THE SOUTHERN BLUE RIDGE FIRE LEARNING NETWORK: A COLLABORATIVE PARTNERSHIP TO RESTORE FIRE-ADAPTED ECOSYSTEMS AND BUILD RESILIENT FORESTS AND COMMUNITIES IN THE SOUTHERN BLUE RIDGE

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ABSTRACT—The Southern Blue Ridge Fire Learning Network (SBR FLN) is a cooperative program between the Forest Service, the Department of the Interior agencies, and The Nature Conservancy. Its goal is to restore forests and grasslands and to make (human) communities safer from fire. Since 2007, the SBR FLN has engaged Federal, State, and private partners to integrate science and local knowledge. Eight landscape teams focus on restoring pine and pine oak forests, primarily through prescribed burning. Common vegetation maps/models are used to identify areas most in need of restoration, and to develop a common vision of restoration needs across the region. A burn prioritization tool ("ecomath") has been developed based on these maps in most landscapes. The modeling has enhanced our understanding of why and where fire is needed, focused planning, and begun to broaden support for burning and restoration through a systematic approach that can be explained. A network of monitoring plots tracks the effectiveness of restoration treatments. A partnership with the Consortium for Appalachian Fire Managers and Scientists (CAFMS) has accelerated transfer of knowledge through workshops, field trips, and webinars. The SBR FLN is currently expanding and integrating some of its activities with the Fire Adapted Communities Learning Network.

INTRODUCTION

The Fire Learning Network (FLN) is a national level cooperative program of the Forest Service, U.S. Department of Agriculture; agencies of the Department of the Interior; and The Nature Conservancy. Its goal is to restore forests and grasslands and to make (human) communities safer from fire working through regional networks. It provides a framework for land managers to collaborate with scientists in the planning and implementation of prescribed fire.

The Southern Blue Ridge Fire Learning Network (SBR FLN) was born out of the recognition by land managers, wildlife biologists, and ecologists that forests across the Southern Appalachian Mountains are changing due to a lack of fire. Recent studies of fire history (Delcourt and Delcourt 1997; Fesenmyer and Christensen 2010; Flatley and others 2012; Lafon and Grissino-Mayer 2007, 2011) show that thousands of years of frequent fires shaped pine and oak forest types across the region until the 19th century, when changes first in land use followed by fire policy led to fire suppression and exclusion (Pyne 1982).

Lack of fire is thought to be related to observed changes in forest structure and composition, leading—particularly in the eastern uplands—to "mesophication" (Nowacki and Abrams 2008). It has led to increased fuel loads and made both forests and human communities more vulnerable to catastrophic fire. In both situations, fire exclusion has worked to the detriment of fire-adapted species such as upland oaks and yellow pines. Reintroducing fire in the Southern Appalachians is expected to benefit pine and oak regeneration (Brose and others 2001, 2006; Elliott and others 2004, Kinkead and others 2013), wildlife (both game and nongame), and a number of rare animal and plant species such as golden-winged warbler (*Vermivora chrysoptera*) and mountain golden heather (*Hudsonia montana)*. In some cases, prescribed fire will also reduce community wildfire risk. Hazardous fuels are an increasing concern in many

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places, and some recent wildfires have been challenging and expensive to control (USDA Forest Service, Pisgah National Forest 2009).

The SBR FLN was formed in 2007 at a meeting of major public land managers (Forest Service, National Park Service, and State land management agencies) as well as nongovernmental organizations interested in forest health (such as The Nature Conservancy, Western North Carolina Alliance, and Land Trust for the Little Tennessee). The group collaboratively identified a project area (fig. 1) and five goals:

1. Enhance landscape-level fire planning to help restore and maintain fire-adapted ecosystems;
2. Transfer lessons learned about fire effects among SBR FLN partners;
3. Develop outreach tools to explain the benefits of fire to public and agency staff;
4. Find opportunities to increase and share resources for implementing prescribed fire; and
5. Exchange information about fire ecology and fire management using a variety of outlets.

The SBR FLN partners have since organized into place-based landscape teams formed by local stakeholders, and developed landscape goals appropriate for their areas and organizational missions (fig. 1). These teams selected focal areas to apply prescribed fire, developed annual work plans, and share ideas across the network through regular conference calls and an annual three-day workshop. The annual workshops provide opportunities for land managers and researchers to discuss lessons learned, network, and peer-review their ideas.

This paper uses examples for each of the goals to describe the methods and approaches used by SBR FLN partners to establish a science-informed restoration approach.

GOAL 1. ENHANCE LANDSCAPE-LEVEL FIRE PLANNING TO RESTORE AND MAINTAIN FIRE-ADAPTED ECOSYSTEMS

Ecological Zone Mapping

Based on the scientific literature and partner expertise, partners identified pine, oak pine, and oak-hickory as fire-influenced forest and woodland types. To identify areas that would potentially benefit most from re-introduction of fire, partners were looking for the best available map/model to show current and potential vegetation in the SBR. Partners settled on ecological zone (ecozone) mapping (Simon and others 2005). Ecological zones in the Southern Appalachian Mountains, identified from intensive field data that defined plant communities, were associated with unique environmental variables characterized by digital models. In 2008, FLN and LANDFIRE provided funding to evaluate the usefulness of an updated ecological zone map to predict landscapes that support fire-adapted plant communities in the SBR. This map was completed by incorporating higher resolution digital elevation data and additional plot data from other areas within the Southern Appalachian Mountains and expanded ecological zone mapping to 5.9 million acres in the Southern Appalachians. Maximum entropy (Phillips and others 2006) was used in place of logistic regression as the statistical analysis tool in model creation, additional field data were collected, and more zones were mapped for a 3rd Approximation of Ecological Zones that expanded the model area to 8.2 million acres (Simon 2011).

Ecological zones are units of land that can support a specific plant community or plant community group based upon environmental factors such as temperature, moisture, and fertility that control vegetation distribution. They are equivalent to biophysical settings, which represent the vegetation that may have been dominant on the landscape prior to Euro-American settlement, and are based on both the current biophysical environment and an approximation of the historical disturbance regime (LANDFIRE 2009). Table 1 provides a snapshot of the distribution of ecozones in each landscape that could benefit from restoration. Each local landscape team has this information to inform management planning.

Network partners have found this common map/model very valuable as a consistent baseline and tool to assess fire needs across all lands. The ecozone map/model also served as a springboard for additional tools such as the burn prioritization referred to as “ecomath,” and a forest structure assessment described below.

Ecomath

One of the landscape teams (Central Escarpment) sought a systematic way to identify burn priorities, and developed a computer-based scoring tool referred to as “ecomath” using ArcMap. The process required scoring various conservation assets in the landscape through a system of weighting and scaling. Factors considered included acreage of fire-adapted native vegetation, special biological areas, presence of rare species benefiting from fire, and anthropogenic early-successional habitat in wildlife openings.

In ArcMap, boundaries of potential burn units were intersected with ecozones, rare species occurrences, Significant Natural Heritage Areas (SNHAs) (North Carolina Natural Heritage Program) and wildlife openings. Ecozone modeling (Simon 2011) was used to delineate boundaries of ecosystem-scale forest types. Forest types were weighted by their historical fire return interval, with forest types where fire is not a significant disturbance weighted as zero (see table 2). The simplistic approach of assigning yellow pine-dominated forests a weight of three and oak dominated forests a weight of one was chosen, based on dendrochronology evidence that fire is two to three times more common in yellow pine forests than oak forests (Flatley and others 2012; Lafon and Grissino-Mayer 2007, 2011; McEwan and others 2013). Acreage of forest was scaled by dividing by 100 so as not to overwhelm other conservation targets such as maintaining important natural areas and management of fire-adapted rare species.

Rare species were weighted based on global and State rarity rankings (Gadd and Finnegan 2010). G1-G3 ranked species were given a weight of 10 points, and S1-S3 ranked species were given a weight of five points. Individual taxa were only counted once per unit, regardless of the number of occurrences. Special emphasis was given to mountain golden heather (*Hudsonia montana* Nutt.). *H. montana* is a restricted endemic whose entire range occurs on two ridges, covering less than 7 acres in total occupied habitat, in the study area. Without fire, this diminutive shrub is typically overtopped and displaced by other woody plants and does not regenerate due to absence of mineral soil (Frost 1990). Because of its affinity for fire and the conservation concern surrounding this plant, it was given a weight of 50 points.

High quality fire-adapted vegetation areas were scored using ratings provided by the North Carolina Natural Heritage Program (Gadd and Finnegan 2010). The top three rankings assigned to SNHAs were given a weight of 15, 10, and 5, respectively, if a SNHA with fire-adapted vegetation overlapped a burn unit. Open areas managed for wildlife were scored by assigning one point for every acre of wildlife opening present in a burn unit. Wildlife opening acreage by burn unit ranged from 0 acres to 16.6 acres.

In all, 42 potential prescribed fire areas totaling over 95,000 acres (38 445 ha) were evaluated, ranging in size from 5,163 acres (2089 ha) to 610 acres (247 ha). Scores ranged from a high of 175 to a low of 7, providing consistent separation in scores between units and giving a clear hierarchy of priorities for conservation-based prescribed fire.

Ecomath has helped managers and stakeholders understand and track which burn units will benefit most from fire. In addition, the process of developing the model, which involved experts from a variety of disciplines (e.g., timber management, fire management, wildlife management, conservation) and organizations, improved relationships and fostered the development of a shared vision. Presentations on the development and use of the tool can be found at http://www.conservationgateway.org/Files/Pages/index-fln-webinar-recordi.aspx.

Forest Structure Assessment to Determine Restoration Goals

While recognizing the need for a restoration goal, we found defining reference or desired condition challenging. We know that ecosystems are naturally variable in their structure, and hence set as restoration goals not just the ecosystem type but also its natural range of variability (NRV). We estimate restoration needs by how far an ecozone's current structure and composition is departed from its NRV in the process summarized below. Accurately assessing ecosystem condition is dependent upon the quality of the data available, and we selected the study area based upon this requirement.

We used the ecozone approach described above to identify ecosystems on the landscape. Another national mapping approach called 'LANDFIRE' uses 'Biophysical Settings' to combine scientific research, historical information, and expert opinion to describe the disturbance probabilities of ecosystems. Biophysical Settings have fewer taxa and are mapped at a broader resolution than ecozones. Both approaches use computer models (Vegetation Dynamic Development Tool, or VDDT) to simulate a NRV. Light Detection and Ranging (LiDAR) data are recognized as one of the most comprehensive and accurate types of data for measuring vegetation structure. We used LiDAR to assess current conditions and then compared how current condition departed from NRV to inform restoration needs.

A study area was defined based on available data to include the overlap of the 2005 Phase III North Carolina LiDAR data and the proclamation boundary of Nantahala-Pisgah National Forest. In total, over 700 000 ha (1,760,000 acres) of forest were evaluated using LiDAR-measured height and Forest Service stand records to estimate forest age, and LiDAR measurements of canopy closure and shrub density to measure those physical characteristics.

In general, we found that ecosystems with a more frequent historical fire return interval were more departed from reference conditions than mesic forests. Of 11 forest ecosystems evaluated (see table 1), 5 were found to be highly departed from reference conditions. Both oak and pine ecosystems' canopies were much more closed than the reference models, while the canopies of cove ecosystems were more open than the reference models. For oak, cove, and spruce ecosystems, the NRV included a much higher proportion of old forests than the 2005 conditions, while the converse was true for shortleaf pine and pine-oak/heath ecosystems. Ecosystems with greater timber value (cove and northern hardwood forests) were found to be more disturbed than ecosystems with less economic value. This analysis indicates that increased fire management and the continued restoration of old-growth conditions would be ecologically beneficial. It will be provided to FLN and landscape partners as a tool to inform their restoration goals and plans.

GOAL 2. TRANSFER LESSONS LEARNED ABOUT FIRE EFFECTS AMONG PARTNERS

The ecozone mapping approach has been expanded across landscapes in the SBR FLN including North Carolina, Tennessee, Georgia, and South Carolina, and National Forest lands outside the boundary of the SBR FLN. Additionally, it has been used successfully for planning in our sister network, the Appalachian FLN, including both the George Washington and Jefferson (GWJeff) National Forests, and in the Coastal Plain of South Carolina on the Francis Marion National Forest.

Additionally, the systematic burn unit prioritization through ecomath has been adapted by other SBR FLN landscapes and across the National forests in North Carolina, and across portions of the Appalachian FLN including the GWJeff National Forests and Shenandoah National Park (Mahan and others 2012). All landscapes used ecozones as a base layer but modified criteria and weighting to meet their landscape needs and address the missions and goals of the agency.

The Cherokee National Forest pioneered ignitions along ridge lines allowing fire to back downhill. They also added burn days by adding a fall season. These practices have been shared during SBR FLN field trips and subsequently expanded to other landscapes.

Monitoring Program

In 2006, the SBR FLN began a monitoring program to assess the effects of operational prescribed fires on forest stand structure and fuels. Monitoring occurs in demonstration burn units established on properties owned or managed by SBR FLN partners including the Forest Service, North Carolina Wildlife Resources Commission, North Carolina State Parks, South Carolina Department of Natural Resources, The Nature Conservancy and the Land Trust for the Little Tennessee. Property managers have committed to restoring a historical fire regime on each demonstration unit, and beginning this effort an initial series of prescribed fires at 3- to 5-year intervals.

Fourteen burn units have been established that extend from eastern Tennessee through western North Carolina into north Georgia and the upstate of South Carolina (fig. 1). Seven units are dominated by oak-hickory communities and seven are dominated by yellow pine communities. Twelve units have been burned once, one unit has been burned twice, and two units have not yet been burned. Nine of the completed burns have been spring burns, and the remaining three have been fall burns.

Our goal is to evaluate the overall effects of prescribed fire on forest structure and fuels and, where possible, tease out how these effects might vary with other factors, such as vegetative community, fire behavior, and season of burn. Fire effects are being monitored using a series of permanent, 0.1-acre plots established prior to each burn. Except for our first unit (where we installed more plots), we have installed 20 plots in or around each burn unit. Fifteen plots were established inside each burn unit and five plots were installed outside the burn unit and in areas where future burns are not planned, as control plots. Demonstration burn units vary in size from approximately 75 acres to over 2,000 acres, and plots are located using systematic randomization. Plot locations were predetermined in ArcGIS by randomly choosing intersections of UTM grid lines that fall within target vegetative communities (Simon 2005, 2011) in areas that are accessible.

All sampling is completed during the growing season. Pre-burn sampling is designed to occur during the summer prior to the first prescribed fire; however, in several cases burns have been delayed one or more years due to weather or other logistical constraints. Post-burn sampling is conducted during the second growing season following the prescribed fire. The following data are collected at each plot:

- A photograph taken from a permanent photopoint.
- Forest overstory: species, diameter at breast height (dbh), crown class, and condition (ranging from 1=healthy to 4=dead) for all trees ≥ 2 inches dbh.
- Tree regeneration (data collected in a 0.02-acre subplot): count of stems by species, height class (1 to 3 feet, 3 to 4.5 feet, and > 4.5 feet), and origin (single stem or stump sprout). All stump sprouts from the same origin are considered as a single plant.
- Ground cover and vegetative life forms (data collected in a 0.02-acre subplot): estimates of percent cover to the nearest 5 percent for bare ground, boulders, moss and lichens, grass and grass-like, herbs, vines, deciduous shrubs, coniferous shrubs (including mountain laurel and rhododendron), mountain laurel (separately), and rhododendron (separately). In addition, we estimated the average height of the top of the shrub layer.

- Fuels: litter depth; duff depth; and 1-hour, 10-hour, 100-hour, and 1,000-hour woody fuels were estimated along three, 50-foot transect lines following procedures outlined by Brown (1974).

- In addition, immediate post-burn sampling was completed in five units to assess fire severity in each plot based on bark char height, percent canopy scorch, and the percent of the plot characterized by each of five severity classes (1=unburned to 5=heavily burned).

The data from 10 demonstration units are currently being analyzed to assess the effects of the first prescribed burn. The results will inform managers of the degree to which forest structure and fuel loadings can be altered by a single burn. These results will also provide a tool to evaluate how well the results from research burns conducted under more tightly controlled conditions can be applied to larger, operational burns.

Collaboration with CAFMS

In 2010, the Joint Fire Science Program sought to connect researchers more closely with land managers to improve the transfer of science information into practice and to direct research more toward answering the questions land managers had. The SBR FLN has partnered with the Consortium of Appalachian Fire Managers and Scientists (CAFMS) since its inception. The partnership has brought mutual benefits by better connecting managers to researchers through workshop topics such as smoke management, and fire effects on bats and rattlesnakes. CAFMS also regularly solicits input from managers on needed research topics to be prioritized for funding through the Joint Fire Science Program.

GOAL 3. DEVELOP OUTREACH MATERIALS REGARDING THE BENEFITS OF FIRE FOR PUBLIC AND AGENCY STAFF

We recognized that we needed to explain to the public and a wider audience why the re-introduction of fire to the mountains was a beneficial change over fire suppression and exclusion practices in the past century. A brochure, *Bringing Fire Back to the Mountains*, was developed and distributed, and more informative press releases for controlled burns as well as wildfires have been shared among partners and with the North Carolina Prescribed Fire Council and distributed to a wider audience than in the past. We have conducted field trips inviting concerned neighbors, reached out to groups that might potentially oppose controlled burns, and shared reviews of lessons learned if burns did not go entirely as expected. It appears that improved outreach efforts are slowly building more public support based on responses and comments our partners receive.

GOAL 4. EXPLORE OPPORTUNITIES TO INCREASE AND SHARE RESOURCES FOR IMPLEMENTATION

The relationship-building that has occurred over the years through regular network activities (FLN meetings, conference calls, project meetings) has proven to be invaluable. Strengthened interpersonal and agency relations are facilitating cross-boundary prescribed burning across the region, allowing landscape teams to garner more resources, improving wildfire outcomes,[2] and creating better public relations outcomes.

The collaboration of a broad partnership in the development of the ecomath tool built trust and capacity that allowed the Central Escarpment landscape team to expand and successfully submit a grant proposal under the Collaborative Forest Landscape Restoration Act. This program has allowed the Forest Service to triple its acres treated through controlled burning in 2013 in this landscape (Kelly 2012).

Partners in North Carolina and Georgia have developed Memoranda of Understanding (with statewide or at least regional scope) that allow sharing of resources for all partners on cross-boundary burns. This allows for larger burns with safer fire lines and less impact, and it provides training opportunities. Multi-jurisdictional burning demonstrates consistency and unity among partnering agencies. Given these partnerships, the Southern Blue Ridge Escarpment landscape team, for example, has boosted their burn acreage by approximately 1,000-2,000 acres per year.

GOAL 5. SHARE FIRE ECOLOGY (E.G., FIRE HISTORY, FIRE EFFECTS) RESOURCES USING A VARIETY OF OUTLETS

SBR FLN partners have given presentations about FLN-related work at international, national, and regional conferences. Webinars hosted through the national FLN provided further opportunities for sharing lessons learned, new tools and ideas developed in other networks, and additional avenues for scientists to share pertinent information. A list of webinars is available on the FLN website (www.conservationgateway.org/fln).

A monthly newsletter (the *FLN Networker*) is published by the national FLN team and shared electronically with partners and interested parties to keep everybody informed on recent findings and training opportunities. This newsletter is mailed to more than 500 people and is regularly forwarded to others across the country. SBR FLN partners are regular contributors. The CAFMS

[2]Personal Communication. 2013. Nicholas Larson, 109 Lawing Drive, Nebo NC 28761.

newsletter is another vehicle for SBR FLN participants to share fire ecology findings.

CONCLUSIONS

We consider our landscape-level assessments and tools such as 'ecomath' as works in progress, designed to further systematic, science-informed restoration planning. We intend to evaluate the effectiveness of restoration actions through our monitoring network as well as research collaborations with CAFMS. The tools developed collaboratively by our partners have been exported to many interested partners and other regional FLN networks. We believe that we are on track and making good progress toward restoring fire-adapted ecosystems that will hopefully be resistant to climate change. Our success is demonstrated by the fact that our network is growing, from five landscapes in 2007 to eight in 2014.

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Table 1—Fire mediated ecozones in each of the original SBR FLN landscapes (ecozone mapping is not yet available for the Georgia Blue Ridge Mountains Landscape)

Landscape	Pine-oak heath	Shortleaf pine[a]	High-elevation red oak	Dry-mesic oak	Dry oak[b]	Mesic oak[c]	Fire mediated ecozones	Non-fire ecozones[d]	Total acres	Percent fire adapted
Southern Blue Ridge Escarpment	14,261	81,207	1,044	109,674	37,493	19,593	263,272	64,091	327,363	80%
Unaka/ Great Smokies	116,009	20,451	19,917	78,357	44,714	180,158	459,606	401,268	860,874	53%
Central Escarpment	41,403	15,136	1,336	17,627	17,022	30,451	122,975	87,907	211,152	58%
South Mountains	3,527	478	0	4,976	10,403	5,656	25,040	8,950	33,990	74%
Northern Escarpment	3,743	0	2,060	4,570	2,466	10,807	23,646	20,844	44,490	53%
New River Headwaters	413	0	1,631	37	89	3,084	5,254	7,470	12,724	41%
Nantahala/ Balsam Mountains	60,497	62,885	39,940	89,826	42,003	166,274	461,425	407,802	869,227	53%

[a]Shortleaf Pine = low elevation pine and shortleaf pine-oak/heath.

[b]Dry Oak = dry oak evergreen heath and dry oak deciduous heath.

[c]Mesic Oak = montane oak-hickory shortleaf pine, montane oak-hickory cove, and montane oak-hickory rich.

[d]Non-fire adapted ecozones include: spruce-fir, northern hardwood slope, northern hardwood cove, rich cove, acidic cove.

Table 2—Ecological departure of ecosystems in the North Carolina Southern Blue Ridge

Ecosystem	Percentage of departure	Historic fire return intervals	Drivers of departure
Dry Oak Forest	80%	10	Too much closed canopy, lacks old-growth
Pine-Oak/Heath[a]	79%	5	Too much closed canopy, too much late-seral
Shortleaf Pine-Oak[a]	71%	3	Too much closed canopy, too much late-seral, lacks early-seral
Dry Mesic Oak-Hickory	71%	14	Too much closed canopy, lacks old-growth
Mesic Oak-Hickory	72%	18	Too much closed canopy, lacks old-growth
High Elevation Red Oak Forest	65%	18	Too much closed canopy, lacks old-growth
Rich Cove Forest	55%	70	Lacks old-growth
Acid Cove Forest	56%	70	Lacks old-growth
Spruce-Fir Forest[a]	39%	500	Too much mid-seral, too little late-seral; questions about species composition
Northern Hardwoods Cove[a]	10%	250	No significant departure, but old-growth not modeled
Northern Hardwoods Slope[a]	4%	250	No significant departure, but old-growth not modeled

[a]Old-growth S-classes are not included in these models.

Note: severely departed ecosystems are indicated in red, moderately departed in yellow, and other in green. Historic fire return intervals are based on LANDFIRE 2009.

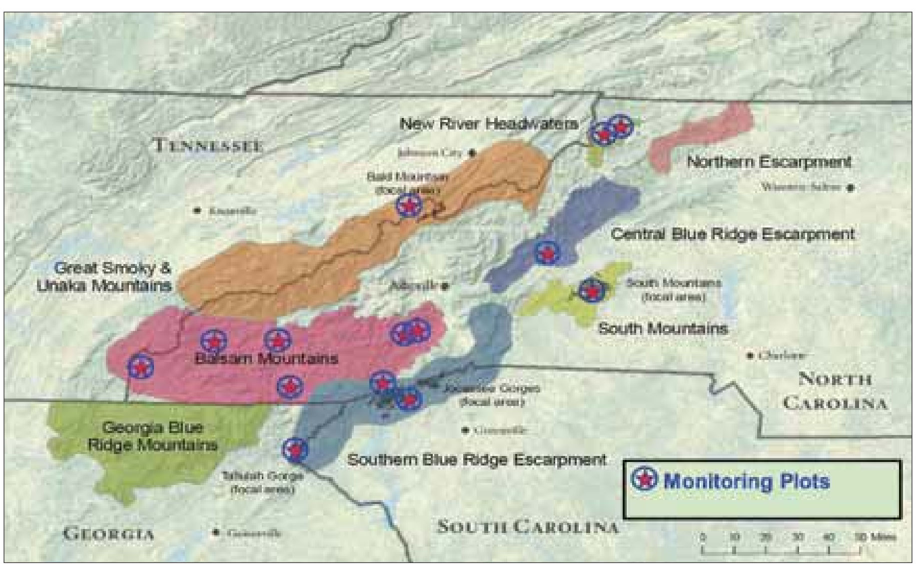

Figure 1—The map shows the eight landscapes and location of monitoring plots in the SBR FLN. Note: The Northern Escarpment and New River Headwaters joined the FLN in 2011, the Georgia Blue Ridge Mountains and Jocassee Gorges Focal area in summer 2013.