MAPPING IRRIGATED LANDS IN THE ACF RIVER BASIN

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Abstract. In Georgia, a critical component of the water demand equation is the consumptive use of water for agricultural irrigation. The University of Georgia, Center for Remote Sensing and Mapping Science (UGA-CRMS), in cooperation with the Georgia Department of Natural Resources, Environmental Protection Division (GDNR-EPD), has developed a digital geographic information system (GIS) database of irrigated lands in Subarea 4 of the Apalachicola-Chattahoochee-Flint (ACF) River Basin. In this project, U.S. Geological Survey (USGS) National Aerial Photography Program (NAPP) color-infrared aerial photographs acquired in the winter of 1999 were scanned, rectified, and interpreted to identify center-pivot irrigation systems. Non-center pivot irrigation acreage was estimated from irrigation survey information. Collectively, these efforts resulted in a digital GIS database, hardcopy maps, and areal statistics describing 475,779 acres of irrigated land in southwest Georgia.

INTRODUCTION

Georgia is currently involved in complex water negotiations with Alabama and Florida. One issue is the equitable apportionment of water in the Apalachicola-Chattahoochee-Flint (ACF) River Basin. To better understand agricultural water demands within the Basin, the Center for Remote Sensing and Mapping Science at the University of Georgia (UGA-CRMS), working in cooperation with Georgia Department of Natural Resources, Environmental Protection Division (GDNR-EPD), has developed a geographic information system (GIS) database of irrigated lands in the Georgia portion of Subarea 4 (10,564 km^2) in the ACF River Basin (Figure 1).

The objective of this study was to map and quantify the extent of center pivot (CP) and non-center pivot (NCP) irrigated lands in Subarea 4 of the ACF Basin. The extent, distribution, and change in CP lands were mapped from 1993 U.S. Geological Survey (USGS) Digital Orthophoto Quarter Quads (DOQQ) and 1999 National Aerial Photography Program (NAPP) color-infrared (CIR) aerial photos of 1:40,000-scale. Non-center pivot irrigation acreage estimates were derived for each county in the study area from information provided by the U.S. Department of Agriculture, Farm Services Agency (USDA-FSA) and the UGA Cooperative Extension Service (UGA-CES).

BACKGROUND

The ACF Basin is of particular concern to Georgia. Over 90% of the State's population, which has doubled from 4 to 8 million over the last 40 years (Odum, 2000), lives in the Basin - with most residing in the Atlanta Metropolitan Area (AMA) (Couch et. al.,

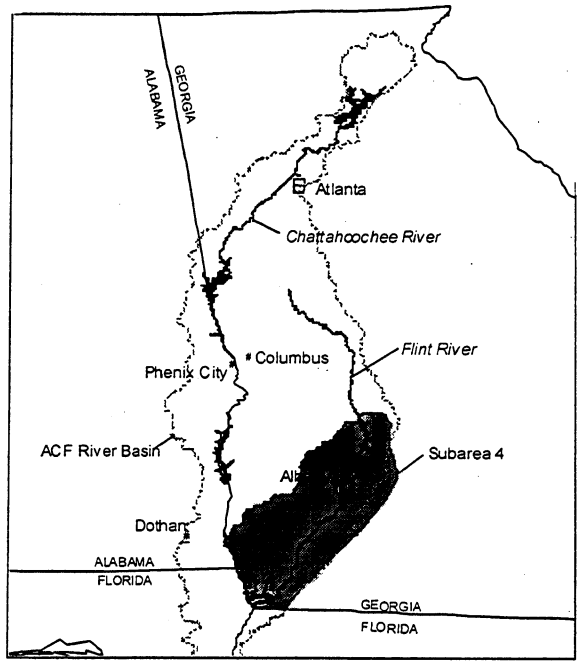

Figure 1. The Georgia portion of Subarea 4 in the ACF River Basin.

1996). Demands on the Chattahoochee River, the major drinking water supply source for the AMA, are projected to exceed the river's minimum flow by 2010 (Odum, 2000). Additional metropolitan areas vying for the water resources of the Basin include Columbus and Albany, Georgia, and Dothan and Phenix City, Alabama.

In addition to urban/industrial water requirements, agricultural irrigation increases the demand on ACF water resources. Irrigation accounts for 25 to 50% of Georgia's consumptive water use (Harrison and Tyson, 1999). Since 1970, irrigated lands in Georgia have increased from 150,000 to approximately 1.5 million acres. A heavy concentration of Georgia's irrigated land is located in the Flint River Basin (Subarea 4) of the ACF. As with the urban/industrial demand, agricultural water use in the ACF Basin is expected to rise (USDA-SCS, 1994).

Study Area

Subarea 4 encompasses all or part of 17 counties in Georgia and is located entirely on the Coastal Plain Physiographic Province. The study area is characterized by diverse agricultural practices and irrigation is the primary consumptive water use (Blood et. al., 1999). Farmers irrigate major crops including corn, cotton, peanuts, soybeans, and wheat with CP and various types of NCP systems.

Existing Knowledge

Several sources of irrigated land acreage estimates exist for Subarea 4 including tri-annual county irrigation surveys undertaken by the UGA-CES (Harrison and Tyson, 1999), GDNR-EPD water withdrawal permits, and studies that incorporate remotely sensed data (Blood et. al., 1999; Letts, 1998). For example, Blood et. al. (1999) mapped CP irrigation acreage from SPOT imagery for Baker, Calhoun, and Terrell counties within Subarea 4, compared the results to UGA-CES surveys, and concluded that the surveys provided a reasonable estimate of irrigated land acreage. Although these studies provide partial information on irrigated acreage in Subarea 4, the area had not been completely mapped from remotely sensed data prior to the UGA-CRMS study.

EXPERIMENTAL DESIGN AND METHODS

In response to the GDNR-EPD requirement for complete, detailed, timely, and objective information describing irrigated land in Subarea 4, the UGA-CRMS: 1) collected existing digital data; 2) scanned and rectified NAPP aerial photos; 3) interpreted CP irrigation sites from DOQQs and NAPP photos; 4) derived irrigated land acreage; and 5) compiled map products needed to depict the extent and location of CP systems.

Data Sources

Data sources included: 1) USGS DOQQs produced from 1993 NAPP panchromatic aerial photos of 1:40,000-scale; 2) USGS CIR NAPP aerial photos recorded in 1999; 3) USGS Digital Raster Graphics (DRG) files corresponding to the 1:24,000-scale topographic map series; and 4) UGA-CES and USDA-FSA county surveys of irrigation systems in the study area. Although SPOT and Landsat-7 satellite images were initially considered for mapping irrigation systems, inadequate spatial resolution and limited availability precluded their use. Therefore, the CP irrigation systems were mapped from the 1993 DOQQs and 1999 NAPP photos. These provided consistent data sets and permitted CP irrigation acreage change between 1993 and 1999 to be determined.

Scanning and Rectification

The 1999 NAPP CIR film transparencies were scanned as black-and-white images at a resolution of 600 dpi using an EPSON *Expression 836XL* scanner (with transparency adapter) controlled by a Dell Dimension personal computer. The resulting TIFF data sets averaged 29 megabytes (Mb) per image or approximately 7.8 gigabytes (GB) of raw image data for Subarea 4.

The scanned 1999 photos were rectified to the Universal Transverse Mercator (UTM) grid for Zone 16 cast on the North American Datum of 1983 (NAD 83). This was accomplished by locating well-defined cultural features (i.e. road intersections) found on both the 1993 USGS DOQQs and the scanned photos. The UTM coordinates of these points were determined from the DOQQs to create ground control point (GCP) files. Similarly, image coordinates of the GCP locations were measured on the scanned photos to provide x, y control point files. These files were used to derive second order polynomial rectification coefficients which, when applied to the 1999 scanned air photos, permitted planimetric positions to be determined to within ± 1 to 2 metres of their true locations. The ground dimension of a pixel in the rectified image was 1.3 metres.

Interpretation

The CP irrigation acreage was systematically delineated from the 1993 DOQQs and 1999 scanned

photos on a county-by-county basis in an ArcView GIS Project environment. Physical characteristics of CP irrigation systems included: 1) circular shape; 2) CP arm structure; 3) field diameters from 250 to 1000 m; and 4) concentric tire grooves in the soil. For purposes of quality control and consistency, CP systems were mapped if: 1) the pivot arm **or** concentric grooves were present; or 2) the field in question had the proper circular geometry **and** the pivot point of the CP structure was identifiable in the center of the field.

Irrigated Land Acreage

At the time of this study, only 285 of the 301 NAPP photographs needed to map CP irrigation in Subarea 4 were available. Therefore, the UGA-CRMS mapped 97% of Subarea 4 directly from 1999 NAPP photos and projected CP acreage for the remaining 3% using a least-squares linear regression based on the relationship between 1999 and 1993 CP acreage values (Figure 2). The strong correlation of $R^2 = .92$ provided a basis for estimating 1999 CP acreage with a high degree of confidence in those areas where the 1999 air photos were not available.

Based on extensive field surveys, experts from the UGA-CES and USDA-FSA prepared independent reports stating the percentage of NCP irrigated lands as a percentage of total irrigated land for each county within the study area. For purposes of this study, NCP irrigation includes portable pipe, cable tow, hose reel, lateral move, solid set, drip/trickle, and athletic/golf systems. Discrepancies between the independently derived NCP percentages were resolved in meetings with UGA-CES and USDA-FSA, resulting in the NCP percentage values listed in Table 1.

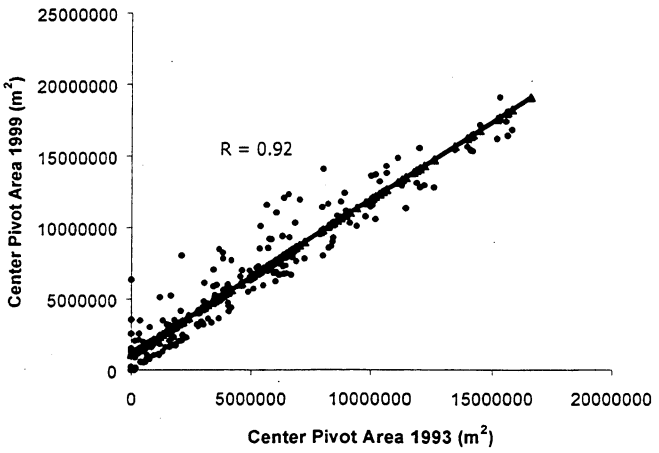

Figure 2. Relationship between 1999 and 1993 CP irrigation acreage.

Given the CP acreage measured from the 1999 air photos and the NCP percentages provided by the UGA-CES and USDA-FSA, it was possible to compute total irrigated land and NCP acreage for each county in the study area using the following expressions:

$$TIA = CPA / (1-(\%NCP/100))$$
$$NCPA = TIA - CPA$$

Where:
- *TIA is the total irrigated acreage*
- *CPA is the center pivot acreage*
- *NCPA is the non-center pivot acreage*
- *%NCP is the percent of total irrigated acreage under non-center pivot*

Database and Maps Products

The digital GIS database included vector files representing 1993 and 1999 center pivot irrigation sites, major roads, streams, lakes, county boundaries, and major cities downloaded from the Georgia GIS Clearinghouse, and the rectified 1999 scanned aerial photographs in raster format. This database was used to produce a series of eleven 1:60,000-scale maps corresponding to the USGS 1:100,000-scale topographic map series boundaries. These maps depict the location and extent of CP irrigation sites mapped for Subarea 4 in 1999, as well as changes that occurred in CP irrigation between 1993 and 1999.

RESULTS

The most significant results of this study are presented in Table 1. The table lists CP acreage for 1993 and 1999 (interpreted and projected), increases in CP acreage from 1993 to 1999, estimated NCP acreage, and the total irrigated land for each county in Subarea 4. The UGA-CRMS mapped 291,643 acres of CP irrigation from 1993 DOQQs and 381,996 CP acres from 1999 aerial photographs. An additional 9,820 CP acres were projected for areas lacking 1999 NAPP photo coverage which resulted in 391,816 acres of CP land in Subarea 4. Center pivot irrigated land increased 100,173 acres (34%) between 1993 and 1999. Based on the percentages derived by UGA-CES and USDA-FSA experts, an estimated 83,963 acres of NCP irrigated land are located in Subarea 4. This figure accounts for less than 20% of the total 475,779 irrigated acres.

Table 1. Irrigation Acreage in Subarea 4

County *	Center Pivot Irrigation 1993 (acres)	Center Pivot Irrigation 1999 (acres)[I]	Center Pivot Irrigation 1999 (acres)[P]	Total Center Pivot Irrigation 1999 (acres)	1993-1999 Increase (acres)	Non-Center Pivot Irrigation (% of total)	Non-Center Pivot Irrigation 1999 (acres)	Total Irrigated Land (acres)
Baker	32,904	38,375	364	38,739	5,835	5	2,039	40,778
Calhoun**	11,876	14,722	164	14,886	3,010	20	3,722	18,608
Crisp**	3,754	11,524	0	11,524	7,770	20	2,881	14,405
Decatur**	47,870	57,379	2,200	59,579	11,709	10	6,620	66,199
Dooly**	1,010	3,104	0	3,104	2,094	5	163	3,267
Dougherty	8,123	9,203	1,913	11,116	2,993	35	5,986	17,102
Early**	15,735	24,435	860	25,295	9,560	25	8,432	33,727
Grady**	2,828	3,254	0	3,254	426	35	1,752	5,006
Lee**	24,670	28,926	2,380	31,306	6,636	25	10,435	41,741
Miller	30,762	45,982	0	45,982	15,220	15	8,114	54,096
Mitchell**	47,610	56,566	1,859	58,425	10,815	30	25,039	83,464
Seminole	35,116	45,831	0	45,831	10,715	5	2,412	48,243
Sumter**	13,386	15,592	0	15,592	2,206	10	1,732	17,324
Terrell**	6,236	10,044	80	10,124	3,888	10	1,125	11,249
Turner**	211	1,384	0	1,384	1,173	35	745	2,129
Worth**	9,552	15,675	0	15,675	6,123	15	2,766	18,441
Total	**291,643**	**381,996**	**9,820**	**391,816**	**100,173**		**83,963**	**475,779**

[I]Acreage interpreted from 1999 color-infrared USGS National Aerial Photography Program photos.
[P]Acreage projected for areas missing 1999 air photos using a statistical regression. See Irrigated Land Acreage. *Colquitt county had no center pivot irrigation systems in the study area.
**Irrigation acreage derived for the portion of the county located within Subarea 4.

CONCLUSIONS

The results of this study provide a detailed description of irrigated lands in Subarea 4. The UGA-CRMS identified 475,779 acres of irrigated land in the Georgia portion of Subarea 4, which is less than the acreage estimated from water withdrawal permits by the GDNR-EPD (Pers. Com., GDNR-EPD). However, the GDNR-EPD estimates may include acreage for irrigation systems that were not installed at the time of this study. The relationships identified between 1999 and 1993 CP irrigation acreage values demonstrate potential for estimating irrigation changes as new systems are installed.

This study was recently extended to include agricultural land of Subarea 4 within Alabama and Florida, thus reflecting Georgia's interest in compiling complete quantitative information on irrigated lands. The resulting acreage and databases derived from these studies may be used in conjunction with other variables to model consumptive agricultural water use in Subarea 4 and to support the GDNR-EPD's implementation of the Georgia Flint River Drought Protection Act.

ACKNOWLEDGEMENT

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