# Severity of Fire Influences the Competitiveness of Different Tree Species

*by Scott G. Culbert, Mary A. Arthur, Jacob J. Muller, Claudia A. Cotton*

In eastern U.S. forests, including those of Kentucky, oak (***Quercus spp.***) and yellow pine species (i.e. shortleaf pine, pitch pine, and Virginia pine) have historically dominated upland forest communities but are now experiencing challenges with regenerating and growing back into canopy-sized trees. These challenges largely stem from "Smokey the Bear" era fire-suppression policies that successfully eliminated nearly all burning in these forests from the early 1900s until about 1980. Prior to this, frequent burning caused forests to be less dense with more open growing conditions, which allowed for oaks and pines that thrive in high-light environments to acquire light and grow. Many of these oaks and pines also have adaptations to withstand fire—thick and rough bark that protects against fire damage, rapidly healing fire wounds, leaf litter that is more flammable, and the ability to resprout from roots—that allowed them to persist when fire would frequently burn through a forest. With fire suppression, species that lack these adaptations were no longer being killed by frequent burning and grew into increasingly dense forest midstories. These species include red maple (***Acer rubrum***), American beech (***Fagus grandifolia***), and yellow-poplar (***Liriodendron tulipifera***), among others. Now these species, which are also more shade-tolerant, tend to dominate forest midstories because they can stand the denser, more shaded conditions that prevent oak and pine seedling growth. If these conditions continue, oak and pine species in forest canopies will eventually be replaced by fire-intolerant species, which would have severe economic and ecological consequences.

Finding solutions to fix these challenges has driven land managers to reintroduce fire into our forests via prescribed burning, which are typically low-severity surface fires. These fires can be beneficial for killing understory maples and stimulating the growth of oak and pine seedlings, but since they are low-severity, they are ineffective at killing larger trees to create the light gaps that oaks and pines need to grow into larger sizes. However, might medium- or high-severity fire, with hotter temperatures and higher flame lengths, have a greater capacity to kill larger trees and create meaningful forest changes that benefit oaks and pines?

An accidental wildfire ignited in 2010 in the Daniel Boone National Forest, Kentucky, provided an opportunity to answer that question by monitoring forest vegetation response over 12 years (Figure 1). Forest

Figure 1. Aerial view of the wildfire that was studied.

communities changed along a gradient of burn severity, with areas that didn't burn at all to areas with nearly 100% mortality of forest vegetation. One year after the fire, there were abundant seedlings and saplings in the burned areas and researchers determined that increasing burn severity did reduce the amount of midstory and canopy-sized trees (Figure 2). By year six, many of those

Figure 2. Initial regrowth in an area that burned at high-severity, one year after the fire.

seedlings and saplings had grown into midstory sizes, but different levels of burn severity affected species differently. With increasing burn severity, the number of oaks and pines that grew into midstory sizes increased, but for fire-intolerant species such as red maple, increased burn severity did not change the rate of growth into midstory sizes. The more open conditions that were created by increasing burn severity, in combination with the growth-stimulating effects of the fire, created an environment that made fire-adapted species more competitive. Unfortunately, higher burn severity was also strongly related to the influx of non-native invasive plant species, particularly Chinese silvergrass (***Miscanthus sinensis***), which was found in 19% of research plots and is known to suppress tree growth, alter litter decomposition rates, and increase flammability.

To see if these results persisted over time, we returned to the same site six years later and found results that were largely similar to previous years. At year 12 post-burn, there was substantial regrowth, with 154% more trees measured than six years before. Similar to year six, we found that the number of fire-intolerant species that grew into larger sizes did not change at different levels of burn severity. We also found that the pine trees that had grown into the midstory at year six were growing larger into sub-canopy sizes by year twelve and were doing so at higher rates in areas with higher burn severity. However, for oak trees, higher burn severity no longer had a relationship with growth into larger sizes, meaning that oak trees grew into larger size classes equally at all levels of burn severity; this was not the case at year six. This is due to the increased midstory density, which creates less open growing conditions. Aside from oaks and pines, when we considered all fire-adapted species together compared to fire-intolerant species, we observed that at low burn severities, fire-intolerant species were significantly more dominant, but at higher burn severities, fire-adapted species became more dominant (Figure 3). The burn severity at which fire-adapted species became more dominant (CBI = ~2.0) is noteworthy, as prescribed fires rarely exceed a CBI value of 1.5. This provides direct evidence that the severities of prescribed fires are not high enough to alter forest conditions in ways that increase the competitiveness of fire-adapted species relative to fire-intolerant species. Unfortunately, we still found that higher burn severity caused greater likelihood of invasive species: Areas with high-severity fires were 34.6 times more likely to have invasive species than low-severity fire (Figure 4). Likewise, Chinese silvergrass was now found on 73% of research plots.

Overall, these results suggest that a single fire with areas of increased severity can provide long-term benefits of altering forest compositions toward fire-adapted species, with yellow pines being able to respond to the fire and grow into sub-canopy sizes within twelve years. To promote oak species growth into larger sizes, it may be necessary to administer a prescribed burn or midstory thinning treatment within six to 12 years following higher-severity fire. However, to safeguard some of the ecosystem benefits of increased burn severity, invasive plant monitoring and control measures must be put into place for several years following any fire, especially one that is high-severity.

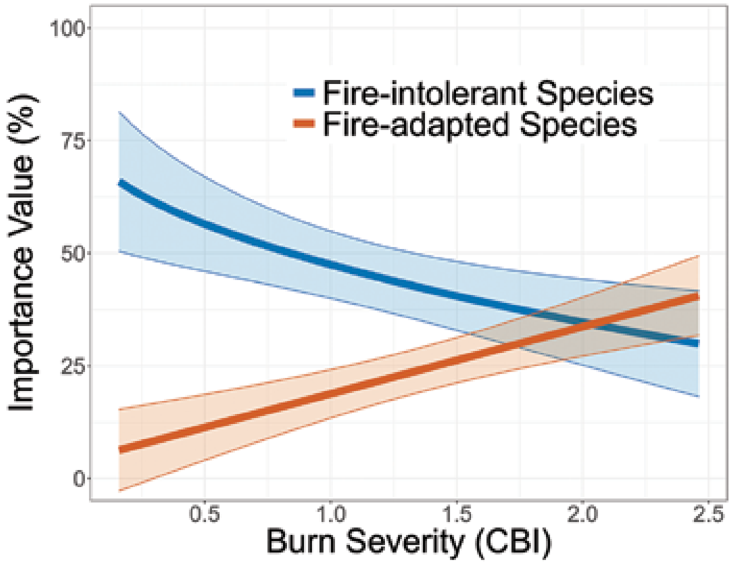


Figure 3. Importance values of fire-adapted and fire-intolerant species across a range of burn severities where low (CBI = 0) represents unburned and high (CBI = 2.5) represents near 100% mortality of vegetation. Importance is synonymous with dominance and is a combination of the number of trees and their size.

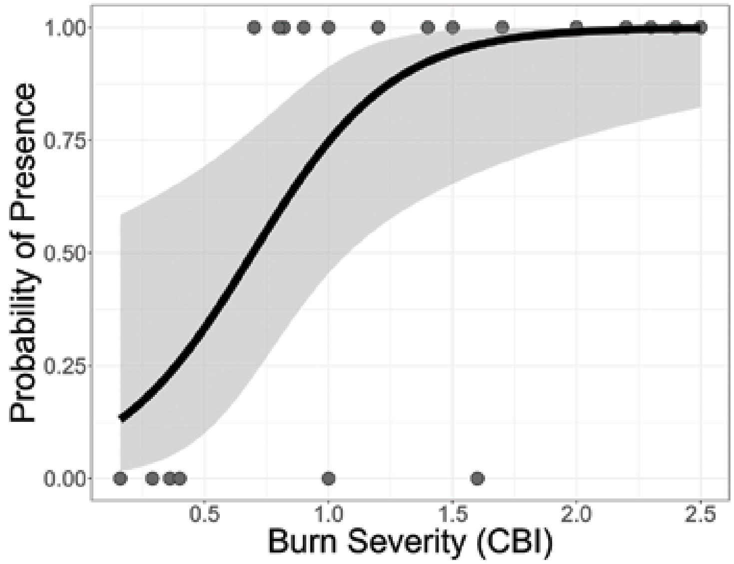


Figure 4. The presence and absence of invasive species at different levels of burn severity, where low (CBI = 0) represents unburned and high (CBI = 2.5) represents near 100% mortality of vegetation.


About the authors: **Scott G. Culbert**, Department of Forestry and Natural Resources, University of Kentucky, Thomas Poe Cooper Building, Lexington, KY 40546-0073

**Mary Arthur**, Ph.D., Professor Emeritus - Forest Ecology, UK Department of Forestry and Natural Resources, Email: mary.arthur@uky.edu

**Jacob Muller**, Ph.D., Assistant Professor of Hardwood Silviculture Extension and Climate Adaptation Specialist, Department of Forestry and Natural Resources, University of Kentucky, Thomas Poe Cooper Building, Lexington, KY 40546-0073. He is also an editor of the Kentucky Woodlands Magazine. Email: jacob.muller@uky.edu

**Claudia A. Cotton**, Ph.D., Forest Soil Scientist, USDA Forest Service, Daniel Boone National Forest, 1700 Bypass Rd., Winchester, KY 40391