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Upland Oak Regeneration

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RESEARCH SUPPORTING SOUND DECISIONS

A burn at Buck Creek, one of the study sites. Credit: University of Kentucky.

Upland Oak Regeneration

Summary

Along the ridgetops and in the coves of Kentucky's Cumberland Plateau, oak forests are in a state of transition. Mature oaks still tower over the forest floor and produce acorns that provide nourishment for wildlife. Those acorns also once ensured new generations of oak from seedlings and saplings. Beneath the canopy, however, a fierce competition for light is placing the future of upland oak forests in jeopardy. Once a frequent visitor that cleared the understory, opened the canopy, and allowed sunlight to penetrate to the forest floor, fire has been basically absent for nearly a century. Reintroduced as part of a Forest Service plan to return fire to the forest, prescribed fire has proven a blunt instrument in giving fire-tolerant and sunlight-dependent oaks a competitive edge over fire-sensitive species that vie for light. In the Daniel Boone National Forest, for at least 15 years, researchers and forest managers have coordinated studies using controlled fire as a management tool. New results from research in the Cumberland Ranger District on the response of oak and two of its competitors, red maple and sassafras, confirm that fire alone may not be sufficient to promote oak regeneration. The studies have, however, revealed new insights about the life history of oak and its competitors and generated new paths of research to explore treatment options and promote long-term survival of healthy oak forests in the Daniel Boone and elsewhere in the Appalachian uplands.

Key Findings

- Evidence is mounting that low intensity prescribed fire alone may not play a large role in encouraging oak regeneration.
- Repeated burning had significant negative effects on survival and growth of both red and white oaks.
- Single and repeated burning reduced canopy cover by a small degree except on one site where the fire burned with unexpected intensity. Oak seedlings, which were larger than elsewhere, responded positively.
- Species that compete for light, such as red maple and sassafras, experienced significant mortality after single or multiple burns, but rebounded quickly and vigorously soon after.

Forest no longer primeval

Throughout the Southern Appalachian hardwood forest region, oaks are a significant source of mast that supports wildlife, and their key role in forest ecology has increased since the demise of the American chestnut, which was decimated by a fungus introduced in the late 19th century. In the early 20th century, as the chestnut died out, the forests were heavily logged.

The Forest Service began acquisition of what is now known as the Daniel Boone National Forest in 1937, the same era that ushered in active fire exclusion. As the forest matured in the absence of major harvesting or fire, the amount of sunlight that reaches the forest floor dwindled as woody species in the subcanopy proliferated. Shade-intolerant and fire-tolerant young oaks now face competition from a number of other native trees, including red maple and sassafras, two species that can tolerate low levels of sunlight and are also theoretically more sensitive to the effects of fire than oak. In practicality, however, though maple has thinner bark than oak, it resprouts vigorously soon after fire and competes with oak seedlings and saplings for nourishment and light. Sassafras also quickly rebounds after fire through prolific root sprouting.

Prolific re-sprouting by sassafras on a plot near Morehead, KY, which burned three times between 2002 and 2007. Credit: Heather Alexander.

Across the region, oak regeneration is problematic," says Mary Arthur, a professor in the Department of Forestry at the University of Kentucky. Arthur and colleagues have been working for more than 15 years in the Daniel Boone to assess the role prescribed fire may play in promoting regeneration of oak species and reducing accumulated fuels. An earlier study, supported by the Daniel Boone National Forest and the Southern Research Station, began in 1995 and raised some concern that prescribed fire alone may not accomplish those goals. (See "Fire Returns to Southern Appalachian Forests," Fire Science Brief 35, January 2009.) A second study funded by the Joint Fire Science Program (JFSP) began in 2002 on the Cumberland District. This study confirms the limited utility of low intensity prescribed fire alone as a management tool in this region, but has improved our understanding of the life history and resource requirements of oaks and their competitors.

Surviving the fires

The six-year round of studies was conducted between 2002 and 2007 on ridgetop and cove landscapes that ranged from dry to moist (sub-xeric to sub-mesic). The three study sites—located at Buck Creek, Chestnut Cliffs, and Wolf Pen—were divided into three sub-sites each, unburned control, infrequent burn schedule, and frequent burn schedule.

Buck Creek Burn, April 2006. Credit: University of Kentucky.

At all sites, the canopy cover and amount of light in the understory were measured using hemispherical photography, which gauges the amount of light in the understory and the density of canopy cover. The researchers also quantified the survival of seedlings of the red oak subgenera, including black oak (*Quercus velutina*), northern red oak (*Quercus rubra*), and scarlet oak (*Quercus coccinea* Muench); the white oak subgenera, including white oak (*Quercus alba*), chestnut oak (*Quercus montana*); red maple (*Acer rubrum L*); and sassafras (*Sassafras albidum* [Nutt. Nees]). In addition, fuel loads of leaf litter and woody fuels were estimated before and after burns.

Study plot near Morehead, KY, showing seedlings flagged as part of long-term research to quantify seedling survival and growth in response to prescribed fire. Credit: Jessi Lyons.

Overall, single and repeated burning temporarily opened the canopy to a small degree, but those effects were quickly negated by resurgence of cover during the following growing season. Burning did not improve the survival of white oak or red oak seedlings compared to unburned treatment, with one exception. Seedlings in the red oak group on one site that burned more severely than planned showed a positive response, a 25 to 30 percent increase in height and basal diameter, but the seedlings in that burn were initially larger than those on the other sites and more of the canopy was opened by the severity of the fire. "The areas with the most intense burn had the most prolific oak growth," says Heather Alexander, a post-doctoral associate at the University of Florida, "but that type of fire is not part of the management scenario." A hot fire that kills off overstory trees creates a better light environment, "but it is tricky. Fire is not a precise tool."

With single and repeated burn treatments, red maple seedling mortality was significant, about 60 percent, but seedlings surviving the fire grew quickly after treatment. Root suckering sassafras survived both fire treatments and grew more vigorously than on unburned sites.

Red maple seedling. Credit: University of Kentucky.

In most upland oak ecosystems, unmanaged fire and prescribed fire are fueled by heavy accumulations of leaf litter. The research team found that, as expected, fire consumed a large proportion of the leaf litter. "Most of the biomass consumed by fire is leaf litter and smaller woody litter, and is replenished during leaf fall," says Arthur. By autumn after treatment, litter load had returned to near pre-burn conditions.

Though the exact pattern of human or lightning ignited fire prior to European settlement is not certain, the two dry seasons, spring and fall, are generally more conducive to sustaining burning than summer. Arthur suggests that future experimentation with fall burning may prove more effective in reducing the sub-canopy cover and promoting oak regeneration than spring burning. In addition, as forestry personnel gain more experience with prescribed fire, more intense fire may be applied in an effort to open the canopy. Targeting areas where oak seedlings and stump sprouting are well established may also reduce oak mortality from fire.

"We are now asking more specific questions about where the stand is in terms of life history," says Arthur. "If you burn at the right time, fire may help new acorns develop but the association of fire itself isn't enough. We need to use it in a more precise way tied to the life history of the oak."

Foiling the wily red maple

Expansion of red maple is occurring at an alarming rate, and not just in the upland forests of Appalachia. Researchers from the University of Kentucky and Pennsylvania State University, Songlin Fei and Kim C. Steiner, have analyzed Forest Service Forest Inventory and Analysis (FIA) data from 1980 through 2005 and found that red maple had increased in density and size in nearly half of the states where it has occurred historically and is spreading west beyond its documented natural range in the East into states such as Illinois and Missouri and even further west to Kansas and Nebraska, with the greatest increases occurring in the late 20th century.

Indeed, red maple is no longer a transient, early successional species; instead, recruitment of new growth is robust, and older trees are maturing into harvestable sizes. Red maple will likely increasingly dominate the overstory in many forests and continue its march westward.

This inevitable trend makes the search for forest management approaches to stem the expansion of red maple a high priority not just in the Daniel Boone National Forest, but throughout the eastern United States.

Heather Alexander, who participated in the upland oak research project, was a doctoral candidate at the University of Kentucky at the time. She has examined some of the ways the red maple gets the upper hand in oak forests. "Red maple behaves like a weed," says Alexander. "It is a native invasive." When naturally ignited wildfire or fire applied by Native Americans were still a part of the forest ecology, "fire was the force that kept red maple in its place," she says. "Once you free it from its natural competitors, it goes haywire."

Red maple is also a water and nutrient "hog." For two years, between 2006 and 2008, Alexander investigated the potential effects of a shift from the chestnut oak and scarlet oak to red maple on the distribution of water and nutrients. During a precipitation event, there are primarily two ways that water and nutrients such as nitrogen reach the ground. Rain either drips through the canopy—throughfall—or is funneled down the stem of the trunk—stemfall—and deposited close to the roots. Alexander collected water and soil samples beneath the canopy. She found that the quantity of throughfall water was up to 9 percent lower under maple than under oaks, but stemflow under red maple was two to three times greater due to the smooth bark of the maple compared to the grooved bark of oak. Not only does this give red maple an edge in water utilization, but stemflow also delivers nutrients and promotes nitrogen cycling in underlying soils, likely giving red maple a nutrient boost.

Prolific sprouting of red maple after a burn. Credit: Heather Alexander.

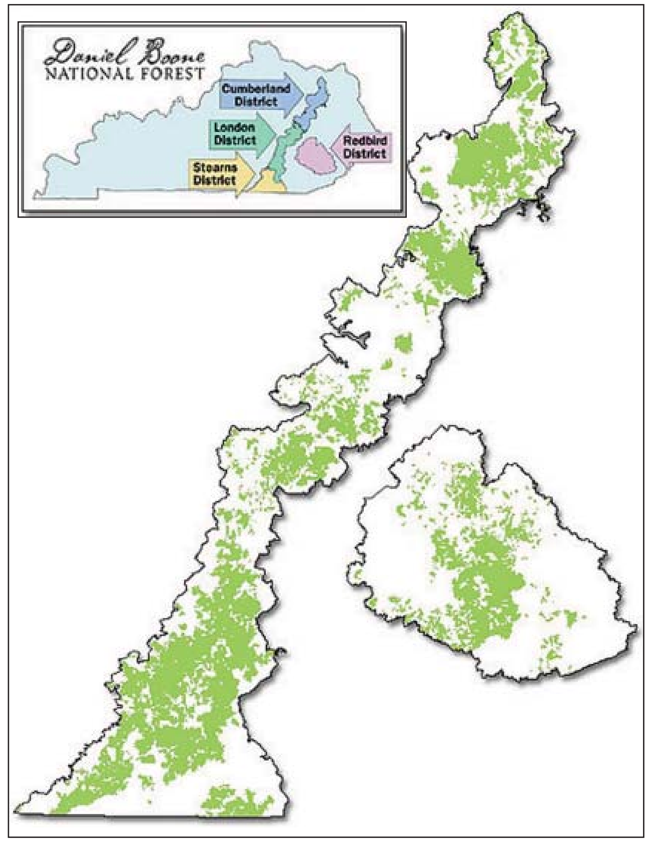
Red maple Scarlet oak Chestnut oak

One two-inch rainfall event generated nearly 38 gallons from a red maple tree compared to 22 and five gallons from scarlet and chestnut oak, respectively. Credit: Heather Alexander.

Though trees are not generally considered a migratory species, they do slowly move in response to changes in climate, hydrology, and soil chemistry. A hotter, and perhaps drier, climate could theoretically favor oaks, which have an extensive root system that helps them survive drought. Red maple, however, may be able to "outsmart" the oaks in this and other ways.

Good fire, bad fire

The Daniel Boone National Forest, originally named the Cumberland National Forest, was formed with an initial purchase of nearly 340,000 acres (137,600 hectares) of private land. Unlike federal lands in most of the western United States, which were never in private ownership, portions of the Daniel Boone have been acquired since its establishment by additional purchases within the Proclamation Boundary, which today delimits an area of about 2,100,000 acres (850,000 hectares), of which approximately one third is now owned by the Forest Service. This has resulted in a checkerboard pattern of private and public ownership which presents a challenge for Forest Service managers, says Nancy J. Ross, a natural resources staff officer with the Daniel Boone. An even greater challenge is the use of fire as a cultural tradition in much of Appalachia. "The early settlers learned from Native Americans the benefits of burning the woods," says Ross. In modern times, however, that practice is a felony: Arson.



Map of Daniel Boone National Forest showing proclamation boundary and lands actually owned by the Forest Service, as of March 15, 2006. Inset map shows ranger districts. Credit: Forest Service Lands Staff.

The Forest Service estimates that of the average 7,000 acres (2,800 hectares) of the Daniel Boone burned each year by wildfire, 80 percent are deliberately set. Because of this cultural tradition and the mixture of public and private land ownership, Daniel Boone National Forest personnel have to carefully craft their message concerning the place of prescribed fire within the forest. "It can be difficult to talk about good and bad fire," says Ross. "We try to explain to the public how carefully we plan prescribed burning and the safety concerns of an unplanned fire." Those issues include smoke and threats to public safety and structures.

Even though severe fire may at times benefit the forest, many people, including some foresters, do not like the idea of killing mature trees. "The mosaic of patterns that burn hotter or cooler or not at all, such as in the riparian zone, is a natural occurrence and should be what we are trying to achieve," says Ross.

Capitalizing on natural disturbance

In February 2003, an ice storm struck northeastern Kentucky from Lexington east to the northernmost section of the Cumberland Ranger District. The event, primarily a canopy disturbance affecting 20,000 acres (8,000 hectares), did not have a significant effect on the fire study sites. Jeffrey Lewis, a silviculture and planning forester with the Cumberland Ranger District and federal cooperator on the JFSP project, saw an opportunity to examine the effects of this natural, canopy-opening disturbance on oak regeneration. Immediately, with initial support from the Forest Service's Southern Research Station, he began an assessment of the degree of damage to determine the response of oak after the storm, which removed on average 50 percent of the canopy. "We wanted to know if trees affected by the storm live, stagnate, recover, or die," says Lewis. The study is tracking the initial response and regeneration of oak five and 10 years after the storm. Salvage operations are not being conducted on the study sites. "We wanted to look just at the effects of the storm," says Lewis. "We had little data on how these areas respond to ice or wind storms in the absence of intervention." So far, the findings show that red oak species for the most part don't recover as readily as the white oak species, though chestnut oak grows somewhat faster than other white oaks. "Chestnut oak dominates little canopy openings better than anything else, but we are getting really good growth overall."

Lewis says the oak stands in the Daniel Boone are overcrowded due to the lack of disturbance, absence of fire, and forest density. "The forests are all over stocked, which leads to declines in the health of the stand. Ice damage was more extensive to individual trees than if the stands were less dense."

Legacy of research

If there is any doubt that hope is common currency in the forestry community, consider that efforts are also underway to re-establish the once blighted chestnut (*Castanea dentata*) to Appalachian forests. "Today's generation of oak is the first that has not had chestnut as a major component of the ecosystem," says Lewis. "The oak was always holding hands with the chestnut." In 2010, in research led by the Southern Research Station, experimental plantings of hybrid and pure chestnut on national forests are being extended to the Cumberland District of the Daniel Boone.

Research findings generated through multiple studies in the Daniel Boone over a period of 15 years suggest that restoration of a healthy upland oak ecosystem may require decades to achieve. Is this a reason for despair? Mary Arthur, who takes the long-term view, thinks not. "Each new round of research adds more precise understanding of the life history of oaks and the native species that compete with them," she says. This information provides managers with improved strategies to encourage plant diversity in upland oak communities.

Management Implications

- Further research is needed to determine how, or whether, fire alone can favor oak regeneration over less fire tolerant competitors.
- The best predictor of oak regeneration after removal of overstory is the presence of viable, competitive sources of seed and stump sprouting.
- Fire managers would benefit from improving their ability to apply more-intense fire in a safe manner in some instances.
- The prescribed burns were conducted in early spring. Further studies are needed to determine whether burning in the fall may improve chances for successful oak regeneration.
- Public acceptance by some foresters, resource managers, and the public of extensive harvesting and high severity fire that kills mature trees is low. Further efforts to educate stakeholders on the benefits of fire are needed.

A dense unburned stand on Whittleton Ridge, KY. Credit: Heather Alexander.

Further Information: Publications and Web Resources

Alexander, H.D., and M.A. Arthur. 2009. Foliar morphology and chemistry of upland oaks, red maple, and sassafras seedlings in response to single and repeated prescribed fires. Canadian Journal of Forest Research 39, 740-754.

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Scientist Profiles

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