POSTER SUMMARY

ACCURACY OF SOLAR RADIATION ESTIMATES IN THE SOUTH AFRICAN SUGAR BELT

SITHOLE P[1], SINGELS A[1] and WALKER S[2]

[1]*South African Sugarcane Research Institute, Private Bag X02, Mount Edgecombe, 4300, South Africa*
[2]*Faculty of Natural and Agricultural Sciences, Dept. of Soil, Crop and Climate Sciences, University of Free State, Box 339, Bloemfontein, 9300, South Africa*
phillemon.sithole@sugar.org.za *abraham.singels@sugar.org.za*
walkers.sci@ufs.ac.za

Abstract

Solar and net radiation (Rs, Rn) are important variables determining crop growth and water use, but are not widely measured and are therefore often estimated. Rs can be estimated from sunshine duration using the Angström-Prescott equation. Rn can be estimated from measured or estimated Rs, using the Wright equation. The objective of this study was to evaluate the accuracy of these methods at Mount Edgecombe and Pongola, and assess its impact on sugarcane reference evapotranspiration (ETo) and growth (Pnet) estimates. Rs estimates were generally higher than measured values at both sites, especially on cloudy days. The percentage bias in Rs estimates causes differences of magnitude in calculated crop growth. Rn is overestimated at low Rn values and underestimated at high Rn values, more so for estimates from sunshine duration than for estimates from measured Rs. Empirical parameters in the estimation equations need calibration for different levels of cloud cover, time of year and site. This should improve estimates of Rs, Rn, ETo and Pnet.

Keywords: estimation, solar radiation, net radiation, sunshine duration, accuracy, sugarcane

Introduction

Solar radiation (Rs is defined as the sum of incoming direct and diffuse shortwave radiation) and net radiation (Rn is the difference between incoming and outgoing short and long wave radiation at the earth's surface) are important variables determining crop water use and growth. Accurate data are essential for sugarcane yield forecasts (Bezuidenhout and Singels, 2007) and evapotranspiration estimates (Singels *et al*., 1999). In the South African sugar industry, Rs was estimated from measured relative sunshine duration (n/N) (Prescott, 1940) until the late 1990s, when pyranometers were introduced at some sites to measure Rs. Discrepancies have since been noted between measured and estimated Rs.

Rn is estimated from either measured or estimated Rs using the equation of Wright (1982). Inaccurate estimations of Rs and Rn result in inaccurate sugarcane evapotranspiration and crop growth predictions.

The objective of this study was to determine the accuracy of Rs and Rn estimates and quantify its impact on sugarcane evapotranspiration and biomass accumulation predictions.

Methods

Daily records of Rs, n/N, maximum and minimum air temperature, maximum and minimum relative humidity, and wind speed for Mount Edgecombe (29^o 42'S and 31^o 2'E) and Pongola (27^o 24'S and 31^o 35'E) for the period 1997 to 2007 were used to estimate Rs, Rn, ETo and Pnet. Daily Rn was measured at Mount Edgecombe from November 2007 until February 2008.

Rs was estimated using Equation 1 (Prescott, 1940):

$$R_S = R_a \left[a + b\left(n/N \right) \right] \qquad (1)$$

where

Rs = solar radiation at the surface (MJ m^2/day)
Ra = extraterrestrial solar radiation (MJ m^2/day)
n, N = actual sunshine duration and maximum possible sunshine duration (h/d)
a, b = empirical parameters (Pongola: a=0.257, b=0.52; Mount Edgecombe: a=0.252, b=0.52; following Glover and McCulloch, 1958).

Equation 2 was used to estimate Rn from measured and estimated Rs (Wright, 1982):

$$Rn = \left[(1-\alpha)R_s - \sigma \frac{(T_{\max K}{}^4 + T_{\min K}{}^4)}{2}(a_1 - 0.139\sqrt{e_d})(a' \frac{Rs}{Rs_o} + b') \right] \qquad (2)$$

where

α = surface albedo
T_{maxK} , T_{minK} = maximum and minimum daily air temperature (^{o}K)
e_d = daily mean actual vapour pressure (kPa)
Rs_o = clear sky short wave radiation (0.75 Ra)
σ = Stephan-Boltzmann constant (MJ m^2/day/K^4)
a_1, a', b' = empirical parameters (0.34, 1.35 and 0.35 respectively).

ETo was calculated using the Penman-Monteith equation as described by McGlinchey and Inman-Bamber (1996), and Pnet was calculated according to the method of Singels and Bezuidenhout (2002).

The accuracy of estimates was quantified using linear regression analysis, R^2, mean bias error (MBE) and root mean square error (RMSE).

Results and Discussion

Rs estimates were generally higher than measured values at both sites, especially on cloudy days (Figure 1a and b). For Pongola, the MBE was 1.6% and 23% for days when n/N was greater (clear days) and less (cloudy days) than 25%, respectively. Estimation errors were also larger on cloudy days than on clear days. Similar trends were observed for Mount Edgecombe.

Calibration of Equation 1 showed that parameters a and b differed with different levels of cloudiness and, to a lesser extent, time of year for both sites. The values were also different between the sites.Errors in Rs will cause relatively larger discrepancies in Pnet calculations, because main-tenance respiration is not affected by Rs. For example, for a crop size of 20 t/ha, a MBE of 5.7% in Rs estimation causes a 6.9% discrepancy in the biomass accumulation calculation.

Rn was overestimated at low values (Rn<11 MJ/m^2/d) and underestimated at high values, more so for estimates from n/N ($Rn_{n/N}$) than for estimates from measured Rs (Rn_{RS}) (see Figure 1c). This trend is similar to the results obtained by Inman-Bamber and McGlinchey (2003) with Rn estimated from measured Rs. Overall, Rn was underestimated and the error for $Rn_{n/N}$ was larger than that for Rn_{RS}.

Errors in Rn estimates caused discrepancies of similar magnitude in calculated ETo. ETo is therefore overestimated at low values and underestimated at high values.

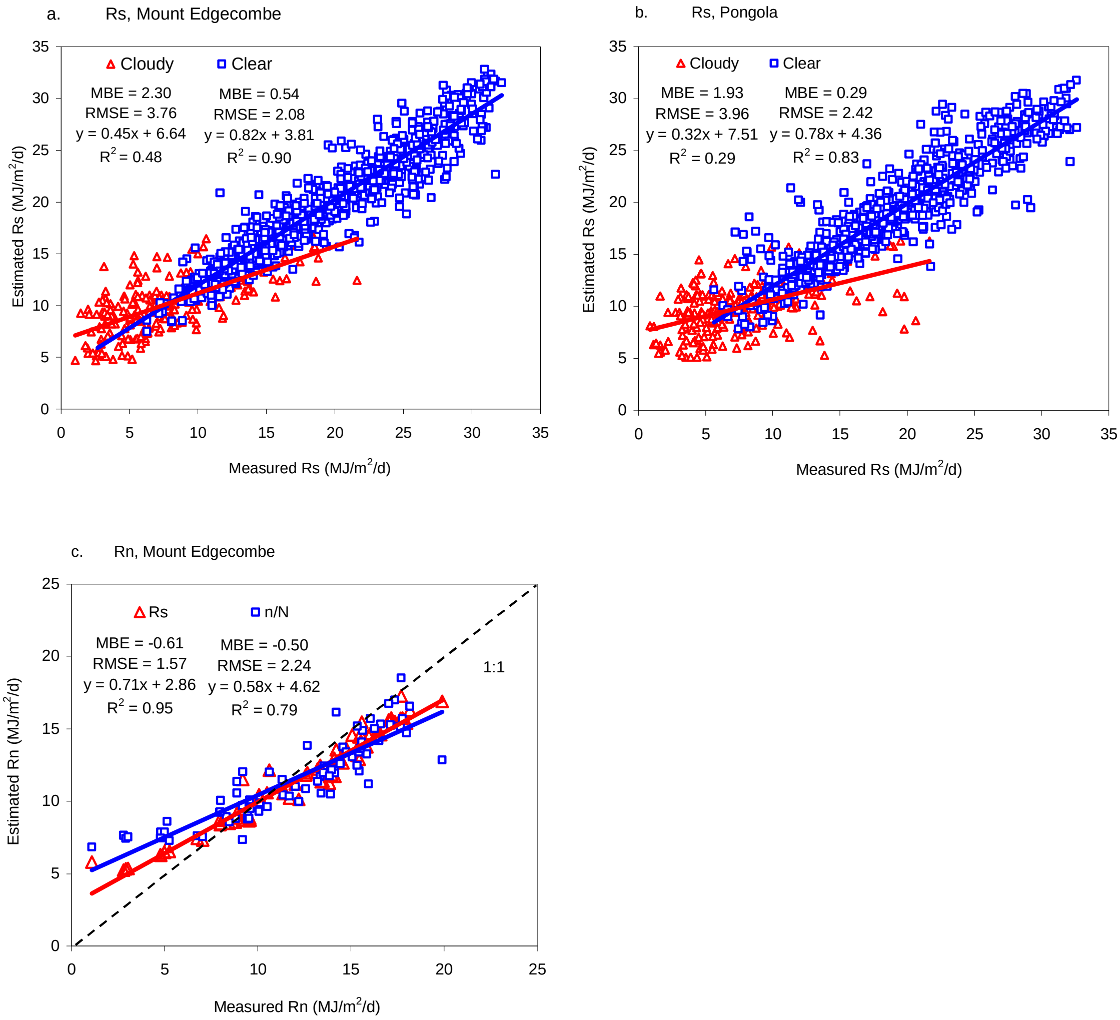

Figure 1. Linear regression between estimated and measured solar radiation (Rs) for Mount Edgecombe (a) and Pongola (b), and between estimated net radiation (Rn) [from measured Rs (Rn_{Rs}) and sunshine duration ($Rn_{n/N}$)] and measured Rn for Mount Edgecombe (c). The mean bias error (MBE), root mean square error (RMSE), regression equation and the coefficient of determination (R^2) are given.

Conclusions

Rs estimates were generally higher than measured values at both sites, especially on cloudy days. Estimation errors were also larger on cloudy days than on clear days.

Rn is overestimated at low values and underestimated at high values, more so for estimates from n/N than for estimates from measured Rs.

Following these findings, estimation equations will be calibrated for different levels of cloud cover, time of year and site, for more accurate estimates of Rs, Rn, ETo and Pnet.

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