

# **Land Cover Classification in the Upstate South Carolina and the Saluda-Reedy Watershed**

**Report submitted to  
the Saluda-Reedy Watershed Consortium &  
the South Carolina Forestry Commission**

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## **Forest Cover Change in Upstate South Carolina**

With rapid changes in land use/land cover occurring across the U.S., remote sensing technology is an essential tool in monitoring urban development and environmental conditions. Using satellite imagery for land cover change detection is possible because changes in light and energy reflectance values that are monitored by the satellite can be translated to changes in land cover categories.

From a strategic perspective, using satellite multispectral imagery such as Landsat Thematic Mapper, offers timely monitoring methods for extensive land areas. The analysis goal is to characterize those areas of important change (e.g. forest clearing or urban land development) between two or more image dates. Our project used a process called unsupervised classification analysis. In this process the computer groups similar reflectance values into numerous classes and the scientist uses samples of aerial photography and other geographic data to define the final classes that are used (eg. developed land, forest land, farm land). Specifically, the imagery was used to derive three classes of forest (deciduous, evergreen and mixed) and then determine the different amounts of those categories in imagery from 1985 and 2000.

Numerous research groups at universities, federal and state agencies use this type of satellite image analysis methodology to produce land cover maps. In the 1990's the U.S. Fish and Wildlife Service contracted with numerous states to produce land cover maps as part of a nation-wide habitat study. Recently, the U.S. Geological Survey and the U.S. Environmental Protection Agency teamed with other federal agencies to produce the Multi-Resolution Land Cover (MRLC) data set for the entire U.S. The Clemson researchers followed that same methodology to produce the land cover data set for upstate South Carolina.

### **Study Methodology**

The study addressed land use and land cover changes in the Upstate region of South Carolina over a 15-year period. This region consists of the following counties: Abbeville, Anderson, Greenville, Greenwood, Laurens, Newberry, Pickens, Spartanburg. The development pattern was the primary focus of this study. The study addresses three aspects of change detection to monitoring natural resources and urban growth:

1. Classification of Land Cover - 1985, 1990, 1995 and 2000
2. Detecting the change over the 15 year period
3. Quantifying the area statistics by year and by counties

The basic premise in using remote sensing data for change detection is that changes in land cover result in changes in light reflectance values that are monitored. Techniques to perform change detection with satellite imagery have become numerous because of increasing versatility in manipulating digital data and increasing computing power.

Remote sensing analysis techniques are available to detect land cover changes from multi-temporal remote sensing data sets. Initiatives to monitor land cover and land use change are increasingly relying on information derived from remotely sensed data because it is cost effective. Such information provides the data link to other techniques designed to understand the human processes behind environmental changes. Remote sensing data analysis is advantageous in that it samples large geographic areas at a fraction of the cost of ground-based surveys. For example, the Forest Inventory Analysis (FIA) also monitors change in forest cover over time. However, that dataset only contains a few sampling points per county and while very useful for multi-state or even statewide analysis, the data becomes filled with error when stratified to the county level. For this study, multispectral satellite images were classified into land cover classes. This image type has a robust capability to identify vegetation and development classes and can be broken down to the county level.

The study used Landsat TM and ETM+ scenes that covered the eight-county study area. Dual dates for the scene were acquired for the change detection. The period selected was the leaf-off period from November to February for 1985, 1990 and 2000. Early leaf-on from April to May was used for 1995 because of the lack of sufficient data in the leaf-off period. This time was preferred because no dense canopy obscured urban development. In addition, the scenes were cloud free in the study area. The scenes were geometrically corrected to less than a pixel root mean square error, registered to Universal Transverse Mercator coordinates, zone 17, North American Datum 1983, and resampled to 30-meter pixels by cubic convolution. The adjacent scenes were then mosaiced together. All six reflective bands from both dates were used for the classification. Land cover mapping was conducted for the study area using both satellite imagery and other geospatial data sets. Briefly, the classification used unsupervised clustering program ISODATA to generate 256 classes. The resulting spectral clusters were grouped into 13 classes using ancillary data sources (e.g., 1992 National Land Cover Data classification and 2001 Impervious Surface Data) as required. The grouping of the unsupervised classification used the ERDAS Imagine Grouping Tool.

## **Classification Scheme**

The 13 thematic classes resemble the well-established Anderson land use/cover classification system (Anderson et al. 1976). The thematic classes are:

**11. Open Water** - All areas of open water with total vegetative cover less than 25 percent.

**21. Developed, Open Space** (Parks, Golf Courses, Open Space) - Vegetation (primarily grasses) planted in developed settings for recreation, erosion control or aesthetic purposes. Impervious surfaces account for less than 20 percent of total cover. Examples include parks, lawns, golf courses, airport grasses and industrial site grasses.

**22. Developed, Low Intensity** - Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for less than 30 percent of total cover. These areas most commonly include single-family housing units.

**23. Developed, Medium Intensity** - Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 30-50 percent of the total cover. These areas most commonly include single-family housing units.

**24. Developed, High Intensity** - Includes highly developed areas such as commercial sites and highly dense residential developments. Examples include apartment complexes, row houses and commercial/industrial developments. Impervious surfaces account for 50 to 100 percent of the total cover.

**31. Barren or Transitional** - Areas characterized by bare rock, gravel, sand, silt, clay or other earthen material. Vegetation is less than 20 percent of total cover. This class includes the early grading associated with new development and the exposed lakeshore line resulting from the drought. It also includes clear cutting of forest land.

**41. Deciduous Forest** - Areas dominated by trees where greater than 75 percent of the tree species shed foliage simultaneously in response to seasonal change.

**42. Evergreen Forest (Coniferous)** - Areas dominated by trees where greater than 75 percent of the tree species maintain their leaves all year. Canopy is never without green foliage.

**43. Mixed Forest Areas** dominated by trees where neither deciduous nor evergreen species are greater than 75 percent of total tree cover.

**81. Open Fields/Pasture** – 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.

**82. Cultivated Crops** - Areas used for the production of crops, such as corn, soybeans, vegetables, tobacco and cotton, typically on an annual cycle.

**91. Woody Wetlands** - Areas where forest or shrub vegetation accounts for greater than 25 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

**92. Emergent Wetlands** - Areas where grass vegetation accounts for greater than 25 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

The classification followed the 2001 National Land Cover Data (NLCD) scheme. It is a modification of the previous 1992 NLCD classes. The new scheme uses percent of impervious surfaces for development classes as opposed to the land uses such as commercial and transportation. Impervious surface is more consistent with the capability of satellite imagery. This new scheme is being used for the National Land Cover Characterization 2001 project. It is a cooperative effort involving several US Federal agencies – USGS, EPA, USFS and NOAA – who will compile land cover data (NLCD 2001) across all 50 states and Puerto Rico and update the 1992 NLCD classification.

The final classification was an aggregation of the 13-classification scheme:

1. **Open Water** – same as class 11 above
2. **Development** – all developed classes 21, 22, 23 and 24
3. **Transitional or Barren** – same as class 31 above
4. **Forest** – all forest classes 41, 42 and 43
5. **Pasture and Cultivated** – both classes 81 and 82
6. **Wetlands** – both classes 91 and 92.

### Urban Classification and Conflict

Steps were taken in processing the data to stratify urban or high intensity classes from rural stratification or cultivated crops. The grouping of the unsupervised classification used the ERDAS Imagine Grouping Tool. The highest priority was given to the development classes. Table 1 shows the conflict among the 13 classes. Developed areas, due to confusion with bare soil, can be classified more accurately if done separately from agricultural or rural areas (Robinson & Nagel, 1990). For this reason, road data were overlaid on the imagery to aid visual identification of urban areas. High intensity development was separated from cultivated land by careful manual delineation around large urban areas approximately over 100 contiguous pixels. The new 2001 impervious surface layer from USGS was used to check for where development would eventually occur in the earlier years, and was also merged into the 2000 scheme.

**Table 1. The Most Frequent Conflict Between Mapped Land Cover Classes.**

<b>Class Name</b>	<b>Primary Conflict</b>	<b>Secondary Conflict</b>
Open Water	Woody Wetlands	Coniferous Forest
Developed Open Space	Open Field/Pasture	Cultivated Crops
Low Intensity Development	Mixed Forest	Open Field/Pasture
Medium Intensity Development	High Intensity Development	Low Intensity Development
High Intensity Development	Medium Intensity Development	Cultivated Cropland
Barren	High Intensity Development	Cultivated Crops
Deciduous Forest	Mixed Forest	Coniferous Forest
Coniferous Forest	Mixed Forest	Woody Wetlands
Mixed Forest	Coniferous Forest	Deciduous Forest
Open Field/Pasture	Cultivated Cropland	Developed Open Space
Cultivated Cropland	High Intensity Development	Barren
Woody Wetlands	Coniferous Forest	Open Water
Emergent Wetlands	Coniferous Forest	Open Water

In comparing the grouping of the classes there were some conflicts. These conflicts result in classification errors that are inherent in any air photo or satellite image analysis. Classification errors for these data sets fell within the acceptable ranges set forth by the National Land Cover Data's (NLCD) Multi-Resolution Land Cover (MRLC) data set. Factors that have contributed to disagreements between mapped land cover include:

- 1) 1990 and 1995 Landsat TM data quality and rectification error,
- 2) Late fall and early winter time periods – clear-cut, bare earth vs. paved urban areas(open fields/pasture, cultivated crops and high intensity development)
- 3) Spatial uncertainty, such as reduced water level from the drought.

## **Appendix A**

### **Land Cover and Tree Cover Classes in the Upstate: 1985 and 2000**



## Land Cover and Tree Cover Classes in the Saluda-Reedy Watershed in 1985 & 2000

Area in Square Miles		
Class Name	1985	2000
1 Open Water	21.315	22.274
2 Developed	121.674	248.033
3 Transitional or Barren	0	18.253
4 Forest	870.775	782.788
5 Pasture or Cultivated	141.925	88.331
6 Wetlands	11.283	7.293
<b>Total</b>	<b>1166.97</b>	<b>1166.97</b>

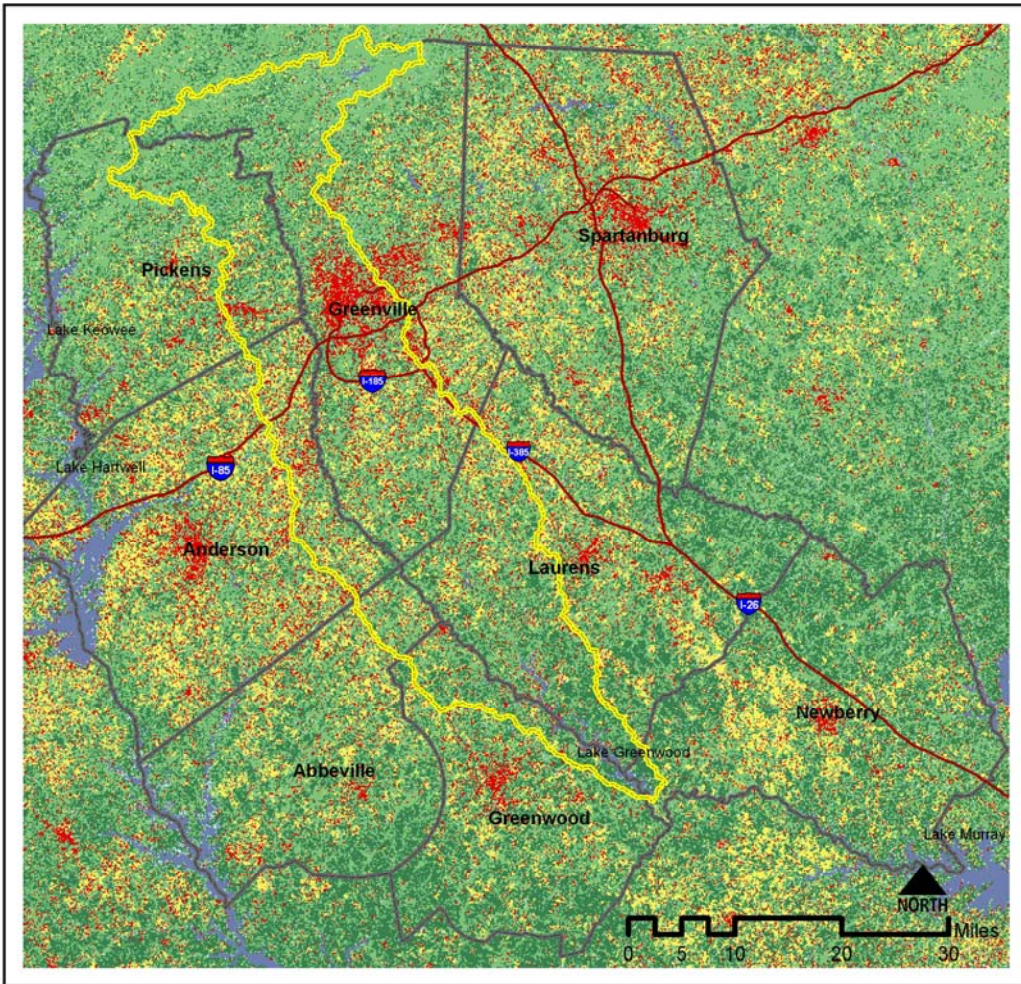
## Individual County Breakouts

<b>Zone: Greenville County</b>	<b>1985</b>	<b>2000</b>
Class Name	Square Miles	Square Miles
Deciduous Forest	423.667	134.259
Evergreen Forest	142.396	205.048
Mixed Forest	15.174	120.551
<b>Zone: Spartanburg County</b>	<b>1985</b>	<b>2000</b>
Class Name	Square Miles	Square Miles
Deciduous Forest	391.695	121.124
Evergreen Forest	156.852	213.833
Mixed Forest	21.337	115.87
<b>Zone: Pickens County</b>	<b>1985</b>	<b>2000</b>
Class Name	Square Miles	Square Miles
Deciduous Forest	271.875	81.678
Evergreen Forest	128.337	182.021
Mixed Forest	5.954	80.05
<b>Zone: Anderson County</b>	<b>1985</b>	<b>2000</b>
Class Name	Square Miles	Square Miles
Deciduous Forest	291.071	112.134
Evergreen Forest	130.025	199.392
Mixed Forest	14.088	92.991
<b>Zone: Laurens County</b>	<b>1985</b>	<b>2000</b>
Class Name	Square Miles	Square Miles
Deciduous Forest	326.844	140.947
Evergreen Forest	212.24	250.3
Mixed Forest	10.863	119.026
<b>Zone: Newberry County</b>	<b>1985</b>	<b>2000</b>
Class Name	Square Miles	Square Miles
Deciduous Forest	245.871	107.239
Evergreen Forest	246.984	275.231
Mixed Forest	9.063	86.813
<b>Zone: Abbeville County</b>	<b>1985</b>	<b>2000</b>
Class Name	Square Miles	Square Miles
Deciduous Forest	222.455	100.658
Evergreen Forest	160.521	204.267
Mixed Forest	6.025	72.761
<b>Zone: Greenwood County</b>	<b>1985</b>	<b>2000</b>
Class Name	Square Miles	Square Miles
Deciduous Forest	186.008	81.51
Evergreen Forest	178.215	197.796
Mixed Forest	4.624	58.279
<b>Totals</b>	<b>3802.184</b>	<b>3353.778</b>

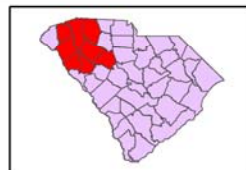
## **Appendix B**

Land Cover and Forest Cover Maps in the Upstate:  
1985 and 2000

## Saluda Reedy Watershed Consortium Land Cover Classification -Year 1985



- |                        |                  |
|------------------------|------------------|
| Saluda Reedy Watershed | Deciduous Forest |
| Interstate High ways   | Evergreen Forest |
| Study County           | Mixed Forest     |
| No Data                | Pasture/Hay      |
| Open Water             | Cultivated Crops |
| Developed Land         | Wetlands         |
| Barren Land            |                  |

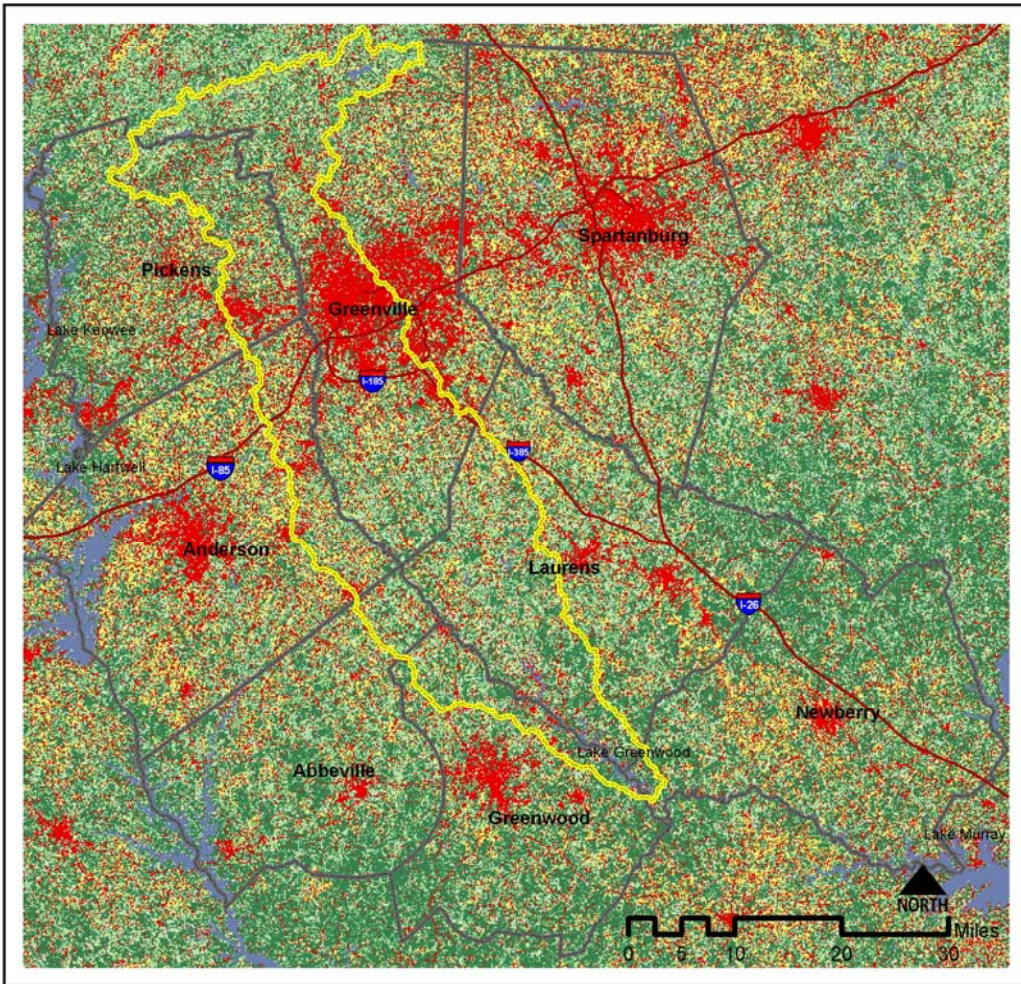


Key Map

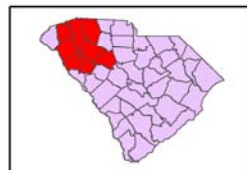


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## Saluda Reedy Watershed Consortium Land Cover Classification -Year 2000



- |                        |                  |
|------------------------|------------------|
| Saluda Reedy Watershed | Deciduous Forest |
| Interstate High ways   | Evergreen Forest |
| Study County           | Mixed Forest     |
| No Data                | Pasture/Hay      |
| Open Water             | Cultivated Crops |
| Developed Land         | Wetlands         |
| Barren Land            |                  |



Key Map



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