# FINAL REPORT
## South Carolina State Wildlife Grant SC-T-F13AF01180
South Carolina Department of Natural Resources
October 1, 2013 – September 30, 2015

Project Title: *Mapping and Classifying Tidal Freshwater Wetlands in the ACE Basin of South Carolina*
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## SUMMARY:

The study area of this project is located in the tidal freshwater zone within the Ashepoo-Combahee-Edisto (ACE) Basin watershed.  The study area extends to the upstream limit of tidal influence on the three ACE Basin rivers, the South Edisto at Givhans, all of the Combahee River, and the Ashepoo River at Walterboro (Figure 1).  The study area is approximately 284,200 acres with ~247,000 acres within Colleton and the remaining acreage in Beaufort and Charleston counties.  This is a rural area, and the landscape is dominated by planted pines (aka Pine Plantations), agricultural lands, and managed wetlands.

The three objectives of the project were to:
 1) Develop an automated mapping tool that applies LiDAR (Light Detection And Ranging) data and remote sensing data to delineate land features within the study area.

 2) Create high resolution land cover maps that will be used to update the 1999 SC Gap Analysis Program (SCGAP) land cover dataset.

 3) Develop agency stand-alone competency in a new spatial analysis tool that will have wide application to SCDNR managed lands throughout the state.

The automated mapping tool that applies LiDAR (Light Detection And Ranging) data and remote sensing data was successfully completed.  With the exception of the final process in step four, the tool requires no input from the user.  The analysis in the final process requires the user to divide the bands into two categories that are associated with the land features, and the analysis creates two new images and partitions the bands into class codes based on elevation and spectral similarity.  Through field surveys and with prior knowledge of the area, land cover associated with the class codes are identified and assigned to the class codes.  A Reclassify technique is provided for the user to group similar class codes or assign names to the codes, and the codes with the same land cover type were grouped.

For this project, the bands were divided into a Forest and a "Not Forest" category.  Field surveys and with prior knowledge of the area, land cover types associated with the Forest and "Not Forest" class codes were identified.  Pines and hardwoods were associated with the codes on the Forest land maps; while the "Not Forest" codes represented the elevation or hydrology regime of the land features.  The Reclassify tool was used to group the class codes in the two new images, based on vegetation or environmental (elevation and hydrology regime) similarity.  The final

land cover map will allow us to detect changes in land use from vegetated to un-vegetated and from natural to cultural land cover that occur at a 1.4-meter resolution.

Planted pines (aka Pine Plantations), agricultural lands, and managed wetlands dominate the landscape in the study area.  The land cover map and the SCGAP map were divided into eleven sections, which are named tile index 1 – 11 in order to identify changes to the SCGAP land classifications between 1992 and 2007. The three major changes that occurred during this time period are: 1) harvesting and regeneration of planted pines; 2) conversion of wetlands to Greentree wetlands or to planted pines; and 3) conversion of upland forest to planted pines.  No changes to the land classification occurred on Tile Index 10 map; while all three major changes were observed on Tile Index 1, 3, 5, and 9 maps.  Two changes occurred on Tile Index 2, 7-8: Mature planted pines were harvested and upland forests were converted to planted pines.  The only change to the SCGAP classification on Tile Index 6 and 11 maps was the conversion of upland forest to planted pine.

An instruction manual that walks the user through the steps of the mapping tool was prepared.  The 24 steps in the manual provide step-by-step instructions per each step of the process, beginning with acquisition of the LiDAR and ending with the creation of a preliminary land cover map.  The first eleven steps focus on data acquisition and management.  The user learns how to select and download the raw LiDAR from the NOAA Office for Coastal Management Geospatial website.  Then, the user is shown how to structure the directory and set up the geodatabases needed for the mapping process.  The next thirteen steps guide the user through the mapping, and a description of the process performed at each step.

**Objective 1:** Develop an automated mapping tool that applies LiDAR (Light Detection And Ranging) data and remote sensing data.

**Accomplishments of Objective 1:** Completed the automated mapping tool (Data Management, LiDAR Process, LiDAR Segmentation, LiDAR-Image Fusion) (Figure 2).  The tool was used to create preliminary land cover maps of the study area within Colleton County (Figure 3). Below is a brief description of the steps of the tool.  The thesis of the graduate student, Melissa Strickland, who assisted with the development of the tool, provides a more detailed description of how the tool works (Strickland 2014).

In the first step (*Create Geodatabases*), all the necessary geodatabases and directories are created in the location the user has chosen. This includes a geodatabase titled "working," where the results of the interpolation and texture tools are stored; and a geodatabase titled "transfer," where the imported LAS to multipoint data is stored; a geodatabase titled "final," where the results of the band ratio, principal components, and mask creation steps are stored; a geodatabase titled "classification," where the isocluster results are stored. Also included are directories for calculations from principal component analysis, band ratio statistics, and isocluster analysis, titled "pc_files," "br_stats," and "iso_sig," respectively.

The second step (*LiDAR Processing*) calculates the LAS statistics, including the number of returns, and separates the LiDAR data into 5 return classes: Last, Lower, Mid, Upper, and All. These classes represent a multistory depiction of an area's three-dimensional structure. The Last

and Lower classes comprise the lower story/ground level, the Mid class comprises the mid-story, while the Upper class comprises the upper story/canopy level; the All class is comprised of all of the structures. Presence or absence of specific return classes alone provides information about the region. For example, a scene with a lack of point data in the fourth return class is likely one with low-lying vegetation, not tall forests. Lack of point data in the third return class could indicate a sparse mid-story.

With the third step (*LiDAR Segmentation*), textural images of the five LiDAR sets (All, Last, Upper, Mid, and Lower returns), are created with interpolation and filtering algorithms and with Principal Component Analysis (PCA). Segmentation is the process of grouping the individual LiDAR points with adjacent ones, creating clusters that represent discrete land features, such as water, trees, or roads and buildings. The two interpolation methods, Inverse Distance Weighting and Nearest Neighbor Algorithm, create the first textural images by using the elevation of LiDAR points to estimate the elevations at points where LiDAR was not measured and then form clusters of the points based on elevation similarity. Next, texture filter techniques are applied to these images to arrange points, based on the vertical and horizontal relationships between them, to create a pattern that is recognizable by the mapper. The PCA analysis combines the results of textural filtering algorithms with spectral wavelength data on the imagery to add the spectral variations of the land features, such as trees and buildings, to enhance the textural filtering image. Figure 4 illustrates how the Segmentation process transformed the LiDAR data for the section of Jacksonboro (Figure 4a) into a filtering textural image that resembles the aerial image of the area (Figure 4b); in fact, it highlights ground features such as the fire lane (in red circle) that are not visible on the aerial image shown in Figure 4c. Next, the Band Rationing techniques sharpen the boundaries between the types of land features on the filtering images such as the marshes and flats that are now visible (Figure 4d).

The fourth step (*LiDAR – Image Fusion*) of the tool creates the preliminary land cover maps. First, a Band Rationing technique is applied that uses the PCA and correlation matrix analysis to pick the best ratios of the two spectral wavelength bands that help users discriminate between land cover types. Then, an unsupervised isocluster analysis combines the eight bands of the PCA analysis and two bands of the Band Rationing technique to create the final textural image (Figure 4e). This analysis also generates a signature file that contains codes that are associated with the bands.

The next process in this step signifies the point where the tool becomes less automated and requires more user input. For the second isocluster analysis, the user places the codes of the images into two categories, such as marsh and other land cover types, and runs the analysis to create separate images for both categories. The analysis partitions the land features into classes based on their vertical position to other features within the category, and it generates signature files for the two new images. A Reclassify technique is provided for the user to group similar class codes or assign names to the codes, and the codes with the same land cover type are grouped. This is the final step in the LiDAR Fusion Method tool.

For this project, the preliminary land cover maps were created for Forest and "Not Forest" categories. Field surveys were conducted to identify the class codes associated with the Forest and "Not Forest" categories, and the analysis was run on the forest and the "Not Forest"

categories.  The analysis partitioned the Forest category (bands 7-10) and "Not Forest" category (bands 1-6) into land cover types based on elevation similarity (Table 1).  In the resultant forest images, two tree types, pines and hardwoods, characterized ground cover associated with the class codes while elevation and hydrology characterized the classes of the "Not Forest" images.  Because the same vegetation type or environmental condition characterized more than one class code, ArcMap Reclassify analysis was used to simplify the class codes (Table 2).  Before running this analysis, the colors associated with the land features must be standardized across the entire study area.  This is an iterative process, and the best approach was to start with two adjacent maps and standardize the color scheme of the two maps by comparing the spectral map signature and land features; then maps are added adjacent to these two maps and the standardization process is repeated.  If unable to standardize the color scheme on an adjacent map, skip over this map and continue the process with other maps in the study area.  At the end of this process, return to the skipped maps; determined how to make the legend color scheme consistent with the other maps.

The high resolution maps provide a baseline dataset of tracking rates and extent of alterations to the ACE Basin tidal freshwater zone due to environmental or anthropogenic stressors.

**Significant Deviations of Objective 1:**   The 716 LiDAR tiles for Colleton County were completed, but the LiDAR tiles for Beaufort and Charleston counties were not available in time to complete these maps with the LiDAR Fusion tool before the end of the grant; however, the tool provides us the ability to do this in the future. Twenty-six of the Colleton tiles downloaded would not process properly; further evaluation of these tile download issues is needed before these areas can be analyzed.

**Objective 2:** Update the 1999 South Carolina Gap Analysis Program (SCGAP) land cover dataset with the high resolution land cover maps.

**Accomplishments of Objective 2:**   The 1999 SCGAP maps were compared to our new maps and area of change were identified.  Planted pines (aka Pine Plantations), agricultural lands, and managed wetlands dominate the landscape in the study area.   The land cover map and the SCGAP map were divided into eleven sections, which are named tile index 1 – 11 (Figure 5) in order to identify changes to the SCGAP land classifications between 1992 and 2007 (Figures 6-15).   The three major changes that occurred during this time period were: 1) harvesting and regeneration of planted pines; 2) conversion of wetlands to Greentree wetlands or to planted pines; and 3) conversion of upland forest to planted pines.  No changes to the land classification occurred on Tile Index 10 map; while all three major changes were observed on Tile Index 1, 3, 5, and 9 maps.  Two changes occurred on Tile Index 2, 7-8: Mature planted pines were harvested and upland forests were converted to planted pines.   The only change to the 1999 SCGAP classification on Tile Index 6 and 11 maps was the conversion of upland forest to planted pine.

**Significant Deviations of Objective 2:** The SCGAP maps housed on the USGS website were reviewed and visual observations were recorded on the Marine Resources Division (MRD) versions of the maps. We have not attempted to request a change to the maps on the USGS website.

**Objective 3:** Develop agency stand-alone competency in a new spatial analysis tool.

**Accomplishments of Objective 3:** An instruction manual that walks the user through the steps of the mapping tool was prepared. The manual provides 24 step-by-step instructions of the mapping process, beginning with acquisition of the LiDAR and ending with the creation of a preliminary land cover map. The first eleven steps focus on data acquisition and management. The user learns how to select and download the raw LiDAR from the NOAA Office for Coastal Management Geospatial website. Then, the user is shown how to structure the directory and set up the geodatabases needed for the mapping process. The next thirteen steps guide the user through the mapping process, and a description of the process performed at each step.

Before starting the mapping process, an aerial imagery must be chosen for the final mapping step. The LIDAR data and aerial imagery should have similar resolution, and data should have been collected relatively close in time, i.e. the LiDAR data for the project was collected during 2007 and the National Agricultural Imagery Program (NAIP) imagery was collected during 2009.

**Significant Deviations of Objective 3:** Instead of conducting training workshops, two presentations were made at the Marine Resources Division Conference that was held during March 2014 and 2015. This conference is attended by representatives from all of the SCDNR divisions. The first talk was about the goals and objectives of the tidal freshwater mapping project, steps of the automated mapping tool, and the user input into preparing the preliminary land cover maps. The second talk provided an update on the mapping efforts and our efforts to cross-walk the MRD classification to the SCGAP classification by integrating photo-interpretation methods with the LiDAR textural images.

Also, the instructions manual was designed to be a stand-alone document that guides the user through the mapping process and provides descriptions of the process performed at each step of the tool. A more detailed description of how the tool works is provided in the thesis of the graduate student, Melissa Strickland, who assisted with the development of the mapping tool (Strickland 2014).

**Literature Cited:**
Garfield, N., K. Madden, S. Upchurch, S. Shull, N. Herold, M. Ferner, and C. Weidman. 2013. Mapping Land Use and Habitat Change in the NERRS: Standard Operating Procedures; Version 2. Companion document to: Recommended Guidelines for Adoption and Implementation of the NERRS Comprehensive Habitat and Land Use Classification System.

Strickland, M.A. 2014. High Resolution Critical Habitat Mapping and Classification of Tidal Freshwater Wetlands in the ACE Basin. Masters of Sciences thesis. College of Charleston, South Carolina. 278 p.

**Estimated Federal Cost:** $12,676
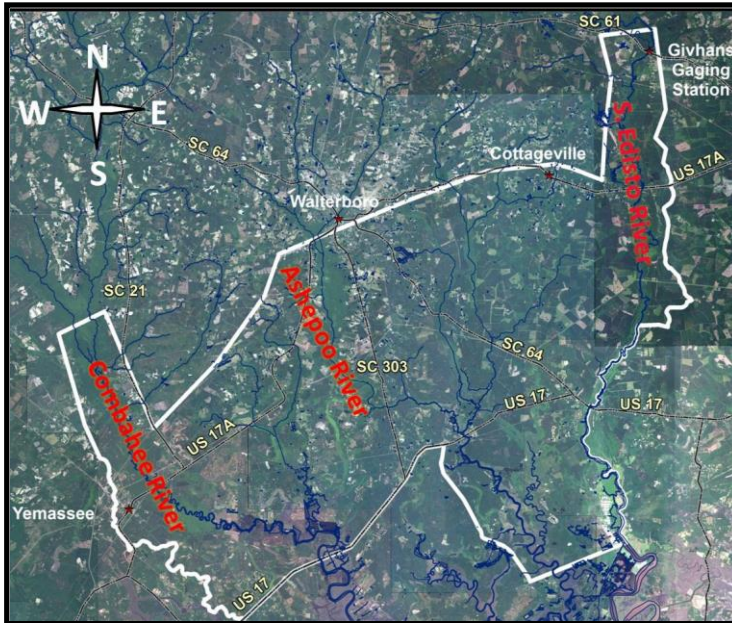
**Recommendations:** Close the grant.

Figure 1.  The approximate extent of the tidal freshwater wetlands in the ACE Basin is indicated by the white line.  This study area is approximately an hour south of Charleston, SC.
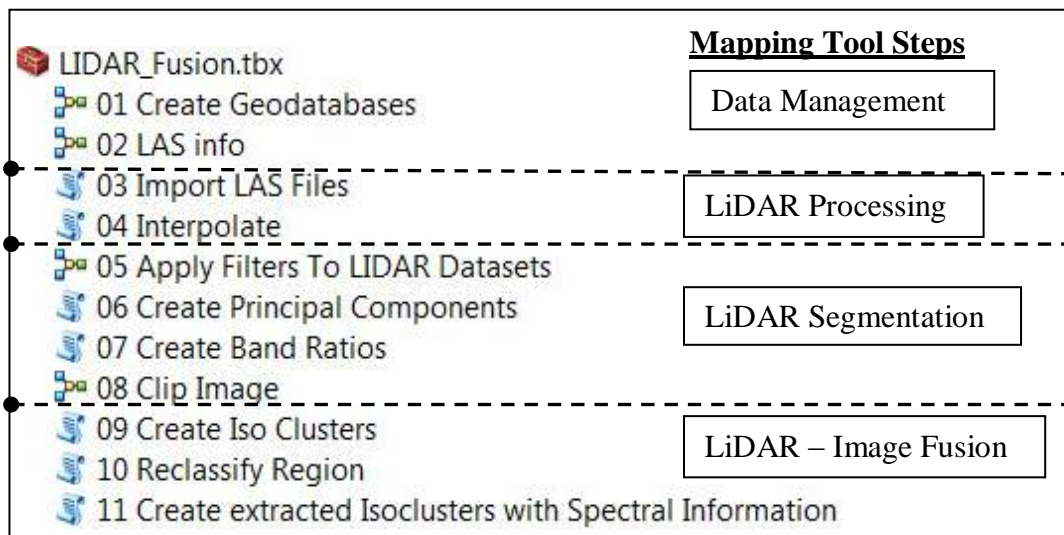


Figure 2.  The automated mapping tool is comprised of the following steps.
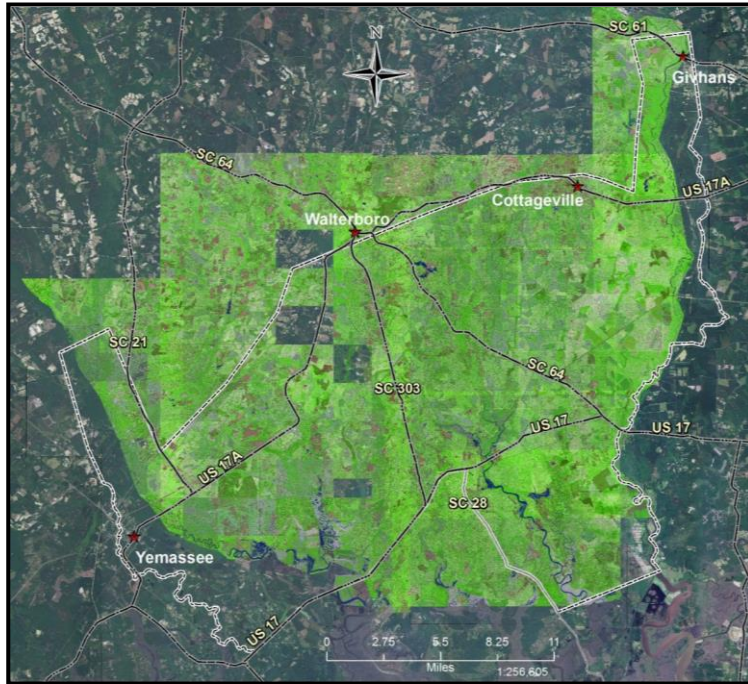
Figure 3. The final textural image below was created by an unsupervised isocluster analysis that combined the eight bands of the Textural Filtering images and the two bands of the Band Rationing images.

The following figures illustrates how the segmentation process of step 3 of the mapping tool transforms the raw LiDAR data into a textural image that resembles an aerial imagery.
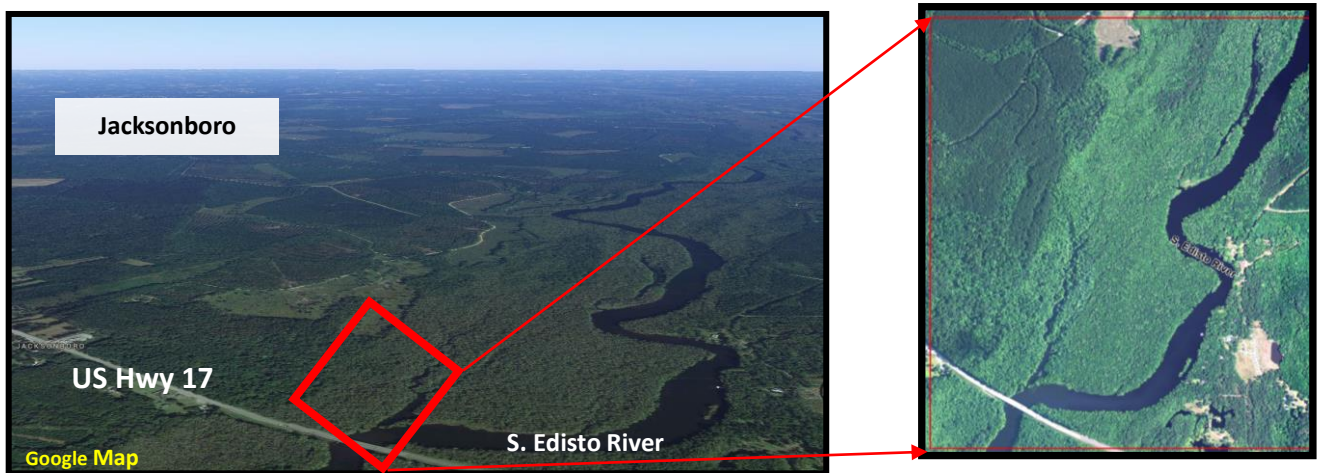


Figure 4a. Using data collected in Jacksonboro, SC as an example.
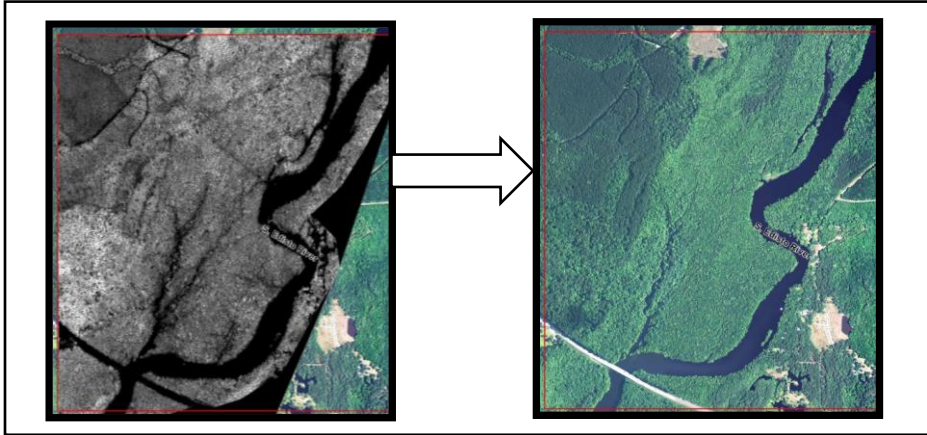
Figure 4b. The raw LiDAR data of the area was transformed into an image that resembles a black & white version of the high resolution aerial image to the right.
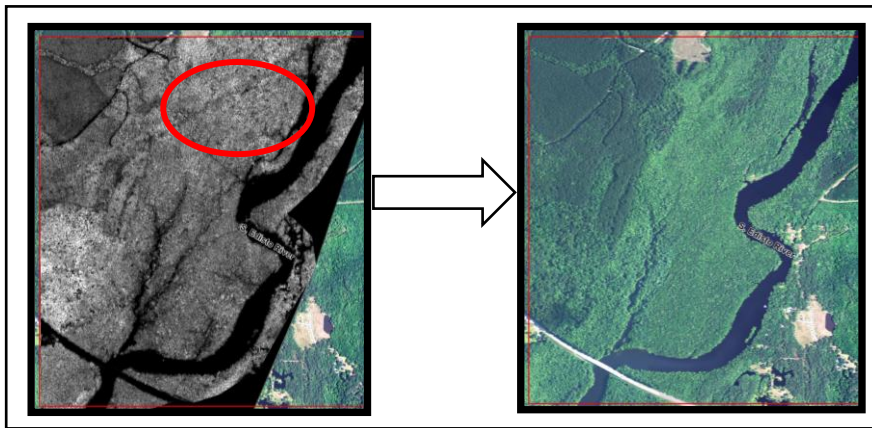


Figure 4c. The Textural Filtering Algorithm highlights ground features such as this fire lane within the red circle that are not visible in the red circle on the aerial image on the right.
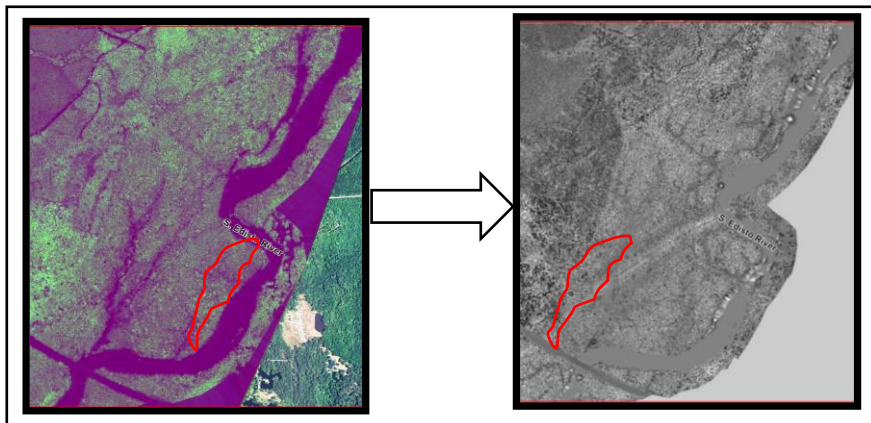


Figure 4d. A Band Rationing Technique was performed in order to sharpen the boundaries between the types of land features on the textural image. In the figure below, notice that, after

the analysis, the marshes & flats along the river within the red area are visible on the new image on the left, but not visible in the red area on the textural image to the right.
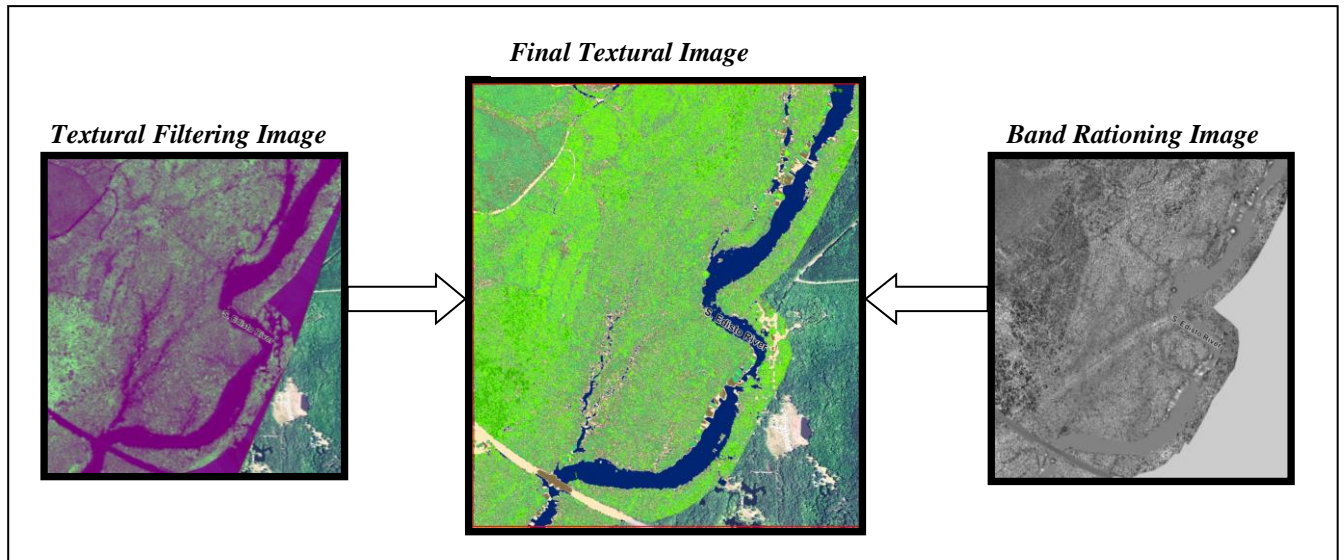


Figure 4e. The final textural image below was created by a second PCA that combined the eight bands of the Textural Filtering image (on the left) and the two bands of the Band Rationing image (on the right).

Table 1. The ground features associated with the Forest and Not Forest class codes.

| Forest Category | | Not Forest Categories | |
|---|---|---|---|
| Class Code | Vegetation Type | Class Code | Vegetation Type |
| 1 | Gaps/Shadows | 1 | Water/ Bare Ground |
| 2 | Gaps/Shadows | 2 | Wet Lands |
| 3 | Short Pines & Hardwoods | 3 | Wet Lands |
| 4 | Mid-size Pines & Hardwoods | 4 | Wet Lands |
| 5 | Mid-size Pines & Hardwoods | 5 | Low-lying Areas |
| 6 | Tall Pines & Hardwoods | 6 | Low-lying Areas |
| 7 | Tall Pines & Hardwoods | 7 | Transitional Upland Areas |
| 8 | Tallest Pines & Hardwoods | 8 | Transitional Upland Areas |
| 9 | Tallest Pines & Hardwoods | 9 | Upland Areas |
| 10 | Tallest Pines & Hardwoods | 10 | Upland Areas |

Table 2. The groupings of class codes used to run the Reclassify analysis.

| Land Features | Isocluster Classes | Reclassify Values | Map Color Tone | Vegetation Type |
|---|---|---|---|---|
| *Forest* | | | | |
| Gaps/Shadows | 1-2 | 6 | brown | All types |
| Short Trees (15-30 feet tall) | 3-4 | 7 | pale green | Pines & Hardwoods |
| Mid-size Trees (30-45 feet tall) | 5 | 8 | light green | Pines & Hardwoods |
| Tall Trees (45-60 feet tall) | 6-7 | 9 | medium green | Pines & Hardwoods |
| Tallest Trees (> 60 feet) | 8-10 | 10 | dark green | Pines & Hardwoods |
| *Not Forest* | | | | |
| Water/ Bare Ground | 1 | 1 | blue | Water/ Bare Ground |
| Wet Lands | 2-4 | 2 | light grey | Wet Lands |
| Low-lying Areas | 5-6 | 3 | medium grey | Low-lying Areas |
| Transitional Upland Areas | 7-8 | 4 | turquoise | Transitional Upland Areas |
| Upland Areas | 9-10 | 5 | light brown | Uplands |
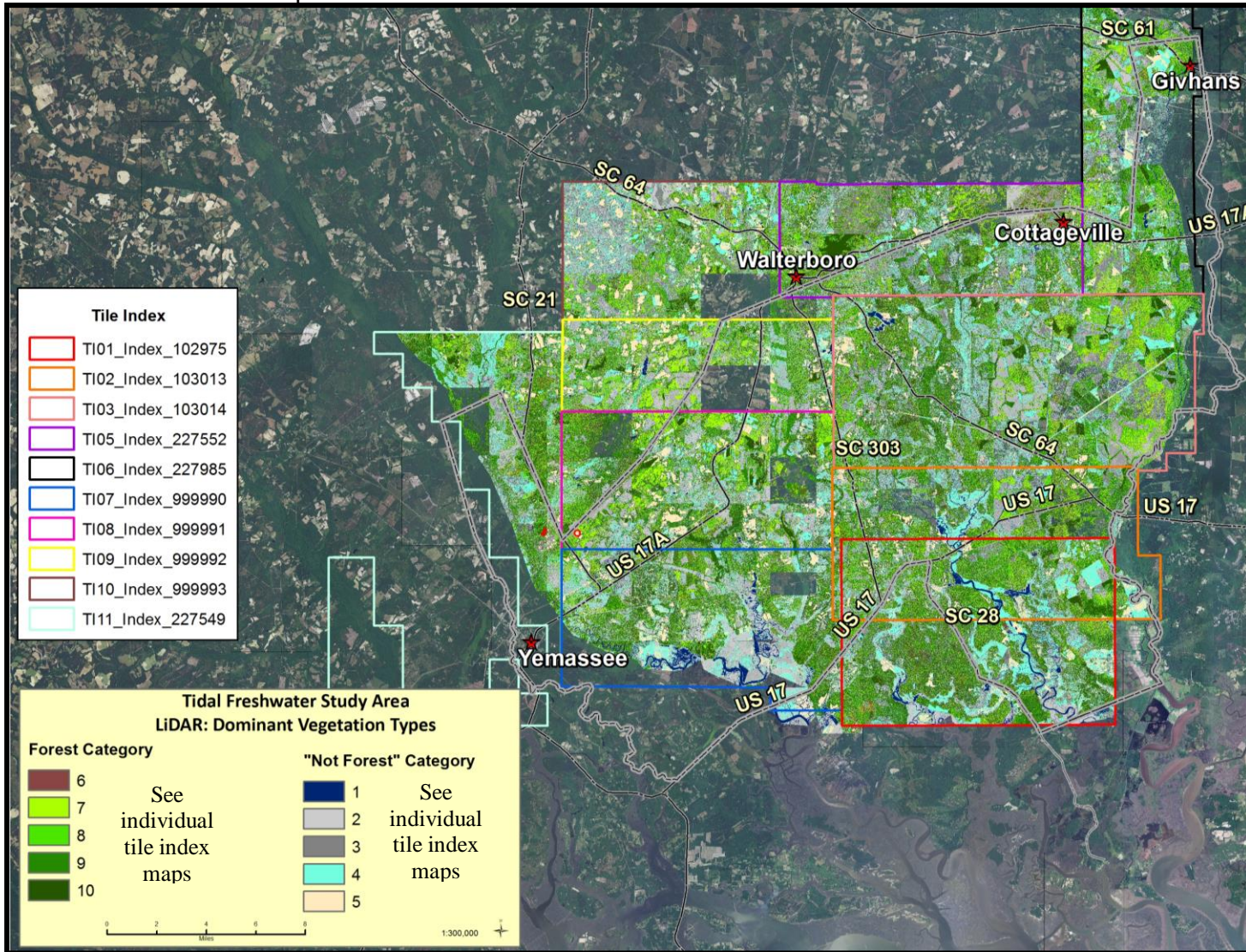
Figure 5. The Forest and "Not Forest" maps were combined to create the following map. The locations of the sections (Tile Index) are delineated.
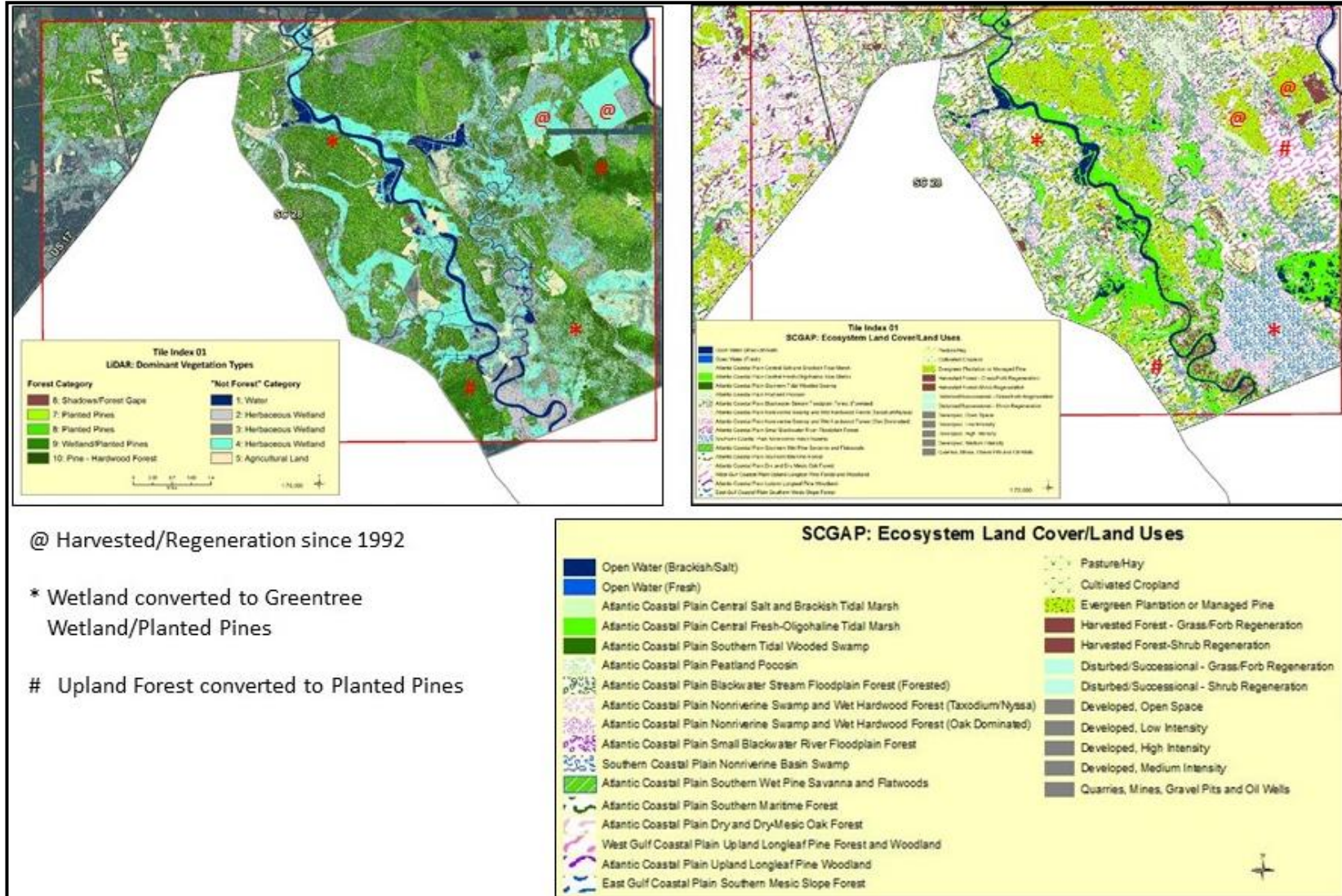
Figure 6. On Tile Index 1 map, all three land use changes were observed: 1) mature planted pines were harvested since 1992; wetlands were converted to planted pines or managed wetlands; and 3) upland forest was converted to planted pines.
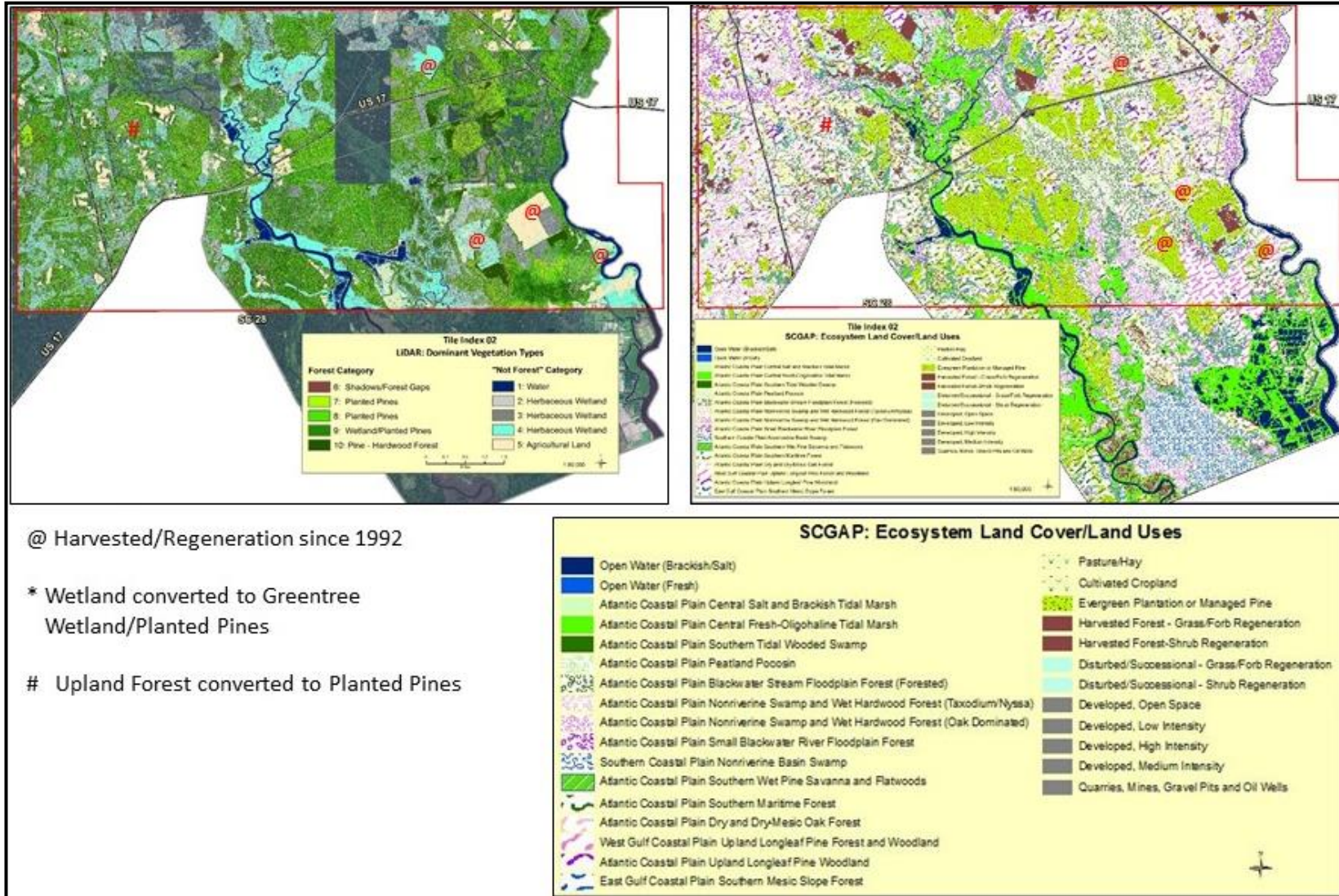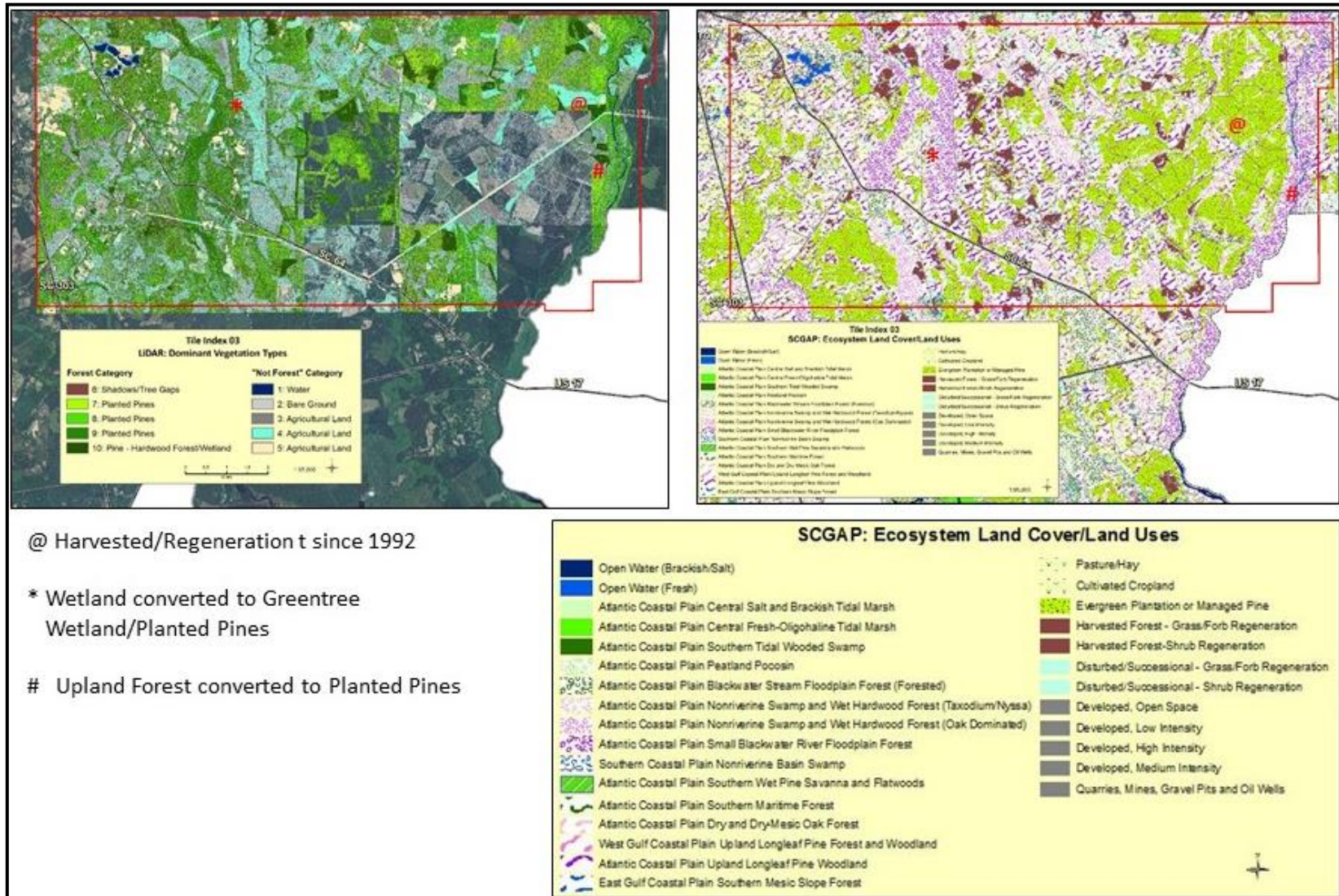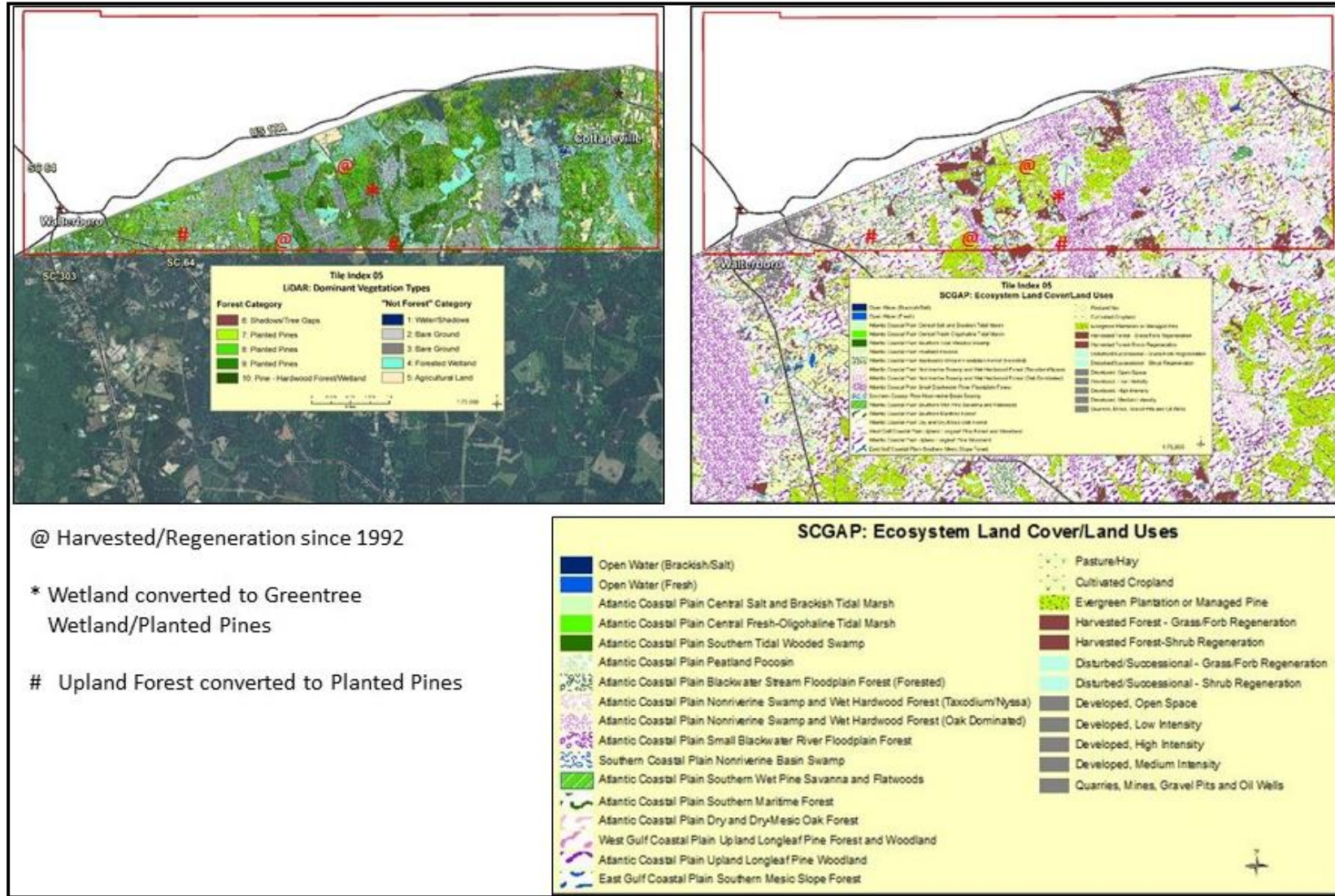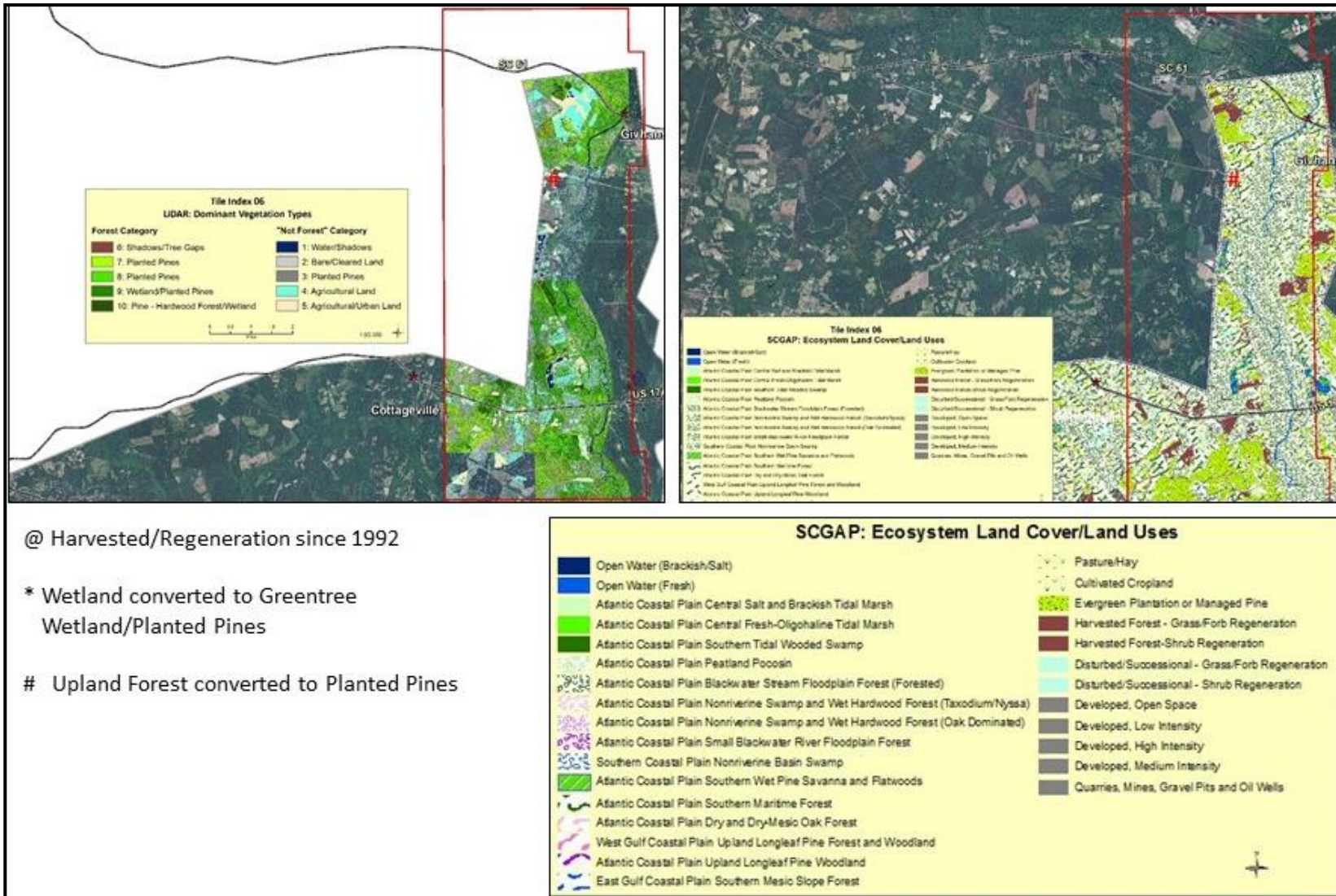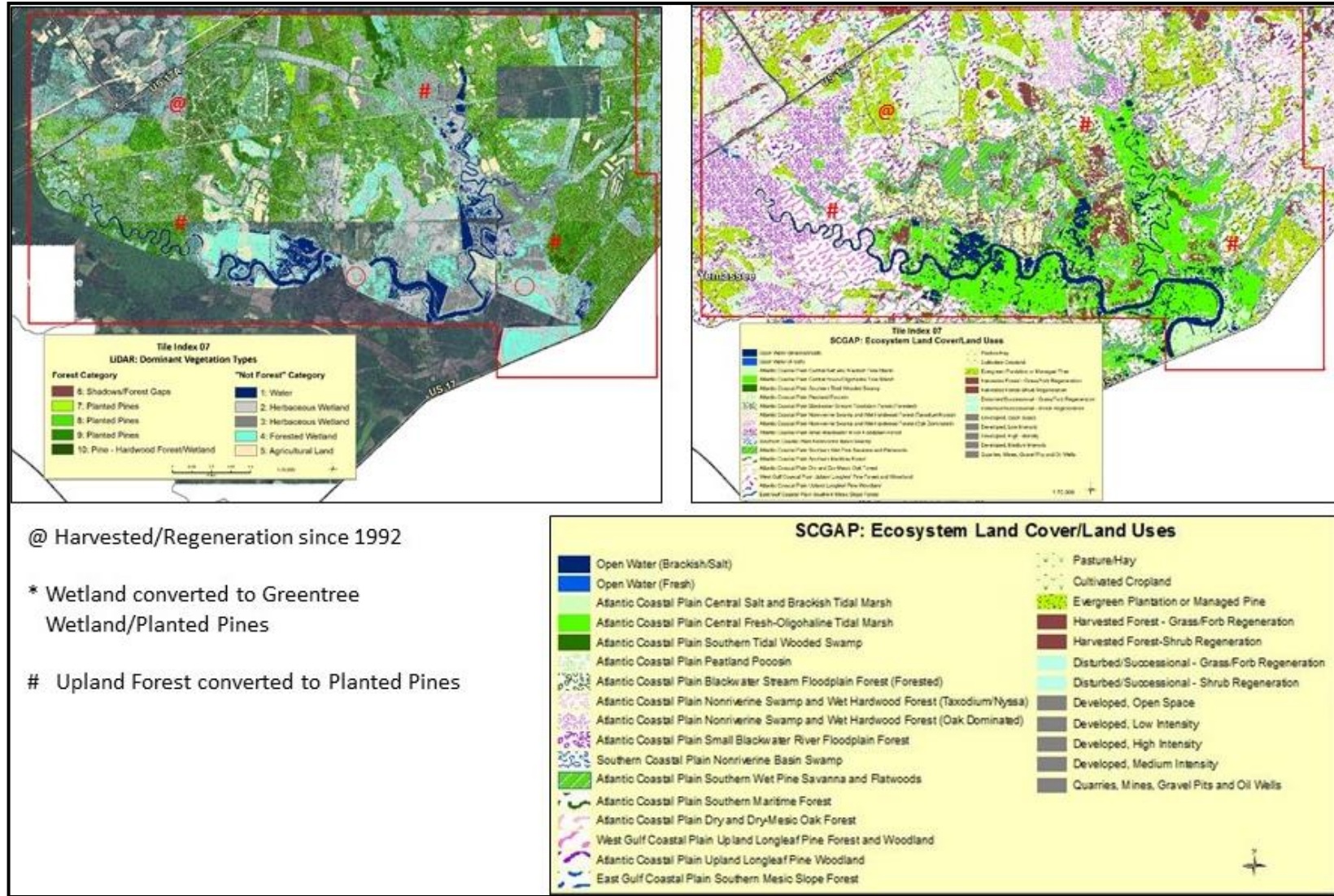
Figure 7. On Tile Index 2 map, two land use changes were observed: 1) mature planted pines were harvested since 1992; and 2) upland forest was converted to planted pines.
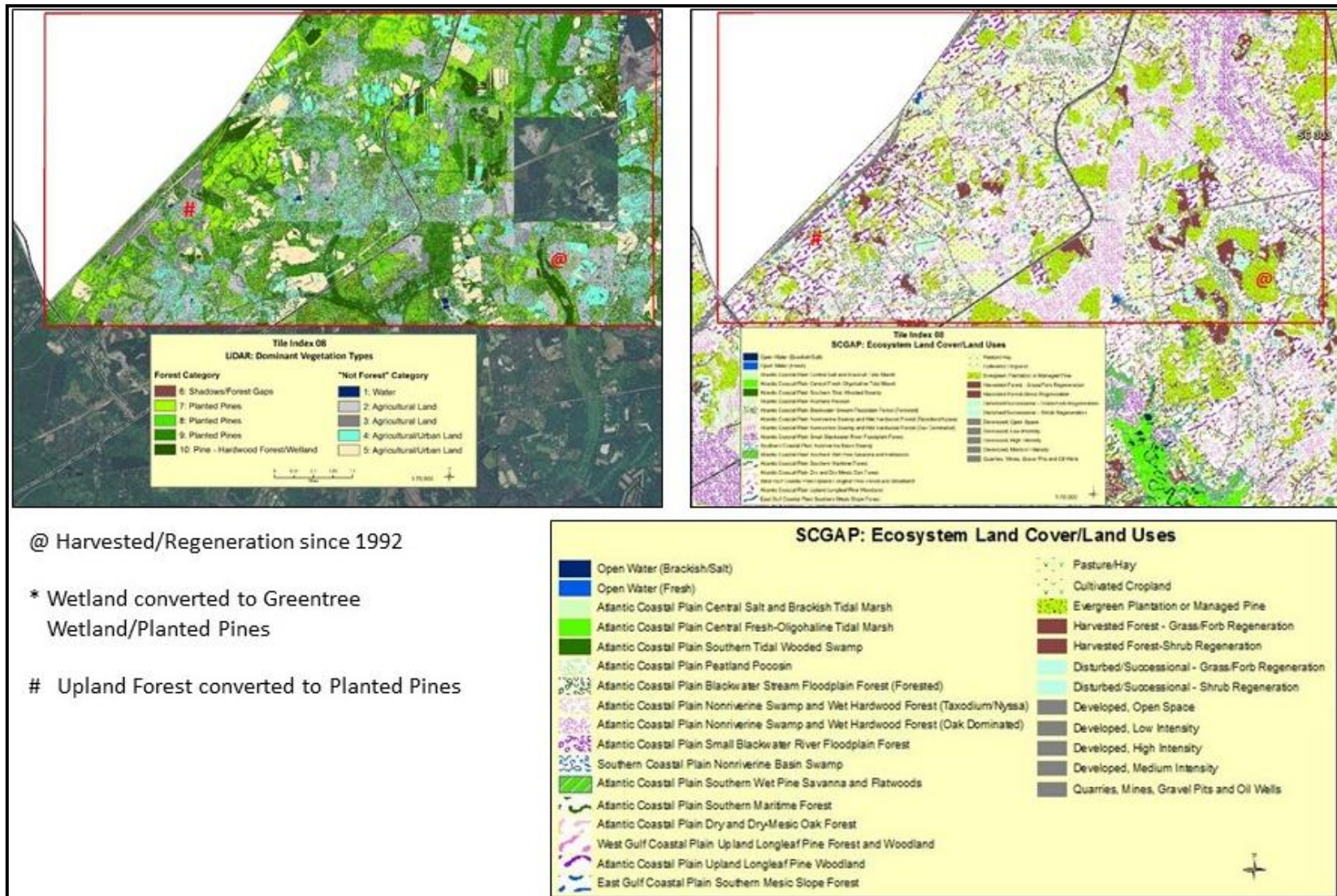
Figure 8. On Tile Index 3 map, all three land use changes were observed: 1) mature planted pines were harvested since 1992; wetlands were converted to planted pines or managed wetlands; and 3) upland forest was converted to planted pines

Figure 9. On Tile Index 5 map, all three land use changes were observed: 1) mature planted pines were harvested since 1992; wetlands were converted to planted pines or managed wetlands; and 3) upland forest was converted to planted pines.

Figure 10. On Tile Index 6 map, upland forest was converted to planted pines.

Figure 11. On Tile Index 7 map, two land use changes were observed: 1) mature planted pines were harvested since 1992; and 2) upland forest was converted to planted pines.

Figure 12. On Tile Index 8 map, two land use changes were observed: 1) mature planted pines were harvested since 1992 and 2) upland forest was converted to planted pines.
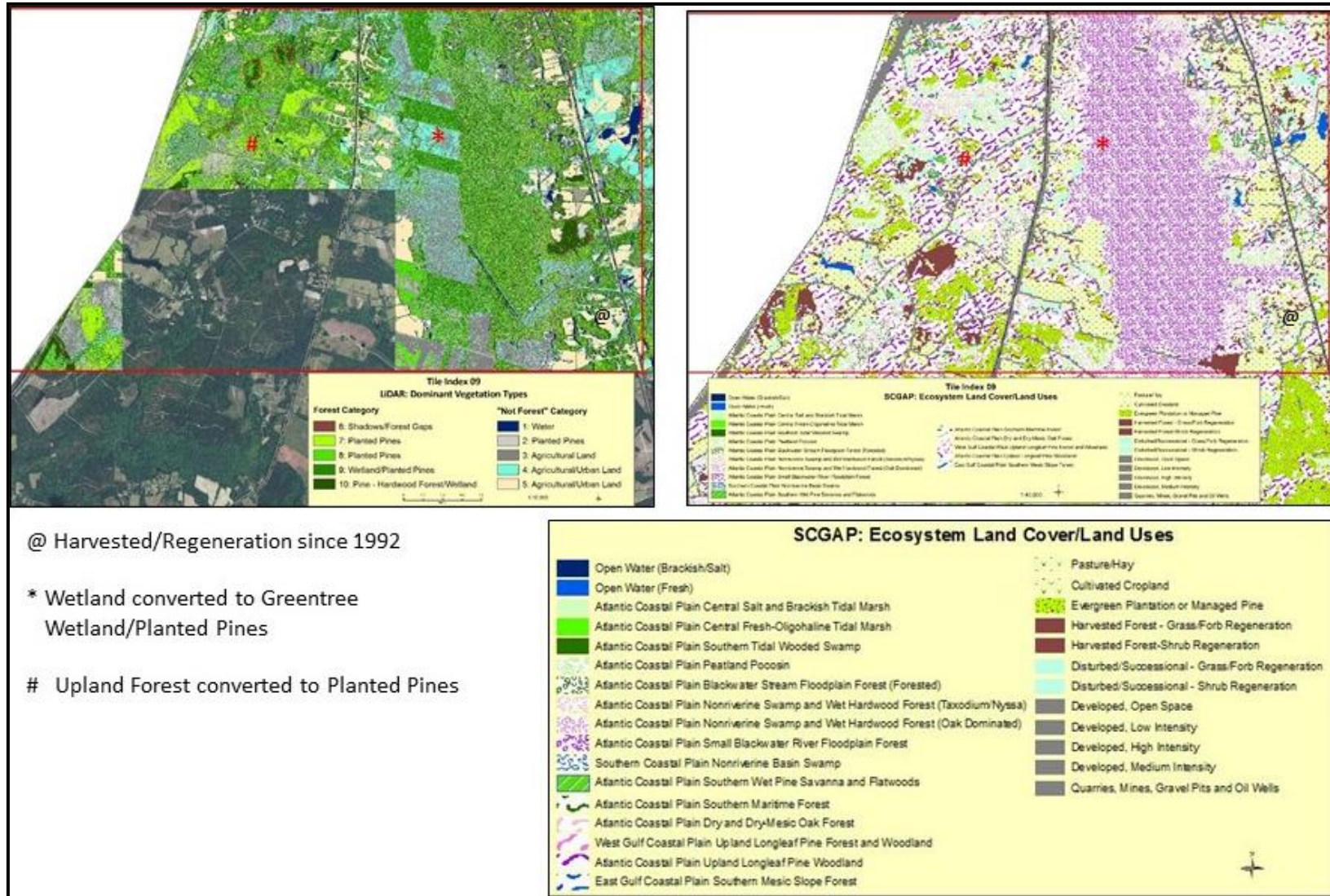
Figure 13. On Tile Index 9 map, all three land use changes were observed: 1) mature planted pines were harvested since 1992; wetlands were converted to planted pines or managed wetlands; and 3) upland forest was converted to planted pines.
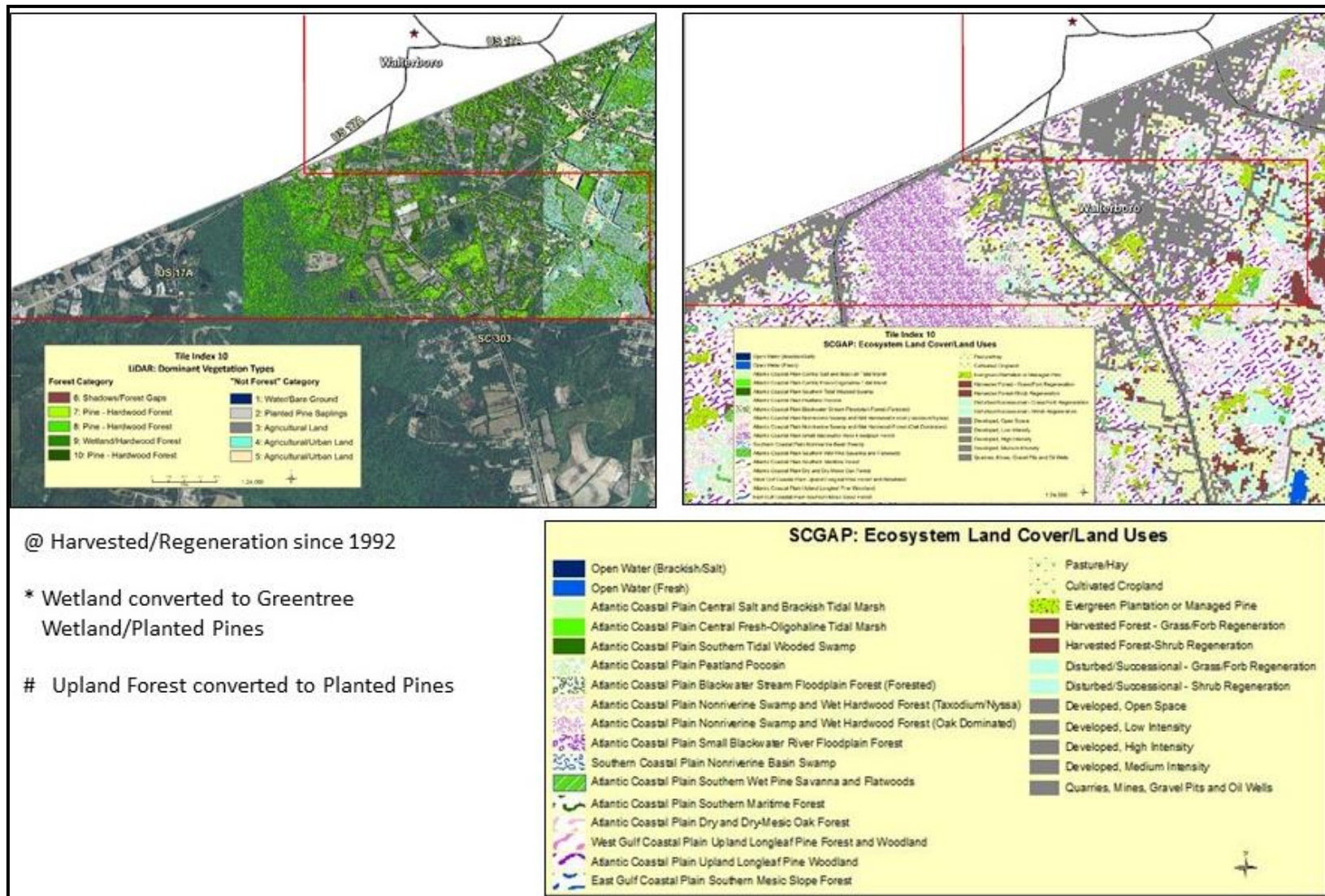
Figure 14. On Tile Index 10 map, none of the three major changes were observed.
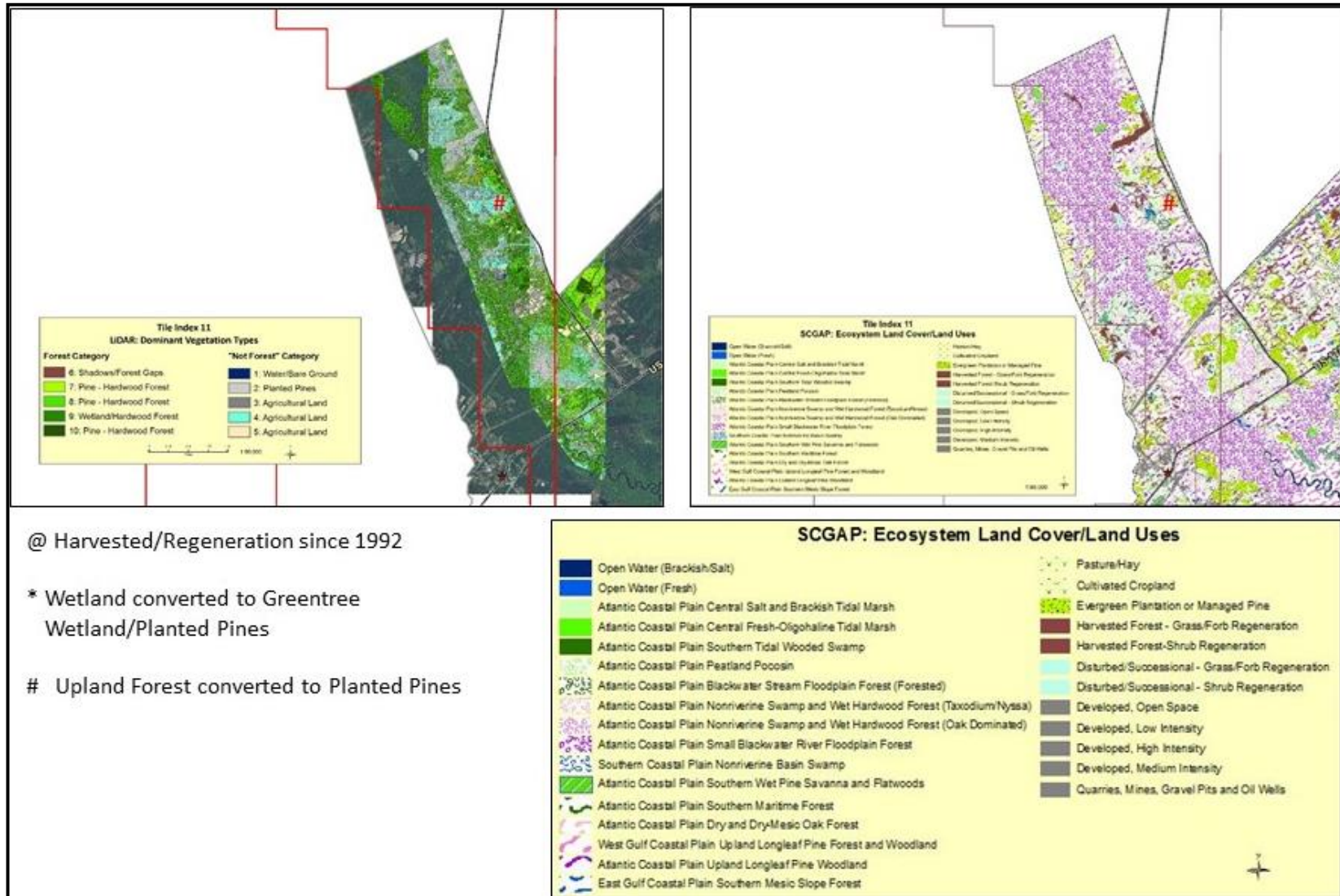
Figure 15. On Tile Index 11 map, one land use change was observed: upland forest was converted to planted pines.