FIELD EVALUATION OF THE ACCURACY OF THE WEB-BASED SIMULATION MODELS *CROPWATERUSE* AND *IRRIGATIONMONITOR*

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Abstract

The software model *CropWaterUse* and its derivative *IrrigationMonitor* are simulation models available in the suite of online tools of the Web-based decision support system Crop-Weather Program (http://cwp.tamu.edu), which was developed to assist research and crop managers (cotton) in South Texas. *CropWaterUse* was developed with a mechanistic modeling approach to simulate the progression of canopy development, crop water use (actual evapotranspiration or ET), soil moisture storage throughout the soil profile, relative plant-available soil water content and cumulative soil water deficit at root depth. Its accuracy was evaluated by comparing state variable outputs, namely, production of main stem nodes, plant height, and cumulative crop water use, to data collected from an irrigated field experiment testing three planting densities. All comparisons resulted in high R^2 (>0.92).

Introduction

Computer-assisted decision support systems can be important tools in the decision-making process in farming, as they can assist crop managers deal with environmental variability and the complex nature of soil-crop-pest-environment interactions. The simulation model *CropWaterUse* and its derivative the model *Irrigation Monitor* are components of a suite of online tools available in the Crop-Weather Program (http://cwp.tamu.edu), an evolving Web-based decision support system developed to assist research and crop managers (cotton) in South Texas (Fernandez and Trolinger, 2007). These tools were designed to support management decisions in rain-fed and irrigated cotton crops.

Unlike other simulation-based irrigation scheduling tools that use potential evapotranspiration (PET) and empirical fixed crop coefficients or fixed crop coefficient curves, the *CropWaterUse* tool was developed using a mechanistic modeling approach to simulate the progression of canopy development, crop water use (actual evapotranspiration or ET), soil moisture storage throughout the soil profile, relative plant-available soil water content and cumulative soil water deficit at root depth. The accuracy of the *CropWaterUse* tool was confirmed using data collected from a monolithic lysimeter in the previous year (Fernandez et al., 2009). However, more evaluations are needed to further confirm the accuracy of this simulation model under other field growing conditions.

This poster presents results from a study conducted to confirm (validate) the accuracy of *CropWaterUse* by comparing (a)) simulated canopy values (plant height and number of main stem nodes) and (b) simulated cumulative crop water use to corresponding data measured in an irrigated cotton experiment testing three plant populations.

Materials and Methods

Brief description of model

The *Crop Water Use* tool is organized around three main simulation components. The first main component calculates the development of the canopy in terms of height, leaf area index, and ground cover using a series of empirical equations relating main-stem plastochron and internode elongation to air temperature (Reddy et al., 1997) and plant height to leaf area index (Marani and Ephrath, 1985). Algorithms were developed to relate expansive growth to soil water content available to the plant (Fernandez, unpublished data, 2002). Soil volume occupied by roots is calculated as a function of canopy growth. The second main component calculates water fluxes from the soil and the canopy separately. Soil evaporation is calculated using the Penman-Monteith equation adapted to a bare soil surface and algorithms to simulate the effect of soil drying on the rate of soil evaporation. Rainfall water infiltration is calculated using an algorithm developed to take into account soil infiltration properties, rate of precipitation, and moisture of the upper layers of the soil. Two soil evaporation fluxes are calculated, one for sunlit soil and the other for soil shaded by the canopy. Canopy transpiration is calculated using also the Penman-Monteith method, where canopy height is a variable and the canopy resistance to water flows is a function of plant available soil water content (McCree and Fernandez, 1989). Crop water use is calculated as the sum of sunlit soil evaporation, shaded soil evaporation, and canopy transpiration prorated on ground cover. The third main component calculates two soil water balances at 0.025-m (1-inch) increments, one for non-rooted soil and another for the rooted soil, using a simple “book keeping” method that takes into account current balance, “gains” (rainfall and irrigation), “losses” (soil evaporation), and maximum water holding capacity. This simple “book keeping” method is applied in “cascade” to all layers of the soil profile from top to bottom. These two soil water balances are merged to obtain the overall soil water deficit at rooting depth.

Field experiment set up

Cotton was grown in a field irrigated with aboveground drip lines at 38” spacing at the Texas AgriLife Research and Extension Center in Corpus Christi. Cotton (cv: ST4554 BIIRF) was planted at 38" conventional row spacing to a uniform density of 8 seeds per row foot at a late date on 5 May 2009. About two weeks after emergence, plants were hand-thinned to three final plant stands of 2, 4, and 6 plants per row foot. Soil type at experimental site is Victoria Clay (Nueces County, VcA). A total irrigation amount of 13.39 inches was applied uniformly across plant densities in 10 events ranging from 0.72 to 1.82 inches from the next day of planting through August 2. The season was exceptionally dry (22% of normal) with a total of 1.6 inches from planting to August 2. Soil moisture was measured using AquaPro capacitance probes (www.aquapro-sensors.com). Weather conditions were measured with an automated weather station (Campbell Scientific) located next to the experiment. Canopy growth (height and main stem nodes) and soil moisture data were obtained immediately prior to irrigation events. Observed cumulative values of crop water use for a particular period were calculated with the following water balance equation:
Crop water use = Rainfall + Irrigation – Soil Water Content Change – Runoff – Percolation, where Runoff and Percolation (negative terms) were assumed to be nil.

Simulation runs

Three 92-d simulation runs were performed, one for each plant population. Initial soil moisture conditions (relative plant available soil water content) for the topsoil (upper 6 inches) and the subsoil (below 6 inches) were assumed to be 90% and 75%, respectively. Plant and soil parameters used for the three runs were identical. Minimum soil and canopy resistances to water vapor flow were set at 30 and 120 $s.m^{-1}$, respectively.

The accuracy of the model was evaluated through the R^2 coefficients of through-the-origin linear regressions of simulated on observed values obtained for each nine simulation runs (three state variables x three plant populations).

Results and Discussion

At the end of the 92-d simulation runs, the simulated progression of main stem nodes per plant followed closely (R^2 ranging from 0.9229 to 0.97421) the values observed in the field in all of the three plant populations studied (Fig. 1). The final number of main stem nodes was highest with the lowest plant population and lowest with the highest plant population. End-of-run simulated values of main stem nodes for the low, medium, and high plant populations were 19.0, 14.9, and 13.6, respectively.

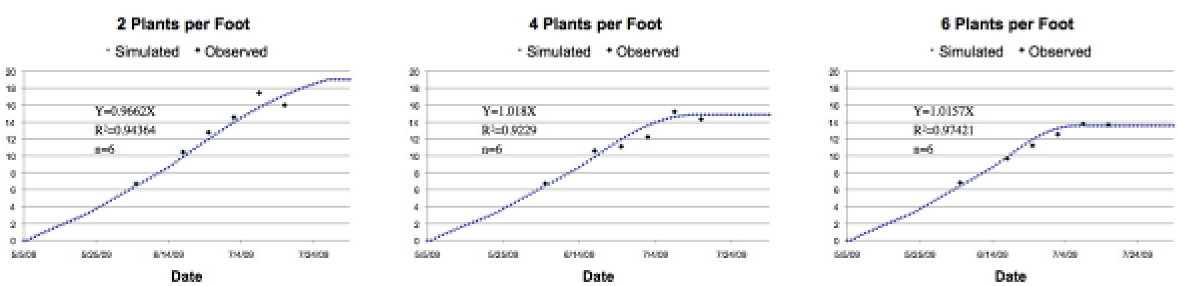

Figure 1. Comparison of the number of main stem nodes per plant observed in field plots planted to a low cotton plant population of 2 plants per foot of row to those simulated by the model *CropWaterUse*.

Similarly, the simulated progression of plant (canopy) height followed closely (R^2 ranging from 0.95971 to 0.96959) the values observed in the field in all of the three plant populations studied (Fig. 2). The final plant height at the end of the 92 d after planting was highest with the lowest plant population and lowest with the highest plant population. Simulated values of plant (canopy) height were 0.93, 0.73, and 0.66 m, and those for LAI were 2.52, 1.96, and 1.78 m^2/m^2, respectively.

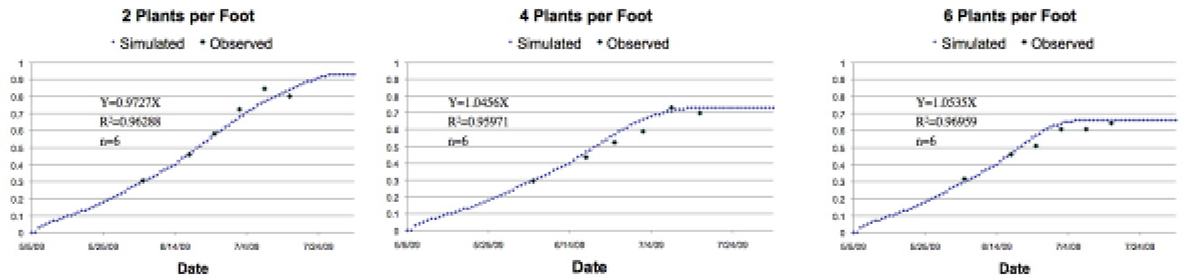

Figure 2. Comparison of the plant (canopy) height (m) observed in field plots planted to three cotton plant populations to those simulated by the model *CropWaterUse*.

Also, at the end of the 92-d simulation runs, the simulated progression of cumulative crop water use (transpiration plus soil evaporation) followed closely (R^2 ranging from 0.96232 to 0.97474) the values observed in the field in all of the three plant populations studied (Fig. 3). At the end of the 92-d simulation periods, simulated cumulative crop water use for the lowest plant population (2 plants/ft) was 648 mm, of which 19.3% was soil evaporation. Corresponding values for the medium (4 plants/ft) and high (6 plants/ft) plant populations were 617 mm and 24.3% and 594 mm and 26.2%, respectively. These simulated values indicate a trend of decreasing water use with increasing plant population probably related to increased inter-plant competition and earlier onset of water stress. An opposite trend was shown for the percent soil water loss, which increased with higher plant populations due to reduced ground cover; 97, 75, and 68%, respectively.

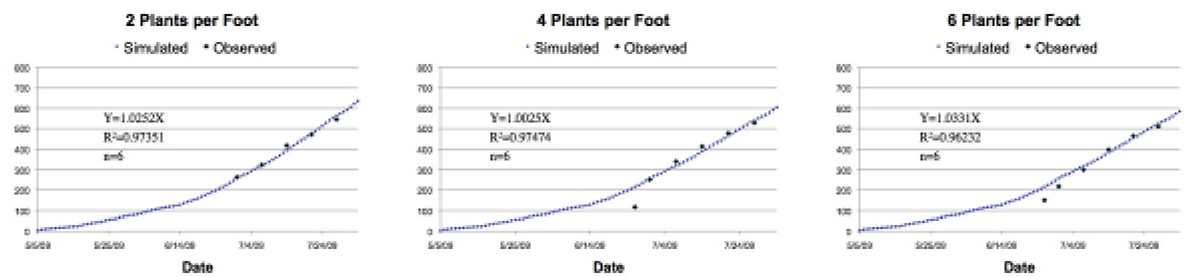

Figure 3. Comparison of the cumulative crop water use (transpiration plus soil evaporation, mm) values observed in field plots planted to three cotton plant populations to those simulated by the model *CropWaterUse*.

The simulated values of main stem nodes, plant height and LAI indicate a decreasing canopy development with increasing plant population, thus partially explaining the simulated outcome of crop water use and percent soil evaporation.

In conclusion, the results obtained in this study confirm that the *CropWaterUse* model is an accurate tool to simulate crop water use of cotton.

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