

Biophysical Settings in the North Zone of the Cherokee National Forest



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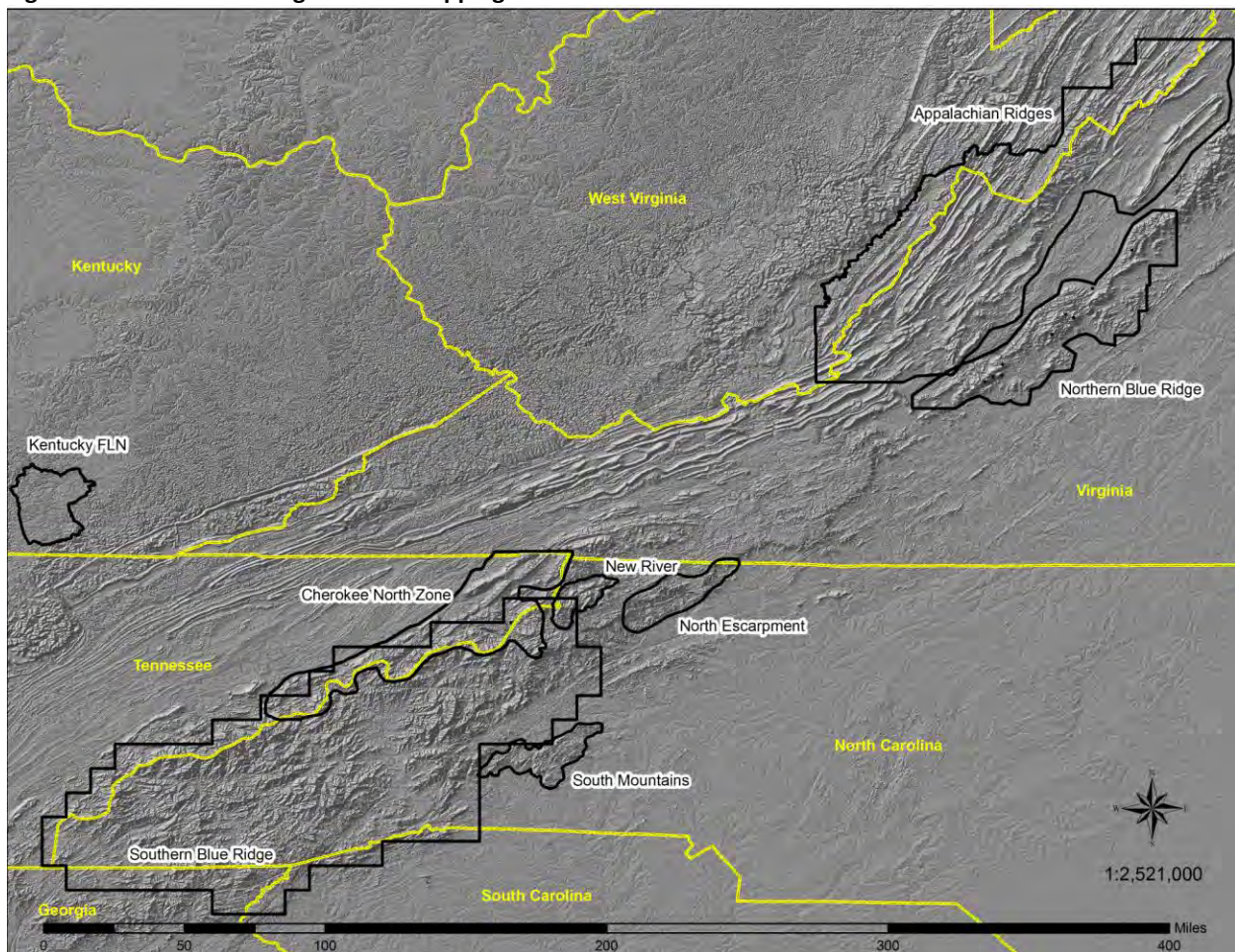
Biophysical Settings (BpS) were mapped in the north zone of the Cherokee National Forest using 18 Ecological Zone models developed from field plots and digital terrain data. These models were aggregated into 12 unique BpS ranging from Southern Appalachian Low-Elevation Pine to Central and Southern Appalachian Spruce-Fir Forest types. Oak dominated BpS accounted for over one-half of the landscape, Cove Forests one-third, and Pine-Oak types 13%. The remaining 5% of the landscape included Northern Hardwood, Spruce-Fir, Riparian systems, Floodplain systems, and Grassy Balds.

INTRODUCTION

Biophysical Settings (BpS) represent the vegetation that may have been dominant on the landscape prior to Euro-American settlement and are based on both the current biophysical environment and an approximation of the historical disturbance regime. Map units are defined by Nature Serve Ecological Systems, a nationally consistent set of mid-scale ecological units (LANDFIRE 2009). Ecological Zones are equivalent to BpS but mapped at a higher resolution and with more vegetation categories. Ecological Zones are units of land that can support a specific plant community or plant community group based upon environmental factors such as temperature, moisture, fertility, and solar radiation that control vegetation distribution. They may or may not represent existing vegetation, but instead, the vegetation that could occur on a site with historical disturbance regimes.

Ecological Zones in the Southern Appalachian Mountains, identified from intensive field data that defined plant communities, were associated with unique environmental variables characterized by digital models (Simon et. al., 2005). These zones were mapped on over 5 million acres by applying logistic regression coefficients to digital terrain models using a geographic information system. In that study, Ecological Zones subdivided the forested landscapes in the Southern Appalachian Mountains into homogeneous units for natural resource planning at a range of scales. Since that study, Ecological Zones have been mapped in Kentucky, in the South Mountains, Northern Escarpment, and New River Fire Learning Network (FLN) landscapes in North Carolina, and in Virginia, centered on the George Washington National Forest (Figure 1). This report documents the methods and results of the most current effort to use Ecological Zone models to map Biophysical Settings in the north zone of the Cherokee National Forest (CNF study area).

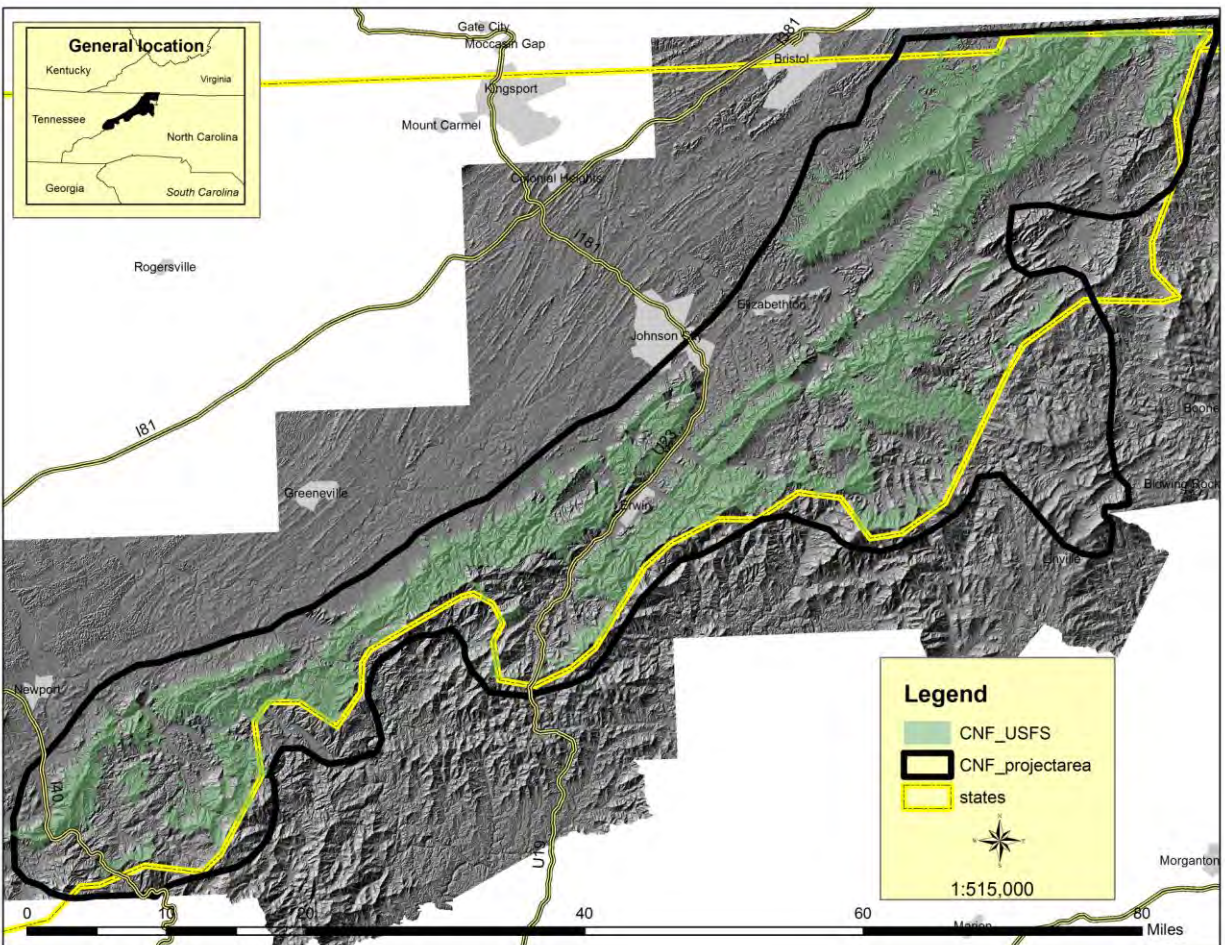
Figure 1. Location of Ecological Zone mapping in the Southeastern U.S.



Ecological Zones - background and uses: Ecological Zones were used in 2001 to define units of land that can support a specific plant community or plant community group based upon environmental and physical factors that control vegetation distribution in North Carolina. Prior to this, comparable environmental models used for ecological classification in the Southeastern U.S. were identified as “plant association predictive models”, “potential vegetation”, or “pre-settlement vegetation”. Specific uses of Ecological Zone models are described in Appendix VI along with a comparison of BpS mapping accuracy using Ecological Zones from the current study and BpS maps developed nationally by LANDFIRE (LANDFIRE 2009).

General description: The CNF study area is approximately 1,022,000 acres in size and is centered on Erwin, Tennessee. The Cherokee National Forest covers approximately 335,700 acres within this area which is split about equally between the Southern Blue Ridge Subsection and the Meta-sedimentary Mountain Subsection. A small portion of the study area is included within the Great Valley of Virginia Subsection which forms its approximate western boundary. The Southern Blue Ridge Subsection is characterized by low rugged mountains, isolated high peaks above 3000 feet, steep slopes, and narrow valleys with numerous rivers and creeks and predominantly metamorphic and igneous geologic types. The Meta-Sedimentary Mountains subsection is characterized by low to moderate (high) relief with ridges generally aligned on a northeast-southwest axis and broad valleys, and predominately sedimentary and metamorphic geologic types. The highest elevations are at Roan High Knob (6,385 feet), Big Bald (5,516 feet) and in the Unaka Mountains (5,180 feet). The lowest elevations are along the French Broad River at the base of Yellow Springs Mountain (1,100 feet) and along the Pigeon River, east of Buzzard Roost (approximately 1,200 feet). Average annual precipitation ranges between 37 to over 80 inches. The closest cities in Tennessee are Erwin, Johnson City, and Newport (Figure 2).

Figure 2. Location of the CNF Study Area



METHODS

“Spatial models built with geographic information systems (GIS) provide a means to interpolate between data points to provide spatially explicit information across broad scales. By accounting for variation in environmental conditions across these broad scales, GIS models can predict the location of ecological communities within a landscape using relationships between vegetation and topography (e.g., Fells 1994, Bolstad et. al. 1998, Phillips 2000) derived from field data” Pearson and Dextraze (2002). The process of interpolating between field data points involves applying coefficients from predictive equations, developed through statistical analyses, to geospatial data that characterize terrain and environmental variables for the target landscape. Care must be taken not to extrapolate to landscapes far away from data points or to landscapes having very different environmental characteristics, therefore, since most of the data was collected on the Cherokee National Forest, Ecological Zone predictions outside of this area are likely less accurate.

A multi-stage process was used to model Ecological Zones in the study area that included: 1) data acquisition, i.e., identifying Ecological Zones at field locations, 2) creating a digital terrain GIS database and extracting environmental data, 3) statistical analysis, 4) spatial modeling, 5) post-processing of digital model outputs, and 6) evaluating the accuracy of Ecological Zone map units.

1) Data acquisition: Approximately 5 weeks, during the 2010 growing season, were spent in the field documenting (through GIS, notes, and photos) the location of plant community types and Ecological Zones that occur across the study area. A laptop computer attached to a Global positioning system (GPS), to enable real-time locational tracking in the field, was used in conjunction with ArcGIS 9.3.1 to document on-site observations of ecological characteristics and to access resource data layers for each site. Sample sites predominantly in forested stands >60 years of age and not recently disturbed, were subjectively selected to represent uniform site conditions, i.e., similar aspect, landform, and species composition. Specifically, these reference sites for plant community types described in the literature for the Southeastern U.S. were targeted for sampling especially if they were in ‘good condition’ and therefore easily recognized. Of equal importance, was the evaluation of where these types occurred, i.e., their pattern on the landscape. ‘Good’ condition plant community types found repeatedly within the same environments were therefore more heavily sampled. Quality control included a nightly review of individual plot photos, Ecological Zone interpretations, and a weekly review of these relationships based upon Nature Serve Ecological Systems (Nature Serve 2010) and LANDFIRE (LANDFIRE 2009) Biophysical Settings Model descriptions.

Ecological Zones were identified at 1,200 sites by evaluating overstory and understory species composition, growth form, stand density, and site factors. Based upon local knowledge and an early review of field observations, field sampling was stratified by elevation to ensure that this ‘major driver’ of plant community distribution in the CNF study area was adequately evaluated (Table 1). In general, elevations between 2,500’ and 4,000’ were under-sampled (especially 3,001’-3500’), and higher and lower elevations were oversampled. Large floodplains, mostly on private land, were assessed from topographic maps and LANDFIRE BpS map units (LANDFIRE 2009) for inclusion as sample points but were not sampled in the field. Of the 1,146 sites visited in the field, 20 plots in Tennessee were sampled in 2008 as part of an accuracy assessment of BpS map units in the Southern Appalachians (Simon 2009), 100 were sampled in North Carolina between 2003 and 2005 in areas adjacent to Tennessee to develop the 1st approximation Ecological Zone mapping in the Southern Appalachians (Simon 2005), and the remaining 1,026 were sampled in the CNF study area in 2010 by forest ecologists and botanists working for Ecological Mapping and Fire Ecology Inc., Asheville, NC, (Steve Simon - owner, and Josh Kelley – independent subcontractor).

Table 1. Land area by elevation class on USFS lands within the CNF study area and Ecological Zone plot sampling intensity within these classes with under-sampled classes highlighted.

elevation class	< 1,500’	1501-2000’	2001-2500’	2501-3000’	3001-3500’	3501-4000’	4001-4500’	4501-5000’	5001-5500’	5501-6000’	> 6000’
% of area	1.4	11.8	23.0	24.0	22.1	12.6	3.4	1.1	0.4	0.1	0.02
% of field sample	2.9	12.6	23.6	20.6	13.2	10.9	9.7	3.8	1.5	1.0	0.2

Ecological Zone classification units are relatively coarse and fairly easy to recognize in the field. In the CNF study area they did not include rare types such as barrens, bogs, cliff-talus, fens, glades, seepage swamps, or small wetlands because the digital data needed to model these unique environments, especially rock outcrops and wetlands, are incomplete or at too coarse a resolution for the objectives of this project. The 19 different Ecological Zones identified in the CNF study area, arranged from wet to xeric moisture regimes, are cross-walked below (Table 2) with Nature Serve Ecological Systems (Nature Serve 2010) and represent the natural plant communities that may have been present during the reference period described in LANDFIRE Biophysical Setting Models (LANDFIRE 2009) for the area. To help in describing the composition of types observed in the field and mapped across the study area, more detailed site and species composition descriptions for Ecological Zones and BpS / Nature Serve Ecological Systems are included in Appendix I. These cross-walks reflect the author’s ongoing refinement of Ecological Zone concepts to better fit local landscapes based upon work between 2008 and 2011, i.e., evaluating Biophysical Setting (BpS) map units in the Southern Appalachians in the Southern Blue Ridge Mountains in North Carolina, South Carolina, Tennessee, and Georgia, and modeling Ecological Zones in the Cumberland Plateau in Kentucky, in North Carolina’s South Mountains and Northern Blue Ridge Escarpment, and in the VA_WVA FLN and George Washington National Forest.

Table 2. Crosswalk between Ecological Zones and BpS / Nature Serve Ecological Systems

Ecological Zone	map code	BpS /NatureServe Ecological System	map code
Grassy Balds	27	Southern Appalachian Shrub and Grass Bald (in part)	27
Spruce	1	Central and Southern Appalachian Spruce-Fir Forest	1
Northern Hardwood Slope	2	Southern Appalachian Northern Hardwood	2
Northern Hardwood Cove	3		
Acidic Cove	4	Southern and Central Appalachian Cove Forest	4
Mixed Oak / Rhododendron	29		
Rich Cove	5		
Riparian Alluvial Forest	6	Central Interior and Appalachian Riparian Systems	6
Riparian Streamside	61		
Large Floodplain	23	Central Interior and Appalachian Floodplain Systems	23
High Elevation Red Oak	8	Central and Southern Appalachian Montane Oak	8
Montane Oak-Hickory (Rich)	24	Southern and Central Appalachian Northern Red Oak-Chestnut Oak (provisional type)	9
Montane Oak-Hickory (Cove)	28		
Montane Oak-Hickory (Slope)	9		
Dry Mesic Oak	13	Southern Appalachian Oak Forest	13
Dry Oak Evergreen Heath	10	Allegheny-Cumberland Dry Oak Forest & Woodland	10
Dry Oak Deciduous Heath	11		
Low Elevation Pine	16	Southern Appalachian Low-Elevation Pine	16
Pine-Oak Heath	18	Southern Appalachian Montane Pine Forest and Woodland	18

2) Creating a digital terrain database: Development of the individual Ecological Zone models began with the creation of a spatial database that describes the study area environment using landform and environmental variables. Site conditions for each field plot were extracted from these 29 landform / environmental models (DTMS) used to characterize these variables in a GIS (Table 3). For statistical analyses, data were stored in a database that included plot number, Ecological Zone, and digital landform / environment values for each plot. The methods used for developing DTMs are described in detail in Appendix III.

Table 3. Environmental variables evaluated for Ecological Zone model inclusion

Aspect (slope direction in degrees)
Aspect (slope direction in cosine of radian degrees)
Curvature of land all directions
Curvature of land in the direction of slope
Curvature of land perpendicular to slope
Distance to stream
Distance to river
Elevation
Distance to carbonate-bearing rocks

Distance to mafic-silicate rocks
 Distance to siliciclastic rocks
 Distance to carbonaceous-sulfidic rocks
 Landform10
 Landform30
 Landform index (from McNab 1993)
 Average annual precipitation
 Local relief
 Difference in elevation from nearest river
 Surface curvature roughness
 Relative slope position – local landscape (from Wilds 1997)
 Relative slope position – mid-level landscape scale
 Slope length
 Slope steepness
 Solar radiation (yearly)
 Solar radiation (growing season)
 Difference in elevation from nearest stream
 Terrain relative moisture index (from Iverson et.al. 1997)
 Terrain shape index (from McNab 1993)
 Valley position

3) Statistical analysis: The relationship between Ecological Zone and environments, described by DTMs, were analyzed and predictive equations developed at this stage of the process. Ecological Zone field locations were used to train habitat suitability models using MAXENT 3.2.1 (Phillips and Dudik 2004). MAXENT (maximum entropy) is a relatively new modeling approach (Phillips, et. al. 2004, 2006) that emphasizes the ecological characteristics of a location where a target species is observed (an Ecological Zone in our case) as the primary focus while presuming nothing about locations where these conditions are not observed. MAXENT, unlike logistic regression, is therefore a “presence only” modeling approach; it used only Ecological Zone presence (the field data points) to estimate individual Ecological Zone models across the study area. MAXENT works by finding the largest spread (maximum entropy) in a geographic dataset of Ecological Zone presences in relation to a set of environmental predictors for these same locations and 100,000+ randomly selected points / pixels within the study area. The MAXENT logistic outputs are continuous estimates of habitat suitability (probability) for each Ecological Zone ranging from zero to one for each pixel within the study area. This process is described in Appendix IV.

4a) Spatial modeling / creating final Ecological Zone and Biophysical Settings map units: To produce a final Ecological Zone (Zone) map, 18 Zone models were merged and each pixel in the study area was first assigned to the Zone having the highest probability for that pixel. In the event of a “tie”, preference was given to the less extensive Zone inherent in the ArcGrid 9.3.1 Merge command preference of order (ESRI 2009). Although MAXENT worked well to predict the distribution of individual Zones, merging the models in this fashion did not always reflect the true field condition because of different model ‘strengths’. To better balance individual Zone model strengths, a ‘sensitivity analysis’ based upon accuracy evaluations (Appendix V), was used to adjust probability levels across the study area for some models. For example, the Pine-Oak Heath Zone had lower probability levels relative to many Zones found at lower- to mid-elevations, especially Dry Oak Evergreen Heath and Dry Oak Deciduous Heath. By increasing Pine-Oak Heath probability levels by .12 across the study area (where Pine-Oak Heath probability values exceeded .55 at elevations between 2,050 and 3,880), the distribution of this Zone and overall accuracy of this type was improved significantly based upon field plots, and local knowledge of this Zone’s distribution.

4b) Mapping Riparian Systems: Riparian systems in the CNF study area were mapped by using a combination of Ecological Zone modeling and stream-side vegetation area modeling. Riparian systems have not been previously mapped using Ecological Zones for several reasons: 1) most riparian systems in the Appalachian Mountains are linear features and occur at a finer scale than the resolution of the ‘square’ pixels used for modeling Ecological

Zones, i.e., the 10 x 10 meter (32.8084 x 32.804 feet) pixel size used in modeling can be significantly larger than the width of riparian areas along linear streams, 2) Ecological Zones are units of land that can support a specific **plant community** or plant community group and because of this emphasis on plants, may not adequately characterize other important factors considered in defining riparian areas such as groundwater, wetlands, and high soil moisture that support riparian dependent species other than plants, and, 3) riparian systems in the Southern Appalachians are most often imbedded within other systems, e.g., Acidic Coves, Rich Coves, Alluvial Forests, and Floodplains. Given these concerns, the following procedure was used for mapping an approximation of riparian systems in the CNF study area:

- a) Use the National Hydrography Dataset (NHD), <http://nhd.usgs.gov/data.html> as a starting point to define streams. Convert streams to raster, and 'drill' them into the existing 10 meter digital elevation model (DEM), i.e., -100 was assigned to the stream raster and this was 'mosaiced' to the DEM. This forces any future stream modeling into the 'ditch' identified by the location of the NHD streams.
- b) Use ArcGIS 9.3.1 (ESRI 2009) hydrology tools and follow stream modeling procedures. Set 13 acres as the threshold value to start a stream; determine stream order (strahler).
- c) Buffer 3rd order streams by 30 feet, 4th and 5th order streams by 100 feet, and 6th, 7th, and 8th order streams by 150 feet; limit output to slopes less than 10%.
- d) Label the result of steps a-c "Riparian_Streamside" Ecological Zone.
- e) Model "Riparian_Alluvial Forest" from field data points using the same procedures for other Zones.
- f) Combine Riparian_Streamside and Riparian_Alluvial Forest to create the BpS 'Central Interior and Appalachian Riparian Systems'.

The estimate of riparian systems using the above procedure is not a substitute for the **Operational Definition of a Riparian Area** described in the Cherokee National Forest Revised Land and Resource Management Plan (USDA 2004b) that states: "*Riparian areas are areas associated with the aquatic ecosystem and that portion of the terrestrial ecosystem that is substantially affected by the presence of surface and groundwater. Riparian areas consist of perennial streams, natural ponds, lakes, wetlands, and adjacent lands with soils, vegetation and landform indicative of high soil moisture or frequent flooding. Riparian areas have variable widths that are determined by ecologically significant boundaries rather than arbitrary distances. The extent of riparian areas is determined on-the-ground using features of soil, landform, and vegetation. No feature is used alone to delineate these ecosystems. Characteristics indicative of these areas are:*

- *Soils – dark colored Entisols, Inceptisols, and Mollisols;*
- *Landform – the 100-year floodplain;*
- *Vegetation – the presence of wetland plants classified as obligates or facultative wetland species as defined by the U.S. Fish and Wildlife Service in the National List of Plants that Occur in Wetlands: Northeast (Region 1). (Reed, P.B., Jr., 1988). "*

5) Post-processing of digital model outputs: Post-processing was used to reduce "data noise" i.e., the number of isolated single 10x10 meter pixels (about 1/40th of an acre in size) within the combined Ecological Zone model area and to improve processing time for converting pixels to polygons. This post-processing included 1 ArcGrid Majority filter command which replaces cells in a raster based on the majority of their contiguous neighboring cells. If there is a desire to produce maps having a defined minimum map unit size, then further processing is recommended using the ESRI "eliminate" command, however this tends to overemphasize the size of major types at the expense of less common types.

6) Assessing the accuracy of Ecological Zone map units: Field plots were used as reference data to evaluate the accuracy of the final Ecological Zone and BpS / Nature Serve Ecological Systems maps. Although this is a biased measure of accuracy because these were the same data used to produce the predictive equations, MAXENT does not force a classification upon a sample plot based upon its location, rather, environmental data from that location is used to model the **entire** landscape with no bias to where a plot is located. Also, using field plots as reference data is a reasonable means of objectively comparing different analysis methods and does indicate how well map composition reflects the plot data composition in these landscapes in comparison to other areas where Ecological Zones have been identified.

RESULTS and DISCUSSION

The location, extent, accuracy, and usefulness of Ecological Zones modeled in the study area were evaluated from the following:

- 1) Field observations,
- 2) Relative importance of environmental factors in predicting Ecological Zones (Tables 4-6),
- 3) Accuracy of map units relative to field sample plot information (Table 7 and Appendix V), and the
- 4) Location and extent of Ecological Zones and BpS / Nature Serve Ecological Systems based on acreage of map units (Tables 8-9), and both broad-scale displays and those relative to topography (Figures 3-7).

1) Field Observations: The most common Ecological Zones observed in the CNF study area were those that support oak-dominated plant communities, especially those on sub-mesic sites, i.e. Montane Oak and xeric to dry sites, i.e., Dry Oak. Many of the Montane Oak sites were dominated by Tulip Poplar, although dominance by Northern Red Oak and Chestnut Oak, the more long-term occupants, was also common. Dry Oak sites were dominated by Chestnut Oak and had two distinct stand and understory conditions; forests to woodlands with a dense mountain laurel understory most often associated with Pine-Oak heath at mid elevations (more common), and woodlands to forests with a dense to sparse huckleberry and blueberry understory and only occasional mountain laurel at mostly mid to lower elevations.

The distribution of plant communities was strongly tied to elevation. Above 4,000' (and slightly lower than this in the most northern portion of study area) Northern Hardwood forests dominated all but the highest peaks (mostly above 4,500-5,000') where Spruce forests occurred. At the lowest elevations (below 2,000'), Ecological Zones that support Low Elevation Pine and Dry-Mesic Oak Forests were dominant along with some Dry Oak. Dry-Mesic oak sites were dominated by white oak with a sparse understory and were situated in slightly concave portions of the landscape or associated with broader floodplains on private land. The Low Elevation Pine type formed distinct patterns on broad low ridges especially on meta-sediments where occasional shortleaf pine was observed. However, most Low Elevation Pine sites have been highly altered by agriculture and past timber harvesting, and their historic structure and composition was difficult to determine. These sites looked similar to extensive Shortleaf pine types observed in Kentucky, North Carolina, and Georgia, and to what has been described historically in lower elevation forests in Virginia. They therefore warranted recognition and fit well with the description for the Nature Serve Southern Appalachian Low Elevation Pine Ecological System.

Between 2,000' and 3,500' the diversity and complexity of Ecological Zones increased. The distinctive and repeated pattern of alternating Pine-Oak Heath and Oak Ecological Zones seen across extensive landscapes in Virginia's Ridge and Valley was more subtle here in the Blue Ridge. But, Pine-Oak Heath still formed unique patterns characteristic of their xeric and hot environments, i.e. upper, convex, west- to south-facing steep slopes. Consequently, the largest stand of Table Mountain Pine – Chestnut Oak (Pine-Oak Heath) was observed on Short Mountain (pictured on the cover page of this report), the leading edge of the first series of ridges lying west of the Great Valley in the southern portion of the study area. Equally distinctive were plant communities in the Mixed-Oak / Rhododendron Ecological Zone that occur on very steep north-facing slopes associated with Acidic Coves found in adjacent drainages. This type is most extensive in the Holston Mountains but occurs throughout the CNF study area and is a dominant type in high precipitation areas along the eastern escarpment in North Carolina, e.g. from Highlands, NC north to the Virginia border.

The Acidic Cove Ecological System occurred across all elevations on highly shaded (protected) sites especially along perennial streams, forming a distinctive drainage pattern imbedded within adjacent more upland types. Rich Coves appeared less common except on or near limestone geology at lower elevations adjacent to private lands. Most of these areas were likely altered in the past due to their high site productivity and gentle slopes and were therefore hard to recognize and classify into an Ecological Zone.

Photo examples for some of these types are included in Appendix II.

2) Relative importance of environmental factors: The relationship between plant community types and the environments in which they occur (the Ecological Zone) can be evaluated by examining the relative importance of environmental variables found by MAXENT to be the best predictors of Ecological Zone location and by assessing the mean values for each variable (Tables 4-6). Some of these relationships are fairly straight-forward, others are not. For example, MAXENT identifies elevation as the primary or secondary environmental factor that defines the distribution of Grassy Balds, Spruce, Northern Hardwood, and High Elevation Red Oak which have the highest mean elevation based upon plot locations, and for Dry-Mesic Oak found at lower elevations (Table 6). Relative slope position is an important variable in defining all the cove-oriented types (Northern Hardwood Cove, Rich Cove, Acidic Cove, Montane Oak cove), i.e., they are always found on lower slopes. In addition, environmental factors, singly or in combination, reflect well those conditions found for types occurring in more unique environments such as Pine-Oak Heath that occurs on convex, upper steep slopes, with a south to west aspect which is indicated by the strong relationship to relief, relative slope position, TSI, and aspect variables. Similarly, slope steepness and valley position are important variables that define the unique Floodplain and Riparian Systems; however, they appear to mask these systems strong relationship to stream distance.

Table 4: Percent contribution of variables used in Ecological Zone models in the CNF study area.

EZONE Code DTM	Gbald	SF	NhS	NhC	Acov	Orho	Rcov	Ripar.	Flood	Hero	MonR	MonS	MonC	Dmok	DryE	DryD	LowP	Poh
Asp_r			-	-	-		2		-	2		-	-	2	-	-	4	4
Asp_c		-	4	+6	2	+15	4	2	-	-		2	2	1	1	+6	2	-
Curve				-	1	-	-	3				2	3	2		-	-	-
Curpl		-	-	-	-	-	2	-				-	-	-	-	-	-	-
Curpr			-	-	-	-	-	-				-	-	-	1	-	-	-
Dstrm	+60	-	1		-12	3	1	-	-	+7	+12	3	-	-	-	-	1	2
Driver		-	3	30	8	4	1	-	-	2		5	-	7	13	2	-	4
Elev	+18	+63 ^{1/2}	+23	+23	-	-	2	-10	2	+13	2	12	-12	-17	3	-6	-9	1
Geo1	2	1	2	2	11	2	-8		2	-		15	13	7	3	-19	1	-
Geo2	2	3	2	-	4	+23	7		-	2	+31	13	20	16	+16	13	8	+12
Geo3		3	-	-	-	-	1	4		5	-	4	1	3	3	-5	-7	2
Geo46	-	4	3	+17	5		3	1	-	-	1	+10	-10	-9	-5	3	-20	2
Lfi	1		-	-	-	-	3			-		2	-	4	-	-	-	4
Lfm10			-	-	-	-	-	+8	-	-	-	2	-	-	1	1	-	4
Lfm30		-		1	2	-	2	3	-			-	-	-	-	-	-	1
Prec		+6	-	-	3	-	4	-	-	-	-	2	3	---	-	7	-13	13
Relief	-	2	3	2	9	+8	+20	-	1	-		5	+5	12	23	-	4	+22
Rivdiff	+10	+15	+51	-	-	+24	2	-	-50	+43	+13	15	4	-	1	5	4	-
Rough	-		1	-	-	-	-		-	-		1	-	4	-	1	--	-
Rsp1	-	- ^{2/}	-	+11	+12	-	+7		-		2	-	+16	2	2	1	-	-8
Rsp2		-	-	-	+12	6	+12	+1	-	-5	1		1	2	4	3	-11	-
Slength	-		-	3	-	-	2	4	4			1	-	-	-	3	-	-
Slope				2	-	-	-	-21	-29		1	1	2	1	4	-	-6	
Solgr			-	1	2	-8	-			-							2	4
Solgw	-				-	4				2		-		3	2		-	
Stmdiff	-	-	3	-	-8	-	-		-	+12		2	+5	2	16	3	3	+4
Trmi		-	-	-	-		3	-				-	-	-	-	-	-	-
Tsi		-	-	-	3	-	-11		2	-	-	-	-		2	-	2	+9
Vpos	-5	-	1	-	1	-	2	+41	+8	4	-33	2	2	2	-	-	1	-
n	11	36	33	34	190	25	87	13	54	48	11	144	70	139	71	28	47	157

^{1/} the + or - sign that precedes the variable value (for variables having at least a 5% contribution) indicates the relational direction of the variable. For example, elevation in Spruce-fir (SF) is +63 which indicates that as elevation increases, so does the 'gain' in the model prediction for this type. No sign indicates either that the gain is not linear or that there is confusion in interpreting the relationship. ^{2/} less than 1% but included in the prediction equation, blank indicates a variable that was not included in the prediction equation.

These relationships were all fairly obvious in the field and from viewing digital terrain data in comparison to individual Ecological Zone models. What was not obvious in the field was the influence of geology that MAXENT revealed and why multiple rock types contribute information for so many Zones. This relationship, however, is likely due to the fact that the influence of rock types was analyzed as a continuous "distance to" variable and not a class variable. Also, relationships between Ecological Zones and environmental variables get confusing because

many variables used in this analysis provide redundant information and are therefore correlated. Elevation, relative slope position, distance to stream, and solar radiation, for example, can all have an influence on temperature and moisture. Although MAXENT ‘finds’ the variable or combination of variables that contribute most to predicting each type, care must be taken in interpreting these relationships because of the complexity of variable interactions and the statistics used in ‘fitting’ models.

Table 5. Mean values for environmental variables that describe temperature, fertility, moisture, and insolation gradients within BpS / Ecological Systems based on plot locations (some values are rounded).

map code	BpS / Ecological System	Temp.	Fertility (Distance to Geologic Type, in 1,000s feet) ^{1/}				Moisture, Temperature, Radiant Energy, and Fertility ^{2/}						
		ELEV. ft.	GEO1	GEO2	GEO3	GEO4	SLOPE	VPOS	RPOS	ASP	SOL	TSI	SDIF
27	Balds	5,780	46.7	0	9.7	46.7	13	2	4	.08	16.3	4.3	660
1	Spruce-Fir	5,135	30.0	6.9	4.5	24.9	37	20	19	.06	14.8	4.4	270
2	Northern Hardwood	4,410	31.9	10.1	2.0	27.1	46	32	35	.45	12.8	-3.2	220
4	Cove Forest	2,790	13.2	36.4	0.5	8.4	43	53	64	-.18	12.7	-10.1	70
6	Riparian Systems	1,590	5.5	42.3	1.3	1.7	5	90	70	-.28	13.4	-8.2	5
8	Montane Oak	4,320	16.8	26.7	0.07	8.8	31	15	7	-.08	15.2	12.0	420
9	Montane Oak-Hickory	3,165	13.6	46.1	0.5	8.6	36	38	35	-.16	13.5	-1.2	150
13	Southern Appalachian Oak	2,240	6.9	54.8	1.5	1.4	34	47	37	-.01	13.6	-2.8	110
10	Dry Oak	2,610	4.5	53.1	0.3	1.6	43	40	19	.01	13.3	7.2	185
16	Low Elevation Pine	1,990	3.9	42.7	0.5	1.1	24	47	18	-.07	14.0	6.6	260
18	Montane Pine	2,680	6.2	44.7	0.2	2.5	46	35	11	-.32	14.2	11.0	257
23	Floodplain Systems	1,610	1.4	57.7	6.6	1.8	2	91	37	.30	13.9	-.03	4

^{1/}Geo1 = Carbonate-bearing rock, Geo2 = Mafic-silicate rock, Geo3 = Siliciclastic rock, Geo4 = Carbonaceous-sulfidic rock. ^{2/}Slope in percent, VPOS = valley position (100 = valley bottom, 0 = major ridge top), RPOS = relative slope position (100 = bottom of slope, 0 = top of secondary or major ridge), ASP = cosine of aspect (smaller = more south, larger = more north), SOL = solar radiation (unit watt hours per square meter in millions), TSI = terrain shape index (land surface shape, negative numbers are degree of concavity, positive numbers are degree of convexity), = SDIF = difference in elevation above the nearest stream (ft).

The importance of environmental and landform factors that control Ecological Zone distribution in the study area can also be evaluated by looking at those variables that were used most often in the models (Table 6). Elevation, the distance to mafic-silicate rocks, and the difference in elevation from the nearest river had at least a 5% contribution in more models than all other variables. Three of the top six variables were associated with geology, and although many of the relationships were “the further away from a rock type the greater the gain in model prediction”, is still an indication of the effect that fertility has on plant community distribution in the study area. Local relief, average annual precipitation, and valley position, within the top 13 variables used, reflect the broader scale influence of landscape configuration and topography, so important in the area, while slope steepness, relative slope position, terrain shape index, and distance to the nearest stream helped to define finer-scale variation in Ecological Zone distribution. These finer scale variables along with elevation have a strong effect on temperature and moisture regimes. On the other hand, solar radiation, terrain relative moisture index, and most surface curvature variables used to describe the finest-scale land surface configuration, made little contribution to the models. This is probably due to redundancy within the environmental variable set, i.e., other variables were better able to explain these same factors. For example, slope steepness, relative slope position, and terrain shape index individually were perhaps better able to explain moisture regime than terrain relative moisture index which combines these same variables into one value (Appendix III).

Table 6. Importance of environmental variables in predicting Ecological Zone occurrence in the CNF study area

Environmental variable	% of models
Elevation	61
Distance to mafic-silicate rocks	50
Difference in elevation from the nearest river	50
Local relief	44
Distance to carbonaceous-sulfidic rocks	39
Distance to carbonate-bearing rocks	33
Relative slope position (broader scale)	28
Relative slope position (finer scale)	28
Distance to closest river	28

Difference in elevation from the nearest stream	22
Distance to closest stream	22
Average annual precipitation	22
Valley position	22
Aspect cosine	17
Slope steepness	17
Terrain shape index	11
Distance to siliciclastic rocks	11
Landform10 (surface shape 10x10 neighborhood)	6
Solar radiation during the entire year	6
Landform30 (surface shape 30x30 neighborhood)	-
Landform index	-
Aspect in degrees	-
Surface curvature (all directions)	-
Surface curvature perpendicular to slope direction	-
Surface curvature in the direction of slope	-
Surface curvature roughness	-
Slope length	-
Solar radiation during the growing season	-
Terrain relative moisture index	-

^{1/} percent of all models where variable made at least a 5% contribution to the prediction gain

3) Map unit accuracy: The following discussion is based on intersecting 1,200 plots with the Ecological Zone and BpS / Nature Serve Ecological Systems maps in the CNF study area. Details of this accuracy evaluation are included in Appendix V. Overall accuracy within the study area for Ecological Zones is 81% and for BpS / Nature Serve Ecological Systems map units is 86%. This compares favorably with other Ecological Zone modeling within the Southern Blue Ridge and in the Kentucky FLN (Table 7). More Ecological Zones were modeled in the CNF study area than in other areas of similar size; this allowed for a finer breakdown of the Dry Oak, Montane Oak, and Acidic Cove types. Most plots misclassified by type occur in similar Ecological Zones (Appendix V).

Grassy Balds, Montane Oak (rich), and Large Floodplains, had the highest accuracy (96-100%) and 7 other types (Spruce-fir, Northern Hardwood Slope, Acidic Cove, Riparian_Alluvial Forest, Montane Oak Slope, Low Elevation Pine, and Pine-Oak Heath) exceeded 81% accuracy, the average for all types. The Montane Oak (Cove) zone had the poorest accuracy (66%) of all types and was confused primarily with other types associated with concave landscape positions such as Acidic Cove, Rich Cove, and Dry-Mesic Oak, however, it was also confused with Mixed Oak / Rhododendron that does not occur in concave positions. The remaining 5 types had accuracy levels between 71% and 76% (Northern Hardwood Cove, Mixed Oak / Rhododendron, Rich Cove, Dry Oak Evergreen Heath, and Dry Oak Deciduous Heath).

Table 7: Comparison of Ecological Zone accuracy across the CNF, GW, Kentucky FLN, and the Southern Blue Ridge (SBR) study areas based on re-intersection of field data with modeled map units

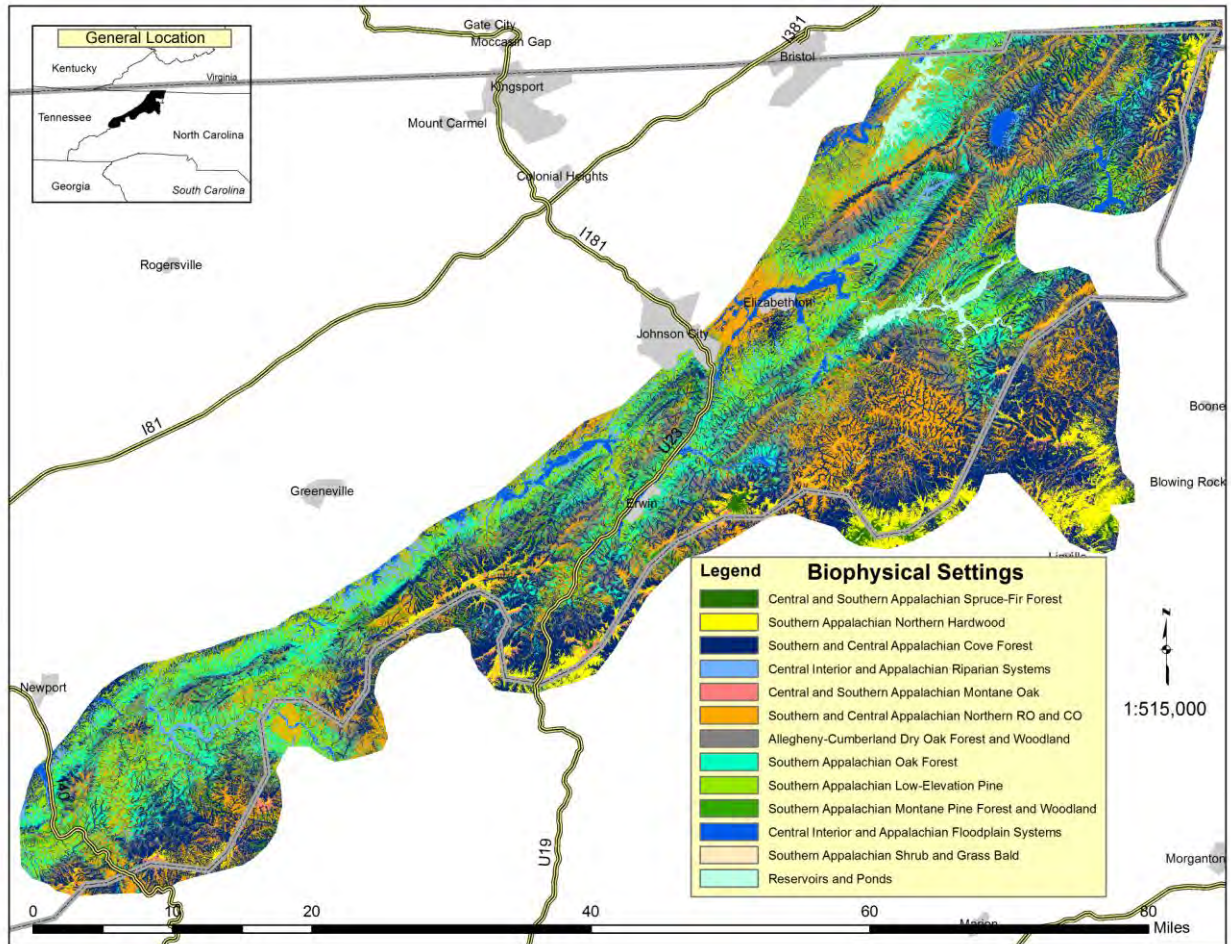
Ecological Zone	Cherokee NF North Zone	George Washington NF		Kentucky FLN	Northern Escarp. SBR	South Mts. SBR	Other SBR
		Appalachian Ridges	Blue Ridge				
Size of area (acres-rounded)	1,021,600	3,761,700	1,026,200	278,000	233,000	217,000	5,600,000
	Percent correct						
Grassy Bald	100	-	-	-	-	-	30
Heath Bald	-	-	-	-	-	-	19
Spruce-Fir	86	89	-	-	-	-	53
N. Hardwood Slope	88	86	81	-	-	-	70
N. Hardwood Cove	71	89	100	-	-	-	23
Acidic Cove	84	83	90	87	93	63	66
Spicebush Cove	-	-	71	-	-	-	-
Rich Cove ^{1/}	76	82	82	92	100	-	51
Alluvial Forest	92	67	94	81	91	100	56
Floodplain	100	78	-	-	-	-	-
High Elevation Red Oak	79	86	84	-	73	-	75
Montane Oak Rich	100	77	68	-	-	-	-
Montane Oak Cove	66	79	-	-	-	-	-
Montane Oak Slope ^{2/}	85	72	80	-	83	67	43
Colluvial Forest	-	70	-	-	-	-	-
Dry-Mesic Oak	78	84	90	77	73	62	27
Dry-Mesic Calcareous Forest	-	81	-	-	-	-	-
Dry Oak Evergreen Heath ^{3/}	75	66	73	83	-	59	27
Dry Oak Deciduous Heath	75	65	71	-	-	-	-
Mixed Oak / Rhododendron	76	-	-	-	83	-	36
Low Elevation Pine ^{4/}	85	90	91	80	-	100	66
Shortleaf P-O Heath	-	-	-	-	-	-	58
Pine-Oak Heath (eastside)	-	82	-	-	-	-	-
Pine-Oak Heath (westside) ^{5/}	82	77	83	-	93	-	58
Pine-Oak Heath (ridges) ^{6/}	-	59	-	79	-	-	-
Pine-Oak Shale Woodland	-	89	-	-	-	-	-
Shale Barren	-	83	-	-	-	-	-
Alkaline Woodland	-	92	-	-	-	-	-
Mafic Glade and Barren	-	-	91	-	-	-	-
OVERALL	81	77	80	82	86	64	52
Most fire-adapted group	94	97	98	95	98	89	83

^{1/} Mesic Forest in Kentucky, ^{2/} typical Montane_submesic Oak ^{3/} Chestnut Oak in SBR, ^{4/} Shortleaf Pine-Oak in SBR, ^{5/} typical POH, ^{6/} "Xeric Pine-Oak" in Kentucky.

4) Ecological Zone location and extent: In general, the model based on MAXENT appears to represent both the location and extent of predicted Ecological Zones observed in the field. An overall-study area view of Biophysical Settings (Figure 3), the aggregation of Ecological Zones based on the crosswalk between these types (Table 2 and Appendix I), shows Southern and Central Appalachian Cove Forest (dark blue) and Southern and Central Appalachian Red-Oak-Chestnut Oak (orange) as the dominant types on the landscape covering about 318,000 acres and 166,000 acres respectively (Table 9). In the southern portion of the study area near Newport, a mosaic of Southern Appalachian Oak Forest (bluish green) and Southern Appalachian Low-Elevation Pine (light green) dominates the landscape. Southern Appalachian Northern Hardwood (yellow), Central and Southern Appalachian Spruce-Fir Forest (dark green), and Central Interior and Appalachian Floodplain Systems (blue) are also distinct types that are closely related to environmental / topographic factors and correspond well to their distributions

observed in the field (Figures 3-5). Southern Appalachian Montane Pine Forest and Woodlands (green), appear as small linear features in distinct patterns associated with a variety of other types and are difficult to distinguish at smaller scales, i.e., in Figure 3 (1:515,000 scale). They are more evident in Figures 5-7 where the largest Southern Appalachian Montane Pine Forest and Woodland (Pine-Oak Heath Ecological Zone) observed in the field at Short Mountain was also modeled as the largest map unit for this type on the Cherokee National Forest (Figure 5).

Figure 3: Biophysical Settings in the CNF Study Area



At larger scales (< 1:24,000), the relationship between topography and Ecological Zones is more evident as is the association between Ecological Zones and Biophysical Settings (Figures 6-7). First of all, the Pine-Oak Heath Ecological Zone is modeled on south and south-west facing, convex, upper slopes just as it was observed in the field. What is more prominent on the landscape is the extent of Southern and Central Appalachian Cove Forests (dark blue) when Acidic Coves (dark blue) are combined with Mixed Oak / Rhododendron (light purple). Both of these Zones occur in highly 'protected' environments (steep north-facing slopes or adjacent to lower slope streams) and have been included by Nature Serve, and the NC and VA Natural Heritage Programs (Nature Serve 2010, Schafale and Weakley 2005, Fleming and Patterson 2010) into one type. The Mixed Oak / Rhododendron Ecological Zone is oak dominated and therefore does not fit well with 'Cove' plant communities that support more 'mixed-mesophytic species'. This Ecological Zone could represent environmental conditions more influenced by fire suppression that have expanded mesophytic conditions more favorable to rhododendron well upslope from coves. Currently, this appears to be the best fit for this Ecological Zone. These two Ecological Zones comprise approximately 14% and 6% of the Cherokee National Forest landscape, respectively, and when combined with the Rich Cove Ecological Zone, account for about 30% of the area defined as Southern and Central Appalachian Cove Forest BpS.

Figure 4: Biophysical Settings at Unicoi Mountain, TN

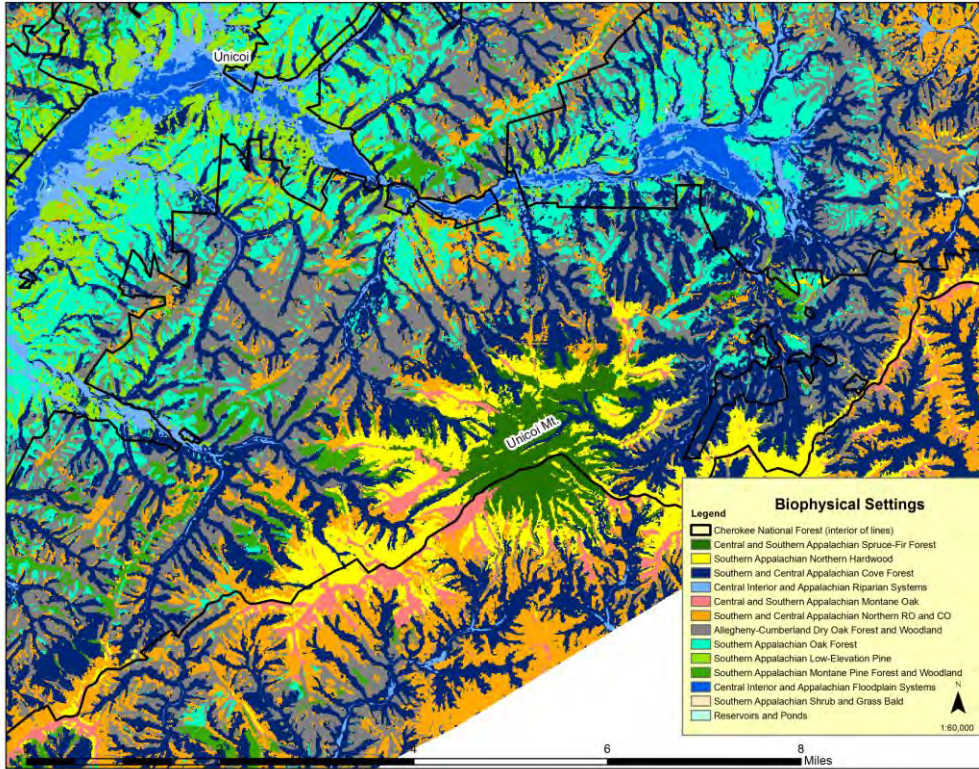


Figure 5: Biophysical Settings around Greene Mountain, TN

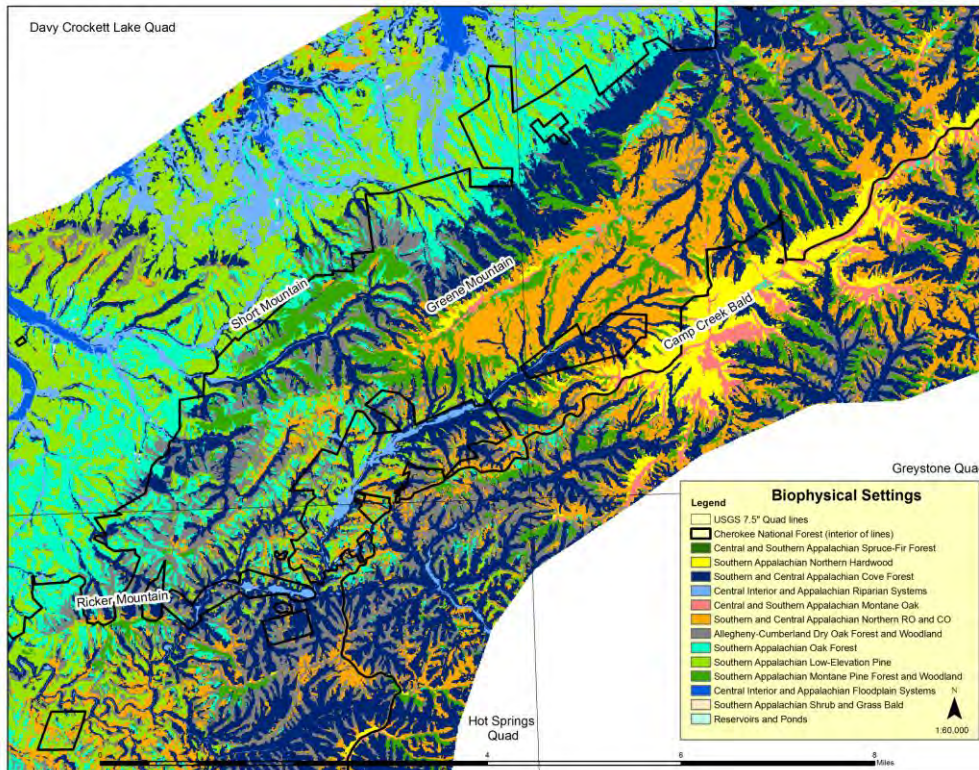


Table 8. Extent of Ecological Zones in the study area and on CNF ownership

map code	Ecological Zones	Total Project area (acres)	% of total	accuracy allplots	CNF acres	% of total
27	Grassy bald	622	0.1	100%	63	0.02
1	Spruce	7,215	0.7	86%	2,234	0.7
2	Northern Hardwood Slope	26,142	2.6	88%	8,141	2.4
3	Northern Hardwood Cove	21,533	2.1	71%	2,448	0.7
4	Acidic Cove	142,143	14.0	84%	46,915	14.0
29	Mixed oak / Rhododendron	33,583	3.3	76%	20,989	6.3
5	Rich Cove	142,121	14.0	76%	31,302	9.3
6	Riparian Alluvial Forest	28,289	2.8	85%	815	0.2
61	Riparian Streamside	12,255	1.2	-- ¹	1,303	0.4
23	Large Floodplains	22,488	2.2	96%	453	0.1
98	Reservoirs and Ponds	13,410	1.3	-- ¹	117	0.03
8	High Elevation Red Oak	13,920	1.4	79%	4,021	1.2
24	Montane Oak-Hickory (rich)	424	0.0	100%	393	0.1
28	Montane Oak-Hickory Cove	69,399	6.8	66%	20,534	6.1
9	Montane Oak-Hickory Slope	95,965	9.4	85%	45,068	13.4
13	Dry Mesic Oak	108,470	10.5	78%	40,579	12.1
10	Dry Oak Evergreen Heath	101,036	9.9	75%	55,365	16.5
11	Dry Oak Deciduous Heath	22,108	2.2	75%	9,495	2.8
16	Low Elevation Pine	126,948	12.4	85%	23,888	7.1
18	Pine-Oak Heath	33,505	3.3	82%	21,583	6.4
	TOTAL	1,021,579	100.0	81%	335,706	100.0

^{1/} From National Hydrography Dataset, <http://nhd.usgs.gov/>

Table 9. Extent of BpS / Ecological Systems in the study area and on CNF ownership

map code	BpS / NatureServe Ecological System	Total acres	% of total	USFS acres	% of total
27	Southern Appalachian Grass and Shrub Bald	622	0.1	63	0.0
1	Central and Southern Appalachian Spruce-Fir Forest	7,215	0.7	2,234	0.7
2	Southern Appalachian Northern Hardwood	47,675	4.7	10,589	3.1
4	Southern and Central Appalachian Cove Forest	317,847	31.1	99,206	29.6
6	Central Interior and Appalachian Riparian Systems	40,544	4.0	2,118	0.6
23	Central Interior and Appalachian Floodplain Systems	22,488	2.2	453	0.1
98	Reservoirs and Ponds	13,410	1.3	117	0.03
8	Central and Southern Appalachian Montane Oak	13,920	1.4	4,021	1.2
9	Southern and Central Appalachian Red Oak-Chestnut Oak	165,788	16.2	65,995	19.6
13	Southern Appalachian Oak Forest	108,470	10.6	40,579	12.1
10	Allegheny-Cumberland Dry Oak Forest and Woodland	123,144	12.1	64,860	19.3
16	Southern Appalachian Low-Elevation Pine	126,948	12.4	23,888	7.1
18	Southern Appalachian Montane Pine Forest and Woodlands	33,505	3.3	21,583	6.4
	TOTAL	1,021,579	100.0	335,706	100.0

Finally, another very noticeable landscape-level mapping change due to aggregating Ecological Zones into BpS is within the Montane Oak type (Figures 6-7). Along broad, higher elevation ridges, the Montane Oak-Hickory Rich (light red) Ecological Zone is 'lumped' with the Southern and Central Appalachian Northern Red Oak-Chestnut Oak BpS (orange), but even more distinctive is the aggregation of Montane Oak-Hickory Coves (dark brown-red) that are oriented along the mid to upper slopes of these mid-elevation drainages into this same BpS (orange).

Figure 6: Ecological Zones around Holston High Point, TN

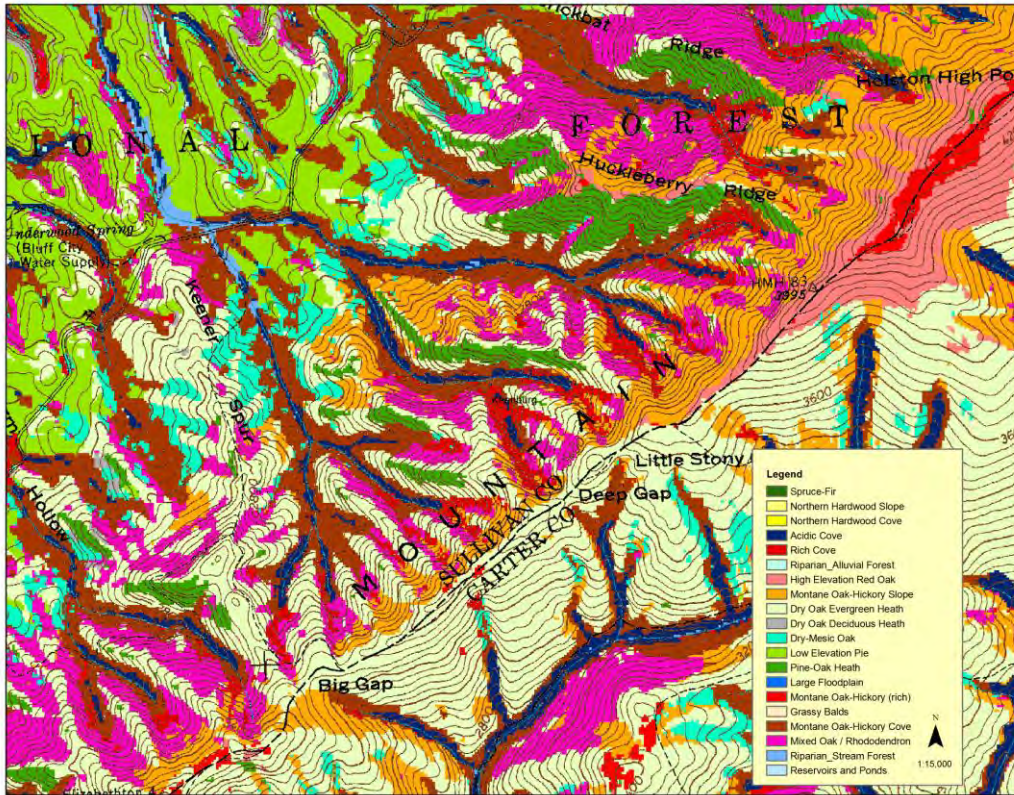
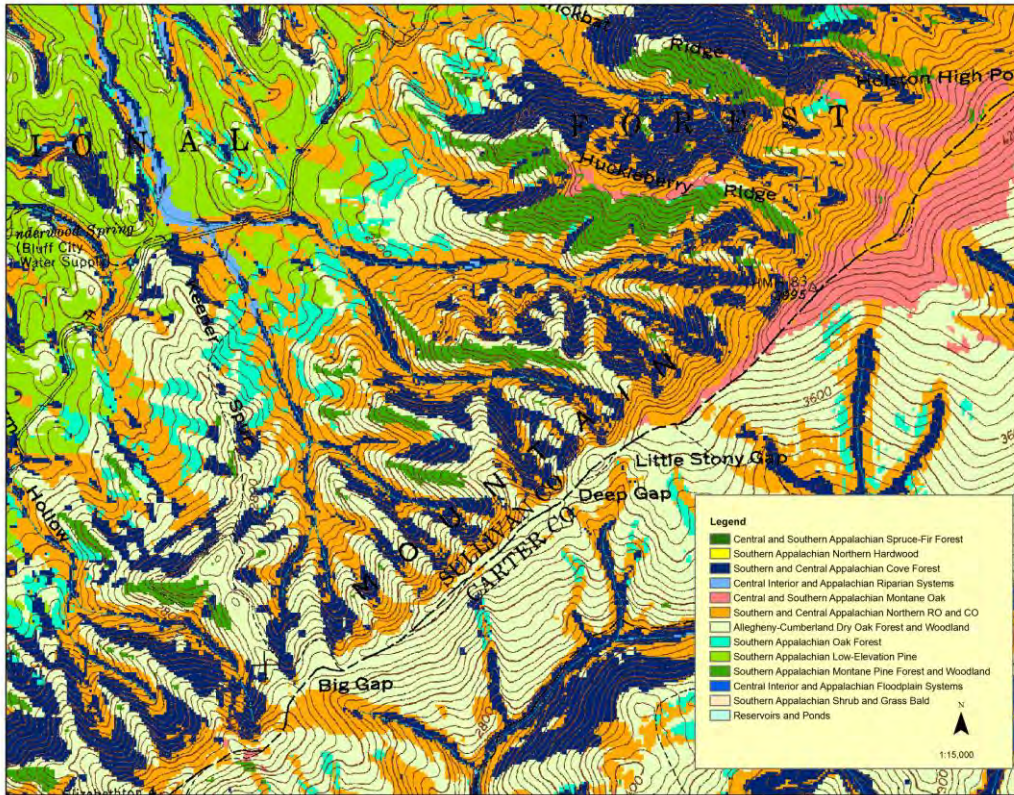


Figure 7: Biophysical Settings around Holston High Point, TN



Improving Map Unit Accuracy

The accuracy of the 1st approximation Ecological Zone map is good in comparison to other similar Ecological Zone modeling efforts in the Southeastern U.S. (Table 7), but can be improved. Model accuracy is affected by several major factors: 1) plot location accuracy, 2) Ecological Zone identification, 3) DTM accuracy, and 4) modeling methods.

1) Plot location accuracy: Incorrect plot locations from poor GPS readings or inaccurate topographic map interpretations can lead to erroneous data and therefore models that do not reflect reality. Furthermore 'ecotone' samples can and may have contributed to modeling errors in the study area. This reality was confirmed by results of the post-processing procedures used to reduce data noise and produce a cleaner product in 2009 within the VA-WVA FLN. Using just 3 majority filters of the 'raw' model, 52 of the 1,321 reference plots (about 4%), shifted into different Ecological Zone map units; 17 of these moved to incorrect classes and thus reduced the overall accuracy by about 2% points. The majority filter command merely replaces individual 1/40th acre cells in a grid based on the majority of their contiguous neighboring cells, a change that would only occur on the edges or interior of a type. These changes observed in plot accuracy indicate the close proximity of these 'shifted' plots to the narrow moisture-temperature-fertility gradients that occur between many Ecological Zones, i.e. the ecotone which is certainly largest around sample sites near ecotones. Although difficult to capture in GIS modeling, this variability in environmental conditions over short distances is common in the CNF study area where numerous Ecological Zones may be encountered while traversing along only a 100 meter transect in highly dissected landscapes.

2) Ecological Zone field identification: The identification of reference condition (the Ecological Zone) at individual site locations is of equal or greater importance as plot location accuracy in developing a truer representation of landscapes that may have existed prior to Euro-American settlement. Ecological Zone models are evaluated from a sample of plot locations in a study area and from the interpretation of data collected from these areas that uses existing vegetation and often only remnant site indicator species. Incorrect identification of the Ecological Zone can therefore have a major impact on the outcome of map unit extent and accuracy especially for those zones that are hard to recognize because of past disturbance or because of lack of experience in the area by the observer. It should also be noted that these field identification 'errors' are likely accounted for by a statistical procedure that evaluates environmental conditions at multiple plots (often in the hundreds), and therefore the models may better represent Ecological Zones than the field evaluation. This is something to consider when analyzing the accuracy assessment matrix (Appendix V).

3) DTM accuracy: The accuracy of DTMs used to reflect temperature, moisture, and fertility gradients, especially geologic / lithologic type in the study area, has a significant impact on Ecological Zone map unit accuracy. Lithology in the study area influences soil fertility, (also slope and aspect), thus having a major influence on the distribution of Ecological Zones across the complex background of temperature and moisture regimes described by other DTMs. Although lithologic map units were aggregated into just four distinct groups, there were still differences between these grouped map units across State lines; not only map line differences but also map unit labeling differences. An improvement in map unit accuracy could be possible by correlating lithologic map units among the State-wide maps. Also, geologic map unit resolution is not fine enough to identify rock types at scales that some Ecological Zones occur, such as Montane Oak-Hickory (rich) that is closely aligned with mafic rocks not often depicted by State-wide geology maps.

4) Modeling methods. The 1st approximation Ecological Zones are based on merging 18 individual Ecological Zone models into one map based upon the zone having the highest probability of occurrence. Although this seems to be a reasonable approach, other techniques might be evaluated. For example, choosing a threshold probability value for each type that maximizes the correct plot inclusion and minimizes inclusion of plots representing other types could be used to map the location of individual zones having their greatest probability of occurrence. This coverage could then be merged with the 1st approximation to fill areas where these conditions are not met.

Literature cited:

- Bolstad, P. V., Swank, W. and Vose, J. 1998. Predicting Southern Appalachian overstory vegetation with digital terrain data. *Landscape Ecology* 13:271-283.
- DOD - Department of Defense, Camp Lejeune Marine Corp Base, 2006. Integrated Natural Resource Management Plan, Camp Lejeune, North Carolina. www.lejeune.usmc.mil/emd/INRMP/INRMP
- ECOMAP. 1993. National hierarchical framework of ecological units. Washington, DC: U.S. Department of Agriculture, Forest Service. 20 pg.
- ESRI, 2009. Environmental Systems Research Institute, Inc. Redland CA.
- Fels, J. E. 1994. Modeling and mapping potential vegetation using digital terrain data. Ph.D. Dissertation, North Carolina.
- Fels, J. E. 1994. Modeling and mapping potential vegetation using digital terrain data. Ph.D. Dissertation, North Carolina State University; Raleigh, North Carolina.
- Fleming, Gary P. and Karen D. Patterson. 2010. Natural Communities of Virginia: Ecological Groups and Community Types. Natural Heritage Technical Report 10-11. Virginia Department of Conservation and Recreation, Division of Natural Heritage, Richmond, Virginia. 35 pages.
- Frost, C.C. 1996. Presettlement vegetation and natural fire regimes of the Croatan National Forest. North Carolina Department of Agriculture, Plant Conservation Program. 128 pp.
- Iverson, L. R., M. E. Dale, C. T. Scott, and A. Prasad. 1997. A GIS-derived integrated moisture index to predict forest composition and productivity of Ohio forests (U. S. A.). *Landscape Ecology* 12:331-348.
- LANDFIRE. **URL:** <http://www.landfire.gov/NationalProductDescriptions20.php> - 43KB - 29 Jan 2009
- McNab, W. H. 1991. Predicting forest type in Bent Creek Experimental Forest from topographic variables. In: Coleman, Sandra S.; Neary, Daniel G., comps. Eds. Proceedings of the sixth biennial southern silvicultural research conference; 1990 October 30-November 1: Memphis, TN. Gen. Tech. Rep. SE-70. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 496-504. (2 vols.)
- McNab, W. H. 1993. A topographic index to quantify the effect of mesoscale landform on site productivity. *Canadian Journal of Forest Research* 23:1100-1107.
- McNab, W. Henry; Avers, Peter E., comps. 1994 Ecological subregions of the United States: Section descriptions. Administrative Publication WO-WSA-5. Washington, DC: U.S. Department of Agriculture, Forest Service. 267p.
- NatureServe. 2010. NatureServe Explorer online. <http://www.natureserve.org> NatureServe, 1101 Wilson Boulevard, 15th Floor, Arlington, VA.
- NHD. 2011. National Hydrography Dataset. U.S. Geological Survey. <http://nhd.usgs.gov/data>
- Pearson, Scott M, and Dawn M. Dextraze. 2002. Mapping Forest Communities of the Jacob Fork Watershed, South Mountains State Park. Mars Hill College Biology Department, Mars Hill, NC.
- Phillips, R. J. 2000. Classification and predictive modeling of plant communities in the Gorges State Park and Gamelands, North Carolina. M.S. thesis. North Carolina State University; Raleigh, North Carolina.

- Phillips, S.J., M. Dudik, and R.E. Shapire. 2004. A maximum entropy approach to species distribution modeling. Pages 655-662 in Proceedings 21st International Conference of Machine Learning, Banff, Canada. ACM Press, New York.
- Phillips, S.J., R.P. Anderson, and R.E. Shapire. 2006. Maximum entropy modeling of species geographic distribution. *Ecol. Modeling* 190:231-259. Phillips, S.J., R.P. Anderson, and R.E. Shapire. 2006.
- Reed, P.B., Jr., 1988. National list of plant species that occur in wetlands. Northeast (Region 1). US Fish Wildl. Serv. Biol. Rep. (88) 26.1.
- Schafale, M.P.; Weakley, A.S. 1990. Classification of natural communities of North Carolina. Raleigh, NC: N.C. Department of Environment, Health, and Natural Resources, Division of Parks and Recreation, North Carolina Natural Heritage Program. 325p.
- Simon, Steven A.,; Collins, Thomas K.; Kauffman, Gary L.; McNab, W. Henry; Ulrey, Christopher J. 2005. Ecological Zones in the Southern Appalachians: first approximation. Res. Pap. SRS-41, Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 41 p.
- Simon, Steven A. 2008. Second Approximation of Ecological Zones in the Southern Appalachian Mountains. The Nature Conservancy, Southern Region. Unpublished report.
- Simon, Steven A. 2009. Ecological Zone mapping in the South Mountains and New River Headwaters Landscapes and Evaluation of fire needs across the Southern Blue Ridge Fire Learning Network. The Nature Conservancy, Southern Region. Unpublished report.
- Simon, Steven A. 2010a. Ecological Zones in the Kentucky Fire Learning Network Project Area. Nature Conservancy, Kentucky Field Office. Unpublished report.
- Simon, Steven A. 2010b. Ecological Zones in the Virginia and West Virginia Fire Learning Network: First Approximate Mapping. Nature Conservancy, Southern Region. Unpublished report.
- Simon, Steven A. 2011. Ecological Zones on the George Washington National Forest: 1st Approximation Mapping, Nature Conservancy, Southern Region. Unpublished report.
- Story, M., and R. Congalton. 1986. Accuracy assessment: a user's perspective. *Photogrammetric Engineering and Remote Sensing*, 52, pp. 397-399.
- USDA. Forest Service. 1995. Classification, Mapping, and Inventory of the Chattooga River Watershed. R8-Regional Office, Atlanta, GA., Unpublished report.
- USDA, Forest Service, 2002. Croatan National Forest Land and Resource Management Plan, Asheville, North Carolina. www.cs.unca.edu/nfsnc/nepa/croatan_plan/croatan_plan.pdf
- USDA, Forest Service, 2004a. Management Indicator Species Habitat and Population Trends, Nantahala and Pisgah National Forests 8/30/2004, National Forests in North Carolina, Asheville, NC. Unpublished report, 815 pgs.
- USDA, Forest Service, 2004b. Cherokee National Forest Revised Land and Resource Management Plan, Forest Service Southern Region, Management Bulletin R8-MB 114A. http://www.fs.fed.us/r8/charokee/planning/final_forest_plan/plan.pdf
- USDA, Forest Service, 2005. The Suppression of Hemlock Woolly Adelgid Infestations on the Nantahala and Pisgah National Forests (USDA 2005), Atlanta, GA. http://www.cs.unca.edu/nfsnc/nepa/hwa_dn.pdf

USDA, Forest Service, 2005. Amending the Nantahala and Pisgah Land and Resources Management Plan – Changing the List of Management Indicator Species, the Species Groups to be Monitored, and Associated Changes to Forest Plan Directions, Asheville, North Carolina. www.cs.unca.edu/nfsnc/nepa/mis_decision.pdf

USDA, Forest Service, 2006. Southern Region Existing Vegetation Mapping Pilot Test Report. Atlanta, Georgia, unpublished report.

USDA, Forest Service, 2009. Uwharrie National Forest Land and Resource Management Plan Revision, Asheville, North Carolina. www.cs.unca.edu/nfsnc/uwharrie_plan/

Wilds, S. P. 1997. Gradient analysis of the distribution of a fungal disease of *Cornus florida* in the Southern Appalachians, Tennessee. *Journal of Vegetation Science* 8:811-818.

Appendix I: Ecological Zone – BpS / Nature Serve Ecological Systems cross-walk

Ecological Zones were cross-walked with LANDFIRE Biophysical Settings (BpS) and Nature Serve Ecological Systems by comparing field observations with descriptions of indicator species and species with high constancy or abundance identified in the “Ecological Zones in the Southern Appalachians: First Approximation” (Simon et. al. 2005), (1st approximation NC), from descriptions of dominant species and site relationships in Nature Serve Ecological Systems (2010), and from LANDFIRE BpS model descriptions (LANDFIRE, 2009). The following was extracted from these sources and from Schafale and Weakley (1990) and Fleming and Patterson (2010). Additional Ecological Zone site or vegetation indicators not included in the 1st approximation NC but identified from local knowledge within the Appalachian Ridges, Blue Ridge and CNF study areas are indicated by *italics*.

In general, it was not difficult to find agreement (to cross-walk) between BpS, which use Nature Serve Ecological Systems to name map units, and Ecological Zones that may break an environmental gradient at different points, except for oak-dominated types. Although ‘fire adaptation’ was not considered in the Ecological Zone breaks, this disturbance component is nonetheless an important factor that can help define the limits of plant community distribution under historic disturbance regimes. Additional information that was used to develop and evaluate the cross-walk included the confusion, i.e., commission and omission errors, among oak-dominated types indicated in the accuracy evaluation matrix (Appendix V), and the landscape distribution of Ecological Zones compared to the distribution of LANDFIRE BpS map units in the study area.

Grassy Balds Ecological Zone

This zone was included in the 2nd approximation of Ecological Zones in the Southern Appalachians and represents sites at the highest elevations within the CNF study area that will not support forested plant communities. Grassy balds occur on the domes of high mountains, usually on gentle slopes and are dominated by herbaceous species with patches of shrubs and small trees. The most characteristic dominant species is mountain oak grass. Other frequent dominants are three-tooth cinquefoil, Canada cinquefoil, white-edge sedge, brown sedge, Pennsylvania sedge, perennial bentgrass, Appalachian haircap moss, and wavy hairgrass (Schafale and Weakley 1990). Within the CNF study area, grassy balds occur only on Roan Mountain.

- BpS / Nature Serve -- Southern Appalachian Shrub and Grass Bald: This ecological system consists of dense herbaceous and shrubland communities in the highest elevational zone of the southern Appalachians, generally above 1524m (5000ft) but occasionally to 1220m (4000ft), and at slightly lower elevations at its northern limit in VA and WV, and in the Cumberland Mountains along the VA-KY border. Vegetation consists either of dense shrub-dominated areas (heath balds) or dense herbaceous cover dominated by grasses or sedges (grassy balds). The combination of high elevation, non-wetland sites and dense herbaceous or shrub vegetation without appreciable rock outcrop conceptually distinguishes this system from all others in the southern Appalachians. However, widespread areas of degraded spruce-fir with grass and shrub cover and the invasion of grassy balds by trees blur the distinction somewhat.

Spruce-Fir Ecological Zone

This zone includes spruce, fir, spruce-fir, and yellow birch-spruce forests and high elevation successional tree, shrub, and sedge communities. This type is the dominant zone at the highest elevations in the Southern Blue Ridge Mountains. Indicator species and species with high constancy or abundance include: Fraser fir, red spruce, mountain ash, yellow birch, mountain woodfern, Pennsylvania sedge, mountain woodsorrel, hobblebush, fire cherry, *clubmoss*, various bryophytes, and Catawba rhododendron.

- BpS / Nature Serve -- Central and Southern Appalachian Spruce-Fir Forest: This system consists of forests in the highest elevation zone of the Blue Ridge and parts of the Central Appalachians generally dominated by red spruce, Fraser fir, or by a mixture of spruce and fir. Elevation and orographic effects make the climate cool and wet, with heavy moisture input from fog as well as high rainfall. Understory species are variable and include rhododendron, mountain woodsorrel, hobblebush, Pennsylvania sedge, mountain ash, and various mosses.

Northern Hardwood Ecological Zones (slope and cove)

This type was split into two zones -- Northern Hardwood Slopes, and Northern Hardwood Coves in the second approximation (Simon 2008), and in the VA_WVA FLN study area. Northern Hardwood Slopes include beech gaps, and Northern Hardwood plant communities occurring on upper slopes and ridges. Indicator species include: American beech, Pennsylvania sedge, northern red oak, *eastern hemlock*, *striped maple*, *sweet birch*, *hay-scented fern*, and Allegheny service berry. Northern Hardwood Coves include high elevation boulder fields, and Northern Hardwood plant communities that occur on toeslopes, and coves, i.e., broad to narrow concave drainages at higher elevations. In the Southern Appalachians, this type can be viewed as the highest elevation extension of Rich Coves. Indicator species and species with high constancy or abundance include yellow birch, sugar maple, black cherry, northern red oak, mountain holly, *Basswood*, Canadian woodnettle, *black cohosh*, *blue cohosh*, and ramps.

- BpS / Nature Serve -- Southern Appalachian Northern Hardwood: High elevation sites in the Southern Appalachians. Generally occurring on all topographic positions above 1372m (4500ft) in the southern extent of the range, elevations may be considerably lower in the northern part of the range. At elevations greater than 1676m (5500ft) (975m in W. Virginia), spruce-fir forests become the predominant type, though the range of this sub-type is extremely limited within this zone. Soils are highly variable, ranging from deep mineral soils to well-developed boulderfields. Soils are most often rocky and acidic, with low base saturation. A thick organic soil layer is frequently present. Overall hydrology is mesic, ranging from wet in bogs, seeps, and the most protected sites to dry-mesic on some exposed upper slopes and ridges. Mesic conditions are maintained by high annual rainfall, frequent fog deposition, low temperatures, and heavy shading.

Acidic Cove Ecological Zone

This zone includes hemlock and mixed hardwood-conifer forests typically dominated by an evergreen understory occurring in narrow coves (ravines) and often extending up on adjacent protected, north-facing slopes. Indicator species and species with high constancy or abundance include great rhododendron, eastern hemlock, black birch, heartleaf species, partridgeberry, mountain doghobble, eastern white pine, yellow-poplar, common greenbrier, chestnut oak, and red maple.

- BpS / Nature Serve – Southern and Central Appalachian Cove Forest: This system consists of mesophytic hardwood or hemlock-hardwood forests of sheltered topographic positions. Examples are generally found on concave slopes that promote moist conditions. The system includes a mosaic of acidic and “rich” coves that may be distinguished by individual plant communities based on perceived difference in soil fertility and species richness. Both acidic and rich coves may occur in the same site, with the acidic coves potentially creeping out of the draw-up to at least midslope on well-protected north-facing slopes. Characteristic species in the canopy include yellow buckeye, sugar maple, white ash, American basswood, tulip poplar, silverbell, eastern hemlock, American beech, and magnolias. Understories can include high diversity and density in the herbaceous layer or a sparse herbaceous layer over-topped by dense rhododendron and / or dog hobble.

Mixed Oak / Rhododendron Ecological Zone

This zone was not included in the 1st approximation NC but was included in the 2nd approximation and labeled “Mixed Oak / Heath”. It is confined to steep, north-facing mid to upper slopes adjacent to the Acidic Cove Ecological Zone and can therefore be considered a refinement of that more cove oriented type. Indicator species and species with high abundance include great rhododendron, northern red oak, chestnut oak, black birch, and tulip poplar.

- BpS / Nature Serve – Southern and Central Appalachian Cove Forest: See description above.

Rich Cove Ecological Zone

This zone includes mixed mesophytic forests typically dominated by a diverse herbaceous understory and occurs in broader coves and on adjacent protected slopes (mostly north to north-east facing). Indicator species and species with high constancy or abundance include black cohosh, American ginseng, blue cohosh, mandarin, bloodroot, northern maidenhair fern, Dutchman's pipe, rattlesnake fern, mountain sweet-cicely, Appalachian basswood, yellow buckeye, white ash, yellow-poplar, *wood nettle*, *cucumber magnolia*, and northern red oak.

- BpS / Nature Serve – Southern and Central Appalachian Cove Forest: This system consists of mesophytic hardwood or hemlock-hardwood forests of sheltered topographic positions. Examples are generally found on concave slopes that promote moist conditions. The system includes a mosaic of acidic and "rich" coves that may be distinguished by individual plant communities based on perceived difference in soil fertility and species richness. Both acidic and rich coves may occur in the same site, with the acidic coves potentially creeping out of the draw-up to at least midslope on well-protected north-facing slopes. Characteristic species in the canopy include yellow buckeye, sugar maple, white ash, American basswood, tulip poplar, silverbell, eastern hemlock, American beech, and magnolias. Understories can include high diversity and density in the herbaceous layer or a sparse herbaceous layer over-topped by dense rhododendron and / or dog hobble.

Riparian Ecological Zones (Riparian_Alluvial Forest & Riparian_Streamside)

These zones were not included in the 1st approximation NC. Riparian_Alluvial Forest was added in the 2nd approximation and labeled "Alluvial Forest". These zones characterize small floodplains that support alluvial forests and imbedded riparian areas and overlap with smaller riparian areas associated with sites adjacent to streams that support Acidic Cove or Rich Cove Ecological Zones. Characteristic trees in these zones include sycamore, river birch, silver maple, tulip poplar, and box elder. The understory is highly variable, depending upon the time since the last flooding event but common species may include paw-paw, spicebush, and switchgrass.

In the CNF study area, this zone was characterized by a combination of statistical modeling based upon plot locations to describe the Riparian_Alluvial component (described in Appendix III) and rule-based decisions dependent on the location of streams identified in the NHD (2011) to describe the Riparian_Streamside component.

- BpS / Nature Serve – Central Appalachian Stream and Riparian: This riparian system occurs over a wide range of elevations and develops on floodplains and shores along river channels that lack a broad flat floodplain due to steeper sideslopes, higher gradient, or both. It may include communities influenced by flooding, erosion, or groundwater seepage. The vegetation is often a mosaic of forest, woodland, shrubland, and herbaceous communities. Common trees include river birch, sycamore, and box elder. Open, flood-scoured rivershore prairies feature switchgrass, big bluestem, and twisted sedge is typical of wetter areas near the channel.

The fluvial features (river terraces, oxbows, alluvial flats, point bars, and streamside levees) typical of (large) river floodplains occur less frequently and on a smaller scale along these small streams. Fine-scale alluvial floodplain features are abundant. In pre-European settlement forests, community diversity in these streamside systems was much more complex than in the modified landscapes of today. Fire, beaver activity, and flooding of varied intensity and frequency created a mosaic whose elements included canebrake, grass and young birch / sycamore beds on reworked gravel or sand bars, beaver ponds, and grass-sedge meadows in abandoned beaver clearings, as well as the streamside zones and mixed hardwood and/or pine forests that make up more than 95% of the cover that exists today. These systems have little to no floodplain development (i.e., floodplains, if present, are not differentiated into levees, ridges, terraces, and abandoned channel segments) and are typically higher gradient than larger floodplains, experiencing periodic, strong flooding of short duration (Nature Serve 2010).

Large Floodplain Ecological Zone

This zone was first included in the VA_WVA FLN and George Washington NF study area. It relies entirely on descriptions from Nature Serve. Most all of the Floodplain Ecological Zone has been highly altered, not in USFS ownership or other conservation tracts, likely farmed by Native Americans, and therefore difficult to characterize.

- BpS / Nature Serve – Central Appalachian River Floodplain: This system encompasses floodplains of medium to large rivers and can include a complex of wetland and upland vegetation on deep alluvial deposits and scoured vegetation on depositional bars and on bedrock where rivers cut through resistant geology. This complex includes floodplain forests in which silver maple, cottonwood, and sycamore are characteristic, as well as herbaceous sloughs, shrub wetlands, riverside prairies and woodlands. Most areas are underwater each spring; microtopography determines how long the various habitats are inundated. Depositional and erosional features may both be present depending on the particular floodplain.

High Elevation Red Oak Ecological Zone

This zone includes forests dominated by northern red oak on exposed slopes and ridges at higher elevations. Site extremity and exposure results in stunted and often windswept tree form, however, there is a broad transition between this extreme and the more common Montane Oak-Hickory (slope) Ecological Zone; the break between these two types is complicated primarily by past management practices, especially timber harvest intensity and ground disturbance. Indicator species and species with high constancy or abundance include: northern red oak, American chestnut, flame azalea, whorled yellow loosestrife, Pennsylvania sedge, speckled wood-lily, highbush blueberry, mountain laurel, *hayscented fern*, *witchhazel*, *striped maple*, and New York fern.

- Bps / Nature Serve -- Central and Southern Appalachian Montane Oak Forest: This generally oak-dominated system is found in the central and southern Appalachian Mountains. These high-elevation deciduous forests occur on exposed sites, including ridgecrests and south- to west-facing slopes. In most associations attributed to this system, the soils are thin, weathered, nutrient-poor, low in organic matter, and acidic. The forests are dominated by oaks, most commonly red oak and white oak with the individuals often stunted or wind-flagged. American chestnut sprouts are common. Characteristic shrubs include mountain holly and early azalea.

Montane Oak-Hickory (rich, slope, cove) Ecological Zones

These zones includes mesic to submesic mixed-oak and oak-hickory forests that occur along broad mid- to higher elevation ridges and smooth to concave slopes below the highest and more narrow ridges where this zone forms a gradual transition to the High Elevation Red Oak and Northern Hardwood zones. It also includes drainage headlands at mid to higher elevations that merge with Rich Coves and Northern Hardwood Cove Ecological Zones, mid to lower elevations in often narrow sub-mesic coves that merge with Dry-Mesic Ecological Zones, and more exposed slopes in very close proximity with High Elevation Red Oak Ecological Zones. Forests in this zone are often floristically diverse. Indicator species and species with high constancy or abundance include: northern red oak, white oak, flowering dogwood, tulip poplar, Canada richweed, mockernut hickory, New York fern, pignut hickory, white ash, chestnut oak, *magnolias*, *sweet birch*, *striped maple*, and *witchhazel*

--- Montane Oak-Hickory (Rich): Dominance by northern red oak characterizes these forests. Community types in this zone are known from the southern part of the Central Appalachians, extending into the extreme northern portions of the Southern Blue Ridge, Southern Ridge and Valley, and Cumberland Mountains. Favorable sites are upper slopes and ridge crests with deep, base-rich soils weathered from mafic and calcareous parent material. The characteristic expression of this community is that of an oak or oak-hickory forest with an herb layer that resembles that of a rich cove forest. Northern red oak is the most constant member of the overstory but usually shares dominance with red hickory, shagbark hickory, and white ash. The shrub layer is typically sparse. Most stands have a lush and generally diverse herb layer; black cohosh and eastern waterleaf are the most characteristic herb species. At higher elevations, where the type is transitional to northern red oak forests, eastern hayscented fern often dominates the herb layer in large clones (Fleming and Patterson, 2010).

--- Montane Oak-Hickory (Cove and Slope): These zones more closely fits the Mesic Oak-Hickory type described in the NC 1st approximation. They are either confined to broad coves and concave lower slopes (cove type) or to the mid-to higher elevation upper slopes and form a broad transition with more exposed, wind-swept types that support High Elevation Red Oak. Indicator species and species with high abundance include northern red oak, tulip poplar, chestnut oak, and New York fern.

- BpS / Nature Serve -- Central and Southern Appalachian Montane Oak Forest: This generally oak-dominated system is found in the central and southern Appalachian Mountains. These high-elevation deciduous forests occur on exposed sites, including ridgelines and south- to west-facing slopes. In most associations attributed to this system, the soils are thin, weathered, nutrient-poor, low in organic matter, and acidic. The forests are dominated by oaks, most commonly red oak and white oak with the individuals often stunted or wind-flagged. American chestnut sprouts are common. Characteristic shrubs include mountain holly and early azalea. **Based on the Nature Serve description for this type, this is an uncomfortable fit in the Montane Oak-Hickory (Slope) Ecological Zone unless a broader Nature Serve concept is assumed that includes more sub-mesic forests.** The majority of this Ecological Zone coincides with the LANDFIRE BpS - Montane Oak Ecological Systems map units within the CNF study area. This may indicate that the LANDFIRE modelers were working with a broader concept (more similar to Ecological Zones) than what is being described in this Nature Serve type.
- BpS / Nature Serve – Southern and Central Appalachian Northern Red Oak-Chestnut Oak Forest (provisional type): This system consists of mixed oak forests on predominantly submesic slopes at elevations from 600 to 1200 m (2000-4000 feet) in the northern part of the Southern Appalachians. It occurs on various topographic positions from lower to upper slopes and crests, in deep, infertile soils. Mature stands have a well-developed canopy of trees 30 m or more tall. Northern Red oak is the leading overstory dominant, with only slightly higher density and basal area than Chestnut oak. Most stands are mixed, although either species can dominate small areas. One or both of the magnolias, Cucumber tree or Fraser’s magnolia, are usually important in the overstory or understory. Minor canopy associates vary and can include White oak, Sweet birch, Red maple, hickories, American beech, Eastern hemlock, and Tulip poplar. Most of the preceding species may be present in the understory, along with Striped maple, Sourwood, White pine, Downy serviceberry, and Allegheny serviceberry, and sprouts of American chestnut. Striped maple is consistently the most important small tree / shrub. Other shrubs that are less constant but sometimes important include Witch-hazel, Great rhododendron, Mountain holly, Maple-leaved viburnum, and Hillside blueberry. The herb layer is often patchy to sparse, with Indian cucumber-root, Galax, Squaw root, New York fern, and Hay-scented fern. In the higher part of the elevational range, however, the latter two ferns may greatly dominate the herb layer and cover more substantial areas (Fleming and Patterson, 2010).

Dry-Mesic Oak Ecological Zone

This zone was included in the Dry and Dry-Mesic Oak-Hickory type in the 1st approximation NC but separated into its components -- Dry Oak and Dry-Mesic Oak in the 2nd approximation both in the KY FLN (Simon 2009) and in the VA_WVA FLN study areas (Simon 2010). This zone is very similar to the Montane Oak-Hickory zone but occurs at lower elevations. It includes dry-mesic, mixed-oak forests that occur along broad lower to mid elevation ridges and smooth to concave slopes and lower elevation drainage headlands, and often narrow, drier coves. Indicator species and species with high constancy or abundance include: *white oak*, *black oak*, scarlet oak, flowering dogwood, sourwood, low bush blueberry, and huckleberries.

- BpS / Nature Serve -- Southern Appalachian Oak Forest: This system consists of predominantly dry-mesic (to dry) forests occurring on open and exposed topography at lower to mid elevations. Characteristic species include chestnut oak, white oak, red oak, black oak, scarlet oak, with varying amounts of hickories, blackgum, and red maple. Some areas (usually on drier sites) now have dense evergreen ericaceous shrub layers. Northward this system grades into Northeastern Interior Dry-Mesic Oak Forest type.

Dry Oak Heath Ecological Zones (evergreen and deciduous heath types)

This zone, called Chestnut Oak Heath in the 1st approximation NC, includes xeric to dry mixed-oak forests typically dominated by an ericaceous (evergreen or deciduous) understory and represents the driest zone where oaks are the dominant species. In general, in the CNF study area, the Dry Oak/deciduous heath zone is more transitional to the Dry-Mesic Oak Ecological Zone and the Dry Oak/evergreen heath zone is more transitional to the Pine-Oak Heath Ecological Zone, however, this varies considerably according to slope position and the predominantly east or west-facing side of major ridges. Further work is needed to differentiate these two zones to separate what is truly an environmental influence and what may be an influence of current fire return interval. Indicator species and species with high constancy or abundance include: chestnut oak, *scarlet oak*, northern red oak, mountain laurel (in the evergreen heath type), *black huckleberry* & *hillside blueberry* (in the deciduous type), red maple, great rhododendron, and sourwood.

- BpS / Nature Serve -- Allegheny-Cumberland Dry Oak Forest and Woodland: These forests were typically dominated by White oak, Black oak, Chestnut oak, and Scarlet oak with lesser amounts of Red maple, Pignut hickory, and Mockernut Hickory. These occur in a variety of situations, most likely on nutrient-poor or acidic soils and, to a much lesser extent, on circumneutral soils. American chestnut was once dominant or codominant in many of these forests and sprouts of American chestnut can often be found where it was formerly a common tree. Small inclusions of Shortleaf pine and/or Virginia Pine may occur, particularly adjacent to escarpments or following fire. In the absence of fire, White pine may invade some stands (Nature Serve 2010). Today, subcanopies and shrub layers are usually well-developed. Some areas (usually on drier sites) now have dense evergreen ericaceous shrub layers of mountain laurel, fetterbush, or on more mesic sites rhododendron. Other areas have more open conditions.

Low Elevation Pine Ecological Zone

This zone includes dry to dry-mesic pine-oak forests dominated by shortleaf pine or pitch pine that occurs at lower elevations on exposed broad ridges and sideslopes. Indicator species and species with high constancy or abundance include: shortleaf pine, *pitch pine*, sourwood, sand hickory, scarlet oak, southern red oak, post oak, hillside blueberry, American holly, featherbells, *black huckleberry*, and spring iris.

- BpS / Nature Serve -- Southern Appalachian Low-Elevation Pine: This system consists of shortleaf pine- and Virginia pine-dominated forests in the lower elevation Southern Appalachians and adjacent Piedmont and Cumberland Plateau. Examples can occur on a variety of topographic and landscape positions, including ridgetops, upper and midslopes, as well as low elevation mountain valleys in the Southern Appalachians. Under current conditions, stands are dominated by shortleaf pine and Virginia pine. Pitch pine may sometimes be present and hardwoods are sometimes abundant, especially dry-site oaks such as southern red oak, chestnut oak, scarlet oak, but also pignut hickory, red maple, and others. The shrub layer may be well-developed, with hillside blueberry, black huckleberry, or other acid-tolerant species most characteristic. Herbs are usually sparse but may include narrowleaf silkgrass and goat's rue.

Pine-Oak Heath Ecological Zone

This zone was included in the Xeric Pine-Oak Heath-Oak Heath type in the 1st approximation NC but separated into three pine-oak heath types in the VA_WVA FLN and GW study areas. This differentiation was not made in the Blue Ridge and CNF study areas. Indicator species and species with high constancy or abundance in all three types include: Table Mountain pine, scarlet oak, chestnut oak, pitch pine, black huckleberry, mountain laurel, hillside blueberry, *bear oak*, and wintergreen. Pine-Oak Heath (Eastside) includes landscapes located on the east side of major ridges where patch sizes are smaller, pitch pine is more common, and black huckleberry is normally more abundant than mountain laurel. Pine-Oak Heath (Westside) includes landscapes located on the west site of major ridges where patch sizes are larger, Table Mountain Pine is more common, and mountain laurel is normally more abundant than black huckleberry. Pine-Oak Heath (Ridgetop) includes exposed sites along mostly narrow ridges. Northern red oak and Catawba rhododendron are common associates in these areas and all trees are more stunted or wind-flagged than in other Pine-Oak Heath Ecological Zones.

- Bps / Nature Serve – Southern Appalachian Montane Pine Forest: This system consists of predominantly evergreen woodland (or more rarely forests) occupying very exposed, convex, often rocky south- and west-facing slopes, ridge spurs, crests, and cliff-tops. Most examples are dominated by Table Mountain pine, often with Pitch pine and / or Virginia pine and occasionally Carolina hemlock. Based on the component Associations, understories commonly include mountain laurel, black huckleberry, and hillside blueberry.

Appendix II: photos of plant communities in selected Ecological Zones

Pine-Oak Heath (Yellow Springs Mountain between Rocky Top and Rocky Top Gap, TN -- at 2,200' elevation)



Pine-Oak Heath (Greene Mountain between Paint Creek and Back Creek, TN -- at 2,770' elevation)



Dry Oak Evergreen Heath (Ridge and Valley, VA – 3,560' elevation)



Dry Oak Evergreen Heath (Head of Halltop Branch, Stone Mountain, TN -- 3,170' elevation)



Montane Oak-Hickory Slope (Holston Mountain, top of Red Eye Ridge, TN – 3,590' elevation)



Montane Oak-Hickory Rich (Blueridge, VA – 3,060' elevation)



Montane Oak-Hickory Cove (Blue Ridge, VA – 2,040' elevation)



Montane Oak-Hickory Slope, (ecotone to High Elevation Red Oak, Rich Mountain, TN – 3,340' elevation)



Dry-Mesic Oak (Big Oak Mountain, head of Big Oak Branch, TN -- 1,830' elevation)



Dry-Mesic Oak (Base of Delaney Mountain, Kettlefoot Wildlife Mgmt. Area, TN – 2,320' elevation)



Dry Oak Deciduous Heath (Meadow Ck. Mts., head of South fork, Yellow Spring Branch, TN – Elev. 1,940)



Appendix III: Methods used in developing Digital Terrain Models (DTMS)

The following DTMs were developed to characterize broad to mid-scale terrain, climate, geology, and solar radiation influences that control temperature, moisture, fertility, and solar inputs on landscapes in the CNF study area. These environmental factors affect the distribution of Ecological Zones and their component plant communities in different landscapes. They were used to develop site specific probability values for each Ecological Zone based upon their correlation to reference field sample locations for each type. All processing of 2nd derivative grids (slope, aspect, etc.) used a 32.8084 ft. DEM (10 meters) except Valley position, Relief, and Solar Radiation, which were evaluated with 98.4252 ft. grid size (30 meter). For the entire CNF study area, all DTMS were projected to or processed as NAD 1983 StatePlane Tennessee FIPS 4100 Feet coordinate system.

1) **elevation (feet)**

Elevation for the Tennessee portion of the study area was extracted from DEMS available at: http://www.tngis.org/10mtr_dems/. These are 10m resolution, 32 bit floating point, grids with a NAD_27_UTM_Zone_17N projection, and D_North_American_1927 Datum. Elevation for the North Carolina portion of the study area was extracted from DEMs available at: <http://www.ncdot.org/it/gis/>. These are 20ft resolution, 16 bit unsigned integer, grids with a NAD_1983_Stateplane_North_Carolina_FIPS_3200_feet projection, and D_North_American_1983 datum.

The following process was used to build the elevation DTM for the study area.

a) Download and mosaic the following DEMS by USGS quad from TN:

bakersville, bald_creek, baldwin_gap, blountville, bluff_city, boone_dam, bristol, carter, carver_gap, cedar_creek, chestnut_hill, chestoa, chuckey, davy_crockett_lk, doe, elizabethton, elk_mills, elk_park, erwin, flag_pond, grayson, greenville, greystone, hartford, holston_valley, hot_springs, huntedale, iron_mountain_gap, johnson_city, jones_cove, jonesborough, keenburg, laurel_bloomery, leesburg, lemon_gap, mountain_city, neddy_mtn, newport, paint_rock, parrottsville, rankin, sams_gap, shady_valley, sherwood, sullivan_gardens, telford, unicoi, watauga, waterville, white_rocks_mtn, zionville.

b) Download and mosaic the following county DEMs from NC:
Avery, Watauga, Madison.

c) change z (feet) values for NC DEMs to meters (mosaic grid * 0.30480), 32 bit floating point, resampling technique = cubic convolution

d) project NC DEM mosaic --- NAD_1983_Stateplane_North_Carolina_FIPS_3200_feet – to
--- NAD_27_UTM_Zone_17N

e) Open a new ArcMap dataframe and add TN and NC DEM mosaics.

f) Use Mosaic to new raster tool to combine the TN and NC data with NC data 'overwriting' the TN data, i.e., in the 'mosaic method' for a final or all_dem (nctn_dem) coverage.

g) change z (meters) from the final dem (nctn_dem) to feet (nctn_dem * 3.28084) for visual and field purposes = nctn_demft. Convert coverage to NAD 1983 StatePlane Tennessee FIPS 4100 Feet coordinate system.

h) All 2nd derivative DTMS were derived from this coverage, the elevation DEM.

2-3) **aspect (raw and transformed)**

Aspect (raw and transformed) is a measure of aspect at each cell location derived from the elevation DEM. The following steps were performed to produce aspect:

- a. GRID function ASPECT from the DEM filled for sinks (elev_fill). = aspectraw
- b. Convert degrees to radians (1 degrees = 0.0174532925 radian), in raster calculator: (ASPECT * 0.0174532925). This is done because cosine measurements for a continuous aspect variable are derived from radians and not degrees.
- c. Calculate cosine using ARC TOOLBOX Spatial Analyst Tools, Math, Trigonometric, Cos. Value varies from -1 to 1 = aspectrans

4) curve

The curvature of a surface at each cell center in a 3x3 neighborhood derived from the DEM: used GRID curvature function. NOTE: if the DEM used has z units (height) in feet while the x,y units are in meters, then a z-factor of 0.3048 (1 ft = 0.3048 meters) must be used and is part of the ESRI tools options for calculation of curvature. This was not necessary for the CNF study area because x,y, and z units were all in feet.

5) curveplan

The curvature of a surface in a 3x3 neighborhood perpendicular to the slope direction derived from the DEM: GRID curvature function with {out_plan_curve} - an optional output grid referred to as the planiform curvature.

6) curvepro

The curvature of surface in a 3x3 neighborhood in the direction of slope derived from the DEM: GRID curvature function with {out_profile_curve} - an optional output grid showing the rate of change of slope for each cell

7) slopep

The rate of maximum change in z value (elevation_ft) from each cell derived from the DEM: GRID function slope with percentrise.

8) solaryr

The yearly solar radiation per cell derived from the DEM. See "Area Solar Radiation" in ARC TOOLBOX, Spatial Analyst Tools, Radiation. Processing was performed on the elevation grid resampled to 98.4252 ft. grid cell size (64x64 meter).

9) solargw

The growing season solar radiation per cell derived from the DEM. See "Area Solar Radiation" in ARC TOOLBOX, Spatial Analyst Tools, Radiation. The growing season was identified as occurring from April 1 to Sept. 30. Processing was performed on the elevation grid resampled to 98.4252 ft. grid cell size (64x64 meter).

10-11) rsp (rsp1, rsp2)

RSP (relative slope position) is an estimate of the slope position at each cell location relative to the nearest ridge and drainage (Wilds 1996). A value of 100 represents the bottom of the slope and 0 the top of the slope (the ridge). Relative slope position uses (1) a threshold level of flow accumulation to represent slope bottom, (2) the difference between mean elevation and highest elevation in a moving window to represent ridges, and (3) flow-length to calculate distance to the top or bottom. Steps to produce RSP performed with the raster calculator:

- a) GRID commands: note* create flowdirection and flowaccumulation (floating point) coverages from the elevationgrid first
- b) streams = con(flowacc < 300, 1)
rsp1 in GW,VA_WVA, and CNF uses 300, 10 meter cells = 7.4 acres for the threshold to start a stream
rsp2 in GW,VA_WVA, and CNF uses 807, 10 meter cells = 20 acres, for the threshold to start a stream
- c) c:\CNF\dtms\slength_calc\streams_flip1 = con(isnull(c:\CNF\dtms\slength_calc\streams300), 1, 0)
- d) c:\CNF\dtms\slength_calc\streams_thin1 = thin(c:\CNF\dtms\slength_calc\streams_flip1)
- e) c:\CNF\dtms\slength_calc\streams2 = setnull(c:\CNF\dtms\slength_calc\streams_thin1 > 0, 1)
- f) setmask streams2 (do in spatial analysis, options)
- g) c:\CNF\dtms\slength_calc\flow_dir2 = c:\CNF\dtms\slength_calc\flowdir
- h) setmask off (do spatial analysis, options)
- i) c:\CNF\dtms\slength_calc\flow_down = flowlength(c:\CNF\dtms\slength_calc\flow_dir2, #, downstream)
- j) c:\CNF\dtms\slength_calc\mean = focalmean(c:\CNF\dtms\gw_dem_meters, rectangle, 10, 10)
- k) c:\CNF\dtms\slength_calc\diff = c:\CNF\dtms\slength_calc\mean - c:\CNF\dtms\gw_dem_meters
- l) c:\CNF\dtms\slength_calc\ridges = con(c:\CNF\dtms\slength_calc\diff < -10, 1, 0)
- m) c:\CNF\dtms\slength_calc\thin_ridges = thin(c:\CNF\dtms\slength_calc\ridges, #, #, #, 15)
- n) c:\CNF\dtms\slength_calc\top = setnull(c:\CNF\dtms\slength_calc\thin_ridges > 0, 1)
- o) setmask top

- p) `c:\CNF\dtms\slength_calc\flow_dir3 = c:\CNF\dtms\slength_calc\flowdir`
- q) `setmask off`
- r) `c:\CNF\dtms\slength_calc\flow_up = flowlength(c:\CNF\dtms\slength_calc\flow_dir3, #, upstream)`
- s) `rsp_float = flow_up / (flow_up + flow_down)` (this puts large number on btm)
- t) `rspa = int(rsp_float * 100)`
- u) `rspb = con(thin_ridges == 1, 0, rspa)`
- v) `rspc = con(streams_thin1 == 1, 100, rspb)`
- w) `rspfinal = focalmean (rspc, rectangle, 3, 3)`

This was run with both 7.4 and 20 acre minimum flow accumulation.

12) **trmi**

TRMI (terrain relative moisture index) is an estimate of the moisture regime for each cell based upon 3 variables: aspect, slope position, and slope curvature using the weighted scalar developed by Parker (1982). TRMI combines aspect, slope, slope configuration (curvature) and relative slope position. The following GRID commands were used in the raster calculator. These commands require additional reclassification tables found in *.rmt files. The directory location for the *.rmt files needs to be specified in the equations. Steps include:

- a) `config_a = reclass(curvepl, plan.rmt)`
- b) `config_b = reclass(curvepr, prof.rmt)`
- c) `config1 = con(config_a < 0 & config_b < 0, 10, 0)`
- d) `config2 = con(config_a == 0 & config_b < 0, 8, 0)`
- e) `config3 = con(config_a < 0 & config_b == 0, 7, 0)`
- f) `config4 = con(config_a == 0 & config_b == 0, 5, 0)`
- g) `config5 = con(config_a > 0 & config_b == 0, 3, 0)`
- h) `config6 = con(config_a == 0 & config_b > 0, 2, 0)`
- i) `config = config1 + config2 + config3 + config4 + config5 + config6`
- j) `trmi_slope = reclass(slope, slope.rmt) *NOTE THAT SLOPE IS MEASURED IN DEGREES FOR THIS EQUATION *`
- k) `trmi_asp = reclass(aspect, aspect.rmt) (USE aspect in degrees)`
- l) `trmi_rsp = reclass(rsp, rsp.rmt) (used rsp1 based on larger drainage area, i.e., 20ac vs 7 ac, see above)`
- m) `trmi_final = trmi_asp + trmi_slope + trmi_rsp + config`
- n) `setnull all trmi values > 100 and fill these with focalmean 3x3 c:\fln_va\dtms\trmi_temp1= con(isnull(c:\CNF\dtms\trmi_final2), focalmean(c:\CNF\dtms\trmi_final2, rectangle, 3,3), c:\CNF\dtms\trmi_final2)`

13) **lfi**

LFI (landform index) is an index of landform shape (site protection) and macro-scale landform derived from the DEM. Larger number = more concave shape, more protected landform. From: *McNab, W.H. 1996. Classification of local- and landscape-scale ecological types in the Southern Appalachian Mountains. Environmental Monitoring and Assessment 39:215-229.* The software TopoMetrix is required to calculate LFI. The calculation of LFI is data intensive and requires very large RAM, and caching capability and therefore will not perform except on rather small DEMs.

Processing lfi from topometrix requires the following steps:

1. clip DEM to reasonable-sized areas and convert the clipped elevation to .asc file
2. run lfi in topometrix and saving as .asc file
3. in ArcMap, convert .asc back to grid as floating point
4. set null for all grid values < -100
5. multiply this grid by 0.001
6. check all grids for projection, this process usually drops the projection and it needs to be redefined
7. mosaic these grids together – using BLEND (the output cell value of the overlapping areas will be a blend of values that overlap; this blend value relies on an algorithm that is weight based and dependent on the distance from the pixel to the edge within the overlapping areas) if there is overlap – which there won't be if

watershed boundaries are used. When watersheds are used as clip areas, the boundary areas, which will show as “nodata” need to be filled. Use the following:

8. `outgrid = con(isnull(lfib), focalmean (lfia, rectangle, 10, 10), lfia) c:\CNF\lfimerge6 = con(isnull(c:\CNF\lfimerge5), focalmean (c:\CNF\lfimerge5, rectangle, 3, 3), c:\CNF\lfimerge5)`

14) dstrm

DSTRM (distance to stream) is a measure of each cell’s distance to the nearest stream, regardless of stream order. Streams are modeled from the elevation DEM using ESRI hydrology tools. The steps were used to produce distance to streams:

Make streams from 32.8084ft DEM (10 meter). Set 13 acres to accumulate water (526 10x10 meter cells, 1633 – 20x20ft cells). In raster calculator = `streamgrid = setnull(flowaccumulation < 526, 1)`. Calculate Euclidean distance to stream (GRID command, `Dstrm = eucdistance stream`).

NOTE: for Riparian BpS approximation, streams were derived starting with the National Hydrography Dataset (NHD), <http://nhd.usgs.gov/data.html>. Streams for the CNF study area were converted to raster, and ‘drilled’ into the existing DEM, i.e., -100 was assigned to the stream raster and mosaiced to the DEM then ESRI stream modeling procedures were followed. This forced flowdirection and flowaccumulation into the ‘ditch’ identified by the location of the NHD streams. As above, 13 acres were set as the threshold value to start a stream and then stream order (strahler) was determined from this output.

15-16) Landform10 and Landform 30

These two metrics estimate landform surface shape within a 10x10 meter and 30x30 meter pixel neighborhood. It is used to characterize narrow and broader ridges observed in the TN study area that may differentiate between High-Elevation Red Oak Forests seen on more narrow ridges from Montane Oak (rich type) seen on slightly broader ridges, and to better characterize the broad landforms at lower elevations that may support Low Elevation Pine. They are calculated by averaging the profile curvature within a moving 10x10 and 30x30 pixel, circular window.

`c:\tn\dtms\lform10 = focalmean (c:\tn\dtms\curvepr, circle, 10)`

`c:\tn\dtms\lform30 = focalmean (c:\tn\dtms\curvepr, circle, 30)`

17-20) Distance to geology type

Combine state geology coverages from Tennessee, North Carolina, and Virginia. Clip to an approximately 8 million acre area. The following steps were used to create the final DTMs.

1. Add item “group” and use Peper et.al (2001), Appendix 2: ‘Table of numerical lithogeochemical codes and original geologic map symbols’ to match geologic map symbols to their appropriate lithogeochemical code and populate the “group” item. The following group codes were used:
 - 1 = CARBONATE-BEARING ROCKS
 - 2 = MAFIC SILICATE ROCKS
 - 3 = SILICICLASTIC ROCKS
 - 46 = CARBONACEOUS-SULFIDIC ROCKS
2. Create 4 separate grids for each of the lithogeochemical groups.
3. Calculate distance (Euclidean) to each of the grids to help ‘smooth’ the differences in scales and mapping resolution.

21) Average Precipitation

Average precipitation in inches. Based on a 30 year average, orographic effects in model. Coverage resampled to 10 meter cell size. Data available at: <http://www.ocs.orst.edu/pub/maps/Precipitation/Total/States/>. Not used for Dry-Mesic Oak because of sharp break in model based upon this variable.

22) Difference in elevation relative to streams

Stream_diff (each cell's difference in elevation relative to the closest stream, is a measure of the difference in elevation of the individual cell and the closest stream (above stream = positive number, below river = negative number). Create a coverage describing river elevations using the raster calculator: river_elev = con(stream_order > 0, elevation from filled dem, 0), i.e., where a 1st order (or higher order) stream occurs, display its elevation. – OR extract by mask, streamgrid = mask, extract from elev_fill – OR c:\CNF\dtms\stream_elev = con(c:\CNF\dtms\stream13 > 0, c:\CNF\dtms\gw_fill_ft, 0)

Fill in areas that are not streams through a series of focalmin commands: outgrid = con(isnull(stream_elev), focalmin (stream_elev, circle, 3), stream_elev). Use 3x3 for at least 10 iterations, then 10x10 for the remainder.
c:\CNF\dtms\temp1 = con(isnull(c:\CNF\dtms\stream_elev), focalmin (c:\CNF\dtms\stream_elev, circle, 3), c:\CNF\dtms\stream_elev)

c:\CNF\dtms\temp2 = con(isnull(c:\CNF\dtms\temp1), focalmin(c:\CNF\dtms\temp1, circle, 3), c:\CNF\dtms\temp1)

This is an attempt to fill in the non-river landscape with the closest river elevation to allow easy subtraction with grid algebra. Repeat 16 iterations (10 – 3x3, 6 – 10x10)

Calculate difference in elevation between each cell and the closest river: river_diff = elevation - river_elevfill

23) Valley position:

Valley position is a measure of the elevational position of a cell relative to the watershed divide and the valley floor. The old method of calculating this DTM used the original DEM (meters x, y, and z) to model streams with a 13 acre accumulation area (see above) and stream order, to identify valley floor and the same DEM to identify watershed divide. The new method determines valley floor from the minimum elevation within a 3000x3000 meter window.

The watershed divide is defined as the maximum elevation within a 3000x3000 meter window, i.e., it is an estimate (model) of where major ridges occur and the elevation of grid cells at those locations. It uses a 30 meter DEM (resampled from the original 10 meter DEM) because: (a) this is a mesoscale indicator meant to evaluate environments at a broader scale than Relative Slope Position, and (b) this reduces computing time considerably.

GRID commands:

The DEM was converted from 10m resolution to 30m resolution to improve analysis speed, but 10m resolution for the GW NF. These coverages were merged.

C:\CNF\dtms\gw_maxelev1=focalmax(c:\CNF\dtms\dem_add_meter,circle,100)

In the expansion of GW, 10m was used and combined with the 30m from the VA_WVA_FLN, used 'blend' in the mosaic process. = GW_maxelev2 (each area had to be clipped inward 3000' to get correct values)

used circle, 100, 100 then focalmean 3,3 rectangle (twice)

Minelev = focalmin(dtm30meter, circle, 100)

Relief = maxelev – minelev

Down = Elevationgrid – minelev

Vposfloat = 1 - (down/relief)

Vpos = int (vposfloat * 100)

Resampled back to 10 meter

24) Local Relief

Local relief is a measure of the difference in elevation between the watershed divide and the valley floor relative to a cell's location. Local Relief uses (1) 4th order and greater streams to represent slope bottom, and (2) the watershed divide defined from the maximum elevation within 3000 meters of the cell to represent ridges. See above procedure for valley position. Set all negative numbers to 0.

25) Profile Curvature Roughness

Developed to characterize the variety of site conditions across the slope due to aspect that is so evident in field sampling and from aerial photography and topographic maps. This broad-scale surface curvature is controlled by bedrock strike and dip. It could be an important variable in modeling the repeated pattern of Pine-Oak Heath Ecological Zones and adjacent Dry Oak or Dry-Mesic Oak Ecological Zones on the 'strike side' of a mountain range, and conversely, the smooth surface on the 'dip side' of the mountain.

Although various methods were evaluated, the following process creates a reasonable surface that reflects the diversity in profile curvature:

- a) Calculate the standard deviation within a window oriented along the major NE trending major ridges within a neighborhood that includes at least 3 patterns of tertiary ridge and drainages on the typical 'strike side' of a mountain range, usually the NW-facing side), i.e., a slice approximately 1000' in length. No tools were available to orient the neighborhood directionally except , the "WEDGE".
- b) Use a wedge start angle = 30, end angle = 70 for 100 cells

NOTE: there are several areas that appear in error, especial a slice in the SW corner of the Waynesboro east quad. This area has the highest SDs and an abrupt boundary to adjacent areas – for no apparent reason except the proximity to a reservoir. However, this is on PVT land and the majority of the output looks very good.

26) Distance to rivers (Rivdist)

Same process as distance to streams but using 4th order and greater streams only.

27) Distance above rivers (i.e., streams equal or greater than 4th order) (Riveldiff)

The following process was used:

- create elevation coverage of 5th order+ streams (rivers) at 32.8084 ft. (10 meters) = rivelev.
river_elev = con(stream_order > 4, larger elev. extent with filled dem, 0)
- expand this elevation to the landscape; this process fills in the non-river landscape with the closest river elevation to allow easy subtraction with grid algebra using the following commands in the raster calculator, i.e., Fill in areas that are not rivers through a series of focalmin commands:

```
c:\CNF\dtms\tempx = con(isnull(c:\CNF\dtms\tempx), focalmin (c:\CNF\dtms\tempx, circle, 3),  
c:\CNF\dtms\tempx)
```

Used 3x3 for 25 iterations, 5x5 for 15 iterations, 10x10 for 5 iterations, 10 x 10 for 15 iterations using rectangle instead of circle which is faster, 30x30 rectangle for 15 iterations, then 50x50 for the remainder.

```
c:\CNF\dtms\temp53 = con(isnull(c:\CNF\dtms\temp52), focalmin (c:\CNF\dtms\temp52, rectangle, 10, 10),  
c:\CNF\dtms\temp52)
```

```
c:\CNF\dtms\temp53 = con(isnull(c:\CNF\dtms\temp52), focalmin (c:\CNF\dtms\temp52, rectangle, 30, 30),  
c:\CNF\dtms\temp52) ... to total of 75, then rectangle 50x50 once ... too long a time, back to 30x30 for a final of  
100 iterations!
```

```
c:\CNF\dtms\temp53 = con(isnull(c:\CNF\dtms\temp52), focalmin (c:\CNF\dtms\temp52, rectangle, 50, 50),  
c:\CNF\dtms\temp52)
```

- subtract elevation from the river_elev_fill $C:\CNF\dtms\rivdiff = C:\CNF\dtms\elev_projarea - c:\CNF\dtms\rivelev_fill$

This creates some areas that are negative (BELOW the river), most of which are reservoirs where the DEM is still showing the elevation below water, at least on the edges. However, some could be due to the constant filling in of nodata areas with the focalmin of elevation that are actually on the other side of the watershed divide and truly below the closest river. To partially fix this:

- change negative values within 300 ft of a river to zero:
 $C:\CNF\dtms\temp1 = \text{con}(c:\CNF\dtms\rivdiff < 0, \text{con}(c:\CNF\dtms\driver < 300, 0, c:\CNF\dtms\rivdiff), c:\CNF\dtms\rivdiff)$

- Change negative values > 3000 ft from river to zero:
 $C:\CNF\dtms\temp2 = \text{con}(c:\CNF\dtms\rivdiff < 0, \text{con}(c:\CNF\dtms\driver > 3000, 0, c:\CNF\dtms\temp1), c:\CNF\dtms\temp1)$

- Fill zero values > 3000 ft from river with focalmax of surrounding areas:
 $C:\CNF\dtms\temp3 = \text{con}(c:\CNF\dtms\temp2 == 0, \text{con}(c:\CNF\dtms\driver > 3000, \text{focalmax}(c:\CNF\dtms\temp2, \text{rectangle}, 10, 10), c:\CNF\dtms\temp2), c:\CNF\dtms\temp2)$

Done 12 times

- Go back to areas near rivers:

- $C:\CNF\dtms\temp13 = \text{con}(c:\CNF\dtms\temp12 < 0, \text{con}(c:\CNF\dtms\driver < 3001, 0, c:\CNF\dtms\temp12), c:\CNF\dtms\temp12)$

The ultimate fix would be to follow a procedure similar to RSP but to specify the bottom at 5th order and greater streams and to specify the top as the 10th order HUC boundaries. This procedure was started without much success and includes inverting the elevation grid to show ridges as bottoms and to use hydrology tools to identify a 'ridge network'.

28) Terrain shape index

This DTM estimates local convexity or concavity slightly broader than curvature and is calculated by subtracting elevation value of center cell from value of each of 8 neighbors.

- a) $C:\CNF\dtms\gw_tsi = c:\CNF\dtms\gw_dem_meters - \text{focalmean}(c:\CNF\dtms\gw_dem_meters, \text{circle}, 5)$

This looks much like curvature from ESRI only a bit smoother.

From: McNab, H.W. 1993. A topographic index to quantify the effect of mesoscale landform on site productivity. *Can. J. For. Res.* 23: 1100-1107.

29) Slopelength

Slope length is an estimate of the cell position along a slope segment, from the ridges (major and tertiary) to the bottom of the slope. The ridges and slope bottom were estimated following similar procedures the RSP calculation (Wilds 1996) equals the sum of 'flowup' and 'flowdown' from rsp1 (uses 7.4 acres to accumulate enough to start stream).

Steps to produce slopelength performed with the raster calculator:

- a) GRID commands: note* create flowdirection and flowaccumulation (floating point) coverages from the elevationgrid first
- b) $C:\CNF\dtms\streams = \text{con}(c:\CNF\dtms\flowacc < 300, 1)$
rsp1 in GW and VA_WVA and TN uses 300, 10 meter cells = 7.4 acres for the threshold to start a stream

- c) `c:\CNF\dtms\streams_flip1 = con(isnull(c:\CNF\dtms\streams300), 1, 0)`
- d) `c:\CNF\dtms\streams_thin1 = thin(c:\CNF\dtms\streams_flip1)`
- e) `c:\CNF\dtms\streams2 = setnull(c:\CNF\dtms\streams_thin1 > 0, 1)`
- f) setmask streams2 (do in spatial analysis, options)
- g) `c:\CNF\dtms\flow_dir2 = c:\CNF\dtms\flowdir`
- h) setmask off (do spatial analysis, options)
- i) `c:\CNF\dtms\flow_down = flowlength(c:\CNF\dtms\flow_dir2, #, downstream)`
- j) `c:\CNF\dtms\mean = focalmean(c:\CNF\dtms\elev_projarea, rectangle, 10, 10)`
- k) `c:\CNF\dtms\diff = c:\CNF\dtms\mean - c:\CNF\dtms\elev_projarea`
- l) `c:\CNF\dtms\ridges = con(c:\CNF\dtms\diff < -10, 1, 0)`
- m) `c:\CNF\dtms\thin_ridges = thin(c:\CNF\dtms\ridges, #, #, #, 15)`
- n) `c:\CNF\dtms\top = setnull(c:\CNF\dtms\thin_ridges > 0, 1)`
- o) setmask top
- p) `c:\CNF\dtms\flow_dir3 = c:\CNF\dtms\flowdir`
- q) setmask off
- r) `c:\CNF\dtms\flow_up = flowlength(c:\CNF\dtms\flow_dir3, #, upstream)`
- s) `c:\CNF\dtms\slopelength1 = c:\CNF\dtms\flow_up + c:\CNF\dtms\flow_down`
- t) extract to study area = slopelength2
- u) `c:\CNF\dtms\slopelength3 = con(isnull(c:\CNF\dtms\slopelength2), focalmean(c:\CNF\dtms\slopelength2, rectangle, 3, 3), c:\CNF\dtms\slopelength2)`
- v) `c:\CNF\dtms\slopelength4 = con(isnull(c:\CNF\dtms\slopelength3), focalmean(c:\CNF\dtms\slopelength3, rectangle,3,3), c:\CNF\dtms\slopelength3)`
- w) `c:\CNF\dtms\slopelength5 = con(c:\CNF\dtms\slopelength4 > 3000, 3000, c:\CNF\dtms\slopelength4)`
- x) `c:\CNF\dtms\slengtfin1 = focalmean(c:\CNF\dtms\slopelength5, rectangle, 3, 3)`
- y) `c:\CNF\dtms\slength2 = con(isnull(c:\CNF\dtms\slength), focalmean(c:\CNF\dtms\slength, rectangle,3,3), c:\CNF\dtms\slength)`
- z) This process results in single pixels at some stream locations that are very different their adjacent pixels; otherwise, the remainder of the coverage looks good.

APPENDIX IV: Analysis Process

Maximum Entropy (MAXENT)

Create DTMs with the same extent as study area boundary: Extract each DTM by Mask (Arc tools) to ensure that grids are the same extent. Covert all Grids to ASCII DO THESE as a BATCH process.

Create CSV file with the following variables: **TYPE, Xcoordinate, Ycoordinate, DTM values.**

Use Hawth tools to attach X, Y to original plot coverage

Use Hawth tools to attach DTM data to points: Hawth Analysis, point intersection.

Export table and check that format, otherwise, strip all but TYPE, X, Y and DTM from file, save as CSV file.

i.e., (open an .xl file and select 'open as dbf', edit if necessary and SAVE AS [MSDOS] CSV file), i.e., (Comma delimited)

Run Maxent

Follow wizard and locate plot data file with attributes

Follow wizard and locate folder with environmental data, wizard inserts all .asc files.

Identify location for results (make separate directory)

Export all the resulting .asc files with floating point to create a Grid for each Ecological Zone.

Maximum probability Grid

Uses multiple Ecological Zone models to determine the maximum value on a cell-by-cell basis within the Analysis window, for example:

```
c:\tn\models3\max3o = max ~
(c:\tn\models3\gbald2, c:\tn\models3\sf2, c:\tn\models3\nhslope2, c:\tn\models3\nhcove2, ~
c:\tn\models3\montoakrich2, c:\tn\models3\montoakcove4, c:\tn\models3\montoakslope3, c:\tn\models3\dmoak4, ~
c:\tn\models3\oakrhodo, c:\tn\models3\rcove2,c:\tn\models3\acove3, c:\tn\models3\hero3, c:\tn\models3\poh4, ~
c:\tn\models3\dryoakkallat2,c:\tn\models3\dryoaklite, c:\tn\models3\floodplain, c:\tn\models3\alluvial3, ~
c:\tn\models3\sloak)
```

Creating the Ecological Zone model

Read each model Grid to compare to the maximum probability for that grid cell; if a match occurs, insert Ecological Zone model code.

```
c:\tn\models3\zoneo = con(c:\tn\models3\max3o == c:\tn\models3\gbald2, 27, ~
c:\tn\models3\max3o == c:\tn\models3\sf2, 1, ~
c:\tn\models3\max3o == c:\tn\models3\nhslope2, 2, ~
c:\tn\models3\max3o == c:\tn\models3\nhcove2, 3, ~
c:\tn\models3\max3o == c:\tn\models3\montoakrich2, 24, ~
c:\tn\models3\max3o == c:\tn\models3\alluvial3, 6, ~
c:\tn\models3\max3o == c:\tn\models3\floodplain, 23, ~
c:\tn\models3\max3o == c:\tn\models3\montoakcove4, 28, ~
c:\tn\models3\max3o == c:\tn\models3\montoakslope3, 9, ~
c:\tn\models3\max3o == c:\tn\models3\oakrhodo, 29, ~
c:\tn\models3\max3o == c:\tn\models3\rcove2, 5, ~
c:\tn\models3\max3o == c:\tn\models3\acove3, 4, ~
c:\tn\models3\max3o == c:\tn\models3\dmoak4, 13, ~
c:\tn\models3\max3o == c:\tn\models3\hero3, 8, ~
c:\tn\models3\max3o == c:\tn\models3\poh4, 18, ~
c:\tn\models3\max3o == c:\tn\models3\dryoakkallat2, 10, ~
c:\tn\models3\max3o == c:\tn\models3\dryoaklite, 11, ~
c:\tn\models3\max3o == c:\tn\models3\sloak, 16, 0)
```

Appendix V: Accuracy Evaluation

Accuracy assessments are essential parts of all vegetation mapping projects but they are time-consuming and expensive especially in mixed ownerships. They provide the basis to compare different map production methods, information regarding the reliability and usefulness of the maps for particular applications, and the support for spatial data used in decision-making processes. It is useful to evaluate accuracy relative to the aerial extent of each class. For example, when a particularly common class (e.g., 10-15% of the map area) has either a very high or a very low accuracy it has a disproportionate effect on the utility of the map for general analysis applications without a corresponding effect on the overall accuracy assessment. Conversely, a relatively rare type (e.g., < 1% of the map area) regardless of its accuracy has relatively little effect on the utility of the map for general analysis applications but has the same effect on the accuracy assessment as the common type.

A true accuracy assessment was not completed for this project, hence the title "Accuracy Evaluation". However, the same procedure was followed, i.e., a comparison was made of reference data for a site to categorized (classified, modeled) data (map units) on the same site. A quantitative accuracy assessment depends on the collection of reference data. Reference data is known information of high accuracy (theoretically 100% accuracy) about a specific area on the ground (the accuracy assessment site). The assumed-true reference data can be obtained from ground visits, photo interpretation, video interpretations, or some combination of these methods. In a map unit accuracy assessment, sites are generally the same type of modeling unit used to create the map. In a true field accuracy assessment, the evaluation would be made around randomly generated points on the ground or more realistically within a 'stand' or other reasonable-size area. For this study, the sample plots were considered the reference data and were buffered by 10 meters (the base resolution of all DTMS) to create a 'fuzzy' boundary between Biophysical settings to better account for ecotones between types. These buffered reference sites were considered 'correctly classified' if they fell even partially within a map unit having the same classification.

Error Matrix

The error matrix (Tables 1, 2) below are a square array in which accuracy assessment sites are tallied by both their classified category and their actual category according to the reference data. For this study, the columns in the matrix represent the classified Ecological Zone map units, while the rows represent the reference data (non-traditional approach). The major diagonal, highlighted in the following table, contains those sites where the classified data agree with the reference data. The nature of errors in the classified map can also be derived from the error matrix. In the matrix, errors (the off-diagonal elements) are shown to be either errors of inclusion (commission errors) or errors of exclusion (omission errors). Commission errors are shown in the off-diagonal matrix cells that form the horizontal row for a particular class. Omission error is represented in the off-diagonal vertical row cells. High errors of omission/commission between two or more classes indicate spectral confusion between these classes.

The following measures of accuracy were derived from the Ecological Zone error matrix.

Overall Accuracy, a common measure of accuracy, is computed by dividing the total correct samples (the diagonal elements) by the total number of assessment sites found in the bottom right cell of the matrix.

Producer's Accuracy, which is based on omission error, is the probability of a reference site being correctly classified. It is calculated by dividing the total number of correct accuracy sites for a class (diagonal elements) by the total number of reference sites for that class found in the right-hand cell of each row (Story and Congalton 1968). Producer's accuracy indicates how many times an Ecological Zone on the ground was identified as that Ecological Zone on the map.

Table 1: Evaluation of Ecological Zones in the Cherokee NF study area from 1,200 field sites

#		1	27	2	3	4	29	5	6	23	8	24	9	28	13	10	11	16	18	total	correct class	
27	grassy bald	12																			12	100.0%
1	spruce		31	3	1	1															36	86.1%
2	nhwood slope			30	1						2		1								34	88.2%
3	nhwood cove	1		2	24	2		1					4								34	70.6%
4	acidic cove				2	160	3	6	1				6	7	2	1		2			190	84.2%
29	oak / rhodo.						19	3						2		1					25	76.0%
5	rich cove			1		6	1	66					5	4	3		1				87	75.9%
6	riparian_alluvial					1			11						1						13	84.6%
23	floodplain								1	52									1		54	96.3%
8	high elev.RO					1					38		5			2				2	48	79.2%
24	montoak_rich											11									11	100.0%
9	montoak_slope					2	2	4			1		122	3	3	5	1	1			144	84.7%
28	montoak_cove					5	4	5					1	46	6	1		2			70	65.7%
13	dmoak					2	2	4			1		1	5	109	5	4	3	3		139	78.4%
10	dryoak/ever.heath						2	1					6	1	4	53			2	2	71	74.6%
11	dryoak/decid.heath						1	1							1	1	21		1	2	28	75.0%
16	lowelevpine								1						4	1			40	1	47	85.1%
18	pine-oak heath						3	1			2			1	5	10	2	5	128		157	81.5%
	TOTAL Correct ^{2/}																				973	81.1%

^{1/} rows are reference (field plot) data, columns are classified (modeled) data, ^{2/} Total Correct percent = 973 (correctly modeled field plots) / 1,200 (total plots)

Table 2: Evaluation of Biophysical Settings in the Cherokee NF study area from 1,200 field sites ^{1/}

#		27	1	2	4	6	23	8	9	13	10	16	18	total	correct class
27	Southern Appalachian Grass and Shrub Bald	12												12	100.0%
1	Central and Southern Appalachian Spruce-Fir Forest		32	4										36	88.9%
2	Southern Appalachian Northern Hardwood		1	60	2			1	4					68	88.2%
4	Southern and Central Appalachian Cove Forest				1	274			20	3	1	3		302	90.7%
6	Central Interior and Appalachian Riparian Systems						13							13	100.0%
23	Central Interior and Appalachian Floodplain Systems							54						54	100.0%
8	Central and Southern Appalachian Montane-Oak					1		38	6		1		2	48	79.2%
9	Southern and Central Appalachian N. Red Oak-Chestnut Oak					22		1	186	10	4	3		226	82.3%
13	Southern Appalachian Oak Forest					4		1	7	116	7	2	2	139	83.5%
10	Allegheny-Cumberland Dry Oak Forest and Woodland					1			8	5	78	3	4	99	78.8%
16	Central Appalachian Low-Elevation Pine									4	1	40	1	46	87.0%
18	Southern Appalachian Montane Pine Forest and Woodland					4		2		3	16	5	127	157	80.9%
	TOTAL Correct ^{2/}													1030	85.8%

^{1/} rows are reference (field plot) data, columns are classified (modeled) data, ^{2/} Total Correct percent = 1030 (correctly modeled field plots) / 1200 (total field plots)

Appendix VI: Use of Ecological Zones

The Chattooga River Ecosystem Management Demonstration Project started in 1993 in South Carolina, Georgia, and North Carolina, was the first attempt at applying environmental models, like those used for developing Ecological Zones, to predict 'potential' plant community distribution across extensive landscapes in the Southeastern U.S. One of the primary goals of this project was to produce an ecological classification that would provide the information for implementing ecosystem management tied to the National Hierarchical Framework of Ecological Units, "a regionalization, classification and mapping system for stratifying the Earth into progressively smaller areas of increasingly uniform ecological potential for use in ecosystem management" (ECOMAP, 1993). What are now termed Ecological Zones were then called "plant association predictive models" or "Potential Vegetation". In the Chattooga project, plant association predictive models were developed, under the guidance of Henry McNab - Southern Forest Service Experiment Station, based upon the relationships between field locations of example plant association types and digitally derived landform factors such as elevation, landform index, and relative slope position (McNab 1991). These models were used in combination with soil maps to develop ecological units at different resolutions, i.e., Landtype Associations, Landtypes, and Landtype Phases.

In 1999, as part of the forest planning process on the Croatan National Forest, pre-settlement vegetation maps, equivalent to Ecological Zones (Frost 1996), were used to develop an Ecological Classification that included: Landtype Associations, Landtypes, and Landtype Phases, "A new tool that needed to be incorporated into the revised Plan" (USDA 2002). An ecological classification system was developed for the Croatan National Forest that provided a basis for ecologically based land management decisions. This classification organized the landscape into "units having similar topography, geology, soil, climate, and natural disturbance regimes" (USDA 2002) and was used to define management areas, management prescription boundaries, standards, and to set forest-wide objectives. Similarly, in 2001, the Forest Service in cooperation with the Department of Defense (DOD), Camp Lejeune Marine Corps. Base, developed an Ecological Classification System (ECS) to guide conservation management decisions for their Integrated Natural Resource Management Plan (INRMP). The ECS was based, in part, on a report titled "Presettlement Vegetation and Natural Fire Regimes of Camp Lejeune" by Cecil Frost, January 24, 2001, a map analogous to Ecological Zones. In DOD's most current INRMP, Camp Lejeune continues to refer to the ECS for overall guidance on the desired future condition for specialized habitat areas, i.e., natural areas (DOD 2006).

In 2001, the staff of the National Forests of North Carolina conducted a status review of management indicator species (MIS) habitats and population trends using Ecological Zone mapping to quantify the amount and distribution of plant community types on the Nantahala and Pisgah National Forests (USDA 2004a). Ecological Zones were also used to identify sites capable of supporting eastern and Carolina hemlock plant communities as part of a conservation area design to prioritize areas for Hemlock Woolly Adelgid control. This conservation area is currently being used to maintain, on portions of the Forests, important hemlock ecosystem functions and to serve as a genetic reserve to maintain a diverse hemlock gene pool 'in situ' (USDA 2005). Ecological Zones were used in the Uwharrie National Forest plan revision process to develop a map of the potential extent of Nature Serve Ecological Systems. This mapping provided the basis for the Ecological Sustainability Analysis and was used to help define management areas, restoration areas, and desired conditions, and to help set objectives and guidelines (USDA, 2009). Ecological Zones were used in a Plan amendment to evaluate the appropriateness of various management indicator species on the Nantahala and Pisgah National Forests (USDA, 2005), and were combined with satellite imagery to map existing vegetation on the Nantahala National Forest in a multi-year, USFS Southern Region pilot project to demonstrate a process for mid-level existing vegetation mapping suitable in the hardwood dominated forests of the Southern Region (USDA 2006).

From 2008 to 2010, Ecological Zones were mapped in the Cumberland Plateau of Kentucky, in the South Mountains, Northern Escarpment, and New River Fire FLN landscapes within the Southern Blue Ridge (SBR) in North Carolina to evaluate the location and extent of fire-adapted plant communities. From 2009

to 2010, Ecological Zones were mapped in the Virginia-West Virginia Fire Learning Network study area and for the George Washington National Forest to evaluate fire-adapted plant communities and to provide vegetation mapping for the Forest Plan revision.

The current project in the north zone of the Cherokee National Forest described in this report was initiated because of concerns about the accuracy of the available, coarse level, LANDFIRE BpS map units used for characterizing the complex ecosystems in the area. The summary below (Table 1) compares that coarse level map to the higher resolution mapping just completed based upon Ecological Zone models.

Table 1. Comparison of the extent and accuracy of TNC 2011 BpS (this project) and LANDFIRE 2009 BpS

map code	Biophysical Settings (BpS)	TNC 2011			LANDFIRE 2009		
		USFS acres	% of total	accuracy allplots ^{1/}	USFS acres	% of total	accuracy allplots ^{1/}
27	Southern Appalachian Grass and Shrub Bald	63	0.0	100%	42	0.01	50%
1	Central and Southern Appalachian Spruce-Fir Forest	2,234	0.7	89%	674	0.2	31%
2	Southern Appalachian Northern Hardwood	10,589	3.1	88%	4,167	1.2	28%
4	Southern and Central Appalachian Cove Forest	99,206	29.6	91%	35,112	10.5	20%
6	Central Interior and Appalachian Riparian Systems	2,118	0.6	100%	30,662	9.1	62%
23	Central Interior and Appalachian Floodplain Systems	453	0.1	100%	1,151	0.3	39%
98	Reservoirs and Ponds	117	0.03	--	443	0.1	--
8	Central and Southern Appalachian Montane Oak	4,021	1.2	79%			
9	Southern and Central Appalachian Red Oak-Chestnut Oak	65,995	19.6	82%	52,996	15.8	36%
13	Southern Appalachian Oak Forest	40,579	12.1	84%	130,000	38.7	64%
10	Allegheny-Cumberland Dry Oak Forest and Woodland	64,860	19.3	79%	8,508	2.5	5%
16	Southern Appalachian Low-Elevation Pine	23,888	7.1	87%	10,845	3.2	15%
18	Southern Appalachian Montane Pine Forest and Woodlands	21,583	6.4	81%	60,539	18.0	20%
	Barren-Rock/Sand/Clay	--	--	--	302	0.09	
	South-Central Interior Mesophytic Forest	--	--	--	122	0.04	
	Southern Ridge and Valley/Cumberland Dry Calcareous Forest	--	--	--	142	0.04	
	TOTAL	335,706	100.0	86%	335,706	100.0	30%

^{1/} from 1,200 field plots described in the "Methods" section.

Appendix VII: Codes for Ecological Zones and BpS /Nature Serve Ecological Systems

Code	Ecological Zone
1	Spruce
2	Northern Hardwood Slope
3	Northern Hardwood Cove
4	Acidic Cove
5	Rich Cove
6	Riparian_Alluvial Forest
8	High Elevation Red Oak
9	Montane Oak Hickory Slope
10	Dry Oak Evergreen Heath
11	Dry Oak Deciduous Heath
13	Dry Mesic Oak
16	Low Elevation Pine
18	Pine-Oak Heath
23	Large Floodplain
24	Montane Oak-Hickory Rich
27	Grassy Bald
28	Montane Oak-Hickory Cove
29	Mixed Oak / Rhododendron
61	Riparian_Streamsides
98	Reservoirs, Lakes, and Ponds

Code	BpS / NatureServe Ecological System
1	Central and Southern Appalachian Spruce-Fir Forest
2	Appalachian (Hemlock)-Northern Hardwood
4	Southern and Central Appalachian Cove Forest
6	Central Interior and Appalachian Riparian Systems
8	Central and Southern Appalachian Montane Oak
9	Southern and Central Appalachian Northern Red Oak-Chestnut Oak Forest
10	Allegheny-Cumberland Dry Oak Forest and Woodland
13	Southern Appalachian Oak Forest
16	Southern Appalachian Low-Elevation Pine
18	Southern Appalachian Montane Pine Forest and Woodland
23	Central Interior and Appalachian Floodplain Systems
27	Southern Appalachian Grass and Shrub Bald

98 Other: Reservoirs, Lakes, and Ponds