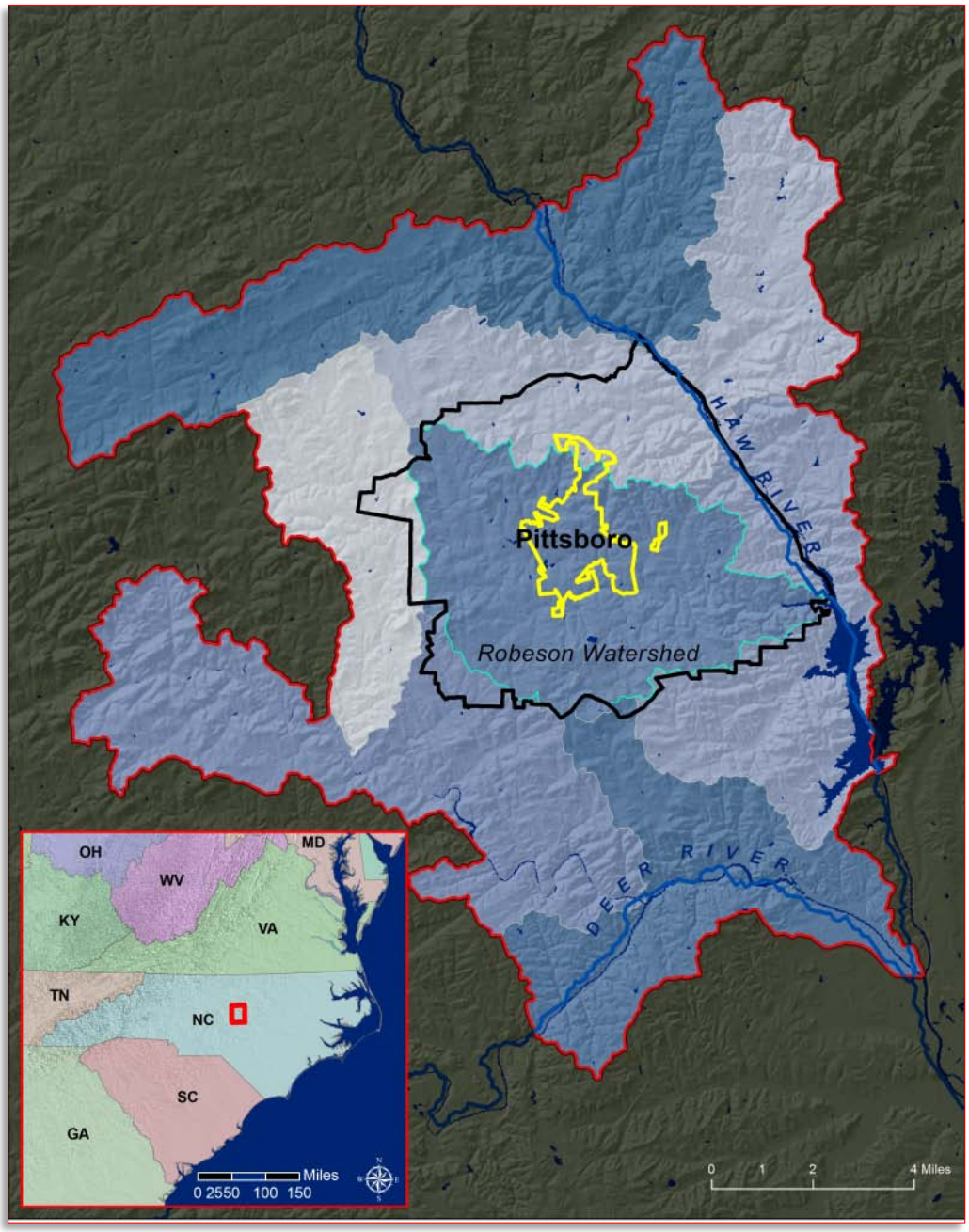
Pittsboro, North Carolina

Land Cover Change Analysis and Urban Tree Canopy Assessment



GLOBAL ecosystem CENTER
9200 Nana Russell Rd. | Owings, MD 20736 | P: 202-290-3530
www.systemecology.org

Contents

Executive Summary 3
Report Overview 5
Moderate Resolution Analysis 5
High-resolution Analysis 7
Analyses Results and Findings 8
Specific Findings – Land Cover Change Analysis 10
Specific Findings – High-resolution 11
Scenario Modeling 17
Robeson Creek Scenario 18
Methodology 22
Moderate-Resolution Land Cover Change Analysis 22
Data Processing 22
Image Classification 23
High-Resolution Analysis – Urban Tree Canopy Assessment 24
Data Processing 24
Image Classification 24
Urban Ecosystem Analysis 25
Quality Assurance/Quality Control 25
About the Urban Ecosystem Analysis 26
TR-55 for Stormwater Runoff 26
L-THIA for Water Quality 26
UFORE Model for Air Pollution and Carbon 27
Maps 28
Project Overview Map 28
Land Cover Change Area 2001-1985 29
Land Cover Change Area 2001-2006 30
Land Cover Change Area 2006-2013 31
Land Cover 1985 32
Land Cover 2001 (NLCD) 33
Land Cover 2006 (NLCD) 34
Land Cover 2013 35
Higher-Resolution Land Cover (1-3m) 36
Canopy by Parcels 36
Canopy by Parcels (Town Core) 37
Zoning and Ecosystem Analysis Area 37
Robeson Creek Watershed 38
Bibliography 39

Executive Summary

The Global Ecosystem Center (GEC) was commissioned by the North Carolina Forest Service to conduct an assessment of the landscape around the Town of Pittsboro, specifically focusing on the town's Extra Territorial Jurisdiction (ETJ). The goal of the project was to document the existing ecological conditions and provide the community with the information needed to address the land use issues they will be facing in the next few months and years.

The assessment was completed in December of 2013 and two products of long term value were delivered: a technical report and an extensive geographical data set.

- The **report** is a reference document that accurately describes the past and present conditions of the land, calculates the economic value of the existing landscape, and provides community leaders with detailed information about how the choices they make today, affect the community in the coming years.
  In addition the **report** describes details about the data assembled for the project, the methods used to convert images into land cover types, the technical formulas used to analyze the data, and finally the methods used to determine ecosystem services. The ecosystem services measured in this project monetize the work performed by the natural system that underpins the community.

- The **geospatial data** is the factual information that accurately describes the structure of the landscape. It includes information extracted from satellite and aerial imagery as well as information describing the soil, water and air. Zoning data from the Town of Pittsboro was used to categorize the data and create summary tables in the report.
  The **data** is especially important to the town of Pittsboro and Chatham County because it can be used daily in their Geographic Information Systems. When land use proposals change, the analysis of the data can be reorganized to match modifications in the proposal.

The data (land cover, soils etc.) are reported in the tables and organized by zoning categories. This organization is considered essential for evaluating the pending requests for changes in the zoning, however, the best way to fit growth and development into the landscape is to organize the data by ecological units so that the planning decisions produce the most long-term benefits to the community. Organizing data by watersheds, as is done here, allows planning and zoning decisions to better incorporate new development into the existing natural features of the land, and the community would benefit from those decisions.

As generally accepted, healthy natural systems filter water and air effectively and reduce energy costs to a community. While they are resilient to change, they can also collapse if the changes are too great. This is called a tipping point. When the information describing the landscape (**the data**) is organized by ecological units (watersheds for example), the impact of development can be better understood and dangerous tipping points avoided. To demonstrate this point, the data for the Robeson watershed has been included in this report (page 18). The tables include an analysis of existing conditions and the impact of various growth scenarios.

The most fundamental ecological unit for calculating the impact of changes in land use is the watershed, or drainage basin. Federal agencies have developed a system for measuring the size and location of watersheds called the Hydrologic Unit Code or HUC. The larger the number of the HUC, the smaller and more accurate is the measure of the watershed. The Pittsboro ETJ contains seven 12 digit HUCs and nine 14 digit HUCs. This report shows the location of the 12 digit watersheds that are all or in-part included in the Pittsboro ETJ.

The seven watersheds cover 121 thousand acres. Rainwater that falls anywhere within the boundaries of these Hydraulic Units drains to the lowest point of the watershed, ultimately flowing into creeks, rivers and lakes. The quality, quantity, and speed of water that moves through a watershed can be determined by entering land cover, soils, and weather data into a hydraulic engineering formula (page 23). The type of land cover in the basin has a big effect on the quality and quantity of stormwater moving through the watershed. For example, a forested watershed produces a steady flow of clean water from most rain events, while one dominated by roads and parking lots flushes water through the basin quickly, transposing pollution and creating stormwater management problems. The pollution entering the streams is directly related to the flow of stormwater. When stormwater flow is reduced, the total load of pollution in the water is reduced.

The seven watersheds are in the early stages of a transition from rural forestland to urban infrastructure. Approximately 9,191 acres of land within the watershed has been converted from forest cover between the years of 1985 and 2011. While this is presently 7.61% of the twelve-digit HUCs, existing development proposals would dramatically change this condition.

As a result of this project, new data exists for the Pittsboro's ETJ that has not been available in the past. Landsat imagery (NASA satellite) has been classified by the GEC technicians using the USGS methodology to National Land Cover Data (NLCD) standards for the year 2013. Also, high-resolution aerial imagery from the National Agricultural Imagery Program has been classified at 3 meter resolution for the ETJ and 1 meter resolution inside the town limits. This new data can now be used for calculating the impact of development on existing air and water resources and to model the impact of future growth.

Report Overview

This report can be divided into six parts:

- Analysis of moderate resolution imagery (30 meter) and National Land Cover (NLCD) data
- Analysis of high-resolution aerial photography (NAIP 1-3 meter resolution)
- Analysis results and findings
    - Specific findings of Moderate-resolution analysis
    - Specific findings of High-resolution analysis
- Ecosystem service modeling including future scenarios
- Methodology
- Ecosystem modeling technical reference

Moderate-Resolution Analysis

The analysis determined changes in the land cover for the seven watersheds spanning a 28 year period from 1985 to 2013. This was done by classifying Landsat satellite imagery into land cover classes. A series of change analyses were conducted comparing land cover between the years 1985-2001, 2001-2006, and 2006-2013. Existing National Land Cover Dataset (NLCD) data from 2001 and 2006 were used for one of the comparisons while the other two resulted from new data produced by the GEC for this project (Figure 1). Data sets for the years 1985 and 2013 were developed using the USGS methodology. The implementation of NLCD's 15 class land cover scheme allows updates to blend seamlessly with existing NLCD datasets.

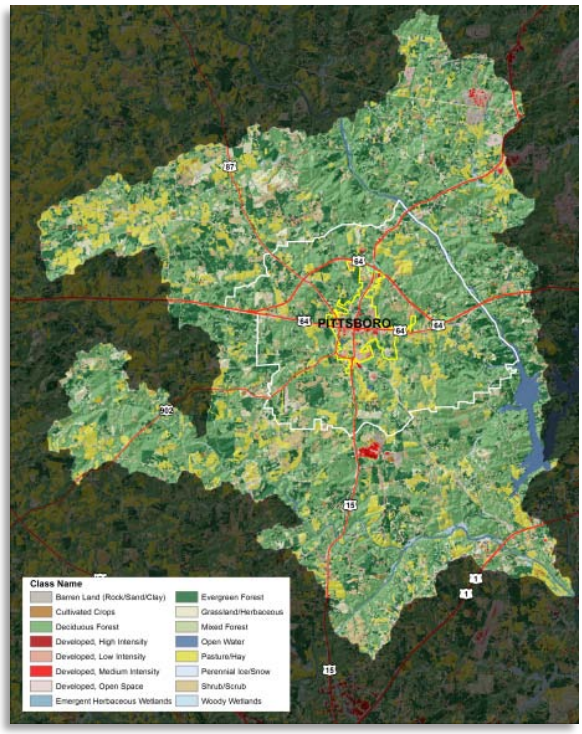


Figure 1: GEC updated NLCD 2013 land cover.

	Color	Class Names
1		Open Water
2		Perennial Ice/Snow
3		Developed, Open Space
4		Developed, Low Intensity
5		Developed, Medium Intensity
6		Developed, High Intensity
7		Barren Land (Rock/Sand/Clay)
8		Deciduous Forest
9		Evergreen Forest
10		Mixed Forest
11		Shrub/Scrub
12		Grassland/Herbaceous
13		Pasture/Hay
14		Cultivated Crops
15		Woody Wetlands
16		Emergent Herbaceous Wetlands

Table 1: USGS's NLCD land cover classification categories.

A NLCD land cover update was done using an object-oriented, supervised, regression tree method called Classification and Regression Tree (CART). Fifteen land cover categories were classified from the Landsat 5 and Landsat 8 imagery (Table 1).

NLCD Land Cover Categories

1. **Open Water** – All areas of open water, generally with less than 25% cover of vegetation or soil.
2. ***Perennial Ice/Snow*** – *'This category is not applicable'*
3. **Developed, Open Space** – Includes areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20 percent of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.
4. **Developed, Low Intensity** – Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20-49 percent of total cover. These areas most commonly include single-family housing units.
5. **Developed, Medium Intensity** – Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50-79 percent of the total cover. These areas most commonly include single-family housing units.
6. **Developed, High Intensity** – Includes highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80 to 100 percent of the total cover.
7. **Barren Land** (Rock/Sand/Clay) – Barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.
8. **Deciduous Forest** – Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75 percent of the tree species shed foliage simultaneously in response to seasonal change.
9. **Evergreen Forest** – Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75 percent of the tree species maintain their leaves all year. Canopy is never without green foliage.
10. **Mixed Forest** – Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75 percent of total tree cover.
11. **Shrub/Scrub** – Areas characterized by natural or semi-natural woody vegetation with aerial stems, generally less than 6 meters tall, with individuals or clumps not touching to interlocking.
    Both evergreen and deciduous species of true shrubs, young trees, and trees or shrubs that are small or stunted because of environmental conditions are included.
12. **Grassland/Herbaceous** – Upland areas characterized by natural or semi-natural herbaceous vegetation; herbaceous vegetation accounts for 75-100 percent of the cover.
13. **Pasture/Hay** – Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20 percent of total vegetation.
14. **Cultivated Crops** – Areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20 percent of total vegetation. This class also includes all land being actively tilled.
15. **Woody Wetlands** – Areas where forest or shrub/scrubland vegetation accounts for greater than 20 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.
16. **Emergent Herbaceous Wetlands** – Areas where forest or shrub/scrubland vegetation accounts for greater than 20 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water. (USGS, 2007)

High-Resolution Analysis

The second part of the analysis provided a detailed measure of the land cover in the town and surrounding ETJ. The high-resolution imagery was obtained from the Aerial Photo Field Office (APFO) of the National Agricultural Imagery Program (NAIP). This imagery is vital to the Urban Tree Canopy Assessment (UTCA) because it is acquired during the agricultural growing season, and therefore, captured the vegetation in full leaf.

The imagery is 1 meter orthorectified aerial photography. It was classified into 1 meter resolution land cover for the areas within the town boundary and 3 meter resolution for the ETJ. The 1 meter classification allows the canopy of individual urban trees to be recorded, which was considered valuable within the town boundary, but not needed for the ETJ analysis (Figure 2).

The Urban Tree Canopy Analysis (UTCA) method used for this project is a technical analysis of the six land cover types including tree cover (also called an Urban Ecosystem Analysis or UEA). This analysis produced a detailed accounting of the land cover for the project area. The findings from the land cover analysis were used to calculate the associated impacts of the landscape on air and water resources. The technology behind the UTCA involves classifying aerial imagery into land cover types using remote sensing and GIS. Ancillary data available from Federal agencies like the National Weather Service and the Natural Resource Conservation Service was then combined with the land cover data classified for each area to populate scientific and engineering algorithms that describe the functions of the landscape. In addition, GIS technology was used to calculate the dollar benefits of the landscape for managing stormwater and improving air and water quality. The assessment provides a wealth of information about the condition of the tree cover (especially within the town boundary) and the financial benefits the natural system provides to the community.

Definitions:

GIS *– Geographic Information System is a mapping platform that lets us visualize, question, analyze, interpret, and understand data to reveal relationships, patterns and trends* (ESRI, 2013)

Remote Sensing *– Remote sensing is the science of obtaining information about objects or areas from a distance, typically from aircraft or satellite* (NOAA, 2013).

Thematic Layer – *Geographic data layer, which organize the spatial and attribute data for a given set of cartographic objects in the area of interest.*

The UTCA highlights tree canopy because the size and condition of the trees are barometers of the condition of the landscape. The size and health of the trees are a direct reading of the quality of the space they occupy. When the land is healthy, the trees are healthy and vice-versa.

The information derived from the assessment is important to the budget managers because it has a direct impact on operating costs. Trees moderate and reduce stormwater flow and therefore the associated stormwater management costs; the more tree coverage the less need for building and maintaining stormwater management facilities. In addition, increasing the percentage of tree cover decreases water pollution and lowers TMDL measures.

The image processing software used were ArcGIS (ArcInfo), ERDAS IMAGINE version 10, and the Overwatch's feature extraction tool called Feature Analyst. A methodology that involves several steps to

produce a high-resolution land cover classification is used by the GEC. Five land cover categories were identified (classified from the imagery Table 2).

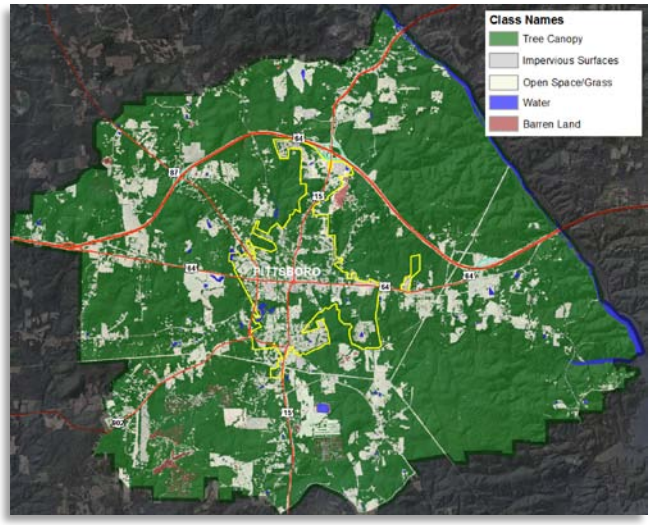


Figure2: Classified land cover for Pittsboro and ETJ.

High-resolution Land Cover Categories		
	Color	Class Names
1		Trees
2		Impervious Surfaces
3		Open Spaces
4		Water
5		Barren Land

Table 2: High-resolution land cover categories.

High-resolution Land Cover Categories

1. **Trees** – All woody vegetations, including deciduous, evergreen, and wetland trees
2. **Impervious Surfaces** – All paved impervious surfaces including roads, sidewalks, driveways, buildings, etc.
3. **Open Spaces** – Pervious areas such as lawn, pastures, agricultural land, recreational and sport fields, etc.
4. **Water** – Water bodies including visible streams, rivers, ponds, lakes, ocean shorelines, reservoirs, and large recreational pools.
5. **Barren Land** – Bare ground with exposed soil including new construction sites, pit mines, beach, river and stream banks, and sand.

Analyses Results and Findings

A 30 meter moderate-resolution land cover change analysis was conducted for the seven 12 digit watersheds that are included in or connected to the Pittsboro ETJ. Watersheds are a fundamental ecological unit and essential for ecological analyses. However, land use decisions are complicated in this area by the political boundaries because the 21,000 acres of land occupied by these watersheds are split between Chatham County and the town of Pittsboro.

The analysis documented the changes that have occurred over a 28 year period. The details are pictured in Figure 3 and detailed in Table 3. The change analyses from 1985 to 2013 indicated that most of the changes had occurred in forest, agricultural, pasture, and urban categories (Table 3). Between 1985 and 2013 a total of 8,159 acres of forested land were lost; while 3,496 acres of urban land and 5,262 acres of agriculture and pasture land were added.

The high-resolution analysis of the town and surrounding ETJ area revealed detailed Land Use/Land Cover (LULC) information. Results from the Urban Ecosystem Analysis (UEA) show that the overall

percentage of tree canopy is in the good range. The town of Pittsboro has tree canopy coverage of 53% while the ETJ area, excluding Pittsboro, has 78% canopy coverage (Table 4 page 14).

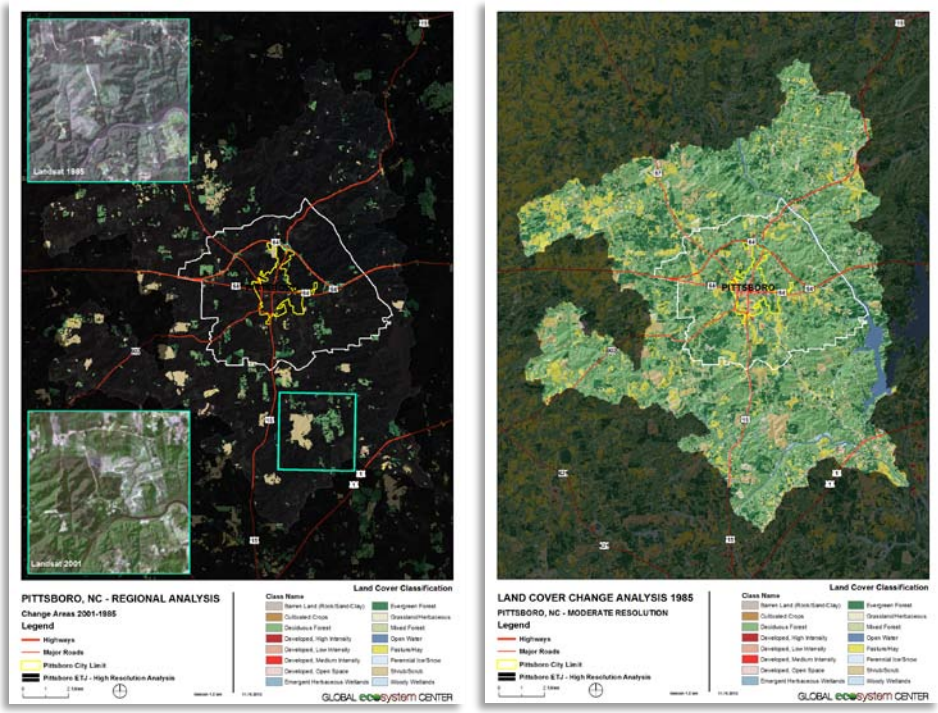


Figure 3: Change areas between 1985 and 2001 and updated 1985 land cover.

Pittsboro Regional Land Cover Statistic 1985 - 2013*										
			Areas in Acres				Change in Acres			
	Color	Class Names	1985	2001	2006	2011	1985-2001	2001-2006	2006-2013	1985-2013
1		Open Water	2,203	2,219	2,215	2,222	15	-4	7	18
2		Perennial Ice/Snow								
3		Developed, Open Space	3,841	4,488	4,543	4,602	647	54	59	761
4		Developed, Low Intensity	455	819	849	2,963	365	30	2,114	2,508
5		Developed, Medium Intensity	115	218	233	273	103	15	40	159
6		Developed, High Intensity	3	33	30	72	30	-3	41	68
7		Barren Land (Rock/Sand/Clay)	279	290	200	552	10	-89	352	273
8		Deciduous Forest	58,003	54,658	56,759	53,777	-3,344	2,100	-2,981	-4,226
9		Evergreen Forest	23,960	24,898	24,146	20,889	937	-752	-3,256	-3,071
10		Mixed Forest	9,239	9,949	9,230	8,377	710	-719	-852	-862
11		Shrub/Scrub	6,225	4,062	2,851	5,192	-2,162	-1,211	2,341	-1,033
12		Grassland/Herbaceous	3,764	5,728	6,908	6,440	1,963	1,180	-468	2,676
13		Pasture/Hay	11,680	12,183	11,558	14,266	502	-624	2,708	2,586
14		Cultivated Crops	374	558	540	436	184	-18	-103	62
15		Woody Wetlands	608	640	649	648	33	8	0	41
16		Emergent Herbaceous Wetlands	33	40	73	73	7	32	0	39
		Total Project Area =	120,783	120,783	120,783	120,783				

**Land cover change analyses is based on 30 meters 2001 and 2006 USGS's NLCD datasets that were updated to 2013 and back-dated to 1985*

Table 3: Land cover change analysis result showing changes in land cover since 1985 to 2013

Specific Findings – Land Cover Change Analysis

Thirty (30) meter resolution Landsat 5 and Landsat 8 imagery was used to conduct two series of land cover change analyses – 2001-1985 and 2006-2013. Land cover change between 2001 and 1985 were based on 2001 NLCD data. These moderate-resolution land cover change analyses uncovered various large scale changes throughout the study area. Expansion of new urban developments were captured in and around the watersheds as the years progressed. The change analysis between 2001 and 1985 showed that Highway 64 was added between this time periods (Figure 4).

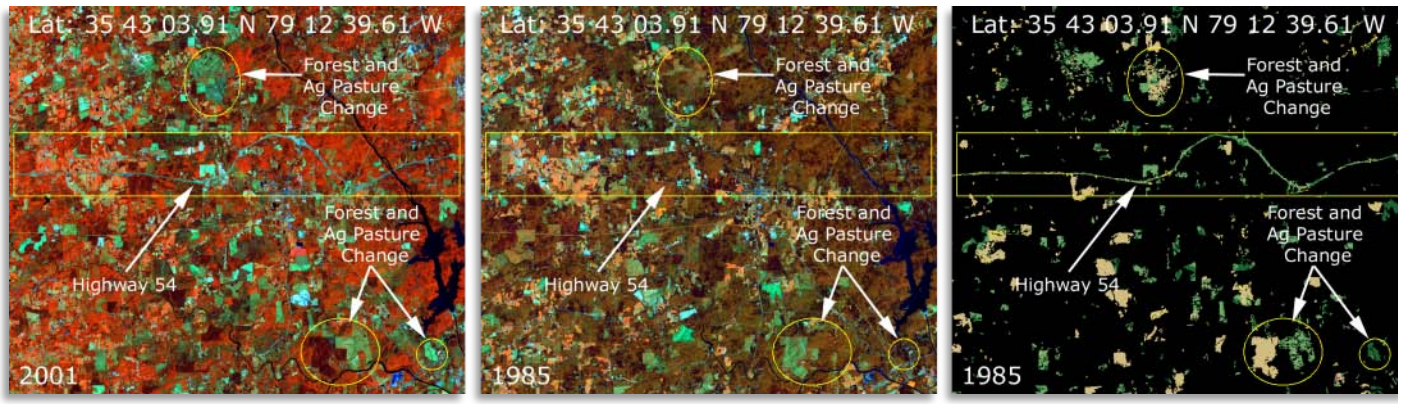


Figure 4: Land cover change detecting new highway in 2001 which was forested areas in 1985 and some forest and ag/pasture changes.

Details of the change areas between 2001 and 1985 are showcased in the map of this report.

The change detection between the year 2006 and 2013 used the existing NLCD set and revealed a lot of changes in urban categories and pasture land. More than 2,000 acres of low intensity development were evident. Similarly, pastures were expanded to over 2,700 acres. Inversely, between the same time periods, over 7,000 acres of forests were lost (Table 4 page 14). Figure 5 shows some of the changes between 2006 and 2013 that were captured by change detection.

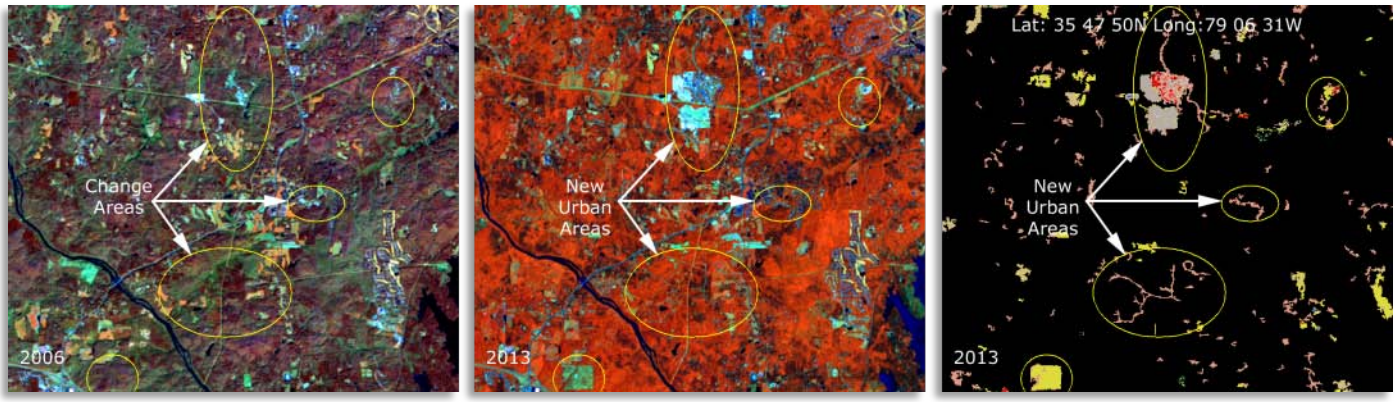


Figure 5: Land cover change revealing new urban areas in 2013. Vegetation on first 2 images shown in false color near-infrared.

Specific Findings – High-resolution

Two sets of high-resolution land cover data were processed for Pittsboro and surrounding ETJ using 2012 imagery. The ETJ dataset was produced in 3 meter spatial resolution, while land covers within the town boundary were produced in 1 meter spatial resolution. Land cover classification revealed that the Town of Pittsboro and its surroundings ETJ areas have healthy tree canopy coverage (Figure 6).

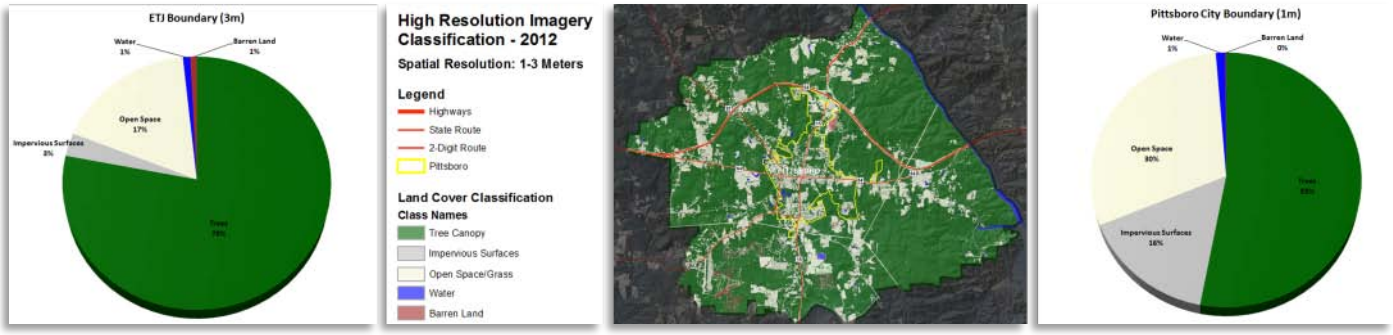


Figure 6: Land cover classes and distribution within ETJ and town boundaries.

The land cover results show that the Town of Pittsboro has 1,195 acres (53%) of tree coverage, while ETJ area has 19,525 acres (78%) of tree coverage (excluding town). Most of the canopy coverage was observed to the east of the town (Map 9 & 10). Within the Pittsboro ETJ, 2,515 acres of forested areas are protected as part of the Southwest Shore Conservation Hubs. This area accounts for 13% of the total forested land in the Pittsboro ETJ (Table 6).

The 53% canopy coverage within the town's boundary has been providing the community with tremendous benefits in terms of pollution reduction, and stormwater runoff. The UTCA has calculated a total savings of $359,727 in air pollution, carbon storage of 51,428 tons, carbon sequestration of 400 tons, and over 10 million cubic feet of stormwater runoff, which accounts to over $32 million dollars at $3 per cubic feet of construction cost to build a stormwater retention facility (Table 4 & 5).

The 78% tree coverage in the ETJ area has been providing astonishing savings and benefits to the region and communities around the town of Pittsboro. The ecosystem services calculations for the ETJ indicates a savings of over $5.9 million in air pollution, including 848,802 tons of carbon stored, and 6,608 tons of carbon sequestered per year. It also shows that over 170 million cubic feet of stormwater runoff is being controlled by the natural system, which can account for over $500 million dollars in construction cost for the stormwater retention facility at $3 per cubic foot (Table 4 & 5). The engineering and scientific models used for the ecosystem services calculations are described on pages 23 and 24 in the section titled "About the Urban Ecosystem Analysis".

The GEC also conducted documented ecosystem services by zoning districts. The zoning boundaries acquired from Chatham County GIS (www.chathamgis.com). The results of this part of the analysis are provided in Table 6 to 9 below.

Pittsboro, North Carolina - Land Cover Land Use Statistics												
		Areas in Acres and Percentage										
Area of Study	Year	Trees	Tree %	Impervious Surfaces	Impervious Surfaces %	Open Space	Open Spaces %	Water	Water %	Barren Land	Barren Land %	Total Area
Pittsboro Town Boundary (1m)	2012	1,195	53.0%	355	15.8%	676	30.0%	26	1.1%	3	0.1%	2,255
ETJ Boundary (3m)	2012	19,725	78.0%	744	2.9%	4,384	17.3%	228	0.9%	203	0.8%	25,284

Table 4: Land cover categories and areas occupied by each categories.

Pittsboro, North Carolina - Ecosystem Analysis									
Area of Study	Total Area	Trees	Trees %	Air Pollution Removal	Air Pollution Removal Value	Carbon Stored	Carbon Sequestered	Stormwater Saved❖	Stormwater Value @ $3 per ft^3
	Acres	Acres	%	lbs/yr	$	Tons		ft^3	$
Pittsboro Town Boundary (1m)	2,255	1,195	53.0%	116,122	$322,456	51,428	400	10,966,611	$32,899,833
ETJ Boundary (3m)	25,284	19,725	78.0%	1,916,568	$5,322,074	848,802	6,608	171,062,145	$513,186,435

❖ *Savings based on runoff calculation if all trees are removed.*

Table 5: UEA result showing ecosystem services based on each town's land cover land use.

		Pittsboro, North Carolina - Land Cover Land Use Statistics - ETJ										
		Areas in Acres and Percentage										
Zoning Name	Year	Trees	Tree %	Impervious Surfaces	Impervious Surfaces %	Open Space	Open Spaces %	Water	Water %	Barren Land	Barren Land %	Total Area
Commercial	2012	33	47.2%	2	2.5%	36	50.3%	0	0.0%	0	0.0%	71
Industrial	2012	318	69.4%	30	6.6%	103	22.4%	1	0.2%	6	1.4%	458
Multi-Unit Plan Development (MUPD)	2012	229	71.3%	3	0.9%	56	17.5%	0	0.0%	33	10.2%	321
Office and Institution	2012	18	73.9%	0	0.8%	6	25.3%	0	0.0%	0	0.0%	24
Residential - Agriculture	2012	3,608	74.4%	121	2.5%	1,059	21.8%	40	0.8%	24	0.5%	4,852
Residential - Agriculture Max 2 Acres	2012	10,945	77.5%	458	3.2%	2,563	18.1%	31	0.2%	131	0.9%	14,128
Residential - Agriculture Max 5 Acres	2012	4,285	85.6%	100	2.0%	465	9.3%	149	3.0%	9	0.2%	5,008
Residential - High Density	2012	25	74.4%	3	10.0%	5	15.6%	0	0.0%	0	0.0%	34
Residential - Low Density	2012	130	65.8%	15	7.7%	52	26.5%	0	0.0%	0	0.0%	197
Residential - Medium Density	2012	61	77.8%	3	3.7%	11	13.8%	4	4.7%	0	0.0%	79
Residential - Medium Density (Mobile Homes)	2012	60	73.1%	2	2.0%	19	23.6%	1	1.3%	0	0.0%	82
Southwest Shores Conservation Hubs	2012	2,515	88.2%	17	0.6%	199	7.0%	119	4.2%	3	0.1%	2,852

Table 6: UEA result showing ecosystem services based on the town's zoning.

Pittsboro, North Carolina: Ecosystem Analysis – ETJ Administration Boundary

Zoning Name	Total Area	Trees	Trees	Air Pollution Removal	Air Pollution Removal Value	Carbon Stored	Carbon Sequestered	Stormwater Saved❖	Stormwater Value @ $3 per ft^3
	Acres	Acres	%	lbs/yr	$	Tons		ft^3	$
Commercial	71	33	47.2%	3,232	$8,975	1,431	11	272,476	$817,428
Industrial	458	318	69.4%	30,881	$85,753	13,676	106	2,883,238	$8,649,714
Multi-Unit Plan Development (MUPD)	321	229	71.3%	22,250	$61,785	9,854	77	2,080,756	$6,242,268
Office and Institution	24	18	73.9%	1,734	$4,815	768	6	157,290	$471,870
Residential - Agriculture	4,852	3,608	74.4%	350,571	$973,494	155,260	1,209	31,592,390	$94,777,170
Residential - Agriculture Max 2 Acres	14,128	10,945	77.5%	1,063,476	$2,953,142	470,988	3,667	92,868,396	$278,605,188
Residential - Agriculture Max 5 Acres	5,008	4,285	85.6%	416,348	$1,156,146	184,391	1,436	38,694,467	$116,083,401
Residential - High Density	34	25	74.4%	2,456	$6,820	1,088	8	235,233	$705,699
Residential - Low Density	197	130	65.8%	12,578	$34,928	5,571	43	1,165,446	$3,496,338
Residential - Medium Density	79	61	77.8%	5,933	$16,475	2,628	20	576,090	$1,728,270
Residential - Medium Density (Mobile Homes)	82	60	73.1%	5,810	$16,133	2,573	20	534,725	$1,604,175
Southwest Shores Conservation Hubs	2,852	2,515	88.2%	244,314	$678,431	108,201	842	22,495,982	$67,487,946

Table 7: UEA result showing ecosystem services based on the town's zoning.

		Pittsboro, North Carolina - Land Cover Land Use Statistics - Town Boundary										
		Areas in Acres and Percentage										
Zoning Name	Year	Trees	Tree %	Impervious Surfaces	Impervious Surfaces %	Open Space	Open Spaces %	Water	Water %	Barren Land	Barren Land %	Total Area
Commercial	2012	89	29.6%	118	39.1%	92	30.5%	2	0.7%	0	0.1%	302
Industrial	2012	155	64.4%	25	10.5%	58	24.1%	2	1.0%	0	0.0%	240
Multi-Unit Plan Development (MUPD)	2012	129	57.9%	29	12.9%	64	28.4%	2	0.7%	0	0.2%	224
Office and Institution	2012	55	34.3%	41	25.6%	64	39.4%	0	0.1%	1	0.7%	162
Residential - Agriculture	2012	18	68.1%	2	8.9%	6	23.0%	0	0.0%	0	0.0%	27
Residential - High Density	2012	170	49.0%	51	14.7%	124	35.7%	2	0.5%	0	0.0%	347
Residential - Low Density	2012	154	51.0%	24	8.0%	110	36.4%	13	4.3%	1	0.3%	301
Residential - Medium Density	2012	368	63.9%	59	10.3%	143	24.9%	5	0.9%	0	0.0%	575
Residential - Medium Density (Mobile Homes)	2012	56	74.6%	4	5.4%	15	20.0%	0	0.0%	0	0.0%	75

Table 8: UEA result showing ecosystem services based the town's zoning

Pittsboro, North Carolina: Ecosystem Analysis – Zoning Districts – Town Boundary

Zoning Name	Total Area	Trees	Trees	Air Pollution Removal	Air Pollution Removal Value	Carbon Stored	Carbon Sequestered	Stormwater Saved❖	Stormwater Value @ $3 per ft^3
	Acres	Acres	%	lbs/yr	$	Tons		ft^3	$
Commercial	302	89	29.6%	8,678	$24,097	3,843	30	889,052	$2,667,156
Industrial	240	155	64.4%	15,025	$41,721	6,654	52	1,419,891	$4,259,673
Multi-Unit Plan Development (MUPD)	224	129	57.9%	12,568	$34,899	5,566	43	1,178,827	$3,536,481
Office and Institution	162	55	34.3%	5,379	$14,936	2,382	19	509,923	$1,529,769
Residential - Agriculture	27	18	68.1%	1,788	$4,965	792	6	168,655	$505,965
Residential - High Density	347	170	49.0%	16,517	$45,866	7,315	57	1,525,253	$4,575,759
Residential - Low Density	301	154	51.0%	14,938	$41,482	6,616	52	1,344,088	$4,032,264
Residential - Medium Density	575	368	63.9%	35,715	$99,175	15,817	123	3,365,530	$10,096,590
Residential - Medium Density (Mobile Homes)	75	56	74.6%	5,404	$15,006	2,393	19	505,650	$1,516,950

❖ *Savings based on runoff calculation if all trees are removed*

Table 9: UEA result showing ecosystem services based the town's zoning.

Scenario Modeling

The GEC conducted 3 scenario modeling exercises to estimate the potential change in ecosystem services for the ETJ. This was done to assist the land use planning officials in estimating the potential impact of proposed zoning changes. The Scenario modeling tool used for this estimate allows the impact of land cover changes to be tested in a digital environment rather than experienced in the real world, where the changes are not reversible. This system uses the models described on pages 22 and 23.

For the scenario development, the GEC analyzed land cover types by altering the percentage of forested land to urban impervious surfaces by 20, 30, and 40% and calculated the UTCA based on the changed land covers. Details of the scenario modeling are in Table 11.

By replacing the existing forestland with 20% impervious surfaces, the result would be an increase in 22 million cubic feet of stormwater valued at $68 million dollars. Similarly, by replacing 30% of the forestland with impervious surfaces, this would expand the stormwater that must be managed to 43 million cubic feet at an estimated cost of $130 million dollars. Finally, the 40% increase in impervious surfaces over the existing forests would result in an additional 65 million cubic feet of stormwater which is estimated to cost $196 million dollars. Details of the other ecosystem services are listed in the tables below.

Pittsboro, North Carolina – ETJ Land Cover Land Use Statistics												
		Areas in Acres and Percentage										
Area of Study	Year	Trees	Tree %	Impervious Surfaces	Impervious Surfaces %	Open Space	Open Spaces %	Water	Water %	Barren Land	Barren Land %	Total Area
ETJ Boundary (3m)	2012	19,725	78.0%	744	2.9%	4,384	17.3%	228	0.9%	203	0.8%	25,284

Area of Study	Total Area	Trees	Trees %	Air Pollution Removal	Air Pollution Removal Value	Carbon Stored	Carbon Sequestered	Stormwater Saved❖	Stormwater Value @ $3 per ft^3
ETJ Boundary (3m)	25,284	19,725	78.0%	1,916,568	$5,322,074	848,802	6,608	171,062,145	$513,186,435

❖ *Savings based on runoff calculation if all trees are removed.*

Table 10: ETJ land cover categories and UTCA results.

Scenario - Pittsboro, North Carolina - Land Cover Land Use Statistics - ETJ												
		Areas in Acres and Percentage										
Scenarios	Year	Trees	Tree %	Impervious Surfaces	Impervious Surfaces %	Open Space	Open Spaces %	Water	Water %	Barren Land	Barren Land %	Total Area
Impervious Increased to 20%	2012	14,690	58.1%	5,790	22.9%	4,374	17.3%	228	0.9%	202	0.8%	25,284
Impervious Increased to 30%	2012	12,162	48.1%	8,319	32.9%	4,374	17.3%	228	0.9%	202	0.8%	25,284
Impervious Increased to 40%	2012	9,633	38.1%	10,847	42.9%	4,374	17.3%	228	0.9%	202	0.8%	25,284

Scenario - Pittsboro, North Carolina - Ecosystem Analysis ETJ									
Zoning Name	Total Area	Trees	Trees	Air Pollution Removal	Air Pollution Removal Value	Carbon Stored	Carbon Sequestered	Stormwater Saved†	Stormwater Value @ $3 per ft^3
	Acres	Acres	%	lbs/yr	$	Tons		ft^3	$
Current Stat - ETJ 2012	25,284	19,725	78.0%	1,916,568	$5,322,074	848,802	6,608	171,062,145	$513,186,435
Impervious Increased to 20%	25,284	14,690	58.1%	1,427,353	$3,963,585	632,141	4,921	-22,963,454	-$68,890,362
Impervious Increased to 30%	25,284	12,162	48.1%	1,181,681	$3,281,385	523,339	4,074	-43,446,059	-$130,338,177
Impervious Increased to 40%	25,284	9,633	38.1%	936,010	$2,599,184	414,536	3,227	-65,563,654	-$196,690,962

† *Decrease in Stormwater saving due to reduce in canopy coverage.*

Table 11: Scenarios showing 20, 30, and 40% tree canopy reduction in ETJ.

Robeson Creek Scenario

The best way to calculate the value of the existing natural system to a community is to organize the land cover data by ecological units. The watershed units are ideal for such analyses.

To demonstrate this point, the GEC calculated the ecosystem services provided by the Robeson Creek and performed scenario modeling calculations for 20%, 30%, and 40% change from forest to urban impervious surfaces. Like the above scenarios, forestland was replaced by impervious surfaces to simulate urban development.

For this analysis there are two maps and two sets of tables (Figure 7). The existing town has been separated from the ETJ for two reasons:

- To simplify the technical analysis
- To more accurately represent the pending growth and development questions since major changes in the landscape will occur in the ETJ area and not within the Town boundary (Figure 7).

The results of the analysis for the Robeson Creek are listed in Tables 12 through 14 below.

Figure 7: Left: Excluding ETJ area from Robeson watershed. Right: Excluding town area from Robeson watershed.

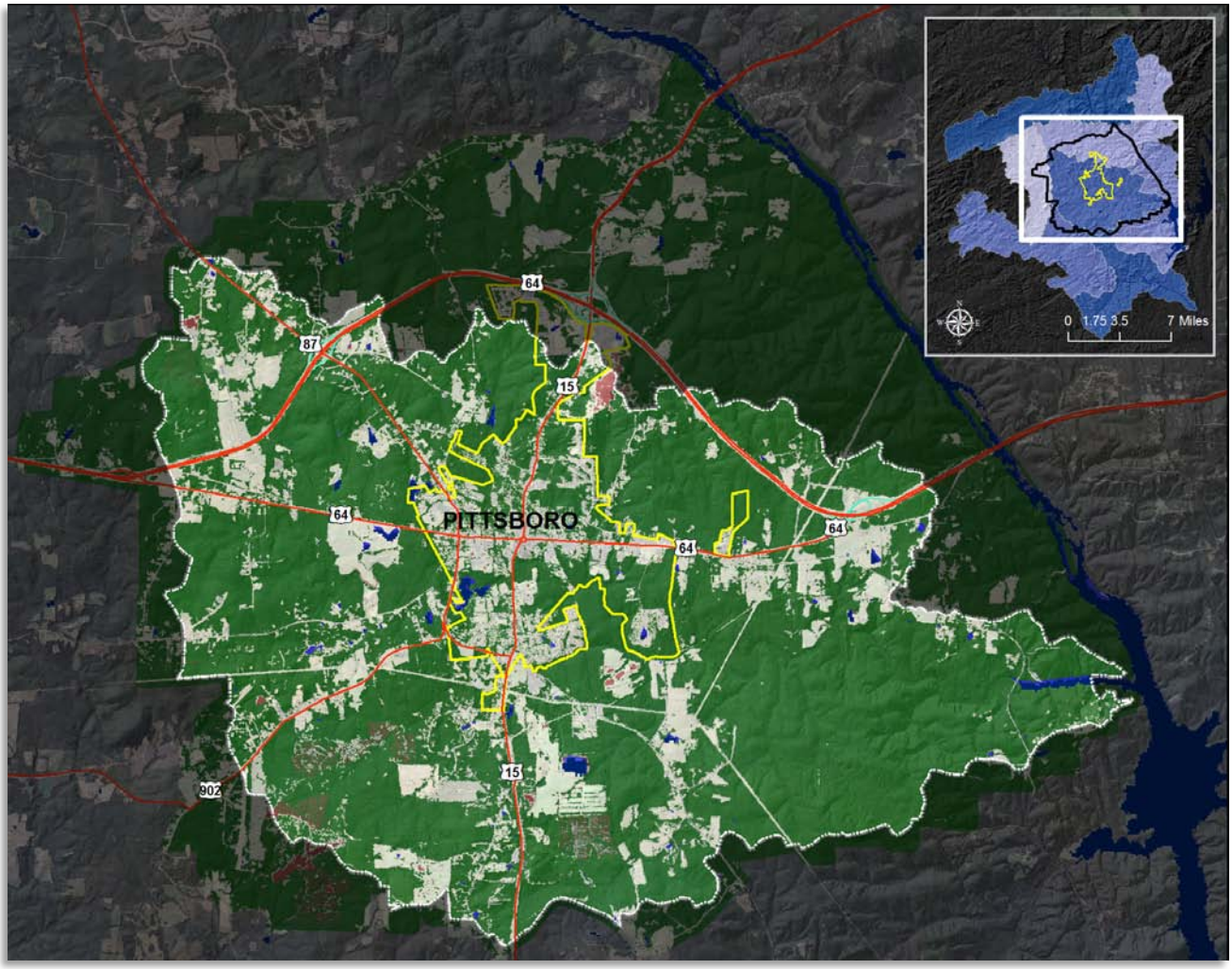


Figure 8: High lighting the Robeson watershed and its land cover

Pittsboro, North Carolina - Ecosystem Analysis - Robeson Watershed									
Area of Study	Total Area	Trees	Trees	Air Pollution Removal	Air Pollution Removal Value	Carbon Stored	Carbon Sequestered	Stormwater Saved❖	Stormwater Value @ $3 per ft^3
	Acres	Acres	%	lbs/yr	$	Tons		ft^3	$
Pittsboro Town Boundary (1m)	2,058	1,123	54.6%	109,147	$303,089	48,339	376	10,295,592	$30,886,776

Scenario - Pittsboro, North Carolina - Ecosystem Analysis ETJ - Robeson Watershed									
Zoning Name	Total Area	Trees	Trees	Air Pollution Removal	Air Pollution Removal Value	Carbon Stored	Carbon Sequestered	Stormwater Saved†	Stormwater Value @ $3 per ft^3
	Acres	Acres	%	lbs/yr	$	Tons		ft^3	$
Pittsboro - ETJ (Robeson) 3m	15,809	12,054	76.2%	1,171,202	$3,252,285	518,698	4,038	102,936,155	$308,808,465

Table 12: Statistic tables showing total land cover coverage for Robeson watershed (HUC-12) with respect to town and ETJ boundaries.

Pittsboro, North Carolina - Land Cover Land Use Statistics - Robeson Watershed												
		Areas in Acres and Percentage										
Area of Study	Year	Trees	Tree %	Impervious Surfaces	Impervious Surfaces %	Open Space	Open Spaces %	Water	Water %	Barren Land	Barren Land %	Total Area
Pittsboro Town - Robeson (1m)	2012	1,123	54.6%	306	14.9%	603	29.3%	23	1.1%	3	0.1%	2,058

Scenario - Pittsboro, North Carolina - Land Cover Land Use Statistics - ETJ - Robeson Watershed												
		Areas in Acres and Percentage										
Scenarios	Year	Trees	Tree %	Impervious Surfaces	Impervious Surfaces %	Open Space	Open Spaces %	Water	Water %	Barren Land	Barren Land %	Total Area
Pittsboro - ETJ Robeson (3m)	2012	12,054	76.2%	470	3.0%	3,064	19.4%	92	0.6%	129	0.8%	15,809

Table 13: Statistic tables showing total land cover coverage for Robeson watershed (HUC-12) with respect to the Town and ETJ boundaries.

Scenario - Pittsboro, North Carolina - Land Cover Land Use Statistics - ETJ - Robeson Watershed												
		Areas in Acres and Percentage										
Scenarios	Year	Trees	Tree %	Impervious Surfaces	Impervious Surfaces %	Open Space	Open Spaces %	Water	Water %	Barren Land	Barren Land %	Total Area
Pittsboro - ETJ Robeson	2012	12,054	76.2%	470	3.0%	3,064	19.4%	92	0.6%	129	0.8%	15,809
Impervious Increased to 20%		8,885	56.2%	3,636	23.0%	3,067	19.4%	95	0.6%	126	0.8%	15,808
Impervious Increased to 30%		7,304	46.2%	5,217	33.0%	3,067	19.4%	95	0.6%	127	0.8%	15,809
Impervious Increased to 40%		5,723	36.2%	6,798	43.0%	3,067	19.4%	95	0.6%	127	0.8%	15,809

Scenario - Pittsboro, North Carolina - Ecosystem Analysis ETJ - Robeson Watershed									
Zoning Name	Total Area	Trees	Trees	Air Pollution Removal	Air Pollution Removal Value	Carbon Stored	Carbon Sequestered	Stormwater Saved†	Stormwater Value @ $3 per ft^3
	Acres	Acres	%	lbs/yr	$	Tons		ft^3	$
Pittsboro - ETJ Robeson 2012	15,809	12,054	76.2%	1,171,202	$3,252,285	518,698	4,038	102,936,155	$308,808,465
Impervious Increased to 20%	15,809	8,885	56.2%	863,263	$2,397,175	382,319	2,976	-13,493,506	-$40,480,518
Impervious Increased to 30%	15,809	7,304	46.2%	709,657	$1,970,632	314,290	2,447	-26,303,797	-$78,911,391
Impervious Increased to 40%	15,809	5,723	36.2%	556,052	$1,544,088	246,262	1,917	-40,136,583	-$120,409,749

† *Decrease in Stormwater saving due to reduce in canopy coverage.*

Table 14: Statistic tables showing total land cover coverage for Robeson watershed (HUC-12) with respect to the Town and ETJ boundaries.

Methodology

Two different methodologies were used to conduct the analysis; one for the moderate-resolution land cover/land change analysis and the other for the high-resolution UTCA. An object-oriented data mining supervised classification called CART was adopted for the moderate-resolution, while a pixel-based supervised classification was chosen for the high-resolution data.

Moderate-Resolution Land Cover Change Analysis

The GEC has great expertise in conducting object-oriented land cover classification using satellite imagery and data mining tools. Utilizing NASA's 30 meter spatial resolution Landsat 5, recently orbited Landsat 8 imagery, and existing NLCD datasets (2001 and 2006), GEC performed the land cover change updates for the years 1985 and 2013. Digital change detections were performed for the year 1985-2001, 2001-2006, and 2006-2013.

Data Processing

For the moderate-resolution land cover change analysis, 30 meter resolution Landsat 5 and Landsat 8 imagery for the path 016 and row 035 were acquired from USGS. The acquired imagery had the least cloud coverage available. Landsat imagery comes in individual spectral bands in geotiff format. The GEC processed the multi-spectral bands into one image layer (Figure 9a). The Landsat 8 data comes in different band order and larger bit size (16 bit) compared to the earlier Landsat imagery. A custom graphic model was developed by GEC to compile and rescale Landsat 8 imagery. This allowed Landsat 8 to be used seamlessly with previous Landsat series data. Once the data was processed, they were clipped to the 7 watershed boundaries (Figure 9b).

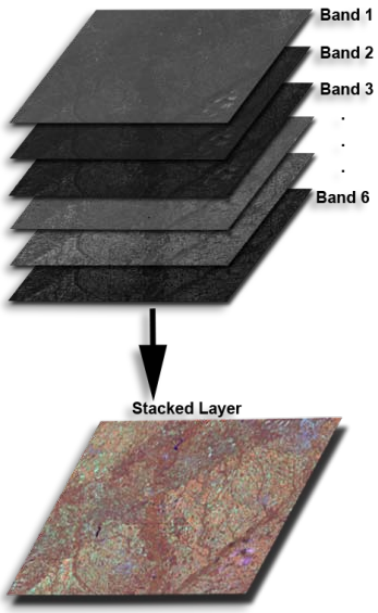
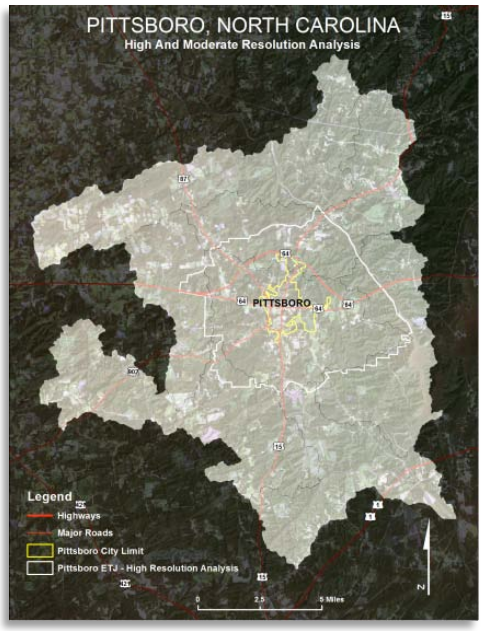


Figure 9a: Layer stack of multi-spectral bands.



9b: Boundary of 7 watersheds combined.

Image Classification

The GEC has adopted the methodology and tools developed by USGS and NOAA to conducted their flagship national (NLCD) and coastal (CCAP) datasets. USGS's custom tool for the image processing software ERDAS Image called the "NLCD Sampling Tool" was used to perform the sophisticated, supervised land cover updates. Figure 10 shows the technical flow and process of the operation.

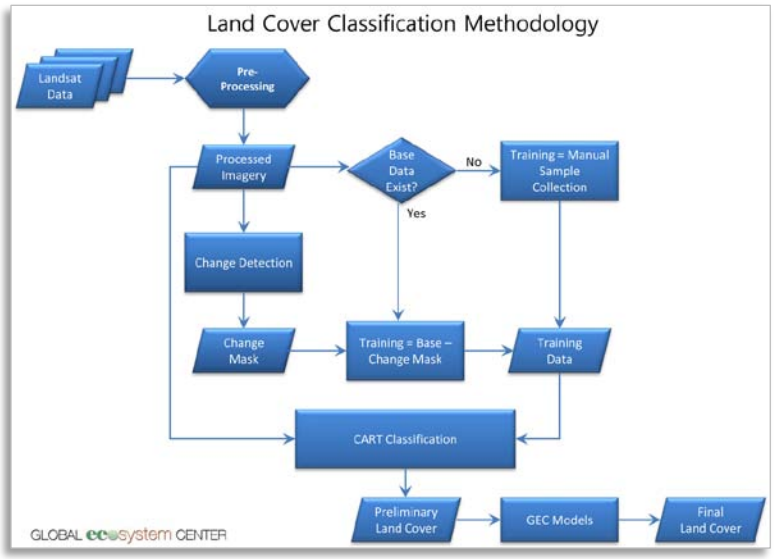


Figure 10: Schematic showing the entire land cover classification process.

This methodology utilizes ancillary data, a powerful regression tree model CART, image processing software ERDAS IMAGINE, USGS's NLCD Sampling Tool, and a data mining software called See5. The CART model uses spectral and ancillary data as predictor variables and LULC classes as the response variables to create a dichotomous "tree" by recursively partitioning the training data into suitable class categories (Miguel Villarreal, 2011).

There are two major steps to perform image classification using the CART method.

Digital Change Detection – Imagery data are paired to perform a digital change detection using ERDAS IMAGINE's built-in function called Change Detection. Using the existing 2001 NLCD dataset as a training data set, change detection was performed between 1985 and 2001 spectral imagery data. Similarly, existing 2006 NLCD datasets were used to perform change detection between the years 2006 and 2011 imagery. The resulting layers are binary masks that represent the possible changes between the pair. As for the change between 2001 and 2006, GEC utilized a graphic modeling tool to separate the change areas between the dates.

CART Classification – A CART classification was performed on 1985 and 2013 imagery using NLCD Sampling Tool in EARDAS IMAGINE and See 5. Based on all the variables such as training layer, spectral signature, and other ancillary data layers, See5 generated rule sets for classification. The final classifications are performed on binary masks. Various graphic model tools and semi-automated processes were conducted to further refine the classification. Finally, the change areas classifications

were overlaid on existing land covers to establish a new updated land cover layer for 1985 and 2013 (Figure 11).

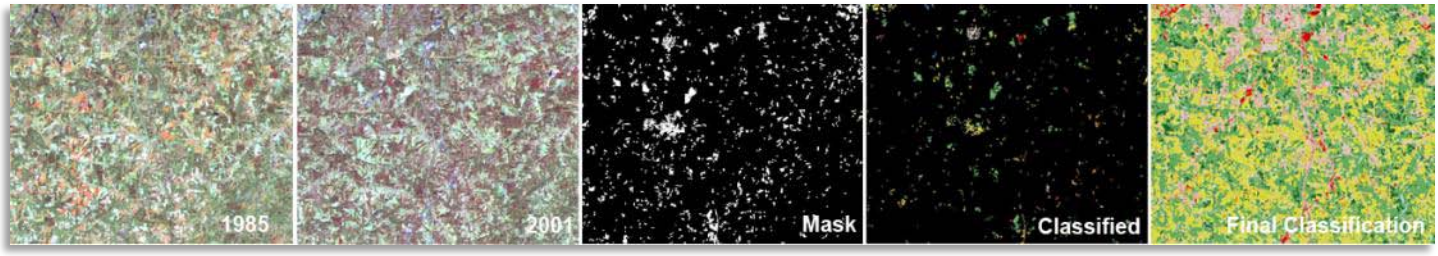


Figure 11: Graphics showing the progression of final land cover data (right) derived from Landsat imagery data sets (left two images).

High-Resolution Analysis – Urban Tree Canopy Assessment

The GEC assesses the condition and value of urban ecosystems through a process called Urban Ecosystem Analysis (UEA). The UEA documents the green infrastructure using remote sensing, image analysis and GIS technology. It calculates the ecosystem services produced by various landscapes using the engineering and scientific models described on pages 22 and 23.

The UEA process was used to analyze the Pittsboro ETJ using high-resolution imagery for the year 2012. The project had three objectives: 1) benchmark the latest canopy cover 2) develop a model from the baseline data that can be used to calculate the impact of future development, and to 3) calculate the economic benefit produced by green infrastructure applications for existing and future development. The data and findings from this study can be used by the communities to determine the best design and management of their future green infrastructure.

Data Processing

Imagery data purchased from NAIP imagery comes as small tiles. The tiles were mosaicked to form a uniform single imagery file for each town. Then the imagery data sets were clipped to a 200 meter buffer around the ETJ administrative boundary.

Image Classification

A pixel-based supervised classification was conducted. An analyst selected training sites within the imagery that were representative of the land cover classes of interest. For example, samples of impervious surfaces throughout the imagery were selected to extract the entire impervious surface category, which included buildings, sidewalks, driveways, roads, and other impervious surfaces. The sampling process and classification iteration were repeated to extract the land cover feature as accurately as possible (Figure 12).

Figure 12: Left – analyst's training sample of buildings (an impervious surface class). Right – classified land cover feature of

Urban Ecosystem Analysis

The finalized high-resolution land cover classifications were used for the Urban Ecosystem Analysis (UEA). This process calculated the value of natural vegetation in air and water pollution, carbon storage and sequestration, and stormwater runoff. Detail of the analysis is provided in "About the Urban Ecosystem Analysis.

High-resolution data produced by the GEC were used as base data layers to compute UEA results. Results produced in Tables revealing the quantities in English units as pounds (lbs), ton, and cubic feet (for volume) and economic indicator and value in dollar (US$) amount.

UEA results were conducted on various administrative boundaries including ETJ, town, and zoning boundaries requested and provided by the local planning agency. The resulting data provides the detailed statistical overview of all UEA areas.

In addition, GEC conducted scenario modeling to determine the ecological impact when converting and altering the existing land cover land use to various hypothetical simulations. The resulting calculation provides crucial information on any such changes in land use prior to the planning and implementation. This calculation provides decision makers with important information.

Quality Assurance/Quality Control

Each data layer went through a rigorous process of quality assurance/quality control (QA/QC) check lists. In addition, each classified land cover data were processed in customized graphic models to ensure the best classification for each land cover. To minimize the human error and inconsistency, almost all the edits were made using graphic models and automated processes. After all the edits and issues were addressed, data layers were processed for delivery, and the high-resolution datasets for the seven cities were set up for the UEA process to produce UTCA results.

About the Urban Ecosystem Analysis

The GEC performed the Urban Tree Canopy Assessment process using land cover data and scientific and engineering models using a 1 meter spatial resolution aerial imagery for the seven cities within Pittsboro watershed. The method of combining geospatial data with scientific and engineering models defines the UEA process and analysis.

The Center has been in operation for 28 years and was previously known as the Urban Ecosystem Center. Prior to becoming the Global Ecosystem Center, it was an operating unit of the non-profit organization American Forests. The staff, philosophy, and system analysis methodology have not changed.

GEC's Urban Ecosystem Analysis is based on the assessment of "ecological structures" – unique combinations of land cover and land use patterns. Each combination performs ecological functions differently and is therefore assigned a different value. For example, a site with heavy tree canopy provides more stormwater reduction benefits than one with a light tree canopy and more impervious surfaces.

The following analytical models were incorporated to produce the UEA results.

TR-55 for Stormwater Runoff

The stormwater runoff calculations incorporate volumes of runoff formulas from the Urban Hydrology of small Watersheds model (TR-55) developed by the U. S. Natural Resources Conservation Service (NRCS), formerly known as the U.S. Soil Conservation Service. Don Woodward, P.E., a hydrologic engineer with NRCS, customized the formula to determine the benefits of trees and other urban vegetation with respect to stormwater management. For greater accuracy, a stormwater analysis was conducted for each Planning District and values were then added together to provide stormwater runoff for the cities across the United States.

UEA calculates the volume of runoff in a 2-year 24-hour storm event that would need to be contained if all trees were removed. UEA calculates two curve numbers for the stormwater analysis; one reflecting existing land cover condition and the other reflecting the replacement of tree canopy in the study area by a user-defined replacement land cover. The differences in curve numbers determine the change in storage volume between the two different land cover scenarios (with and without trees). To determine the dollar amount of stormwater related savings resulting from tree canopy, this calculated volume is then multiplied by the user-specified local construction cost. Default construction cost in UEA is $2 per ft^3.

http://www.hydrocad.net/tr-55.htm

L-THIA for Water Quality

Using values from the U.S. Environmental Protection Agency (EPA) and Purdue University's Long-Term Hydrological Impact Assessment (L-THIA) spreadsheet water quality model, NRCS developed the water quality model. This model estimates the changes in the concentration of the pollutants in runoff during

a typical storm event given the change in the land cover from the existing trees to a no-tree condition. This model estimates the event's mean concentration of nitrogen, phosphorus, suspended solids, zinc, lead, cadmium, chromium, chemical oxygen demand (COD), and biological oxygen demand (BOD). Pollutant values are shown as a percentage of change.

https://engineering.purdue.edu/mapserve/LTHIA7/

UFORE Model for Air Pollution and Carbon

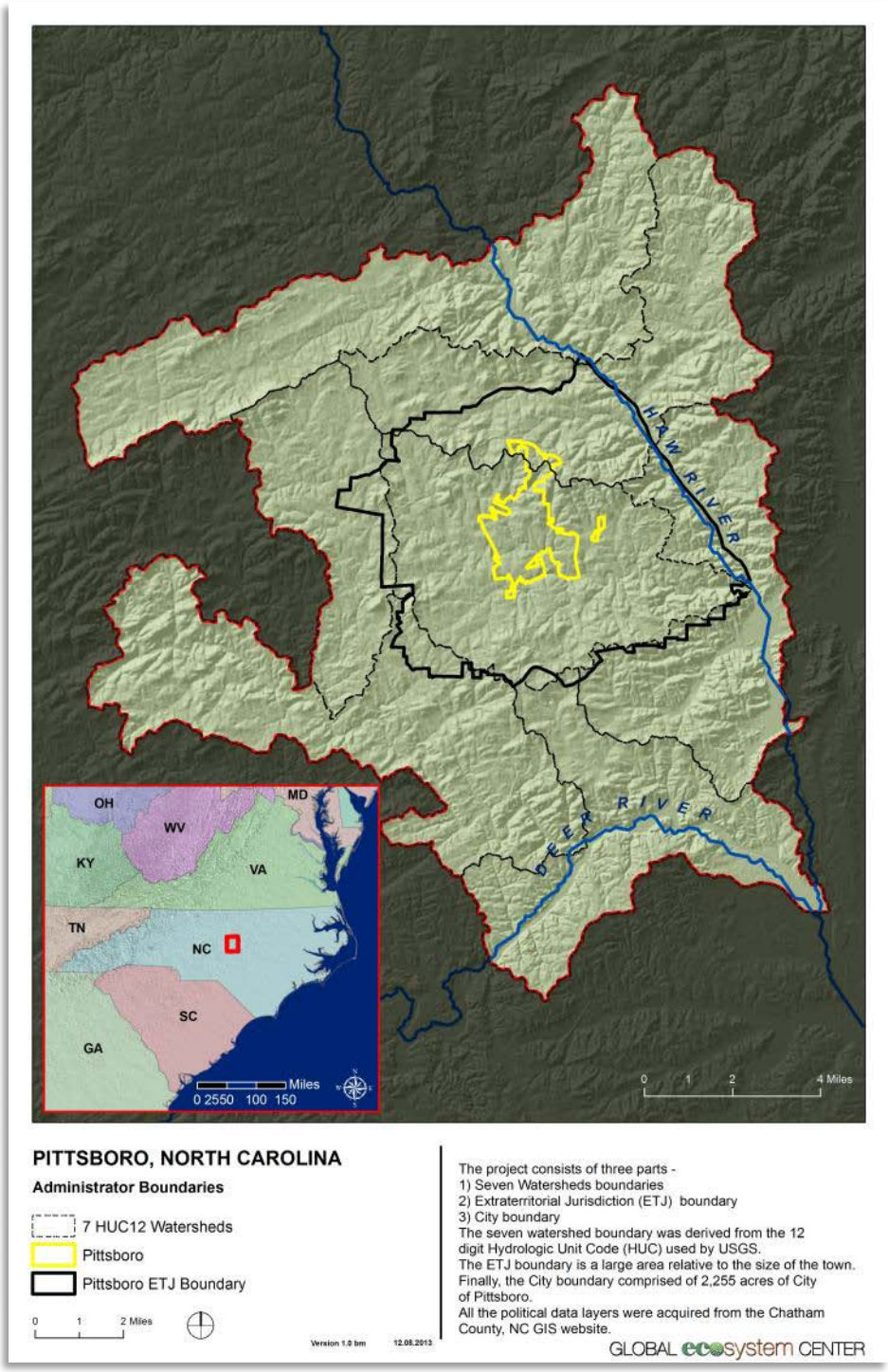
UEA uses formulas from a model developed by David Nowak, PhD, USDA Forest Service. The model estimates how many pounds of ozone, sulfur dioxide, nitrogen dioxide, and carbon monoxide, are deposited in tree canopies as well as the amount of carbon sequestered. The Urban Forest Effects (UFORE) model is based on data collected in 55 U.S. cities. Dollar values for air pollutants are based on averaging the externality costs set by the State Public Commission in each state. Externality costs are the indirect costs to society, such as rising health care expenditures as a result of air pollutants' detrimental effects on human health.

http://www.nrs.fs.fed.us/pubs/jrnl/2008/nrs_2008_nowak_001.pdf

Maps

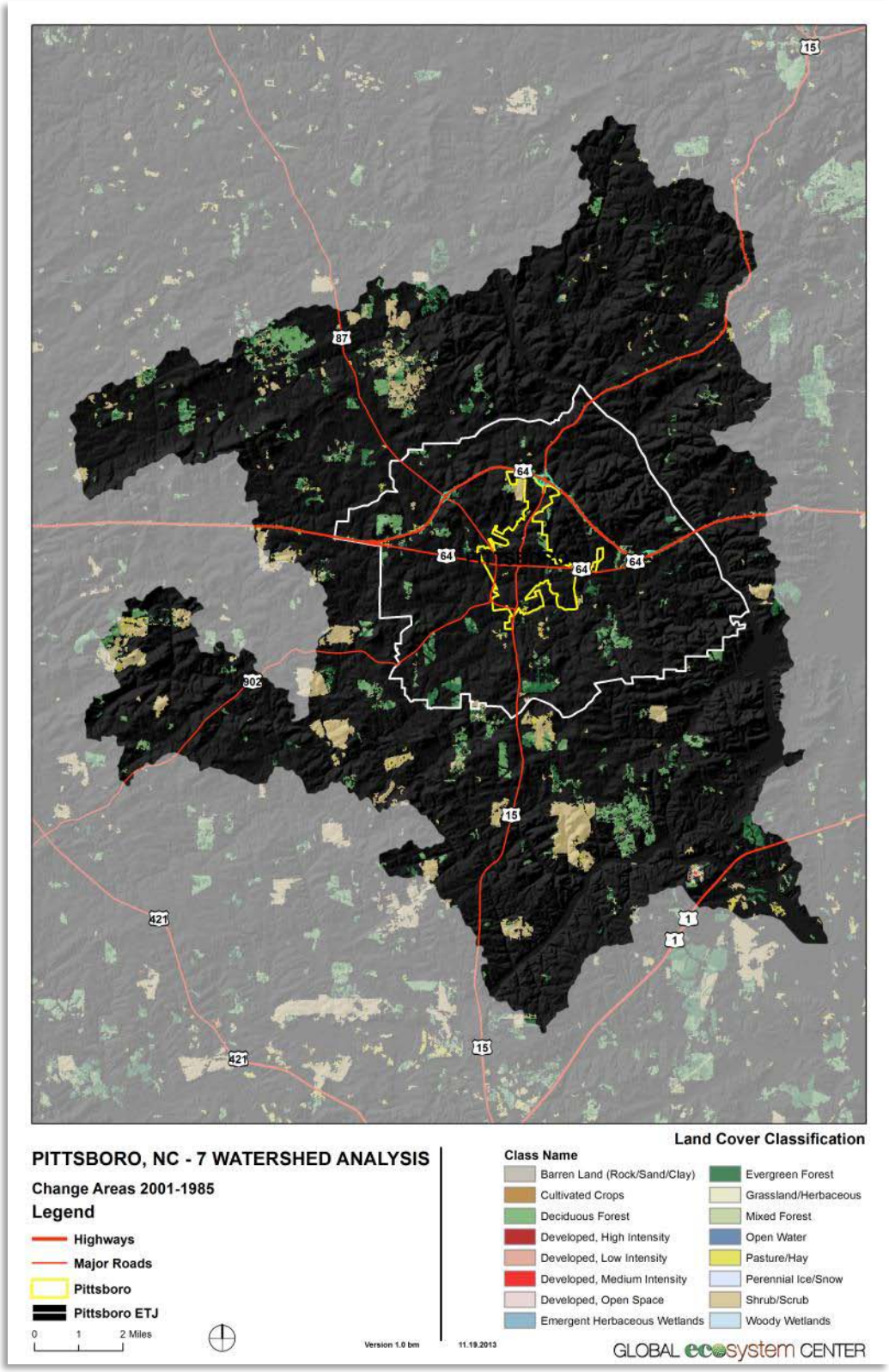
The following maps display the product and data produced by the GEC for this project. These maps include moderate and high-resolution land cover analyses.

Project Overview Map



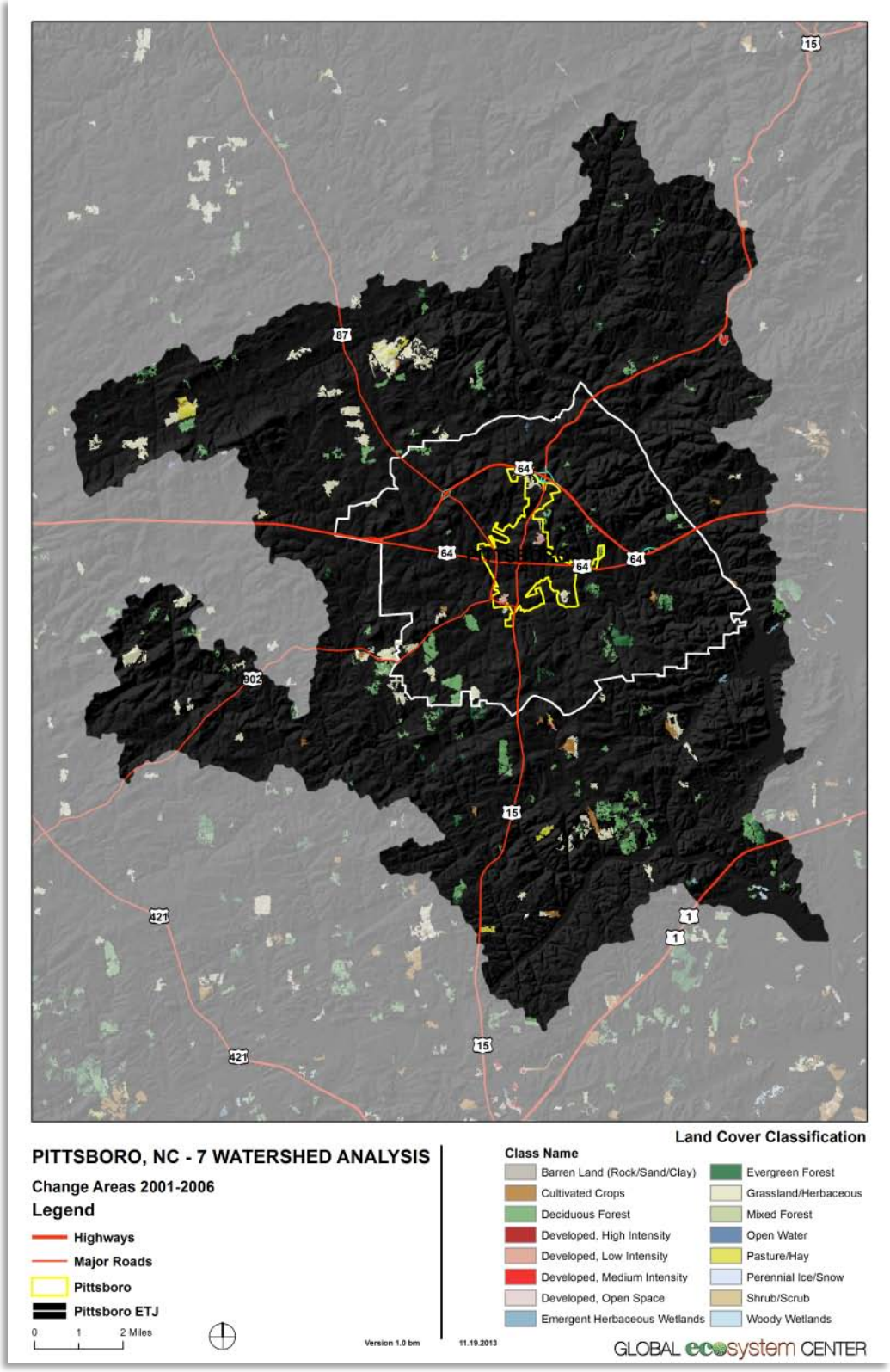
Map 1: Pittsboro project areas consist of 7 watershed, ETJ, and town boundaries.

Land Cover Change Area 2001-1985



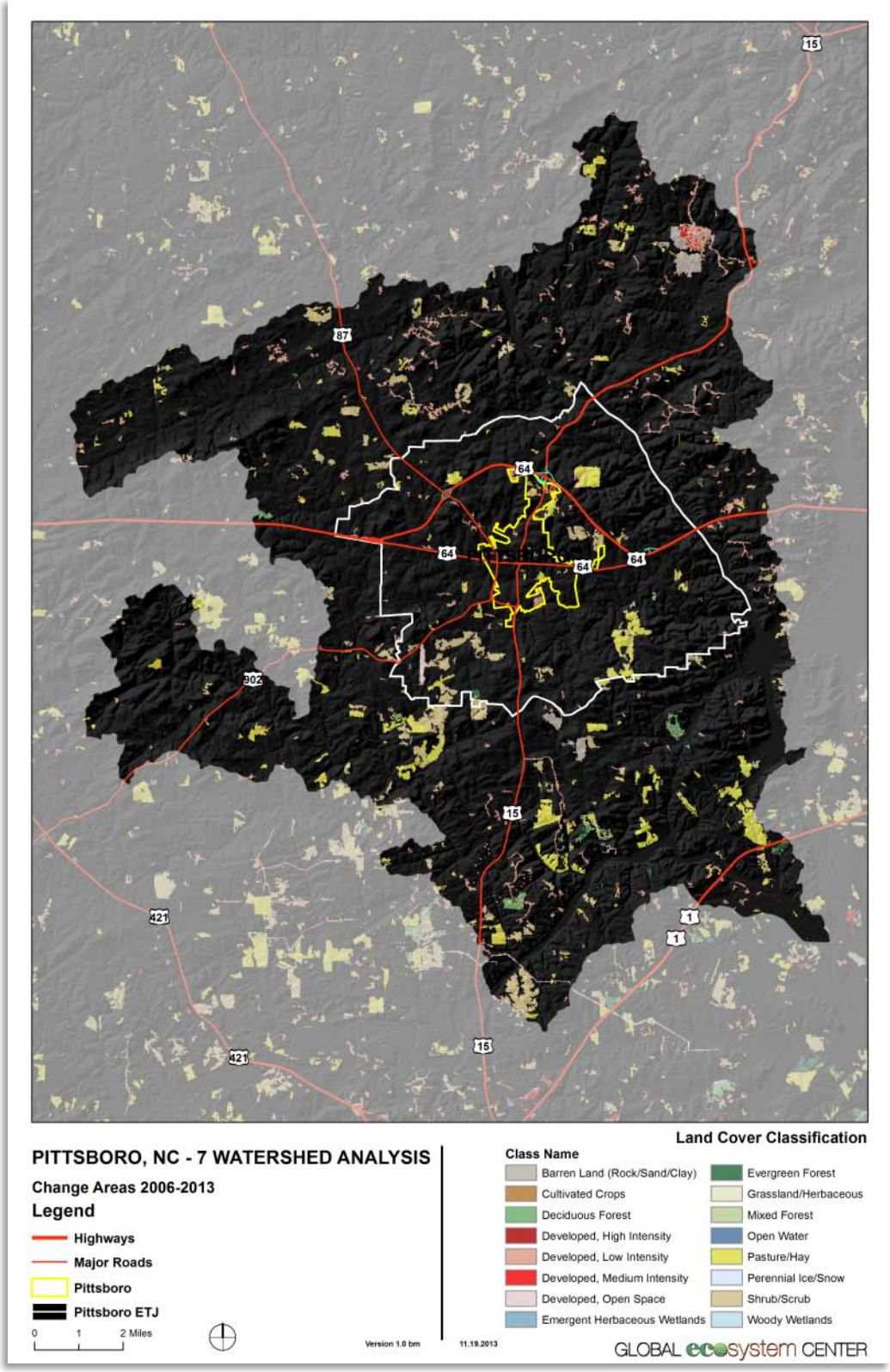
Map 2: Moderate resolution change areas 2001(NLCD) – 1985.

Land Cover Change Area 2001-2006



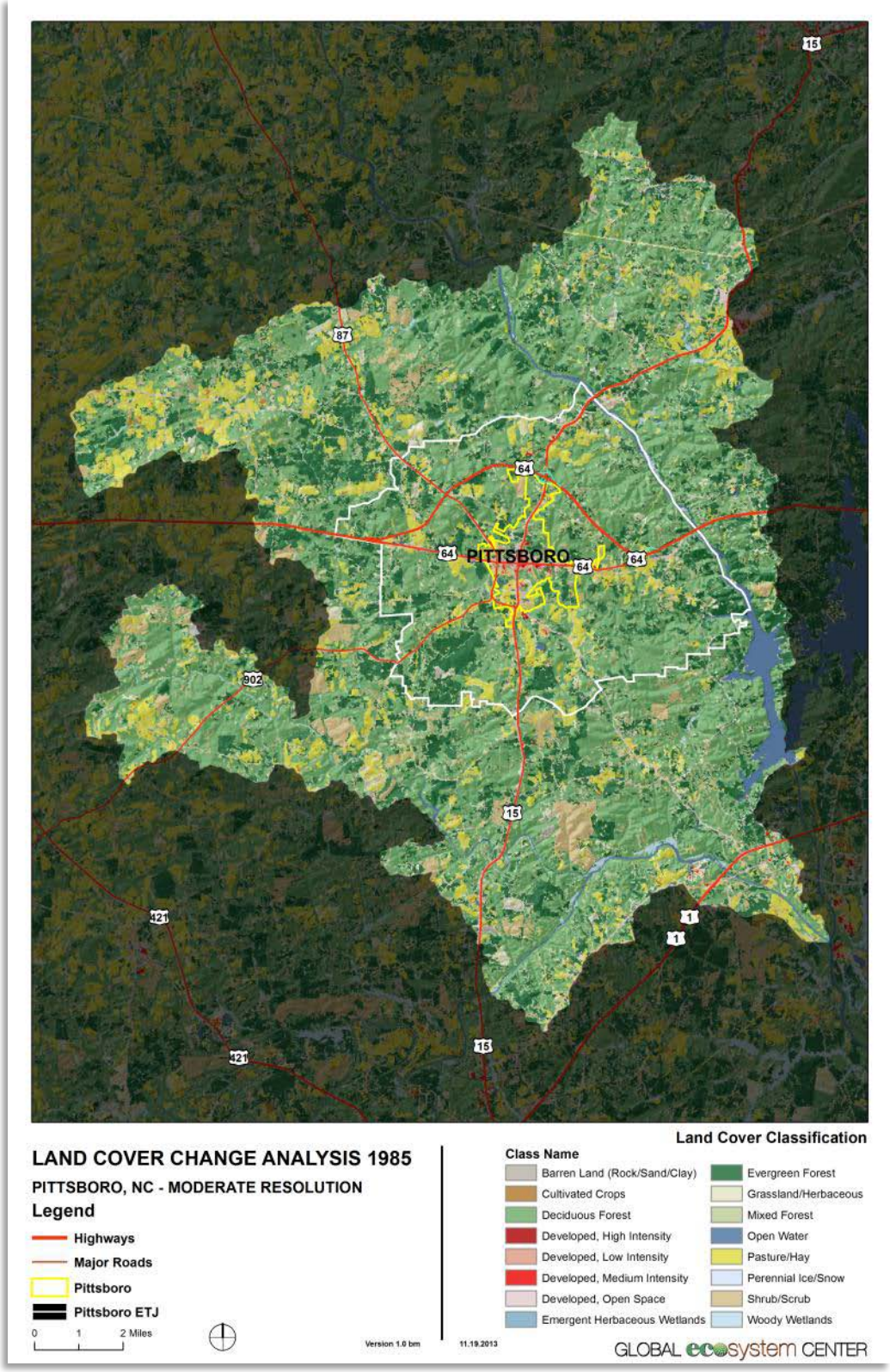
Map 3: Moderate resolution change areas 2001 (NLCD) – 2006 (NLCD).

Land Cover Change Area 2006-2013



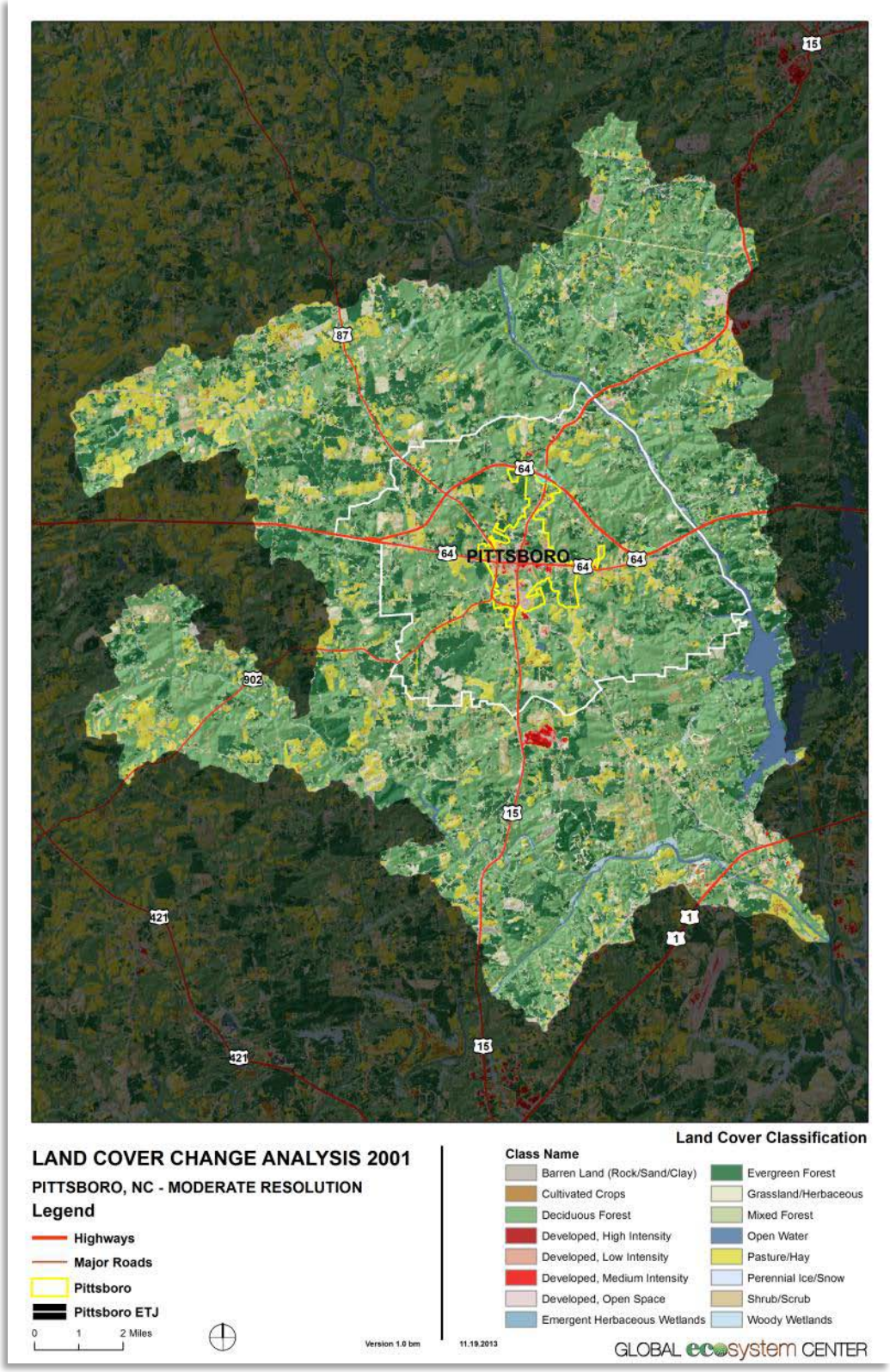
Map 4: Moderate resolution change areas 2006 (NLCD) – 2013.

Land Cover 1985



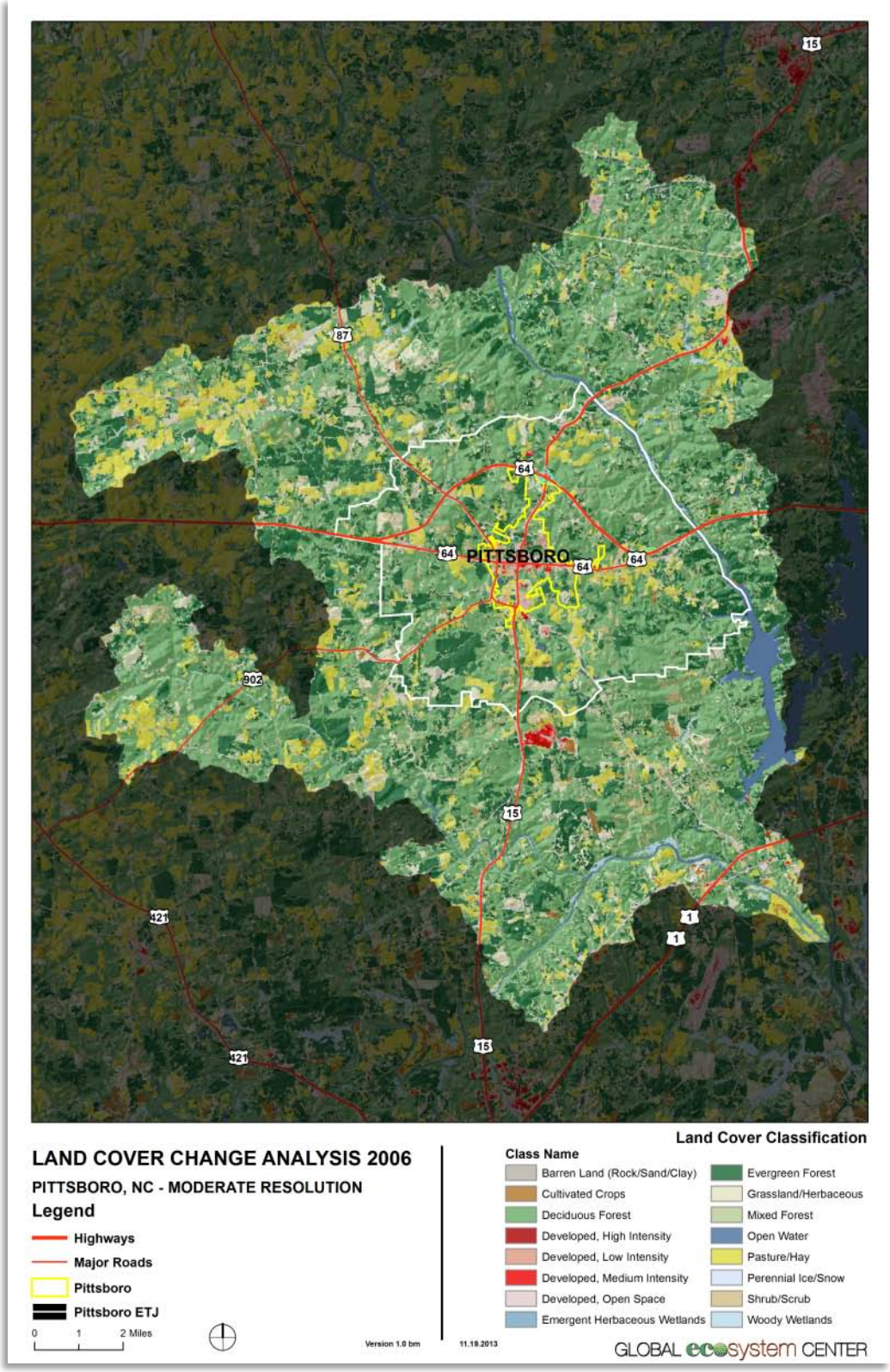
Map 5: Moderate resolution classified land cover 1985 (GEC).

Land Cover 2001 (NLCD)



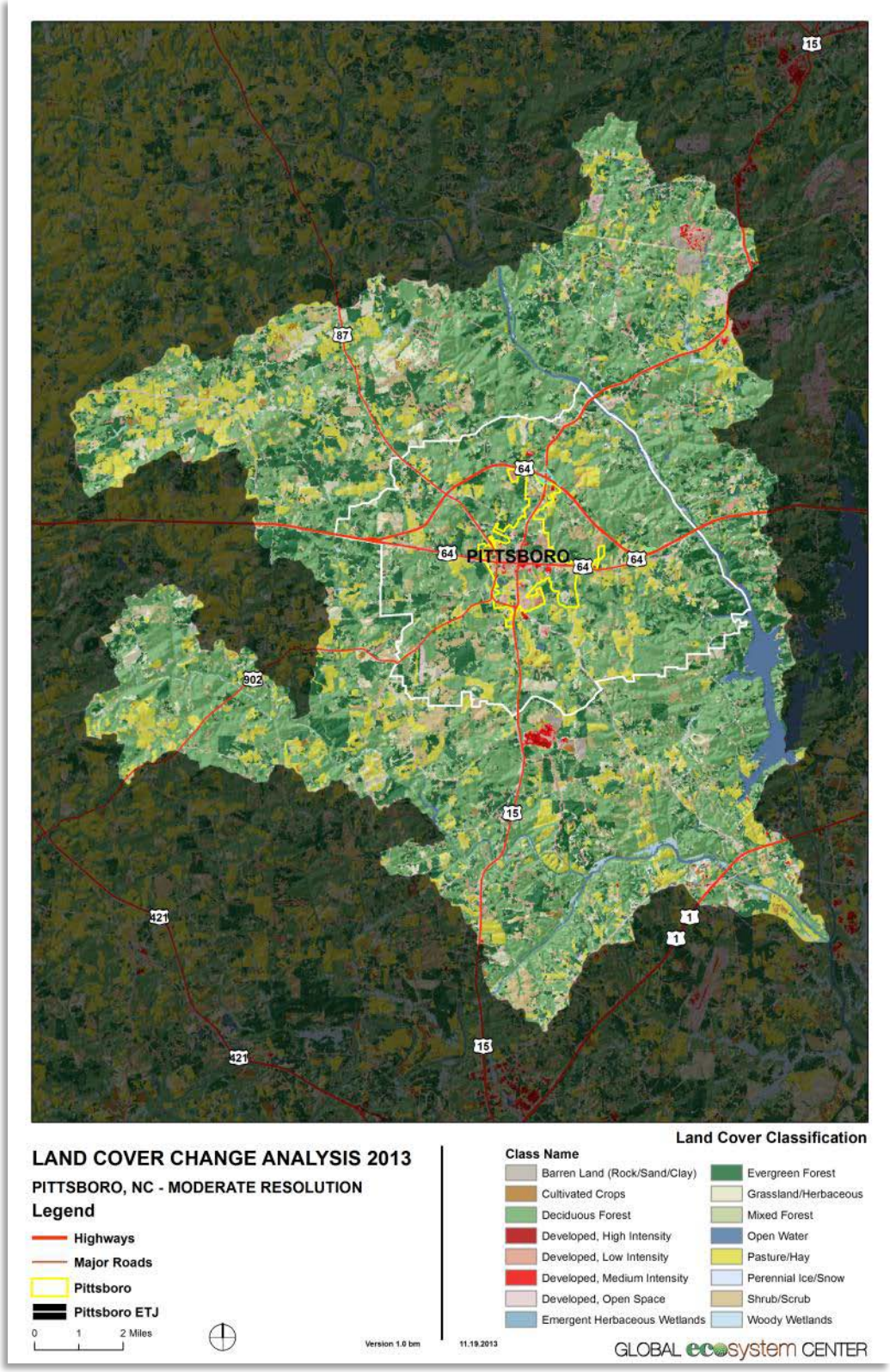
Map 6: Moderate resolution classified land cover 2001 (NLCD).

Land Cover 2006 (NLCD)



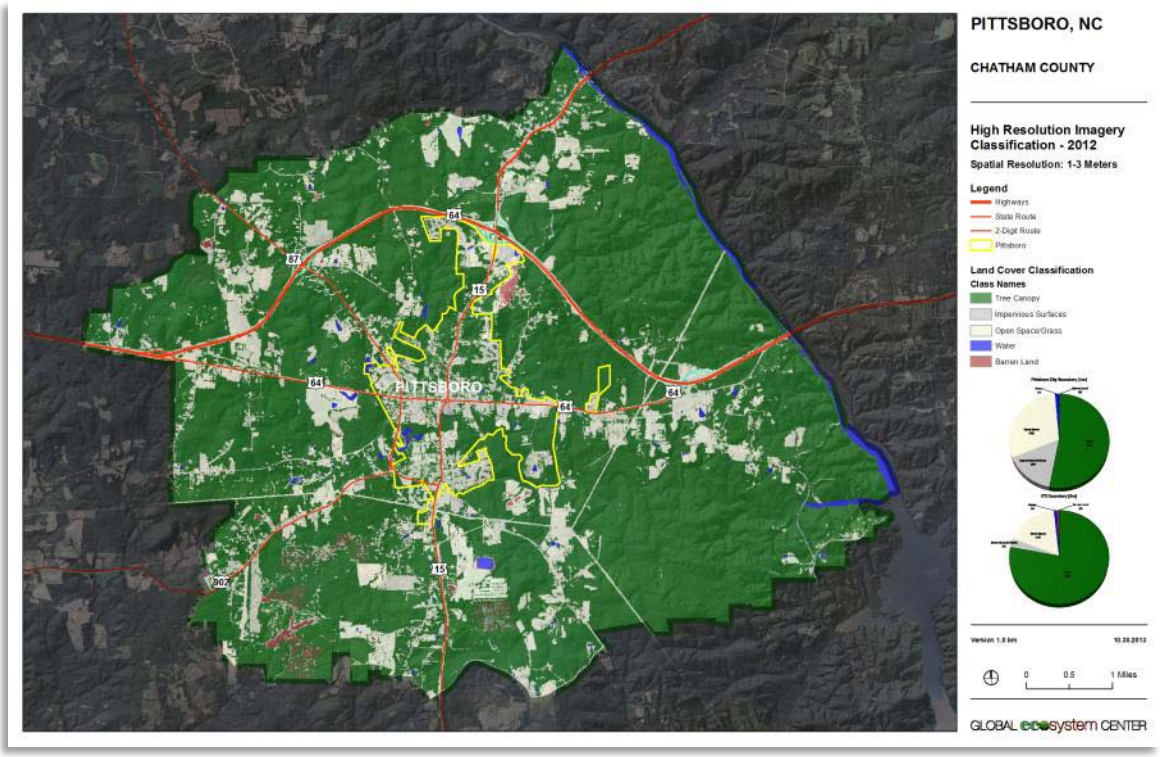
Map 7: Moderate resolution classified land cover 2006 (NLCD).

Land Cover 2013



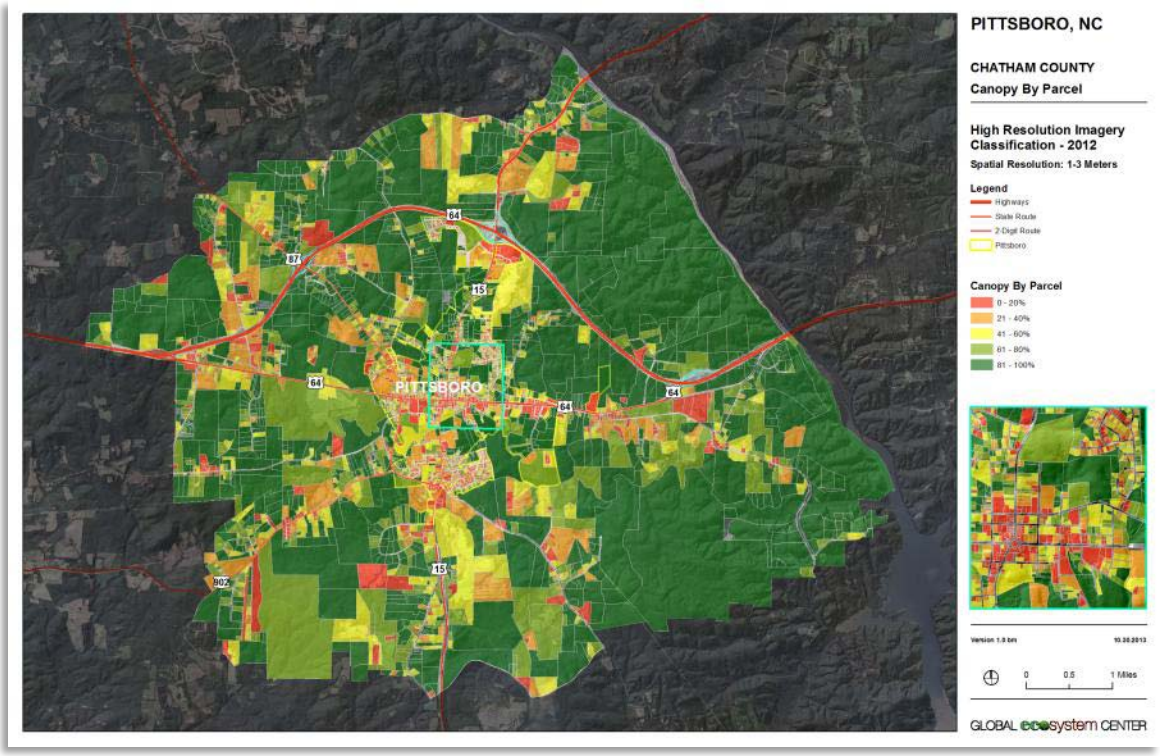
Map 8: Moderate resolution classified land cover 2013 (GEC).

Higher-Resolution Land Cover (1-3m)



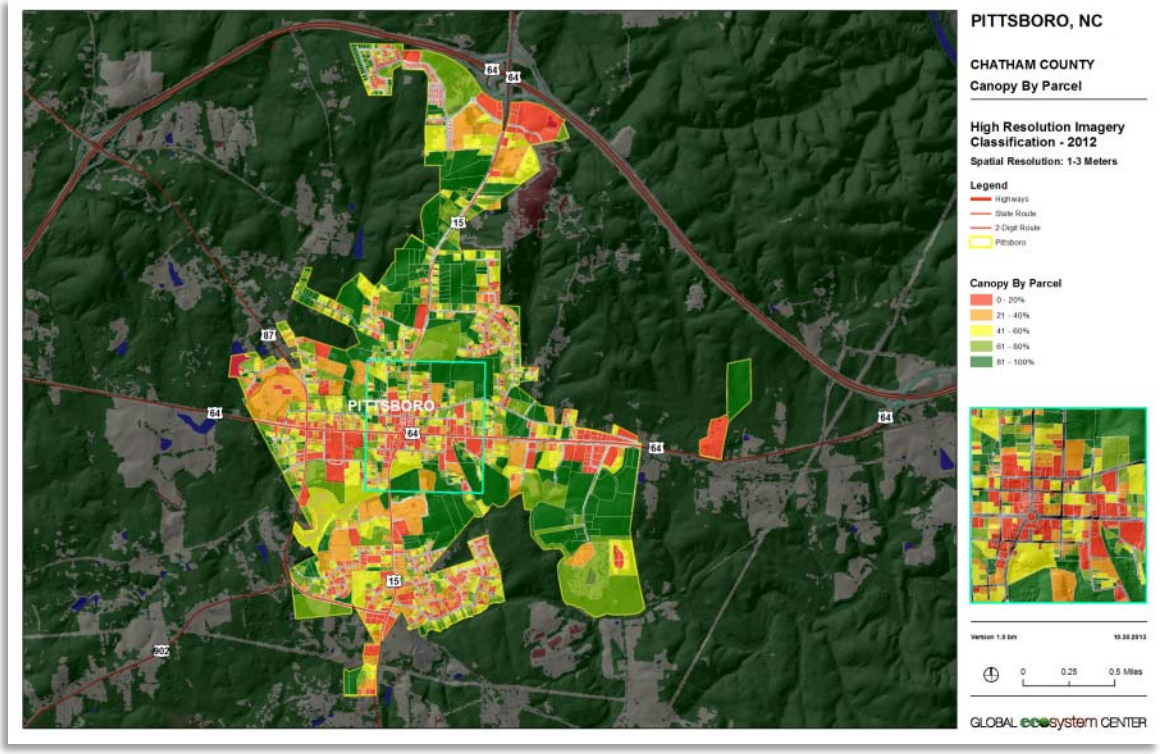
Map 9: Higher resolution classified land cover 2012 (GEC).

Canopy by Parcels



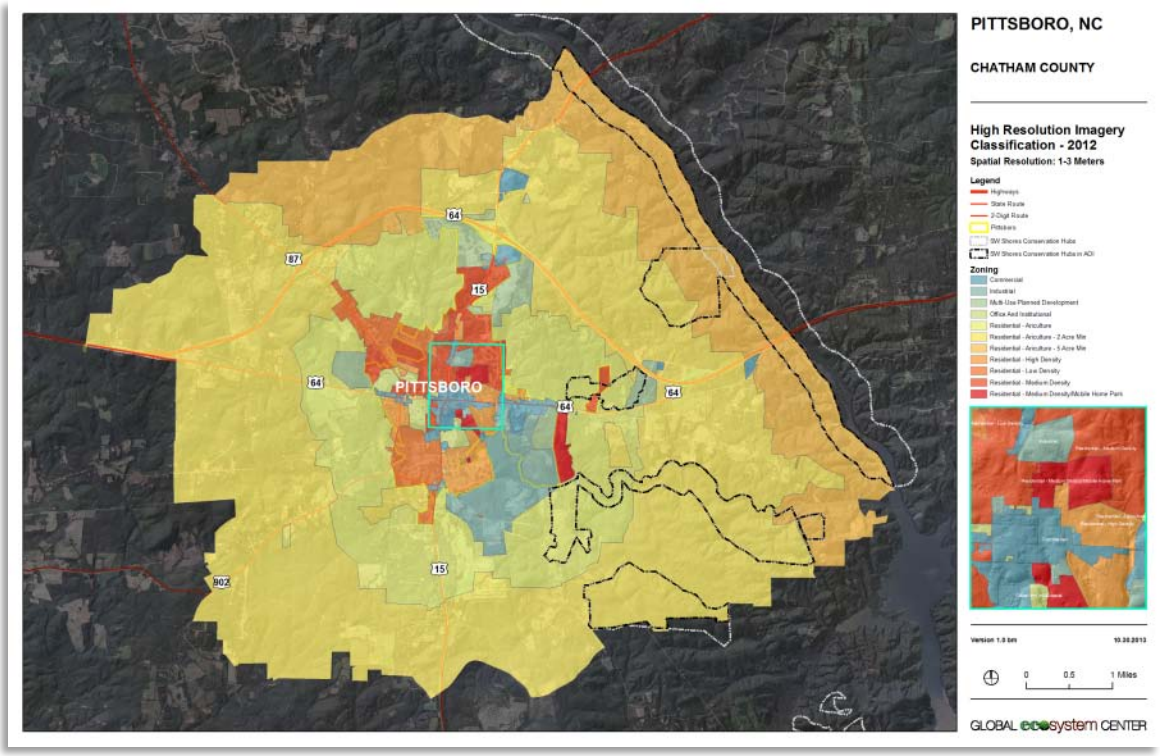
Map 10: Higher resolution classified land cover ETJ – Canopy by Parcels 2012 (GEC).

Canopy by Parcels (Town Core)



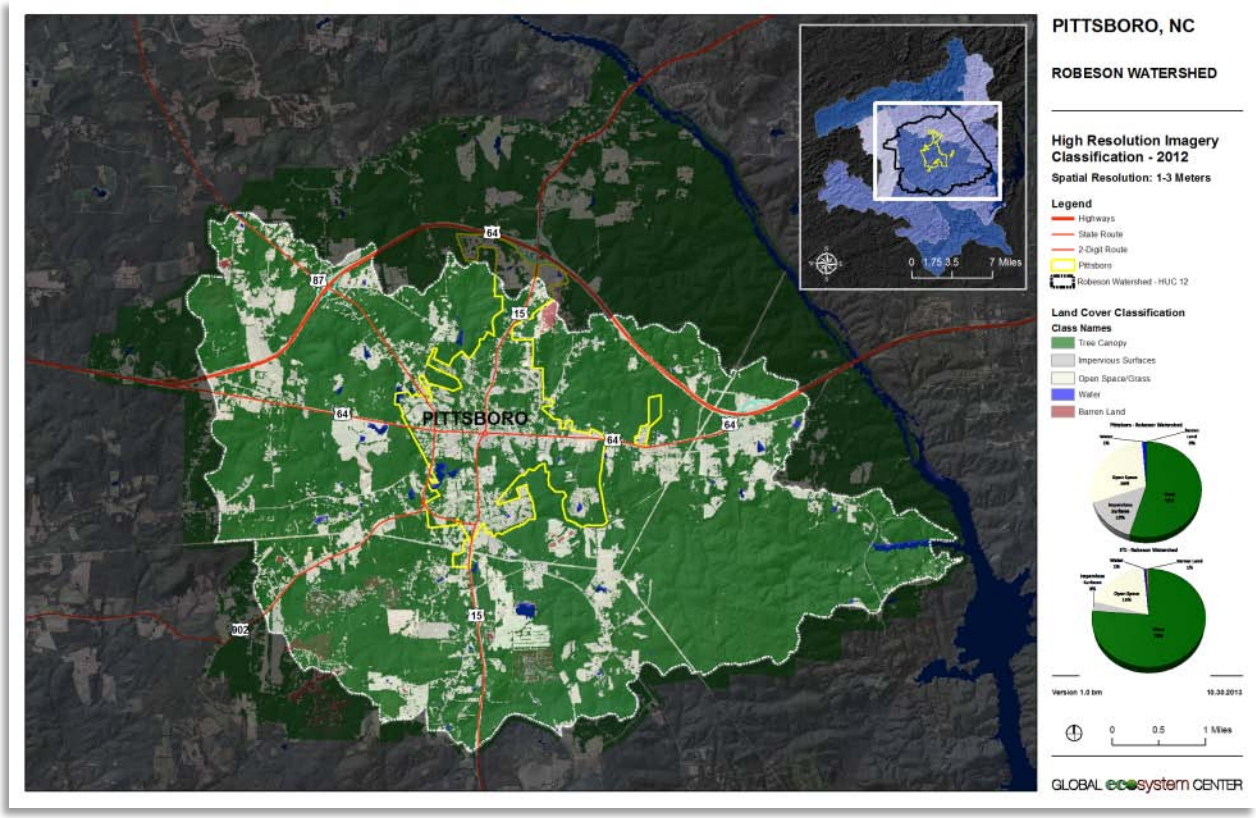
Map 11: Higher resolution classified land cover Town of Pittsboro 2012 (GEC).

Zoning and Ecosystem Analysis Area



Map 12: ETJ and Town of Pittsboro zoning districts and SW Shores Conservation Hubs.

Robeson Creek Watershed



Map 13: Spatial reference and land cover map of Robeson Creek watershed (dotted black boundary).

Bibliography

ESRI. (2013). *What is GIS?* Retrieved from http://www.esri.com/what-is-gis/overview#overview_panel

Miguel Villarreal, L. N. (2011). A Multitemporal (1979-2009) Land Use/Land-Cover Dataset of the Binational Santa Cruz Watershed. *Open-File Report 2011-1131* , p. 10.

NOAA. (2013). *National Oceanic And Atmospheric Administration*. Retrieved from National Ocean Service: http://oceanservice.noaa.gov/facts/remotesensing.html

USGS. (2007). *Multi-Resolution Land Characteristics Consortium (MRLC)*. Retrieved from U. S. Environmental Protection Agency: http://www.epa.gov/mrlc/definitions.html