Crop Evapotranspiration and Crop Coefficients – Sources of Uncertainty

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Introduction

Actual evapotranspiration (ETa) is an essential part of the crop water balance (McMahon et al., 2013), and its quantification remains a complex issue in water management, especially, for crops grown under rainfed conditions. Estimated daily actual evapotranspiration is required for many major practical purposes such as the quantification of water use efficiency and scheduling of irrigation events.

The RZWQM2 is an environmental one-dimensional system model for simulating water movement, plant growth, chemical transport, nitrogen/carbon dynamics, and biological response of agricultural management practices (Ahuja et al., 2000). The model requires extensive input data such as weather data, soil information data, crop growth data, and management practices. It is a helpful tool to simulate soil water components and crop growth parameters.

The objectives of this research were to enhance the understanding of quantifying actual evapotranspiration and to evaluate the performance of the RZWQM2 when calibrating the soil hydraulic property input for the soybean growing season and then validating it in the corn growing season.

Materials and Methods

Two experiments were conducted at Spindletop Research Farm, Lexington, Kentucky. Soybean and corn were grown in 2015 and 2016, respectively. ET was quantified based on three approaches which are i) water balance approach, ii) Penman-Monteith approach (FAO), and iii) simulated by RZWQM. Crop coefficient (Kc) was quantified based on three methods i) measured ET and reference crop ET, ii) simulated ET and reference crop ET, and the FAO method. Soil water flux at the lower profile boundary was calculated based on Darcy's law for the days of measured soil water content.

RZWQM2 was calibrated during the growing season of soybean, and it was validated during the growing season of corn. In both years the model was run from January 1 to December 31, and the initial conditions of the soil water content were set on the planting date.

The average of three replicates for each measured soil property (soil texture, bulk density, saturated hydraulic conductivity, water content at 0.33 and 15 bar) from each depth were used as input data for RZWQM2 to simulate the soil water dynamics and evapotranspiration during the soybean and corn growing seasons initially without calibration (Table 1). Then the model was calibrated by modifying the soil hydraulic property input parameters slightly, as well as the plant part was calibrated at this time by modifying the crop growth parameters slightly. The same calibrated soil input parameters were used to validate the model during the corn growing season. Also, the parameters of the corn crop were calibrated during the simulation phase.

The accuracies of simulated results were evaluated by using: (i) Root Mean Squared Error (RMSE); (ii) Mean Bias Error (MBE); and (iii) percentage difference (%E).

Table 1 Soil physical and hydraulic properties for soil profile

		Input data before calibration				Input data after calibration			
Soil depth (cm)	Soil texture	Bulk density (g/cm3)	Hydrau. Conduc. (cm/h)	Ɵ at 0.33 bar (cm3/cm3)	Ɵ at 15 bar (cm3/cm3)	Bulk density (g/cm3)	Hydrau. Conduc. (cm/h)	Ɵ at 0.33 bar (cm3/cm3)	Ɵ at 15 bar (cm3/cm3)
10	silty loam	1.46	0.44	0.33	0.19	1.4	0.44	0.31	0.14
20	sity loam	1.4	0.7	0.33	0.19	1.45	0.65	0.32	0.2
30	silty clay loam	1.39	0.95	0.33	0.23	1.43	0.6	0.34	0.22
40	silty clay loam	1.45	0.5	0.34	0.25	1.45	0.5	0.34	0.23
50	silty clay loam	1.48	0.13	0.37	0.27	1.5	0.15	0.35	0.25
60	silty clay	1.45	0.2	0.37	0.28	1.47	0.2	0.36	0.27
70	silty clay	1.4	0.3	0.39	0.3	1.43	0.25	0.38	0.3
80	clay	1.4	0.7	0.39	0.31	1.4	0.5	0.38	0.3
90	clay	1.37	1.2	0.4	0.33	1.37	0.88	0.39	0.33
150	clay	1.39	0.8	0.4	0.33	1.4	0.7	0.39	0.33

Calibrated Results during Soybean Growing Season

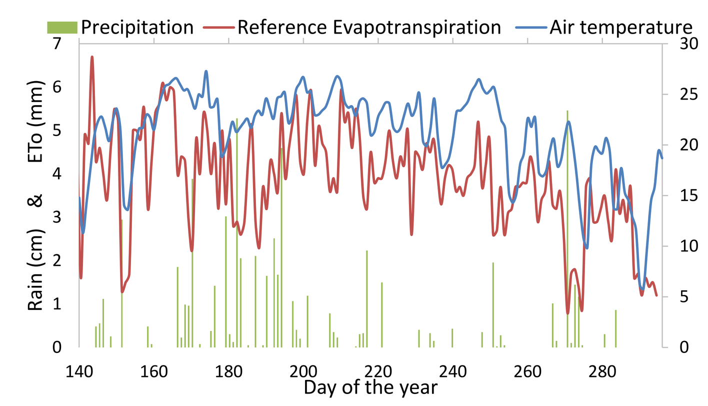

Fig. 1. Precipitation, air temperature, and reference evapotranspiration during the soybean growing season.

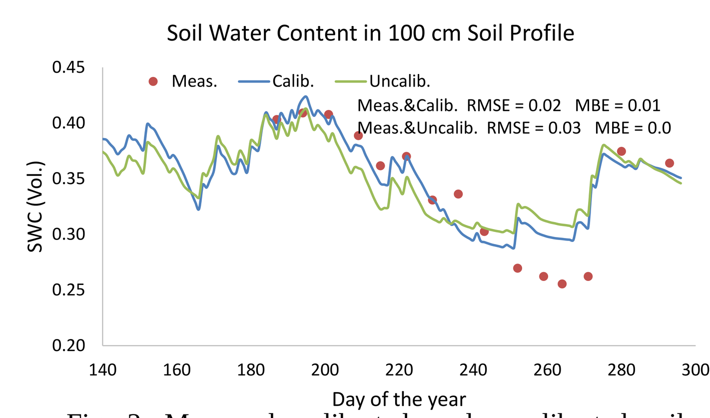

Fig. 2. Measured, calibrated, and uncalibrated soil water content during the soybean growing season.

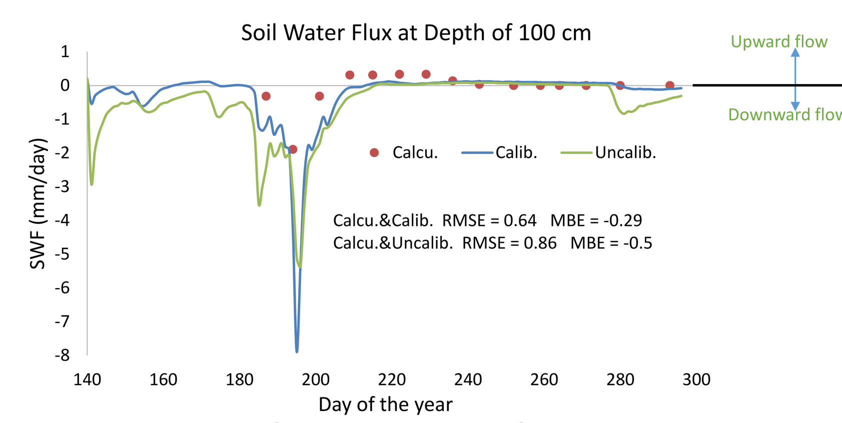

Fig. 3. Soil water flux at the lower profile boundary for calculated flux and flux of calibrated and uncalibrated soil hydraulic properties during the soybean growing season.

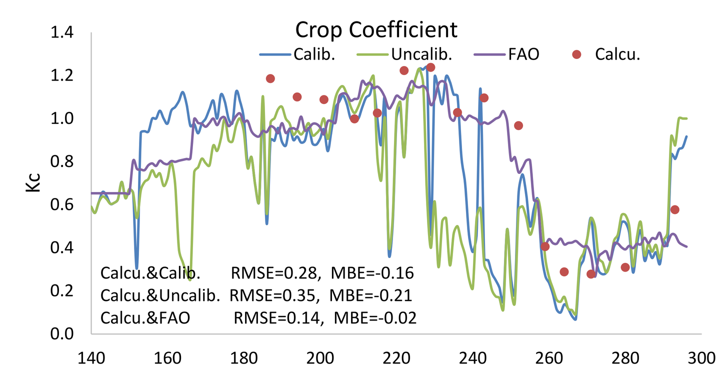

Fig. 4. Crop coefficient of calculated, FAO, and uncalibrated, and calibrated soil hydraulic properties during the soybean growing season.

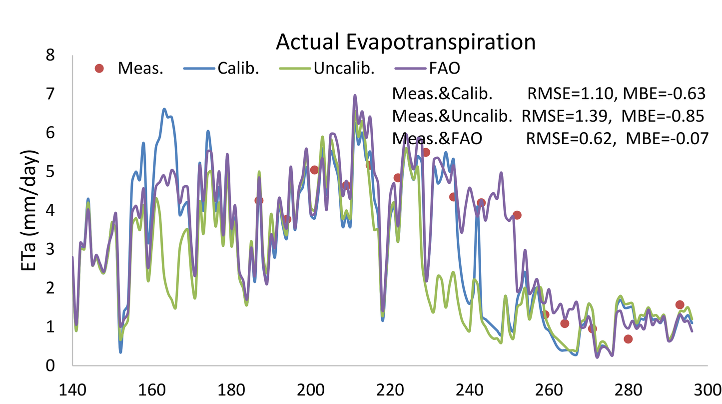

Fig. 5. Actual evapotranspiration of measured, FAO, and uncalibrated, and calibrated soil hydraulic properties during the soybean growing season.

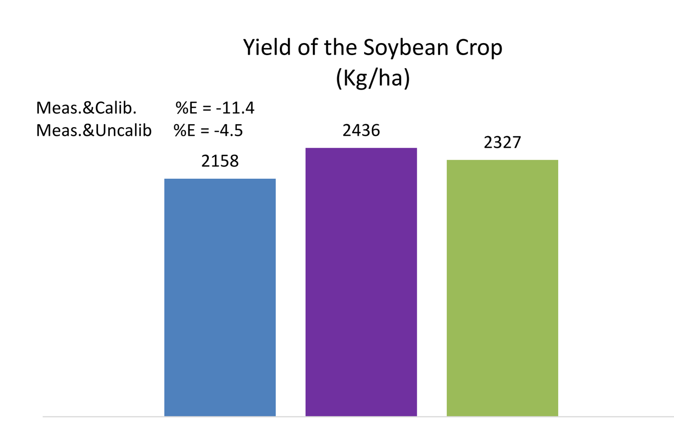

Fig. 6. Soybean yield of measured, and calibrated and uncalibrated soil properties.

Validated Results during Corn Growing Season

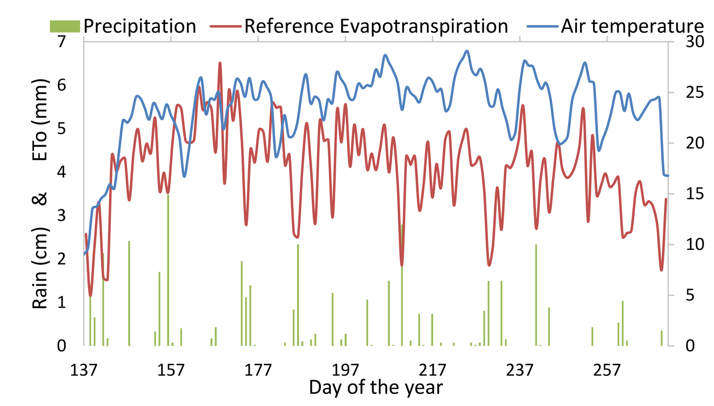

Fig. 7. Precipitation, air temperature, and reference evapotranspiration during the corn growing season.

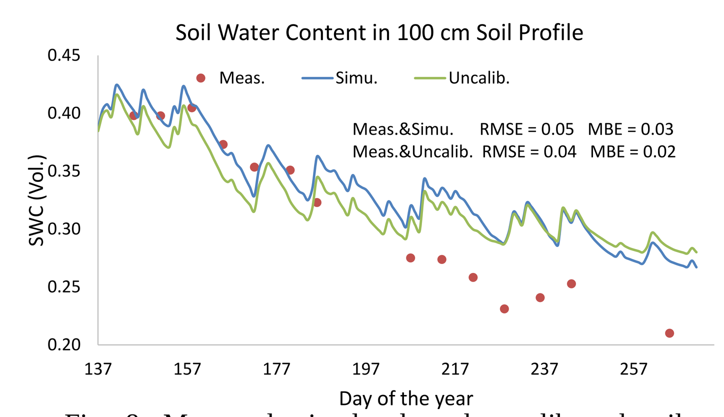

Fig. 8. Measured, simulated, and uncalibrated soil water content during the corn growing season.

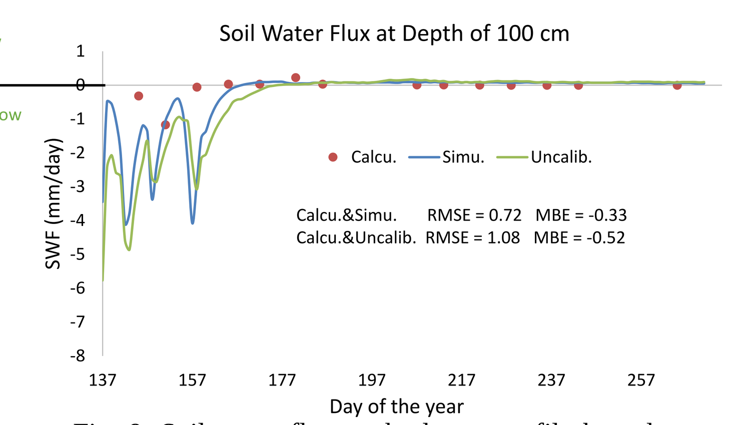

Fig. 9. Soil water flux at the lower profile boundary for calculated flux, simulated flux and flux of uncalibrated soil hydraulic properties during the corn growing season.

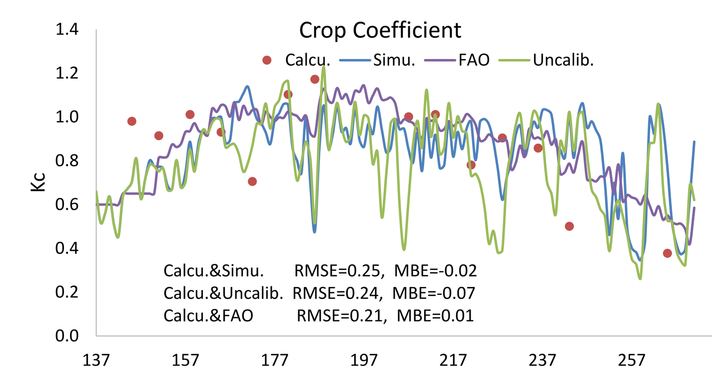

Fig. 10. Crop coefficient of calculated, FAO, simulated, and uncalibrated soil hydraulic properties during the corn growing season.

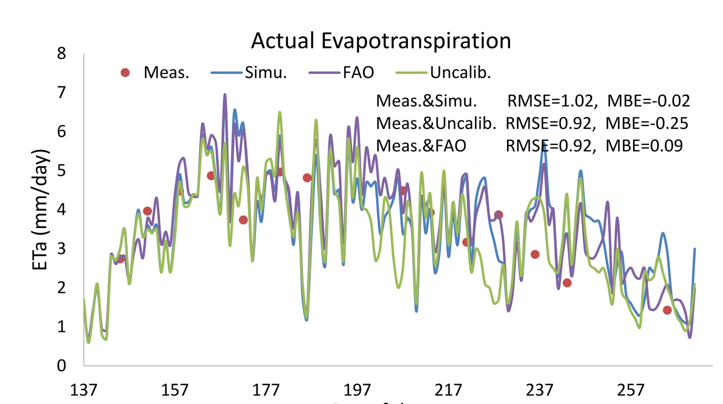

Fig. 11. Actual evapotranspiration of measured, FAO, simulated and uncalibrated soil hydraulic properties during the corn growing season.

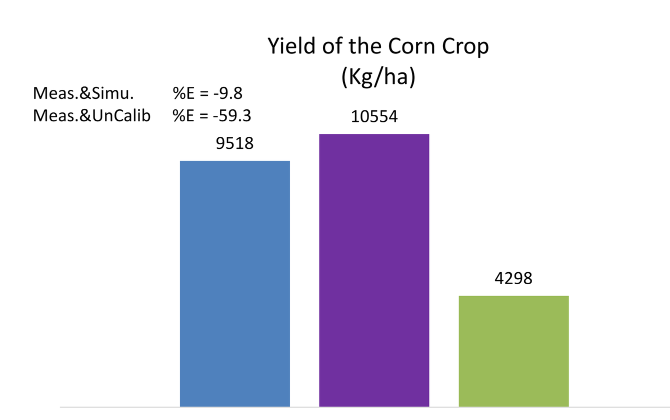

Fig. 12. Corn yield of measured, simulated and uncalibrated soil properties.

Results and Discussion

Actual crop evapotranspiration was successfully calculated by soil water balance approach under rainfed conditions for soybean and corn crop (Figs. 5 & 11). RZWQM2 was very sensitive to the calibration process. It well simulated the soil water content for the root zone soil profile (0 - 100 cm) during the growing season of soybean after calibration process as well as during validation process of the corn growing season (Figs. 2 & 8). Soil water content was better simulated during a period of wet soil conditions than during dry conditions during both calibration and validation phase.

Soil water flux at depth 100 cm was well simulated especially during the dry period when the hydraulic conductivity was low (Figs. 3 & 9).

The evapotranspiration and crop coefficient were highly affected by calibrating the soil and plant parts of the model due to their relevance to the simulated soil water content and plant response variables (Figs. 4, 5, 10 & 11). After the calibration, the model performed better with regard to evapotranspiration and crop coefficient. Simulated evapotranspiration and crop coefficient during the validation season for corn were slightly better than the results during the previous season after calibration.

RZWQM2 performed better after calibrating the soil and crop parameters than before which confirms the sensitivity of the RZWQM2 to the calibration. Also, it showed a good performance when the soil part was calibrated under soybean and validated under corn.

Conclusion

Actual crop evapotranspiration and crop coefficient were successfully quantified for crops grown under rainfed conditions. RZWQM2 presents a good performance to simulate soil water dynamics and crop evapotranspiration. Moreover, it was better after calibrating the crop parameters and soil input parameters in the range of measured soil properties due to the importance of the crop and soil measurements. Also, it shows a high accuracy when the calibration and validation phases were under different crops.

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References

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