ESTIMATING STATEWIDE IRRIGATION REQUIREMENTS USING A CROP SIMULATION MODEL

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Abstract. An understanding of water needs in agriculture is a critical input in resolving the water resource issues that confront the state of Georgia. Unfortunately, how much water is required and how much water is actually being used for irrigation is unknown. The objective of this study was to estimate water demand for irrigation for the entire state of Georgia using a crop simulation model. The irrigation requirements for all the counties where irrigated cotton, corn, peanut and soybean were grown in 2000, 2001 and 2002 were estimated using the Environmental Policy Integrated Climate (EPIC) model. These counties were distributed across seven regions; with three regions, i.e., Flint Basin, Central Coastal Plain and Coastal Zone, representing the major growing areas. The combined irrigation withdrawal in the Flint Basin, Central Coastal Plain and Coastal Zone accounted for about 98% and 99% of the statewide total irrigation withdrawal in 2000 and 2001, respectively, mainly due to large irrigated acreage in those regions. Statewide total irrigation withdrawal was estimated to be 199,125 Mgallons in 2000 and 114,101 Mgallons in 2001. These irrigation requirements will vary from year to year depending on the spatial and temporal distribution of rainfall during the growing season. Total irrigated acreage also had a major impact on irrigation withdrawal. We will implement the model for other crops to determine the total irrigation withdrawals for agriculture in the state of Georgia.

INTRODUCTION

An understanding of water needs in agriculture is a critical input in resolving the water resource issues that currently confront the state of Georgia. These include the tri-state (Alabama, Florida and Georgia) negotiations on a water allocation formula, the pending applications for agricultural irrigation withdrawal permits, and cropping and water management strategies that protect critical habitats and water users during a drought. Agricultural irrigators in Georgia are required to have a permit, but they are not required to report their water use. Over 20,000 permits have been issued, and nearly 2,000 new applications were pending in the Flint River basin alone in 2002. Approval of these new applications depends on a better understanding of water use for irrigation, outcomes of the tri-state negotiations for a water allocation formula, and effects of the current drought and water pumping for irrigation and other uses on river flows (Thomas et al., 2000). Unfortunately, how much water is required and how much water is actually being used for irrigation is currently unknown.

The Agricultural Water: Potential Use and Management Program in Georgia (Ag. Water PUMPING) program was initiated in 1998 to estimate agricultural water use across the entire state of Georgia through a combination of monitoring and modeling (www.AgWaterPumping.net; Thomas et al., 1999). The monitoring program was designed to provide an "average" indication of how much water is being withdrawn for crop production (Thomas et al., 2001). The modeling program aims to estimate the total (statewide) water use for irrigation in Georgia using geostatistics, geographic information system (GIS), and crop simulation models. Geostatistical interpolation techniques and GIS are being implemented on the data from the monitoring program to derive a model on water use for irrigation across Georgia (Boken et al., 2003). At the same time, the use of a crop simulation model for estimating water demand for irrigation is being evaluated. The objective of this study was to estimate the water demand for irrigation for the entire state of Georgia using a crop simulation model.

METHODS

Cotton, corn, peanut and soybean are major crops in Georgia. In 2000, these crops accounted for about 78% of the total irrigated acreage in Georgia (Harrison, 2001). The irrigation requirements for the 2000, 2001 and 2002 growing seasons for cotton, corn, peanut and soybean were estimated using the Environmental Policy Integrated Climate (EPIC) model version 8120. EPIC has a single crop model that handles multiple crops to simulate crop growth, soil and plant water and nitrogen and phosphorus balance, and crop and soil management (Williams et al., 1989; Meinardus et al., 1998). The model runs on a daily time step and inputs include data on weather variables, crop parameters, soil parameters, and crop and soil management practices. In EPIC, irrigation can be scheduled by the user or conducted automatically by the model. Required inputs for the automatic option include a threshold value to trigger the irrigation applications and the maximum amount per application.

The input data for EPIC were obtained for all the counties where irrigated cotton, corn, peanut and soybean were grown in 2000, 2001 and 2002. These counties were distributed across seven regions; with three regions, i.e., Flint Basin, Central Coastal Plain and Coastal Zone, representing the major growing areas. It was assumed that farms within the same county have similar management practices. The weather data from stations located within each county or the nearest weather station were used. Daily solar radiation, maximum and minimum air temperature, precipitation, relative humidity and wind speed for 2000, 2001 and 2002 were obtained from the weather records of the Georgia Automated Environmental Monitoring Network (www.Georgiaweather.net; Hoogenboom, 2001). We did not know the soil on which the crops were grown in each county. Hence, we assumed that they were grown on the dominant soil in a county. Using a soil map, the dominant soil for each county was selected and the values for various soil parameters at different depths were obtained from the state soil geographic (STATSGO) data base (USDA, 1994b). The selected planting dates were May 5 for both cotton and peanut, May 25 for soybean, April 15 for corn in north Georgia (above latitude 34^{o} N), and March 15 for corn in the rest of Georgia (below latitude 34^{o} N).

The simulation was set at one year and was initiated on January 1. Initial soil water content was estimated automatically by the model based on average annual rainfall. The plant water stress level to trigger automatic irrigation was set at 0.95 and the maximum amount per application was 1.2 inches. An irrigation efficiency of 75% was assumed. For 2000 and 2001, the simulated irrigation amount (inches) was multiplied with the irrigated acreage to determine the irrigation withdrawal (Mgallons) in each county. Data on crop irrigated acreage by county for 2000 was obtained from the 2000 Georgia Irrigation Survey (Harrison, 2001). There was no available data on crop irrigated acreage by county for 2001. Hence, crop irrigated acreage was estimated using the equation:

$$CIA_{2001} = \frac{CIA_{2000}}{CHA_{2000}} \text{ x } CHA_{2001}$$

where CIA_{2000} and CIA_{2001} are the crop irrigated acreage for 2000 and 2001, respectively, and CHA_{2000} and CHA_{2001} are the crop harvested acreage for 2000 and 2001, respectively. Data on crop harvested acreage by county were provided by the Georgia Agricultural Statistics Service (www.nass.usda.gov/ga). Data on crop harvested acreage for 2002 were not available; hence, irrigation withdrawal for that year could not be estimated.

RESULTS AND DISCUSSION

For all regions except the Coastal Zone, the total rainfall during the growing season (March-October) was lower in 2000 than in 2001. The amount of rainfall in 2002 was similar to that in 2001, except for the Chattahoochee Basin and the Coastal Zone. In 2000 and 2001, the total rainfall from March to October varied widely across the regions of the state. In 2000, Northeast Georgia had the lowest rainfall total (19.8 inches) while the Northern Tier had the highest rainfall total (29.0 inches). In 2001, total rainfall was lowest in the Coastal Zone (24.9 inches) and was highest in the Flint Basin (33.5 inches).

Table 1 shows the irrigation requirements for the 2000, 2001 and 2002 growing seasons for cotton, corn, peanut and soybean. In 2000, the irrigation amount was the highest for corn in all regions except the ACT Basin. This trend was not evident in 2001. For all crops in 2000 and 2002, irrigation amount was lowest in the Coastal Zone. Except for corn in 2002 and soybean in 2001 and 2002, Northeast Georgia had the highest average amount of irrigation among the seven regions.

However, due to small irrigated acreage, irrigation withdrawal was much lower in Northeast Georgia compared with irrigation withdrawal in the Flint Basin, Central Coastal Plain and Coastal Zone. The combined irrigation withdrawal in the Flint Basin, Central Coastal Plain and Coastal Zone accounted for about 98% and 99% of the statewide total irrigation withdrawal in 2000 and 2001, respectively, mainly due to large irrigated acreage in those regions. In both years, the combined irrigated acreage in the Flint Basin, Central Coastal Plain and Coastal Zone accounted for about 99% of the total irrigated acreage for the four crops. Total irrigation withdrawal was lower in 2001 (114,101 Mgallons) compared with that in 2000 (199,125 Mgallons).

These results indicate that the irrigation requirements could vary from one region to another and from year to year depending on the spatial and temporal distribution of rainfall during the growing season. Total irrigated acreage also had a major impact on irrigation withdrawal. It would be interesting to see if the regional pattern in irrigation withdrawal would change when other crops are considered, particularly the winter crops.

Table 1. Total irrigation requirements for the 2000, 2001 and 2002 growing seasons.

Region	2000				2001				2002	
	Avg. amount (in.)	Std. Dev. (in.)	Total irrigated area (acres)	Irrigation withdrawal (Mgallons)	Avg. amount (in.)	Std. Dev. (in.)	Total irrigated area (acres)	Irrigation withdrawal (Mgallons)	Avg. amount (in.)	Std. Dev. (in.)
Cotton										
Northeast Georgia	13.2	1.8	1,894	664	9.4	1.9	1,894	570	13.9	1.7
ACT Basin	7.9	0.0	500	107	4.7	0.0	500	64	12.6	0.0
Flint Basin	7.2	4.6	324,197	50,104	3.8	3.5	371,858	31,051	5.6	3.6
Central Coastal Plain	8.3	4.5	253,178	52,100	4.7	3.6	270,556	31,255	8.0	5.3
Coastal Zone	3.8	3.4	65,921	8,132	3.1	3.5	71,072	8,594	4.4	4.3
Corn										
Northern Tier	7.1	3.3	181	38	0.8	1.1	181	5	13.4	1.1
Northeast Georgia	18.5	1.7	3,105	1,621	5.4	1.1	3,105	431	9.6	1.5
ACT Basin	7.2	2.6	3,500	693	0.0	0.0	3,181	0	9.1	2.6
Chattahoochee Basin	16.0	2.1	915	364	5.0	3.2	915	114	6.8	3.5
Flint Basin	8.4	3.1	108,817	24,857	2.9	3.0	95,443	5,344	6.9	4.2
Central Coastal Plain	9.1	4.3	51,538	13,743	4.2	3.1	52,565	6,037	7.9	3.2
Coastal Zone	7.1	4.8	26,950	4,580	4.7	2.2	23,299	2,700	5.4	2.6
Peanut										
Flint Basin	4.7	3.5	196,564	22,651	2.7	2.8	202,661	12,555	4.2	2.5
Central Coastal Plain	5.3	3.6	86,768	14,794	4.0	3.3	92,071	9,682	5.8	4.0
Coastal Zone	4.6	3.5	22,250	2,494	3.6	3.4	27,871	3,020	3.4	3.0
Soybean										
Northeast Georgia	10.0	0.9	420	121	7.9	4.2	355	77	12.1	1.8
ACT Basin	7.9	1.6	425	83	4.7	0.0	435	56	14.7	0.9
Chattahoochee Basin	6.3	0.0	310	53	9.4	4.5	310	87	9.4	2.2
Flint Basin	4.5	2.8	5,253	433	3.7	3.8	5,242	231	3.3	3.2
Central Coastal Plain	4.6	3.0	5,825	1,065	5.5	2.6	8,675	1,738	5.4	4.1
Coastal Zone	2.7	2.4	9,500	428	3.8	2.4	9,040	490	3.1	3.1
Total for the 4 crops			**1,168,011**	**199,125**			**1,241,229**	**114,101**		

CONCLUSIONS

The combined irrigation withdrawal in the Flint Basin, Central Coastal Plain and Coastal Zone accounted for about 98% and 99% of the statewide total irrigation withdrawal in 2000 and 2001, respectively, mainly due to large irrigated acreage in those regions. Total irrigation withdrawal was lower in 2001 compared with that in 2000. The irrigation requirements could vary from one region to another and from year to year depending on the spatial and temporal distribution of rainfall during the growing season. Total irrigated acreage also had a major impact on irrigation withdrawal.

This study showed that the EPIC model can be a useful tool for determining statewide water demand for irrigation. We will implement the model for other crops to determine the total irrigation withdrawals for agriculture in the state of Georgia.

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