Evaluation of Radiation Partitioning Models at Bushland, Texas

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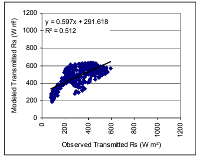
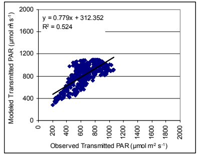
Upland Cotton



Transmitted Shortwave

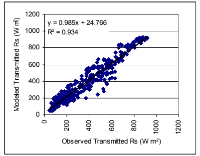


Transmitted PAR

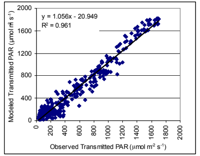
Table 1. Model agreement parameters for cotton (2007 season).

	Transmitted Rs W m^{-2}		Transmitted PAR μmol m^{-2} s^{-1}	
	EE	CN98	EE	CN98
n	347	347	347	347
Slope	0.457	0.594	0.666	0.775
Intercept	283.8	293.0	460.6	315.2
r^2	0.503	0.509	0.533	0.521
RMSE	144.0	187.8	281.9	226.6
Bias	110.2	163.1	247.7	171.9

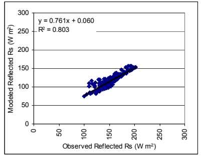
Grain Corn



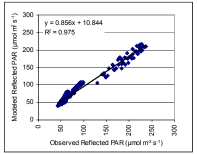
Transmitted Shortwave



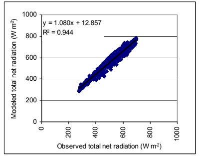
Transmitted PAR



Reflected Shortwave



Reflected PAR

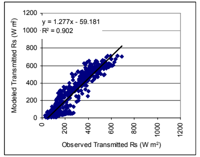


Total Net Radiation

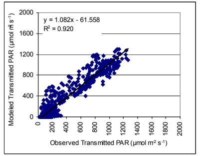
Table 2. Model agreement parameters for grain corn (1989 and 2007 seasons).

	Transmitted Rs W m^{-2}		Transmitted PAR μmol m^{-2} s^{-1}		Reflected Rs W m^{-2}		Reflected PAR μmol m^{-2} s^{-1}		Total net radiation W m^{-2}	
	EE	CN98	EE	CN98	EE	CN98	EE	CN98	EE	CN98
n	545	545	545	545	154	154	154	154	476	476
Slope	0.980	0.985	1.033	1.056	0.508	0.761	0.862	0.856	0.966	1.080
Intercept	-55.1	24.8	42.5	-20.9	68.5	0.1	8.2	10.8	39.3	12.9
r^2	0.910	0.934	0.956	0.961	0.132	0.803	0.986	0.975	0.938	0.944
RMSE	89.9	59.9	110.7	94.6	31.8	37.8	13.5	14.1	33.4	61.2
Bias	-60.7	20.5	55.5	0.9	-6.5	-36.4	-7.5	-5.6	21.8	54.5

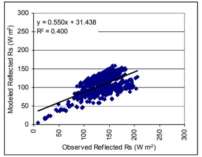
Grain Sorghum



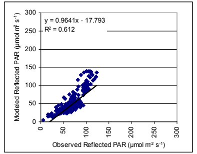
Transmitted Shortwave



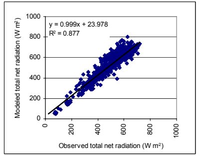
Transmitted PAR



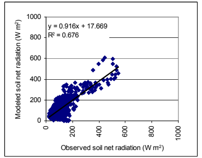
Reflected Shortwave



Reflected PAR



Total Net Radiation



Soil Net Radiation

Table 3. Model agreement parameters for grain sorghum (1988 and 2007 seasons).

	Transmitted Rs W m^{-2}		Transmitted PAR μmol m^{-2} s^{-1}		Reflected Rs W m^{-2}		Reflected PAR μmol m^{-2} s^{-1}		Total net radiation W m^{-2}		Soil net radiation W m^{-2}	
	EE	CN98	EE	CN98	EE	CN98	EE	CN98	EE	CN98	Simple	CN98
n	789	789	789	789	789	789	532	532	789	789	532	532
Slope	1.060	1.277	0.979	1.082	1.155	0.550	1.275	0.964	0.911	0.999	0.948	0.916
Intercept	-0.6	-59.2	122.2	-61.6	-5.4	31.4	-9.3	-17.8	9.9	24.0	47.048	17.669
r^2	0.874	0.902	0.871	0.920	0.531	0.400	0.782	0.612	0.886	0.877	0.675	0.676
RMSE	69.5	84.9	180.5	125.8	36.0	38.1	15.4	24.0	55.2	51.8	74.5	61.1
Bias	14.2	9.1	113.4	-26.9	15.6	-29.6	9.4	-20.2	-35.9	23.3	40.0	6.3

Abstract

Crop growth and soil-vegetation-atmosphere continuum energy transfer models often require estimates of net radiation components, such as photosynthetic, solar, and longwave radiation to both the canopy and soil. We evaluated the 1998 radiation partitioning model of Campbell and Norman (CN98). The CN98 model partitions canopy transmittance and canopy albedo into their direct and diffuse components in the visible and near infrared spectrums and accounts for different transmittance and albedo characteristics of the soil and canopy. Visible, near-infrared, direct, and diffuse radiation components are computed as functions of solar zenith angle, leaf area index (LAI), leaf angle distribution, canopy geometry, leaf absorption, and soil albedo. We also evaluated a simpler exponential extinction model (EE) that assumes constant transmittance and albedo values. Model output was compared with measurements of photosynthetic photon flux and solar irradiance transmitted to the soil and reflected from the canopy, net radiation transmitted to the soil, and total net radiation measured over the canopy for cotton, corn, and grain sorghum. Calculations of all parameters were similar for both models, although CN98 resulted in smaller RMSE and bias for seven out of thirteen comparisons. The RMSE between modeled and measured values was usually within twenty to thirty percent of observed means, and all RMSE values were within fifty percent of observed means.

Introduction

Radiation, as partitioned to soil and vegetation layers, is the primary driver for crop growth, evapotranspiration (ET), and the energy balance of vegetated surfaces. Radiation partitioning models have universal application in hydrology, meteorology, and crop and soil science. Effective water resource management in irrigated regions, for example, require accurate estimates of ET, which can be accomplished with two-source energy balance models (Kustas and Norman, 1999; Colaizzi et al, 2005). These models require that transmission of shortwave radiation through the canopy to the soil be specified initially.

The complexity of the radiative transfer models are constrained by available input data. Therefore, the most commonly used models require only incident global radiation and basic knowledge of canopy characteristics, such as leaf area index (LAI), leaf angle distribution, height and width, row orientation, and row spacing. As canopy characteristics are often specific to crop type and growth stage, they can be estimated somewhat reliably from knowledge of local cultural practices, accumulated heat units, and reflectance measurements from remote sensing platforms.

The objective of this study was to evaluate a common radiation partitioning model using two approaches to compute canopy transmittance and albedo. The model was evaluated for cotton, corn, and grain sorghum, which are important row crops for the Texas High Plains economy.

Procedure

The present study was conducted at the USDA-ARS Conservation and Production Research Laboratory, Bushland, TX, USA (35° 11' N lat., 102° 06' W long., 1,170 m elevation M.S.L.).

Incoming shortwave solar radiation (Rs), incoming photosynthetic active radiation (IPAR), transmitted shortwave radiation (TRs), and transmitted PAR (TPAR) were measured for grain corn (*Zea mays* L.; 1989 and 2007 seasons), grain sorghum (*Sorghum bicolor* L.; 1988 and 2007 seasons), and upland cotton (*Gossypium hirsutum* L.; 2007 season). Reflected shortwave (RRs), reflected PAR (RPAR), and total net radiation (Rn) were measured for corn (1989 only) and grain sorghum (RPAR measured in 1988 only). Soil net radiation was measured for grain sorghum (1988 only). Net longwave radiation was computed with the Stephan-Boltzmann relation using soil and canopy temperatures measured with infrared thermometers, and air temperature. All measurements consisted of 5- to 30-min averages from 0900 to 1600 for clear sky conditions. Howell et al. (1997) gives additional details of the 1988 grain sorghum and 1989 corn experiments. The response of line sensors designed to measure transmitted radiation through a canopy (i.e., PAR bars and tube solarimeters) depend on azimuth angle of deployment (Mungai et al., 1997), which was accounted for during calibration.

Canopy transmittance and albedo were computed using two approaches. The first approach assumed a simple exponential extinction model for transmittance and constant albedo, herein referred to as EE. The second approach used the model of Campbell and Norman (1998), herein referred to as CN98. In the CN98 approach, canopy transmittance and canopy albedo are partitioned into direct and diffuse components in the visible and near infrared spectrums, and each component is computed as functions of solar zenith angle, leaf area index (LAI), leaf angle distribution, canopy geometry, leaf absorption, and soil albedo. Models were evaluated on the basis of slope, intercept, coefficient of determination (r^2), root mean square error (RMSE), and bias.

Results

The relative performance of the EE and CN98 approaches were similar for most parameters for cotton (Table 1), corn (Table 2), and grain sorghum (Table 3). Scatter plots of modeled vs. observed radiation components are shown for the CN98 approach only. Transmitted solar radiation (TRs) had a smaller RMSE using the EE approach for cotton and grain sorghum; however, the CN98 approach resulted in smaller RMSE for corn. Transmitted photosynthetically active radiation (TPAR) resulted in smaller RMSE using the CN98 approach for all three crops, especially grain sorghum, suggesting that the CN98 may be preferable for studies concerned with the visible spectrum.

For cotton, measurements of TRs and TPAR were much less than modeled values (Table 1 and scatter plots). This occurred during most of the day until air and surface temperatures reached daily maxima. The relative error had a strong correlation with time of day (data not shown), although no relationship was observed with various longwave energy components or their respective differences (e.g., longwave radiation computed from sky, soil, or instrument temperatures). Because the cotton canopy never completely shaded the soil (due to limited irrigation and heat unit availability), line sensors may have been more subject to temperature gradients until mid-afternoon.

Reflected solar radiation (RRs) had less linearity (r^2) between measured and modeled values for corn (Table 2) and grain sorghum (Table 3) compared with TRs or TPAR for both the EE and CN98 approaches. For reflected PAR (RPAR), both approaches had nearly identical results. For total net radiation (Rn), smaller RMSE and bias were observed for EE for corn (Table 2) and CN98 for grain sorghum (Table 3). The CN98 model also resulted in smaller RMSE and bias for soil net radiation (Table 3).

Conclusion

Two radiation partitioning models were evaluated for upland cotton, grain corn, and grain sorghum, at Bushland, TX. Measurements of transmitted and reflected solar radiation, transmitted and reflected photosynthetically active radiation, total net radiation, and soil net radiation were compared to modeled values, where canopy transmittance and albedo were computed using two approaches (EE and CN98). Results from these approaches did not greatly differ from each other in most cases, with the more complex CN98 approach giving slightly better results for seven out of the thirteen comparisons for various crop parameters. The RMSE between modeled and measured values were usually within twenty to thirty percent of observed means, and were all within fifty percent.

References

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