2006 Beltwide Cotton Conferences, San Antonio, Texas - January 3 - 6, 2006

VALIDATION OF A COTTON-WEATHER SIMULATION MODEL: FACTORS OF AGRONOMIC INTEREST

Carlos J. Fernandez
Texas A&M University
Corpus Christi, TX
Jose C. Medeiros
Texas A&M University/EMBRAPA
Lubbock, TX
Jill Booker and Robert Lascano
Texas A&M University
Lubbock, TX

Abstract

Due to the weather variability in the Texas High Plains, cotton growers are many times faced with a myriad of decisions of what and when a crop management should be used for a specific task. Mainly, these decisions deal with irrigation, defoliation, fertilization, and pest management and are all influenced by weather. Thus, a management program, which consists of several crop simulation models, was designed to aid in agricultural decisions and assist growers to use management practices considering environmental factors. The objective of this work was to validate a simulation model by comparing measured and simulated values of field data obtained with cotton grown near Halfway, TX. We compared measured and simulated values of canopy development, water use and soil water in irrigated cotton. We conclude that the proposed cotton simulation model shows potential to be used as a management tool by cotton producers in the Texas High Plains.

Introduction

Cotton planners and producers are confronted in their *decision-making* with the interaction of many factors. One factor, *weather* is unpredictable, and has a large impact on the in-season management of the crop and its final yield. Weather variability in Texas High Plains causes many difficulties on the decisions of *when* and *what crop management* should be used for a specific task. For example, irrigation, defoliation, fertilization, pest management are all influenced by weather. Because of the complexity in managing the crop, the use of crop simulation models continues to increase, particularly by crop consultants. The complexity of existing models varies according to the number of parameters that are simulated. For example, models of water application, flow and evapotranspiration (Saxton et al., 1986, Lascano, 2005), agricultural chemicals and fertilizer application (Beck and Searcy, 2001; Melkonian et al., 2005; Kersebaun et al., 2005) and crop growth (Brukler et al., 2000; Denux et al., 2005; Soler et al., 2005) have been proposed.

For cotton management several models have been developed, such as **GOSSYM** (Baker et al., 1983), which has been widely used in the United States (Clouse and Searcy, 2005); **COTTONS** (Jallas et al., 1999) that focuses on the simulation of plant population and competition; **Cotton2K** (Marani, 2005) a derivative from GOSSYM model, and more recently **MyCWP** (Fernandez, 2002) developed for cotton management in South Texas.

Once a model is introduced for application to a specific region it is important and necessary to evaluate the model by comparing simulated results to measured ones. For example, Clouse and Searcy, 2005 evaluated three cotton growth models (GOSSYM, COTTONS and Cotton2K) for their ability to respond to their potential for site-specific management of lint yield in Lubbock, TX. They found that the Cotton2K model was the best of the three models tested to analyze the effects of varying levels of water applications in a site-specific crop management system. In Southwest Georgia, Guerra et al., 2005, tested a cotton growth model developed at the University of Georgia, and they obtained good agreement between measured and simulated biomass for all plant components tested.

Most simulation models use an approach to simulate crop growth based on two key parameters: the fraction of photosynthetically active radiation and the crop's leaf area index (LAI) (Niu et al., 2005; Kemanian et al., 2005) as state (input) variables. The MyCWP cotton model proposed by Fernandez, 2005 is also based on this premise and our objective was to evaluate the applicability of this model, developed for South Texas conditions, to simulate cotton grown in the Texas High Plains, a semiarid area with different soils and weather conditions to those for which the model was developed. The model was evaluated by comparing measured and simulated values of experimental data obtained with cotton grown at the Helms experimental farm located near Halfway, TX.

Materials and Methods

Model description

The model MyCWP is an *online* cluster of applications available to the public at http://cwp.tamu.edu/. It offers links to weather data and provides a suite of management tools available to crop managers in the Coastal Bend and Upper Coast of Texas. This program simulates the progression of cotton growth and canopy development, crop water use, soil water storage throughout the soil profile, and cumulative soil water deficit in the root zone. This application tool performs calculations at hourly steps, and it is organized around three main components. The *first* main component calculates the development of the canopy in terms of height, LAI, and ground cover using a series of empirical equations relating main-stem plastochron and internode elongation to ambient temperature, and plant height to LAI. New algorithms were developed to relate expansive growth to soil water content available in the root zone to the plant. Soil volume occupied by roots is calculated as a function of canopy growth. The *second* main component calculates water fluxes from the canopy-soil surface complex. Soil and transpiration water vapor fluxes are calculated using the Penman-Monteith method modified to take into account effects of topsoil water on soil water evaporation (E) and of plant available soil water content on plant transpiration (T). Crop water use is calculated as the sum of E and T prorated based on ground cover. The *third* main component, calculates the soil water balance at 2.5-cm increments using a procedure similar to the one described for the *Soil Moisture* tool. Two soil water balances are calculated, one for non-rooted soil and another for the rooted soil. Outputs are displayed in charts and tables.

In our study the following data were used as inputs to the MyCWP model:

Inputs:

- Soil Survey for Hale County
- Irrigation time and amount
- Hourly weather (Halfway, TX Weather Station, 2003)
- Bed Spacing
- Row Direction
- Cultivar
- Planting date, depth, and rate

Outputs:

- Leaf area index
- Plant height
- Nodes numbers
- Available water content

Experimental Procedures

The experiment was conducted at the Texas Agricultural Experiment Station at the Helm's farm (long. 101° 57', lat. 34° 11', alt. 1045 m), on an Olton Sandy Loam soil (fine, mixed, thermic Aridic Paleustolls). Cotton, variety Paymaster-2326 RR, planted at 56,000 seed Acre^{-1} on 5 May 2003 on 15.8 acres of a ¼ mile center pivot. The treatments consisted of 3 different rates of irrigation: 60%, 80% and 100% of the evapotranspiration (ET) and 12 replications, through 4 spans and 3 manifolds per span, which was uniformly applied using a LEPA irrigation system. Base rate was 80% of ET. For model validation we used the 60 and 100% irrigation treatments; hereafter, referred to as low and high irrigation rate, respectively.

From July to September, plant samples and number of nodes per plant were collected and measured every other week. Soil volumetric water content (VWC) was measured at 12 sites using neutron attenuation with tubes spread across the field. From the sampled plants, plant height, number of leaves, and LAI were measured. The VWC measurements were taken in 0.3-m increments to 1.5-m depth using a neutron probe (CPN Corporation, Model 503, Hydroprobe, Martinez, CA). Hourly weather data for the 2003 season were obtained from the Halfway Weather

Station, located 2 miles south of the research plot. Means, standard deviations, standard errors, and correlations were calculated using SAS (SAS Institute, 1990).

Results and Discussions

A comparison between measured and calculated values of LAI, plant height, nodes numbers, and available water content, were done for the 2003 season for both the low and high irrigation rate. The results of this comparison are shown on Fig. 1 – 8. At the high irrigation treatment good agreement was obtained between calculated and measured *LAI* (Fig. 1).This result is significant because the LAI is strongly correlated to the canopy status, biomass and crop behavior (Denux et al., 2005, Croquil and Bordes, 2005). In Figure 2 measured and calculated values of *plant height* also show good agreement and on Figure 3 measured and calculated *nodes number* also show good agreement. In Figs. 1-3 the calculated values are all within the standard error (SE) of the measured values throughout the growing season. However, notice that no measurements were made early in the season when the plants are exponentially growing. Nevertheless, the agreement between calculated and measured values is in good agreement for the high irrigation treatment. A comparison between calculated and measured values of total water content in the root zone is shown in Fig. 4 for the high irrigation treatment. Early in the season calculated values are larger than measured ones and this disagreement decreases during the later part of the growing season.

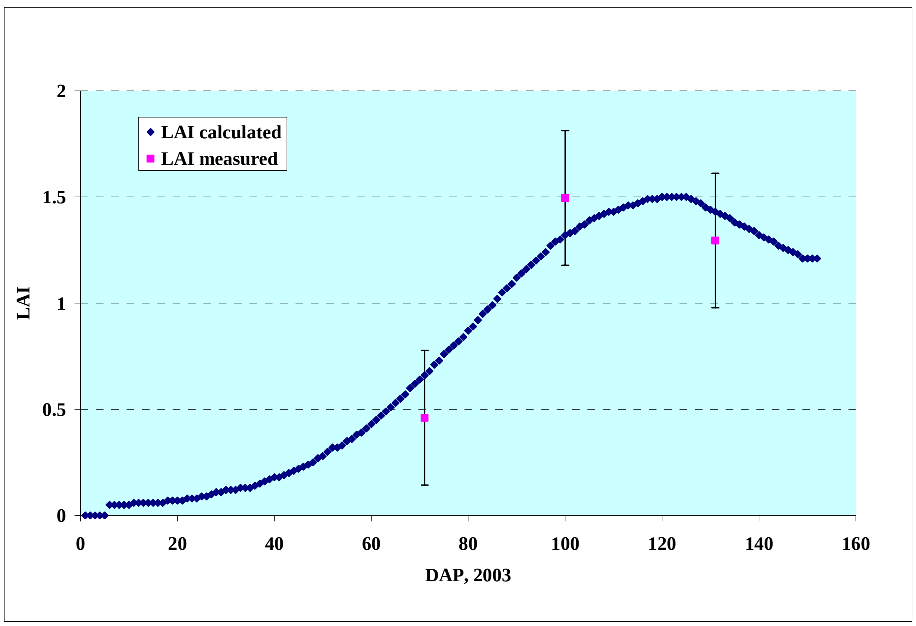

Figure 1. Measured and calculated LAI for 100% of ET, 2003

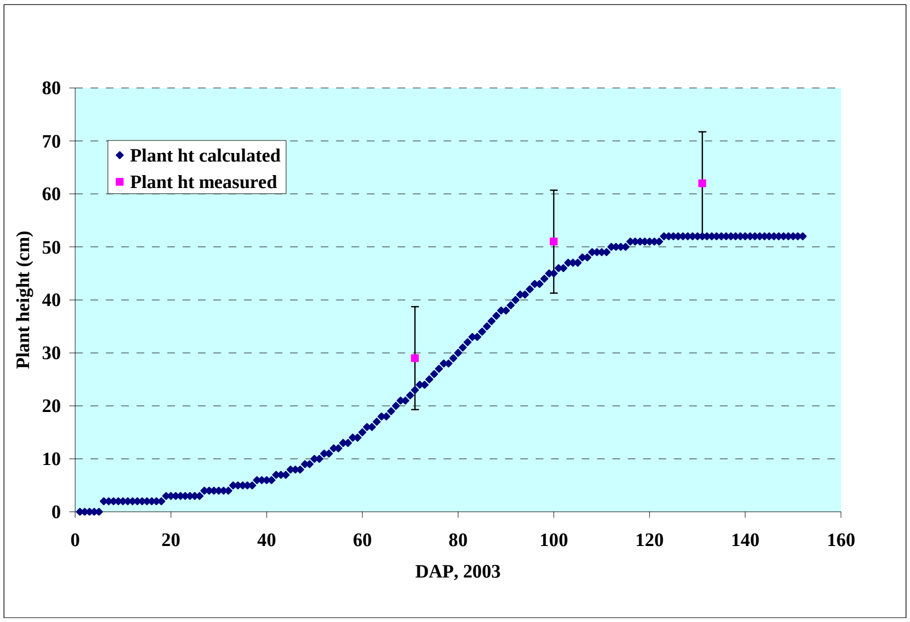

Figure 2. Measured and calculated Plant height for 100% of ET, 2003

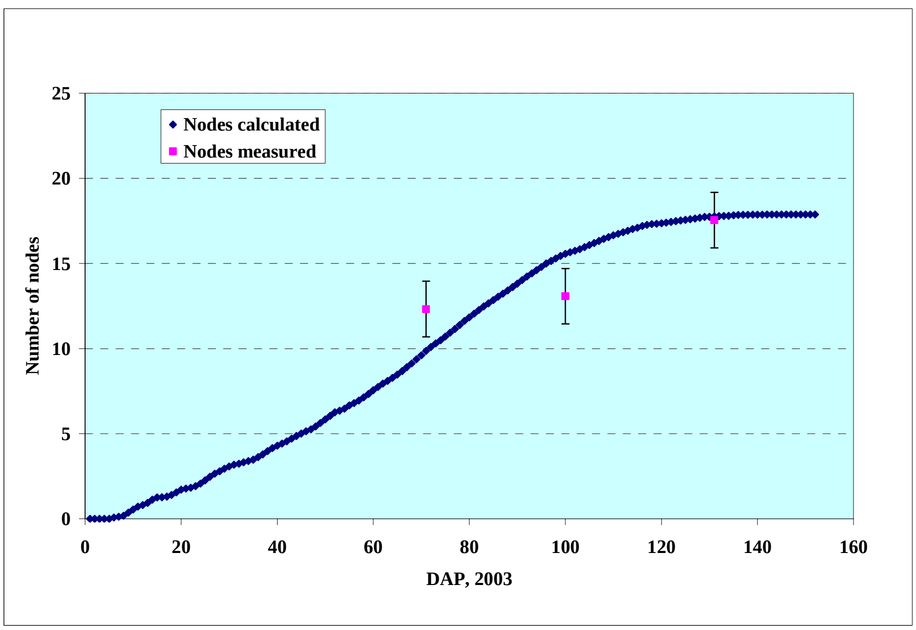

Figure 3. Measured and calculated nodes number for 100% of ET, 2003

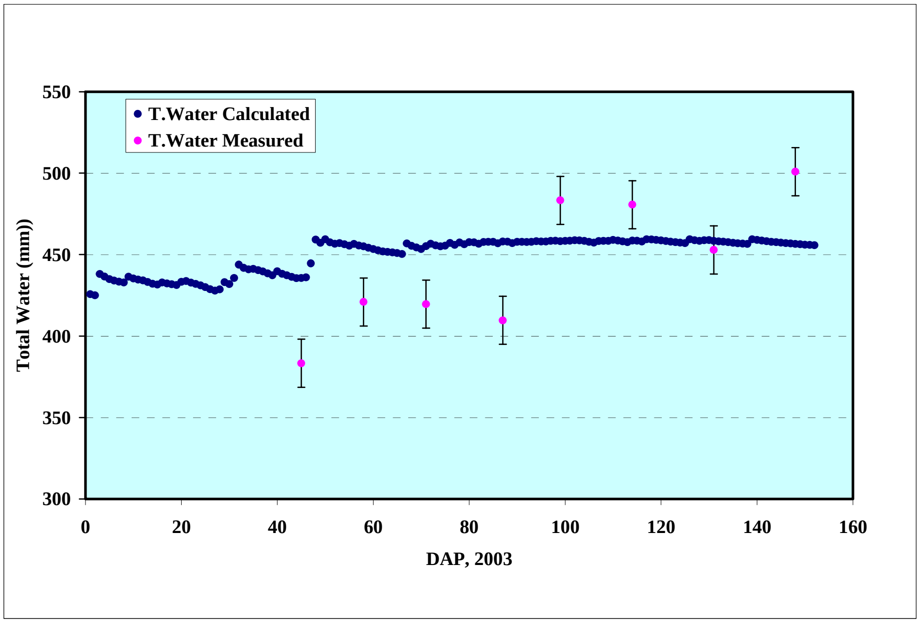

Figure 4. Measured and calculated total water for 100% of ET, 2003

Results of the comparison between measured and calculated values of LAI, plant height, node numbers and total water content for the low irrigation treatment were not as good (Fig. 5 — 8) as those obtained with the high irrigation treatment. Calculated values of LAI (Fig. 5) and total water content (Fig. 6) overestimated measured values. However, calculated values of plant height (Fig. 7) and node numbers (Fig. 8) tended to be in agreement with measured values. The overestimation of total water content (Fig. 8) is probably due to using erroneous input values of soil texture in the model. The part of the field with the low irrigation treatment was sandier and thus with a much lower total water available for crop growth.

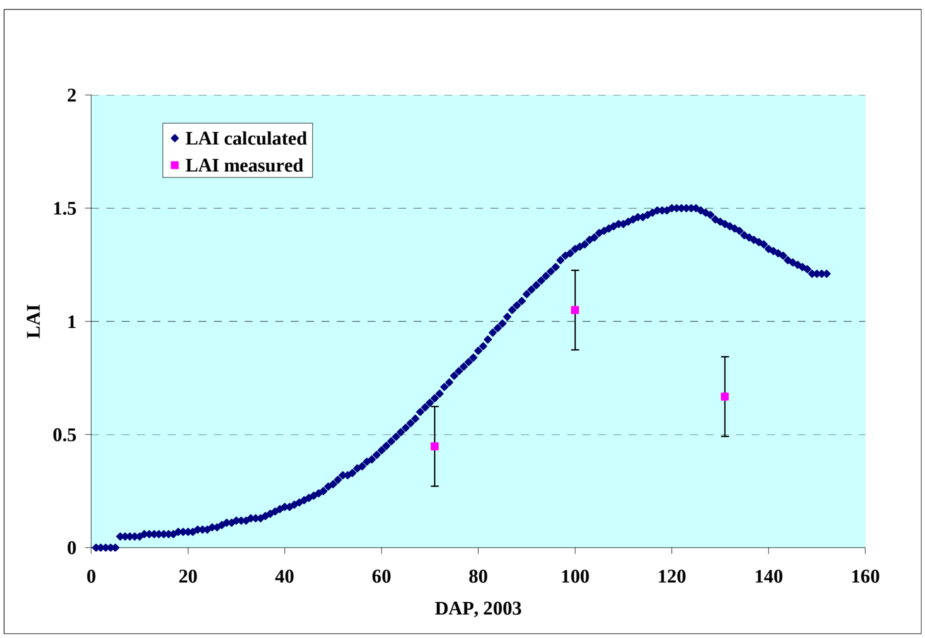

Figure 5. Measured and calculated LAI for 60% of ET, 2003

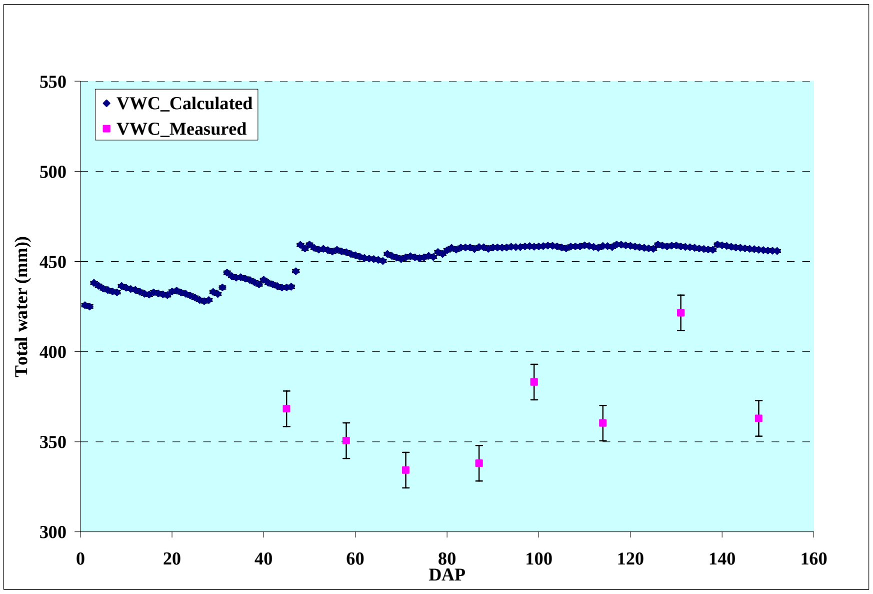

Figure 6. Measured and calculated total water content for 60% of ET, 2003

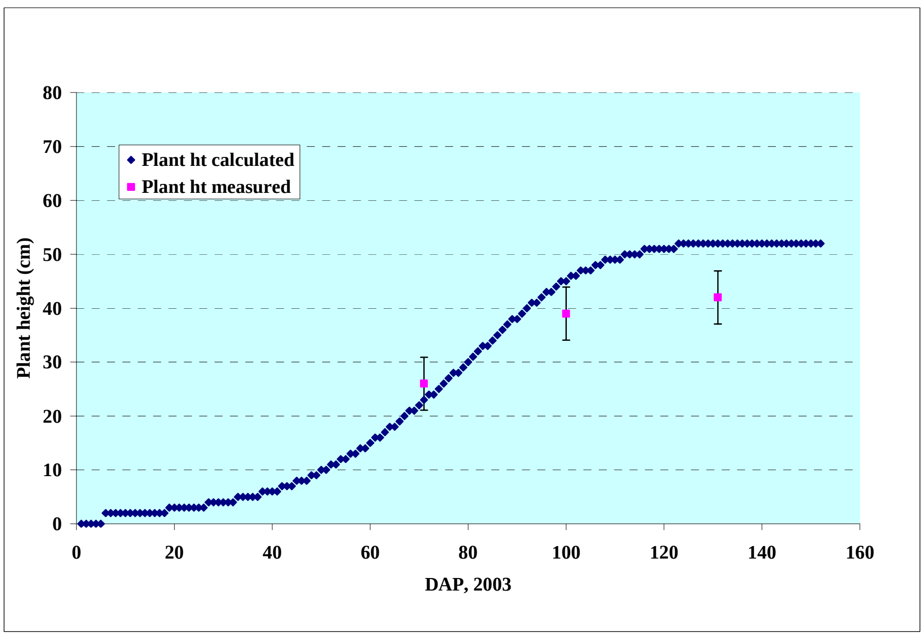

Figure 7. Measured and calculated plant height for 60% of ET, 2003

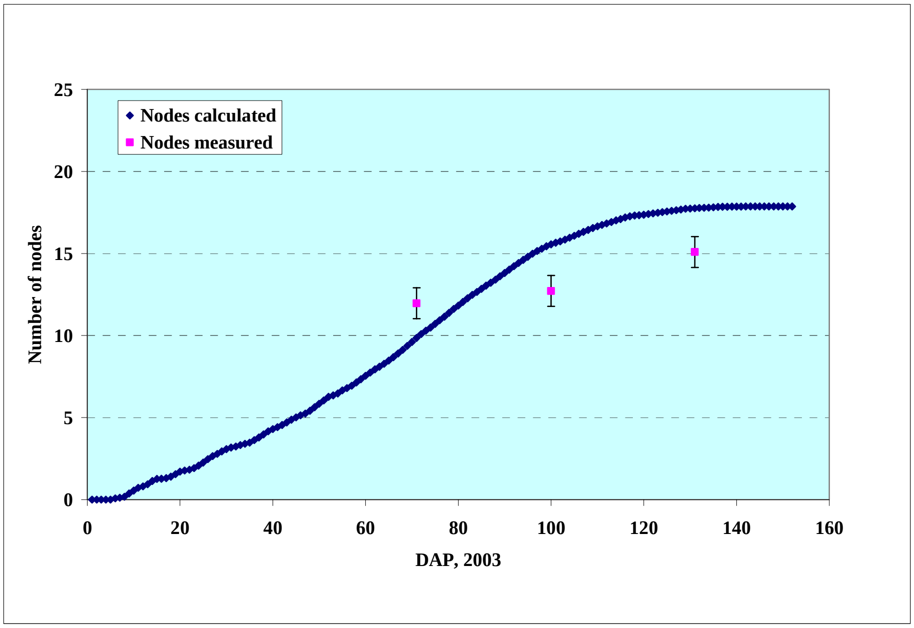

Figure 8. Measured and calculated number of nodes for 60% of ET, 2003

Conclusions

Results with the high rate of irrigation showed good agreement between measured and calculated values. However, the comparison for the low irrigation treatment was not as good particularly for LAI and total water content in the root zone. We speculate that this discrepancy was due to using erroneous input values for soil parameters in the model. Nevertheless, with the results obtained this model shows potential to be used as a management tool by cotton producers in the Texas High Plains.

Acknowledgment

This work was conducted under the auspices of the Texas A&M University – Texas Agricultural Experiment Station, Lubbock, TX and supported by Brazilian Agricultural Research Corporation – EMBRAPA. The facilities of United States Department of Agriculture - Agricultural Research Service (USDA-ARS), Lubbock, TX for this research was greatly appreciated.

References

Baker, D.N., Lambert, J.R., McKinion, J.M. 1983. A simulator of crop growth and yield. South Carolina Agricultural Experiment Station Technical Bulletin 1089, Clemson University, Clemson, SC.

Beck, A.D., and Searcy, S.W. 2001. A plant height sensor for real time, variable rate application. *In*: Dugger, C.P and Richter, D.A. (Ed) Proceeding Beltwide Cotton Conferences, Memphis, TN. National Cotton Council of America. Volume 1, 307-311.

Bruckler, L., Lafolie, F., Ruy, S., and Bertuzzi, P. 2000. Modeling the agricultural and environmental consequences of non-uniform irrigation on a maize crop at field scale. *In*: *Proceedings of the fifth International Conference on Precision Agriculture*, Bloomington, MN. ASA/CSSA/SSSA, CD-ROM

Clouse, R.W., and Searcy, S.W. 2005. Cotton model simulation of applied water – yield relations for the Texas High Plains. *In*: Proceeding Beltwide Cotton Conferences, New Orleans, LA. National Cotton Council of America. CD-ROM.

Coquil, B., and Bordes, J.P. 2005. FARMSTAR: an efficient decision support tool for near real time crop management from satellite images *In*: Precision Agriculture'05. Wageningen Academic Publication. Netherlands. P. 873-880. CD-ROM.

Denux, J.P. Jacquin, A., Touriño, I., and Cheret, V. 2005. Time series analysis of high spatial resolution SPOT images for wheat grow monitoring. *In*: Precision Agriculture'05. Wageningen Academic Publication. p. 787-792. CD-ROM

Fernandez, C.J. 2002. Crop water use. Available at: http://cwp.tamu.edu/. Acessed on 15 December 2005.

Guerra, L.C., Garcia y Garcia, A., Hoogeboom, G., Bednarz, C.W., and Jones, J.W. 2005. Evaluation of a new model to simulate growth and development of cotton. *In*: 97th International Annual Meeting, Salt Lake City, UT. ASA/CSSA/SSSA, CD-ROM

Jallas, E., Sequeira, R., Martim, P., Cretenet, M., Turner, S., and McKinion, J. 1999. Virtual Cottons, the firstborn of the next generation of simulation model. *In*: Dugger ,C.P and Richter, D.A. (Ed) Proceeding Beltwide Cotton Conferences, Memphis, TN. National Cotton Council of America. Volume 1, 393-395.

Kemanian, A.R., Stockle, O., and Huggins, D.R. 2005. Modeling biomass allocation to leaves in grain crops. *In*: 97th International Annual Meeting, Salt Lake City, UT. ASA/CSSA/SSSA, CD-ROM.

Kersebaun, K.C.; Reuter, H.I.; Lorenz, K.; and Wendroth, O. 2005. Long term simulation of soil/crop interactions to estimate management zones and consequences for site-specific nitrogen management considering water protection. *In*: Precision Agriculture'05. Wageningen Academic Publication. p. 795-802. CD-ROM

Lascano, R.J., and Van Bavel, H. 2005. Calculation of potential and reference evapotranspiration. *In*: 97th International Annual Meeting, Salt Lake City, UT. ASA/CSSA/SSSA, CD-ROM.

Marani, A. n.d. Cotton2K Model Version 4.0. The Robert H. Smith Institute of Plant Sciences and Genetics in Agriculture, Hebrew University. Available at: http://departments.agri.huji.ac.il/plantscience/cotton/ Acessed on 8 December, 2005.

Melkonian, J., Van Es, H., Kay, B., and Schindelbeck, R.R. 2005. Maize N uptake, growth and yield in response to variable soil N: Model simulations Vs field trials. *In*: 97th International Annual Meeting, Salt Lake City, UT. ASA/CSSA/SSSA, CD-ROM.

Niu, X., Warner, E., and Petersen, G. 2005. Application of modis LAI and FPAR products to crop yield modeling. *In*: 97th International Annual Meeting, Salt Lake City, UT. ASA/CSSA/SSSA, CD-ROM.

SAS Institute Inc. 1990. SAS Prodedure Guide, Version 6, Third Edition, Cary, NC. 705pp.

Saxton, K.E., Rawls, J.W., Romberger, J.S., and Papendick, R.I. 1986. Estimating generalized soil-water characteristics from texture. *Soil Science of America Journal*. 50(4):1031-1036.

Soler, C.M.T., Maman, N., Zhang, X., Mason, S.C., and Hoogenboom, G. 2005. Determining optimum planting dates for pearl millet for two contrasting environments using a modeling approach. In: 97th International Annual Meeting, Salt Lake City, UT. ASA/CSSA/SSSA, CD-ROM.