

A Geospatial Characterization of Ecologically Significant Areas Impacted by  
Current and Potential Co-firing Woody Biomass Feedstock Demand in North  
Carolina

By

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## Introduction

### Working Towards Cleaner and More Sustainable Electricity Generation

North Carolina faces the difficult task of evolving from carbon-intensive fossil fuels as our principal source for utility-scale electricity generation to sustainable and cleaner options. North Carolina enacted the *Renewable Energy and Energy Efficiency Portfolio Standard (REPS)* in 2007 to promote environmental enhancement, economic development, and greater energy security. To achieve these lofty goals, REPS set aside a minimum share of future power generation for renewable energy<sup>i</sup> (Hurlbut 2008, Jentgen 2012).

Other influences have affected how existing utility-scale plants are used, which plants are retired, and what types of new plants are being built. These include sustained low natural gas prices, higher coal prices, slow growth in electricity demand, an aging, inefficient collection of coal plants, and State and Federal legislation aimed at reducing air pollutants (AEO2012). Specifically, North Carolina adopted the Clean Smokestacks Act (SB 1078) in 2002<sup>ii</sup>; while the Environmental Protection Agency (EPA) implemented the Mercury and Air Toxics Standards (Utility MACT Rule<sup>iii</sup>) and Cross-State Air Pollution Rule (CSAPR<sup>iv</sup>).

Utilities have acted swiftly in reaction to several of these influences. Coal-fueled electricity generation in the United States has been reduced from 50 percent to 34 percent between 2008 and 2012 (AEO2012). Progress Energy Carolinas<sup>v</sup> has retired one-third of its coal-generating fleet (1,600 MW) and aims to replace it with 2,159MW of natural gas-fueled generation by the end of 2013. Duke Energy, on the other hand, recently retired 588MW of coal-fueled generation and aims to replace it with 1,240MW of natural gas-fueled generation by the end of 2013 and 825MW of coal-fueled generation by the end of 2012 (Progress Energy 2012, Duke Energy 2012).

### REPS and its Effect on Woody Biomass Feedstock Demand

In order to meet REPS requirements and ultimately advance the replacement of coal-powered generation, Duke Energy challenged the REPS definition of biomass before the N.C. Utilities Commission in 2010. Subsequently, the case was appealed to the N.C. Court of Appeals in 2011 by the Environmental Defense Fund (EDF) and the N.C. Sustainable Energy Association (NCSEA). Judge Steelman's Court of Appeals judgment confirmed the N.C. Utility Commission's finding "that wood derived from whole trees in

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<sup>i</sup> Investor-owned utilities: 12.5% by 2021, Electric cooperatives, municipal utilities: 10% by 2018 (DSIRE 2012)

<sup>ii</sup> aims to reduce 73% of nitrogen oxide emissions by 2009 and 73% of sulfur dioxide emissions by 2013

<sup>iii</sup> The Utility MACT Rule requires all U.S. coal- and oil-fired power plants with capacities greater than 25 megawatts to meet emission limits consistent with the average performance of the top 12 percent of existing units—known as the maximum achievable control technology. MATS applies to three pollutants: mercury, hydrogen chloride (HCl), and fine particulate matter (PM<sub>2.5</sub>).

<sup>iv</sup> CSAPR was struck down by a Federal Appeals Court on August 21<sup>st</sup>, 2012.

<sup>v</sup> Progress Energy Carolinas merged with Duke Energy on July 3, 2012.

primary harvest is a 'biomass resource' and thus a 'renewable energy resource' within the meaning of the statute" (COA11-142 2011). Duke's broad definition of biomass was contested in the Court of Appeals on the grounds that whole trees should not be included in the REPS biomass definition. The decision by the N.C. Court of Appeals may ultimately play a major role in influencing woody biomass's inclusion in meeting a large portion of the REPS requirements through co-firing techniques.

According to Duke Energy's pre-registration hearing brief sent to the N.C. Utilities Commission, Duke intends on using cost-effective wood fuels, including harvested trees as a means to meet future REPS requirements. Specifically, Duke Energy began testing co-firing woody biomass in two of their coal-fueled power plants in 2009<sup>vi</sup> to prove the viability, reliability, sustainability and cost-effectiveness of biomass co-firing in their plants. (Kaylor 2010). They are fighting for the inclusion of whole trees in the REPS definition of biomass because co-firing woody biomass makes use of existing power generation and infrastructure with the lowest cost of generation for renewable energy (Sullivan 2010).

The utilities are focusing on using whole trees for co-firing because of the many limiting factors of woody biomass as a fuel source. Woody biomass, unlike coal, is distributed over a large area. High transportation costs caused by widespread distribution generally limit the bounds of biomass harvest to a 50-mile service area. Woody biomass contains less energy<sup>vii</sup> and higher moisture content compared to coal. Therefore, a considerable amount is needed to meet the typical 15-20% co-fired with coal (Hunt 2009). To make co-firing woody biomass cost effective, utilities need to identify long-term, concentrated quantities of woody biomass within a 50-mile radius of a plant. Including full trees in these quantities is likely essential to meeting long-term co-firing woody biomass demand.

## **Consideration of Ecologically Significant Areas**

Despite several environmental benefits from co-firing woody biomass with coal,<sup>viii</sup> some have questioned whether biomass harvesting is environmentally favorable when performed on a large scale (Searchinger et al. 2008, Schulze et al 2012). Because of these concerns, it is important to consider ecologically significant areas when harvesting for woody biomass. Water supply watersheds, riparian buffers, significant natural heritage areas, and protected and Managed Conservation Areas all should be excluded from use as co-firing feedstock, if possible. Some of these areas already have extensive protection while others are left vulnerable.

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<sup>vi</sup> Buck Steam Station in Salisbury, NC and Lee Steam Station in Williamson, SC using RECs

<sup>vii</sup> about one-third that of coal by wet weight

<sup>viii</sup> Biomass feedstock contains seventy-five times less sulfur than coal and co-firing can aid in reducing sulfur dioxide (SO<sub>2</sub>) emissions. Demonstration tests have shown that biomass co-firing with coal can also lead to lower nitrogen oxide (NO<sub>x</sub>) emissions. Perhaps the most significant environmental benefit of biomass, however, is a potential reduction in carbon dioxide (CO<sub>2</sub>) emissions (Haq 2002).

A spatial characterization of ecologically significant areas impacted by current and potential co-firing woody biomass demand in North Carolina was created using Geographic Information System (GIS) software. The purposes of the spatial characterization are to (1) determine the impact of removing ecologically significant areas from a 50-mile service area of woody biomass available around each potential co-firing coal plant in North Carolina (2) identify the sensitivity of woody biomass co-firing feedstock availability within the co-firing plants' service areas to environmental concerns and (3) differentiate between the available types of woody biomass co-firing feedstock (hardwood, natural pine, planted pine).

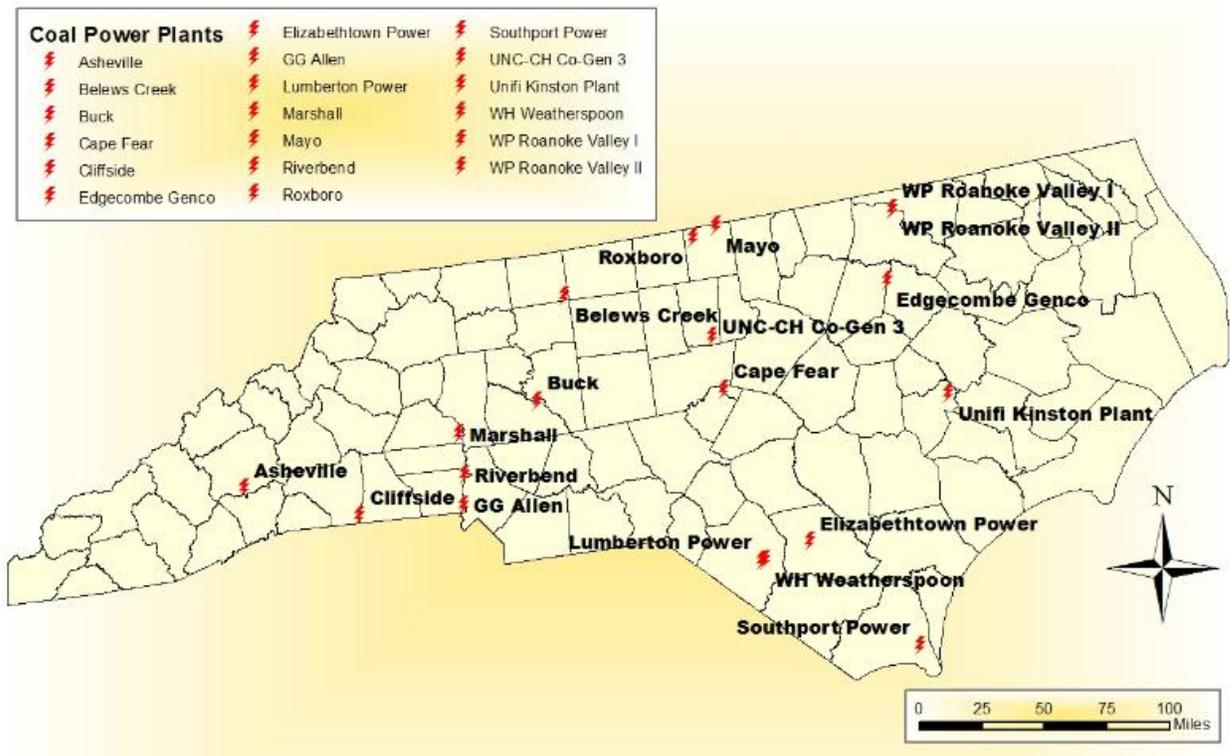
## Methods

In this study, 50-mile service areas surrounding potential co-firing power plants in North Carolina were created. The service areas represent the economically harvestable woody biomass encircling each power plant in North Carolina. Existing land cover and spatial ecological data were used to determine the sensitivity of woody biomass co-firing feedstock supply to ecological concerns and non-harvestable areas. The following section includes a descriptive account of the data sets and procedures used in the creation of the geospatial characterization.

### Creating Geographic Coordinates for Co-firing Plants

A latitude- and longitude-based point shapefile was created to represent the geospatial coordinates of nineteen potential co-firing coal plants in North Carolina. The latitude and longitude data was obtained from U.S. Energy Information Administration (EIA) data and the Environmental Protection Agency's (EPA) eGrid 2012 version 1.0 data (EIA-923 2009-2012, EPA 2012). Analysis and explanation of the selection process are located in the Discussion. A Microsoft Excel 2010 spreadsheet of plant longitudes and latitudes was inserted into ArcMap 10.0 to create the point shapefile.

**Figure 1 – Selected Coal Plants**



## Creating Service Areas around each Co-firing Plant

50-mile service areas were created around each power plant point and clipped to the North Carolina border. The service areas characterize the potential geospatial location of all economically harvestable woody biomass encircling each power plant in North Carolina. The service area's boundary was achieved by constraining the driving distance of the road network surrounding the power plant points to 50 miles. The road network was adapted from the ESRI Street Maps 2009 layer (ESRI 2009). Additionally, the service area established a 1,000 meter buffer around each street found in each service area's road network. The service areas were clipped to the North Carolina border using the 2010 Census Tiger/Line North Carolina State-Line Boundary Outline dataset (USDC Tiger 2010). The nineteen service areas were then added to ArcMap 10.0 for further analysis.

**Figure 2 – Coal Plants and Service Areas**



## Layers Selected for Analysis

To identify the sensitivity of woody biomass co-firing feedstock supply to ecological concerns and non-harvestable areas, a land cover dataset, produced

by the U.S. Geological Survey's (USGS) Southeast Gap Analysis Program (SEGAP), was selected and added to ArcMap 10.0. Additionally, six datasets containing ecologically sensitive (ES) areas were chosen and added to represent areas of ecological concern and non-harvestable areas. The six datasets are Protected (Conservation) Areas of North Carolina (PAD\_US\_NC), Managed (Conservation) Areas of N.C. (McAREA), Significant Natural Heritage Areas (SNHA), Water Supply Watersheds (WSW), and two (Polygon and Line) 1:24,000-scale North Carolina Hydrography dataset layers. Several layers were considered but ultimately rejected for inclusion as ES layers. Analysis and explanation of the selection process is located in the Discussion.

### **Layers Selected for Analysis Background**

The SEGAP land cover dataset was created by USGS's GAP Analysis Program (GAP) by combining multi-season satellite imagery (Landsat ETM+), a digital elevation model (DEM) dataset, and vegetation classes drawn from NatureServe's Ecological System Classification and the 2001 National Land Cover Dataset (NLCD) (BSIC 2010, GAP Analysis 2006, MLRC NLCD 2001). The spatial resolution of the raster dataset is set at 30 meters. Analysis and explanation of the accuracy of this dataset can be found in the Discussion.

The ES layers were created for multiple purposes by multiple organizations. The PAD\_US dataset was created by USGS's GAP to delineate public and private lands owned and managed for conservation of biological diversity and other natural, recreational, and cultural uses. The dataset provides geographic boundaries of public land ownership and voluntarily provided private conservation lands (GAP 2011). In order to represent public- and privately-owned lands and easements that are of conservation interest, the McAREA dataset was created by the North Carolina Natural Heritage Program (NCNHP) (McAREA 2012). Also created by the NCNHP, the SNHA dataset represents areas of ecologically significant natural communities or rare species in North Carolina (SNHA 2012). Created by the N.C. Division of Water Quality (NCDWQ) in cooperation with the N.C. Center for Geographic Information and Analysis (NCGIA), The WSW dataset represents protected and critical areas surrounding water supply intakes directly affected by development. The two (Polygon/Line) 1:24,000-scale North Carolina Hydrography datasets were also jointly created by the NCDWQ and NCGIA. The datasets represent surface water features across the state including streams, rivers, lakes, ponds, reservoirs, and shorelines (NCGIA 2007).

### **Preparation of Data Layers**

A land cover layer representing only woody biomass feedstock supply was created from the SEGAP land cover layer. Thirty-six forested SEGAP classes were selected as being representative of woody biomass feedstock supply and crosswalked into four categories: Natural Pine, Planted Pine, Hardwood, and

Mixed. A table of the selected SEGAP classes and their representative crosswalk category is located in Appendix B.

The four crosswalk categories were created to better represent familiar forest management categories for woody biomass feedstock supply. The SEGAP class Evergreen Plantations was selected and placed into the crosswalk as Planted Pine. A few steps were required to create the Natural Pine, Hardwood, and Mixed crosswalk categories. The thirty-six forested SEGAP classes found in North Carolina were linked by GAP to four NLCD forest classes, (41) Deciduous Forest, (42) Evergreen Forest, (43) Mixed Forest, and (91) Forested Wetland (GAP Analysis 2006, (MLRC NLCD 2001). The three crosswalk categories were based on this linkage. The switch of terminology from deciduous and evergreen to hardwood and natural pine required broadleaf evergreen SEGAP classes to be switched to the hardwood crosswalk category. The SEGAP classes linked with the Forested Wetland NLCD class were distributed between the crosswalk categories based on their dominant specie(s) and were only included if they were considered harvestable.

The two 1:24,000-scale Hydrography datasets were combined to develop a 50-ft riparian buffer around all surface waters in North Carolina. The buffer was developed on each side of lined waterways and outside each polygon feature. The buffer width was based on a generalized representation of North Carolina's current buffer rules. The rules, where present, typically prevent most harvesting activities within the buffer zones (Neuse River 2000).

To evaluate woody biomass feedstock supply within each service area (woody biomass service area), the woody biomass layer was converted to polygon from raster and then clipped to each service area's boundary in ArcMap 10.0. The resulting nineteen woody biomass service area datasets were saved as shapefiles. To isolate the ecologically significant areas inside of each of the service areas, the ES datasets were clipped to the geographical extent of each service area and saved as shapefiles in ArcMap 10.0.

### **Removal of Ecologically Significant Areas from the Woody Biomass Service Areas**

The ES layers were individually and cumulatively erased from each of the nineteen woody biomass service areas. The ES layers were erased using the Erase tool in ArcMap 10.0. The resulting shapefiles represent economically harvestable woody biomass encircling each power plant when ecologically significant areas are considered.

### **Generating Values and Creating Results**

Before the ES layers were erased from each woody biomass service area, an area field was added to the attribute table of each woody biomass service

area layer. The calculate geometry function was used to calculate the area of woody biomass feedstock supply before and after removing each ES layer and when the ES layers were cumulatively removed. The area located in each woody biomass service area before removing the ES layers was recorded in Table 1 of the Results section.

Table 2 re-lists the data from Table 1 to compare with the individual and cumulative ES layer acreage erased from each service area. Table 3 was created by dividing the individual and cumulative erase values from Table 2 with the data from Table 1.

The area of woody biomass feedstock supply after each ES layer was removed was recorded in the columns labeled “Biomass Acreage after Erasing [ES layer]” in Table 4. The acreage of woody biomass feedstock supply available after cumulatively removing all the ES layers was recorded in the “Biomass Acres after Cumulative Erase” column of Table 4. The acreage of woody biomass feedstock supply within each crosswalk category was determined and the resulting values were recorded in Table 5. The total amount of pine in Table 5 was calculated by summing the amount of natural pine and planted pine within each service area.

### **Metadata and Procedure Log**

Metadata and a procedure log can be found in section 1 and 2 of the Appendix. The metadata explains the data accumulation and creation process of the dataset layers used. The metadata also provides geographical projections and known errors, including strengths, weaknesses, opportunities, and threats. The procedure log records the process employed to assemble the dataset layers into ArcMap 10.0 and the subsequent modification of the dataset layers.

## Results

The Results consist of five tables and several figures in three subsections, Woody Biomass Feedstock Acreage in each Service Area, Woody Biomass Feedstock Acreage Removed by Erasing Ecologically Sensitive Areas Layers and Woody Biomass Feedstock Acreage Left after Erasing Ecologically Sensitive Areas Layers. Basically, the three sections list what biomass was in the service areas before considering the ecologically significant areas, what was removed by the ES areas, and what was left after erasing the ES areas.

The tables generally contain a list of acreage or percentage values highlighting either woody biomass feedstock or ecologically significant areas. Table 1 contains data concerning the acreage of woody biomass feedstock in each service area before any erase. On the other hand, Table 2 and Table 3 list the acreage and percentage of erase by the ecologically significant areas and Table 4 and 5 list the amount of woody biomass feedstock acreage available (in general and via crosswalk) after erasing the ecologically significant areas. The individually erased acreage or percentage values from Table 2 through Table 4 do not sum to the cumulatively erased acreage or percentage values in the same tables. The reason for this is due to overlap among the ES layers not being counted in the cumulative erase. The values highlighted in green are those values within each column with the highest amount of ES removal or biomass remaining for that particular column of data. On the other hand, the values highlighted in red are those with the lowest amount of ES removal or biomass remaining.

The figures generally display the spatial coverage of ecologically significant areas and woody biomass feedstock. Specifically, Figure 3 spatially displays the ES acreage erased from all service areas across the state. Figures 4 through 9 spatially display the range of biomass removed by the ES layers, individually and cumulatively. The service areas are ranked by color dependent on the amount of biomass removed from each service area. Figure 10 spatially displays the distribution of woody biomass feedstock available across all the service areas after erasing all of the ES layers. Figure 11 spatially displays the distribution of woody biomass feedstock within the Lumberton Power service area after removing the ES layers. Figure 12 and 13 perform the same function but highlight the availability of planted pine across the state.

## Woody Biomass Feedstock Acreage in each Service Area

Table 1 – Biomass Acreage in each 50-mile Service Area

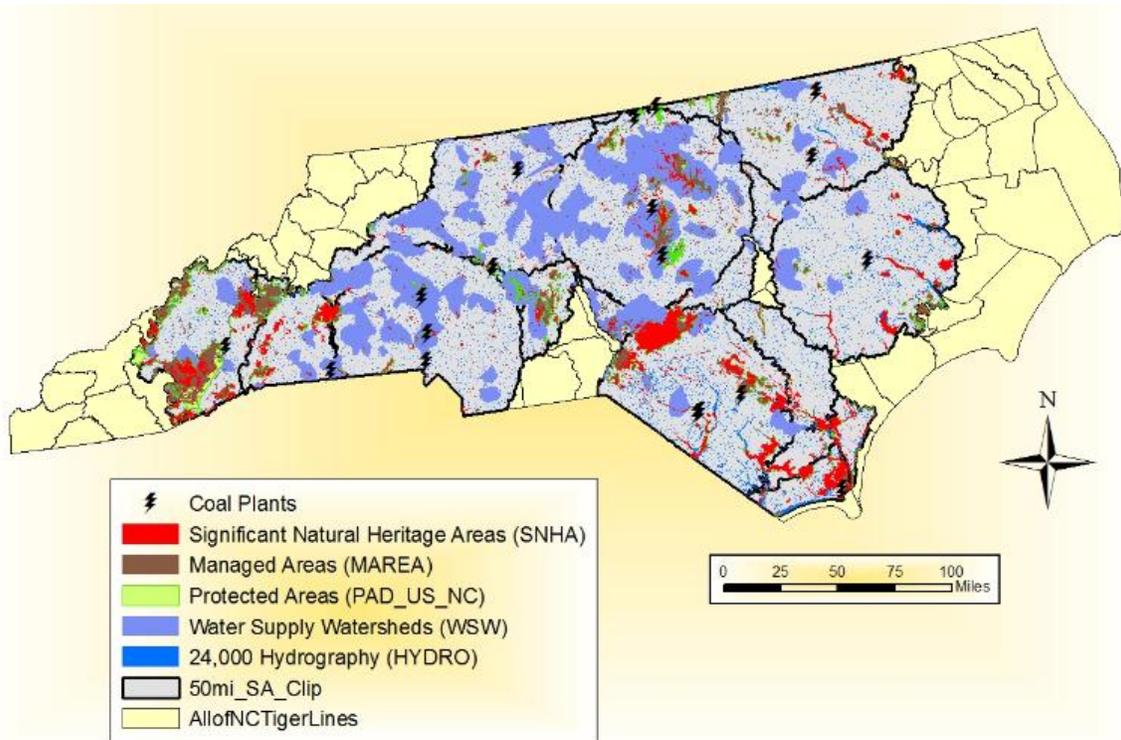
Power Plant Name	Biomass Acreage in each 50-mile Service Area
Asheville	1,665,824
Belews Creek	1,268,708
Buck	1,514,560
Cape Fear	1,869,993
Cliffside	919,838
Edgecombe Genco	1,641,648
Elizabethtown Power	1,689,794
GG Allen	884,491
Lumberton Power	1,368,171
Marshall	1,429,415
Mayo	1,013,415
Riverbend	1,145,055
Roxboro	1,032,826
Southport Power	651,347
UNC-CH Co-Gen 3	2,010,115
Unifi Kinston Plant	1,569,381
WH Witherspoon	1,391,188
WP Roanoke Valley I	1,210,511
WP Roanoke Valley II	1,210,511

## Woody Biomass Feedstock Acreage Removed by Erasing Ecologically Sensitive Areas Layers

Table 2 – Acreage Erased by Ecologically Significant Layers

Power Plant Name	Biomass Acreage in 50-mile Service Area	PAD_US_NC Acres Erased	WSW Acres Erased	McAREA Acres Erased	SNHA Acres Erased	Hydro Acres Erased	All Acres Cumulatively Erased
Asheville	1,665,824	298,893	271,571	282,160	102,304	62	546,165
Belews Creek	1,268,708	3,630	401,909	5,761	4,819	220	409,688
Buck	1,514,560	13,467	496,612	16,890	7,494	459	511,026
Cape Fear	1,869,993	137,216	768,974	173,795	135,829	2,184	866,608
Cliffside	919,838	36,312	196,577	38,743	44,080	64	250,541
Edgecombe Genco	1,641,648	3,579	198,953	14,573	8,914	1,680	220,214
Elizabethtown Power	1,689,794	53,385	78,771	63,747	65,782	10,045	168,130
GG Allen	884,491	2,197	290,194	4,965	4,561	268	294,706
Lumberton Power	1,368,171	141,265	114,096	158,875	134,934	8,853	267,845
Marshall	1,429,415	11,132	502,230	14,231	12,724	381	512,657
Mayo	1,013,415	20,331	423,774	36,150	12,533	715	445,359
Riverbend	1,145,055	6,122	351,769	10,054	8,629	295	358,660
Roxboro	1,032,826	20,636	413,688	33,677	13,528	733	432,960
Southport Power	651,347	7,432	21,881	14,606	33,980	6,164	66,908
UNC-CH Co-Gen 3	2,010,115	33,417	837,644	51,707	24,477	1,621	860,140
Unifi Kinston Plant	1,569,381	11,314	76,139	14,864	15,110	6,523	107,697
WH Witherspoon	1,391,188	139,379	110,090	156,508	134,427	8,951	263,155
WP Roanoke Valley I	1,210,511	4,716	105,931	16,791	9,708	1,142	128,190
WP Roanoke Valley II	1,210,511	4,716	105,931	16,791	9,708	1,142	128,190

**Figure 3 – ES Layers Erased from Service Areas**



**Table 3 – Percentage of Biomass within each Service Area Erased by ES Layers**

Power Plant Name	%PAD Erased from Service Area	%WSW Erased from Service Area	%McAREA Erased from Service Area	%SNHA Erased from Service Area	%Hydro Erased from Service Area	%All Cumulatively Erased
Asheville	18%	16%	17%	6%	0.00%	33%
Belews Creek	<1%	32%	<1%	<1%	0.02%	32%
Buck	1%	33%	1%	<1%	0.03%	34%
Cape Fear	7%	41%	9%	7%	0.12%	46%
Cliffside	4%	21%	4%	5%	0.01%	27%
Edgecombe Genco	<1%	12%	<1%	<1%	0.10%	13%
Elizabethtown Power	3%	5%	4%	4%	0.59%	10%
GG Allen	<1%	33%	<1%	<1%	0.03%	33%
Lumberton Power	10%	8%	12%	10%	0.65%	20%
Marshall	<1%	35%	1%	<1%	0.03%	36%
Mayo	2%	42%	4%	1%	0.07%	44%
Riverbend	<1%	31%	<1%	<1%	0.03%	31%
Roxboro	2%	40%	3%	1%	0.07%	42%
Southport Power	1%	3%	2%	5%	0.95%	10%
UNC-CH Co-Gen 3	2%	42%	3%	1%	0.08%	43%
Unifi Kinston Plant	1%	5%	<1%	<1%	0.42%	7%
WH Witherspoon	10%	8%	11%	10%	0.64%	19%
WP Roanoke Valley I	<1%	9%	1%	<1%	0.09%	11%
WP Roanoke Valley II	<1%	9%	1%	<1%	0.09%	11%

Figure 4 – Percent Biomass Cumulatively Erased by ES Layers

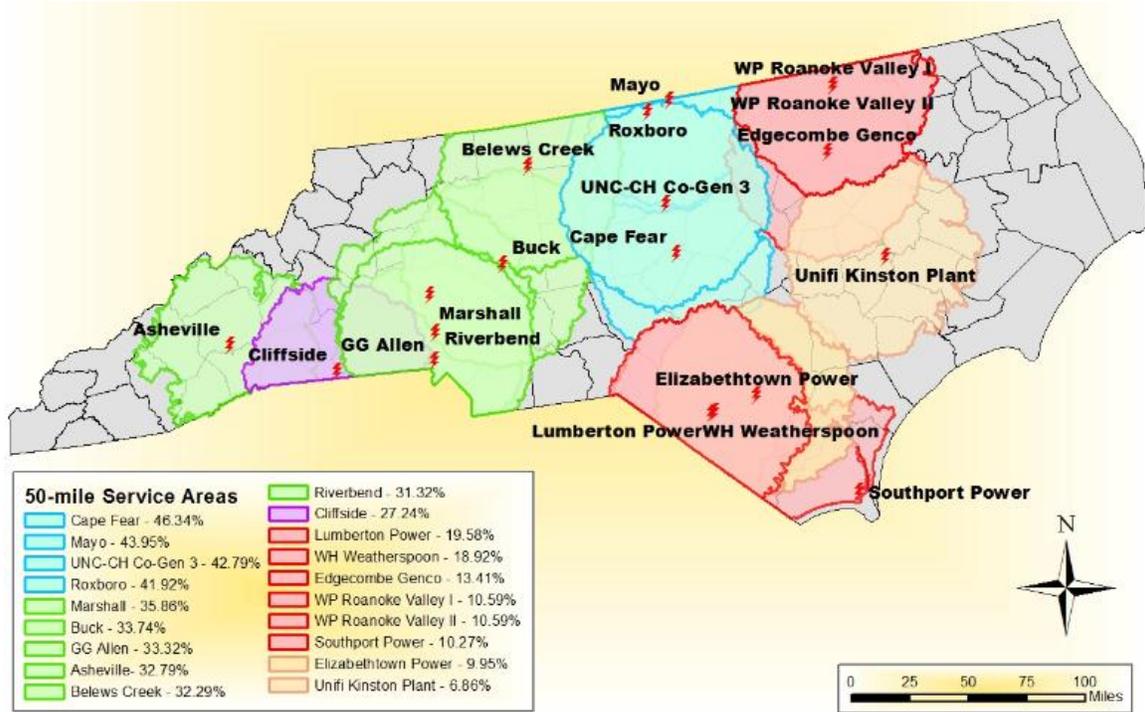


Figure 5 - Percent Biomass Erased by Riparian Buffer Layer

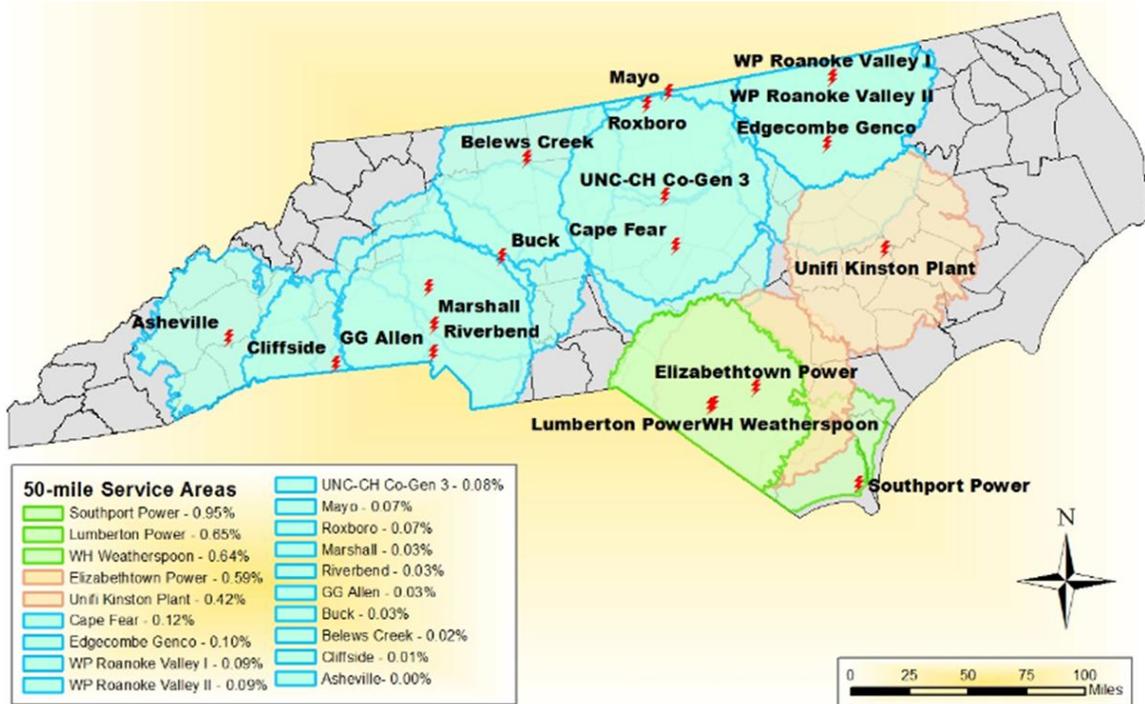


Figure 6 - Percent Biomass Erased by Significant Natural Heritage Layer

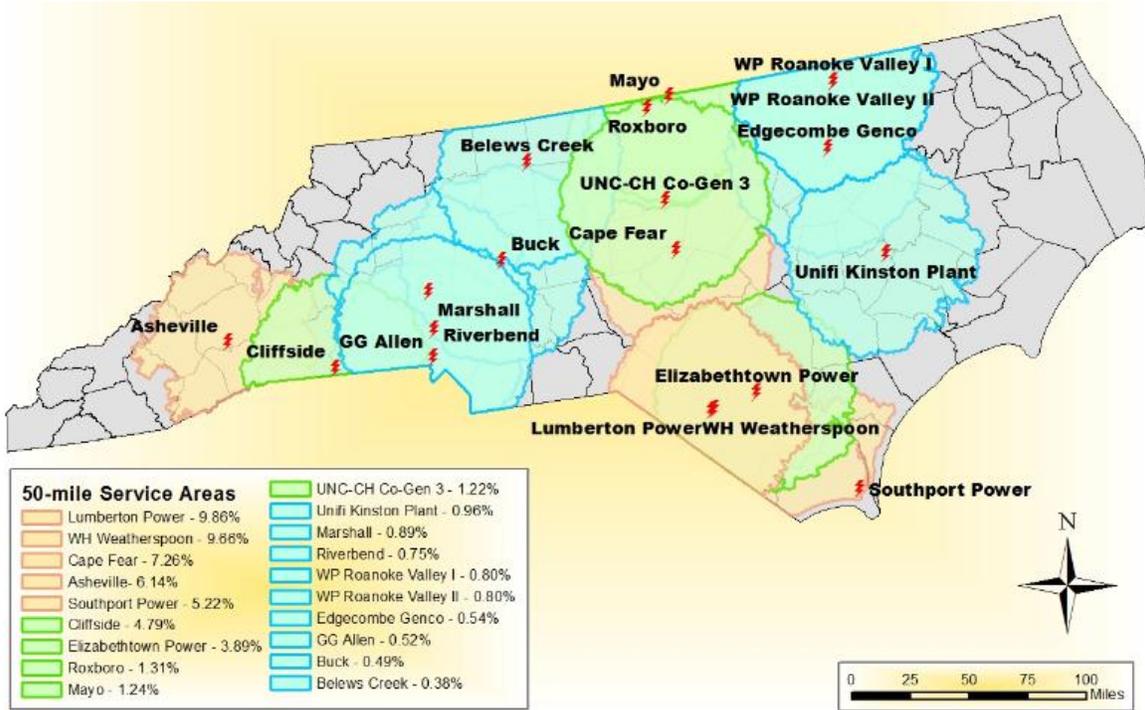


Figure 7 - Percent Biomass Erased by Managed Conservation Areas Layer

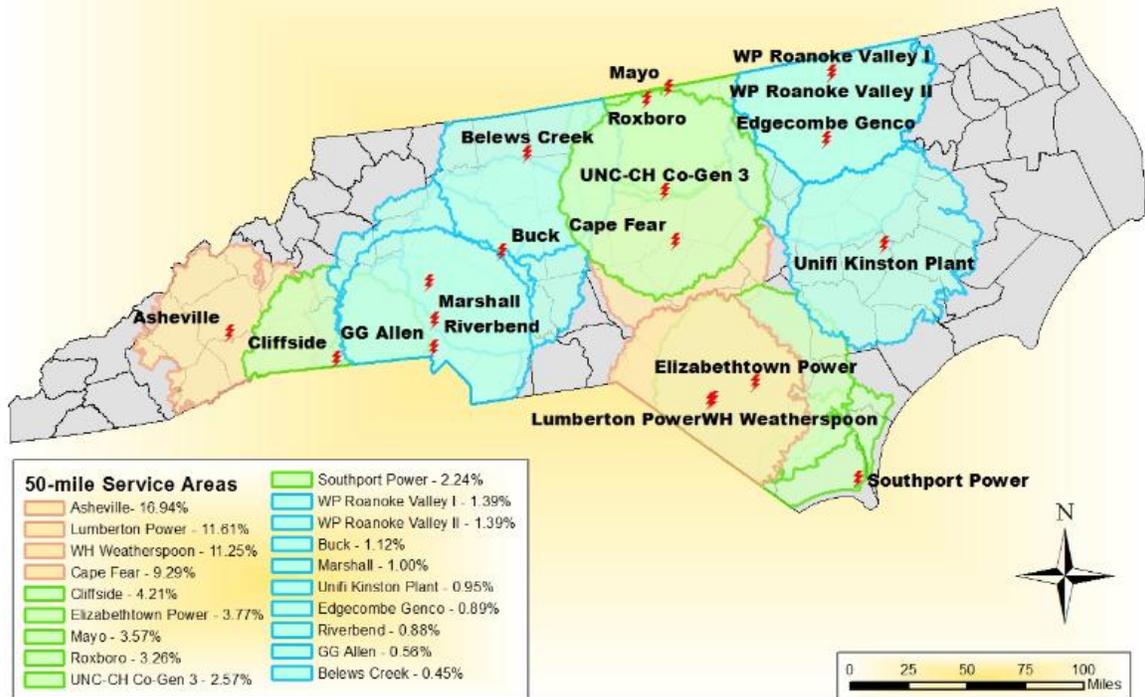


Figure 8 - Percent Biomass Erased by Protected Conservation Areas Layer

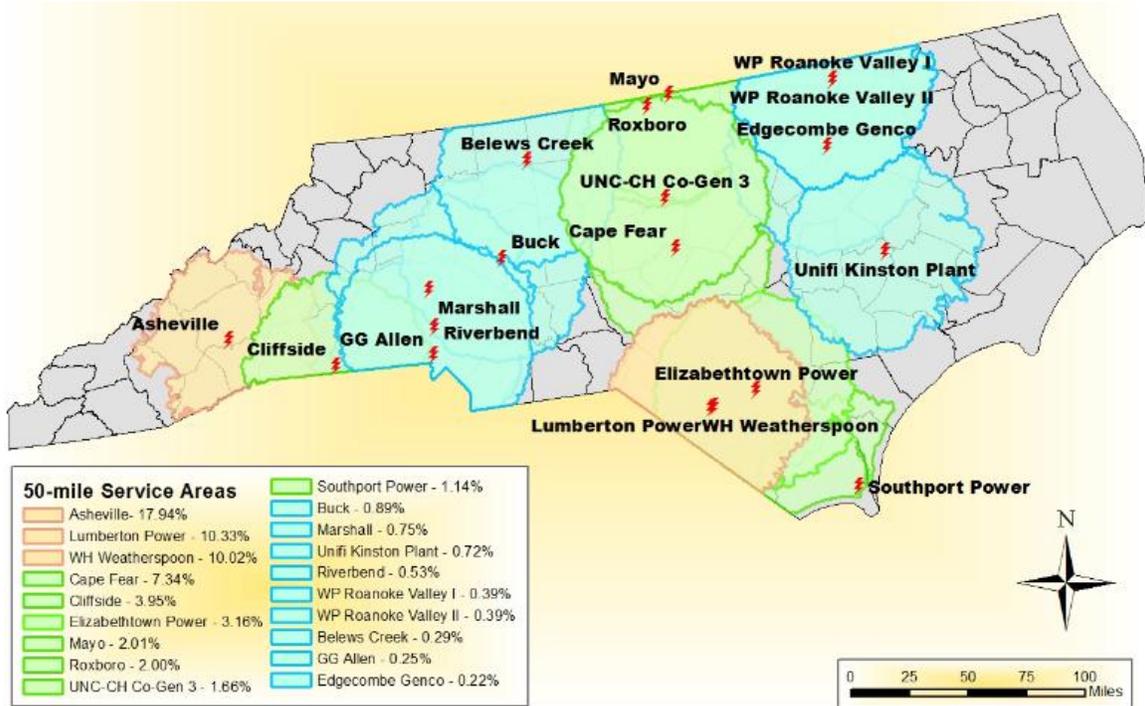
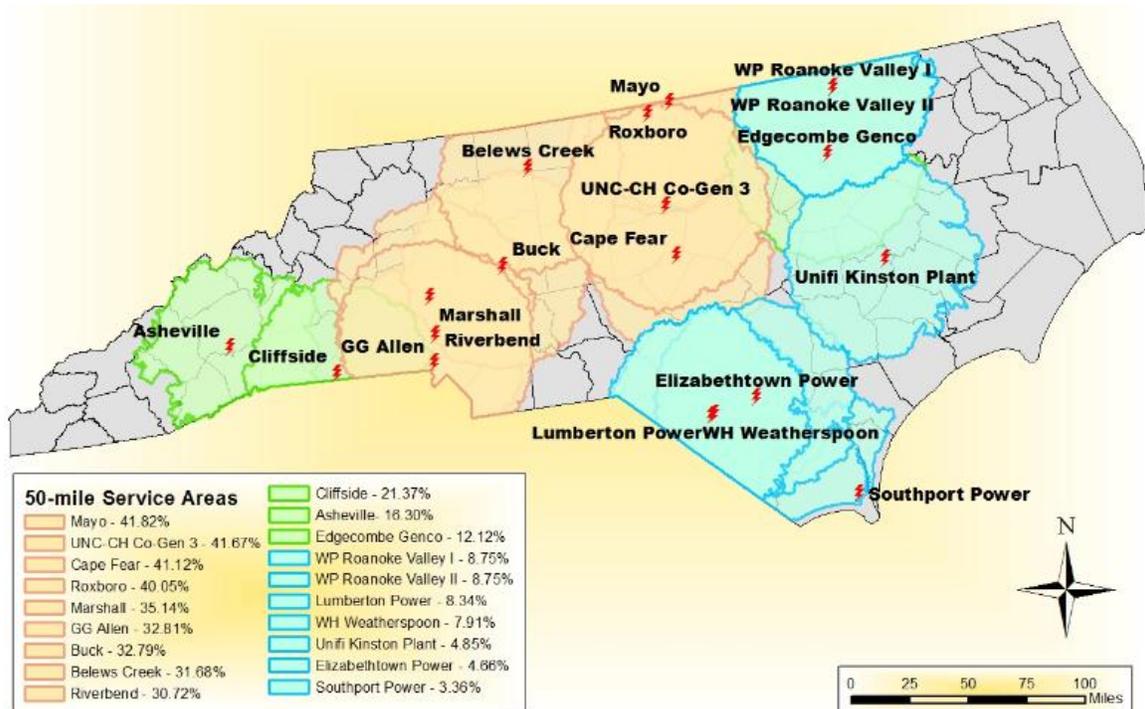


Figure 9 - Percent Biomass Erased by Water Supply Watershed Layer



## Woody Biomass Feedstock Acreage Remaining after Erasing Ecologically Sensitive Areas Layers

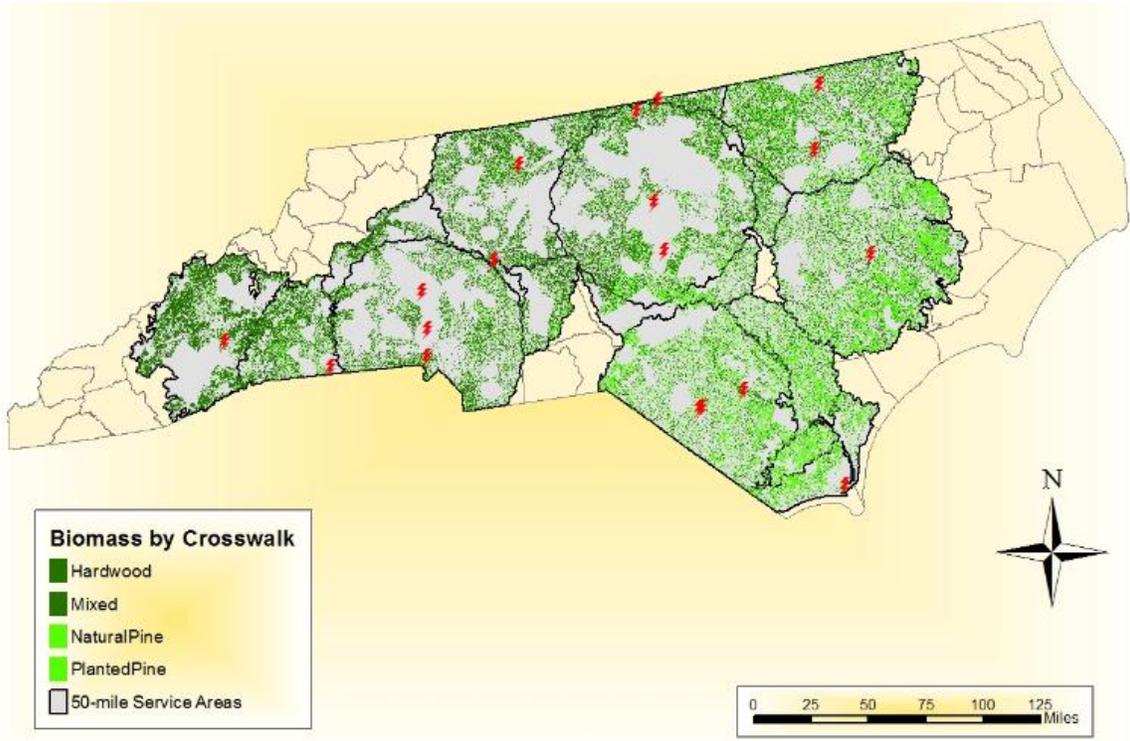
Table 4- Biomass Acreage Available After Erasing Ecologically Significant Layers

Power Plant Name	Biomass Acreage in 50-mile Service Area	Biomass Acres after Erasing PAD_US_NC	Biomass Acres after Erasing WSW	Biomass Acres after Erasing McAREA	Biomass Acres after Erasing SNHA	Biomass Acres after Erasing 50-ft Hydro Buffer	Biomass Acres after Cumulative Erase
Asheville	1,665,824	1,366,931	1,394,253	1,383,664	1,563,520	1,665,762	1,119,659
Belews Creek	1,268,708	1,265,078	866,799	1,262,947	1,263,889	1,268,489	859,021
Buck	1,514,560	1,501,093	1,017,948	1,497,670	1,507,066	1,514,101	1,003,534
Cape Fear	1,869,993	1,732,777	1,101,018	1,696,198	1,734,164	1,867,809	1,003,385
Cliffside	919,838	883,525	723,261	881,095	875,758	919,774	669,297
Edgecombe Genco	1,641,648	1,638,069	1,442,696	1,627,076	1,632,735	1,639,968	1,421,434
Elizabethtown Power	1,689,794	1,636,409	1,611,023	1,626,047	1,624,013	1,679,749	1,521,664
GG Allen	884,491	882,294	594,297	879,526	879,930	884,223	589,785
Lumberton Power	1,368,171	1,226,906	1,254,074	1,209,295	1,233,237	1,359,317	1,100,326
Marshall	1,429,415	1,418,284	927,185	1,415,184	1,416,691	1,429,035	916,758
Mayo	1,013,415	993,084	589,640	977,264	1,000,882	1,012,699	568,055
Riverbend	1,145,055	1,138,933	793,286	1,135,001	1,136,426	1,144,760	786,395
Roxboro	1,032,826	1,012,190	619,138	999,149	1,019,298	1,032,093	599,867
Southport Power	651,347	643,916	629,466	636,742	617,367	645,183	584,440
UNC-CH Co-Gen 3	2,010,115	1,976,698	1,172,471	1,958,408	1,985,638	2,008,495	1,149,975
Unifi Kinston Plant	1,569,381	1,558,067	1,493,242	1,554,517	1,554,270	1,562,858	1,461,684
WH Witherspoon	1,391,188	1,251,809	1,281,099	1,234,680	1,256,761	1,382,237	1,128,034
WP Roanoke Valley I	1,210,511	1,205,795	1,104,579	1,193,720	1,200,803	1,209,368	1,082,321
WP Roanoke Valley II	1,210,511	1,205,795	1,104,579	1,193,720	1,200,803	1,209,368	1,082,321

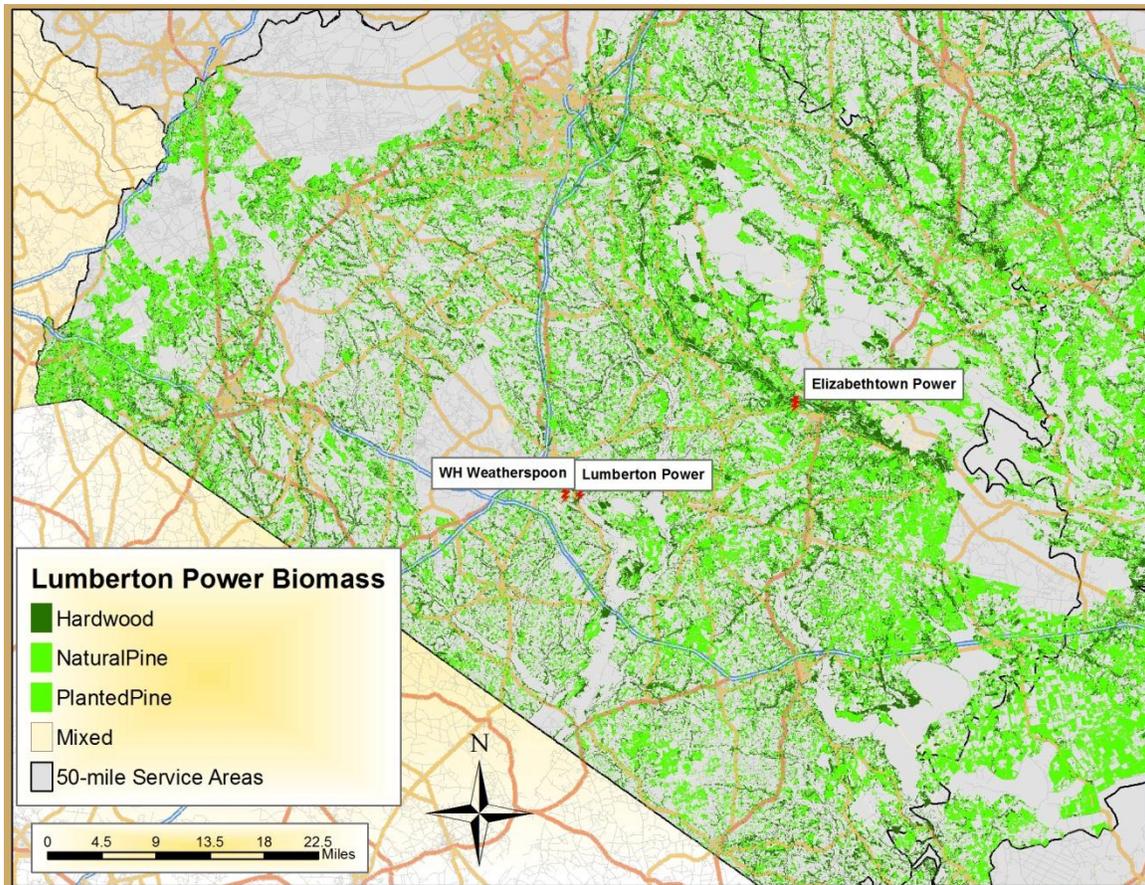
**Table 5 – Acreage of Biomass within each Crosswalk Category after Cumulative Erase of ES Layers**

Power Plant Name	Planted Pine	Natural Pine	All Pine	Hardwood	Mixed
Asheville	43,571	58,544	102,115	1,012,444	5,099
Belews Creek	77,001	44,851	121,852	568,356	37,605
Buck	132,478	52,680	185,158	766,230	52,146
Cape Fear	175,584	218,384	393,968	535,292	74,125
Cliffside	75,894	40,973	116,867	535,259	17,171
Edgecombe Genco	326,210	262,290	588,501	778,291	54,642
Elizabethtown Power	248,817	650,000	898,817	622,847	0
GG Allen	86,038	38,454	124,492	434,563	30,731
Lumberton Power	131,357	503,696	635,053	465,272	0
Marshall	112,489	51,346	163,835	712,505	40,418
Mayo	111,985	29,684	141,669	365,843	60,542
Riverbend	113,857	51,517	165,374	579,346	41,674
Roxboro	104,878	31,283	136,161	408,923	54,782
Southport Power	158,993	209,495	368,488	215,952	0
UNC-CH Co-Gen 3	221,349	123,978	345,328	697,207	107,441
Unifi Kinston Plant	345,077	461,099	806,176	655,508	0
WH Witherspoon	140,567	512,178	652,745	475,289	0
WP Roanoke Valley I	314,442	123,174	437,616	609,423	35,282
WP Roanoke Valley II	314,442	123,174	437,616	609,423	35,282

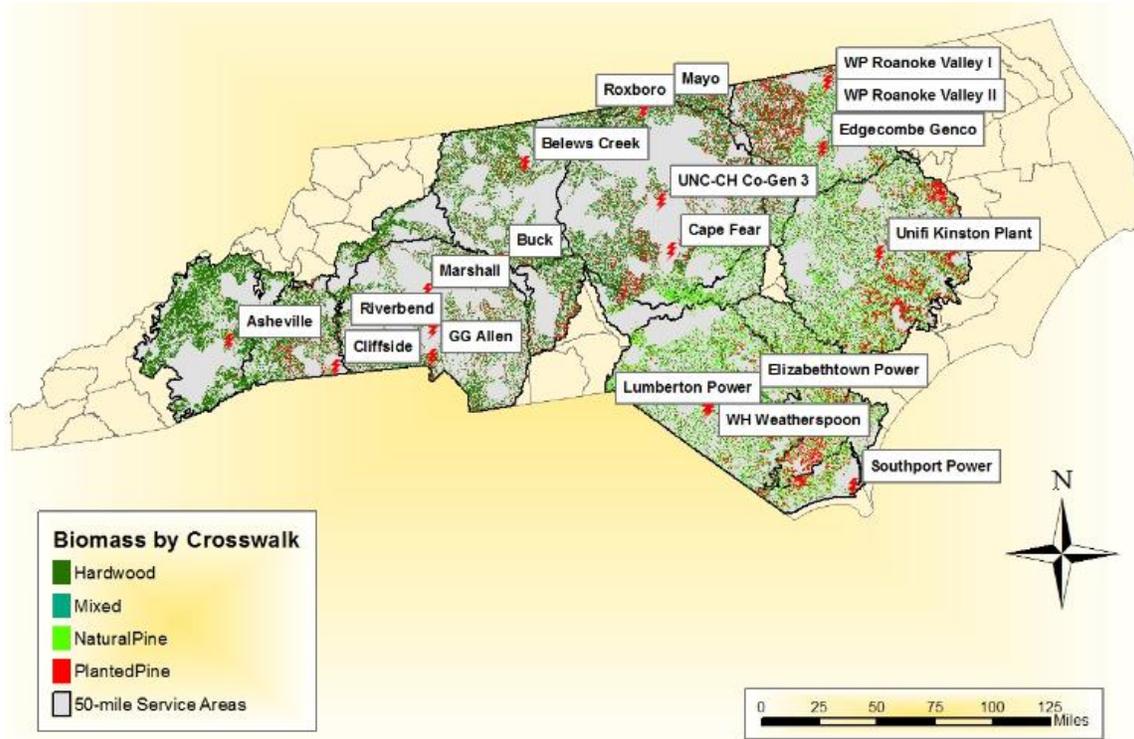
**Figure 10 - Biomass Acreage Available in Service Areas after Erasing ES Layers**



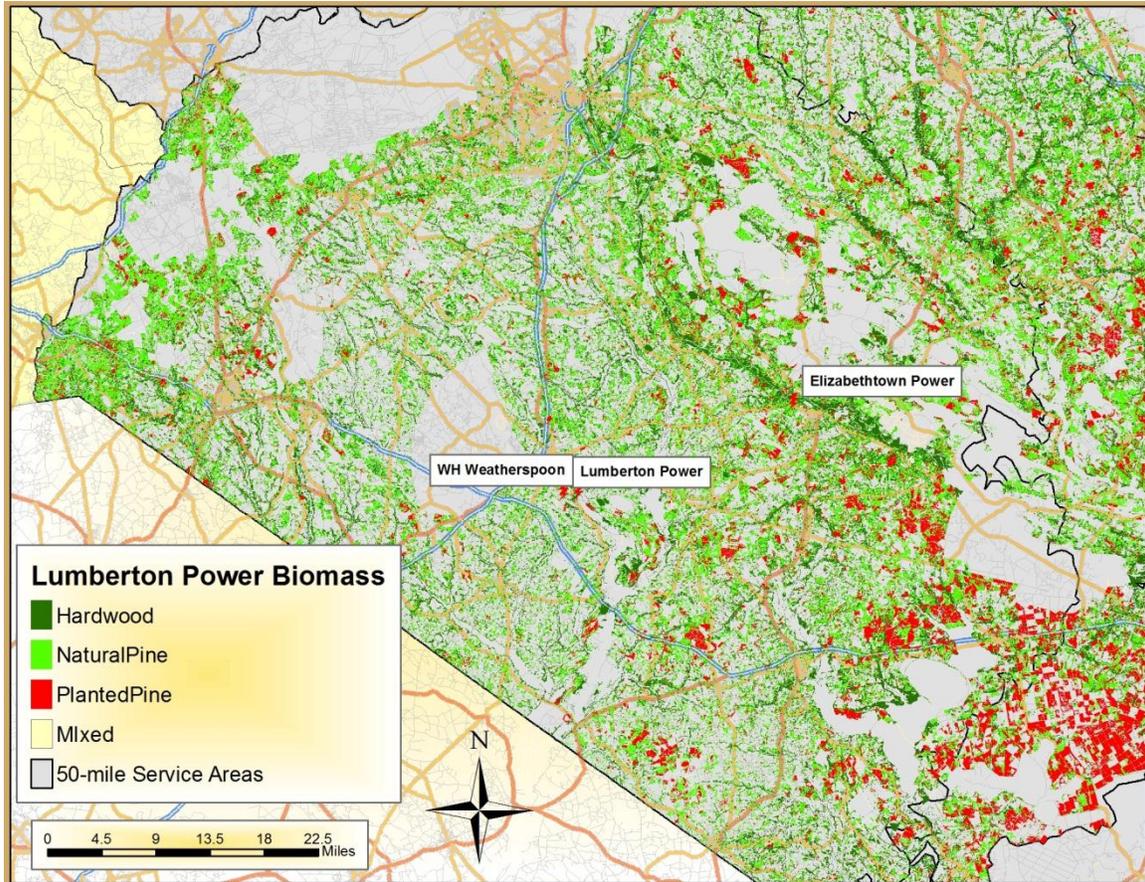
**Figure 11 - Biomass Acreage Available in Lumberton Power Service Area after Erasing ES Layers**



**Figure 12 - Biomass Acreage in each Crosswalk Category after Cumulative Erase of ES Layers**



**Figure 13 - Crosswalked Biomass Acreage Available in Lumberton Service Area after Erasing ES Layers**



## **Discussion**

### **Effects of Erasing the ES Layers on Available Woody Biomass Feedstock Supply**

Coal plant service areas located within each of the three major regions of North Carolina (Southern Appalachian, Piedmont & Coastal Plain) were affected by the removal of ecologically significant areas from available woody biomass feedstock differently. The McAREA and PAD layers removed the most woody biomass feedstock supply from the single Southern Appalachian region plant (Asheville). Conversely, the WSW layer affected the woody biomass feedstock supply in the Piedmont the most (UNC-CH, Roxboro, Marshall, Cape Fear). The Hydro and SNHA layers affected those in the Coastal Plain the most (Southport, Lumberton, Witherspoon, and Elizabethtown). Cumulatively, the service areas in the Piedmont (Cape Fear, Mayo, Roxboro) had the most biomass removed due to the sheer volume of acreage removed by the WSW layer. The plants in the Coastal Plain (Unifi Kinston, Roanoke Valley I/II, Elizabethtown, Southport) were least affected by the WSW dataset and therefore had the least woody biomass feedstock supply removed.

As previously mentioned, the WSW layer removed the largest amount of woody biomass feedstock acreage across all plants while the Hydro dataset removed the least. The McAREA and PAD layers removed the second and third highest amount of biomass while the SNHA layer removed the second lowest amount. Cumulative removal of woody biomass ranged from 6.86% removal within the 50-mile service area of the Unifi Kinston plant to 46.34% of the biomass found in the Cape Fear plant's service area. The average amount of biomass removed by the ES layers was 26.41%.

### **Types of Woody Biomass Feedstock Available after Erasing the ES Layers**

As expected, the Coastal Plain service areas contain the highest acreage of pine biomass while the Piedmont and Southern Appalachian plants contain a high amount of hardwood biomass. The least amount of available natural pine biomass feedstock lies around those plants in the north-central section of the Piedmont region (Mayo, Roxboro). The Southern Appalachian region has the least acreage of planted pine (Asheville). The Asheville plant also contains the least amount of combined planted and natural pine in its service area. The majority of the mixed biomass available is in the Piedmont region. There is little to no mixed forest available for the plants of the Southern Appalachian and Coastal Plain regions.

### **Accuracy of GIS datasets**

#### **Geospatial Accuracy**

It is important to accurately depict the underlying distribution of data, especially when using statistical data. This can be a difficult task since the whole point of characterizing data spatially is to generalize the data to identify spatial patterns (Coulson 1987). When generalizing data to reveal intrinsic spatial patterns, it is important to remain accurate to the distribution of data. The SEGAP land cover dataset geospatially relies heavily on the 2001 NLCD land cover dataset (BSIC 2010, GAP Analysis 2006, MLRC NLCD 2001). When analyzing the NLCD dataset across multiple spatial extents, the mapped forest area matches up at a high percentage with the true area of the land cover classes<sup>ix</sup> (Wickham et al. 2010, Hollister et al. 2004). Therefore, the geospatial accuracy of the NLCD dataset and subsequently the SEGAP dataset should not be of concern within the broad confines of this project.

### **Thematic Accuracy**

Since the SEGAP group of researchers increased the number of thematic classes from the NLCD grouping of classes, there is potential for greater thematic inaccuracy (Wickham et al. 2010, Hollister et al. 2004). A way to reduce the amount of thematic inaccuracy is to generalize the categories provided (Evans 1977). The crosswalk established in this project increases the thematic accuracy associated with the SEGAP land cover dataset. The only crosswalk category reducing thematic accuracy is the planted pine category.

### **Ecologically Significant Layers not selected for Analysis**

Several other potential ES layers focusing on ecological concerns were considered but rejected for inclusion due to either a high level of overlay or the lack of a suitable layer. A biodiversity layer representing the areas in North Carolina with healthy ecosystems was never located. The Biodiversity/Wildlife Habitat Assessment (BWHA) and the Natural Heritage Element Occurrences (NHEO) layers created by the North Carolina Heritage Program and the USGS GAP Species Richness layer were considered inadequate for this project's analysis. In coordination with each other, the ES layers selected reasonably represent the majority of the areas containing high to moderate biodiversity in North Carolina. Additionally, a layer containing the density, age, and/or growth rates of forests in North Carolina was never located. It was determined creating one was unfeasible. The Lands Managed for Conservation and Open Space (LMCOS) layer created by NCCGIA in 2002 was considered outdated and contained a high level of overlay with the McAREA layer selected. The McAREA layer had 5.1 million unique acres comparatively with 2.1 million unique acres for the LMCOS layer.

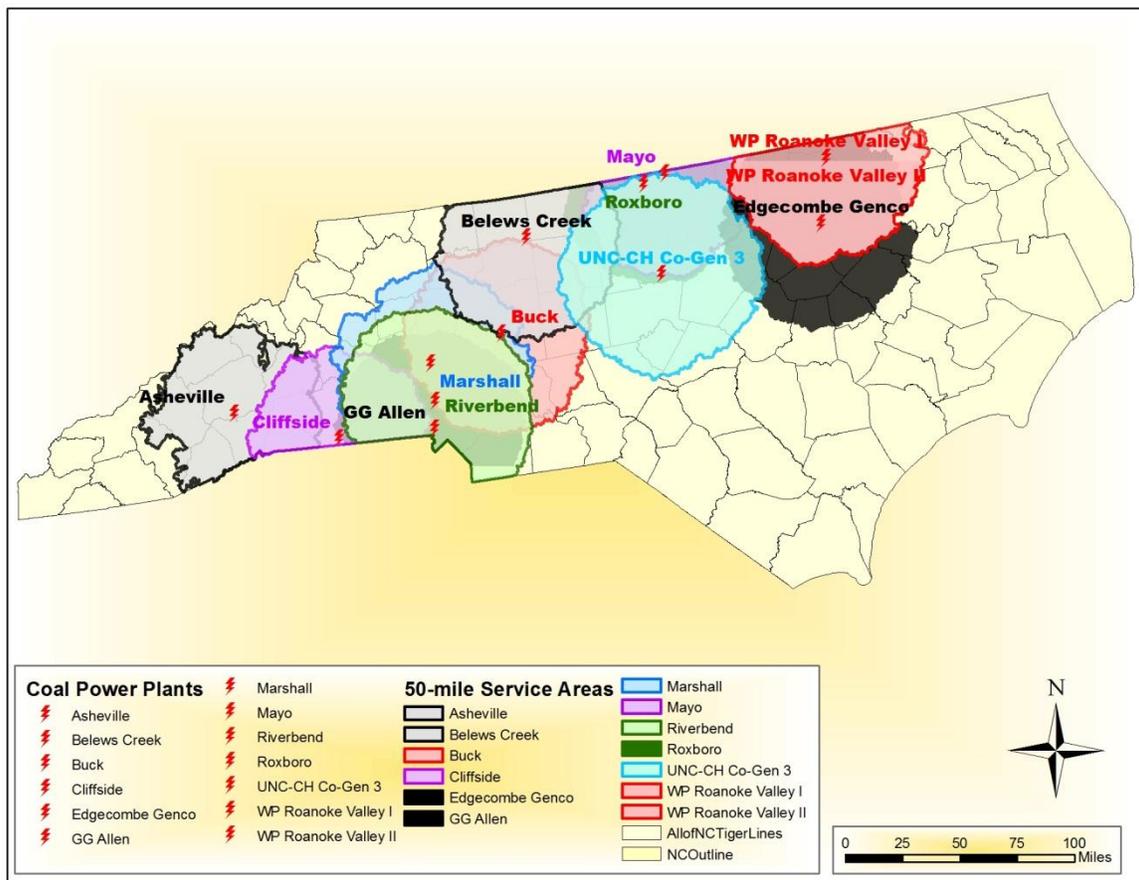
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<sup>ix</sup> The 2010 Wickham et al. study found that forest users' accuracy was 87% for the 2001 NLCD LULC dataset while the Hollister study found 80.4% forest users' accuracy.

## Inaccuracy in the Coal Plant Selection Process

The coal plant selection process contained a high amount of inaccuracy and dated analysis. Several of the plants chosen for inclusion no longer use coal for electricity generation. The state of North Carolina is currently in the midst of a five to ten year shift from coal powered electricity generation to natural gas generation. Figure 14 displays the plants in North Carolina currently (as of December 2012) producing electricity generation using coal. The six plants that were removed include Cape Fear, Elizabethtown Power, Lumberton Power, Southport Power, Unifi Kinston, and WH Weatherspoon. Table 6 offers a list of retirement dates for various coal plants in the state as well as whether the plants are retrofitted for co-firing. Two plants no longer using coal, Elizabethtown Power and Lumberton Power, currently have permits submitted to the state in order to begin producing electricity again. The plants were retrofitted to potentially co-fire biomass with coal in 2012.

**Figure 14 - Coal Plants and Service Areas not currently retired**



**Table 6 – Co-firing Coal Plant Notes**

Plant Name	Notes: Retire Dates, Co-firing Status
Asheville	
Belews Creek	
Buck	Boilers 3,4 Retired in 2011, Boilers 5-6 Retire in "near future"
Cape Fear	Retired in 2011 and October 2012
Cliffside	Boilers 1-4 Retired in 2012, Boiler 6 operational in 2012 (new "carbon neutral plant" with 825 MW by 2018)
Edgecombe Genco	
Elizabethtown Power	Retired in 2009, CFPP Retrofit Proposed 25MW biomass plant in 2012, coal usage still approved via permit
GG Allen	
Lumberton Power	Retired in 2009, CFPP Retrofit Proposed 25MW biomass plant in 2012, coal usage still approved via permit
Marshall	
Mayo	
Riverbend	Retires in 2015
Roxboro	
Southport Power	Retired in 2009, Upgraded for co-firing
UNC-CH Co-Gen 3	Retires in 2020
Unifi Kinston Plant	Retired in 2008
WH Witherspoon	Retired in 2011
WP Roanoke Valley I	
WP Roanoke Valley II	
Dan River	Retired January 2012
LV Sutton	Retires in 2013
HF Lee	Retired September 2012
Roxboro	Retired in 2009, Upgraded for co-firing

**Inaccuracy in the Service Area Creation Process**

Inaccuracy may exist in the 50-mile distance set for the extent of the service areas. The distance was assumed based upon the available road network data, transportation costs<sup>x</sup> of woody biomass feedstock, the value of biomass, and the distribution patterns of biomass (Gonzalez et al. 2011). However, there are groups performing similar analyses where the distance is set anywhere from 30 to 70-miles (FiberAnalytics 2012). Since 50 miles is in the middle of the accepted range, it can be assumed the 50-mile distance should be representative of the harvestable woody biomass feedstock around potential co-firing plants in North Carolina.

<sup>x</sup> 13 cents/ton/mile

## **South Carolina and Virginia Coal Plant Service Areas Extending into North Carolina were excluded from this Analysis**

If considered in this analysis, competition from plants in neighboring states would decrease the amount of woody biomass feedstock available in several service areas. Due to time constraints, these plants were not included in this project. The results are not as accurate as they potentially could be with these plants excluded from analysis. Future iterations of this project could consider adding these plants and their service areas into the analysis, especially if overlap between the service areas is considered.

## **Woody Biomass Feedstock Overlap among the North Carolina Service Areas was not considered**

If overlap, much like competition from neighboring states, had been considered for this project, the results would have been altered. The level of available woody biomass feedstock would comprehensively decrease in most service areas. In future iterations of this project, the number of times a service area contained overlap from neighboring service areas could be considered and documented. Areas with high service area overlap would likely need to be assigned to one or two service areas and removed from the others. This would promote increased accuracy in the feedstock supply acreage numbers.

## **Using Forest Inventory Analysis (FIA) & Timber Production Output (TPO) Data may have made the Results more Accurate**

The use of land cover acreage data to compile the results is an accurate way of spatially characterizing woody biomass feedstock supply. In some ways, considering FIA and TPO data could offer a more refined distribution of woody biomass feedstock in the state. The major issue surrounding these data is they only exist at the county level. The reliance on county-level data complicates a situation where a service area transgresses only a portion of a county. A percentage system could be established to increase geospatial accuracy. However, the exact spatial location of the county-level data values is not known and therefore the most exact values can only be found at the county level. Since the various ES layers are not limited to the county-level, it makes sense to use woody biomass land cover data as well.

## **Conclusions**

Co-firing with woody biomass feedstock has great short-term potential, even in a state where utilities have recently prioritized natural gas electricity production and historically favored coal powered electricity generation. Without a subsidy for woody biomass in North Carolina, there are some plants already using biomass<sup>xi</sup> and some planning to use biomass in the future<sup>xii</sup>. The REPS

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<sup>xi</sup> Craven County Wood Energy in New Bern and Coastal Carolina Clean Power in Kenansville

requirements have to be met by some form of in-state renewable resource and woody biomass is currently one of the cheapest options to meet the requirements. Will Duke Energy utilize woody biomass resources in North Carolina or will they go elsewhere to meet their REPS requirements?

As indicated in the Searchinger et al (2008) and Schulze et al. (2012) articles, caution should be taken when harvesting woody biomass. This is especially true considering Duke Energy will be using roundwood to meet their REPS requirements. It is the hope of this project they consider and avoid ecologically significant areas when they choose locations to harvest for woody biomass co-firing.

When ecologically significant areas in North Carolina are considered, the results indicate the choice of co-firing coal plant may be affected. Some plants appear favorable for co-firing woody biomass feedstock without considering ES areas but become less favorable when ES areas are considered. Due to the regenerative properties of pine versus hardwood, among other factors, the best potential areas for co-firing lie in the Coastal Plain. This is why there is so much planted pine in the Coastal Plain. Adding to these influences, the coal plants least affected by ES areas are located in the Coastal Plain.

Discord remains between woody biomass feedstock supply and the location of most coal plants in North Carolina. The majority of coal plants in North Carolina lie in the Piedmont where there is significantly less pine and an increasingly higher percentage of hardwood, especially after removing the ES layers. On the other hand, the Coastal Plain has an abundant amount of woody biomass feedstock before and after removing the ES layers. This is mainly due to the high amount of pine plantations found in the region comparatively to other regions.

Utilities in North Carolina would be wise to consider the impact of ecologically significant areas on woody biomass feedstock supply. The Piedmont is where they would likely harvest the majority of their woody biomass for co-firing due to the high density of coal plants. Unfortunately, this is also where the most impact would occur to ES areas. If the utilities are interested in locating the best source of non ES-impacted woody biomass feedstock, they will look to the Coastal Plain for supply.

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<sup>xii</sup> Lumberton Power and Elizabethtown Power were retrofitted to use biomass in addition to coal and they both recently submitted permits to solely burn biomass in the future. Additionally, Hartford Renewable Energy and IP Riegelwood have proposed to use biomass in their plants for the future.

## References

- “A Gap Analysis of North Carolina: April 2006 Final Report.” 2006. Biodiversity and Spatial Information Center, USGS North Carolina Cooperative Fish & Wildlife Research Unit, NC State University.  
<http://www.basic.ncsu.edu/ncgap/NCFinal%20Report.pdf>
- Biodiversity and Spatial Information Center (BSIC), USGS North Carolina Cooperative Fish & Wildlife Research Unit, NC State University. 2010. *Southeast Gap Analysis Project Land Cover Mapping*.  
<http://www.basic.ncsu.edu/segap/index.html>
- 2012 Clean Smokestacks Act Report. 2012. North Carolina Department of Environment and Natural Resources, Division of Air Quality.  
[http://daq.state.nc.us/news/leg/2012\\_Clean\\_Smokestacks\\_Act\\_Report.pdf](http://daq.state.nc.us/news/leg/2012_Clean_Smokestacks_Act_Report.pdf)
- Air Permit Review – Lumberton Energy, LLC*. 2012. North Carolina Division of Air Quality.  
[http://www.ncair.org/permits/permit\\_reviews/lumberton\\_rev\\_08242012.pdf](http://www.ncair.org/permits/permit_reviews/lumberton_rev_08242012.pdf)
- Coulson, Michael R.C. 1987. In the matter of class intervals for choropleth maps: With particular reference to the work of George F. Jenks. *Cartographica* 24 (2): 16-39.
- Department of Environment and Natural Resources – Division of Parks and Recreation,, North Carolina Natural Heritage Program. *Managed (Conservation) Areas of North Carolina*. 2012. Biotics Database. Department of Environment and Natural Resources, Raleigh, North Carolina. [www.ncnhp.org](http://www.ncnhp.org)
- Department of Environment and Natural Resources – Division of Parks and Recreation, North Carolina Natural Heritage Program. Significant Natural Heritage Areas. 2012. Biotics Database. Department of Environment and Natural Resources, Raleigh, North Carolina. [www.ncnhp.org](http://www.ncnhp.org)
- Database of State Incentives for Renewables and Efficiency (DSIRE).  
<http://www.dsireusa.org/incentives/>. Accessed 10/19/2012.
- “Duke Energy Project Overview – New Natural Gas Generation.” 2012.  
<http://www.duke-energy.com>. Accessed 10/19/2012.
- EIA Form-923 2009. United States Energy Information Administration. 2009.  
<http://www.eia.gov/electricity/data/eia923/index.html>.

- EIA Form-923 2010. United States Energy Information Administration. 2010. <http://www.eia.gov/electricity/data/eia923/index.html>.
- EIA Form-923 2011. United States Energy Information Administration. 2011. <http://www.eia.gov/electricity/data/eia923/index.html>.
- EIA Form-923 through August, 2012. United States Energy Information Administration. 2012. <http://www.eia.gov/electricity/data/eia923/index.html>.
- EPA eGRID2012 Version 1.0. 2012. <http://www.epa.gov/eGRID>. Accessed 1/24/2012.
- Esri StreetMap Premium. 2009. Esri. <http://www.esri.com/data/streetmap/index.html>
- Evans, Ian S. 1977. The selection of class intervals. *Transactions of the Institute of British Geographers New Series* 2: 98-124
- “Roundwood, Biomass, and Wood Resides.” 2012. FiberAnalytics. North Carolina State University. <http://www.ces.ncsu.edu/nreos/fiber/atlas/wood.php>
- General Assembly of North Carolina. *Renewable Energy and Energy Efficiency Portfolio Standard (REPS)*. Session Law 2007-397. Senate Bill 3.
- Gonzalez, R., Phillips, R., Saloni, D., Jameel, H., Abt, R., Pirraglia, A., & Wright, J. (2011). Biomass to energy in the southern united states: supply chain and delivered cost. *BioResources*, 6(3), 2954-2976.
- Hollister et al. 2004. “Thematic accuracy of the NLCD 2001 landcover for the conterminous United States.” *Photogrammetric Engineering & Remote Sensing*. v.70 n.4, 405-414. [http://www.asprs.org/a/publications/pers/2004journal/april/2004\\_apr\\_405-414.pdf](http://www.asprs.org/a/publications/pers/2004journal/april/2004_apr_405-414.pdf)
- Hunt, T. and D. Tennant. 2009. “Co-firing Biomass.” *Power Engineering*. v.113 n.11, 226-229.
- Hurlbut, D. 2008. “State Clean Energy Practices: Renewable Portfolio Standards.” *National Renewable Energy Laboratory*. Technical Report: NREL/TP---670-43512.
- Jentgen, M. 2012. “An assessment of Renewable Portfolio Standards and potential for expansion in the southeastern United States.” Duke University, Sanford School of Policy.

[http://dukespace.lib.duke.edu/dspace/bitstream/handle/10161/5188/Jentgen\\_MP\\_final\\_v2.pdf?sequence=4](http://dukespace.lib.duke.edu/dspace/bitstream/handle/10161/5188/Jentgen_MP_final_v2.pdf?sequence=4)

Kaylor, R. 2010. *Pre-Hearing Brief, N.C. Utilities Commission.*

<http://www.pfpi.net/wp-content/uploads/2011/04/Duke-pre-hearing-testimony.pdf>

Mutli-Resolution Land Characteristics Consortium (MRLC). *National Land Cover Database.* 2001. <http://www.mrlc.gov/>

Neuse River Basin: Nutrient Sensitive Waters Management Strategy: Protection and Maintenance of Existing Riparian Buffers. 15A N.C.A.C. 2B. 0233. 2000. <http://reports.oah.state.nc.us/ncac.asp> Accessed 10/19/2012.

North Carolina Center for Geographic Information & Analysis. 2007. *Statewide 24k Hydrography (lines).* <http://www.nconemap.com/>

North Carolina Center for Geographic Information & Analysis. 2007. *Statewide 24k Hydrography (polygons).* <http://www.nconemap.com/>

“Progress Energy Carolinas to retire two coal-fired power plants Oct. 1.” 2012. Duke Energy. <http://www.duke-energy.com/news/releases/2012092801.asp> Accessed 10/19/2012.

Sackett, J. “Proposed and Existing Woody Biomass Facilities in the Southeastern US.” 2012. Southern Environmental Law Center. [http://www.southernenvironment.org/uploads/fck/file/biomass/biomass\\_facilities\\_map\\_table\\_071012.pdf](http://www.southernenvironment.org/uploads/fck/file/biomass/biomass_facilities_map_table_071012.pdf)

Schulze et al. 2012. “Large-scale bioenergy from additional harvest of foreign biomass is neither sustainable nor greenhouse gas neutral.” *GCB Bioenergy*. doi: 10.1111/j.1757-1707.2012.01169.x.

Searchinger et al. 2008. “Use of U.S. Croplands for Biofuels Increases Greenhouse Gases Through Emissions from Land-Use Change.” *Science* v.319 n.2, 1238-1240.

Sullivan, K. and R. Miejer 2010. “Co-Firing Biomass with Coal.” *Power Engineering* v114 n5, 14.

United States Department of Commerce, United States Census Bureau, Geography Division, Geographic Products Branch. 2010. *North Carolina TIGER/Line County Shapefile.* <http://www.nconemap.com/>

United States Energy Information Administration (EIA). 2012. *Annual Energy Outlook 2012 with Projections to 2035*. DOE/EIA-0383. Washington, DC: US EIA. <http://www.eia.gov/forecasts/aeo/>

United States Geological Survey, Gap Analysis Program (GAP). 2011. Protected Conservation Areas Database of the United States (PADUS), version 1.2. <http://gapanalysis.usgs.gov/padus/data/>

Wickham et al. 2010. "Thematic accuracy of the NLCD 2001 landcover for the conterminous United States." *Remote Sensing of Environment*. V114 n6, 1286-1296.

"TechLine: Wood Biomass for Energy." 2004. Forest Products Laboratory. <http://www.fpl.fs.fed.us/documnts/techline/wood-biomass-for-energy.pdf>

## **Appendices**

### **Appendix A: Metadata**

The featured datasets incorporated into this characterization include the United States Geological Survey (USGS) Southeast Gap Analysis Program's Land Cover dataset (SEGAP), the USGS National GAP's Protected Conservation Areas Database of the United States North Carolina dataset (PAD\_US\_NC), North Carolina Natural Heritage Program's February 2012 Managed Conservation Areas of NC (McAREA) and Significant Natural Heritage Areas (SNHA) datasets, North Carolina Geographic Information Analysis/Division of Water Quality's Water Supply Watersheds (WSW) and 1:24,000-scale Hydrography with Water Classifications (Polygons & Lines), ESRI's 2009 Streetmaps, and the U.S. Census Bureau's TIGER/Line North Carolina County Subdivisions dataset. Additionally, a latitude and longitude based point shapefile was created from EIA data to represent the location of co-firing coal plants in North Carolina.

#### **Southeast GAP Land Cover (LC\_SEGAP\_NC)**

##### **Publication Date**

October 13, 2010

##### **Projection**

USA\_Contiguous\_Albers\_Equal\_Area\_Conic\_USGS\_version

##### **Abstract**

Land cover mapping is generally performed by adopting a land cover classification system, delineating areas of relative homogeneity, and then labeling these areas using categories defined by the classification system (GAP Analysis 2006). The SEGAP land cover dataset originates from multi-season satellite imagery (Landsat ETM+) from 1999-2001 in conjunction with 30m digital elevation model (DEM) derived datasets (e.g. elevation, landform) from 1999 to model natural and semi-natural vegetation. Vegetation classes were drawn from NatureServe's Ecological System Classification. Additionally, the land cover layer included land use classes that were employed to describe areas where natural vegetation has been altered. In many areas of the country these classes were derived from the National Land Cover Dataset (NLCD). For the majority of classes and, in most areas of the country, a decision tree classifier was used to discriminate ecological system types. In some areas of the country, more manual techniques were used to discriminate small patch systems and systems not distinguishable through topography. The data contains multiple levels of thematic

detail. At the most detailed level natural vegetation is represented by NatureServe's Ecological System classification.

### **Data Accumulation & Creation Process**

A variety of mapping methods were employed to model ecological systems in their assigned mapping zones (established from NLCD 2001). Where applicable, decision tree classifiers were used. Decision tree classification was implemented through the use of a custom interface for ERDAS Imagine (developed under contract by Earthsat, Corp. for USGS EROS Data Center) and See5 software ([www.rulequest.com](http://www.rulequest.com)). Land cover types that were not mapped using decision tree classifiers typically had too few reference samples due to their sparse occurrence on the landscape or poor discrimination among or between spectrally similar cover classes (e.g. mesic vs. dry-mesic forested systems) to yield an acceptable result. Where the decision tree could not be used, other techniques such as localized unsupervised classification, area of interest inclusion/exclusion masks, and expert decision rules were used to map these cover classes.

### **Known Errors & Limitations**

Mapping zones were mosaicked by the BASIC team. During the mosaic process, a limited number of gross errors were identified for editing prior to the generation of the final mosaic. These included erroneous data omission, recoding errors, and systems mistakenly mapped outside of NatureServe ranges.

### **Protected Conservation Areas of the United States (PAD\_US\_NC)**

#### **Publication Date**

February 22, 2011

#### **Projection**

USA\_Contiguous\_Albers\_Equal\_Area\_Conic\_USGS\_version

#### **Abstract**

PAD\_US\_NC is a dataset that characterizes public and private lands owned and managed for conservation of biological diversity and other natural, recreational, and cultural uses. The dataset specifically offers geographic boundaries of public land ownership (primarily federal and state) and voluntarily provided private conservation lands (e.g., Nature Conservancy Preserves or land trust easements) from authoritative data sources. Each parcel is coded as lands managed for different levels of biological protection, as multiple use lands that may support extractive uses, or as lands with no known mandate for permanent protection. All coded PAD\_US\_NC parcels were included in this characterization.

### **Data Accumulation & Creation Process**

The dataset was developed by aggregating state by state inventories, as well as federal agency and national conservation organization data. Boundaries, and their descriptors, available in spatial databases from land management agencies are the desired and primary data sources. If these authoritative sources are unavailable, or the agency recommends another source, data may be incorporated by other aggregators such as non-governmental organizations.

### **Known Errors & Limitations**

As GAP does not alter source boundaries, inconsistencies in data quality or scale are present. Given these differences, GAP recommends PAD-US for use in landscape analyses of 1:100,000 or greater. While parcel level data is increasingly available, protected area boundaries should be considered representative of management rather than legal boundaries for regulation or acquisition.

GAP also relies on source data for protected area descriptors (e.g. name, owner, designation date) and translates multiple data formats into the PAD-US schema. When information is unavailable or contains errors the overall utility of PAD-US suffers. GAP addresses comments that improve the data but, ultimately, depends on the integration of suggested edits in source data to avoid the repetition of errors in future updates.

PAD-US is updated annually. However, given current resources, this does not include a complete update of all land types across the nation. An update summary is available for each version, while boundary and conservation measure update dates are documented for each record in the 'GIS Source Date' and 'GAP Code Source Date' fields in the PAD-US geodatabase, respectively.

### **Significant Natural Heritage Areas (SNHA)**

#### **Publication Date**

February 2012

#### **Projection**

NAD\_1983\_StatePlane\_North\_Carolina\_FIPS\_3200

#### **Abstract**

The North Carolina Department of Environment and Natural Resources, Division of Parks and Recreation, Natural Heritage Program in cooperation with the NC Center for Geographic Information and Analysis, developed the Significant Natural Heritage Areas digital data to determine the areas containing ecologically significant natural communities or rare species. Using ESRI's ARC/INFO GIS software, the data set was built for arc and polygon topology using the "build" command. The data set was then cleaned with a fuzzy tolerance of 1 foot.

### **Data Accumulation & Creation Process**

Natural Area boundaries were delineated by NHP field biologists. Precision varies. The cartographic method used for the majority of the sites was for the biologist to survey not just the area where the rare species occurred, but the high quality habitat the species may inhabit as well. This area was delineated onto a photocopy of a USGS 1:24,000 topographic map. The delineated map was then brought back to the NHP offices where it was then transferred onto an original USGS paper base map. This map was then digitized by NHP.

### **Known Errors or Limitations**

Due to its dynamic nature, this data becomes outdated very quickly.

### **Managed (Conservation) Areas of North Carolina (McAREA)**

#### **Publication Date**

February 2012

#### **Projection**

NAD\_1983\_StatePlane\_North\_Carolina\_FIPS\_3200

### **Abstract**

The North Carolina Natural Heritage Program developed the Managed Conservation Areas (or McAREA) shapefile to document public- and privately-owned lands and easements that are of some conservation interest. The property boundaries used in this coverage were acquired from a wide variety of sources, and in many cases these boundaries are approximate. Because of these inaccuracies, this coverage is intended to be used as an aid to conservation planning only and not as a substitute for land survey data. Inclusion in this coverage is arbitrary and in no way implies that included areas are protected or accessible to the public.

### **Data Accumulation & Creation Process**

Source data was obtained from a variety of sources. Boundaries of federal lands, such as national parks and forest, wildlife refuges, and military bases, were primarily obtained from federal agencies; when primary sources were not available, county cadastral data<sup>xiii</sup> were used instead. State agencies provided boundaries for state parks & natural areas, state forests, game lands, coastal reserves, plant conservation preserves, and other state-owned lands & easements. Boundaries of local parks and easements were provided by local governments or were copied from county cadastral data. Boundaries of private nature preserves and easements were obtained from private land trusts and conservation organizations. The original compilation included boundaries digitized from lines drawn on paper USGS topographic maps. These have largely

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<sup>xiii</sup> a comprehensive register of the metes-and-bounds real property that details ownership, tenure, precise location, dimensions, cultivations (if rural), and the value of individual parcels of land.

been replaced with better data, as updates tend to be digital in origin in recent years. Initially attempts were made to resolve boundary discrepancies, but this is no longer done, and as a result minor overlaps or gaps often occur between adjacent properties. Processing includes integration of all polygons and attribution of each polygon. Quality control includes checks for attribute consistency to enable efficient querying and symbolization.

### **Known Errors & Limitations**

Managed Conservation Areas are consistently represented as polygons that approximate property boundaries. Nonetheless, inclusion in this dataset is arbitrary and in no way implies that included areas are protected or accessible to the public. In some instances, boundaries of adjacent properties provided by different sources may be inconsistent, creating minor overlaps or gaps in Managed Conservation Areas of conservation interest. Given the tendency to publish quarterly, the discrepancies are not resolved each time a source dataset is integrated in the compilation.

### **Water Supply Watersheds (WSW)**

#### **Publication Date**

July 1, 2007

#### **Projection**

NAD\_1983\_StatePlane\_North\_Carolina\_FIPS\_3200

#### **Abstract**

The North Carolina Department of Environment and Natural Resources, Division of Water Quality, in cooperation with the NC Center for Geographic Information and Analysis, developed the digital Water Supply Watersheds data to enhance planning, siting, and impact analysis in areas directly affecting water supply intakes. This file outlines the extent of protected and critical areas and stream classifications for areas around water supply watersheds in which development directly affects a water supply intake. This file enables users to identify the areas which have special restrictions for building and development based on water supply intakes. This file is updated as changes occur.

#### **Data Accumulation & Creation Process**

Water supply watershed boundaries were delineated by DWQ cartographers interpolating ridgelines on 24k paper USGS 7.5 minute topographic maps. Boundaries were delineated around known water supply intakes. Intakes on streams or rivers had critical areas delineated as ridgelines or half mile buffers, whichever was closest, upstream of the intake location. Protected Conservation Areas were delineated with ridgelines or ten mile buffers, which ever was closer. For intakes on lakes and reservoirs, buffers were delineated from the apparent pool elevation of the water body as shown on the

USGS quadrangle using the same limits as above. Boundaries were reviewed by DWQ staff. NCCGIA digitized these boundaries and attributed them with DWQ classification information, river basin and stream names, and acres per polygon. The digital files were plotted and overlaid to the originals and linework and label corrections were made. After the linework was digitized by NCCGIA, DWQ staff reviewed the linework and attributes for accuracy. DWQ supplies CGIA with updates as they occur.

### **Known Errors & Limitations**

These data represent the locations and identities of Water Supply Watersheds in North Carolina as mapped by the NCDWQ. Each watershed is labeled with either a protected or critical area classification. All boundaries are approved by DWQ whether they are the original DWQ boundaries or changes to original boundaries submitted for revision by local or county governments.

### **24K Hydrography**

#### **Publication Date**

Unknown (Metadata dated June 10, 2011)

#### **Projection**

NAD\_1983\_StatePlane\_North\_Carolina\_FIPS\_3200

#### **Abstract**

The North Carolina Center for Geographic Information and Analysis, in cooperation with the North Carolina Division of Water Quality, developed this digital hydrography dataset with Use Support information and water quality classifications to enhance planning, siting and impact analysis. This dataset enables users to identify surface water features which have special restrictions for building and development based on the locations of the features and their water quality classifications. Surface waters consist of streams, rivers, lakes, ponds, reservoirs, and shorelines. This file also enables users to determine whether surface water is meeting its intended water quality uses. The linework is based on the USGS 1:24,000-scale Digital Line Graphs but has had additions from other sources as needed to include the hydrographic features in the stream classification codes. The data are updated as changes occur.

#### **Data Accumulation & Creation Process**

The statewide 1:24,000 hydrography tiles were edgematched and mapjoined. The neatlines and extraneous labels points were removed. The coverages were clipped to the North Carolina river basin boundaries derived from the HUNCRB data layer. Each river basin was edited such that index numbers matched their corresponding stream reach. Attributes were re-named and edited in cooperation with the Division of Water quality. CGIA and DWQ updates the digital files as needed.

Water quality for specific stream reaches were assessed by DWQ and a use support ratings assigned. This rating identifies how well a stream reach meets its designated uses. Ratings and additional attributes are maintained in an ACCESS database and updated by river basin on a 5-year rotation. The Division of Water Quality joins these data to the 24k hydrography data layer. DWQ provides CGIA with updates as they occur either from a new assessment, reclassification or correction.

#### **Known Errors & Limitations**

NCGIA has software that checks for topology. There are no duplicate features, but coincident lines are maintained between data layers where appropriate. Polygonal features begin and end at the same point. They also contain no over- or under-shoots. Linear features are continuous where appropriate (ex. dangling arcs are removed if they are not required).

#### **ESRI Street Maps 2009**

##### **Publication Date**

2009

##### **Projection**

NAD\_1983\_StatePlane\_North\_Carolina\_FIPS\_3200

##### **Data Accumulation & Creation Process**

None

##### **Known Errors & Limitations**

None

#### **2010 Census Tiger/Line North Carolina County Subdivisions & North Carolina State-Line Boundary Outline Shapefile**

##### **Publication Date**

2010

##### **Projection**

NAD\_1983\_StatePlane\_North\_Carolina\_FIPS\_3200

##### **Abstract**

The TIGER/Line Files are shapefiles that are an extract of selected geographic and cartographic information from the U.S. Census Bureau's Master Address File / Topologically Integrated Geographic Encoding and Referencing (MAF/TIGER) Database (MTDB).

##### **Data Accumulation & Creation Process**

None

## **Known Errors & Limitations**

The Census Bureau performed automated tests to ensure logical consistency and limits of shapefiles. Segments making up the outer and inner boundaries of a polygon tie end-to-end to completely enclose the area. All polygons are tested for closure. The Census Bureau uses its internally developed geographic update system to enhance and modify spatial and attribute data in the Census MAF/TIGER database.

The Census Bureau performed spatial data tests for logical consistency of the codes during the compilation of the original Census MAF/TIGER database files. Feature attribute information has been examined but has not been fully tested for consistency. For the TIGER/Line Shapefiles, the Point and Vector Object Count for the G-polygon SDTS Point and Vector Object Type reflects the number of records in the shapefile attribute table. For multi-polygon features, only one attribute record exists for each multi-polygon rather than one attribute record per individual G-polygon component of the multi-polygon feature. TIGER/Line Shapefile multi-polygons are an exception to the G-polygon object type classification. Therefore, when multi-polygons exist in a shapefile, the object count will be less than the actual number of G-polygons.

## **Appendix B: Procedure Log**

**Projection Coordinate System:** Albers Conical Equal Area  
**Geographic Coordinate System:** GCS\_NA1983

### **Data:**

NC\_WoodBoiler\_List.xlsx  
MAREA.shp  
WSW.shp  
PAD\_US\_NC.shp  
SNHA.shp  
Hydro24k\_arc.shp  
Hydro24k\_poly.shp  
Lc\_segap\_nc.raster (Grid file)  
Streets.sdc (ESRI Streetmaps 2009)  
NCOOutline.shp (NC Border)  
AllofNCTigerLines.shp (NC Border with Counties)

### **Combine the 2 Hydrography Shapefiles into a single Shapefile**

Buffer Tool - Line  
Input: hydro24k\_arc  
Distance/Linear Unit: 50ft  
Side Type: FULL  
End: ROUND  
Dissolve: None

Output: hydro24k\_arc\_Buffer

Buffer Tool - Polygon

Input: hydro24k\_poly

Distance/Linear Unit: 50ft

Side Type: FULL

End: ROUND

Dissolve: None

Output: hydro24k\_poly\_Buffer

Intersect Tool – Locate common polygons between 2 datasets

Input Features: hydro24k\_arc\_Buffer, hydro24k\_poly\_Buffer

Join Attributes: ALL

Output: hydro24k\_arc\_Buffer\_Intersec

Erase Tool - Line

Input: hydro24k\_arc\_Buffer

Erase: hydro24k\_arc\_Buffer\_Intersec

Output: hydro24k\_arc\_Buffer\_Erase

Erase Tool - Polygon

Input: hydro24k\_poly\_Buffer

Erase: hydro24k\_arc\_Buffer\_Intersec

Output: hydro24k\_poly\_Buffer\_Erase

Merge Tool – Merge the 2 Erase Shapefiles

Input: hydro24k\_poly\_Buffer\_Erase, hydro24k\_arc\_Buffer\_Erase

Output: **hydro24k\_poly\_Buffer\_Erase\_M.shp**

**Add Coal Plant Latitude/Longitudes as a Point Shapefile**

Add NC\_WoodBoiler\_List.xlsx

Display XY Data:

X Field: LON

Y Field: LAT

Z Field: None

Output: NC\_WoodBoiler\_List.dbf

Export Data:

Export: All Features

Use Same Coordinate System as: this layer's source data

Output Feature Class: **CoalPlants\_NC.shp**

**Create Service Areas**

In Network Analyst

Load ESRI StreetMap 2009 layer

Select "New Service Area"

Load Locations: CoalPlants\_NC.shp

Open **Service Area** Properties  
Under Polygon Generation Tab:  
Multiple Facilities Option: Overlapping  
Overlap Type: Disks  
Generate Polygons: checkmark  
Trim Polygon: checkmark and 1000m  
Under Analysis Settings Tab:  
Impedence: Length (miles)  
Default Breaks: 50  
Direction: Away from Facility  
One Way/Turn Restriction: checkmarked  
Solve  
Output: **50mi\_ServAr.shp**

### **Clipping Service Areas to North Carolina Border**

#### Clip Tool

Input Features: 50mi\_ServAr.shp  
Clip Features: NCOutline.shp  
Output Feature Class: **50mi\_SA\_Clip.shp**

### **Split Service Areas into Separate Shapefiles**

#### Split Tool

Input: 50mi\_SA\_Clip.shp  
Split Features: 50mi\_SA\_Clip.shp  
Split Field: Plant\_Name  
Target Workspace: c:\Users\ValuedCustomer\Docs\Project\segap\_SA  
Output: **Asheville.shp, Belews\_Creek.shp, Buck.shp, Cape\_Fear.shp, Cliffside.shp, Edgecomb\_Genco.shp, Elizabethtown\_Power.shp, GG\_Allen.shp, Lumberton\_Power.shp, Marshall.shp, Mayo.shp, Riverbend.shp, Roxboro.shp, Southport\_Power.shp, UNC\_Co\_Gen.shp, Unifi\_Kinston.shp, WH\_Weatherspoon.shp, WP\_Roanoke\_Valley\_I.shp, WP\_Roanoke\_Valley\_II.shp**

### **Extract Woody Biomass Classes out of SEGAP Land Cover**

#### Extract by Attribute Tool

Input Raster: lc\_segap\_nc  
Where Clause: Where "Rowid" = 39 OR "Rowid" = 40 OR "Rowid" = 42 OR "Rowid" = 43 OR "Rowid" = 55 OR "Rowid" = 66 OR "Rowid" = 68 OR "Rowid" = 71 OR "Rowid" = 72 OR "Rowid" = 73 OR "Rowid" = 85 OR "Rowid" = 86 OR "Rowid" = 90 OR "Rowid" = 91 OR "Rowid" = 92 OR "Rowid" = 93 OR "Rowid" = 98 OR "Rowid" = 100 v 103 OR "Rowid" = 104 OR "Rowid" = 108 OR "Rowid" = 151 OR "Rowid" = 152 OR "Rowid" = 153 OR "Rowid" = 154 OR "Rowid" = 161 OR "Rowid" = 164 OR "Rowid" = 165 OR "Rowid" = 167 OR "Rowid" = 168 v 173 OR "Rowid" = 174 OR "Rowid" = 183 OR "Rowid" = 253  
Output Raster: **segap\_biomass.raster**

## **Raster to Polygon**

### Raster to Polygon Tool

Input Raster: segap\_biomass.raster

Field (optional): VALUE

Output polygon features: **segap\_biopoly.shp**

## **Transfer Named Info from Raster to Polygon**

Open Raster Attribute Table

Export Attribute Table as a .dbf

Save as Type: dBASE Table

Output: **segap\_biom.dbf**

Open segap\_biopoly.shp

Add New Field: VALUE (Type: Double)

Field Calculator: GRIDCODE = VALUE

### Join Data

Join Attributes from a Table

1. VALUE

2. segap\_biom.dbf

3. VALUE

Keep All Records

Save joined segap\_biopoly.shp as segap\_biomass\_polygon.shp

Remove Join

## **Clip Woody Biomass Shapefile to each Service Area**

Clip Tool - Repeat Clip for each Service Area (Asheville Service Area used as an example for all the other service areas)

Input Features: segap\_biomass\_polygons.shp

Clip Features: Asheville.shp

Output Feature Class: **Ash\_Clip.shp, Bel\_Cr\_Clip.shp, etc**

## **Add Area Field in each Woody Biomass Clipped Service Area**

Open Ash\_Clip.shp - Repeat for each service area (Asheville Service Area used as an example for all the other service areas)

Add New Field – Area (Type: Double)

Calculate Geometry on Area Field

Property: Area

Use Coordinate System of Data Frame

Units: Acres

Perform Statistics on the Area, Record Sum in Table 1

## **Erase Ecologically Significant Layers from each Woody Biomass Service Area**

Erase Tool – Repeat Clip for each Service Area (Asheville Woody Biomass Service Area used as an example for all the other service areas)

Input Features: marea.shp

Erase Features: Ash\_Clip.shp

Output Feature Class: Ash\_EraseMAREA

Calculate Geometry on Area Field

Property: Area

Use Coordinate System of Data Frame

Units: Acres

Perform Statistics on the Area, Record Sum

Erase Tool

Input Features: snha.shp

Erase Features: Ash\_Clip.shp

Output Feature Class: Ash\_EraseSNHA

Calculate Geometry on Area Field

Property: Area

Use Coordinate System of Data Frame

Units: Acres

Perform Statistics on the Area, Record Sum

Erase Tool

Input Features: PAD\_US\_NC.shp

Clip Features: Ash\_Clip.shp

Output Feature Class: Ash\_ErasePAD

Calculate Geometry on Area Field

Property: Area

Use Coordinate System of Data Frame

Units: Acres

Perform Statistics on the Area, Record Sum

Clip Tool

Input Features: WSW.shp

Clip Features: Ash\_Clip.shp

Output Feature Class: Ash\_EraseWSW

Calculate Geometry on Area Field

Property: Area

Use Coordinate System of Data Frame

Units: Acres

Perform Statistics on the Area, Record Sum

Clip Tool

Input Features: hydro24k\_poly\_Buffer\_Erase\_M.shp

Clip Features: Ash\_Clip.shp  
Output Feature Class: Ash\_EraseHYDRO

Calculate Geometry on Area Field

Property: Area  
Use Coordinate System of Data Frame  
Units: Acres  
Perform Statistics on the Area, Record Sum

**Erase ES Layers Cumulatively from each Woody Biomass Service Area**

Erase Tool - Repeat for each service area (Asheville Woody Biomass Service Area used as an example for all the other service areas)  
Input Features: Ash\_Clip\_EraseHydro.shp  
Erase Features: snha.shp  
Output Feature Ash\_er\_h\_s.shp

Erase Tool - Repeat for each service area (Asheville Woody Biomass Service Area used as an example for all the other service areas)  
Input Features: Ash\_Clip\_er\_h\_s.shp  
Erase Features: marea.shp  
Output Feature Ash\_er\_h\_s\_m.shp

Erase Tool - Repeat for each service area (Asheville Woody Biomass Service Area used as an example for all the other service areas)  
Input Features: Ash\_Clip\_er\_h\_s\_m.shp  
Erase Features: wsw.shp  
Output Feature Ash\_er\_h\_s\_m\_w.shp

Erase Tool - Repeat for each service area (Asheville Woody Biomass Service Area used as an example for all the other service areas)  
Input Features: Ash\_Clip\_er\_h\_s\_m\_w.shp  
Erase Features: PAD\_US\_NC.shp  
Output Feature **Ashbiomass\_NoECs.shp, BelCrbiomass\_NoECs.shp, etc.**

**Add Forest Crossblock Field to Cumulative Erase Service Area Shapefiles**  
Create Excel Database matching Map Values to Forest Type  
Create: Crossblock.xlsx

**SEGAP Classes**

39 Atlantic Coastal Plain Dry/Dry Mesic Oak Forest  
40 Atlantic Coastal Plain Mesic Hardwood/Mixed Forest  
42 Central/Southern Appalachian Montane Oak Forest  
43 Central/Southern Appalachian Northern Hardwood Forest  
55 Central/Southern Appalachian Cove Forest  
56 Central/Southern Appalachian Oak Forest  
66 Southern Piedmont Dry Oak(Pine) Forest – HW Modifier  
68 Southern Piedmont Mesic Forest  
71 Evergreen Plantations  
72 Atlantic Coastal Plain Central Maritime Forest  
73 Atlantic Coastal Plain Northern Maritime Forest  
75 Central/Southern Appalachian Spruce-Fir Forest  
85 Central/Southern Appalachian Low Mountain Forest

**Crosswalk Classes**

Hardwood  
Hardwood  
Hardwood  
Hardwood  
Hardwood  
Hardwood  
Hardwood  
Hardwood  
Planted Pine  
Hardwood  
Hardwood  
Natural Pine  
Natural Pine

86 Southern Piedmont Dry-Oak(Pine) Forest – Loblolly Pine Modifier	Natural Pine
90 A.C.P. Fall-Line Sandhills LLPine Woodland-Loblolly Modifier	Natural Pine
91 A.C.P. Fall-Line Sandhills LLPine Wd. - Open Understory Mod.	Natural Pine
92 A.C.P. Fall-Line Sandhills LLPine Wd. - Scrub/Shrub Understory	Natural Pine
93 Atlantic Coastal Plain Upland Longleaf Pine Woodland	Natural Pine
98 Southern Appalachian Montane Pine Forest & Woodland	Natural Pine
100 Southeast Interior Longleaf Pine Woodland	Natural Pine
103 Southern Ridge/Valley Dry Calcareous Forest – Pine Modifier	Mixed
104 Appalachian Hemlock – Hardwood Forest	Hardwood
108 Southern Piedmont Dry-Oak (Pine) Forest – Mixed Modifier	Mixed
151 A.C.P. Blackwater Stream Floodplain Forest – Forest Modifier	Hardwood
152 Atlantic Coastal Plain Brownwater Stream Floodplain Forest	Hardwood
153 Atlantic Coastal Plain Blackwater River Floodplain Forest	Hardwood
154 Atlantic Coastal Plain Brownwater River Floodplain Forest	Hardwood
161 Central/Southern Interior Large Floodplain – Forest Modifier	Hardwood
164 Southern Piedmont Large Floodplain Forest – Forest Modifier	Hardwood
165 Southern Piedmont Small Floodplain/Riparian Forest	Hardwood
167 Atlantic Coastal Plain Nonriverine Swamp/Wet Hardwood Forest	Hardwood
168 A.C.P. Nonriverine Swamp/Wet HW Forest – Oak Dominant Mod.	Hardwood
173 Atlantic Coastal Plain Clay Based Carolina bay Forested Wetland	Hardwood
174 A.C.P. Northern Basin Swamp/Wet Hardwood Forest	Hardwood
183 A.C.P. Northern Wet Longleaf Pine Savannah/Flatwoods	Natural Pine
253 Central/Southern Appalachian Oak Forest – Xeric	Hardwood

Add Sheet1\$ from Crossblock.xlsx to ArcMap via Arc Catalog

Add New Field to Sheet1\$: “Forest Type” (Text)

Join Sheet1\$ to Ashbiomass\_No\_EC.s.shp (Repeat for all other service areas)

1. VALUE
2. Sheet1\$
3. VALUE
4. Keep All Records

Field Calculator: Forest Type field from Sheet1\$ to Ashbiomass\_No\_EC.s.shp  
(Repeat for all Service Areas)

Remove Join

Calculate Geometry on Area Field

Property: Area

Use Coordinate System of Data Frame

Units: Acres

Perform Statistics on the Area, Record Sum