

MORE THAN BUCKS AND ACRES: ASSESSING THE VALUE OF CONSERVED LANDS

*by*

Ginevra L. Ryman  
Dr. Jennifer Swenson, advisor  
May 2010

Masters project submitted in partial fulfillment of the  
requirements for the Master of Environmental Management degree in  
the Nicholas School of the Environment of  
Duke University  
2010

## **Abstract**

Many non-profit conservation organizations resort to measuring their success in term of acres protected and dollars raised, also known as ‘bucks and acres’, for lack of better indicators. However, it is unclear how well bucks and acres actually measure progress toward mission driven goals such as the conservation of biodiversity. Many land trusts are now in the process of creating new indicators to better measure their progress. This study assesses the conservation benefits of the Southern Appalachian Highlands Conservancy lands at both a landscape and parcel level. My analysis focused on 1) parcel-specific and cumulative conservation benefits of biodiversity protection, 2) landscape connectivity, and 3) scenic viewsheds. The conservancy has protected high proportions of Significant Natural Heritage Areas when compared to other private lands in the study area. However, private lands tended to have higher modeled species biodiversity than lands protected by the conservancy. Other commonly observed spatial benefits provided by Southern Appalachian Highlands Conservancy projects were contiguity with other protected parcels, buffering of publically protected lands, and protection of scenic viewsheds from the Blue Ridge Parkway and Appalachian Trail. It is important for land trusts to be able to demonstrate that they are meeting their goals to private funders, their members, as well as to the general public. These findings will assist the Southern Appalachian Highlands Conservancy in measuring their conservation success, demonstrating their progress to funding organizations and the public, and to serve as a baseline measure.

## TABLE OF CONTENTS

<b>ABSTRACT</b> .....	<b>i</b>
<b>TABLE OF CONTENTS</b> .....	<b>ii</b>
<b>ABBREVIATIONS</b> .....	<b>iii</b>
<b>INTRODUCTION</b> .....	<b>1-4</b>
<b>METHODS</b>	
<b>STUDY AREA</b> .....	<b>5-6</b>
<b>BIODIVERSITY</b> .....	<b>7-12</b>
<b>CONNECTIVITY</b> .....	<b>12-16</b>
<b>SCENIC VIEWSHED</b> .....	<b>17-19</b>
<b>RESULTS</b>	
<b>BIODIVERSITY</b> .....	<b>20-25</b>
<b>CONNECTIVITY</b> .....	<b>25-36</b>
<b>SCENIC VIEWSHED</b> .....	<b>37-40</b>
<b>DISCUSSION</b> .....	<b>40-46</b>
<b>CONCLUSION</b> .....	<b>47</b>
<b>ACKNOWLEDGEMENTS</b> .....	<b>47</b>
<b>REFERENCES</b> .....	<b>48-53</b>
<b>APPENDIX</b> .....	<b>54-59</b>

## **ABBREVIATIONS**

**DEM – Digital Elevation Model**

**NED- National Elevation Dataset**

**NHEO- Natural Heritage Element Occurrence**

**SAHC- Southern Appalachian Highlands Conservancy**

**SNHA- Significant Natural Heritage Area**

**TCI- Topographic Convergence Index**

## Introduction

Throughout the United States population growth is leading to the development and subdivision of privately owned lands for residential properties (Brown et al. 2005). This residential development threatens to remove valuable agricultural lands from production, harm water quality, eliminate wildlife habitat, spoil scenic views, and fragment wildlife corridors (Hansen et al. 2005, McKinney 2002). The public is progressively more aware of the negative impacts of increasing development and has voted for numerous conservation-related ballot measures in many parts of the country (Kline 2006). The Nature Conservancy has backed 164 successful ballot measures resulting in approximately 46.8 billion dollars in public funding for conservation (The Nature Conservancy, *public comm.*). Although the traditional approach to land conservation has been public acquisition; voluntary, incentive based conservation on private land has become a popular conservation tool (Merenlender et al. 2004). This shift in conservation strategies means that public funding from ballot measures supports private as well as public land conservation efforts.

Private non-profit charitable organizations commonly known as 'land trusts' use a combination of methods to protect land. Land trusts sometimes acquire land through a fee-simple purchase and then own and manage the property themselves. This conservation technique is best suited for land that requires intensive management, is home to sensitive animal or plant populations, or that allows public access. While the land trust benefits from complete control of the property, it often has high costs in terms of initial investment and management (Fairfax et al. 2005). In many cases it is in the best interest of the land owner or land trust to instead protect the land from development through a conservation easement. A conservation easement is a

voluntary, negotiated agreement between a land owner and a land trust or government agency that limits development and possibly other activities that affect conservation values.

Conservation easements can allow land owners to continue living on and using their land, while simultaneously permanently protecting habitat or open space. Public funding is frequently used to support fee-simple acquisition by land trusts as well the purchase of conservation easements.

In addition to public funding from conservation-related ballot measures, a federal income tax credit program was established to help promote voluntary conservation strategies (26 US Code 170(h)). Several states including North Carolina have also established state conservation tax credit programs. Donations of property or easements may also offer substantial estate tax relief when the property is passed on to heirs, because easements lower property value. In order for a donated conservation easement to qualify for federal or state income tax benefits they must meet certain IRS standards, including the demonstration of benefit to the public by meeting specific conservation purposes. Because of the substantial public investment in private conservation it is important to ensure that the acquisitions and conservation easements adequately deliver conservation value. Merenlender et al. (2004) call for increased research efforts to quantify the benefits and costs of private land conservation and to determine the effectiveness of private land conservation to meet conservation goals, such as protecting water quality or biodiversity. Several of the financial incentives for conservation, however, are currently at risk of being lost including the enhanced conservation easement incentive which expired in 2009. As many states deal with budget crises there have been proposals to alter nonprofit tax exemptions, and proposals to place new levies on nonprofits (Land Trust Alliance 2010). With tax incentives and funding sources at risk it is now more important than ever to completely document the full benefits of private land conservation at multiple scales.

Currently the most common measure of success used by land trusts is ‘bucks and acres’, the amount of money raised per year and the acres of land protected. However, it remains unclear how accurate bucks and acres are in terms of measuring real progress toward a land trust’s mission. Many nonprofits are now working to develop and implement more effective mission impact measures (Sawhill and Williamson 2001). The Nature Conservancy developed a model to measure their success in three broad areas: impact, activity, and capacity (Sawhill and Williamson 2001). Researchers have also recently begun to qualitatively and quantitatively characterize and analyze conservation easements (Kiesecker et al. 2007, Wallace et al. 2008, Yuan-Farrell et al. 2005, Rissman et al. 2007). Wallace et al. (2008) conducted a landscape-level spatial analysis of all privately owned conservation lands in Larimer County, Colorado. The spatial analysis exposed parcel specific benefits not contained in conservation documents or recognized by most landowners. Rissman et al. (2007) investigated the stated conservation goals, types of permitted activities, and amount of development allowed in conservation easements held by The Nature Conservancy. Kiesecker et al. (2007) examined the temporal patterns in the stated goals of conservation easements held by The Nature Conservancy. They found that easements did follow conservation principals and that they were becoming more strategic over time. While studying conservation easement documents is an important initial step, more quantitative research into the on-the-ground benefits such as that conducted by Wallace et al. (2008), is needed to determine whether land trusts are actually meeting conservation goals and providing public benefit.

This project investigates all the land protected by the Southern Appalachian Highlands Conservancy (SAHC) land trust. The Southern Appalachian Highlands Conservancy officially became a non-profit corporation in 1974. The first two purposes of the organization are:

- (1) The location, preservation, and protection of areas of natural beauty in the southern Appalachian states, and the encouragement of preservation of such areas for the use and benefit of the general public.
- (2) The conservation of the natural resources of the Southern Appalachian region, including land, water, open space, and the plant and animal life therein.

The aim of this project is to determine to what extent the Southern Appalachian Highlands Conservancy is meeting their stated conservation goals. The data created through this project will serve as a baseline to measure future progress in achieving their stated goals. To determine the criteria the Southern Appalachian Highlands Conservancy uses to measure conservation success I met with the executive director and the land protection director. In this meeting we decided the four main criteria would be (1) protection of biodiversity (2) protection of water quality (3) ability to increase habitat connectivity at the landscape scale and (4) protection of scenic values. Although the land trust has a farmland protection program it was begun relatively recently and its success is more difficult to define with easily measureable criteria. Due to time constraints the results of the water quality analysis will not be presented in this report, but will be given to the land trust once completed. Each separate criterion will be measured by one or more indicator variables. Select criteria will then be compared among Southern Appalachian Highlands Conservancy lands, publically owned conservation lands, and private lands to determine how well the Southern Appalachian Highlands Conservancy is doing in terms of protecting land with the highest conservation values possible.

## Methods

### *Study Area*

As of 2009, the Southern Appalachian Highlands Conservancy owned 30 properties in fee simple, held 90 conservation easements, and has assisted with the acquisition or transfer of 18 properties. These lands cover 13 counties in Western North Carolina and Eastern Tennessee (Ashe, Avery, Buncombe, Carter, Greene, Haywood, Jackson, Macon, Madison, Mitchell, McDowell, Unicoi, and Yancey) (Figure 1) and cover 1,600 hectares. Their projects are concentrated in five focal areas: the Highlands of Roan, the Great Smoky Mountains and Balsam Mountains, the Newfound and Walnut Mountains, the Black and Craggy Mountains, and the Appalachian Trail and mountains of East Tennessee (Appendix, Figure 1). For the purpose of this study, Ashe County and Macon County and the easements located within them were not included in the analysis because they were isolated from all the other counties. Under recommendation from the Southern Appalachian Highlands Conservancy, Cocke County, Tennessee has also been included in the analysis because it is a region where they will be focusing future conservation efforts and it falls within their Eastern Tennessee and Appalachian Trail priority region. Several properties that the Southern Appalachian Highlands Conservancy owns were not included in the analysis because they had been donated as trade lands that could later be sold to fund conservation efforts or kept as housing for seasonal employees. These properties were very small and not acquired for the benefits of biodiversity support, water quality, connectivity or preserving scenic viewsheds. Because they were acquired for different purposes they were not included with the rest of the properties.

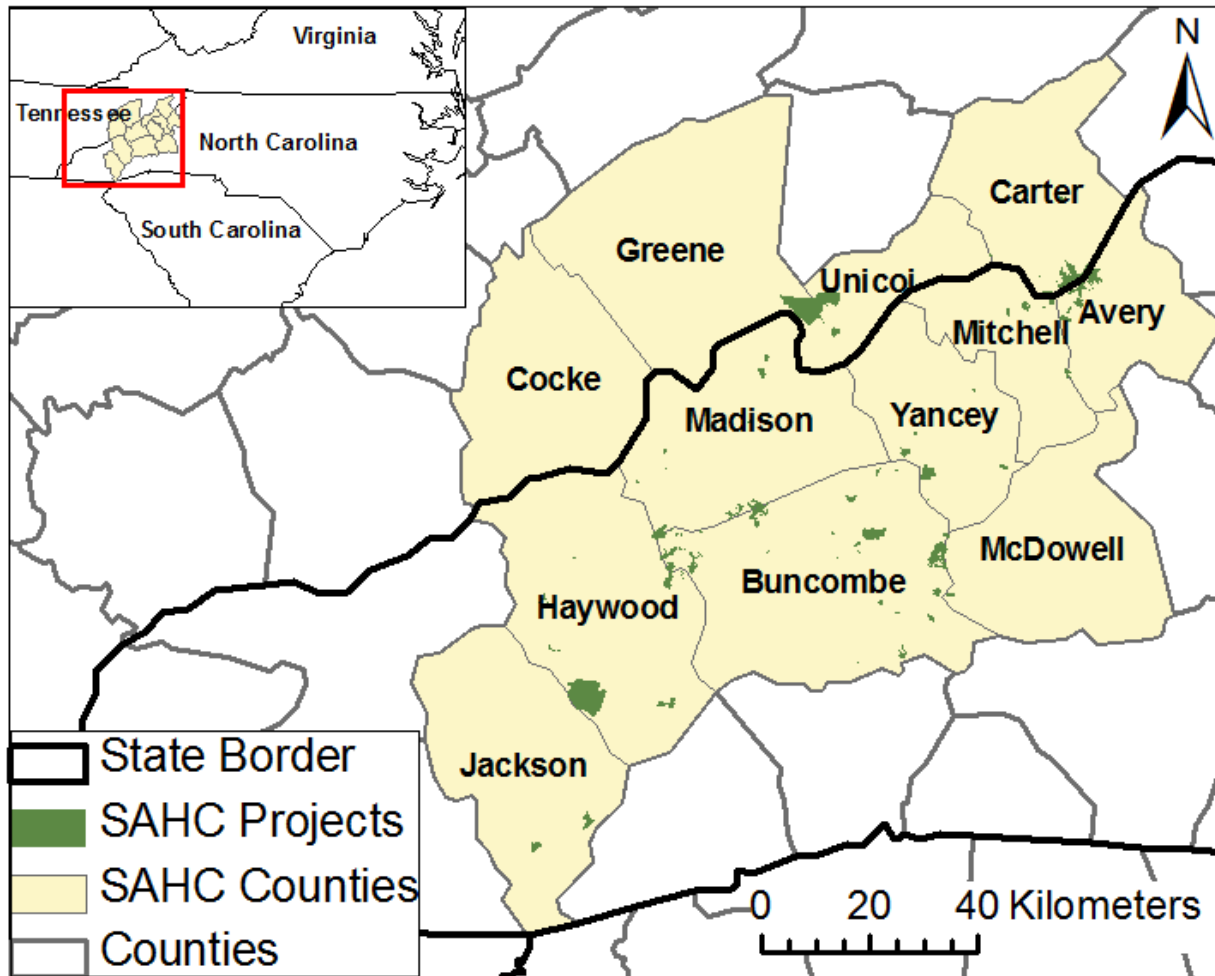


Figure 1. Lands protected by the Southern Appalachian Highlands Conservancy within the 12 county study region.

### *Biodiversity*

Biodiversity preservation benefits humans by providing recreational opportunities to view and hunt wildlife, as well as through the provision of ecosystem services (Costanza et al. 1997). A central element of the Southern Appalachian Highlands Conservancy’s mission is the protection of unique plant and animal habitat. The Southern Appalachian Highlands Conservancy prioritizes acquisitions by determining if a project would: (1) protect a known endangered,

threatened, or rare species; (2) provide critical habitat for native species; (3) protect special or rare plant or animal communities; (4) protect a wildlife corridor; (5) buffer an area of valuable wildlife habitat; or (6) buffer areas adjacent to rare plant or animal communities or populations. Several of these criteria are relatively simple for the planning staff to assess such as whether a project protects a known endangered species or if it buffers already protected habitat. However, the biological diversity of the Southern Appalachian Highlands Conservancy’s holdings is difficult to assess in the absence of complete biological surveys. Most land trusts do not have the capacity to intensively survey their properties and must rely on data compiled by the government such as natural heritage element occurrences. Given the challenge of directly measuring biodiversity for conservation planning, researchers have begun advocating for the use of biodiversity surrogates and modeled species richness to inform planning (Ferrier 2002, Peterson et al. 2000). The issue of determining important wildlife corridors will be discussed in the next section. To measure progress towards the goal of protecting biodiversity I used six indicators which are all easily measureable (Table 1).

Table 1. Indicators used in the biodiversity analysis and their sources.

Indicator	Source
Land cover richness	Southeast regional GAP Land Use/ Land Cover product
Land cover evenness	Derived from the Southeast regional GAP Land Use/ Land Cover product
Biophysical unit richness	Derived from National Elevation Dataset
Biophysical unit evenness	Derived from National Elevation Dataset
Area of Significant Natural Heritage Areas (SNHA)	SNHA from NC OneMap (Natural Heritage Program)
Modeled species richness	Southeast regional GAP program

Examples of biodiversity surrogates include classified habitat types and biophysical units rather than estimates of the number of species within a habitat patch. It is assumed that a habitat patch containing several unique habitat types has the potential to support all species associated with each of the habitat types. The biophysical unit approach enhances the information in a

typical vegetation map with topographic information that estimates finer scale habitat characteristics like soil moisture and solar radiation. These biophysical constraints determine plant species and community distributions. The higher the number of unique biophysical units there are within a property, in theory, the more different species or plant communities it can support. This concept is then extended to the distribution of animal species because many animals depend on specific plant community types. Leddick (2008) found that biophysical units and vegetation community types as biodiversity surrogates have the potential to be used for conservation prioritization efforts.

This study uses unique biophysical units and classified habitat types as measures of biodiversity support potential. Leddick (2008) created unique biophysical units (environmental zipcodes) for Western North Carolina using five elevation classes approximately 350 meters in height, three classes for topographic convergence index (soil moisture), and three classes of potential solar radiation giving a total of 45 unique biophysical units. I followed the methods in Leddick (2008) to create unique biophysical units for all regions of the study area including Tennessee. A 30-meter resolution digital elevation model (DEM), available as part of the National Elevation Dataset was downloaded from the US Geological Survey and used to generate physical proxies (including elevation, potential solar radiation load, and topographic convergence) (Gesch 2007). Elevation was broken into five classes at approximately 350 meters intervals. Intervals for topographic convergence index and potential solar radiation were chosen based on natural heritage element occurrences of plant species and communities from North Carolina. To accomplish this tuning I first excluded all natural heritage element occurrences with greater than one kilometer error. This measure of error is provided by the North Carolina Natural Heritage Program database which assigns a radius, or 'precision' value to each element

occurrence. Next, the selected element occurrences were then sampled for topographic convergence index and potential solar radiation. This process appends each occurrence with the value of each environmental variable at the corresponding sample location. I then used a natural Jenk's breaks classification to divide the natural heritage element occurrences into three classes and identify thresholds for topographic convergence index and potential solar radiation (Appendix, Table 1). This produced three biologically relevant classes for each variable and when combined with the five classes of elevation, resulted in a total of 47 unique biophysical units for the study region (Figure 2).

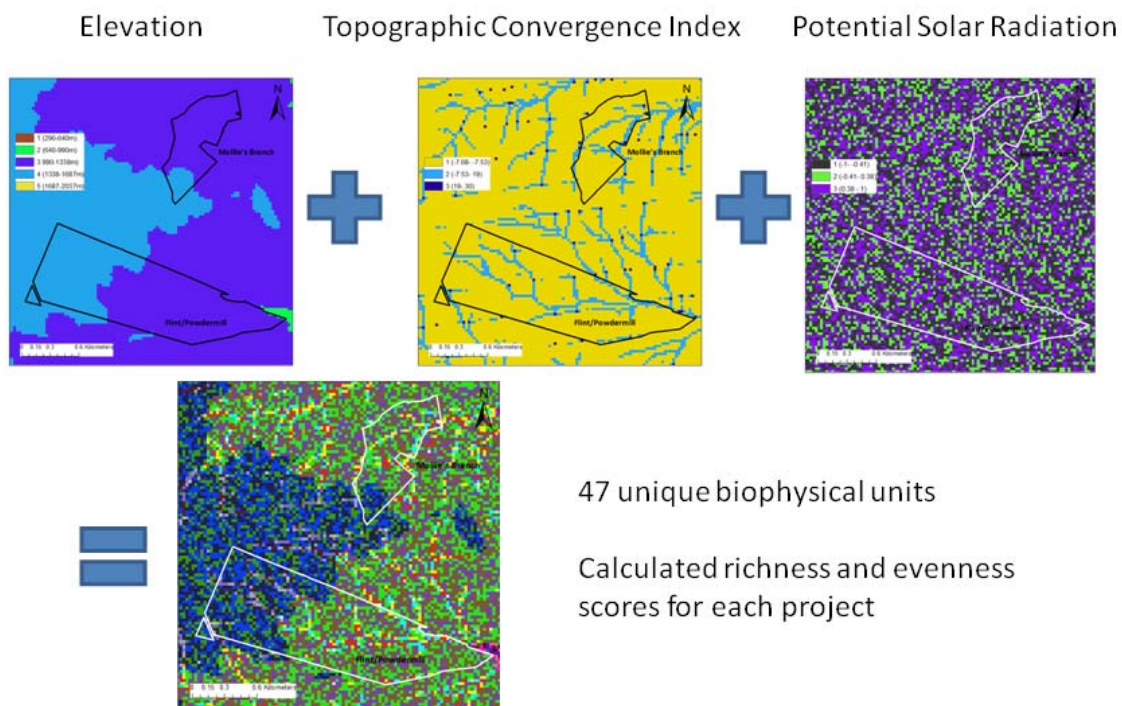


Figure 2. Schematic of the creation of unique biophysical units.

The most straightforward correlate of species diversity is the total number of classified habitat types or unique biophysical units within a property. Properties with high richness scores

have high levels of habitat and environmental diversity, which is assumed to support a greater number of species. I also calculated the Shannon Diversity Index (Brower 1977), to account for the relative area of each land cover class or unique biophysical unit and provide a diversity measure that is sensitive to dominance.  $H' = -\sum p_i * \log p_i$

Here,  $p_i = n_i/N_i$ , where  $n_i$  is the area of the specific biophysical unit or land cover type and  $N_i$  is the total area of the property itself. The dominance of one or more land cover or biophysical units will reduce the Shannon diversity score for that property.

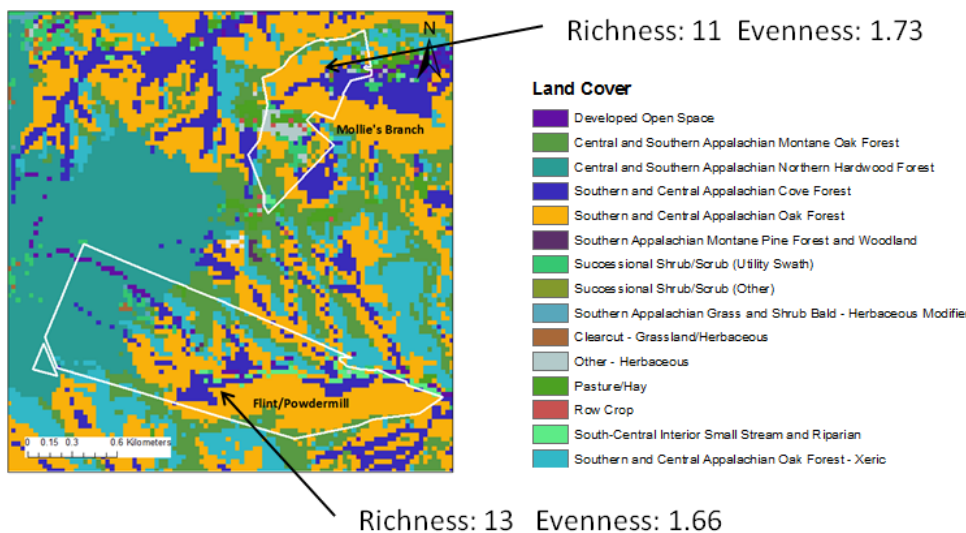


Figure 3. Example land cover richness and evenness scores for properties (Flint/Powdermill and Mollie’s Branch) owned by the Southern Appalachian Highlands Conservancy.

In addition to estimating biodiversity support potential of each project, I also used modeled vertebrate biodiversity. I obtained modeled species richness from the Southeast regional GAP analysis program, which uses known species occurrences and deductive modeling to predict bird, mammal, reptile, and amphibian ranges. The maximum and average modeled GAP

richness was calculated for each project and the results were compared to the biophysical unit and land cover biodiversity metrics.

I also overlaid Significant Natural Heritage Areas with Southern Appalachian Highlands Conservancy lands and calculated the total number and acres protected Significant Natural Heritage Areas. Maps of Significant Natural Heritage Areas were obtained from the NC Natural Heritage Program (Appendix, Figure 2). Since there was no equivalent of Significant Natural Heritage Areas in Tennessee I only analyzed the Southern Appalachian Highlands Conservancy projects that were in North Carolina.

Another important component of this study is a comparison of the conservation values of Southern Appalachian Highlands Conservancy projects and publically owned conservation areas, as well as all other privately owned lands. I set out to test the assumption that Southern Appalachian Highlands Conservancy project lands and publically protected lands have greater conservation value than privately owned lands, not managed for conservation. I created layers of all Southern Appalachian Highlands Conservancy lands, all publically owned conservation lands, and all privately owned lands excluding Southern Appalachian Highlands Conservancy projects and other non-profit conservation groups (Table 2).

Table 2. The three land management types and their data sources.

Land Management Type	Data Source
SAHC project (fee-simple, easement, or other)	SAHC
Publically Conserved (Federal, State, County, Municipal)	NC OneMap layer of lands managed for conservation and open space, TN State Parks, TN Spatial Data server National Parks, and National Forests
Private (not managed by conservation organization)	Entire region not publically conserved or managed for conservation by a private conservation organization

There is some overlap between the layer of Southern Appalachian Highlands Conservancy projects and publically owned conservation areas because the Southern Appalachian Highlands Conservancy has transferred properties to governments, and assisted the government in the acquisition of properties for state publically protected areas. I used stratified random sampling with a minimum distance of 100 meters to sample the Southern Appalachian Highlands Conservancy projects so that there was at least one point within a project and about one per 10 ha within all projects that were greater than 10 ha. This produced a total of 1,986 points. I then randomly selected 1,986 points in both the private lands and public conservation lands. I sampled each point for the average modeled biodiversity score from the Southeast Regional GAP biodiversity layer, and compared the results using a one-way ANOVA. I completed a multiple comparison of means using all possible Tukey contrasts to determine if the groups were statistically significant from one another. Finally, I checked for correlations among the indicators to see if they agreed with one another. I used Pearson's product-moment correlation to test for significance of the correlations. All statistics were performed in Microsoft Excel 2007.

### *Connectivity*

The Southern Appalachian Highlands Conservancy works to achieve their goal of habitat protection on a landscape scale through the protection of wildlife corridors. However, they currently have no way of knowing which lands are the most important to landscape connectivity. Connectivity is a measure of the ability of an organism to move among habitat patches across a landscape. It is dependent on the structure of the landscape patches as well as the ability of the

organism to move between patches (Tischendorf and Fahrig 2000). Structural connectivity describes the spatial arrangement of habitat patches within a non-habitat matrix, and functional connectivity is an organism's behavioral response to the landscape structure. Species vary in their ability to disperse, allowing a landscape to be functionally connected for some but not all species (Bunn et al. 2000).

Landscape scale habitat protection was assessed by several different metrics. First a simple test of adjacency to other protected public and private lands was conducted. Next, I identified functionally connected habitat for multiple species using graph network analysis to identify patches and scales important for connectivity.

In order to create a graph network for analysis, it is necessary to identify a landscape of focal habitat. Because the predominant land cover in this region is forest I investigated forest connectivity by selecting all areas of closed forest as habitat. I used deciduous, evergreen, and mixed forest land cover types as defined by the 2001 National Land Cover Dataset, as the focal habitat type for this analysis (Homer et al. 2004). I identified forest patches using the 2001 National Land Cover Dataset, and then 'burned in' primary and secondary roads and ramps from 2009 TIGER line and National Atlas data (Figure 4). The process of 'burning in' roads sets the land cover of all cells that contain a primary or secondary road to 'not forest'. This is done in case the land cover data set did not properly classify a cell as being developed. The study region is heavily forested (73.3%) and contains several large forest patches that dominate the region. In terms of providing recommendations to the land trust of which areas are most important for connectivity this is not very useful because it is not feasible to protect land on such a large scale. To address this problem I subdivided the habitat patches by catchments, using the National

Hydrography Dataset Plus (U.S. EPA and USGS 2006). This will give the land trust finer scale information on which properties are important to protect and preserve connectivity.

I excluded patches smaller than 100 hectares, and then calculated each catchment's effective habitat area. Catchments that contained forest patches larger than 100 ha formed the basis for the graph network analysis. Contiguous forest patches, without catchment boundaries, were also identified. The GIS model I created to do this can be seen in Figure 3 of the appendix.

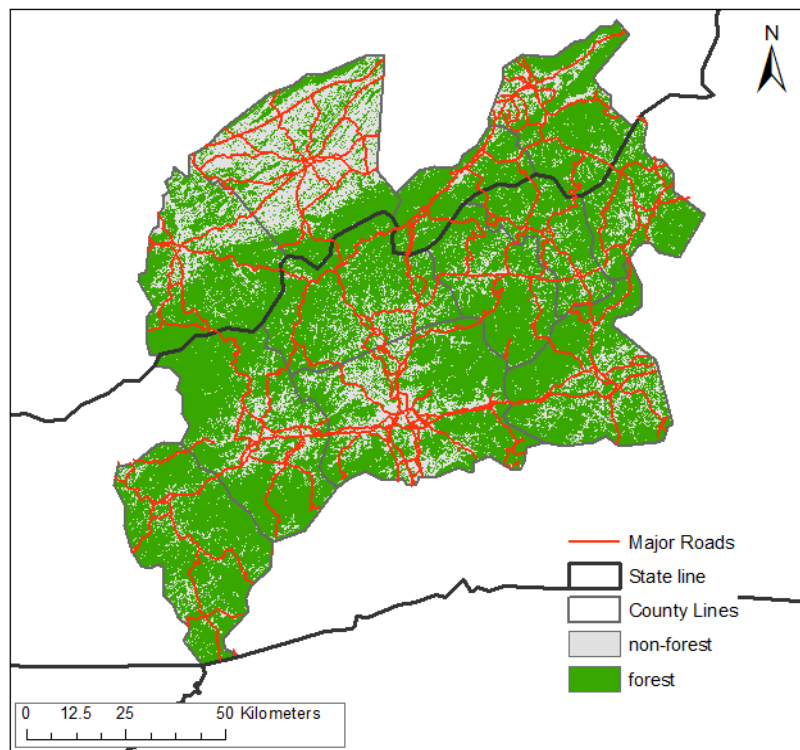


Figure 4. Forested habitat was identified from the National Land Cover Dataset categories, evergreen, deciduous, and mixed forest. Primary and secondary roads from Tiger 2009 census and National Atlas data were overlaid and coded as non-forest habitat.

Before discussing the graph network analysis, it is important to have an understanding of the basic concepts of graph theory and its applications to landscape connectivity. As it relates to connectivity analysis, a graph is a mathematical representation of a landscape (Urban and Keitt

2001; Bunn et al. 2000). *Nodes* represent habitat patches and *edges* represent connections between patches (Urban and Keitt 2001). Edges reflect the ability of an organism to traverse the landscape from one patch to another, and are not necessarily physically connected. A *graph* is a set of nodes and edges, and can be represented by a diagram (Figure 5). A *path* is a route through a sequence of nodes, so that no node is visited more than once. A graph is *connected* if every node is able to be reached through paths by all other nodes. For example, the graph in Figure 5A is connected. However, if the edges *bd* and *bc* are removed the graph is no longer connected and now contains two subgraphs, also known as *components* (Figure 5B).

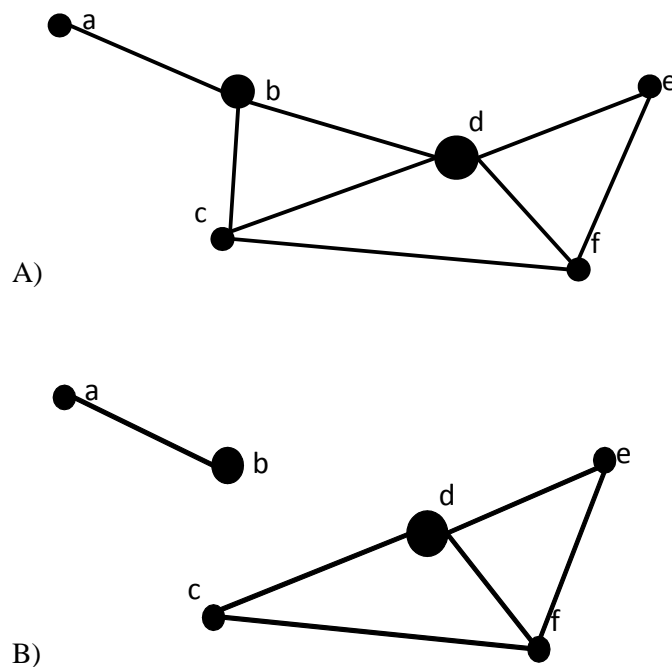


Figure 5. A) An example of a graph defined by the sets of  $p = 6$  nodes  $\{a, b, c, d, e, f\}$  and  $q = 8$  edges  $\{ab, bd, de, ef, df, cf, cd, bc\}$ . Node size corresponds to the betweenness score. B) An example of a disconnected graph containing two components.

The *betweenness* of a node is the number of shortest paths on which that node lies (Bodin and Norberg 2001; Proulx et al. 2005). A node with high betweenness is important to the

maintenance of landscape connectivity because it is involved with many shortest paths between habitat patches. In Figures 5A node  $d$  has the highest betweenness because it has four shortest paths that pass through it.

To simulate a range of species dispersal abilities I used the graph operation edge thresholding. This incrementally decreases the greatest possible length of all edges in a graph. As the allowed distance between nodes gets shorter, the graph begins to lose connectivity and break up into components. This method allows for an investigation into how the landscape appears to organisms with different dispersal capabilities (Urban and Keitt 2001). For example a bear may be able to walk several kilometers between patches, where a snake may only be able to travel several hundred meters between patches.

A graph network of the forested catchments was created using the centroids of the forested catchments as nodes. To add ecological realism I created a cost surface raster by reclassifying the National Land Cover Dataset to reflect the difficulty of crossing the land cover type for a forest dwelling species (Appendix, Table 2). This cost surface was then converted to a triangular irregular network (TIN) with the edges of the tin representing the possible paths. The edge-to-edge distance between nodes takes into consideration the cost of traversing different land covers.

This graph network was created and analyzed using the ConnMod tool, a custom written function in the Python programming language using the NetworkX module (Ben Best, *personal comm.*, Hagberg et al. 2008). The graph was analyzed for connectivity using the graph operations discussed above. As edges were thresholded at intervals of 1% the maximum edge weight, and the number of components was calculated. Betweenness values for each forested catchment were also calculated.

## *Viewshed*

A central element to the Southern Appalachian Highlands Conservancy's mission is the protection of the scenic beauty of the mountains of Western North Carolina and East Tennessee. When a new project is under consideration its scenic attributes are analyzed to determine whether it is significantly visible to the general public from the Highlands of Roan, the Appalachian trail, the Blue Ridge Parkway or another scenic byway, recreational trails, or public streams, rivers, or lakes, or a road of regional or local importance. Scenic preservation from the Appalachian Trail and the Highlands of Roan are especially important to the Southern Appalachian Highlands Conservancy. The Southern Appalachian Highlands Conservancy was formed in 1974 by efforts to permanently protect land in the Highlands of Roan to reroute the Appalachian Trail. The Appalachian Trail and Blue Ridge parkway both bisect the study region (Figure 6) and play important roles in the tourism of the region.

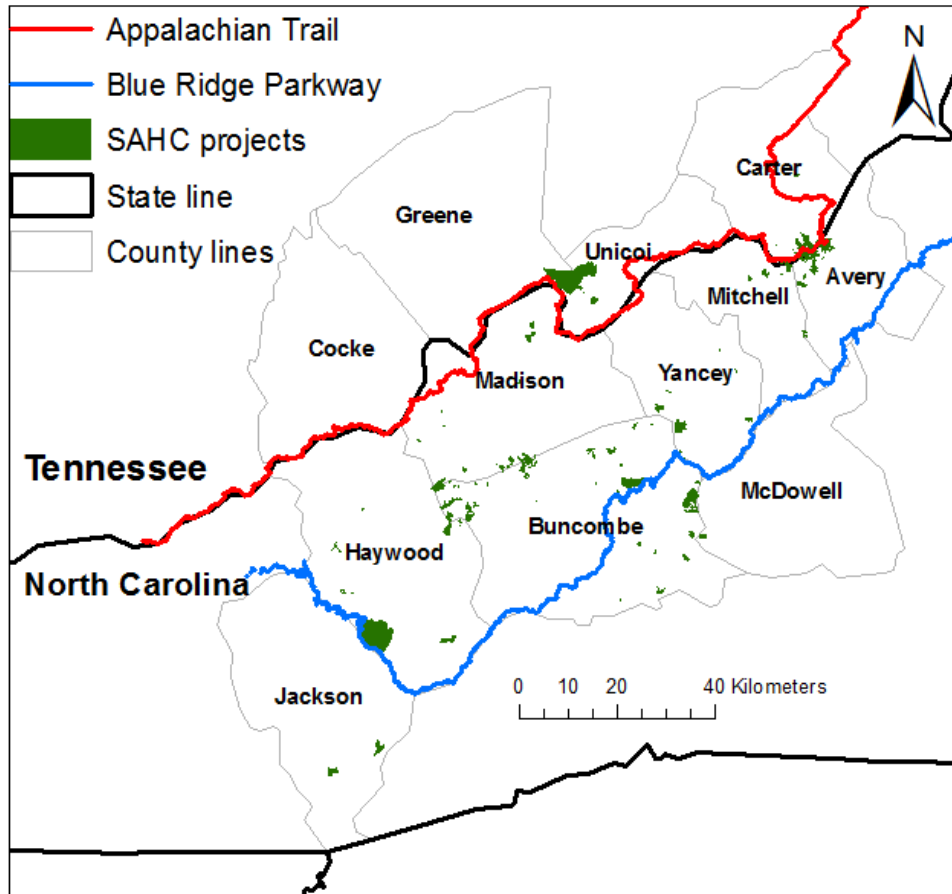


Figure 6. The location of the Appalachian Trail and scenic Blue Ridge Parkway within the 12 county study region.

To create a viewshed for the Blue Ridge Parkway and Appalachian Trail I used the 90 meter National Elevation Dataset that is available from the USGS. There are finer resolution digital elevation models available including 30-meter and 10-meter models for Western North Carolina, however, their finer scale makes running a viewshed analysis too computationally intensive for an area this size. A kml file created by the Blue Ridge Parkway’s landscape architect was downloaded from the Google Earth community forum. The file contains segments of roads as well as all the overlooks and scenic points. I selected all the line segments

representing scenic overlooks for use in the viewshed analysis. Lastly a vector polyline of the Appalachian Trail was acquired from the Appalachian Trail Conference and National Park Service. Sixteen kilometer buffers were created around the Appalachian Trail and Blue Ridge Parkway lines, and the analysis was restricted to within those buffers. The viewshed analysis was completed using the ArcGIS Spatial Analyst extension. The tool was run once for the Blue Ridge Parkway using the layer of overlooks as the input for the observer features, and again for the Appalachian Trail using the trail polyline as the observer features.

The viewshed for the Blue Ridge parkway and the Southern Appalachian Highlands Conservancy properties were converted into KML files and added into a Google Earth document. This Google Earth tool allows users to simply click on any location and see the number of times it is visible from overlooks.

Finally I completed a comparison of the viewshed protection of the Southern Appalachian Highlands Conservancy projects and publically owned conservation areas, as well as all other privately owned lands. I set out to test the assumption that the Southern Appalachian Highlands Conservancy project lands and publically protected lands have greater proportions of their area visible from the Appalachian Trail and Blue Ridge Parkway than privately owned lands, not managed for conservation. I created layers of all the Southern Appalachian Highlands Conservancy lands, all publically owned conservation lands, and all privately owned lands excluding Southern Appalachian Highlands Conservancy projects and other non-profit conservation groups (Table 2). From this I calculated the proportion of each land management type that was visible from the Blue Ridge Parkway and Appalachian Trail.

## Results

### *Biodiversity*

There were 43 GAP land cover types found within the study region and 47 unique biophysical units. Parcel level patterns of richness and evenness of the biodiversity surrogate biophysical units were shifted right and were higher than distributions of richness and evenness of land cover types (Figure 7). The average modeled diversity score was also calculated for each project. Four Southern Appalachian Highlands Conservancy projects (Waynesville Watershed, Rocky Fork, Edwards, and Montreat) are in the top ten for both biophysical unit richness and land cover richness (Appendix, Tables 3-4). However, only one project in the top ten in terms of modeled species biodiversity was in the top ten of land cover richness (Ager/Clark/Hamilton), and none were shared in common with the biophysical unit richness top ten (Appendix, Tables 3-5).

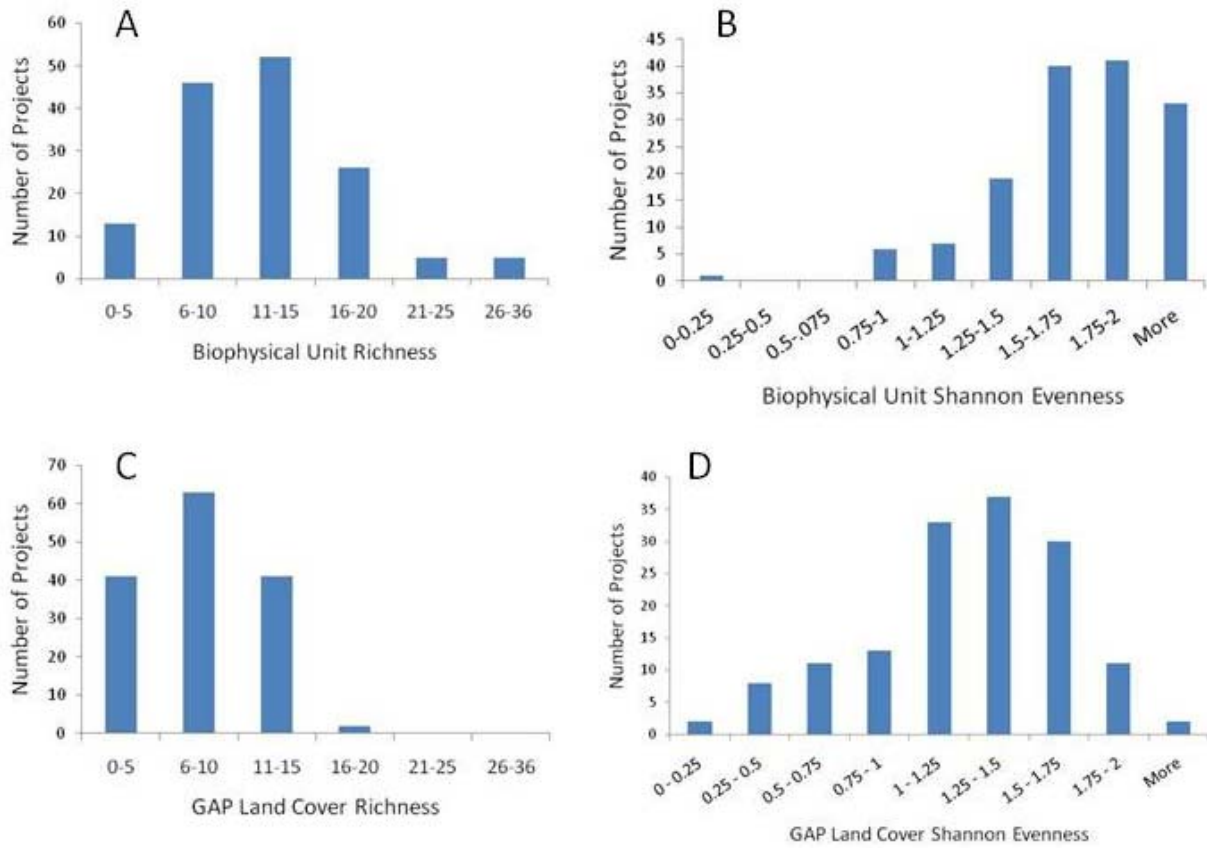


Figure 7. Distributions of the biodiversity surrogate indicators for all of Southern Appalachian Highlands Conservancy projects. a) biophysical unit richness b) biophysical unit evenness c) GAP land cover richness d) GAP land cover evenness.

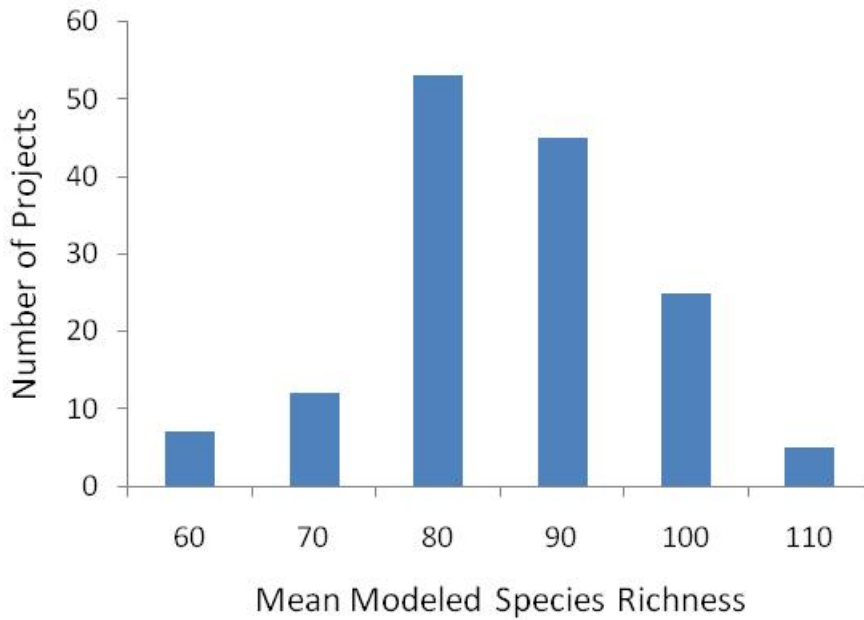


Figure 8. Distribution of mean modeled species richness for all Southern Appalachian Highlands Conservancy projects.

Mean modeled species richness was normally distributed across the Southern Appalachian Highlands Conservancy projects (Figure 8). A comparison among different land management types revealed that modeled biodiversity differed between Southern Appalachian Highlands Conservancy projects, public, and private lands (ANOVA:  $F = 158.59$ ,  $p < 0.0001$ ). A Tukey comparison demonstrated that private lands with a modeled biodiversity of 87 were significantly higher than Southern Appalachian Highlands Conservancy lands and publically conserved lands with average modeled biodiversity scores of 78.3 and 79.4 respectively (Figure 9).

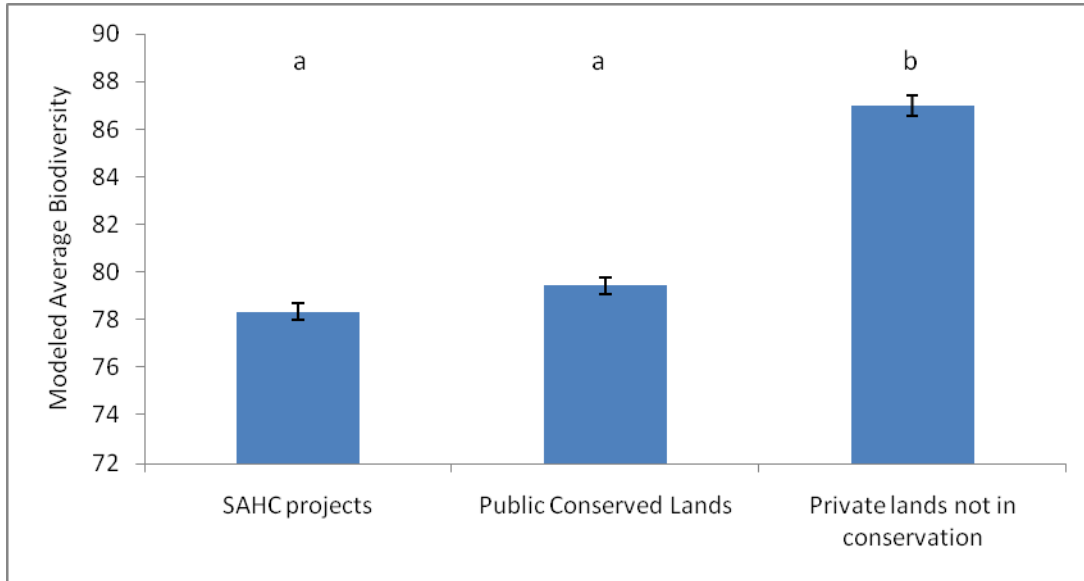


Figure 9. The average mean modeled biodiversity, and +/- standard error for private lands, publically conserved lands, and Southern Appalachian Highlands Conservancy lands. Letters represent significant differences between groups.

A comparison of all the indicators revealed significant correlations among all the pairs of variables except modeled biodiversity and biophysical unit richness, and modeled biodiversity and biophysical unit evenness (Table 3).

Table 3. A correlation matrix among all biodiversity variables. Significance values were calculated by a Pearson-product moment correlation. The two non-significant correlations are highlighted in yellow.

	Land Cover richness	Land Cover evenness	Biophysical unit richness	Biophysical unit evenness	Modeled Biodiversity
Land Cover richness	1	0.647***	0.556***	0.494***	0.284***
Land Cover evenness		1	0.448***	0.493***	0.442***
Biophysical unit richness			1	0.773***	-0.138
Biophysical unit evenness				1	-0.005
Modeled Biodiversity					1
	P<0.05 *	p<0.01**	p<0.001***		

There are 315 Significant Natural Heritage Areas (SNHAs) within the study region totaling 100,066 hectares. Of those, 34 have been protected by Southern Appalachian Highlands Conservancy projects for a total of 5,926 hectares or 5.9% of the total designated Significant Natural Heritage Area area. This number gives the appearance that few Significant Natural Heritage Areas are protected, but in reality 63,669 hectares covering 167 Significant Natural Heritage Areas are managed by government agencies for conservation and open space. A total of 77,743 hectares (179 SNHA) are either publically or privately protected including lands protected by the Southern Appalachian Highlands Conservancy. Significant Natural Heritage Areas still remain completely unprotected, and 24,543 hectares in total remain unprotected on private lands.

The comparison among ownership types found that Southern Appalachian Highlands Conservancy projects have a proportionally higher level of protection of Significant Natural Heritage Areas than publically conserved lands or privately owned lands (Table 4). Since the Southern Appalachian Highlands Conservancy has transferred some properties to governments and assisted the government in the acquisition of properties for state publically protected areas there is some overlap between the layer of Southern Appalachian Highlands Conservancy projects and publically owned conservation areas.

Table 4. Results of the overlay of Significant Natural Heritage Areas with the three land ownership types. Includes proportion of land in each management type that is within a Significant Natural Heritage Area.

<b>Ownership</b>	<b>Total area (ha)</b>	<b># of SNHA</b>	<b>Area within SNHA(ha)</b>	<b>% of land in SNHA</b>
SAHC projects	19806	34	5926	29.92
Publicly Conserved lands	300024	167	63669	21.22
Private (not in conservation)	971460	252	24543	2.53
All Conserved Lands	333223	179	77743	23.33

### *Connectivity*

The analysis revealed that 51 of the Southern Appalachian Highlands Conservancy projects (34% of projects) are completely within or adjacent to publically conserved lands. Sixty projects (40%) are 100 meters or closer to publically conserved lands, and 71(48% percent) are within 0.5 kilometer. The analysis also revealed that 87 Southern Appalachian Highlands Conservancy projects are adjacent to other Southern Appalachian Highlands Conservancy projects.

Forested lands covered 73.3% of the study area, and existed in 10,636 discrete patches (Figure 4). After removing forest patches smaller than 100 ha, 170 discrete patches remained (Figure 10). The presence of several very large patches revealed the need to subset the patches further for the connectivity analysis. Five patches are over 36,000 ha. When these large patches were bounded by catchments, the analysis identified 2,749 forest patches greater than 100 ha in size in 2,662 catchments (Figure 11). This is less than 37% of the 7,307 original catchments in the study area; many catchments were removed because they were smaller than 100 ha. (Of 7,307 total catchments, 63 % were larger than 100 ha; see Appendix, Figure 4). The percent forest cover of these 2,662 catchments was calculated as effective area (Figure 12). Fifty-nine percent of the 2,662 catchments containing forest patches greater than 100 ha contained more than 75% forest cover (Figure 13).

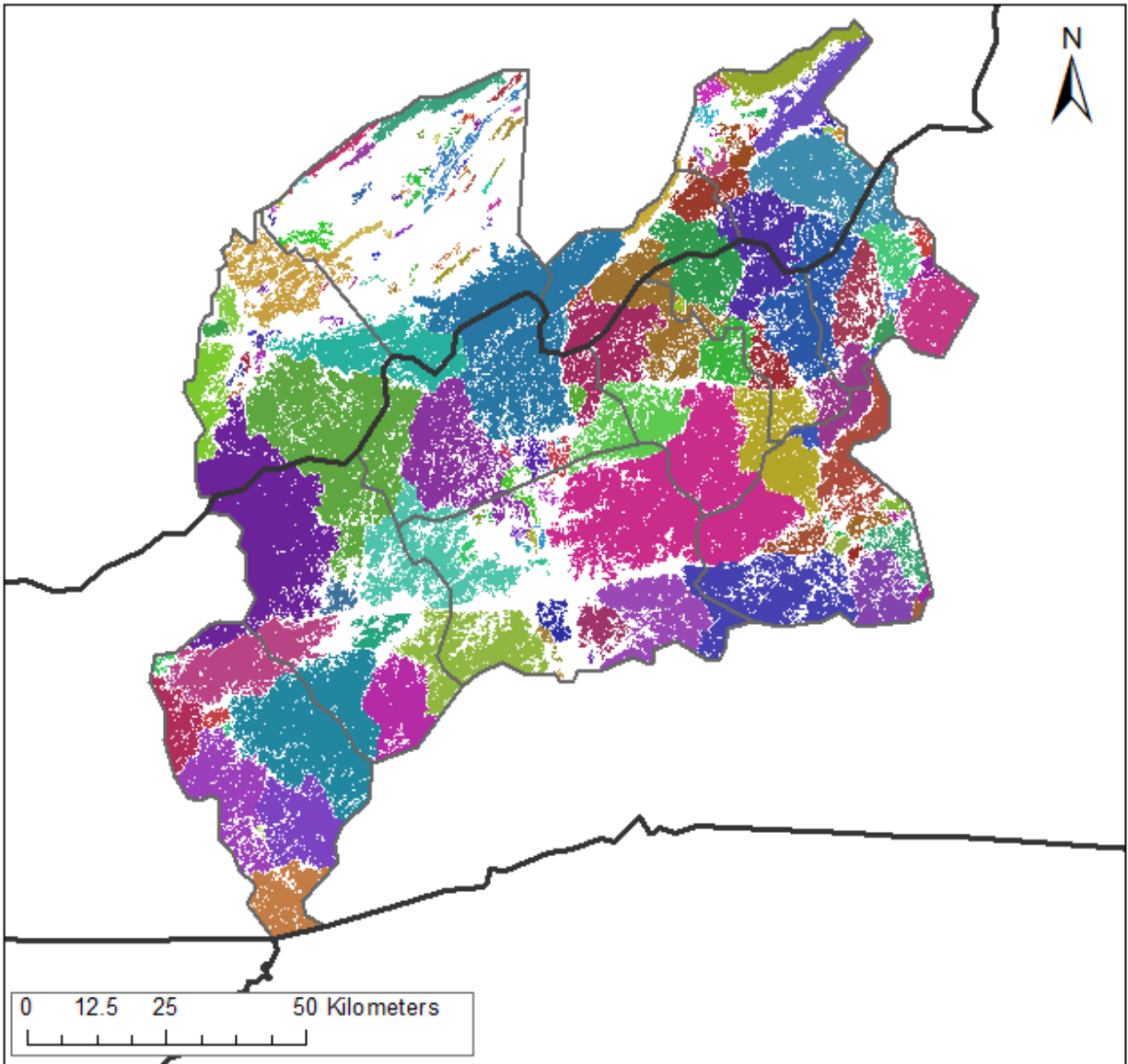


Figure 10. Discrete forest patches greater than 100 ha, not restricted by catchments. Colors are randomly assigned and distinguish individual forest patches. Because the region is so heavily forested, many patches are very large.

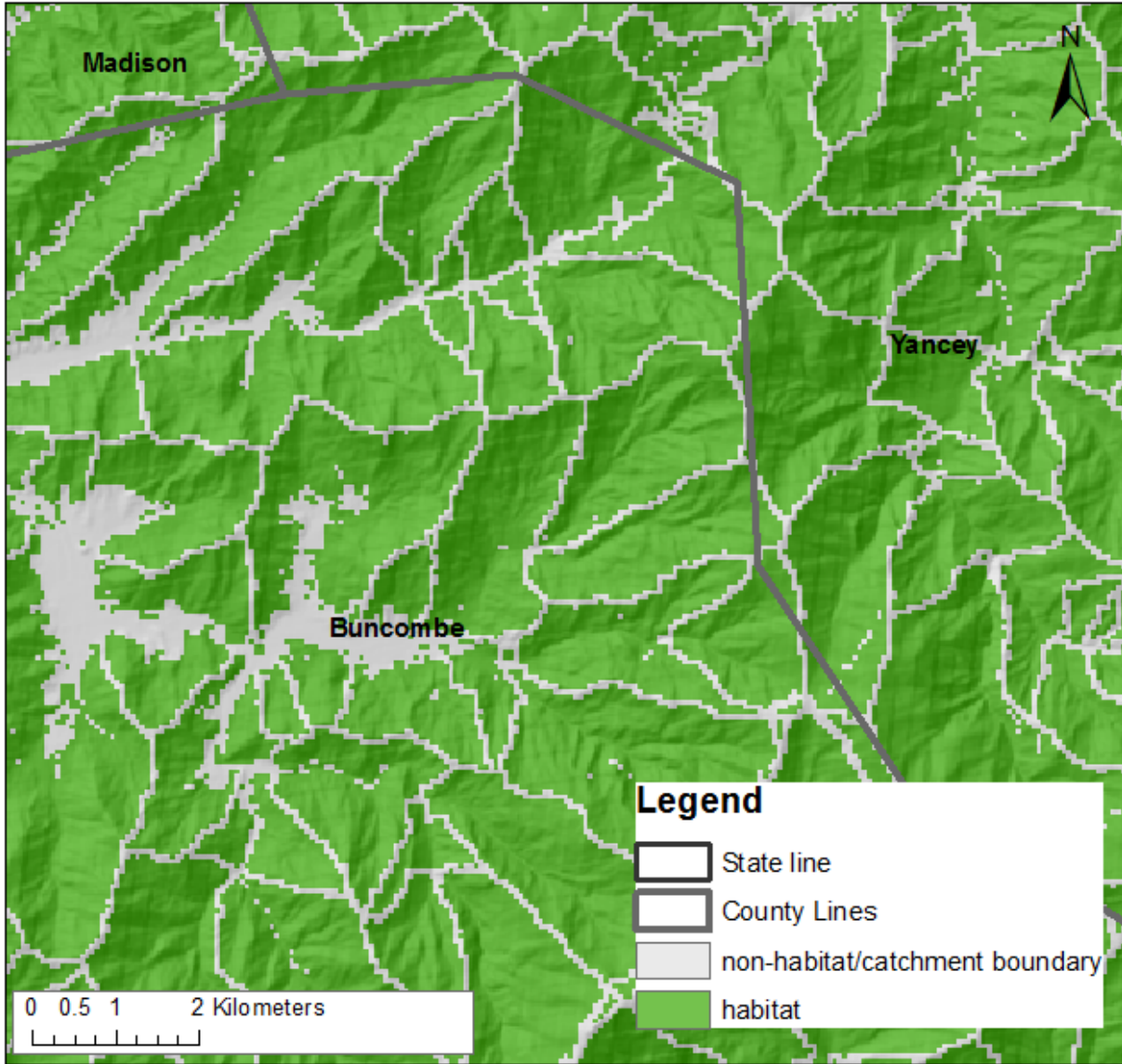


Figure 11. Habitat patches larger than 100 ha within catchment boundaries.

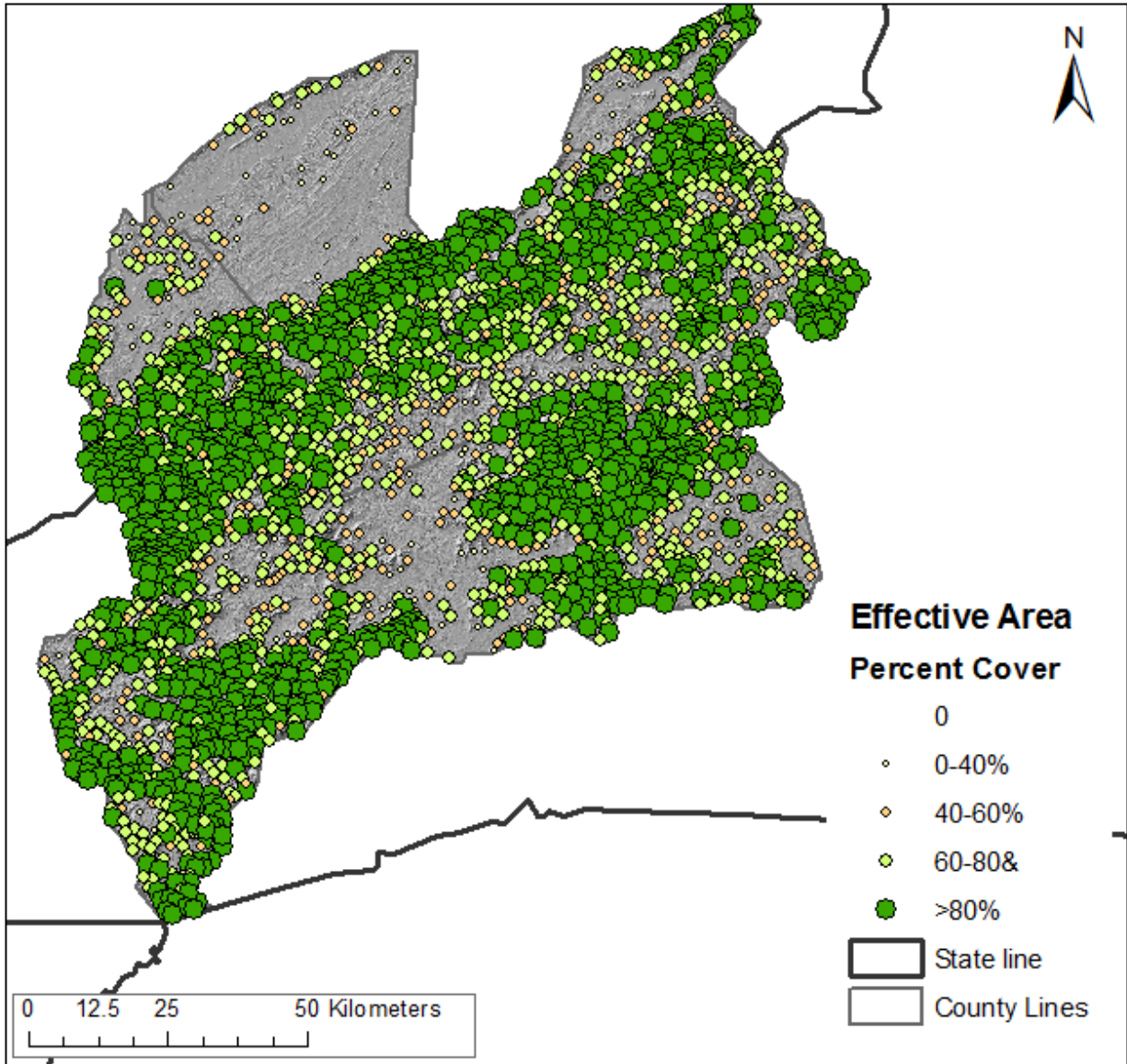


Figure 12. Effective forest area, calculated as percent forest cover. This graph only includes information for catchments that contain over 100 ha of a contiguous forest patch.

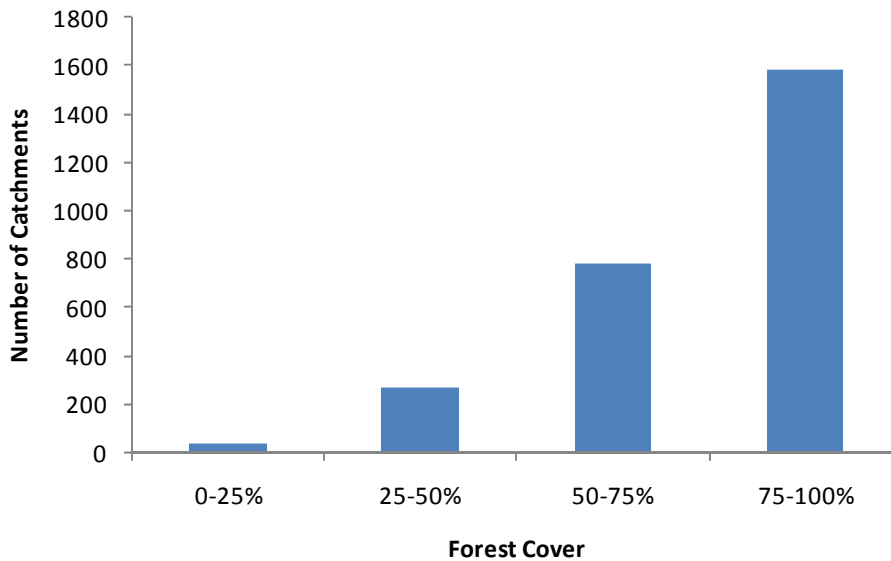


Figure 13. Distribution of the proportion of effective area in catchments containing patches greater than 100ha.

A graph network was created, and edges were thresholded at intervals of 1% of the maximum edge weight. This network can be seen in Figure 14 at maximum edge weights of 20,000, 10,000, and 4,000 cost units. At 20,000 cost units the graph is highly connected. At 10,000 cost units there are fewer edges, and several disconnected patches or subgraphs (Figure 15). In Figure 16, however, at a threshold of 4,000 cost units, many disconnected subgraphs and patches have emerged. These results are reflected in the connectivity metric, number of components. As the threshold distance decreases, the number of graph components increases (Figure 17). At a threshold between 18,000 and 4,000 cost units, the number of components quickly increases as the graph disconnects. Further analysis to refine this cost distance will help indicate what species distinguish this landscape as connected, based on their ability to disperse across these cost distances.

Betweenness is defined as the number of shortest paths between all pairs of nodes that pass through the focal node. (Figure 18). Due to high computational demand required to calculate least cost paths for the entire study region, the analysis was run for a subset of the study region centered on Greene County, Tennessee. This region was selected because of the large gap between forested catchments in the center of the county. High betweenness values indicate the importance of a node to preserving the connectivity of the network. The catchments with the highest betweenness values in the subset of the study region are found as a string of patches along southern Greene County, Tennessee (Figure 18). This is likely because those patches are connecting the backbone of protected land along the Appalachian Trail.

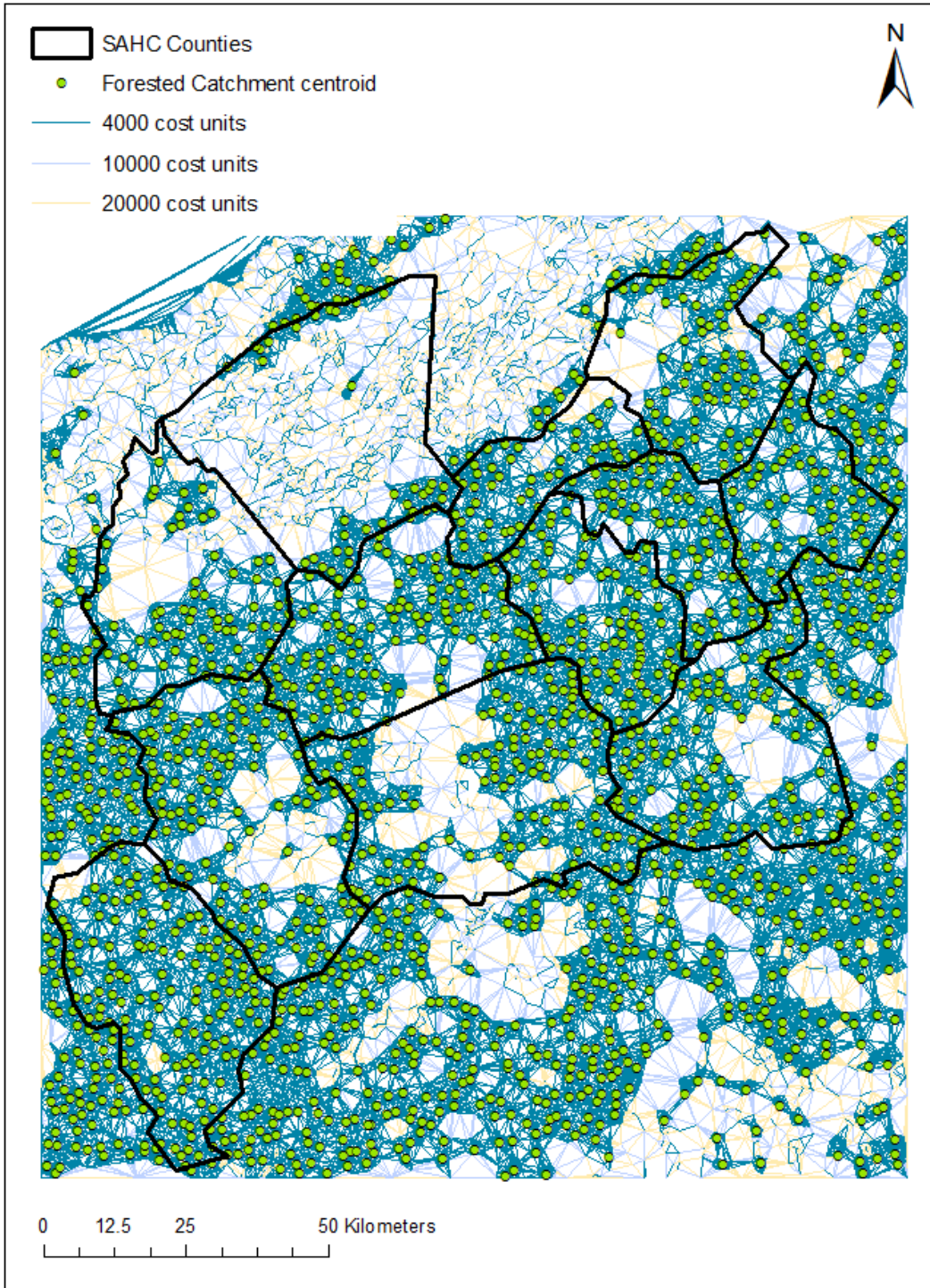


Figure 14. A graph network with edge lengths of 20,000, 10,000, and 4,000 cost units in the 12 county study region.

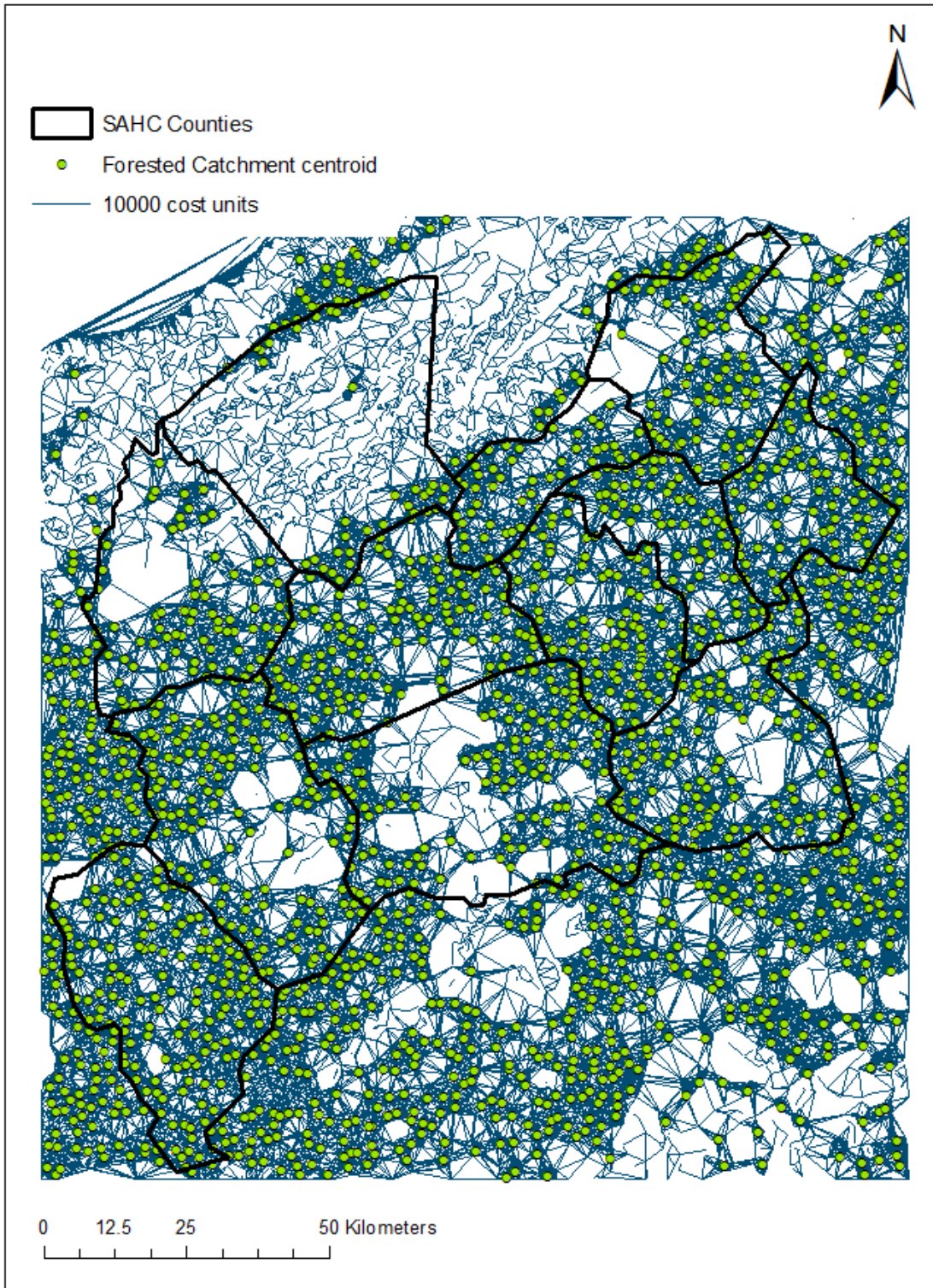


Figure 15. A graph network with edge threshold lengths of 10,000 cost units in the 12 county study region.

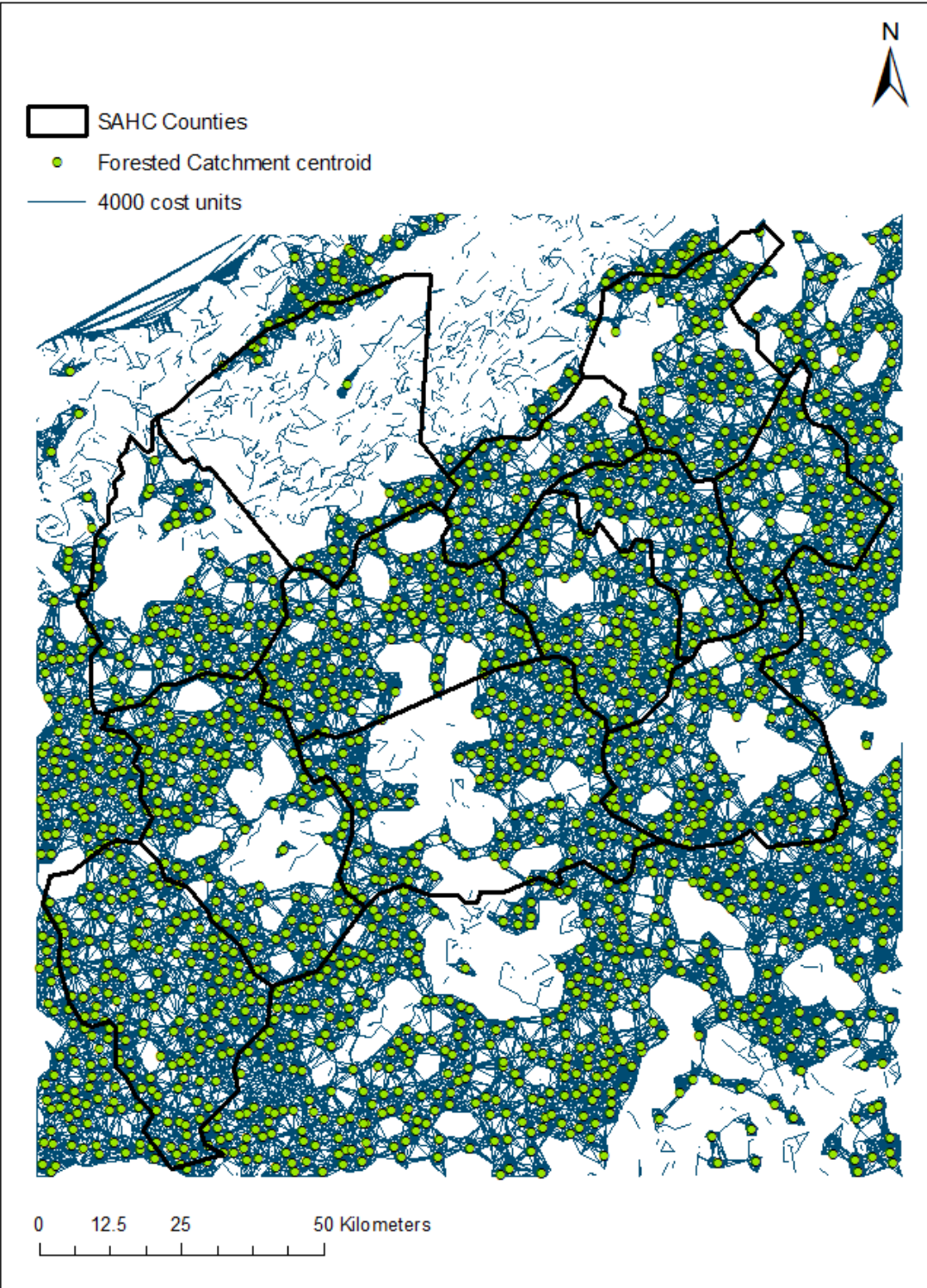


Figure 16. A graph network with edge threshold lengths of 4,000 cost units in the 12 county study region.

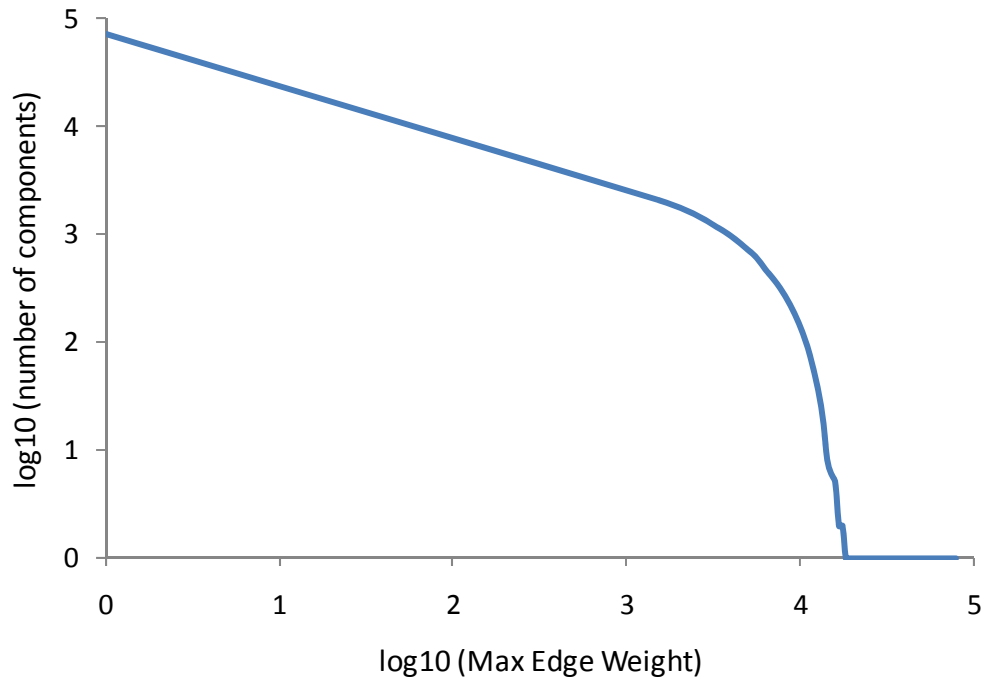


Figure 17. Edge thinning. Trend in number of components as a function of maximum edge weight. The number of components increases as edges are sequentially removed from the landscape graph.

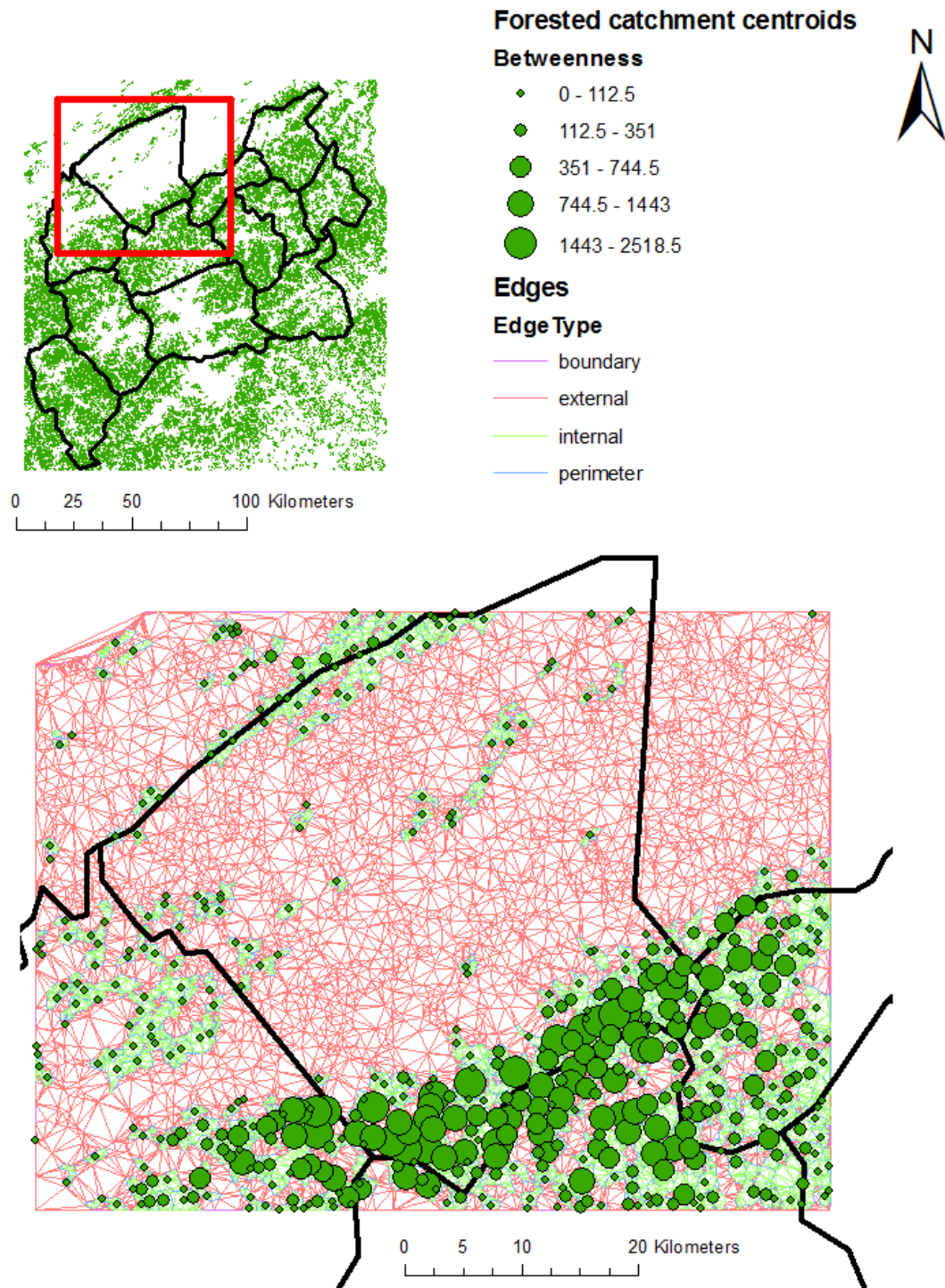


Figure 18. Betweenness values for forested catchments for a subset of the study area.

Betweenness is calculated as the number of shortest paths the focal node lies on.

## *Viewshed*

Of the 67 project areas within the 16 kilometer buffer of the Blue Ridge Parkway, all are at least partially within the viewshed (Figure 15). 29 projects have between 75 and 100 percent visibility from the Blue Ridge Parkway (Figure 16). Of the 64 project areas within the 16 kilometer buffer of the Appalachian Trail, all are at least partially within the viewshed (Figure 17).

Approximately 76% of the total area of Southern Appalachian Highlands Conservancy protected lands within the 16 kilometer buffer of the Appalachian Trail is visible from the trail (Figure 18).

The comparison among ownership types found that Southern Appalachian Highlands Conservancy projects have a proportionally higher level of their projects found in the Blue Ridge Parkway viewshed (40.1%) than privately owned lands (32.3%), but is relatively equal to publically protected lands (40.2%, Table 5). Publically conserved lands have the highest proportion of area visible from the AT, followed by Southern Appalachian Highlands Conservancy projects, and private lands (Table 5).

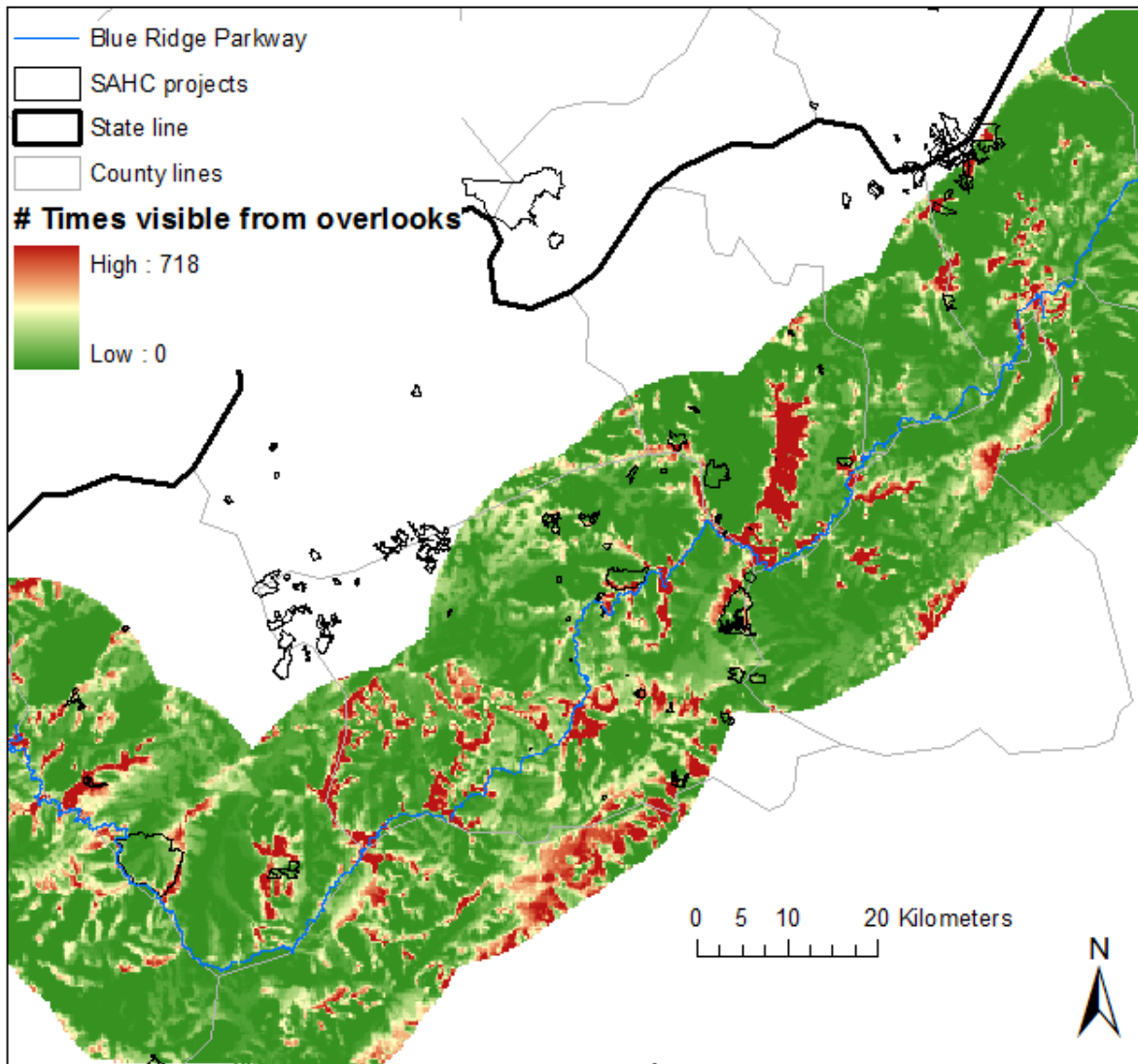


Figure 6. Viewshed within 16km buffer of Blue Ridge Parkway. Southern Appalachian Highlands Conservancy projects are outlined in black.

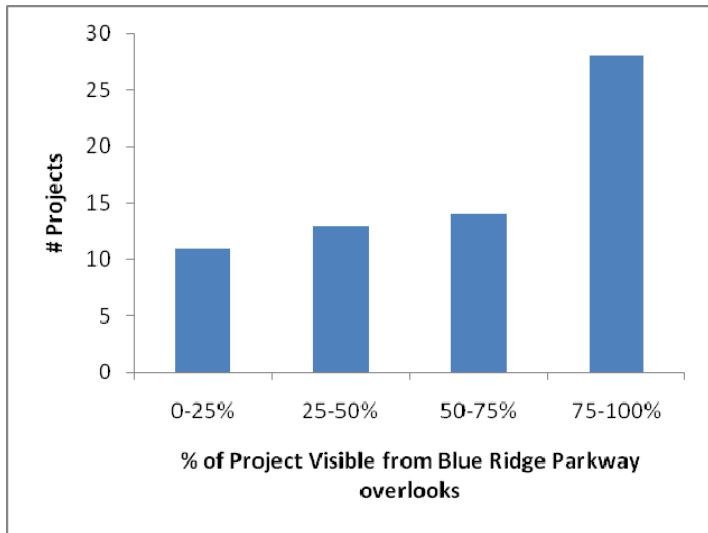


Figure 7. Distribution of project's percent visibility from the Blue Ridge Parkway overlooks.

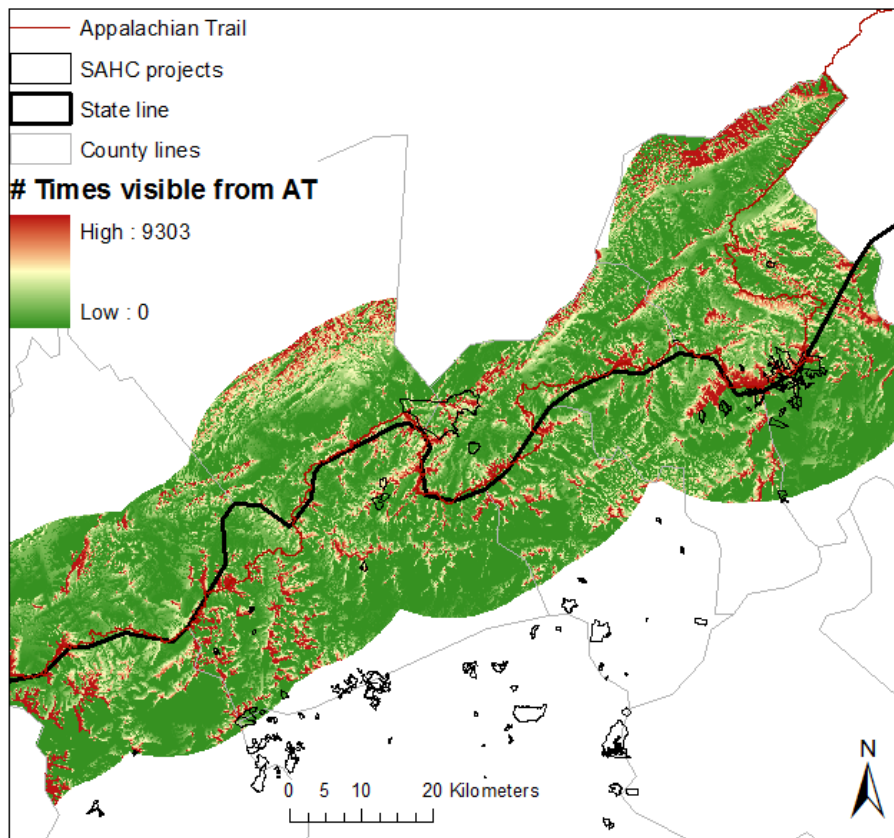


Figure 8. Viewshed within 16km buffer of Appalachian Trail. Southern Appalachian Highlands Conservancy projects are outline in black.

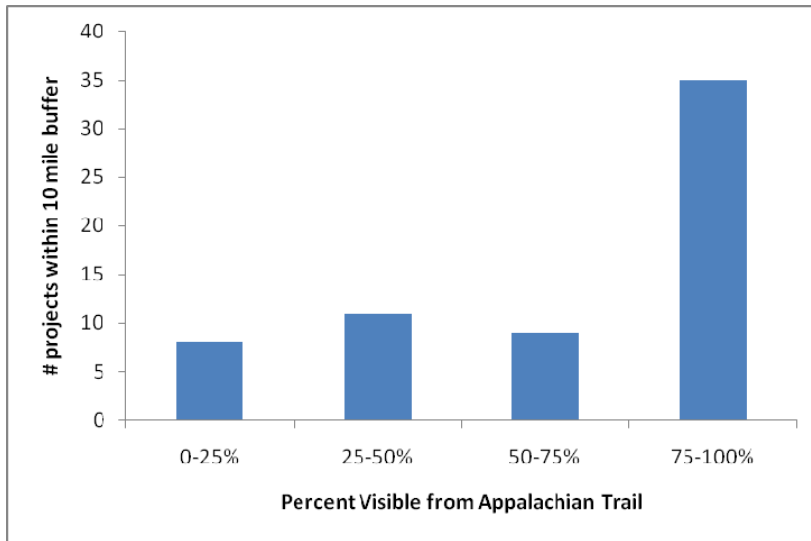


Figure 9. Distribution of project's percent visibility from the Appalachian Trail.

Table 3. Results of the overlay of the Blue Ridge Parkway viewshed and Appalachian Trail viewshed with the three land ownership types. Includes proportion of land in each management type that is visible from each.

Ownership	% visible from BRP	% visible from AT
SAHC projects	40.14	19.63
Publicly Conserved lands	40.17	26.38
Private (not in conservation)	32.28	13.15

## Discussion

With tax incentives and funding sources at risk it is now more important than ever to completely document the full benefits of private land conservation at the parcel, landscape, and program levels. I have taken initial steps to examine the benefits associated with the Southern Appalachian Highlands Conservancy projects. The analysis revealed many spatial benefits

provided by Southern Appalachian Highlands Conservancy projects including contiguity with other SAHC parcels, protection of Significant Natural Heritage Areas, and protection of the Blue Ridge Parkway viewshed. Comparison among land ownership types gave varying results, but Southern Appalachian Highlands Conservancy lands tended to have high values for several conservation measures. The graph analysis identified catchments that are most important to preserving connectivity. Landscape-scale metrics such as connectivity should be combined with estimates of biodiversity support potential to generate a more complete measure of conservation value.

### *Biodiversity*

Biodiversity surrogates will be useful for the land trust to use when making decisions about which new projects to pursue, by allowing for comparisons between projects in areas where biodiversity data is lacking. However, it remains to be seen which biodiversity surrogate; land cover, or biophysical zipcodes comes closer to accurately capturing the complex aspects of biodiversity. The approach of using land cover as a proxy for biodiversity has a rich history in ecology (Bourgeron 1988, Hunter et al. 1988, Noss 1996) and makes a good starting point for analyzing biodiversity when an accurate land cover map is available. It is also important to note that biodiversity indicators give estimates of the biodiversity support potential of an area, not its actual biodiversity.

While modeled species biodiversity was correlated with land cover richness, it was not significantly correlated with biophysical unit richness or evenness measures. Modeled biodiversity was created by the Southeast regional GAP program using deductive modeling which relied heavily on maps of land cover so it is not surprising that it is correlated with the two

land cover measures. There are a number of possible explanations for this result. It could be that either biophysical units do not capture biodiversity well, or that the modeled biodiversity is not very accurate. It could also be that they each contain unique information on different aspects of biodiversity. Biodiversity units are based on environmental variables that are important in determining plant species and community distributions. Perhaps the weak correlation occurred because the modeled biodiversity was only for vertebrates. It is also likely that land cover types vary in the degree to which they support different species and communities. Biodiversity surrogates could be weighted using biological inventories such as Natural Heritage Data. Unweighted surrogates may actually represent the biodiversity support potential, and not the current biodiversity value. Regardless of the cause of their differences, because they are uncorrelated both are worth using to assess biodiversity. Biophysical units may also prove useful in identifying areas of high restoration potential. Even if land is currently degraded its unique biophysical characteristics may make it able to support and maintain biological diversity in the long term.

The comparison of modeled biodiversity among land management types revealed high modeled biodiversity on private lands. This suggests that there are still many lands that are rich in vertebrate biodiversity to conserve. The Southern Appalachian Highlands conservancy should use the layer of modeled biodiversity in tandem with the biodiversity surrogates when assessing potential projects. The conservancy is doing well protecting significant natural heritage areas, although almost 25,000 ha remain unprotected. They should focus their protection efforts on the remaining unprotected Significant Natural Heritage Areas.

## *Connectivity*

Southern Appalachian Highlands Conservancy lands play a vital role in the connectivity of the landscape. Their projects help buffer publically conserved lands (40% of projects are within 100 meters of a publically conserved area) and also aid in the creation of publically protected areas. They also are doing a good job at clustering their projects. The analysis revealed that 87 Southern Appalachian Highlands Conservancy projects (58%) are adjacent to other Southern Appalachian Highlands Conservancy projects.

The landscape of Western North Carolina and East Tennessee is still heavily forested (73% of the study area). This resulted in several very large habitat patches and necessitated splitting up the patches by catchments. For the results to be useful to the Southern Appalachian Highlands Conservancy they must be at the scale that they carry out their conservation work. This study attempts to find a balance between small assessment units and large habitat patches. I originally wanted to investigate connectivity of patches greater than 100ha, but this ran into computational issues. By having the threshold set at 250 ha, many of the catchments were removed from the analysis without considering their effective area. With improvements in computer speeds and memory future study should attempt the connectivity analysis at a finer scale.

## *Viewshed*

If computational power was not an issue, the viewshed analysis should be run with the entire length of the Blue Ridge Parkway like it was with the Appalachian Trail. There are many spectacular views while driving along the Parkway, not just at the scenic overlooks that were

used in this analysis. I also restricted the analysis to within a 16 kilometer buffer from the center line of the Blue Ridge Parkway and Appalachian Trail due to computational restrictions. If possible it would be beneficial to extend the buffer. On clear days it is sometimes possible to see over 60 miles from the Parkway. Also I was forced to resample the viewshed raster to an even coarser resolution, so that it was possible to display in Google Earth for the online tool.

The accuracy of the DEM and the algorithm used to create the viewshed can have major impacts on the precision of this tool. One main assumption of the tool is that the DEM used in the creation of the viewshed is accurate. Viewshed analysis may overestimate the amount of visible area because objects like trees and buildings are not incorporated into most DEMs which represent the elevation of bare ground. This analysis is underestimating the viewshed visible from the entire length of the parkway because I only analyzed areas visible from scenic overlooks. However, neither of the viewsheds take canopy cover into consideration which could lead to overestimation. The choice of the higher resolution DEM and the smaller number of viewpoints was due to the computational constraints.

The Google Earth tool will enable land trusts and other groups concerned with viewshed protection to easily determine if a property is within the viewshed of the Blue Ridge parkway (Figure 19). Many NGOs do not have advanced GIS capabilities or own the necessary spatial analysis extension to conduct viewshed analyses. This tool can be used by anyone with access to the internet and working knowledge of Google Earth. The land protection staff at the Southern Appalachian Highlands Conservancy currently uses the time consuming method of using Google Earth, zooming into a property and trying to determine if the parkway or other scenic highways are visible. This tool can easily be distributed to other decision making parties including board members. Board members spend time visiting properties and investigating real estate listings to

determine if the project has conservation value. This tool will enable land protection staff and board members to determine with the click of a button if a property meets the project selection criteria of being located within an important viewshed. Similar tools can be created for the Appalachian Trail viewshed and other indicators if the Southern Appalachian Highlands Conservancy believes it would be useful.

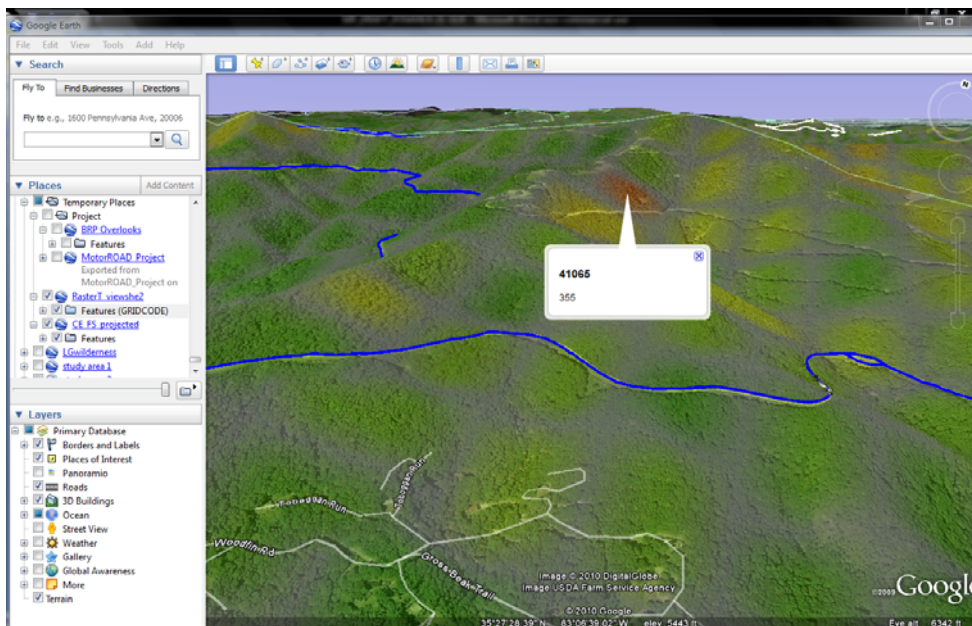


Figure 10. Screen shot from Google Earth Viewshed tool. The Blue Ridge Parkway is the blue line. The lower number represents the number of times this point is visible from overlooks along the Parkway.

## FUTURE DIRECTIONS

A central element to the Southern Appalachian Highlands Conservancy's mission is the protection of clean water. Many land trusts in North Carolina that have water protection as one

of their main goals apply for financial support from North Carolina's Clean Water Management Trust Fund (CWMTF). The Fund has supported the Southern Appalachian Highlands Conservancy through grants to acquire properties and easements as buffers, mini-grants to cover transaction fees for donated properties, and support for planning within sensitive watersheds. The Southern Appalachian Highlands Conservancy prioritizes projects by evaluating whether they would protect a Tennessee Scenic River, a North Carolina Natural and Scenic River or a Federal Wild and Scenic River, or waters with a supplemental water quality classification of one or more of the following: Future Water Supply, High Quality Waters, Outstanding Resource Waters, Trout Waters, or Unique Wetlands. They also investigate whether the project would permanently protect all wetlands, streams, and springs on the property from anthropogenic sedimentation, erosion or siltation or result in protections that would cause or enable significant water quality restoration. Additionally they can consider if the project would protect floodplain that could otherwise be developed. The integration of some of these water quality indicators would be greatly beneficial to the land trust. Hydrological models should be used to identify which lands contribute most to runoff, and which lands are most important to protect as buffers for waterways.

The next step will be working with the land trust to establish easily measurable goals based on some of the indicators presented in this study. Some of examples of indicator based goals are, by 2015, the Southern Appalachian Highlands Conservancy will protect 500 additional hectares of Significant Natural Heritage Areas or, the Southern Appalachian Highlands Conservancy will incorporate modeled biodiversity as well as the use of biodiversity surrogates into the planning process.

## **Conclusion**

GIS maps of the indicator variables will be given to Southern Appalachian Highlands Conservancy to use for future conservation planning. These maps will enable the organization to better describe the conservation benefits of each parcel in the conservation easement documentation. Use of the indicators presented in this report will assist the land trust in measuring their conservation success and help demonstrate their progress to funding organizations and the public.

## **Acknowledgements**

I would like to thank my advisor, Jennifer Swenson for advice and editing. I want to thank Dean Urban for some of the suggestions of indicators and for server space. I would like to thank Ben Best for designing the ConnMod tool, and helping with the connectivity analysis. I would like to thank John Fay for assistance with creation of the Google Earth Tool. I would also like to thank everyone at the Southern Appalachian Highlands Conservancy, especially Michelle Pugliese for her guidance and advice. Finally, I would like to thank Sean Menke for editing and moral support.

## Literary Citations

Aric A. Hagberg, Daniel A. Schult and Pieter J. Swart. 2008. Exploring network structure, dynamics, and function using NetworkX , in Proceedings of the 7th Python in Science Conference (SciPy2008), Gäel Varoquaux, Travis Vaught, and Jarrod Millman (Eds), (Pasadena, CA USA), pp. 11–15.

Beers, T.W., Dress, P.E., and Wensel, L.C. 1966. Aspect transformation in site productivity research. *J. For.* 64: 691–692.

Beven, K.J., and Kirkby, M.J. 1979. A physically based, variable contributing area model of basin hydrology. *Hydrol. Sci. Bull.*24: 43–69.

Bodin, O. and J. Norberg 2007. A network approach for analyzing spatially structured populations in fragmented landscapes." *Landscape Ecology* 22: 31-44.

Bourgeron, P. S. 1988. Advantages and limitations of ecological classification for the protection of ecosystems. *Conservation Biology*. 2:218–220.

Brower J.E. and J.H. Zar. *Field and laboratory methods for general ecology*. Dubuque, Iowa: W.C. Brown Company, 1977.

Brown, D. G., K. M. Johnson, T. R. Loveland, and D. M. Theobald. 2005. Rural land-use trends in the conterminous United States, 1950-2000. Pages 1851-1863. Ecological Society of America.

Bunn, A. G., D. L. Urban, et al. 2000. Landscape connectivity: A conservation application of

graph theory. *Journal of Environmental Management* 59: 265-278.

Costanza, R., R. d'Arge, R. deGroot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R. V. Oneill, J. Paruelo, R. G. Raskin, P. Sutton, and M. vandenBelt. 1997. The value of the world's ecosystem services and natural capital. *Nature* **387**:253-260.

Fairfax, S.K., L. Gwin, M.A. King, L. Raymond, and L. Watt. 2005. *Buying nature: the limits of land acquisition as a conservation strategy, 1780-2004*. The MIT Press, Cambridge, Massachusetts.

Ferrier, S. 2002. Mapping spatial pattern in biodiversity for regional conservation planning: where to from here? *Systematic Biology* 51(2): 331-363.

Gesch, D.B. 2007. The National Elevation Dataset, in Maune, D., ed., *Digital Elevation Model Technologies and Applications: The DEM Users Manual, 2nd Edition*: Bethesda, Maryland, American Society for Photogrammetry and Remote Sensing, p. 99-118.

Hansen, A. J., R. L. Knight, J. M. Marzluff, S. Powell, K. Brown, P. H. Gude, and A. Jones. 2005. Effects of exurban development on biodiversity: Patterns, mechanisms, and research needs. Pages 1893-1905. *Ecological Society of America*.

Homer, C. C. Huang, L. Yang, B. Wylie and M. Coan. 2004. Development of a 2001 National Landcover Database for the United States. *Photogrammetric Engineering and Remote Sensing*, Vol. 70, No. 7, July 2004, pp. 829-840.

Hunter, M. L., G. L. Jacobson, and T. Webb. 1988. Paleoecology and the coarse-filter approach to maintaining biological diversity. *Conserv. Biol.* 2:375–385.

Kiesecker, J. M., T. Comendant, T. Grandmason, E. Gray, C. Hall, R. Hilsenbeck, P. Kareiva, L. Lozier, P. Naehu, A. Rissman, M. R. Shaw, and M. Zankel. 2007. Conservation easements in context: a quantitative analysis of their use by The Nature Conservancy. *Frontiers in Ecology and the Environment* 5:125-130.

Kline, J. 2006. Public demand for preserving local open space. *Society & Natural Resources* 19:645-659.

Land Trust Alliance. 2010 Advocates Alert, Nonprofit Tax Exemptions Under Attack -- Relationships are Key! <http://www.landtrustalliance.org/policy/advocates/adv-030910>

Leddick, Jessie. 2008. Assessing the biodiversity support potential of forest patches for conservation planning. Duke University, Nicholas School of the Environment. Thesis.

Lookingbill, T. & D. Urban. 2005. Gradient analysis, the next generation: Towards more plant-relevant explanatory variables. *Canadian Journal of Forest Research* 35:1744-1753.

McKinney, M. L. 2002. Urbanization, biodiversity, and conservation. *Bioscience* 52:883-890.

Merenlender, A. M., L. Huntsinger, G. Guthey, and S. K. Fairfax. 2004. Land trusts and conservation easements: Who is conserving what for whom? *Conservation Biology* 18:65-75.

Minor, E. S. and D. L. Urban. 2008. A graph-theory framework for evaluating landscape connectivity and conservation planning. *Conservation Biology* 22:297-307.

National atlas: U.S. Geological Survey, 199911, Major Roads of the United States: U.S. Geological Survey, Reston, Virginia.

NC DENR, Div. of Parks and Recreation, Natura, 20100101, Significant Natural Heritage Areas: NC DENR, Div. of Parks and Recreation, Natural Heritage Program, Raleigh, North Carolina.

NC Center for Geographic Information and Analysis, 20020228, onemap\_prod.SDEADMIN.lmcos: NC Center for Geographic Information and Analysis, Raleigh, North Carolina.

Noss, R. F. 1996. Ecosystems as conservation targets. *Trends in Ecology and Evolution*. 11:351

Proulx, S. R., D. E. L. Promislow, et al. 2005. Network thinking in ecology and evolution. *Trends in Ecology and Evolution* 20(6): 345-353.

Rissman, A. R., L. Lozier, T. Comendant, P. Kareiva, J. M. Kiesecker, M. R. Shaw, and A. M. Merenlender. 2007. Conservation easements: Biodiversity protection and private use. *Conservation Biology* 21:709-718.

Southeast GAP Analysis Project. Land Cover Data. Geo-Data Server.

<http://www.basic.ncsu.edu/segap/>

Tennessee State Parks and Natural Areas: <http://www.state.tn.us/environment/parks/gis/data/>

Tennessee Spatial data server layer of national forests, national parks, and TVA reservoirs

[http://www.tngis.org/frequently\\_accessed\\_data.html](http://www.tngis.org/frequently_accessed_data.html).

The Nature Conservancy (<http://www.nature.org/aboutus/howwework/methods/art29415.html>)

Last Accessed April 24, 2010.

Theobald, D. M. 2006. Exploring the functional connectivity of landscapes using landscape networks. *Connectivity Conservation*. K. R. Crooks and M. Sanjayan. Cambridge, Cambridge University Press: 416-443.

Tischendorf, L. 2001. Can landscape indices predict ecological processes consistently? *Landscape Ecology* 16: 235-254.

Tischendorf, L. and L. Fahrig. 2000a. How should we measure landscape connectivity? *Landscape Ecology* 15: 633-641.

Urban, D. L. and T. H. Keitt. 2001. Landscape connectivity: A graph-theoretic perspective. *Ecology* 82(5): 1205-1218.

U.S. Environmental Protection Agency and United States Geological Survey (2006). NHDPlus User Guide. T. Dewald, T. Bondelid, C. Johnston et al: 97.

Wallace, G. N., D. M. Theobald, T. Ernst, and K. King. 2008. Assessing the ecological and social benefits of private land conservation in Colorado. *Conservation Biology* 22:284-296.

Yuan-Farrell, C., M. Marvier, D. Press, and P. Kareiva. 2005. Conservation easements as a conservation strategy: Is there a sense to the spatial distribution of easements? *Natural Areas Journal* 25:282-289.

## Appendix

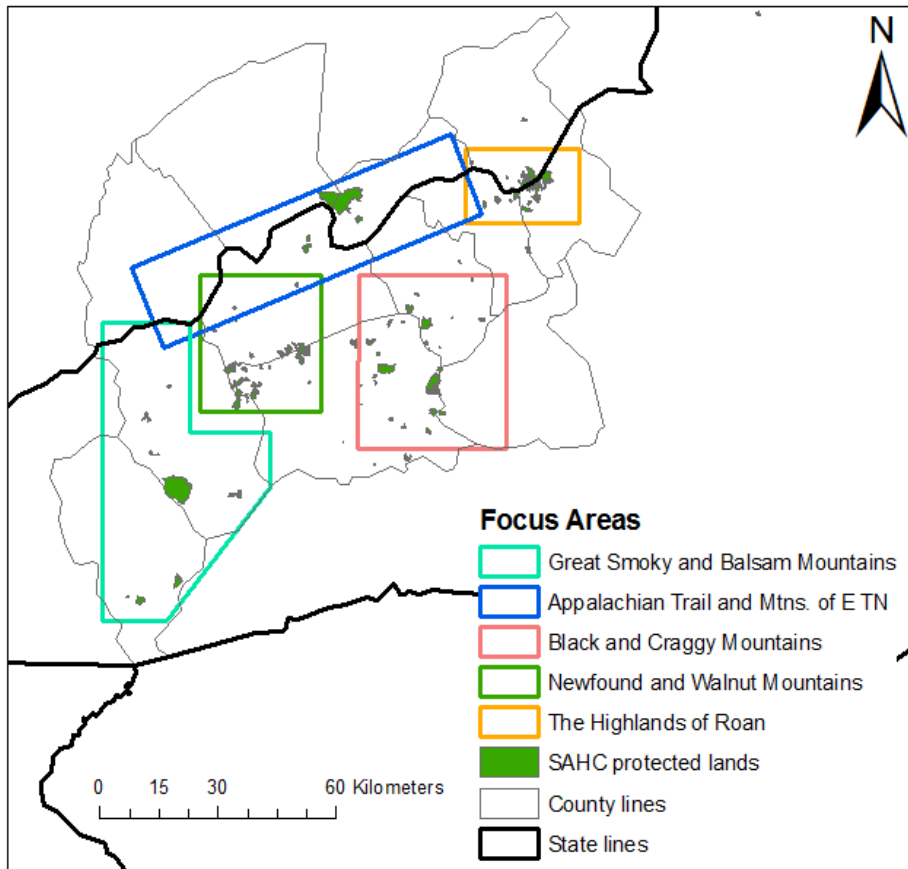


Figure 1. Priority focus regions of the Southern Appalachian Highlands Conservancy.

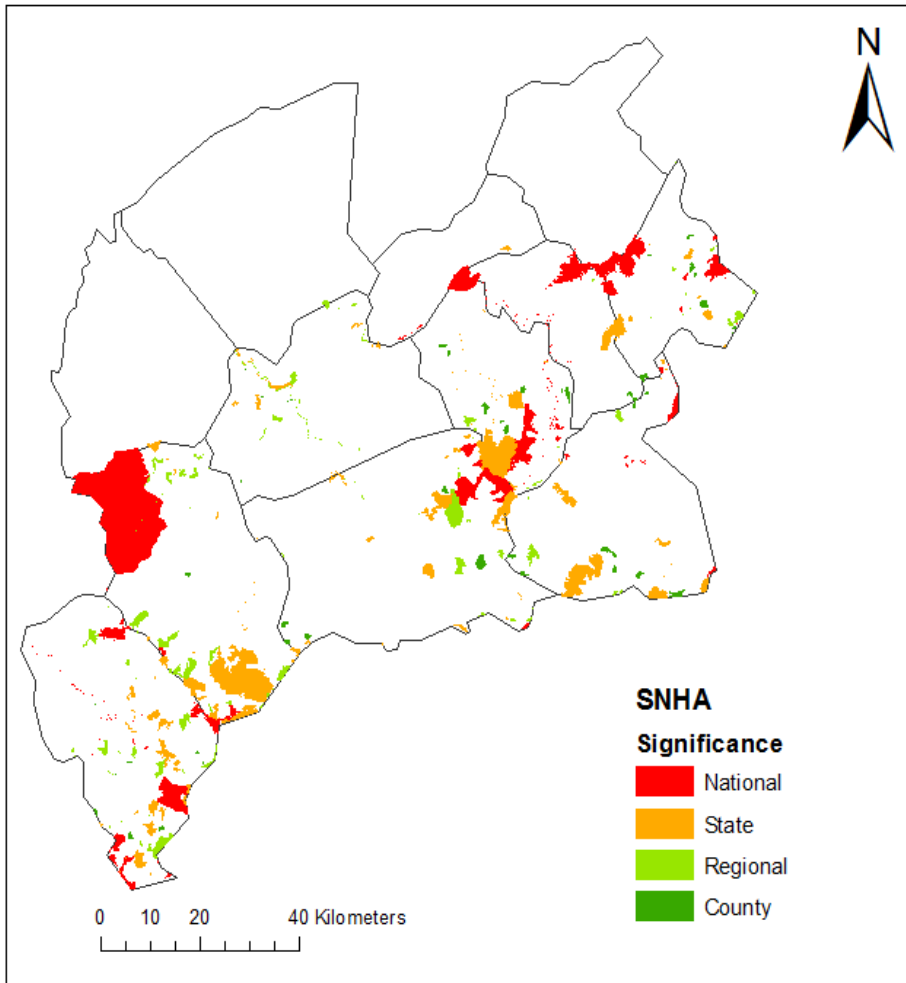


Figure 2. Distribution of Significant Natural Heritage Areas within the study region. Significance is color coded with red= national significance, orange = state significance, light green = regional significance, and dark green = county significance.

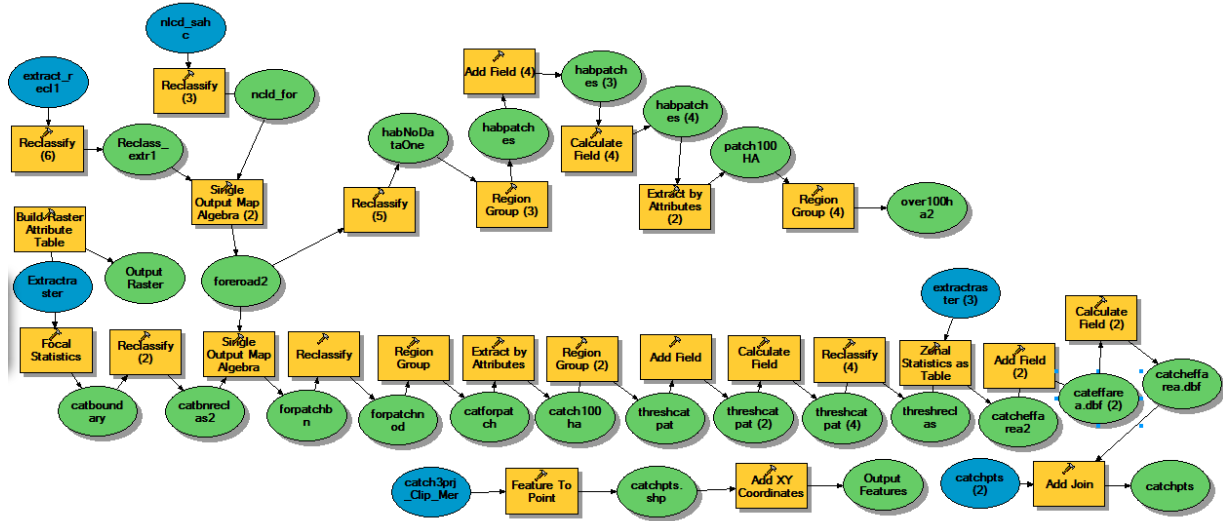


Figure 3. Model used to create forest patches greater than 100 ha, and then bound them by National Hydrography Dataset Catchment boundaries.

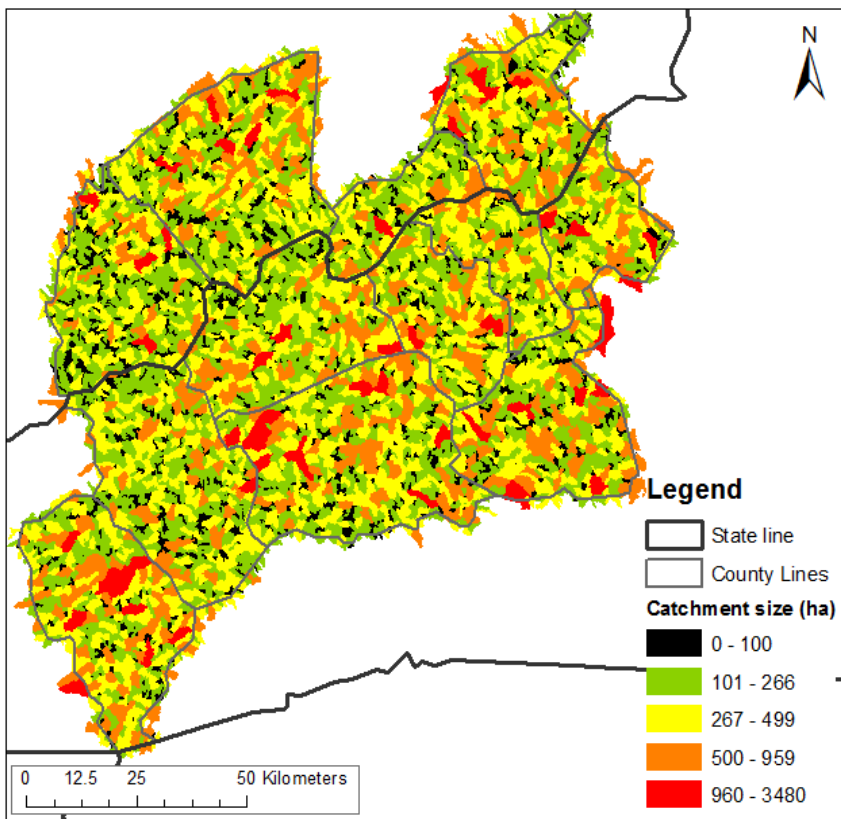


Figure 4. Catchment size. Catchments in black are less than 100 ha in size, and were excluded from the analysis regardless of their forest cover.

Table 1. Breaks used to create the temperature class map, the soil moisture class maps, and the solar exposure class map from the elevation, TCI, and solar exposure datasets, respectively.

	<b>Breaks</b>	<b>New Value</b>
<b>Elevation</b>	290 - 640	1
	640 - 990	2
	990 - 1338	3
	1338 - 1687	4
	1687 - 2037	5
<b>TCI</b>	-7.68 - -7.53	1
	-7.53 - 19	2
	19 - 30	3
<b>Potential Radiation</b>	-1 - -0.41	1
	-0.41 - 0.38	2
	0.38 - 1	3

Table 2. Costs assigned to land covers for the creation of the cost raster, used to create a cost surface for the connectivity analysis.

<b>Land Cover</b>	<b>Cost</b>
Open Water	30
Developed, Open Space	10
Developed, Low Intensity	20
Developed, Medium Intensity	30
Developed, High Intensity	50
Barren Land (Rock/Sand/Clay)	10
Deciduous Forest	1
Evergreen Forest	1
Mixed Forest	1
Shrub/Scrub	5
Grassland/Herbaceous	20
Pasture/Hay	30
Cultivated Crops	30
Woody Wetlands	1
Emergent Herbaceous Wetlands	10

Table 3. Top ten property richness values in terms of unique biophysical units.

Property Name	Zipcode Richness	Type	Area (ha)
Waynesville Watershed	36	Easement	3332
Rocky Fork	30	Other	3579
Edwards	29	Easement	519
Montreat Wilderness	27	Easement	1055
Woodfin Watershed	27	Easement	743
Long Branch Env. Center	25	Easement	240
Jayne	23	Easement	158
Huskins	22	Other	123
Hampton Creek Cove State Natural Area	21	Other	280
Julian	21	Other	651

Table 4. Projects with the top ten patch richness values in terms of GAP land cover classes in descending order of patch richness.

Project Name	Area (ha)	Richness of GAP land cover types	Type of Transaction
Waynesville Watershed	3331	20	Easement
Rocky Fork	3578	18	Other
CP and L	1064	15	Other
Claxton Farm Area B	122	15	Easement
Edwards	519	15	Easement
Ager/Clarke/Hamilton	103	14	Easement
Bee Branch	200	14	Easement
Bowness	424	14	other
Gott Family Farm	91	14	Easement
Montreat Wilderness	1054	14	Easement

Table 5. Projects with the top ten average modeled species richness in descending order of richness.

Project Name	Mean Modeled Species Richness	Area (ha)
Rudisill	106.549	12.96
Biltmore Forest	101.471	1.53
Brown Cabins	101.000	0.09
Gordon	100.742	19.17
Ager/Clarke/Hamilton	100.087	103.41
The Point at Glenville Lake	98.031	2.88
Wishart	97.953	11.52
Myrtle Duckett Farm II	97.842	30.69
Shook	97.775	24.39
Nilsen	96.908	19.62