AGRICULTURAL WATER CONSUMPTION IN THE ACT/ACF RIVER BASINS: APPROACHES FOR PROJECTING IRRIGATED ACREAGE AND AMOUNTS

Elizabeth R. Blood[1], James E. Hook[2], and Kerry A. Harrison[3]

AUTHORS: [1]J.W. Jones Ecological Research Center, Route 2, Box 2324, Newton, Georgia 31770; [2]NESPAL and Crop and Soil Sciences Department, UGA College of Agricultural and Environmental Sciences (CEAS), Tifton Campus, Tifton, Georgia 31793; and [3]Biological and Agricultural Engineering, UGA CEAS, Tifton Campus, Tifton, Georgia 31793.
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Abstract. Accurate assessment of current and future irrigation in the ACT/ACF river basins requires quantification of agricultural irrigation. Irrigated acreage is difficult to measure and project. No systematic monitoring of agricultural water application rates or irrigation volume occurs. Secondary sources must be combined with irrigation acreage estimates to derive irrigation water-use. Several sources and techniques available for determining irrigated acreage and water-use were compared. These approaches included surveys of farmers and experts, physical checks at random locations, manual and computer analysis of remotely sensed images, crop models, and farmer-reported irrigation intentions. Four counties in Southwest Georgia with predominantly fixed irrigation systems were evaluated. There was good agreement among acres and irrigation volumes determined from surveys, physical checks, models, and image analysis. The four county total irrigation volume averaged 63.5 mgd for these approaches. The Comprehensive Basins Study and the DNR-EPD permitted irrigation volumes were higher than these four approaches by 65% and 160%, respectively. Where mobile irrigation systems are in use differences were greater. Each method has its flaws, gaps, and overlaps.

INTRODUCTION

During 1999, a tri-state water compact is being formulated between Georgia, Florida, and Alabama to manage water-use, allow adequate economic growth, and maintain natural resources in the Apalachicola-Chattahoochee-Flint (ACF) River Basin. Agricultural irrigation in the Flint River portion of the ACF Basin, is the largest consumptive use of water below the Fall Line in Georgia. While few dispute this finding, the precise quantity of irrigation water used is open to debate. Privacy protection for business records of individual farmers and difficulties in quantifying a variable that changes every year adds to that complexity. Crop rotations change timing of irrigation; weather determines how much, if any, irrigation will be applied; and portable irrigation systems are used to irrigate different fields, particularly to protect against disaster in the most severe droughts. However, several techniques are available for determining irrigated acreage.

No direct monitoring data are available to quantify irrigation water-use. All large agricultural water-users are required by Georgia Department of Natural Resources Environmental Protection Division (DNR-EPD) to have irrigation water withdrawal permits. Irrigation pump maximum capacity, water source, and intended irrigated acres are required for the permit. Water-use reporting is voluntary and not a condition of the permit. Therefore, irrigation water-use must be derived from secondary sources.

The Comprehensive Basins Study provided an independent estimate of irrigation water-use and is being used as the basis for the tri-state negotiations (USDA-SCS, 1994). The current and future irrigation estimates in the Comprehensive Basins were based on 1992 acreage of major crops irrigated and average application rates. The University of Georgia's Cooperative Extension Service's survey of irrigated acres, crops, and water application amounts formed the basis for the Comprehensive Basins Study. Future irrigated acreage, crop distributions, and annual average water application rates were based on the best professional judgements of leading agricultural experts. The annual application rates range from a low of 4.9 inches for a wet year, 10 inches for a normal year, and 18 inches for a drought year.

Questions have been raised about the annual application amounts, crop distributions, and irrigated acreage estimates and future projections used in the Comprehensive Basins Study. Differences due to weather, crop type, perceived markets, and farming practices can yield vastly different irrigated acreage, water withdrawal estimates, and future-year projections (Hook et al., 1999). This study evaluated several methods for deriving irrigated acreage, water application rates, and annual irrigation water volume for four counties in SW Georgia, and compares these results with the Comprehensive Basins Study 1995 projected irrigated acres and irrigation withdrawals.

BACKGROUND

Surveys, water withdrawal permit information, and remote sensing (e.g. aerial photography) approaches have been used to quantify agricultural crop and irrigation acreage. Since 1970, the University of Georgia Cooperative Extension Service has conducted approximately tri-annual county irrigation surveys estimating crop acreage, crop irrigated acreage, irrigation amounts, irrigation systems and irrigation water sources (Harrison and Tyson, 1999). The estimates in the surveys are determined by a professional assessment by the county agricultural extension agents. The tri-annual county irrigated acres form the basis for other estimates including the US Department of Agriculture (USDA) crop reporting service and the National Resources Conservation Service (NRCS) estimates.

The National Agricultural Statistics Service (NASS) conducts and reports annual crop surveys and a five-year survey of crop production and irrigated acres (USDA, 1995). The NRCS conducts five year natural resources inventories (NRI) that include soils, crops, conservation practices, and irrigation practices (USDA, 1994). Additionally, the NRCS has developed spatial data associated with the resource inventories. Another source for irrigated acre estimates is the GA DNR-EPD agricultural water-use permits. Finally, landuse classification of satellite imagery and photo-interpretation of aerial photography provide quantitative "snap-shots" of agricultural landuse, crops, and irrigated acres (Houhoulis and Michener, 1998).

Acreage information is combined with field studies, statistical and simulation modeling, voluntary water-use reporting, and professional judgement to derive irrigation water volume used for crop production. Crop water application rates derived from the tri-annual irrigation surveys conducted by the University of Georgia agricultural extension agents are widely used (Harrison and Tyson, 1999). For these surveys, the county agents provide the crop-specific water application rate for their county for the year of the survey. Field studies directly measuring crop water needs have been incorporated into simulation models that predict crop water demands under differing weather conditions (Hook, 1994; Hook and Thomas, 1995; Hook et al., 1999; Alexandrov and Hoogenboom, 1999).

Agricultural water demand derived for the Comprehensive Basins Study relied on the synthesis of available data and the knowledge of agricultural experts to develop current and future agricultural water-use (USDA-SCS, 1994). Voluntary reporting is variable and varies from best professional judgement, interpretation from secondary information (e.g. irrigation system pump usage and pump capacity converted to gallons), to volumes directly measured. A combined effort by the Southwest Georgia Agribusiness Association (SWGAA) and the USDA National Peanut Laboratory in Dawson, GA has compiled the best measured farmer irrigation records for southwest Georgia counties (see Hook et al., 1999 for details). Two studies underway will provide additional information on irrigation water-use. The Benchmark Farms Study funded by GA DNR-EPD was a voluntary measurement of irrigation quantities for a subset of irrigation systems in Georgia. The ongoing University of Georgia Ag Water Pumping Study will monitor randomly selected fields, representing a range of crops, weather, irrigation practices, soils and agricultural management that characterize agricultural irrigation (Thomas et al., 1999).

RESULTS AND DISCUSSION

Four counties (Baker, Calhoun, Terrell, and Webster) in Southwest Georgia were selected to evaluate the differences among irrigated acres, water application rates and irrigation volumes. These counties represent the range of crops, soils, and irrigation systems found below the fall line (Table 1). To minimize variation in acreage and volumes derived, 1995 was chosen as the base year for the analyses. This selection was necessary because center pivot irrigation systems have been rapidly expanding in Southwest Georgia for the

Table 1. Irrigation acreage for 1995 by county. Planted acres are provided by USDA Agricultural Statistics Service. The DNR-EPD is irrigation acres as indicated on permit or permit application. Comprehensive Basins Study 1995 acres projected from 1992 irrigation survey. Irrigation survey acres and percentage center pivot irrigation are provided by the University of Georgia Agricultural Extension Agents for each county. Digitized acres represent center pivot irrigated acres from October 1995 SPOT satellite image which was processed using ARCINFO.

County	Planted Acres	Permitted	Comprehensive Basins Study	Irrigation Survey	Percent Center Pivot Irrigation	Total Digitized Center Pivot
			acres			
Webster	17,600	19,604	20,370	8,225	50%	6,205
Terrell	50,130	29,872	22,720	24,064	87%	18,232
Calhoun	43,420	41,730	40,181	23,764	83%	19,025
Baker	49,470	56,019	57,792	42,212	95%	44,680
Total	160,620	147,225	141,063	98,265		88,142

past decade. A broad array of information was available for that year. The irrigation survey, Comprehensive Basins Study future projections, digitized satellite images, and the Southwest Georgia Agribusiness Association farmer irrigation records were available for 1995. The DNR-EPD information represents permits that would be implemented prior to 1996. Because the irrigation survey is widely used and forms the basis for other acreage estimates, we will use it to compare to the other methods for determining irrigated acres. In addition, inter-annual differences in rainfall deficits can greatly affect the amount of irrigation water used (Alexandrov and Hoogenboom, 1999; Hook et al., 1999). There was good agreement among the surveys, image analysis, and modeling approaches in determining water application rates and irrigation volumes. An average water application rate and irrigation volume were calculated for the four approaches and will be used for comparison among methods.

For this study, digital acreage estimates were obtained using October 1995 SPOT satellite images for the four counties and ArcInfo software to identify and create polygons of center pivot systems. The respective county agricultural extension agents verified center pivot polygons.

Irrigated acreage estimates are shown in Table 1. The DNR-EPD permitted and the Comprehensive Basins Study 1995 projected total acreage for the four counties were higher than the irrigation survey acreage by 50% and 38%, respectively. The digitized irrigated acres were 10% lower than the irrigation survey for the four-county total.

The EPD permitted and Comprehensive Basins Study irrigated acres were generally higher for each of the four counties than the irrigation survey acres and the digitized irrigated acres. With the exception of Baker County, the digitized irrigated acres were lower than the other three estimates. Baker County had the largest irrigated acres and the largest percentage of center pivot irrigation. The digitized irrigated acres were similar to acreage irrigated by center pivots for Baker, Terrell and Calhoun counties. The largest differences among methods were for Webster County with estimates ranging from a high of 238% (DNR-EPD permitted acreage) to a low of 90% (digitized irrigated acreage) of the irrigation survey acres. This county had the lowest percentage of crops irrigated and the lowest use of center pivot irrigation.

The farmer data, crop model, irrigation survey, and Comprehensive Basins Study normal year water application rates were similar and averaged 9.3 inches (Table 2.). The 15 inches indicated on the DNR-EPD permits was higher than all other estimates, but similar to the Comprehensive Basins Study dry year estimate of 18 inches. The 4.8 inch application rate is similar to the Comprehensive Basins Study wet year estimate. Average water application rates differed by less than 6% among the four counties.

Differences in both the irrigated acreage estimates and crop water application rates affected the calculation of irrigation water withdrawn. The four-county total irrigation volume estimates varied by over 117 million gallons per day (mgd) (Table 3). The

Table 2. Irrigation amount in inches per year for 1995 by county. Irrigation application rates are crop-weighted amounts for each county. The DNR-EPD is irrigation amount as indicated on permit or permit application. Comprehensive Basins Study is reported application rates. The Comprehensive Basins Study normal year represents application rate assuming regional average rainfall. Crop model predictions of average annual irrigation amounts for the 30-year weather records of 1961 to 1990 for four to 6 locations in the basin as predicted by J.E. Hook and reported to EPD March 24, 1998. Farmer volunteered data of average annual irrigation amounts for 1992 to 1997 based on recorded pumping records as summarized by Hook et al. (1998).

County	Permit	Comprehensive Basins Study	Comprehensive Basins Study Normal Year	1995 Irrigation Survey	Crop Model	Farmer Data
			inches			
Webster	16.2	3.0	10	9.5	9.4	8.3
Terrell	14.6	4.1	10	10.1	9.1	8.6
Calhoun	12.9	4.6	10	9.1	9.7	9.7
Baker	16.5	5.2	10	7.2	9.0	8.9
Average	15.1	4.3	10	9.0	9.3	8.9

greatest similarities among estimates were for the crop model, irrigation survey, farmers data, and digitized acres approaches. Irrigation quantities for these three approaches averaged 63.5 mgd. The digitized irrigation volume estimate was slightly lower due to a lower irrigated acreage. Both the higher acreage and higher crop application rates contributed to the DNR-EPD permitted volume being 2.6 times greater than the average of the four methods. The Comprehensive Basins Study method was 65% greater than the average of the four methods. Higher irrigated acreage contributes to the differences between the normal year irrigation volume predicted for the Comprehensive Basins Study and the other three estimates.

The average irrigation volumes differed by three to over five fold for the four counties. Terrell County withdrew the lowest volume and Baker County the greatest. Regardless of the method for calculating the volume, the differences among counties were largely determined by the acreage under irrigation.

If irrigation water-use is not directly quantified, then estimates must be derived from secondary sources. These secondary sources may include crop type, crop acreage, crop water needs, soil characteristics (e.g. texture or water holding capacity), irrigated acreage, and irrigation system characteristics (e.g. pump capacity). The resulting irrigation water-use estimates have some inherent error from the completeness of information, resolution of data sources, and the ability to discriminate irrigation systems. The most widely used irrigation survey provided a basis for comparison of secondary source estimates. The irrigation survey is the primary source for crop acreage, crop specific irrigated acreage and crop water application rates. The crop model incorporates many of these secondary sources (crop type, crop water needs, soil characteristics, and climate varying factors (Hook and Thomas, 1995) to predict water application rates. The irrigation volumes calculated using farmer's irrigation records, crop model water application rates, irrigation survey irrigated acres and application rates, and the digitized irrigated acres were in close agreement. Small differences were due to the ability to digitize implemented irrigation systems.

This method specifically targets center pivot systems that can be discerned in an agricultural matrix. For Terrell, Calhoun and Baker Counties, the digitized irrigated acres averaged within 2% of acres identified in the irrigation surveys as under center pivot irrigation. The method underestimates acreage when mobile or rectangular irrigation systems are employed. Webster County irrigation volume differences are due in part to the large proportion (50%) of irrigation that is not center pivot.

CONCLUSIONS

Best professional judgement is a critical factor in deriving estimates of irrigated acres and thus, irrigation volume. All the methods used in this paper

Table 3. 1995 Daily irrigation volumes (millions of gallons per day). The permit is irrigation volume is calculated from the the DNR-EPD permit irrigated acres and permit irrigation amount. The Comprehensive Basins estimate is based on 1992 projected acres to 1995 and the reported crop-weighted irrigation amount. The Comprehensive Basins Study normal year amount is based on 10 inch irrigation amount and the 1995 projected irrigated acres. The 1995 irrigation survey is the survey reported irrigated acres and crop-weighted survey irrigation application rates. The irrigation survey/farmers data is calculated from the 1995 irrigation survey and the farmer water application rate. The Crop Model is based on the 1995 irrigation survey irrigated acres and the crop model irrigation amounts. The digitized acres method is based on the digitized center pivot irrigation acres and the farmer irrigation application rates.

County	Permit	Comprehensive Basins Study	Comprehensive Basins Study Normal Year	1995 Irrigation Survey	Irrigation Survey Acres / Farmers Data	Crop Model	Digitized Acres
			millions of gallons per day				
Webster	23.6	4.6	15.2	5.8	5.1	5.7	3.8
Terrell	32.5	7.0	16.9	18.1	15.4	16.4	11.7
Calhoun	40.1	13.8	29.9	16.0	17.2	17.1	13.8
Baker	68.8	22.6	43.0	22.6	27.8	28.3	29.4
Total	165.0	48	105.0	62.5	65.5	67.5	58.7

involve professional judgement to one degree or another. The DNR-EPD permitted irrigated acres and the irrigation survey irrigated acres are dependent on individual farmers' and extension specialists' knowledge of the area that center pivots or mobile irrigation systems will cover. Close agreement between the digitized acres and county center pivot acres suggest that the irrigation survey is providing a good estimate of irrigated acreage. The higher acreage with the DNR-EPD permits may reflect a maximizing of future options. Shifting agricultural field use, anticipating future crop planting strategies, and providing a margin of error may contribute to the larger permitted acreage. Anticipation of drought water deficits would contribute to maximizing irrigation system implementation and optimal pump capacity. The Comprehensive Basins Study was based on the 1992 irrigation survey and judgements for future irrigation acreage and application rates. The normal year 10-inch application rate was supported by the other approaches, but the increased irrigated acreage was not. In this case, anticipated irrigation system growth was not as large as projected for these four counties.

The assessment of irrigation estimates for these four counties indicates that continued refinement of information is needed as future water policy is developed. Studies such as the ongoing University of Georgia Ag Water Pumping Study are needed to provide quantitative estimates of irrigation water withdrawals (Thomas et al., 1999). In addition, collaborative interactions between the agricultural extension agents and other researchers using remote sensing will aid in improving spatial estimates of irrigated acreage.

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