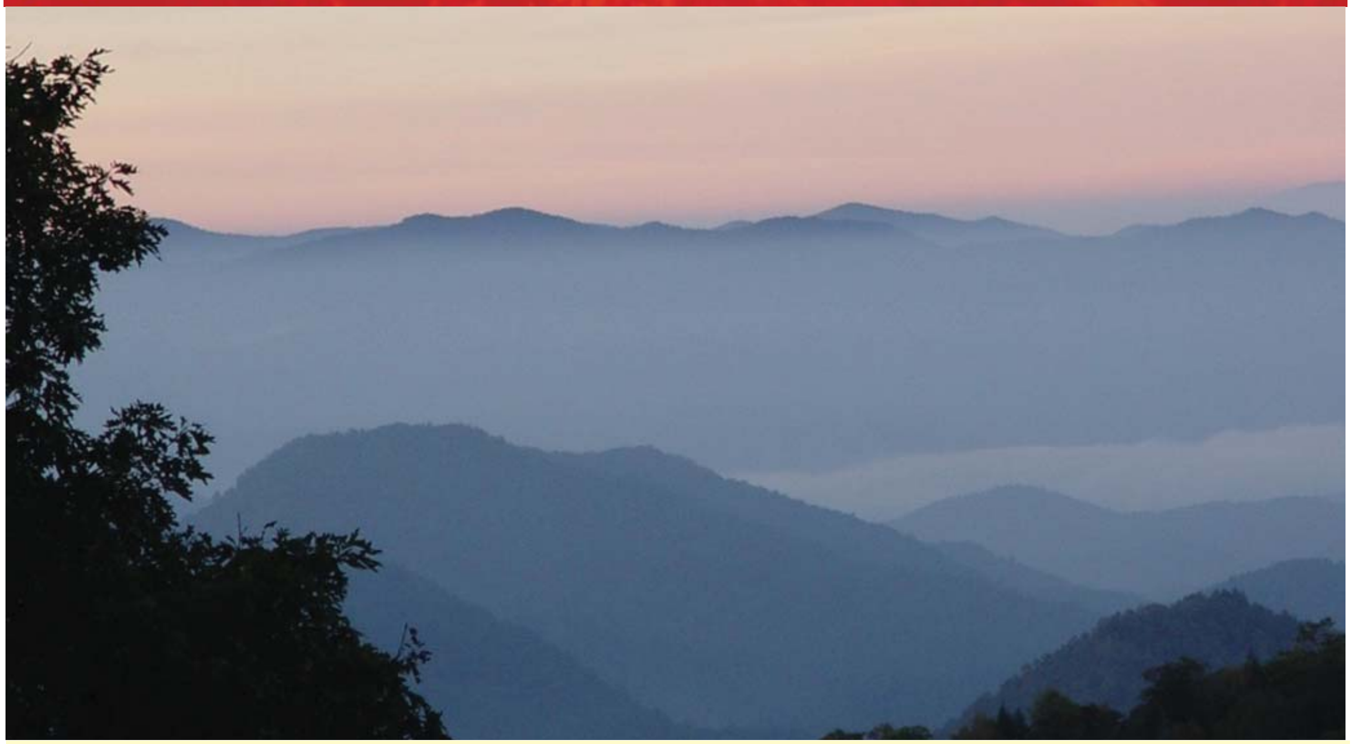
Joint Fire Science Program

Fire Science Brief

RESEARCH SUPPORTING SOUND DECISIONS



Though the Southern Appalachian Mountains are older than many mountain chains in the West, scant information previously existed on fuel types, distribution of fuels, and characteristics and placement of disturbance events.

Naked Eyes and Hyperspectral Images Build Fuel Maps in the Southern Appalachian Mountains

Summary

With the limited knowledge previously available about the types of fuels, and how they are distributed in the southern Appalachian Mountains, managers have faced difficulties in developing fire plans for the region, including whether or where to apply prescribed fire. For this study, the scientists took a two phase approach to determine fuel loads on the land—by ground surveys, and by remote sensing technology using hyperspectral images. Examining over 1,000 study plots in diverse topographic locations affected by various disturbances (or no disturbance) across four states, the researchers found few differences in undisturbed plots regardless of topographic location. This means that fuel accumulation is no greater on highly productive sites than on less productive sites. Problem fuels such as the shrubs mountain laurel and rhododendron were not as common as the researchers anticipated, and may be a concern in only limited areas. Disturbance history and type played a greater role in determining fuel loads than topographic location. Fire decreased some fuels while beetle attack, harvesting, and windthrow increased most fuels. The second phase of the study used remote sensing and the Strom Thurmond Institute Hyperspectral Library to detect and map rhododendron and mountain laurel under the thick canopy found in the region, helping the scientists see into vast areas and remote terrain.

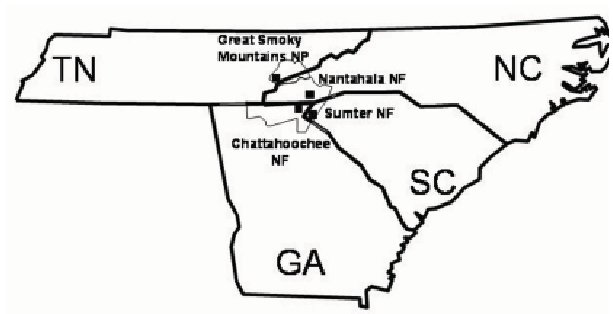
Key Findings

- On undisturbed plots, fuel accumulation is no greater on highly productive sites than on less productive sites.
- Problem fuels such as the shrubs mountain laurel and rhododendron were less common than expected and may be a concern in only limited areas.
- Disturbance history and type of disturbance played a greater role in determining fuel loads than topographic position.
- One-hour fuels, such as small twigs and branches, were significantly higher on beetle-killed plots than on undisturbed plots, while larger woody fuels tended to be greater in plots subjected to beetle attack, fire, and wind.
- The advantages of using hyperspectral imagery for mapping includes improved spatial resolution, and using this data to identify members of the understory plant community helps managers identify fuel loads on a landscape without having to trudge through it.

Introduction

As anybody with young family members in distant states or countries can tell you, children grow up fast. Without photographs, long-distance aunts, uncles, cousins who gather for holidays or reunions will miss the intervening changes that happen quickly in youthful relatives. A human life span is quick, a maximum of maybe a hundred years, and the quickest portion is infant to adult. Not so with the world we walk on. On many landscapes, it is hard to recognize changes taking place (barring major disturbances) that happen over great lengths of time. Hundreds of millions of years ago, continents collided, inland seas formed, land folded and faulted and fractured into the northeast to southwest trending range of the southern Appalachian Mountains. Geologic events, over a span no one could witness, created the diverse environments, landscapes, habitats, soils, aspects, elevations, weather patterns and disturbances we see there today. Erosion over millennia has worked over places, reducing those mountains just as it will the Rockies and Cascades. Geology is a long-running, mostly slow-moving story, with episodic jumps and jolts in the narrative. Without mapping and photographing and documenting, we can't perceive creep along a fault line that occurs at a rate of two inches a year. Or compare the margin of this year's glacial ice with that of, say, fifty or sixty years ago. By looking at vegetation maps, we can see the extent of forest cover, and perhaps discover a transition occurring from open canopy to a closed one, or even discern desertification spreading into formerly fertile lands. Before they are able to make informed plans, land managers must know what the conditions are.

With very little information previously existing on the types of plants, and their distributions, managers had very little to go on regarding the kinds of fuels in the southern Appalachian Mountains. Developing fire plans, and determining when and if to apply prescribed burns was hampered. Tom Waldrop, supervisory research forester with the Forest Service's Southern Research Station, and his team, set out to fill this void with a two-phase approach: by mapping fuels using ground surveys, and taking it to another level, so to speak, using high flying equipment to deliver hyperspectral images that could see into vast areas and difficult terrain.



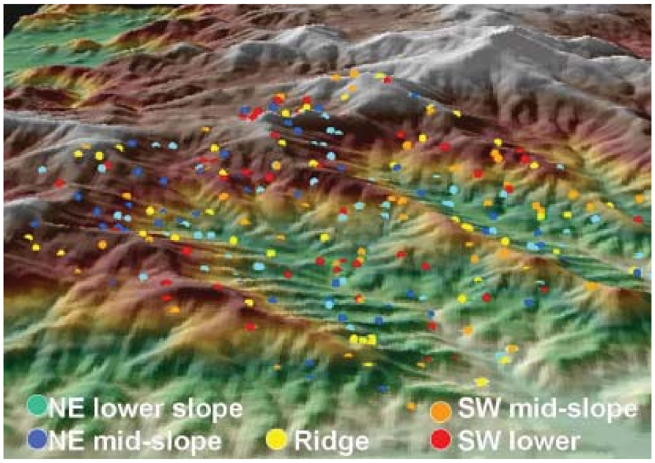
Covering a 10-square mile study area in each of four states in the Southern Appalachian Mountains, plot samples the researchers gathered enabled them to produce the first detailed fuel maps of the region.

Classifying fuels, phase one

To what extent, and how fast, are southern Appalachian Forests, used to fire, changing from fire-dependent pine and hardwood communities to hardwood-dominated stands? What is happening in the understory with shrubs such as mountain laurel and rhododendron that can be problem fuels?

Planning prescribed fire is a problem in southern Appalachian forests for a number of reasons: vegetation conditions are not known, communities continue to creep up and into wild lands, and the major causes of wildfire in this region are set by human hands—accidentally, by burning debris, and intentionally, by arson. For phase one of this study, Waldrop's team booted up and suited up to see if their assumptions about the distribution of fuels (that variability would be high among combinations of aspect and slope position) were correct. Picking plots randomly with the software ArcView geographic information system, and trudging through terrain, the team sampled four study areas 10-square miles in size over three years in Sumter National Forest in northwestern South Carolina, Chattahoochee National Forest in northeastern Georgia, Nantahala National Forest in western North Carolina, and Great Smoky Mountains National Park in southeastern Tennessee. The scientists selected the study plots that would provide a full range of topographic positions—short, steep slopes; lower elevations; higher elevations; long ridges; deep ravines; more productive sites, less productive sites; drier sites and rainy, rainy, rainy ones—and that were located where active burning programs were in place so managers would benefit from the data regarding fuels the team collected.

For 1,000-hour fuels, such as fallen trees, they recorded girth and type (whether hardwood or softwood), and if the wood was sound or rotten. They estimated the amount of shrubs, such as mountain laurel, rhododendron, lowbush blueberry and highbush blueberry that contribute more to fire behavior than other live fuels, and measured the depth of organic litter. They looked at the landscape for signs of disturbance and assigned a category—none, fire, logging, kill by southern pine beetle, windthrow—for what they saw. Then they mapped out the story.



Sample plots situated on the landscape were chosen randomly, and covered topographic positions with different elevations and slope aspects.

Cartography by sweat

Did fuel loading vary by topographic position? Going into this study, the scientists assumed that different plant communities and sites that were more productive versus less productive (related to slope aspect and position) would create different patterns of fuel loading. They looked for signs of disturbance—how undisturbed sites compared to disturbed sites in fuel amounts, and if different disturbance events produced different fuel characteristics.

Most of the 1,008 plots the team measured had no signs of recent disturbance—70 percent—and for both disturbed and undisturbed plots, plant species were similar regardless of location variables such as height, and slope aspect (the slope's relation to cardinal direction, and therefore, the sun). Oak dominated all sites followed by pines. Chestnut oak and scarlet oak preferred dry sites, northern red oak preferred the moist. Downed woody fuel amounts were mostly similar in undisturbed plots regardless of topographic position; likewise for 10-hour (large twigs and branches), 100-hour (limbs), and 1,000-hour (large limbs and tree trunks) fuels. One-hour fuels (small twigs and branches) were much lower on ridge plots than all other topographic positions. The scientists found heavier amounts of organic litter on the ridges, and lighter amounts downhill on southwestern and northeastern slopes, which indicated to them that additional leaves, dying and dropping, were not keeping up with decomposition which was working faster on the wetter sites. Shrubs were absent from the majority of the plots, the team found, but when they spotted mountain laurel and rhododendron, they were growing in clumps—a problem fuel since they act as a ladder for fire to climb up into the crowns of trees. Though the shrubs grew at all combinations of slope and aspect, mountain laurel was much more abundant on southwest upper slopes, where fire danger is high, and rhododendron was more common on moist lower slopes and northeast plots.

The scientists saw disturbed areas more often on ridges and southwest slopes than northeast slopes, where southern pine beetle (pictured above along with a beetle killed stand) harvesting, or fire was three to five times more likely on those exposed sites.

Disturbance events had occurred in all four study areas, affecting 30 percent of the sampled plots. Fire was the most common, wind second. The scientists saw disturbed areas more often on ridges and southwest slopes than northeast slopes, where southern pine beetle, harvesting, or fire was three to five times more likely on those exposed sites. Though the scientists also expected more windthrow on exposed sites, that disturbance type was equally observed across all topopgraphic positions. Fuel patterns on disturbed plots were very similar to undisturbed plots with the exception of 1,000-hour fuels (large limbs and trunks). These the scientists found in greater amounts at lower elevations, possibly due to the laws of gravity that move objects in our world in one direction, or possibly because lower topographic positions produce more trees. Fuels loads were also affected by the type of disturbance a plot experienced: burned plots decreased litter but increased small woody fuels such as small trees and shrubs; beetle attacks led to increased 1-, 10-, 100-, and 1,000-hour fuels and fuel height (depth of piles of fuel above ground); harvesting decreased 100-hour and 1,000 fuels (probably by removing those fuels from the site), as well as problem shrubs; windfall toppled trees and thus increased 100- and 1,000-hour fuels for example.

The facts seemed contrary to common sense. "For many fuel variables, there was no difference in loading across topographic positions if the plots showed no signs of recent disturbance," Waldrop offers. "Masses of litter and 1-hour fuels varied significantly among slope-aspect positions, but masses of 10-, 100-, and 1,000-hour fuels and fuel height did not vary. This result was surprising because of the large sample size used for analysis (705 undisturbed plots)." The big revelation: The scientists suggest differences in the amounts of fuels produced at sites were balanced by the rate of decomposition. Productive sites had higher decomposition rates which removed the higher amounts of fuels sooner—thus, there exists low amounts of variation among undisturbed plots.

With the team having compiled exhaustive amounts of data using this large sample size, their phase one project—the first widespread descriptions of fuels in the southern Appalachian Mountains—provided real numbers on fuel loads in undisturbed areas. For disturbed plots or plots with densities of the problem shrubs, the team found fuels varied greatly. To identify this pattern easily, the team proceeded on to phase two—using the non-visible sight of remote sensing technology.

Photos of Rhododendron (left) and Mountain laurel.

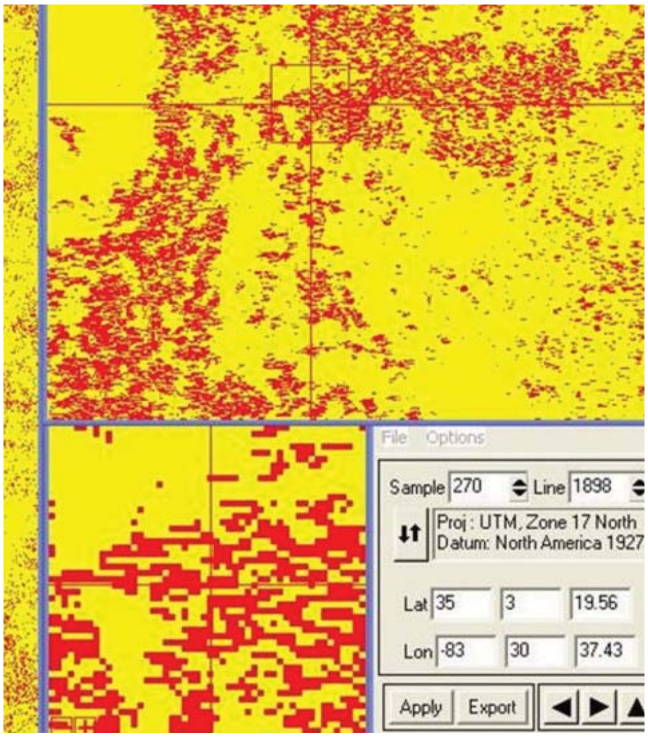
Classifying fuels, phase two

Reality is what our senses allow us. If we saw, as some other species do, a picture of the world might be told by heat, or sound, or glow. All objects emit radiation in different amounts and at various wavelengths. The complete electromagnetic spectrum stretches from high frequency, short-wavelength gamma rays, to low frequency, long-wavelength radio waves. Ultraviolet rays are outside of the human range of vision—but bees can see it, and flowers glow like neon in their world. Infrared is also beyond the ability of our naked eyes, but some fish can see it. So can spiders. Though our basic senses limit how we perceive the world, the technology we've developed allows us to tap into expansive realms, to recognize patterns, and map them into images we can finally see—with our good eyes or 20–20 corrected vision.

"Hyper" in hyperspectral means "too many," indicating the large number of measured wavelength bands hyperspectral images use. Because the images give so much spectral information, the technology can give detailed pictures, much more so than other types of data acquired by remote sensing. Hyperspectral imaging looks at the percentage of light hitting, and then being reflected off an object or material. Objects reflect and absorb light differently—these unique patterns can identify a specific material, and because of the density of information hyperspectral images deliver, this technology can distinguish between materials that are spectrally very similar. Scientists then compare the spectral images the technology delivers with a reference spectrum. This reference spectrum comes from spectral libraries—in this study, the scientists developed the Strom Thurmond Institute Hyperspectral Library, which includes hyperspectral profiles of shrub species in the understory study area that cannot be found in other spectral libraries.

Flying aboard aircraft, the spectrometer in an imaging sensor (bottom) reads a reflectance spectrum for each pixel it will use to build an image. Image measurements are taken using many narrow contiguous wavelength bands, creating a complete spectrum for each pixel of the image.

After the scientists classified fuel types and loads using their ground measurements in phase one, they wanted to know if they could determine specific fuels using aerial images created with hyperspectral image technology. Because rhododendron and mountain laurel exacerbate fire behavior, identifying this understory fuel problem is important to managers. But mapping on foot is time-consuming, labor intensive, and costly. Could hyperspectral images craft accurate maps of those fuels? The scientists used one study area in the Nantahala National Forest for this part of the project. By comparing what the images delivered to what they knew the characteristics were on the ground, and by employing techniques to adjust and correct for distorting variables, the scientists found their hyperspectral image analysis identified and classified rhododendron with 90 percent accuracy. Waldrop and his team believe using hyperspectral data to identify plant species in the understory, to map distributions of those species that are a concern, and to track changes over time in those distributions is a boon to forest researchers and land managers. Hyperspectral technology can offer managers, Waldrop explains, the ability to assess the implications of changes in species distributions, and obtain rough assessments of fuel loads without the labor of time consuming ground surveys. By following a path humanity has walked over millennia, feet and eyes track changes on the land. By using advanced technology, we can see the details of our world in a whole new light. Thus, two roads converge in a distant wood.



Rhododendron: Identified, classified, and mapped.

Management Implications

- Managers can use the descriptions of fuels, and the numbers for fuel loading on undisturbed plots developed in this study to craft fire plans or model fire behavior scenarios. If additional fuel measurements are needed, managers can use this project's findings for guidance in determining where to place study plots.
- Greater variety in fuels occurred on disturbed plots, or places where dense shrubs grew. Managers can easily identify these sites using remote sensing or stand management records.
- Managers can refer to hyperspectral data to identify understory plants, to map distributions of plant species, and to track changes over time in those distributions. With hyperspectral data, managers can assess the implications of changes in the distributions of plant species, and make rough evaluations of fuel loads on a landscape without having to trudge through time-consuming and labor-intensive ground surveys.

Further Information: Publications and Web Resources

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Scientist Profile

Dr. Thomas A. Waldrop is Supervisory Research Forester with the Southern Research Station's Center for Forest Disturbance Science. Located, at Clemson, SC, he leads the Center's Fire Science Team. The team examines questions of restoration, ecology, impacts, and fire prescriptions on ecosystems ranging from tropical forests to the southern Appalachian Mountains. Waldrop's personal research deals with restoration of fire-dependent ecosystems, fuel reduction impacts, and application of fire to the southern Appalachian Mountains. He manages the Piedmont and Appalachian study sites of the National Fire and Fire Surrogate Study.

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Results presented in JFSP Final Reports may not have been peer-reviewed and should be interpreted as tentative until published in a peer-reviewed source.

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