

AGRICULTURAL WATER CONSUMPTION IN THE A.C.F. RIVER BASIN: CURRENT APPROACHES FOR QUANTIFYING IRRIGATION IN GEORGIA

James E. Hook¹, Elizabeth R. Blood², Daniel L. Thomas³, Kerry A. Harrison³, and Ralph Powell⁴

AUTHORS: ¹National Environmentally Sound Production Agriculture Lab and Crop and Soil Sciences Dept., The University of Georgia, College of Agricultural and Environmental Sciences (CAES) Tifton Campus, Tifton, GA 31793; ²J.W. Jones Ecological Research Center, Newton, GA 31770; ³Biological and Agricultural Engineering Department, Tifton, GA 31793; ⁴Georgia Power, Bainbridge, GA 31717.
REFERENCE: *Proceedings of the 1999 Georgia Water Resources Conference*, held March 30 to 31, 1999, University of Georgia, Athens. Kathryn J. Hatcher, Editor, Institute of Ecology, University of Georgia, Athens, Georgia.

Abstract. In the Flint River portion of the Tri-state Apalachicola, Chattahoochee and Flint (ACF) Basin agricultural irrigation is the largest consumer of water; yet, there has been no previous reporting of irrigation withdrawal amounts or times. Effective and fair allocation requires an accurate assessment of current use and needs. Our objective was to project monthly water needs for most of Georgia's crops for wet, dry and normal years using crop growth and water use models and long-term weather records. For normal years, predicted irrigation agreed with the 10 in./yr used in ACF formulas; in dry years it was less than the formula's 18 in./yr. Time of withdrawal varied widely by crop, but no combination of crops would result in the monthly April to August distribution of 2, 17, 42, 25, 14% of total annual irrigation used as an initial basis for negotiations. Farmer supplied data showed an even wider range of irrigation periods than model predictions. Human factors that affect irrigation in ways unrelated to crop water-needs make prediction of irrigation water consumption more difficult. Projected monthly withdrawals for irrigation should be modified to reflect current and projected acreage and water needs by specific crops.

INTRODUCTION

At the start of ACF negotiations, Georgia's Department of Natural (DNR) sought an independent estimate on the amount and timing of irrigation water withdrawals. The Comprehensive Study (USDA-SCS, 1994) provides most of the data that is used as a basis for negotiations for an allocation formula for the compacts. However, several individuals and groups questioned the rather static values of the study's annual distribution of withdrawals and annual totals for drought, normal and wet years. This paper reports modeled and farmer volunteered data on irrigation amounts and timing and discusses limitations of all projections for irrigation withdrawals.

BACKGROUND AND RELATED WORK

Georgia farmers withdraw surface and ground water for irrigation from dispersed sources, most of which have been developed on their property. They apply amounts that vary from week to week and year to year based upon weather, crop type and growth stage, soil conditions, judgements on the potential for profits, and several other factors. The timing, amount, and source of those withdrawals are becoming increasingly important to regional water planners.

Currently, DNR's Agriculture Water Withdrawal Permits are the only means the agency has to regulate agriculture water use. These permits, however, merely limit the source and the maximum pumping rate. Because irrigation systems require large instantaneous capacities, the permitted pumping rates are high. In the Flint Basin, the installed and permitted pumping capacity of the irrigation systems is a staggering 8.45 billion gallons per day. Fortunately, the combined capacity never occurs at one time, and individual pumps are used only a small fraction of the year. However, the value points out the difficulty of using permitted pump capacity as an aid in meeting Georgia's allocation requirements.

The importance of irrigation water use to Georgia's water resource management has led to several attempts to determine amounts of water needed for irrigation in each sub-basin of the ACT/ACF. The University of Georgia's Cooperative Extension Service surveys its agents to determine irrigated acres, crops, amounts of water, and type of irrigation (Harrison and Tyson, 1999). The values are used widely, and they were the initial estimates used in the Comprehensive Study (USDA-SCS, 1994) that became the basis for Compact negotiations. The estimates of irrigated acreage may be the closest value of land area receiving water (Blood et al., 1999). However, the survey's estimates of irrigation amounts are less reliable. They represent only one year's application, an estimate

that may be high in a drought year like 1998, the base year of the current survey, or low in a wet year like 1995.

In the Comprehensive Study (USDA-SCS, 1994), irrigation amounts were estimated for the crops irrigated most often, and based on the current and projected crops, an estimate was made for water withdrawals. That estimate gave a static distribution of withdrawals — 2, 17, 42, 25, 14% of annual total irrigation would occur in April through August, respectively. Farmers would apply a low of 4.9 in. for wet years, 10 in. for average years, and 18 in. for drought years. While other methods including crop model estimates were reported in the study, this simple formula was assumed to be a reasonable basis for negotiations.

Monitoring actual use would seem to be a logical means for determining irrigation amounts. Georgia currently permits nearly 19,000 agricultural users. Record keeping, reporting, verification, and compliance on this number of permits are currently considered prohibitively expensive. An alternative approach would monitor pumping on randomly selected, representative irrigation systems (Thomas et al., 1999). The results of the sample would be interpolated for counties and basins within years to provide a measure of water use. However, obtaining a long-enough time span to project use for the future would require several years. In the approach reported here irrigation predictions were made using crop models and farmer volunteered data. The purpose of the project reported here was to determine potential water withdrawals by month for Georgia's primary irrigated crops during dry, normal, and wet years.

EXPERIMENTAL DESIGN

Use of crop growth and water use models to predict water withdrawals was based on procedures of earlier studies for a limited number of crops (Hook, 1994, Hook et al., 1995). For each water basin, defined by DNR as the counties above selected gaging stations, we selected four to six meteorological stations in or adjacent to the basin with records from 1961 to 1990. For locations lacking solar radiation measurements, values were interpolated by distance weighting from the closest two stations with those records. This preserved the high spatial variability of rainfall using several stations, while supplying the less variable solar radiation needed for some of the models.

For each basin, an array with ten cells provided ten choices of soil types with known soil water characteristics. The proportion of soil types distributed in those cells was related to the approximate ($\pm 10\%$) area of those soil types

in agricultural areas of the basin. Planting dates were described with an earliest, optimal, and latest date, and harvest or maturity dates were determined by the crop models or by the average length of time to the middle of the harvest seasons.

As in the earlier studies, CERES-Maize, PNUTGRO, and SOYGRO were used to determine irrigation needs of corn, peanut and soybean, respectively. For cotton, tobacco, tomato/pepper, melons, squash/cucumber, and snap beans a generic crop evaporation model was fitted to the soil water balance routines of CERES. Potential crop evaporation was determined from meteorological data using the modified Priestly-Taylor approach of WATBAL. This was multiplied by a crop coefficient determined from curves derived from research in south Georgia by D. A. Smittle, J. R. Stansell, and L. Samples (personal communication and summarized in Harrison and Tyson, 1993). Rooting depths were multiplied by the same crop coefficients, from the initial depth of seeding to the maximum depth of rooting to get daily water extraction zones.

For each region and crop, the model made 100 simulations. For each simulation, a weather station, weather year, soil type, and crop variety (for corn, peanut, and soybean) was chosen by random selection with replacement. Planting dates were selected from a random-normal distribution of dates centered on the optimal planting date. Each of the 100 possible representations of irrigated crop production provided dates and amounts of irrigation that would be needed to keep production within 93 to 97%, on average, of the optimal no water stress yields. Irrigation was summed by calendar months. Runs were then ranked from highest to lowest yield loss (corn, peanut and soybean) or highest to lowest total season irrigation amounts (all other crops). The average of the upper quartile was taken as irrigation amounts needed for drought years, the average of the two middle quartiles, normal years, and average of the lowest quartile, wet years.

In addition to the modeling approach to estimate water use, the Southwest Georgia Agribusiness Association gathered actual farmer irrigation records as an independent check on modeled and DNR projections of monthly irrigation amounts. A total of 17 growers provided 373 crop years of data from the 1991 to 1997 period. Additionally, the USDA National Peanut Laboratory in Dawson, Georgia, provided summaries of monthly irrigation use for 11 years on more than 400 grower fields. A total of 76 crop years for corn, 65 for cotton, 452 for peanut, and 30 for soybean, provided a

good representation of irrigation amounts as the farmers actually schedule and apply it.

RESULTS AND DISCUSSION

Monthly irrigation that would be pumped onto seven crops in normal years is shown for one basin (Table 1.) Amounts assume 80% irrigation application efficiency. Results are shown as quartile means but could easily be reported as probability distribution functions for each month for use in hydrological modeling. The 10 in. predicted for corn and cotton agrees with the DNR formula 10 in. for normal years, but amounts predicted for other crops were lower. The total annual irrigation predicted for dry years varied by crop from 10.6 to 16.2 in., but all were below DNR's estimate of 18 in.

Monthly distribution of irrigation did not follow DNR's formula, the Comprehensive Study ratios of 2, 17,

42, 25, 14% of annual total in April through August with the peak use in June. Corn had equivalent irrigation needs in May and June; peanut, soybean, and cotton had peak needs after June. While the actual monthly irrigation percentages would depend upon the relative proportions of crops actually being irrigated, no mix would give a sharp peak use for June.

Farmer data shows wider spread of irrigation applications than the models (Table 2). This is due in part to the models did not include double crops (spring and fall tomatoes and beans, for example). Also there are factors not related to crop water requirements that influence when and how much irrigation farmers apply. The years represented in the farmer data, 1991 to 1997, also differ from the years used in the model simulations, 1961 to 1990.

Table 1. Predicted Irrigation Amounts by Crop for the Lower Flint Basin of the ACF Study Area.
(Monthly irrigation averages were computed as the mean of the two middle quartiles of a ranking based on total yearly irrigation amount.)

Crop	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
	in.												in.
Corn	-	0.044	0.293	0.065	3.981	4.063	1.653	-	-	-	-	-	10.08
Cotton	-	-	-	0.043	0.463	2.281	2.56	1.96	2.18	0.564	-	-	10.00
Peanut	-	-	-	-	-	0.163	1.441	1.310	0.95	0.097	-	-	3.95
Soybean	-	-	-	-	-	0.163	1.935	1.612	2.441	0.362	-	-	6.50
Tomato/Pepper	-	-	0.032	1.350	3.462	3.282	1.230	-	-	-	-	-	9.35
Melon	-	-	0.032	0.201	3.232	2.852	0.564	-	-	-	-	-	6.86
Snap Beans (spring)	-	0.03	2.701	2.181	-	-	-	-	-	-	-	-	4.91

Table 2. Average Monthly Irrigation Water Use Reported by Selected Farmers in the Lower Flint Basin During the 1991 to 1997 Growing Seasons

Crop	No. of Records	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
		in.												in.
Corn	76	-	-	0.17	0.87	3.29	2.99	0.72	0.09	0.36	0.18	0.04	-	8.70
Cotton	65	-	-	0.03	0.42	0.97	1.35	2.53	2.26	1.80	0.34	-	-	9.70
Peanuts	452	-	-	0.02	0.37	0.77	1.21	2.06	1.87	0.81	0.04	-	-	7.15
Soybeans	30	-	0.03	0.16	0.55	0.57	0.54	1.03	1.67	1.43	0.39	-	-	6.36
Tomato	11	-	-	0.14	0.55	3.02	2.87	0.03	0.92	4.03	3.02	0.32	-	14.89
Peas	3	-	-	0.26	1.73	3.83	6.42	0.85	1.95	6.13	1.24	-	-	22.4

Irrigation amounts differed by basin (data not shown). The basins near the Florida border required 13 to 85% less irrigation, depending upon crop, than those in the upper reaches of the Flint and Chattahoochee. Areas closest to the Gulf of Mexico typically receive more rain and have lower mean summer temperatures.

Whether amounts and timing are predicted by models or measured on farms, the irrigated area planted to each crop must be known to determine impact on specific aquifers or watersheds. While surveys may help determine what has been planted, future planting intentions are very difficult to predict. Commodity prices, planting in other region or countries, products in storage, foreign markets, government programs, and a farmer's preference, equipment and labor affect the planting decision. This makes planted area highly volatile. In recent years, Georgia's corn, soybean and cotton area has varied from 0.6 to 2.0, from 0.2 to 2.4, from 0.1 to 1.4 million acres, respectively. As noted above, the choice of crop will heavily influence when and how much water is withdrawn.

Irrigation applications are made to prevent yield reducing water stress in crops. However, there are other factors that are more difficult to predict that affect when or how much a farmer applies. Ultimately, economic factors determine when to irrigate. But, in addition to prices received for commodities and costs of irrigating, the farmer's willingness to take risks, their expectation of profits, the amount of their production loans, their participation in private and government crop insurance programs, and even the availability of drought disaster payments affect whether they turn on that irrigation when crop stress begins.

Farmers also irrigate for reasons other than reducing crop stress. Preseason irrigation for tillage, stand establishment, or weed control, in-season application of fertilizers, and preharvest irrigation to aid digging are common. So too is extra watering to maintain shipping and market standards for fresh fruits and vegetable. Threats of disease, conversely, may lead a grower to withhold a needed irrigation. Many of these factors will need to be anticipated in future estimates of irrigation amounts and timing in the ACF River Basin.

ACKNOWLEDGEMENTS

The authors would like to thank the Georgia Department of Natural Resources for partial funding of the project. They also thank Dr. Marshall Lamb of the National Peanut Laboratory, Dawson, GA for providing farmer records of irrigated peanut.

LITERATURE CITED

- Blood, E. R., J. E. Hook, and K. A. Harrison. 1999. Agricultural water consumption in the ACT/ACF River Basins: Approaches for Projecting Irrigated Acreage. In K. J. Hatcher (ed.) *Proceedings of the 1999 Georgia Water Resources Conference*. Univ. of Georgia Institute of Ecology, Athens, Ga.
- Harrison, K. A. and A. W. Tyson. 1993. Irrigation Scheduling Methods. B-974. Georgia Cooperative Extension Service, Athens, Ga.
- Harrison, K. A. and A. W. Tyson. 1999. Irrigation survey for Georgia. In K. J. Hatcher (ed.) *Proceedings of the 1999 Georgia Water Resources Conference*. Univ. of Georgia Institute of Ecology, Athens, Ga.
- Hook, J. E. 1994. Using Crop Models to Plan Water Withdrawals for Irrigation in Drought Years. *Agricultural Systems* 45:271-289.
- Hook, J.E. and D.L. Thomas. 1995. Projected seasonal water consumption and water restrictions for row crops irrigation in the A.C.F. Basin. p 276-279. In K. J. Hatcher (ed.) *Proceedings of the 1995 Georgia Water Resources Conference*. Carl Vinson Inst. Govt., Univ. of Ga., Athens, GA 30602
- Hook, J.E., K.A. Harrison, and D.L. Thomas. 1998. Analysis of water use by growers in Southwest Georgia. Report to SW Ga. Agribusiness Assoc. and Ga. Dept. of Nat. Resources. NESPAL Rep. 98-01, Univ. of Georgia NESPAL, Tifton, GA.
- Thomas, D. L. Cathy Myers-Roche, K. A. Harrison, J. E. Hook, A. W. Tyson, G. Hoogenboom, and W. I Segars. 1999. Ag Water Pumping: A New Program to Evaluate Agricultural Water Use in Georgia. In K. J. Hatcher (ed.) *Proceedings of the 1999 Georgia Water Resources Conference*. Univ. of Georgia Institute of Ecology, Athens, Ga.
- USDA-SCS. 1994. *ACT/ACF River Basins Comprehensive Study: Agriculture Water Demand*. Technical Report. August, 1994. USDA Soil Conservation Service, Auburn, AL. 303p.