Synthesizing the history of fire and oak development in the Appalachian Region

Adam T. Naito[1], Charles W. Lafon[2], William T. Flatley[3], Sally P. Horn[4], Thomas A. Waldrop[5]

[1]School of Natural Resources and the Environment, University of Arizona; [2]Department of Geography, Texas A&M University; [3]Department of Geography, University of Central Arkansas; [4]Department of Geography, University of Tennessee, Knoxville; [5]retired, U.S. Department of Agriculture, Forest Service, Sourthern Research Station

Introduction

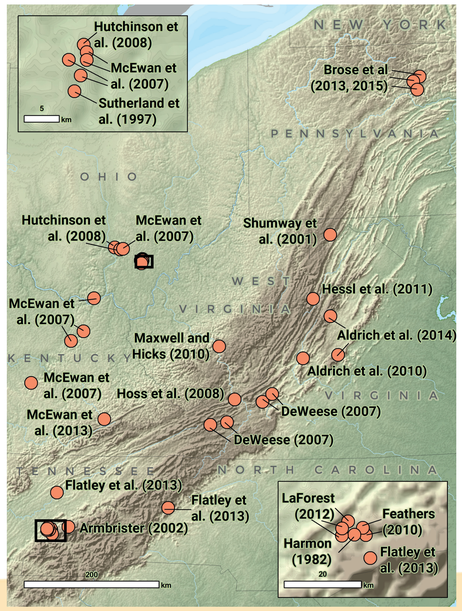
- Declines and ongoing replacement of oak (*Quercus*) and pine (*Pinus*) by mesophytic species in the Appalachian region suggest that vegetation developed under a history of frequent burning prior to the fire-exclusion era (c. 1930). During the pre-exclusion period, frequent, low-severity fires maintained an overstory of fire-adapted oak and pine species while minimizing recruitment of both fire-adapted and fire-sensitive mesophytic species in the understory.

- High-resolution fire scar data, combined with stand age structure analysis, can elucidate how vegetation developed under historical fire regimes, and how vegetation changed under fire exclusion.

- Through the use of statistical software like FHX2 and FHAES, researchers may calculate a variety of statistics regarding fire interval (periods between different fire events). These may include the mean fire interval (MFI), Weibull median interval (WMI), lower exceedance interval (LEI), and upper exceedance interval (UEI). Generally, 75% of all fire intervals between the LEI and UEI. Fire interval periods below the LEI are unusually short, while fire interval periods above the UEI are unusually long.

Landscape in the Blue Ridge Mountains (James River Face Wilderness, Jefferson National Forest) on which the oak-pine mosaic is prevalent.

Study Area



A map of the entire Appalachian region and the locations of the study sites synthesized in this study.

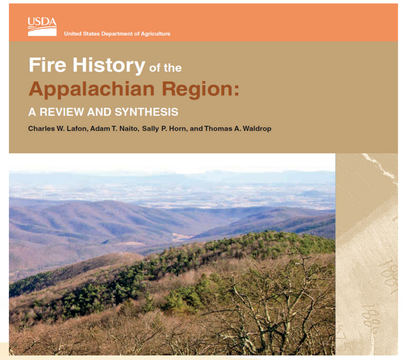
Methods

- As part of a General Technical Report for the US Forest Service, we conducted a synthesis of the literature to examine the role fire has played in vegetation development in the Appalachian region.

- We identified 19 studies representing 40 sites that reported analyses of pre-exclusion fire history in the Appalachian region.

- Our synthesis allowed us to examine historic fire regimes across the Appalachian region and comment on the impact they may have had on vegetation development, particularly as they relate to pine and oak.

Oak-pine mosaic on an Appalachian slope in Jefferson National Forest. Pine stands are visible as the dark patches covering the west-facing slopes of spurs and surrounded by hardwood forest matrix. Pine stands were sampled to learn about fire history on the entire landscape, as well as in the intervening oak stands.



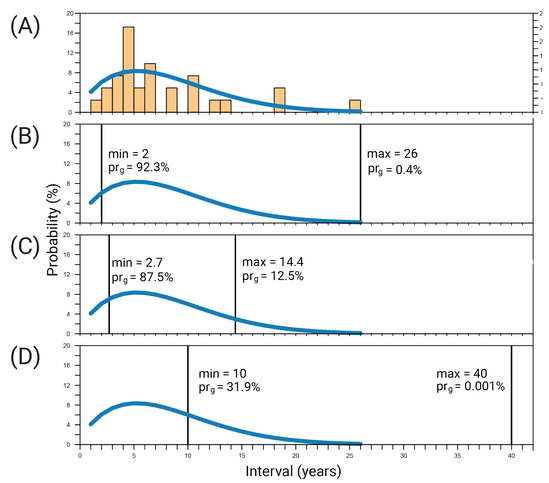
The USFS General Technical Report developed by several of the authors on this poster.

Results

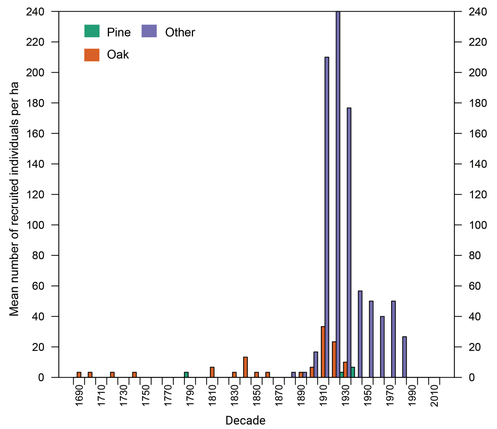
- Composite MFI varies between 1.9 years and 19.5 years across much of the Appalachian Mountains, with an **average of 6.8 years** across all sites.
  - LEI (Lower Exceedance Interval) and UEI (Upper Exceedance Interval), which estimate the bounds within most of fire intervals fell, indicate that about 75% of fire intervals ranged between about 2 and 15 years.
  - However, the occasional longer intervals were likely important ecologically, especially for tree establishment.

- Oak seedling establishment may require an interval of >10 years to enable seedlings to grow large enough to survive subsequent fires. We estimated the probability of any specific interval using the modeled Weibull distribution to determine whether the pre-exclusion regime could have favored oak. We find that roughly one-third of fire intervals exceeded this critical length.

- Age structure analysis suggests that oak and pine readily recruited into the understory during the pre-exclusion area. Recruitment declined significantly under fire exclusion, while mesophytic (other) species became heavily favored.



Weibull distribution of filtered composite fire interval data from Reddish Knob, VA, demonstrating (A) frequency distribution of fire intervals (orange bars) with modeled probability distribution superimposed (blue line), (B) modeled probabilities of fire intervals between the minimum of 2 years and maximum of 26 years, (C) the modeled probabilities of the lower (LEI) and upper (UEI) exceedance intervals, and (D) the modeled probabilities of a 10-year and 40-year fire return interval.



The mean number of all tree species recruited per hecatre per decade in the chestnut oak stands at the Licklog Ridge site in Tennessee (based on data from Flatley et al. 2013). The "other" species include various species aside from oaks and pines. The oaks were established regularly under the regime of frequent burning, whereas the other tree species were primarily recruited during the fire exclusion period (after c. 1910–1930).

Discussion and Implications

- The fire interval statistics reported in these studies—or that we calculated from them—indicate that fires burned frequently across the Appalachian region before the era of fire exclusion.

- The regime of frequent fires appears to have favored oak and pine dominance by killing mesophytic competitors, while the occasional longer interval (>10 years) enabled oak seedlings and sprouts to grow to a fire-resistant size before the next fire. Under the pre-exclusion fire regime, oak could be maintained indefinitely, with young plants replacing those lost in the overstory. Chestnut oak (*Quercus montana*) was especially favored under the historic fire regime, as to some extent were white oak (*Q. alba*), scarlet oak (*Q. coccinea*), and black oak (*Q. velutina*).

- Immediately following fire exclusion, mesophytic species (e.g., red maple, *Acer rubrum*) rapidly recruited and contributed to a more diverse tree assemblage. In time, as fire-adapted oaks disappear from the overstory, these mesophytic understory species will likely assume overstory dominance. This ongoing shift is altering the topographic patterning of forest vegetation across entire landscapes.