# EVALUATION OF ESTIMATED RADIATION SOLAR DATA FOR USING IN APSIM/ORYZA CROP MODEL

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Apresentado no XVII Congresso Brasileiro de Agrometeorologia – 18 a 21 de julho de 2011 – SESC Centro de Turismo de Guarapari, Guarapari - ES.

**ABSTRACT**: Crop model application for upland rice at Centro Oeste region is limited due to lack of daily solar global radiation set data. Therefore, five different solar radiation models proposed by Bristow & Campbell (BC), Hargreaves (HG), Donatelli & Campbell (CD), Donatalli & Bellocchi (DB) and Donatelli et al. (modular mode DCBB) were calibrated with the objective to identify and quantify the errors of simulated Rs on the upland rice yield, biomass and leaf area simulated by crop model ORYZA/APSIM. Based on the results obtained in this study it is possible to conclude that simulated upland rice yield is the most sensitive variable for using estimated global solar radiation. The empirical solar radiation models that showed better performances for crop model using were CD, DB and BC
**KEYWORDS:** yield, upland rice.

AVALIAÇÃO DE DADOS DE RADIAÇÃO SOLAR GLOBAL ESTIMADA PARA APLICAÇÃO NO MODELO DE SIMULAÇÃO DE CULTURA ORYZA/APSIM

**RESUMO:** A aplicação de modelos de simulação do crescimento, desenvolvimento e produtividade para a cultura do arroz de terras altas no Centro Oeste é limitada devido à escassa disponibilidade de séries históricas de dados diários de radiação solar global . Assim, cinco diferentes modelos para estimar dados de radiação global diários propostos por Bristow & Campbell (BC), Hargreaves (HG), Donatelli & Campbell (CD), Donatalli & Bellocchi (DB) e Donatelli et al. (modular DCBB) foram calibrados com a finalidade de identificar e quantificar os erros da radiação solar estimada (Rs) na produtividade, biomassa acumulada e índice de área foliar estimada pelo modelo de simulação ORIZA/APSIM. Baseado nos resultados obtidos nesse estudo pode-se concluir que a produtividade simulada do arroz de terras altas é a variável do modelo mais sensível a utilização de radiação solar estimada. Os modelos empíricos para estimar radiação solar global diária que apresentaram as melhores performances para utilização em modelos de simulação de culturas foram CD, DB e BC.

**PALAVRAS-CHAVE:** produtividade, arroz de terras altas.

**INTRODUTION**: The greatest limitation for crop model application at Centro-Oeste region is the lack of climate data. Among the climate variable data input for crop model, global radiation (Rs) is the most limiting. Probably, due to intensive agriculture starts after 80´s in this region. Rs is the driving factor controlling photosynthesis and evapotranspiration and is consequently an important weather variable for various agro-ecological studies. The number of meteorological stations recording Rs is low and can be a severe limitation for site-specific investigations with crop growth models. In the other hand, air temperature is an all-important parameter recorded by all meteorological stations. To overcome this limitation, researches have been carried out in the past to model the physical relation between maximum and minimum temperatures and Rs. These models use daily air extreme temperature to estimate atmospheric transmissivity and are attractive due to lower data requirement and computation cost. The objective of this study was to provide reliable methods for estimating radiation in Goiás State, Brazil, by calibrating the models proposed by Bristow & Campbell (1984), Hargreaves et al. (1982), Donatelli & Campbell (1998), Donatelli & Bellocchi (2001) and Donatelli et al. (2003) at 9 locations and to identify and quantify the errors of simulated Rs on the upland rice yield, biomass and leaf area simulated by crop model ORYZA/APSIM 2000.

**MATERIAL AND METHODS:** Crop model ORYZA is an explanatory and dynamic eco-physiological simulation model of the 'School of De Wit' and it was coupled to decision support APSIM (Agricultural Production Systems Simulator). This model simulates rice phenology, leaf area development, biomass production, yield and nitrogen accumulation in response to environmental variables such as temperature, solar radiation, soil water and nitrogen. In this study it was used five different empirical models for estimating $R_s$: BC - Bristow & Campbell (1984) modified by Donatelli & Campbell, (1998); HG - Hargreaves et al. (1982) modified by Hunt et al. (1998); CD - Donatelli & Campbell, (1998); DB - Donatalli & Bellocchi (2001) and DCBB – modular model (Donatelli et al., 2003):

$$\mathrm{R_{sBC}} = 0.75\left[1 - \exp\left(\frac{-\mathrm{b}\Delta\mathrm{T_i}^{\mathrm{c}}}{\Delta\mathrm{T_{avg}}}\right)\right] R_a \quad (1)$$

$$\mathrm{R_{sCD}} = 0.75\left[1 - \exp\left(-\mathrm{b}\left(0.017\exp\left(\exp\left(-0.053\Delta\mathrm{T_{avg}}\right)\right)\right)\Delta\mathrm{T_i^2} f_1(\mathrm{T_{min}})\right)\right] R_a \quad (2)$$

$$\mathrm{R_{sDB}} = 0.75[1 - f_2(\mathrm{i})]\left[1 - \exp\left(\frac{-\mathrm{b}\Delta\mathrm{T_i^2}}{\Delta\mathrm{T_{avg}}}\right)\right] R_a \quad (3)$$

$$\mathrm{R_{sDCBB}} = 0.75[1 + f_2(\mathrm{i})]\left[\frac{-\mathrm{b}\Delta\mathrm{T_i^2} f_1(\mathrm{T_{min}})}{\Delta\mathrm{T_{avg}}}\right] R_a \quad (4)$$

$$R_{s_{\mathrm{HG}}} = \mathrm{b}\ \mathrm{R_a}\sqrt{\mathrm{T_{max}} - \mathrm{T_{min}}} + c \quad (5)$$

where $\Delta T_i = T_{maxi} - (T_{mini} + T_{mini}+1)/2$, *b* and *c* are location specific empirical parameters which are calibrated by using measured data; $\Delta T_{avg}$ is the mobile week temperature based on centred mobile mean (as the average over 7 d around) of maximum and minimum temperature (ºC); $f_1(T_{min}) = e^{\left(\frac{T_{min}}{T_{nc}}\right)}$ , being $T_{nc}$ the summer night temperature factor to avoid underestimation of solar radiation in summer; $f_2(i) = c1[\sin(i \times c_2 \times \pi/180) + \cos(i \times f_3(c_2) \times \pi/180)]$, i = day of year, $c_1$ and $c_2$ are empiric model parameters for general seasonal factors. In the equation defining $f_2(i)$, $f_3(c_2) = 1 - 1.9 \times c_3 + 3.83 \times c_3^2$, where $c_3 = c_2 - \mathrm{integer}(c_2)$. $R_a$ is the daily potential radiation ($MJ.m^2/day$). The parameters *b* and *c* for BC, CD, DB and DCBB models were fitted by minimizing the root mean squared error. The parameters *b* and *c* for HG model were fitted by iteration method using the nls function from R software. $T_{nc}$ and $c_1$ and $c_2$ parameters were fitted by minimizing pattern index based on $T_{min}$ ($T_{nc}$) and day of year ($c_1$ and $c_2$). In this study, due to facilities computation, for BC model we used the $\Delta T_{avg}$ instead of mean monthly temperature. For all models, even years were used for calibration and odd years for evaluation. Observed daily maximum and minimum temperatures and global solar radiation have been obtained for 9 weather stations in Goiás state (Table 1). The weather data were provided from Meteorological and Hydrological System of Goiás State (SIMEHGO). The crop model ORIZA/APSIM 2000 for upland rice was employed to simulate crop responses to historic and estimated solar radiation. Inputs to this model include daily weather data (minimum and maximum temperature, precipitation and solar irradiance), soil properties, initial soil water content, cultivar genetic characteristics, planting date, and N fertilizer management. This study considered 9 locations and three planting dates, begin of planting season, 1/11, middle of planting season, 1/12 and end of planting season, 31/12. The soil properties used in the model represent the most common soil type, Oxisols, covering 46% of the region. The cultivar characteristics used in ORYZA/APSIM model was derived from BRS Primavera. The row spacing and nitrogen fertilization represent the local recommendation for upland rice in the region, 35 cm and 20 kg/ha of N at the planting date, 40 kg/ha at begin of tillering, and 40 kg/ha at begin of panicle initiation. Soil water balance and N dynamics were enabling for these simulations. Simulation starts at least 6 months before each planting data. No irrigation was used. The crop model outputs analyzed in this study were yield; maximum accumulated biomass; maximum leaf area index; accumulated solar radiation and precipitation by crop cycle. The applicability of the estimated solar radiation to crop models was evaluated by computing the RRMSE and MAE between crop simulation output yield, biomass, maximum leaf area index (LAI) and solar radiation accumulated (SRA) by crop cycle derived from measured and estimated solar radiation.

**RESULTS AND DISCUTIONS**: Considering all data set, yield expressed to be the most sensitive crop model output for estimated solar radiation. The RRMSE for yield ranged from 10.52 to 12.53 (Table 2) among solar radiation models used in this study. The MAE ranged from 247 to 341 kg/ha. For yield, all solar radiation models can be classified as good (10% ≤ RRMSE < 20%), being DB the most accuracy with the lowest value for RRMSE. CD model expressed the lowest value for MAE. Basically, the CD, DB and BC had similar performance for yield. The worst performance is showed by HG model. For maximum biomass accumulated, BC model showed to be the best accuracy and CD model has the lowest value of MAE. Also, the worst performance was obtained with HG model. However, for maximum accumulated biomass, all models were classified as excellent. For LAI, BC model also expressed to be the best accuracy. CD model showed the lowest MAE. For this variable, BC, CD, DB and DCBB can be classified as excellent and HG as good. For SRA, BC also expressed the best accuracy, showing the lowest value of RRMSE. However, CD had lower value of MAE than BC. For this variable, BC, CD and HG can be classified as excellent (RRMSE < 10%) and DCBB (10% ≤ RRMSE < 20%) as good.
The simulated yield performance from estimated solar radiation was highly affected by planting dates (Figure 1a). The first and second planting dates, 1° of November and 1° of December, showed the worst performance for simulated yield. In these planting dates all solar radiation models were classified as good (10% ≤ RRMSE < 20%). The reason for that is probably the high variation and amount of precipitation in those dates as showed by Figure 3. The highest MAE (Figure 1b) was obtained at 1° of December. This date has also the highest variation for accumulated precipitation (Fig. 2). The third planting date, 31 of December, showed the highest simulated yield performance for all solar radiation models. In this planting date, the BC, DC, HG and DB were classified as excellent (RRMSE < 10%). Only DCBB

model was classified as good. This planting date showed the lowest median for accumulated precipitation by crop cycle (Fig. 2).

**Table 1**. Weather station localization, altitude, period and number of years used in this study.

| ID | Weather Station name | Lat (°) | Lon (°) | Alt (m) | Period | # of years |
|---|---|---|---|---|---|---|
| 01 | Ceres | 15.31 | 49.60 | 739 | 2002-2007 | 6 |
| 02 | Anápolis | 16.33 | 48.95 | 1136 | 2005-2008 | 4 |
| 03 | Anicuns | 16.46 | 49.96 | 692 | 2006-2009 | 4 |
| 04 | Vianópolis | 16.74 | 48.52 | 1110 | 2004-2007 | 4 |
| 05 | Cristalina | 16.77 | 47.61 | 1189 | 2005-2008 | 4 |
| 06 | Palmeiras de Goiás | 16.80 | 49.93 | 596 | 2000/2001 and 2004/2005 | 4 |
| 07 | Jandaia | 17.05 | 50.15 | 637 | 2005-2008 | 4 |
| 08 | Vicentinópolis | 17.74 | 49.81 | 648 | 2000-2005 | 6 |
| 09 | Jataí | 17.88 | 51.71 | 696 | 2004-2009 | 6 |

ID – identification; Lat – latitude; Lon – longitude; Alt – altitude.

**Table 2**. Performance of solar radiation models according to crop growth simulated output, yield, biomass, LAI and solar radiation accumulated (SRA) by crop cycle. BC Bristow-Campbell; HG Hargreaves; CD Donatelli-Campbell; DB Donatalli-Bellocchi and DCBB modular model.

| Crop Model Output | BC | | CD | | DB | | DCBB | | HG | |
|---|---|---|---|---|---|---|---|---|---|---|
| | RRMSE | MAE | RRMSE | MAE | RRMSE | MAE | RRMSE | MAE | RRMSE | MAE |
| Yield (kg/ha) | 11.31 | 262 | 10.85 | 248 | 10.52 | 282.7 | 12.42 | 289 | 12.53 | 341.9 |
| Biomass (kg/ha | 4.39 | 456 | 5.65 | 415 | 6.03 | 578.4 | 5.48 | 487 | 8.75 | 891.7 |
| LAI | 5.93 | 0.20 | 7.43 | 0.17 | 8.41 | 0.25 | 7.32 | 0.20 | 11.12 | 0.32 |
| SRA ($MJ.m^2/day$) | 5.49 | 85 | 5.57 | 84.5 | 6.77 | 106.6 | 10.31 | 161 | 6.89 | 106.8 |

RRMSE - relative root mean square error (%); MAE - (mean absolute error ($MJ.m^2/day$))

**CONCLUSION:**

**-** Yield expressed to be the most sensitive crop model output for estimated solar radiation;

- The empirical solar radiation models that showed better performance for ORYZA/APSIM crop model using were CD, DB and BC.

**REFERENCES**:


Bristow, K.L.; Campbell, G.S. On the relationship between incoming solar radiation and daily maximum and minimum temperature. **Agric. For. Meteorol**. v.31, p. 159-166. 1984.

Hargreaves, G.H.; Samani, Z.A. Estimating potential evapotranspiration. **J. Irrigation and Drainage Div.** v.108, p. 225-230. 1982.

Hunt, L.A., Kucharb, L., Swanton, C.J. Estimation of solar radiation for use in crop modeling. **Agric. For. Meteorol**., v.91, p.293–300. 1998.

Donatelli, M., Campbell, G.S. A simple model to estimate global solar radiation. In: Proc. ESA Congr., 5th, Nitra, Slovak Republic, 28 June–2 July 1998. The Slovak Agric. Univ., Nitra, Slovak Republic, p. 133–134. 1998

Donatelli, M., Bellocchi, G. Estimate of daily global solar radiation: new developments in the software RadEst3.00. In: Proceedings of the Second International Symposium Modelling Cropping Systems, 16–18 July 2001, Florence, Italy, p. 213–214. 2001

Donatelli M, Bellocchi G, Fontana F. RadEst 3: a software to estimate daily radiation data from commonly available meteorological variables. **European Journal of Agronomy**, v.18, p.363–367, 2003.

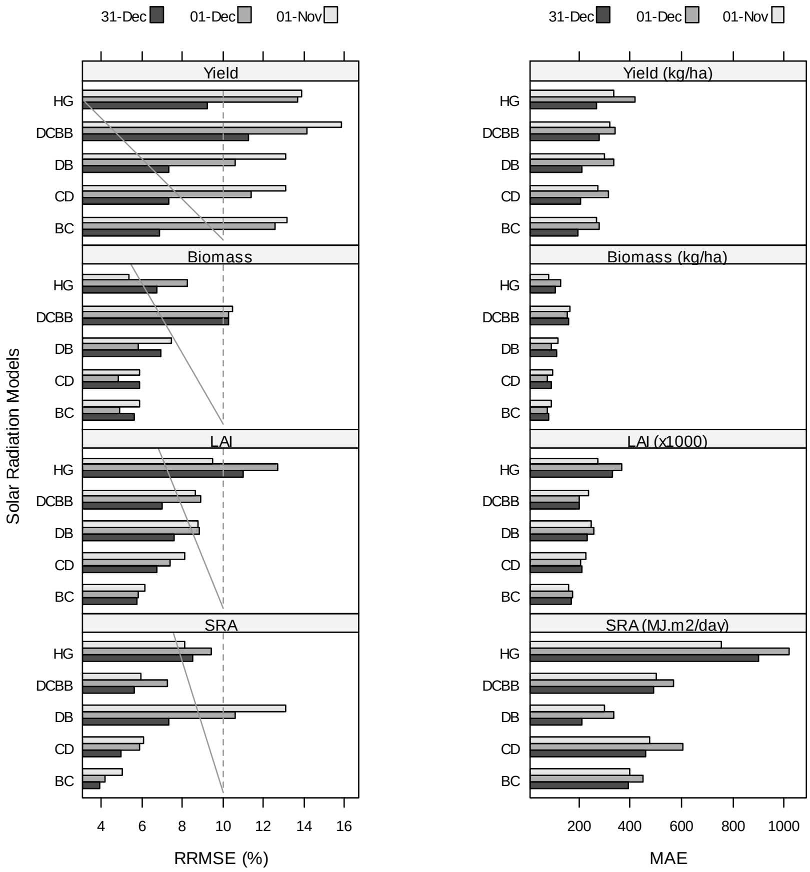


Figure 1. Performance of the solar radiation models according to crop growth simulated output. a) RRMSE – relative root mean square error, b) MAE – mean absolute error.

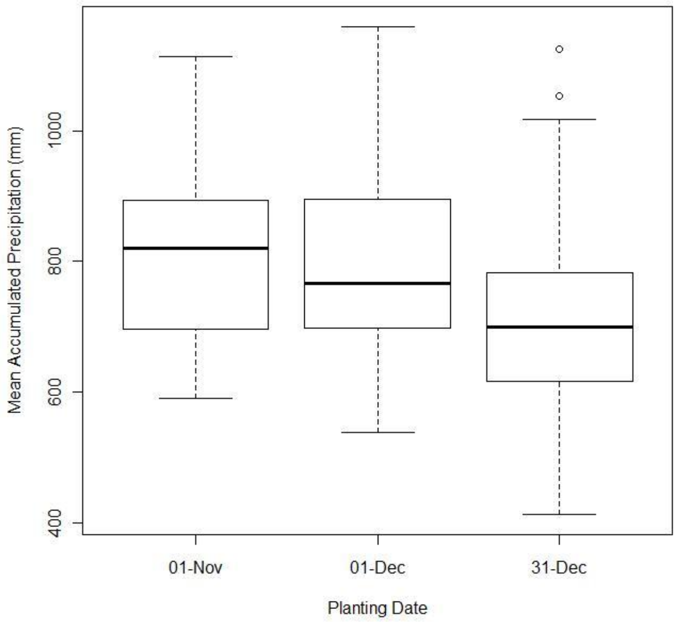


Figure 2. Variation and median for accumulated precipitation by crop cycle for upland rice by planting date.