Joint Fire Science Program
Fire Science Brief
RESEARCH SUPPORTING SOUND DECISIONS

Credit: USDA Forest Service, Fire and Fire Surrogates Study.

Earth and Fire: Forests Rely on Healthy Soils for a Well-rounded Diet

Summary

Historically, frequent low-intensity, dormant-season fire shaped the landscape across a variety of forests in the United States, from eastern hardwood and hardwood/conifer mixtures to western coniferous forests. Decades of fire exclusion have resulted in heavy fuel loads and increased threat of severe wildfire compared to historic conditions in most forest types and also resulted in changes in forest composition compared to historic conditions. The Fire and Fire Surrogates Study (FFS) is the first to apply a standard experimental design to compare thinning, thinning followed by prescribed fire, and prescribed fire alone across a wide spectrum of ecological and economic variables. An important, though often overlooked, component of forest health is the soil. Recent research is demonstrating that fire has complex effects on soil composition, and thus forest health, compared to mechanical or chemical treatments.

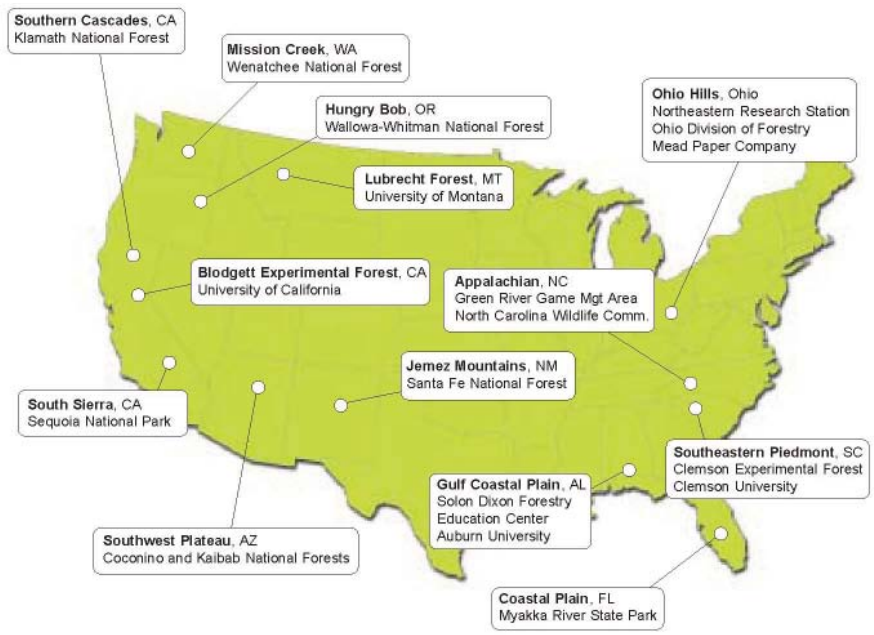
Key Findings

- The belowground effects of fire on soils are not as obvious as those on the visible, aboveground forest, but are crucial to the overall health of the forest.
- In general, low-intensity prescribed fire does not heat the ground to the point that soil organisms and ecological processes are adversely affected.
- In the short term, in eastern oak forests, fire increases the pH of the soil by depositing ash. In forests adversely affected by enhanced nitrification due to deposition of nitrogen in acid rain, this may slightly lower the amount of nitrate leaching into streams and groundwater. Higher pH also increases the availability of calcium, improving soil fertility. The long-term effects of fire on soil fertility are not known.
- Fire does not appear to affect the storage of carbon in the soil in the short term in oak forests, but the long-term effects are unknown.
- High-intensity fire, for example in coniferous forests or chaparral, creates a water repellant layer in the mineral soil, leading to sheet erosion and lack of groundwater recharge. Smoldering fire consumes tree roots and destabilizes slopes.
- Low- to moderate-intensity fire in oak forests exposes the mineral soil, but the tree roots are not consumed. Since the forest floor in not entirely consumed by fires at these temperatures, erosion is less severe than in high-intensity fire conditions.

To b(urn) or not to b(urn)…

That is the question. A long-term, nationwide study will give resource managers solid scientific grounds on which to base the answers.

Restoration of historic ecosystems and ecosystem services, and reduction of wildfire hazard: that is the two-fisted goal of the FFS Study. The study explores forest types in nine states in the continental 48 states that went from frequent low-intensity fire to infrequent severe fire today. "The scope of the project is almost unprecedented in fire ecology studies," says Ralph Boerner, a soil ecologist and professor of Evolution, Ecology and Organismal Biology at Ohio State University.



The study sites. Source: USDA Forest Service, FFS Study.

Funded by the Joint Fire Science Program since 2000, the FFS Study uses a common experimental design to compare the use of fire alone, mechanical thinning followed by fire, mechanical thinning alone, and no treatment at all—the control—at 12 current experimental sites on federal, state, and private lands.

Researchers from a range of disciplines assess seven sets of variables at each site: wildlife, tree pathology, vegetation, fire and fuels, entomology (bark beetles, for example), treatment costs and utilization (economics), and soils and forest floor. By rigorously applying the same experimental design to these varied ecosystems, a picture of the risks and benefits of the treatment regimens is emerging. "We are now analyzing data from the first six years of the FFS studies," says Boerner. The long-range ambition is to continue assessing the experimental treatments over a much longer time period, from 25 to 30 years. "We want to monitor the health of these ecosystems for the long haul."

A self-proclaimed, died-in-the wool, eastern hardwoods person, Boerner says the reason we have pine and oak and hickory in the eastern part of the country is due to the frequent occurrence of fire. Fire exclusion beginning early in the 20th century led to the proliferation of species such as maple and tuliptree, or thickets of mountain laurel and rhododendron, which choke the forest, compete for light, and crowd out the oak and hickory stands that provide nourishment for wildlife.

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Our view of what constitutes a pristine forest has evolved over time. "Today, pristine means a mosaic with unburned and recently burned, a patchwork of different ages that allows for greater diversity. It doesn't mean *undisturbed*," he says.

What is emerging from the experiments, however, is not a strict recipe for restoring forest health. In a forest next to a recreational area, for example, aesthetics and social aspects might dictate that thinning is a better treatment than fire to promote sustainability. "You may not want to take a chance of fire getting loose or blackening the forest floor," he says. In addition, air quality considerations and permitting regulations under the National Environmental Policy Act might preclude the use of fire in the wildland/urban interface. A local landowner group might also prefer thinning for aesthetic and safety reasons.

"The purpose of the study is to give resource managers the scientific information they need to weigh the ecological concerns along with the social, political, and economic issues in the decision-making process," Boerner says.

Sampling at the soil surface. Credit: USDA Southern Research Station, FFS Study.

Mechanical thinning with a Bobcat. Credit: USDA Southern Research Station, FFS Study.

Healthy soils, healthy forests

To the casual observer, there is little difference in walking through a forest that has been managed by mechanical thinning, prescribed fire, or a combination of the two. But conditions at and beneath the soil surface tell a more complicated story. In fact, the long-term health of the forest depends on the soils that nourish it, elements not visible to the naked eye.

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"When people think about the effect of fire, they think of trees, vegetation, animals, and insects," says Boerner. "In the soil studies portion of the Fire and Fire Surrogate experiments, we monitor what goes on in the soil with fire, or thinning, or no treatment at all, to assess the health of the ecosystem for the long haul."

At each of the sites, researchers take samples at the soil surface and below ground before and after the four treatment regimens: an untreated control, low-intensity prescribed fire alone, mechanical treatment only, such as lopping and chopping, and thinning followed by fire.

These treatments have potentially beneficial or harmful effects on four parameters that determine soil composition and health: erosion, nutrition, nitrogen, and organic matter. Resource managers, like physicians, can use this information to minimize adverse effects on forest health. "A cardinal rule of the Hippocratic oath is first, do no harm," Boerner says.

Though all the data have not been compiled for every experimental site, initial findings suggest that in eastern hardwood forests, fire does little or no harm. "That should not be surprising since fire has been part of the ecosystem for 4,000 years or longer." Most everything in the system is adapted to and shaped by frequent, low-intensity fire. "The organisms in the soil do not notice that the fire went by, they co-evolved with fire." FFS researchers in other parts of the country apply the same treatments to different forest types, such as Ponderosa pine and mixed conifers in the west. "We are still trying to work out if that is the case in the western forests."

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Researchers have also measured 110,000 trees to determine to what degree the treatment affects the amount of carbon the ecosystem can store in the forest floor, in dead logs, and in live vegetation. "We are crunching a lot of data," Boerner says.

There is not just one factor that tells the whole story. "The basic science allows us to look at how these pieces of the puzzle come together, so we can say to a manager, if you can only measure one thing—such as calcium, microbial activity, or organic matter—measure this element. It will give you a reasonably good view of the health of the soil."

Trees need a square meal too

Erosion: The first, purely physical, sampling looks at how much of the mineral soil surface gets exposed and how much gets compacted, which affects the rate of erosion. "We look at the amount of erosion if you take off the duff and woody debris that allows water to sink in rather than run off," Boerner says. Compaction affects the ability of water to percolate into the soil rather than run off the surface. "The physical aspect affects erosion and therefore water quality, an ecosystem service."

Credit: USDA Forest Service, Erosion Risk Management Tool User Manual.

Nutrition: The nutritional quality of the soil helps determine whether plants and animals survive and thrive. Soil nutritional status is determined by measuring soil pH and the availability of minerals to trees. "Calcium, phosphorous, and potassium in dissolved forms are the milk, fish, and bananas of the plants that take them up and ultimately determine the success of the animals that eat the plants and nuts in the forest."

Nitrogen: The availability of nitrogen historically has been the limiting factor for tree growth, the requirement in least supply. That's why traditional agricultural practices include application of nitrogen to boost plant growth. Currently, however, acid rain in some regions of the United States has led to nitrogen saturation and leaching of nitrates into ground and stream water. "I suspect that nitrogen deficit may still prevail in most of the western states and perhaps in Gulf coastal Florida, where acid deposition is less of a problem than in the rest of the eastern United States."

Organic matter: The living and dead organic matter—from rotting vegetation, dead animals, and fungi, for example—is critical to the health of the trees and other vegetation. Organic matter traps water and adds nutrients to the soil. "When there is no rain, organic matter holds nutrients in the soil. When organic matter decays, the nutrients don't drain out, they stay there for the plants, the microbes, and the small animals that live there."

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Back to the future: Lessons from the past

"In places I have been in the Carolinas, I have seen the canopy open up after fire. It helps a multitude of wildlife, and the wildflowers just go crazy where you have these spring burns…Jack-in-the Pulpits, Lady's Slippers, things you would not see under a closed canopy," says Skip Still, Wildlife Biologist with South Carolina's Department of Natural Resources.

In the late 18th century, as William Bartram rode horseback from the coastal Carolina lowlands to the uplands of the Piedmont, over the Appalachian peaks and down into the Tennessee Valley, he took careful botanical notes of the landscape through which he traveled. He often described majestic stands of oak and hickory trees…and easy going through the understory: "spacious high forests and flowery lawns…grassy glade or lawn bordering the river" (from *Travels of William Bartram*, 1791).

Today, much of the terrain he covered would be impassible to a mounted human. Indeed, in some places the traveler would be better off with a machete than a horse.

The landscape Bartram described was the result of thousands of years of natural and anthropogenic fire. "The paleoecological record tells of significant fire," says Boerner. Before human populations became numerous, natural fire was climate driven. Early on, the eastern climate was warmer and drier and more amenable to lightning fire. As the indigenous populations grew, and the climate became cooler and moister, human-caused fires increased in frequency. "Until the native population crashed after European settlement, fire frequency had stayed pretty stable for 4,000 years."

Before human populations became numerous, natural fire was climate driven.

When Hazel R. and Paul A. Delcourt wanted to determine the impacts of pre-Columbian people on the forests of the southern Appalachians, they couldn't rely on the written historical record. Instead, the Delcourts, professors in the Department of Ecology and Evolutionary Biology at the University of Tennessee, Knoxville, dug down 40 centimeters into a peat bog in the Blue Ridge region of North Carolina. Using analysis of fossil pollen and radiocarbon dating of charcoal in the core samples, and building on the work of other researchers, they were able to construct a "snapshot" of the forest composition and document the history of fire across a time span of nearly 4,000 years.

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The portrait they present, published in the journal *Conservation Biology* in 1997, shows a predominance of oak and chestnut with a grassy understory and, in the alluvial plains, evidence of herbs and cultigens, including maize, that indicate human agricultural activities. The chestnut, of course, was wiped out by an introduced fungal disease, and hickory has enlarged its niche in the mixed hardwood forests.

The stated purpose of the Delcourts' research was to establish a baseline for an ecosystem management plan that promotes an oak "orchard" or a mix of hardwood and fire-tolerant pine that has been in decline since the early 20th century. They maintain this management goal may require the judicious reintroduction of prescribed fire.

"The restoration goal is not a philosophical return to the age of the 'noble savage,' it's a practical and empirical one," says Boerner. "We are after ecosystems that are sustainable in terms of their own processes and the services they give us like clean air and clean water. Fire suppressed forests don't do that," he says.

Further Information: Publications and Web Resources

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Management Implications

- The current condition of forests across the continental 48 states is an artifact of management based on fire suppression beginning early in the 20th century. Reintroducing fire to encourage pre-suppression forest conditions, however, requires balancing economic, social, and ecological consequences.
- The soil component of the FFS studies can help resource managers better understand the health of the ecosystem over the long haul.
- Fire is only one of several tools in the toolkit of the resource manager or forester. Aesthetics and social considerations sometimes dictate that thinning is a better way than fire to promote sustainability.
- The data obtained from the FFS studies provide the scientific information to weigh along with the social, political, and economic implications of land management and ecosystem restoration.

Scientist Profile

Ralph E. J. Boerner, who earned a Ph.D. at Rutgers University under the father of landscape ecology, Richard Forman, is a professor of Evolution, Ecology, and Organismal Biology at Ohio State University. His research focuses on the effects of fire, atmospheric deposition, landscape structure, and management on the ecology of the soil and forest floor in northern and southern temperate zones.

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The information in this Brief is written from JFSP Project Number 99-S-01, which is available at www.firescience.gov.

An Interagency Research, Development, and Applications Partnership

JFSP *Fire Science Brief* is published monthly. Our goal is to help managers find and use the best available fire science information.

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