Ecological Zones on the Jefferson National Forest Study Area: First Approximation

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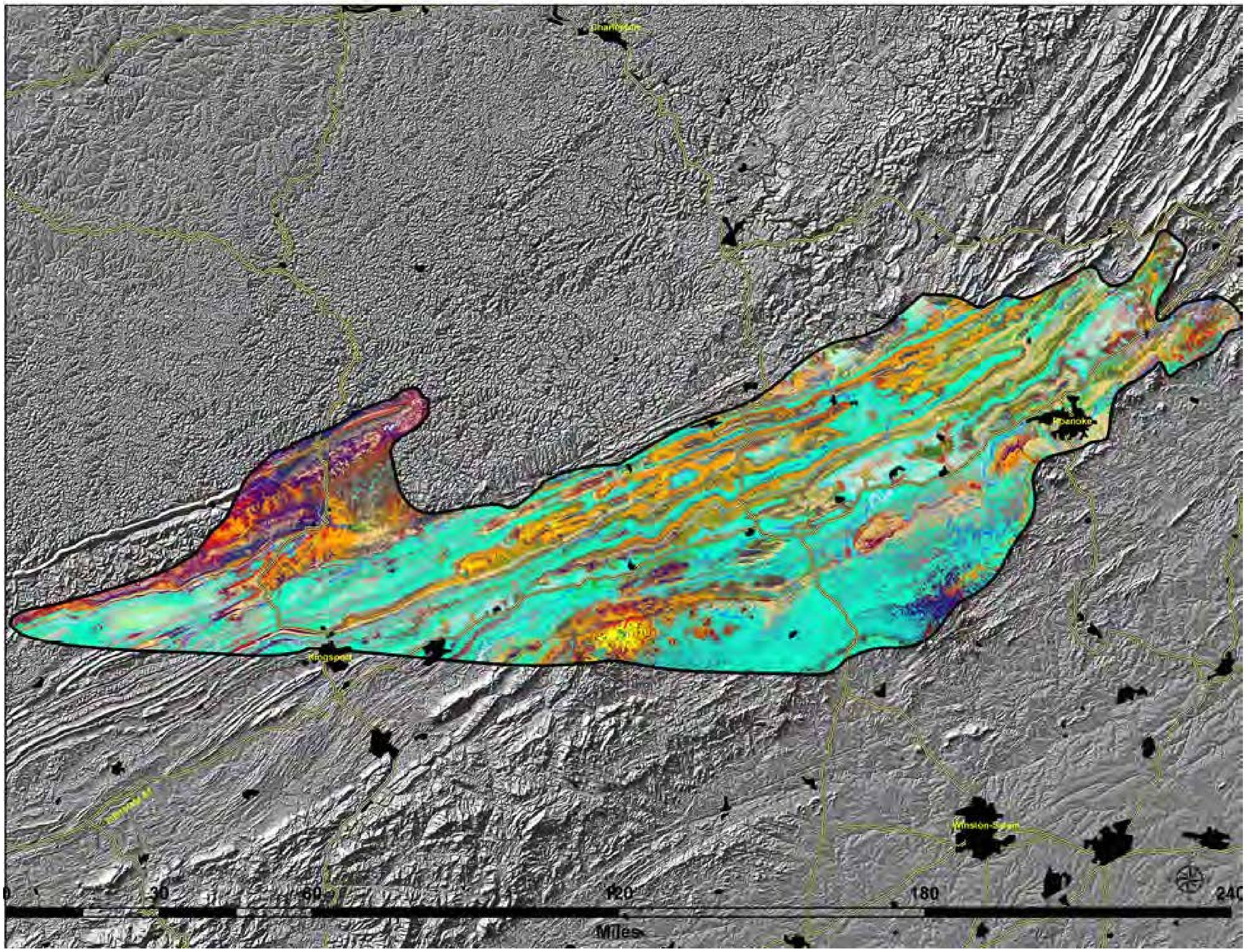

A 1st approximation of Ecological Zones centered on the Jefferson National Forest, Great Valley of Virginia, the Northern Ridge and Valley, and Central Blue Ridge Mountains was developed from 4,900 field reference sites, 34 computer-generated environmental variables, and analysis and adjustment of ecotone boundaries using local environmental relationships between types. Oak-dominated Ecological Zones, about equally distributed on carbonate- and non-carbonate-bearing rock, (mapped bluish green, orange, and dark gray respectively) accounted for about 68% of the nearly 6 million acre landscape, Cove Ecological Zones 19% (red & dark blue), and Pine-Oak Ecological Zones 5% (green). The remaining 8% of the landscape included Alluvial Forest, Floodplain, Barrens, Glades, Northern Hardwood, and Spruce-Fir.

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The Central Appalachians FLN engages federal, state and private land management agencies, academic institutions, and non-profit organizations in a collaborative effort to enhance capacity to implement ecological fire management. Partners in Virginia and West Virginia include: USDA Forest Service, The Nature Conservancy, Virginia Department of Conservation and Recreation, Virginia Department of Forestry, Virginia Department of Game and Inland Fisheries, Virginia Department of Corrections, West Virginia Department of Forestry, West Virginia Department of Natural Resources, National Park Service, US Fish and Wildlife Service, National Weather Service, Arcadia University, West Virginia University, and Virginia Tech. For more information, please visit: www.conservationgateway.org/fln

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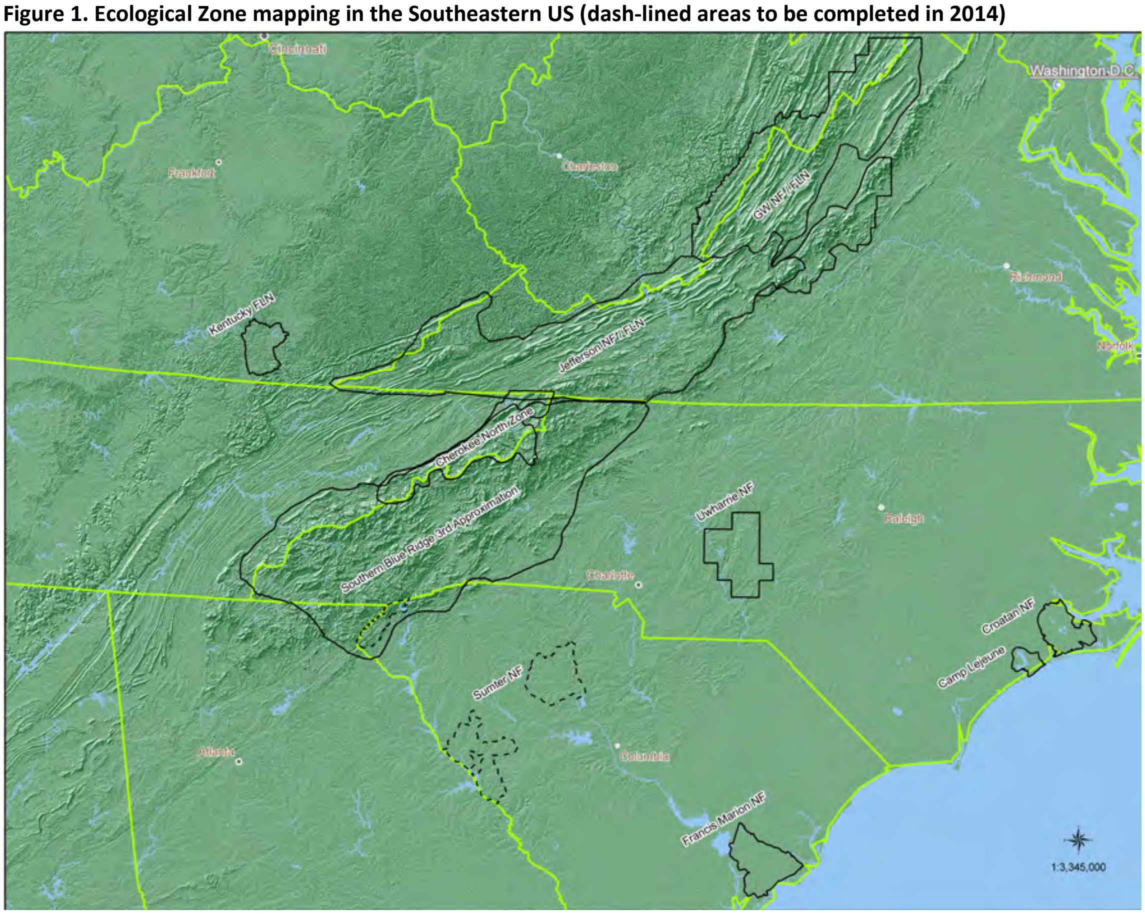
INTRODUCTION

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 are equivalent to Biophysical Settings (BpS) which 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. BpS map units are defined by Nature Serve Ecological Systems, a nationally consistent set of mid-scale ecological units (LANDFIRE 2009). Ecological Zones are mapped at a higher resolution than BpS, have more categories, and use abbreviated Nature Serve names.

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 2001 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, Tennessee, in the Uwharrie Mountains, and the South Mountains, Northern Escarpment, and New River Fire Learning Network (FLN) landscapes in North Carolina, and in Virginia and West Virginia, centered on the George Washington National Forest (Figure 1). This report documents the methods and results of the most current effort to improve Ecological Zone models and mapping in the Jefferson National Forest study area (study area).

Figure 1. Ecological Zone mapping in the Southeastern US (dash-lined areas to be completed in 2014)



Jefferson NF study area Ecological Zones - background: Ecological Zones were used in 2010 to map fire-adapted landscapes within the Allegheny Highlands and West Virginia Fire Learning Networks centered on the George Washington National Forest. In 2012, The U.S. Forest Service and The Nature Conservancy provided support to map Ecological Zones on adjacent landscapes centered on the Jefferson National Forest and included most notably, the Appalachian Trail Corridor, the Blue Ridge Parkway, Clinch Mountain Wildlife Management Area, The Big Survey Wildlife Management Area, Cumberland Gap National Historical Park, Grayson Highlands State Park, Breaks Interstate Park, New River State Park, Hungry Mother State Park, Cleveland Barrens State Natural Area Preserve, Mountain Lake Biological Station, Pedlar Hills Glades State Natural Area Preserve, The Cedars State Natural Area Preserve, Natural Tunnel State Park, Pinnacle State Natural Area Preserve, and intervening private lands.

General description:
The study area includes 3 Ecological Provinces and 5 Ecological Sections (Cleland and others 2007); Provinces include the Eastern Broadleaf Forest which has a continental-type climate of cold winters and warm summers, the Central Appalachian Broadleaf Forest-Coniferous Forest-Meadow Province which has a temperate climate with cool summers and short, mild winters, and a very small portion of the Southeastern Mixed Forest Province which has generally uniform maritime climate with mild winters and hot, humid summers.

Ecological Sections (Figure 2) include, in descending order of size, the: Northern Ridge and Valley (54% of the study area), Blue Ridge Mountains-Northern Sub-Section (25%), Northern Cumberland Mountains (12%), Central Ridge and Valley (7%), Allegheny Mountains (2%), and the Central Appalachian Piedmont (< 1% of the study area). The Northern Ridge and Valley Section has broad, shallow, northeast-southwest parallel valleys underlain primarily by carbonate formations separated by low ridges having sandstone cap rocks. The oak-hickory cover type makes up most of the forests. The surface of the Blue Ridge Mountains Section is a gently west-sloping plateau defined on the east by a steep escarpment. Topography consists of moderately high (2,500 – 4,000 feet), highly weathered mountain ranges, with scattered higher-elevation peaks over 5,500 feet. The Precambrian-Cambrian bedrock geology is mostly metamorphosed gneiss and schist formed from recrystallization of non-carbonate sedimentary, volcanic, or igneous parent rock material. Most gentle lower slopes were cleared for subsistence agriculture during the 1800s and most forests had been selectively logged by the early 1900s. The climate of this section is cooler and wetter than that of adjoining sections. The Northern Cumberland Mountains terrain consists of long monoclinal mountains and dissected uplands. Rock formations are level-bedded sandstones that have been eroded to form mountainous terrain. The Central Ridge and Valley Section has a maturely dissected landscape of open hills with folded, faulted, and uplifted belts of parallel valleys and ridges. Carbonate rock formations dominate. Existing cover type is mainly agricultural and urban. Small areas of natural cover types remain consisting of forests of oak-hickory, oak-pine, and white pine. The Allegheny Mountains Section has a maturely dissected plateau characterized by high, sharp ridges, low mountains, and narrow valleys. Bedrock consists of shales, siltstones, carbonates, and sandstones. The least extensive Section in the project area, the Central Appalachian Piedmont Section, has a moderately dissected plain with high and low hills underlain by metamorphic formations of schists and phylites that have weathered to form thick saprolite and deep soils with heavy clay subhorizons.

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. Since most of the data on the Jefferson NF study area was collected on federal, state, and TNC, Ecological Zone predictions outside of these areas 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) modeling individual Ecological Zones and evaluating ecotones, i.e., the transition between Ecological Zones using local environments, 5) post-processing of digital model outputs, and 6) evaluating the accuracy of Ecological Zone map units.

1) <u>Data acquisition</u>: Ecological Zones were identified at over 3,900 sample areas by evaluating overstory and understory species composition, growth form, stand density, and site factors. 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 if they were in 'good condition' and therefore more 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 more heavily sampled. A laptop computer attached to a global positioning system (GPS), to enable real-time location tracking in the field, was used in conjunction with ArcGIS to document on-site observations of ecological characteristics and to access resource data layers for each site.

Table 1. Plot intensity and data sources / investigators in the JEFF NF Study area

Study Area	Plots	Field Investigators / Data sources
George Washington NF 1st approximation	60	S.Simon
Jefferson NF 1st approximation	665	Josh Kelly (primarily in the Iron Mts.)
	290	Josh Kelly & S.Simon
	660	VA Natural Heritage Program
	2,925	S.Simon
Total Jefferson NF 1st approximation	4,600	

Ecological Zones were also described for nearly 700 additional plots, collected within the project area during the past 15+ years by Virginia Natural Heritage Botanists (Table 1). This data, in addition to including information on more common types such as Basic Oak-Hickory Forest, Dry-Mesic and Dry Calcareous Forests, also included data for less common types such as Central and Southern Appalachian Spruce-Fir Forests, Limestone and Dolomite Barrens, and Shale Barrens. This allowed the author a means of evaluating local ecological interpretations by visiting established plots within the area. In total, nearly 4,600 plots were used to characterize Ecological Zones in the project area (Table 1, Figure 2).

Ecological Zone classification units are relatively coarse and fairly easy to recognize in the field. They do not include rare types such as bogs, cliff-talus, fens, glades, seepage swamps, small wetlands, or cedar cliffs because the digital data needed to model these unique environments are incomplete or at too coarse a resolution. The 27 different Ecological Zones identified in the study area, arranged from wet to xeric moisture regimes, are cross-walked with Virginia Natural Heritage Ecological Groups (Fleming and Patterson 2010), and Nature Serve Ecological Systems (NatureServe 2010) to help in describing the composition of types observed in the field and mapped across the study area (Table 2). More detailed site and species composition descriptions for Ecological Zones, Nature Serve Ecological Systems, and Virginia Natural Heritage Community groups are in Appendix I. This cross-walk reflects the author's ongoing adjustment of Ecological Zone concepts to fit local landscapes based upon work between 2008 and 2012 evaluating Biophysical Setting (BpS) map units (LANDFIRE 2009), in the Southern Blue Ridge Mountains in North Carolina, South Carolina, Tennessee, and Georgia, and modeling Ecological Zones in the Cumberland Plateau in Kentucky, Allegheny Mts., Central and Northern Blue Ridge Mountains, and Ridge and Valley.

Table 2. Crosswalk between Ecological Zones, Virginia Heritage Program Ecological Groups, and BpS / Ecological Systems

Ecological Zone	map code	Virginia Heritage Program Ecological Groups	NatureServe Ecological System
Grass Bald	30	Grass and Shrub Balds (in part)	Southern Appalachian Grass and Shrub Bald (in part)
Spruce	1	Spruce and Fir Forests	Central and Southern Appalachian Spruce-Fir Forest
Northern Hardwood Slope	2	Northern Hardwood Forests	Appalachian (Hemlock)-Northern Hardwood Southern Appalachian Northern Hardwood
Northern Hardwood Cove	3	High Elevation Rich Cove Forests	
Acidic Cove	4	Acidic Cove Forests High Elevation Acidic Cove Forest	Southern and Central Appalachian Cove Forest
Mixed Oak / Rhododendron	44	Oak / Heath Forests (in part)	
Rich Cove	5	Rich Cove and Slope Forests	
Rich Slope	55		
Alluvial Forest	6	Piedmont / Mountain Alluvial Forests	Central Appalachian Stream and Riparian
Floodplain Forest	23	Piedmont / Mountain Floodplain Forests	Central Appalachian River Floodplain
High Elevation Red Oak	8	Northern Red Oak Forests Oak / Heath Forests (in part)	Central and Southern Appalachian Montane Oak
Montane Oak-Hickory (Rich)	24	Montane Mixed Oak & Oak-Hickory-Forest (Rich)	Southern and Central Appalachian Northern Red Oak-Chestnut Oak
Montane Oak-Hickory (Cove)	15	Montane Mixed Oak and Oak-Hickory Forests	
Montane Oak-Hickory (Slope)	9		
Dry Mesic Oak	13	Acidic Oak-Hickory Forests	Southern Appalachian Oak Forest
Basic Oak-Hickory	31	Basic Oak-Hickory Forests	Northeastern Interior Dry-Mesic Oak Forest
Dry Mesic Calcareous Forest	14	Dry-Mesic Calcareous Forests	
Dry Calcareous Forest	17	Montane Dry Calcareous Forests and Woodlands	Southern Ridge & Valley /Cumberland Dry Calcareous Forest Central Appalachian Alkaline Glade and Woodland
Limestone-Dolomite Barren	29	Limestone and Dolomite Barrens	Southern Ridge and Valley Calcareous Glade and Woodland
Dry Oak Evergreen Heath	10	Oak / Heath Forests (in part)	Central Appalachian Dry Oak-Pine Forest
Dry Oak Deciduous Heath	11		
Pine-Oak Heath	18	Pine-Oak / Heath Woodlands	Southern Appalachian Montane Pine Forest and Woodland
Shortleaf Pine Oak	16	Mountain / Piedmont Acidic Woodlands?	Southern Appalachian Low-Elevation Pine
Xeric Pine-Oak	222	Mountain / Piedmont Acidic Woodlands	Central Appalachian Pine-Oak Rocky Woodland
Acid Glade	27		
Shale Barren	21	Central Appalachian Shale Barrens	Appalachian Shale Barrens
Pine-Oak Shale	22		

Field plots were primarily on public land and therefore clustered across the study area (Figure 2). This resulted in several elevation zones where reference plant communities were 'over-sampled' and other elevation zones that were 'under-sampled' because of access difficulty or poorer vegetation condition. Ecological Zones describe different environments; elevation is a major 'driver' of these environments because it affects temperature and moisture, and reflects major differences in geology in the study area. Therefore it was assumed, in the following analysis, that plot sampling was adequate if the full range (and 'extent') of elevation was sampled proportionately (such as would occur in stratified sampling). Depending upon the perspective of scale, elevations between 1,000 and 2,500' were under-sampled across the project area but adequately sampled on USFS lands (Table 3). On the other hand, USFS land on elevations between 2,500 and 3,000' could be considered under-sampled (22.7% of plots on 29.2% of USFS land) although this represents over 1000 plots within this elevation class. Likewise, elevations from 1,000-1,500' on other conservation land could be considered under-sampled and elevations > 3,000' could be considered over-sampled (Table 3) in all ownership categories.

Figure 2. Field reference plots in the Jefferson NF project area: 1st Approximation

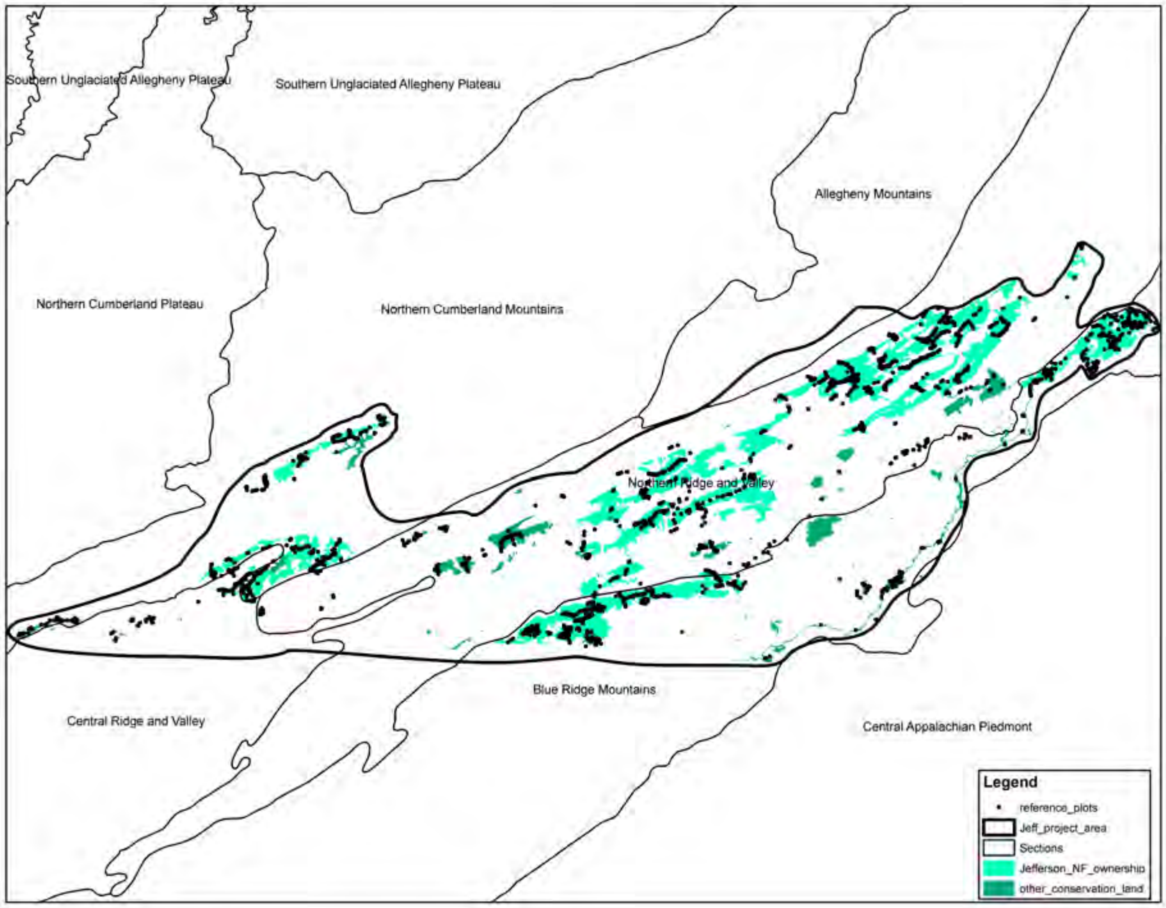


Table 3. Ecological Zone plot sampling intensity by elevation class within the project area (under-sampled[1/] classes highlighted).

elevation class	< 1,000'	1,000-1,499'	1,500-1,999'	2,000-2,499'	2,500-2,999'	3,000-3,499'	3,500-3,999'	4,000-4,499'	≥ 4,500'
Jefferson NF Project area – all lands (5,673,560 acres)									
% plots	1.2	4.6	15.7	21.7	22.7	19.4	9.6	3.0	2.2
% of area	0.9	10.6	22.9	32.5	22.6	7.1	2.6	0.6	0.2
Jefferson NF ownership (725,945 acres)									
% of area	0.6	5.1	11.8	22.6	29.2	19.5	7.9	2.0	1.4
Other Conservation Lands (165,530 acres)									
% of area	0.4	11.1	19.7	16.2	24.7	13.5	9.9	3.4	1.0

[1/] a greater than 5% difference between plots and proportional area representation

2) Creating a digital terrain database: Development of the individual Ecological Zone models began with the creation of a spatial database that described the study area environment using landform and environmental variables. Site conditions for each field plot were extracted from these 34 landform / environmental models (DTMS) in a Geographic information system (Table 4). For statistical analyses, data were stored in a database that included plot number, Ecological Zone, and digital landform / environment value for each plot. The methods used for developing DTMs are described in detail in Appendix III and VIII.

Table 4. Environmental variables evaluated in Ecological Zone models

Aspect (degrees)
Aspect (cosine-degrees)
Curvature of land (all directions)
Curvature of land (direction of slope)
Curvature of land (perpendicular to slope)
Elevation
Flow accumulation (up)
Flow accumulation (down)
Geology (distance to rock type)
Carbonate-bearing
Felsic Igneous and Metamorphic
Siliciclastic
Mixed geology over carbonate rock
Shale
Mafic and Ultramafic
Tuff
Lava
Conglomerate-phyllite-siltstone
Quartzite-sandstone
Landform10 (10x10 pixel neighborhood)
Landform30 (30x30 pixel neighborhood)
Landform index (from McNab 1993)
Precipitation (30 year average from 1971-2000)
Relief (local)
Relative slope position – local landscape (from Wilds 1997)
Relative slope position – mid-level landscape scale (Wilds modified)
Slope length
Slope steepness
Solar radiation (yearly)
Stream influence
difference in elevation from nearest stream
distance to nearest stream
River influence (4^{th} order and greater streams)
difference in elevation from nearest river
distance to nearest river
Terrain shape index (from McNab 1993)
Valley position

3) <u>Statistical analysis</u>: 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 used in earlier Ecological Zone work, is therefore a "presence only" modeling approach; it used only Ecological Zone presence (the field reference data) 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 for each Ecological Zone ranging from zero to one for each pixel within the study area. The process for developing models for 27 mid-scale Ecological Zones occurring in the project area is described in Appendix IV.

4a) <u>Spatial modeling / creating preliminary Ecological Zone map units</u>: To produce a preliminary aggregate Ecological Zone map, the 27 Zone models were merged and each pixel in the study area was 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 by adjusting the ArcGrid 9.3.1 Merge command preference of order (ESRI 2009).

4b) <u>Evaluating the transition area between Ecological Zones (ecotones)</u>: Although MAXENT worked well to predict the distribution of individual Zones, merging multiple Zone models did not always match the field reference data. This was apparently due to different model 'strengths' but also to the confusion between types occurring in similar environments. These model and field plot discrepancies (classification errors) were predominantly in the transition area between Zones, i.e., the ecotone. To better balance individual Zone model strengths and improve the overall model accuracy, an analysis of these ecotones was completed. This analysis used accuracy evaluations based upon reference plots (appendix VII) at different modeling stages and within different landscapes to determine the environmental conditions, e.g., an elevation range, a slope position, etc. where minor adjustments in model probability levels would result in reduced confusion (error) between classes (types). It was assumed that, because reference plots are used to 'train' Zone suitability models in MAXENT, the environmental relationships observed at these locations should also 'train' 'correct' adjustments elsewhere. For example, Pine-Oak Heath reference sites on less convex slopes (the ecotone with less xeric sites) had slightly lower MAXENT probabilities relative to other Zones at these same locations, especially Dry-Oak/Deciduous Heath. A negative value of curvature indicates a more concave surface; a positive value indicates a more convex surface. Pine-Oak Heath is more common at a curvature value that exceeds 100 but can be found on extremely convex slopes (curvature > 300). By slightly increasing (less than 10%) all Pine-Oak Heath model probability levels within a narrow segment of the environment (e.g., curvature > -15 but less than 135), the distribution of this Zone and overall accuracy of this type could be improved judged by further accuracy evaluations and local knowledge of this Zone's distribution. This process is discussed in detail in Appendix V and VI.

5) <u>Post-processing of digital model outputs</u>: Post-processing was used to reduce "data noise" i.e., the number of isolated single 30x30 foot 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 8 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.

6) <u>Assessing the accuracy of Ecological Zone map units</u>: Field plots were used as reference data to evaluate the accuracy of the final Ecological Zone 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 DISCUSSSION

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

1) The relative importance of environmental factors in predicting Ecological Zones (Tables 5-8),
2) influence of local environments on competing Zones, i.e., adjustments within the ecotone (Figures 3-4, appendix VI),
3) accuracy of map units relative to field reference plots (Table 9, appendix VII),
4) predicted elevation range of Ecological Zones,
5) location and extent of Ecological Zones based on acreage of map units (Table 10), elevation distribution (Tables 12-13), and mid-scale displays of Ecological Zones relative to topography (Figures 5-10), and the,
6) extent of fire-adapted plant communities within Ecological Systems and their mapped accuracy (Table 14, Appendix VII).

<u>1) Relative importance of environmental factors</u>: The importance of temperature, moisture, and fertility factors that control Ecological Zone distribution, can be evaluated by looking at those DTM variables that were most often used in the study area that made the most contribution to prediction gain in the Zone models (Table 5). River influence (distance to river or difference in elevation above the nearest river), and distance to siliciclastic geology were used most often, i.e., they made a 5% contribution to prediction gain in over one-half of the models. Elevation, local relief and distance to carbonate rock had at least a 5% gain in other Ecological Zones in model area 1 (Ridge and Valley) or model area 2 (Blue Ridge Mts.) in at least 50% of the Zone models. Overall, 5 of the top 10 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", this is still an indication of the effect that fertility is predicted to have on plant community distribution in the study area. Local relief and precipitation, also within the top 10 variables used, reflect the broader scale influence of topography on moisture and temperature gradients, important in the area, while relative slope position slope steepness, and surface shape (within the top 20 variables) helped to define finer-scale variation in Ecological Zone distribution.

Table 5. Importance of environmental variables for predicting Ecological Zones in the study area

	% of models [1/]		
Environmental variable	NW_I81	SE_I81	TOTAL_area
Difference in elevation or distance from the nearest river (Rivdiff, Rivdist)	61	59	60
Distance to siliciclastic rock	52	50	51
Elevation	44	50	47
Local relief	44	50	47
Distance to felsic igneous rock or to metamorphic rock	48	27	38
Distance to mixed geology over carbonate rock	57	18	37
Difference in elevation or distance from the nearest stream (Strmdiff, Strmdist)	35	32	33
Distance to shale rock	48	14	31
Distance to mafic igneous rock	26	32	29
Average annual precipitation	17	36	27
Distance to carbonate rock	35	14	24
Relative slope position (fine or broad scale)	22	23	22
Slope steepness	17	23	20
Valley position	22	18	20
Slope direction (Aspect degrees, Aspect cosine, Solar radiation)	22	18	20
Landform index	9	14	11
Surface shape (TSI, Curve, Curvepl, Curvepr)	17	0	9
Quartzite-Sandstone rock	0	14	7
Conglomerate_Phyllite_Siltstone	0	14	7
Flowaccumulation (down)	4	9	7
Lava rock	0	9	5
Tuff rock	0	5	2
Flowaccumulation (up)	4	0	2
Solar radiation	4	0	2
Landform Shape (Lndform10, Lndform30)	0	0	0
Slope length	0	0	0

[1/] percent of all models where variable made at least a 5% contribution to the prediction gain

Table 6. Mean values for environmental variables that describe temperature, fertility, and moisture gradients within Ecological Systems from 4,500+ reference plot locations arranged from high to low elevation (some values rounded).

		Temp.	Fertility (Distance to Bedrock Type, in 1,000s of feet) [1/]						Moisture, Temperature, Radiant Energy, and Fertility [2/]							
map code	BpS / Ecological System	ELEV. ft.	GEO1	GEO2	GE03	GEO4	GEO5	GEO6	SLOPE	VPOS	RPOS1	ASP	RIVDIFF	RELIEF	LFI	PREC
30	Grass Bald	5,150	8.80	2.90	1.00	8.80	7.30	19.30	19	12	13	-380	5,340	530	0.50	58
1	Spruce-Fir	5,055	7.70	2.10	1.00	8.70	6.80	20.50	21	24	30	-280	4,560	550	0.90	58
2	Northern HW Slope	4,300	6.50	16.20	0.95	6.20	7.10	32.50	33	28	33	250	3,455	500	1.45	54
3	Northern HW Cove	4,010	5.80	15.10	0.50	6.00	7.00	31.80	30	44	68	205	2,400	510	1.90	54
8	High Elevation Red Oak	3,730	4.90	28.00	2.20	4.00	6.40	43.20	26	15	12	68	3,850	480	0.85	46
24	Montane Oak Rich	3,520	4.10	31.90	1.30	3.30	5.60	44.55	26	18	12	-85	3,700	470	0.94	47
9	Montane Oak Slope	3,070	3.00	36.60	1.20	2.90	4.75	48.75	37	37	31	40	2,500	460	1.74	46
27	Acid Glade	2,870	1.00	29.90	0.00	0.20	1.10	48.30	45	19	25	-830	3,770	470	1.40	41
44	Mixed Oak/Rhododendron	2,660	4.50	48.10	2.95	4.50	6.70	58.65	51	48	29	310	2,100	430	2.50	47
10	Dry Oak/Evergreen Heath	2,660	2.45	41.00	0.80	2.25	4.80	52.00	36	45	26	-250	2,100	450	1.60	45
5	Rich Cove Forest	2,640	3.80	44.90	2.50	3.40	7.00	53.20	33	55	67	270	1,830	450	2.60	48
15	Montane Oak Cove	2,580	2.00	39.40	0.45	1.80	3.70	51.40	28	56	75	90	1,700	450	2.50	45
4	Acidic Cove Forest	2,540	3.50	43.75	1.30	3.40	5.20	53.50	26	68	78	50	960	415	2.55	46
11	Dry Oak/Deciduous Heath	2,540	1.70	29.30	0.60	1.50	5.10	44.10	33	47	21	-130	1,900	415	1.50	42
18	Pine-Oak Heath	2,490	1.55	24.80	0.30	1.90	2.40	41.90	39	51	21	-250	1,900	430	1.70	42
31	Basic Oak-Hickory	2,400	11.90	0.03	8.60	13.70	23.60	12.50	35	49	39	-130	2,040	500	1.90	49
55	Rich Slope Forest	2,260	1.20	44.90	1.05	0.90	1.80	80.10	48	56	43	450	2,010	475	2.55	47
13	Dry-Mesic Oak	2,075	1.90	45.10	0.55	1.80	2.50	57.20	28	68	44	-290	1,050	410	1.80	43
14	Dry-Mesic Calcareous Forest	2,070	0.75	64.80	2.30	0.70	2.20	68.90	36	60	41	-65	1,200	370	1.95	44
16	Shortleaf Pine-Oak	1,980	1.40	28.90	0.70	1.65	1.75	47.20	16	75	19	85	740	380	1.10	40
222	Pine-Oak Shale Woodland	1,940	2.10	26.00	0.80	2.20	0.10	43.35	34	77	22	-650	570	320	1.80	40
17	Dry Calcareous Forest	1,875	0.55	60.70	3.65	1.40	2.30	63.70	48	56	26	-280	1,200	300	2.10	44
6	Alluvial Forest	1,860	2.40	39.70	1.50	2.70	3.80	51.40	9	91	76	-160	80	340	2.10	44
23	Floodplain Forest	1,780	2.50	35.25	1.40	1.40	5.10	45.60	7	96	54	90	40	330	1.70	41
22	Xeric Pine-Oak	1,730	4.20	1.20	0.00	2.15	13.10	22.00	55	54	41	-580	1,780	480	2.60	43
29	Limestone-Dolomite Barren	1,690	1.10	83.85	4.40	2.90	3.05	82.00	40	58	25	-610	720	215	1.60	46
21	Shale Barren	1,540	2.20	21.58	0.85	2.70	1.50	36.70	66	75	28	-150	470	240	2.80	39

[1/] Geo1 = Carbonate-bearing rock, Geo2 = Mafic-igneous & metamorphic rock, Geo3 = Siliciclastic rock, Geo4 = Mixed over Carbonate rock, Geo5 = Shale, Geo6 = Mafic & Ultramafic. [2/] Slope in percent; VPOS = valley position (100 = valley bottom, 0 = major ridge top); RPOS 1 = relative slope position (100 = bottom of slope, 0 = top of secondary or major ridge); ASP = cosine of aspect (smaller = more south or more open, larger = more north); RIVDIFF = elevation difference from the nearest river; RELIEF = difference in elevation between the watershed divide and valley floor; LFI = landform 'protection', larger number more protected, smaller number more exposed; PREC = 30 year average precipitation in inches.

The relationship between plant community type and the environments in which they occur (the Ecological Zone) can also 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 6-8). Some of these relationships are fairly straight-forward, others are not. For example, MAXENT (Tables 7-8) identified elevation as the primary variable that defines the distribution of Grassy Balds, High Elevation Red Oak, and Northern Hardwood (slope and cove), which, along with Spruce-Fir have the highest mean elevation based upon plot locations (Table 6). Similarly, mid- to fine-scale variables relating to landform protection (Lfi), and slope position (Rsp1, Rsp2) were important in defining all the cove-oriented types (Northern Hardwood Cove, Rich Cove, Acidic Cove, and Montane Oak cove. In addition, other environmental variables used by MAXENT (when not 'masked' by the influence of geology), singly or in combination, reflect well those conditions found for types occurring in more unique or limited environments such as Xeric Pine-Oak that occurs at some of the lowest elevations, south- and west-facing slopes in the project area, or Floodplains that occur in the lowest valley positions and nearest to rivers. However, even in these types, relief, and geology often had a large influence on broader landscape distribution predicted with the MAXENT modeling. This resulted in the need to use finer scale variables to refine boundary (ecotone) differences among adjacent types.

Table 7. Percent contribution of variables used in Ecological Zone models in study area 1 (northwest of interstate 81).

EZONE	NhS	NhC	Acove	Orhodo	Rslope	Rcove	Alluvial	Flood	Hero	MonR	MonS	MonC	Dmoak	DM Calc	Dry Calc	Lime Barren	DryE	DryD	Sloak	Poh	PO Shale	Shale Barren	Acidic Glade
Asp_r	+1	-	-	+8	-	-	-	-		-	-	-	-	-	+4	+3	+3	-	+2	+18	+7		
Asp_c	2	+4	-	-	-	-	1	-	-	-	+1	+2	-	1	-3	-9	-1	-	-	-9	-9	-	+12
Curve				-	-	-			-					-	2				-				
Curpl			-	-	3	-6	-			-	-	-	-		-	-	-	-	-	-	-		-
Curpr		-				-	-			-		-				1	-	-		-	1		
Driver	3	+4	-2	3	-5	-4	-14		+5	+1	2	-	1	-5	-5	-6	-	-	-	-	-5	-29	
Dstrm			-4	-4	-	-	-1		+1	1		6	-	-	-	-	2	1	2	-	2		+9
Elev	+69[1/]	+65	+3	4	-	8	+1	2	+58	2	59	5	-6	4	2	-	6	2	-8	3		5	
Flwdw	-[2/]		6	-	-	-	-	-	-	3		-	-	-	2		-		-	-	-		
Flwup		+2	-	-	+6	-		-	-	-	-	-	1	-		-1	-	+1		-	-4		-
Geo1	+10	+2	12	-17	1	4	-		1	-	-2	-4	20	+3	+2	5	7	-15	-6	+3	3		-1
Geo2			2	5	+7	+1	2	+2	3	-	2	-1	5	+7	7	8	3	-	12	-14	15	-13	-6
Geo3	-3	-	-13	-	3	1	1	-	-	-14	-12	-9	-5	23	31	37	-20	-10	-8	-4	2	-	-16
Geo4	-3	1	1	-14	-18	-9	-	-12	1	-8	-6	-4	16	-15	1	+7	-15	-14	-7	-3	-	+3	-17
Geo5	-	-	-	-	-	-	-5	4	2	-	+3	6	+15	+9	5	12	+2	10	+28	10	-33	-20	-3
Geo6			8	+3	6	+4	-		1	-	3		+5	12	6	-	+6	-	-	-			
Geo7			-	-	-	-						-	-	-	-		-	-	-	-	-		
Geo8			-	-	-	-						-	-	-	-		-	-	-	-	-		
Geo9			-	-	-	-						-	-	-	-		-	-	-	-	-		
Geo10			-	-	-	-						-	-	-	-		-	-	-	-	-		
LF10			+3	-2	-	-1	+2	-	-	-	-	-	-	-		-	-	-		-	-		
LF30			-	-	-	-		+2	-			-	-	-	-	-	2	-	-		+3	-1	
Lfi	-	+5	+1	+3	+2	+3	-	-	-	-		-	-	-	2	-	-2	-1	-10	-		-	
Prec	-		+2	11	+2	+6	-	-	-	-	1	+2	+2	-	-	-	3	+2	2	+5	-6	-	-
Rivdiff		-5	-	1	-	-	-54	-41	-	-11	-	+6	-	-	-		3	+7	+3	+4	-		+8
Relief	-4	-1	4	8	+15	+12	-	1	-		4	12	+10	+11	+6		17	12	-	11	-	-2	
Rsp1		5	+12	-2	-	+2	+4	-	-	-12	-	26	-	-	-		-	-4	3	-2	-1	-1	-
Rsp2	-	4	+20	-	3	-	6	-		-	-	1	-	+1	-	-	-	-	-				-
Sdiff	-	-	1	+6	+2		-2	-	+3	16	1	-	-	-	+10	+4	-5	-	-1	+5	-5		+27
Sleng			-	-	+2	-	-					-		-	-		-	-	-	-	-		
Slope		-	-	+7	8	-	-	-2	-		-	-2	-	-	+7	+4	-	-	-	-	1	+25	-
Solar	-	-	-	-	-14	-2			-1	-	-	-	4	-	-	-	-	4	1	-	-		-1
Tsi	-	-	+2	-		-32		-		-	-	-8	2	-	2		-	+6	-	+7	-		
Vpos	-5		-		-	-1	+3	+31	-21	-28	-3	2	3	-6	-	-	-	-3	+2	-	-	-	-
# plots	48	18	321	64	90	194	49	32	148	55	452	77	359	173	108	31	270	227	100	280	26	10	16

[1/] the + or – sign that precedes the variable value indicates the relational direction of the variable. For example, elevation in Spruce-fir (SF) is +69 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. The environmental variable with highest gain when used in isolation is highlighted in blue.

Table 8. Percent contribution of variables used in Ecological Zone models in study area 2 (southeast of interstate 81).

EZONE	Gbald	SF	NhS	NhC	Acove	Orhodo	Rcove	Alluvial	Flood	Hero	MonR	MonS	MonC	Dmoak	Basic OH	DM Calc	Dry Calc	DryE	DryD	Sloak	Poh	Xeric Poh
Asp_r		- [2]	-	-	-	3	-3			-	-	-	-	-5	-	-	+2	1	1		+5	
Asp_c	-	-	1	1	-	-	+3	2	-	2	-	-	+2	3	2	-	-5	-	-	2	3	-8
Curve			-				-					-				-		-	-			
Curpl				-	-	-	-					-	3	-	-						-	-
Curpr				-	-	1	-		3		-	-	-	-				-				
Driver	+7	+1	+2	+3		2	4		-9	-	-	-	-1	-	-	-17	-17	-	1	4	+1	6
Dstrm	1	-	-		-20	-	-	-1	-1	-	-2		-	+1	+1		-	-1	-	-	-	
Elev	+86	+7 [1]	+63	+2	2	12	3	-15	5	+15	+10	2	-	-16	-1	1		3	1	-10	1	-14
Flwdw				-3	-		-	+5		+9	3	-	-			-	-	-	-	-	2	
Flwup			-		-	1	-		1		-	-	-	-	1	-	2	-		+2	-	
Geo1			3	-	-	1	-			+3	2	-	1	-1	-7	-22	-14	-	2	-	-	+4
Geo2	-			-	-	-	4	-1	-	+1	1	+2	+9	+5	-14	18	-6	+2	+4	+24	+1	3
Geo3		2	-	-	16	+34	-	-11	-2	1	8	-10	+10	-37	+4	4	1	7	4	-11	14	-40
Geo4		-	-		1	-	-2		-1	3	-4	6	-	-7	-	-	-4	2	5	+9	-	-
Geo5	-	-1	-	-	3	3	+4	+2	+2	-	2	+5	1	2	+6		-	+2	+2	-5	-3	
Geo6	-			-	3	10	7			1	2	8	+4	5	5			9	2	+4	16	+3
Geo7		-35	4	-	-		-					-	-					-			-	
Geo8		-38	-	-60	-		-					-	-					-			-	
Geo9					-		-					-	-					-7	-8		-7	
Geo10					-		-					-	-					-10	-37		-12	
LF10			-		-	-			-	-		-	-	2	+3	-		-	-	2	-	
LF30					+2	-	-		+2		-	-	-	1		-1		-	-	3		-
Lfi			-	-	+10	-	+25				-	1	+7	+1		-			-	-3	-	-
Prec	-		+8	6	+8	+3	+12		-3	12	-	+10	-	+2		-18	-20	2	2	-	2	-
Rivdiff		+14	1	8	-	-	1	-10		+22	+60	8	-1	2	+19	+5		-3	-6	-2	+5	
Relief			12	-	7	16	+16	+4		+12		+37	+29	1	+18	-	2	+37	+10	+2	+8	+3
Rsp1	1		-	-	-		5			-3	-1	-	+9		-		-	-	-2	-6	-	1
Rsp2	-1		-	+11	+18	-	2	+4		-	-	-	+17	-	1	-	-	-	-		-	-
Sdiff	-		-	-	2	+3	-	-34	-	+4	-	2	1	-	5	-		6	-5	-3	+12	+6
Sleng			-	-	-	-	-		-		-	-	-		7			-			-	-
Slope		-		-	1	+8	-		-	1	-1	-	-	-	-3	6	+26	-	-	-7	-	8
Solar	-		-	-	-	-	-			-		-	+1	-				1	+2		-	2
Tsi	-	-		-			2		-		-	-	-1		-1	-		-	-		+2	
Vpos	-1	1			-1		-	+6	+68	-11	-1	-4	-	5	-	-	-	-1	-3	1	-	-
# plots	35	12	87	45	154	35	119	14	13	73	45	229	28	79	21	19	19	153	106	15	110	15

[1] the + or – sign that precedes the variable value indicates the relational direction of the variable. For example, elevation in Spruce-fir (SF) is +7 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. The environmental variable with highest gain when used in isolation is highlighted in blue.

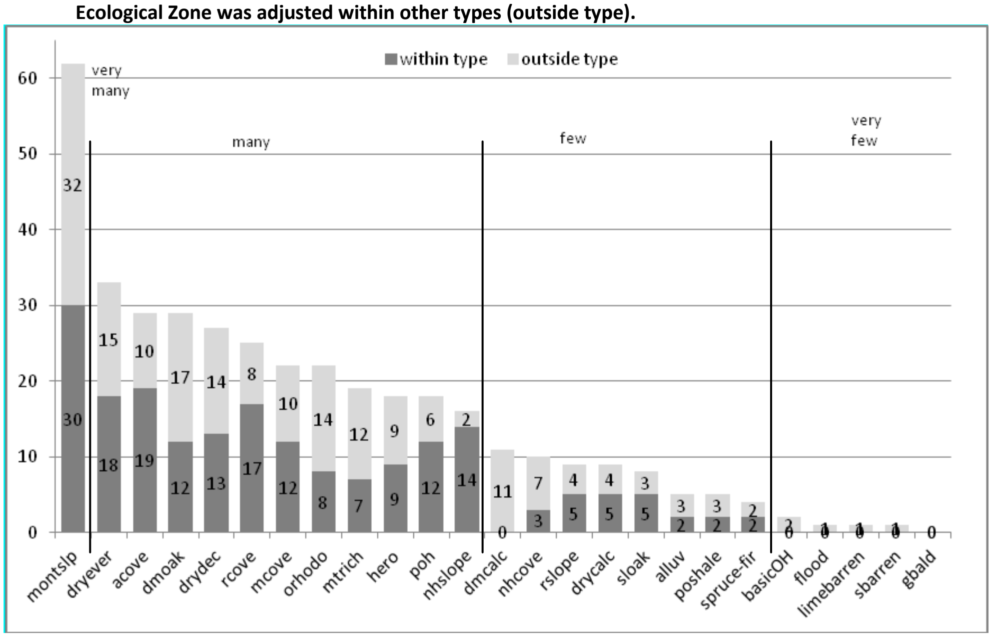
Ecological Zone patterns as they relate to topography and landform were apparent in the field and from viewing digital terrain data for individual Ecological Zone models. What was not obvious in the field was the influence of geology that MAXENT revealed and how / why multiple rock types contribute information for so many Zones. This relationship is most probably 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.

2) Influence of local environments on ecotones and model adjustments made: Environmental variable (DTM) values at ecotones were analyzed to better balance different Zone model strengths and reduce confusion between types occurring in similar environments. This analysis was used to identify the environmental conditions where minor adjustments in model probability levels could result in reduced confusion between classes. To limit broad-brush refinements of Zone models, ecotone adjustments were made separately within 'model area 1' (northwest of Interstate 81) and 'model area 2' (southeast of Interstate 81).

Total adjustments: Adjustments of the ecotone between models can be evaluated from two perspectives; the total number of adjustments made within an Ecological Zone, and the total number of times that Zone was adjusted within other types. These are referred to as 'within type' and 'outside type' adjustments respectively (Figure 1). If both types of adjustments are considered, the Ecological Zones can be grouped into the following 4 ecotone adjustment categories (arranged from most to least adjustments):

Very many	Many	Few	Very few
Montane Oak (Slope)	Dry-Oak/Evergreen Heath	Dry-Mesic Calcareous Forest	Basic Oak-Hickory
	Acidic Cove	Northern Hardwood Cove	Floodplain
	Dry-Mesic Oak	Rich Slope	Lime-Dolomite Barren
	Dry-Oak/Deciduous Heath	Dry Calcareous Forest	Shale Barren
	Montane Oak (Cove)	Shortleaf Pine-Oak	Grass Bald
	Rich Cove	Alluvial Forest	
	Mixed Oak/Rhododendron	Pine-Oak Shale	
	Montane Oak (Rich)	Spruce-Fir	
	High Elevation Red Oak		
	Pine-Oak Heath		
	Northern Hardwood Slope		

Figure 3. Number of ecotone adjustments within an Ecological Zone (within type) and the number of times that Ecological Zone was adjusted within other types (outside type).



There were 62 adjustments made to create the final Montane Oak Slope model, 30 'within type' and 32 'outside type' (Figure 3), the most of all types. This type accounts for about 9% of the total acres in the 5.6 million+ project area and therefore has an extensive ecotone with other types, but this only partially explains the reason for needing such a large number of adjustments. These 'matrix' forests are highly variable, include numerous Plant Associations, and, in the authors' opinion, are not adequately defined in the NatureServe Ecological System structure, a structure followed closely in developing all Ecological Zone models. Furthermore, extensive logging and loss of American chestnut and other type indicators make accurate Zone identification difficult in this area, which could have resulted in greater confusion among types.

The second category 'many' accounts for about 45% of the landscape and includes the remainder of the more-extensive Ecological Zones that support 'matrix' forests. This category also includes the High Elevation Red Oak type that occurs in only 1% of the area but because of its landscape position on ridges and upper slopes, forms an extensive ecotone with Montane Oak Slopes and Northern Hardwood Slopes. The remainder of the Ecological Zones (15 total) represent nearly half of the area and needed few, very few ecotone, or no adjustments of the original Maxent models to reduce type confusion. This is primarily due to their occurrence in more distinct environments, e.g., the highest elevations (Spruce-Fir or Grass Balds), the lowest elevations in flats near rivers (Floodplains), or on distinct geologic substrates (Shale Barrens and Pine-Oak Shale on shale rock only), and the numerous types that, by definition, occur only on carbonate-bearing rock, e.g., Dry-Mesic and Dry Calcareous Forest, Basic Oak-Hickory, and Lime-Dolomite Barren. Fewer (50% less) ecotone adjustments were used in the Jefferson study area 1st Approximation Ecological Zone models than were needed in the Southern Blue Ridge 3rd Approximation to produce models of roughly equal (≈ 80%) Zone accuracy.

Topographic/environmental variables used most frequently to describe local environments that might refine ecotone boundaries between types were clearly fine-scale and included: surface curvature, elevation, and stream influence (Figure 4). These variables were used over 20 times each in the nearly 200 adjustments made between the preliminary and final Ecological Zone models (Appendix V, Table 3). A combination of fine- and mid-scale variables that included landform shape, slope percent, river influence, and relative slope position, were frequently used. Less and least frequently used were mid-scale to broader-scale variables. This contrasts greatly from variables used in the original Maxent models for each type. While curvature and landform shape were used frequently to adjust ecotone boundaries (nearly ½ of the models used these variables), they had at least a 5% contribution to prediction gain in less than 12% of the Maxent models (Table 5). Similarly, slope length, provided gain in only one Maxent model (Rich Slope in model area 1, Table 7), but was used in 22% of the models for ecotone adjustments. Conversely, relief, and siliclastic geology which had significant contributions in Maxent models were among the least frequently used variables in the ecotone adjustments.

Figure 4. Environmental variables (Dtms[1/]) used in Ecological ecotone adjustments

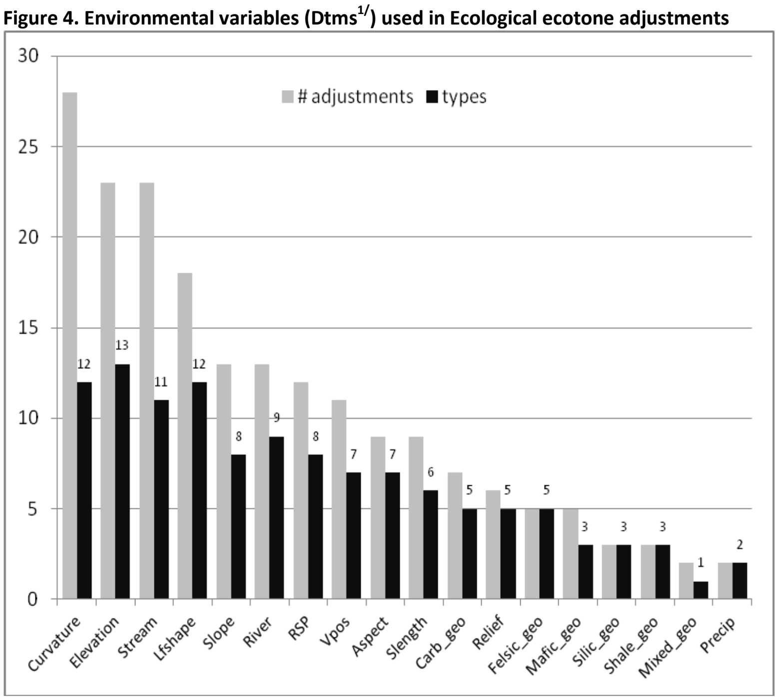


Table 9: Comparison of environmental variable use in ecotone adjustments vs. Maxent models

Variable[1/]	Ecotone adjustments	Maxent models [1/]	% difference in variable use
	% of types variable used		
Curvature	44	9	35
LFshape	44	11	33
Slength	22	0	22
Slope	30	20	10
Stream	41	33	8
RSP	30	22	8
Aspect	26	20	6
Vpos	26	20	6
Elevation	48	47	1
Carb_geo	10	24	-14
Mafic_geo	11	29	-18
Felsic_geo	19	38	-19
Precip	7	27	-20
Shale_geo	11	31	-20
River	33	60	-27
Relief	19	47	-28
Mixed_geo	3	37	-34
Silic_geo	11	51	-40

[1/] where variable made at least a 5% contribution to model prediction gain

3) Map unit accuracy: An **accuracy assessment** using random plot sampling was not completed for this project. However, a similar process that compares reference field data assignments to classified (modeled) data for the same site was completed. Details of this analysis (termed an **accuracy evaluation**) are presented in Appendix VII. Although this is a biased measure of accuracy, because these are the same data used to produce the MAXENT predictive equations, it is a reasonable means of objectively comparing how well map composition reflects field data within the project area and across different landscapes where Ecological Zones have been developed in the Southeastern US. In addition, it was instrumental in evaluating ecotones to improve map unit boundary accuracy among Zones.

Based on this accuracy evaluation (Table 10), Ecological Zone mapping accuracy within the study area was estimated at 83% within predominantly Ridge and Valley landscapes (model area 1) and 80% within predominantly Blue Ridge Mountains landscapes (model area 2). When Ecological Zones are aggregated to BpS / Ecological Systems, overall accuracy improves slightly to 84% (appendix VII, Table 3) based on intersecting 4,600 plots with the final Ecological Zone models / map units. This compares favorably to (or better than) other Ecological Zone modeling within the Appalachians, Allegheny Mountains, and Cumberland Mts. (where Zones were mapped) considering the size and number of Zones modeled, and considerably better than earlier Ecological Zone modeling in the Southern Blue Ridge.

Over one-half of the types had accuracy values exceeding the average Ecological Zone accuracy in at least one of the model areas. They include: Northern Hardwood Slope and Cove, Acidic Cove, Rich Slope, Alluvial Forest, Floodplain, Montane Oak Cove, Dry-Mesic Calcareous Forest, Limestone-Dolomite Barren, Basic Oak-Hickory, Shortleaf Pine-Oak, Pine-Oak Shale Woodland, Shale Barren, and Acidic Glade. Seven of these types were estimated to exceed 90% accuracy (Table 10). Dry-Oak / Deciduous Heath had the lowest accuracy of all types (72-74% in model areas 1 and 2 respectively) and were confused primarily with Dry-Oak Evergreen Heath, Montane Oak Slope, Dry-Mesic Oak, and Pine-Oak Heath (Appendix VII). Other types with accuracy levels below average in model area 1 include: Montane Oak Rich, and Dry-Oak / Evergreen Heath; in model area 2 they include: Mixed Oak Rhododendron, Rich Cove, High Elevation Red Oak, and Montane Oak Slope.

4) Predicted elevation range of Ecological Zones: The distribution of Ecological Zones on the Jefferson NF project area is strongly tied to elevation. How well the Zone models fit this observation can be assessed by examining both the proportion of different Zones within elevational classes and the proportion of Zones within elevational classes relative to an individual Zone's area-wide distribution. This is different from looking just at the mean values of environmental variables based on the reference plot locations (Table 6) that are point location averages. Proportion averages are landscape averages that include the entire predicted range of the individual Ecological Zone and can be used to judge how well model predictions fit landscape observations. For example, the models predict that elevations greater than 5000' elevation are dominated (96% of the landscape) by just 3 Ecological Zones, Spruce-Fir, Northern Hardwood Slope, and Grass Bald (Table 13) and that all Grass Bald and Spruce-Fir and 77% of Northern Hardwood Slope occur above 4,500' elevation (Table 14). This seems to fit general observations made in the field but likely does not characterize finer scale plant communities such as stream-head wetlands or rock outcrops at these higher elevations.

At elevations less than 1,000', Dry-Mesic Oak, Alluvial Forest, Floodplain Forest, and Rich Cove Forest are the dominant predicted types (Table 13), but are also a significant part of the landscape from 1,000 to 3,000' in elevation. Similarly, Montane Oak Slope is the near-dominant Zone (one-half of the landscape) between 3,000 and 4,000', but this Zone is predicted to be more extensive, i.e., from 2,000' to 5,000'; an observation also made in the field. Not surprising is the wide predicted distribution of Montane Oak Cove, Acidic Cove, Dry-Mesic Calcareous Forest, Mixed Oak/Rhododendron, and Dry-Oak/Evergreen Heath which comprise at least 1% of 8 of the 10 elevation classes analyzed.

Table 10. Ecological Zone accuracy across the Appalachian Mountains study areas (a dash Indicates that the Zone was not modeled in that study area)

Ecological Zone	Jefferson NF Project Area [1/]		George Washington NF Project Area		3rd Approx. Southern Blue Ridge	Cherokee NF North Zone
	Ridge & Valley	Blue Ridge	Ridge & Valley	Blue Ridge		
Size of area (acres-rounded)	3,733,290	1,940,220	3,761,700	1,026,200	8,234,470	1,021,600
Percent correct classification						
Grassy Bald	-	83	-	-	74	100
Heath Bald	-	-	-	-	74	-
Spruce-Fir	-	83	89	-	89	86
Northern Hardwood Slope	90	85	86	81	73	88
Northern Hardwood Cove	94	89	89	100	80	71
Acidic Cove	86	83	83	90	81	84
Mixed Oak / Rhododendron	83	74	-	-	68	76
Spicebush Cove	-	-	-	71	-	-
Rich Cove	81	76	82	82	81	76
Rich Slope	89	-	-	-	-	-
Alluvial Forest	92	93	67	94	78	92
Floodplain	97	85	78	-	94	100
High Elevation Red Oak	82	74	86	84	81	79
Montane Oak Rich	76	80	77	68	82	100
Montane Oak Cove	86	89	79	-	69	66
Montane Oak Slope	83	76	72	80	75	85
Collegial Forest	-	-	70	-	-	-
Dry-Mesic Oak	84	82	84	90	74	78
Dry-Mesic Calcareous Forest	88	95	81	-	-	-
Dry-Calcareous Forest	84	79	-	-	-	-
Limestone-Dolomite Barren	87	-	-	-	-	-
Basic Oak-Hickory	-	86	-	-	-	-
Dry Oak Evergreen Heath	74	81	66	73	69	75
Dry Oak Deciduous Heath	72	74	65	71	78	75
Shortleaf-Pine Oak	86	80	90	91	88	85
Shortleaf P-O Heath	-	-	-	-	82	-
Pine-Oak Heath (eastside)	-	-	82	-	-	-
Pine-Oak Heath (westside) [2/]	80	79	77	83	82	82
Pine-Oak Heath (ridges)	-	-	59	-	-	-
Xeric Pine-Oak	-	88	-	-	-	-
Pine-Oak Shale Woodland	92	-	89	-	-	-
Shale Barren	90	-	83	-	-	-
Acid Glade	94	-	-	-	-	-
Alkaline Woodland	-	-	92	-	-	-
Mafic Glade and Barren	-	-	-	91	-	-
OVERALL	83	80	77	80	79	81
Most fire-adapted group	98	96	97	98	93	94
Number of Zones	23	22	23	15	20	18

[1/] includes a 516,091 acre overlap with the GW project area, [2/] typical Pine-Oak Heath

Table 13. Percent of elevation class within different Ecological Zones [1/]

Ecological Zone	Elevation class (feet) < 1,000	1,000-1,499	1,500-1,999	2,000-2,499	2,500 2,999	3,000-3,499	3,500 3,999	4,000 4,499	4,500 5,000	> 5,000	# elev. classes	% total area
Grass Bald										17	2	0.04
Spruce-Fir									9	44	2	0.04
Northern HW Slope							2	18	42	34	4	0.3
Northern HW Cove							5	15	15	2	4	0.3
High Elevation Red Oak				1		1	12	18	3		5	0.6
Montane Oak Rich					1	3	7	18	19	1	6	0.8
Montane Oak Slope			1	2	16	40	48	21	9	2	9	8.7
Acid Glade					1	1					2	0.1
Mixed Oak/Rhododendron		2	6	5	5	8	4	3	1		8	4.9
Dry Oak/Evergreen Heath	4	2	3	5	6	10	9	3	2		9	5.0
Rich Cove Forest	11	11	9	7	5	7	4	2			8	1.4
Montane Oak Cove	1	1	1	2	3	2	1	1	1		9	1.8
Acidic Cove Forest	4	3	4	6	7	6	3				8	5.3
Dry Oak/Deciduous Heath	3	3	2	4	5	5	1				7	3.8
Pine-Oak Heath	1	1	3	3	4	3					6	2.6
Basic Oak-Hickory		1	2	3	10	3					5	3.9
Rich Slope Forest	2	3	2	1	1	1					6	1.4
Dry-Mesic Oak	22	20	15	14	8	1					6	12.3
Dry-Mesic Calcareous Forest	2	16	30	31	24	7	3	1			8	24.6
Shortleaf Pine-Oak	1	3	1	3							4	1.8
Pine-Oak Shale Woodland		1									1	0.3
Dry Calcareous Forest	8	16	12	7	1						5	7.1
Alluvial Forest	20	10	4	4	3	1					6	4.4
Floodplain Forest	18	4	2	2							4	1.9
Xeric Pine-Oak	1	1									2	0.3
Limestone-Dolomite Barren		2	1								2	0.5
Shale Barren	1	1	1								3	0.3
Lakes			1								1	0.1
Landscape acreage	52,070	600,790	1,298,551	1,846,030	1,279,450	403,360	148,210	31,210	11,030	2,810		
% of project area	.09	1.1	22.9	32.5	22.6	7.1	2.6	.05	.01	.001		
# of Zones (with at least 1%)	16	19	19	17	16	16	12	10	11	6		

[1/] for example, the Spruce-fir Ecological Zone covers 44% of landscapes > 5000' in elevation.

Table 14. Percent of Ecological Zones within elevation class

Ecological Zone	Elevation in feet < 1,000	1,000-1,499	1,500-1,999	2,000-2,499	2,500-2,999	3,000-3,499	3,500-3,999	4,000-4,499	4,500-5,000	> 5,000	predominant range [2/]
Grass Bald										100	> 5,000
Spruce-Fir									45	55	> 4,500
Northern HW Slope						3	20	39	31	7	3,500-5,000
Northern HW Cove						6	52	31	11		3500-4500
High Elevation Red Oak				9	1	16	54	17	1		3,000-4,500
Montane Oak Rich			1	8	23	27	24	13	4		2,500-5,000
Montane Oak Slope				9	41	33	14	1	2		2,500-4,000
Dry Oak/Evergreen Heath		4	14	33	29	15	5				2,500-3,500
Acid Glade			5	22	38	31	4				2,000-3,500
Basic Oak-Hickory		3	9	24	58	6					2,000-3,000
Mixed Oak/Rhododendron		4	29	32	22	11	2				1,500-3,000
Montane Oak Cove		5	16	30	37	10	2				1,500-3,000
Acidic Cove Forest	1	6	18	35	31	8	1				1,500-3,000
Dry Oak/Deciduous Heath		9	15	36	31	9					1,500-3,000
Pine-Oak Heath		2	23	36	31	8					1,500-3,000
Dry-Mesic Calcareous Forest		7	28	40	22	2					1,500-3,000
Rich Cove Forest	1	16	27	30	17	7	1				1,000-3,000
Rich Slope Forest	1	21	38	25	11	3	1				1,000-2,500
Dry-Mesic Oak	2	17	29	38	14						1,000-2,500
Shortleaf Pine-Oak	1	19	15	55	10						1,000-2,500
Pine-Oak Shale Woodland	4	24	24	34	14						1,000-2,500
Dry Calcareous Forest	1	24	39	34	2						1,000-2,500
Alluvial Forest	4	25	21	32	18						1,000-2,500
Floodplain Forest	9	22	29	36	5						1,000-2,500
Xeric Pine-Oak	1	33	23	38	5						1,000-2,500
Limestone-Dolomite Barren		41	46	11	2						1,000-2,500
Shale Barren	3	44	19	32	2						1,000-2,500

[1/] i.e., 55% of the Spruce-Fir Zone occurs at elevation > 5,000' and 45% occurs between 4,500' and 5,000'. [2/] elevation where Ecological Zone is concentrated

5) <u>Ecological Zone location and extent</u>: In general, the Jefferson NF model based on MAXENT with ecotone adjustments appears to represent the location and extent of Ecological Zones observed in the field. Oak-dominated Ecological Zones, about equally distributed on carbonate- and non-carbonate-bearing rock, are predicted on about 68% of the nearly 6 million acre landscape, Cove Ecological Zones 19%, and Pine-Oak Ecological Zones 5% (Table 11). The remaining 8% of the landscape included Alluvial Forest, Floodplain, Barrens, Glades, Northern Hardwood, and Spruce-Fir. Dry-Mesic Calcareous Forests are predicted on nearly 25% of the landscape, but occur primarily on private land and just 4% of USFS land. Grass balds have the least extent (< 500 acres) and are confined to the Mount Rogers area. Spruce-Fir was only modeled in the Blue Ridge Mountains however it is known to occur in small pockets at the highest elevations in the Ridge and Valley portion of the project area but was not sampled there. Five Ecological Zones were unique to the Ridge and Valley's limestone, dolomite, shale, and sandstone landscapes. They include: Rich Slopes, Limestone-Dolomite Barrens, Acidic Glades, Pine-Oak Shale, and Shale Barrens. Four Ecological Zones were unique to the Blue Ridge Mountains metamorphic and igneous geology. These include Grass Bald, Spruce-Fir, Basic Oak-Hickory, and Xeric Pine-Oak.

At larger scales (< 1:24,000), the relationship between topography and Ecological Zones is most obvious as is the association among Ecological Zones (Figures. 5-10). At higher elevations, Zone patterns appear more controlled by elevation, slope, and surface configuration than by drainage pattern as they seem to be at lower elevations, although slope position and surface shape are important at all elevations. The distribution of Zones is fairly consistent at higher elevations and not apparently controlled by geology except at very fine-scales. The sequence (from ridgeline to midslope) of Spruce-Fir (with imbedded Grassy Balds), Northern Hardwood Slopes (convex surfaces), Northern Hardwood Coves (concave surfaces), High Elevation Red Oak and Montane Oak Rich, and Montane Oak Slopes with Rich Coves at lower elevations is fairly consistent in the Blue Ridge portion of the project area. The span of this sequence depends upon the elevation of individual mountain ridges, those above 5000' in elevation often have this full range of Zones (Figure 5), and those from 3,000 to 4,500' elevation (especially in the Ridge and Valley) usually start the upper limits of this sequence with High Elevation Red Oak (Figures 6 & 8).

The striking pattern of alternating Pine-Oak Heath and Oak-dominated Ecological Zones that repeats itself across landscapes throughout the project area, is more subtle in the Blue Ridge. In the Ridge and Valley, the sequence of types on highly dissected slopes on the northwest-facing side of major ridges is variable but may include at the higher elevations, Pine-Oak Heath on west-facing slopes, Montane Oak on northwest to north-facing slopes, and Montane Oak Cove in the intervening small drainages (Figure 8). On lower elevation ridges, this sequence may include Pine-Oak Heath on west-facing slopes, Dry-Oak Heath (evergreen or deciduous type), with Acidic Cove or Montane Oak Cove in the intervening small drainages (Figure 7). Strong Ecological Zone patterns also controlled by aspect and site protection, i.e., shading, are evident in the Cumberland Mountains portion of the project area. Dry-Mesic Oak and Dry-Oak/Evergreen Heath often form the matrix with drainages in dendritic patterns dominated by Rich Slopes at lower elevation gorges and Mixed Oak/Rhododendron on projected upper slopes (Figure 9); this is not unlike the pattern seen in the KY FLN. Between 2,000 and 3,000' elevation in the Ridge and Valley, which represents about 55% of the project area, Montane Oak and Dry-Mesic Oak may form the matrix with Acidic Coves and Alluvial Forests in drainages with highly patterned Pine-Oak and Oak-dominated slopes (Figure 10).

Table 11. Extent of Ecological Zones in the Jefferson NF project area (1 majority filter, acres rounded)

Ecological Zone	Total all lands		Jefferson National Forest		Other Conservation Land[1/]		Model Area1 Ridge and Valley (predominantly)	Model Area 2 Blue Ridge Mts. (predominantly)	
	acres	percent	acres	percent	acres	percent	acres		Map code
Total	5,673,560	100.0	725,945	100.0	165,530	100.0	3,733,290	1,940,220	
Grass Bald	490	.01	480	0.07	10	0.01	0	490	30
Spruce-Fir	2,240	0.04	2,060	0.3	70	0.04	0	2,240	1
Northern Hardwood (slope)	14,390	0.3	7,180	1.0	3,280	2.0	3,850	10,540	2
Northern Hardwood (cove)	14,650	0.3	7,350	1.0	2,740	1.7	5,780	8,870	3
Rich Cove	405,410	7.2	26,820	3.7	8,940	5.4	264,240	141,165	5
Rich Slope	79,740	1.4	3,130	0.4	2,645	1.6	79,730	10	55
Acidic Cove	302,040	5.3	43,690	6.0	10,850	6.6	173,990	128,050	4
Mixed Oak / Rhododendron	278,940	4.9	29,180	4.0	13,900	8.4	215,670	63,270	44
Alluvial Forest	246,830	4.4	5,330	0.7	4,290	2.6	119,620	127,210	6
Floodplain	109,670	1.9	1,500	0.2	1,350	0.8	48,970	60,700	23
Lakes	7,730	0.1	0	0	3,350	2.0	2,330	5,390	99
High Elevation Red Oak	32,580	0.6	10,580	1.5	2,860	1.7	24,210	8,370	8
Montane Oak (rich)	43,800	0.8	9,810	1.3	2,390	1.5	10,660	33,140	24
Montane Oak (slope)	493,880	8.7	160,240	22.1	29,330	17.7	370,260	123,610	9
Montane Oak (cove)	99,290	1.8	25,340	3.5	3,860	2.3	78,190	21,100	15
Dry-Mesic Oak	694,870	12.3	119,800	16.5	21,870	13.2	485,490	209,360	13
Dry-Mesic Calcareous Forest	1,397,510	24.6	31,470	4.3	17,660	10.7	842,220	555,290	14
Basic Oak-Hickory	221,870	3.9	5,090	0.7	6,940	4.2	0	221,865	31
Dry Calcareous Forest	404,170	7.1	3,750	0.5	6,270	3.8	356,650	47,520	17
Limestone-Dolomite Barren	27,415	0.5	100	0.01	810	0.5	27,410	0	29
Dry Oak Evergreen Heath	280,910	5.0	97,980	13.5	6,820	4.1	215,240	65,670	10
Dry Oak Deciduous Heath	213,170	3.8	64,450	8.9	5,150	3.1	181,970	31,200	11
Shortleaf Pine-Oak	98,970	1.7	10,990	1.5	1,100	0.7	56,860	42,110	16
Pine-Oak Heath	147,690	2.6	45,660	6.3	6,400	3.9	132,040	15,650	18
Xeric Pine-Oak	17,390	0.3	4,580	0.6	1,090	0.7	0	17,390	222
Acidic Glade	6,450	0.1	2,180	0.3	970	0.6	6,450	0	27
Pine-Oak Shale	16,440	0.3	4,940	0.7	420	0.3	16,440	0	22
Shale Barren	15,050	0.3	2,280	0.3	160	0.1	15,050	5	21
Percent of total		100.0	725,945	12.7	165,930	2.9	65.8	34.2	

[1/] Table 12

Table 12. Management Agencies within 'conservation lands' outside the Jefferson National Forest

Management Agency	acres
Boy Scouts Blue Ridge Mountains Council	16,346
Breaks Interstate Park Commission	2,332
City of Bristol	430
City of Norton	28
City of Radford	85
City of Roanoke	1,703
Lee County	179
Montgomery County	120
Municipal Government	42
Patrick County Recreation Department	195
Private	346
Radford University	343
Roanoke County	12,457
Tennessee Valley Authority	1,453
The Nature Conservancy	4,580
Town of Big Stone Gap	3,334
Town of Blacksburg	56
Town of Pearisburg	28
University of Virginia	535
US Army Corps of Engineers	8,591
US Army Reserve - 99th Reg Support Center	100
US Department of the Army	7,185
US Fish and Wildlife Service	138
US National Park Service	34,243
VA Dept of Conservation and Recreation	16,025
VA Dept of Forestry	5,362
VA Dept of Game and Inland Fisheries	49,143
VA Dept. of Conservation and Recreation	26
VA Outdoors Foundation	20
Virginia Recreational Authority	384
Washington Co Park Authority	92
TOTAL	165,915

Figure 5. Ecological Zones at Mount Rogers Virginia

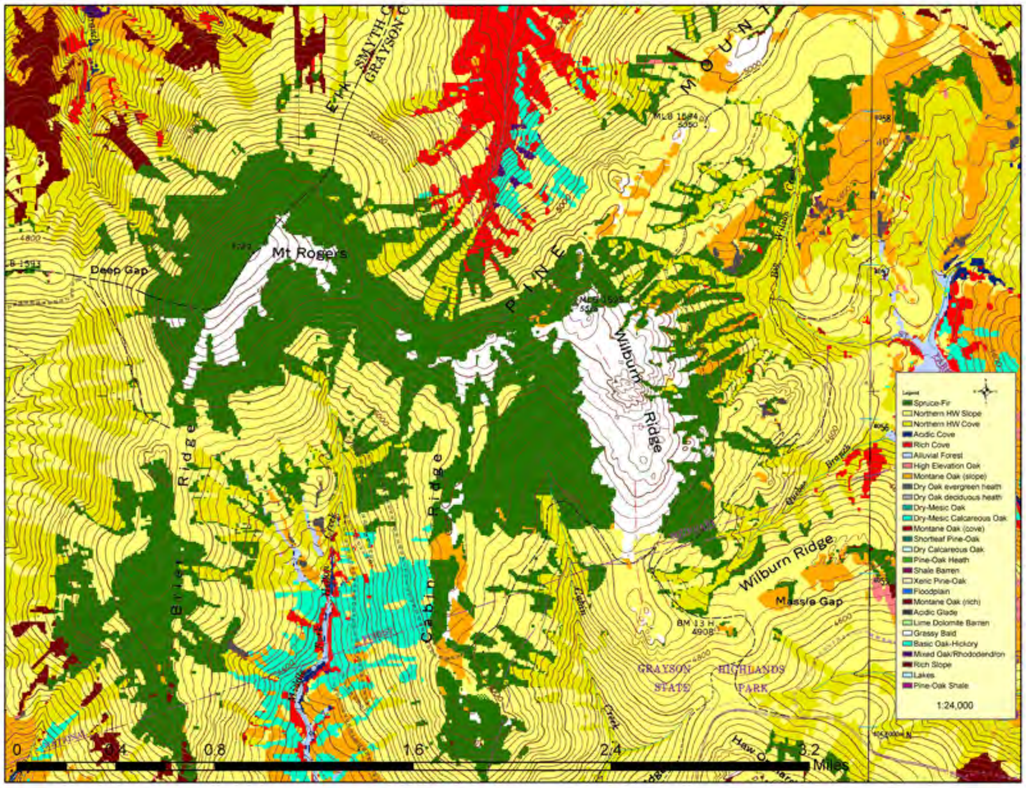


Figure 6. Thunder Hill, Blue Ridge Mountains

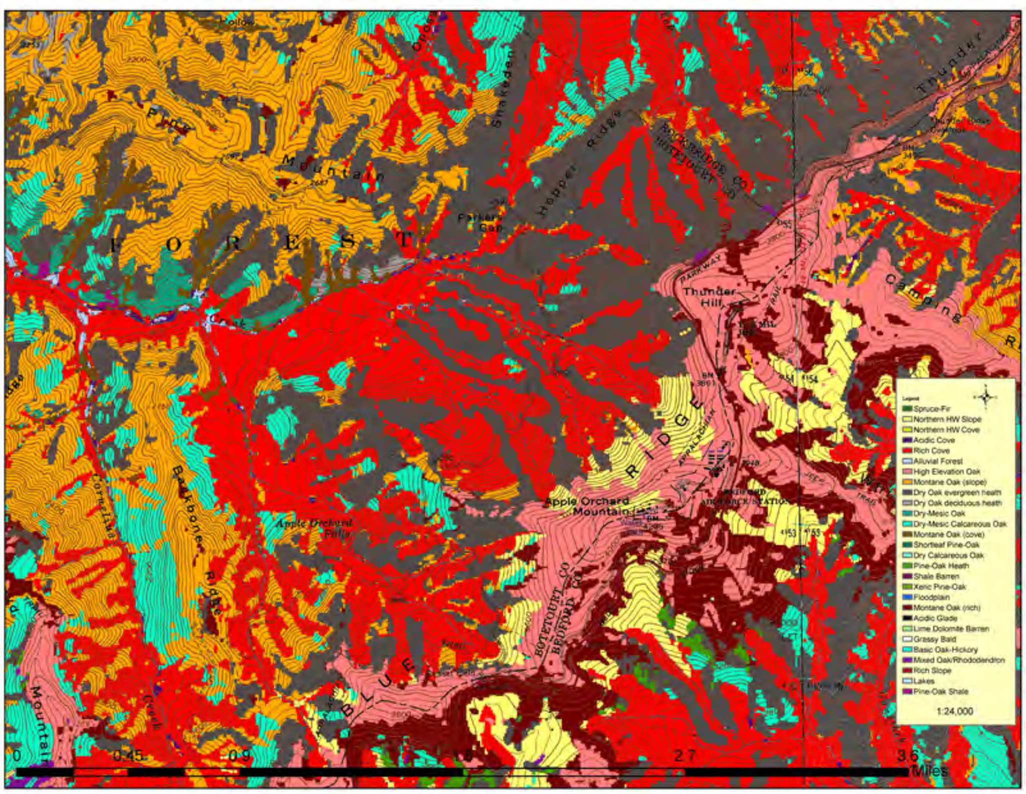


Figure 7. Ecological Zones at North Mountain, Virginia

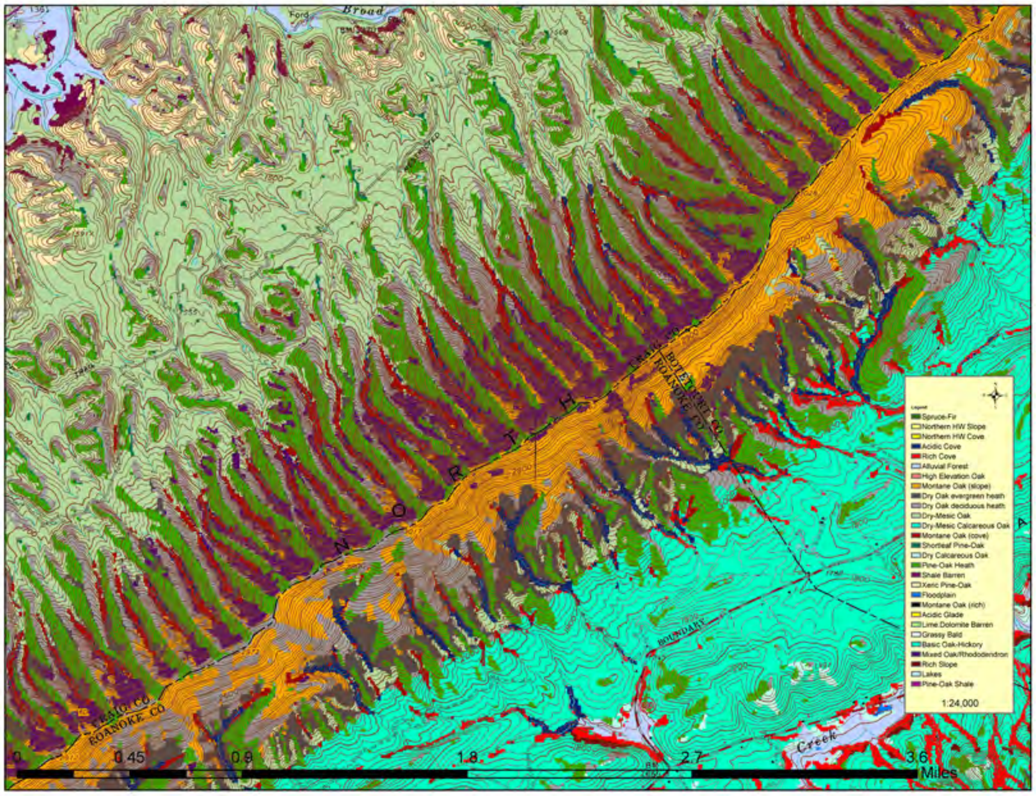


Figure 8. Ecological Zones at Clinch Mountain, Virginia

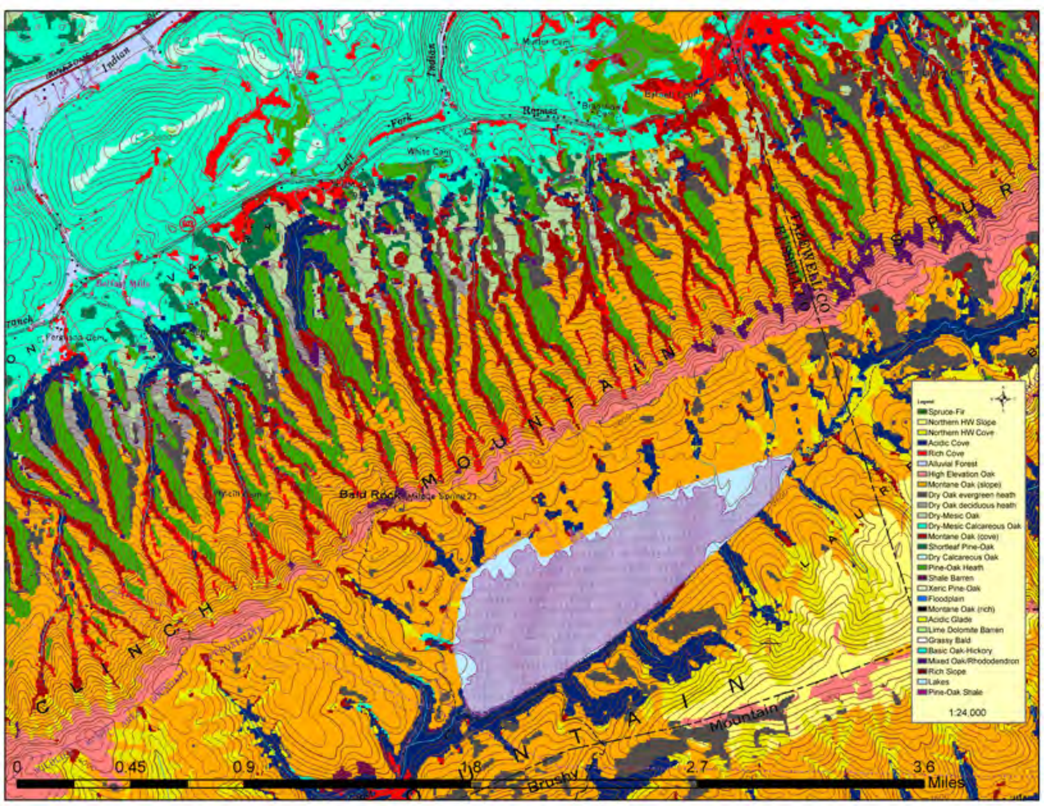


Figure 9. Breaks Interstate Park

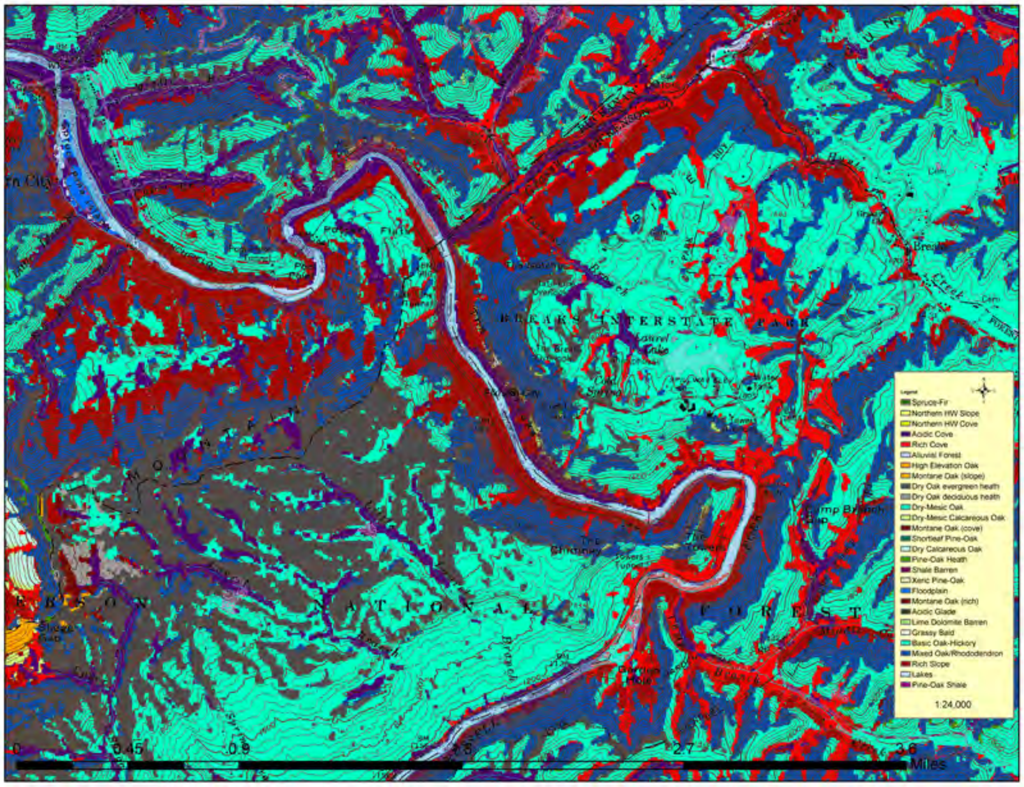
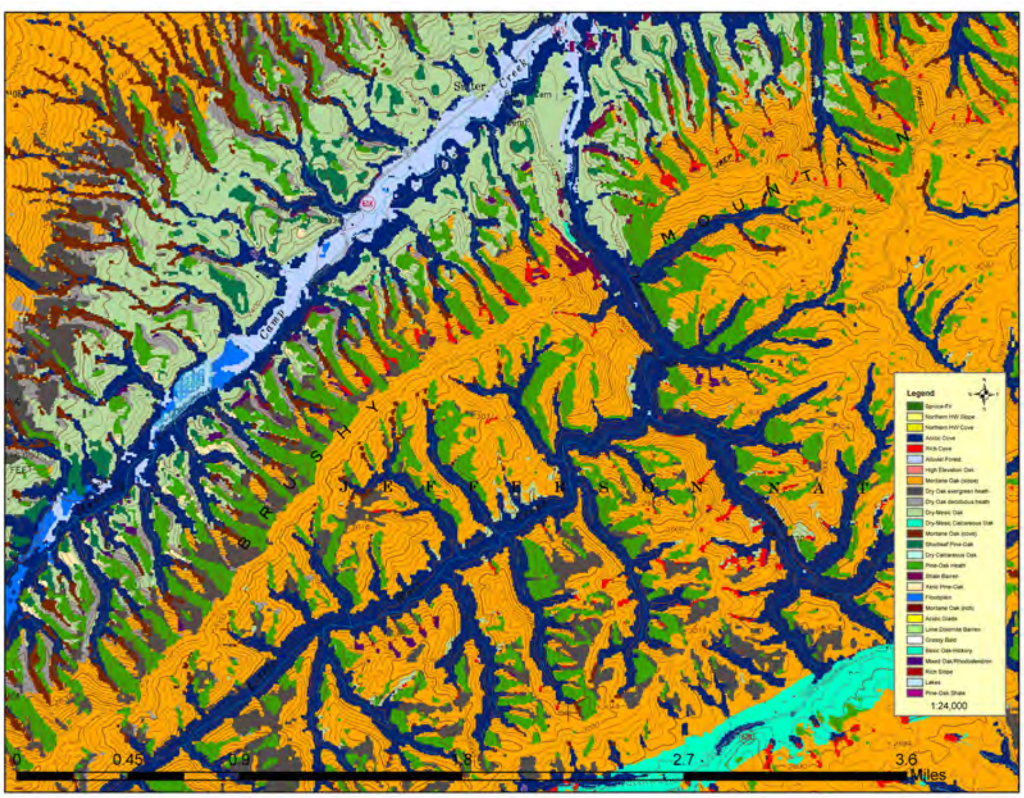


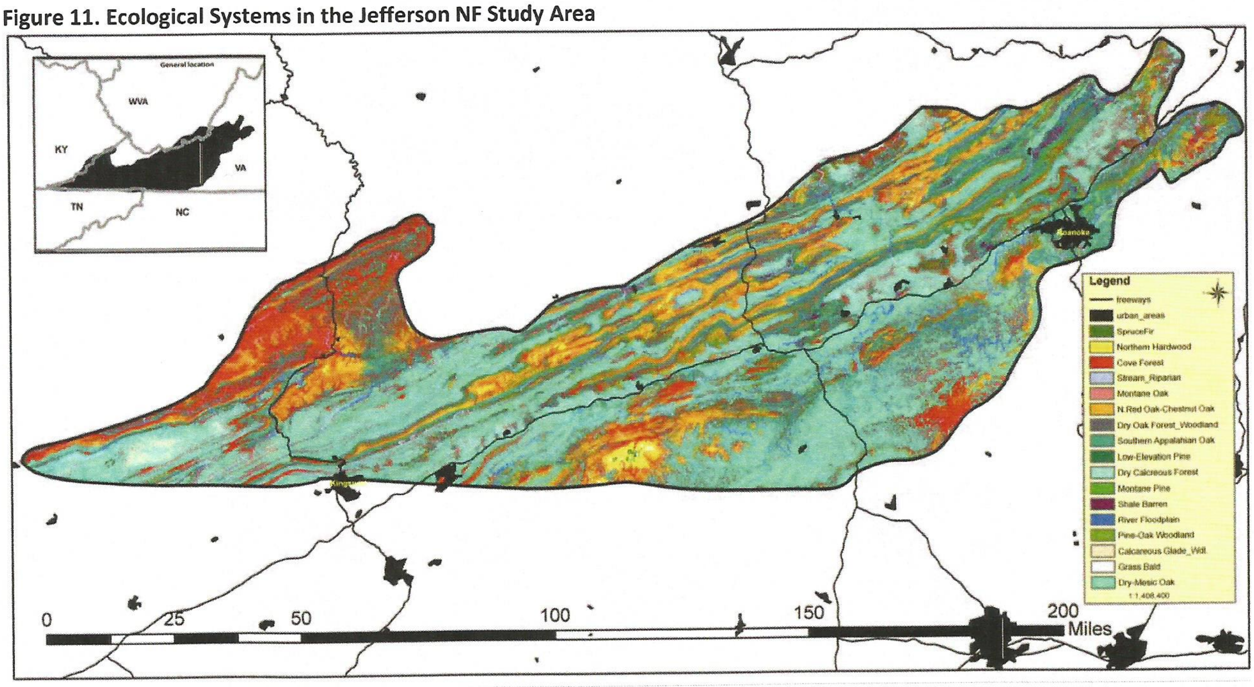
Figure 10. Ecological Zones at Brushy Mountain



5) Extent and location of Ecological Systems and fire-adapted plant communities: The extent of less fire-adapted and more fire-adapted plant communities, was evaluated using the same classes assessed in the Southern Blue Ridge Fire Learning Network (FLN), Allegheny FLN, and the Kentucky FLN Ecological Zone mapping projects (Simon 2008, 2010, 2011a, 2011b). These two classes are based on target communities identified by the SBR FLN in 2008 for restoring fire regimes (http://www.tncfire.org/training_usfln_SBRfln.htm). They include pine-oak heath, shortleaf pine-oak, dry-mesic oak-hickory, and high-elevation red oak forests (and their equivalent Ecological Systems); the assumption was made that more mesic zones (alluvial forests, floodplains, coves, northern hardwood, and spruce-fir) were less fire-adapted. A refinement of these groups is possible, and may use methods described in *"Rule-based Mapping of Fire-adapted Vegetation and Fire Regimes for the Monongahela National Forest"*, (Tomas-Van Gundy et. al. 2007). For the Jefferson NF project, the following similar Ecological Systems were included in the more fire-adapted group: Central Appalachian Alkaline Glade and Woodland – Southern Ridge and Valley/Cumberland Dry Calcareous Forest, Southern Ridge and Valley Calcareous Glade and Woodland, Northeastern Interior Dry-Mesic Oak Forest (calcareous substrates), Central Appalachian Pine-Oak Rocky Woodland, and Appalachian Shale Barren. The latter three types were also included in the more fire-adapted category in the GW Ecological Zone project area.

Ecological System maps for the Jefferson NF project area can be used to identify landscapes that support fire-adapted plant communities (Figures 11-12). Ninety-eight percent of the reference plots occurring in types considered as more fire-adapted are found within Ecological Systems correctly modeled as more fire-adapted (Appendix 7, Table 3). Conversely, 91% of reference plots occurring in types considered as less fire-adapted were mapped in Ecological Systems considered less fire-adapted.

Figure 11. Ecological Systems in the Jefferson NF Study Area

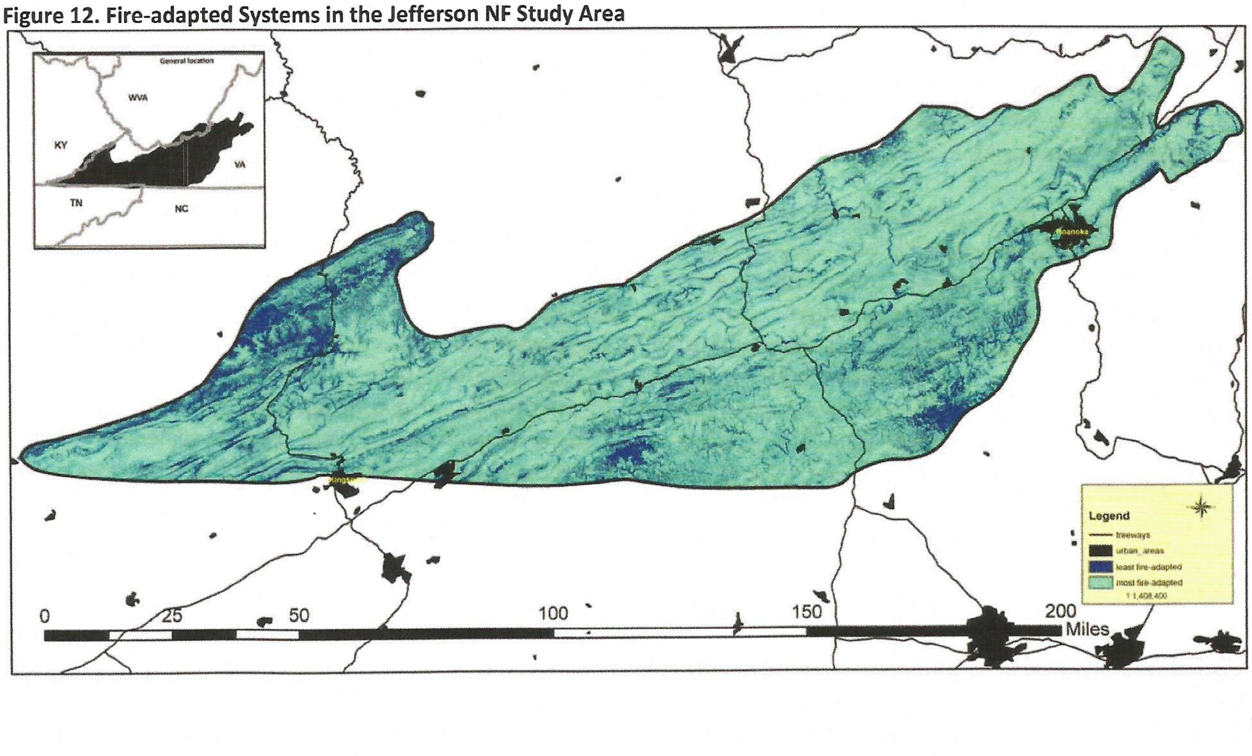


Ecological Zone and Nature Serve Ecological System maps can also be used to evaluate fire restoration needs in different areas (Tables 10, 11, and 15), for example, on USFS land versus other conservation land within the project area. Although USFS land, because of its greater proportion of federal or state land in the project area obviously has the greatest number of acres that might need restoration through the use of controlled-burning or mechanical methods, the relative proportion of a type within an ownership may indicate differences in priorities. For example, Northeastern Interior Dry-Mesic Oak Forest accounts for a larger proportion of "other conservation lands" than USFS lands. However, USFS land overall has a much higher proportion of more fire-adapted types (83%) than private lands or other conservation lands (69%), and the GW NF appears to have a greater proportion of these types than the Jefferson NF (Table 15).

Table 15. Extent of BpS / Ecological Systems in the Jefferson NF project area

map code	Bps / Ecological System	Total Study Area		USFS Land		Other Conserve. Land	
		acres	%	acres	%	acres	%
30	Southern Appalachian Grass and Shrub Bald	490	0.01	480	0.07	10	0.01
1	Central and Southern Appalachian Spruce-Fir Forest	2,240	0.04	2,060	0.3	70	0.04
2	Southern Appalachian Northern Hardwood	29,030	0.5	14,530	2.0	6,015	3.6
4	Southern and Central Appalachian Cove Forest	1,066,130	18.8	102,830	14.2	36,330	22.0
6	Central Appalachian Stream and Riparian	246,830	4.4	5,330	0.7	4,290	2.6
23	Central Appalachian River Floodplain	109,670	1.9	1,500	0.2	1,350	0.8
99	Lakes	7,730	0.1	0	0	3,350	2.0
8	Central and Southern Appalachian Montane Oak	32,580	0.6	10,580	1.5	2,860	1.7
9	Southern and Central Appalachian Red Oak-Chestnut Oak	636,960	11.2	195,390	26.9	35,590	21.5
13	Southern Appalachian Oak Forest	694,870	12.3	119,800	16.5	21,870	13.2
31	Northeastern Interior Dry-Mesic Oak Forest	1,619,380	28.5	36,560	5.0	24,605	14.9
17	Southern Ridge and Valley / Cumberland Dry Calcareous Forest	404,170	7.1	3,750	0.5	6,270	3.4
29	Southern Ridge and Valley Calcareous Glade and Woodland	27,410	0.5	100	0.01	810	0.5
10	Allegheny-Cumberland Dry Oak Forest and Woodland	494,080	8.7	162,430	22.4	11,980	7.2
16	Southern Appalachian Low-Elevation Pine	98,970	1.7	10,990	1.5	1,100	0.7
18	Southern Appalachian Montane Pine Forest and Woodlands	147,690	2.6	45,660	6.3	6,400	3.9
27	Central Appalachian Pine-Oak Rocky Woodland	23,840	0.4	6,760	1.0	2,060	1.2
21	Central Appalachian Shale Barren	31,490	0.6	7,220	1.0	580	0.4
	TOTAL Jefferson National Forest Project Area	5,673,560		724,970		165,530	
	Least fire-adapted	1,462,120	25%	126,730	17%	51,415	31%
	Most fire-adapted	4,211,440	75%	599,240	83%	114,125	69%
	TOTAL George Washington National Forest Project Area	4,787,080		922,810		249,595	
	Least fire-adapted	947,185	20%	122,730	13%	31,365	13%
	Most fire-adapted	3,839,890	80%	800,075	87%	218,230	87%

Figure 12. Fire-adapted Systems in the Jefferson NF Study Area



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 10), 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. Using just 1 majority filter of the 'raw' models resulted in a shift of 2-4% of reference plots into different Ecological Zone map units. The majority filter command (in the Jefferson NF study) merely replaced 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 map unit shifts indicate the close proximity of some reference 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 type boundaries. Although difficult to capture in GIS modeling, this variability in environmental conditions over short distances is common in the Appalachians 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 true 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 observer experience in the area. It should also be noted that these field identification 'errors' are likely accounted for by the MAXENT statistical procedure that evaluates environmental conditions at multiple plots (often in the upper hundreds), and therefore *the models may better represent Ecological Zones better than some field evaluations*. This is something to consider when analyzing an accuracy assessment matrix (Appendix VII).

3) DTM accuracy: The accuracy of DTMs used to reflect temperature, moisture, and fertility gradients, has a significant impact on Ecological Zone map unit accuracy. Geology 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 geology map units were aggregated into just 10 distinct groups (Appendix III, VIII), there were still differences between these grouped map units across State lines, and across ownerships; not only map line differences but also map unit labeling differences. An improvement in map unit accuracy could be possible by correlating geologic 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 Rich that is closely aligned with mafic rocks not often depicted by State-wide geology maps.

4) Modeling methods. The 1st approximation Ecological Zones on the Jefferson NF project area are based on merging 27 individual Ecological Zone models into one map based upon the zone having the highest probability of occurrence and adjustments along ecotones. 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 maximum probability model to fill areas where these conditions are not met.

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the appendixes for this document are in a separate file