

SPATIAL TEMPORAL ANALYSIS OF SELECTED CYPRESS FORESTS IN SOUTH  
GEORGIA FROM 1988 TO 2013

by

CHARLES LESLEY JORDAN

(Under the Direction of Gary T. Green and Lawrence Morris)

ABSTRACT

Throughout the southern United States there is growing controversy around the perceived increase of cypress being used for low value mulch and declines in cypress use as high value timber that has been associated with overharvest, particularly of young stands of cypress. This research evaluated if and how cypress resources in Georgia have changed in forest type or area over 25 years and if results from a survey of Georgia landowners and Georgia forestry professional's perceptions of cypress trends in Georgia are consistent with the results of these analyses. Results from a temporal analysis of the study area bordering Pierce and Brantley Counties, GA using ISODATA unsupervised classification of aerial photographs indicate a slight decline in cypress resources in southern Georgia, while a temporal analysis of Landsat TM imagery indicated an increase in cypress. Results, while limited by high variability, tend to confirm perceptions of cypress resources from the survey.

INDEX WORDS: CYPRESS, FORESTRY, GEORGIA, LANDSAT, UNITED STATES

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A Thesis Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment  
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## CHAPTER 1

### INTRODUCTION

Throughout the southern United States cypress use and regeneration is of concern. A growing controversy around the increase in use of cypress for low-value mulch and a decline in cypress use for lumber has resulted in a perception that young cypress stands are being overharvested. This has prompted the need for research on changes in the cypress resource (Brown, 2009). A review of research on Georgia's cypress resource, conducted from May 2013 to October 2013 at the Warnell School of Forestry and Natural Resources in the University of Georgia, suggested that natural cypress regeneration occurs well on some sites while it does not on others (Morris, Jackson Ogden, Jordan, 2013). Cypress typically grows in freshwater wetlands (Mattoon, 1915), and it can be hard to accurately measure and evaluate the current state of an isolated cypress forest. Mapping, using aerial photography and satellite-based sensors is a common way to map forests that are hard to reach (Welch, Madden, & Doren, 1991). Using computer based mapping technology it is possible to gain accurate measurements and data about wetland forests while also saving time and money on field mensuration (Huguenin, Karaska, Blaricom, & Jenson, 1997; Everitt, Yang, Fletcher, Davis, & Drawe, 2004),

Pond cypress (*Taxodium ascendens*) and bald cypress (*Taxodium distichum*) require a specific sequence of conditions to regenerate naturally. Cypress seeds must germinate during periods of low water on moist ground. Following germination, periodic flooding and drying creates the ideal environment for cypress seedlings to thrive, as long as flood waters do not cover the seedlings or last too long (Demaree, 1932). Cypress is one of the few conifers that has the

ability to sprout new growth from cut stumps (Wilhite & Toliver, 1990). However, conditions must be favorable for stump sprouting and, oftentimes, stump sprouts only occur at one-quarter to one-half of original stand density (Randall, Duryea, Vince, & English 2005). Following sprouting from seed or stump sprouts, cypress requires full sunlight to thrive because they have a low tolerance to shade (Mattoon, 1915). The need for full sun can result in succession towards a mixed forest of bay, swamp tupelo, or swamp maple if adequate sunlight and appropriate hydrological conditions are not available (Hamilton, 1982; Conner, Toliver, & Sklar, 1986; Casey & Ewel, 2006).

Human changes to the natural environment, such as the building of dams, canals, and dikes, or river re-routing can be very detrimental to the success of natural cypress regeneration. The resulting hydrological changes from re-routing water flow or backing up water flow can reduce cypress seed germination and sprouting (Conner & Toliver, 1990; Keim et al., 2006; Palta et al., 2012). However, cypress stump sprouts have been found to grow well in flooded areas (Keim et al., 2006) when cut at or near mean high water level (Randall et al., 2005). Due to changing hydrology in the swamps where cypress grow, it has been found that planting of cypress seedlings is necessary in most environments to successfully regenerate cypress forests after harvesting (Conner & Toliver, 1990; Lundberg et al., 2011; Randall et al., 2005).

Research has been conducted on the most time and cost efficient ways of planting cypress seedlings grown in nurseries (Lundberg et al., 2011; Williston, Shropshire, & Balmer, 1980). Lundberg et al. (2011) found planting 80% bare root seedlings and 20% potted seedlings to be the most cost effective way to plant cypress. Potted seedlings are more expensive than bare root seedlings, require more time to plant, but have a higher chance for survival. Bare root seedlings

take less time to plant and are cheaper, but survival is more variable and can often be very low (Lundberg et al., 2011).

Bettinger (2011) recently completed an evaluation of 100 independent cypress domes in Brantley County, GA using geospatial techniques with aerial photographs. Bettinger found cypress domes in the Brantley County study area decreased in area an average of 22% from 1940 to 2007. In conclusion he stated “It would seem that a much more expansive assessment would be the next step in determining whether these changes are locally influenced or regionally pervasive given change in the socioeconomic character of the southern United States over this same period of time. Thus, a broader distribution of samples will be necessary to determine whether the trends and relationships noted here hold true throughout the natural range of the cypress resource” (Bettinger, 2011, p. 576).

### **Purpose and Objectives**

This research examined how selected cypress forests in South Georgia have changed, if at all, over the past 25 years and if the perceptions of landowners and professionals on the status of the cypress resources from a survey completed by Morris et al. (2013) are congruent with the results of these analyses. Specific objectives are to:

1. Using geospatial techniques with historical and current aerial photography, measure area of cypress stands within Pierce and Brantley Counties, Georgia, in 1980s, 1990s, 2000, 2013;
2. Measure cypress stand acreage change over the 25-year time period;
3. Compare results of cypress stand measurement to results from questionnaires sent to GA landowners and registered forestry professionals measuring their perceptions of the cypress resource.

## **Study Area**

The study area for this research covers approximately 94.5 km<sup>2</sup> located near Hoboken, GA, USA between Pierce and Brantley Counties (Figure 1). This area was selected for its variety of land cover types including developed, agriculture, on-going timber management, swamp, and scattered cypress forests (figures 2 and 3). The climate is typical of southern Georgia. In the winter months average lows are in the high 30's F to low 40's F with highs in the mid 60's F to low 70's F. In the summer months, temperatures range from the low 70's F to mid 90's F. Average annual precipitation is 50.44 inches, with the wettest month being August. Elevation for this area is 15 to 43 m above sea level. Soils in this area are commonly mapped in coastal plains and range from thermic Fluvaquentic Endoaquepts to thermic Cumulic Humaquepts. These soils tend to be poorly to very poorly drained clay soils, with periods of flooding and slopes of 0 to 2 percent (NRCS Web Soil Survey, n.d.).

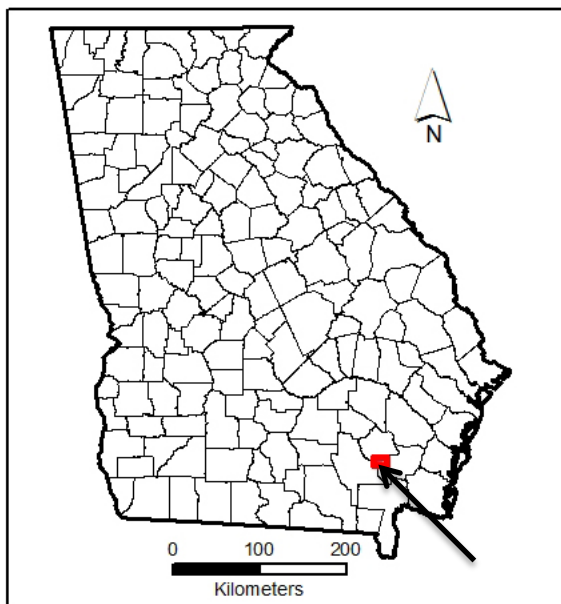


Figure 1.  
Location of Study Area in Southern Georgia,  
USA on the Border Between Pierce and  
Brantley Counties, Near Hoboken, GA.

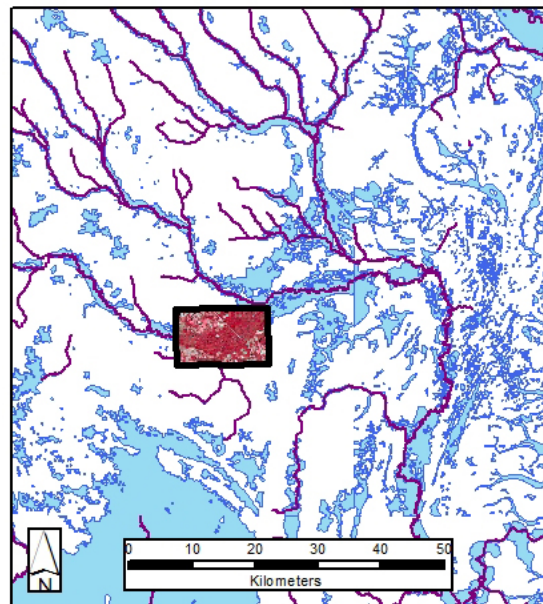


Figure 2.  
Inset Map of Study Area with Rivers and  
Water Bodies

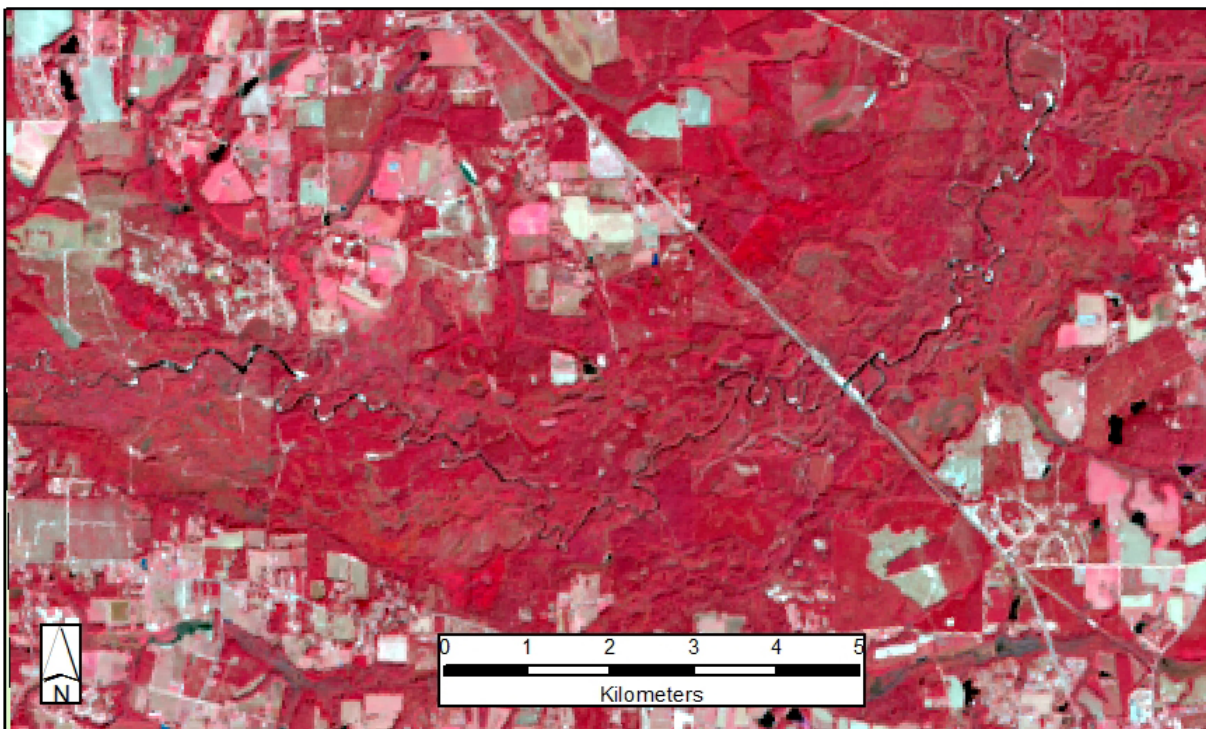


Figure 3. Color Infrared Landsat 8 Image of Study Area on March 17, 2013.

## CHAPTER 2

### LITERATURE AND SURVEY REVIEW

#### **Current Status of Cypress**

Cypress thrives in seasonally flooded environments of freshwater marshes and swamps and can be found naturally throughout the Southern United States (U.S.) The natural range of cypress (Figure 4) is from Texas following the Gulf of Mexico to the Atlantic Ocean to Virginia and up the Mississippi River to as far north as Illinois (Williston et al., 1980; Mattoon, 1915).

The U.S. Department of Agriculture, Forest Inventory Analysis (FIA) classification system classifies cypress within the cypress-tupelo class. The current FIA cypress classification contains both pond cypress and bald cypress. The forest type codes used in the 2008 and the 2010 FIA Cypress fact sheet are 607 for bald cypress/water tupelo and 609 for bald cypress/pond cypress. Code 607 contains 25 to 50% cypress and code 609 contains greater than 50% cypress. Both classification codes were combined to form the cypress-tupelo classification because the exact density of cypress could not be confirmed from the data used (Greis, Brown, & Bentley, 2012).

In the Southern U.S. (Alabama, Arkansas, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia) there are roughly 3.4 million acres of cypress-tupelo timberland with the majority being in Florida and Louisiana. In 2010, Georgia was estimated to contain 8.4 percent of the total cypress-tupelo acreage in the U.S. with cypress-tupelo making up 1.2 percent of all timberland in Georgia (Greis et al., 2012). The total is approximately 285,600 acres of cypress-tupelo timberland in Georgia. According to

the most recent FIA report (Greis et al., 2012), cypress-tupelo acreage in Georgia has decreased approximately 5 percent between 2005 and 2010. However, cypress volume in Georgia has remained stable between 2005 and 2010 indicating the decline in cypress-tupelo acreage was a result of tupelo being removed or increased cypress volume on remaining acres. Relatively small amounts of cypress timberland in Georgia are publicly owned (11.5% or 32,844 acres) and the remainder (88.5% or 252,756 acres) is privately owned.

Recent increases in the use of cypress for mulch, and the perception that this has resulted in overharvest of cypress stands has created controversy (Brown, 2009; Save Our Cypress Coalition, n.d.). Cypress harvests have fluctuated greatly. Over the eight-year period from 2001 to 2009, there was a five million ft<sup>3</sup> per year decrease in cypress harvests in Georgia. However, the variability among harvests was high. For example, in 2003, 14.5 million ft<sup>3</sup> of cypress was harvested. Cypress harvest declined to 11 million ft<sup>3</sup> in 2005, and declined in 2007 to 10 million ft<sup>3</sup>. In 2009, only five million ft<sup>3</sup> of Georgia's cypress was harvested. Of this five million ft<sup>3</sup> of cypress, 1.9 million ft<sup>3</sup> was processed for mulch and 3.1 million ft<sup>3</sup> was processed into saw logs for lumber (Greis et al., 2012).

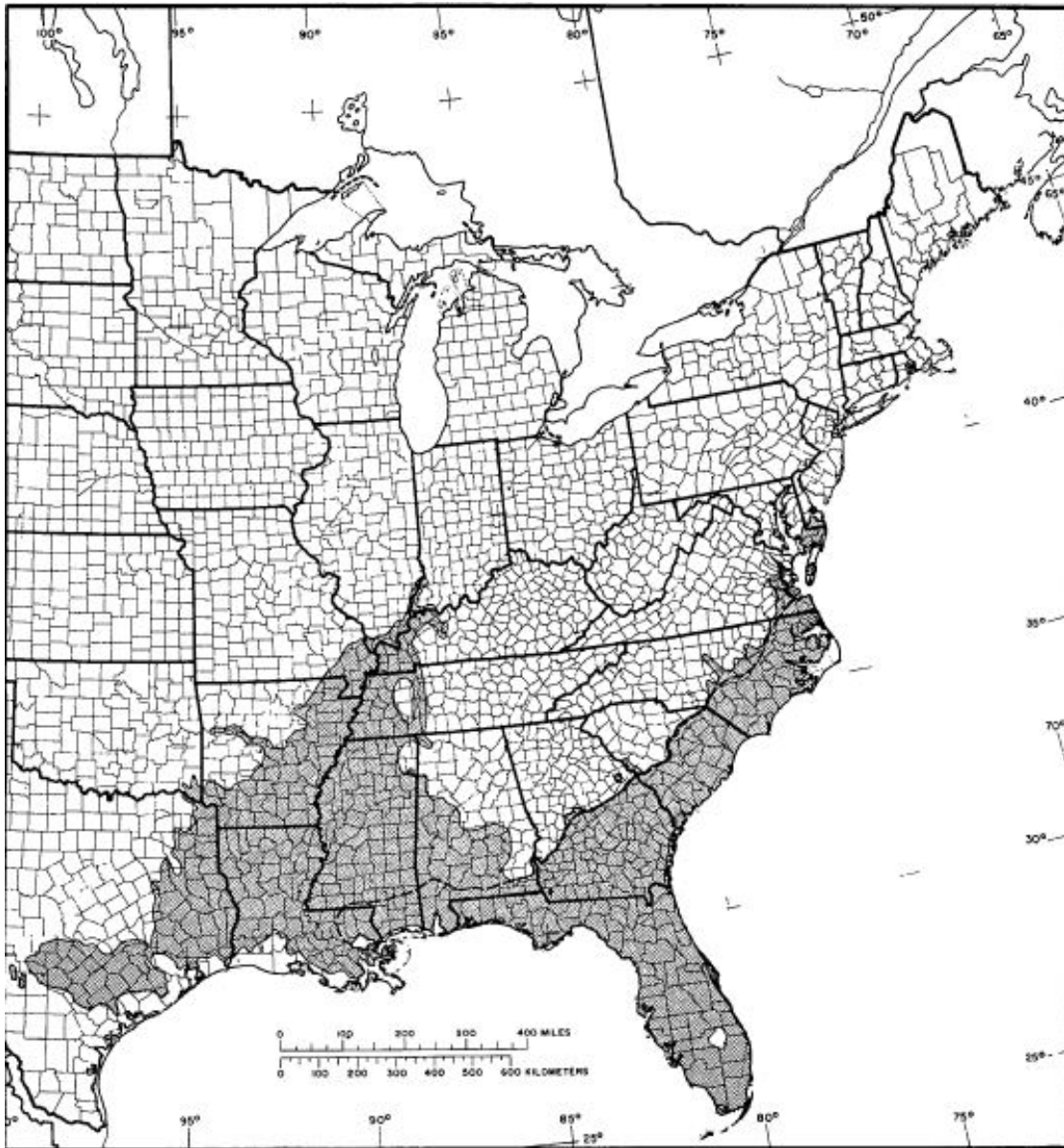


Figure 4. Distribution of Cypress Natural Range in the United States. The Dashed Line Shows the Northernmost Limit of Pond Cypress (Williston et al., 1980).

## Regeneration

Cypress regeneration is well studied (Aust et al., 1997, 2006; Casey & Ewel, 2006; Conner et al., 1986; Ewel et al., 1989; Ewel, 1996; Keim et al., 2006; Randall et al., 2005; Williston et al., 1980). Brown (2009) stated that natural regeneration of cypress will only return 25% to 50% of the stand to pre-harvest cypress stocking levels. Many researchers support this

opinion (Conner, Toliver & Skylar 1986). Conner et al. (1986) studied natural regeneration at a logged cypress stand in Barataria Basin, LA and included four separate stands of bald cypress, which had been logged the previous growing season. Following the first growing season after harvest, logged stands were surveyed for the presence of stump sprouts. Among all four logged stands of bald cypress, 73 to 79% of the stumps had sprouted. From years two and three after harvest, mortality accounted for 75% of all stump sprouts. After the fourth growing season post-harvest 21% of all stump sprouts remained (Conner et al., 1986).

Keim et al. (2006) surveyed stump sprouts in selected bald cypress stands in Louisiana, logged between 10 and 41 years prior to 2006. The survey noted variation in the presence and vigor of stump sprouts among study sites. No examination into a relationship between mortality and site conditions was developed. Researchers found many stump sprouts growing on decaying stumps, indicating sprouts would not grow to become dominant trees (Keim et al., 2006).

### **Vegetation Mapping with Remote Sensing**

Research has also been conducted using computer technology with imagery to classify vegetation. Uses of these techniques vary widely from monitoring agriculture (Rembold et al., 2013) to assessing amounts of fuel for wildfires (Mallinis et al., 2014). The main two sources of remotely sensed imagery for vegetation mapping are aerial photographs and satellite imagery. Aerial photographs are images taken from an aircraft, typically resulting in high-resolution products for detailed mapping. Satellite images are images taken from satellites orbiting the earth at around 900 km nominal altitude (Lillesand et al., 2004). Mapping wetlands can be challenging when taking field-based measurements. Remote sensing approaches are particularly useful for mapping wetland areas due to the difficulty in accessing and completing field-based

measurements (Welch et al., 1999). Wetlands are an important natural resource due to the diversity of species, and functions in ecosystems (Casey & Ewel, 2006).

Aerial photography has been used to conduct an extensive mapping effort in south Florida's Everglades National Park and Big Cypress National Preserve (Welch et al. 1999). The project was not well suited towards using existing satellite imagery due to the high spatial resolution and scale needed to discern details. Aerial photographs captured in color infrared were flown at a scale of 1: 40,000 in January, March and December of both 1994 and 1995 by the U.S. Geological Survey (USGS) for the National Aerial Photography Program (NAPP). For the purposes of classification and accurate mapping, aerial photographs were enlarged to 1: 10,000 scale prints, approximately  $1 \times 1$  m in size. Manual interpretation was conducted in stereo while viewing the original positive transparencies and tracing cypress patches on clear plastic overlays registered to the enlarged prints. Only the line work was then digitized and georectified using ground control derived from SPOT satellite images (georectified with field surveyed ground control points). The aerial photographs were not scanned due to file size limitations and computer processing speed in 1995. Edited polygons were input to ArcInfo and attributed to create a seamless vegetation digital database that included cypress communities ranging from dwarf cypress in Everglades National Park to cypress strands and domes in Big Cypress National Preserve. Resulting hardcopy map products for the National Park Service were at a scale of 1: 15,000 depicting vegetation coverage as well as off road vehicle (ORV) trails within the 10,000 km<sup>2</sup> study area.

Bettinger (2011) used aerial photographs to investigate if cypress dome characteristics changed over time in Brantley County, GA. Aerial photographs were ideal for this research due to the time period used and spatial resolution needed. Bettinger examined one hundred spatially

independent cypress domes in Brantley County, GA from 1940 to 2007. Spatial resolution of the black-and-white and color-infrared aerial photographs ranged from 0.9 m (1940) to 1 m (2007). The scale used to delineate cypress dome boundaries ranged from 1:2,000 to 1:4,000. Bettinger found about a 22% total decrease in cypress dome cover from 1940 to 2007. In 1940, many of the cypress domes were surrounded by agriculture. From 1940 to 2007 much of the landscape surrounding cypress domes in this study has changed to managed pine plantations. Bettinger (2011) associated the increase in managed pine plantations and decrease of agriculture surrounding cypress domes to changes in cypress dome size and shape (Bettinger, 2011).

The suggested scale for identifying small features and assessing human influence on a landscape is 1: 20,000 (Bettinger, 2011). Bettinger found 1: 20,000 to be inadequate for locating and measuring small cypress domes in Brantley County, GA. To better identify and accurately measure these small features, Bettinger used a scale of 1: 5,000. This scale was said to be a reasonable compromise between efficiency and accuracy for aerial photograph interpretation. Digitizing vegetation with manual interpretation of color-infrared aerial photographs is time intensive, but allows for knowledge and experience to play a role in determining the vegetation classes (Everitt et al., 2004; Welch et al., 1999).

Satellite imagery is often in a raster (pixel based) format, which allows for unsupervised or supervised classification of vegetation and land cover based on reflectance values of the target areas. Based on a specific spectral signature, computer algorithms are used to discern differences in the brightness values of individual pixels in multiple spectral bands and similar pixels are classified in the same class. Following unsupervised classification, users must manually classify the classes created by the computer based on what type of vegetation is present and classify it as such. Supervised classification techniques rely on users to create training samples of target

vegetation or land cover, which a computer then uses to classify an image (Bolstad, 2013; Campbell & Wynne, 2011; Lillesand et al., 2004).

Huguenin et al. (1997) published a study examining the use of subpixel classification techniques for use with Landsat Thematic Mapper (TM) imagery. Landsat TM imagery is typically used for analyzing land cover over large areas due to the data being free and widely available, with each image covering 34, 225 km<sup>2</sup> (185 × 185 km). Pixel size of Landsat TM imagery is 30 m by 30 m, making it challenging to assess detail within a pixel. Subpixel image classification methods can be used when the land cover smaller than one pixel needs to be known. Subpixel classification allows a user to identify materials of interest (MOI) within a pixel if the MOI covers at least 20 percent of the pixel. Huguenin et al. (1997) used subpixel processing to examine bald cypress and tupelo gum trees in South Carolina and Georgia. Classification defined pixels containing 70 percent cypress and 30 percent tupelo as mixed cypress-tupelo. Many of the pixels that contained cypress also contained tupelo, supporting Huguenin et al. (1997) in their decision to use subpixel classification due to mixed pixels. Resulting accuracy from classification was very good, with cypress at 89 % total species accuracy and tupelo at 91% total species accuracy.

In 2009, Wang and Lang published a study focusing on subpixel classification of Landsat 7 ETM+ imagery to detect cypress canopies in Florida's panhandle. Using ERDAS Imagine's Subpixel classification tool they were able to accurately classify cypress forests in their study area. One research objective was to see if signatures derived from one scene could be applied to another scene with any accuracy. Results indicated signatures could be applied elsewhere with caution (Wang and Lang, 2009).

Everitt et al. (2004) used color-infrared aerial photographs and QuickBird satellite imagery to map the wetland vegetation of a marsh approximately 30 miles north of Sinton, TX. The purpose of this study was primarily to identify light reflectance characteristics of major plant species in the area, and secondly to assess differences in the accuracy of the two different methods of vegetation mapping, ISODATA and manual air photo interpretation. Using the Iterative Self Organizing Data Analysis (ISODATA) technique of unsupervised classification, the authors achieved an overall accuracy of 69.0%. Using air photo interpretation techniques the authors achieved an overall accuracy of 87.0%. Leading to the conclusion that manual air photo interpretation techniques have the potential to be more accurate than unsupervised ISODATA classification of satellite imagery (Everitt et al., 2004).

### **Mapping of Temporal Changes in Cypress and Other Vegetation**

Limited geospatial research has been conducted on changes in cypress stands over time to determine how well stands grow back after harvest, or how they change naturally. In the previously described study of Bettinger (2011) aerial photographs with a spatial resolution of 0.9-m were used to study how cypress domes in Brantley County, GA changed between 1940 and 2007. Species composition within the domes was unclear due to black and white photographs and were all classified as cypress domes. Bettinger (2011) found a 22% average decrease in cypress dome area. Even though the overall area had decreased, the shape of domes stayed the same. As Bettinger explained, the cypress domes selected in Brantley County, GA were surrounded by agriculture in 1940's, which gradually changed to commercial forestry by 2007. Fire can drastically change the species composition of cypress domes by destroying roots and seeds, leading to the presence of other hardwoods or invasive species. However, controlled fire around the edges of drier cypress domes can be used to keep out unwanted species of

vegetation. Recent changes in land ownership from timber companies to private parties and real estate investment trusts has the potential to change the future of cypress domes in the South. When cypress domes are drained to increase acreage for development, succession towards red maple or Chinese privet is possible (Bettinger, 2011).

### **Landowner and Professional Forester Knowledge and Perceptions of Cypress**

Morris et al. (2013) developed a survey for Georgia forest landowners addressing attitudes, perceptions, and forest practices used in cypress management (Appendix A). They mailed these surveys to 1,414 Georgia landowners and had a response rate of 37.7%. The amount of land owned ranged from an acre to thousands of acres in Georgia. Many landowners did not report having any cypress present on their property (340 respondents), while 122 respondents reported having pond cypress and/or bald cypress on their property. Based on Greis et al. (2012) estimate of Georgia's cypress resources these 122 landowners own 17.2% of cypress acreage in Georgia. Respondents to this survey owned their land for an average of 30 years and ranged in age from 51 to 70 years old (Morris et al., 2013).

Responses from questions regarding cypress harvests varied on the 2013 Cypress Survey of Georgia landowners. Only 24 of the 122 respondents with cypress on their property reported having cypress harvested. Harvests of cypress occurred opportunistically when adjacent stands of other trees were being harvested and consisted of cypress and bottomland hardwoods or cypress mixed with pine. Landowners (75%) reported having harvested cypress stands once during their period of ownership or memory. When asked if they believed cypress acreage has changed in the past 10 years, landowners reported they believed that cypress acreage has not increased in the last 10 years and roughly one-third believe there is less cypress production now than in the past 10 years (Morris et al., 2013).

Morris et al. (2013) also developed a survey for Georgia forestry professionals addressing attitudes, perceptions, and forest practices used in cypress management (Appendix C). They mailed these surveys to 344 Georgia forestry professionals living in the Lower Coastal Plain counties of Georgia and had a response rate of 35% (117 respondents) for registered foresters who may encounter cypress on their client's property. Seventy-eight of the registered foresters reported there is no cypress on the properties they currently manage. Thirty-nine of the registered foresters reported they do currently manage properties from 70 acres to thousands of acres that do contain pond cypress and/or bald cypress. According to Greis et al. (2012), Georgia's cypress resource is estimated to be 285,600 acres, and these 39 registered foresters account for all cypress acreage in Georgia. Respondents to this survey had been managing or consulting property for over 20 years and ranged in age from 51 to 70 years old (Morris et al., 2013).

Responses from the 2013 Cypress Survey of Forestry Professionals involving cypress management varied. Twenty-seven of the 39 forestry professionals involved with the cypress management indicated they have been a part of a cypress harvest in the past 10 years. Similar to the Georgia landowners, the forestry professionals reported harvesting cypress from mixed stands of bottomland hardwoods or cypress mixed with pine during the harvest of another mixed stand. Since 2003, these harvests account for 29,235 acres of bald cypress and 14,225 acres of pond cypress and 1,615 acres of mixed cypress in Georgia. Many of the forestry professionals in Georgia (87.2%) believed that cypress acreage has stayed stable or decrease in the past 10 years, and 84.6% of respondents believed that the availability of cypress stumpage has remained stable or declined over the past 10 years (Morris et al., 2013).

## CHAPTER 3

### METHODOLOGY

#### **Data Sources**

The National Map archive operated by the United States Geological Survey (USGS) has a number of maps and data available for public download. Subsequently, the majority of data used in this research was attained through the National Map archive (satellite imagery, NAPP, and NAIP air photos), the University of Georgia Map Library Archives (NAPP) or through the Georgia GIS clearinghouse (DOQQ air photos, counties, state boundaries and hydrology layers). Data from surveys of Georgia landowners and forestry professionals were gathered in Fall 2013 as a part of a project funded by the National Council for Air and Stream Improvement (NCASI). Final results from the landowner and forestry professional survey completed by Morris et al. (2013) were analyzed and compiled into a final professional report submitted to NCASI in March 2014. Results from this report will be used in the discussion section of this thesis.

#### **Aerial Photographs**

Cypress is most clearly discriminated from other species on color infrared (CIR) aerial photographs (Madden et al., 1999). CIR Images are available from National Aerial Photography Program (NAPP) aerial photographs, USGS Digital Orthophoto Quadrangle (DOQ), Quarter Quadrangle (DOQQ) aerial photographs, and National Agriculture Imagery Program (NAIP) images. All data were downloaded from the National Map database operated by the USGS or from the Georgia GIS Clearinghouse hosted by the Georgia Institute of Technology and the University of Georgia Map Library. Imagery (Table 1) consisted of CIR NAPP for 1988 (Figure

5), CIR DOQQs for 1999 (Figure 6), and four-band NAIP for 2010 (Figure 7). The scanned NAPP photos from 1988 were downloaded without spatial reference information, and required georeferencing before any analysis could be completed.

The NAPP images are taken at 1:40,000 scale on either black-and-white (panchromatic) or CIR film, scanned with 1-m spatial resolution, and made available for download without spatial reference data attached (USGS National Aerial Photography Program, n.d.). The DOQs and DOQQs are aerial photographs that have been scanned, georeferenced, corrected for terrain relief and camera tilt. DOQs are referred to as 7.5-minutes, meaning they cover an area of 7.5-minutes of longitude and 7.5-minutes of latitude corresponding to a standard 1:24,000 scale USGS topographic quadrangle map. The DOQQs are 3.75-minute quarter-quads, so they cover an area of 3.75-minutes longitude and 3.75 minutes latitude and correspond to one quarter of a USGS topographic map. Both DOQ and DOQQ products have 1-m spatial resolution and have planimetric accuracy of approximately 3 to 4 meters (USGS Digital Orthophoto Quadrangle, n.d.). The NAIP is four-band leaf-on imagery acquired by the USDA's Farm Service Agency, at a spatial resolution of 1-m (National Agriculture Imagery Program, August, 2013).

Table 1.  
*Aerial Photography Used for Classification and Temporal Analysis*

Year	1988	1999	2010
Imagery Date	02/16/1988	02/07/1999	09/10/2010
Imagery Type	NAPP	USGS DOQQ	NAIP
Location	Hoboken, GA	Hoboken, GA	Hoboken, GA
Pixel Size (m)	1-m	1-m	1-m
Coordinate System	NAD_83_UTM_zone_17N	NAD_83_UTM_zone_17N	NAD_83_UTM_zone_17N
Number of Bands	3	3	4

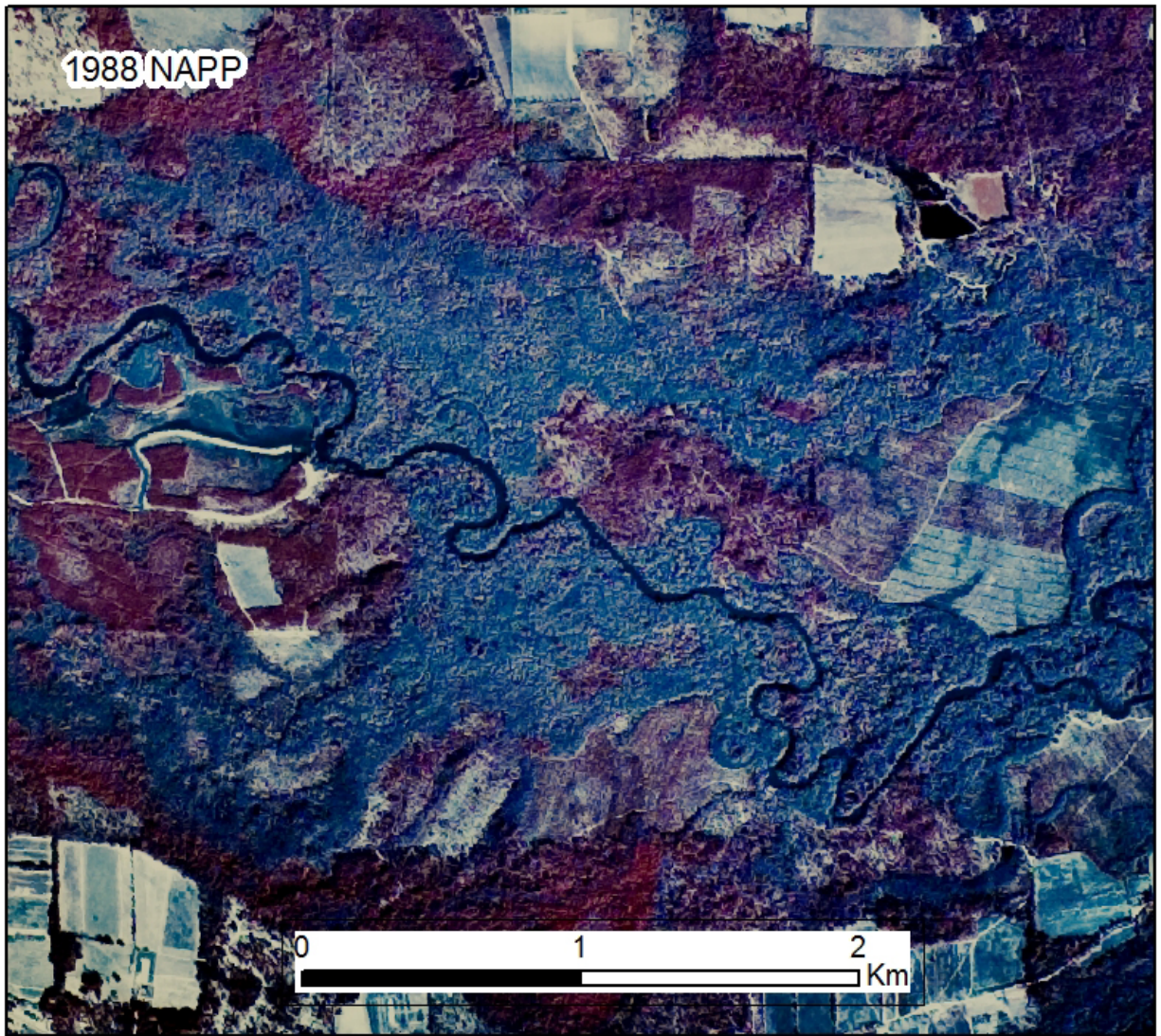


Figure 5. 1988 CIR NAPP Subset, Hoboken, GA

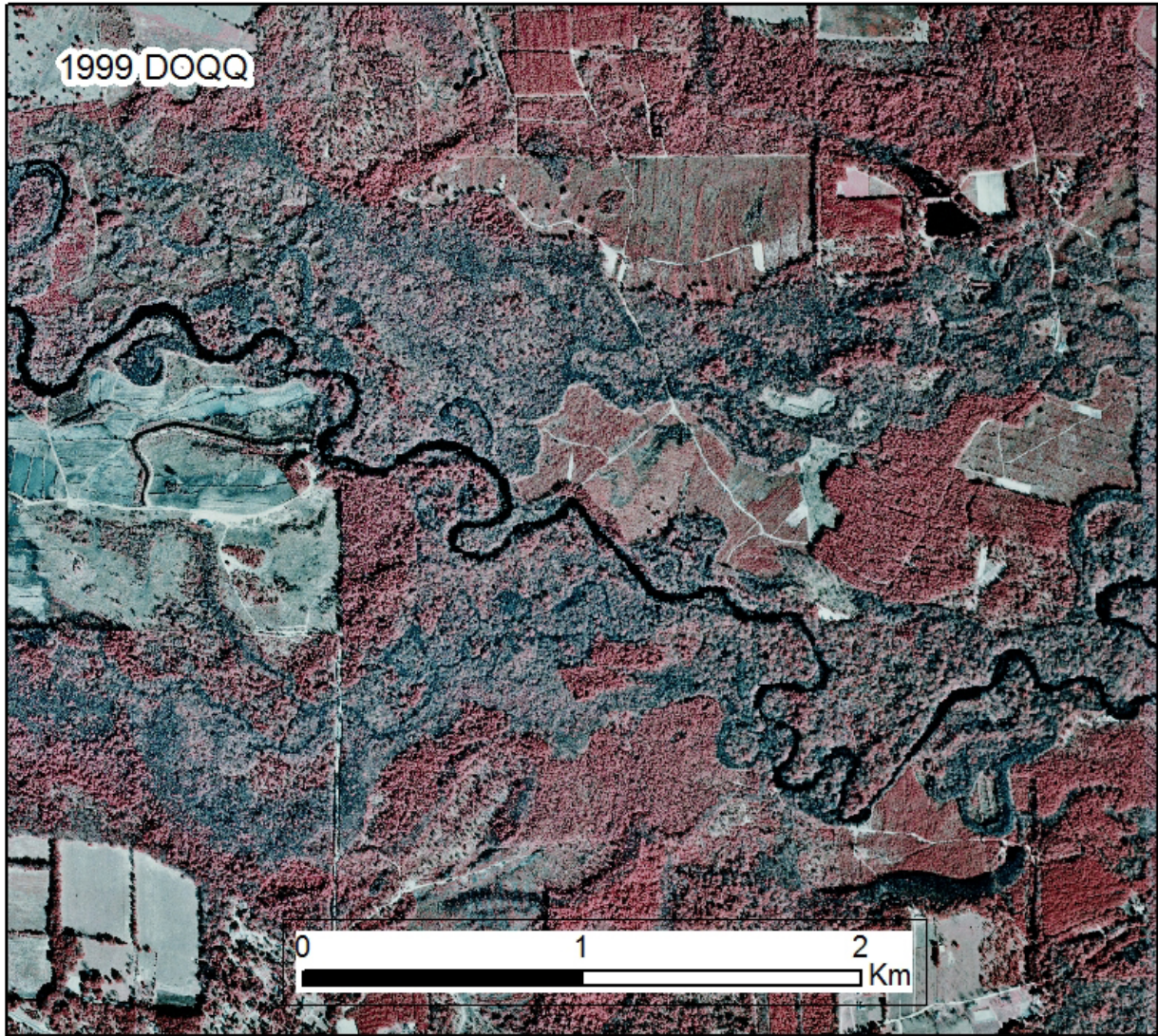


Figure 6. 1999 CIR DOQQ Subset, Hoboken, GA

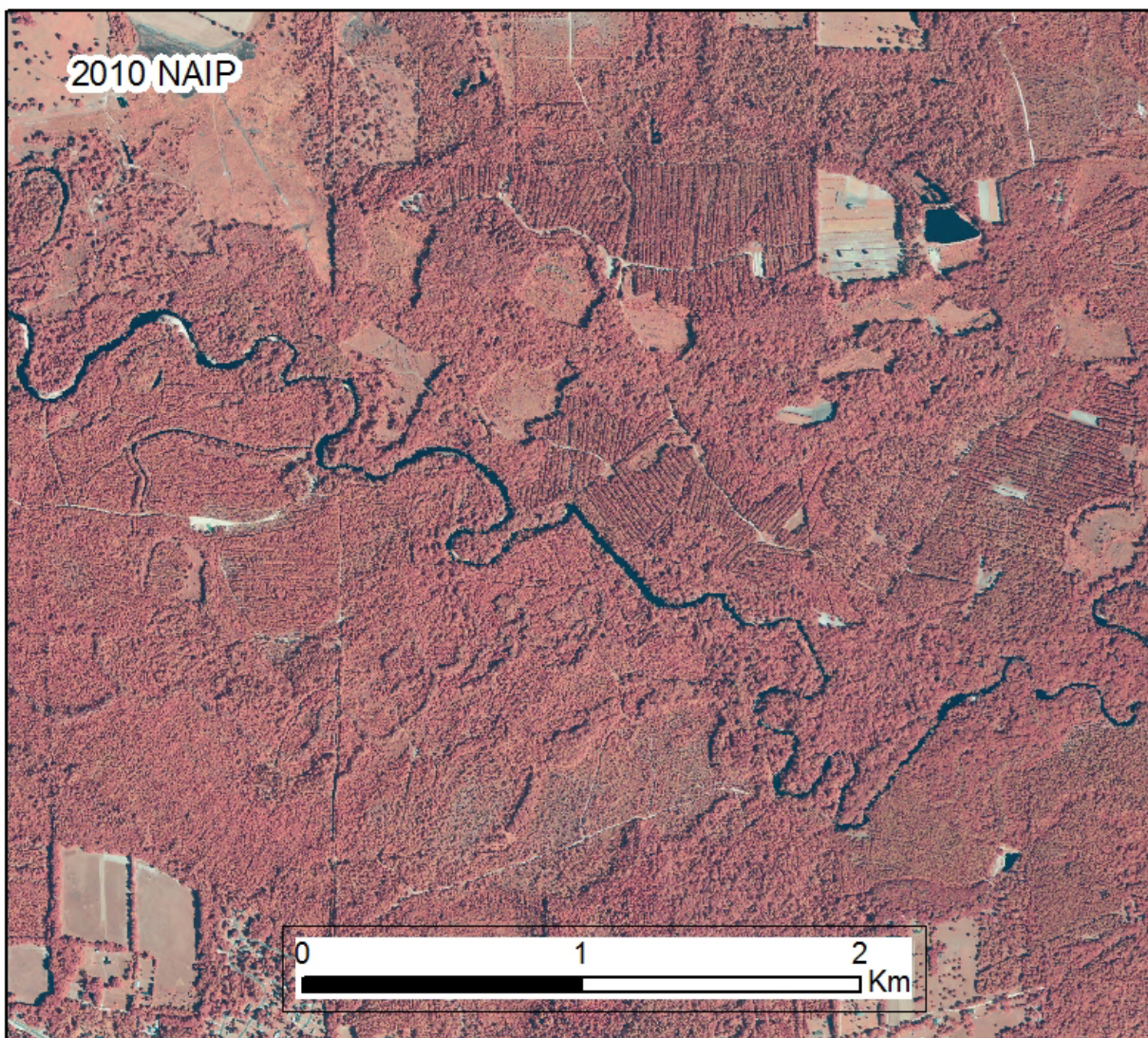


Figure 7. 2010 4-Band NAIP Subset, Hoboken, GA

## Satellite Imagery

Satellite imagery of high spatial resolution on the order of 1 to 5-m pixel sizes has improved since the first imaging satellite, Corona, and has become available to the public (Bolstad, 2012; Jensen, 2007). High-resolution satellite imagery (Ikonos, Quickbird, GeoEye) has been available since 1999, but is expensive to acquire and does not have the temporal availability for this project. Landsat TM imagery is available for free download for the National Map over a wide variety of dates. There have been eight Landsat missions, and data are available from Landsat 1 starting in 1972 (Figure 8). However, the spatial resolution of Landsat satellite image data from missions one through three at 80 meters and Landsat missions four through eight at 30 meters may not be adequate for mapping small isolated cypress stands in confidence (Lillesand et al., 2004; Welch et al., 1999).

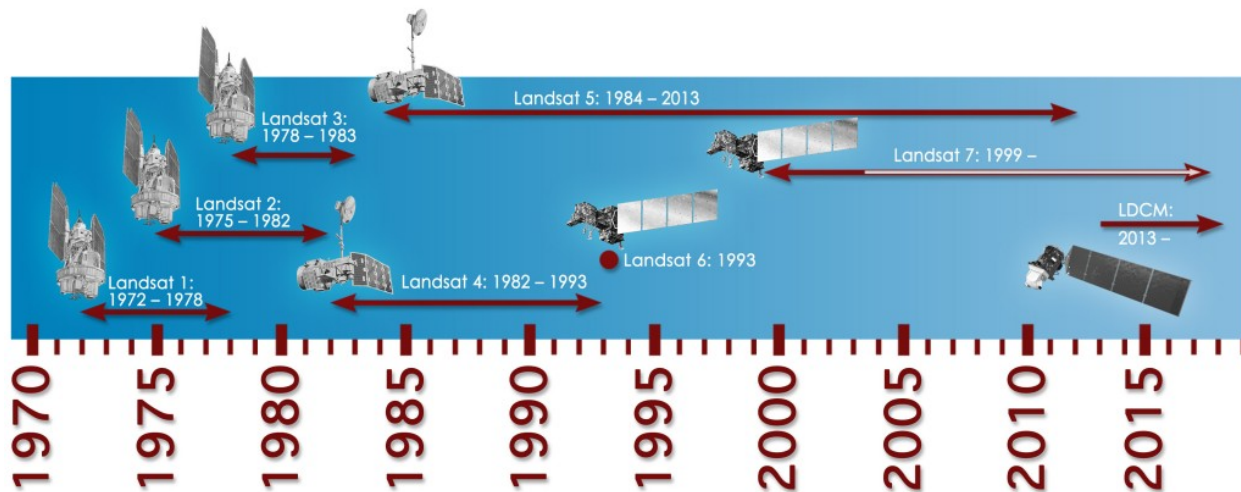


Figure 8. Timeline of Landsat Missions (NASA, 2014).

Landsat images were downloaded from the National Map, Earth Explorer interface managed by the U.S. Department of the Interior, USGS. Satellite imagery from 1988 (Figure 9) was obtained through the Landsat 5 satellite program equipped with both Multispectral Scanner (MSS) and TM sensors. Imagery from 2001 (Figure 10) was obtained from the Landsat 7

program equipped with Enhanced Thematic Mapper Plus (ETM+) sensor. Imagery from 2013 (Figure 11) was obtained from the Landsat 8 program equipped with the Operational Land Imager (OLI) and Thermal Infrared Sensors (TIRS). Landsat satellites produce image products that area considered moderate resolution. Landsat 5 has a spatial resolution of 82-m for MSS bands one through four, and 30-m for TM bands one through seven (U.S. Geological Survey, 2013, May; Campbell & Wynne, 2004). Landsat 7 ETM + has 30-m spatial resolution for visible light, near infrared and short wave infrared, a 60-m thermal band, and a 15-m panchromatic band. Landsat 8 has a spatial resolution of 30-m for OLI multispectral bands one through seven, 15-m for OLI panchromatic band eight, and 30-m for TIRS bands ten and eleven (U.S. Geological Survey, 2013, August). Imagery details can be seen in Table 2.

Table 2.

*Satellite Imagery Used for Classification and Temporal Analysis*

Year	1988	2001	2013
Imagery Date	4/14/88	10/3/01	3/17/13
Imagery Type	Landsat 5 TM	Landsat 7 ETM+	Landsat 8
Location	Path 17, Row 38	Path 17, Row 38	Path 17, Row 38
Pixel Size (m)	28.5, 28.5	28.5, 28.5	30, 30
Coordinate System	WGS_84_UTM_zone_17N	WGS_84_UTM_zone_17N	WGS_84_UTM_zone_17N
Number of Bands	6	6	7
Band Combination	5,3,7	5,3,2	5,4,3

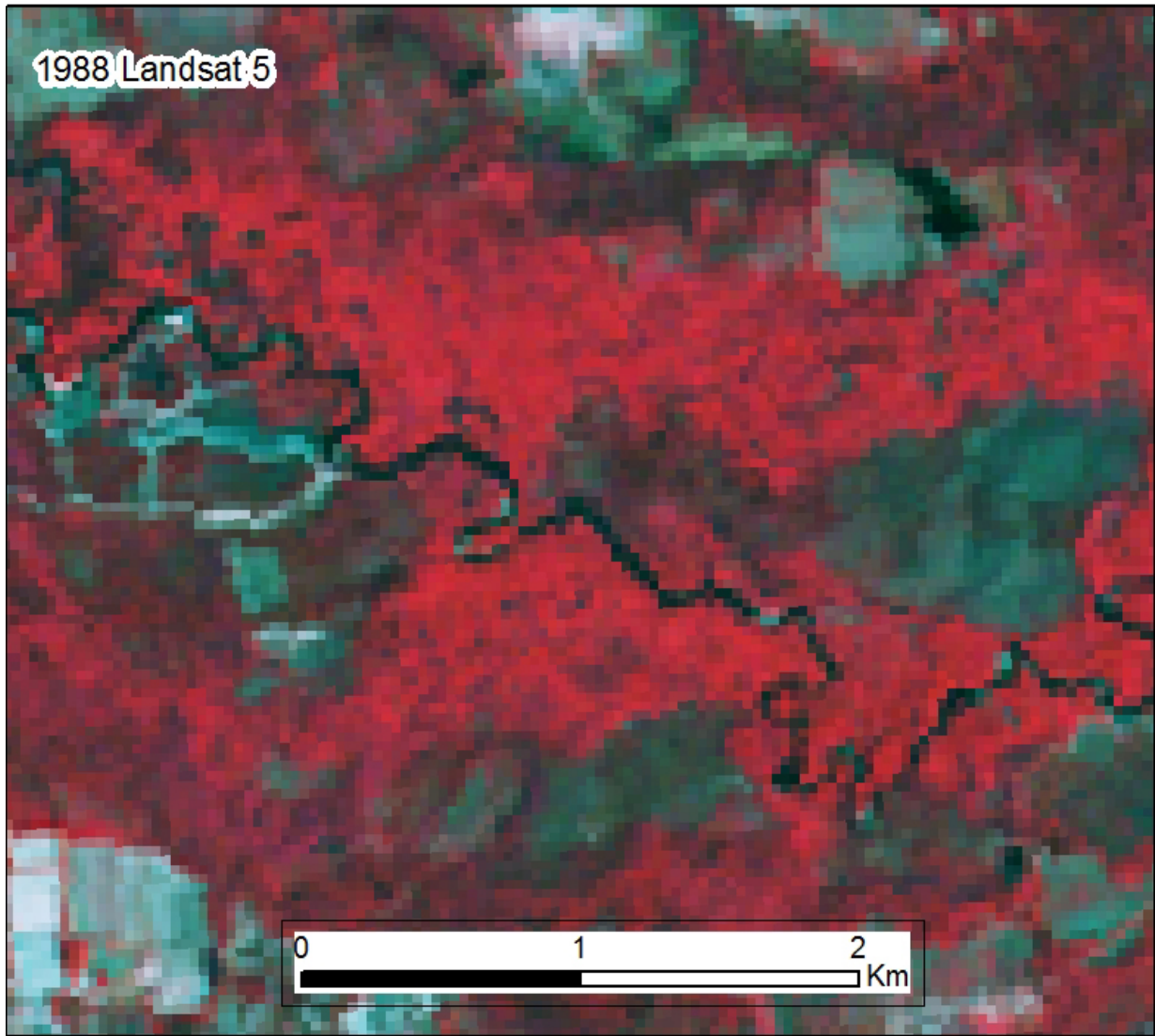


Figure 9. 1988 Landsat 5 TM Subset

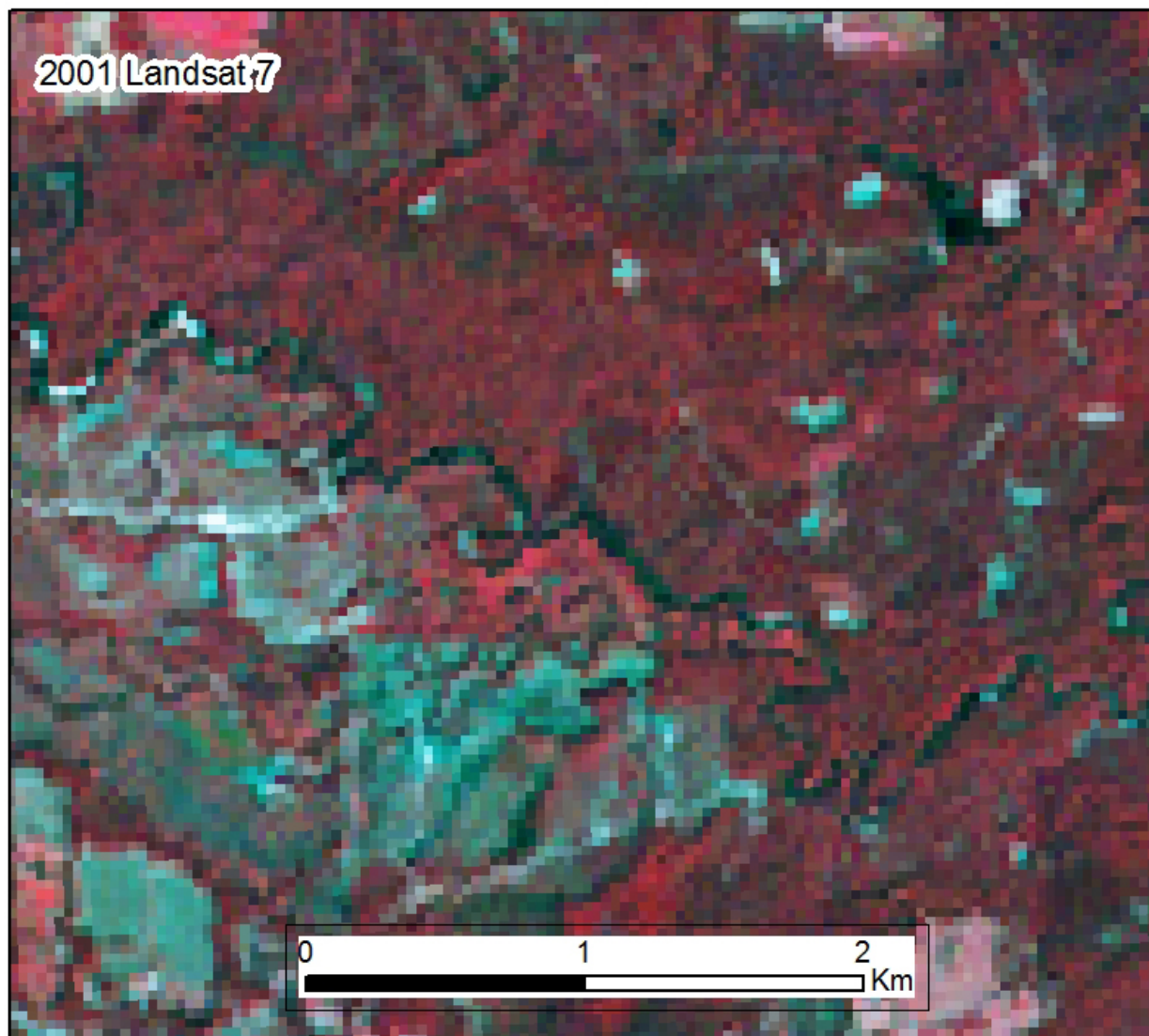


Figure 10. 2001 Landsat 7 ETM Subset

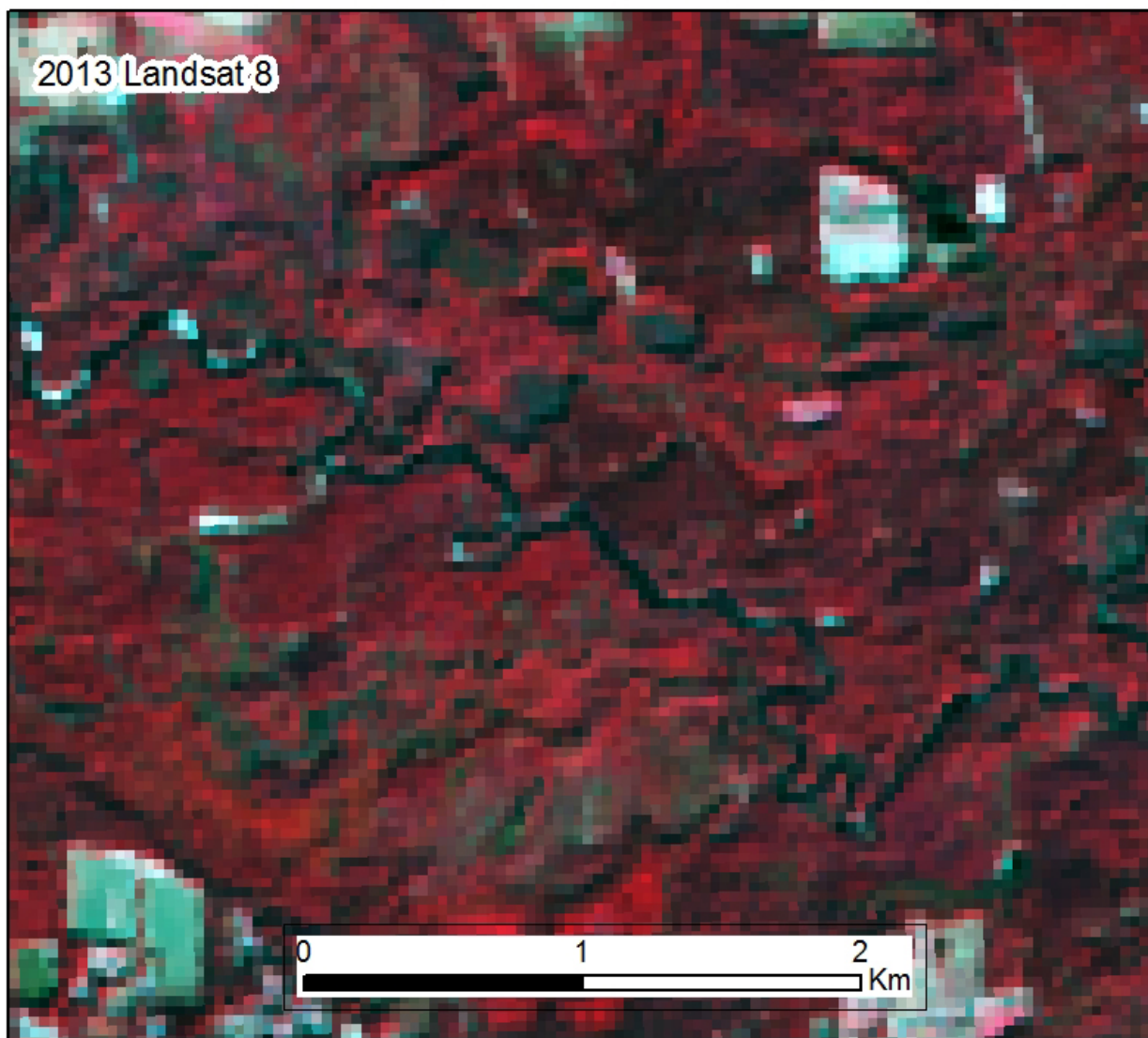


Figure 11. 2013 Landsat 8 OLI Subset

## **Classification Approach**

There are three objectives guiding the workflow of this project: (1) Using geospatial techniques with historical and current aerial photography, measure area of cypress stands within Pierce and Brantley Counties, Georgia, in 1980's, 1990's, 2000, 2013; (2) Measure cypress stand acreage change over the 25-year time period; (3) Compare results of cypress stand measurement to results from questionnaires sent to GA landowners and registered forestry professionals measuring their perceptions of the cypress resource. Based on those three objectives, the workflow for this project is as follows. The first step was to determine an area of South Georgia with the presence of cypress with appropriate aerial photographs and/or remotely sensed imagery. Once the study area was identified, ArcGIS 10.1 with historical aerial photographs to identify and classify selected cypress stands in each county creating a spatial temporal geodatabase of cypress forests. After identifying and classifying the imagery, analysis of classified cypress stands with the best available imagery within each decade (1981 – 1991, 1992 – 2002 and 2003 – 2013) was used to determine if there has been a change in size or stand composition to develop trends in Georgia's cypress resources.

In this research, color infrared imagery was needed to discern cypress from other types of vegetation. With color infrared imagery cypress appears white to gray in color with light tone, coarse texture, dense canopy in either extensive strands or domes (Madden et al., 1999). All imagery used for this research was either obtained in color infrared or various band combinations were used to achieve color infrared imagery, such as with Landsat. Using Landsat imagery requires preprocessing of images to create the desired image bands and effects for specific uses (Lillesand et al., 2004).

The classification method used for this research was Iterative Self-Organizing Data Analysis (ISODATA) classification, which can be found as the 'Iso Cluster Unsupervised Classification' tool in ArcGIS 10.1. ISODATA unsupervised classification is a variant of the K-means unsupervised classification algorithm, which analyzes clusters of pixels and allows the number of clusters to change with each iteration of the algorithm. After each iteration the statistics of each cluster is evaluated to gauge if the distance between two clusters is less than a predetermined distance, which in this case is one pixel. If the clusters are less than the set distance they are merged together. However, a cluster may be split in two if the standard deviation is greater than the set value. After the algorithm has evaluated all pixel-based clusters, all pixels are then reclassified into revised classes set by the user. The process continues until no significant statistical differences are found or the algorithm reaches a maximum number of iterations (Campbell & Wynne, 2011; Lillesand et al., 2004).

Classifications of land cover within the study area were modeled after the USGS Anderson Classification system (Table 3). This classification system was developed for classifying land cover from remotely sensed data. Benefits of this classification system are it is designed to be modified to use as much or as little detail as it needed for a particular project, by breaking down the classes into levels I, II, and III (Anderson et al., 1976).

Table 3.  
*Classification System*

<b>Class Number</b>	<b>Aerial Photograph Classification</b>	<b>Landsat Imagery Classification</b>
1	Water	Water
2	Moisture/Shadow	Evergreen
3	Deciduous Forest	Cypress-Mixed
4	Cypress-Tupelo	Mixed Forest
5	Cypress-Mixed	Agriculture
6	Evergreen Forest	Disturbed/Human Influence
7	Mixed Forest	
8	Agriculture	
9	Barren/Disturbed	
10	Barren/Agriculture	

### **Aerial Photograph Analyses**

The study area used for this research covers two air photo tiles equaling approximately 94.5 km<sup>2</sup> in Hoboken, GA, USA. Hoboken was selected for its variety of land cover types including a large amount of cypress forest. Three dates representing three decades were selected for this study, 1988, 1999, and 2010.

Initially, tiles were mosaicked then exported to a new raster layer containing both tiles used and then clipped to the study area if needed. Mosaicking of aerial photography was used to make classification of the study area more accurate eliminating the overlap, if any, of the two tiles (Lillesand et al., 2004). Images were classified using Iso Cluster unsupervised classification tool in ArcGIS. Iso Cluster analyzes the individual pixel value of each pixel in the selected raster image and classifies the image based on pixel brightness values and the desired number of classes by the user. This classification allowed large areas of vegetation to be quickly classified through an automated process. Such unsupervised classification required manual post-processing to determine the individual classes. After classification majority filtering was used. Majority filtering replaces cells based on the majority value of neighboring cells. For example, if three of

the four cells within a two by two window are classified as class four (cypress-tupelo), ArcGIS then converts the remaining cell to class four (Lillesand et al., 2004).

Data from 1988 were downloaded from the National Map, Earth Explorer interface. To acquire color infrared aerial photographs from this time, National Aerial Photography Program (NAPP) imagery was used for 1988. The NAPP aerial photographs were flown at a scale of 1:40,000 ft. on February 16, 1988. When downloaded, NAPP photos do not have spatial reference data so they need to be georeferenced to a ground coordinate system. All NAPP aerial photographs used were georeferenced to North American Datum (NAD) 1983, Universal Transverse Mercator (UTM) Zone 17 North on an existing USGS DOQ of the desired area with a minimum of 15 Ground Control Points (GCPs) and Root Means Squared Error (RMSE) of 4.9 m. Color Infrared DOQQs were downloaded from the Georgia GIS Clearinghouse server for 1999 (Imagery flown February 7, 1999). The NAIP imagery (4-Band) for 2010 (Imagery flown September 10, 2010) was downloaded from the National Map, Earth Explorer. Figures 5, 6, and 7 depict subset examples of image quality and color differences for years 1988, 1999, and 2010.

Following the creation of new raster files from mosaics, aerial photograph-based data for each year were classified into 20 unique classes using Iso Cluster Unsupervised classification within ArcGIS. For all years, 1988, 1999, and 2010, majority filtering was used to generalize or smooth all pixels within the classified image. Majority filtering was completed automatically for the entire classified image for each year. Upon completion of classification and filtering, the 20 classes were re-classified and merged into 10 distinct classes to represent a more accurate class definition as well as to reduce some of the noise created by unsupervised classification. Due to color differences in each year of aerial photographs the software did not consistently distinguish

between classes 9, 10. To correct for this, classes 9, 10 were merged into Class 9, Barren/Disturbed, resulting in nine final classes (Table 4).

### **Satellite Image Analyses**

Years 1988, 2001, and 2013 were included in this study to analyze potential change in selected cypress forests over the past 25 years in Pierce and Brantley counties. All analyses were completed using ArcGIS 10.1 with historic and current Landsat imagery to identify and classify selected cypress stands in each county creating a spatial temporal geodatabase of cypress forests. After identifying and classifying the imagery, temporal analysis of classified cypress stands was completed to determine if there was a change in size or stand composition from 1988 to 2013.

Landsat images were downloaded in a package of multiple separate bands and combined to form the desired band combinations as well as reduce overall file size. The ‘Composite Bands’ tool in ArcGIS 10.1 was used to combine bands to create seven-band color infrared (CIR) satellite images of the study area (Campbell & Wynne, 2011). Following creation of new seven-band CIR images, each year was classified into 25 classes using the ‘ISO Cluster Unsupervised Classification’ tool within ArcGIS 10.1.

Due to large (30 × 30 m) pixel size for years 1988 and 2013, no filtering methods were utilized to smooth classified pixels in the images. Upon completion of classification the 25 classes were re-classified and merged into six classes to represent more accurate class definitions, as well as to reduce some of the noise created in unsupervised classification (Bolstad, 2012). The resulting classes are water (1), evergreen (2), mixed cypress (3), mixed forest (4), agriculture (5), and human influence/disturbed (6). The human influence/disturbed class encompasses urban areas, roads, and harvested forest.

Table 4.  
*Reclassification Example - 1988 CIR NAPP Classified Imagery*

Pixel Value	Original Classification	New Class #	Final Classification	Final Class #
1	Water	1	Water	1
2	Moisture/Shadow	2	Moisture/Shadow	2
3	Evergreen	6	Deciduous Forest	3
4	Water/Moisture	2	Cypress-Tupelo	4
5	Moisture	2	Cypress Mixed	5
6	Cypress	4	Evergreen Forest	6
7	Cypress	4	Mixed Forest	7
8	Evergreen	6	Agriculture	8
9	Agriculture	7	Barren/Disturbed	9
10	Mixed Forest	7		
11	Cypress	4		
12	Agriculture	8		
13	Harvested	9		
14	Cypress Mixed	5		
15	Harvested	9		
16	Cypress Mixed	5		
17	Cypress Mixed	5		
18	Moisture	2		
19	Barren/Agriculture	10		
20	Barren/Agriculture	10		

### Accuracy Assessment

Accuracy assessment was completed by comparing 120 random points within the study area to the original image and classified raster. To ensure an even distribution of points throughout the image, as well as a large sampling of classes four and five, an 800-m zone was created around the river. Seventy random points were placed within this near-river zone and the remaining 50 points were randomly located outside of this zone. At each random point, the land cover type was determined by visually examining the unclassified image. After a land cover type was determined, the classified raster was then examined at the same 120 random points to see if the computer accurately classified the individual pixels of the image. The process of visually checking each of the 120 random points was completed for each year, 1988, 1999, and 2010. A

confusion matrix was used to determine the producer and user accuracy from the overall accuracy assessment. Producer's accuracy is how well the training pixels in each land cover type are classified. User's accuracy is the probability that a classified pixel represents that same classification on the ground (Bolstad, 2012; Campbell & Wynne, 2011; Congalton, 2009; Lillesand et al., 2004).

## CHAPTER 4

### RESULTS

#### **Aerial Photography**

Unsupervised classification of aerial photographs using ArcGIS resulted in nine final classes, representing various types of land cover. The final set of classes included: (1) Water, (2) Moisture or Shadow, (3) Deciduous Forest, (4) Cypress-tupelo, (5) Mixed Cypress, (6) Evergreen Forest, (7) Mixed Forest, (8) Agriculture, and (9) Barren/Disturbed. Accuracy of the classes varied depending on the year and specific color of the individual images. Despite all images being color infrared, tone and brightness for each image varied. This variation in color among images resulted in differing amount of accuracy for each class.

A temporal analysis of the study area in Hoboken, GA resulted in some overall variability during the 25 year time period. Table 5 depicts areas (ha) and percentages of total area for each land cover class in years 1988, 1999, and 2010. Differences in total area for each year can be attributed to pixels with no data attached to them. To correct for slight differences in total area for each year, the totals were averaged. The average total area (ha) was used for determining: % of total, % change, and area change (Table 6).

Table 5  
*Analysis of Land Cover in Study Area Based on Aerial Photography –Totals (ha)*

Classification	1988		1999		2010	
	Area (ha)	% of Total	Area (ha)	% of Total	Area (ha)	% of Total
Water (1)	465.58	4.89	524.02	5.51	489.49	5.15
Moisture/Shadow (2)	1659.77	17.43	550.03	5.78	1659.76	17.45
Deciduous Forest (3)	349.39	3.67	593.50	6.24	1276.75	13.42
Cypress-Tupelo (4)	818.00	8.59	854.57	8.98	537.62	5.65
Cypress-Mixed (5)	1700.73	17.87	1428.84	15.01	1302.98	13.70
Evergreen Forest (6)	1238.53	13.01	2021.58	21.24	1436.76	15.11
Mixed Forest (7)	870.02	9.14	498.57	5.24	0.00	0.00
Agriculture (8)	500.15	5.25	910.69	9.57	1714.98	18.03
Barren/Disturbed (9)	1917.59	20.14	2136.29	22.44	1092.73	11.49
Totals	9519.77		9518.09		9511.07	
Average Total	9516.31 ha					

Table 6  
*Temporal Analyses of Land Cover in Study Area Based on Aerial Photography*

Classification	Change (%)			Area Change (ha)		
	1988 - 1999	1999 - 2010	1988 - 2010	1988 - 1999	1999 - 2010	1988 - 2010
Water (1)	0.62	-0.36	0.26	58.05	-34.26	24.74
Moisture/Shadow (2)	-11.66	11.67	0.02	-1109.60	1110.55	1.90
Deciduous Forest (3)	2.57	7.19	9.75	244.57	684.22	927.84
Cypress-Tupelo (4)	0.39	-3.33	-2.94	37.11	-316.89	-279.78
Cypress-Mixed (5)	-2.85	-1.31	-4.17	-271.22	-124.66	-396.83
Evergreen Forest (6)	8.23	-6.13	2.10	783.19	-583.35	199.84
Mixed Forest (7)	-3.90	-5.24	0.00	-371.14	0.00	0.00
Agriculture (8)	4.31	8.46	12.78	410.15	805.08	1216.18
Barren/Disturbed (9)	2.30	-10.96	-8.65	218.88	-1042.99	-823.16

### Satellite Imagery

The unsupervised classification of Landsat imagery for years 1988, 2001, and 2013 resulted in six final classes, representing various types of landcover. The six classes included (1) water (2) evergreen forest, (3) mixed cypress, (4) mixed forest, (5) agriculture, and (6) human

influence or disturbed (figures 12, 13, and 14). Note that this classification did not identify pure cypress stands, thus, interpretation regarding increases in non-cypress components within nearly pure cypress stands are not possible. The analysis of land cover within the study area based on Landsat imagery can be seen in Table 7.

From 1988 to 2013, there has been a 2102.68 ha (22.06%) increase in mixed cypress forests, a 669.28 ha (7.02%) increase in agricultural areas, and a 1963.46 ha (20.6%) decrease in disturbed areas of human influence (Table 8).

Table 7  
*Analysis of Land Cover in Study Area Based on Landsat Imagery –Totals (ha)*

Classification	1988		2001		2013	
	Area (ha)	% of Total	Area (ha)	% of Total	Area (ha)	% of Total
Water (1)	469.89	4.93	53.93	0.57	313.47	3.29
Evergreen (2)	1719.13	18.04	2309.39	24.23	1605.15	16.84
Cypress Mixed (3)	581.57	6.10	628.11	6.59	2684.25	28.17
Mixed Forest (4)	847.01	8.89	3330.88	34.95	304.11	3.19
Agriculture (5)	3551.81	37.27	2740.78	28.76	4221.09	44.29
Disturbed/Human Influence (6)	2362.43	24.79	468.75	4.92	398.97	4.19
Sum of Classes	9531.83		9531.84		9527.04	
Average Total			9530.24			

Table 8  
*Temporal Analyses of Land Cover in Study Area Based on Landsat Imagery*

Classification	Change (%)			Area Change (ha)		
	1988 to 2001	2001 to 2013	1988 to 2013	1988 to 2001	2001 to 2013	1988 to 2013
Water (1)	-4.36	2.72	-1.64	-415.95	259.54	-156.42
Evergreen (2)	6.19	-7.39	-1.20	590.26	-704.24	-113.98
Cypress Mixed (3)	0.49	21.57	22.06	46.54	2056.14	2102.68
Mixed Forest (4)	26.06	-31.76	-5.70	2483.86	-3026.76	-542.90
Agriculture (5)	-8.51	15.53	7.02	-811.03	1480.31	669.28
Disturbed/Human Influence (6)	-19.87	-0.73	-20.60	-1893.68	-69.78	-1963.46

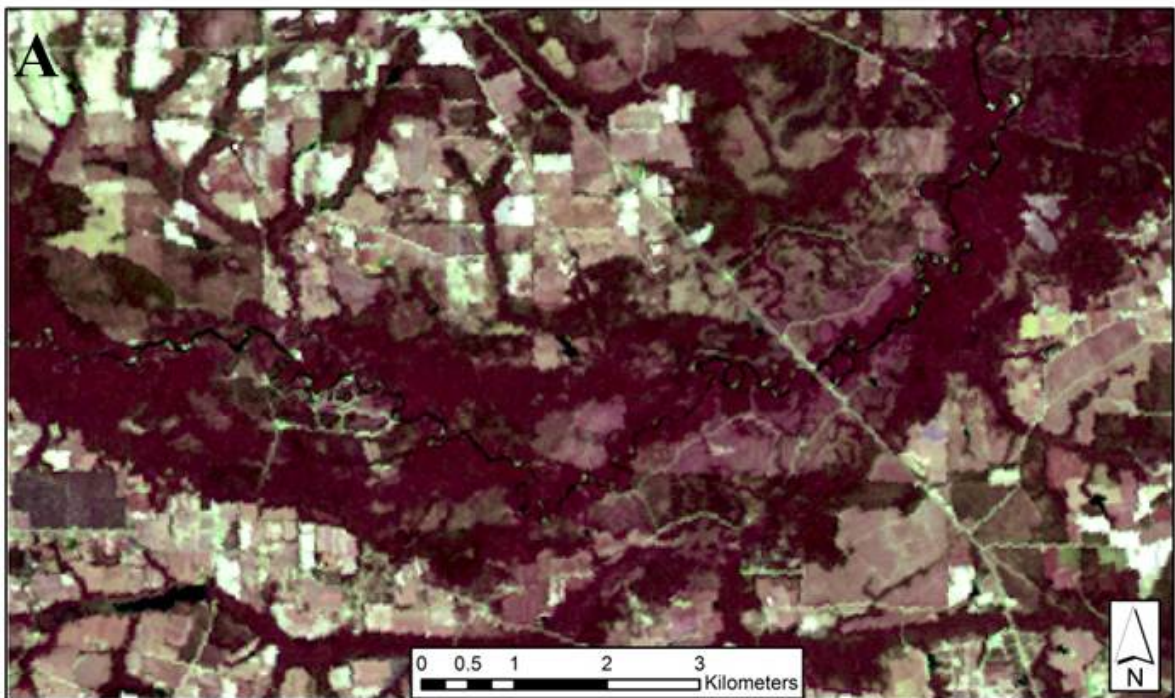


Figure 12a. Landsat 5 ETM+ Image Taken April 14, 1988 of Study Area.

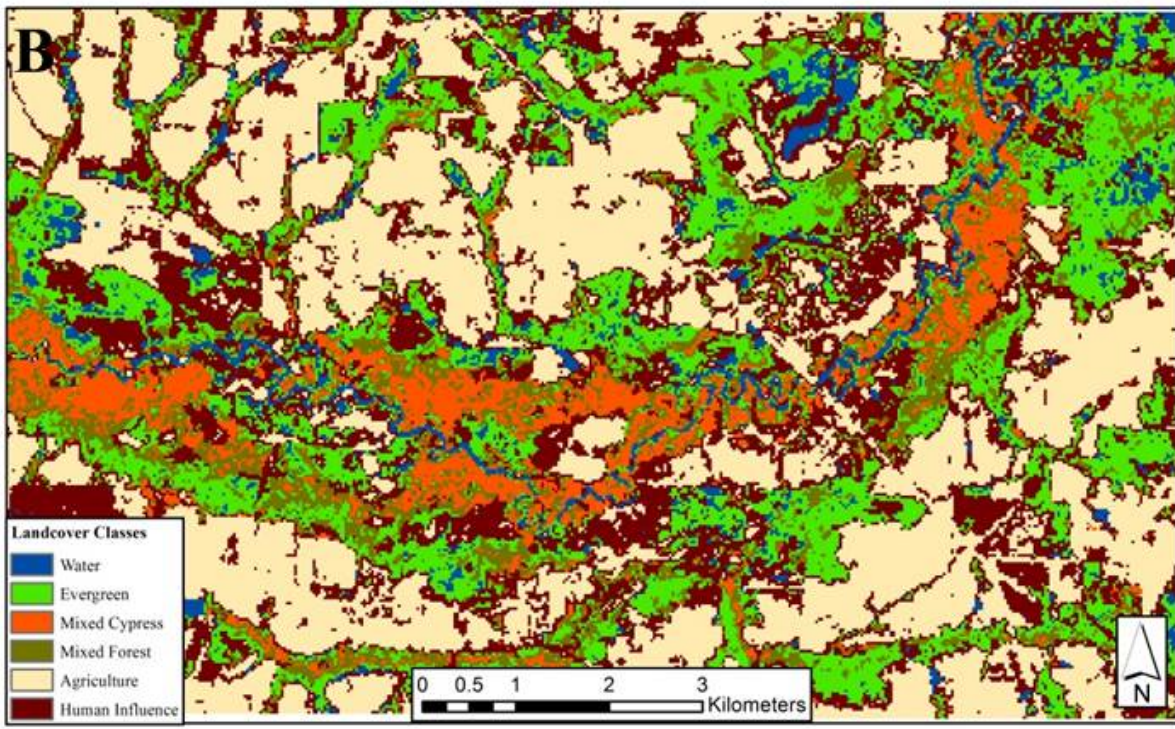


Figure 12b. Classified Landsat 5 ETM+ Image Taken April 14, 1988 of Study Area.

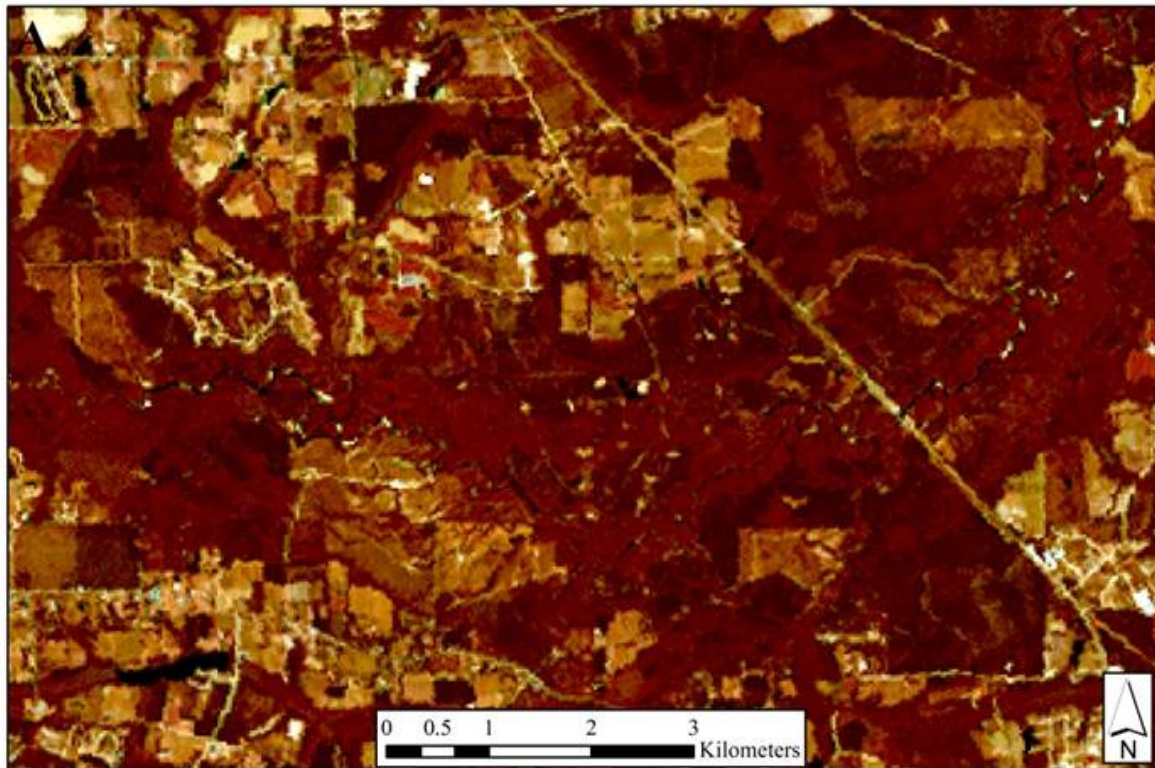


Figure 13a. Landsat 7 Image Taken October 3, 2001 of Study Area.

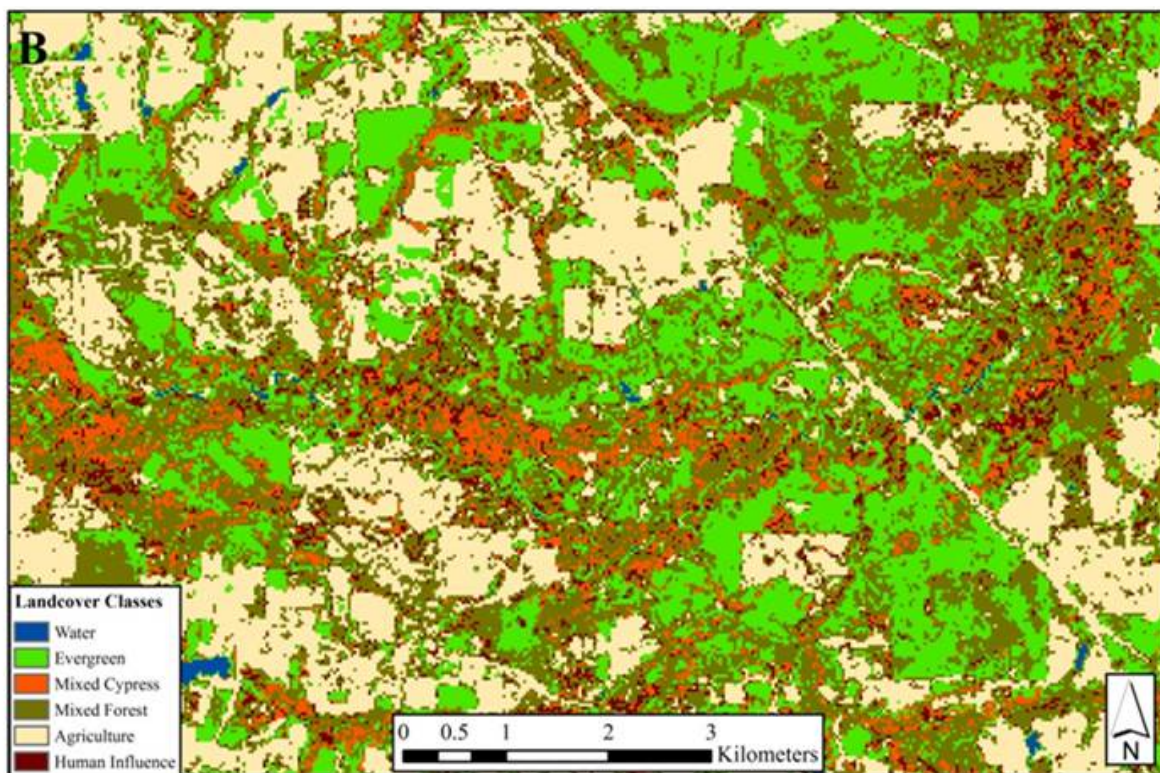


Figure 13b. Classified Landsat 7 Image Taken October 3, 2001 of Study Area.

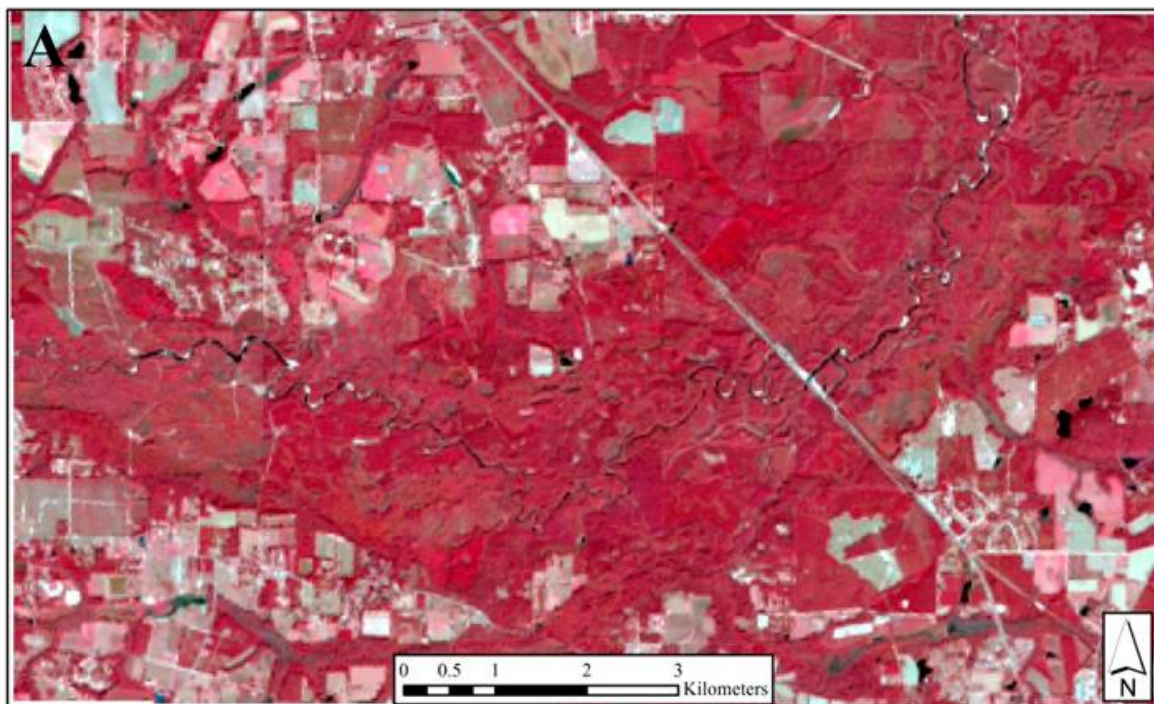


Figure 14a. Landsat 8 Image Taken March 17, 2013 of Study Area.

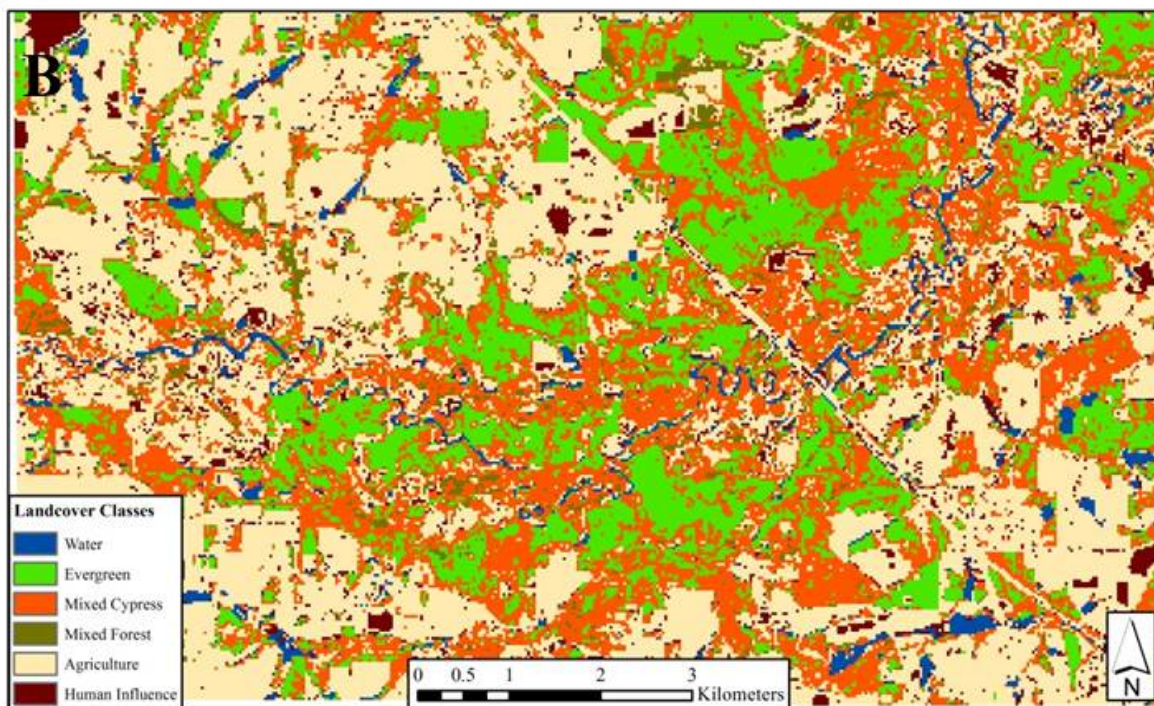


Figure 14b. Classified Landsat 8 Image Taken March 17, 2013 of Study Area.

### Accuracy Assessment: Aerial Photographs

Overall accuracy was determined by dividing the number of correctly classified random points in the accuracy assessment by the total number of random points used (120). Overall accuracies for years 1988, 1999, and 2010 were 82.50%, 69.17%, and 65.00% respectively. Producer and user accuracy for each year of classified imagery is provided in Table 9. The confusion matrices for 1988, 1999 and 2010 are provided in Table 10, 11 and 12, respectively. Variability in cypress classification accuracy can be attributed to classes 2, 6, 8, and 9 being classified as cypress.

Table 9  
*Producer & User Accuracy of Aerial Photograph Unsupervised Classification (Percentages)*

Land Cover Classes	1988 CIR NAPP		1999 CIR DOQQ		2010 4-Band NAIP	
	Producer's Accuracy	User's Accuracy	Producer's Accuracy	User's Accuracy	Producer's Accuracy	User's Accuracy
Water (1)	100.00	66.67	87.50	77.78	100.00	66.67
Moisture/Shadow (2)	91.30	80.77	66.67	85.71	88.89	80.00
Deciduous Forest (3)	100.00	100.00	50.00	100.00	80.00	61.54
Cypress-Tupelo (4)	76.92	100.00	100.00	78.57	75.00	54.55
Cypress-Mixed (5)	79.17	73.08	52.38	61.11	52.38	68.75
Evergreen Forest (6)	92.86	100.00	70.00	100.00	73.68	60.87
Mixed Forest (7)	90.00	64.29	50.00	62.50	0.00	0.00
Agriculture (8)	25.00	50.00	55.56	26.32	68.75	57.89
Barren/Disturbed (9)	85.00	94.44	83.33	68.18	40.00	66.67
Overall Accuracy	82.50		69.17		65.00	

Table 10

*Confusion Matrix: Accuracy Assessment of Classified 1988 CIR NAPP of Study Site. Producer and User Accuracies in Percent.*

Classification Data	Training Set Data (Known Cover Types)										User Accuracy (%)
	Water	Moisture/Shadow	Deciduous	Cypress-Tupelo	Cypress-Mixed	Evergreen	Mixed Forest	Agriculture	Barren/Disturbed	Row Total	
Water (1)	2	0	0	0	1	0	0	0	0	3	66.7
Moisture/Shadow (2)	0	21	0	3	2	0	0	0	0	26	80.8
Deciduous Forest (3)	0	0	6	0	0	0	0	0	0	6	100.0
Cypress-Tupelo (4)	0	0	0	10	0	0	0	0	0	10	100.0
Cypress-Mixed (5)	0	1	0	0	19	1	0	3	2	26	73.1
Evergreen Forest (6)	0	0	0	0	0	13	0	0	0	13	100.0
Mixed Forest (7)	0	0	0	0	1	0	9	3	1	14	64.3
Agriculture (8)	0	1	0	0	0	0	1	2	0	4	50.0
Barren/Disturbed (9)	0	0	0	0	1	0	0	0	17	18	94.4
<b>Column Total</b>	<b>2</b>	<b>23</b>	<b>6</b>	<b>13</b>	<b>24</b>	<b>14</b>	<b>10</b>	<b>8</b>	<b>20</b>	<b>120</b>	
<b>Producer Accuracy</b>	<b>100.0</b>	<b>91.3</b>	<b>100.0</b>	<b>76.9</b>	<b>79.2</b>	<b>92.9</b>	<b>90.0</b>	<b>25.0</b>	<b>85.0</b>		<b>82.5</b>

Table 11

*Confusion Matrix: Accuracy Assessment of Classified 1999 CIR DOQQ Data of Study Site. Producer and User Accuracies in Percent.*

Classification Data	Training Set Data (Known Cover Types)										User Accuracy (%)
	Water	Moisture/Shadow	Deciduous	Cypress-Tupelo	Cypress-Mixed	Evergreen	Mixed Forest	Agriculture	Barren/Disturbed	Row Total	
Water (1)	7	2	0	0	0	0	0	0	0	9	77.8
Moisture/Shadow (2)	1	6	0	0	0	0	0	0	0	7	85.7
Deciduous Forest (3)	0	0	2	0	0	0	0	0	0	2	100.0
Cypress-Tupelo (4)	0	0	0	11	2	1	0	0	0	14	78.6
Cypress-Mixed (5)	0	1	0	0	11	0	0	3	3	18	61.1
Evergreen Forest (6)	0	0	0	0	0	21	0	0	0	21	100.0
Mixed Forest (7)	0	0	0	0	0	3	5	0	0	8	62.5
Agriculture (8)	0	0	2	0	5	4	3	5	0	19	26.3
Barren/Disturbed (9)	0	0	0	0	3	1	2	1	15	22	68.2
<b>Column Total</b>	<b>8</b>	<b>9</b>	<b>4</b>	<b>11</b>	<b>21</b>	<b>30</b>	<b>10</b>	<b>9</b>	<b>18</b>	<b>120</b>	
<b>Producer Accuracy</b>	<b>87.5</b>	<b>66.7</b>	<b>50.0</b>	<b>100.0</b>	<b>52.4</b>	<b>70.0</b>	<b>50.0</b>	<b>55.6</b>	<b>83.3</b>		<b>69.2</b>

Table 12

*Confusion Matrix: Accuracy Assessment of Classified 2010 4-Band NAIP Data of Study Site Producer and User Accuracies in Percent.*

Classification Data	Training Set Data (Known Cover Types)									User Accuracy (%)	
	Water	Moisture/Shadow	Deciduous	Cypress-Tupelo	Cypress-Mixed	Evergreen	Mixed Forest	Agriculture	Barren/Disturbed		Row Total
Water (1)	4	2	0	0	0	0	0	0	0	6	66.7
Moisture/Shadow (2)	0	16	2	0	1	0	0	0	1	20	80.0
Deciduous Forest (3)	0	0	8	0	4	0	0	1	0	13	61.5
Cypress-Tupelo (4)	0	0	0	6	0	1	2	0	2	11	54.6
Cypress-Mixed (5)	0	0	0	0	11	2	0	1	2	16	68.8
Evergreen Forest (6)	0	0	0	1	5	14	0	1	2	23	60.9
Mixed Forest (7)	0	0	0	0	0	0	0	0	0	0	0.0
Agriculture (8)	0	0	0	0	0	2	1	11	5	19	57.9
Barren/Disturbed (9)	0	0	0	1	0	0	1	2	8	12	66.7
<b>Column Total</b>	<b>4</b>	<b>18</b>	<b>10</b>	<b>8</b>	<b>21</b>	<b>19</b>	<b>4</b>	<b>16</b>	<b>20</b>	<b>120</b>	
<b>Producer Accuracy</b>	<b>100.0</b>	<b>88.9</b>	<b>80.0</b>	<b>75.0</b>	<b>52.4</b>	<b>75.7</b>	<b>0.0</b>	<b>68.8</b>	<b>40.0</b>		<b>65.0</b>

### Accuracy Assessment: Satellite Imagery

Resulting accuracy from classification of 1988, 2001, and 2013 Landsat imagery was very poor. Overall accuracy of each year's classified imagery was less than 50 percent, with 37.5 percent for 1988, 31.67 percent for 2001, and 37.5 percent for 2013. Resulting accuracy percentages of individual classes for each year is shown in Table 13. The confusion matrices for 1988, 2001, and 2013 are provided in tables 14, 15, and 16 respectively.

Table 13  
*Producer and User Accuracy for Landsat Classification, Years 1988, 2001, and 2013 (Percentages).*

Land Cover Classes	1988		2001		2013	
	Producer's Accuracy	User's Accuracy	Producer's Accuracy	User's Accuracy	Producer's Accuracy	User's Accuracy
Water (1)	0.00	0.00	0.00	0.00	40.00	40.00
Evergreen Forest (2)	55.56	43.48	34.38	52.38	25.93	63.64
Cypress-Mixed (3)	18.75	42.86	21.88	63.64	60.61	52.63
Mixed Forest (4)	16.67	16.67	60.00	18.75	0.00	0.00
Agriculture (5)	55.17	53.33	81.82	29.03	92.86	23.64
Barren/Disturbed (6)	41.67	31.25	10.53	22.22	12.00	60.00
Overall Accuracy	37.50		31.67		37.50	

Table 14  
*Confusion Matrix: Accuracy Assessment of Classified 1988 Landsat 5 ETM Imagery of Study Site. Producer and User Accuracies in Percent.*

Classification Data	Training Set Data (Known Cover Types)							User Accuracy
	Water	Evergreen Forest	Cypress Mixed	Mixed Forest	Agriculture	Human Influence	Row Total	
Water (1)	0	0	1	1	1	0	3	0.0
Evergreen Forest (2)	0	10	7	3	2	1	23	43.5
Cypress-Mixed (3)	0	0	6	1	5	2	14	42.9
Mixed Forest (4)	0	5	8	3	1	1	18	16.7
Agriculture (5)	1	1	1	1	16	10	30	53.3
Barren/Disturbed (6)	0	2	9	7	4	10	32	31.3
<b>Column Total</b>	<b>1</b>	<b>18</b>	<b>32</b>	<b>16</b>	<b>29</b>	<b>24</b>	<b>120</b>	
<b>Producer Accuracy</b>	<b>0.0</b>	<b>55.7</b>	<b>18.8</b>	<b>16.7</b>	<b>55.2</b>	<b>41.7</b>		<b>37.5</b>

Table 15  
*Confusion Matrix: Accuracy Assessment of Classified 2001 Landsat 7  
 Imagery of Study Site. Producer and User Accuracies in Percent.*

Training Set Data (Known Cover Types)								User's Accuracy
Classification Data	Water	Evergreen Forest	Cypress Mixed	Mixed Forest	Agriculture	Barren / Disturbed	Row Total	
Water (1)	0	0	0	0	0	0	0	0.0
Evergreen Forest (2)	2	11	3	2	1	2	21	52.4
Cypress-Mixed (3)	2	0	7	1	0	1	11	63.6
Mixed Forest (4)	5	15	17	9	1	1	48	18.8
Agriculture (5)	2	3	1	3	9	13	31	29.0
Barren/Disturbed (6)	0	3	4	0	0	2	9	22.2
<b>Column Total</b>	<b>11</b>	<b>32</b>	<b>32</b>	<b>15</b>	<b>11</b>	<b>19</b>	<b>120</b>	
<b>Producer's Accuracy</b>	<b>0.0</b>	<b>34.4</b>	<b>21.9</b>	<b>60.0</b>	<b>81.8</b>	<b>10.5</b>		<b>31.7</b>

Table 16  
*Confusion Matrix: Accuracy Assessment of Classified 2013 Landsat 8  
 Imagery of Study Site. Producer and User Accuracies in Percent.*

Training Set Data (Known Cover Types)							User Accuracy	
Classification Data	Water	Evergreen Forest	Cypress Mixed	Mixed Forest	Agriculture	Human Influence		
Water (1)	2	2	0	0	0	1	5	40.0
Evergreen Forest (2)	1	7	1	1	1	0	11	63.6
Cypress-Mixed (3)	0	6	20	8	0	4	38	52.6
Mixed Forest (4)	1	3	2	0	0	0	6	0.0
Agriculture (5)	1	9	10	5	13	17	55	23.6
Barren/Disturbed (6)	0	0	0	2	0	3	5	60.0
<b>Column Total</b>	<b>5</b>	<b>27</b>	<b>33</b>	<b>16</b>	<b>14</b>	<b>25</b>	<b>120</b>	
<b>Producer Accuracy</b>	<b>40.0</b>	<b>25.9</b>	<b>60.6</b>	<b>0.0</b>	<b>92.9</b>	<b>12.0</b>		<b>37.5</b>

## CHAPTER 5

### DISCUSSION

#### **Evaluating Changes in the Cypress Resources**

Temporal analysis of cypress forests within the study area resulted in substantial variability. The study area, located on the borders of Pierce and Brantley Counties in south Georgia, USA, was chosen for its variety of land cover types and the presence of cypress. Overall accuracy for aerial photography years 1988, 1999 and 2010 were 82.5%, 69.2% and 65.0%, respectively. Overall accuracy for satellite imagery years 1988, 2001 and 2013 were 37.5%, 31.7% and 37.5%, respectively.

If we examine Figure 15, unclassified and classified aerial photography for 1999, there is a large clear-cut area on the western side of the image that was classified primarily as cypress-mixed. There are several such errors in the unsupervised classification of these images. These errors seem to come from similarities in color of the original images between moisture (dark blue/black), new growth (dark pink), cypress (dark blue), and cypress-mixed (pink and dark blue). Confused classes such as, Class 8 (agriculture), classes 9, 10, and 11 (Barren), and sometimes Class 5 (Cypress-Mixed) tend to have higher areas in the temporal analyses. These errors could be corrected for by use of similar data for each year.

Aerial photography from 1988 was obtained from the National Map archive and the University of Georgia Map Library. Unfortunately, the data appeared to have lost some of its clarity before or during the archiving process. The result was imagery that had ideal color for determining different types of land cover, but was challenging when trying to discern small

details (Figure 16). Surprisingly, the classified aerial photography from 1988 had a higher overall accuracy than classified aerial photography for 1999 (Figure 15) and 2010 (Figure 17). Using aerial photographs has the benefit of high resolution from a small pixel size (1-m), but differences in color from year to year affect the ability of a computer to complete unsupervised classification with acceptable accuracy. Differences in color may be attributed to the DPI original film images were scanned with, time of day the photographs were taken, camera angle, etc. Many of these factors cannot be corrected without the original film, or re-scanning at a higher DPI.

One of the underlying goals of this research was to use simple classification methods that could be utilized and implemented by people with little GIS experience for use in practical applications. However, using widely available free imagery and commonly used classification techniques resulted in moderate to poor accuracy for both aerial photography and Landsat satellite imagery. For this research, temporal availability was necessary to determine a change in the cypress resource in Georgia, which led to the decision to use Landsat. Landsat imagery dating back to 1972 can be downloaded for free from the National Map archive operated by the USGS. Landsat MSS imagery from 1972 through 1982 has a spatial resolution of approximately 80-m and Landsat TM imagery from 1982 through 2013 has a spatial resolution of 30-m. Throughout all missions of Landsat satellites the number of bands for each sensor has remained consistent, making data well suited for temporal analyses. The majority of the study area used in this research contained cypress forests greater than the 30-m pixel size of more recent Landsat TM imagery. Landsat TM and OLI imagery should be considered a viable option for future research in temporal mapping of larger cypress forests in Georgia.

Improved results with the same or similar data could also be achieved by using hybrid classification techniques. Hybrid classification involves the use of multiple types of classification techniques to map land cover. Using this hybrid technique it is possible to achieve higher accuracy than using just one classification method. Zhang et al. (2011) compared the use of maximum likelihood classifier (MLC) and hybrid classification techniques with Landsat TM imagery to map a coastal wetland environment in China. Zhang et al. (2011) chose 135 training samples sites for MLC in order to have representative samples of each class. Hybrid classification methods involved the use of Linear Spectral Mixture Analysis (LSMA), thresholding techniques, unsupervised classification for each class, and post processing with expert rules (Zhang et al., 2011). LSMA is considered an accurate way of extracting quantitative subpixel information based on physical properties. The principal assumption with LSMA is that each pixel is made up of a variety of land cover types, referred to as endmembers (Adams et al., 1995). Zhang et al. (2011) selected four endmembers for classification of their coastal wetlands study site, saltwater, fresh water, vegetation, and soil. Following LSMA, thresholding was conducted by generating a minimum threshold for each class. Pixels that did not meet the minimum threshold were classified as other. Unsupervised classification was then used to classify the spectral classes and reclassified by the analyst into correct classes. Post-processing of classified images with expert knowledge was the last step in creating a classified wetlands land cover map. Knowledge of where certain species and land cover types occur was used to correct confused classes. Accuracy assessment of both MLC and hybrid classification resulted good overall accuracy for both types of classification. However, hybrid classification resulted in higher overall accuracy at 93.38% and MLC at 82.12% (Zhang et al., 2011).

Overall accuracy and ease of use in classifying cypress could potentially be improved by the use of supervised classification methods such as maximum likelihood supervised classification, sub-pixel classification, or a hybrid approach as described in Zhang et al (2011). Landsat's inherently large pixel size did not work well with regard to classifying small and scattered cypress stands using ISODATA unsupervised classification. The use of one of the aforementioned classification techniques could improve accuracy for determining cypress within a bottomland hardwood forest. Through the advent of high resolution Unmanned Aerial Sensors (UAS) ground truthing and assessing regrowth of cut over cypress stands has now become fiscally possible for companies interested in cypress forestry. Future research should evaluate how well maximum likelihood supervised classification, sub-pixel classification or hybrid methods can be used to monitor cypress forests over time in conjunction with field work using UAS to determine more efficient ways to evaluate the status of cypress forests using geospatial techniques (Watts, Ambrosia, & Hinkley, 2012). The creation of an image interpretation key for identifying cypress signatures for supervised classification should also be developed to aid in future research.

### **Comparing Landowner and Professional Perceptions and Observed Changes in the Cypress Resource**

Results from analyses of available aerial photographs indicate a decline in the cypress resource of 2.94% for cypress-tupelo and 4.17% for mixed cypress occurred during the last 22 years from 1988 to 2010. While results from analyses of available Landsat imagery indicated a drastic increase of 22.06% in mixed cypress over the last 25 years from 1988 to 2013. In a recent survey of Georgia landowners and forestry professionals (Morris et al., 2013) there was a general consensus that harvests of cypress had increased and there was a reduction in the cypress

resources. These perceptions were particularly true of landowners (Table 17) and forestry professionals in Georgia (Table 18). Results from the analyses completed in this study, while limited by high variability, would tend to confirm that these perceptions are correct. While the reasons behind the reduction are not clear, changes in both species composition within area that had been classified as cypress 20 to 30 years ago, as well as, encroachment of pine plantations into areas previously supporting cypress, likely contribute to this reduction.

Table 17  
*Georgia Landowner's Perceptions of Cypress Change Over Last Decade*

General consensus that cypress acreage has not increased in the past 10 years	
Less land in cypress than in the past 10 years	32% (39 of 122)
Same amount of land in cypress as in past 10 years	36.9% (45 of 122)
Can't tell if there is more or less land in cypress as in past 10 years	22.1% (27 of 122)
More cypress acreage than last 10 years	0.8% (1 of 122)
No response	7.4% (9 of 122)
Has the availability of cypress stumpage declined in last 10 years?	
Less cypress stumpage available than in the past 10 years	33.6% (41 of 122)
Same amount of cypress stumpage as in the last 10 years	14.8% (18 of 122)
Cannot tell if there is more or less cypress stumpage	36.9% (45 of 122)
More cypress stumpage available than in past 10 years	0.8% (1 of 122)
No response	12.3% (15 of 122)

Table 18  
*Georgia Forestry Professionals Perceptions of Cypress Change Over Last Decade*

General consensus that cypress acreage has not increased in the past 10 years	
Less land in cypress than in the past 10 years	43.6% (17 of 39)
Same amount of land in cypress as in past 10 years	43.6% (17 of 39)
Can't tell if there is more or less land in cypress as in past 10 years	7.7% (3 of 39)
More cypress acreage than last 10 years	0% (0 of 122)
No response	0% (0 of 122)
Has the availability of cypress stumpage declined in last 10 years?	
Less cypress stumpage available than in the past 10 years	66.7% (26 of 39)
Same amount of cypress stumpage as in the last 10 years	17.9% (7 of 39)
Cannot tell if cypress stumpage has changed	12.8% (5 of 39)
More cypress acreage than last 10 years	0% (0 of 39)
No response	2.6% (1 of 39)

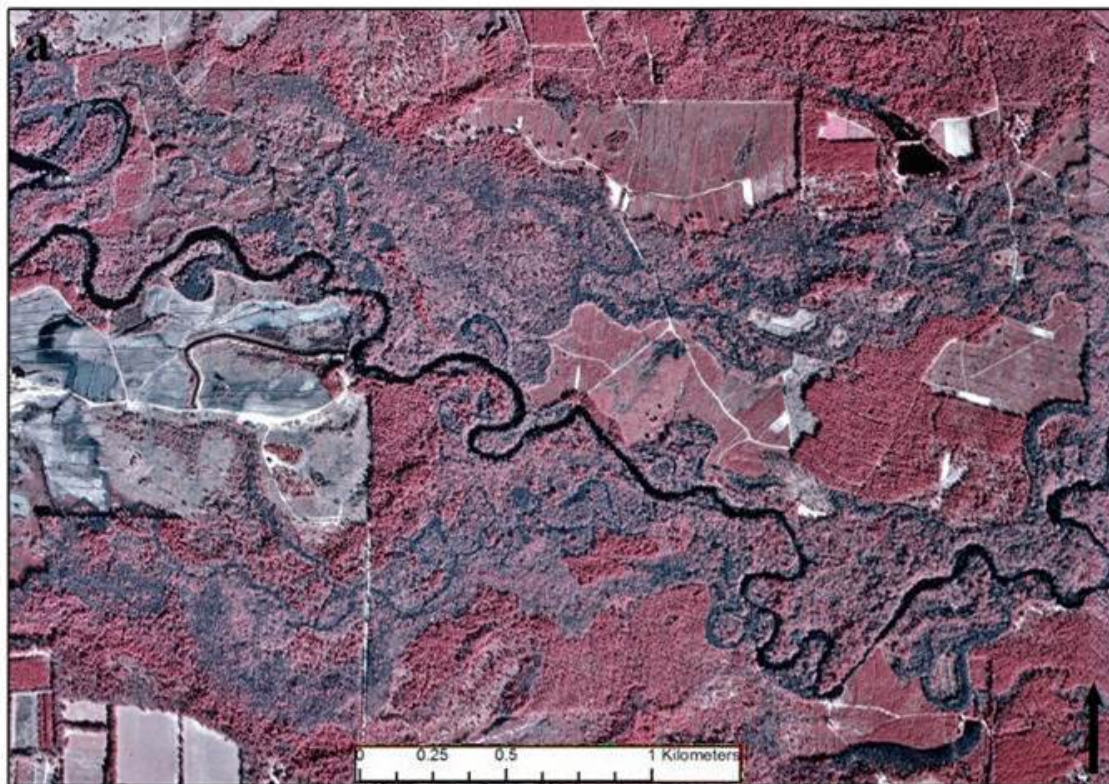


Figure 15a. CIR DOQQ Image of Hoboken, GA from 1999.

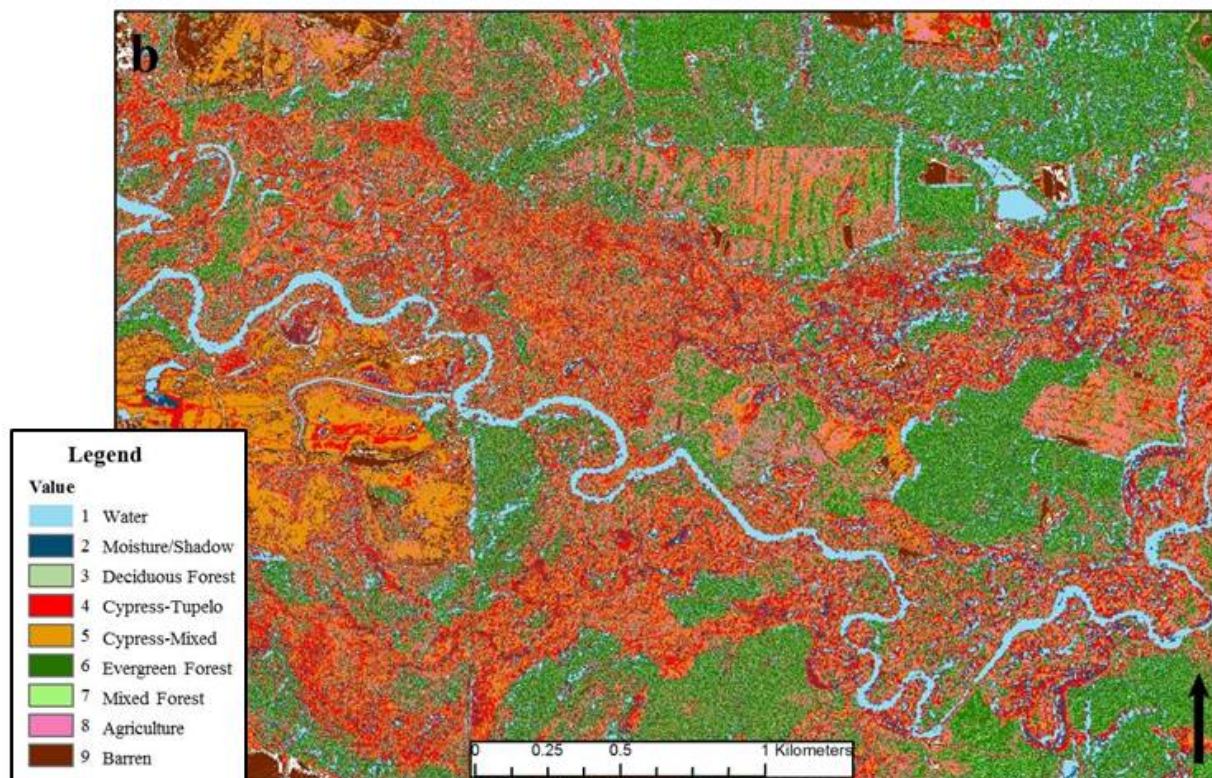


Figure 15b. Classified CIR DOQQ Image of Hoboken, GA from 1999.

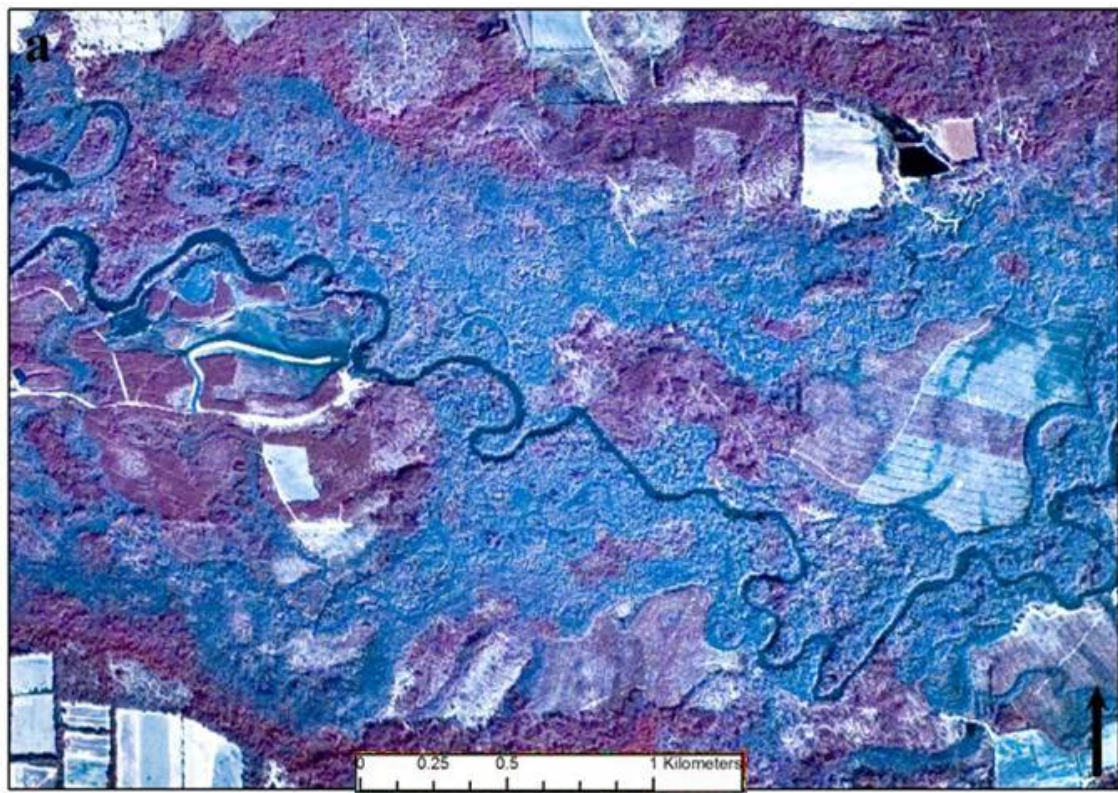


Figure 16a. CIR NAPP Image of Hoboken, GA from 1988.

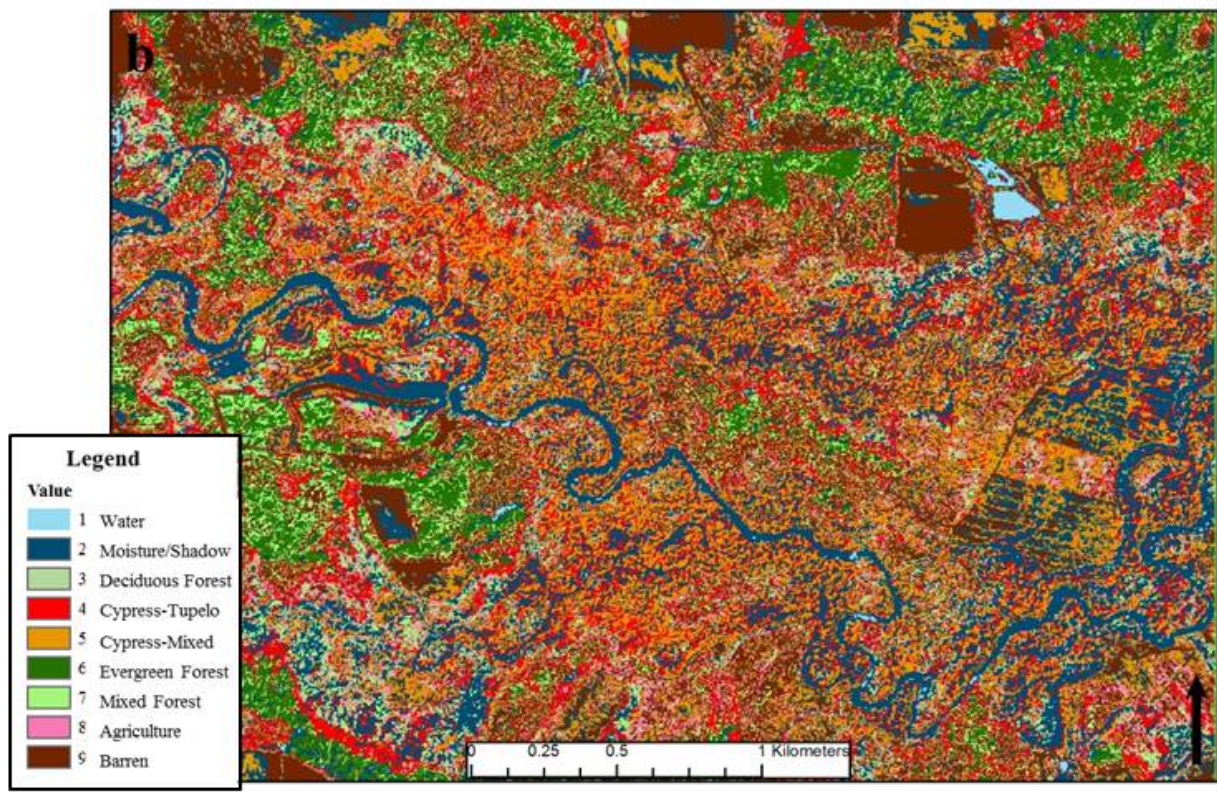


Figure 16b. Classified of CIR NAPP Image of Hoboken, GA from 1988.

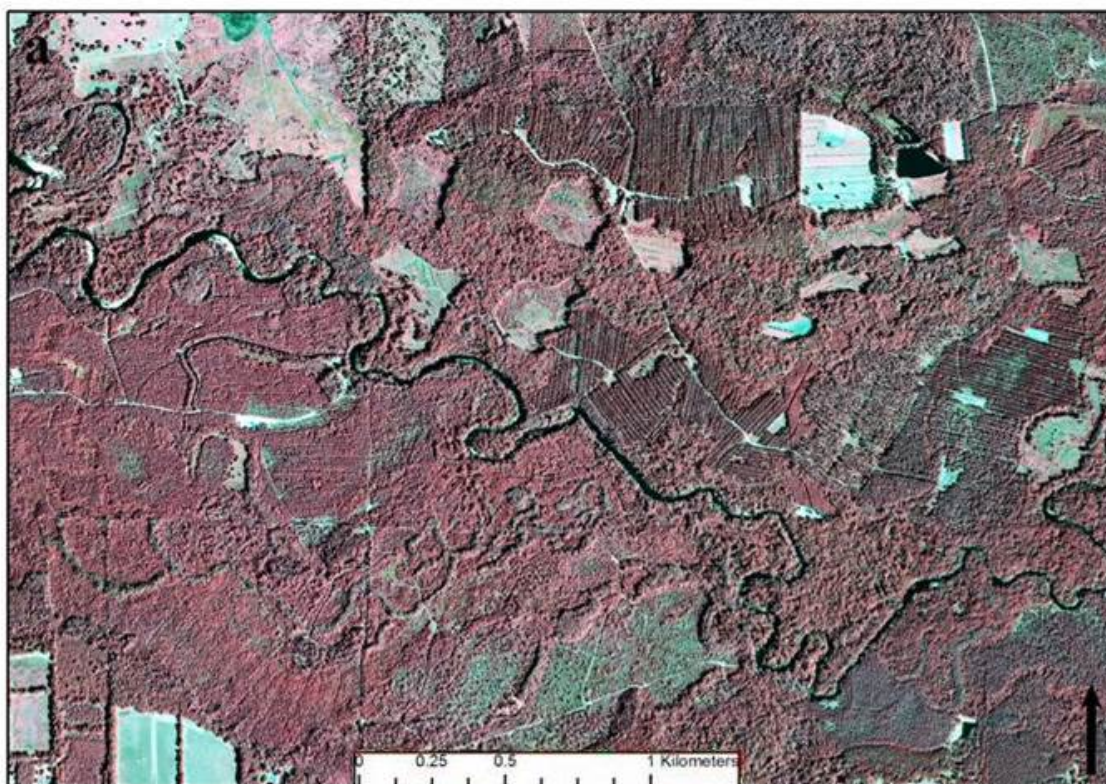


Figure 17a. Four-Band NAIP Image of Hoboken, GA from 2010.

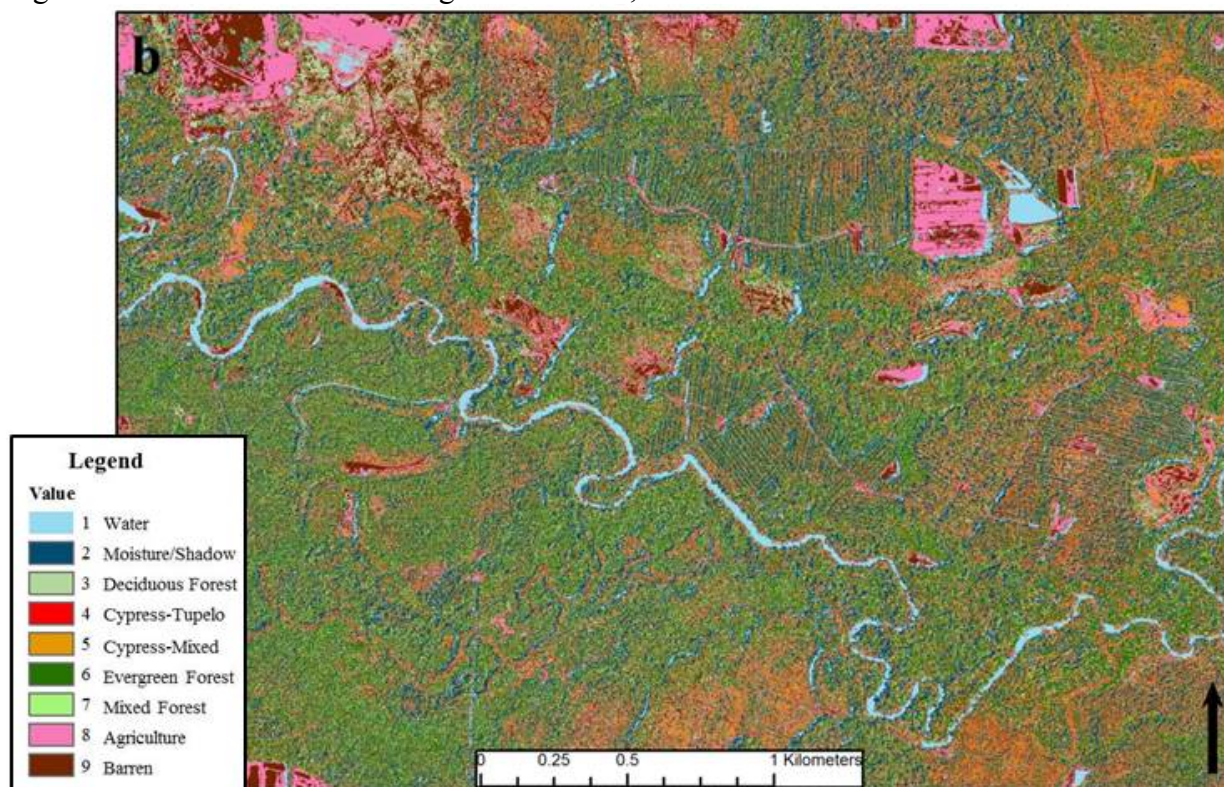


Figure 17b. Classified of Four-Band NAIP Image of Hoboken, GA from 2010.

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APPENDIX A

2013 CYPRESS SURVEY INSTRUMENT FOR GEORGIA LANDOWNERS



July 15, 2013

Dear prospective survey participant:

I invite and encourage you to participate in the enclosed survey of Georgia landowners whose property includes pond and/or bald cypress. The survey is one component of a research project entitled "An evaluation of Cypress Utilization and Regeneration in the US Southeast and Identification of Silvicultural Options for Cypress". The purpose of the study is to assess the current status of cypress production and regeneration in Georgia, and with your help, to identify methods for improving cypress production. The research is funded by the National Council on Air and Stream Improvement and has the cooperation and approval of the Georgia Forestry Commission and the Georgia Forestry Association. *If you do not own or manage lands upon which cypress is present or could be grown, I apologize for having contacted you in error or caused any inconvenience. Please return the survey, and I will remove you from the contact list.*

The survey should take 20 to 30 minutes to complete. There are no risks associated with this survey. Your participation is voluntary, and you may choose not to take part without any penalty or loss of benefits to which you are otherwise entitled, but please return your survey so that you can be removed from our mailing list. By completing and returning this questionnaire, you are agreeing to participate in the survey portion of this research project. Though not completely anonymous, your answers will be kept strictly confidential. The results of the survey may be published, but will be presented in summary form only. No individual information will be identifiable.

If you have any questions about this research project, please feel free to call me at (706) 207-2634 or send an e-mail to me at [lmorris@uga.edu](mailto:lmorris@uga.edu). You may also contact my research coordinator, Ms. Lee Ogden at [logden@uga.edu](mailto:logden@uga.edu) or (706) 542-1069. Questions or concerns about your rights as a research participant should be directed to The Chairperson, University of Georgia Institutional Review Board, 629 Boyd GSRC, Athens, Georgia 30602; telephone (706) 542-3199; email address [irb@uga.edu](mailto:irb@uga.edu).

Thank you for your consideration! Please keep this letter for your records.

Sincerely,

Dr. Larry Morris, Professor of Forest Soils

Athens, Georgia 30602-2152  
Telephone: 706.542.2686 • Fax: 706.542.8356 • <http://www.warnell.uga.edu>  
An Equal Opportunity/Affirmative Action Institution

## 2013 Georgia Cypress Survey

Please help us to evaluate the current status of pond cypress and baldcypress in Georgia and potentially improve methods of managing and regenerating cypress by answering this brief survey. It may take approximately 20 to 30 minutes to complete. Your responses will be strictly confidential. Compiled and anonymous results will be made available to you through multiple outreach opportunities. (Note: Pages are double-sided, so please don't forget to answer any questions.) If possible, please return by August 9. Thank you for your participation.

## Section A: Extent of cypress in Georgia

1. Do you own land that has baldcypress and/or pond cypress trees on it?

YES \_\_\_\_\_ NO \_\_\_\_\_

IF NO, we apologize for any inconvenience, but please return the survey in the pre-paid envelope provided so that we can remove you from the survey participation list. Thank you!

IF YES,

- (a) How many acres\* contain pond cypress or baldcypress?

\_\_\_\_\_ acres with baldcypress (*Taxodium distichum* var. *distichum*)

\_\_\_\_\_ acres with pond cypress (*Taxodium distichum* var. *nutans*)

\_\_\_\_\_ acres with both types of cypress

Note: If you own multiple parcels, please consider them combined, or feel free to be more specific on the back of the last page or on a separate sheet of paper.

- (b) How many acres\* of all types of woodland or forest do you own in total?

\_\_\_\_\_ acres

2. How long have you owned this land? \_\_\_\_\_ years

3. Do you have a management plan for the cypress component of the land(s)?

Yes \_\_\_\_\_ No \_\_\_\_\_

4. Have you harvested cypress from your land? YES \_\_\_\_\_ NO \_\_\_\_\_  
 a. IF NO, please skip to the next section B: Regeneration.

b. If YES, when was the most recent harvest (month or season, and year)?  
 \_\_\_\_\_

\* If you are more comfortable using metric units, please include your units.

c. What were the soil moisture conditions at the time of the harvest?

- (a) Extremely dry
- (b) Dry
- (c) Neither too dry nor too wet
- (d) Wet
- (e) Flooded
- (f) Don't recall or don't know

d. How many acres of cypress were harvested?

\_\_\_\_\_ acres with baldcypress (*Taxodium distichum* var *distichum*)  
 \_\_\_\_\_ acres with pond cypress (*Taxodium distichum* var *nutans*)  
 \_\_\_\_\_ acres with both types of cypress  
 \_\_\_\_\_ not sure how many acres

5. What type of feller was used?

- (a) saw-head (cuts the tree)
- (b) shear-head (shears the tree)
- (c) man with chainsaw
- (d) other (please specify) \_\_\_\_\_
- (e) not sure

6. How low were the stumps cut?

- (a) As close to the ground as possible
- (b) At the mid-point of the butt swell
- (c) Above the high water mark
- (d) Other
- (e) Don't know

7. What method of harvesting was used? (circle all that apply)
- (a) tracked vehicles for felling
  - (b) wheeled vehicles for skidding
  - (c) helicopter skidding
  - (d) cable skidding
  - (e) mats or planks
  - (f) other (please specify) \_\_\_\_\_
  - (g) not sure
8. From what type of stand(s) was the cypress harvested?
- (a) Pure stands of cypress, as in a cypress dome
  - (b) Stands that are predominantly baldcypress-water tupelo
  - (c) Mixed stands of cypress and bottomland hardwoods
  - (d) Mixed stands that include pine
  - (e) Other (please specify) \_\_\_\_\_
9. How often have you harvested cypress from any individual stand or tract?
- (a) Just once
  - (b) Twice since I have owned it, or since it has been in the family
  - (c) Three or more times since I have owned it, or since it has been in the family
  - (d) It had been harvested before I acquired the property
  - (e) I do not know the prior harvest history
10. What single factor most influenced your decision on when to harvest the cypress?
- (a) When it was accessible (i.e. site drier due to drought)
  - (b) When the demand for cypress was high
  - (c) When the rest of the mixed stand was being harvested
  - (d) When I harvested an adjacent stand, and it was dry enough to access the cypress stand
  - (e) When conditions were favorable for regeneration
  - (f) Other (please specify) \_\_\_\_\_

## Section B: Cypress Regeneration

11. Have you consulted or accessed any technical information regarding cypress regeneration or cypress silviculture? (circle all that apply)
- (a) Yes, I worked with a private consultant or registered forester
  - (b) Yes, I spoke with the Georgia Forestry Commission
  - (c) Yes, I spoke with other cypress land owners
  - (d) Yes, I found information on the internet
  - (e) Other: (please specify) \_\_\_\_\_
- 
- (f) No, I did not seek any technical information
12. Have you heard, read, or been told that cypress will regenerate by stump sprouts after a harvest? YES \_\_\_\_\_ NO \_\_\_\_\_
13. Do you take an active role in regenerating cypress on the land that you own?  
YES \_\_\_\_\_ NO \_\_\_\_\_ (please skip to (b))
- a. If YES, what method(s) do you use? (Circle all that apply)
    - 1. Site preparation (please specify) \_\_\_\_\_
    - 2. Seeding with cypress seeds
    - 3. Planting cypress seedlings
    - 4. Competition control to release cypress
    - 5. Timing the harvest to coincide with favorable regeneration factors
    - 6. Other (please explain) \_\_\_\_\_
  - b. If NO, what kind(s) of natural regeneration occurred?
    - 1. Stump sprouts
    - 2. Seedlings
    - 3. Both stump sprouts and seedlings have been observed
    - 4. None has been observed
    - 5. Do not know yet
  - c. If NO, on a scale of 0 to 10, please indicate with an "X" on the line below how successful natural regeneration of cypress been?
 

0	1	2	3	4	5	6	7	8	9	10
unsuccessful	somewhat successful				successful			very successful		

14. Cypress needs moist conditions for seed germination, followed by a dry (non-flooded) period for successful seedling establishment. Please place an X on the line to indicate how likely would you be to postpone a harvest until those conditions are anticipated?

0    1    2    3    4    5    6    7    8    9    10  
 not at all likely      might postpone      likely to postpone      would definitely postpone

15. Considering the type(s) of stand(s) from which you have harvested cypress, what percentage of the subsequent stand(s) still include(s) cypress in the species mix?

0    10    20    30    40    50    60    70    80    90    100%  
 none                  some of the stand(s)      most of the stand(s)      all of the stand(s)

16. Has the cypress portion of the stand(s) decreased, stayed about the same as the pre-harvest stand, or increased?

0    1    2    3    4    5    6    7    8    9    10  
 decreased      decreased slightly      remained about the same      increased

17. Have you had problems with animals, insects, or diseases destroying your cypress seedlings or cypress sprouts? (Check all that apply)

- a. Nutria
- b. Feral pigs or hogs
- c. Deer (continued on the next page)
- d. Beaver
- e. Insects like the Cypress leaf roller
- f. Other (please specify)

---

g. Not sure

18. On the basis of your personal observations on your land and on other cypress land in the area, has cypress acreage changed in the past 10 years?

- (a) Yes, there is more land in cypress production
- (b) No, there is less land in cypress production
- (c) Cypress acreage is about the same
- (d) Can't tell

19. On the basis of your personal observations, has the availability of cypress stumpage declined in the last 10 years?
- (a) Yes, there is less cypress stumpage available
  - (b) No, there is more cypress stumpage available
  - (c) Cypress stumpage availability is about the same
  - (d) Can't tell

Section C. Demographics:

20. In addition to being a cypress landowner, are you also the land manager, a consulting forester, or a combination of those? Please specify.
- \_\_\_\_\_
21. Do you reside on [one of] the property or properties described in the survey?  
YES \_\_\_\_\_ NO \_\_\_\_\_
22. Please indicate your age group: (a) 18 – 30 (b) 31-50 (c) 51- 69 (d) 70 or older
23. What is your gender? (a) male (b) female (c) prefer not to answer
24. Using 1 as the most important reason and 7 as the least important reason, please rank the following statements to indicate how important maintaining a healthy, sustainable cypress component on your land is to you as an individual.
- \_\_\_\_\_ It's important to keep cypress as a "symbol of the South"
- \_\_\_\_\_ It's important to keep this kind of property in my family
- \_\_\_\_\_ It's important to keep cypress for its impacts on wildlife habitat
- \_\_\_\_\_ It's important to keep cypress for its impacts on water quality
- \_\_\_\_\_ It's important to keep cypress for its timber value
- \_\_\_\_\_ It's important for another reason (please specify) \_\_\_\_\_
- \_\_\_\_\_ It's not particularly important to me.
25. Are you a member of any environmentally-based groups such as the Longleaf Alliance or the Georgia Conservancy? YES \_\_\_\_\_ NO \_\_\_\_\_  
If yes, please specify what group(s) \_\_\_\_\_
26. By placing an X on the scale below, please indicate your level of interest in participating in a Cypress Alliance (patterned after the Longleaf Alliance) that would involve multiple stakeholders in the protection/preservation of sustainable cypress ecosystems?
- 0    1    2    3    4    5    6    7    8    9    10
- no interest    somewhat interested    likely to participate    definitely interested

27. By placing an X on the scale below, please indicate your level of interest attending technical training on sustainable cypress harvesting and replanting techniques/methods?
- 0    1    2    3    4    5    6    7    8    9    10
- no interest    somewhat interested    likely to participate    definitely interested
28. By placing an X on the scale below, please indicate how familiar you are with “Georgia’s Best Management Practices for Forestry”.
- 0    1    2    3    4    5    6    7    8    9    10
- I’m unaware of them    I’m familiar with them    I follow them    I helped write them!
29. What sources of technical forest management information would you be likely to follow and implement? (Check all that apply.)
- University of Georgia – Warnell School of Forestry and Natural Resources
  - Georgia Forestry Commission
  - Georgia Forestry Association
  - Consulting or industry forester
  - Web-based information if endorsed by one of the above
  - Landowners/managers I know who have experience with managing cypress
  - Other: please specify
30. Would you be interested in learning more about managing cypress and ensuring its regeneration? YES \_\_\_\_\_ NO \_\_\_\_\_
- If YES, please check the formats that interest you from the list that follows:
- Fact sheet or written information
  - Workshop with instructors
  - Web-based workshop with Interactive (live) instructors, allowing for questions
  - Web information that I can access when convenient for me
  - I prefer that my forester/land manager learn this information and help guide me
31. What suggestions would you make for inclusion in best management guidelines specifically for cypress or for the types of wetlands in which cypress is found? (Please use as much space as you need, including the back of this page or additional paper, if necessary.)

Thank you for your participation. If you have any questions about this survey, please refer to the cover letter for contact information. If you would like to be contacted about particular issues related to cypress management, please include your name, company affiliation (if applicable), mailing address, county of ownership, phone number, and/or email address. We will forward your request to the appropriate person(s).

APPENDIX B

2013 RESULTS OF CYPRESS SURVEY FOR GEORGIA LANDOWNERS

Table 1. Acreage of baldcypress, pond cypress, all cypress, and all woodland for 122 respondents, and length of time of ownership.

	Baldcypress	Pond Cypress	Both cypress	All woodland	Time owned
Mean	43	21	743	3,031	31
Median	10	13	30	367	30
Smallest	1	1	1	20	1
Largest	400	100	25,000	210,000	141
Frequency	43	31	59	118	127**
Sum	1,844	653	43,096	357,836	-

\*\* Greater than 122 because of multiple properties owned.

Table 2. Acreage of baldcypress, pond cypress, both cypress and all woodland for the 24 respondents who reported having harvested cypress, and the acres of cypress they harvested between 1980 and 2013.

	Bald-cypress	Bald-cypress harvested	Pond cypress	Pond cypress harvested	Both cypress	Both cypress harvested	All woodlands
Mean	127	39	38	13	2,556	73	12,274
Median	50	12 to 40	25	15	125	20 to 50	500
Smallest	25	5	2.5	8	1	4	20
Largest	400	125	100	15	25,000	400	210,000
Count	5	6	9	3	15	8	25*
Sum	1,843	237	653	39	38,342	587	357,748

\* Greater than 24 because of multiple properties owned.

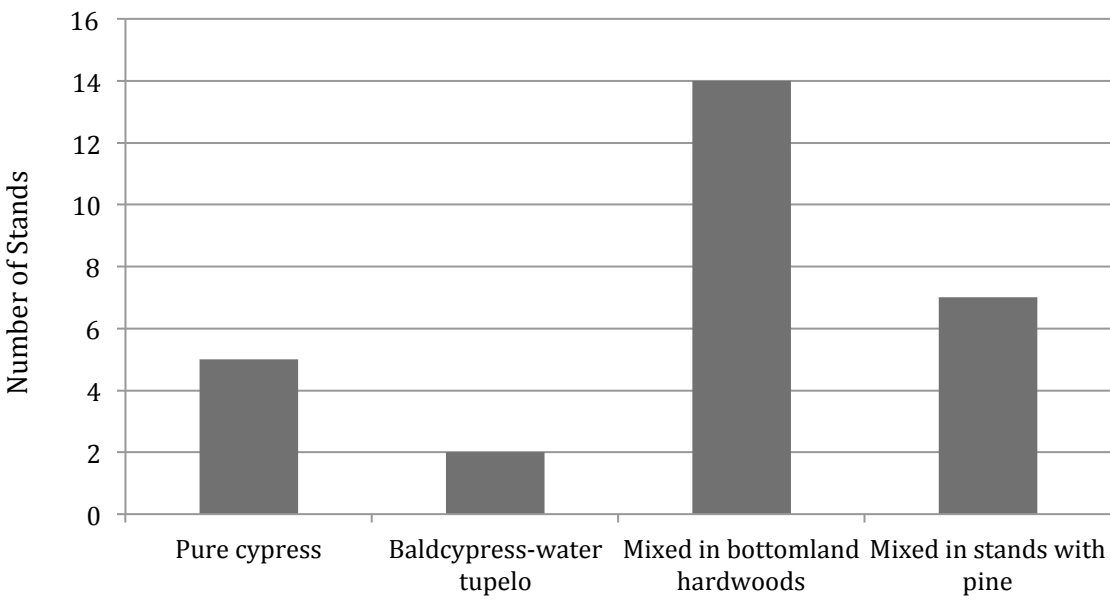


Fig. 1. Composition of 27 stands from which cypress has been harvested since 1984 as reported by Georgia landowners in the survey

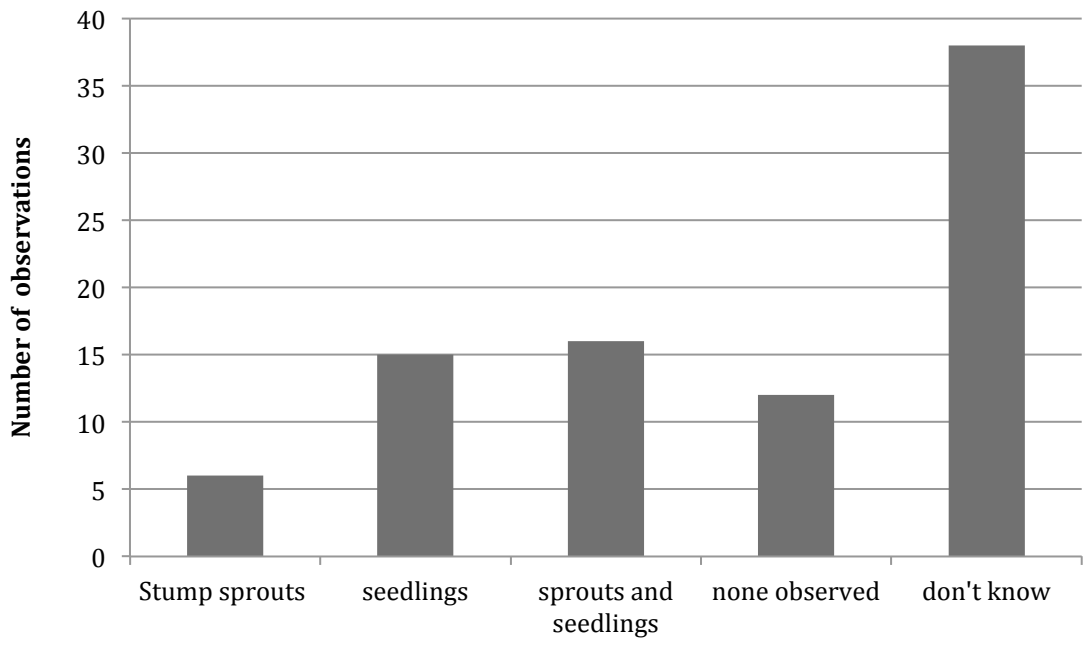


Fig 2. Types of natural cypress regeneration observed by surveyed landowners on their properties (from a total of 87 respondents).

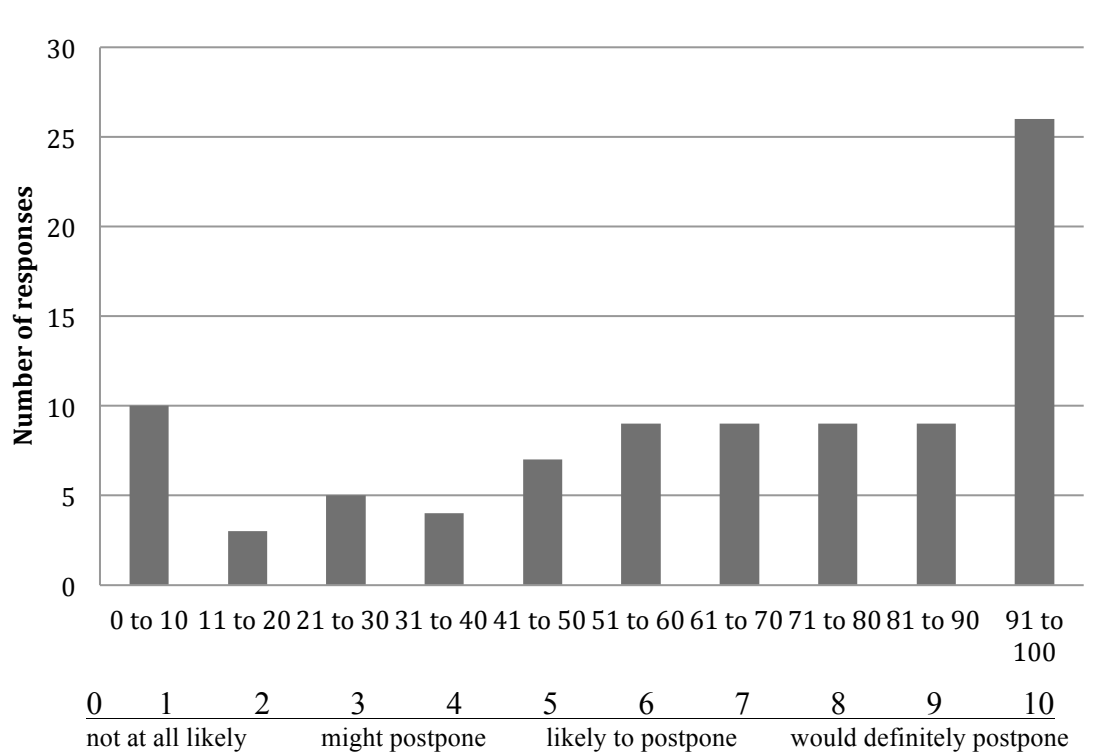


Fig. 3. Likelihood (in percent chance) of postponing a cypress harvest in anticipation of better regeneration conditions

Table 3. Reasons for maintaining a cypress as a healthy component of forest stands as ranked (1=most important, 7= least important) by survey respondents

Statement	Ranking Result	Average Score
It's important to keep cypress as a "symbol of the South"	4	3.48
It's important to keep this kind of property in my family	3	2.66
It's important to keep cypress for its impacts on wildlife habitat	2	2.42
It's important to keep cypress for its impacts on water quality	1	2.24
It's important to keep cypress for its timber value	5	3.76
It's important for another reason (please specify)	6	4.51
It's not particularly important to me	7	5.43

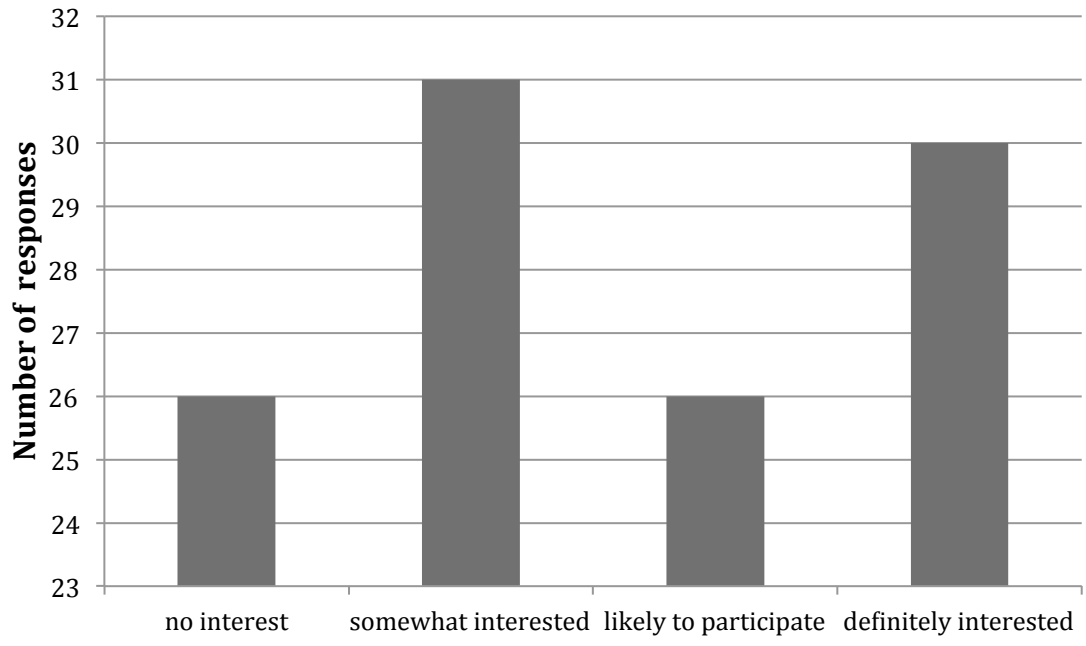


Fig. 4 Respondents indicated interest in participating in a cypress alliance similar to the Longleaf Alliance.

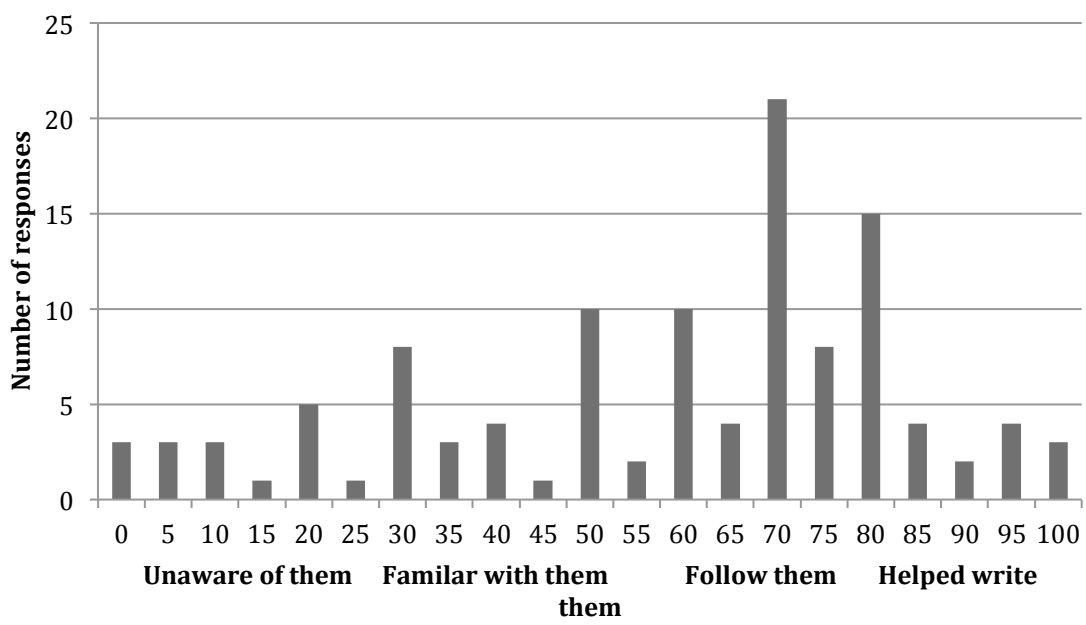


Fig. 5 Familiarity with Georgia BMPs reported by respondents to the Landowner Survey

Table 4. Preferred sources of forest management information among landowners as ranked by survey respondents

Source of Technical Management Information	Number of respondents	Ranking
University of Georgia – Warnell School of Forestry and Natural Resources	84	2
Georgia Forestry Commission	92	1
Georgia Forestry Association	61	4
Consulting or industry forester	78	3
Web-based information if endorsed by one of the above	52	5
Landowners/managers I know with experience managing cypress	48	6
Other	1	8
No response	6	7

APPENDIX C

2013 CYPRESS SURVEY INSTRUMENT FOR GEORGIA FORESTRY PROFESSIONALS



August 26, 2013

Dear prospective survey participant:

I invite and encourage you to participate in the enclosed survey of registered foresters whose Georgia clients' properties includes pond and/or bald cypress. The survey is one component of a research project entitled "An evaluation of Cypress Utilization and Regeneration in the US Southeast and Identification of Silvicultural Options for Cypress". The purpose of the study is to assess the current status of cypress production and regeneration in Georgia, and to identify methods for improving cypress production. The research is funded by the National Council on Air and Stream Improvement and has the cooperation and approval of the Georgia Forestry Commission and the Georgia Forestry Association. *If you do not advise or consult for or manage lands upon which cypress is present or could be grown, I apologize for having contacted you in error or caused any inconvenience. Please return the survey, and I will remove you from the contact list.*

The survey should take 25 to 30 minutes to complete. There are no risks associated with this survey. Your participation is voluntary, and you may choose not to take part without any penalty or loss of benefits to which you are otherwise entitled, but please return your survey so that you can be removed from our mailing list. By completing and returning this questionnaire, you are agreeing to participate in the survey portion of this research project. Though not completely anonymous, your answers will be kept strictly confidential. The results of the survey may be published, but will be presented in summary form only. No individual information will be identifiable.

If you have any questions about this research project, please feel free to call me at (706) 207-2634 or send an e-mail to me at [lmorris@uga.edu](mailto:lmorris@uga.edu). You may also contact my research coordinator, Ms. Lee Ogden at [logden@uga.edu](mailto:logden@uga.edu) or (706) 542-1069. Questions or concerns about your rights as a research participant should be directed to The Chairperson, University of Georgia Institutional Review Board, 629 Boyd GSRC, Athens, Georgia 30602; telephone (706) 542-3199; email address [irb@uga.edu](mailto:irb@uga.edu).

Thank you for your consideration! Please keep this letter for your records.

Sincerely,

Dr. Larry Morris, Professor of Forest Soils

Athens, Georgia 30602-2152  
Telephone: 706.542.2686 • Fax: 706.542.8356 • <http://www.warnell.uga.edu>  
An Equal Opportunity/Affirmative Action Institution

## 2013 Georgia Cypress Survey of Registered Foresters

Please help us to evaluate the current status of pond cypress and baldcypress in Georgia and improve methods of managing and regenerating cypress by answering this brief survey. It may take approximately 20 to 30 minutes to complete. Your responses will be strictly confidential. Compiled and anonymous results will be made available through multiple outreach opportunities. (Note: Pages are double-sided, so please don't forget to answer any questions.) If possible, please return by September 13. Thank you for your participation.

## Section A: Extent of cypress in Georgia

1. Do you advise or consult on and/or manage land in Georgia that includes baldcypress and/or pond cypress? YES \_\_\_\_\_ NO \_\_\_\_\_

IF NO, we apologize for any inconvenience, but please return the survey in the pre-paid envelope provided so that we can remove you from the survey participation list. Thank you!

IF YES,

- (a) How many acres contain cypress?

\_\_\_\_\_ acres with baldcypress (*Taxodium distichum*), but no pond cypress

\_\_\_\_\_ acres with pond cypress (*Taxodium ascendens*), but no baldcypress

\_\_\_\_\_ acres with both types of cypress

Note: If you advise/consult on or manage multiple parcels, please consider them combined, or feel free to be more specific on the back of the last page or on a separate sheet of paper.

- (b) How many acres of all types of woodland or forestland in Georgia do you advise/consult or manage in total?

\_\_\_\_\_ acres

- a. How long have you advised/consulted or managed land that includes cypress?

\_\_\_\_\_ years

2. Do you recommend a written management plan for the cypress component of the lands?

YES \_\_\_\_\_ NO \_\_\_\_\_

3. Is there a demand or markets for cypress in your area?

YES \_\_\_\_\_ NO \_\_\_\_\_

4. Have you advised/consulted or managed a harvest that included cypress?  
 YES \_\_\_\_\_ NO \_\_\_\_\_
- a. IF NO, please skip to the next section B: Regeneration.
- b. If YES, when was the most recent harvest (month or season, and year)?  
 \_\_\_\_\_
- c. What were the soil moisture conditions at the time of the cypress harvest?
- i. Extremely dry
  - ii. Dry
  - iii. Normal or average
  - iv. Wet
  - v. Flooded
  - vi. Don't recall or don't know
- d. How many acres of cypress were harvested?
- \_\_\_\_\_ acres with baldcypress (*Taxodium distichum*)  
 \_\_\_\_\_ acres with pond cypress (*Taxodium ascendens*)  
 \_\_\_\_\_ acres with both types of cypress  
 \_\_\_\_\_ not sure how many acres
5. What type of feller was used?
- (h) saw-head
  - (i) shear-head
  - (j) man with chainsaw
  - (k) other (please specify) \_\_\_\_\_
  - (l) not sure
6. How low were the stumps cut?
- (f) As close to the ground as possible
  - (g) At the mid-point of the butt swell
  - (h) Above the high water mark
  - (i) Other
  - (j) Don't know
7. What methods of extraction were used? (circle all that apply)
- (f) tracked vehicles for felling
  - (g) wheeled vehicles for skidding
  - (h) helicopter skidding
  - (i) cable skidding
  - (j) mats or planks
  - (m) other (please specify) \_\_\_\_\_
  - (n) not sure

8. From what type of stands was the cypress harvested?
- (f) Pure stands of cypress, as in a cypress dome
  - (g) Stands that are predominantly baldcypress-water tupelo
  - (h) Mixed stands of cypress and bottomland hardwoods
  - (i) Mixed stands that include pine
  - (j) Other (please specify) \_\_\_\_\_
9. How often has cypress been harvested from any individual stand or tract?
- (f) Just once
  - (g) Twice since I have advised/consulted or managed it
  - (h) Three or more times since I have advised/consulted or managed it
  - (i) It had been harvested before I became involved with the property
  - (j) I do not know the prior harvest history
10. What single factor most influenced the decision on when to harvest the cypress?
- (g) When it was accessible (i.e. site drier due to drought)
  - (h) When the demand for cypress was high
  - (i) When the rest of the mixed stand was being harvested
  - (j) When they harvested an adjacent stand, and it was dry enough to access the cypress stand
  - (k) When conditions were favorable for regeneration
  - (l) Other (please specify) \_\_\_\_\_
11. Considering the types of stands from which cypress has been harvested, what percentage of the subsequent stands still include cypress in the species mix?
- |      |    |                    |    |    |                    |    |    |                   |    |      |
|------|----|--------------------|----|----|--------------------|----|----|-------------------|----|------|
| 0    | 10 | 20                 | 30 | 40 | 50                 | 60 | 70 | 80                | 90 | 100% |
| none |    | some of the stands |    |    | most of the stands |    |    | all of the stands |    |      |
12. Has the cypress portion of the stands decreased, stayed about the same as the pre-harvest stand, or increased?
- |           |    |                    |    |    |    |                         |    |    |    |           |
|-----------|----|--------------------|----|----|----|-------------------------|----|----|----|-----------|
| 0         | 10 | 20                 | 30 | 40 | 50 | 60                      | 70 | 80 | 90 | 100       |
| decreased |    | decreased slightly |    |    |    | remained about the same |    |    |    | increased |

## Section B: Cypress Regeneration

13. Have you accessed any technical information regarding cypress regeneration or cypress silviculture? (circle all that apply)

- (a) Yes, I spoke with another private consultant or registered forester
- (b) Yes, I spoke with the Georgia Forestry Commission
- (c) Yes, I spoke with cypress land owners
- (d) Yes, I found information on the internet
- (e) Other: (please specify)

---

(f) No, I did not seek any technical information

14. Have you told or advised landowners that cypress will regenerate by stump sprouts after a harvest? YES \_\_\_\_\_ NO \_\_\_\_\_

15. Do you recommend that the landowner take an active role in regenerating cypress?

YES \_\_\_\_\_ NO \_\_\_\_\_ (please skip to (b))

a. If YES, what method(s) do you recommend? (Circle all that apply)

7. Site preparation (please specify) \_\_\_\_\_

8. Seeding with cypress seeds

9. Planting cypress seedlings

10. Competition control to release cypress

11. Timing the harvest to coincide with favorable regeneration factors

12. Other (please explain) \_\_\_\_\_

b. If NO, what kind(s) of natural regeneration have you observed?

6. Stump sprouts

7. Seedlings

8. Both stump sprouts and seedlings

9. None has been observed

10. Do not know yet

c. If NO, on a scale of 0 to 100, please indicate with an "X" on the line below how successful natural regeneration of cypress been?

0	10	20	30	40	50	60	70	80	90	100
unsuccessful		somewhat successful				successful			very successful	

d. Do you normally do a follow-up regeneration check (perhaps 3 to 5 years post-harvest) to determine regeneration success and/or cypress stocking levels?

YES \_\_\_\_\_ NO \_\_\_\_\_

16. Cypress needs moist conditions for seed germination, followed by a dry (non-flooded) period for successful seedling establishment. Please place an X on the line to indicate how likely you would be to suggest or recommend the postponement of a harvest until those conditions are anticipated?

0    10    20    30    40    50    60    70    80    90    100  
 not at all likely    →    might suggest    →    likely to recommend    →    would recommend

17. Have there been problems with animals, insects, or diseases destroying cypress seedlings or stump sprouts? (Circle all that apply)
- Nutria
  - Feral pigs or hogs
  - Deer
  - Beaver (continued on next page)
  - Insects like the Cypress leaf roller
  - Other (please specify) \_\_\_\_\_
  - Not sure

18. On the basis of your personal observations on your lands and on other cypress land in the area, has cypress acreage changed in the past 10 years?
- Yes, there is more land in cypress production
  - No, there is less land in cypress production
  - Cypress acreage is about the same
  - Can't tell

19. On the basis of your personal observations, has the availability of cypress stumpage declined in the last 10 years?
- Yes, there is less cypress stumpage available
  - No, there is more cypress stumpage available
  - Cypress stumpage availability is about the same
  - Can't tell

Section C. Demographics:

20. Please indicate your age group: (a) 18 – 30 (b) 31-50 (c) 51- 69 (d) 70 or older

21. What is your gender? (a) male (b) female (c) prefer not to answer

22. Please indicate your level of knowledge, experience and confidence in cypress silviculture, management, and regeneration?

0    10    20    30    40    50    60    70    80    90    100  
 Not much experience or knowledge    →    →    Extensive experience or knowledge

23. Using 1 as the most important reason and 7 as the least important reason, please rank the following statements to indicate how important maintaining a healthy, sustainable cypress component in the landscape is to you.

It's important to keep cypress as a "symbol of the South"  
 It's important to keep cypress for its impacts on wildlife habitat  
 It's important to keep cypress for its impacts on water quality  
 It's important to keep cypress for its timber value  
 It's important for another reason (please specify) \_\_\_\_\_  
 It's not particularly important to me.

24. Are you a member of any environmentally-based groups such as the Longleaf Alliance or the Georgia Conservancy? YES \_\_\_\_\_ NO \_\_\_\_\_  
 If yes, please specify what group(s) \_\_\_\_\_

25. By placing an X on the scale below, please indicate your level of interest in participating in a Cypress Alliance (patterned after the Longleaf Alliance) that would involve multiple stakeholders in the protection/preservation of sustainable cypress ecosystems?

0    10    20    30    40    50    60    70    80    90    100  
 no interest    somewhat interested    likely to participate    definitely interested

26. By placing an X on the scale below, please indicate your level of interest attending technical training on sustainable cypress harvesting and replanting techniques/methods?

0    10    20    30    40    50    60    70    80    90    100  
 no interest    somewhat interested    likely to participate    definitely interested

27. By placing an X on the scale below, please indicate how familiar you are with "Georgia's Best Management Practices for Forestry".

0    1    2    3    4    5    6    7    8    9    10  
 I'm unaware of them    I'm familiar with them    I know them well    I helped write them!

28. What sources of technical cypress management information would you be likely to follow and implement? (Circle all that apply.)
- University of Georgia – Warnell School of Forestry and Natural Resources
  - Georgia Forestry Commission
  - Georgia Forestry Association
  - Consulting or industry forester
  - Web-based information if endorsed by one of the above
  - Landowners/managers I know who have experience with managing cypress
  - Other: please specify
- 

29. Are you interested in learning more about managing cypress and ensuring its regeneration? YES \_\_\_\_\_ NO \_\_\_\_\_

If YES, please circle the formats that interest you from the list that follows:

- Fact sheet or written information
  - Workshop with instructors
  - Web-based workshop with Interactive (live) instructors, allowing for questions
  - Web information that I can access when convenient for me
30. What suggestions would you make for inclusion in best management guidelines specifically for cypress or for the types of wetlands in which cypress is found? (Please use as much space as you need, including the back of this page or additional paper, if necessary.)

Thank you for your participation. If you have any questions about this survey, please refer to the cover letter for contact information. If you would like to be contacted about particular issues related to cypress management, please include your name, company affiliation (if applicable), mailing address, phone number, and/or email address. We will forward your request to the appropriate person(s).

APPENDIX D

2013 RESULTS OF CYPRESS SURVEY FOR GEORGIA FORESTRY PROFESSIONALS

Table 1. Acreage of baldcypress, pond cypress, mixed cypress, and all woodlands reported managed by 39 registered and consulting foresters, and length of time managed by those responding individuals.

	Baldcypress	Pond Cypress	Mixed Cypress	All Woodland	Years Managed
Mean	7,407	11,346	4,219	201,505	23
Median	500 to 1,000	1,000	1,000	30,000	20
Smallest	70	20	10	20	5
Largest	> 60,000	100,000	24,000	210,000	60
Number of tracts*	14	14	22	---	--
Total acres	103,691	158,846	92,809	7,657,172	

\* Total greater than 39 because of multiple properties managed by some respondents.

Table 2. Statistics for area (acres) of harvested tracts containing baldcypress, pond cypress, and both cypress species harvested between 1980 and 2013 as reported by 27 forestry professionals (Note: not all 27 respondents specified acreage by species.)

	Bald-Cypress	Pond Cypress	Both Cypress
Mean area	4,146	2,371	179
Median area	60	60 to 200	50
Smallest area	20	5	10
Largest area	28,800	13,650	645
Number of tracts	7	6	10
Sum of acreage	29,235	14,225	1,615

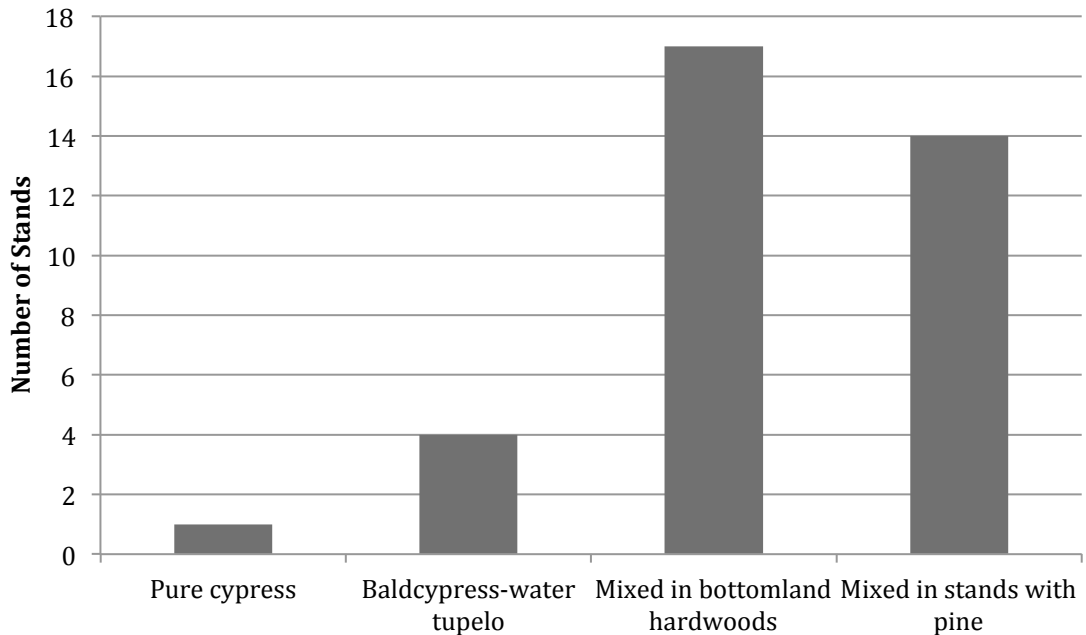


Fig. 1. Stand composition of 36 tracts harvested since 2003 that forestry professionals reported contained cypress.

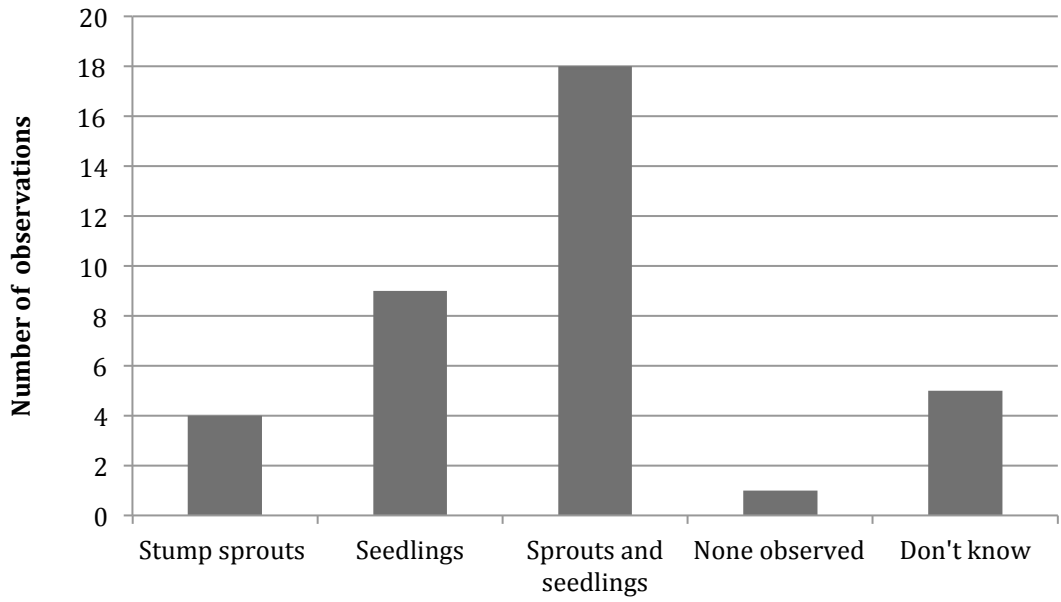


Fig. 2. Types of cypress natural regeneration observed by forestry professionals on the properties they manage.

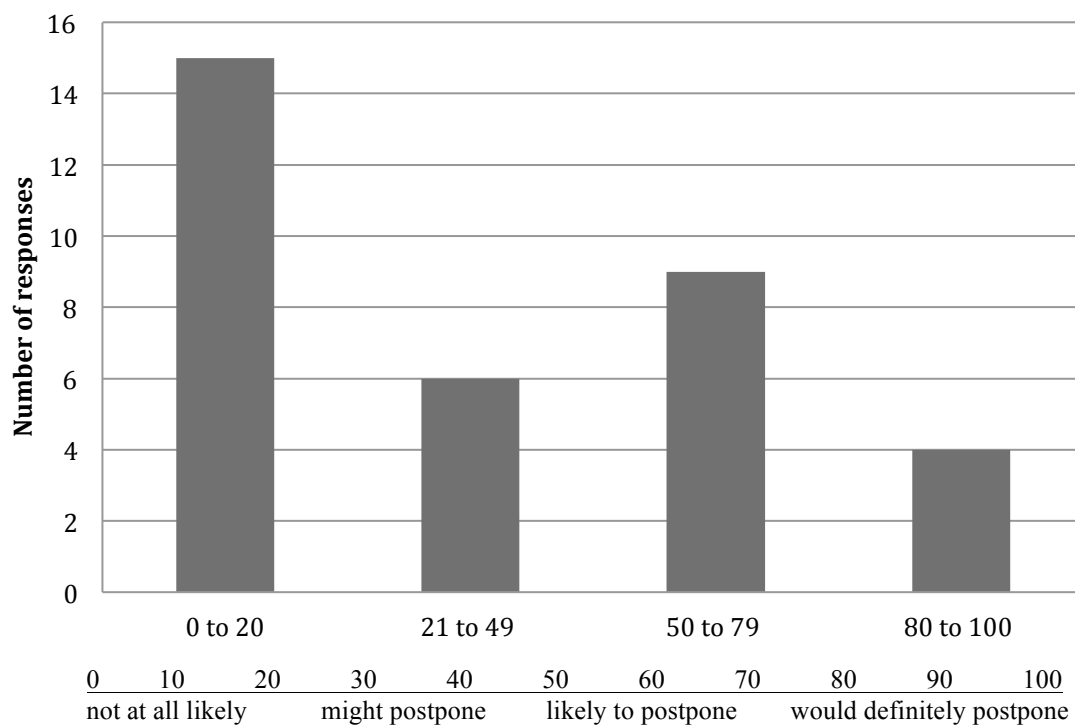


Fig. 3 Likelihood (in percent chance) of postponing a cypress harvest in anticipation of better regeneration conditions

Table 3. Reasons for maintaining a cypress as a healthy component of forest stands as ranked by forestry professionals (1=most important, 6= least important) by survey respondents

Statement	Ranking	Average Score
It's important to keep cypress as a "symbol of the South"	5	4.22
It's important to keep cypress for its impacts on wildlife habitat	3	2.95
It's important to keep cypress for its impacts on water quality	1	2.32
It's important to keep cypress for its timber value	2	2.81
It's important for another reason (please specify)	4	3.58
It's not particularly important to me	6	5.56

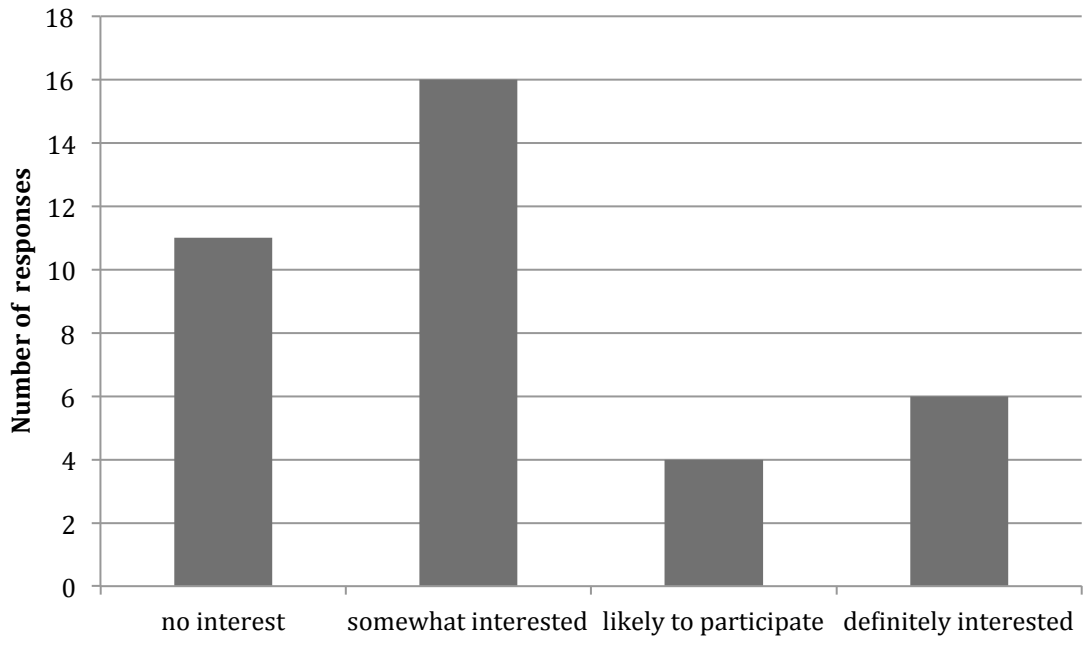


Fig 5. Professional forester interest in participating in a Cypress Alliance similar to the Longleaf Alliance

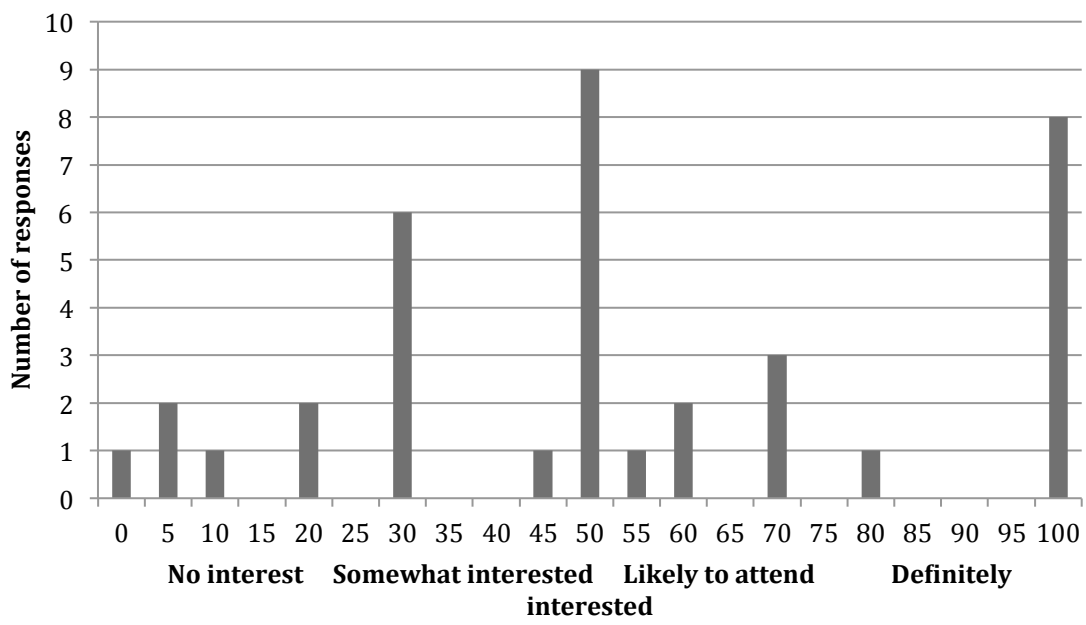


Fig. 6. Interest in attending technical training on sustainable cypress harvesting and replanting techniques/methods.

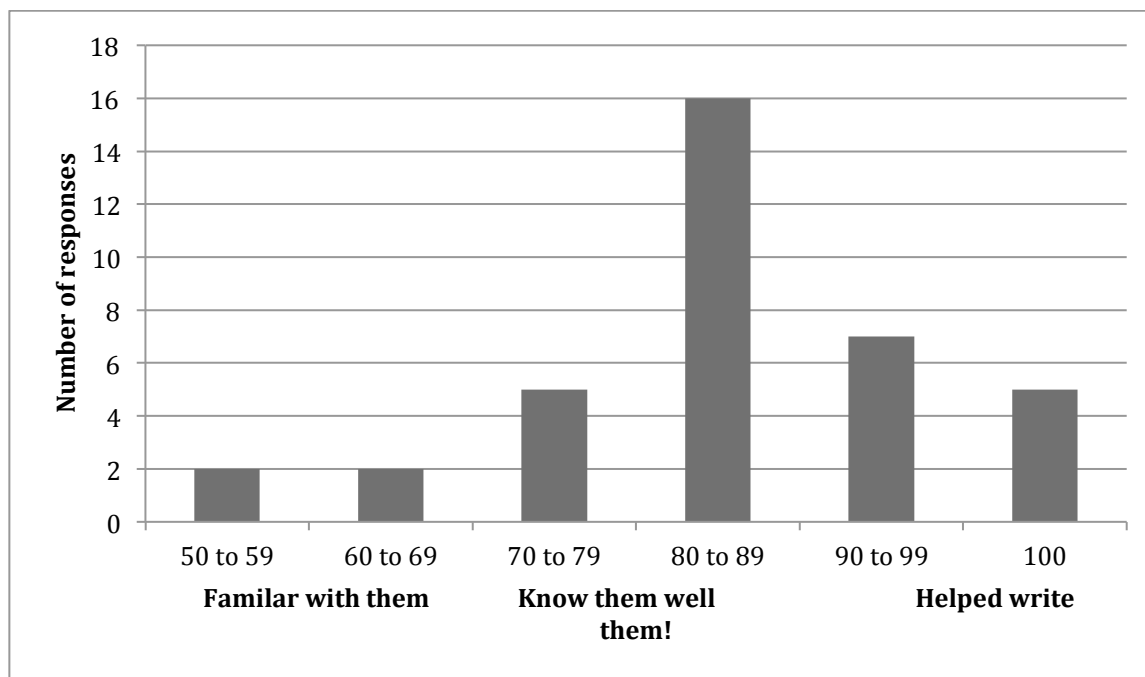


Fig. 7. Familiarity of registered and consulting foresters with "Georgia's Best Management Practices for Forestry."