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Long-Term Ecological Effects of Prescribed Burning and Mechanical Treatments on Eastern Oak Forests

This science brief has been modified to clarify statements made to the original text.

Eastern oak (*Quercus* spp.) forests in the United States have experienced significant ecological changes over the past century due to fire exclusion and land-use changes. Historically, anthropogenic (human-ignited) fire regimes maintained oak dominance by reducing mesophytic (shade-tolerant, fire-intolerant) competitors, such as red maple (*Acer rubrum*) and American beech (*Fagus grandifolia*). With the loss of fire across the landscape, these species have become more abundant, suppressed oak regeneration, and altered forest structure in a process known as mesophication.

Natural resource managers seeking to reverse mesophication and restore oak forest communities need the best available science to support forest management strategies aimed at sustaining oak ecosystems.

Two Decades of Research

In 2000, researchers established the Ohio Hills Fire and Fire Surrogate (FFS) study site comprising three study locations within the southern unglaciated Allegheny Plateau. Each location was divided into four treatment units:

- Control unit: no treatment
- Mechanical partial harvest unit: mechanical treatments involving commercial partial harvesting and reducing basal area by about 30 percent
- Prescribed fire unit: fire treatments conducted in early spring at years 1, 5, 10, and 16
- Combination unit: mechanical partial harvest and repeated prescribed fire

KEY MANAGEMENT CONSIDERATIONS

- Prescribed fire is a useful tool for creating a heterogenous landscape. Patches of overstory mortality can enhance habitat diversity and improve habitat quality for a wide range of wildlife species.
- Repeated prescribed fires with or without mechanical treatments were found to be effective in reducing mesophication across upland sites by reducing stand density, creating canopy openings on dry sites, and increasing oak-hickory regeneration and ground layer diversity.
- After two decades of fire treatments, mesophytic tree density was reduced, increased oak regeneration occurred on dry and intermediate sites, and higher ground-layer diversity was present across the landscape.
- Fire treatments reduced duff and fine fuel loading, reducing the likelihood of high intensity wildfire and severe effects on the overstory, but these fuels had largely recovered within 6 years of the last prescribed fire. These prescribed fires, by design, also created patches of high overstory mortality that resulted in longer term increases in large woody fuel loads. Overall fire behavior was modulated by topography, with greater consumption, fire intensity, and fire effects observed on drier sites.

Spring dormant season prescribed fire at the Zaleski State Forest in Ohio. USDA Forest Service photo by Todd Hutchinson.

The primary objective of the study was to determine whether repeated prescribed fire, mechanical partial harvest, and the combination could achieve the following goals:

- Reduce the dominance of mesophytic midstory and sapling competitors
- Increase the abundance of large oak-hickory regeneration
- Enhance ground-layer plant diversity
- Create fuel beds that support prescribed fire
- Reduce the risk of high-severity wildfire

Todd Hutchinson, a research ecologist with the U.S. Department of Agriculture, Forest Service, Northern Research Station, and colleagues analyzed 20 years of data from the study of treatment effects on vegetation and fuels and published a paper of the results.

Research Findings

Vegetation and Forest Structure

Prescribed fire and the combination of mechanical treatments and prescribed fire effectively reversed mesophication, but mechanical treatment alone did not. Specifically, prescribed fire treatments reduced the density of mesophytic midstory trees and saplings across all site conditions. This effect was more pronounced on drier sites where fuel consumption and fire intensity were higher due to lower fuel moistures and modestly higher fine fuel loads.

Oak and hickory advance regeneration increased substantially on dry and intermediate landscape positions following fire treatments. These treatments also promoted a more open forest structure, which is conducive to oak regeneration. Contributing to the more open conditions was relatively high overstory mortality that occurred on some dry sites in the early burns, an objective on these fires that is not general to prescribed burning in mixed-oak forests.

Ground-Layer Diversity

Prescribed fire significantly increased ground-layer plant diversity across all site conditions. Fire treatments enhanced the richness of native perennial herbs, creating distinct plant communities compared to untreated areas.

Open forest structure and robust oak regeneration after multiple prescribed fires. USDA Forest Service photo by Todd Hutchinson.

The increased diversity was attributed to the reduction in understory tree competition and shading, which allowed more light to reach the forest floor and exposed mineral soil facilitated greater establishment of herbaceous species from the seed bank.

Fuel Beds and Fire Behavior

Fire treatments had a complex effect on fuel beds. Just before the year 16 prescribed fires (6 years after the last fire), fine fuels loadings had largely returned to levels seen in controls. The year 16 prescribed fires reduced fine fuel loading by about 50 percent based on an immediate pre- and post-fire samples with consumption being higher on drier sites. In contrast, large woody consumption levels were low in these fires (less than 10 percent). Overstory mortality from the early fires and limited large woody consumption resulted in longer term increases in loading of large woody fuels, particularly on dry sites. Fire behavior was modulated by topography, with higher intensities observed on drier sites.

Topographic Variation

The study highlighted the significant role of topography in influencing fire effects. On dry sites, where fuel accumulation and drying rates were higher, ecological impacts were more pronounced. These sites showed greater reductions in mesophytic tree density; however, increased oak regeneration and higher ground-layer diversity also occurred where fire intensity was low or moderate.

"This 20-year investigation demonstrates that repeated prescribed fire treatments can promote oak and hickory regeneration."– Todd Hutchinson

Applying Findings to Management

The study findings underscore the importance of periodic fire in eastern oak forests. Repeated prescribed fire of moderate intensity effectively reduces the abundance of mesophytic species, promotes oak and hickory regeneration, and enhances ground-layer plant diversity. The study also emphasizes the need for adaptive management strategies that consider topographic variability. Fire generally reduced mesophytic tree density in the midstory and sapling strata across all site conditions, while leading to substantial gains in the abundance of large oak-hickory advance regeneration on dry and intermediate landscape positions.

Fine fuels are reduced by fires and, thereby, reduce wildfire hazard while litter-dominated fuel beds recover. Based on wildfire effects on oaks in long-unburned stands, duff consumption accomplished during prescribed fires may also be a way to reduce risks that wildfires will cause severe effects on the oak overstory during dry periods when duff is available for combustion. While fine fuels recover relatively quickly, overstory mortality on dry sites can result in longer term increases in large woody fuel loads as these trees fall. Elevated overstory mortality was an objective of early fires in this study as a means of boosting oak regeneration and has also been an objective where restoration of woodland groundcover is an objective. Other studies that have used more conservative firing practices repeated over multiple fires have also improved oak regeneration without the increased woody fuel loads. As such, repeated prescribed fire appears to be the key factor in creating conditions for oak regeneration.

Fire plays a critical role in managing eastern oak forests. "This 20-year investigation demonstrates that repeated prescribed fire treatments can promote oak and hickory regeneration," says Hutchinson, "and underscores the importance of integrating fire management with silvicultural practices to maintain forest health, enhance biodiversity, and mitigate wildfire risk."

Groundlayer plants on a mesic site after repeated prescribed fires; groundlayer diversity increased across all site types. USDA Forest Service photo by Todd Hutchinson.

PROJECT LEADS

Todd Hutchinson is a research ecologist with the Ecological Sustainability of Central Appalachian Forests research work unit of the Northern Research Station. Hutchinson's interests include oak regeneration, fire ecology of oak woodlands, and adaptive silviculture in eastern oak forests.

Andrea Brandon-Hennig is the author of this Rooted in Research Science Brief.

FURTHER READING

Hutchinson, Todd F.; Adams, Bryce T.; Dickinson, Matthew B.; Heckel, Maryjane; Royo, Alejandro A.; Thomas-Van Gundy, Melissa A. 2024. Sustaining eastern oak forests: Synergistic effects of fire and topography on vegetation and fuels. Ecological Applications. 34(3): e2948. https://doi.org/10.1002/eap.2948.

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For questions on Rooted in Research, please contact Andrea Brandon-Hennig. Technical editing by Carol Hollar-Zwick. Design and layout by Jeremy Siegrist.

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