THE POTENTIAL OF A DECISION SUPPORT SYSTEM TO SIMULATE IRRIGATION SCHEDULING IN SOUTHWEST GEORGIA

Axel Garcia y Garcia[1], Larry C. Guerra[1], Gerrit Hoogenboom[1], James E. Hook[2], and Kerry A. Harrison[3]

AUTHORS: [1] Department of Biological and Agricultural Engineering, The University of Georgia, 1109 Experiment Street, Griffin, GA 30223-1797, e-mail: agarcia@griffin.uga.edu; lguerra@griffin.uga.edu, guerrit@griffin.uga.edu; [2] Department of Crop and Soil Sciences, The University of Georgia, National Environmentally Sound Production Agriculture Laboratory, P.O. Box 748, 2356 Rainwater Road, Tifton, GA 31793-0748, e-mail: jimhook@uga.edu; [3] Department of Biological and Agricultural Engineering, The University of Georgia, College of Agricultural and Environmental Sciences, Tifton Campus, Tifton, GA 31793-0748, e-mail: kharriso@uga.edu.

REFERENCE: *Proceedings of the 2005 Georgia Water Resources Conference*, held April 25-27, 2005, at The University of Georgia. Kathryn J. Hatcher, editor, Institute of Ecology, The University of Georgia, Athens, Georgia.

Abstract. A decision support system was used to simulate irrigation scheduling for maize, cotton, and peanut for the 2001 to 2004 cropping seasons in southwest Georgia. The results were compared with observed data from the Agricultural Water Pumping (AWP) project. The comparison of the cumulative distribution functions between simulated and observed monthly amounts of irrigation showed significant differences for the three crops. However, almost 50% of the simulated cotton and peanut monthly amounts of irrigation were adequately correlated with the observed data. The analysis and comparison of the observed and simulated irrigation scheduling showed the potential that the Decision Support System for Agrotechnology Transfer (DSSAT) crop simulation models can be used as a tool for on-farm irrigation scheduling.

INTRODUCTION

Based on their level of technology, farmers irrigate using several criteria, such as (i) intuition, (ii) calendar days since the last rainfall or irrigation, and (iii) crop evapotranspiration. A farmer's intuition is, in fact, based on his/her experience and local knowledge of the soil-crop-weather conditions. This criterion seems to be adequate for farmers in order to better manage their different activities. The number of days since the last rainfall or irrigation event is a practical water balance, which takes into account knowledge of local soil water content status. This criterion seems to be the one most common used by farmers. However, evapotranspiration integrates the continuum of the soil-plant-atmosphere and it should be the principal procedure for irrigation scheduling.

Because the crop's water demand is a function of plant type, the stage of development, local soil characteristics and atmospheric conditions, the total amount of water used by a crop is not as important as *when* and *how much* water to apply, which is critical for irrigation scheduling. The agronomic definition of irrigation scheduling is the farmer's decision process on *when* to irrigate and *how much* water to apply in order to optimize crop production and maximize profit while maintaining a reasonable high irrigation efficiency. This requires knowledge and information that makes irrigation scheduling a very complex decision process (Pereira, 1996). Since decision support systems integrate most of the components of a cropping system, their use seems to be an appropriate tool for determining *when* and *how much* water to apply at a field level (Guerra et al., 2004).

The Decision Support System for Agrotechnology Transfer (DSSAT) v4.0 (Hoogenboom et al., 2004) is a computer-based program that predicts yield and water use as a function of crop management and soil and weather conditions. The DSSAT soil water balance module, a one-dimensional model, computes the daily changes in soil water content by soil layer due to infiltration of rainfall and irrigation, vertical drainage, unsaturated flow, soil evaporation, and root water uptake; as described by Ritchie (1998). Irrigation can be applied on specific dates with specified irrigation amount or can be controlled by plant available water. If plant available water drops below a specific fraction of water holding capacity in the irrigation management depth, an irrigation event is triggered. The irrigation amount applied can be either a fixed amount or it can refill the profile to the management depth. When irrigation is applied, the amount applied is added to the amount of rainfall for that day in order to compute infiltration and runoff. The drainage of water through the profile is first calculated based on an overall soil drainage parameter assumed to be constant with depth. If the saturated hydraulic conductivity of any layer is less than the computed vertical drainage through that layer, actual drainage is limited to the conductivity value, and water accumulates above that layer (Jones et al., 2003).

The objective of this study was to evaluate the potential of using the DSSAT crop simulation models for irrigation scheduling for different crops in Georgia.

MATERIALS AND METHODS

Irrigation data were obtained from six fields of three farmers located in southwest Georgia. These fields were monitored from 2001 to 2004 under the auspices of the Agricultural Water Pumping (AWP; www.AgWaterPumping.net) program to determine water use for maize, cotton, and peanut (Hook et al., 2004). During the four years, the six farmers' fields had a combination of cotton, maize, or peanut as the main crop, including cotton ten times, maize five times and peanut nine times.

The DSSAT v4.0 was used to simulate irrigation scheduling, including the decision on when to irrigate and how much water to apply. For maize and cotton simulations, initial runs allowed to determine the best irrigation management depth (IMD) and irrigation threshold (IT) on 45 cm and 60%, respectively. For peanut simulations the IMD and the IT were set to 35 cm and 50%, respectively (Garcia y Garcia et al., 2004). The soil profile information was obtained from the National Resources Conservation Service (NRCS; http://www.nrcs.usda.gov) and the weather data for the nearest weather stations (Newton, Baker County and Camilla Mitchell County), were obtained from the Georgia Automated Environmental Monitoring Network (www.GeorgiaWeather.net).

The degree of relationship between observed and simulated irrigation amounts was determined through the Pearson's coefficient of correlation (*r*). Correlation coefficients can range from -1 to +1. The value of -1 represents a perfect negative correlation while a value of +1 represents a perfect positive correlation. A value of 0 represents a lack of correlation. In addition, the homogeneity of the irrigation amounts was evaluated throughout an analysis of the cumulative distribution functions (CDF) of the monthly data. The Kolmogorov-Smirnov's test can detect the difference that might exist between two distribution functions based on a statistic, called the D-statistic. The smaller the D-statistic, the smaller the difference between the two distributions at a given probability level (*p*-value). The statistical analyses were performed using the SAS Insight procedure (SAS Institute, 1999).

RESULTS AND DISCUSSION

The two cotton fields were located in both Baker and Mitchell counties; the maize field was located in Mitchell County, and the peanut fields were located in both Baker and Mitchell counties (Table 1).

The weather conditions during the cropping seasons are shown in Figure 1 for Newton (Baker County) and in Figure 2 for Camilla (Mitchell County). Except for the 2004 cropping season when the month of March was exceptionally dry with 24 mm of rainfall in Baker and 16 mm of rainfall in Mitchell, satisfactory rainfall was observed for this month during the other cropping seasons. In addition, a small amount of rain was also observed for the next two months, mainly during the month of May. For both locations, a better rainfall distribution was observed from the month of June to the month of August.

A lower total amount of water was applied for cotton and the largest amount was applied for maize. For cotton, the total irrigation amounts ranged from 30 mm during the 2001 and 2003 cropping seasons to 245 mm for the 2002 and 2004 cropping seasons. Except for the 2001 cropping season, the cotton fields in Baker received more water than the cotton fields in Mitchell. The average total amount was 184 mm with a deviation of 85 mm. For maize, the total irrigation amounts ranged from 251 mm during the 2003 cropping season to almost 855 mm in 2002. The average total amount was 508 mm with a deviation of 218 mm. For peanut, the total irrigation amounts ranged from 46 mm during the 2003 cropping season to 410 mm during the 2001 cropping season. The peanut fields in Mitchell County received more water than the peanut fields in Baker County. The average total amount applied was 181 mm with a deviation of 115 mm (Table 1).

For the typical cropping season from March to November and for both weather station locations the hottest and wettest year was 2002. The maximum air temperatures and rainfall recorded for Newton (Baker County) were as high as 36.3^{o}C and 1336 mm, respectively while 36.8^{o}C maximum air temperature and 1221 mm of rainfall were recorded for Camilla (Mitchell County). The higher irrigation amount applied in maize was observed in 2002 (Table 1). However, no reasons were found to support this higher amount. Both the cotton and peanut crops are usually planted from the end of April to the middle of May. The increase of the air temperature and irregular rainfall during that period makes necessary the increase of the amount of water applied to guaranty proper soil moisture, needed for an adequate initial crop growth and development.

The coldest year was 2003 with maximum air temperatures as high as 33^{o}C for the both Baker and Mitchell locations and rainfall as low as 88 mm in Baker County and as low as 78 mm in Mitchell County.

Table 1. Total irrigation amounts (TIA) observed during the four cropping seasons that were analyzed, and the crop's average and standard deviation of the total irrigation amounts.

Season	Cotton			Maize			Peanut		
	Field #	Location	TIA (mm)	Field #	Location	TIA (mm)	Field #	Location	TIA (mm)
	1	Baker	30.2	5	Mitchell	476.4	2	Baker	183.2
2001	3	Mitchell	135.4				6	Mitchell	410.3
	4	Mitchell	184.1						
2002	2	Baker	245.3	5	Mitchell	854.8	1	Baker	210.2
	4	Mitchell	211.7	6	Mitchell	462.8	3	Mitchell	229.0
2003	1	Baker	73.3	6	Mitchell	251.0	2	Baker	48.3
	3	Mitchell	30.7				4	Mitchell	46.6
							5	Mitchell	102.4
	2	Baker	245.3	5	Mitchell	496.0	1	Baker	137.2
2004	3	Mitchell	109.4				6	Mitchell	265.9
	4	Mitchell	131.3						
Average			133.9			508.2			181.4
Standard Deviation			85.2			217.7			115.5

Smaller irrigation amounts were applied in cotton, maize, and peanut during 2003 (Table 1), probably due to the better distribution of rainfall during this cropping season (Figure 1 and Figure 2). The deviations of the irrigation amounts observed in Table 1 are caused by several factors. This includes the different planting dates, the inter-annual and intra-seasonal weather variation previously discussed, and irrigation management. Except in 2002, maize was usually planted during the first half of March, cotton was usually planted during the middle April, and peanut during the first half of May. The irrigation management varies from farmer to farmers and is, probably, one of the major components of this deviation.

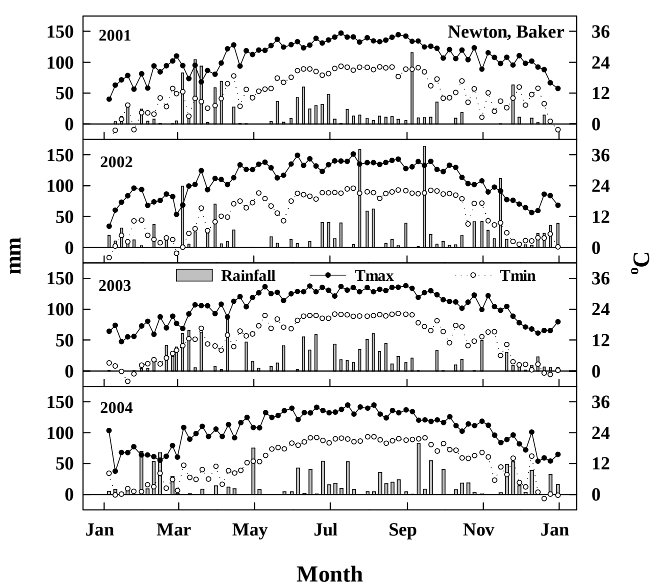

Figure 1. Five-day cumulative rainfall and five-day average maximum and minimum air temperature observed in Newton, Baker, during the four year cropping seasons analyzed in this study.

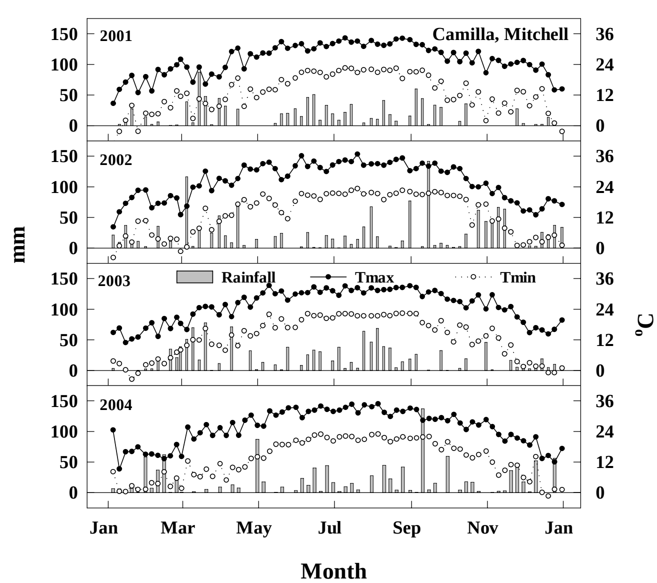

Figure 2. Five-day cumulative rainfall and five-day average maximum and minimum air temperature observed in Camilla, Mitchell, during the four year cropping seasons analyzed in this study.

In 2003, the adequate rainfall distribution during March and April for maize as well as the middle May planting date for cotton and peanut that avoid the scarce rainfall at the beginning of that month clearly reflected the lowest irrigation amounts observed during this year for the three crops when compared to the other years (Table 1).

The results of the comparison between observed and simulated irrigation amounts for peanut are presented in Table 2. For most of the fields, the *r* between monthly observed and simulated irrigation amounts were higher than 0.60. However, this correlation was significant for one field during the 2001 cropping season, one field in 2002, and two fields in 2004. The low *r* found during the 2003 cropping season, mainly for fields number 2 an 4, was probably due to irrigation management, since this year had an adequate rainfall distribution at the beginning of the season and from June to August that probably permitted more flexibility on the decision when to irrigate.

The comparison between the observed and simulated CDF of each peanut field showed a significant difference between the monthly irrigation amounts during the four cropping seasons that were studied (Table 2). These results are not atypical, since we are comparing on-farm irrigation applications with estimations from computer models. Farmers, for instance, make practical decisions, such as a continuation of irrigation if rainfall occurs after irrigation has been initiated. These are decisions that a model cannot take into account. However, the potential of the DSSAT models as a tool for irrigation scheduling purposes was demonstrated.

Table 2. Coefficient of correlation (*r*) and Kolmogorov-Smirnov test statistic (D) for the comparison of monthly irrigation amounts from simulated and observed data

Cropping Season	Location	Field #	*r*	D
2001	Baker	2	0.656	0.286*
2001	Mitchell	6	0.846*	0.571*
2002	Baker	1	0.475	0.429*
2002	Mitchell	3	0.896*	0.429*
2003	Baker	2	0.584	0.571*
2003	Mitchell	4	0.547	0.571*
2003	Mitchell	5	0.684	0.571*
2004	Baker	1	0.738*	0.286*
2004	Mitchell	6	0.958*	0.286*

Values with a * have a significantly correlation or a cumulative distribution function that is significantly different at $p < 0.05$.

The comparison of the observed and simulated irrigation amounts for cotton and maize, not presented here, provided correlations similar to those obtained for peanut. For most of the cotton and maize fields, the coefficient of correlation between observed and simulated irrigation amounts were higher than 0.70 and 0.63, respectively. Thus, results from the DSSAT models permitted adequate estimates of the monthly irrigation amounts required by the crops.

CONCLUSION

The analysis and comparison of the observed and simulated irrigation scheduling showed the potential of the DSSAT models to be used as a tool for on-farm and regional irrigation scheduling.

REFERENCES

Garcia y Garcia, A., L. C. Guerra, and G. Hoogenboom, Simulating peanut irrigation water use and yield in farmers' fields in southwest Georgia. Proceedings of the Biological Systems Simulation Conference, Gainesville, FL., March 8-10, 2004

Guerra, L.C., G. Hoogenboom, V.K. Voken, J.E. Hook, D.L. Thomas, K.A. Harrison, 2004. Evaluation of the EPIC model for simulating crop yield and irrigation demand. *Transactions of the ASAE*, 47(6):2091-2100.

Hoogenboom, G., J. W. Jones, P. W. Wilkens, C. H. Porter, W. D. Batchelor, L. A. Hunt, K. J. Boote, U. Singh, O. Uryasev, W. T. Bowen, A. J. Gijsman, A. S. du Toit, J. W. White, and G. Y. Tsuji, 2004. Decision Support System for Agrotechnology Transfer Version 4.0, [CD-ROM]. University of Hawaii, Honolulu, HI.

Hook, J.E., K.A. Harrison, G. Hoogenboom, and D. Thomas, 2004. Ag water pumping: final report. Statewide irrigation monitoring, EPD cooperative agreement number: 764-890147, UGA ID 25-21-RF327-107. 135pp.

Pereira, L.S., 1996. Inter-relationships between irrigation scheduling methods and on-farm irrigation systems. In: Irrigation Scheduling: From Theory to Practice - Proceedings of the ICID/FAO Workshop on Irrigation Scheduling (Water Reports 8)

Ritchie, J. T., 1998. Soil water balance and plant water stress. In: Tsugi, G. Y.; Hoogenboom, G. and Thornton P. K. (Eds.). *Understanding Options for Agricultural Production*. Kluwer Academic Publishers, 41-54.

SAS Institute, 1999. SAS Online Doc, Version 8. SAS Institute, Cary, NC.