2006 Land Cover Map for the Southern Appalachian Study Area

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Abstract:

Satellite imagery (mosaicked +ETM and TM imagery satellite imagery from late 2005 through mid-2006) were downloaded from the web for spring, leafoff, and leafon conditions (Fig. 2). From these layers we derived tasseled cap bands 1,2,3. Other data used included digital elevation models (DEMs), DEM slope calculations, and 2006 NAPP DOQQs (used for training sets). We classified imagery using classification and regression tree method (CART) using a combination of Landsat TM imagery and ancillary data. The specific CART program used was See5, which implements a gain ratio criterion in tree development and pruning (Quinlan, 1993). We used boosting and cross-validation to improve classification accuracy (boosting) and estimate accuracy (cross-validation).

Objective:

Mapping land cover using data (Landsat TM and ETM+) to match previous land cover maps for the Southern Appalachians (e.g., 1986, 1991, 1996 developed by Coweeta LTER personnel; 2001 developed by NARSAL lab at UGA as the NLCD map for zone 57). Coordinate System: UTM Zone 17N, WSG84 datum

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Southern Appalachian Study Area

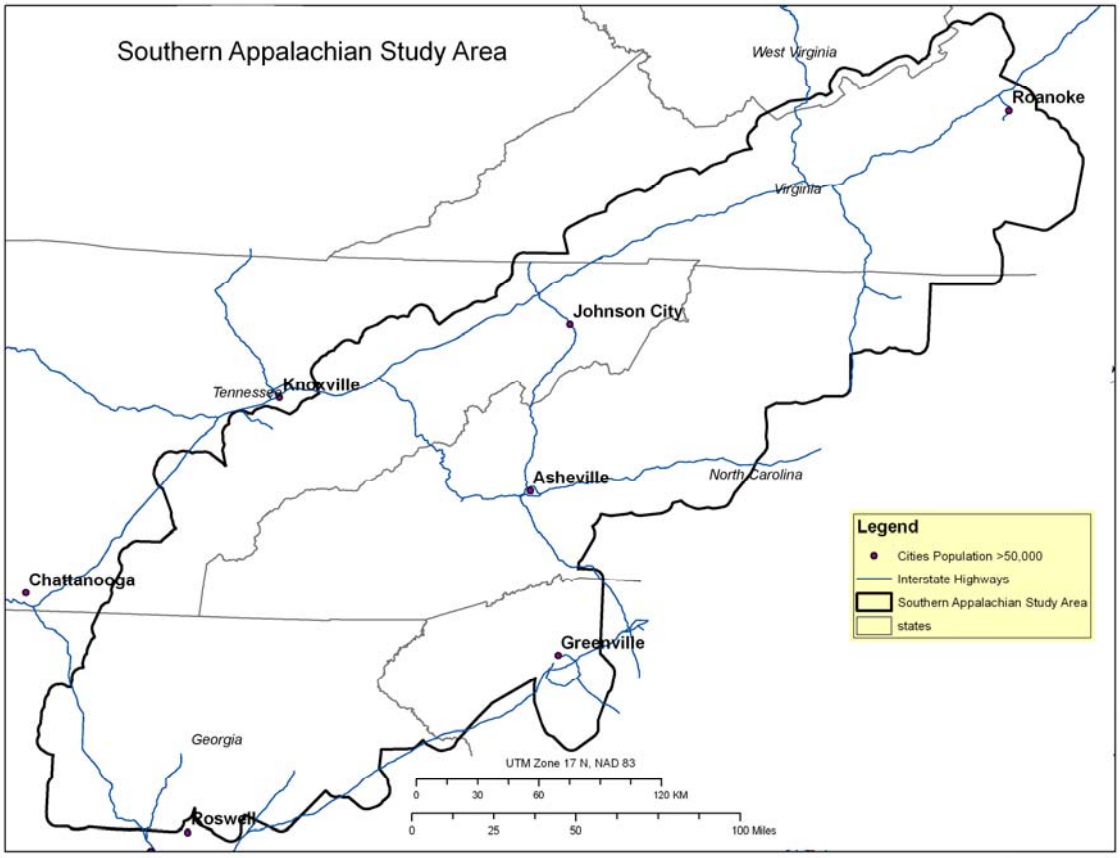

Figure 1. Southern Appalachian Study Area.

Methods Overview:

The land cover classification was achieved by use of a classification and decision tree method (DT) using a combination of Landsat imagery and ancillary data. The specific DT program employed is called C5, which implements a gain ratio criterion in tree development and pruning (Quinlan, 1993). C5 also implemented several advanced features that can aid and improve land cover classification, including boosting and cross-validation. Boosting is a technique for improving classification accuracy, while cross-validation can provide certain level of estimation regarding the land cover classification quality. Sixty boosts and 10-fold cross-validation were done for each classification strata (see below). In addition, C5 can generate a confidence estimate for each classified pixel and record the associated classification logic in a text file that can be readily interpreted and incorporated into a metadata system. To conduct the land cover classification using DT, a large quantity of training data is required. Training data were collected from g USGS DOQQs. Following the development of the best classification through decision tree modeling, additional steps were required to complete the final land cover product. The four classes in urban and suburban areas were determined 2001 Zone 57 NLCD and classes derived from the above DT classification. The threshold for the four classes in 2001 was: (1) developed open space (imperviousness < 20%), (2) low-intensity developed (imperviousness from 20 - 49%), (3) medium intensity developed (imperviousness from 50 -79%), and (4) high-intensity developed (imperviousness > 79%). The completed single pixel product was then generalized to a 1 acre (approximately 5 ETM+ 30 m pixel patch) minimum mapping unit for all classes but 24 (Developed, High Intensity: 2 acre/10 pixels) and 11 (Open Water: 1 pixel) using a "smart eliminate" algorithm. This aggregation program subsumes pixels from the single pixel level to a 5-pixel patch using a queens algorithm at doubling intervals. The algorithm consults a weighting matrix to guide merging of cover types by similarity, resulting in a product that preserves land cover logic as much as possible.

Obtain imagery for all scenes for 3 seasons (winter, spring, summer)

Landsat ETM+ and TM images for the study area were downloaded directly from USGS online archives. The data was downloaded as separate Tiff images, imported into Erdas Imagine format, and layer-stacked into 6-band Imagine files (band 6, the thermal band, was not included). The specific image id, season, and TM row-path combination for images downloaded are listed in Table 1.

Table 1. Original Landsat scenes used in each mosaic

image#	Season	TM Row	TM Path/ Column
l5016034_03420060409_6bnd.img	spring	34	16
l5017034_03420070403_6bnd.img	spring	34	17
l5017035_03520070521_6bnd.img	spring	35	17
l5018034_03420070410_6bnd.img	spring	34	18
l5018035_03520070410_6bnd.img	spring	35	18
l5018036_03620050420_6bnd.img	spring	36	18
l5019035_03520070417_6bnd.img	spring	35	19
l5019036_03620070417_6bnd.img	spring	36	19
l5017034_03420070825_6bnd.img	summer	34	17
l5017035_03520070825_6bnd.img	summer	35	17
l5018034_03420060712_6bnd.img	summer	34	18
l5018035_03520060610_6bnd.img	summer	35	18
l5018036_03620060610_6bnd.img	summer	36	18
l5019035_03520060703_6bnd.img	summer	35	19
l5019036_03620060703_6bnd.img	summer	36	19
l5017034_03420061126_6bnd.img	winter	34	17
l5017035_03520061126_6bnd.img	winter	35	17
l5018034_03420070104_6bnd.img	winter	34	18
l5018036_03620070205_6bnd.img	winter	36	18
l5019035_03520070228_6bnd.img	winter	35	19
l5019036_03620070228_6bnd.img	winter	36	19
l5018035_03520070120_6bnd.img	winter	35	18

Mosaic scenes together

Stacked images for each season were mosaicked together into single images for the entire study area using the MOSAIC PRO tool in Imagine 9.3. Band 1, which records reflectance in the blue portion of the EM spectrum and generally is of poorer quality due to atmospheric contamination, was dropped from inclusion in the mosaics. All images in the mosaic process used an active area, and nearest neighbor resampling (not the best setting in retrospect). The Exclude Areas function was used to exclude water and clouds in the mosaic process and automatic color balancing, and histogram matching was used. Mosaics were clipped with a study area mask representing the study area plus 5km buffer around the study area (so_app_studyarea5kBuffer.shp).

Three-band Tasseled Cap images were created for each season using the Imagine Tasseled Cap tool and defaults for Landsat TM and ETM+ imagery.

Table 2. Final TM Mosaics (5-band [no-blue]) and 3-band Tasseled Cap images

1. spring_gr_fin_clip_b.img
2. spring_tc_gr_fin_Clip.img
3. sumr_gr_fin_clip_b.img
4. sumr_tc_gr_fin_Clip.img
5. wint_gr_fin_clip_b.img
6. wint_tc_gr_fin_Clip.img

Ancillary GIS layer development

Ancillary GIS data layers were developed to include in the image classifications. A 30m digital elevation model (DEM) was used to develop additional layers: percent slope, aspect, and Slope Position Index.

Aspect was recoded into 16 classes (0 22.5625 1;22.5625 45.125 2;45.125 67.6875 3;67.6875 90.25 4;90.25 112.8125 5;112.8125 135.375 6;135.375 157.9375 7;157.9375 180.5 8;180.5 203.0625 9;203.0625 225.625 10;225.625 248.1875 11;248.1875 270.75 12;270.75 293.3125 13;293.3125 315.875 14;315.875 338.4375 15;338.4375 359.9 16).

Slope Position Index was calculated using a 7x7 moving window and ranges from 1-6 where: 1=valley, 2=toe slope, 3=flat, 4=midslope, 5=upper slopes, and 6=ridges.

Training Data Development

We interpreted land cover classes using high resolution digital orthophotography (DOQQs) and developed ground points for each target land cover class. These data were obtained from USGS. DOQQ s were used as "visual truth" layers to classify the points used for the dependent layer. We used an existing ArcGIS shapefile that contained interpreted points for 1996 and 2001 land cover data as a starting point and interpreted the 2006 land cover for these and additional points. A single interpreter was used initially (HA), and then checked by a separate individual (JHC) in cases of problematic areas or class values. New points were added in some cases where not enough points were originally established in the 2001 work (Urban [21,22,23,24] and Forest classes [41,42,43] specifically were targeted). A total of 4,965 points were interpreted (Table 4). The shapefile was originally converted to raster, but it would not work as such with the NLCD sampling tool. Instead, the point shapefile was exported as .txt format and as such was successfully used in the NLCD sampling tool to sample the input layers for SEE5 classification.

Table 3. DOQQs used to identify 2006 land cover :

DOQQs
n_3608216_sw_17_1_20030912.tif
n_3708043_se_17_2_20050907.tif
n_3708060_sw_17_2_20050907.tif
n_3608033_se_17_1_20060717.tif
n_3408202_ne_17_1_20060610.tif
n_3708160_se_17_2_20050911.tif
n_3708163_se_17_2_20050805.tif
n_3608360_ne_17_1_20070617.tif
n_3608364_nw_17_1_20061204.tif
n_3608249_nw_17_1_20061209.tif
n_3608252_se_17_1_20061211.tif
n_3608101_se_17_2_20050802.tif
n_3608122_ne_17_2_20050805.tif
n_3608125_nw_17_1_20070103.tif
n_3608127_ne_17_1_20060718.tif
n_3608132_ne_17_1_20060717.tif
n_3608136_se_17_1_20060718.tif
n_3608145_nw_17_1_20060718.tif
n_3608160_se_17_1_20060718.tif
n_3608022_nw_17_2_20050908.tif
n_3508424_nw_16_1_20060921.tif
n_3508445_sw_16_1_20061205.tif
n_3508306_se_17_1_20070111.tif
n_3508325_se_17_1_20061202.tif
n_3508337_ne_17_1_20061002.tif
n_3508341_sw_17_1_20061013.tif
n_3508357_se_17_1_20061013.tif
n_3508363_ne_17_1_20060921.tif
n_3508226_nw_17_1_20060915.tif
n_3508238_se_17_1_20060701.tif
n_3508244_ne_17_1_20060802.tif
n_3508101_sw_17_1_20060731.tif
n_3508126_se_17_1_20060701.tif
n_3408406_nw_16_2_20060701.tif
n_3408421_sw_16_2_20060702.tif
n_3408444_nw_16_2_20060718.tif

Table 4. Number of training points for each land cover class interpreted from DOQQs.

LC Class	# of Points
11	110
21	165
22	178
23	121
24	131
31	118
41	1805
42	526
43	475
52	292
71	270
81	505
82	129
90	101
95	38
Total	4964

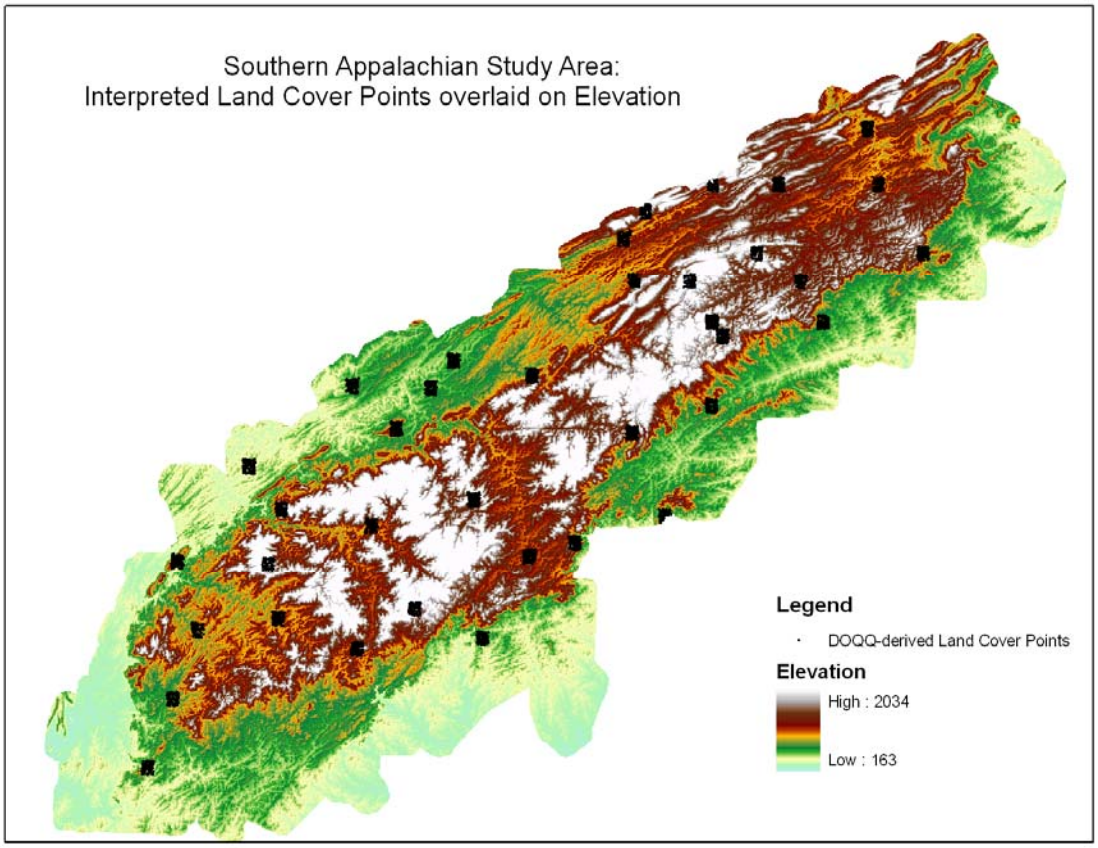

Figure 2. Training sites overlaid on Elevation for Southern Appalachian Study Area.

Hierarchical classification

The following steps were followed to develop the 2006 land cover map.

1. The individual classes were grouped into 3 strata (1: 31,52,81,82,71,95; 2: 41, 42, 43, 90; 3: 11,21,22,23).
2. A SEE5 classification was run using these three strata to develop a top-level mask.
3. The resulting classes were used to segment the input layers into three separate strata (i.e., pixels of each class value were separated into 3 different mask files).
4. Strata 1:
    a. Winter TM image plus derived layers used to separate 52 from other classes
    b. Winter and spring images plus derived layers used to differentiate class 31,71,81,82 with elevation mask used to recode 31 below 900m as 82.
5. Strata 2:
    a. Winter and summer images plus derived layers used
6. Strata 3:
    a. Summer images plus derived layers used
7. Classifications for each strata were then combined into a mosaic

Running SEE5 classifications

The following steps were followed to develop the See5 classifications.

1. The NLCD sampling tool (within the NLCD Mapping Tool for Erdas Imagine) was used to sample the following data layers at the training sample locations
    a. Winter TM 5-band mosaic (no blue or thermal bands)
    b. Spring TM 5-band mosaic (no blue or thermal bands)
    c. Summer TM 5-band mosaic (no blue or thermal bands)
    d. Winter Tasseled Cap 3-band mosaic
    e. Spring Tasseled Cap 3-band mosaic
    f. Summer Tasseled Cap 3-band mosaic
    g. Elevation
    h. Percent Slope
    i. 16-class Aspect
    j. 6-class Slope Position Index
2. SEE5 used to build trees with boost and cross-validation options checked and set to 60 boosting trials and 10 fold cross-validation.
3. SEE5 was run again (with cross validation not checked) to get output showing percentage errors for each tree for 60 trials and total using 10% hold out for each trial, and cross-validation results for 10 folds and a confusion matrix table.
4. A classified Imagine image was created using the SEE5 rulesets and the See5 Classifier tool in the NLCD mapping tool add-on for Imagine

Table 5. Strata-specific SEE5 boosting and cross-validation results

Strata	# Training Samples	# Testing Samples	Boosting Training Data	Boosting Test Data
Base All 1	3940	985	1.4	16.4
Base 1	1086	271	0.0	38.7
Base 2	2233	558	0.6	22.4
Base 3	273	68	0.4	30.9
Base All Updated for Urban Classes	3672	918	1.4	16.4
Base 3 Updated for Urban Classes	531	133	0.2	39.8

Post-classification GIS Rules

1. Roads and urban from 2001 land cover layer were burned into the mosaic
2. Wetlands from 2001 land cover layer were burned into the mosaic
3. All classes in 2001 were burned into areas with clouds in the 2006 imagery
4. Smart Eliminate was used to create MMU similar to 2001 imagery
5. Mosaic was co-registered to other dates of land cover and projected from UTM zone 17 WGS 1984 datum to UTM zone 17 NAD83 datum to match other land cover data

The Smart Eliminate procedure is included as a tool within the NLCD Mapping Tool for Imagine. It allows the user to "eliminate" pixels that occur in patches that are smaller than a user-defined minimum size, the "minimum mapping unit". Different land cover classes have different inherent scales of heterogeneity and hence required different MMU settings. We went through several attempts to emulate the level of clumping observed in the 2001 land cover map to set our MMU values and class weightings to match the 2001 map (Table 6)

Table 6. Smart Eliminate settings for each land cover class. MMU is in cells (30m) and Weights indicate classes that are likely (in order of highest to lowest) to be confused.

Class	MMU	Weight
0	0	NA
11	1	
21	5	
22	5	
23	5	22
24	10	23,22
31	5	
41	5	43
42	5	43
43	5	
52	5	43,41
71	5	82,81
81	5	82
82	5	81
90	5	
95	5	

Accuracy Assessment

The information on data quality for the Southern Appalachian 2006 land cover map was generated by the Decision Tree algorithm that conducts a cross-validation for assessing classification and prediction reliability. No formal independent accuracy assessment of 2006 Southern Appalachian land cover has been made. The regression tree algorithm employed offers a cross-validation option for assessing classification and prediction reliability. Cross-validation can provide relatively reliable estimates for land cover predictions if the reference data used for cross-validation are collected based on a statistically valid sampling design. For Southern Appalachian land cover modeling, a 10-fold cross-validation was conducted by dividing the entire training data set into 10 subsets of equal size. For each model run, an accuracy estimate was derived using one subset to evaluate the model prediction (with the model developed using the remaining training samples). This process was repeated 10 times. After all 10 runs, an average value of all accuracy estimates from the 10 runs were computed. Users should be cautioned that these cross-validation results provide users with only first-order estimates of data quality, and should not be considered a formal accuracy assessment. This land cover map and all documents pertaining to it are considered "provisional " until a formal accuracy assessment can be conducted.

We conducted several comparisons of our classification with the original training data points (Table 6) as well as 4, 052 land use and land cover (LULC) polygons from a separate CWT-funded study within Macon County using 2009-2010 DOQQs (K.C. Love, J. Hepinstall-Cymerman, J. Chamblee). We compared the centroid of each polygon with the 2006 land cover map (Table 8).

Table 7. Accuracy assessment table using training data sites and final 2006 land cover map.

A. Number of points falling in each land cover combination. Diagonal represents agreement.

	DOQQ-derived Land Cover															
Map Land Cover	11	21	22	23	24	31	41	42	43	52	71	81	82	90	95	Total
11	59			1		2								1	2	65
21	6	58	68	21	11	13	7	14	9	7	9	9	1	2	10	245
22	1	11	45	53	23	6				1						140
23		2	1	22	47	1				1						74
24				1	36	3										40
31	2	2	6	10	10	35	2			1	1	1	7	1		78
41	34	15	6	1		16	1697	80	246	112	48	11	9	36	13	2324
42	1	2				2	22	395	104	11	1			4	2	544
43		3				2	29	27	109	12	6		1	3	2	194
52		14	2	1	2	10	19	3	3	100	18	4	2		1	179
71		8	5	2		15	7			14	86	14	9			160
81	4	47	42	6	2	10	8	1	1	28	97	464	60	5	2	777
82	1	1	1	2		2			1	2	3	1	40	1		55
90	2					1	12	5	2	2		1		48	6	79
Grand Total	110	163	176	120	131	118	1803	525	475	291	269	505	129	101	38	4954

B. Proportion of Map land cover class in each DOQQ class

	DOQQ-derived Land Cover															
Map Land Cover	11	21	22	23	24	31	41	42	43	52	71	81	82	90	95	Total
11	0.91	-	-	0.02	-	0.03	-	-	-	-	-	-	-	0.02	0.03	1
21	0.02	0.24	0.28	0.09	0.04	0.05	0.03	0.06	0.04	0.03	0.04	0.04	0.00	0.01	0.04	1
22																1

	0.01	0.08	0.32	0.38	0.16	0.04	-	-	-	0.01	-	-	-	-	-	
23	-	0.03	0.01	0.30	0.64	0.01	-	-	-	0.01	-	-	-	-	-	1
24	-	-	-	0.03	0.90	0.08	-	-	-	-	-	-	-	-	-	1
31	0.03	0.03	0.08	0.13	0.13	0.45	0.03	-	-	0.01	0.01	0.01	0.09	0.01	-	1
41	0.01	0.01	0.00	0.00	-	0.01	0.73	0.03	0.11	0.05	0.02	0.00	0.00	0.02	0.01	1
42	0.00	0.00	-	-	-	0.00	0.04	0.73	0.19	0.02	0.00	-	-	0.01	0.00	1
43	-	0.02	-	-	-	0.01	0.15	0.14	0.56	0.06	0.03	-	0.01	0.02	0.01	1
52	-	0.08	0.01	0.01	0.01	0.06	0.11	0.02	0.02	0.56	0.10	0.02	0.01	-	0.01	1
71	-	0.05	0.03	0.01	-	0.09	0.04	-	-	0.09	0.54	0.09	0.06	-	-	1
81	0.01	0.06	0.05	0.01	0.00	0.01	0.01	0.00	0.00	0.04	0.12	0.60	0.08	0.01	0.00	1
82	0.02	0.02	0.02	0.04	-	0.04	-	-	0.02	0.04	0.05	0.02	0.73	0.02	-	1
90	0.03	-	-	-	-	0.01	0.15	0.06	0.03	0.03	-	0.01	-	0.61	0.08	1
C. Proportion of DOQQ land cover class in each Map class																
	DOQQ-derived Land Cover															
Map Land Cover	11	21	22	23	24	31	41	42	43	52	71	81	82	90	95	
11	0.54	-	-	0.01	-	0.02	-	-	-	-	-	-	-	0.01	0.05	
21	0.05	0.36	0.39	0.18	0.08	0.11	0.00	0.03	0.02	0.02	0.03	0.02	0.01	0.02	0.26	
22	0.01	0.07	0.26	0.44	0.18	0.05	-	-	-	0.00	-	-	-	-	-	
23	-	0.01	0.01	0.18	0.36	0.01	-	-	-	0.00	-	-	-	-	-	

24	-	-	-	0.01	0.27	0.03	-	-	-	-	-	-	-	-	-	
31	0.02	0.01	0.03	0.08	0.08	0.30	0.00	-	-	0.00	0.00	0.00	0.05	0.01	-	
41	0.31	0.09	0.03	0.01	-	0.14	0.94	0.15	0.52	0.38	0.18	0.02	0.07	0.36	0.34	
42	0.01	0.01	-	-	-	0.02	0.01	0.75	0.22	0.04	0.00	-	-	0.04	0.05	
43	-	0.02	-	-	-	0.02	0.02	0.05	0.23	0.04	0.02	-	0.01	0.03	0.05	
52	-	0.09	0.01	0.01	0.02	0.08	0.01	0.01	0.01	0.34	0.07	0.01	0.02	-	0.03	
71	-	0.05	0.03	0.02	-	0.13	0.00	-	-	0.05	0.32	0.03	0.07	-	-	
81	0.04	0.29	0.24	0.05	0.02	0.08	0.00	0.00	0.00	0.10	0.36	0.92	0.47	0.05	0.05	
82	0.01	0.01	0.01	0.02	-	0.02	-	-	0.00	0.01	0.01	0.00	0.31	0.01	-	
90	0.02	-	-	-	-	0.01	0.01	0.01	0.00	0.01	-	0.00	-	0.48	0.16	
Grand Total	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	

Table 8. Comparison to DOQQ-derived land use/land cover polygons for CWT Nine Synoptic Watersheds and selected bird survey points (PF Barlow's 2010 sites) within Macon County, NC.

2010 DOQQ-derived Land Use/Land Cover Class	Lakes	Ponds/Resevoirs	Rivers	Streams	Single Family Residential with Lawn	Single Family Residential	Lawn	Golf Course	Developed, Low Intensity	Developed, Medium Intensity	Developed, High Intensity	Paved Roads	Unpaved Roads	Barren Land (Rock/Sand/Clay)	Rock Outcrop	Deciduous Forest	Evergreen Forest.	Mixed Forest	Shrub/Scrub	Grassland/Herbaceous	Pasture/Hay	Cultivated Crops	Palustrine Forested Wetland	Palustrine Scrub/Shrub Wetland	Emergent Wetland	
2006 Land Cover Class	111	112	131	132	211	212	213	214	220	230	240	241	242	310	311	410	420	430	520	710	810	820	910	920	950	Total
Open Water		1			1																					2
Developed, Open Space	2	21	2	3	141	186	15	38	31	9	2	394	24			132	55	18	39		27	1				1140
Developed, Low Intensity				17	6	5		13	13	11	101	1			6	2	1	8							184	
Developed, Medium Intensity			1				3	5	20	39				1										69		
Devloped, High Intensity								1		6	6														13	
Barren Land		1			10	1	1		1	6		5	2				1		2		1	1				32
Deciduous Forest		30	3	1	112	284	13		8			140	103		3	365	88	89	66	1	20	3	2	1		1332
Evergreen Forest		1	1		3	11	2		1		1	7	1			21	80	22	1							152
Mixed Forest		3			13	36	1			1		8	2			34	29	30	9		3					169
Shrub/Scrub		2		1	66	51	6		2	1		17	12			41	10	5	32		15					261
Grassland/Herbaceous		2			35	25	2					19	7			11	5	3	13	1	10					133
Pasture/Hay		14	1	5	167	27	14		14	2	2	58	6	3		40	13	8	48		135	5		1		563
Cultivated Crops																					1					1
Woody Wetlands																			1							1
Emergent Wetlands																										0

Total	2	75	7	10	566	627	59	38	74	37	42	794	158	3	3	651	283	176	219	2	212	10	2	2	0	4052

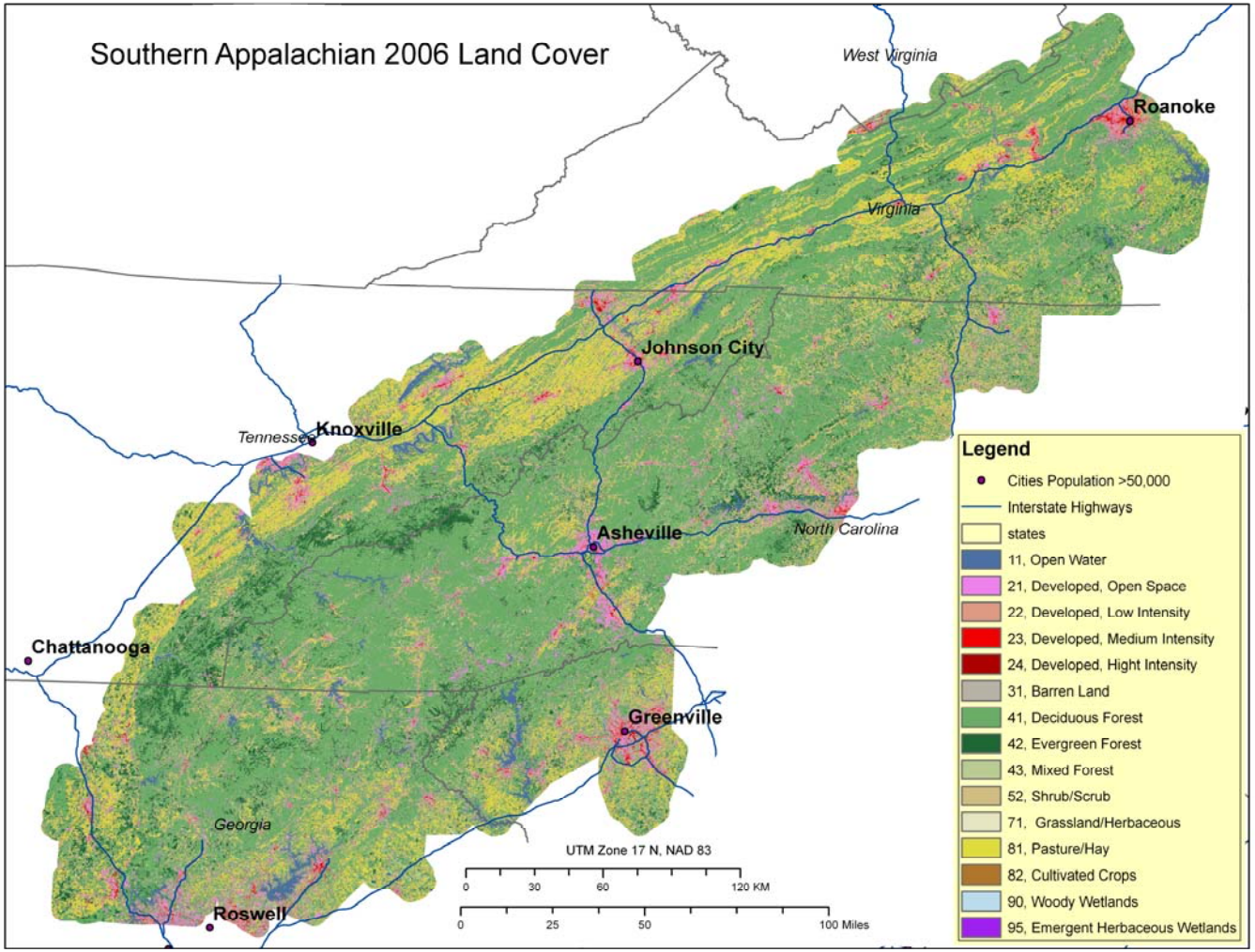

Figure 3. Overview map of 2006 land cover data.

Comparisons with other land cover datasets for the Southern Appalachians

We had access to land cover maps for 1986, 1991, 1996, 2001 for the study area. Visual comparisons between the maps indicated that the Smart Eliminate procedure had been applied to some dates (2001 and 2006), but not others (1986, 991, 1996). We applied the same Smart Eliminate procedure to the earlier dates to make the comparisons below.

Table 9. Area (km^2) of each land cover class across time in the Southern Appalachian study area.

	1986	**1991**	**1995**	**2001**	**2006**
Water	1365	1330	1319	1277	1315
Dev. Open Space	6297	6185	6026	5294	6168
Dev. Low Inten.	665	799	897	1618	1703
Dev. Med. Inten.	193	239	280	445	484
Dev. High Inten.	41	58	73	169	188
Barren	96	94	52	226	729
Decid. Forest	41529	44775	49828	47049	41751
Everg. Forest	10207	9160	7403	6082	7955
Mixed Forest	2695	3601	660	2876	5257
Shrub/Scrub	400	993	595	1060	3012
Grass/Herb	704	305	586	1827	1410
Pasture/Hay	17585	15138	14861	14576	12562
Crops	1346	475	683	686	464
Forested Wet.	176	175	172	283	277
Non-For. Wet.	27	26	26	2	2

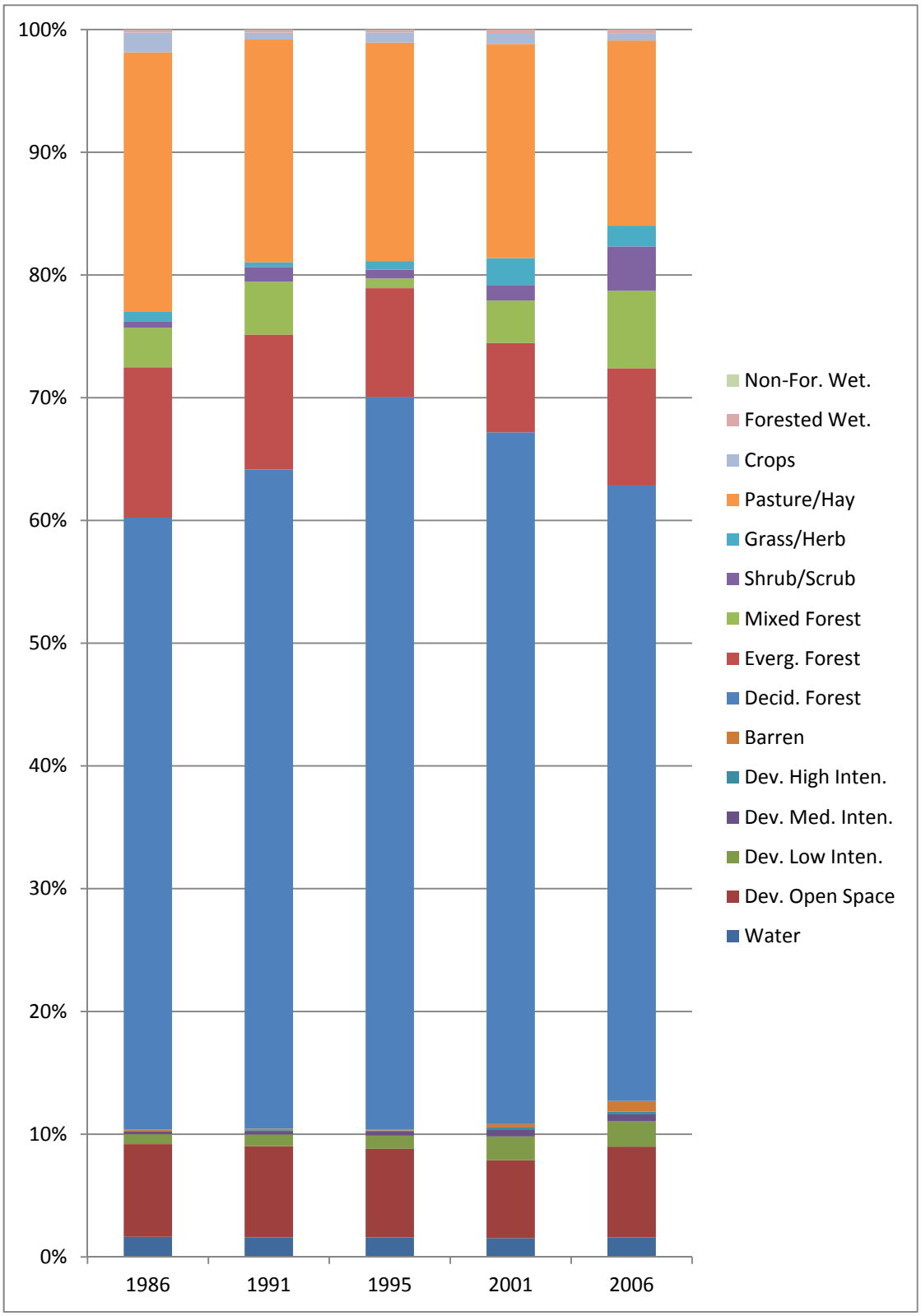

Figure 4. Land cover percentages of the Southern Appalachian study area from 1986 to 2006.

Appendix A**. Target Land Cover Classes and Class Definitions**

The NLCD land cover classes are described and interpreted for 2006 land cover as follows:

Open Water (11) - All areas of open water, generally with less than 25% cover of vegetation or soil.

Developed, Open Space (21) - 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

Developed, Low Intensity (22) - 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.

Developed, Medium Intensity (23) - 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.

Developed, High Intensity (24) - 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 to100 percent of the total cover.

Barren Land (Rock/Sand/Clay) (31) - 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.

Deciduous Forest (41) - 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.

Evergreen Forest (42) - 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.

Mixed Forest (43) - 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.

Shrub/Scrub (52) - Areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions.

Grassland/Herbaceous (71) - Areas dominated by grammanoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.

Pasture/Hay (81) - 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.

Cultivated Crops (82) - 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.

Woody Wetlands (90) - Areas where forest or shrubland vegetation accounts for greater than 20 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

Emergent Herbaceous Wetlands (95) - Areas where perennial herbaceous vegetation accounts for greater than 80 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.