Modeling Evapotranspiration Using an Aerodynamic Temperature and Remote Sensing Approach

Colorado State University

GRADUATE STUDENT SHOWCASE

CELEBRATING RESEARCH AND CREATIVITY

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Introduction

- According to Hoekstra and Chapagain (2006), irrigation water applied for expanding crop yield for food production is about 6390 Gm³/year. That places irrigation as one of the major water consumptive use on a global scale;
- Adequate Irrigation water management practices play a crucial role on increasing crop yield and preserving soil and water resources;
- Models to predict how much water crops consume for decision-making purposes have been developed solving the surface energy balance budget (SEBB) for latent heat flux (λE) as a residual term coupled with remote sensing techniques and they have been shown useful for predicting crop water consumptive (Chavez et al, 2009);
- Models to estimate sensible heat flux (H), one component of the SEBB often tend to neglect or make assumptions about the surface aerodynamic temperature (T_o), a critical term when not addressed correctly, add significant bias to the crop evapotranspiration (ET_c) estimation when applying the SEBB concept (Chebounni et al, 1995; Chebounni et al, 1996; Gowda et al, 2007);
- This project aims to improve the model for ET_c by improving H model through the understanding of the mechanisms that influence T_o and posterior development of an empirical model for T_o based on weather data and remote sensing data to increase accuracy of modeled H, and, therefore, the assessment of crop water consumptive use.

Methodology

$$\lambda E = R_n - G - H$$

(SEBB model for latent heat flux determination as a residual term)

$$R_n = (1-\alpha)R_s + \epsilon_s \epsilon_a \sigma T_a^4 - \epsilon_s \sigma T_s^4$$

(Net radiation model)

$$G = a_1 \cdot ln(T_s) + a_2 \cdot e^{OSAVI} + a_3 \cdot R_n^2 \alpha^3 + a_4 \cdot f_c^5$$

(Proposed Soil heat flux model)

$$H = \rho_a \cdot Cp_a \cdot \left(\frac{T_o - T_a}{r_{ah}}\right)$$

(Sensible heat flux model)

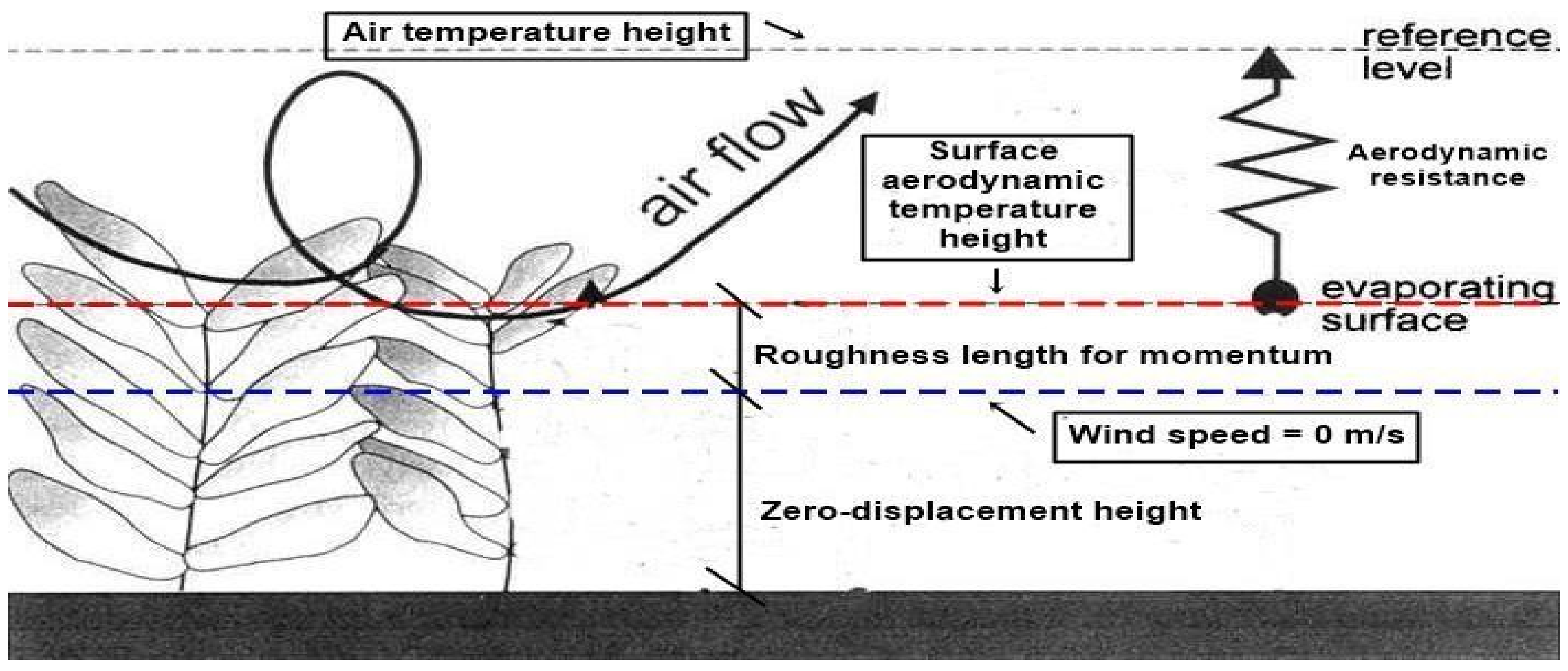


Figure 1 – Illustration of the physical processes that derive the sensible heat flux (Modified FAO-24 manual).

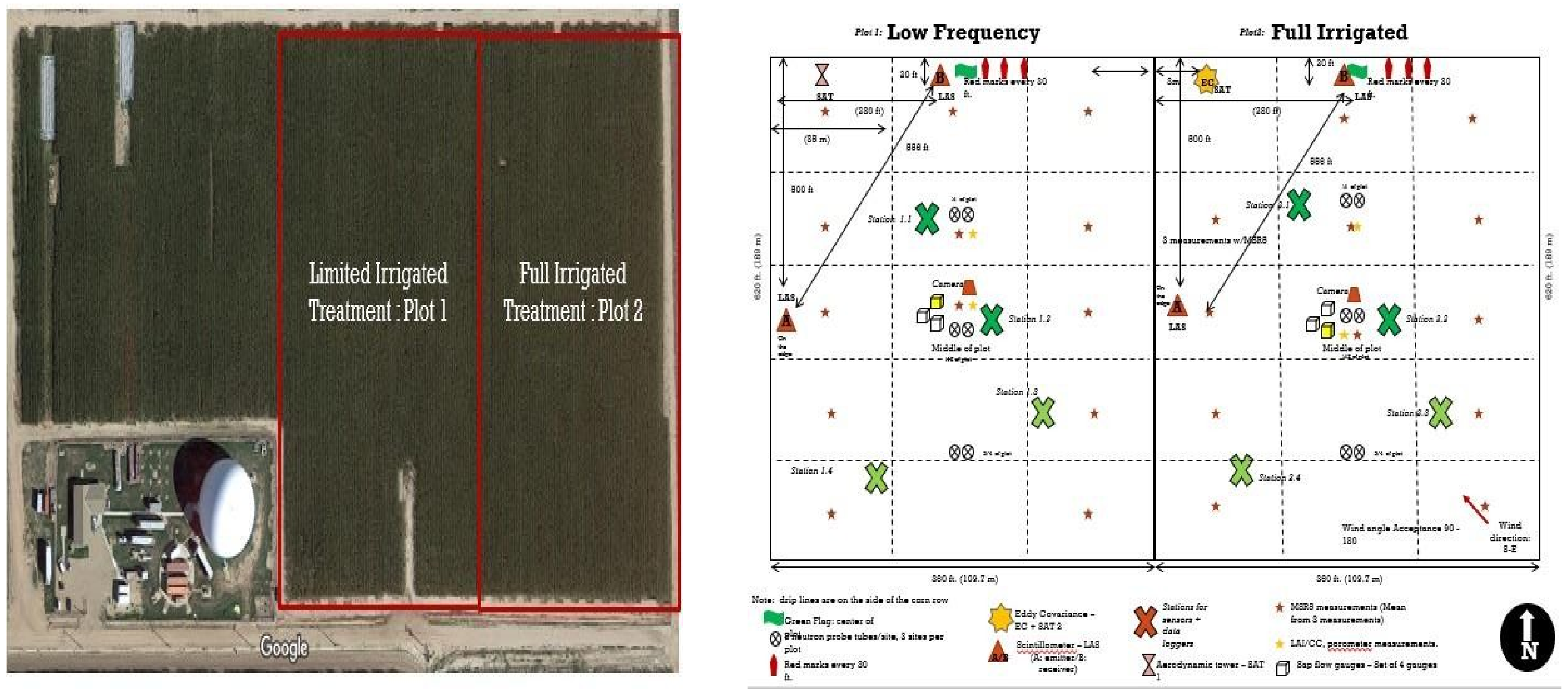


Figure 2 – USDA Limited Irrigation Research Field (LIRF) fields (on the left) and the experiment arrangement of sensors (on the right) in 2017.

- The experiment was implemented on USDA research farm facility located nearby Greeley, CO, at approximated coordinates of latitude 40° 26' 46.5'' (N 40.44625), longitude 104° 38' 13.5'' (W 104.63708), and elevation of 1432 meters MSL. Both fields 01 and 02 were corn fields and the irrigation system was subsurface drip irrigation;
- Total of 120 sensors (60 sensors per field) installed to collect data for modeling and measuring all components of the SEBB. Measured data includes, but not limited to, canopy temperature, net radiation, soil water content at different depths, sensible heat, latent heat, soil heat flux plates, soil temperature, multispectral canopy reflectance, precipitation, etc.;
- Measurements collected every minute and averaged every 15 minutes during growing season of 2017 and 2018;
- Remote sensing data measurements (reflectance) were done once or twice per week. A total of six stations per treatment plot were established for measurements;
- Two stations on each field were meant to only measure air temperature inside the canopy at different heights (0.20 m, 0.50 m, 0.75 m, 1 m, and 2 m) to identify the effective height for T_o throughout the growing season;

Preliminary results and discussion

- The data from 2017 has indicated that the modeled net radiation is within range of error of 10 % reported on other publications (figure 4) and the proposed model for soil heat flux performed better than the existing models showing smaller percent error for both different treatment fields (figure 5);

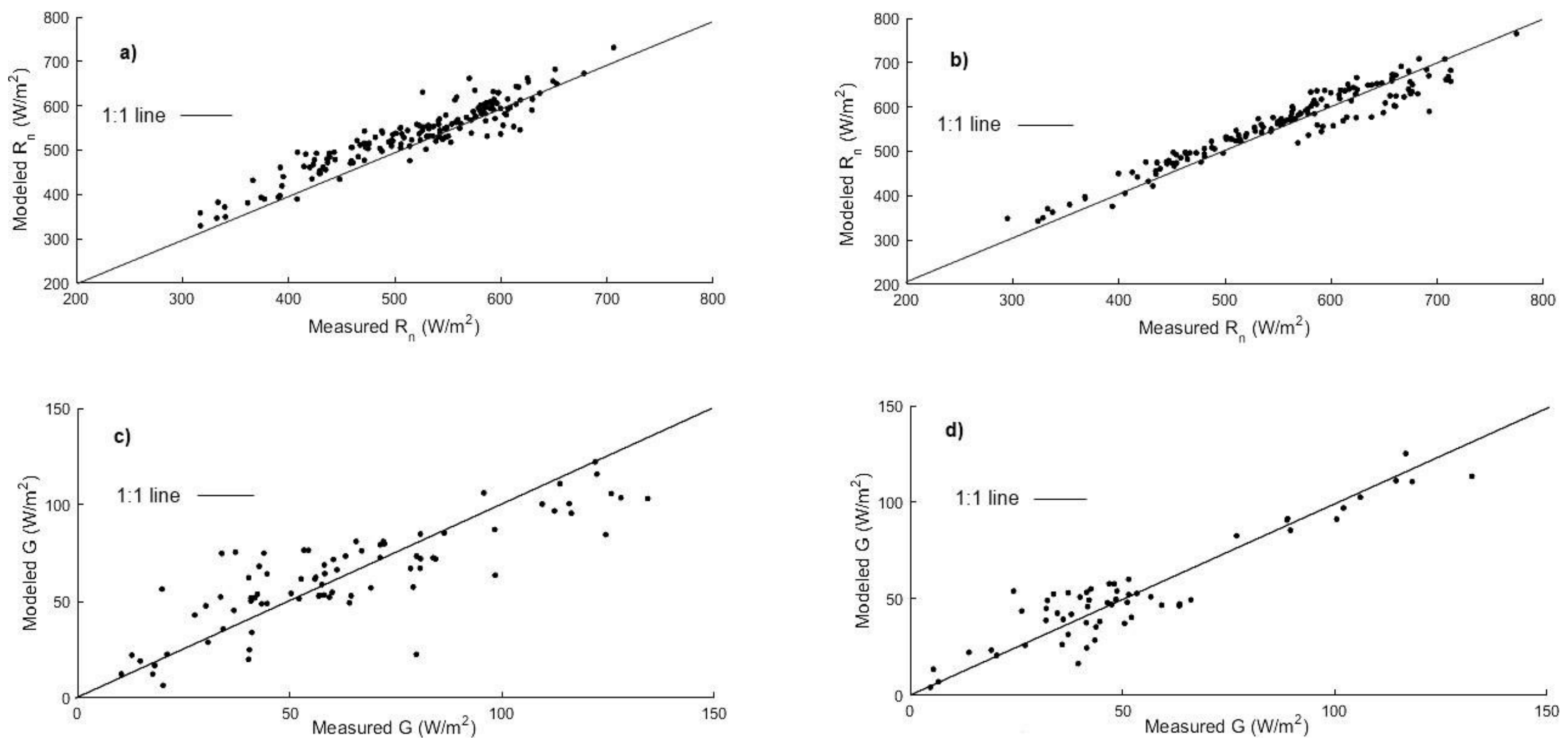
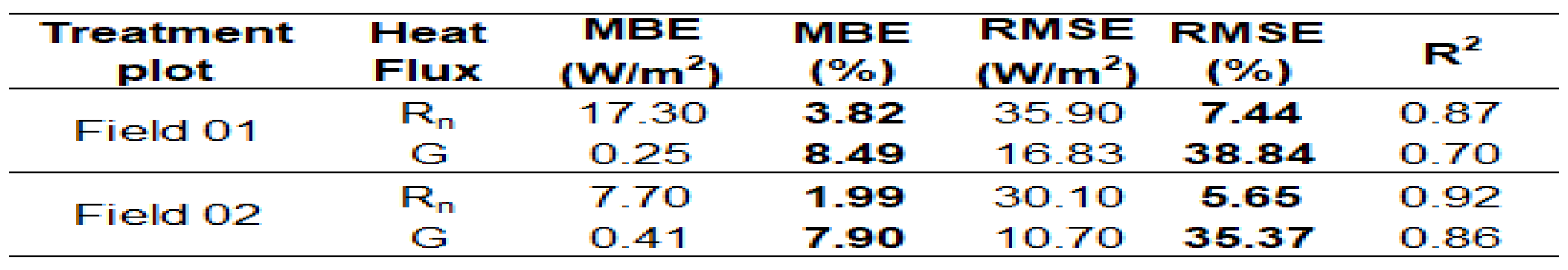
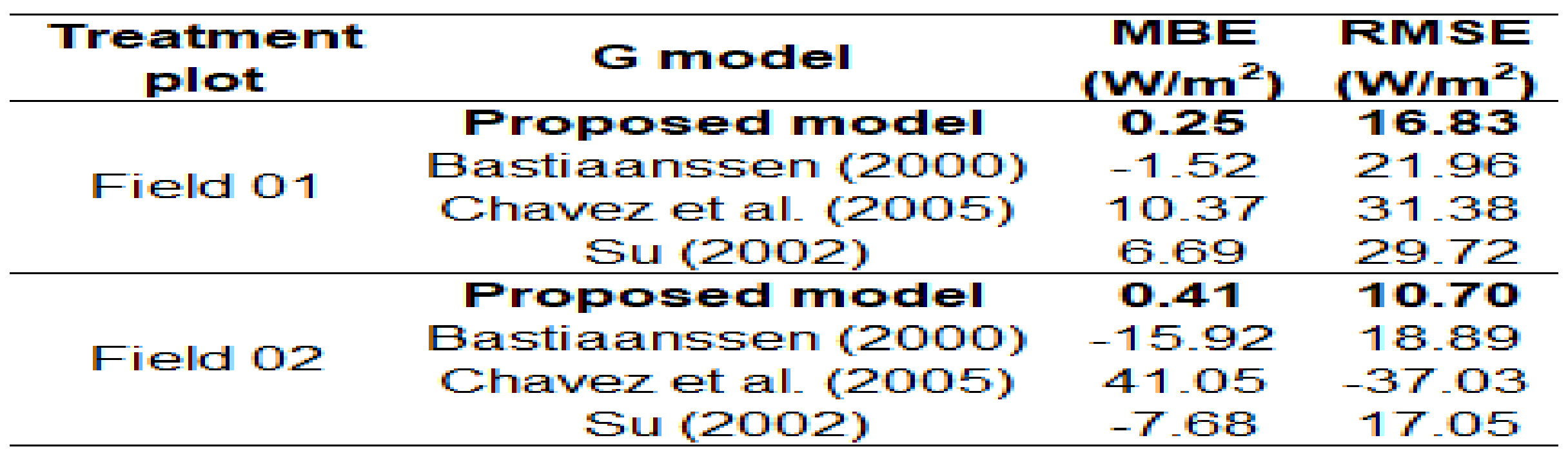


Figure 3 – Comparison analysis between measured and modeled heat fluxes for 2017 hourly data around noon (10 am – 2 pm). Graphs (a) and (c) refer, respectively, to R_n and G for field 01. Graphs (b) and (d) refer to R_n ang G for field 02, respectively.



Treatment plot	Heat Flux	MBE (W/m²)	MBE (%)	RMSE (W/m²)	RMSE (%)	R²
Field 01	R_n	17.30	**3.82**	35.90	**7.44**	0.87
	G	0.25	**8.49**	16.83	**38.84**	0.70
Field 02	R_n	7.70	**1.99**	30.10	**5.65**	0.92
	G	0.41	**7.90**	10.70	**35.37**	0.86

Figure 4 – Statistical analysis for R_n and G models for each field using hourly data from 2017 around noon (10 am-2pm).



Treatment plot	G model	MBE (W/m²)	RMSE (W/m²)
Field 01	**Proposed model**	**0.25**	**16.83**
	Bastiaanssen (2000)	-1.52	21.96
	Chavez et al. (2005)	10.37	31.38
	Su (2002)	6.69	29.72
Field 02	**Proposed model**	**0.41**	**10.70**
	Bastiaanssen (2000)	-15.92	18.89
	Chavez et al. (2005)	41.05	-37.03
	Su (2002)	-7.68	17.05

Figure 5 – Statistical analysis comparison among different G models for each field using data from 2017.

Future directions

Next steps are:

- Identify how the height at which T_o happens to occur changes throughout the season as a function of crop growth, wind patterns above the surface, and biomass changes over;
- Develop an empirical equation using weather and remote sensing data for estimating T_o;
- Estimate evapotranspiration using the SEBB approach and compare the modeled ET with measured ET data, and perform statistical inference between the treatment plots to understand the influence of different irrigation practices on all components of the SEBB;

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