Adamawa State University Journal of Scientific Research
ISSN: 2251-0702 (Paper)
Volume 5 Number 2, August, 2017
http//www.adsujsr.com

Comparison of Two Models Ratkowsky (1990) and Campbell and Donatelli (1998) to Estimate Global Solar Radiation in Yola and Maiduguri Location

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Abstract

Two empirical temperature-based global solar radiations (Rg) models; Ratkowsky (1990) and Campbell and Donatelli (1998) were used to estimate global solar radiation for Yola and Maiduguri locations with the objective of comparing the two performed model (equation) and recommend it for predicting solar radiation in the study area based on the value of the root-mean square error (RMSE) calculated from the estimated values. The root-mean square error values of Ratkowsky (1990) model for Yola and Maiduguri location is 0.00814 $MJ/m^2/day$ and 0.0257 $MJ/m^2/day$ respectively and the root mean square error (RMSE) for Campbell and Donatelli (1998) for the two locations is 0.0117 $MJ/m^2/day$ and0.0224 $MJ/m^2/day$ respectively. From the least value of the root mean square error (RMSE) the best model for Yola is Rathkowsky (1990) and for Maiduguri is Campbell and Donatelli (1998). Therefore the adopted models for predicting solar radiation from temperature data for Yola is Ratkowsky (1990) given by this equation and for $R_g = \delta_1 R_x[1 - \exp(-\delta_2 T_d^{0.5} - \delta_3 T_d - \delta_4 T_d^2)]$ while for Maiduguri is Campbell and Donatelli (1998) given by this equation $R_g = \varepsilon_1 R_x(1 - \exp\{-\varepsilon_2 0.017\exp[\exp(-0.053T_{av})]T_r^2 \times \exp(T_{mn}/\varepsilon_3)\})$.

Keywords: Global solar radiation, Temperature, Root Mean Square Error (RMSE)

Introduction

Solar radiation that reaches the earth's surface, called global solar radiation Rg, is a fundamental driving variable of many plant physiological processes, such as evapotranspiration, photosynthesis, carbohydrate partitioning, and biomass growth (Cengiz *et al.*, 1981; Boote and Loomis, 1991; Allen, 1997; Wu *et al.*, 2007). In addition to other weather variables, Rg is required by most crop models as a key input to simulate crop responses because crop growth is based on several plant physiological processes that involve the utilization of Rg (Meinke *et al.*, 1995; Mahmood and Hubbard 2002; Mavromatis and Jagtap, 2005). To reflect the seasonal variability and trends in crop production, crop models need weather data of sufficient length (Meinke *et al.*, 1995). Therefore, complete and accurate site-specific data on Rg are of considerable importance (Wu *et al.*, 2007). Increasing interest in modeling radiation-driven processes has created a higher demand for Rg data (Castellvi, 2001).

Materials and Methods

The data collected for the purpose of this work include:

- Monthly mean-maximum temperature for ten years from 2001 to 2010.
- Monthly mean-minimum temperature for ten years from 2001 to 2010.
- Monthly mean solar radiation for ten years from 2001 to 2010.

Data Analysis

The data were evaluated using the two proposed models (Ratkowsky 1990, Campbell and Donatelli 1998), taking account of commonly measured meteorological variable (temperature). To estimate the radiation transmissivity of the atmosphere, temperature based models uses daily maximum and minimum air temperatures with the assumption that maximum temperature T_{mx} decreases, but minimum temperature T_{mn} increases with increased cloudiness and that T_{mx} increases but T_{mn} decreases with clear skies.

(i). Ratkowsky (1990) followed the Bristow and Campbell (1984) approach but used T_d as change in temperature and also introducing a correction factor for seasonality effects occurring in mid latitude areas. Using the correction factor, Ratkowsky (1990) model for global solar radiation R_g is given as;

$$R_g = \delta_1 R_x \left[1 - exp\left(-\delta_2 T_d^{0.5} - \delta_3 T_d - \delta_4 T_d^2\right)\right] \qquad (1)$$

Where

R_x = *Extraterrestrial Solar Radiation*

T_d = *Change in temperature*

δ_1, δ_2, δ_3 *and* δ_4 = *Emperical Coefficient*

(ii). Campbell and Donatelli (1998) also account for seasonal – variation effects in clear sky transmissivity and changes in temperature T_d at wide variety of sites using daily average temperature T_{av} and minimum temperature T_{mn}. The global solar radiation R_g using this model is given as;

$$R_g = \varepsilon_1 R_x (1 - exp\{-\varepsilon_2 0.017 exp[exp(-0.053 T_{av})] T_r^2 \times exp(T_{mn}/\varepsilon_3)\}) \qquad (2)$$

Where

$\varepsilon_1, \varepsilon_2, \varepsilon_3$ = *Emperical Coefficient*

The expressions for the RMSE (Mjm^{-2}day^{-1} is;

$$RMSE = \left[\frac{\sum(\bar{H}_{ical} - \bar{H}_{imeas})^2}{n}\right] ½ \qquad (3)$$

Where $\bar{H}_{ical}$ and $\bar{H}_{imeas}$ are the ith calculated and measure values respectively, of solar radiation, n is the total number of observations. RMSE provides information on short- term performance of the models. It is always positive. The demerit of this parameter is that a single value of high error leads to higher value of RMSE. It is recommended that a low RMSE is desirable for good estimation (Akpabio and Etuk, 2003).

Results

Equations (1) and (2) were used to compute the global solar radiation for the period under review to ascertain which of the two models is best for the two locations. Figures 1 to 4 shows the comparison between the observed and calculated values of the global solar radiation for the two locations.

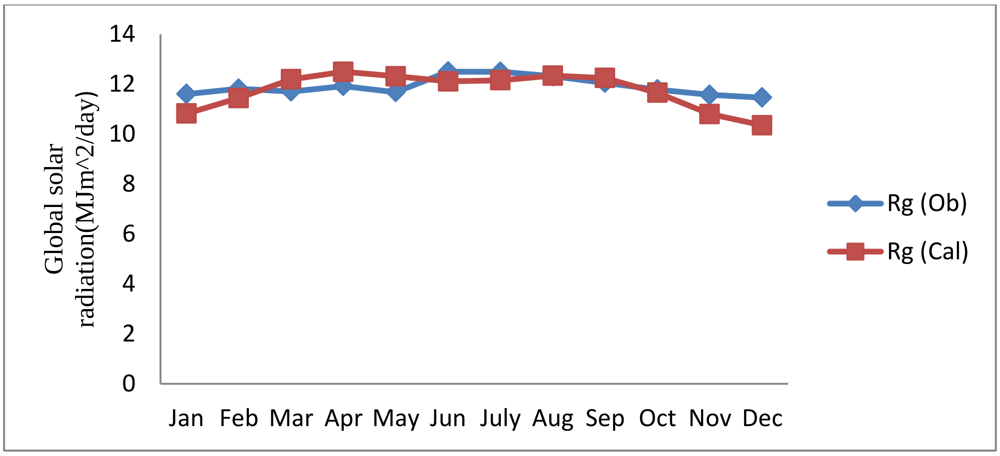

Figure 1: Comparison between the measured and the calculated values for Yola location using the Ratkowsky (1990) model

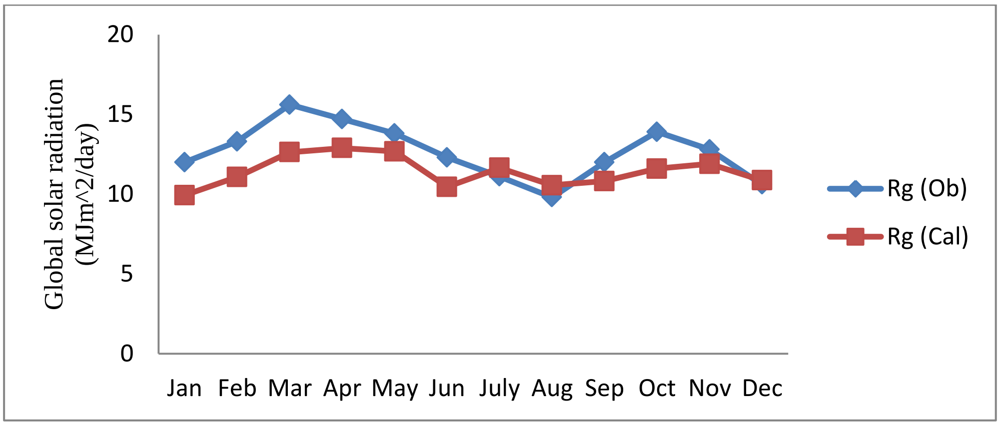

Figure 2: Comparison between the observed and the calculated values for Maiduguri location using the Ratkowsky (1990) model

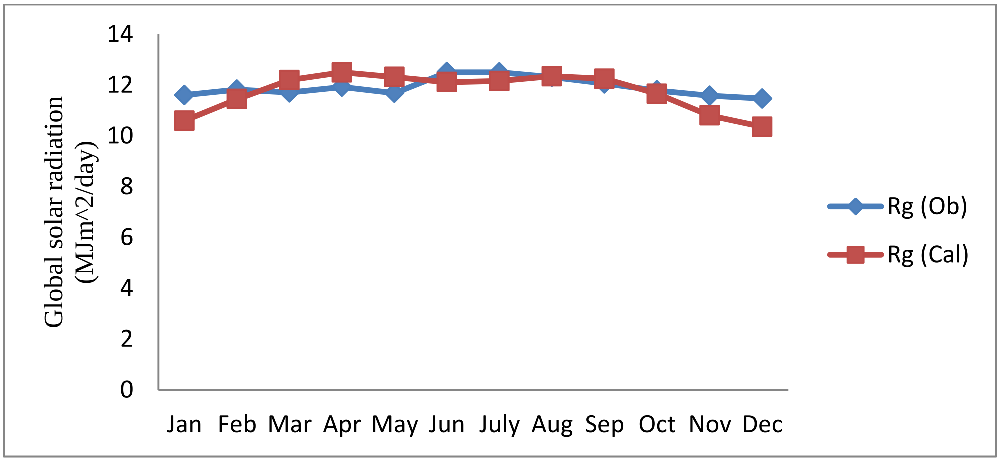

Figure 3: Comparison between the observed and the calculated values for Yola location using Campbell and Donatelli (1998) model

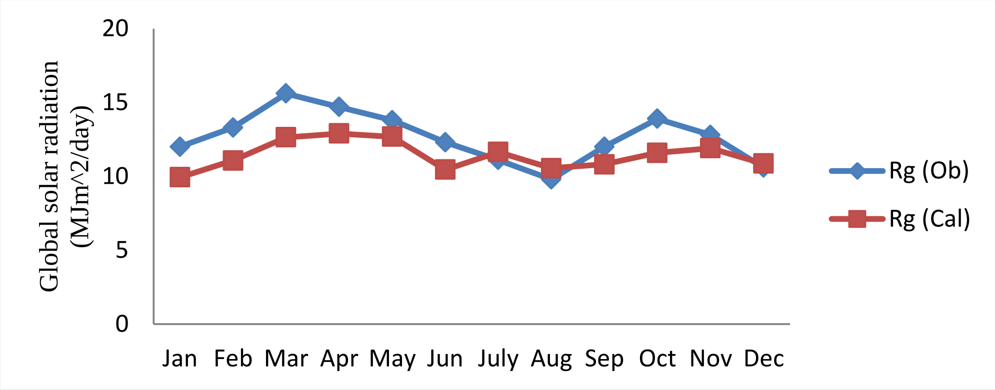

Figure 4: Comparison between the observed and the calculated values for Maiduguri location using Campbell and Donatelli (1998) model

Discussion

From figure 1 it was observed that there is a good agreement between the measured and the calculated values of the global solar radiation for yola location where we have the lowest value of the root mean square error (RMSE) from equation (3) as 0.00814 MJ/m^2/day while in figure 2 there is a similar agreement between the measured and the calculated values for Maiduguri location with a root mean square error value of 0.0257 MJ/m^2/day which is not a very good value for predicting the global solar radiation for Maiduguri location. In figure 3 we have a root mean square error (RMSE) value of 0.0117 MJ/m^2/day which is much greater than the error in the Ratkowsky model, while in figure 4 there is a good agreement between the observed and the calculated values based on the root mean square error of 0.0224 MJ/m^2/day for Campbell and Donatelli model the best performed model for predicting solar radiation in the two location with their respective error is Ratkowsky model for Yola location and Campbell and Donatelli for Maiduguri location.

Conclusion

In conclusion the development of the confrontation was performed using a series of measurements of global and diffuse solar radiation on a horizontal surface, therefore judging from the values of the root mean square error values (RMSE) which gave a better prediction of Rg indicate that about 95% of variation in the monthly mean daily solar radiation Rg on a horizontal surface can be accounted using the Ratkowsky (1990) model for Yola location and Campbell and Donatelli (1998) model for Maiduguri location.

Acknowledgment

We are pleased to acknowledge the Nigerian Metrological Agency, Abuja office for providing radiation data for the purpose of this work.

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