Arboledas, L., 2001. Performance reduction of solar irradiance parametric models due to limitations in required aerosol data: case of the CPCR2 model. Theor. Appl. Climatol., 69: 253-263.
[28] Ouali, K. and Alkama, R. 2014. A new Model of global solar radiation based on meteorological data in Bejaia City (Algeria). Energy Procedia., 50: 670 – 676.
[29] Okonkwo.; N, G. and Sc, M., 2014. Estimating global solar radiation from temperature data in minna location. European Scientific Journal., 10(15): 1857 – 7881.
[30] Rivington, M.; Bellocchi, G.; Matthews, K. B. and Buchan, K., 2005. Evaluation of three model estimations of solar radiation at 24 UK stations. Agricultural and Forest Meteorology., 132: 228–243.
[31] Riza, D. F. A.; Gilani, S. I. H.; and Aris, M.S., 2011. Hourly solar radiation estimation using ambient temperature and relative humidity data. International Journal of Environmental Science and Development., 3(2).
[32] Sabziparvar, Ali. A. and Farahani, M. M., 2009. An improved estimation of daily clear- sky biologically EER from broadband global solar radiation. Int. J. Biometeorol., 53: 239–245.
[33] Sabziparvar, Ali. A.; Sabziparvar.; Mousavi, R.; Marofi, S.; Heidari, M.; and Ebrahimi Pak, N. A. 2014. Calibration of angström-prescott solar radiation model for more accurate estimation of reference evapotranspiration in the absence of observed solar radiation (AEMS)., 6-7.
[34] Sarkar, N. I., 2016. Estimation of solar radiation from cloud covers data of Bangladesh. Renewable., 3: 11.
[35] Samani, Z., 2000. Estimating solar radiation and evapotranspiration using minimum climatological data. Journal of Irrigation and Drainage Engineering., 126 (4): 0733-9437.
[36] Shamim, M.; Bray, M.; Remesan, R. and Han, D., 2015. A hybrid modelling approach for assessing solar radiation. Theor .Appl. Climatol., 122: 403–420.
[37] Toğrul, I. T., 2009. Estimation of solar radiation from angstroms coefficients by using geographical and meteorological data in bishkek, Kyrgyzstan. Is bilimi ve Teknigi Dergisi., 29(2): 99-108.
[38] Tabari, H.; T, P. H.; Willems, P. And Martinez, C., 2014. Validation and calibration of solar radiation equations for estimating daily reference evapotranspiration at cool semi-arid and arid locations. Hydrological Sciences Journal., DOI: 10.1080/02626667.2014.947293.
[39] Prem, W. P. and Paz, J. O.; 2011. Evaluation of Various Methods for Estimating Global Solar Radiation in the Southeastern United States., DOI: 10.1175/JAMC-D-11-0141.1.
[40] Xu, C. Y. and Singh, V. P., 2000. Evaluation and generalization of radiation-based methods for calculating evaporation. Hydrol. Process., 14(2): 339-349.
[41] Yakubu, D. and W, M. D., 2012. Relationship between the global solar radiation and the sunshine duration in abuja, Nigeria. issn., 5(3): 1943-2429.
[42] Zhang, Y. L.; Qin, B. Q. and Chen, W. M., 2004. Analysis of 40 year records of solar radiation data in Shanghai, Nanjing and Hangzhou in Eastern China. Theor. Appl. Climatol., 78: 217–227.
[43] Zamani, M., (2015). Temperature-based estimation of global solar radiation using soft computing methodologies. Theor. Appl. Climatol., doi:10.1007/s00704-015-1487-x.