# Fire Suppression and Mesophication of Oak Landscapes

**Heather D. Alexander**
**Auburn University**
**6 May 2021**

# This Presentation is the Result of Many Conversations with My Co-Authors

Forum

## Mesophication of Oak Landscapes: Evidence, Knowledge Gaps, and Future Research

*BioScience 2021*

HEATHER D. ALEXANDER, COURTNEY SIEGERT, J. STEPHEN BREWER, JESSE KREYE, MARCUS A. LASHLEY, JENNIFER K. MCDANIEL, ALISON K. PAULSON, HEIDI J. RENNINGER, AND J. MORGAN VARNER

Heather Alexander
Forest &
Fire Ecologist
Auburn

Courtney Siegert
Forest Hydrologist
MS State

Steve Brewer
Plant Ecologist
Ole Miss

Jesse Kreye
Fire Ecologist
Penn State

Marcus Lashley
Wildlife Ecologist
Univ of Florida

Jennifer McDaniel
Forest & Fire
Ecologist
UGA

Alison Paulson
Forest & Fire
Ecologist
UC Davis

Heidi Renninger
Forest Ecophysiologist
MS State

Morgan Varner
Fire Ecologist
Tall Timbers

# Pre-settlement, Oaks Dominated the Eastern U.S.

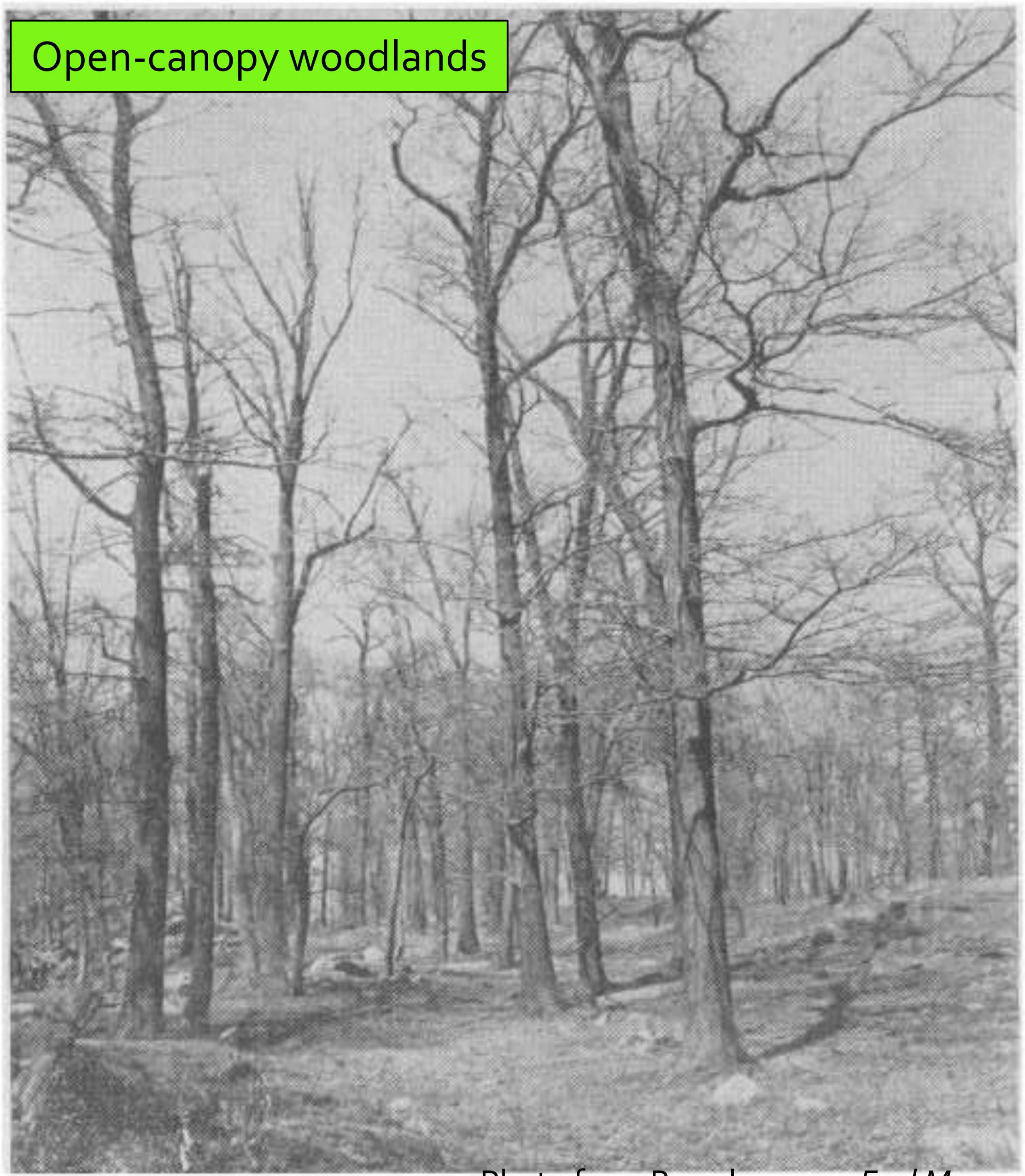
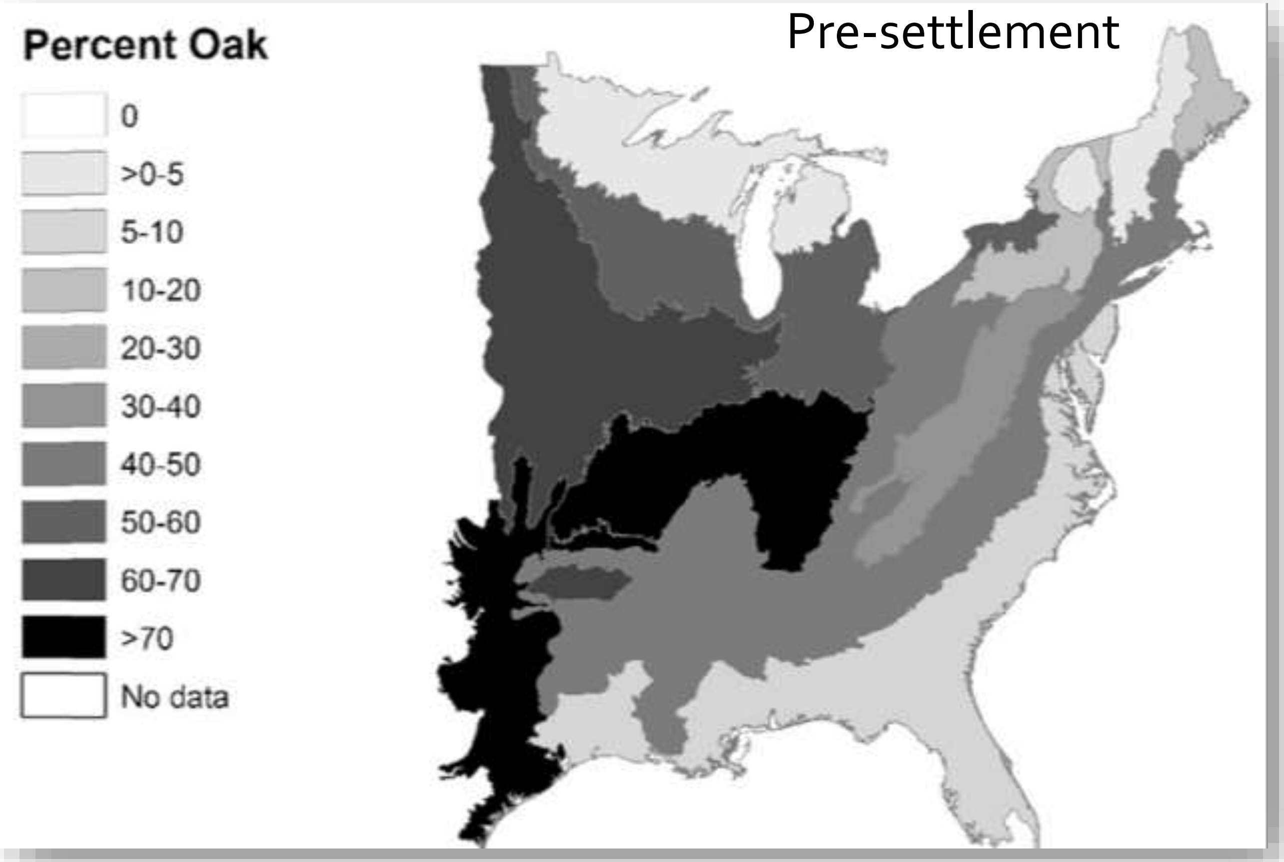


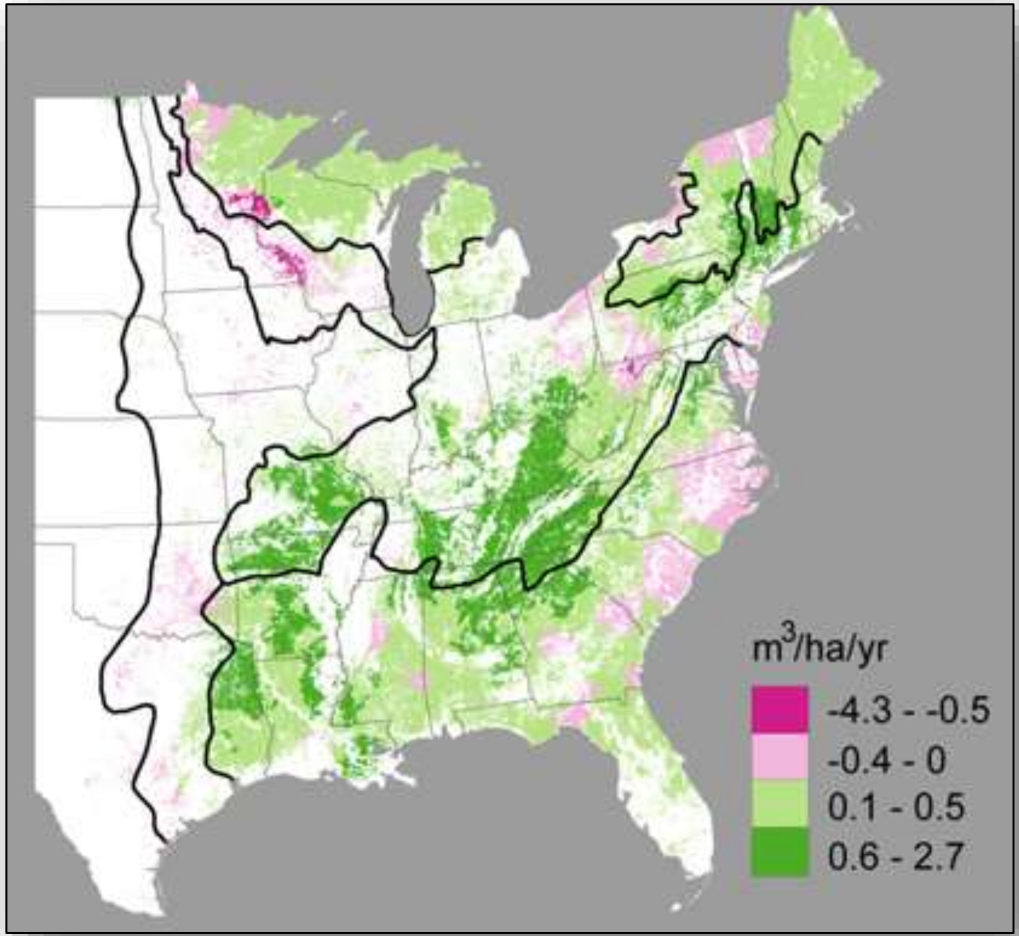

Photo from Bromley 1935, *Ecol Monog*




Hanberry and Nowacki 2016, *Qua Sci Rev*

# Today, Oak Landscapes Still Dominate

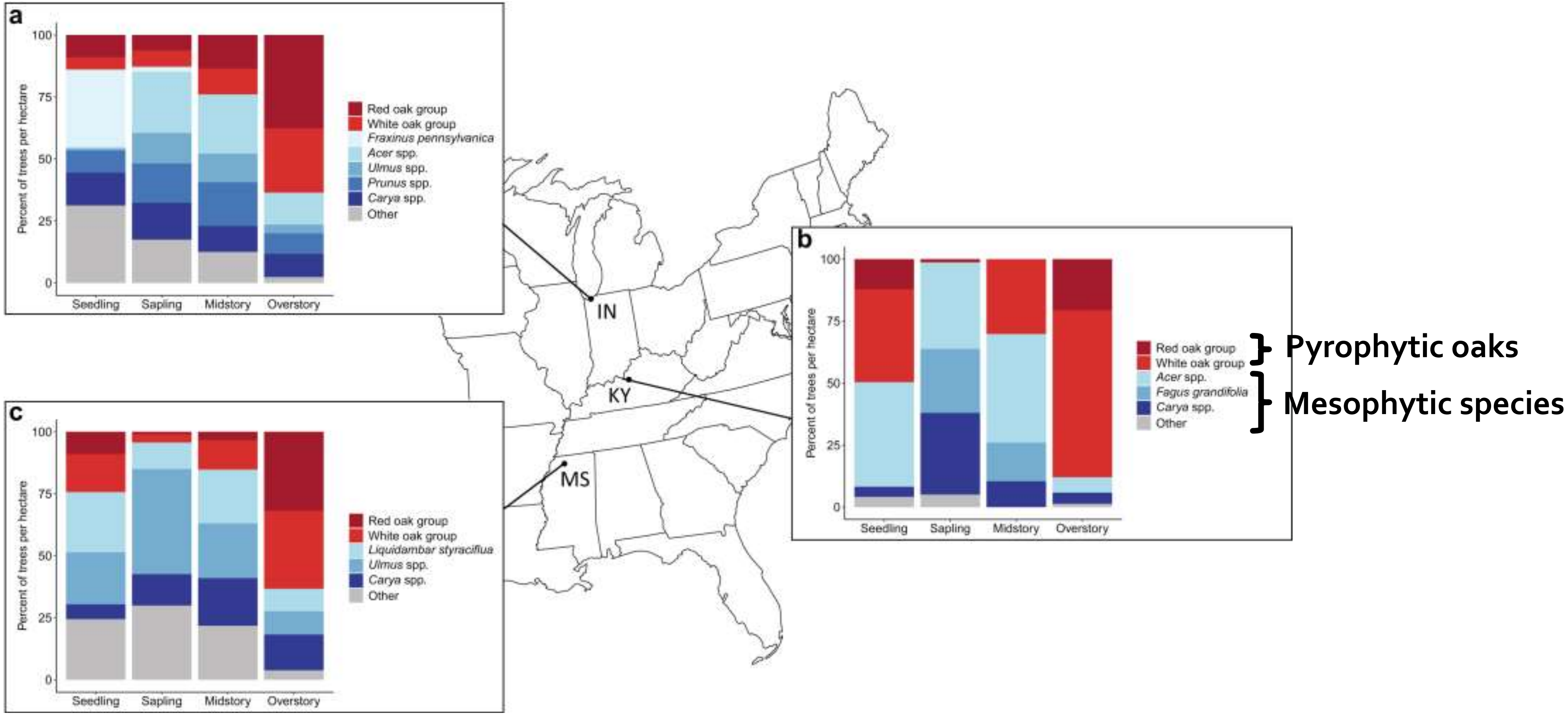
Oak volume change (1980-2005)




Fei et al., 2011, *FEM*


http://www2.ca.uky.edu/forestry/maehrbearky.php

# Shade-Loving, Fire-Sensitive Species Are Replacing Oaks




Alexander, et al., *BioScience* 2021

# Why Does This Shift Matter?

*Management and Conservation Article*

## Forestry Matters: Decline of Oaks Will Impact Wildlife in Hardwood Forests


**WILLIAM J. MCSHEA,**[1] *National Zoological Park, Conservation and Research Center, 1500 Remount Road, Front Royal, VA 22630, USA*

**WILLIAM M. HEALY,** *United States Department of Agriculture Forest Service (Retired), P.O. Box 187, Smithville, WV 26178, USA*

**PATRICK DEVERS,** *Conservation Management Institute, 1900 Kraft Drive, Suite 250, Blacksburg, VA 24061, USA*

**TODD FEARER,** *Department of Fisheries and Wildlife Sciences, Virginia Polytechnic Institute and State University, Cheatum Hall, Blacksburg, VA 24061, USA*

**FRANK H. KOCH,** *Department of Forestry and Environmental Resources, North Carolina State University, 3041 Cornwallis Road, Research Triangle Park, NC 27709, USA*

**DEAN STAUFFER,** *Department of Fisheries and Wildlife Sciences, Virginia Polytechnic Institute and State University, Cheatum Hall, Blacksburg, VA 24061, USA*

**JEFF WALDON,** *Conservation Management Institute, 1900 Kraft Drive, Suite 250, Blacksburg, VA 24061, USA*


*J. of Wild Mgmt* 2005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## Open forest ecosystems: An excluded state


Brice B. Hanberry[a,*], Don C. Bragg[b], Heather D. Alexander[c]

[a] USDA Forest Service, Rocky Mountain Research Station, 8221 Mt. Rushmore Road, Rapid City, SD 57702, United States
[b] USDA Forest Service, Southern Research Station, P.O. Box 3516 UAM, Monticello, AR 71656, United States
[c] Department of Forestry, Forest and Wildlife Research Center, 775 Stone Blvd., Mississippi State University, Mississippi State, MS 39762, United States


## Bourbon's Effort to Sustain White Oak Necessary for Future

By SYDNI ANDERSON • JUN 8, 2017

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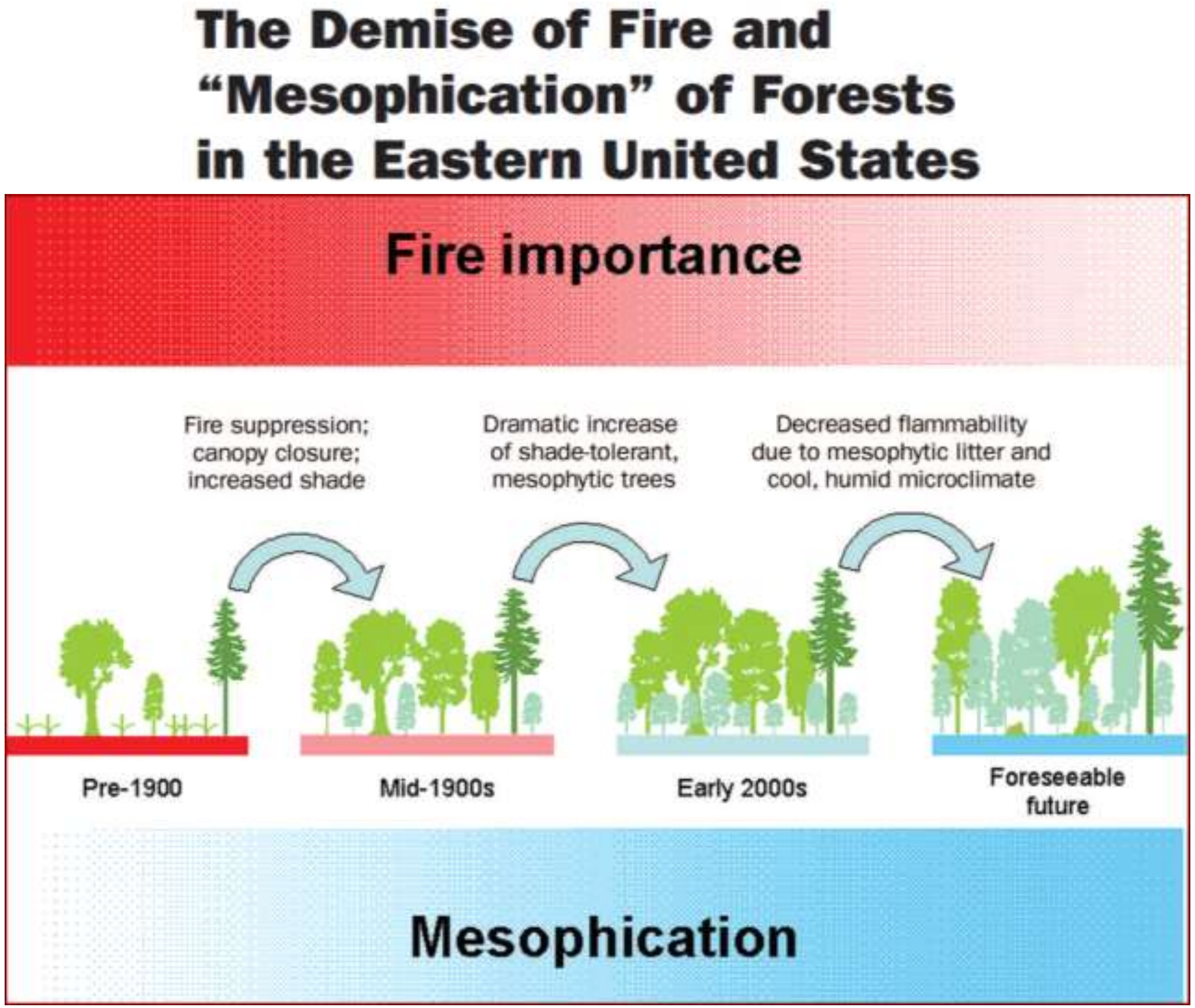
A stave company building a mill in Marshall County is working to sustainably harvest white oak.

White oak is native to the eastern U.S. - including Kentucky - and is not threatened as a species. Bourbon barrels are commonly made of white oak because the wood is watertight and adds flavor.

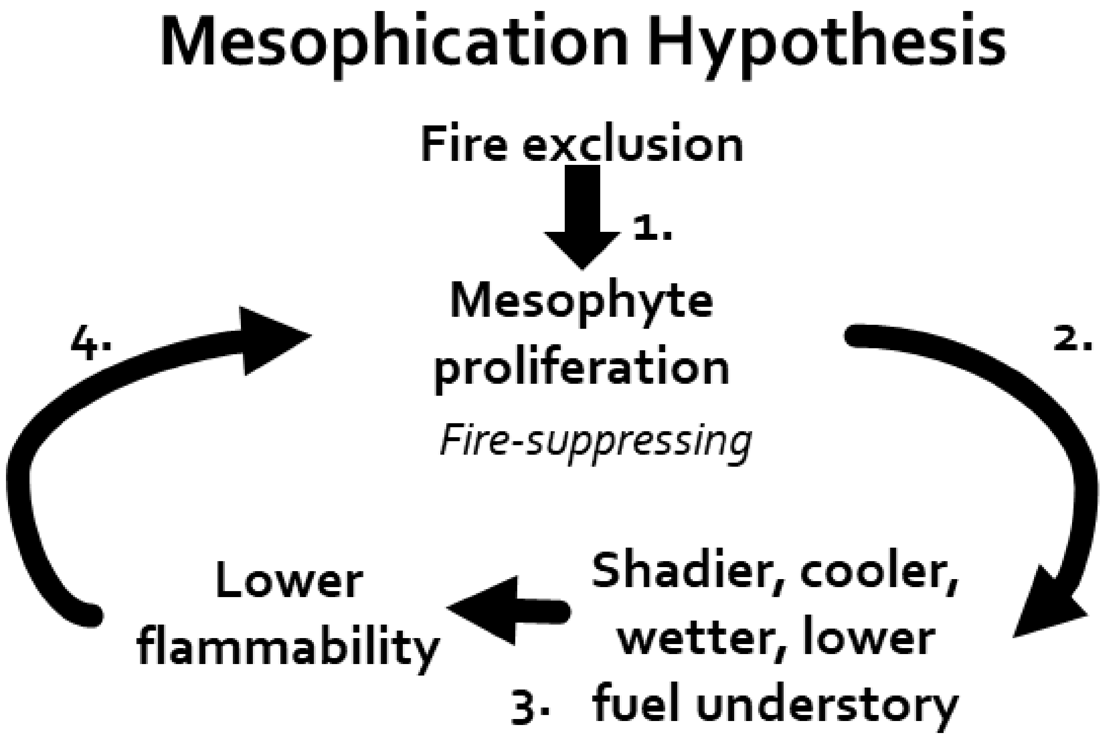
http://wkms.org/post/bourbons-effort-sustain-white-oak-necessary-future

# Can Mesophication Explain Why This Shift Is Happening?




Nowacki and Abrams 2008, *BioScience*

# A Step-By-Step Look at the Mesophication Hypothesis

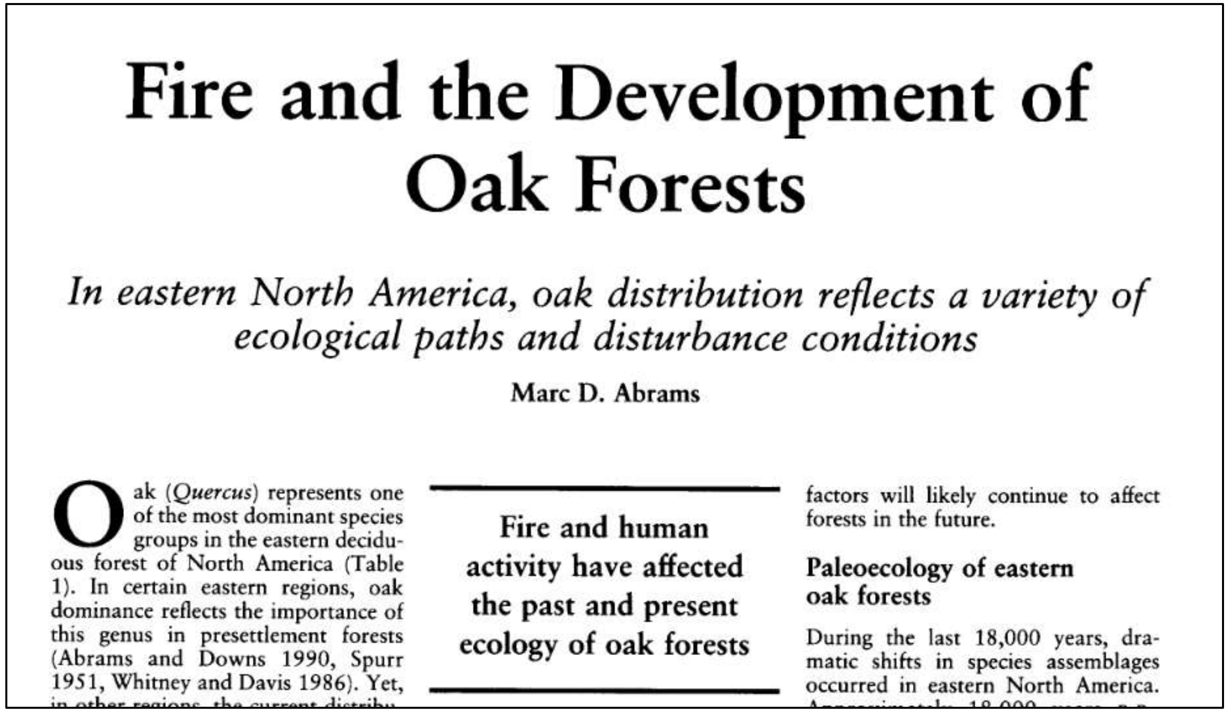



**Important to Note:**

- Mesophication is more than compositional shifts (that's just Phase 1)
- It's a positive feedback cycle where mesophytes perpetuate conditions that foster their continued proliferation over that of pyrophytic species (Phases 2-4)

Alexander, et al., *BioScience* 2021

# Phase 1: Fire exclusion, mesophyte spread, and declining oak dominance



# Fire and the Development of Oak Forests

*In eastern North America, oak distribution reflects a variety of ecological paths and disturbance conditions*

Marc D. Abrams

Oak (*Quercus*) represents one of the most dominant species groups in the eastern deciduous forest of North America (Table 1). In certain eastern regions, oak dominance reflects the importance of this genus in presettlement forests (Abrams and Downs 1990, Spurr 1951, Whitney and Davis 1986). Yet,

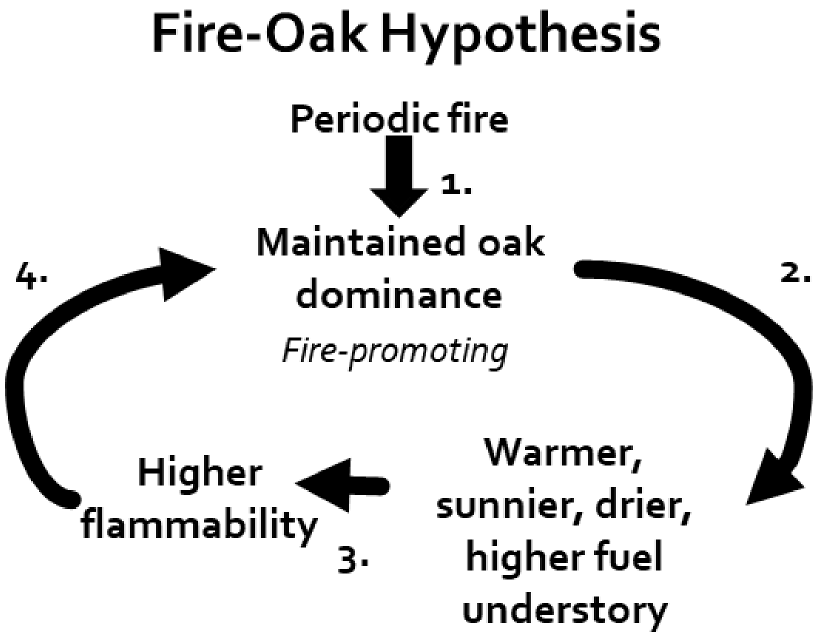
**Fire and human activity have affected the past and present ecology of oak forests**

factors will likely continue to affect forests in the future.

**Paleoecology of eastern oak forests**

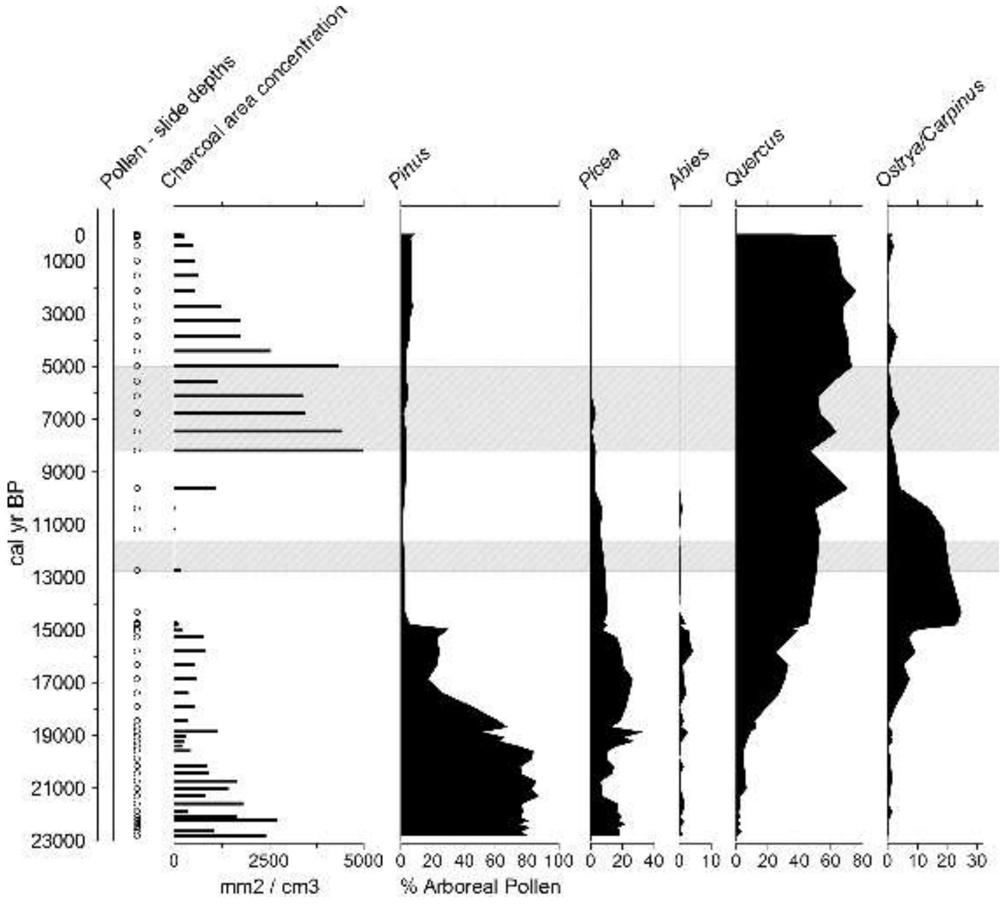
During the last 18,000 years, dramatic shifts in species assemblages occurred in eastern North America.

Abrams 1992, *BioScience*.



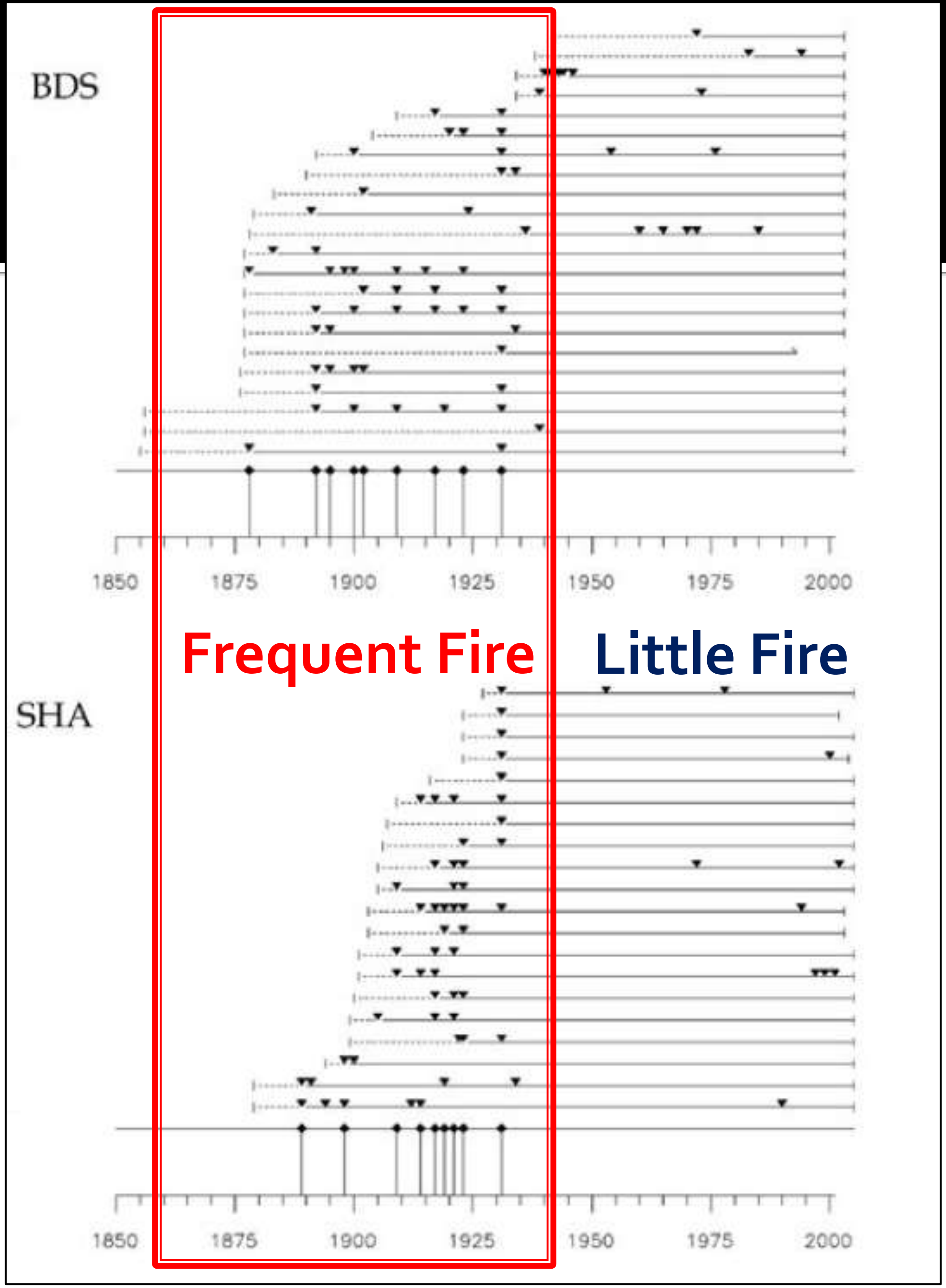

Alexander, et al., *BioScience* 2021

# Paleorecord & Oak Adaptations to Fire



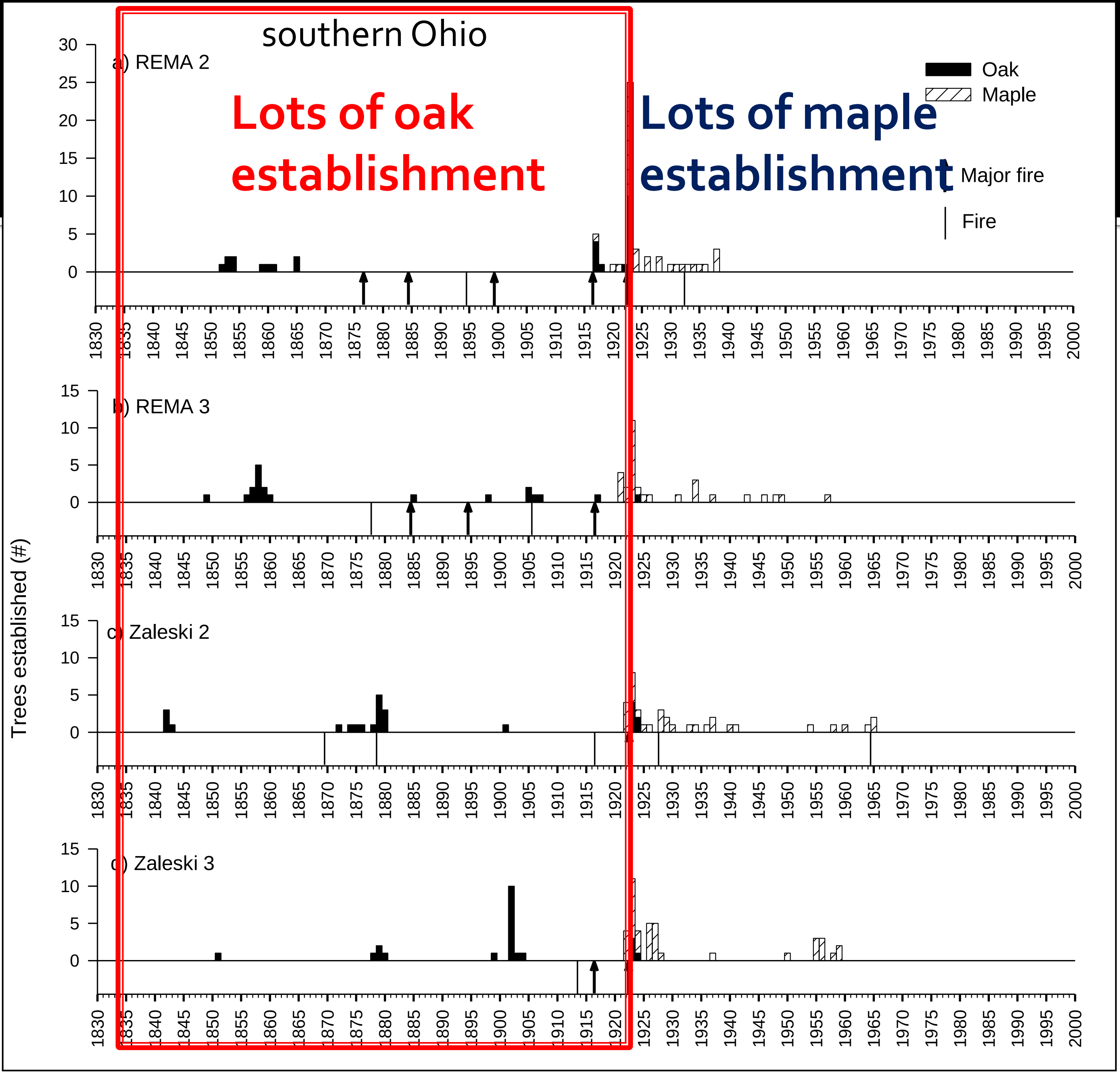

Ballard et al., 2017, *Palynology*

# Fire Scar Analyses


McEwan et al. 2007, *J of Veg Sci*

# Tree Establishment Dates




Hutchinson et al. 2008, *FEM*

# Historical Accounts

- "On one subject, all are in accord and that is the observation that the original forest was, in most places, extremely open and parklike, due to the universal factor of fire, fostered by the original inhabitants to facilitate travel and hunting." – Bromley, 1935, *Ecol Monogr*

To quote from Thomas Morton[3] (1632), "the Salvages are accustomed to set fire of the country in all places where they come; and to burn it, twize a yeare, vixe, at the Spring, and at the fall of the leafe. The reason that moves them to do so, is because it would be otherwise so overgrown with underweedes[4] that it would be all a copice wood, and the people could not be able in any wise to passe through the country out of a beaten path. . . . The burning of the grasse destroyes the underwoods, and so scorcheth the elder trees, that it shrinks them, and hinders their growth very much: So that hee that will look to finde large trees, and good tymber, must not depend upon the help of a woodden prospect to find them on the upland ground; but must seeke for them . . . in the lower grounds where the grounds are wett when the country is fired. . . . For when the fire is once kindled, it dilates and spreads itself against as with the winde; burning continually night and day, until a shower of raine falls to quench it. And this custome of firing the country is the means to make it passable, and by that meanes the trees growe here and there as in our parks: and makes the country very beautifull, and commodius."

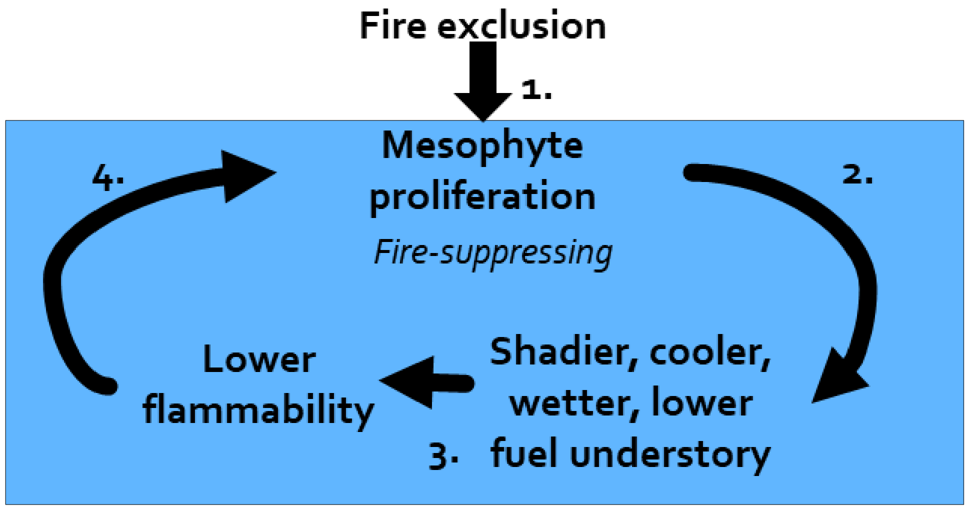
# Lots of Other Things That Could Have Contributed to Mesophication

- Wet, humid climate with reduced droughts over last century
  - (McEwan et al. 2011; Pederson et al. 2013, 2015; Kutta and Hubbart 2018)
- Altered herbivore pressure
  - Increased deer browse (Thomas-Van Gundy et al. 2014, McWilliams et al. 2018, Kelly 2019)
  - Loss of herbivory from wood bison and eastern elk (Hanberry 2019; Hanberry et al. 2020, Mueller et al. 2020)
- Loss of passenger pigeons and canopy disturbances/fuel inputs (Ellsworth and McComb 2003)
- Loss of highly flammable American chestnut (Kane et al. 2018)
- Increased nitrogen deposition that favors mesophytes (Thomas et al. 2010)

# Successfully Managing for Upland Oaks TODAY…

- Depends <u>on current-day limitations to fire</u>, which may hinge on vegetation-fire feedback loops that act to promote or suppress fire (i.e., phases 2-4 of the mesophication hypothesis)

**Mesophication Hypothesis**



# Fire Exclusion Clearly Important For Oak Regeneration BUT…

- Lots of other things going on
- Not as easy as simply returning fire to the landscape

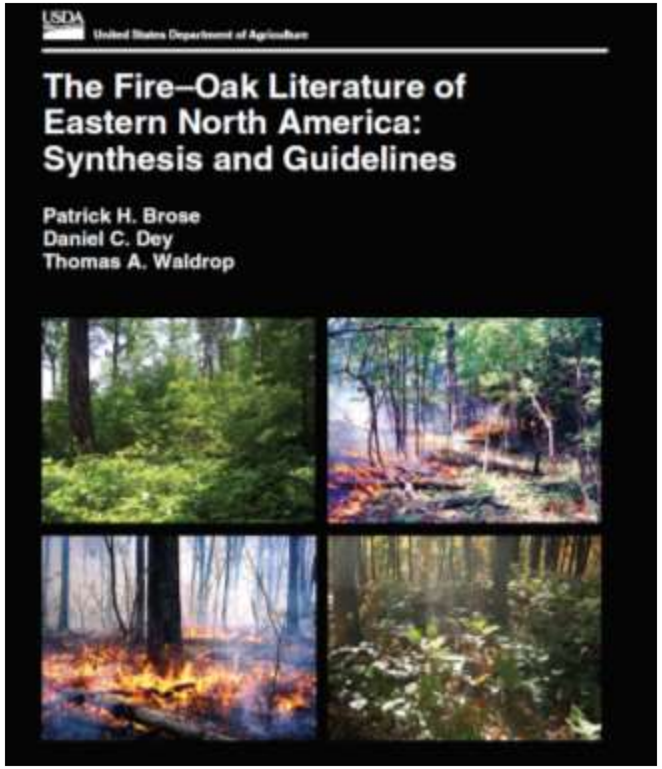


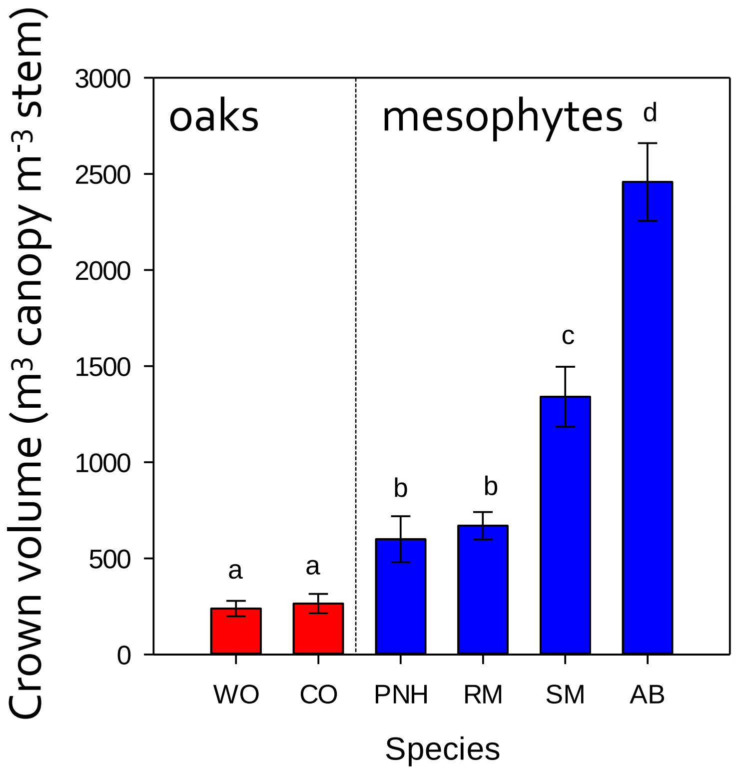

Table 5.—Distribution of prescribed fire projects conducted in mature oak forests by the number of burns and the effect on oak regeneration process. Note the trend of increasingly positive effects on oak as the number of fires increase from one to more than two.

| | Number of Fires | | | |
|---|---|---|---|---|
| Effect on Oak | Single (1) | Dual (2) | Multiple (>2) | Total |
| Positive | 0 | 6 | 5 | 11 |
| Ambiguous | 4 | 4 | 1 | 9 |
| Negative | 7 | 2 | 2 | 11 |
| Total | 11 | 12 | 8 | 31 |

2014; https://www.fs.fed.us/nrs/pubs/gtr/gtr_nrs135.pdf

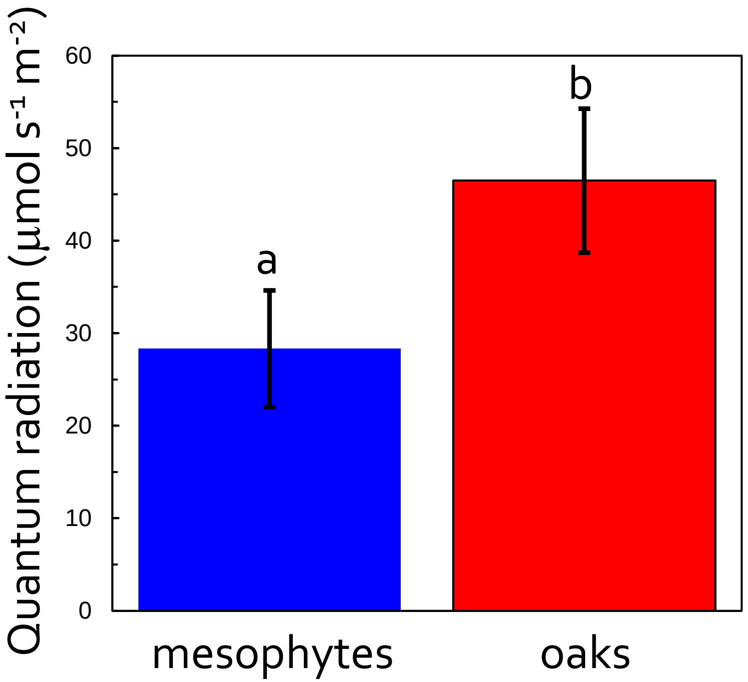
# Phase 2: Mesophytes Create Shady, Cool, Humid Understories with High Fuel Moisture and Low Fuel Loads

# Mesophytes Have Denser Crowns That Decrease Understory Light




Oak: shallow, narrow crown

Mesophyte: wide, spreading crown




Babl, et al, 2020, *FEM*

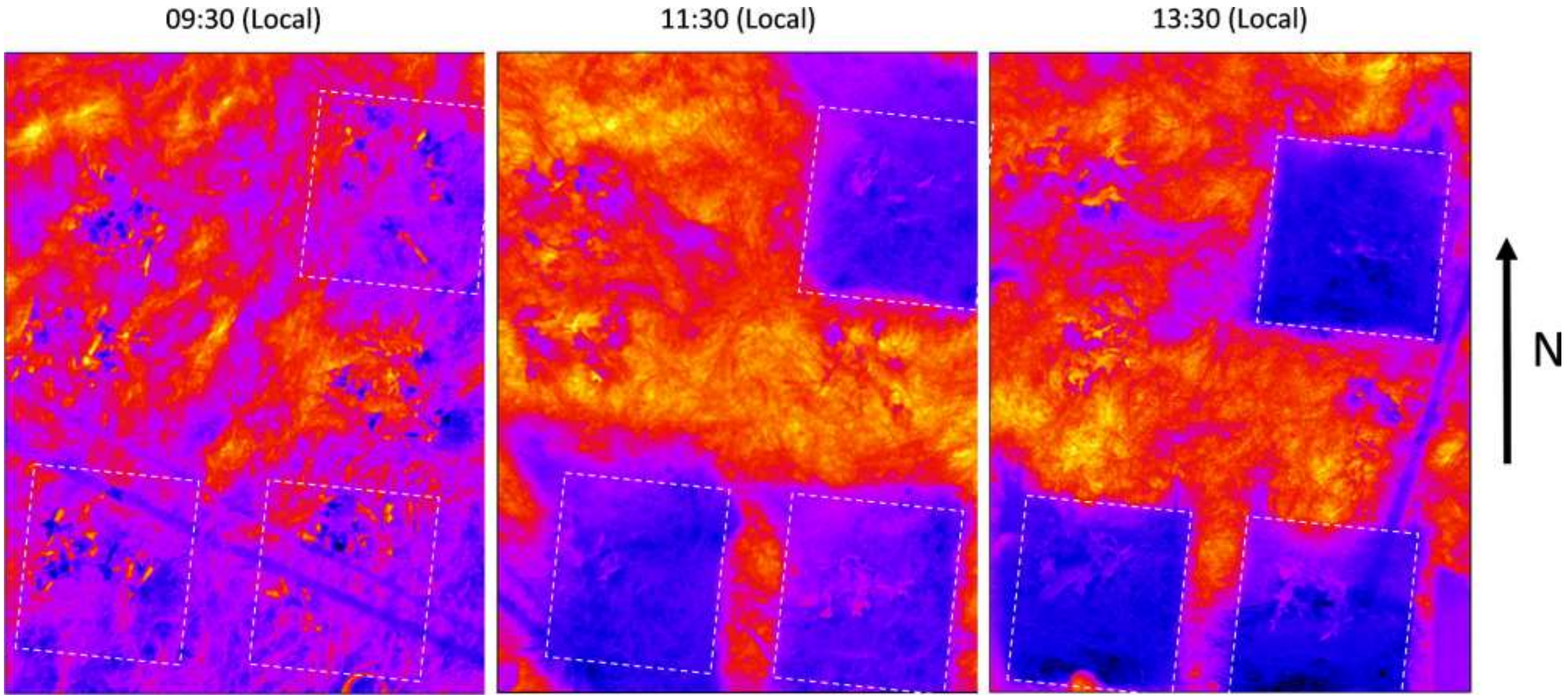
Error bars ± SE; different letters denote significant differences ($p < 0.05$)

Siegert, Alexander, et al., Unpubl Data

# This Decrease in Light Reduces Fuel Temperature

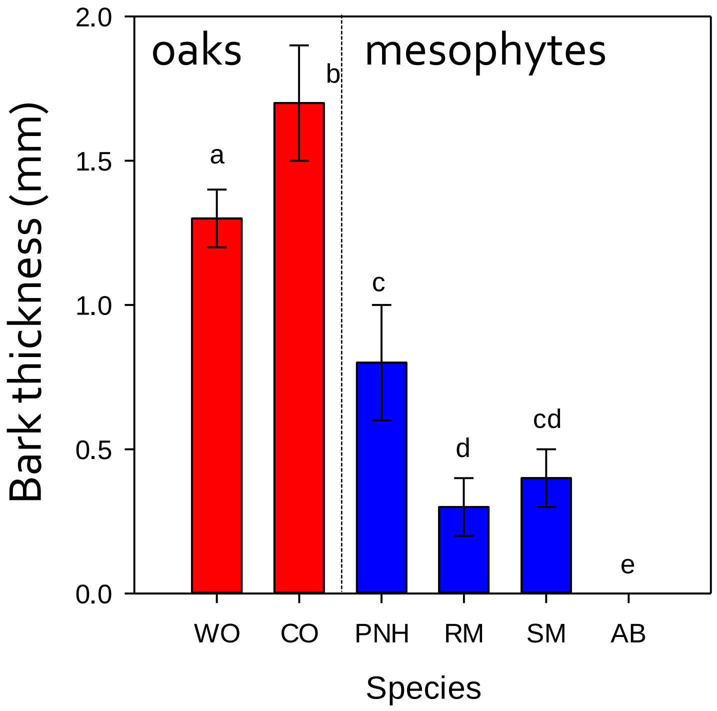
Kreye, et al, 2018, *CJFR*

# Increased Shade Decreases Fuel Temperature



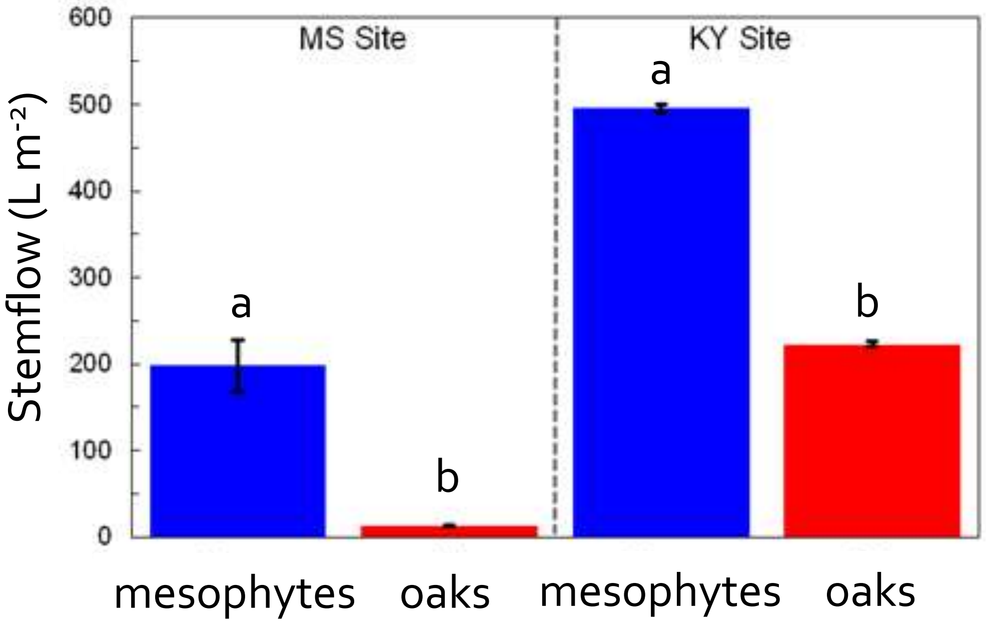

Kreye, et al, 2018, *CJFR*

# Mesophytes Often Have Thinner, Smoother Bark That Generates More Stemflow




Oak:
thick, rough bark

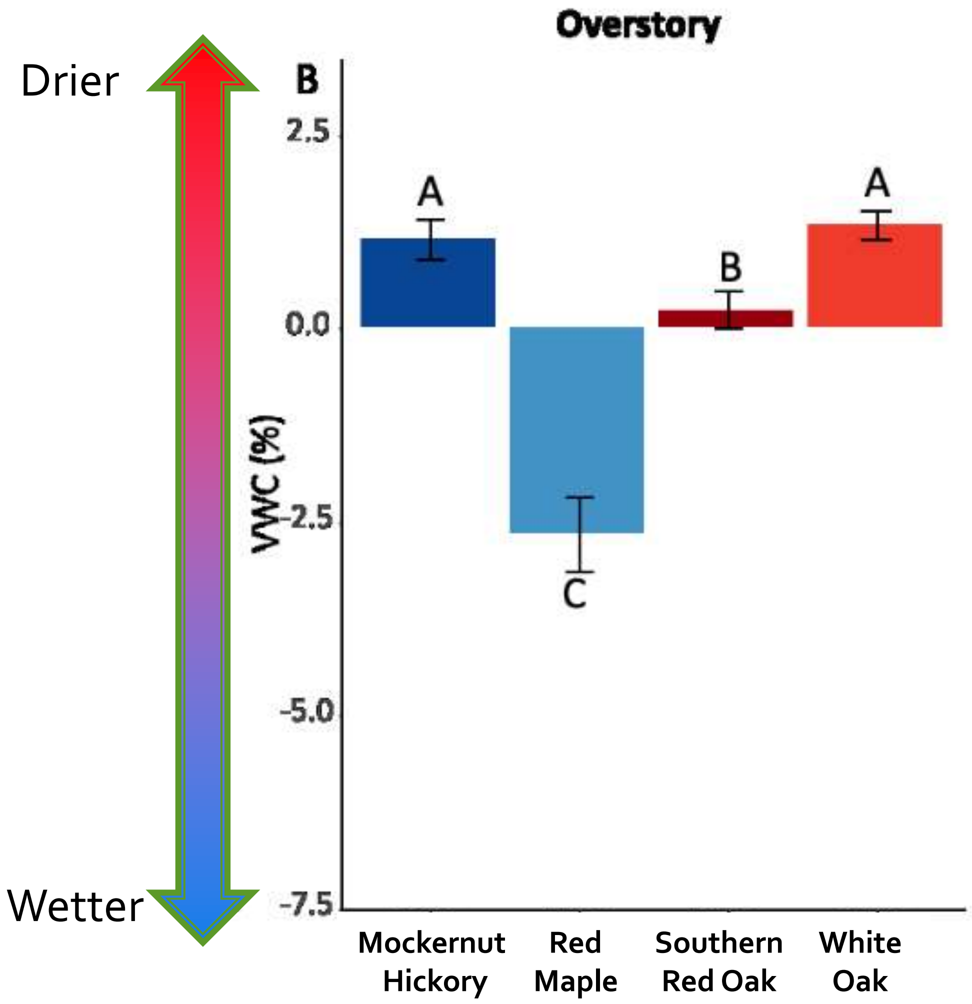
Mesophyte:
thin, smooth bark




Babl, et al, 2020, *FEM*
Error bars ± SE; different letters denote significant differences ($p < 0.05$)

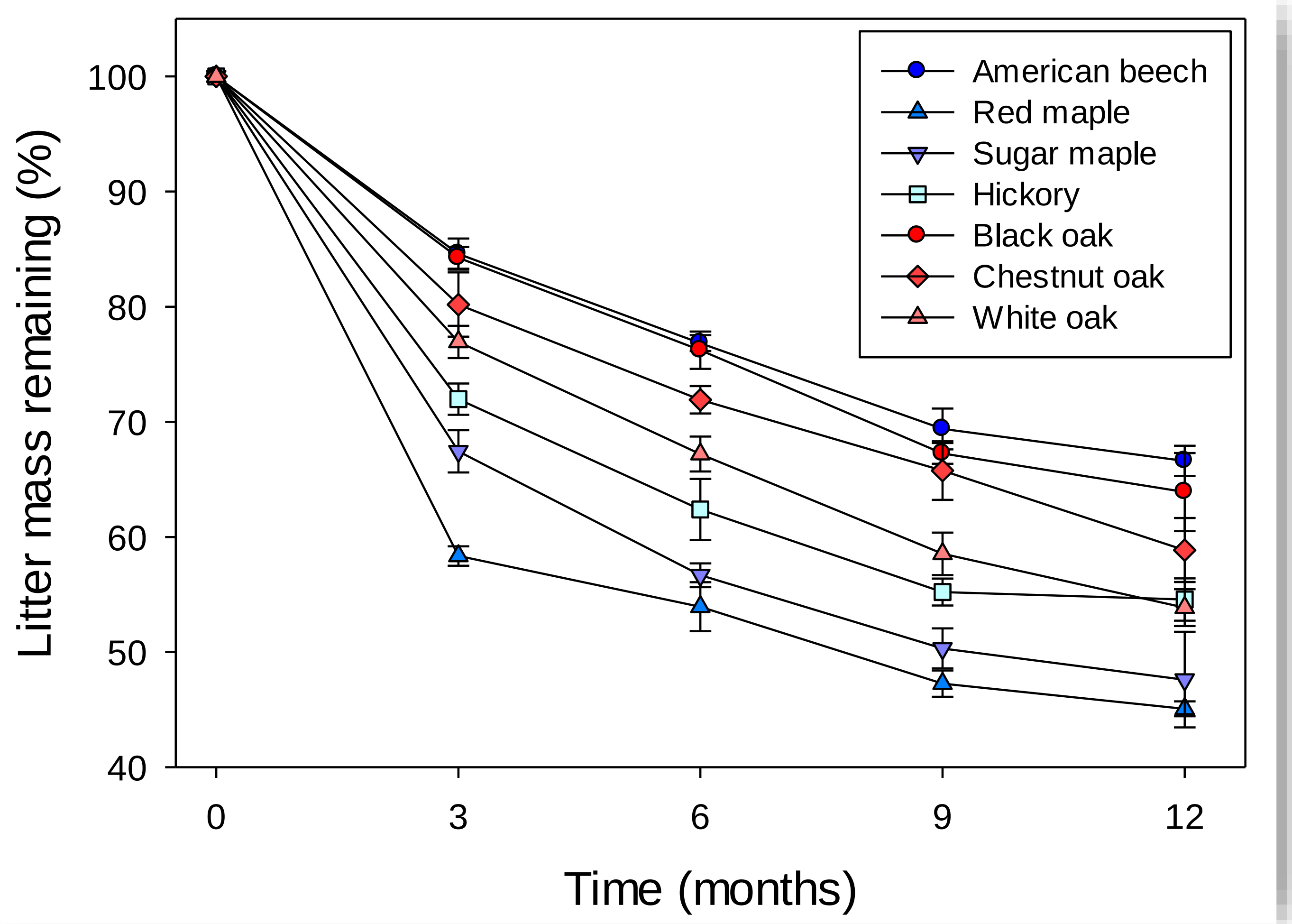
MS = Siegert, Unpubl Data
KY = Alexander and Arthur, 2010, *CJFR*

# More Stemflow Can Increase Soil Moisture Near Mesophytes




Drotar, Siegert, Alexander, Varner, In Prep

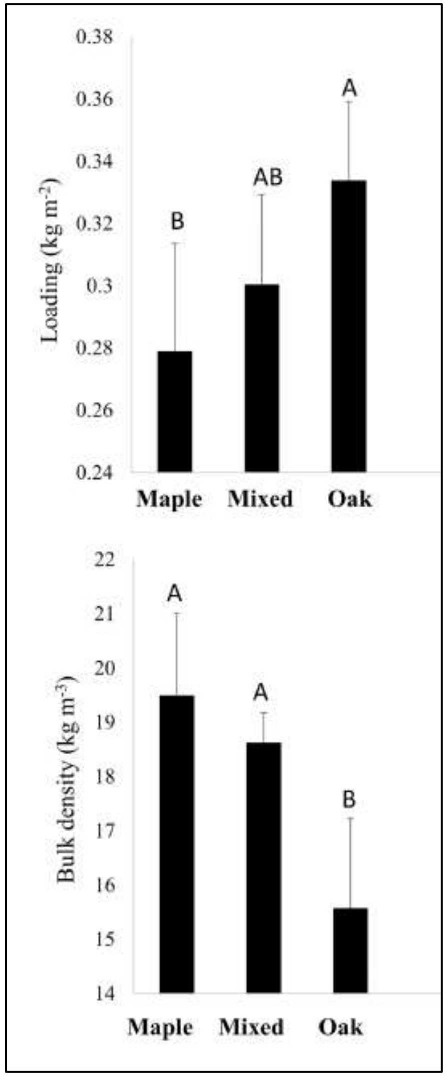
# Mesophyte Leaf Litter Often Decomposes Faster Than Oak Litter

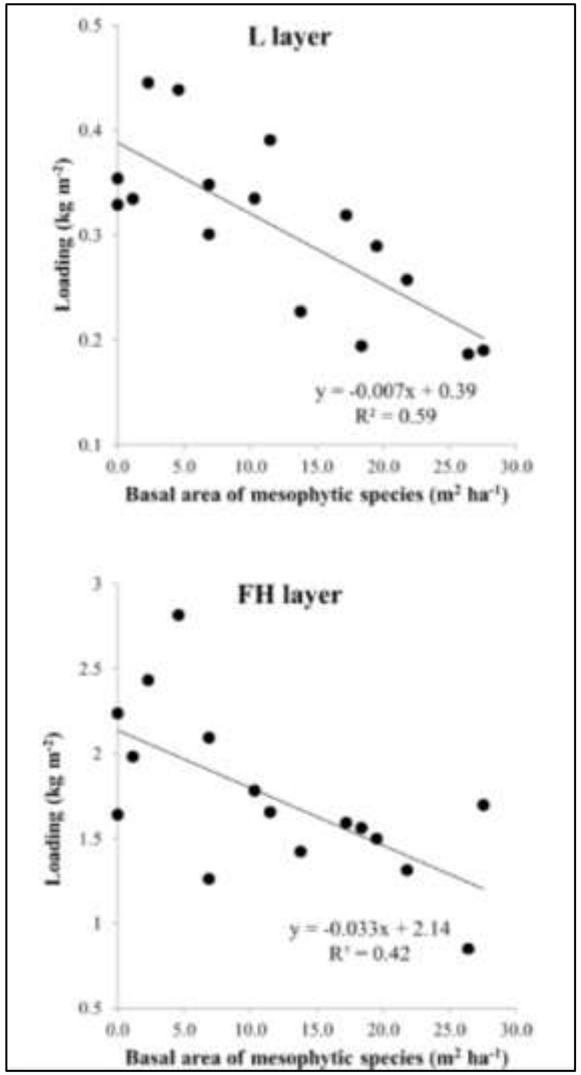



A switch from oak to maple dominance could decrease fuel loads by 400 kg/ha/yr

Babl, Alexander, Nation, et al, *In Prep*

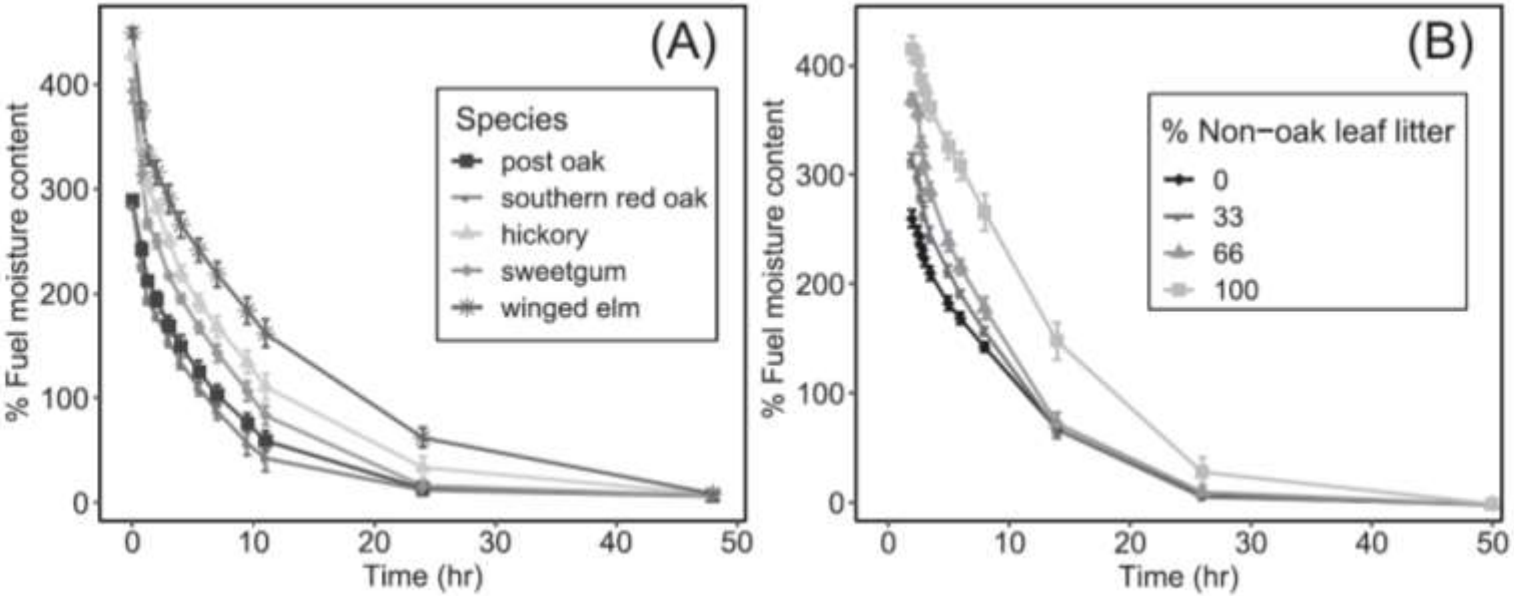
# Fuel Loads Decline with Increased Mesophyte Contribution to Stand Basal Area




Dickinson, et al. 2016, *PLOS One*

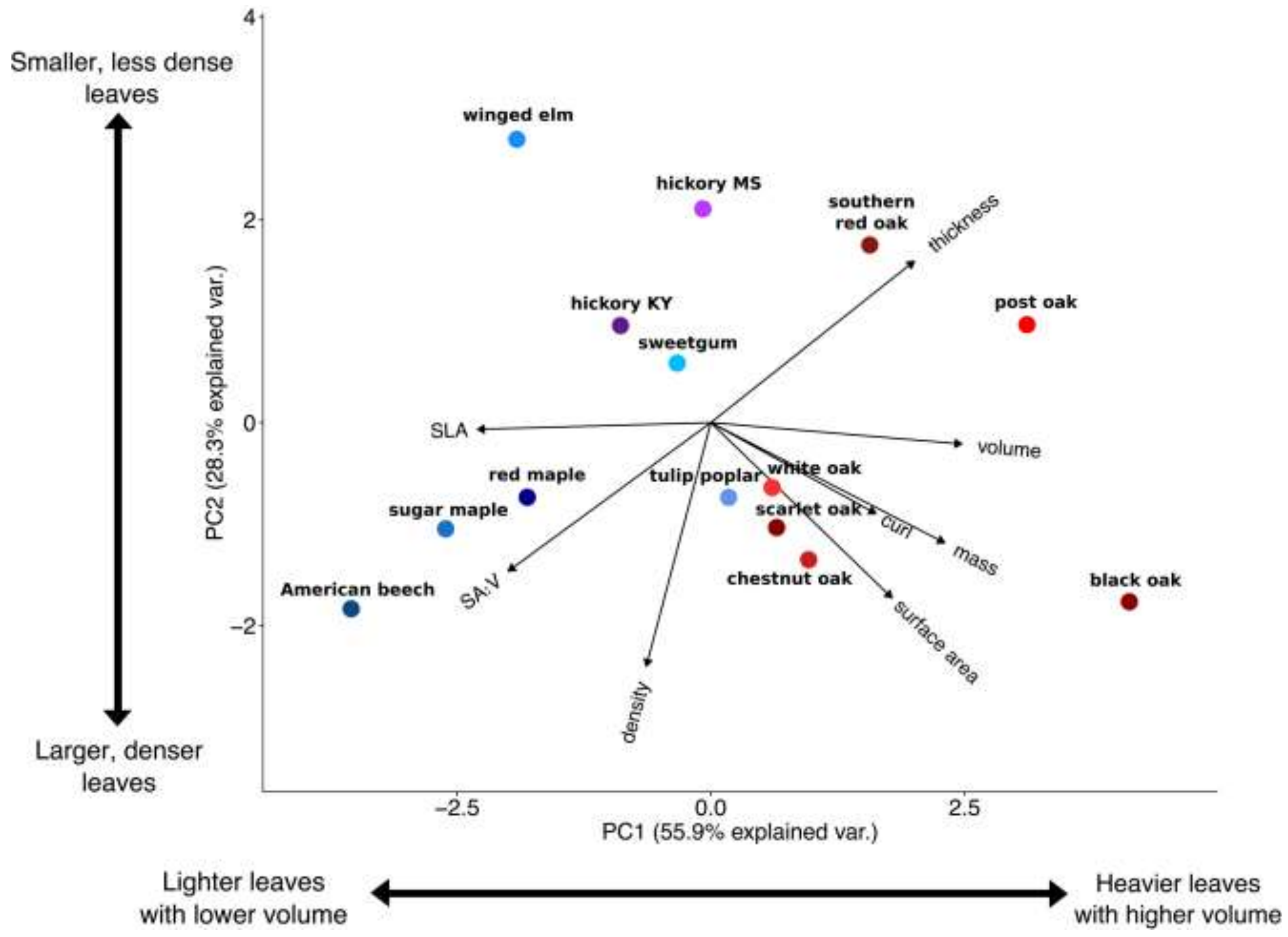
# Mesophyte Leaf Litter is Moister and Dries Slower Than Oak Litter




Litter soaked in water for 24 hours
Drained and placed in elevated pans to dry
Dried for 48 hours and weighed periodically

McDaniel, et al., *2021, FEM*

# Differential Moisture Responses Linked to Differences in Leaf Morphology

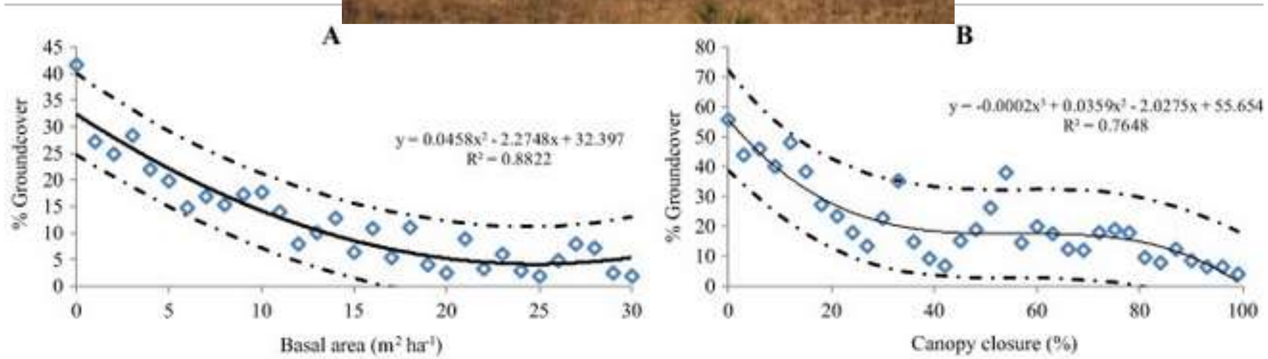



Alexander, et al., *BioScience* 2021

# A Shaded Understory Beneath Mesophytes Also Reduces Fuels by Altering Ground-Layer Vegetation

Closed-Canopy Stand with Oak Overstory and Mesophytic Understory and Leaf Litter Fuel Bed

More Open-Canopied Stand with Oak Overstory, Scant Midstory and Herbaceous Fuel Bed




Vander Yacht, et al. 2017, *FEM*

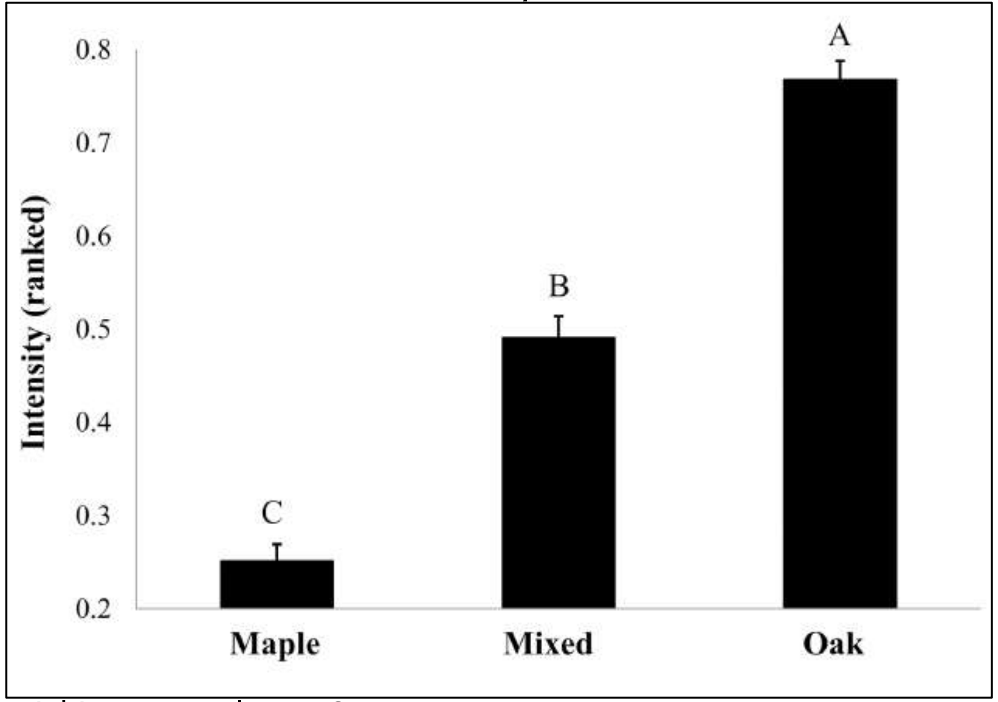
# Phase 3: Shadier, cooler, wetter environment, leaf litter fuels, and lower fuel loads beneath mesophytes reduces flammability

Fire In Forest with Leaf Litter Fuel Bed

Fire In Forest with Herbaceous Fuel Bed

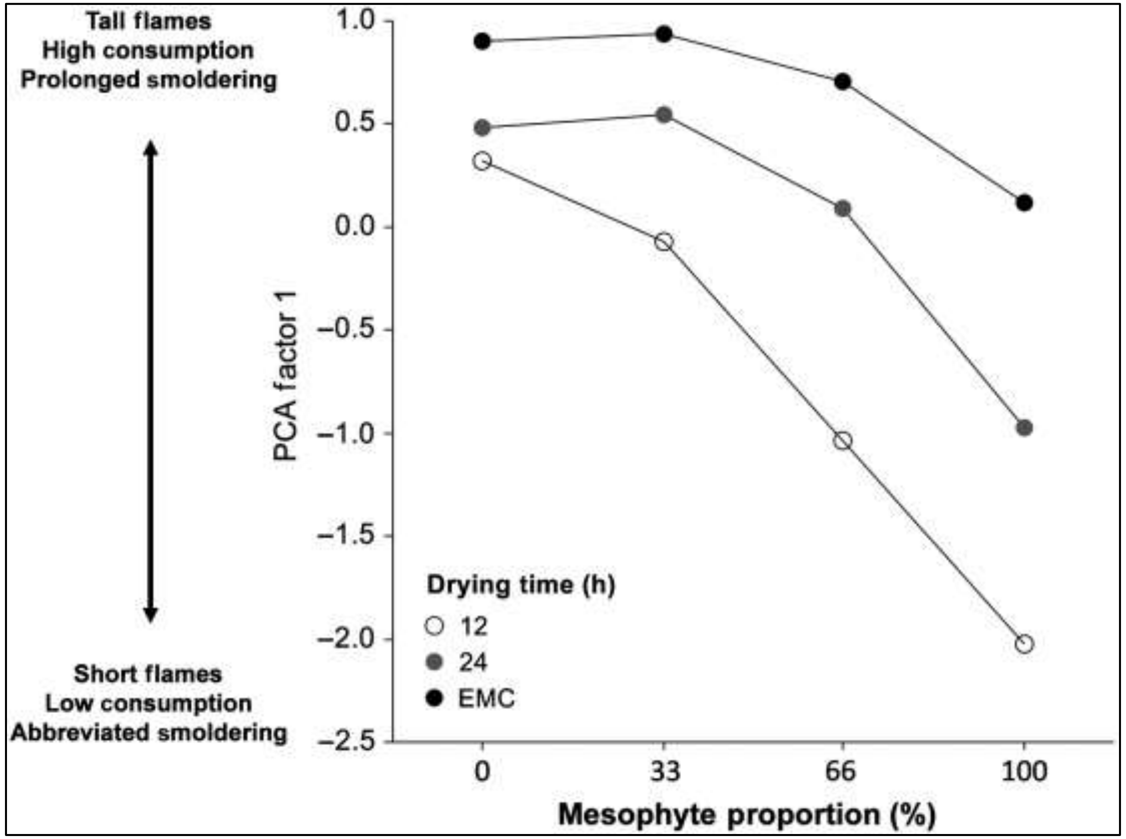
# Increasing Mesophyte Litter to Fuelbed Decreases Flammability

Modeled Fireline Intensity




Dickinson, et al., 2016

Laboratory Combustion Experiments




Kreye, et al, 2018, *FEM*

# Field Burns Confirm These Trends

Fuel beds constructed of oak or mesophytic litter

Ignited and measured flammability metrics

Oak fuel beds burned easily

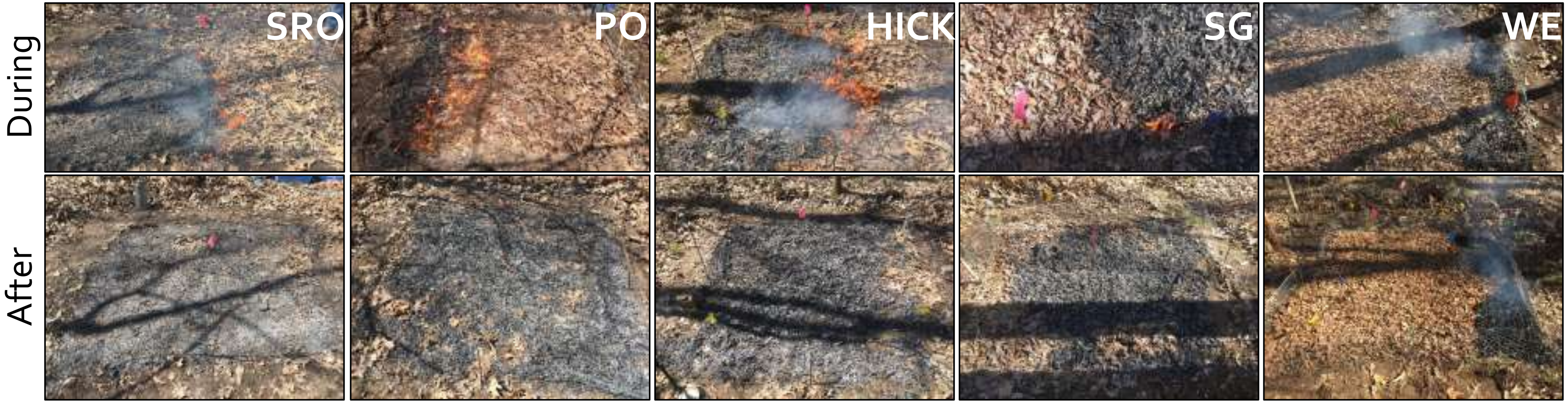
Winged elm fuel beds often failed to ignite

McDaniel, et al., 2021 FEM



30

# Field Burns Confirm These Trends




Faster spread
Higher temperature
Taller flames
Greater area burned

**Decreasing Flammability?**

Slower spread
Lower temperature
Shorter flames
Smaller area burned

# Field Burning Southern Red Oak Litter

# Field Burning Sweetgum Litter

# Phase 4: Shadier, cooler, moister, and reduced flammability beneath mesophytes promote mesophytes and hinder oaks

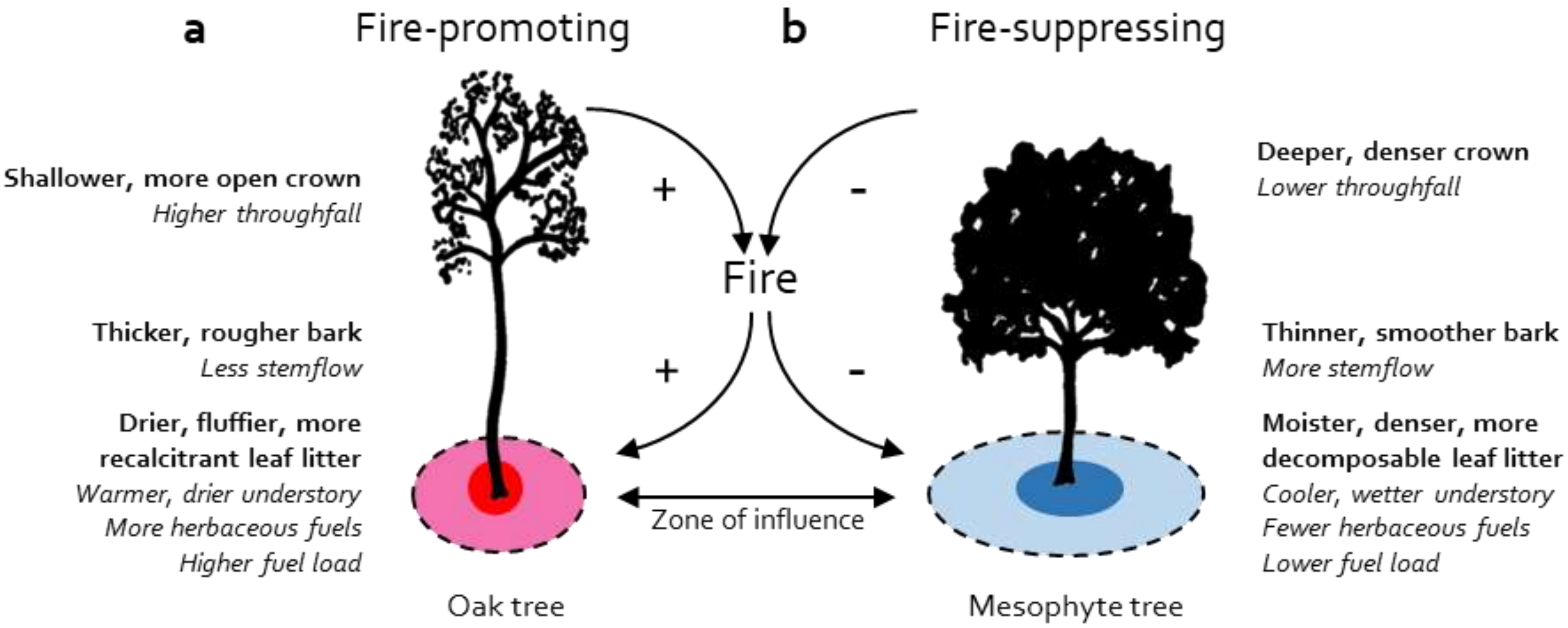
TABLE 5. Predicted mortality rate (%/5 years) for saplings of each species under ambient light levels predicted for each canopy species (gap light index, GLI, using the relative hits model)

| | Canopy species | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | FAGR | TSCA | ACSA | BELU | PRSE | PIST | ACRU | FRAM | QURU |
| GLI | 0.6 | 0.9 | 3.0 | 2.9 | 6.9 | 6.1 | 4.1 | 6.9 | 7.4 |
| Sapling species | | | | | | | | | |
| FAGR | 2.6 | 2.5 | 2.2 | 2.2 | 2.1 | 2.1 | 2.2 | 2.1 | 2.1 |
| TSCA | 3.0 | 1.2 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| ACSA | 11.8 | 4.8 | 0.6 | 0.6 | 0.2 | 0.3 | 0.4 | 0.2 | 0.2 |
| BELU | 20.4 | 11.2 | 2.3 | 2.4 | 1.0 | 1.1 | 1.7 | 1.0 | 1.0 |
| PRSE | 25.0 | 8.5 | 0.1 | 0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| PIST | 30.0 | 22.8 | 5.0 | 5.5 | 0.5 | 0.8 | 2.5 | 0.5 | 0.4 |
| ACRU | 56.0 | 34.4 | 2.7 | 3.1 | 0.1 | 0.2 | 0.1 | 0.1 | 0.1 |
| FRAM | 68.1 | 46.8 | 5.9 | 6.5 | 0.5 | 0.7 | 2.6 | 0.5 | 0.4 |
| QURU | 76.8 | 57.3 | 6.6 | 7.5 | 0.1 | 0.2 | 2.1 | 0.1 | 0.1 |

NOTE: Mortality rates were computed for saplings 2 cm DBH at the beginning of the 5-year period, using functional relationships between light and growth (Pacala et al. 1993) and relationships between growth and mortality given in R.K. Kobe et al. (see footnote 4). Because of the extremely large confidence intervals on our estimates of light extinction by yellow birch and white pine (Table 4), we have used the observed GLI data from fish-eye photographs (Fig. 2) for estimates of GLI in monospecific stands of those two species. Species are listed in order of decreasing shade tolerance (see Tables 1 and 2).

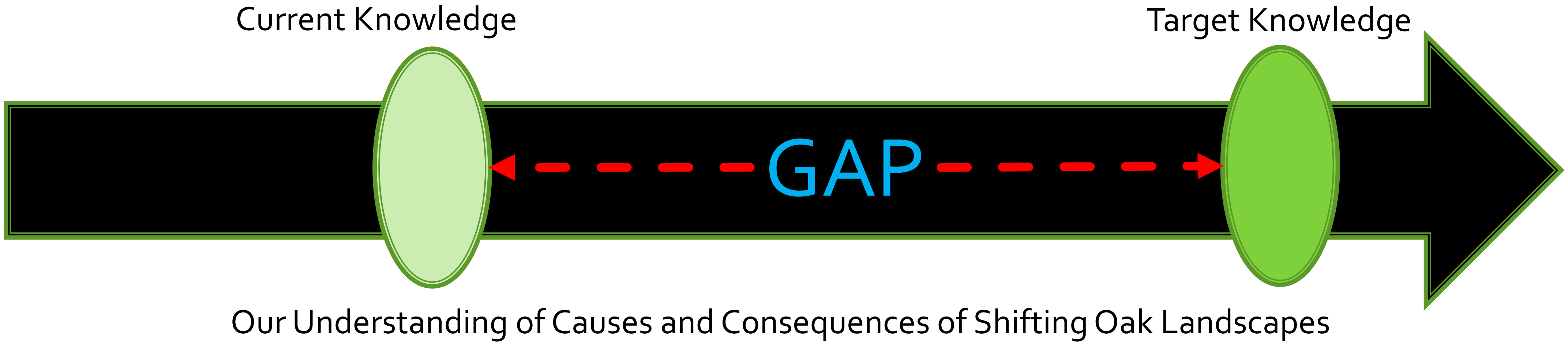
Canham, et al., *1994 CJFR*

# Tree Traits Can Reinforce or Suppress Fire Leading to Self-Perpetuating Conditions

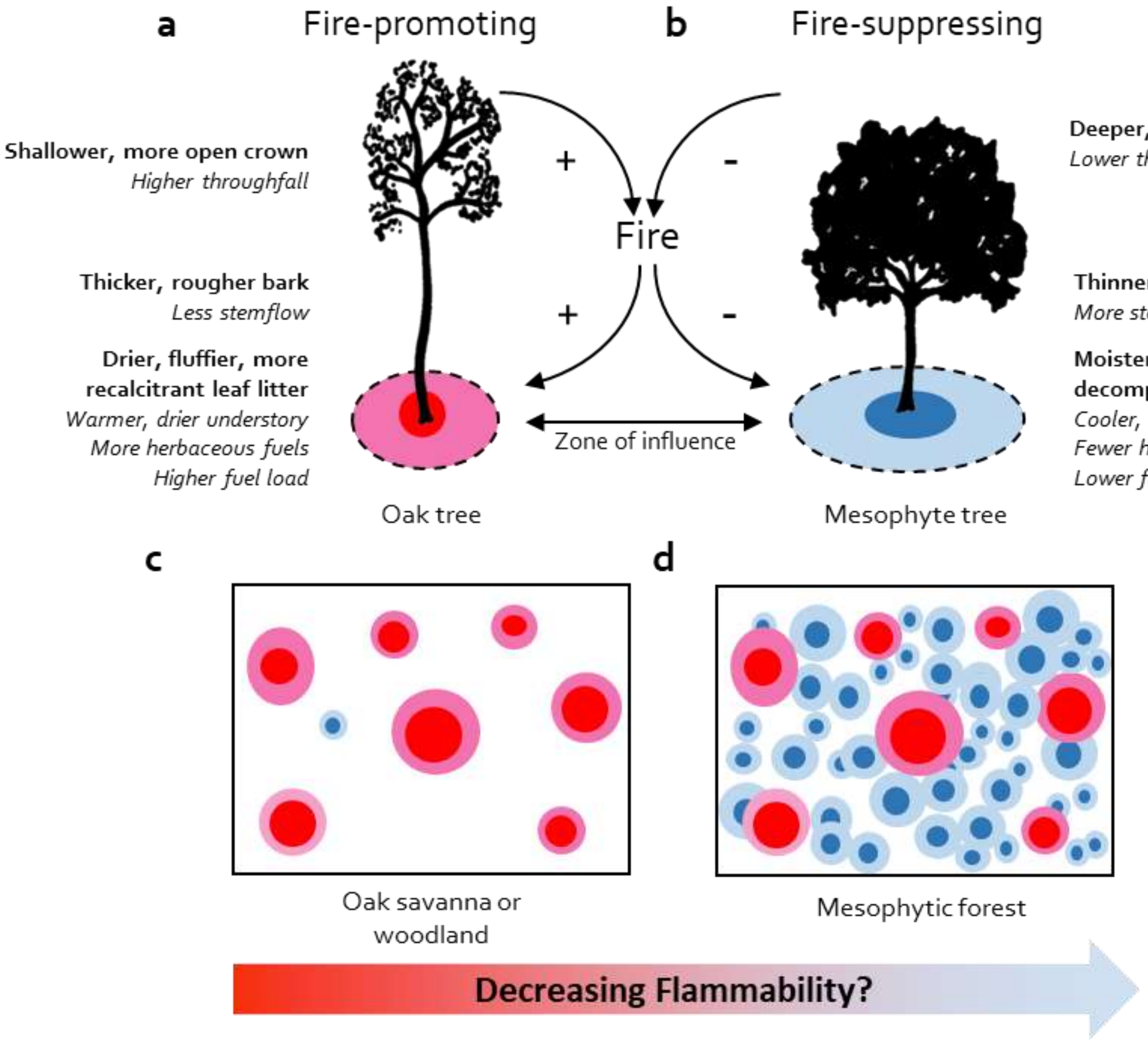



Alexander, et al., *BioScience* 2021

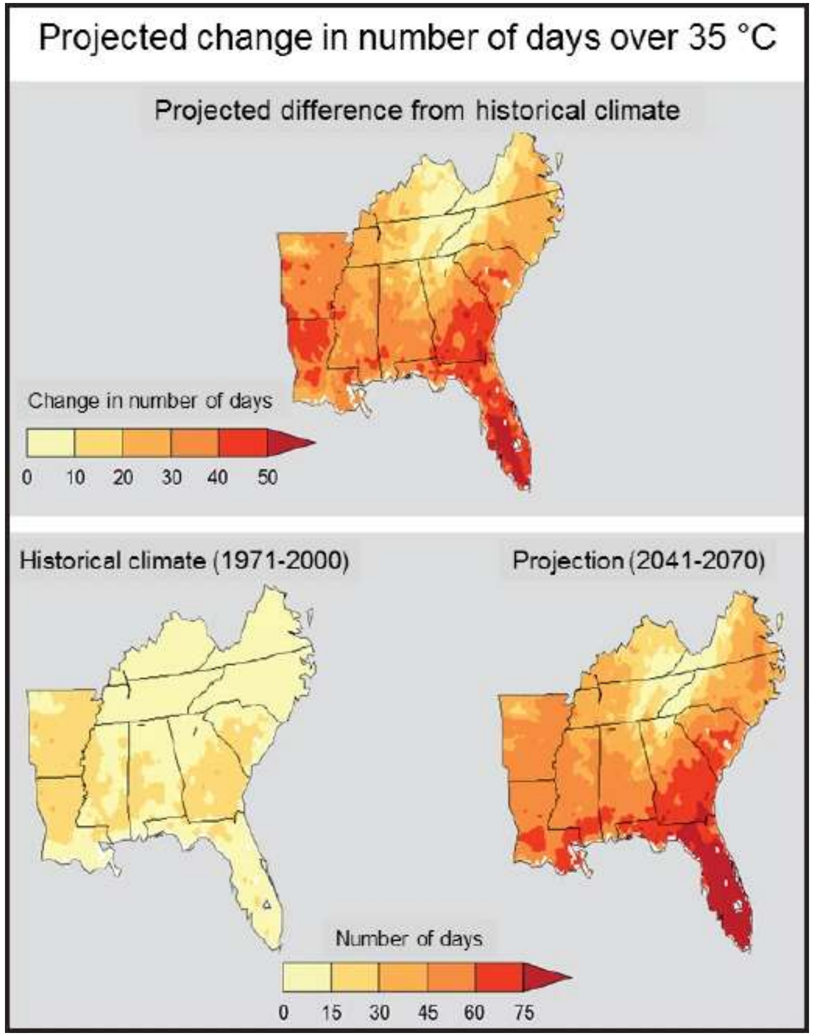
# Key Knowledge Gaps Remain



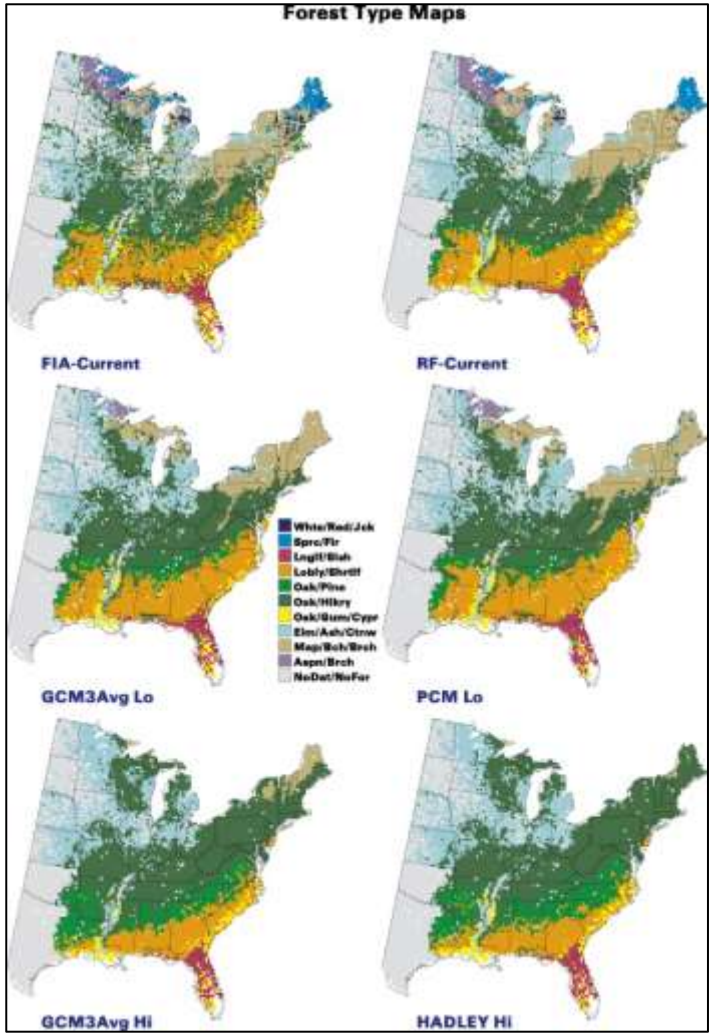
# Can self-perpetuating processes propagate to the stand and landscape scale?



# Can these processes overcome broadscale phenomena like climate change and its interaction with fire potential?

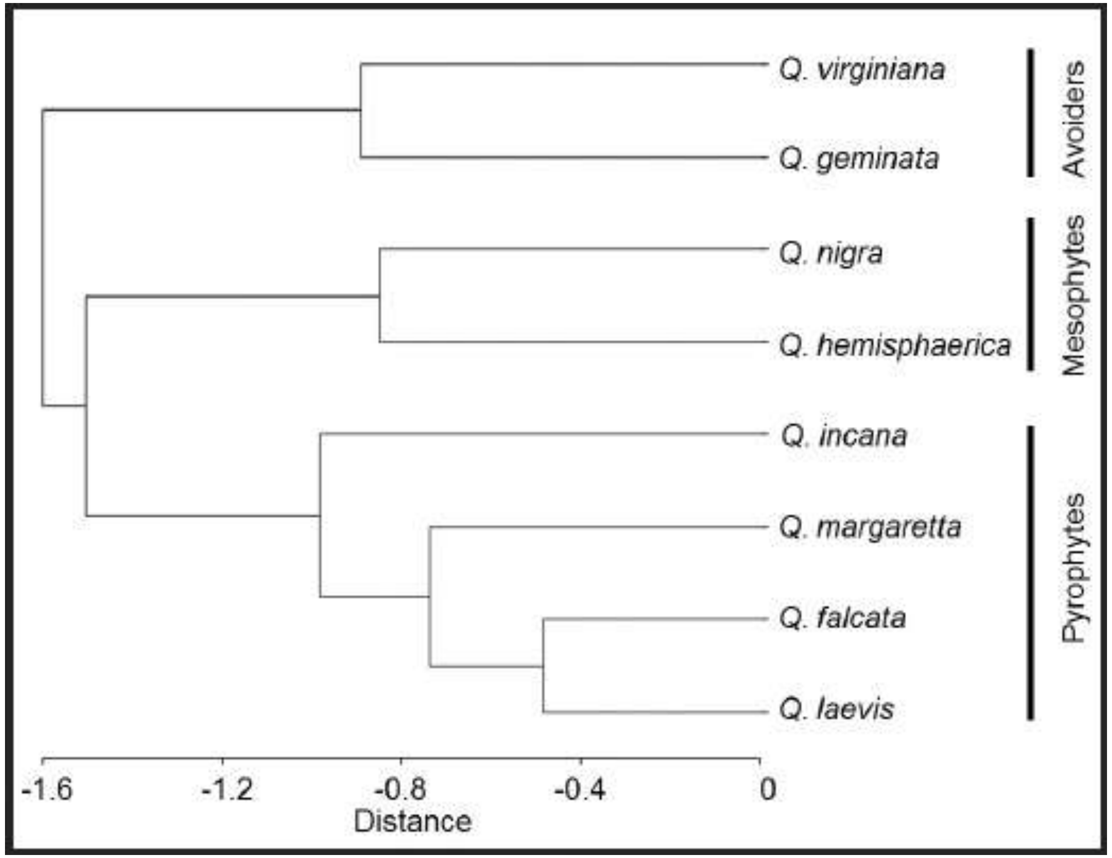



Vose and Elliott 2016, *Fire Ecology*

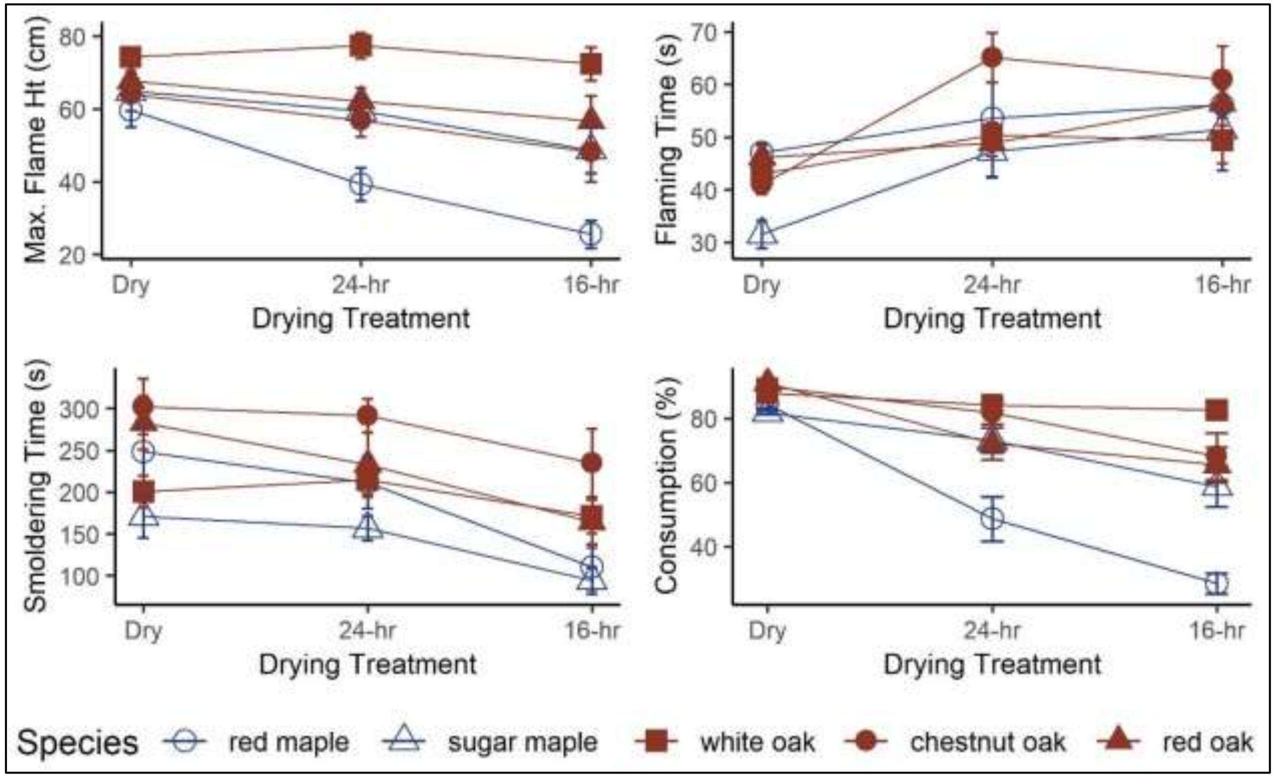



Iverson et al. 2008, *FEM*

# How Important Are Species-Level Differences?




Varner, et al., 2016 *Fire Ecology*




Kane, et al., *2021 FEM*

# How Do We Apply Small-Scale Results to *In Situ* Wildland Fires?

Kane et al. 2016

http://ocm.auburn.edu/newsroom/news_articles/2021/04/211432-researcher-studying-controlled-burns.php

# Take Home Thoughts

- Mesophication is more than compositional shifts; it's a positive feedback cycle where tree traits act to reinforce or suppress fire

- Shifting the mesophytic state back to open-canopied savannas and woodlands by reintroducing fire alone, the primary disturbance thought to induce this shift, is often not enough.

- Is this because there's been insufficient time for fire restoration efforts to work, because fire exclusion interacts with other factors to limit oak regeneration, or because feedback loops between mesophytes and their understory reduce flammability and promote their own persistence, decreasing the effectiveness of fire?

- Many knowledge gaps that we need to explore.

# Questions