Southern Blue Ridge: Core Forest Delineation

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Executive Summary

The Southern Blue Ridge (SBR) ecoregion is a nationally recognized biodiversity hotspot that contains 9.4 million acres of forested landscape stretching across five states (Georgia, North Carolina, South Carolina, Tennessee, and Virginia). This landscape is well known for its intact temperate forest stratified across a large elevation and climate gradient which produces unique and diverse landforms, plant communities, as well as bedrock geologies. These variations in SBR support the highest salamander diversity worldwide, high densities of forest breeding birds, 400 rare plant species, and 120 endemic terrestrial communities (Anderson et al. 2013, Hunter et al. 1999). The urgency to understand where and how to best protect this vital region has increased with the encroachment of human development, climate change, and disturbances (natural and human) that are occurring throughout this valuable landscape.

Recently, SBR priority conservation areas were identified by The Nature Conservancy through an analysis of matrix forests which identified 83 large blocks that are relatively unfragmented forest (Anderson et al. 2013). In this analysis a matrix forest was defined as a large area (greater than or equal to 15,000 acres) of heterogeneous, relatively undeveloped forested areas (i.e. areas containing at least 80% deciduous forest, evergreen forest, or forest scrub). These forests are considered to be large enough to be resistant to the effects of catastrophic events (i.e. hurricanes, tornadoes, ice storms) and resilient enough to return to a positive state of ecological productivity and species composition following disturbances (Anderson and Bernstein 2003). The boundary of each block was delineated by any major fragmenting feature (interstates, railroads, large lakes, etc.). These blocks were then prioritized across the SBR to identify which matrix forest blocks best represented a range of ecological land units (ELU). These ELUs contain combinations of elevation, bedrock geology, and land forms that make them each unique, however some matrix forests are more similar to some than to others. These characteristics create a wide range of environmental conditions often correlated with high biodiversity. Thus through conservation of a wide array of large forest blocks, a wide range of biodiversity will be supported, and it will maintain or improve ecosystem function as changes within the environment occur, including climate disruption.

While these matrix forest blocks are relatively undeveloped, they do contain elements of multiple-use landscapes. The concern with multiple-use landscapes in these areas is that these blocks could contain minor fragmenting features or be managed in such a way that might not support biodiversity (i.e. extraction). These minor fragmenting features are defined as features such as minor roads (county, Forest Service, logging etc.), motorized recreation trails or other landscape features that could impede movement of organisms across the matrix block or downsize habitat. To meet the habitat needs of SBR organisms it is necessary to identify and evaluate unfragmented core forests that will reside within priority matrix forests to be managed for biodiversity.

The goal of this report is to build upon previous analysis of SBR matrix forest blocks using aerial photography and geospatial analysis to identify **core forests** within each of these blocks. A **core forest** is defined as a heterogeneous landscape with minimal (i.e. hiking trails) or no fragmenting features that contain at least 5,000 acre **interior forest** surrounded by a 100m buffer. The **buffer** is a part of the core forest which surrounds and protects the 5,000 acre (or larger) interior forest from any multiple-use disturbances (such as off road vehicle trails) that may take place in the matrix forest block. Core forests are a key component in the long-term SBR conservation strategy as they “provide the opportunity for relatively natural processes to occur or be mimicked through management, resulting in a healthy range of structural and compositional forest attributes" (Anderson et al. 2013).[1]

The accompanying report summarizes the **five step delineation of core forests** involving:

1. Identify minor (or multiple use) fragmenting features in forest matrix blocks.
2. Delineate core forests that do not contain minor fragmenting features.
3. Document current land owner and management of core forests.
4. Calculate and evaluate core forests based on density of minimally fragmenting features, shape index values, and biodiversity potential.
5. Use aerial photographs to review core forests identified by GIS software to look for any mistakes made in land cover classification.

This study identified 200 potential core forests within the SBR intended to be used by TNC and its partners to further refine the ecoregion's conservation strategies. It is estimated that these 200 core forests account for 2,875,373 acres of land. More specifically 57% of the total land within matrix forest blocks was identified as core forest. Additionally, all but five of the 83 matrix forest blocks contained at least one core forest. These promising results are meant to guide TNC and its partners in conserving a diverse forest network for long-term biodiversity protection through informing land acquisition, forest management, and monitoring. More specifically, within the SBR, Nantahala and Pisgah National Forests are currently undergoing Land & Resource Management Plan revision which could incorporate protection of significant core forests in the new plan. The identification of a forest matrix network with embedded core forests is a key component in long term preservation of ecosystem processes within Nantahala and Pisgah National Forests and throughout the SBR (Anderson 2008).

[1] It is important to note at this stage, all sites identified in this report as a core forest are considered potential sites which should be further evaluated with input from local experts.

Introduction

The Nature Conservancy's vision in conserving the Southern Blue Ridge ecoregion (SBR) consists of a large matrix forest network with embedded core conservation areas. The forest matrix serves as a multiple use or working forest allowing sustainable timber harvest and recreation opportunities. Although the matrix forest blocks are relatively undeveloped, they are multiple-use landscapes that do contain fragmenting features. Core forests are a critical component to a diverse forested network as when they are managed for ecosystem functions it boosts resiliency. Having a resilient ecosystem allows species to adapt within a dynamic environment such that as the forest changes, species have the space and diversity of habitat to adapt to these changes (Gunderson 2000). These core forests being nested within the matrix forest blocks support a healthy diverse forested ecosystem (Anderson et al. 2013). The objective of this analysis was to delineate and describe potential ***core forests*** within the Southern Blue Ridge ecoregion's matrix forest blocks for the purpose of informing acquisition, forest management, and other conservation strategies. While this report is written for an audience that largely understands Geographic Information Systems and mapping, the results can be applied widely by many others.

The outcome of this analysis is intended to be used by TNC and its partners for strategy development and implementation within the Southern Blue Ridge ecoregion, including US Forest Service plan revisions, strategic land acquisition, preserve management, and monitoring, among other things. The resulting shapefile is intended to be used in conjunction with other conservation data, including secured areas (GAP status information), parcel and landowner information, agency planning prescriptions, and other analyses results that are currently underway like the Southeastern Resiliency Analysis. Some of these additional data layers are located within the SBR Core Forest Analysis Geodatabase, Conservation Areas feature class dataset.

Definitions

Landscape Metrics

Landscape metrics are used to evaluate whether a feature (i.e. road, river, etc.) fragments the landscape. A fragmenting feature separates large tracts of contiguous forest into smaller, isolated tracts, resulting in the degradation of natural communities, impediments to animal and plant movement, and alteration of ecological processes. A non-fragmenting feature is a feature such as a hiking trail; whose impact on organisms in the landscape is so minimal that it does not greatly impede the movement of organisms. The effects of these landscape features vary depending on the scale and species being considered therefore they are assigned into the following categories:

Major Fragmenting Features: Category A

Major fragmenting features include major roads, lakes and large rivers (>3,681 $miles^2$ drainage area). Major roads were categorized as road classes 1-4 which include interstate highways, state roads and some county road systems with speed limits greater than or equal to 35 mph.

Minor Fragmenting Features: Category B

Minor fragmenting features include local road systems with speed limits less than 35 mph, including national forest roads designated as Maintenance Level 3-5; railways; motorized recreation trails; major electric transmission lines; natural gas pipelines; and non-forested areas. Non-forested areas were defined as areas that were classified as developed, barren, planted or cultivated, according to the 2006 National Land Cover Database.

Non-Fragmenting Features: Category C

Non-fragmenting features include national forest roads designated as Maintenance Level 1 or 2, as well as non-motorized trails. These roads are most likely only open seasonally and accessible only by high clearance vehicles, and many are gated and only used for administrative purposes (USFS, 2010). Additionally, because these are relatively inactive roads there is high potential for decommission by the Forest Service. It is recommended that the features identified as Category C in this analysis undergo a more rigorous analysis on a case by case basis if they are to be implemented in conservation initiatives.

Matrix Forest Blocks

For the Southern Blue Ridge, matrix forest blocks are blocks of contiguous, large (greater than or equal to 15,000 acres), relatively undeveloped land containing a minimum of 80% forest cover. These areas are bounded by major fragmenting features (Category A) (Figure 1).

Potential Core Forest

A potential **core forest** (herein referred to as core forest) is a heterogeneous forested landscape with no fragmenting features that contains at least 5,000 acres of **interior forest** surrounded by a 100m buffer. The **buffer** is a part of the core forest which surrounds and protects the 5,000 acre (or larger) interior forest from any multiple-use disturbances (such as off road vehicle trails) that may take place in the matrix forest block. ***The boundary of the Core Forest is intended to serve as the primary boundary for core forest protection actions.*** *"Potential" is used in reference to core forests and due to the scale of this analysis. Actual boundaries of these areas may change after further ground-truthing.*

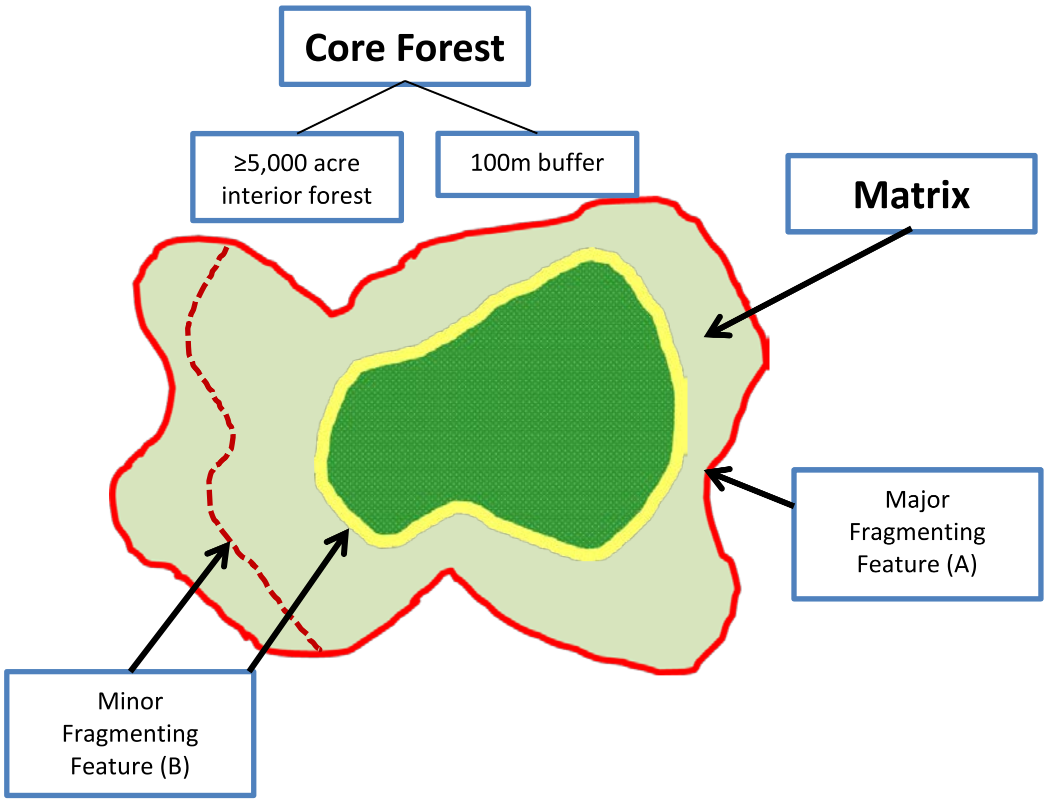


Figure 1. Picture description of matrix forest block and core forest

Delineating and Verifying Core Forests

GIS data was acquired from a number of sources including TNC, US Forest Service, and ESRI (Appendix A and B). Criteria for delineation of core forests was developed that included:

> A core forest must contain at least 5,000 acres of interior forest surrounded by a 100m forested buffer to ensure the interior of the forest is 100m from any major or minor fragmenting features.

Forested areas were first selected out of the 2006 National Land Cover Database (30m cells) (Appendix C). Forested areas included deciduous forest, evergreen forest, mixed forest, dwarf scrub, unmanaged grasslands and herbaceous areas, woody wetlands, emergent herbaceous wetlands, and open water. Although wetlands and open water are not usually considered forest, they were considered as non-fragmenting natural features in the landscape and were therefore classified as forested areas for this analysis.

Under guidance from the Pennsylvania Conservation Forest Analysis (2007), a core forest delineation model was built in ArcGIS Desktop's modelbuilder. All major and minor fragmenting features were converted to a 30m raster grid, embedded within the NLCD forested layer, and then reclassified as NoData. Reclassifying these areas as NoData removes these cells from any further analysis. The resulting raster data layer contained only forested land and non-fragmenting features which was converted to a shapefile. Converting the desired forested raster data to a shapefile creates polygons of unfragmented forested land to be evaluated for core forest consideration. Resulting polygons formed multipart polygon features; therefore, these polygons were broken apart into single features.

The next step is to evaluate these possible core forests to see which areas had at least 5,000 acres of interior forest. These polygons were given a 100m interior buffer (Figure 2).

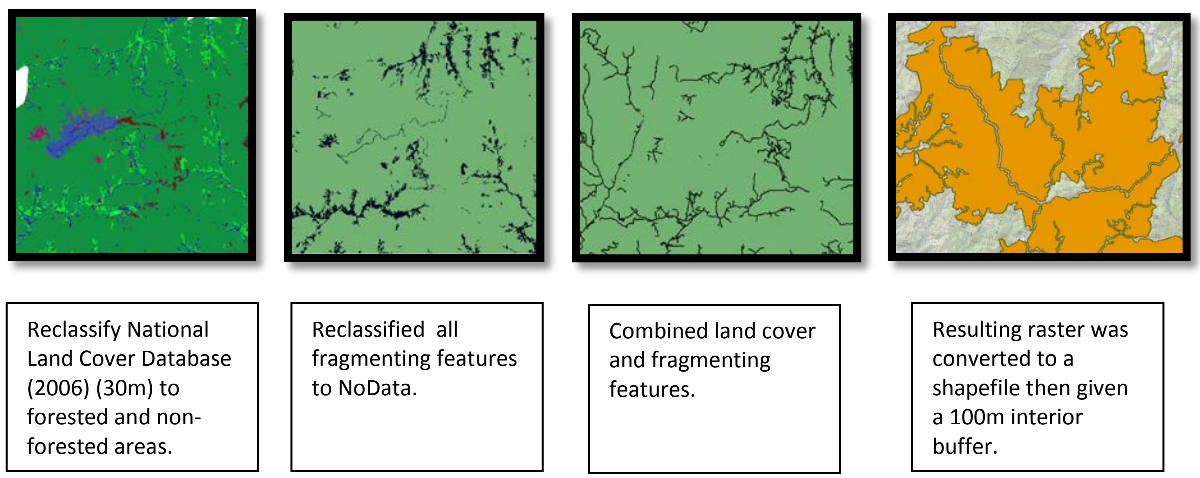


Figure 2. Graphic description of core forest delineation

The area (acres) and perimeter were calculated for each interior forest and all areas less than 5,000 acres were removed from further analysis. The resulting forests were selected as potential interior forest and surrounded by a 100m forested buffer, thus identifying core forests. The measure tool was used to check the perimeter of the 100m buffer of several core forests to verify that the buffers were at least 100m wide.

Identified core forests were spatially joined to the matrix forest block shapefile in order to append matrix block information to identified core forests. Each core forest was assigned an ID value that corresponded to the matrix block in which it was embedded. In instances where multiple core forests were delineated within the same matrix forest block, the area was assigned corresponding alpha-numeric ID’s in no particular order (e.g., three cores within matrix forest block 15 would be named 15a, 15b, 15c). The spatial join of the matrix forest block shapefile to the core forests attribute table was examined by going through each core forest record and validating that each of these areas was joined with the correct matrix forest block information. Some core forests were assigned incorrect matrix forest block information. This tended to happen within core forests that were adjacent to the border of a matrix block. The attribute table was updated to reflect the correct information.

Validation of removing all major and minor fragmenting features was done through intersecting the resulting core forest shapefile. Since all fragmenting features were converted to NoData and given a

100m buffer, none should exist within the identified areas. The results of the intersection validated that no major and minor fragmenting features were located within the identified core forests.

Calculating Core Forests Metrics

Accurately identifying potential core forest locations was the first step in selecting areas for conservation. This purpose of this report is not only to identify locations of core forests but also to include several landscape metrics to be considered in future analysis for prioritization.

Forest Service Road Density

Road density within core forests (miles/mile^2) was calculated to assist in guiding future discussions with the Forest Service and other land managers about compatible management practices within these core forests. In this preliminary analysis these roads are considered non-fragmenting features as our research suggests they have extremely low usage of vehicles, seasonal closures, and a high chance of being decommissioned it is important to understand their density in core forests. However, it is important to note that these roads will need to be evaluated on a case by case basis as it is possible they could be considered fragmentors upon further evaluation. Density information is provided to allow and encourage future analysis of this topic.

To calculate Forest Service road density, forest roads designated as Maintenance Level 1 or 2 were extracted out of the Forest Service Roads travel route layers for four of the five National Forests within the Southern Blue Ridge ecoregion (Nantahala-Pisgah National Forest, Sumter National Forest, Cherokee National Forest, and Chattahoochee-Oconee National Forest) and then intersected with core forests. The geometry of the GIS_Acres field was updated to reflect correct mileage distances and then the summarize tool was used to create an output table of the sum of forest road mileages per potential core area. This output was joined to the core forest's shapefile and a new field, SQ_Miles, was created. The miles for each core forest and Interior Forest was then calculated using the calculate geometry tool. Finally, a new field was added to the core forest shapefiles called FR12_Densi. The field calculator was used to calculate the density of Maintenance Level 1 & 2 forest roads per area (miles/mile^2) within the Southern Blue Ridge ecoregion by dividing the sum of miles within each Core Forest by the total square miles of the potential core area (WADNR, 2004; USFS, 2008). Within the Nantahala-Pisgah National Forest, identified areas were clipped to the forest management boundary, and road densities were calculated for portions of the areas that fell only within the Nantahala-Pisgah National Forest.

GAP Status & Land Ownership

Acreages for GAP status designations within core forests were calculated[2]. The Acres field in the resulting files was updated, and the summarize tool was used to create a table that summarized the total acreage within each GAP designation status. To calculate the acreage of core forests that were outside of secured lands, the erase tool was used to remove core forests that fell within the secured areas boundaries, thereby leaving only the portions of the areas that were unsecured. The acres field was updated in the output file and the statistics tool was used to obtain the total acreage of unsecured lands within both the core forest's data.

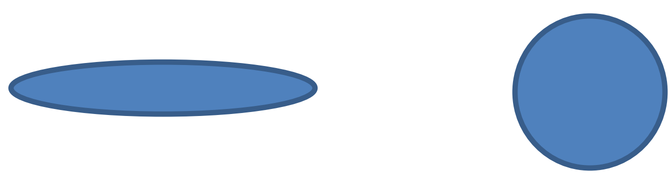
Land ownership was also listed within the GAP status layer's attribute table. The same process was repeated to calculate land ownership based on the feetype_org attribute field.

[2] The S_A_internal_plusTNmrgWIldernessMultiparts shapefile, GAPSNRedit attribute field, was used to assess GAP status within Core and Interior Forests.

Perimeter to Area Metrics

The matrix forest blocks which form the foundation of this study's core forest delineation identifies areas of critical forest protection based on specific viability criteria, including area size. Size criteria was based on the size and frequency of natural disturbances as well as habitat needed by selected interior forest species and is further discussed in "Southern Blue Ridge: An Analysis of Matrix Forests" (Anderson and Bernstein 2003). Patch shape also affects habitat quality for forest interior dependent species. In general, circular or square shaped patches have more interior compared to patches of the same area that are more complex in shape. Additionally, simple shapes are more desirable because a complex shape is more susceptible to fragmentation should any loss of habitat occur. There are several shape indexes that can be used to evaluate a core forest's shape. This analysis focused on a perimeter to area shape index and fractal dimension. All calculations focused on the interior portion of the core forest and did not include the 100m buffer.

A simple measurement for a core forest's shape is a perimeter to area ratio; however, a straightforward measurement of perimeter to area fails to correct for variations in size. Alternatively, a perimeter to area shape index (a measure of "circularity"), corrects for this issue as it compares the complexity of a shape to a circle. The more compact a shape the area is, the more likely it is to resemble a circle. Circularity is a ratio, and is therefore dimensionless, allowing the results of the shape index to be comparable to each other regardless of the core forest's size. Shape index values range between 0.0 – 1.0 with values approaching 1.0 representing more circularity and values closer to 0.0 representing thinner, longer areas (Figure 3). For this analysis, shape indexes closer to 1.0 were considered more desirable.



Values range from 0.0 to 1.0. Values close to 0.0 represent long, thin shapes (left) and areas close to 1.0 represent compact, circular shapes (right).

Figure 3. Shape Index

Shape index was calculated for core forests using equation 1 below (Craig, N.M., 2009).

$$\sqrt{}((\,Interior\ Core\ Area) \div ((Interior\ Core\ Perimeter{}^\wedge 2)/4\pi) \qquad (1)$$

Another shape index, fractal dimension (f.d.), measures the degree of the core forest's complexity. The complexity of the shape is related to the complexity of the shape's boundaries. Less complex shapes have simple, straighter boundaries compared to more complex shapes that have more complex boundaries. As a result, more complex shapes are likely to have less interior compared to shapes that have simpler shapes (Figure 4).

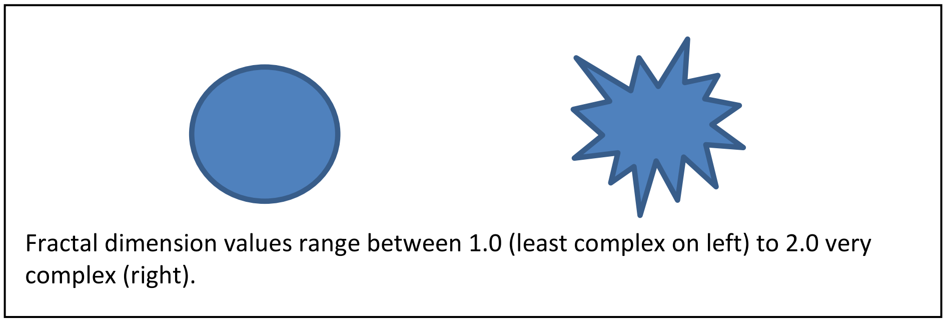


Figure 4. Fractal Dimensions

Fractal dimension values range between 1.0-2.0, with more complex shapes having values closer to 2.0. For the purposes of this analysis fractal dimensions closer to 1.0 were considered more desirable. Various equations exist for calculating fractal dimensions. Fractal dimension within this analysis was calculated using Equation 2 below (Turner et al., 2001).

$$2 \times (\log\ perimeter / \log area) \tag{2}$$

It should be noted that a core forest with a higher (worse) fractal dimension need to be evaluated on a case by case basis. It is possible that a large complex core forest may still be large enough to contain an interior forested area with a lower (better) fractal dimension score (Figure 5).

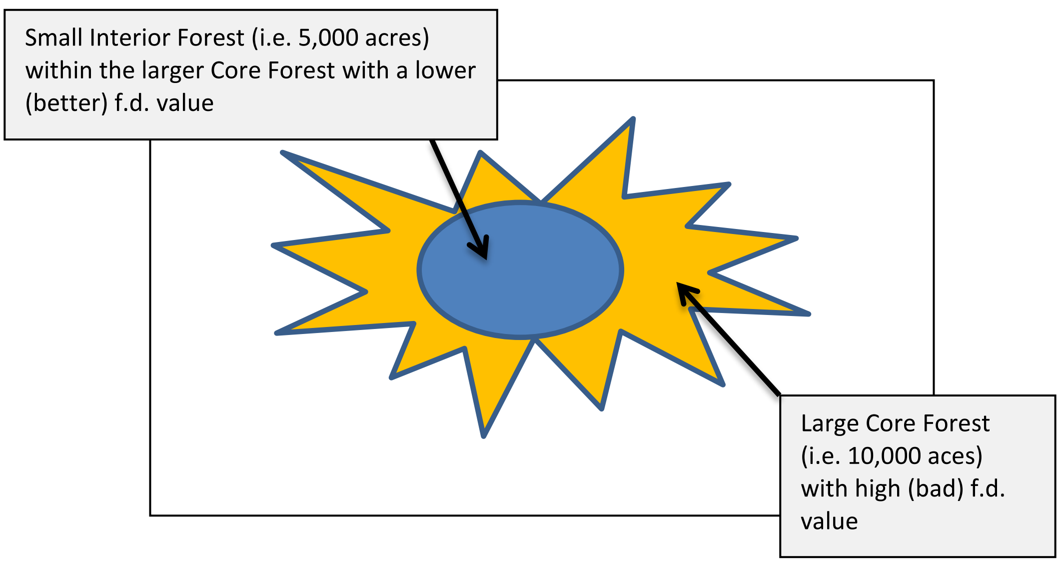


Figure 5. Example of how a large core forest with a higher (bad) fractal dimension value may contain a smaller Interior Forest with a lower (better) fractal dimensions value

Evaluation of Core Forests Identified by GIS Software

Core forests within NC were "air-truthed" using imagery data (2010 North Carolina Statewide, 6-inch, true-color, leaf-off, orthoimagery). The imagery was flown from January 2010 – April 2010. Core forests within Virginia, Tennessee, Georgia, and South Carolina were air-truthed using ESRI online imagery. At the time of this analysis, ESRI imagery was last updated in June 2012 and included high resolution (1m) leaf-on images within the United States. Additionally, a 500m by 500m grid was created as a reference to enable orderly air-truthing. Each grid block was numbered according to its position in the grid (row-column), and the grid was followed starting from the patches upper most left corner to the bottom most right corner.

As a result of time limitations, not all of the core forests were air-truthed. In order to record which areas had been air-truthed, a new field was added to the attribute tabled called "Air_truthe" and each record was given a value of Y (Yes) or N (No). Of the 200 core forests, a total of 83 were air-truthed.

The focus of the air-truthing was to evaluate correct land-use classification. Some core forests contained holes where presumably the land-use was classified as non-forested. These holes were checked against the imagery and in many cases, these holes were incorrectly classified. For example, rock faces or cliffs were classified as developed areas (Figure 6). In areas where this occurred, the polygon was closed in.

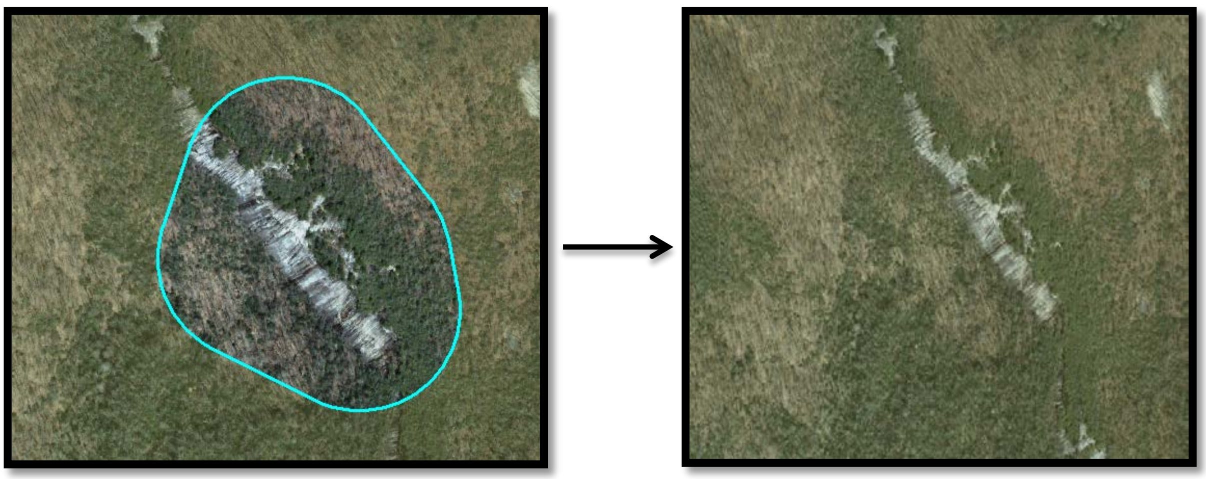


Figure 6. Example: core forests classified as development

Additionally, there were many areas close to roads where development (i.e. houses) were classified as forested and needed to be cut out (Figure 7).

Figure 7. Example: Developed area classified as core forest

In some places TIGER road files, which were more detailed than the ESRI detailed streets shapefile used for the analysis, were consulted to assist in cutting out the least amount of area as possible (Figure 8).

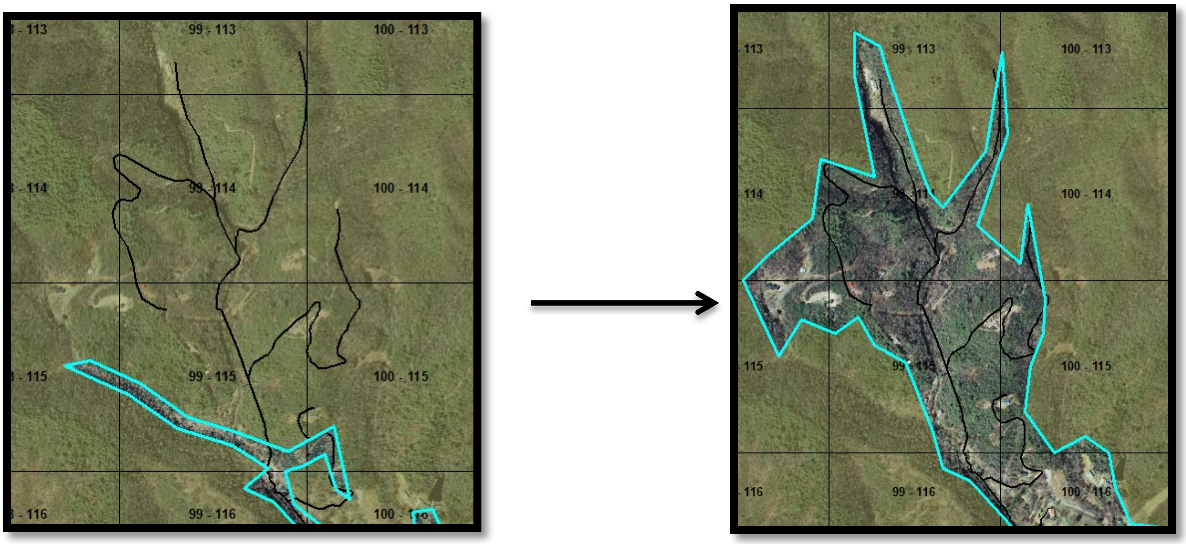


Figure 8. Example: Using TIGER roads to supplement ESRI roads for carving out developed areas

Lastly, the ESRI detailed roads dataset contained some small, stand-alone road segments within core forests that resulted in creating large buffered areas. When these areas of small stand-alone road segments were compared against Forest Service road data, it was found that these segments usually corresponded with Maintenance Level 1 & 2 roads. Since Maintenance Level 1 & 2 roads (Category C) were not considered fragmenting features within this analysis these buffered areas were deleted (Figure 9).

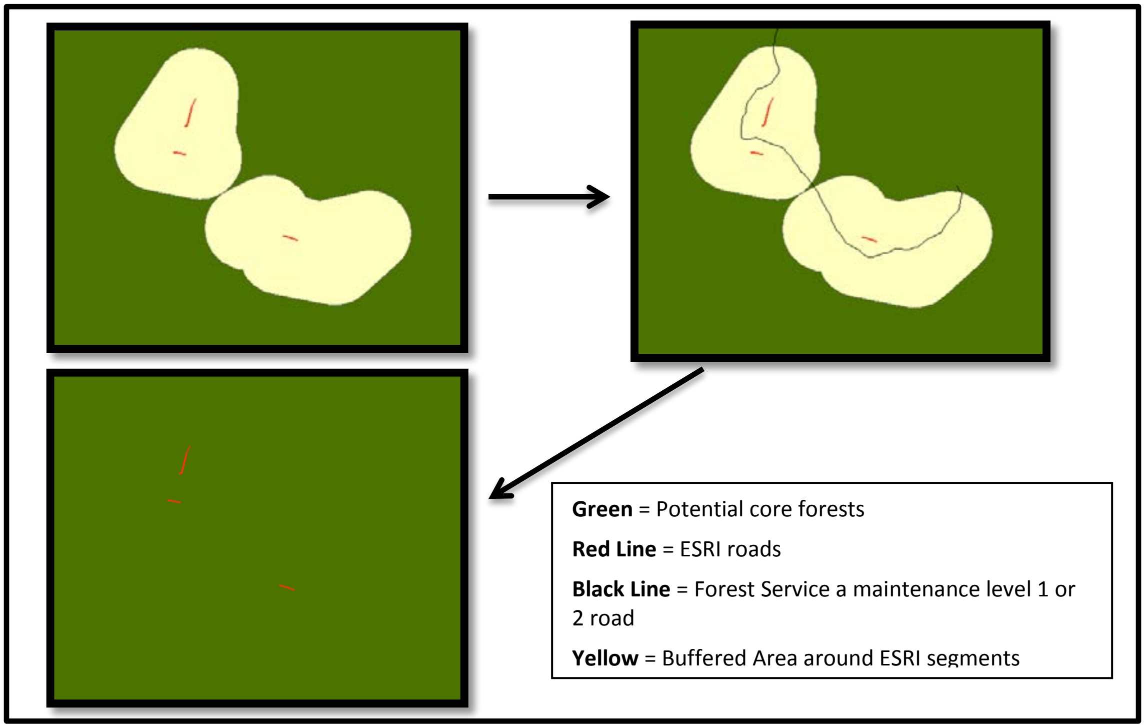


Figure 9. Example: Incomplete road segments overlapping Forest Service Maintenance Level 1 & 2 Roads

Results & Discussion

The core forest delineation results are presented within two main sections. The first section presents the results for the entire Southern Blue Ridge ecoregion (Figure 10). The second section presents the results specific to the core forests that fall at least partially within the Nantahala-Pisgah National Forest. The core forests within the Nantahala and Pisgah National Forests were given a specific focus for two main reasons. First, every core forest's that falls at least partially within the forest boundaries was air-truthed. Secondly, the Nantahala-Pisgah National Forest has just begun the revision process for their Land and Resource Management Plan (October 2012) and this analysis should be incorporated into that revision. To demonstrate how this analysis can be applied to guiding conservation actions within core forests, it was necessary to review statistics for these areas separately.

Core Forests within Southern Blue Ridge Ecoregion

Initially this delineation yielded a total of 195 core forests. After air-truthing the initial results there were a total of 200 core forests totaling 2,875,373 acres or approximately 57% of the matrix forest block areas within the Southern Blue Ridge ecoregion. Of the 83 matrix forest blocks, 5 blocks (Honeycut Mt., Mt. Bridge West, Bull Mountain, Cowee, and Meadow Creek Mountain) did not contain any core forests. Statistics were calculated for the interior forested region residing within a core forest and did not include area associated with the 100m perimeter buffer. The core forest with the smallest interior forest is located within the Cohutta forest block and is 5,053 acres, while the largest is located within the Great Smokies West block and is 234,547 acres. The mean interior forest area is 14,420 acres, and the median is 9,337 acres (Table 1).

Table 1. Acreages of interior forests located within the Southern Blue Ridge Ecoregion

Acreage Classes	Total Acreage of Interior Forests	Number of Interior Forests
5,000 – 10,000 acres	742,781	107
10,001 – 15,000 acres	541,619	42
15,001 – 20,000 acres	378,321	22
20,001 – 25,000 acres	258,283	12
25,001 – 30,000 acres	84,262	3
30,001 – 35,000 acres	91,114	3
35,001 – 40,000 acres	37,429	1
40,001 – 45,000 acres	41,894	1
45,001 – 50,000 acres	0	0
50,001 acres or greater	699,671	6
TOTAL ACREAGE	2,875,373	200

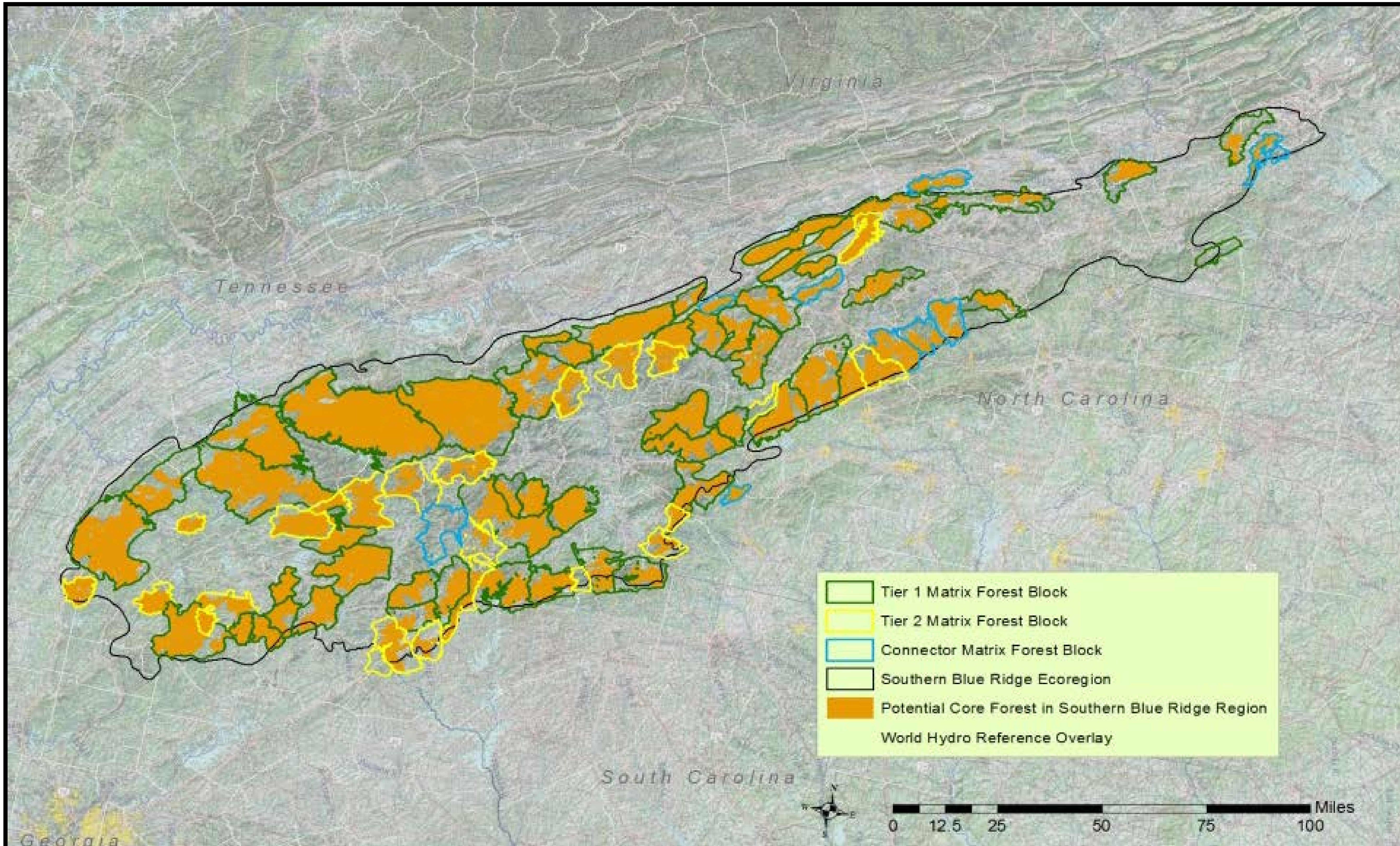


Figure 10. Core Forests in Southern Blue Ridge Ecoregion

GAP Status of Core Forests

Gap status statistics were calculated for core forests and their interior forested area. Nearly 24% (761,216 acres) of land within the core forests fall within GAP 1 secured lands (lands permanently protected for biodiversity), and just over 3% of land (99,101 acres) within core forests fall within GAP 2 secured lands (land permanently protected to maintain a primarily natural state). GAP 1 and 2 are the preferred status for core forests (Table 2, Figure 11).

Almost 45% (1,451,300 acres) of the core forests fall within areas designated as GAP 3, lands permanently secured for multiple uses. Approximately 29% (925,078 acres) of core forests are either designated as GAP 4 (unmanaged for biodiversity) or are unsecured[3] (Table 2). Core forests may contain more than one GAP status designation.

Table 2. GAP status acreages within Southern Blue Ridge Ecoregion Core Forests

GAP Status	Acres of Core Forest
GAP 0	261
GAP 1[1]	761,216
GAP 2[2]	99,101
GAP 3[3]	1,451,300
GAP 4[4]	38,824
GAP 9[5]	3,837
Unsecured Areas	886,254

[1]Lands permanently protected for biodiversity
[2]Lands permanently protected to maintain a primarily natural state
[3]Lands permanently secured for multiple uses
[4]Lands not managed for biodiversity and currently do not have a management plan
[5]GAP status unknown

[3] It was noticed during the evaluation process that some areas within the National Forest were "unsecured" according to TNC's secured areas layer indicating that this layer needs to be updated in order to reflect current management boundaries. This data should be drilled down into and verified for any specific project.

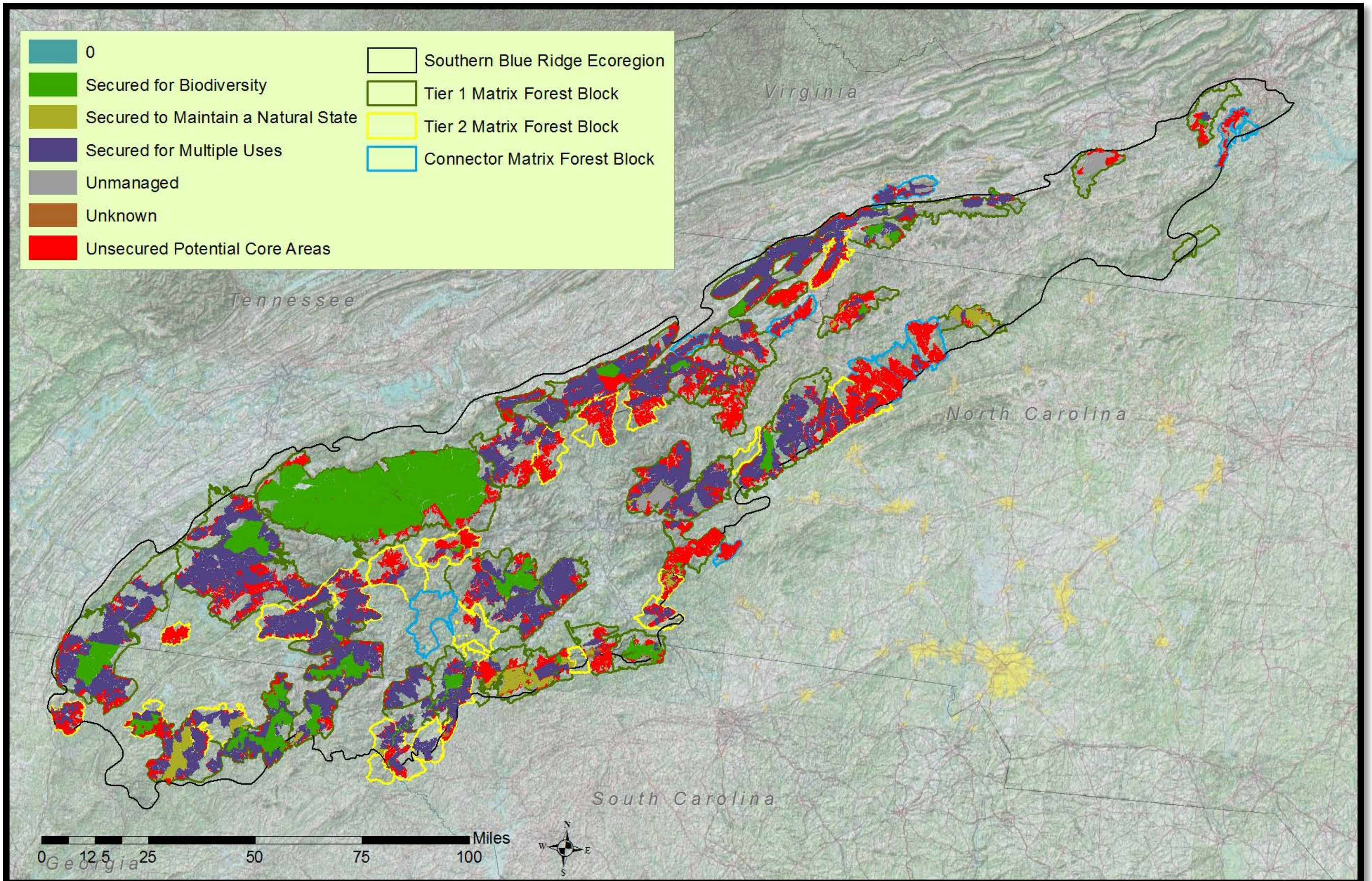


Figure 11. GAP Status of Core Forests in Southern Blue Ridge Ecoregion

Land Ownership of Core Forests

Over 66% of core forests are owned by the federal government (2,127,306 acres). Over 95,400 acres of core forests are state owned lands; 55,232 acres are owned by private land owners; 37,000 acres are owned by private-non-profit organizations, and just over 17,000 acres are owned by local municipalities. Over 880,000 acres fall outside secured areas implying that nearly 28% of core forests (24% of their interior) are within private ownership (Table 3, Figure 13).

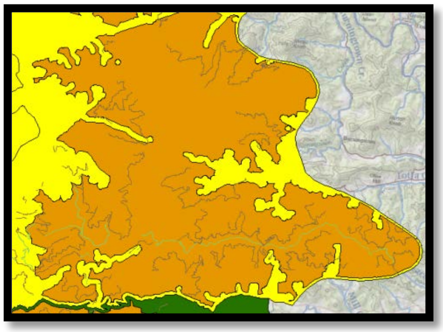
Table 3. Land ownership of core and interior forests within the Southern Blue Ridge Ecoregion

Landowner	Acres of Core Forest
Federal Ownership	2,127,306
State Ownership	95,450
Private Ownership	55,232
Private Non-Profit Ownership	37,000
Local Municipality Ownership	17,376
Unknown	4,102
Unsecured Areas	886,254

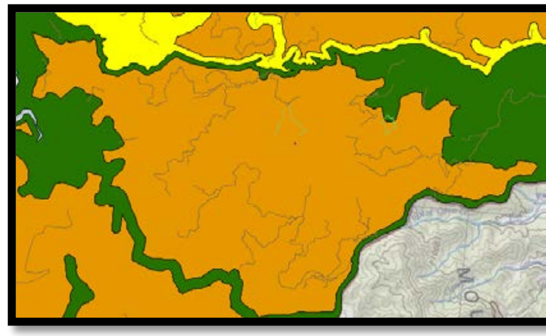
Road Density within Core Forests

The Southern Blue Ridge ecoregion contains five National Forests; Nantahala-Pisgah National Forest, Chattahoochee-Oconee National Forest; Cherokee National Forest, Sumter National Forest, and George Washington-Jefferson National Forest. Forest Service road information was available for all forests except the George Washington-Jefferson National Forest. National forest roads designated as Maintenance Level 1 make up approximately 20% of the forest road system, and most are closed to public access. Maintenance Level 2 roads account for approximately 58% of the forest road system.

Based on the four National Forests in which GIS road data was available, there is a total of 1,787 miles of Maintenance Level 1 & 2 Forest Service Roads located within 129 of the 200 core forests (Table 4). These roads average 13.85 miles/core forest or a density of approximately 2 miles/mile^2. The Little Tennessee matrix forest block and associated core forest has the highest mileage of Maintenance Level 1 & 2 roads, while Chunky Gal matrix forest block has the highest road density within the identified core forests (Figure 12).



Little Tennessee Core Forest
Maintenance Level 1 & 2 Miles: 95.27
Maintenance Level 1 & 2 Density: 1.82 $mile/mile^2$



Chunky Gal Core Forest
Maintenance Level 1 & 2 Miles: 33.01 Miles
Maintenance Level 1 & 2 Density: 2.02 $mile/mile^2$

Figure 12. Road Miles and Density of Maintenance Level 1 & 2 within 2 core forests

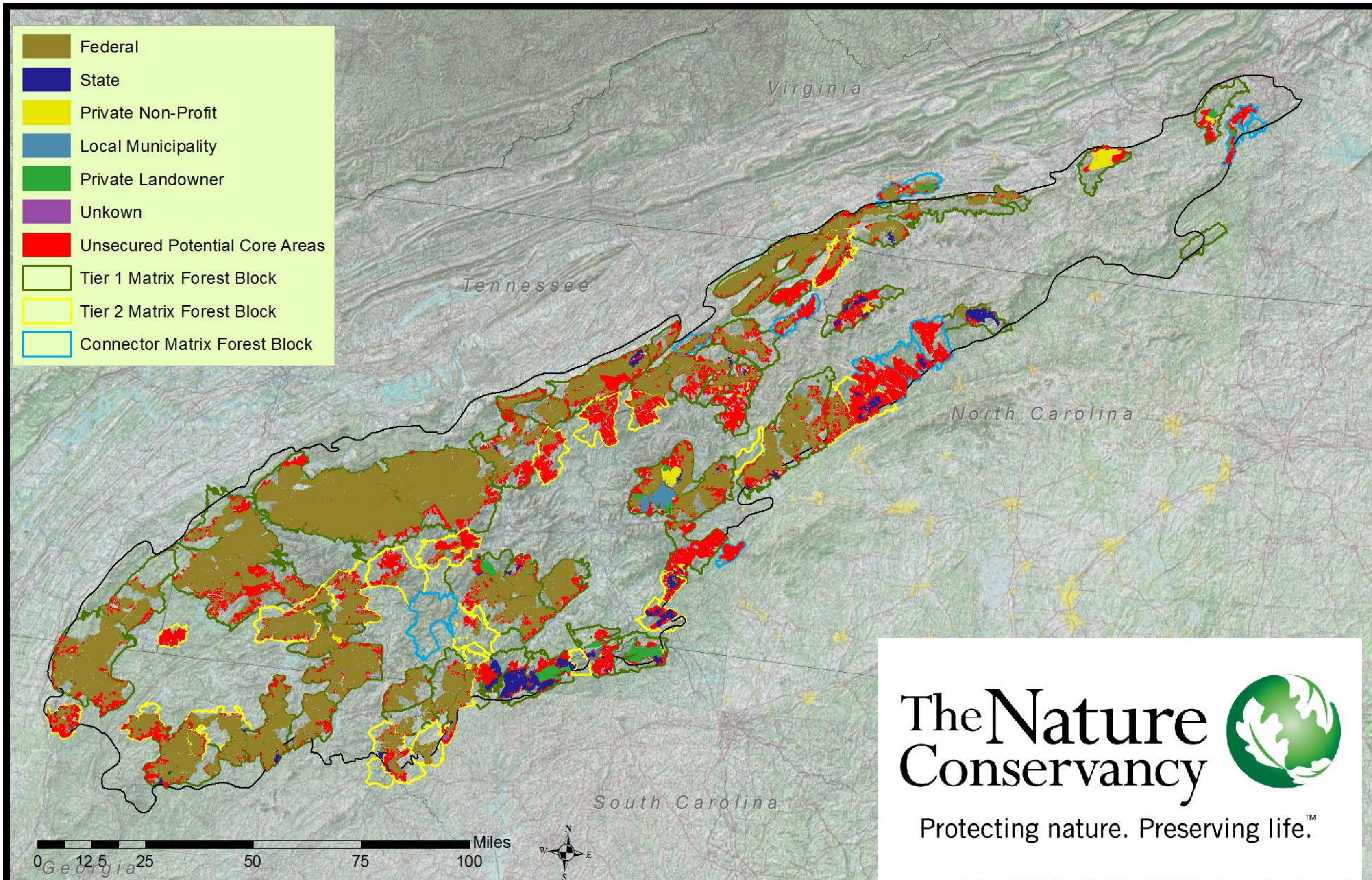


Figure 13. Land Ownership of Core Forests in Southern Blue Ridge Ecoregion

Table 4. Summary of Forest Service Roads Maintenance Level 1 & 2 Mileage and Densities in Southern Blue Ridge

Statistic	Core Forests		Interior Forests	
	Miles of Maintenance level 1 and 2 Roads	Density of Maintenance level 1 & 2 Roads (miles/mile^2)	Miles of Maintenance level 1 and 2 Roads	Density of Maintenance level 1 & 2 Roads (miles/mile^2)
Minimum	0.24	0.02	0.06	0.01
Maximum	95.27	2.02	89.68	2.15
Mean	13.85	0.59	12.03	0.59
St. Deviation	15.14	0.45	13.85	0.48
Sum	1,786.81	--	1,539.56	N/A

Shape Index Metrics

Shape Index results show that overall, most of the interior forests deviate away from resembling the ideal shape of a circle (shape index mean = 0.327), however, the average interior forest boundary is not extremely complex in shape (fractal dimension mean = 1.276) (Table 5, Figure 14).

Table 5. Shape index values of core forests

	Minimum	Maximum	Mean	St. Deviation
Shape Index	0.136	0.696	0.327	0.100
Fractal Dimension	1.192	1.356	1.276	0.032

Minimum shape index Matrix Forest Block Roan Mt. East PIF ID 8a	Mean shape index Matrix Forest Block Asheville Watershed PIF ID 21b	Maximum shape index Matrix Forest Block Mt. Rodgers PIF 77b

Minimum fractal dimension Matrix Forest Block Mt. Rodgers PIF ID 77b	Mean fracatal dimension Matrix Forest Block Duncan Ridge PIF ID 49b	Maximum fractal dimension Matrix Forest Block Roan Mt. East PIF ID 8a

Figure 14. Example illustrations of shape index and fractal dimensions of core forests

Core Forests within Nantahala-Pisgah National Forest

Of the 200 identified core forests within the Southern Blue Ridge ecoregion, 75 fall at least partially within the Nantahala-Pisgah National Forest boundaries. None of the areas fall completely within the Nantahala-Pisgah National Forest, rather, they share boundaries with adjacent landowners. Given that identifying adjacent landowners will be an important step in conservation planning efforts during the Nantahala-Pisgah National Forest Land and Resource Management Plan revision, we felt it was necessary to report statistics relevant to the entire core forests that fell within the boundaries of the forest rather than clipping them to the forest boundaries. Road density calculations for Maintenance Level 1 & 2 roads were an exception to this reasoning. In order to accurately capture the density of these roads within the forest boundaries, areas were clipped to the forest boundaries and road density values were calculated based on miles/mile^2 within the Nantahala-Pisgah National Forest.

Nantahala-Pisgah had core forests with interior areas ranging between 5,274 acres (within Panthertown Valley matrix forest block) to 93,822 acres (within Joyce Kilmer/Unicoi Mts./Slick Rock matrix forest block). The mean value was 15,445 acres, and the median was 24,719 acres (Table 6).

Table 6. Acreages of Core forest's interior within Nantahala/Pisgah National Forest

Interior Forest Acreage	Total Acreage of Interior Forest	Number of Interior Forests
5,000 – 10,000 acres	235,972	33
10,001 – 15,000 acres	260,542	21
15,001 – 20,000 acres	118,477	7
20,001 – 25,000 acres	131,361	6
25,001 – 30,000 acres	84,262	3
30,001 – 35,000 acres	0.0	0
35,001 acres or greater	327,725	5

Forest Service Maintenance Level 1 & 2 roads were clipped to the Nantahala-Pisgah management layer boundaries in order to evaluate the total mileage and approximate density (miles/mile^2) within each core forest within Nantahala-Pisgah National Forest boundaries. Of the 75 core forests within, a total of 68 contained just over 900 miles collectively of Maintenance Level 1 & 2 roads, with an average of 12.01 miles existing within each core forest or a density of approximately 0.85 miles/mile^2. Similar to core forests within the Southern Blue Ridge ecoregion, the Little Tennessee core forest contained the highest mileage of Maintenance Level 1 & 2 roads (90 miles). Core forests within the Max Patch matrix forest block contained the highest road density (6.51 miles/mile^2).

A total of 814 miles of Maintenance Level 1 & 2 roads were found within the interior forests located within Nantahala/Pisgah National Forest, with an average of 10.86 miles within each area or approximately 0.85 miles/mile^2 (Table 7).

Table 7. Summary of Forest Service road mileage and density within Nantahala-Pisgah National Forest

Statistic	Core Forests		Interior Forests	
	Miles of Maintenance Level 1 and 2 Roads	Density of Maintenance Level 1 & 2 Roads (miles/mile^2)	Miles of Maintenance Level 1 and 2 Roads	Density of Maintenance Level 1 & 2 Roads (miles/mile^2)
Minimum	0.00	0.00	0.00	0.00
Maximum	94.97	6.51	89.60	6.18
Mean	12.01	0.85	10.86	0.85
St. Deviation	15.08	0.88	13.91	0.84
Sum	901.22	--	814.37	--

GAP Status of Core and Interior Forests

Since most of the core forests overlap Nantahala-Pisgah boundaries, acreages for each GAP status may include lands outside of Forest Service management. Almost 28% (761,216 acres) of these core forests are designated as GAP 1 and less than 4% are designated as GAP 2. For the purposes of this analysis GAP 1 and 2 status are ideal designations for core forests. Nearly 53% (1,451,300 acres) of core forests are designated as GAP 3 (lands permanently secured for multiple uses) (Table 8, Figure 15).

Almost 14% (369,698 acres) of core forests that include national forest land are unsecured. Of this 14%, 45,810 acres fall directly within the Nantahala-Pisgah National Forest boundaries, of which 33,516 acres are designated as private inholdings within the forest. The remaining 12,294 acres are distributed across the remaining management areas. Given that these remaining areas are actually part of secured lands, it can be implied that the current secured areas shapefile needs to be updated to reflect current management boundaries for secured lands within the Nantahala-Pisgah National Forest.

Table 8. GAP status acreages of core andi interior forests that include Nantahala/Pisgah National Forest

GAP Status	Acres of Core Forest	Acres of Interior Forest
GAP 0	261	233
GAP 1[1]	761,216	118,929
GAP 2[2]	99,101	7830
GAP 3[3]	1,451,300	741,826
GAP 4[4]	38,824	17,357
GAP 9[5]	3,837	0.0
Outside Secured Areas	369,698	275,831

[1]Lands permanently protected for biodiversity
[2]Lands permanently protected to maintain a primarily natural state
[3]Lands permanently secured for multiple uses
[4]Lands not managed for biodiversity and currently do not have a management plan
[5]GAP status unknown

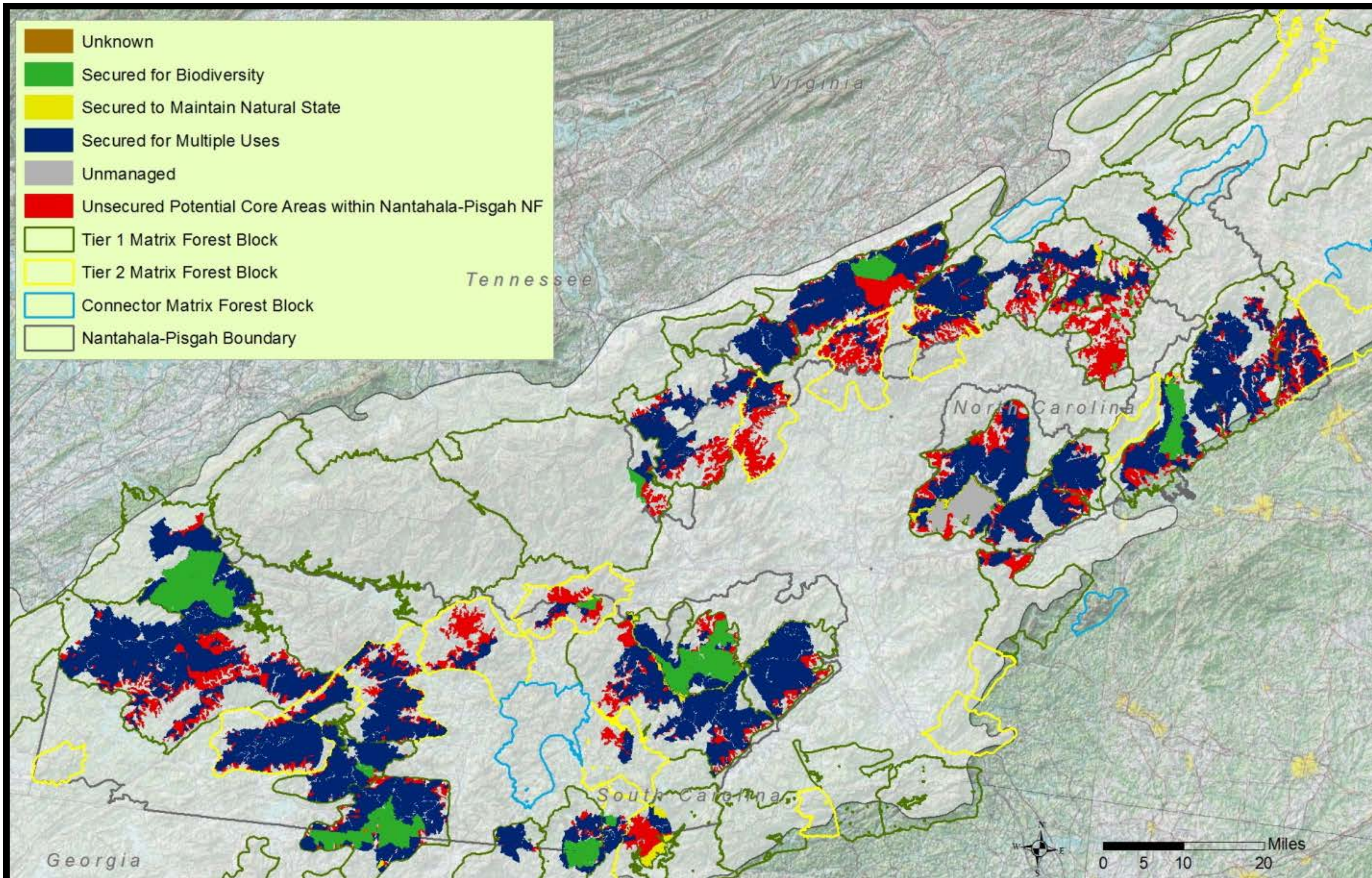


Figure 15. GAP Status of Core Forests within Nantahala-Pisgah National Forest

Limitations of Analysis

The core forests delineated within this analysis are intended to be used as an initial discussion point with partnering agencies (i.e. U.S. Forest Service) and are by no means definitive in their extent. The results of these delineations are dependent upon the inputs of statewide and national datasets and are therefore best suited for regional, broad scale planning. Finer, smaller scale planning should incorporate more locally based county and city datasets. As finer scale assessment occurs and results are further ground-truthed it is anticipated that the boundaries of these core forests will be adjusted to reflect the most current field conditions.

Additionally, only Forest Service Road data layers (Cherokee, Sumter, Chattahochee-Oconee, and Nantahala-Pisgah) were obtained to supplement the ESRI Street layer for this analysis. Additional supplemental road information for local, state, and National parks, or state forests were not obtained. Therefore, it is possible that some identified core forests may be further fragmented by Category B fragmenting features.

Lastly, there was no attempt to define core forests by unique landcover types. Therefore, it is possible that core forests could be composed of a mix of forested areas and contain areas traditionally defined as edge. This analysis defined edge as the boundary of the core forest where it transitions to matrix forest More formal definitions of edge habitat define edge as the transition between one landcover type to another (i.e. deciduous forest to scrub forest). It is acknowledged that some of the core forests may contain a mix of forest cover types as well as open mountain balds (i.e. Roan Mountain). A more detailed analysis that differentiates between land cover types may arrive at different results as it relates to perimeter to area metrics.

Future Use of Data

As previously mentioned, the author of this report intends for the outcome(s) of this analysis to be used by The Nature Conservancy and its partners for strategy development and implementation within the Southern Blue Ridge ecoregion, including US Forest Service plan revisions, strategic land acquisition, preserve management, and monitoring, among other things. The resulting shapefiles are intended to be used in conjunction with other conservation data, including secured areas (GAP status information), parcel and landowner information, agency planning prescriptions, as well as with other data that is currently under development like the Southeastern Resiliency Analysis. Again, ***the author re-emphasizes the need to reference the core forest boundaries when guiding conservation actions toward core compatible land uses in order to maintain the current size, current, or improved condition of core forests.***

To further assist in this process two final packages were created in order to share GIS information with TNC staff and partners. One package was created for ArcGIS Explorer users and one package was created for ArcGIS Desktop users.

ArcGIS Explorer is a free GIS viewer made available by Environmental Sciences Research Institute (ESRI) (http://www.esri.com/software/arcgis/explorer) that gives users an easy way to explore, visualize, and share GIS information. With ArcGIS Explorer TNC staff and partners can import and view shapefiles, layers, and feature classes. They can perform spatial queries and view spatial information along with easily accessible ESRI web maps. Spatial results from this analysis along with additional related spatial data (i.e. conservation areas, national forest areas) were packaged into relevant layer files to be easily imported and viewed within ArcGIS Explorer. A layer package (.lpk file) is a single, convenient, ready-to-use file containing an ArcGIS Desktop map layer or group of layers and the data it uses. Additionally it allows the creator to display only relevant attribute information in a clear and concise format as well as symbolize the data, making the information more intuitive upon examination. Once a layer package has been added to ArcGIS Explorer, users can work with its contents like any other layer. For example, you can click layer features to identify them, view a layer package's legend, hide and show its layers, etc. Also included in this package is a copy of the metadata for PCF and PIF areas, this report, *Southern Blue Ridge Ecoregion Core Forest Delineation* and directions on how to download, install, and use ArcGIS Explorer for purposes of viewing these results.

ArcGIS Desktop users have more tools available to examine and explore spatial data. As a result, the spatial results from this analysis along with additional related spatial data (i.e. conservation areas, national forest areas) were grouped as a map package. A map package (.mpk) contains the map file (.mxd) and the data in which the .mxd file references. After opening a map package ArcGIS Desktop users will have access to all feature classes referenced within the map package in a geodatabase as well as be able to view the data and perform spatial analysis. Similar to the layer package, the map package for ArcGIS Desktop users will also contain a copy of this report as well as directions for opening and viewing the map package, and directions on accessing the relevant data within the references geodatabase. Metadata for all of the core and Interior Forests has been updated and is viewable within ArcCatalog.

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Appendix A. GIS Data Collection & Preparation

GIS layers were collected from a variety of sources including The Nature Conservancy, The U.S. Forest Service, and ESRI (Table 1). Original data sources were stored in a folder titled "Original" and organized according to the agency from which the data was obtained. All layers except the National Land Cover Database layer were originally in vector format. The NLCD (2006) was a 30m raster grid. All data layers were then clipped to the Southern Blue Ridge matrix forest block boundaries, and then projected to NAD 1983 UTM Zone 17N. Processed data layers were then transferred into a personal geodatabase called SBRCoreAnalysis. Organization of the geodatabase is outlined in Appendix B.

Environment Settings

Current Workspace: C:\ArcGIS\TNC\SBRCoreAnalysis\SBRCoreAnalysis.gdb
Scratch Workspace: C:\ArcGIS\TNC\SBRCoreAnalysis\Scratch
Extent: Matrix forest blocks
Mask: Matrix forest blocks
Cell Size: 30m
Projection: NAD_1983_UTM_Zone_17N

Layer Name	Description	Source
SBRboundary_UTMn17	Southern Blue Ridge Boundary	TNC
Forest_matrix_boundary	Matrix forest blocks	TNC
CNP_OHVtrails	OHV Trails within the Nantahala/Pisgah and Chattahochee/Oconee NF	Chattahoochee – USFS Website Nantahala/Pisgah – Hugh Irwin
Esristreets_nofr12	ESRI Streets 2007	NCSU Database – also available with ArcMAP package
Etransline_utm	Significant market electric transmission lines	Ventyx (TNC)
Ng_pipe_utm	Natural Gas Pipelines	Ventyx (TNC)
FR_345	Forest Service Roads Maintenance Level 3, 4, & 5 for Sumter, Chattahochee/Oconee, Nantahala/Pisgah, and Cherokee NF	USFS websites
Railways	Railways	TIGER 2010

NLCD_utm	National Land Cover Database 2006	USGS website
Orthoimagery **NC**	2010 Statewide Orthoimagery, true color, leaf-off, 6-inch pixel	NC One Map WMS: http://imagery.nconemap.com/arcgis/services/2010_Orthoimagery/ImageServer/WMSServer?
Orthoimagery **TN, SC, VA, GA**	ESRI Imagery June 2010, 1m resolution, leaf on	ArcGIS online

Appendix B. Data Organization

The purpose of Appendix B is to provide a brief description of all the materials within the SBRCoreAnalysis Folder.

Folder Structure

\Edited Cores – contains edited shapefiles for potential core areas

\Intial_Cores – contains original shapefiles of all potential core areas greater than or equal to 5,000 acres

\Original – contains all the original data before pre-processing

\Scratch – held all the intermediate data while running the model to delineate potential core areas. Most of this intermediate data has been deleted.

\Tables – tables that can be joined to the potential cores shapefile by core_id

\CoreSBRAnalysis.gbd – geodatabase containing all preprocessed feature classes. Also contains a toolbox with all relevant tools and a model used to delineate the initial cores. The structure of the geodatabase is outlined within the next section.

\Packages – contains 2 zipfiles, one for ArcGIS Explorer users and one for ArcGIS Desktop users. Detatils of each zipfile contents are discussed within the Future Data Uses section of this report.

Geodatabase Structure

Name: SBRCoreAnalysis

Location: C:/ArcGIS/TNC/SBRCoreAnalysis/SBRCoreAnalysis

- I. SBRCoreAnalysis.gbd
  - a. CategoryB_Frags
    - i. CNP_OHVtrails
    - ii. Esristreets_nofr12
    - iii. Etansline_utm
    - iv. FR_345
    - v. Ng_pipe_utm
    - vi. railways
  - b. Category C_Frags
    - i. FR_12
    - ii. No_OHV_trails
  - c. Conservation_Areas
    - i. Ch_CONP_Roadless
    - ii. Forest_matrix_blocks
    - iii. Gap_status
    - iv. RoadlessAreas
    - v. SNP_Wilderness
    - vi. WildStdyAreasNP
  - d. Managed_Areas
    - i. MgmtAreasC
    - ii. MgmtAreasNP
  - e. SBR_Core_Areas
    - i. Pcf_sbr
    - ii. Pcf_sbr_unsecured
    - iii. Picf_sbr
    - iv. Picf_sbrgpowner
    - v. Picf_SBRgapstatus
  - f. NP_Core Areas
    - i. Pcf_np
    - ii. Picf_np
  - g. Core_gap_owner (table)
  - h. Core_gapsbr (table)
  - i. Mtn_Treasures
  - j. NLCD_UTM
  - k. NPBoundary
  - l. SBRboundary_UTMn17

Appendix C. Initial Core Forest Delineation Model