MAPPING IRRIGATED LANDS IN SOUTHWEST GEORGIA

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DEPARTMENT OF NATURAL RESOURCES
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Cooperative Agreement Number: 649-990205

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INTRODUCTION

Georgia, one of the "wetter" states in the United States, contains 113,000 km (70,146 mi.) of rivers/streams/ditches, 1620 km^2 (626 $mi.^2$) of impounded lakes and ponds, and receives an average rainfall of approximately 127 cm/year (50 in./year) (Georgia's Environment, 1999). However, numerous conflicts over water demand, use, and allocation have occurred. The most notable of these conflicts is the "Tri-State Water Wars" between the states of Alabama, Florida, and Georgia (Kundell and Tetens, 1998). At issue is the equitable apportionment of water in the Appalachicola-Chattahoochee-Flint (ACF) and Alabama-Coosa-Tallapoosa (ACT) River Basins.

Water issues facing the ACF Basin are of particular concern to Georgia. Nearly 90% of the State's population, which has doubled from 4 to 8 million over the last 40 years, lives in the Basin - with most residing in the Atlanta Metropolitan Area (AMA) (Couch et. al., 1996; Odum, 2000). Water 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 ACF Basin include Columbus and Albany, Georgia, and Dothan and Phenix City, Alabama.

A critical component of Georgia's water demand/allocation equation is the consumptive use of water for agricultural irrigation in the Flint River Basin of the ACF. Irrigation accounts for 25 to 50% of Georgia's consumptive water use with irrigated lands increasing from 150,000 acres (607 km^2) to approximately 1.5 million acres (6072 km^2) since 1970 (Harrison and Tyson, 1999). A heavy concentration of this irrigated land is located in the Flint River Basin of the ACF. However, the distribution and extent of irrigated land in southwest Georgia was unknown. Therefore, at the request of the Georgia Department of Natural Resources, Environmental Protection Division (GDNR-EPD), The University of Georgia Center for Remote Sensing and Mapping Science (UGA-CRMS) developed a geographic information system (GIS) database of irrigated lands in Subarea 4 (10,564 km^2/4078 $mi.^2$) and Area A (2,182 km^2/843 $mi.^2$) of the ACF Basin (Figures 1 and 2).

This report provides a detailed explanation of the procedures used by the UGA-CRMS to map irrigated lands in southwest Georgia. For the purposes of this study, irrigated lands are divided into two categories: 1) center pivot irrigation (CP) and; 2) non-center pivot irrigation (NCP). The UGA-CRMS mapped CP acreage in Subarea 4 from U.S. Geological Survey (USGS) National Aerial Photography Program (NAPP) photos recorded in 1993 and 1999 (Figure 3). Center pivot acreage in Area A was also mapped from the 1993 air photos. However, CP acreage for Area A and those portions of Subarea 4 lacking 1999 NAPP photo coverage at the time of this study was estimated using a least-squares linear regression relationship developed from 1993 and 1999 CP area statistics.

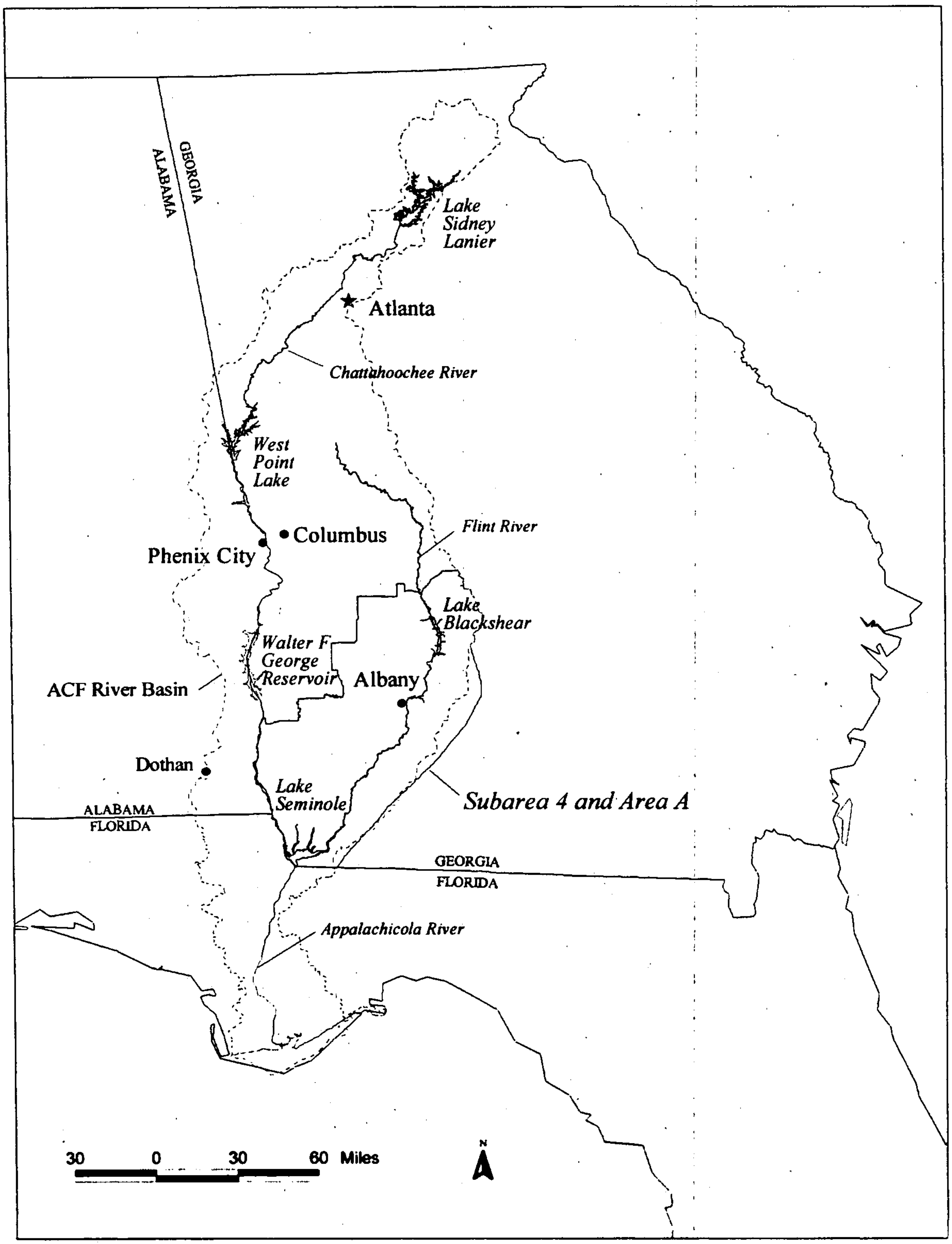

Figure 1. The combined Subarea 4 and Area A study area (shaded) lies primarily within the ACF River Basin (dashed line).

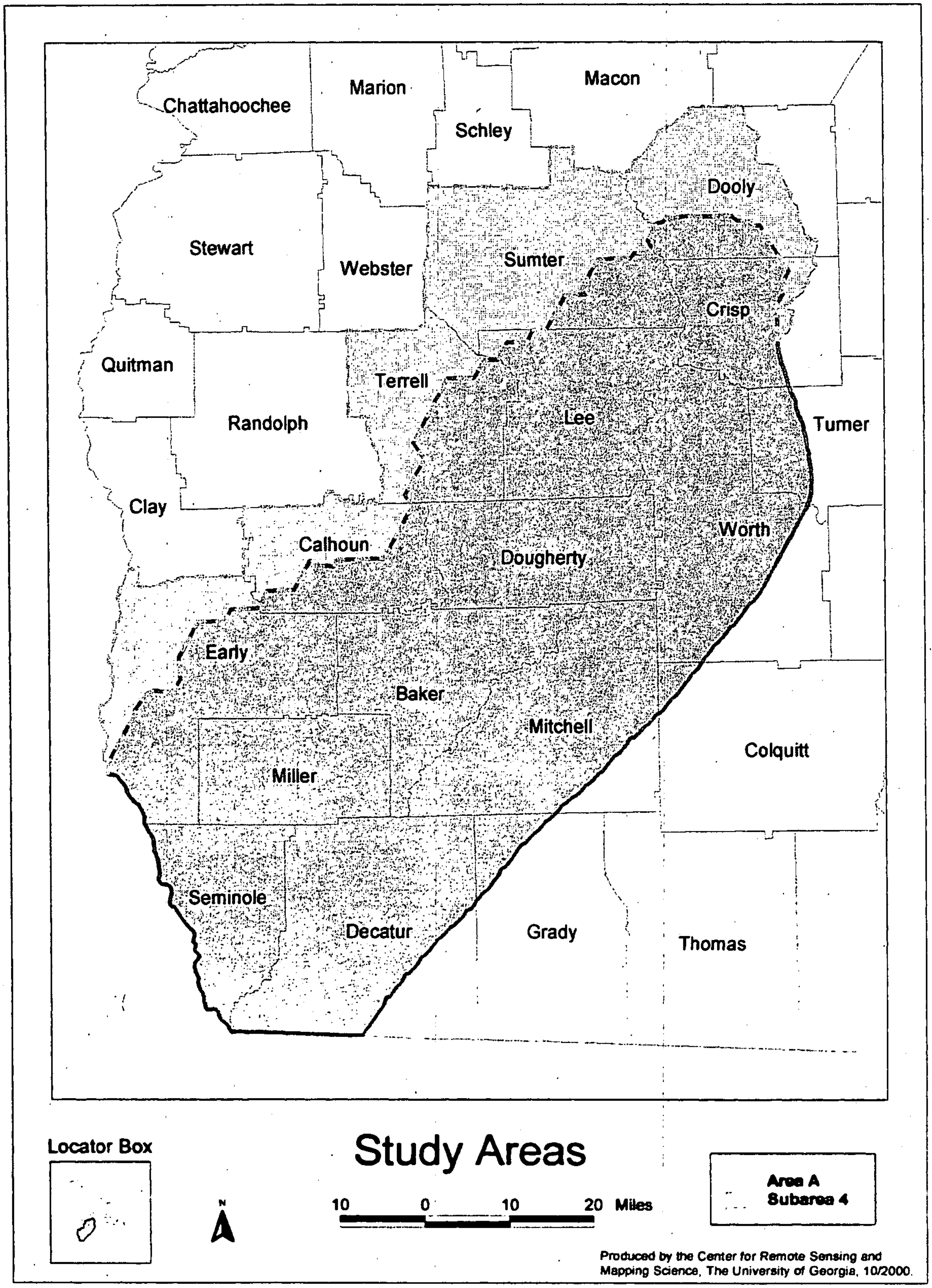

Figure 2. Subarea 4 (dark gray) accounts for most of the combined study area.

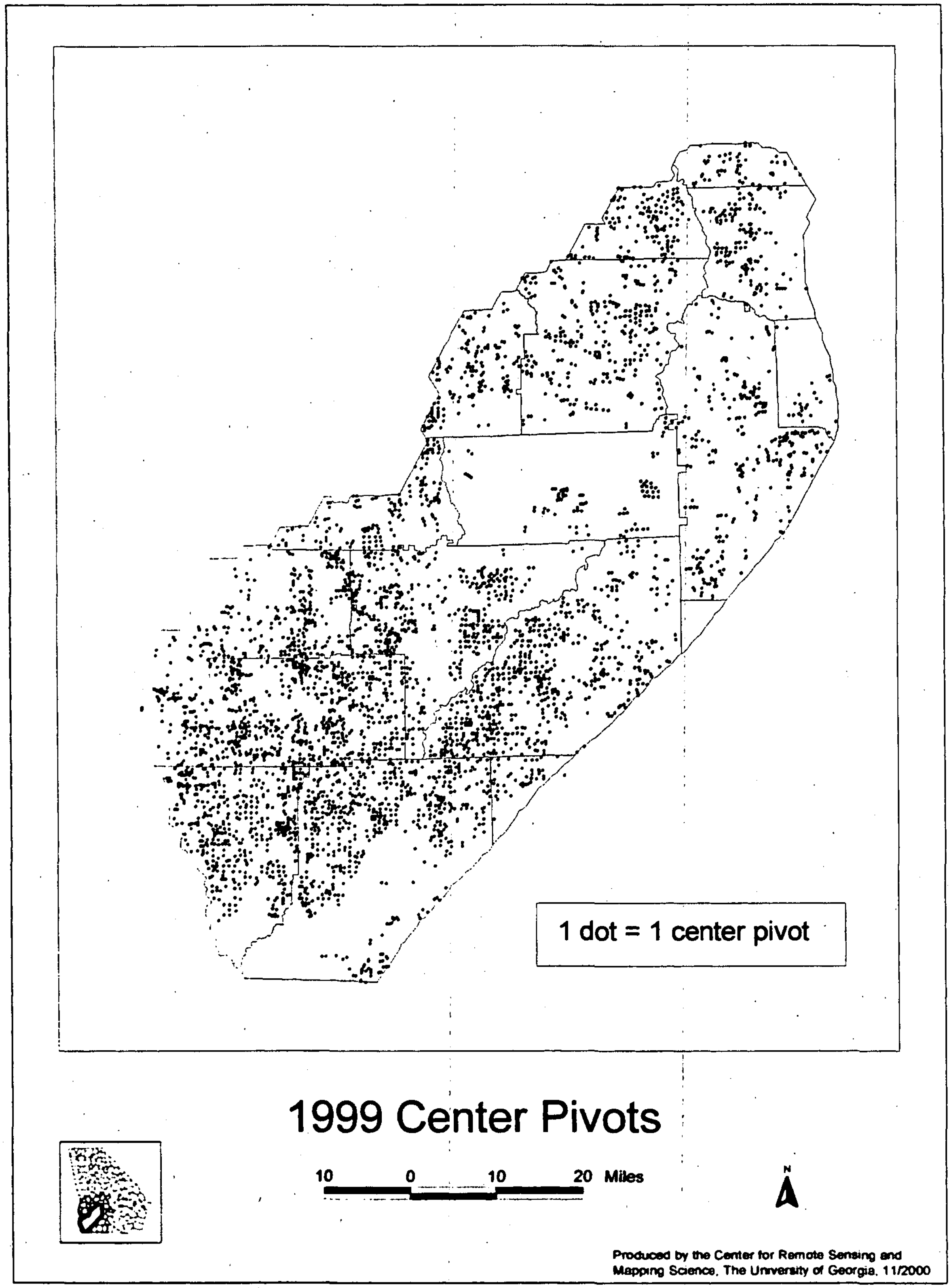

Figure 3. The distribution of Subarea 4 CP systems in 1999 reveals a concentration of irrigated land in the southwest portion of the study area.

STUDY AREA

The ACF Basin includes parts of the Blue Ridge, Piedmont, and Coastal Plain Physiographic Provinces and is predominantly forested (58%) (Frick et. al., 1995). Agriculture (29%), urban/suburban (5%), wetland (5%), and water (3%) account for the remaining land cover. The Basin has a temperate climate.

The Chattahoochee River originates in northeast Georgia and the headwaters of the Flint River begin south of Atlanta (Figure 1). These rivers converge at Lake Seminole, one of sixteen main-stem river impoundments in the ACF Basin, to form the Apalachicola River at the Alabama, Florida, and Georgia border. The Apalachicola flows 130 km (81 mi.) southward through one of the most ecologically diverse regions in the United States before emptying into the Gulf of Mexico.

In Georgia, Subarea 4 and Area A encompass all or part of 17 counties and the combined study area is located entirely on the Coastal Plain Physiographic Province. Agricultural irrigation is the major consumptive water use in the study area (Blood et. al., 1999). Major crops include corn, cotton, peanuts, soybeans, and wheat. Peanuts account for the largest percentage of irrigated land and water use (USDA-SCS, 1994). Within the study area, farmers irrigate crops using CP and various NCP systems, including traveling gun, solid-set, and drip/trickle (Figure 4). Non-center pivot irrigation is generally labor intensive and less efficient than CP (Harrison and Tyson, 1999). Consequently, NCP accounts for less than 20% of total irrigated land in the study area.

Field operations within the study area are varied and complex. Factors affecting the timing of planting, irrigation, and harvest include the weather, economics, crop type, and planting cycles. Because climate and soils allow for single, double, and even triple cropping, farmers have considerable flexibility in scheduling field events. Figure 5 depicts typical field operations for five major crops in the study area. As shown in this figure, the window of coincident irrigation between four of these crop types is very narrow, roughly the month of July.

DATA SOURCES

Several data sources were required to develop the irrigated land database (Figure 6). These include: 1) USGS black-and-white Digital Orthophoto Quarter Quadrangles (DOQQs) produced from 1:40,000-scale, 1993 National Aerial Photography Program (NAPP) photos; 2) color-infrared (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) satellite images recorded as part of the French SPOT and U.S. Landsat programs.

NAPP Aerial Photos and Digital Orthophoto Quarter Quadrangles

The USGS acquired 1:40,000-scale panchromatic NAPP photographs of Subarea 4 and Area A in the winter of 1993-1994 and CIR photographs during the winter of 1999. Three hundred and eighty USGS DOQQs prepared from the 1993-1994 NAPP photos were employed to develop a digital database of CP sites in Subarea 4 and Area A. These DOQQs have a

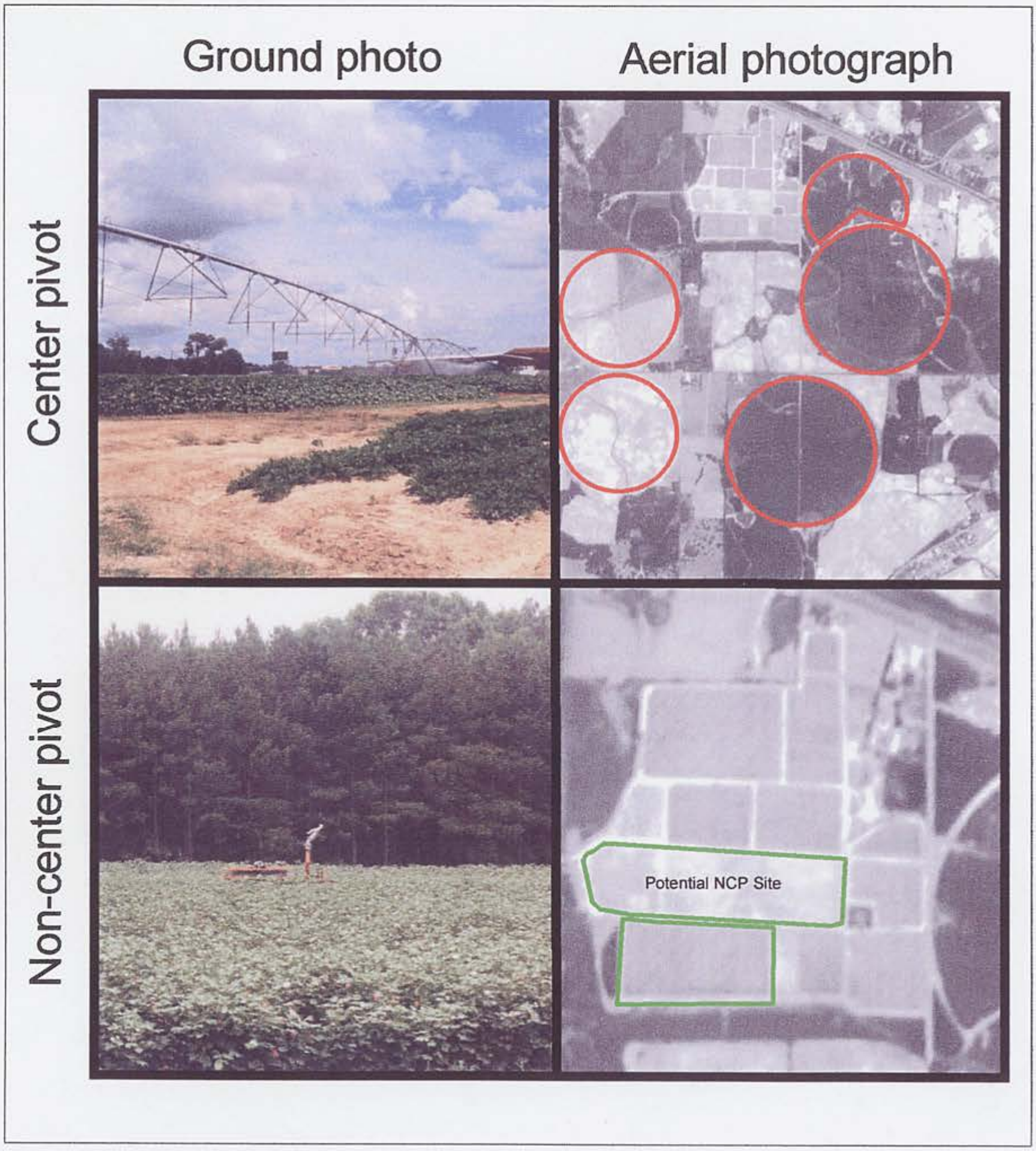

Figure 4. Center pivot systems create a distinct circular footprint that can be identified from NAPP photographs. Conversely, it is not possible to visually interpret NCP sites from the aerial photographs.

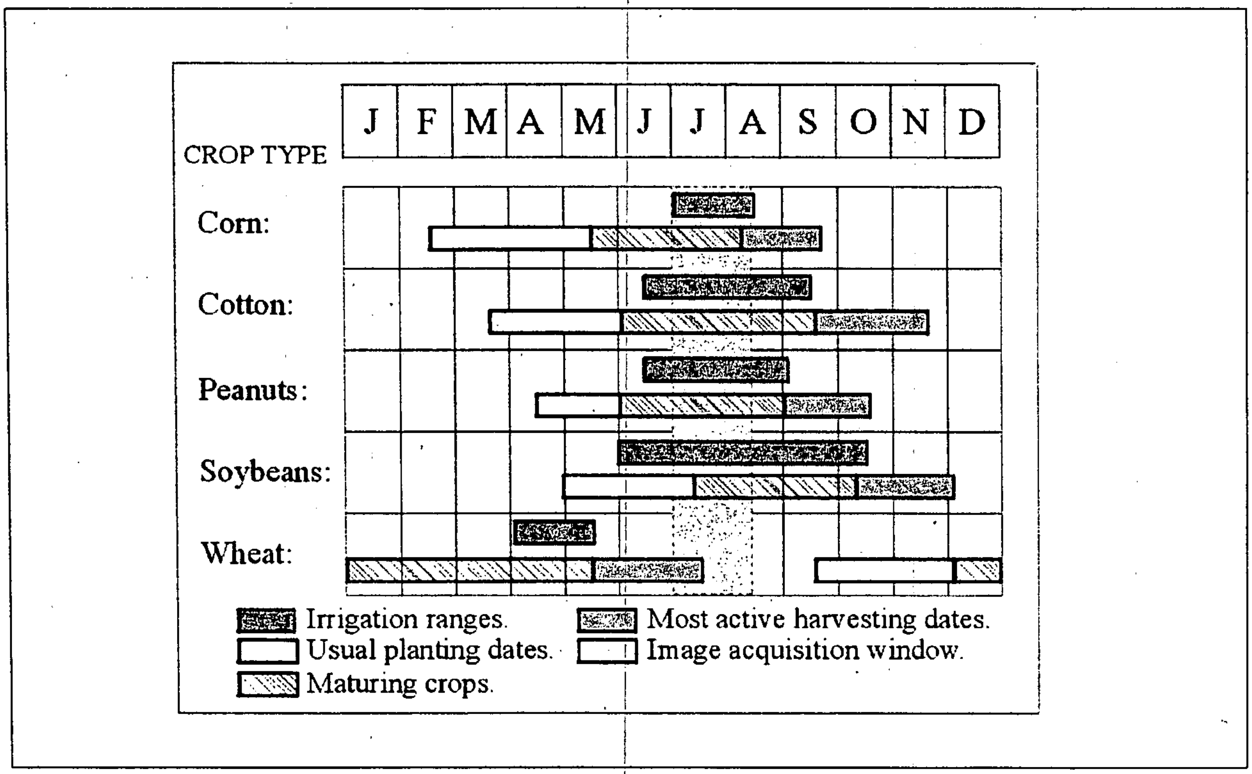

Figure 5. This crop calendar depicts planting, irrigation, and harvest dates for five major crops in the study area. July, a period of coincident irrigation, is the optimum month for satellite image acquisition.

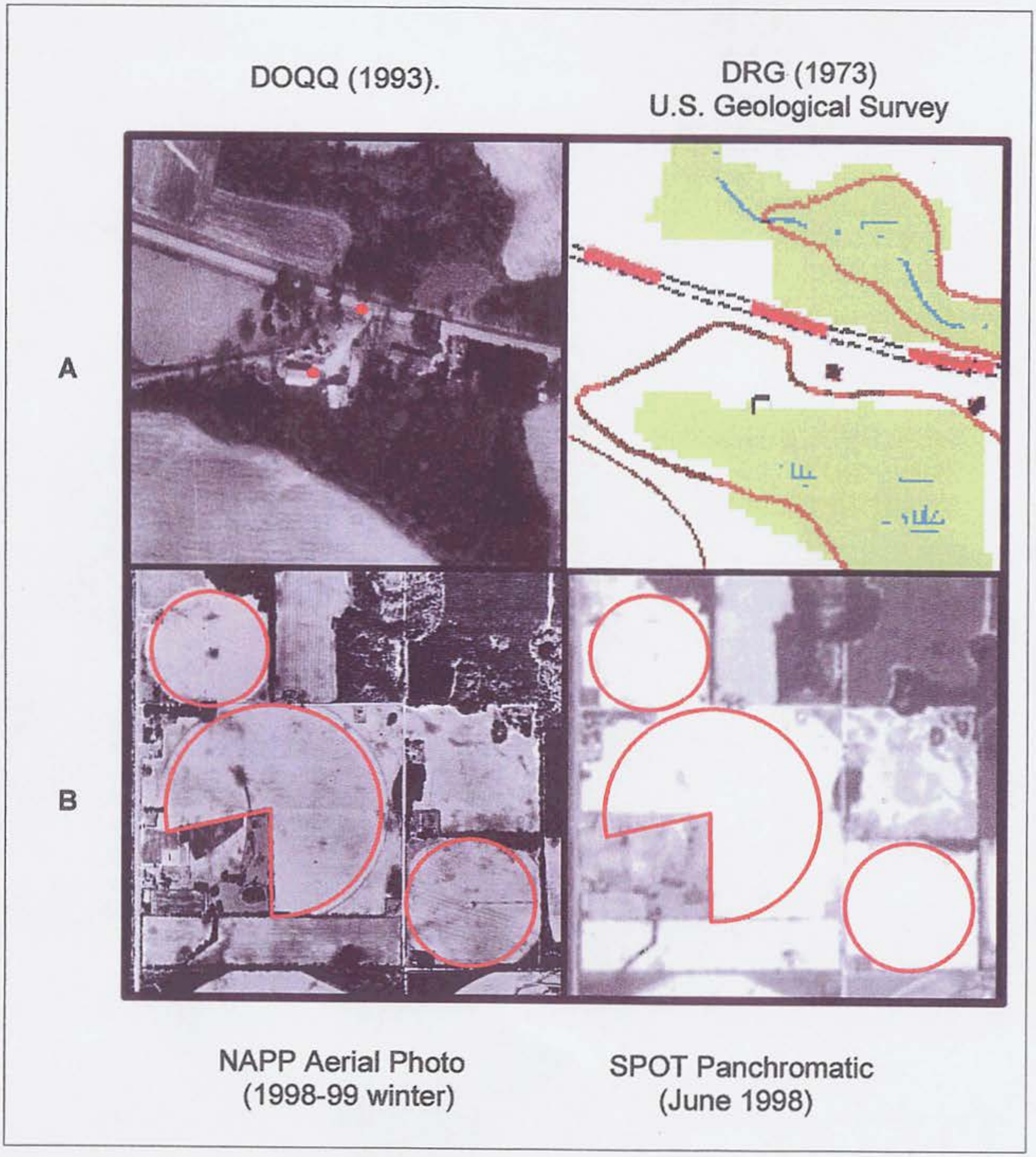

Figure 6. 1993 DOQQs and DRG files served as the ground control reference used to rectify the 1999 NAPP photos (Row A). The DOQQs were selected as the primary control source because they provide superior geometric accuracy and resolution. Similarly, NAPP photos were chosen for CP site interpretation over satellite images (SPOT) due to superior resolution.

nominal ground resolution of 1-meter, are projected to the Universal Transverse Mercator (UTM) coordinate system, and cast on the North American Datum of 1983 (NAD 83).

More than 300 CIR NAPP photos were required to map CP sites in Subarea 4 during 1999. However, due to gaps in the 1999 NAPP coverage only 285 photos were available at the time of this study. Therefore, the UGA-CRMS employed statistical regression techniques to estimate CP acreage for Area A and those portions of Subarea 4 lacking photo coverage.

Digital Raster Graphics

Digital raster graphic (DRG) files are digital map files that are produced by the USGS by scanning 1:24,000-scale topographic maps at a resolution of 250 dots per inch (USGS, 1999). The scanned images are registered to the UTM coordinate system and cast on the datum of the source map. In most cases, the North American Datum of 1927 (NAD 27) is employed as the reference horizontal datum. Alternatively, DRGs may be referenced to NAD 83. In this study, DRGs were used to identify ground control in areas bordering Alabama and Florida where DOQQ coverage was missing.

Satellite Imagery

In order to reliably estimate NCP acreage using satellite imagery and image processing techniques, the UGA-CRMS required multispectral imagery acquired during the 1999 growing season and coincident with the area's diverse crop and irrigation calendars (see Figure 5). The U.S. Landsat and the French SPOT satellite programs were considered for use in this aspect of the study. However, only one relatively cloud-free Landsat 7 ETM + image was available during the irrigation period and even then clouds were present over the study area (Figures 7 and 8). Multispectral images available from SPOT in 1999 were recorded on dates outside the window of coincident irrigation for the major crop types in the study area (Figure 9). Difficulties in obtaining cloud-free coverage eliminated the possibility of using multispectral satellite imagery to estimate NCP acreage.

The UGA-CRMS also considered using satellite imagery to map CP in areas where NAPP photographs were not available. However, neither the 15-m Landsat 7 ETM+ nor the 10-m SPOT panchromatic images were of sufficient resolution to comprehensively map CP sites. Although it is possible to map large CP sites from SPOT or Landsat imagery, small CP systems were not easily discerned.

DATABASE DEVELOPMENT AND MAP PRODUCTION

The digital database, hardcopy maps, and statistics describing the extent of irrigation in southwest Georgia were developed using a series of steps that included the: 1) scanning and rectification of NAPP aerial photographs; 2) interpretation and mapping of center pivot irrigation sites; and 3) derivation of irrigated land area statistics.

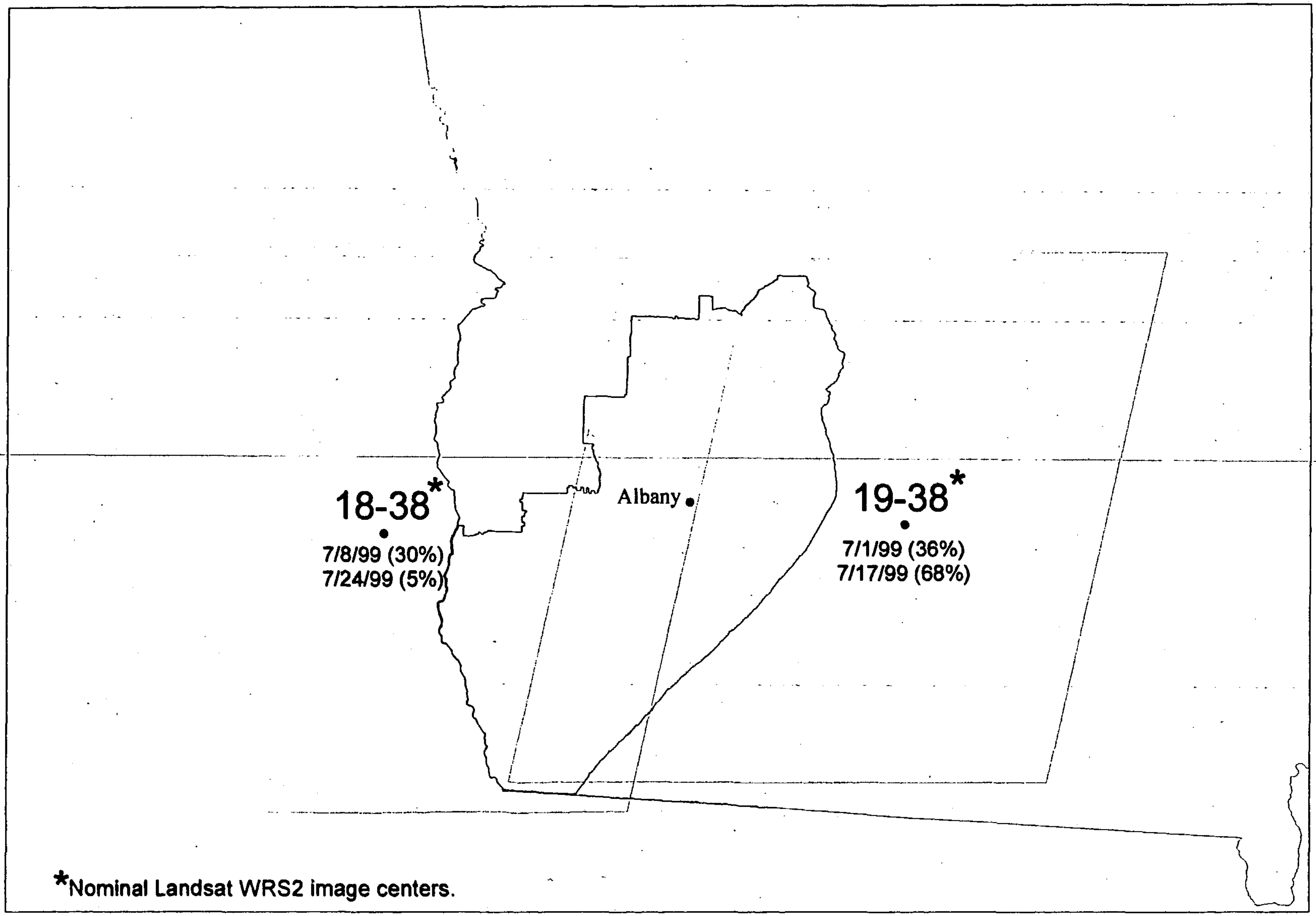

Figure 7. Landsat 7 ETM+ imagery captured during July of 1999 was not suitable for use in determining NCP acreage due to excessive cloud cover.

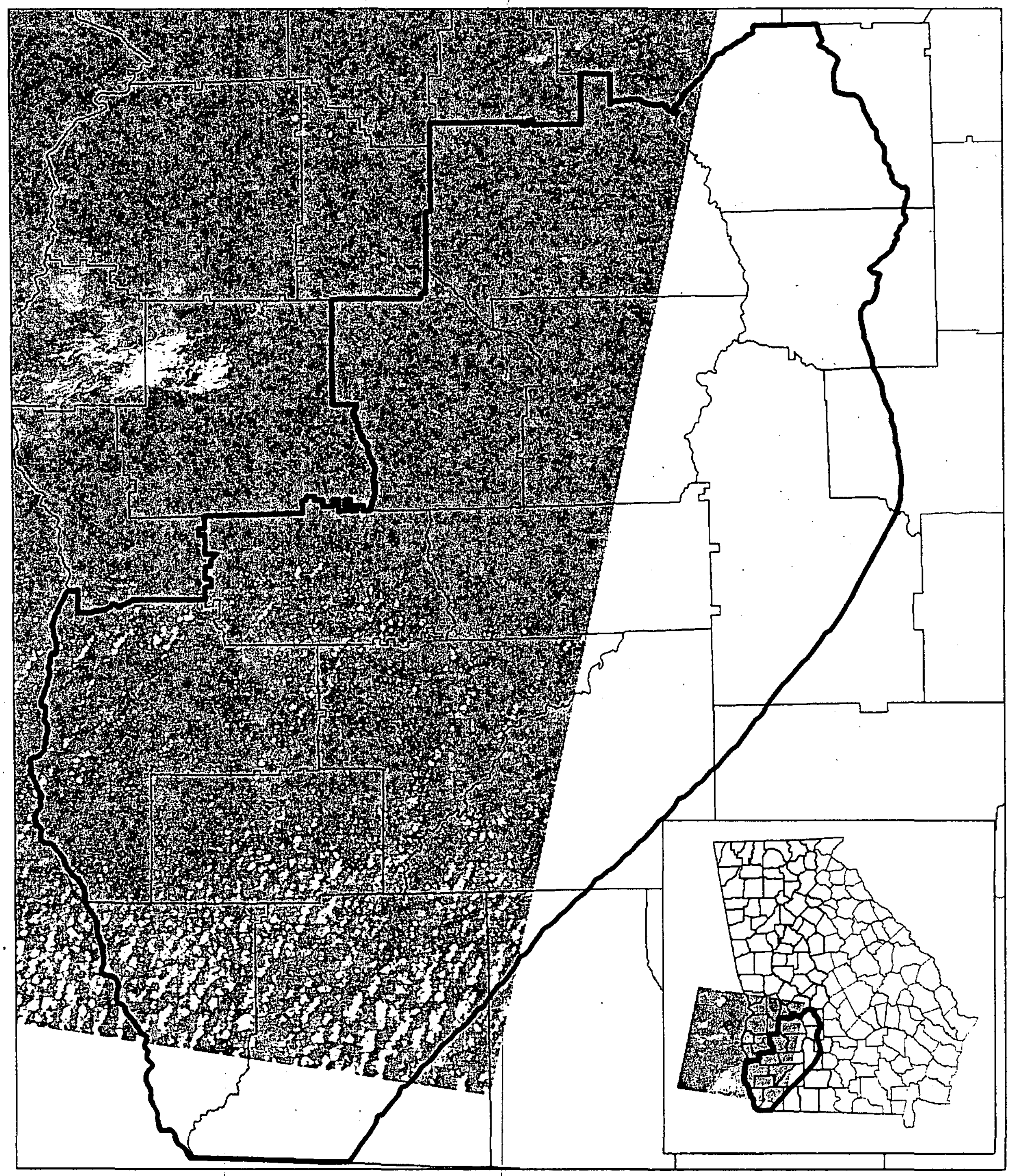

Figure 8. The Landsat 7 ETM + image recorded on July 24, 1999 had cloud cover concentrated over the study area.

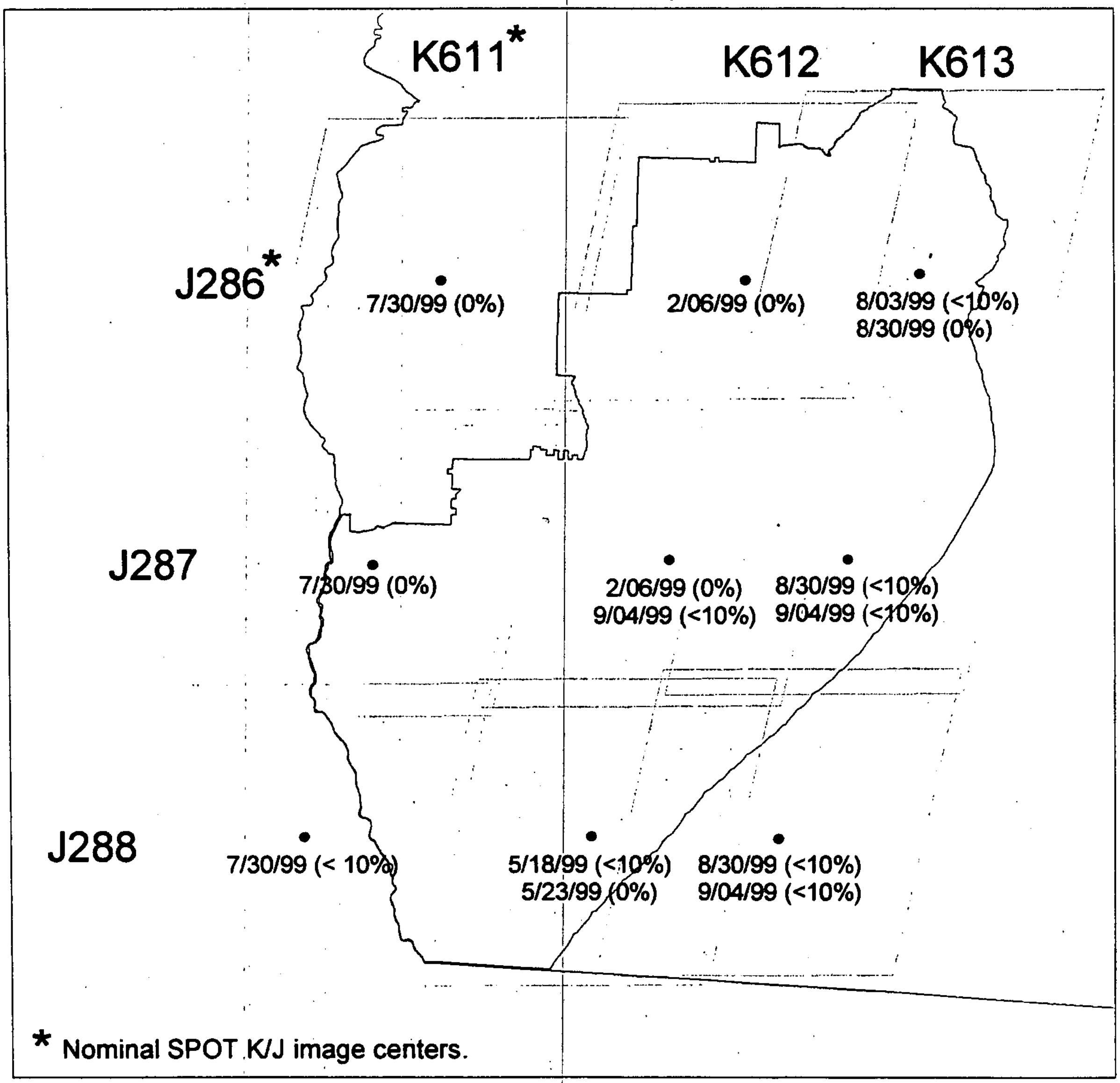

Figure 9. Although many of the SPOT images available for the study area in 1999 are cloud-free, most were captured outside the window of coincident irrigation, the month of July.

Scanning

The 1:40,000-scale 1999 NAPP film transparencies were scanned using an EPSON *Expression 836XL* scanner (with a transparency adapter) controlled by a Dell Dimension personal computer (Figure 10). In order to reduce data volume, the CIR NAPP film transparencies were scanned at 600 dpi to create 8-bit black-and-white Tagged Image File Format (TIFF) images. The resulting TIFF images averaged 29 megabytes per photo or roughly 7.8 gigabytes of raw image data for the 285 photos covering Subarea 4.

Rectification

The *R-WEL*, Inc. Desktop Mapping System (DMS) Softcopy Extension for ArcView was employed on Dell personal computers to measure planimetric ground and image coordinates from the DOQQs and the scanned 1999 NAPP photographs, respectively (Figure 11). Well-defined features, such as road intersections, served as ground control. These control points were measured on the DOQQs and their coordinates referenced to the UTM (Zone 16) coordinate system (NAD 83) (Figure12). The same features were then located and measured on the NAPP photographs.

The ground and image coordinates were then used to derive rectification coefficients for each NAPP photo using a second-degree polynomial equation. During the subsequent rectification process, each image was resampled to a 1.3 metre pixel resolution, resulting in panchromatic image files of approximately 32 MB in size. Planimetric errors in the rectified images were typically on the order of ± 1 to 5 metres (RMSE). These images were saved as ERDAS LAN files to facilitate display and interpretation using the ESRI ArcView software.

Interpretation

The ArcView software was employed to delineate CP sites in a 'heads-up' digitizing environment on a county-by-county basis for both 1993 and 1999 (Figure 13). Physical characteristics used in the interpretation of sites from digital images included: 1) shape; 2) tone and texture; 3) concentric tire grooves in the soil; and 4) pivot structure. The footprint (shape) on the ground is circular, though partial systems may appear as a semi-circle or some other portion of a circle (Figure 14a). Frequently, farmers cluster CP systems into groups of two or more as shown in Figure 14b. It is also common to find stand-alone systems situated in square or rectangular fields to maximize irrigated acreage (Figure 14c).

Tone and texture are important characteristics in the visual interpretation of CP sites. The 1993 and 1999 NAPP photos were recorded during the winter months when many of the irrigated fields lie fallow. These bare fields generally have a bright tone, while natural vegetation and planted fields appear darker (Figure 14d). However, when winter crops are present, tonal differences between the irrigated field and the surrounding areas are not always distinct. In these cases, texture becomes important in the interpretation of sites. For example, forested land appears coarser in texture than planted or fallow cropland (Figure 14d). The presence of brightly toned dirt roads that often times surround a site also aided in the

Figure 10. The 1999 NAPP photos were scanned using an EPSON Expression 836 XL scanner.

Figure 11. Ground control points were measured with DMS Softcopy for ArcView.

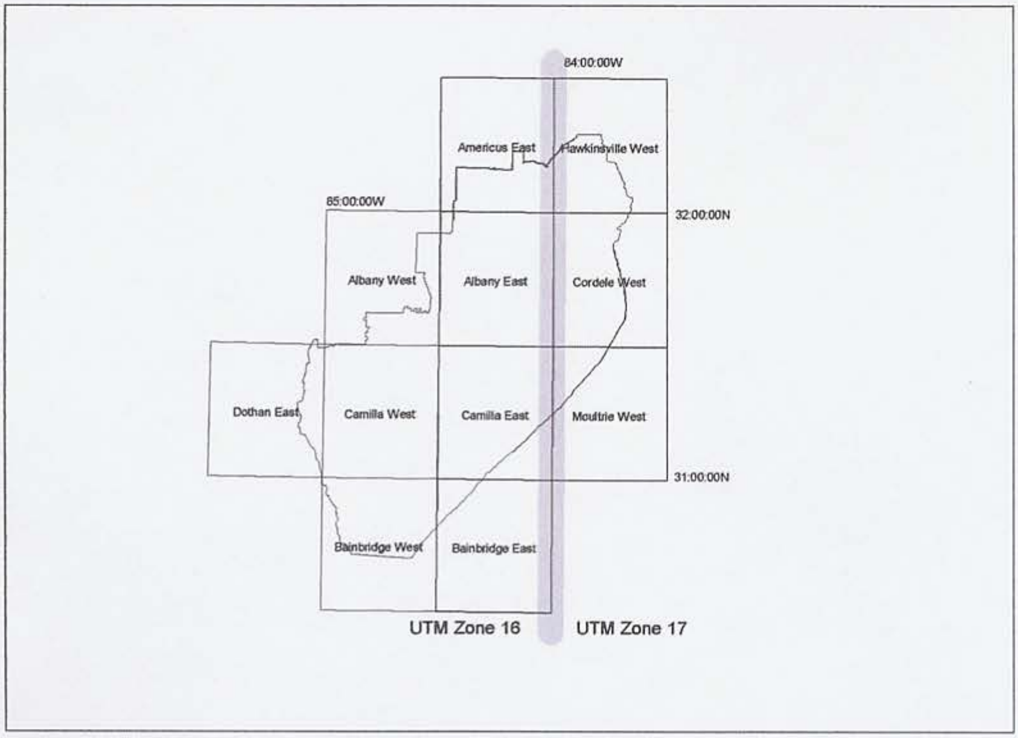

Figure 12. Photos in UTM Zone 17 were rectified using UTM Zone 16 coordinates in order to produce a seamless database of the study area. Large format maps are keyed to the USGS 1:100,000-scale mapsheet index.

Figure 13. Center pivot irrigation sites were mapped in a heads-up digitizing environment using ArcView.

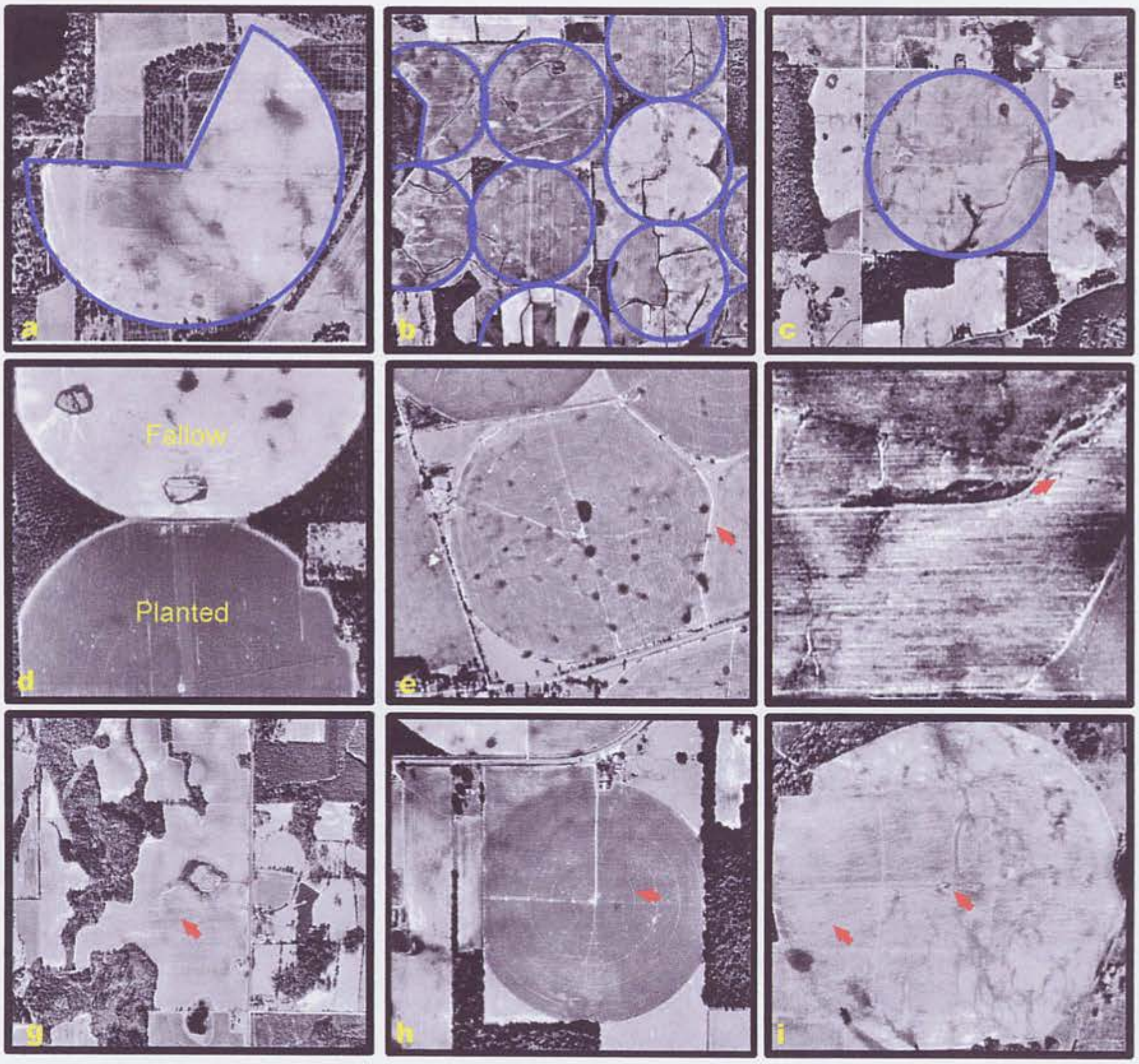

Figure 14. a. Partial CP site. b. Cluster of CP sites. c. Center pivot site in a rectangular field. d. Fallow vs. planted field surrounded by forest. e. Center pivot site surrounded by a brightly toned dirt road. f. Tonal variations obscure CP identification. g. Tonal differences and circular shape absent. h. Concentric tire grooves made by CP structure. i. Center pivot structure and pivot point.

interpretation (Figure 14e). Although tone and texture generally help to define a site, variations caused by sinkholes, multiple crop types, wetland areas, and shadows sometimes obscured CP identification (Figure 14f and 14g).

Additional characteristics associated with CP sites include: 1) structure; and 2) concentric grooves (tire tracks) left by a revolving structure. These features are important in identifying CP sites where neither shape nor tonal variations allow for the identification of a CP site. The CP structure is a linear feature, which may be lighter or darker in tone than its surroundings, with regularly spaced perpendicular protrusions (tires). In some cases, the structure is very pronounced while at other times it is only detectable through close inspection and/or image enhancement. Center pivot systems also produce concentric grooves in the soil that are often visible where the structure passed through a wet portion of a field or a winter crop (Figure 14h).

Due to the critical nature of this study, UGA-CRMS employed quality control measures to ensure the accurate interpretation of all CP sites in the study area. For example, the DOQQs and scanned photos were displayed at a scale of 1:12,000 or larger during the interpretation process. Further, sites were only mapped if: 1) the pivot arm or concentric grooves were present; or 2) a field had the proper circular geometry and the pivot point of the structure could be identified in the center of the field (Figure 14i). Upon completion, a second interpreter reviewed the initial delineation to ensure that all sites in the study area were accurately identified.

Mapping

The ArcView shapefiles resulting from the interpretation process were converted into Arc/Info coverage format in order to build spatial topology, edgematch center pivots crossing county boundaries, and perform overlay change analysis. These procedures were carried out in Arc/Info Version 7.2 for UNIX running on a Sun Ultra 60 Workstation. Once processed, the Arc/Info coverages were employed in the development of eleven 1:60,000-scale hardcopy maps corresponding to the USGS 1:100,000-scale topographic map series (Figures 12 and 15). ArcView software was then employed to produce maps depicting CP sites in Subarea 4 and Area A for 1999, and changes that occurred in CP acreage between 1993 and 1999. These maps also include a 1999 scanned photo mosaic, county boundaries, major highways, rivers, lakes, and cities.

Derivation of Irrigated Land Values

Center pivot acreage in 1993 was derived entirely from the interpretation of USGS DOQQs. However, the USGS was only able to provide UGA-CRMS with 285 of the 301 photographs required to map CP sites in Subarea 4 during 1999. Aerial photos were not obtained for Area A in 1999. Therefore, the UGA-CRMS mapped 97% of Subarea 4 directly from 1999 NAPP photos and estimated acreage for the remaining 3% using a least squares linear regression technique (Figures 16 and 17). In this approach, CP acreage was determined for each DOQQ area. The acreage values for 1999 were then plotted against the 1993 values and a regression line was fitted, which yielded an R^2 value of 0.92. This strong correlation permitted the 1999

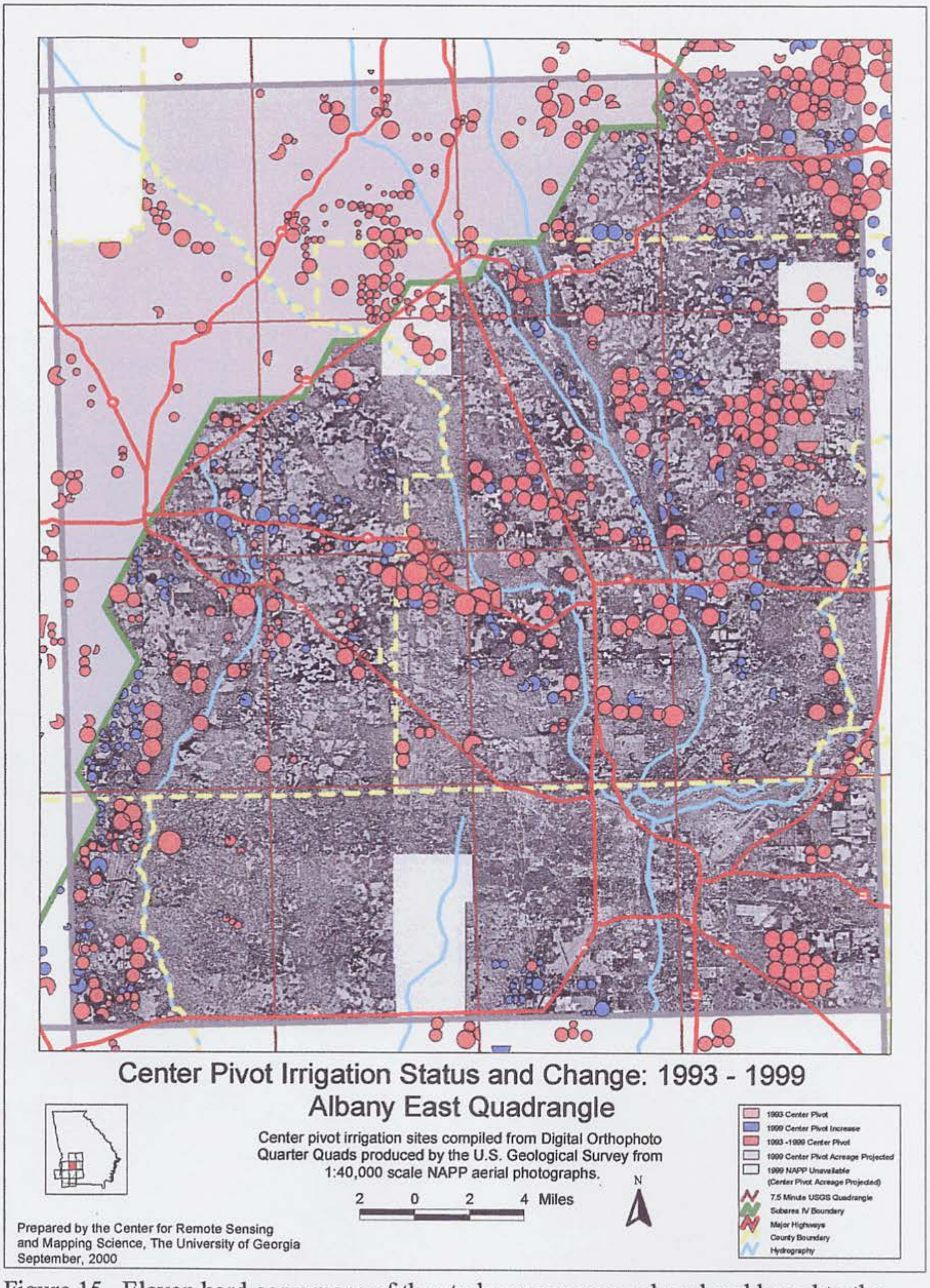

Figure 15. Eleven hard copy maps of the study area were produced and keyed to the USGS 1:100,000-scale map series. For areas lacking 1999 NAPP photo coverage, it was assumed that CP sites mapped for 1993 still existed in 1999.

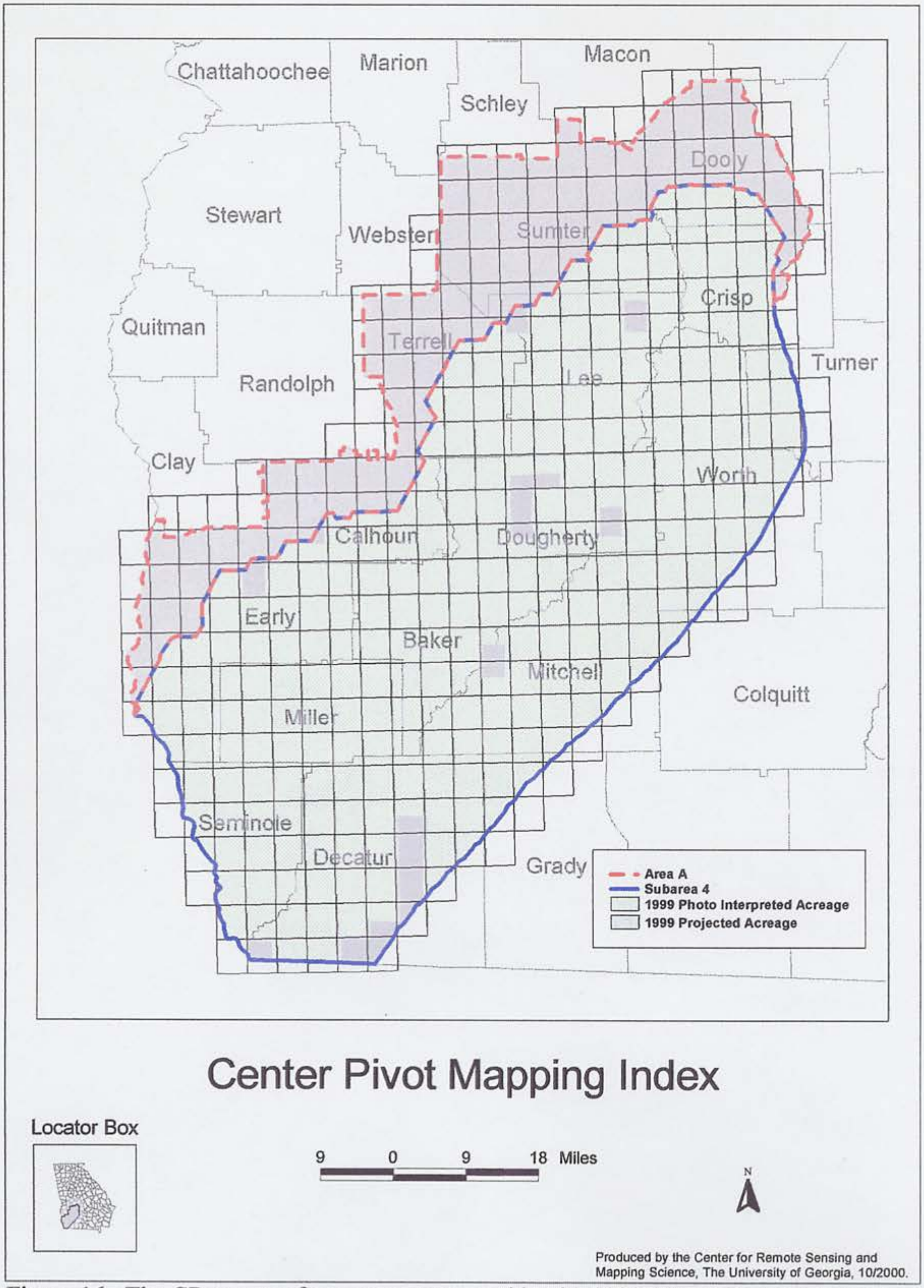

Figure 16. The CP acreage for areas not covered by the 1999 NAPP photos (shown in gray) was estimated using least-square regression techniques.

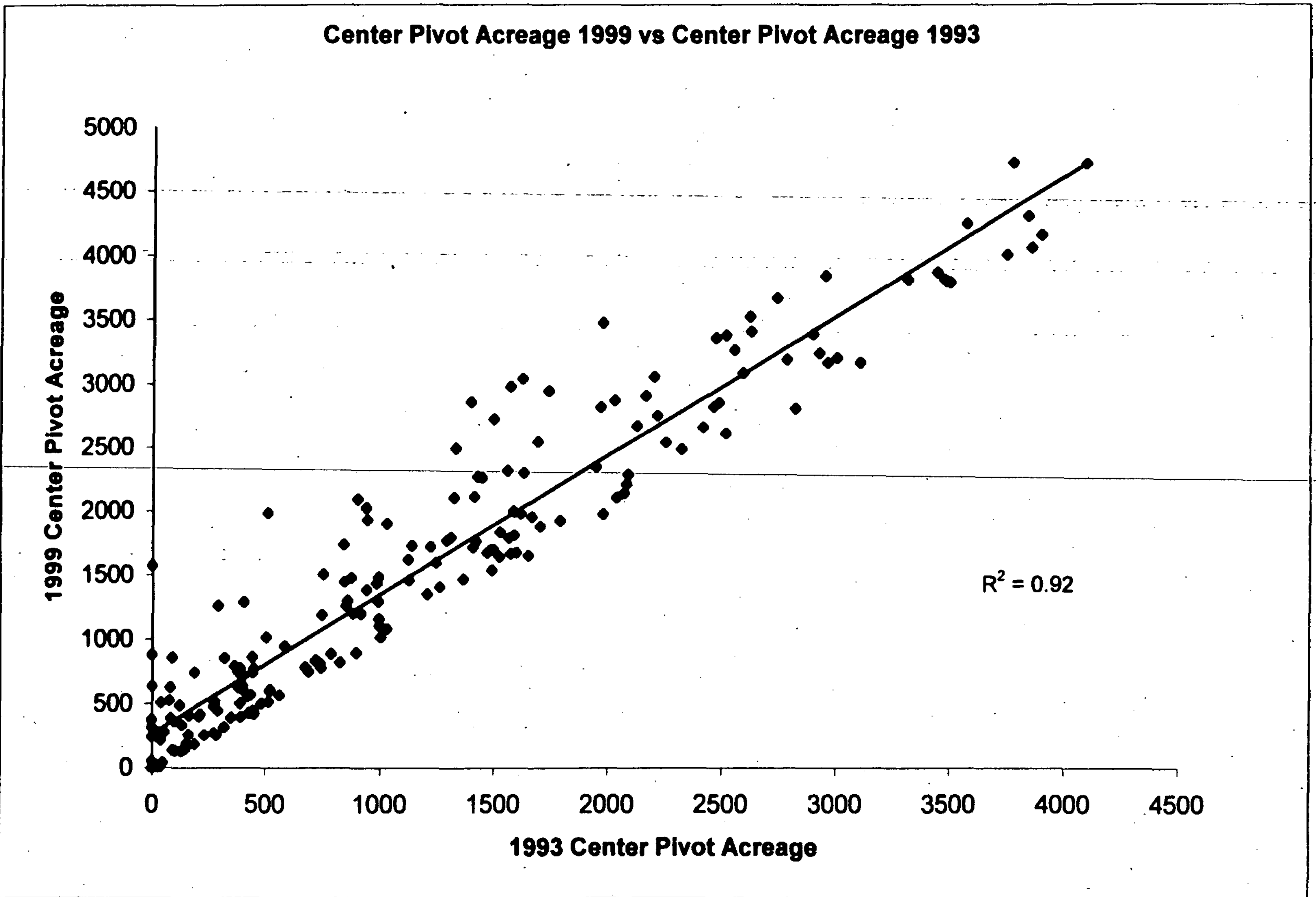

Figure 17. The least-squares regression was developed by plotting 1999 CP acreage vs. 1993 CP acreage and resulted in a strong correlation with a R^2 value of 0.92.

acreage to be estimated with confidence for those small areas within Subarea 4 lacking NAPP photo coverage. This approach was extended to derive 1999 CP acreage estimates for Area A.

The UGA-CRMS calculated NCP acreage based on the percentage of total irrigated land under NCP practices, an approach supported by experts working at the UGA Cooperative Extension Service (UGA-CES), and the USDA's Farm Services Agency (USDA-FSA) and Natural Resource Conservation Service (USDA-NRCS). This process began with the USDA-FSA's development of county-based reports for the study area that stated the percentage of total irrigated land under NCP practices. In this survey NCP systems included portable pipe, cable tow, hose reel, lateral move, solid set, drip/trickle, and athletic/golf units. Technical staff from the UGA-CES also developed a set of percentages describing NCP for each county, based on extensive field investigations and professional knowledge. Discrepancies between the derived NCP percentages were resolved, resulting in NCP percentages representative of the portion of each county within the study area (Table 1).

Table 1. Percent of total irrigated land under NCP practices.

County	Percent of Irrigated Land Under NCP Practices	County	Percent of Irrigated Land Under NCP Practices
Baker	5	Lee	25
Calhoun	20	Miller	15
Crisp	20	Mitchell	30
Decatur	10	Seminole	5
Dooly	5	Sumter	10
Dougherty	35	Terrell	10
Early	25	Turner	35
Grady	35	Worth	15

Given the 1999 CP acreage and the NCP percentages provided by the UGA-CES and USDA-FSA, it was possible to compute total irrigated acreage 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 practices.*

Total irrigated acreage for the study area (Subarea 4 and Area A) was then calculated by summing the values for the 16 counties with the following expression:

$$TIL = \sum_{i=1}^{16} TIA_c$$

Where:
- *TIL is the total irrigated acreage for the study area.*
- *TIAc is the total irrigated acreage within the study area for each county.*

IRRIGATED LAND ACREAGE

The primary objective of this study was to determine the extent and location of irrigated lands in Subarea 4 and Area A in the Flint River Basin for 1993 and 1999. Multiple datasets, mapping techniques, and statistical estimation methods were employed to determine the location and extent of irrigation in the study area. The most significant findings resulting from this study are detailed in the paragraphs below.

1993 Center Pivot Irrigation Acreage

When this project began the USGS had not yet released the 1999 NAPP aerial photographs. Consequently, the project was expanded to include mapping CP sites from 1993 USGS DOQQs as well as from the 1999 NAPP photos. Based on the interpretation of 1993 DOQQs, the UGA-CRMS identified **291,643** acres of farmland under CP practices in Subarea 4 and **38,659** acres in Area A. County-based acreage for 1993 is listed in Table 2.

Table 2. Center pivot acreage mapped from 1993 USGS DOQQs.

County	Subarea 4 (acres)	Area A (acres)	Total (acres)
Baker	32,904	0	32,904
Calhoun	11,876	6,291	18,167
Crisp	3,754	141	3,895
Decatur	47,870	0	47,870
Dooly	1,010	5,974	6,984
Dougherty	8,123	0	8,123
Early	15,735	2,302	18,037
Grady	2,828	0	2,828
Lee	24,670	2,021	26,691
Miller	30,762	0	30,762
Mitchell	47,610	0	47,610
Seminole	35,116	0	35,116
Sumter	13,386	15,775	29,161
Terrell	6,236	6,155	12,391
Turner	211	0	211
Worth	9,552	0	9,552
Total	291,643	38,659	330,302

1999 Center Pivot Irrigation Acreage

Two methods were used to compute CP acreage for 1999: 1) interpretation of air photos; and 2) statistical regression. In Subarea 4, sites were primarily mapped from air photos. Because some 1999 NAPP photos were unavailable at the time of this study, acreage for approximately 3 % of Subarea 4 and all of Area A was calculated using statistical regression techniques. Based on these methods **381,996** acres were mapped for Subarea 4 and **9,820** acres were estimated, resulting in a total of **391,816** acres in Subarea 4 (**Table 3**). In Area A, **60,414** acres were projected using the regression, for a total of **452,230** acres in 1999. Based primarily on interpretation of the 1993 USGS DOQQs and the 1999 scanned air photos, acreage has increased by **100,173** acres (34%) in Subarea 4. Similarly, it is estimated that CP acreage increased by **21,755** acres (56 %) from 1993 to 1999 in Area A for a total increase in CP acreage of **121,928** acres for the entire study area.

Table 3. Center pivot acreage mapped from 1999 NAPP photos.

County *	Subarea 4[I] (acres)	Subarea 4[P] (acres)	Subarea 4 Total (acres)	Area A[I] (acres)	Area A[P] (acres)	Area A Total (acres)	Total (acres)
Baker	38,375	364	38,739	0	0	0	38,739
Calhoun **	14,722	164	14,886	0	9,530	9,530	24,416
Crisp **	11,524	0	11,524	0	427	427	11,951
Decatur **	57,379	2,200	59,579	0	0	0	59,579
Dooly **	3,104	0	3,104	0	9,383	9,383	12,487
Dougherty	9,203	1,913	11,116	0	0	0	11,116
Early **	24,435	860	25,295	0	4,970	4,970	30,265
Grady **	3,254	0	3,254	0	0	0	3,254
Lee **	28,926	2,380	31,306	0	2,345	2,345	33,651
Miller	45,982	0	45,982	0	0	0	45,982
Mitchell **	56,566	1,859	58,425	0	0	0	58,425
Seminole	45,831	0	45,831	0	0	0	45,831
Sumter **	15,592	0	15,592	0	24,042	24,042	39,634
Terrell **	10,044	80	10,124	0	9,717	9,717	19,841
Turner **	1,384	0	1,384	0	0	0	1,384
Worth **	15,675	0	15,675	0	0	0	15,675
Total	**381,996**	**9,820**	**391,816**	**0**	**60,414**	**60,414**	**452,230**

[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.
* Colquitt county had no center pivot irrigation systems in the study area.
** Irrigated acreage derived only for the portion of the county located within study area.

1999 Non-Center Pivot Irrigation Acreage

The final NCP percentages are representative of the portion of each county within the study area ranged from 5 to 35 percent and reflected the diverse agricultural composition of the area. The previously given equations and procedures were employed to compute NCP acreage for each county (**Table 4**). There were **83,963** acres in Subarea 4 and **9,174** acres in Area A for a total of **93,137** acres. It was not possible to compute 1993 NCP acreage.

Table 4. Calculated NCP acreage for 1999.

County	Subarea 4(acres)	Area A (acres)	Total (acres)
Baker	2,039	0	2,039
Calhoun	3,722	2,383	6,105
Crisp	2,881	107	2,988
Decatur	6,620	0	6,620
Dooly	163	494	657
Dougherty	5,986	0	5,986
Early	8,432	1,657	10,089
Grady	1,752	0	1,752
Lee	10,435	782	11,217
Miller	8,114	0	8,114
Mitchell	25,039	0	25,039
Seminole	2,412	0	2,412
Sumter	1,732	2,671	4,403
Terrell	1,125	1,080	2,205
Turner	745	0	745
Worth	2,766	0	2,766
Total	83,963	9,174	93,137

1999 Total Irrigation Acreage

The total irrigated acreage for 1999 is the sum of the 1999 CP and NCP acreage. There were **475,779** acres in Subarea 4 and **69,588** acres in Area A for a total of **545,367** acres of irrigated land in 1999. Because accurate estimates of NCP acreage in 1993 are not available, the total irrigated land acreage in 1993 is unknown. County-based irrigated acreage for 1999 is listed in Table 5.

Table 5. Total irrigated acreage for Subarea 4 and Area A in 1999.

County	Subarea 4(acres)			Area A (acres)			Total (acres)
	CP	NCP	SubTotal	CP	NCP	SubTotal	
Baker	38,739	2,039	40,778	0	0	0	40,778
Calhoun	14,886	3,722	18,608	9,530	2,383	11,913	30,521
Crisp	11,524	2,881	14,405	427	107	534	14,939
Decatur	59,579	6,620	66,199	0	0	0	66,199
Dooly	3,104	163	3,267	9,383	494	9,877	13,144
Dougherty	11,116	5,986	17,102	0	0	0	17,102
Early	25,295	8,432	33,727	4,970	1,657	6,627	40,354
Grady	3,254	1,752	5,006	0	0	0	5,006
Lee	31,306	10,435	41,741	2,345	782	3,127	44,868
Miller	45,982	8,114	54,096	0	0	0	54,096
Mitchell	58,425	25,039	83,464	0	0	0	83,464
Seminole	45,831	2,412	48,243	0	0	0	48,243
Sumter	15,592	1,732	17,324	24,042	2,671	26,713	44,037
Terrell	10,124	1,125	11,249	9,717	1,080	10,797	22,046
Turner	1,384	745	2,129	0	0	0	2,129
Worth	15,675	2,766	18,441	0	0	0	18,441
Total	391,816	83,963	475,779	60,414	9,174	69,588	545,367

CONCLUSIONS AND SUMMARY

The UGA-CRMS mapped irrigated lands in Subarea 4 and Area A (an extension of Subarea 4) for both 1993 and 1999. This study incorporated aerial photos, satellite imagery, and statistical techniques to describe the extent of irrigated land. Development of a GIS database for CP sites from DOQQs and scanned air photos proved to be an efficient means of assessing irrigation conditions for this large study area. The CP sites were generally visible on the DOQQs and air photos and this can be attributed to the fact that the photos were acquired during the winter months when many agricultural fields were fallow.

The timing of this study precluded the use of satellite imagery to identify NCP sites. Generally, the satellite imagery required to detect NCP sites was either unavailable during the period of coincident irrigation for major crop types or contained excessive cloud cover. However, satellite imagery and/or hyperspectral data may be used to identify NCP sites given adequate time to coordinate the acquisition of imagery and to monitor ground conditions at selected sites during image acquisition. In this study, the UGA-CRMS employed alternative methods to estimate NCP and total irrigated acreage in the study area. These methods incorporated field survey and professional knowledge regarding the extent of NCP in the study area.

The irrigation values presented in this report are significantly lower than anticipated by the GDNR-EPD at the beginning of this study. However, the GDNR-EPD estimates may include acreage for irrigation systems that were not installed at the time of this study. Based on the remote sensing techniques employed and the knowledge of field conditions in the study area provided by representatives from the UGA-CES and USDA-FSA, it is believed that the irrigated acreage described in this report is reliable and sound. The resulting acreage derived from this study may be used in conjunction with application flow rates and other variables to model consumptive agricultural water use in Subarea 4 and to support the GDNR-EPD implementation of the Georgia Flint River Drought Protection Act. Summary findings are listed below.

<u>1993</u>

- Center pivot irrigated lands equaled 291,643 acres in Subarea 4 and 38,659 acres in Area A for a total of 330,302 acres.

<u>1999</u>

- Center pivot irrigated lands equaled 391,816 acres in Subarea 4 and 60,414 acres in Area A for a total of 452,230 acres.
- Non-center pivot irrigated lands equaled 83,963 acres in Subarea 4 and 9,174 acres in Area A for a total of 93,137 acres.
- Total irrigated lands equaled 475,779 acres in Subarea 4 and 69,588 acres in Area A for a total of 545,367 acres.

<u>1993 - 1999</u>

- From 1993 to 1999, center pivot irrigated lands increased by 100,173 acres in Subarea 4 and 21,755 acres in Area A for a total increase of 121,928 acres.

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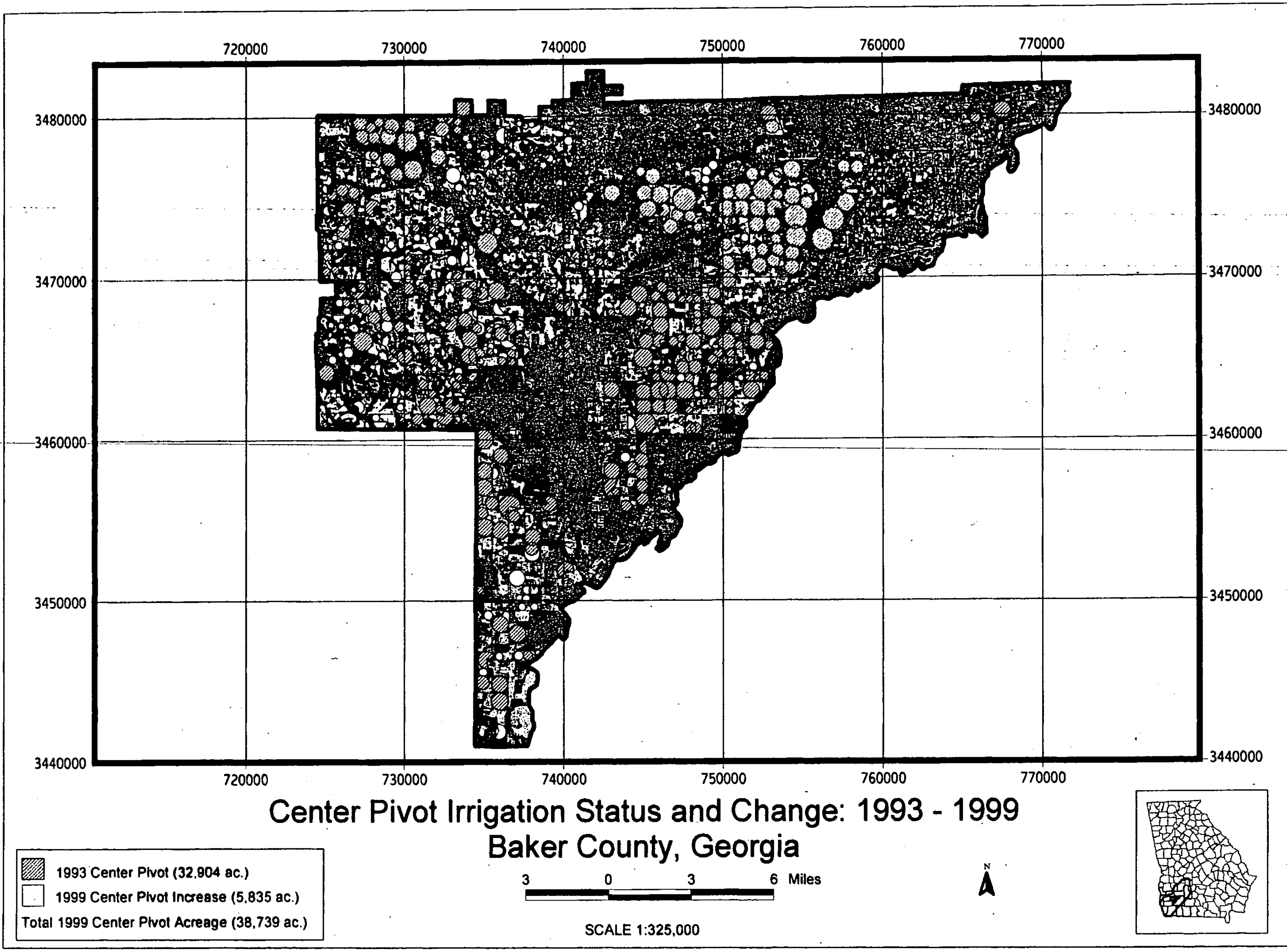
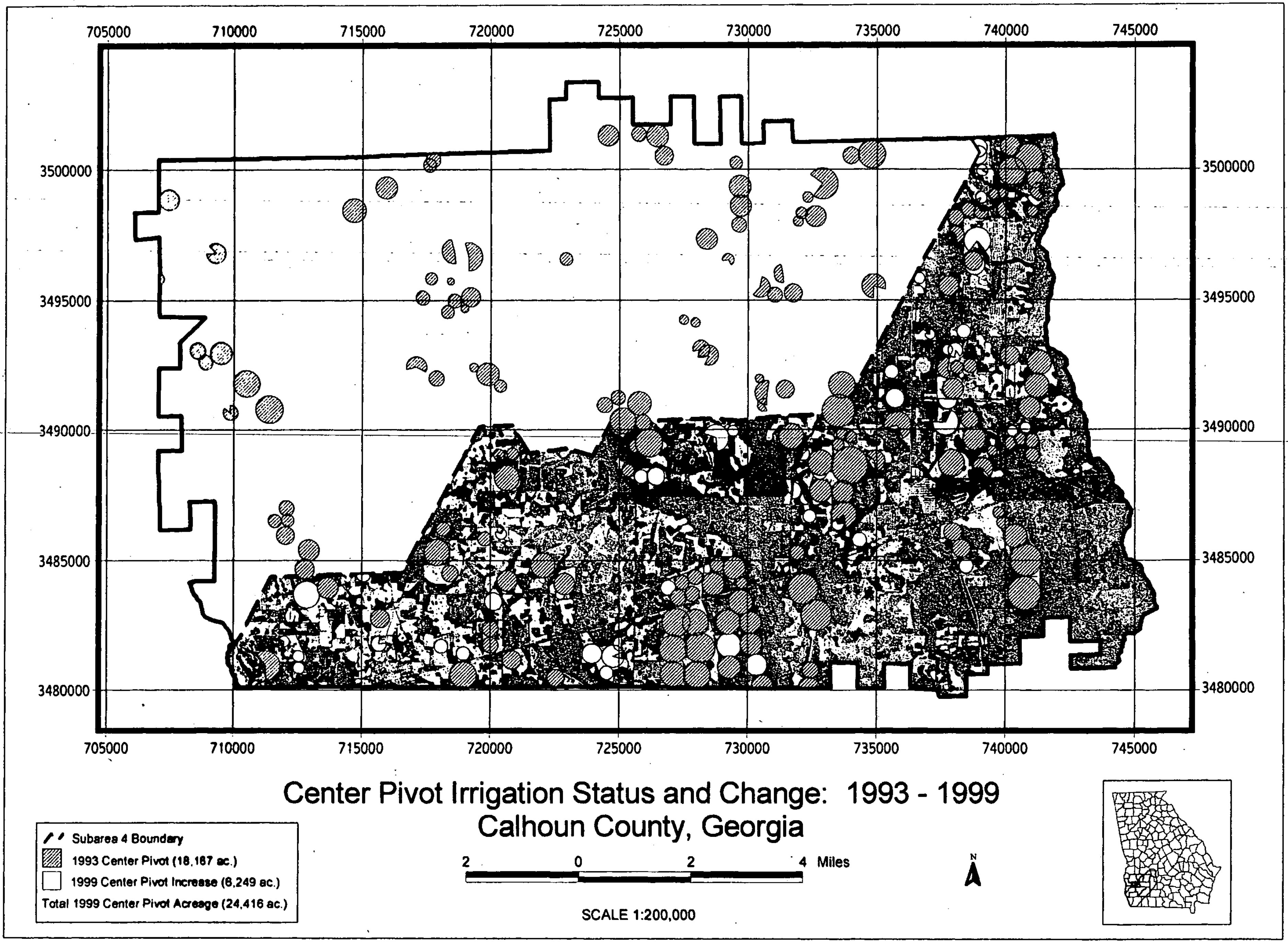
APPENDIX A

Contents:

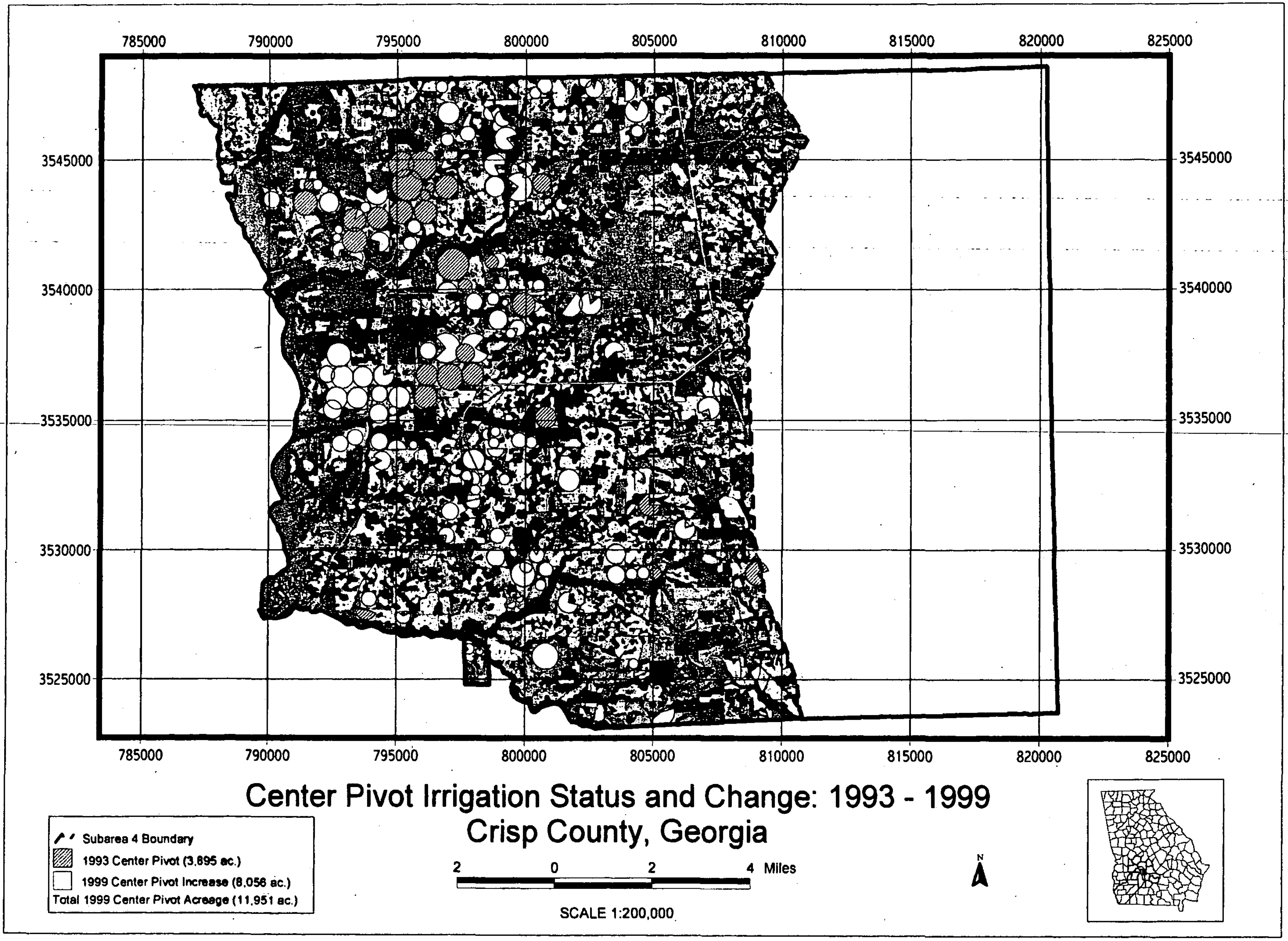
Sixteen county-based, small-scale maps: Center Pivot Irrigation Status and Change: 1993 - 1999 for Subarea 4 and Area A. Refer to Tables 2 and 3.



Center Pivot Irrigation Status and Change: 1993 - 1999
Baker County, Georgia



Center Pivot Irrigation Status and Change: 1993 - 1999
Calhoun County, Georgia



Center Pivot Irrigation Status and Change: 1993 - 1999
Crisp County, Georgia

Subarea 4 Boundary
1993 Center Pivot (3,895 ac.)
1999 Center Pivot Increase (8,056 ac.)
Total 1999 Center Pivot Acreage (11,951 ac.)

2 0 2 4 Miles

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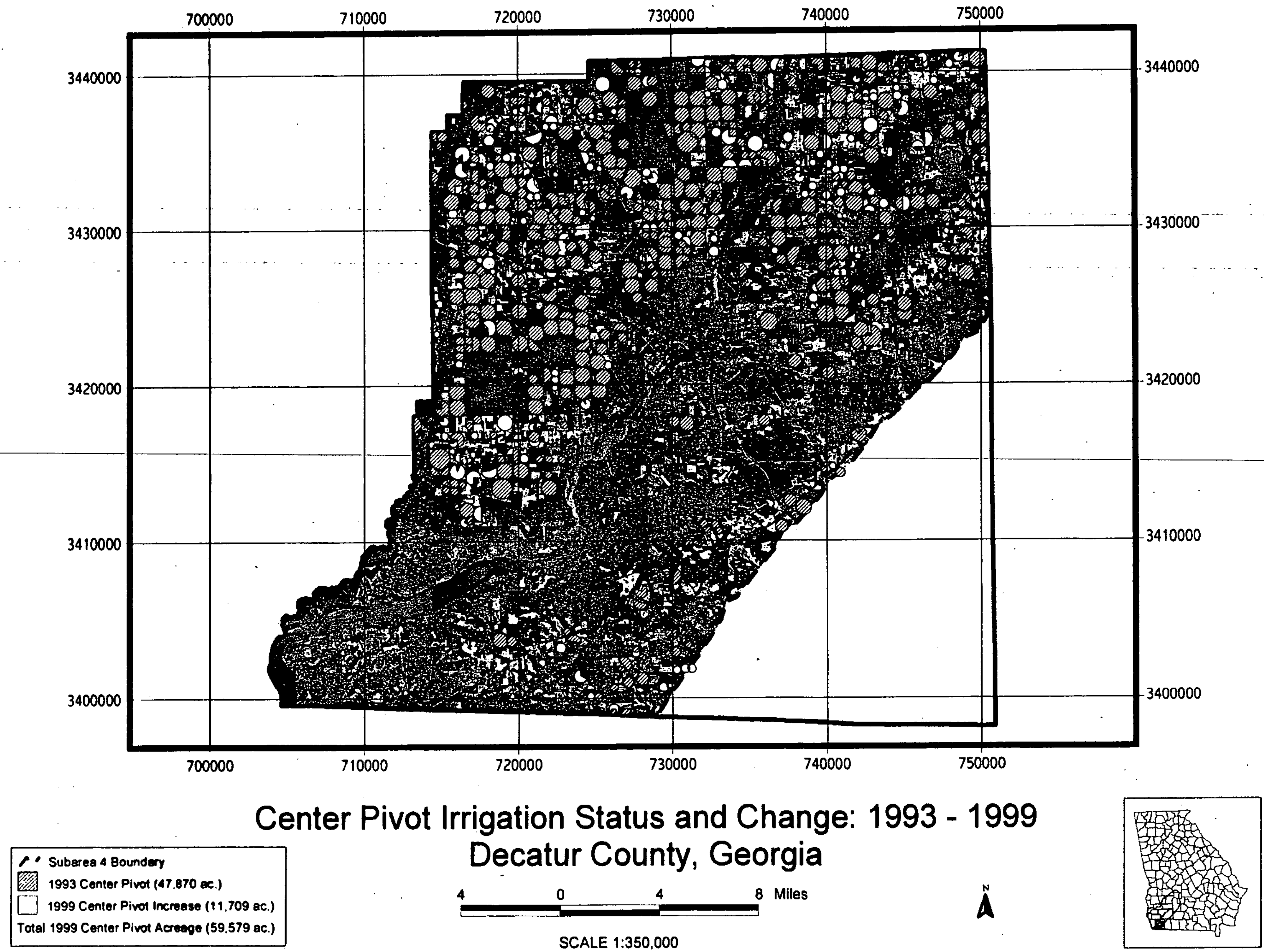
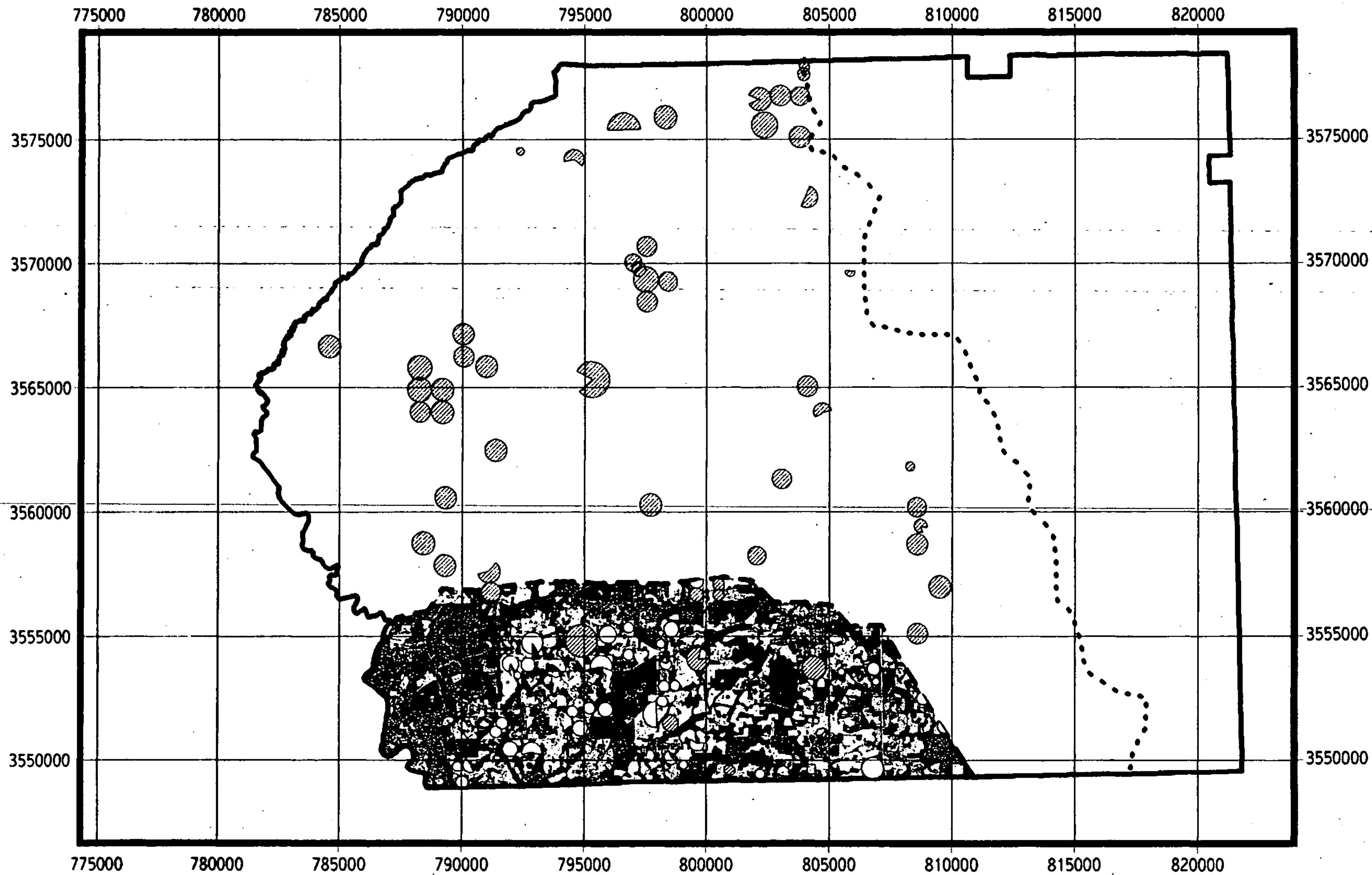


Center Pivot Irrigation Status and Change: 1993 - 1999
Decatur County, Georgia



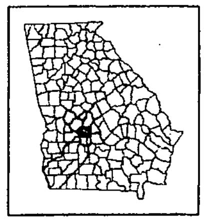
Center Pivot Irrigation Status and Change: 1993 - 1999
Dooly County, Georgia

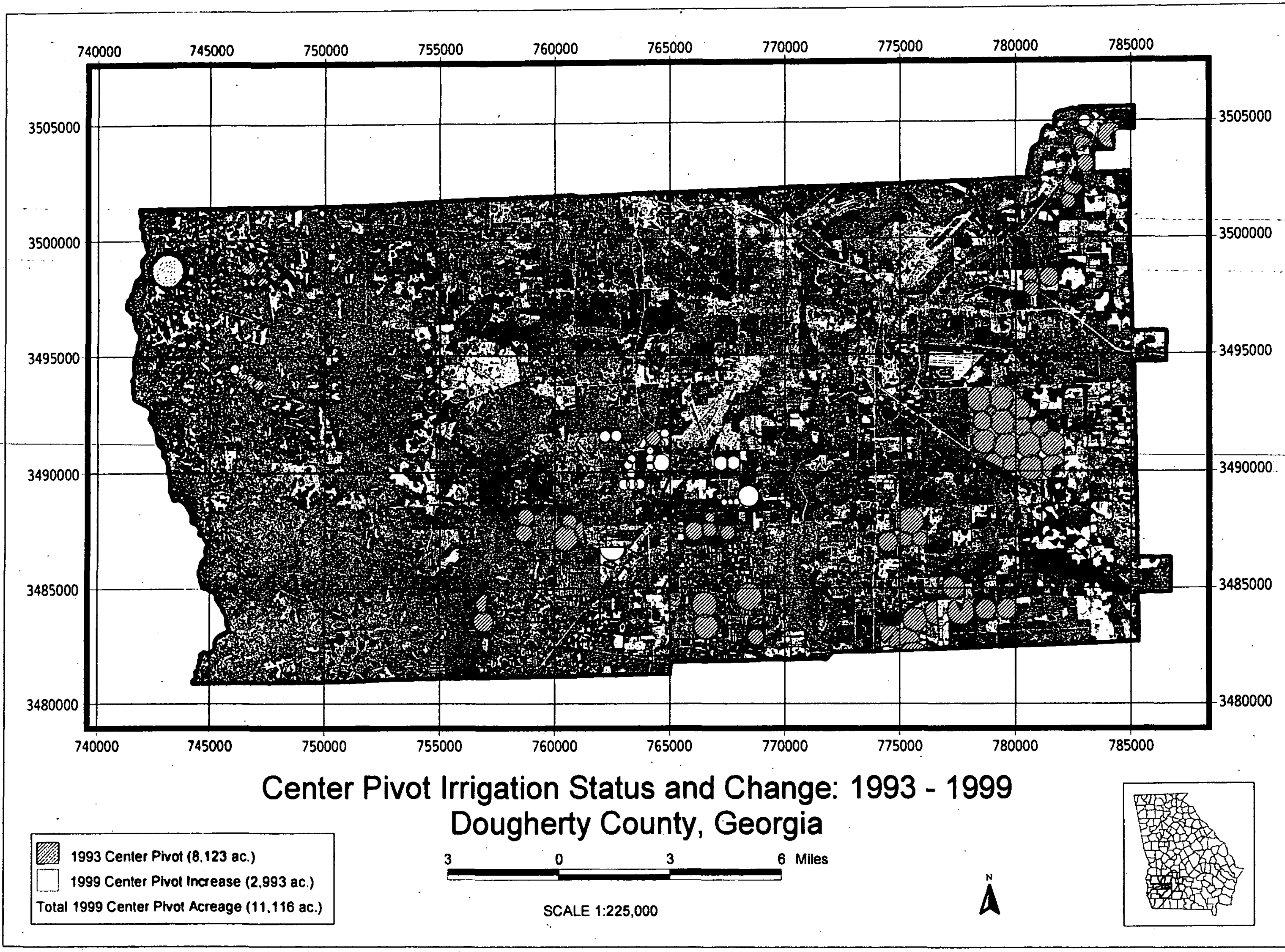
Area A Boundary
Subarea 4 Boundary
1993 Center Pivot (6,984 ac.)
1999 Center Pivot Increase (5,503 ac.)
Total 1999 Center Pivot Acreage (12,487 ac.)

2 0 2 4 Miles

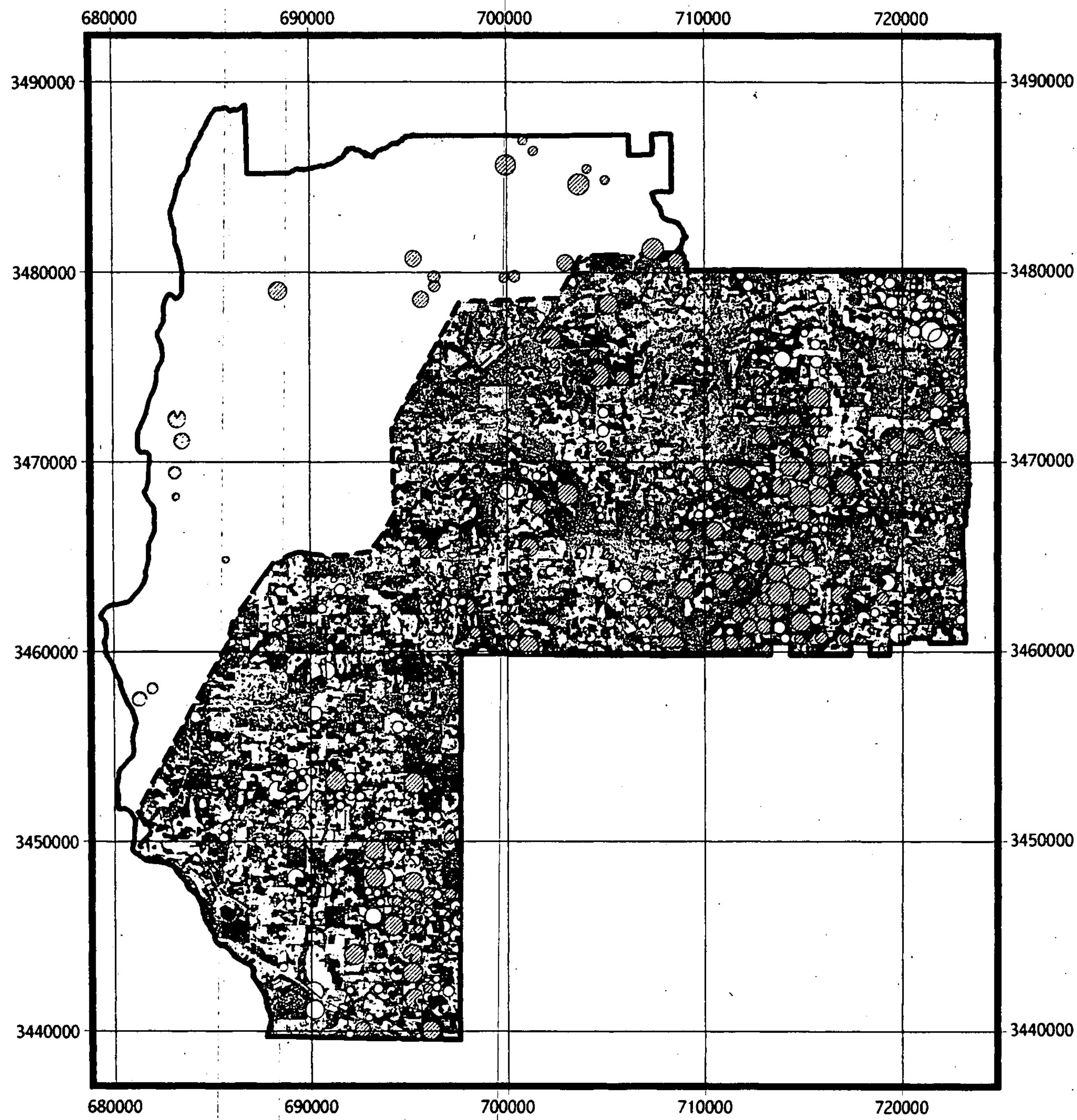
SCALE 1: 250,000

N





Center Pivot Irrigation Status and Change: 1993 - 1999
Dougherty County, Georgia

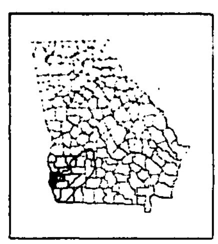


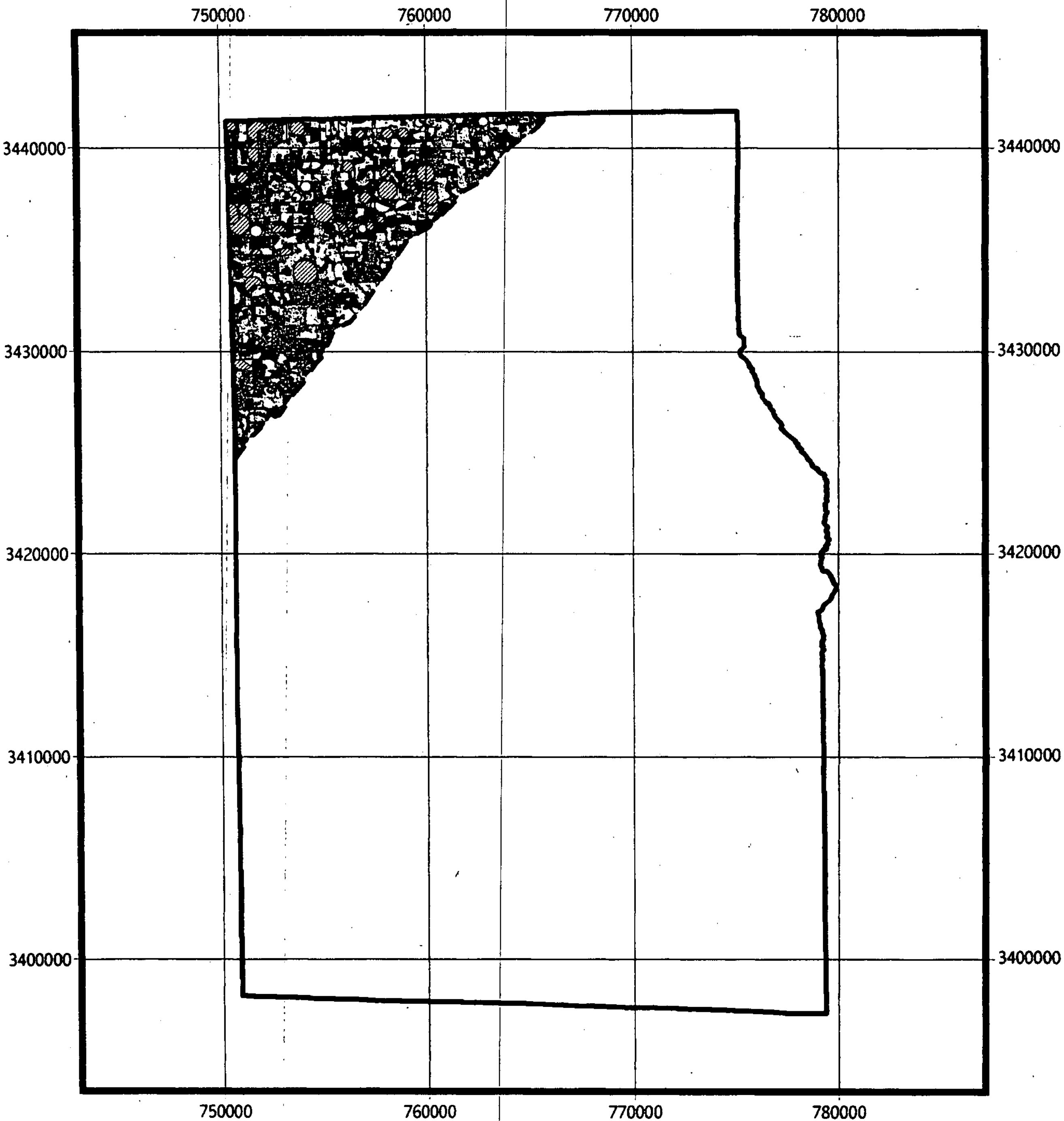
Center Pivot Irrigation and Change: 1993 - 1999
Early County, Georgia

3 0 3 6 Miles

SCALE 1:325,000

Subarea 4 Boundary
1993 Center Pivot (18,037 ac.)
1999 Center Pivot Increase (12,228 ac.)
Total 1999 Center Pivot Acreage (30,265 ac.)





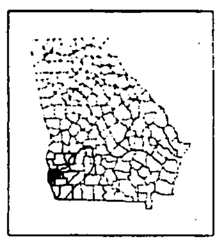
Center Pivot Irrigation and Change: 1993 - 1999
Grady County, Georgia

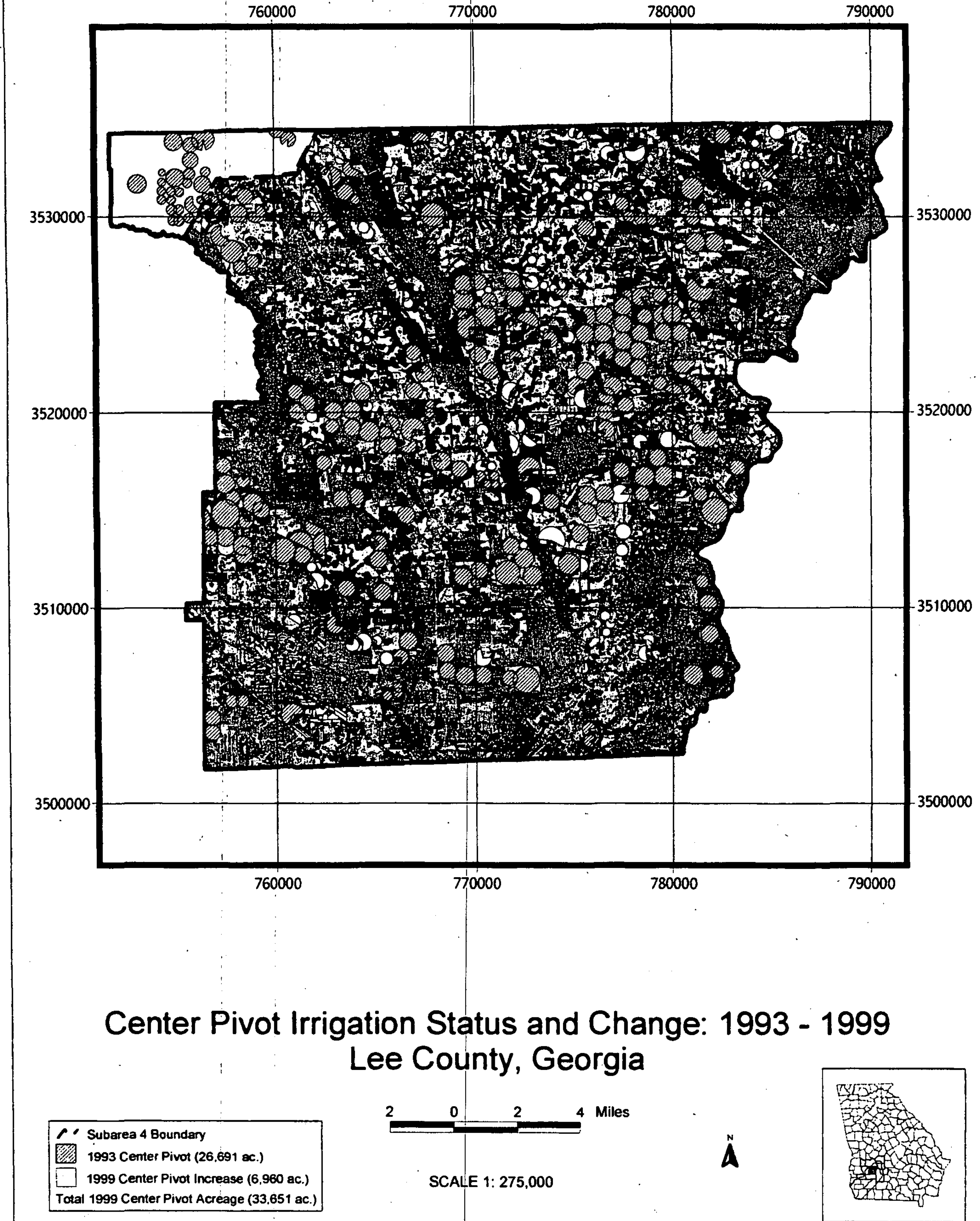
3 0 3 6 Miles

SCALE 1:325,000

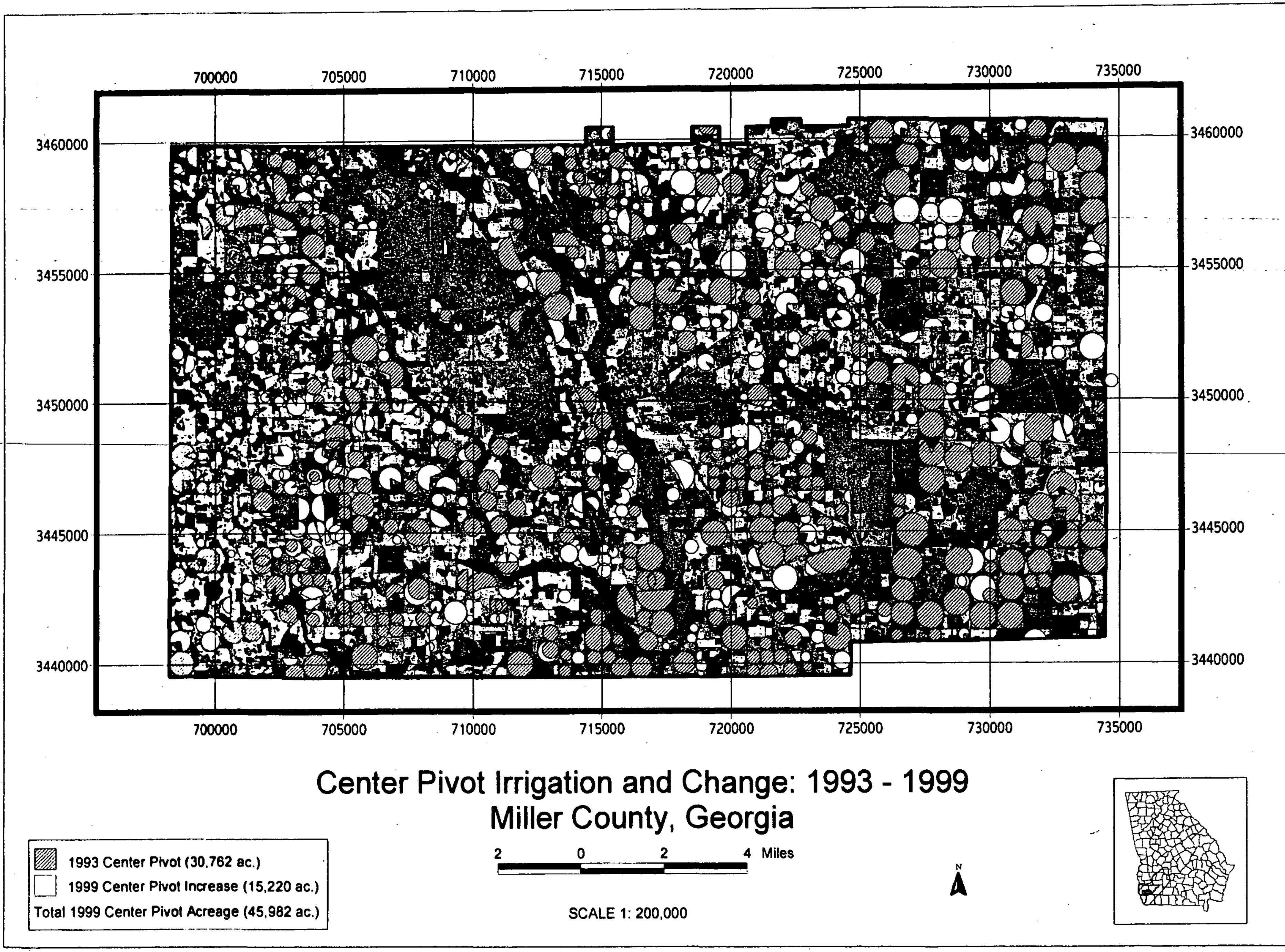
Subarea 4 Boundary
1993 Center Pivot (2,828 ac.)
1999 Center Pivot Increase (426 ac.)
Total 1999 Center Pivot Acreage (3,254 ac.)

N





Center Pivot Irrigation Status and Change: 1993 - 1999
Lee County, Georgia



700000
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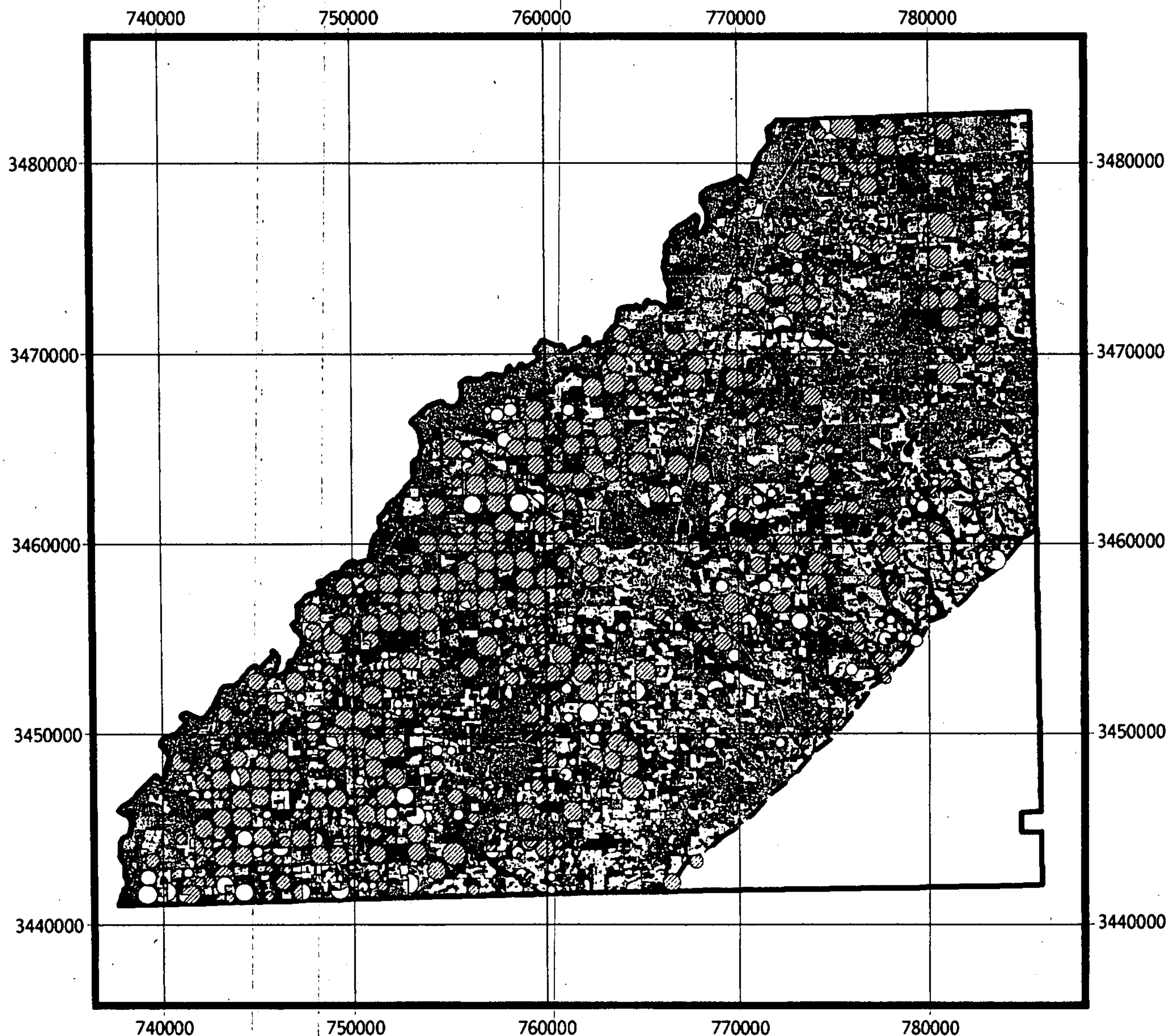
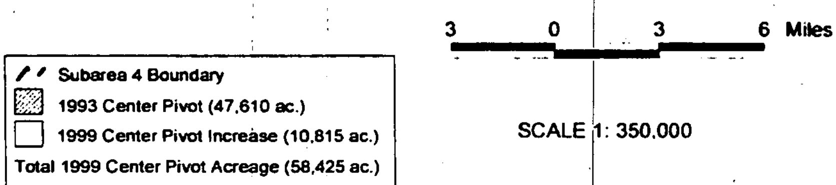
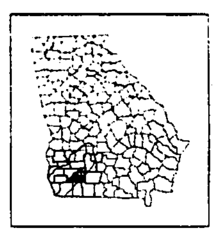
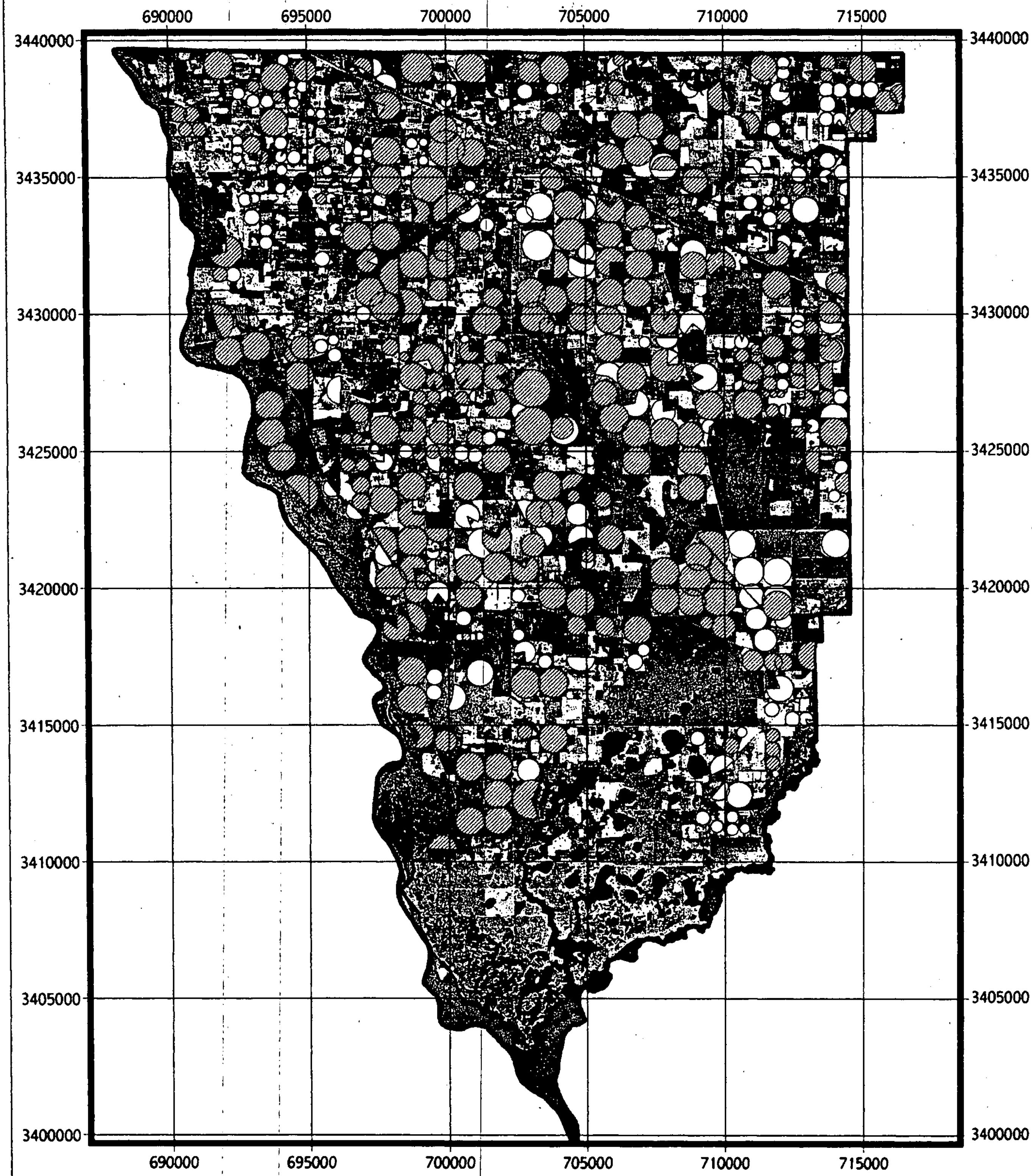
3445000
3440000
Center Pivot Irrigation and Change: 1993 - 1999
Miller County, Georgia
1993 Center Pivot (30,762 ac.)
1999 Center Pivot Increase (15,220 ac.)
Total 1999 Center Pivot Acreage (45,982 ac.)
2 0 2 4 Miles
SCALE 1: 200,000
N



Center Pivot Irrigation Status and Change: 1993 - 1999
Mitchell County, Georgia







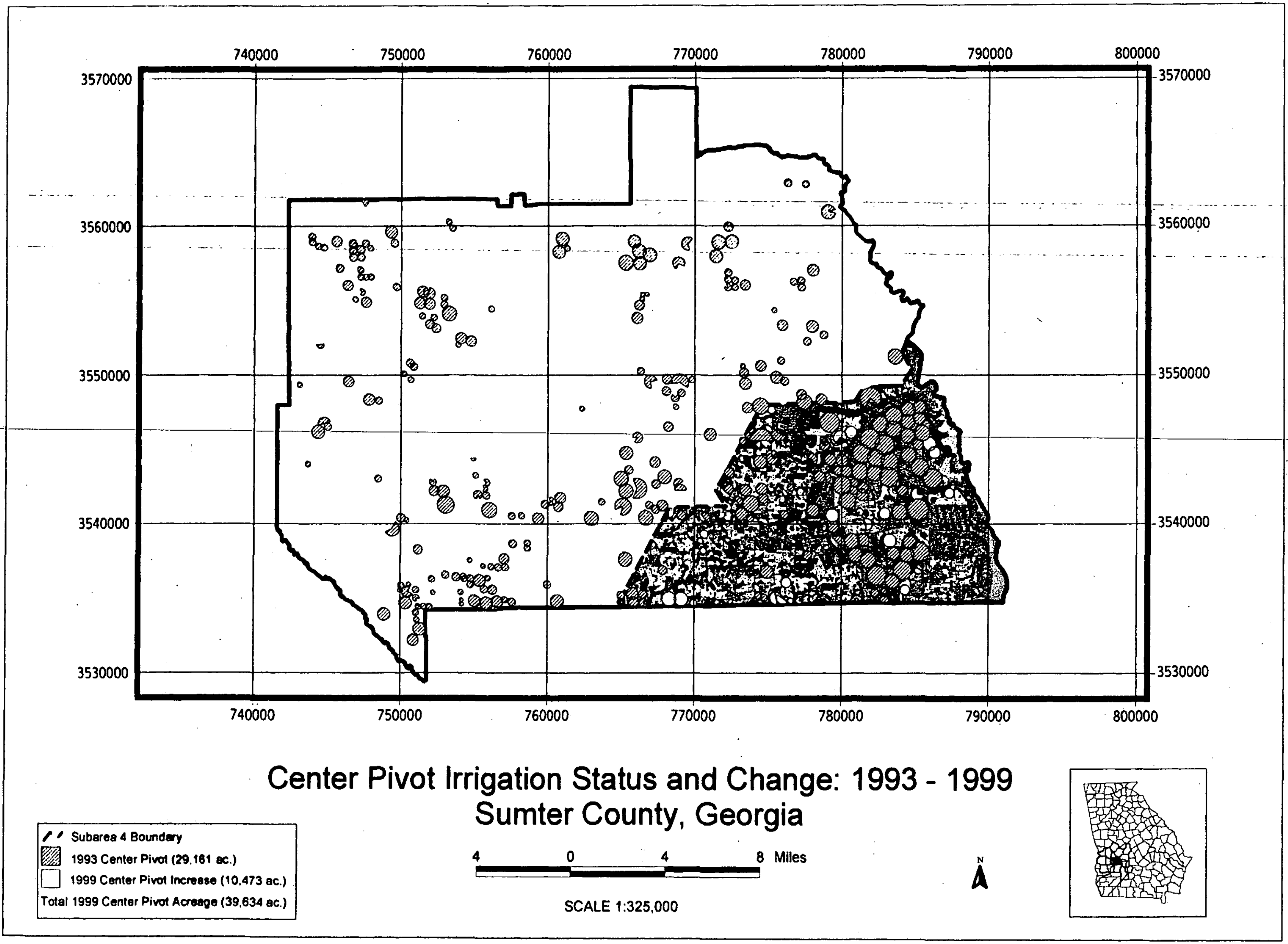
Center Pivot Irrigation Status and Change: 1993 -1999
Seminole County, Georgia

1993 Center Pivot (35,116 ac.)
1999 Center Pivot Increase (10,715 ac.)
Total 1999 Center Pivot Acreage (45,831 ac.)

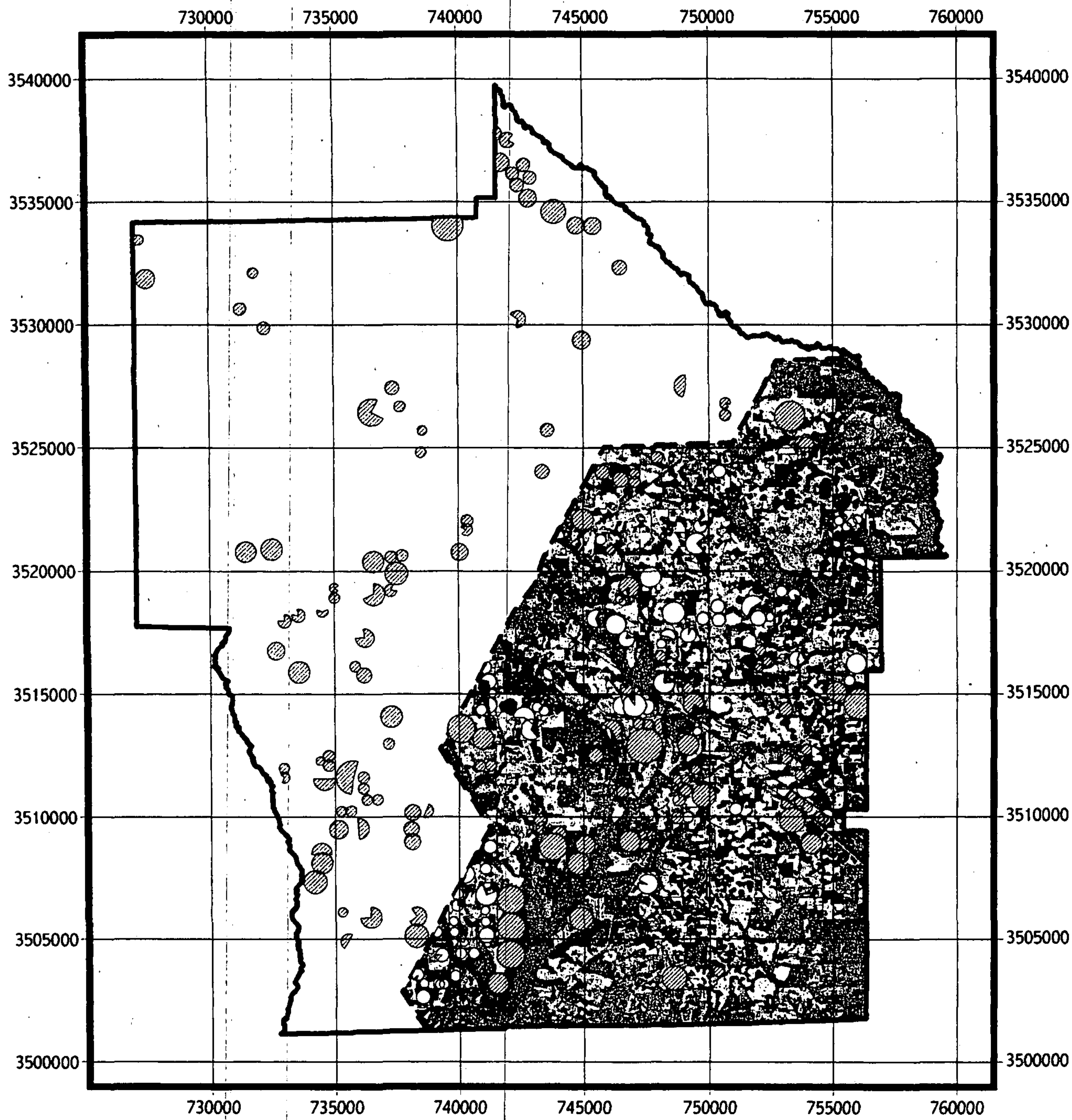
2 0 2 4 Miles

SCALE 1:250,000

N



Center Pivot Irrigation Status and Change: 1993 - 1999
Sumter County, Georgia



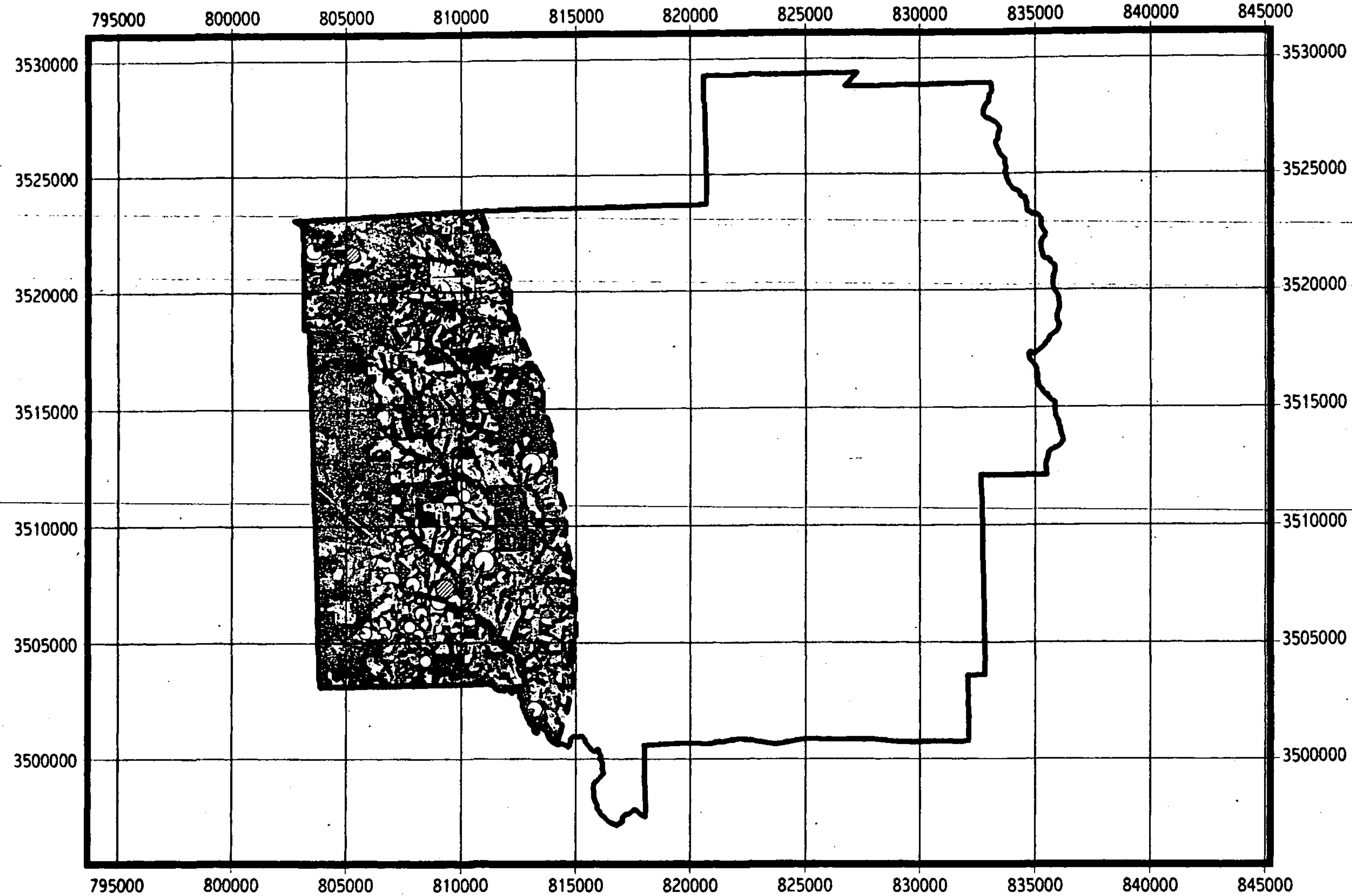
Center Pivot Irrigation and Change: 1993 - 1999
Terrell County, Georgia

3 0 3 6 Miles

SCALE 1:250,000

Subarea 4 Boundary
1993 Center Pivot (12,391 ac.)
1999 Center Pivot Increase (7,450 ac.)
Total 1999 Center Pivot Acreage (19,841 ac.)

N

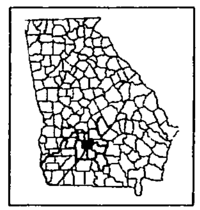


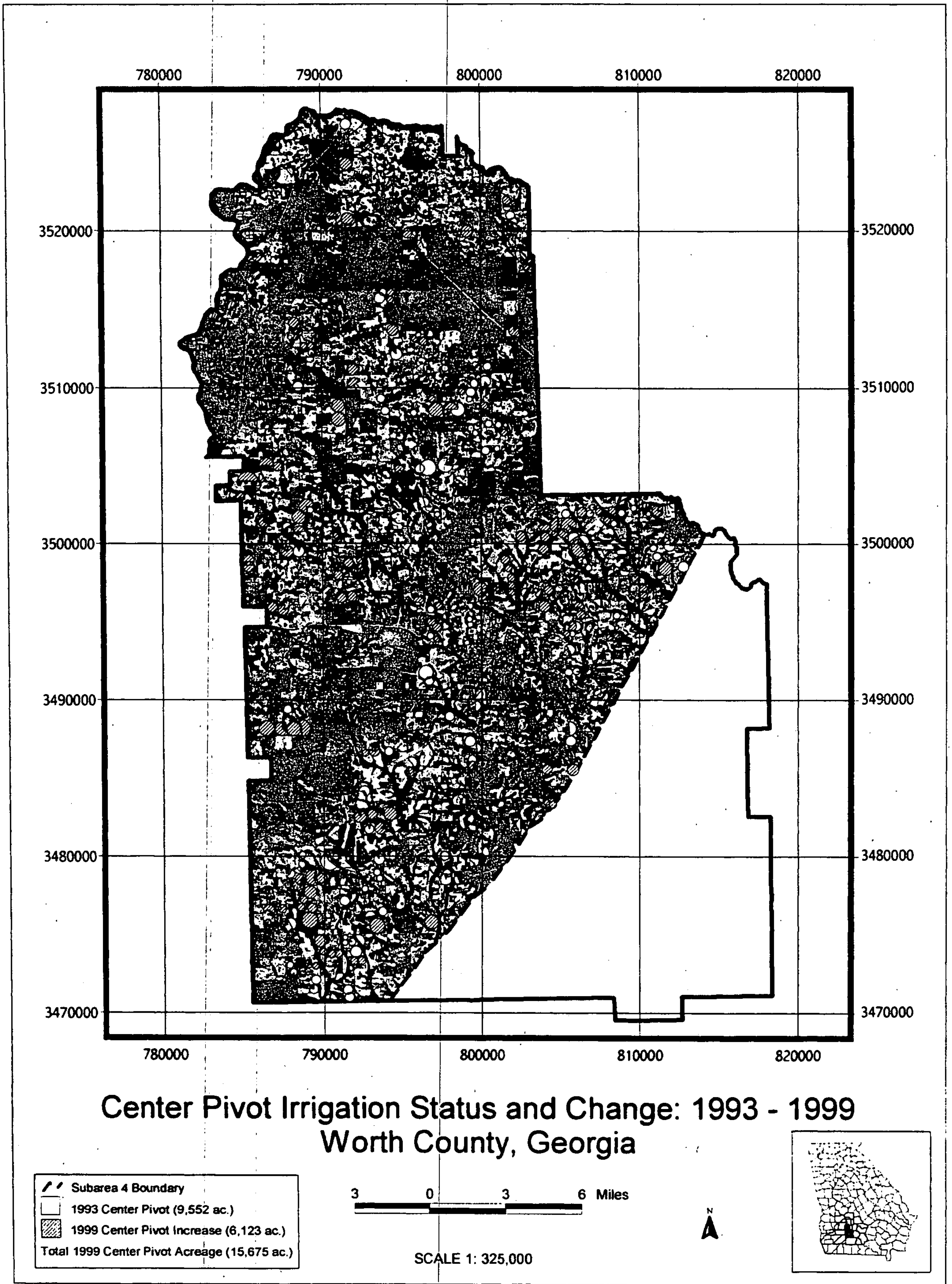
Center Pivot Irrigation Status and Change: 1993 - 1999
Turner County, Georgia

- Subarea 4 Boundary
- 1993 Center Pivot (211 ac.)
- 1999 Center Pivot Increase (1,173 ac.)
- Total 1999 Center Pivot Acreage (1,384 ac.)

4 0 4 8 Miles

SCALE 1: 275,000



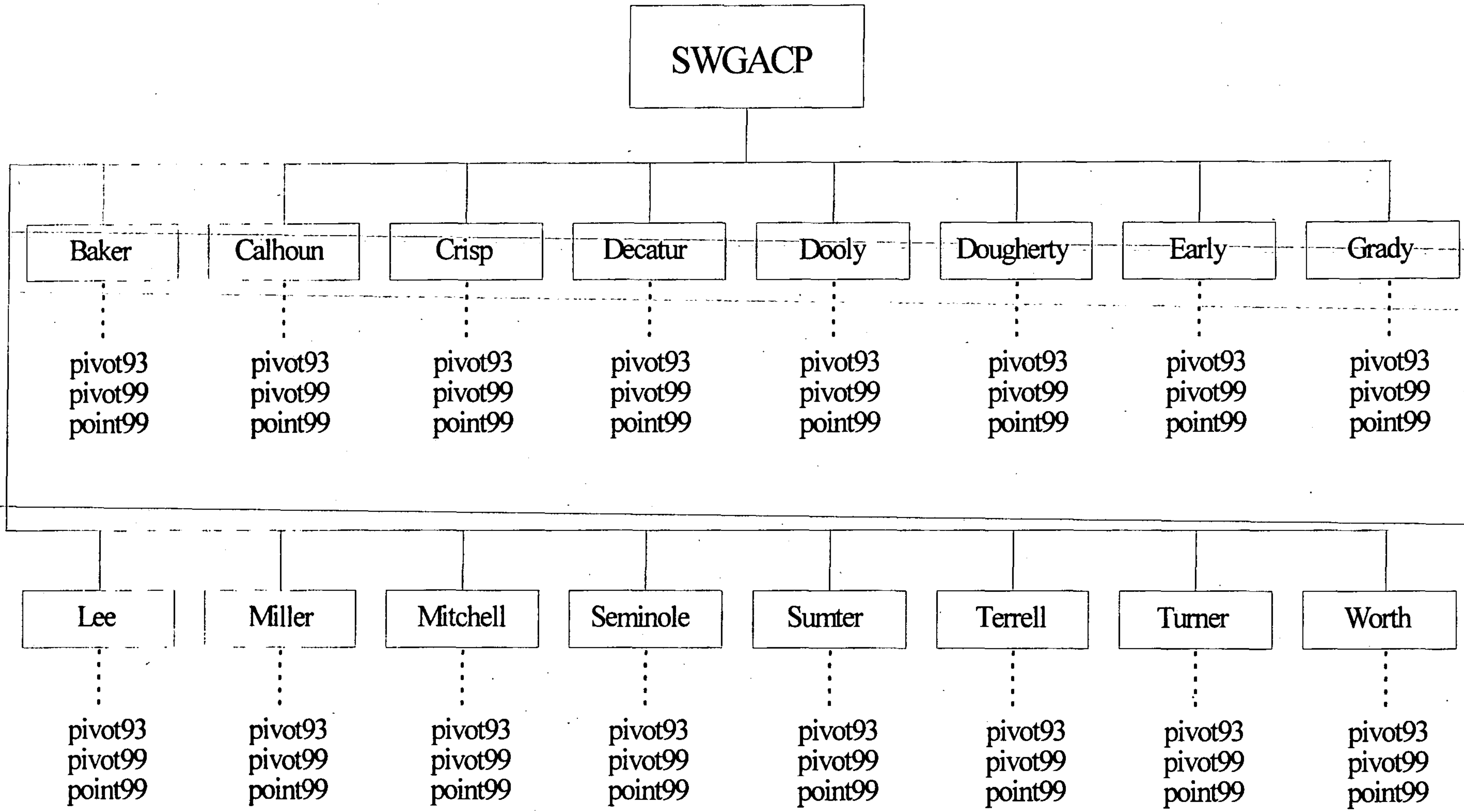


Center Pivot Irrigation Status and Change: 1993 - 1999
Worth County, Georgia

APPENDIX B

Contents:

Data structure of the county-based Arc/Info coverages representing 1993 and 1999 center pivot irrigation sites in the study area.



Pivot93: Center pivot irrigation systems delineated from the 1993 USGS DOQQs.
Pivot99: Center pivot irrigation systems delineated from the rectified 1999 NAPP photos.
Point99: Pivot points of the 1999 center pivot systems.

Coordinate System:
Projection: Universal Trasverse Mercator
Zone: 16
Datum North American Datum on 1983

APPENDIX C

<u>Contents:</u>

Documentation describing the CD-ROMs containing the rectified NAPP photos and forwarded to the Georgia Environmental Protection Division on December 4, 2000.

The University of Georgia

Center for Remote Sensing
and Mapping Science (CRMS)

Roy Welch, Ph.D., Director

December 4, 2000

Mr. Nolton Johnson, Chief
Water Resources Branch
Georgia Environmental Protection Division
Suite 1362 East Floyd Tower
205 Butler Street
Atlanta, Georgia 30334

Dear Mr. Johnson,

Please find enclosed 22 CDROMs containing the rectified 1999 NAPP photographs used to map center pivot irrigation sites under CA-649-999205, Amendment # 1. As per our agreement, the photos were scanned in black and white at 600 dots per inch and rectified to the UTM Zone 16 coordinate system, cast on the North American Datum of 1983. The nominal ground resolution of each image is 1.3 x 1.3 meters. All images are saved in ERDAS LAN format and compatible for use in Arcview GIS Software. A final report describing these efforts will follow shortly.

If you require any further assistance at this time please contact me at (706) 542-2918.

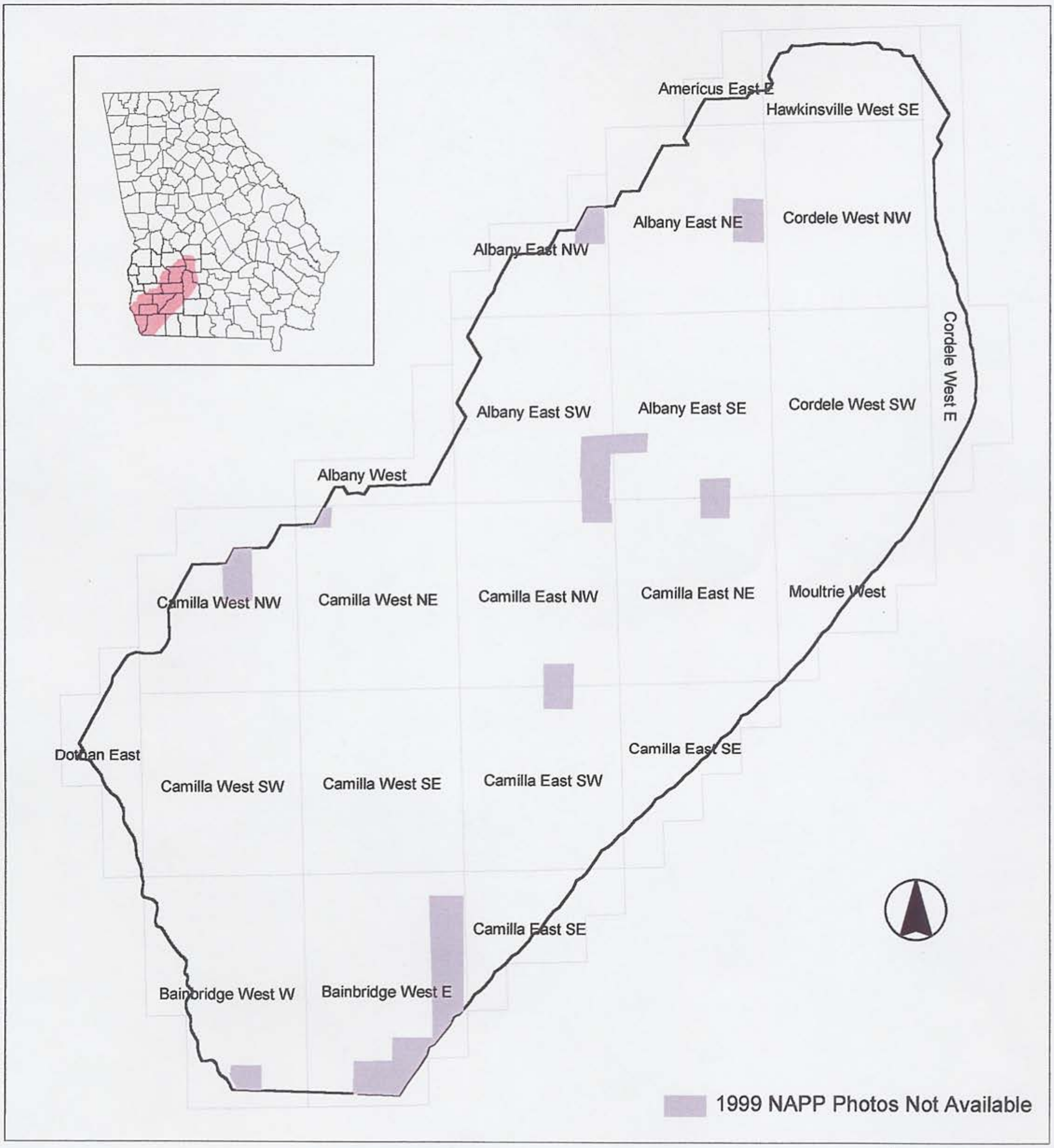
Sincerely,

Dr. Roy Welch, Director
Distinguished Research Professor
Geography, Ecology and Marine Sciences

Enclosures:
CDROM Index and Files

Received by: ____________ Date: 12/5/00

Department of Geography • Athens, Georgia 30602-2503 • (706) 542-2359 • Fax (706) 542-2358



CDROM INDEX

Southwest Georgia Irrigation Mapping Project

Produced by the Center for Remote Sensing and Mapping Science. The University of Georgia, Athens, Georgia. (12/00)

CDROM Index and File List

Albany East NE	Albany East NW	Albany East SE	Albany East SW	Albany W
114_020R.LAN	105_051R.LAN	114_026R.LAN	105_043R.LAN	107_234R.LAN
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114_024R.LAN	109_186R.LAN	114_029R.LAN	105_047R.LAN	
114_067R.LAN	109_188R.LAN	114_032R.LAN	105_049R.LAN	
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115_133R.LAN		115_125R.LAN	109_251R.LAN	
115_137R.LAN		115_127R.LAN	109_253R.LAN	
115_138R.LAN		115_129R.LAN	109_255R.LAN	
		115_131R.LAN		

Americus East E	Bainbridge W E	Bainbridge W W	Camilla East NE	Camilla East NW
115_081R.LAN	106_048R.LAN	110_167R.LAN	114_034R.LAN	105_035R.LAN
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	117_105R.LAN	117_164R.LAN	115_119R.LAN	109_241R.LAN
	117_107R.LAN	117_166R.LAN	115_121R.LAN	109_243R.LAN
	117_109R.LAN	117_168R.LAN	115_123R.LAN	109_245R.LAN
			117_003R.LAN	

Camilla East SE	Camilla East SW	Camilla West NE	Camilla West NW	Camilla West SE
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105_005R.LAN	105_031R.LAN	106_021R.LAN	108_071R.LAN	106_029R.LAN
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109_216R.LAN	109_060R.LAN	106_070R.LAN	117_126R.LAN	107_244R.LAN
109_231R.LAN	109_208R.LAN	107_240R.LAN	117_128R.LAN	107_246R.LAN
114_042R.LAN	109_210R.LAN	107_242R.LAN	117_130R.LAN	109_026R.LAN

CDROM Index and File List

Camilla East SE	Camilla East SW	Camilla West NE	Camilla West NW	Camilla West SE
114_044R.LAN	109_212R.LAN	109_018R.LAN	117_178R.LAN	109_027R.LAN
114_047R.LAN	109_233R.LAN	109_020R.LAN	117_180R.LAN	109_029R.LAN
114_049R.LAN	109_235R.LAN	109_022R.LAN		109_030R.LAN
115_107R.LAN	109_237R.LAN	109_024R.LAN		109_032R.LAN
115_109R.LAN	109_239R.LAN	117_115R.LAN		117_089R.LAN
117_005R.LAN		117_116R.LAN		117_110R.LAN
117_073R.LAN				117_112R.LAN
117_075R.LAN				

Camilla West SW	Cordele West E	Cordele West NW	Cordele West SW	Dothan E
108_059R.LAN	141_014R.LAN	135_015R.LAN	135_023R.LAN	108_046R.LAN
108_061R.LAN	141_016R.LAN	135_017R.LAN	135_025R.LAN	108_048R.LAN
108_063R.LAN	141_018R.LAN	135_019R.LAN	135_026R.LAN	110_147R.LAN
108_065R.LAN	141_020R.LAN	135_021R.LAN	135_028R.LAN	110_149R.LAN
111_014R.LAN	141_022R.LAN	135_096R.LAN	135_029R.LAN	110_151R.LAN
111_016R.LAN	141_024R.LAN	135_098R.LAN	135_088R.LAN	110_153R.LAN
111_018R.LAN	141_025R.LAN	135_100R.LAN	135_090R.LAN	
111_020R.LAN	141_027R.LAN	135_102R.LAN	135_092R.LAN	
117_132R.LAN	141_028R.LAN	135_125R.LAN	135_094R.LAN	
117_134R.LAN	141_030R.LAN	135_127R.LAN	135_133R.LAN	
117_136R.LAN	141_032R.LAN	135_129R.LAN	135_135R.LAN	
117_138R.LAN		135_131R.LAN	135_137R.LAN	
117_170R.LAN		135_206R.LAN	135_139R.LAN	
117_172R.LAN		135_208R.LAN	135_198R.LAN	
117_174R.LAN		135_210R.LAN	135_200R.LAN	
117_176R.LAN		135_212R.LAN	135_202R.LAN	
			135_204R.LAN	

Hawkinsville West SE	Moultry West
135_011R.LAN	135_031R.LAN
135_013R.LAN	135_033R.LAN
135_104R.LAN	135_035R.LAN
135_106R.LAN	135_037R.LAN
135_121R.LAN	135_080R.LAN
135_123R.LAN	135_082R.LAN
135_214R.LAN	135_084R.LAN
135_216R.LAN	135_086R.LAN
	135_141R.LAN
	135_143R.LAN
	135_196R.LAN

APPENDIX D

Contents:

Litts, Thomas, Heather Russell, Adrian Thomas and Roy Welch, 2001. Mapping Irrigated Lands in the ACF River Basin. In: Proceedings of the 2001 Georgia Water Resources Conference, held March 26-27, 2001, at The University of Georgia, Athens, Georgia. Katheryn J. Hatcher, editor, Institute of Ecology, The University of Georgia, Athens, Georgia, pp. 79-83.

MAPPING IRRIGATED LANDS IN THE ACF RIVER BASIN

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REFERENCE: Proceedings of the 2001 Georgia Water Resources Conference, held March 26-27, 2001, at The University of Georgia, Athens, Georgia. Kathryn J. Hatcher, editor, Institute of Ecology, The University of Georgia, Athens, Georgia.

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).

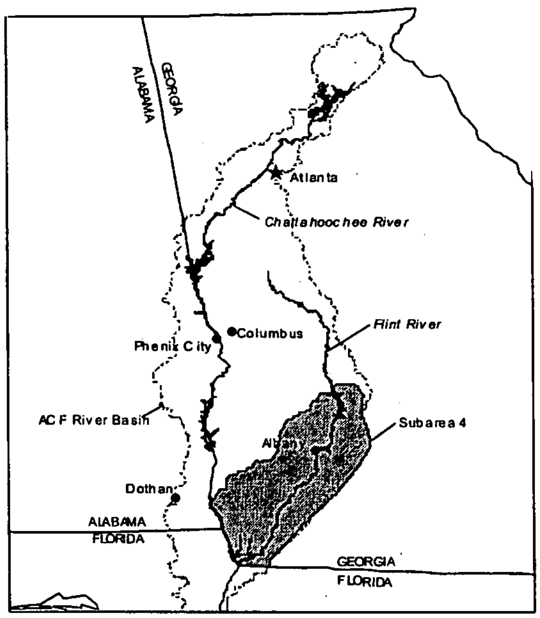

Figure 1. The Georgia portion of Subarea 4 in the ACF River Basin.

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., 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.

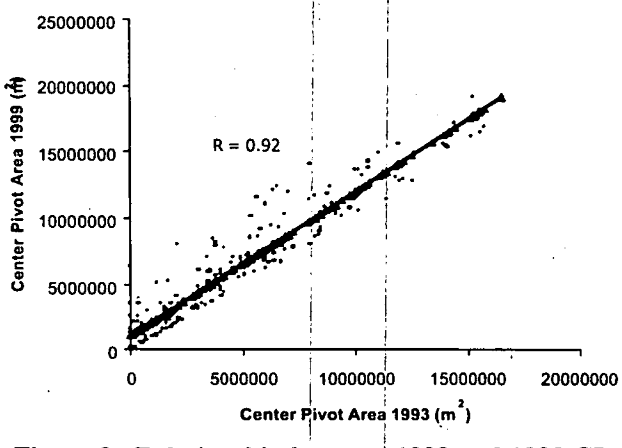

Figure 2. Relationship between 1999 and 1993 CP irrigation acreage.

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.

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.

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.

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.

ACKNOWLEDGEMENT

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