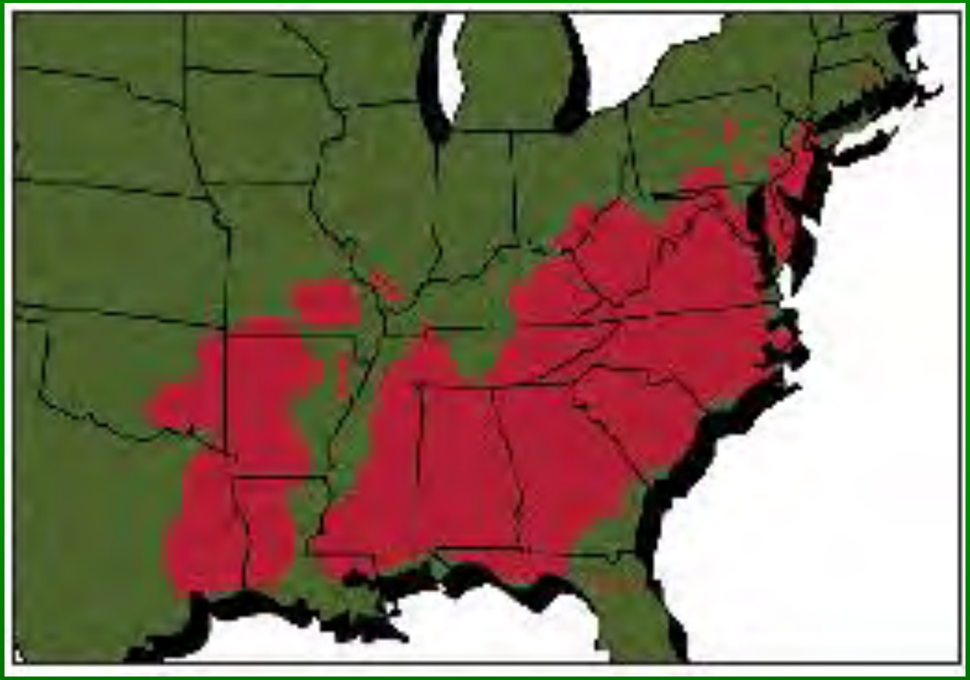
A Leisurely Look at the History of Shortleaf Pine Research and Development in Missouri

Steve Shifley (USFS Retired), channeling
John Kabrick & Dan Dey (USFS Northern Research Station)
and Ben Knapp (MU School of Natural Resources)

Why shortleaf pine?

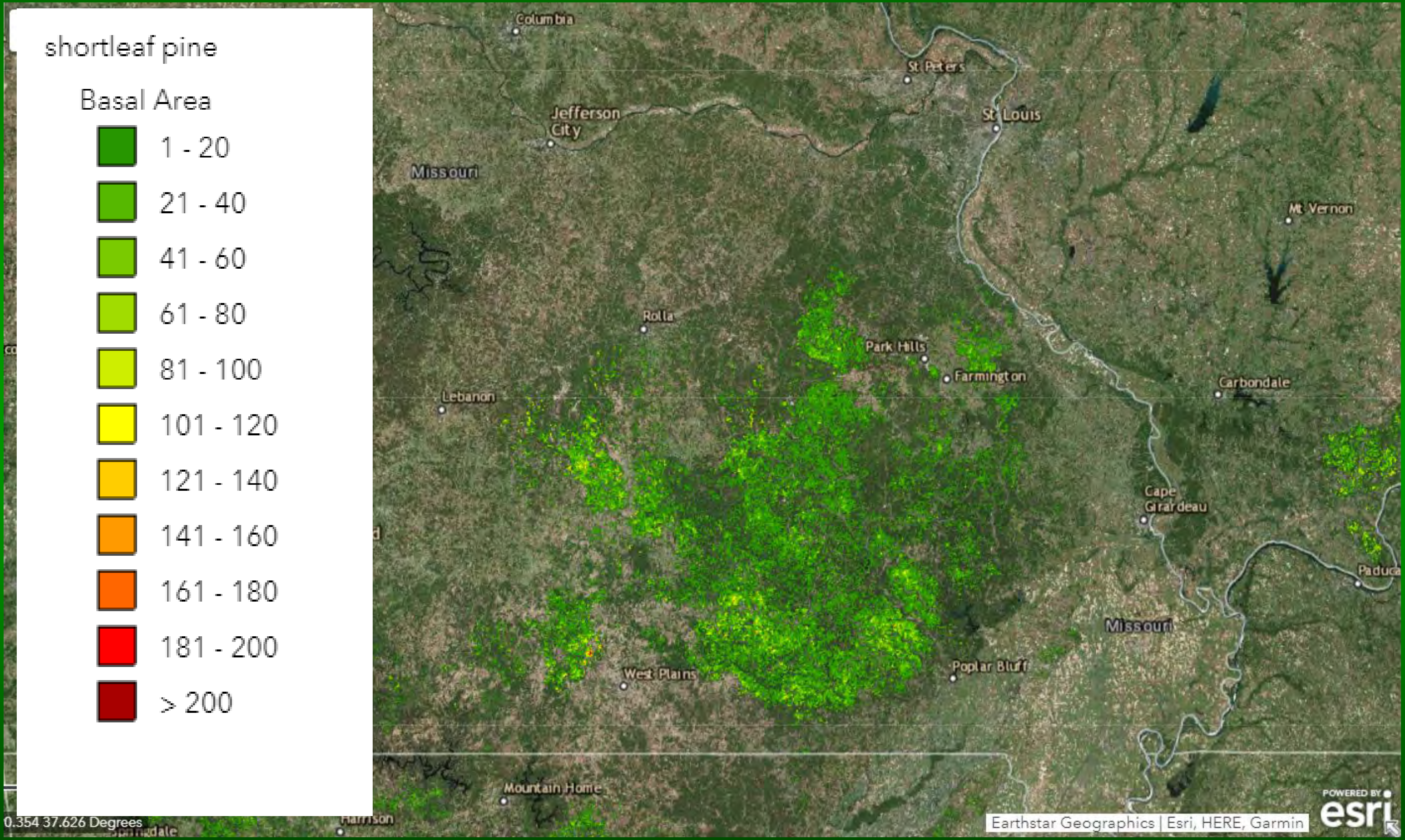
- Excellent wood properties and form
- Tight grain, small knots
- Long-lived
- Drought tolerant
- Ecologically significant
  - Great diversity in associated herbaceous flora and wildlife
- Economically significant?

Shortleaf pine range

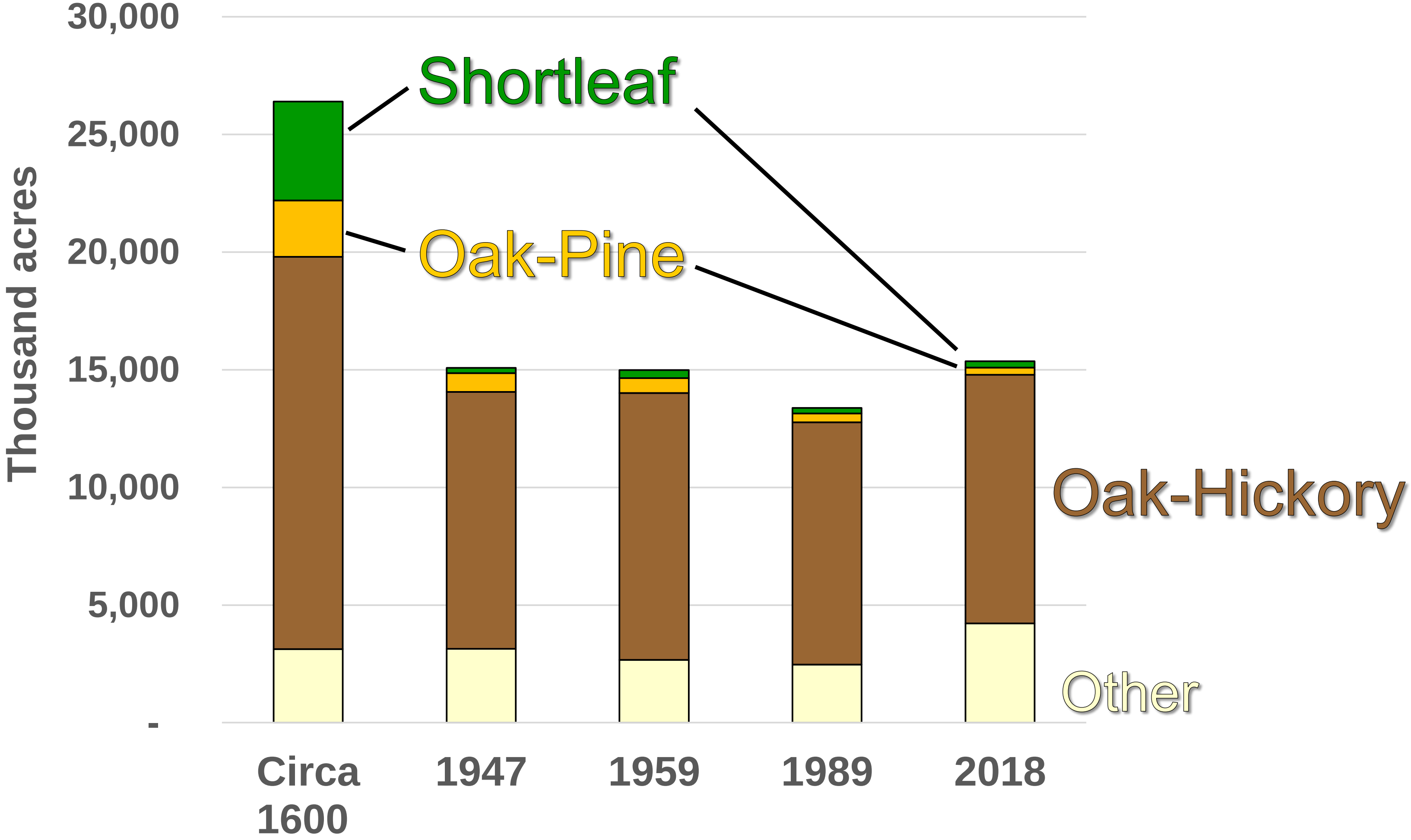


- Occurs throughout the south and the southern Central Hardwood Region
- In Missouri:
  - Once dominant on 4.2 million acres
  - Once prominent on additional 2.4 million acres

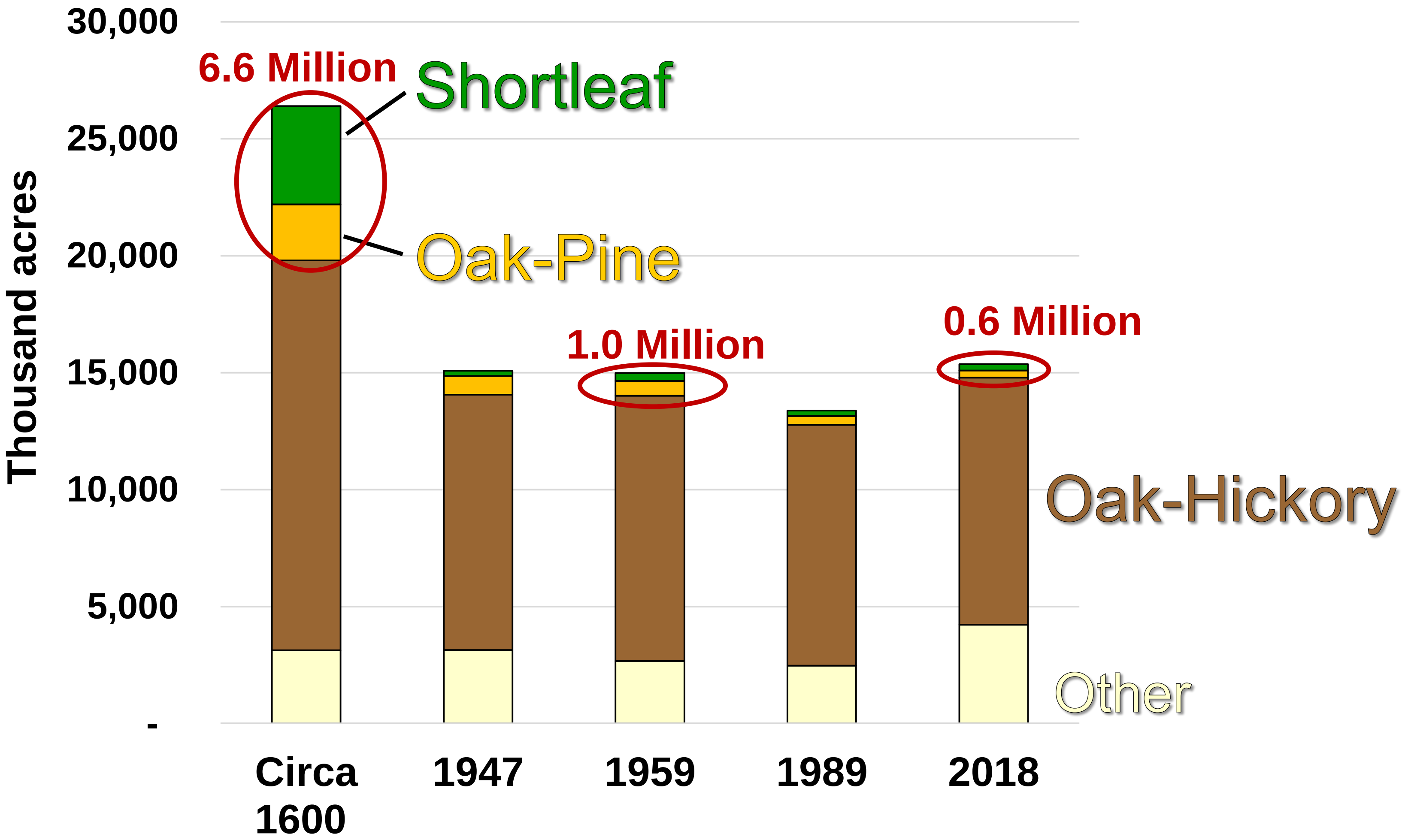
Distribution of SLP in Missouri



Missouri Area by Forest Type Over Time



Missouri Area by Forest Type Over Time

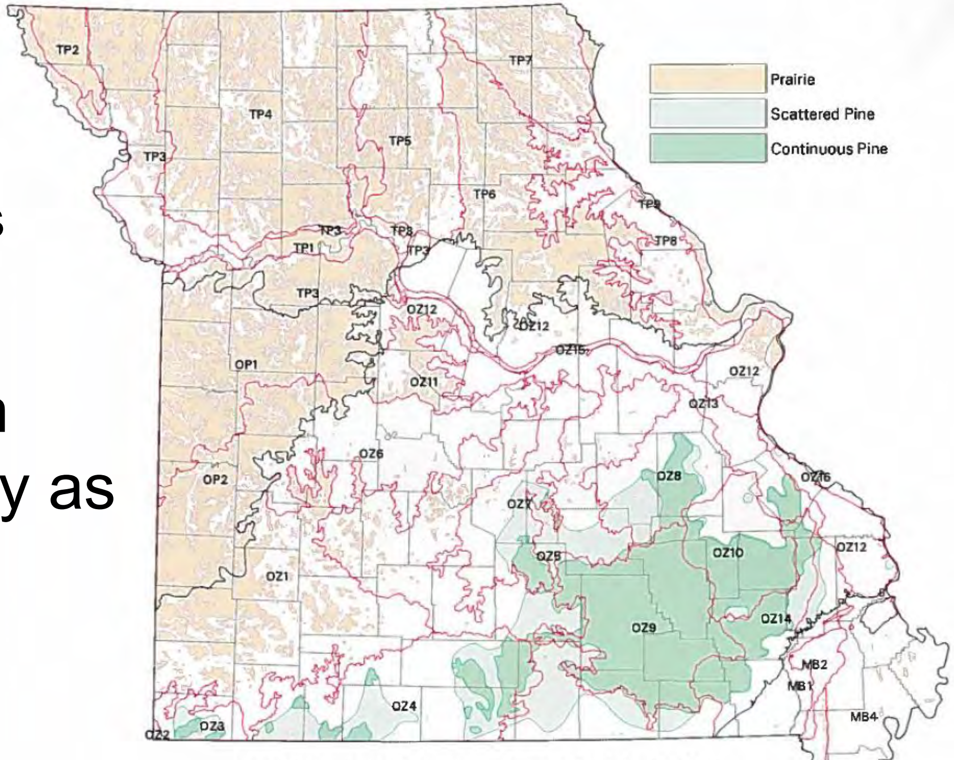


Several site factors have been associated with shortleaf pine occurrence:

- Geology: Roubidoux sandstone
- Aspect: south-facing slopes
- Little to no loess

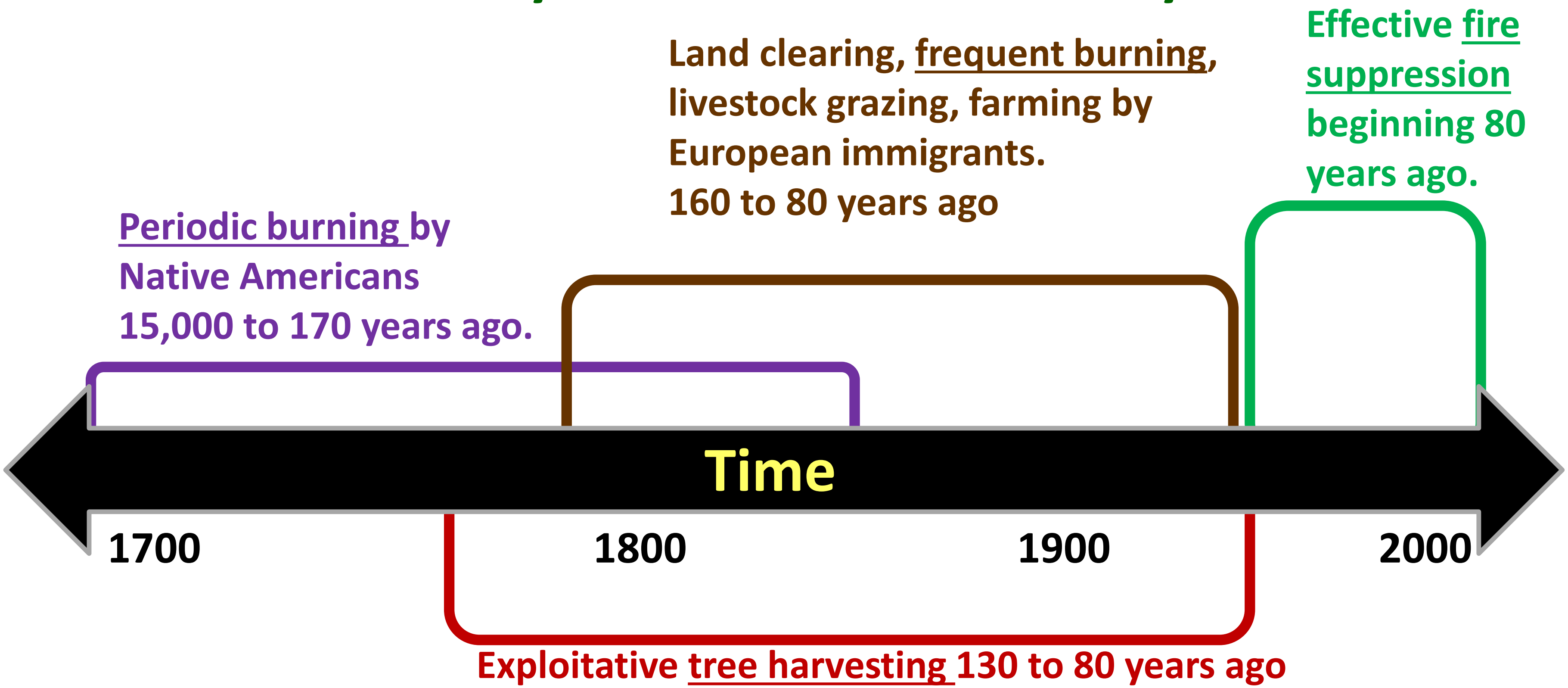
Shortleaf pine occurred in pure stands but commonly as mixtures of pine-oak

Nigh and Schroeder (2002)

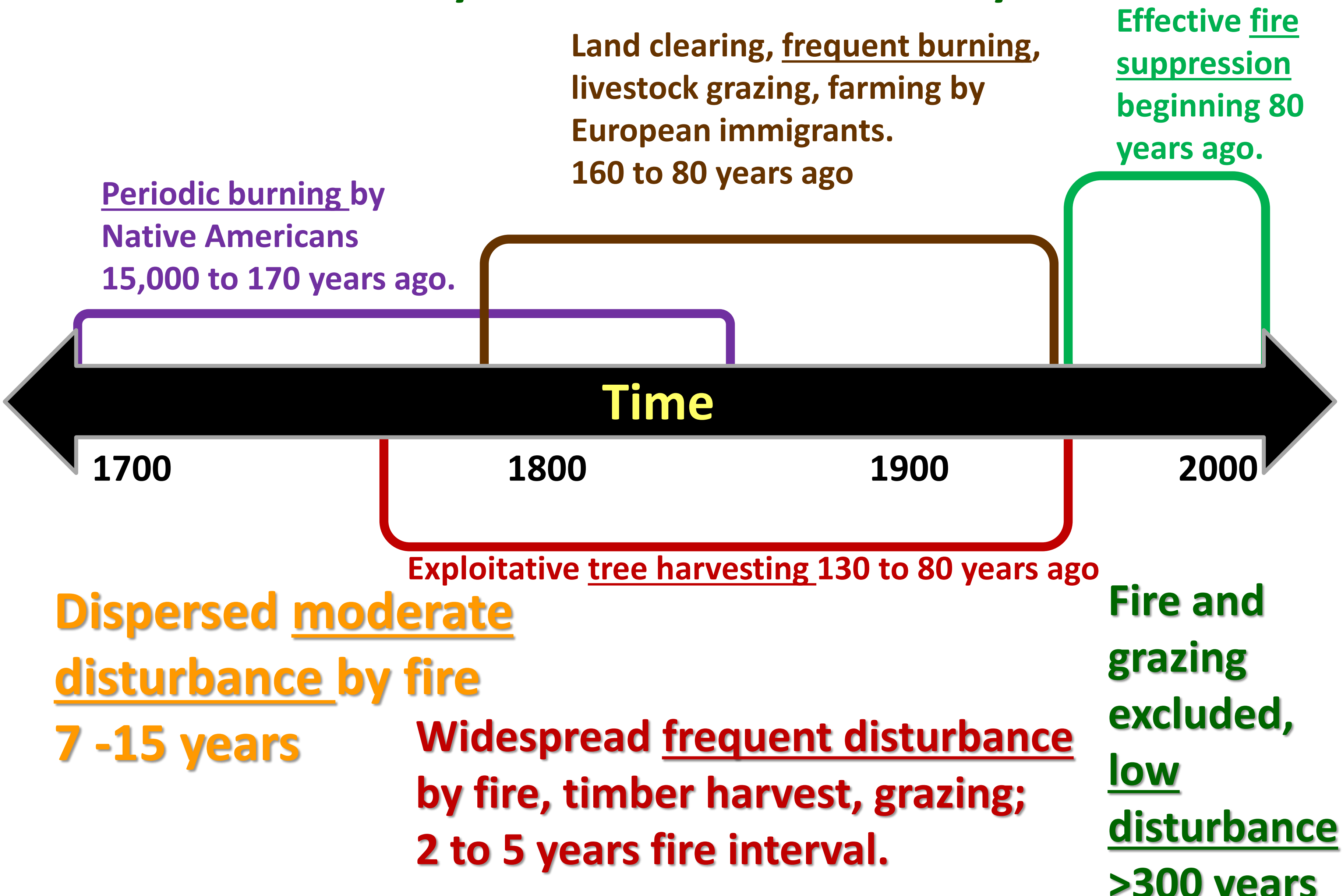


Presettlement Distribution of Prairie & Pine

Disturbance History in Midwest Forest Ecosystems



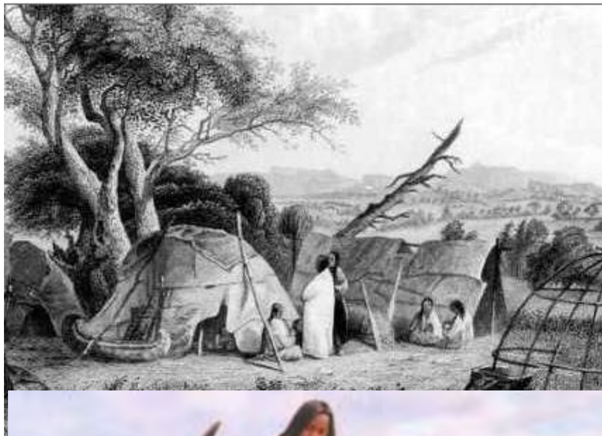
Disturbance History in Midwest Forest Ecosystems

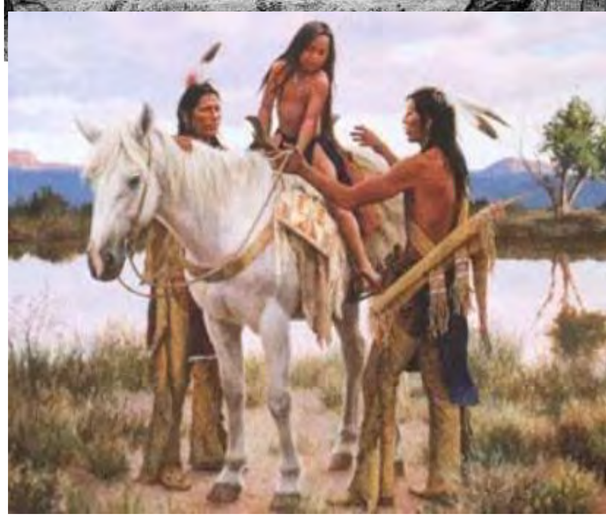


Disturbance History in Midwest Forest Ecosystems

Time

1700 | 1800 | 1900 | 2000



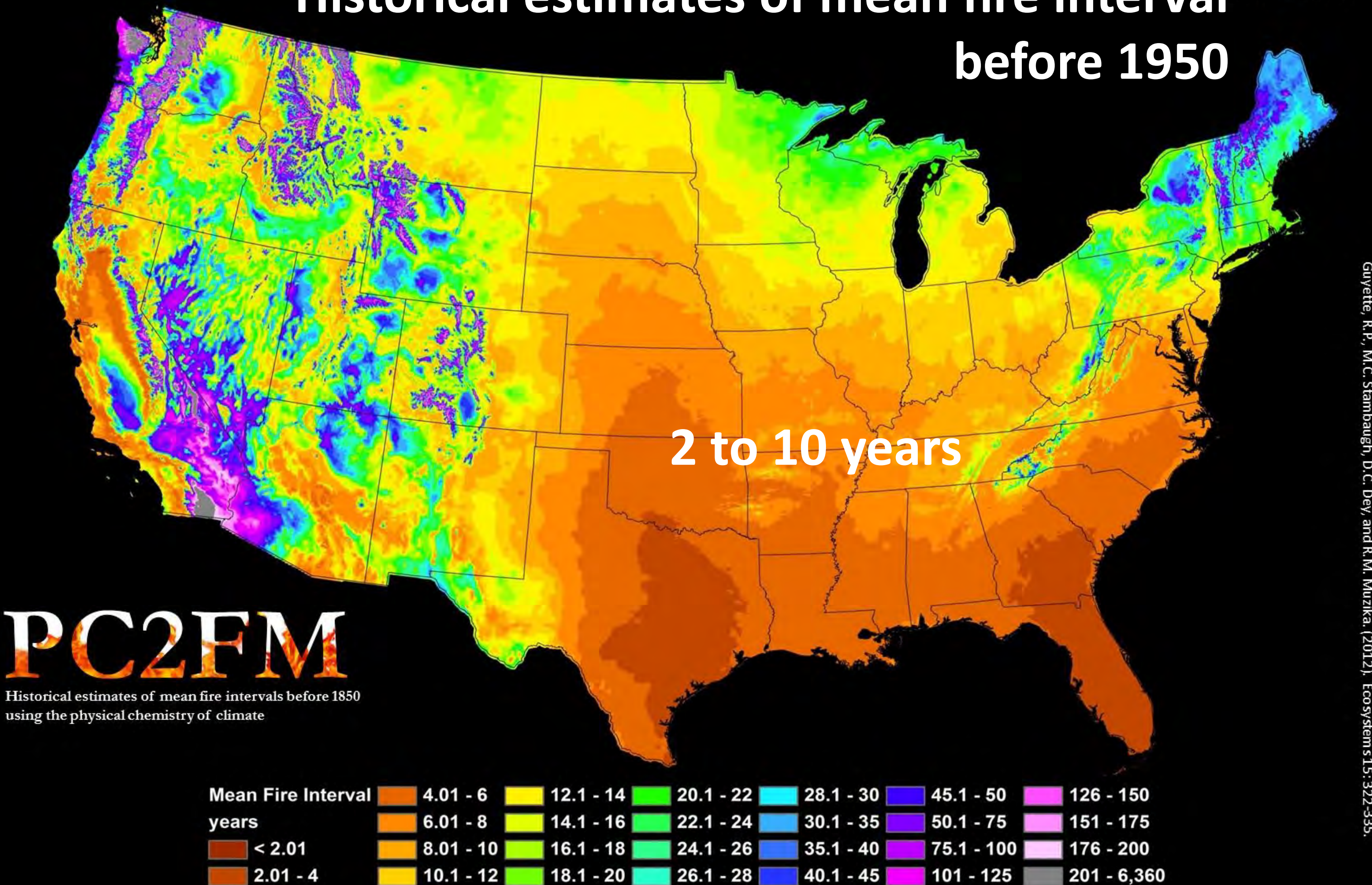


Fire and grazing excluded from forests, <u>low disturbance >300 years</u>

<u>Moderate disturbance</u>, dispersed fire;
7 to 15 years

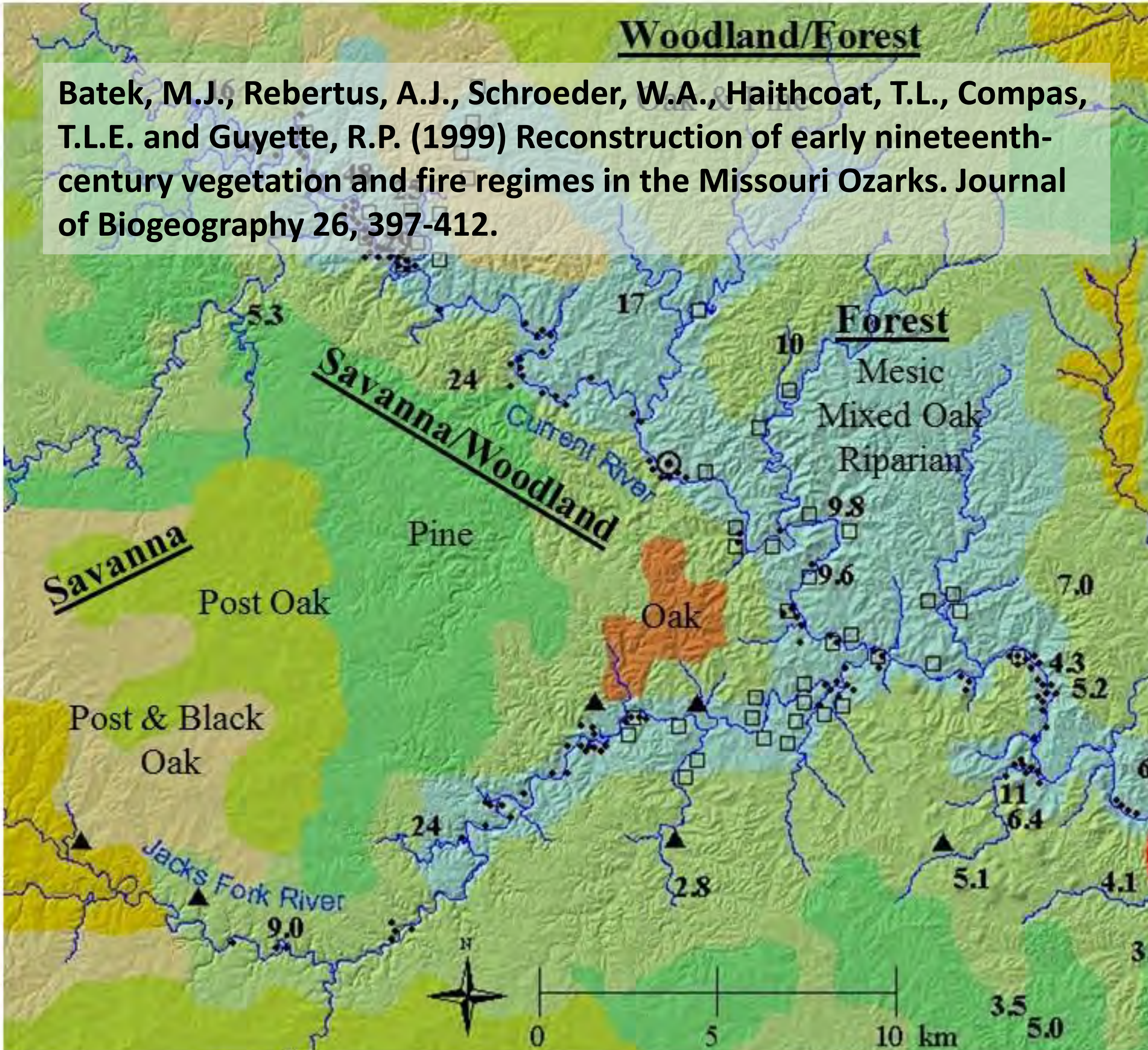
Widespread <u>frequent disturbance</u> by fire, timber harvest, grazing; 2 to 5 years

Historical estimates of mean fire interval before 1950



Guyette, R.P., Stambaugh, M.C., Dey, D.C. and Muzika, R.M. (2012) Predicting fire frequency with chemistry and climate. *Ecosystems* 15, 322-335.

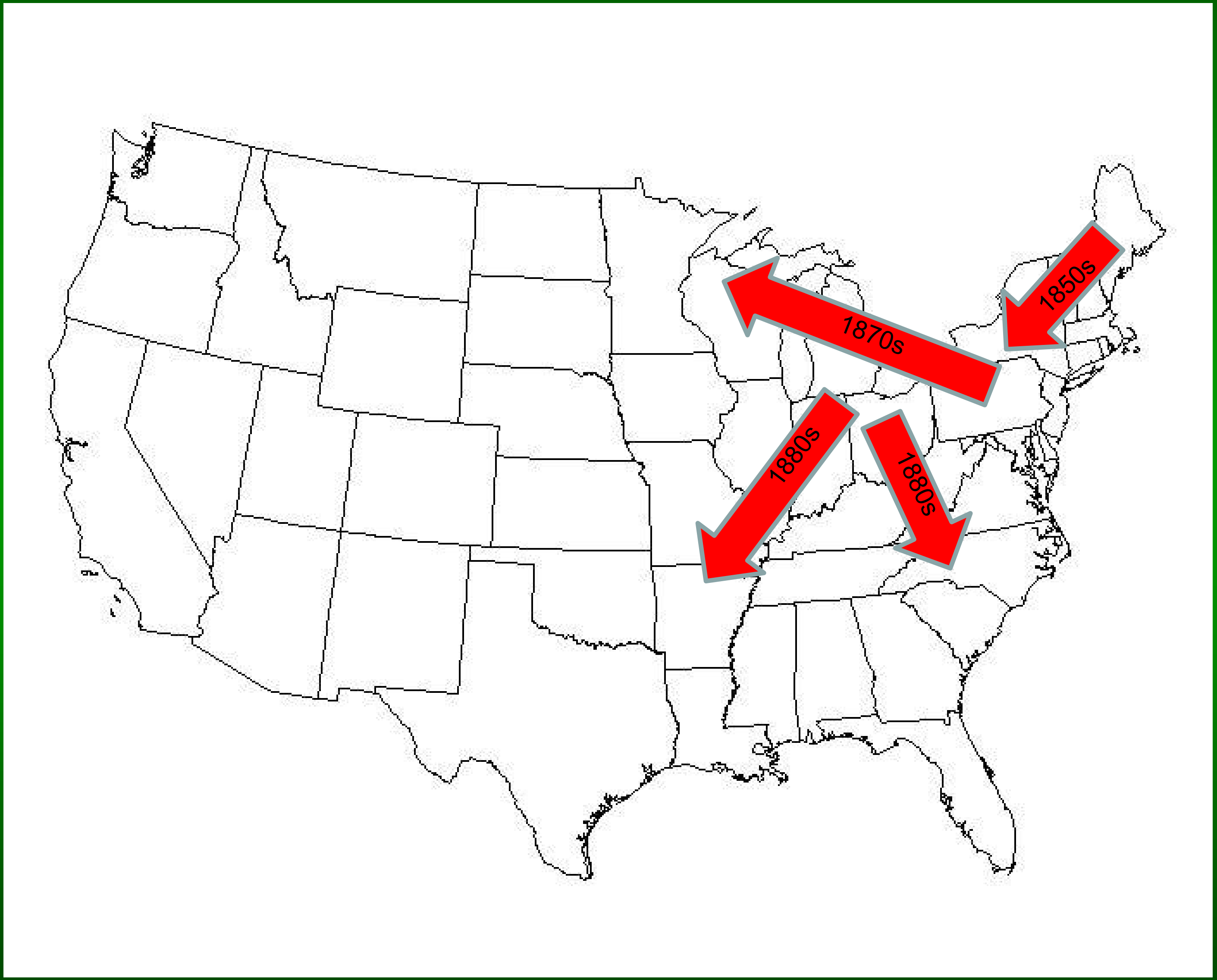
Batek, M.J., Rebertus, A.J., Schroeder, W.A., Haithcoat, T.L., Compas, T.L.E. and Guyette, R.P. (1999) Reconstruction of early nineteenth-century vegetation and fire regimes in the Missouri Ozarks. Journal of Biogeography 26, 397-412.



Historical shortleaf pine in Missouri

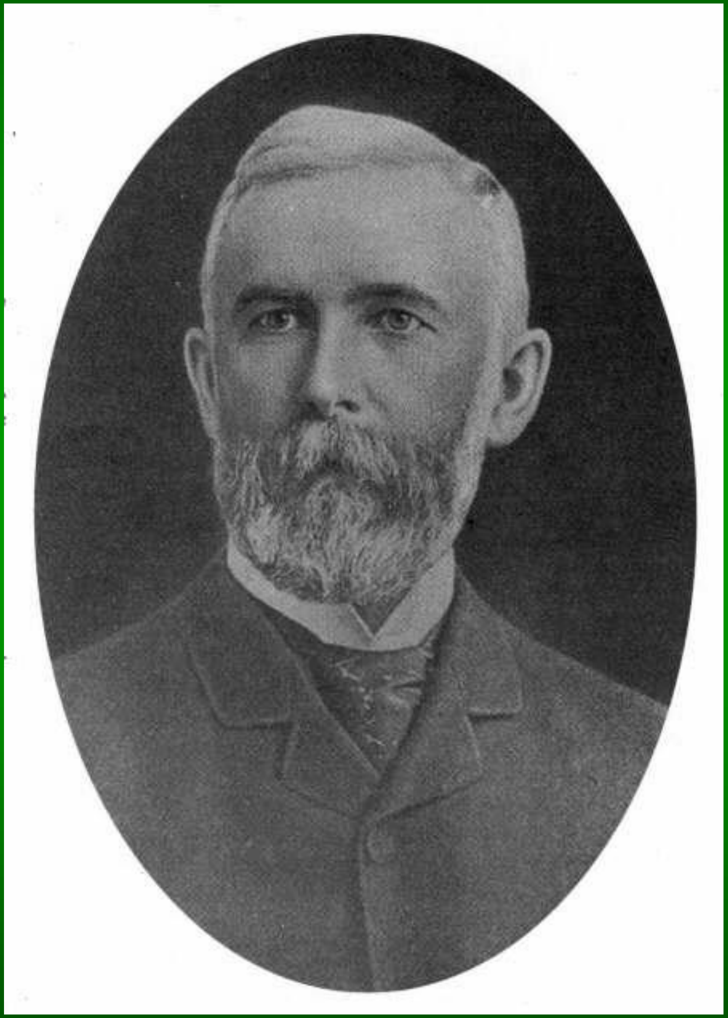
- Relatively "open" with Graminoid understory
- Few pure stands; common associated hardwoods were white, post, and black oak
- Volumes: 4,000 to 25,000 bd ft per acre
- Shortleaf brought the lumber industry to Missouri in the late 1800's

Lumbering "frontier"



The Pennsylvania connection

- O.H.P. Williams, Pittsburg, PA, sold PA holdings in 1870s
- Williams and son-in-law E.B. Grandin purchased MO timberland in 1870s but had to wait for arrival of railroads to begin lumbering
- 1880s the newly-founded Missouri Lumber and Mining Company built a large mill in “Grandin”
- PA financiers included lumber dealer J.B. White, Banker L.L. Hunter, “oil man” J.L. Grandin.



E.B. Grandin, Tidioute, PA

Rafferty 1992

Missouri logging

- Narrow gage “tram lines” were built into the forest
- Crews sawed trees into logs and hauled them to the tram lines
- Tram lines were temporary; tracks were bumpy and accidents were common causing injury to work crews and damage to equipment

Western Historical Manuscript Collection - University of Missouri – State Historical Society of Missouri

Missouri logging

- Mobile logging camps occurred along tram lines
- Workers receipt script worth about $2.50 per day to use at company stores

Mobile logging camp of Cordz-Fisher Lumber Company of Birch Tree. Camp on tram line 12 miles south of Birch Tree at Pat Pond. Note open stand of mature shortleaf pine (Rafferty 1992).

The Grandin Mills

- In Grandin, trams brought logs to Toliver Pond, a 3.5-acre sinkhole pond
- The logs were cleaned and stored in the pond until they were ready to be sawn
- Crews used pike poles to direct logs towards a conveyor which lifted the logs into the mill

The Grandin Mills

- Two mills:
  - The “big mill” had one circular saw, a band saw, and a gang saw
  - The “little mill” had lath and shingle mills
  - Daily output was 160,000 bd ft lumber, 48,000 bd ft of lath, and 28,000 bd ft of shingles

Western Historical Manuscript Collection - University of Missouri – State Historical Society of Missouri

Source: Missouri Department of Conservation

The Grandin Mills

Western Historical Manuscript Collection - University of Missouri – State Historical Society of Missouri

- Operation: 1887-1909
- Moved to West Eminence in 1909
- At production height, timber from 70 acres per day were harvested
- Minimum size: 14 inches at the stump.
- By 1901, 213,017 acres had been cut

Galloway 1961, Cunningham 2007

Missouri's big mills

- Missouri Lumber and Mining Co. (Grandin, later at West Eminence)
- Holaday-Klotz Land and Lumber Co. (Greenville)
- Clarkson (Leeper)
- Cordz-Fisher Lumber Co. (Birch Tree)
- Ozark Land and Lumber Co. (Winona)
- Bunker-Culler Lumber Co. (Bunker)

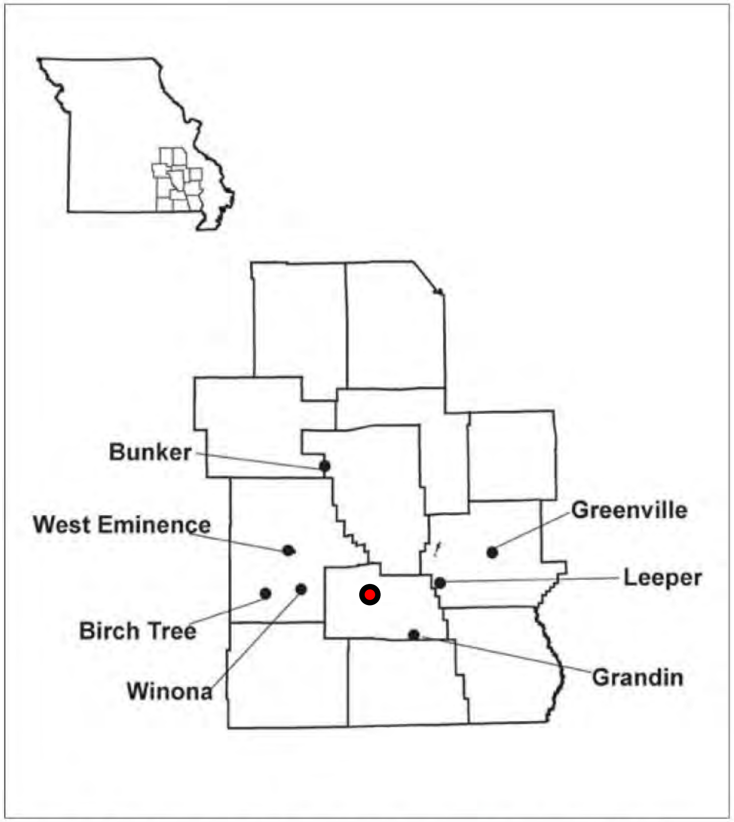


Figure 2.—Towns with large pine sawmilling operations between 1880 and 1920.

Cunningham 2007

Western Historical Manuscript Collection - University of Missouri – State Historical Society of Missouri

Open range

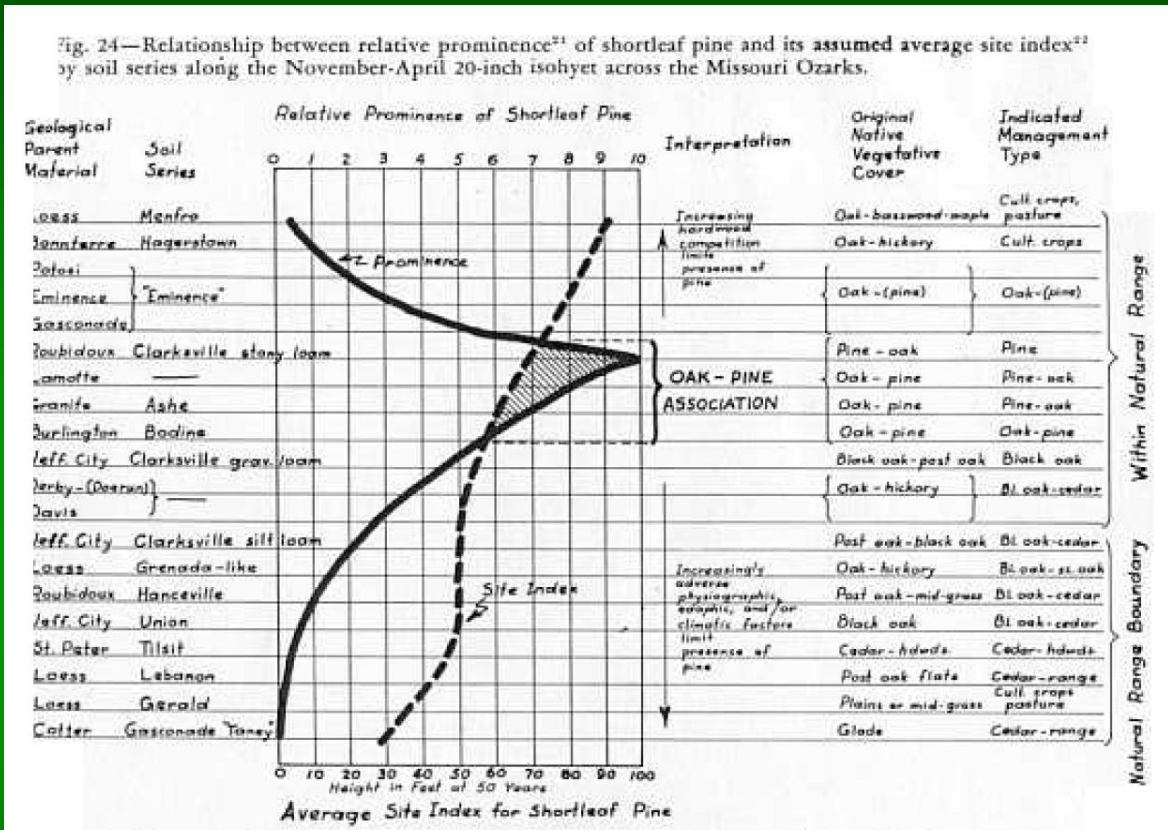
Roots of shortleaf pine research

- Mark Twain and Clark National Forests established 1930s
  - Recognized that shortleaf pine would materially increase the productivity
  - Reestablishing and managing shortleaf pine was an important focus
  - Early efforts were directed at releasing pines
  - CCC active in both pine release in existing stands and planting pines

Former pine sites

- Disturbance regime favored hardwoods rather than pine
- Black oak and scarlet oak achieve rapid growth on “poor” sites

Shortleaf pine sites



Roubidoux formation (sandstone)

Gasconade formation (cherty dolomite)

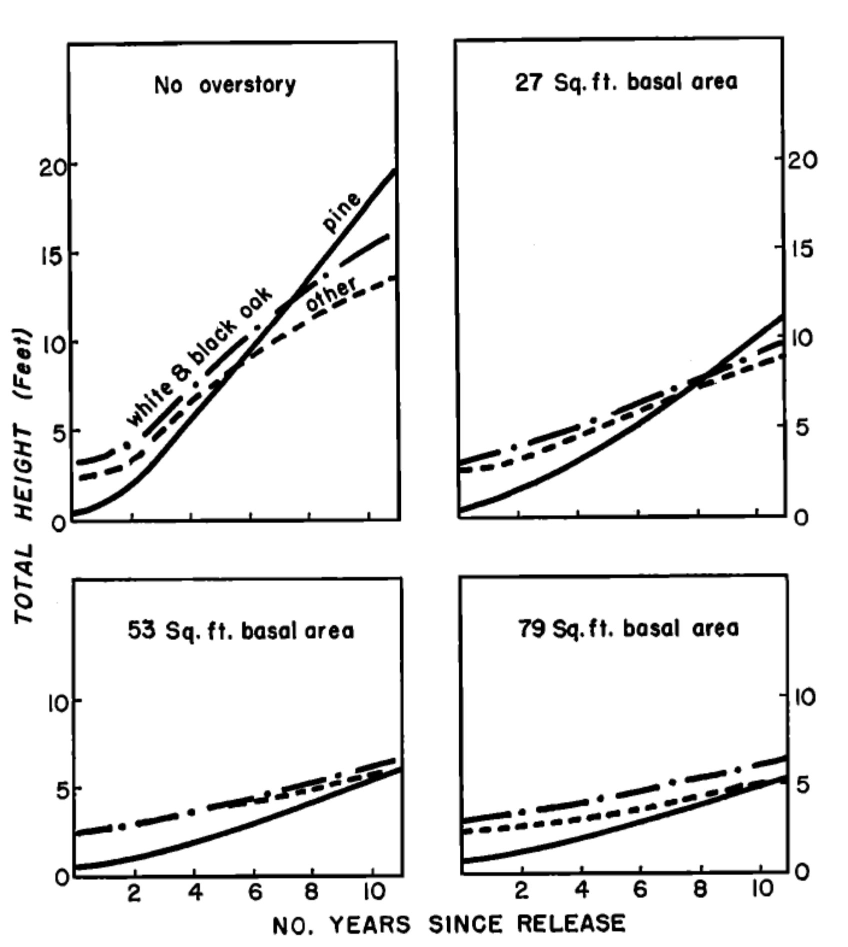
Precambrian granite (rhyolite)

- Well-drained soils
- No fragipan, claypan, or discontinuity
- Low nutrient supply

Fletcher and McDermott 1957

Roots of shortleaf pine research

Reproduction



Research initiated in 1938
Clark and Mark Twain National Forests
(Brinkman and Liming 1961)

- Overhead release increased the growth rate of desirable species (white oak, black oak, shortleaf pine)
- Response differed by species:
  - White oak, black oak, pine favored (over post oak and blackjack oak)
  - Shortleaf pine favored by under low overstory densities

Roots of shortleaf pine research

- Sinkin Experimental Forest established in 1950
  - The first study examined relationships between density and yield in pine stands

Pine stocking 1952

Pine stocking 2002

Roots of shortleaf pine research

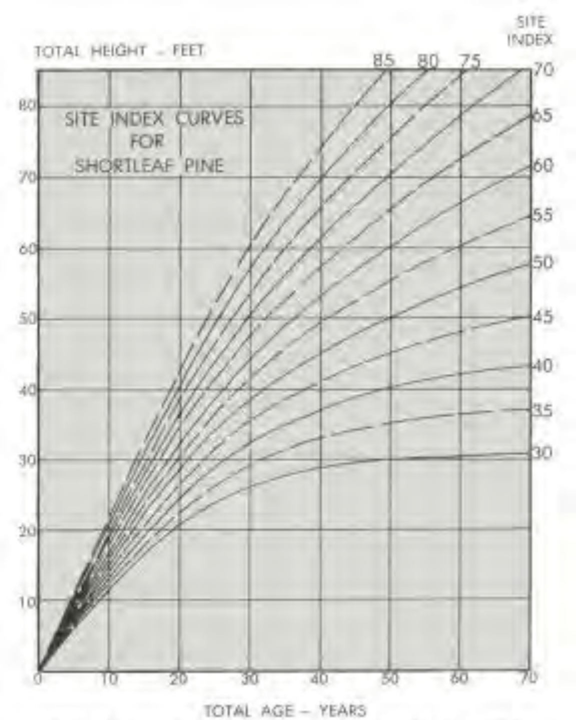
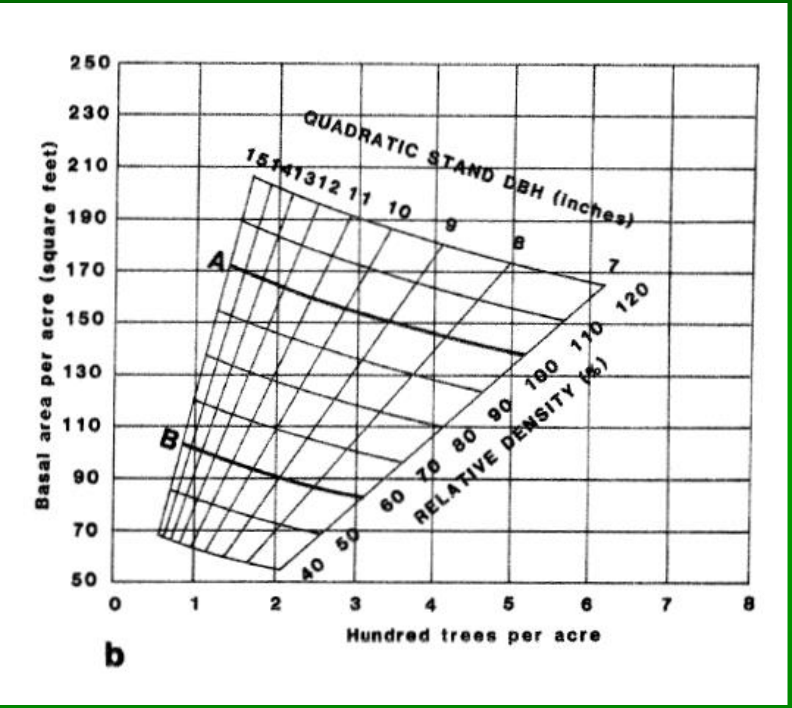


Figure 3. Site index curves for shortleaf pine in Missouri (from Nash 1963).



Stocking% = 0.008798N + 0.009435∑D + 0.00253 ∑ D^2

Nash 1963

Rogers 1982

Roots of shortleaf pine research

- Provenance tests (1950s)
  - Seed collected in AR, LA, MS, MO NJ, GA, VA, and TN
  - Seedlings grown in the state nurseries and planted in experimental forests
  - Missouri tests indicated greater survival and growth using northern seed sources

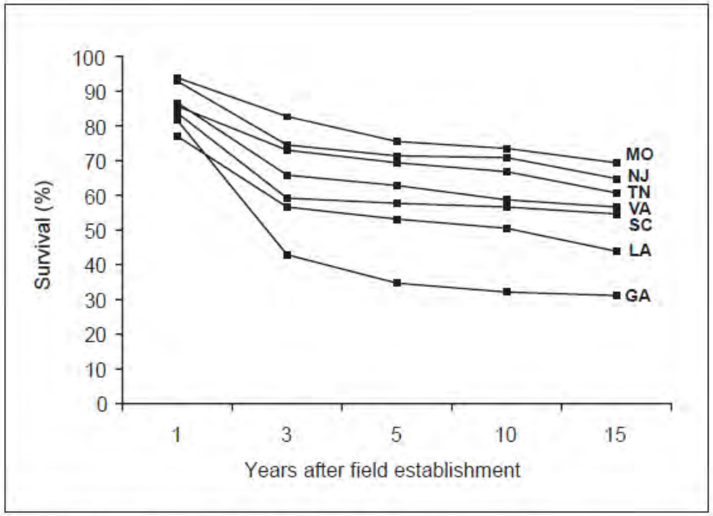


Figure 3.—Survival of shortleaf pine provenances established in Missouri in Test 444.

Ken Davidson (retired) and John Kabrick examine shortleaf pine provenance test 444 on the Sinkin Experimental Forest. Seedlings were planted in 1955.

Gwaze et al. 2007

Roots of shortleaf pine research

- Direct seedling vs. planting
- Role of site preparation for direct seeding

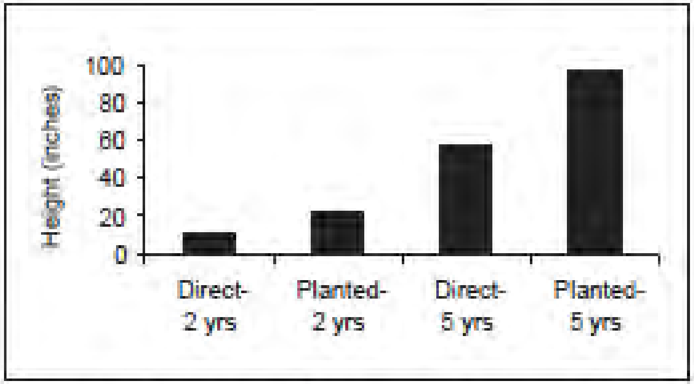


Figure 1.—Comparison of direct seeded and planted seedlings at Indian Trail Conservation Area, Dent County (Brunk 1977).

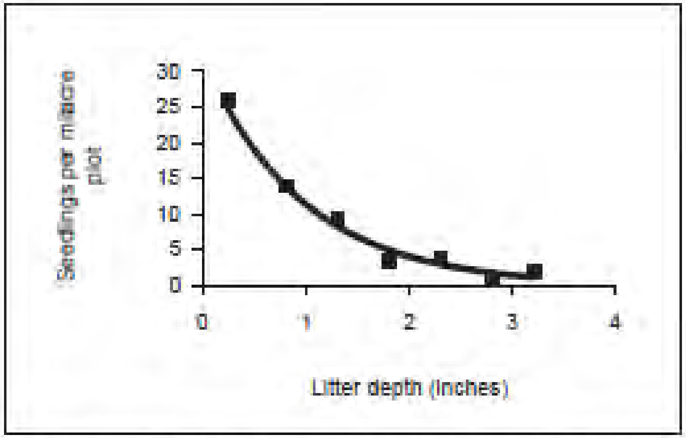
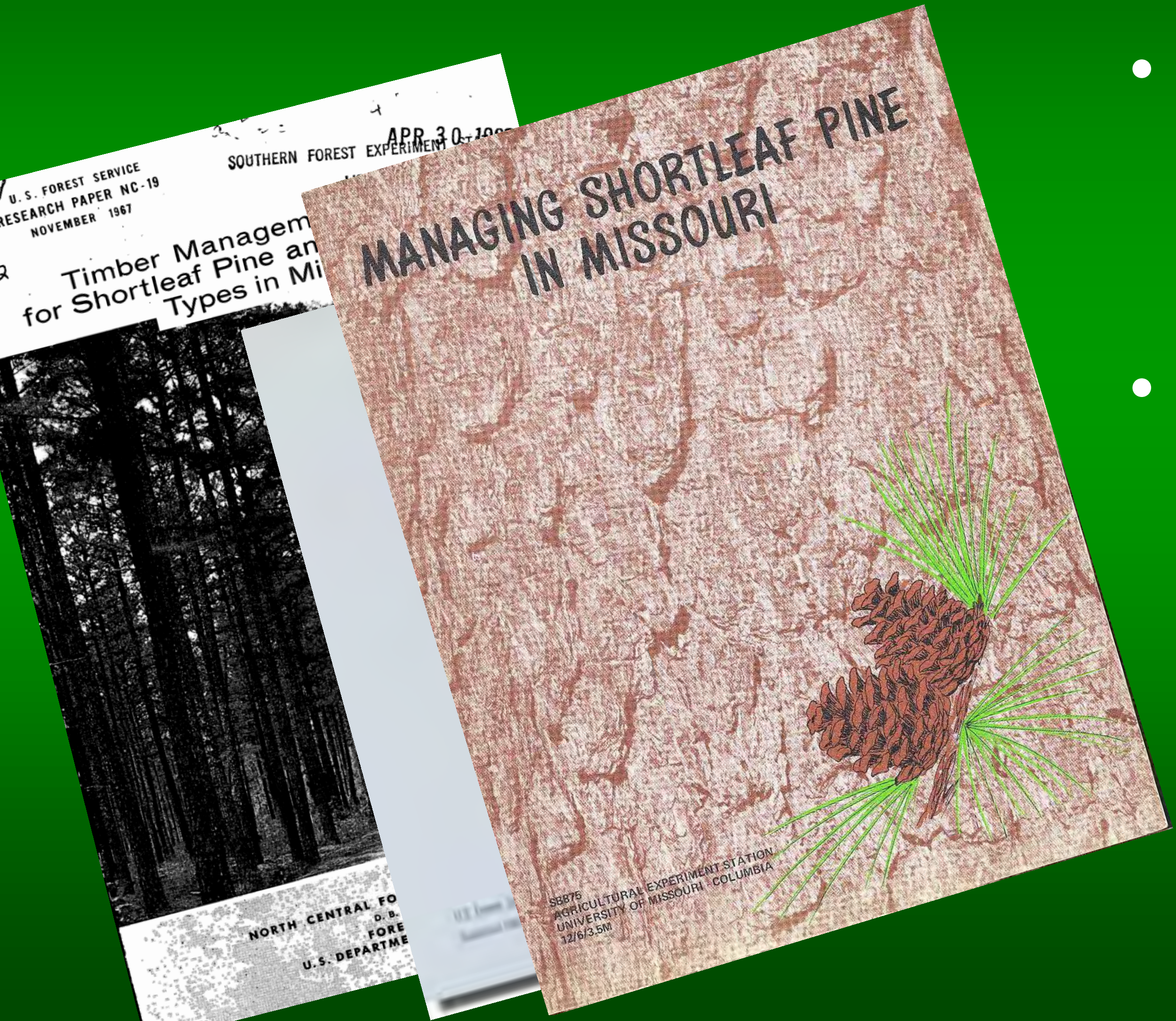


Figure 2.—Relationship between average litter depth and establishment of pine seedlings (adapted from Grano 1949).

The culmination of Tree- and Stand-Scale SLP R&D



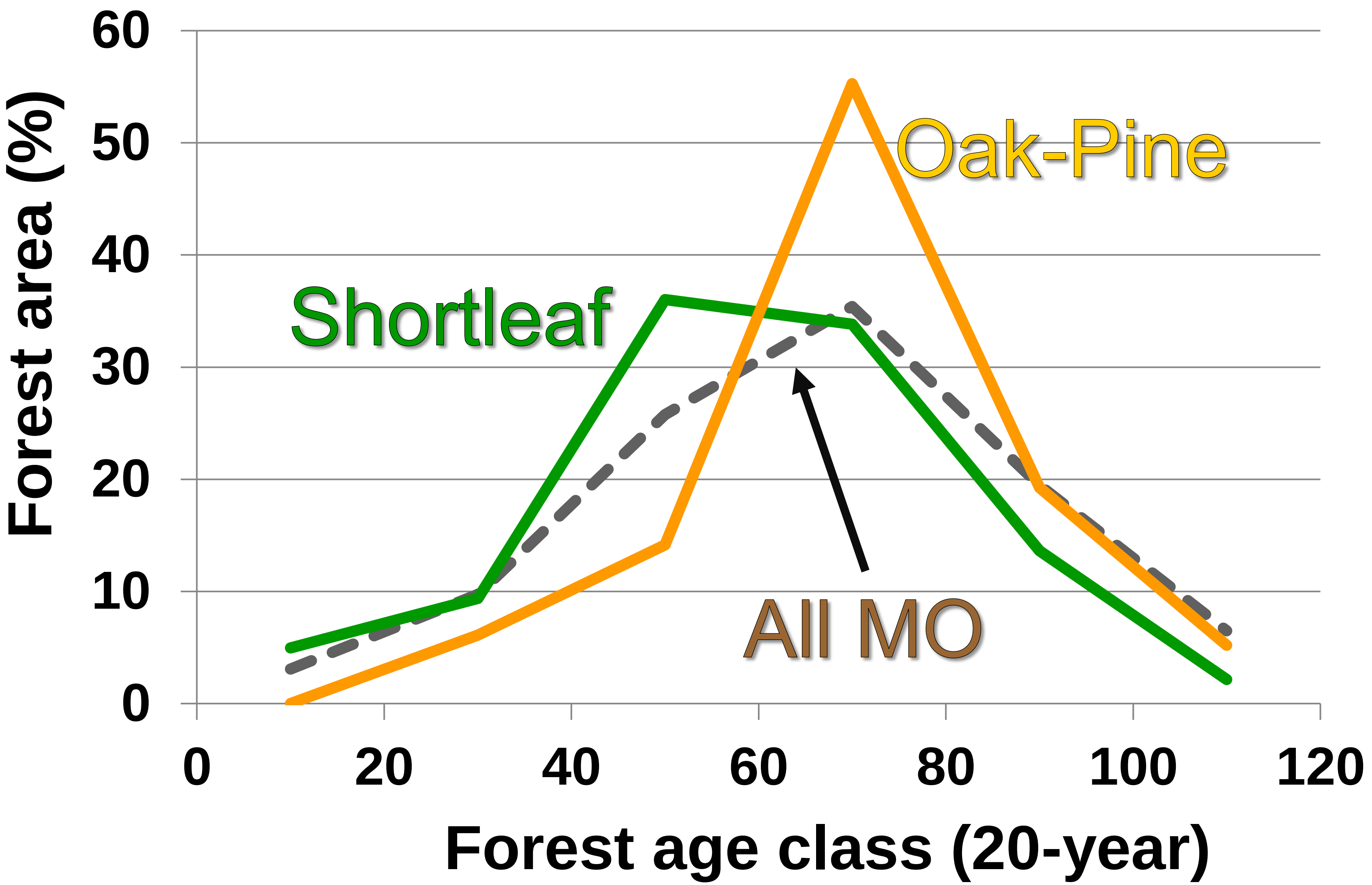
- **Managing Shortleaf Pine in Missouri. 1968. Ken Brinkman and Richard Smith.**
- **Timber management guide for shortleaf pine and oak-pine types in Missouri. 1967. Ken Brinkman and Nelson Rogers.**

Managing Shortleaf Pine in Missouri, 1968

- Management of shortleaf pine can be profitable in Missouri.
- Pines of post-size or larger are marketable, often at twice the price of oaks.
- On suitable sites remove the overstory (clearcut) and control competing hardwoods (chemically or mechanically).
- Prescribed burning may be necessary to prepare the seedbed.
- Where the black oak site index ranges from 45 to 65, managed pine stands will produce 40 % more volume than oaks.
- Potential for pine dbh of 17 to 19 inches by age 70.
- Manage pine and oak-pine types as even-aged stands. Thin at 8- to 10-year intervals beginning about age 25.
- Economic rotation age is 60 to 70 years on most sites.

Sustainable Forest Management

Missouri Forest Area by Age Class, 2018



Renewed interest in shortleaf pine

Restoring shortleaf pine is a means for

- Mitigating chronic oak decline
- Increasing landscape diversity
  - structural
  - vegetation
  - wildlife habitat

Renewed interest in shortleaf pine

CFLR – Collaborative Forest Landscape Restoration

Restoring pine and oak-pine natural communities

Rough sunflower

Blueberry
Thomas G. Barnes @ USDA-NRCS PLANTS Database

Painted bunting

Issue: Establishing and recruiting pine when absent or inadequate

Issue: Establishing and recruiting pine when absent or inadequate

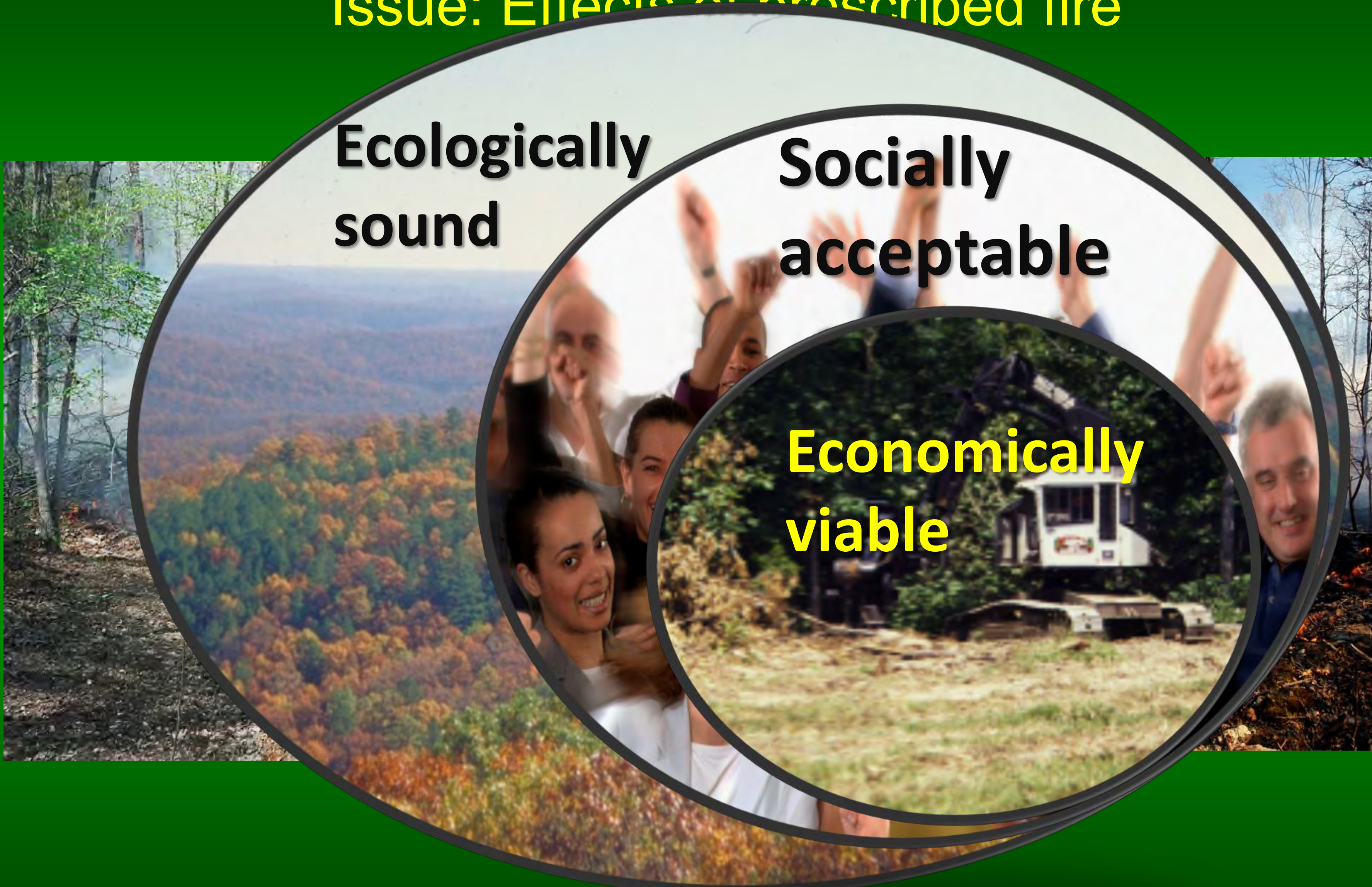
Issue: Recruiting pine under a partial overstory

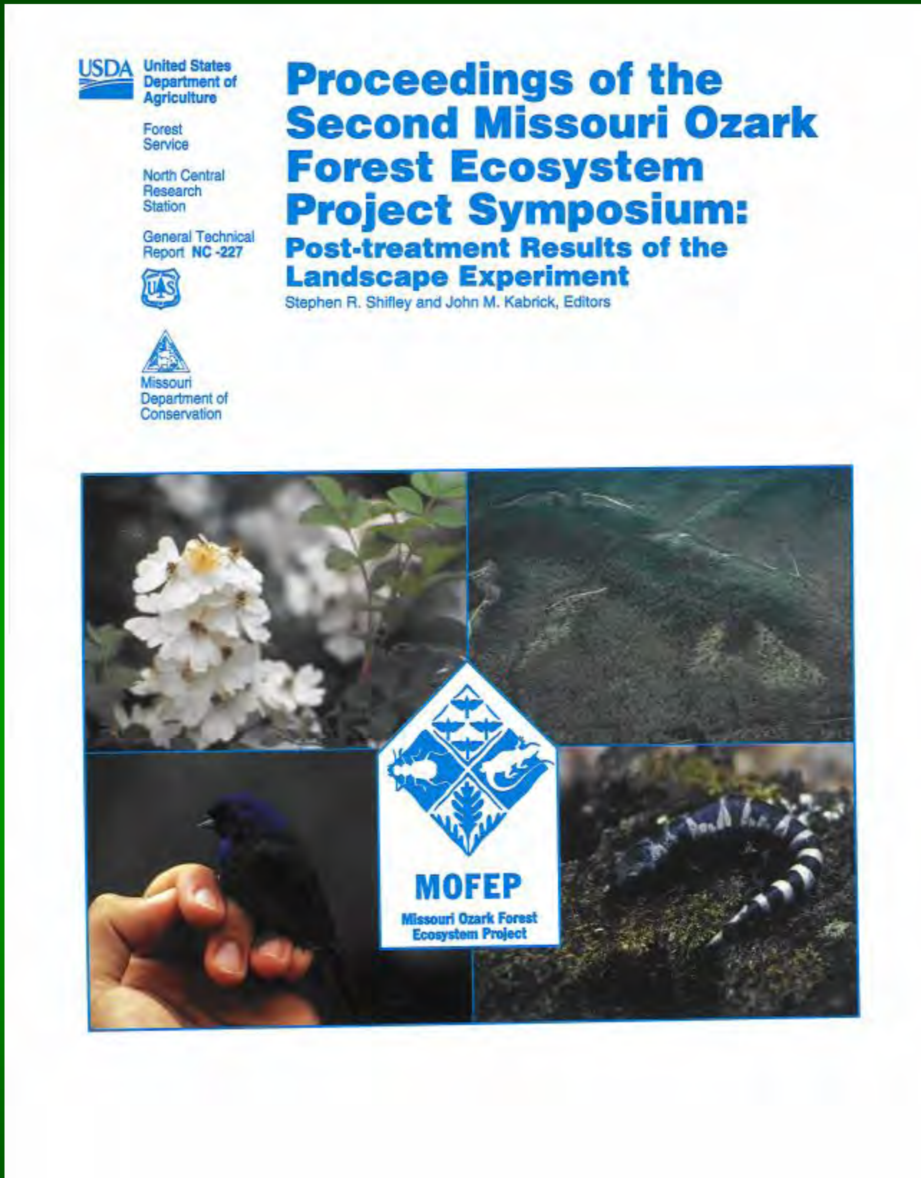
Regeneration harvest, Mark Twain NF

- Why?
  - Aesthetics
  - Plant community management
- Consequences?
  - Reduced pine survival
  - Reduced pine growth

Issue: Effects of prescribed fire

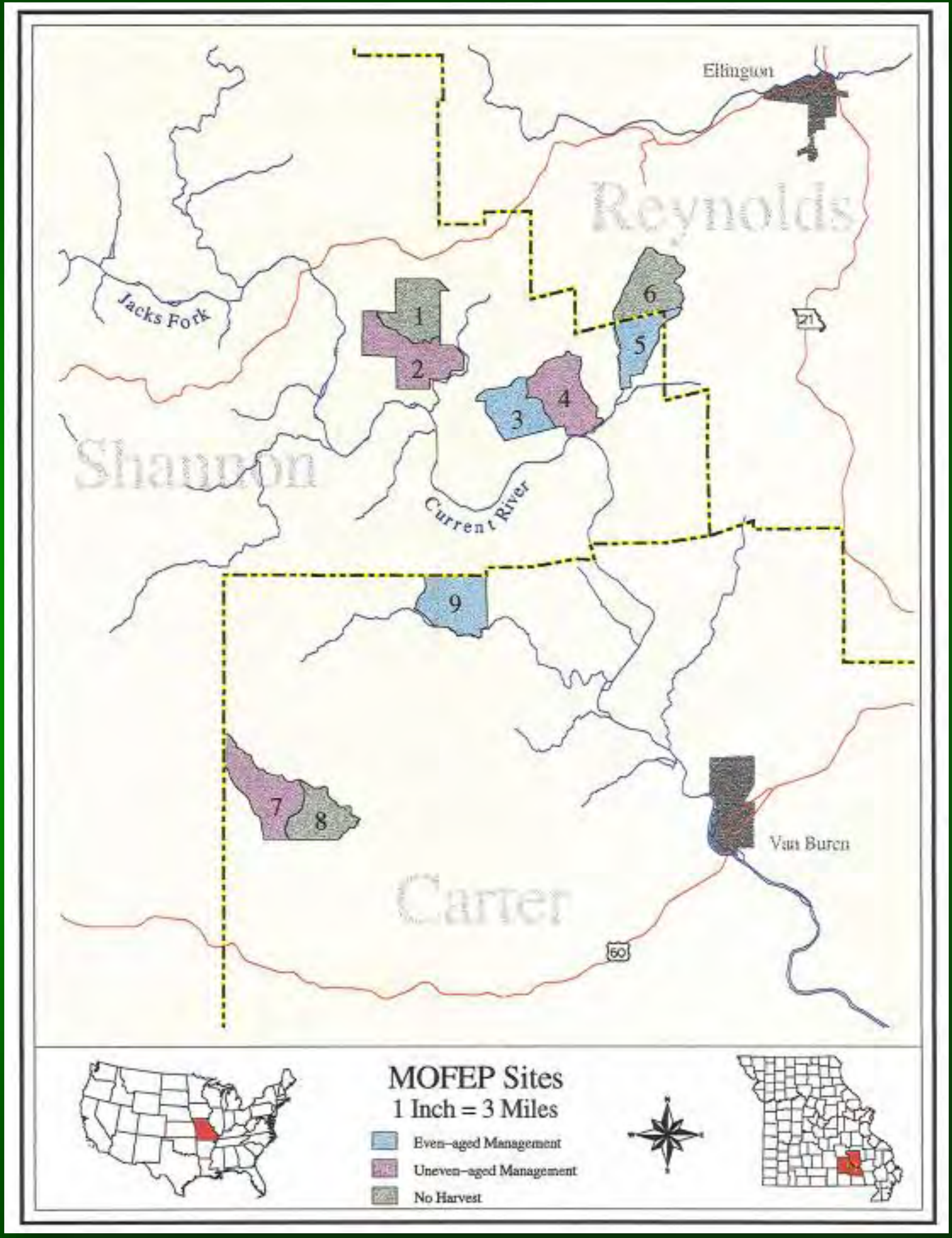
Issue: Effects of prescribed fire





Missouri
Ozark
Forest
Ecosystem
Project

Established 1991 by Missouri Department of Conservation



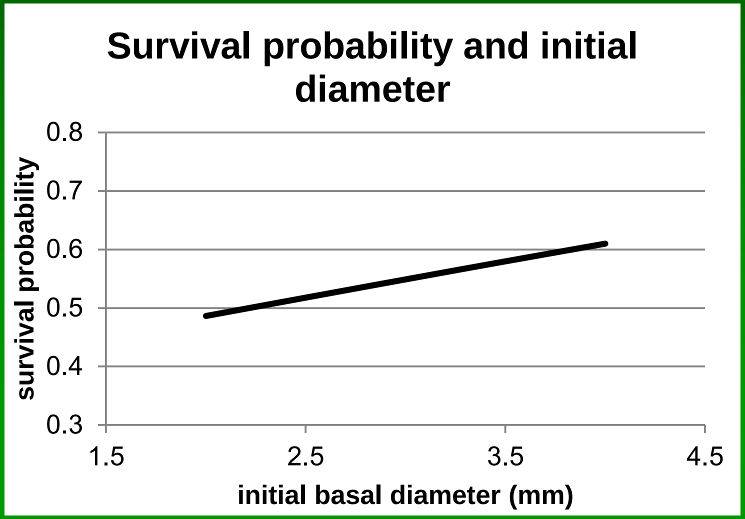
Ellington
Reynolds
Jacks Fork
1
2
3
4
5
6
21
Shannon
Current River
9
7
8
Van Buren
Carter
60
MOFEP Sites
1 Inch = 3 Miles
Even-aged Management
Uneven-aged Management
No Harvest

Recent studies (MOFEP)

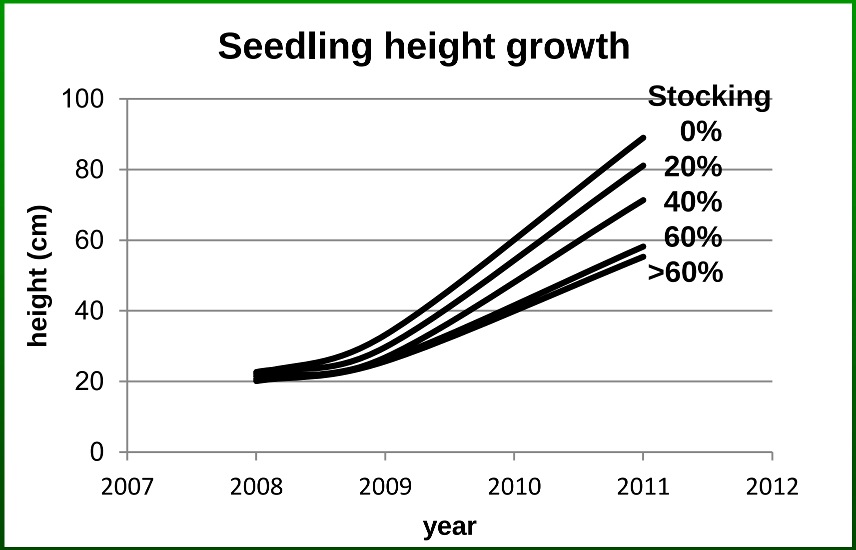
- Missouri Ozark Forest Ecosystem Study (MO Dept. Cons)
  - Leave seed trees
  - Scarify ground via skidders
  - To date this has failed to regenerate shortleaf pine

Jensen and Kabrick 2008

Recent studies (MOFEP)

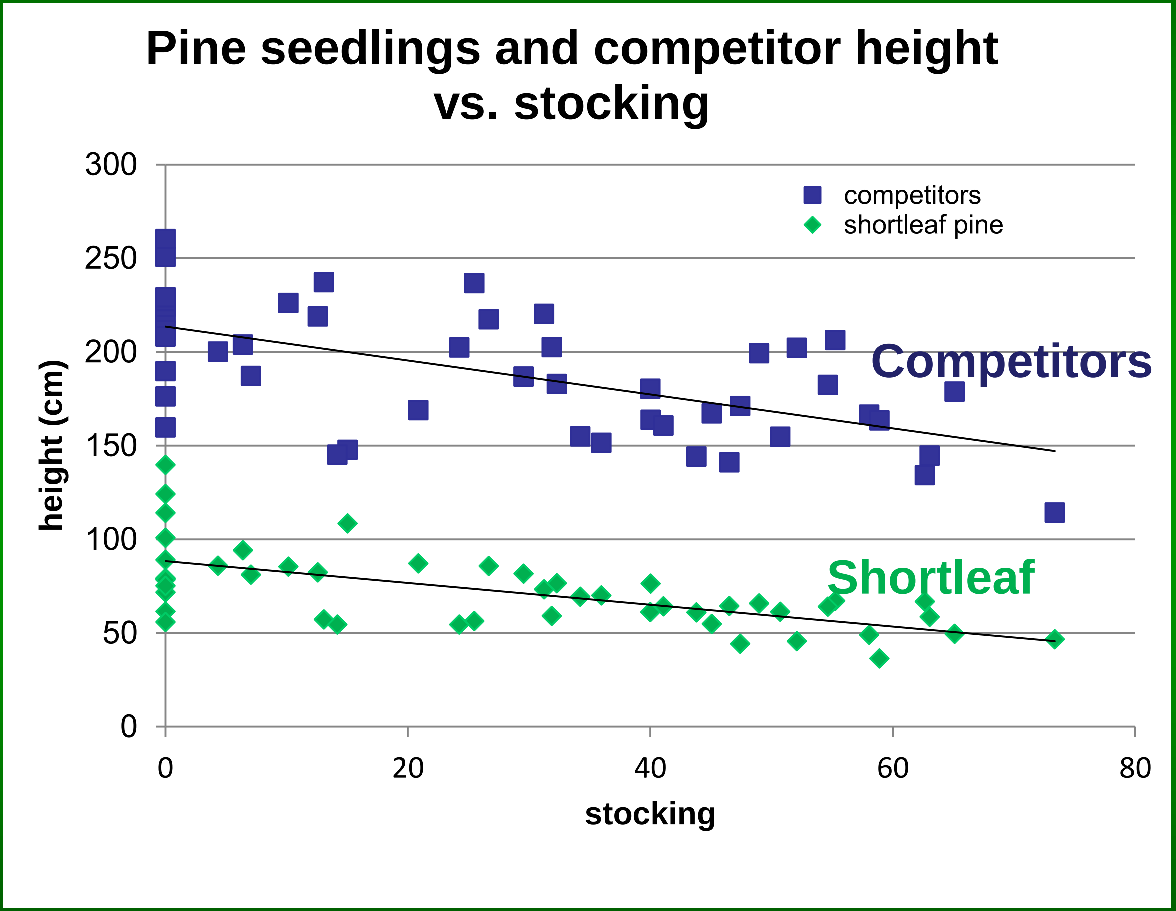



0% stocking




60% stocking

Recent studies (MOFEP)



Recent studies (MTNF, NRS)

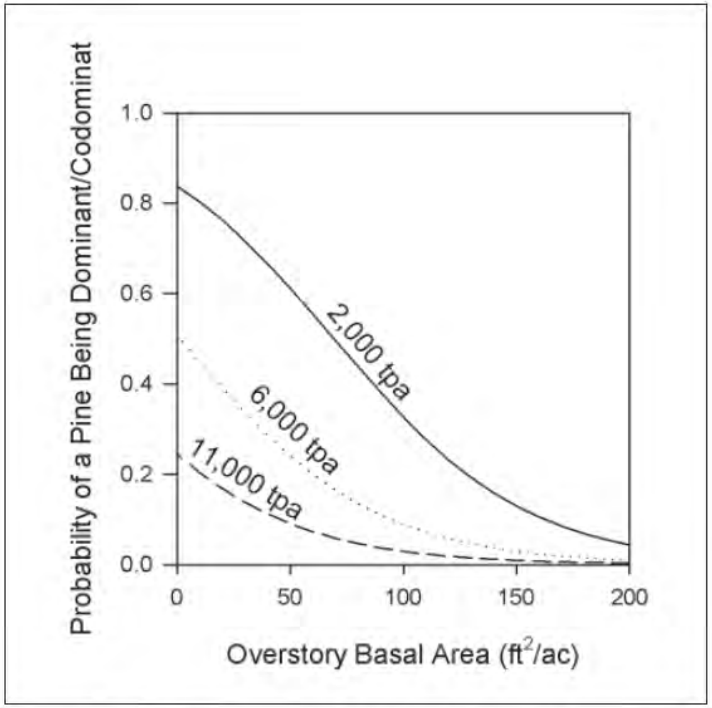


Figure 5.—Probability of a given pine being dominant/codominant for a given understory density (TPA) by overstory basal area (ft^2/ac). There is a 50 percent probability of a given pine being dominant/codominant with 2,000 TPA mixed-species reproduction at 70 ft^2/ac basal area and with 6,000 TPA mixed-species reproduction at 10 ft^2/ac basal area.

Doyle Henken
District Silviculturist (retired), MTNF

David Gwaze
National Silviculturist,
USDA Forest Service

Charly Studyvin
Silviculturist, MTNF

Blizzard et al. 2007

Recent studies (MTNF)

- Understory release
  - Mechanical
  - Chemical
  - thermal

Recent studies (LTSP)

North American Long-Term Soil Productivity Program (LTSP)

- Effects of carbon removal and compaction on site productivity
- Missouri installation: Shortleaf pine, white oak, northern red oak are featured

Recent studies (LTSP)

Table 2. --Average survival, total height, and diameter at breast height (DBH) of shortleaf pine as affected by three levels of soil compaction and weed control, 9 years after planting.

Treatment	Survival Percent	Total height cm	DBH mm
Compaction			
None	72a	586.3a[1]	96.5a
Medium	65a	613.7b	103.3b
Severe	70a	641.0b	112.9b
p value	0.2781	<0.0001	0.0019
Weed control			
With	69a	632.9a	131.3a
Without	70a	603.5b	82.1b
p value	0.1102	<0.0202	0.0001

[1]In each column, within compaction and weed control levels, values followed by the same letters are not significantly different according to Duncan Multiple Range test.

North American Long-Term Soil Productivity Program (LTSP)

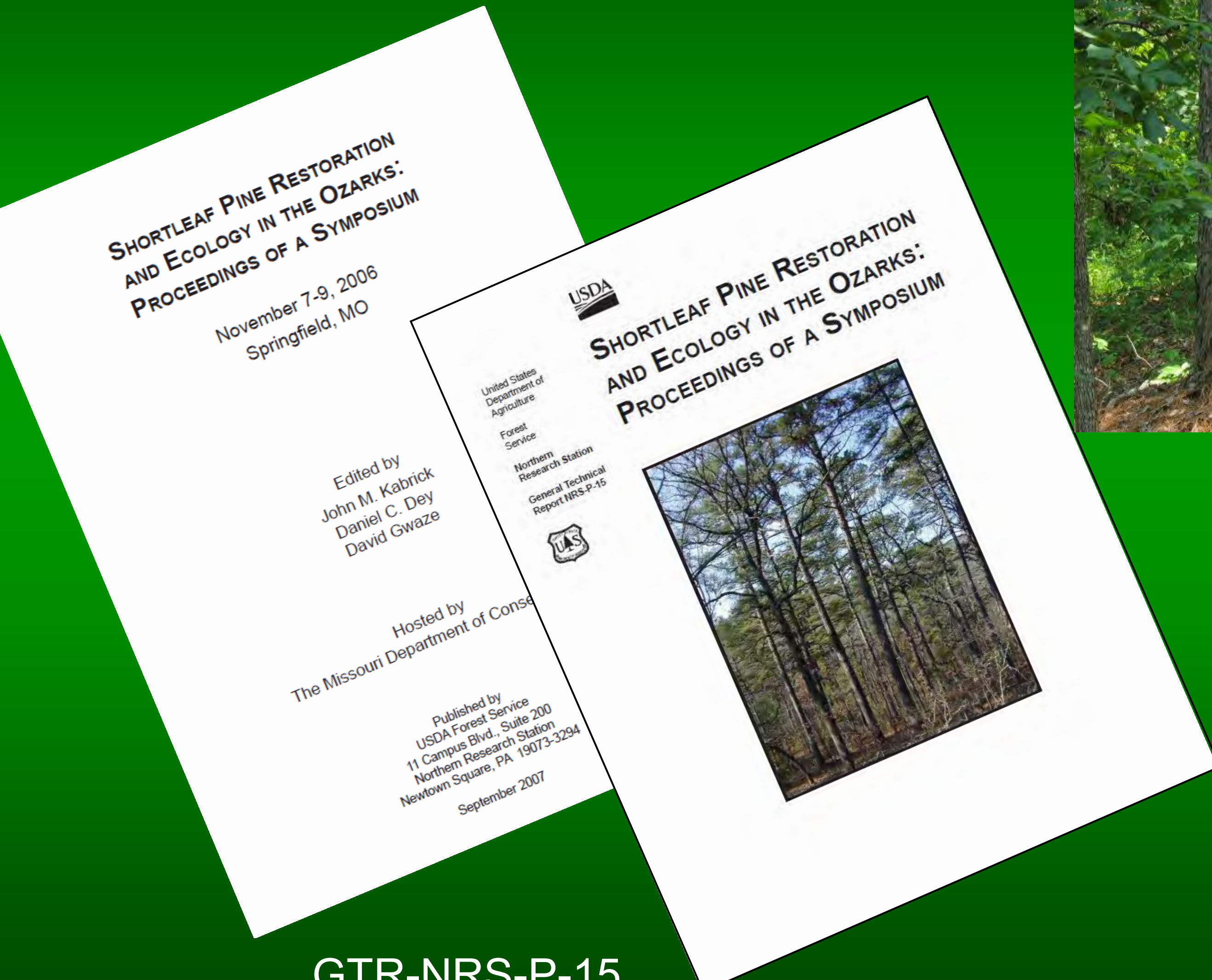
- Effects of carbon removal and compaction on site productivity
- Missouri installation: Shortleaf pine, white oak, northern red oak are featured

Recent studies

- Burned every three to four years
- Reproduction and ground flora monitored

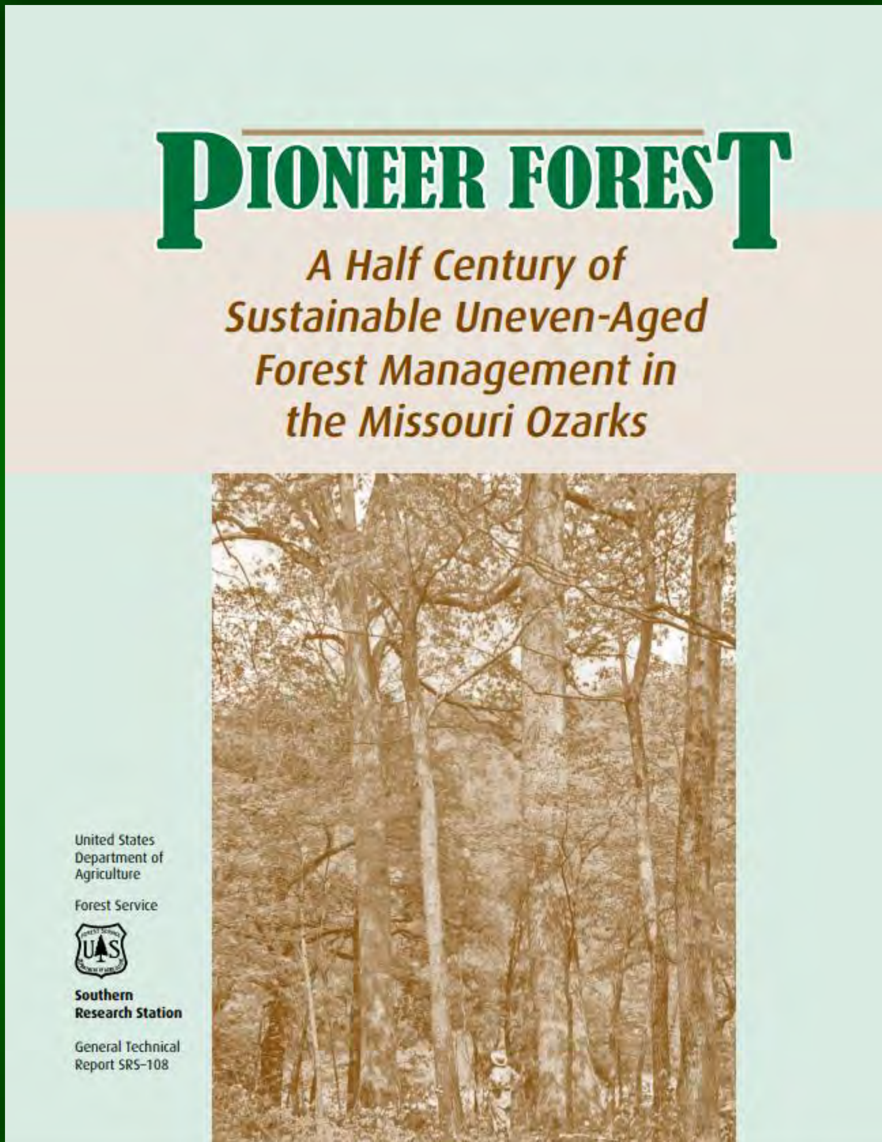
Shortleaf pine savanna, Sinkin Experimental Forest

Synthesis



GTR-NRS-P-15

- 200 registrants
- 44 presentations
- 9 posters
- 27 manuscripts
- 14 abstracts

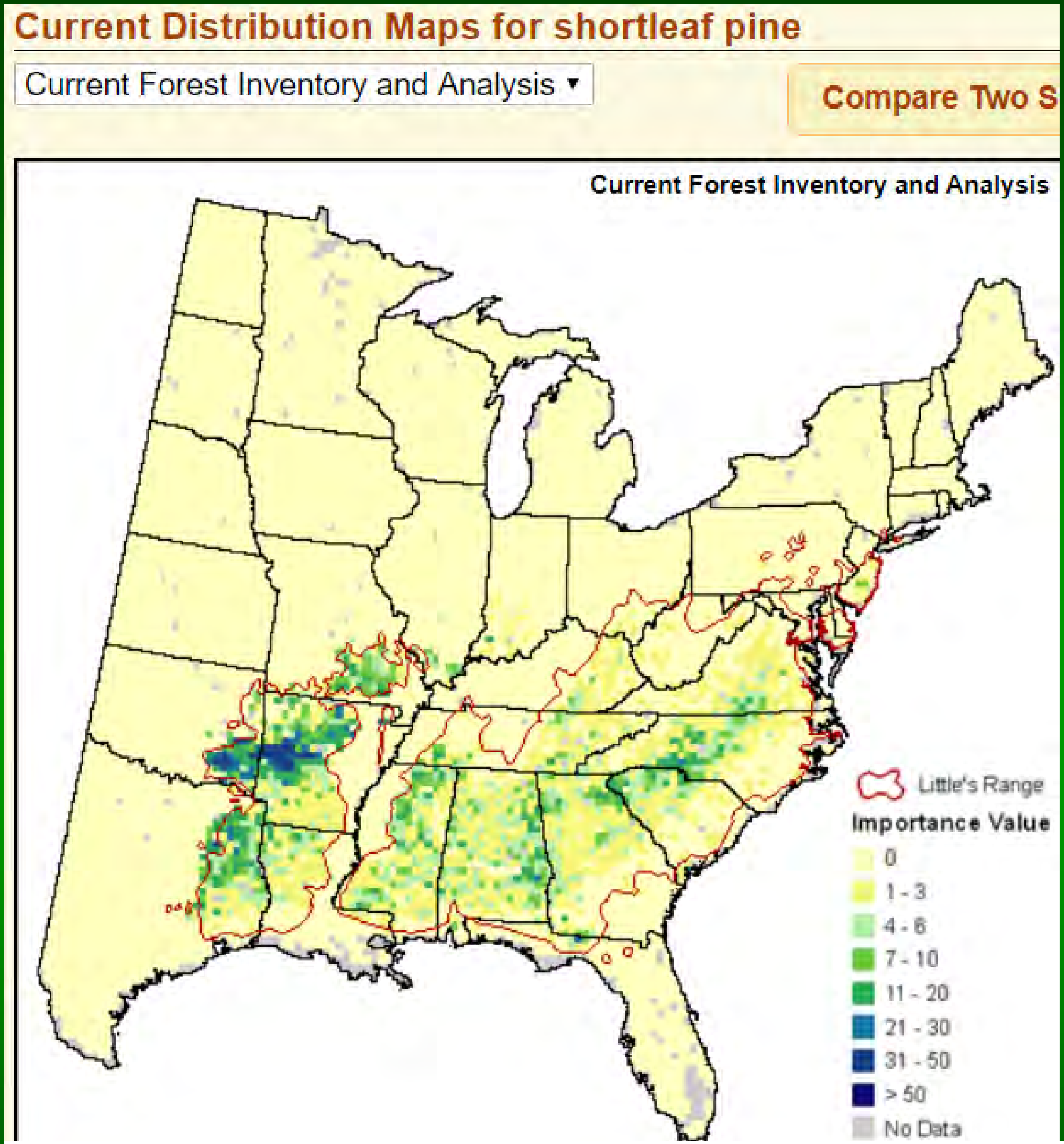


- LAD Foundation
- Approximately 200,000 acres
- Oak and oak-pine
- Actively managed
  - uneven-aged
  - pine restoration
- CFI system 1957 to present

Interest in mixedwoods

- Mixedwoods are stands containing mixtures of hardwoods and softwoods, with < 75-80% of either
- Ozarks efforts to manage pine-oak mixedwoods are challenged by shortleaf pine regeneration issues.
- Benefits include:
  - Restoration of natural communities
  - Compatibility with woodland management
  - Diversification of timber products
  - Mitigation of forest health issues
  - Adaptability to future conditions

58

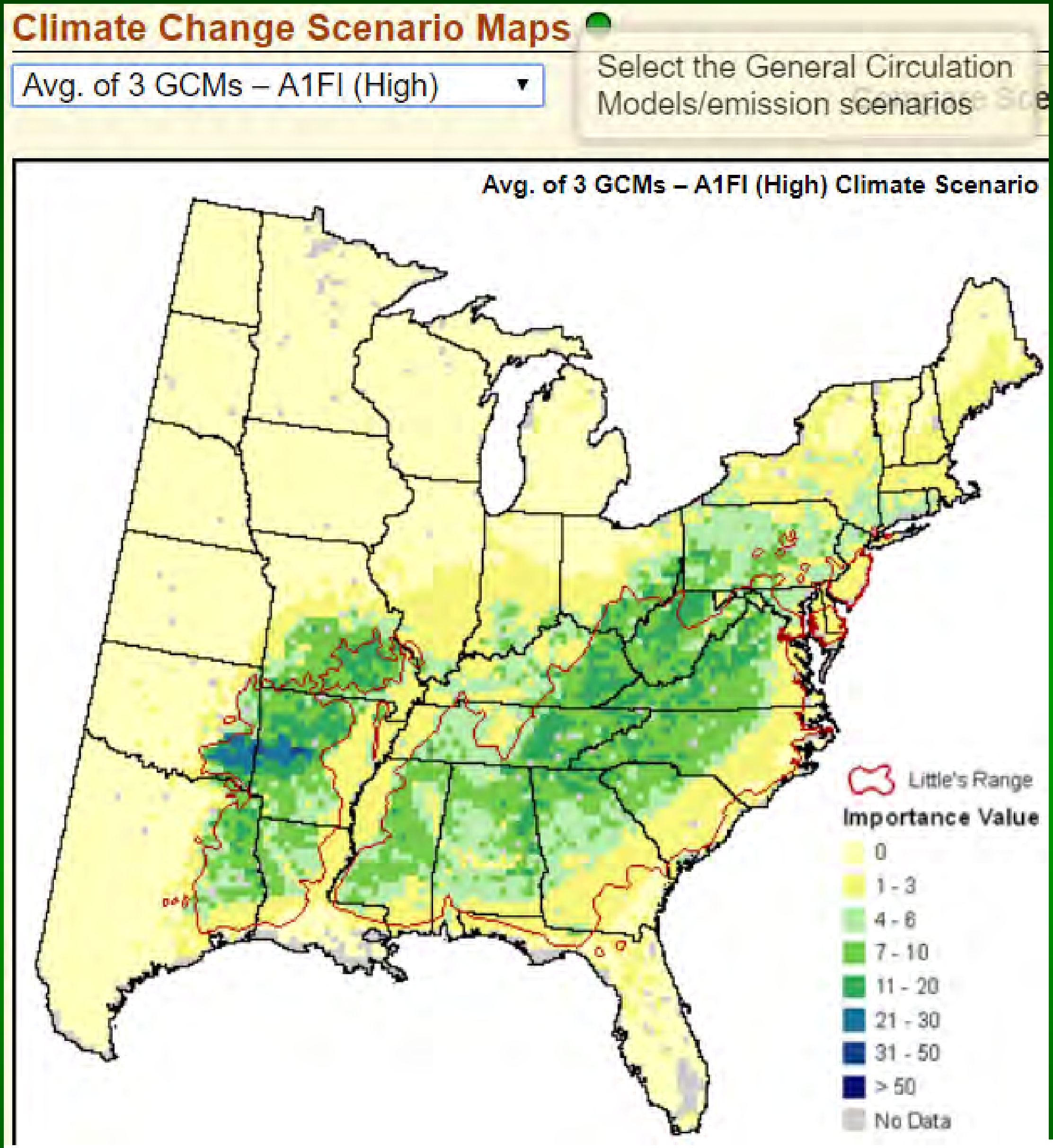


Climate Change Atlas

https://www.fs.fed.us/nrs/atlas/

Current Shortleaf Distribution

Prasad, A. M., L. R. Iverson., S. Matthews., M. Peters. 2007-ongoing. A Climate Change Atlas for 134 Forest Tree Species of the Eastern United States [database]. http://www.nrs.fs.fed.us/atlas/tree, Northern Research Station, USDA Forest Service, Delaware, Ohio.



Climate Change Atlas

https://www.fs.fed.us/nrs/atlas/

Modeled Shortleaf Distribution, 2100

Average for "High" Emissions

Prasad, A. M., L. R. Iverson., S. Matthews., M. Peters. 2007-ongoing. A Climate Change Atlas for 134 Forest Tree Species of the Eastern United States [database]. **http://www.nrs.fs.fed.us/atlas/tree**, Northern Research Station, USDA Forest Service, Delaware, Ohio.

Summary

- Early SLP research focused on timber production.
- Emphasis has changed from products to ecosystem services.
- Current R&D directed towards quantifying SLP establishment, growth, and developmental dynamics in a ecosystem restoration context.

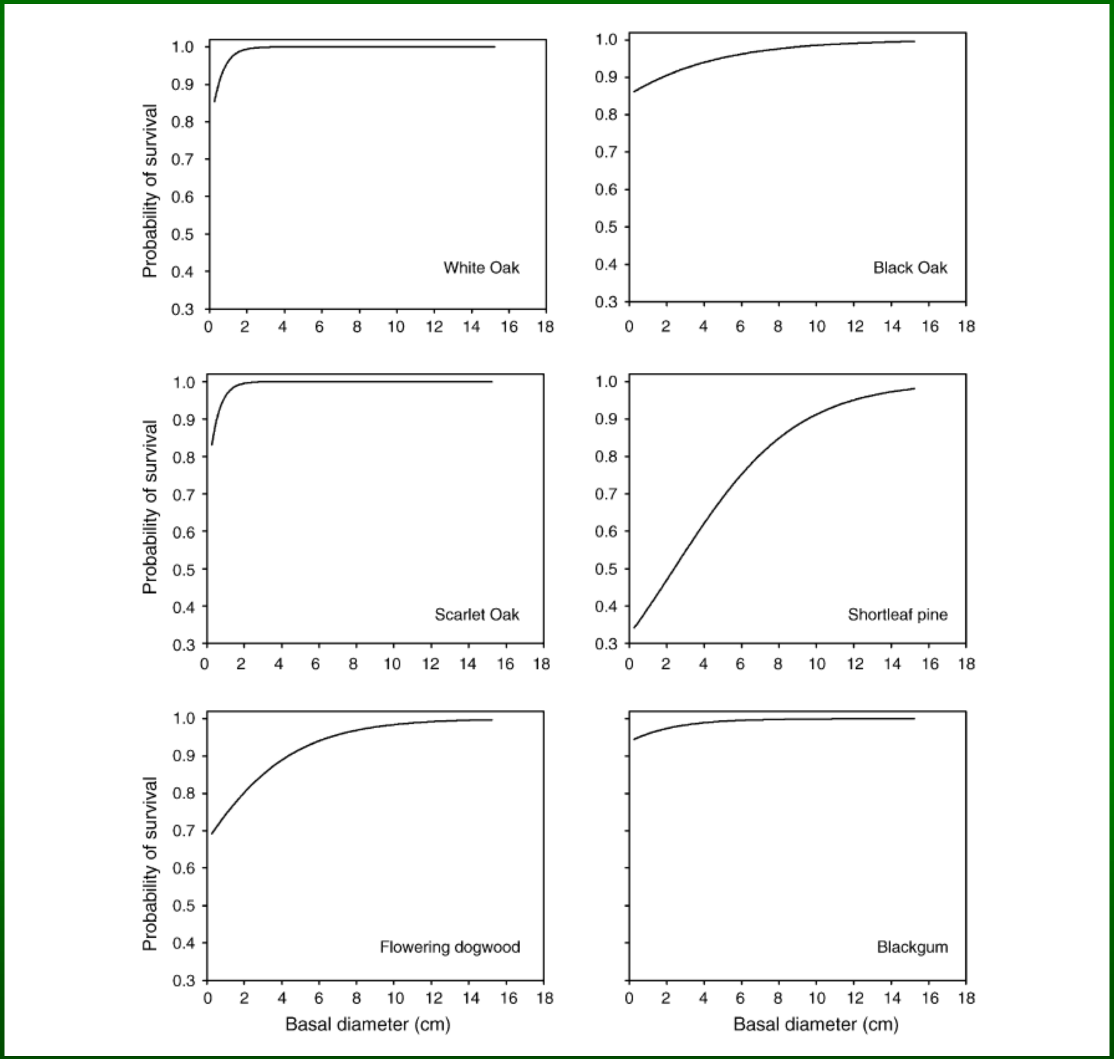
Summary

- 70 years of R&D at tree, stand, and landscape scales.
- Blessed with numerous landscape-scale studies that include SLP as a component
  - CFLRP, MOFEP, LTSP, Pioneer Forest, FIA, LANDIS, Climate, Mixedwoods…
- Huge synthesis opportunities.
- Need place-based implementation.

Recent studies (NRS, MDC)

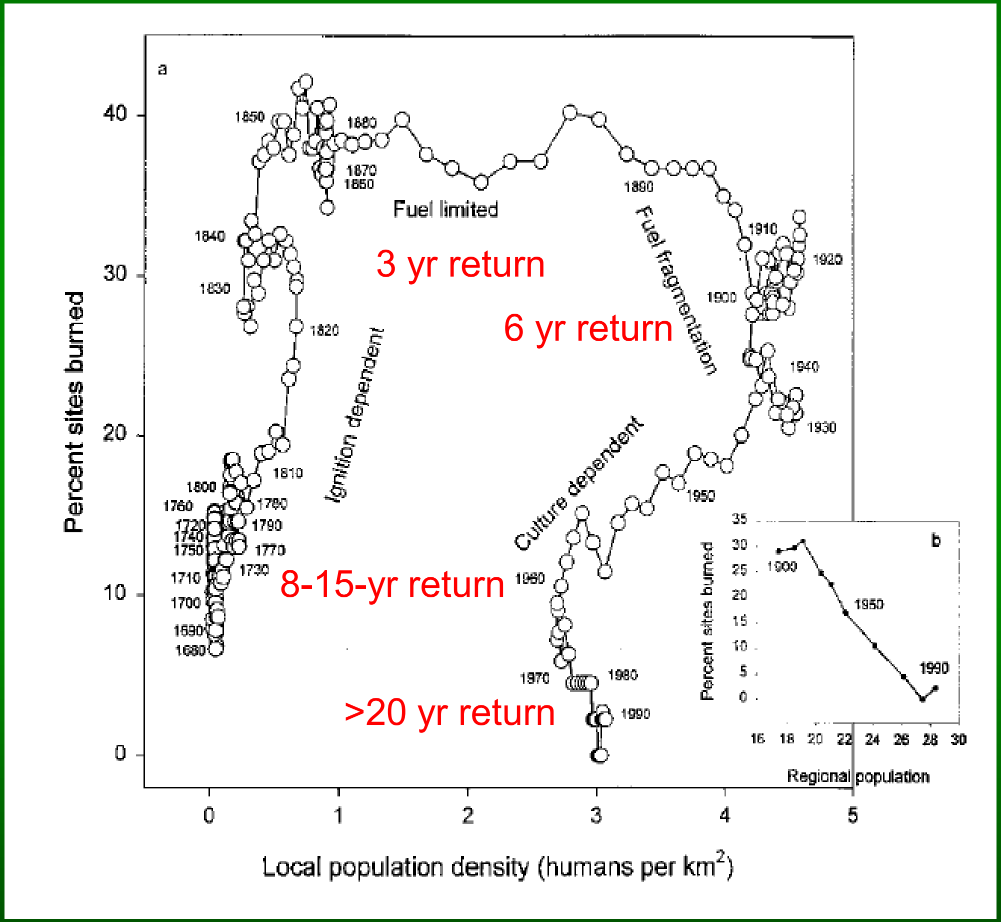
Survival probability following a prescribed burn

- Prescribed fire
  - Shortleaf pine are fire-adapted
  - Hardwoods appear to resprout more vigorously



Dey and Hartman 2005

Recent studies



- Fire histories
  - Fire frequency when most of the shortleaf pine became established was low

Guyette et al. 2002

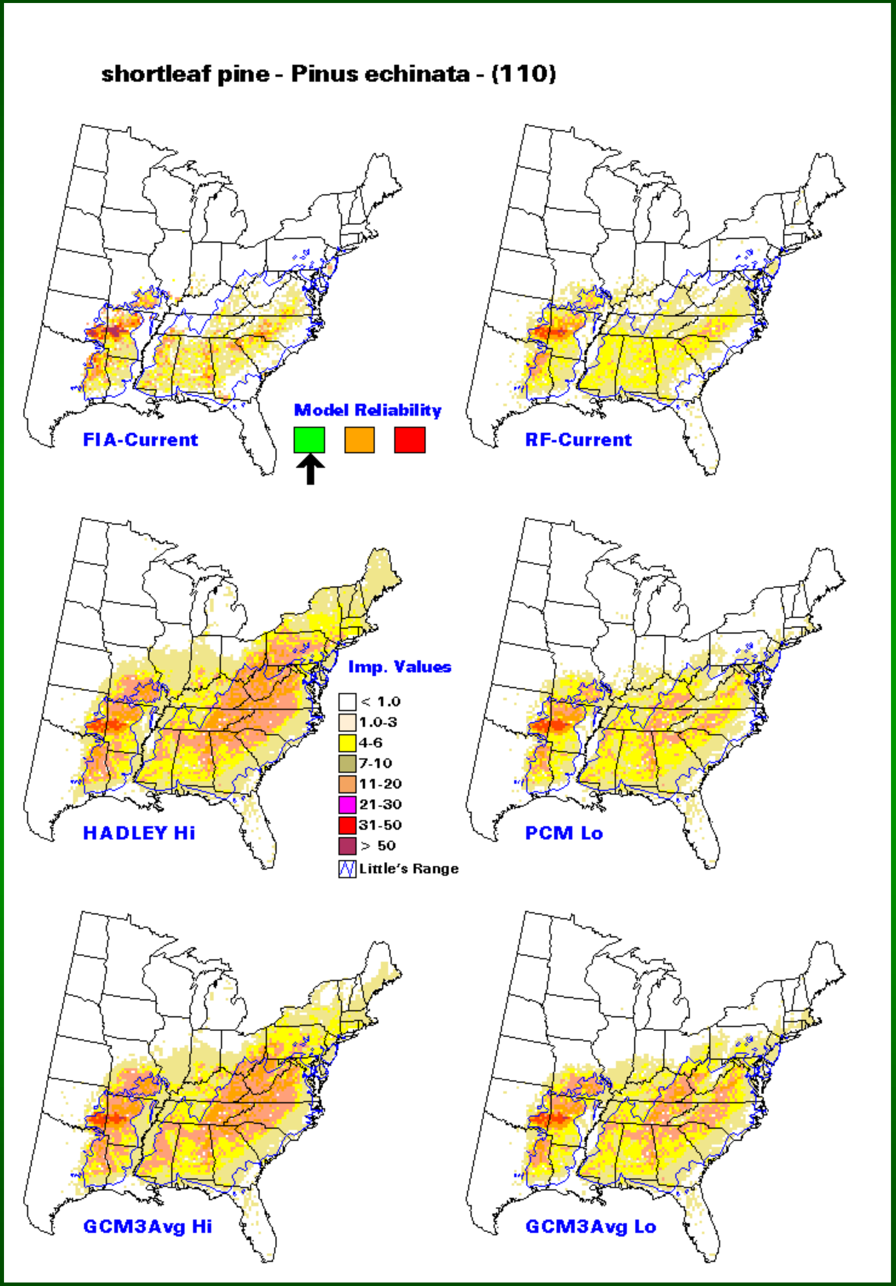
Shortleaf pine today

State	Growing stock volume (million cubic feet)	Net growth (million cubic feet)
Arkansas	3,410	101
Mississippi	1,530	73
Texas	1,512	45
Alabama	1,098	46
Oklahoma	1,019	63
Missouri	798	25
Pennsylvania	0.802	0.004
West Virginia	12.8	-0.4

Moser et al. 2007

- MOFEP
- CFLRP
- PIONEER

- Shortleaf pine in the future…



Prasad, A. M., L. R. Iverson., S. Matthews., M. Peters. 2007-ongoing. A Climate Change Atlas for 134 Forest Tree Species of the Eastern United States [database]. http://www.nrs.fs.fed.us/atlas/tree, Northern Research Station, USDA Forest Service, Delaware, Ohio.

Using regeneration ecology to understand development and maintenance of shortleaf pine-oak mixedwoods of Missouri, USA

Benjamin O. Knapp[1], John M. Kabrick[2], Daniel C. Dey[2], and Lance A. Vickers[1]

North American Forest Ecology Workshop
June 25, 2019
Flagstaff, AZ

[1]University of Missouri; [2]USDA Forest Service, Northern Research Station

Mixedwoods in Missouri

- Mixedwoods are stands containing mixtures of hardwoods and softwoods, with < 75-80% of either component
- Missouri: shortleaf pine and oak-hickory mixtures

- Efforts to manage pine-oak mixedwoods are challenged by shortleaf pine regeneration issues

- Regeneration issues at an intersection of historical legacies, shortleaf pine ecology, and contemporary management practices

- <u>Objectives are to discuss:</u>
  1) historical context
  2) shortleaf pine regeneration ecology
  3) pathways to mixedwoods in Missouri
  4) management recommendations

70

Interest in mixedwoods

- Restoration of natural communities
- Compatibility with woodland management
- Diversification of timber products
- Mitigation of forest health issues
- Adaptability to future conditions

71

Historical context

Historically, shortleaf pine was a dominant species in the Ozarks

Historical loss of shortleaf pine

Measure	Scale	Location	Historic	Current and future	Percent of historic conditions	Source
Area	Ozark oak pine forests	Missouri Ozarks	1.1 million ha[2]	0.17 million ha	15%	Cunningham and Hauser (1989)
Stem density, no plantations	335 ha	MOFEP 8 SE MO	17,143 stems ha^{-1}	5,744 stems ha^{-1}	34%	Guyette & Dey (1997)
Stem density with plantations	335 ha	MOFEP 8 SE MO	17,381 stems ha^{-1}	9,239 stems ha^{-1}	53%	Guyette & Dey (1997)
Spatial occurrence	29,000 km^2	Oak-pine region of MO	47 % (IMI)	9.6 % (LULC)	20%[c]	Hamilton (2003)
Wood volume	2 ac cut over oak-pine forest	Reynolds Co. MO.	11.4 m[4]	1.5 m[3]	13%	Record (1910)
Predicted % of landscape with pine	century model estimate[d]	Oak-hickory pine forests	60% (with fire)	10% (with no fire)	17%	Guyette and others (2004)
Basal area	335 ha	MOFEP 8 ridge tops	2.3 m^2 ha^{-1}	0.83 m^2 ha^{-1}	35%	Voelker (2004)
Mean					22% without plantations	

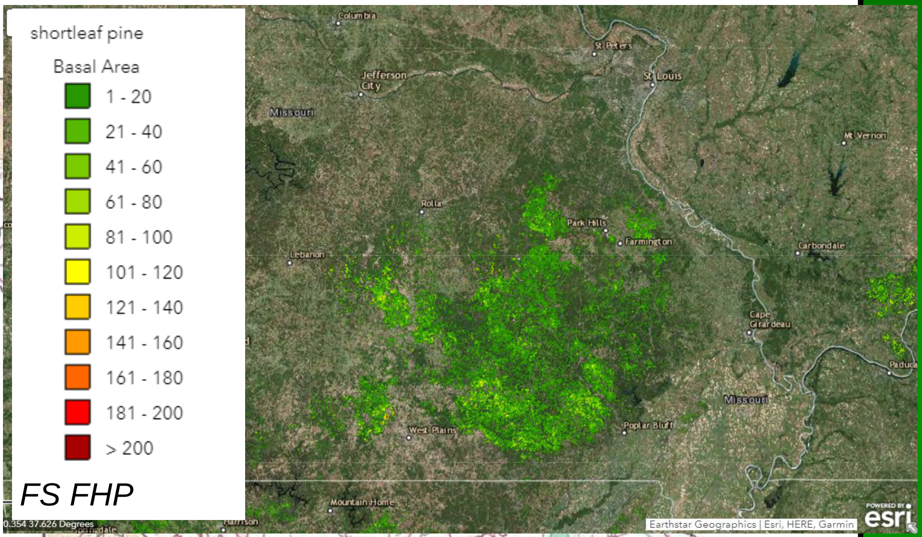
Guyette et al. 2007

Distribution of shortleaf pine

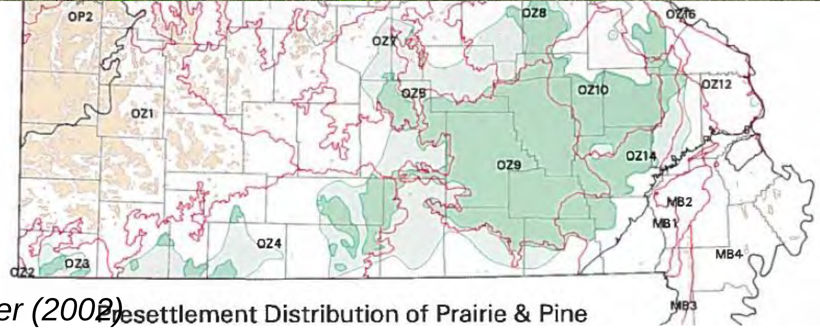
Several site factors have been associated with shortleaf pine occurrence:

- Geology: Roubidoux sandstone
- Aspect: south-facing slopes
- Little to no loess

Shortleaf pine occurred in pure stands but commonly as mixtures of pine-oak



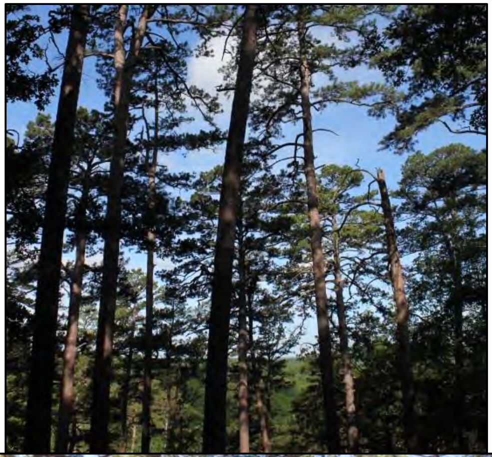
FS FHP



Nigh and Schroeder (2002)

Distribution of shortleaf pine

Stands dominated by shortleaf pine occur in the contemporary landscape but are relatively rare

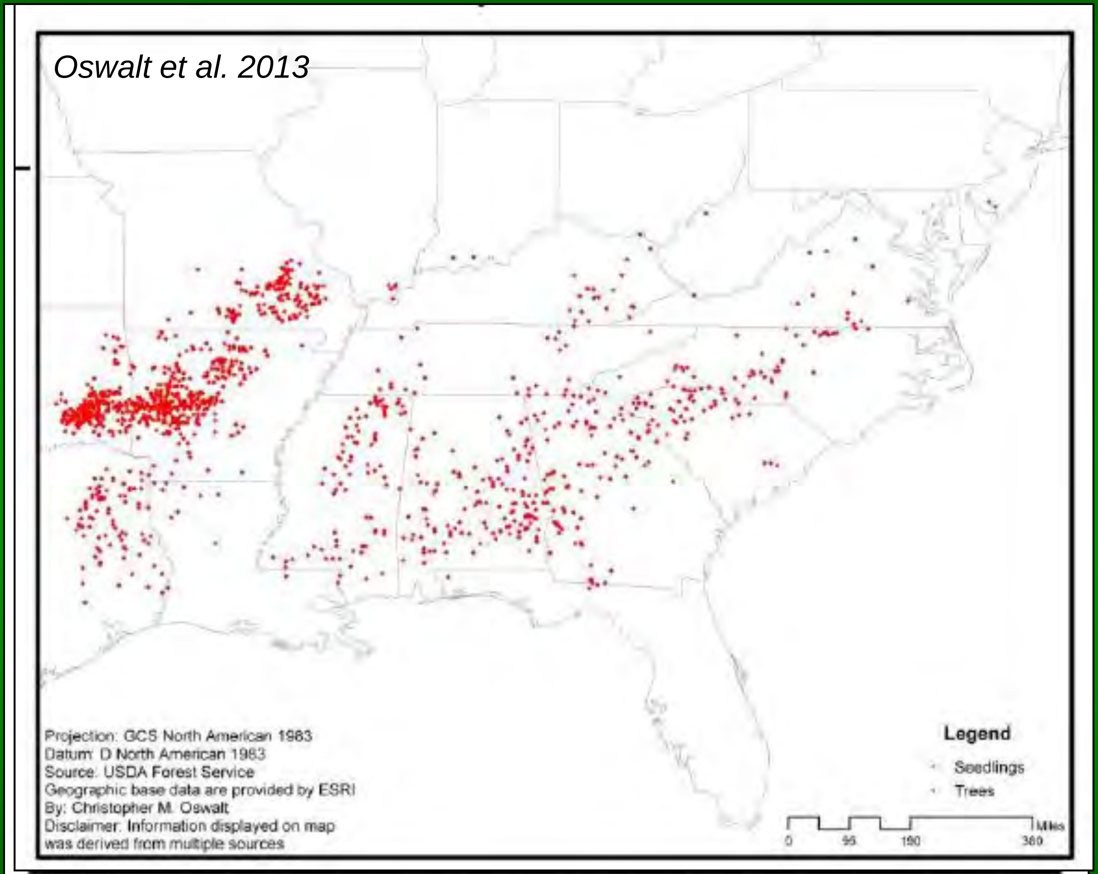


- Many pure pine stands within the region were established through reforestation programs of the 1930s or 1960s
  - Often included intensive treatments such as mechanical disturbance and complete competition control

Distribution of shortleaf pine

Despite the occurrence of shortleaf pine throughout the Ozarks, regeneration is often scarce

- 5:1 ratio of relative abundance of canopy trees to regeneration *(Moser et al. 2007)*



Approximate location of current FIA plots with at least 1 shortleaf pine greater than or equal to 1 inch DBH.

Shortleaf pine regeneration ecology

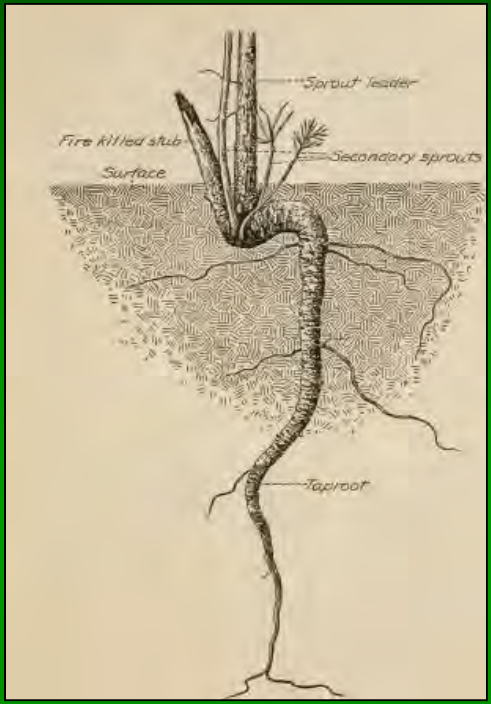
Previous research has largely informed managers as to shortleaf pine regeneration requirements

Key stages of regeneration cycle

- Seed production
- Germination
- Competitive status
  - New seedlings
  - Saplings

Fire adaptation: seedling sprouting

- Similar to hardwoods, shortleaf pine seedlings sprout following disturbance
- Shade tolerance of shortleaf pine does not allow accumulation of advance reproduction



Competitive recruitment

Recruitment into the canopy requires sustained growth that exceeds that of competing vegetation

Abundant hardwoods create challenges for recruitment

Treatments that reduce competition increase shortleaf pine growth

- Canopy reduction
- Sub-canopy density

Example: underplanting study

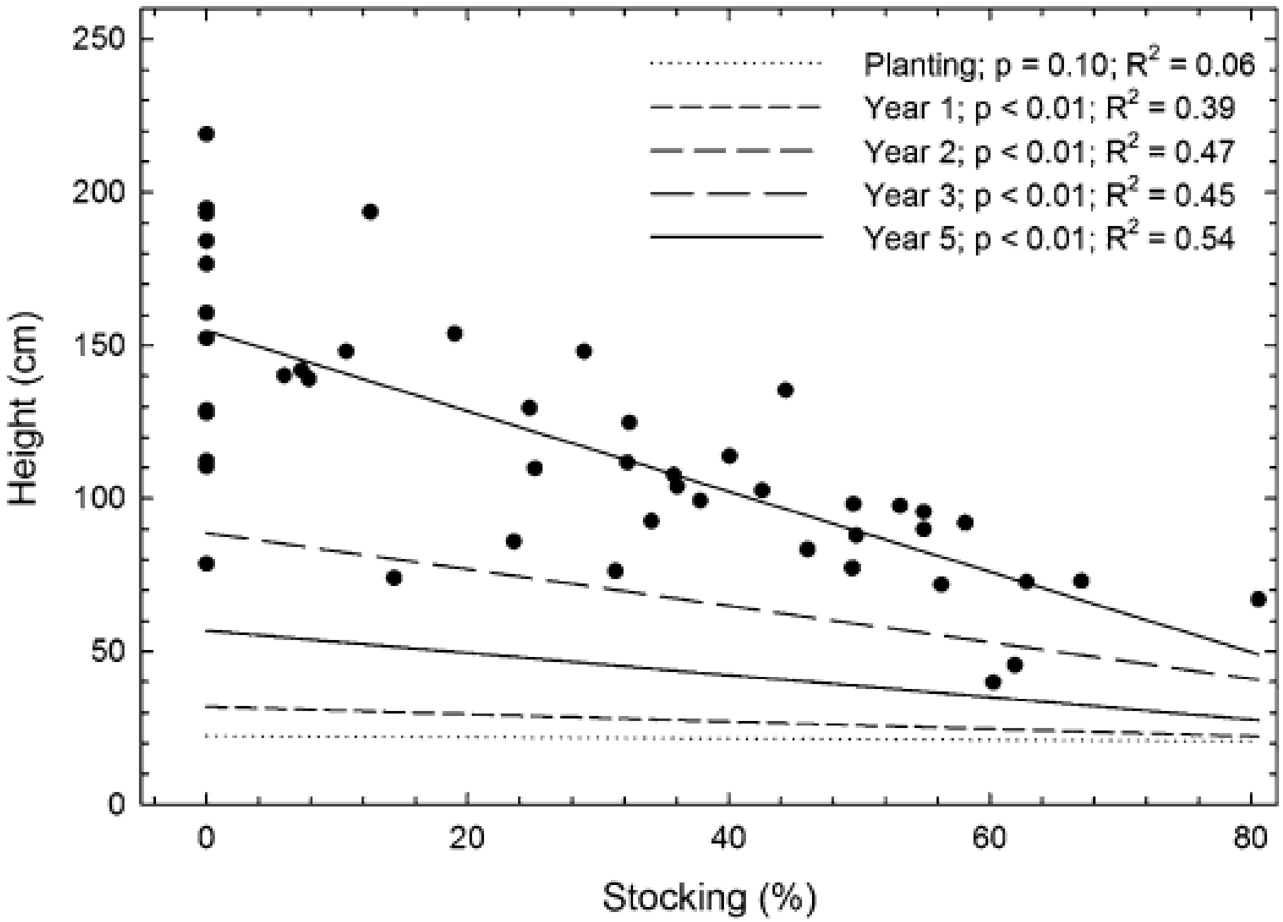
Sinkin Experimental Forest in Dent County, MO

- 48 plots with gradient of overstory density levels
- 30 shortleaf pine seedlings planted within each plot in April 2008
- Survival and growth of shortleaf measured over 10 growing seasons
- Competitor size measured

Example: underplanting study

Shortleaf pine

- Survival at year 5 not affected by overstory density
- Growth reduced by overstory stocking

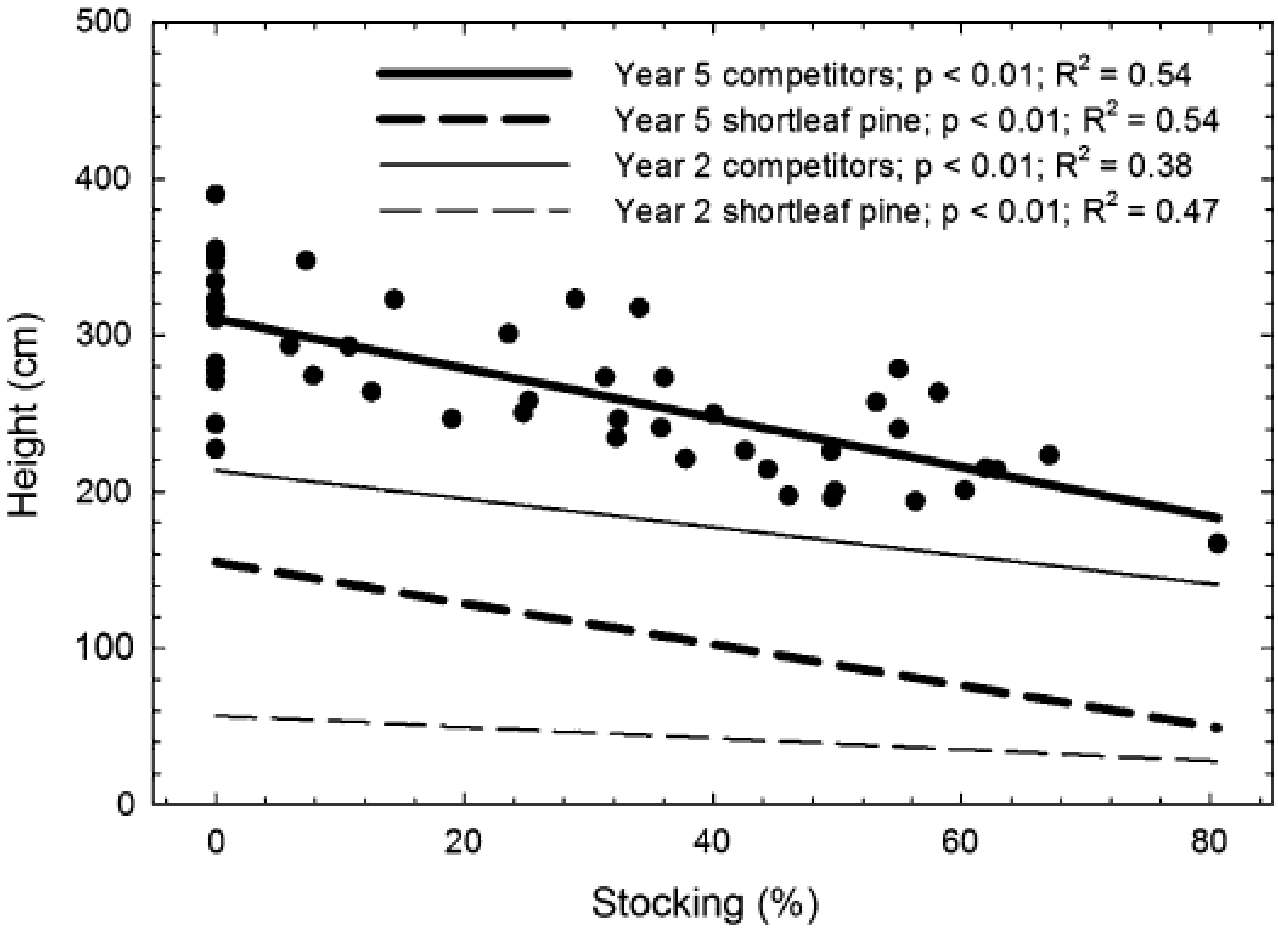


Kabrick et al. 2015

Example: underplanting study

Hardwoods

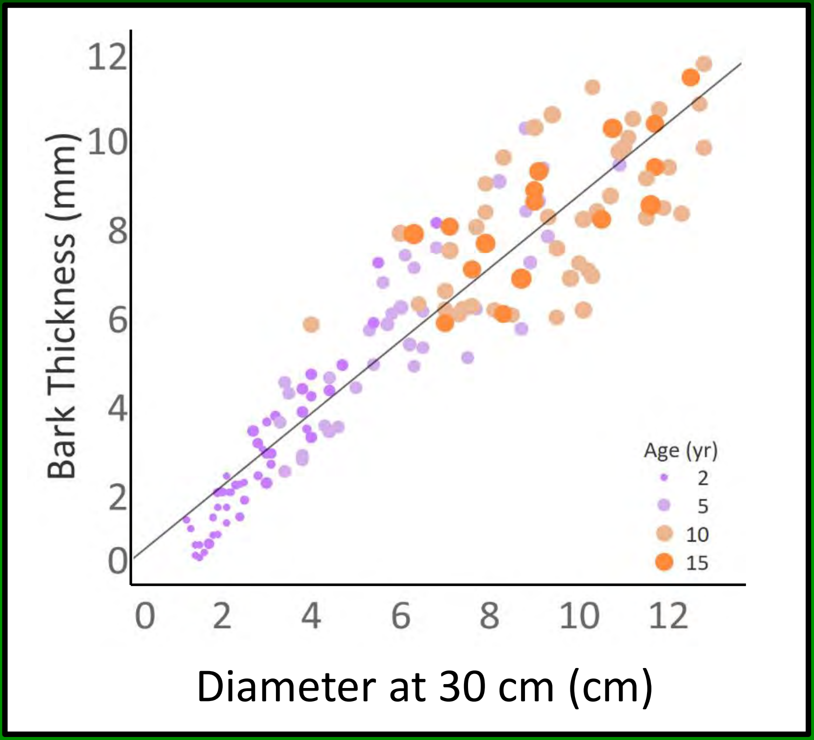
- Competitor height also reduced by overstory
- Shortleaf pine consistently smaller than HW



Kabrick et al. 2015

Fire adaptation: bark thickness

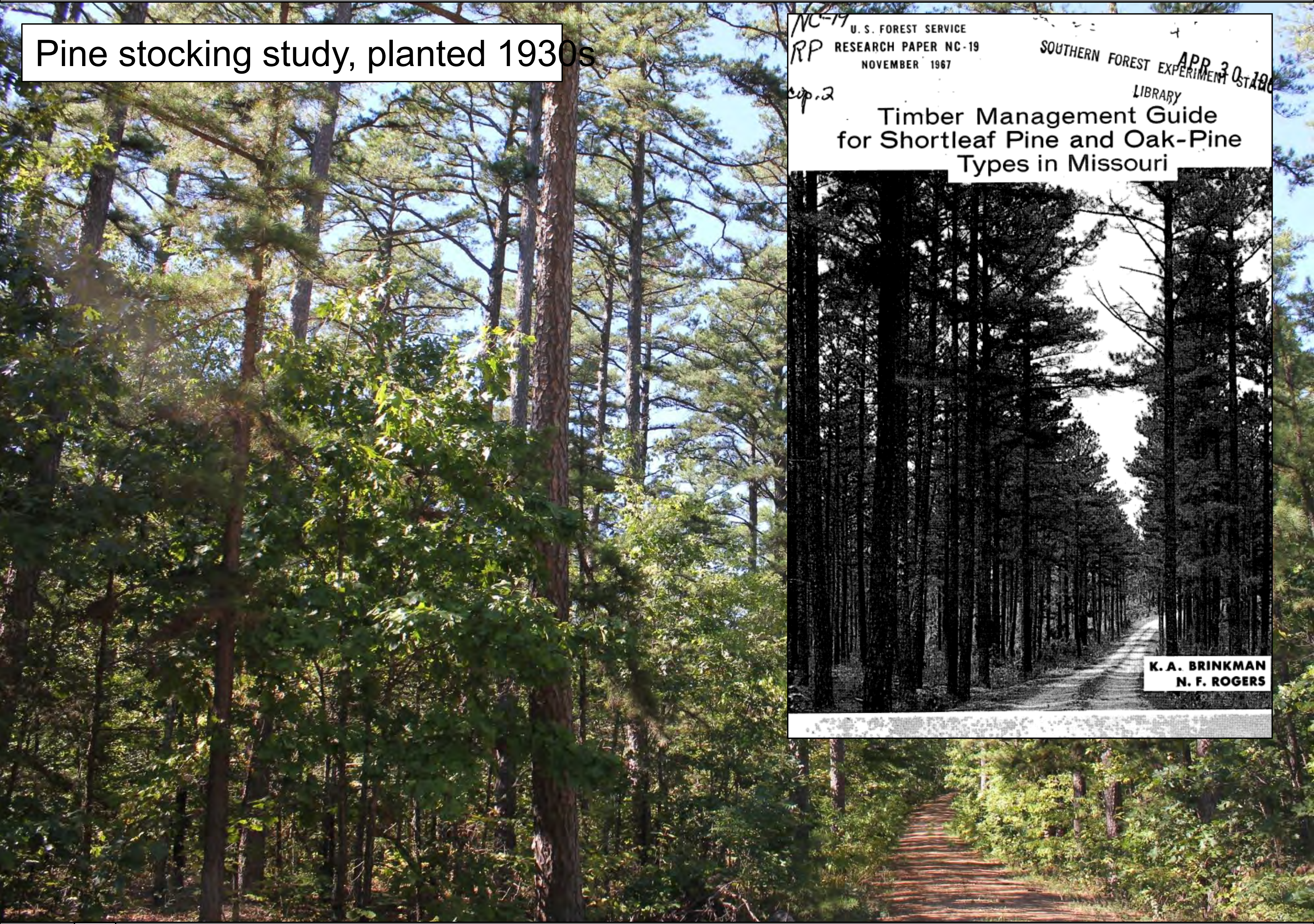
- Shortleaf pine bark thickness develops faster than most competing hardwoods, providing earlier resistance to top-kill from frequent fire



Shortleaf pine and disturbance

- Disturbance is critical to shortleaf pine regeneration
- Range of possible disturbance intensity
  - Near-stand replacement disturbance (e.g., mid- to high-severity fire)
  - Low intensity disturbance with proper frequency

Pine stocking study, planted 1930s


NC-19
RP
cop.2

U.S. FOREST SERVICE
RESEARCH PAPER NC-19
NOVEMBER 1967

Timber Management Guide
for Shortleaf Pine and Oak-Pine
Types in Missouri

K. A. BRINKMAN
N. F. ROGERS

Old-growth shortleaf pine and younger oak

Missouri Ozark Forest Ecosystem Project

Long-term, landscape-scale forest management experiment

Occupies approximately 10,00
acres of Ozark forest

Treatments

- Even-aged: shelterwood, clearcut with reserves
- Uneven-aged: single-tree, group selection
- Control

REVIEW ARTICLE

J. For. 112(5):513–524
http://dx.doi.org/10.5849/jof.13-102

silviculture

Missouri Ozark Forest Ecosystem Project: A Long-Term, Landscape-Scale, Collaborative Forest Management Research Project

Benjamin O. Knapp, Matthew G. Olson, David R. Larsen, John M. Kabrick, and Randy G. Jensen

The Missouri Ozark Forest Ecosystem Project (MOFEP) is a long-term, landscape-scale study that exemplifies a model of forest research emphasizing interagency and multidiscipline collaboration. Established in 1989 in the Ozark Highlands of southeastern Missouri, MOFEP uses a randomized complete block design to test the effects of three forest management systems (even-aged management, uneven-aged management, and no-harvest management) on response variables across a range of disciplines. Within this overarching experimental design, other studies have been nested to address specific research questions across spatial and temporal scales. This project is driven by management needs and is designed to evaluate the effects of forest management systems practiced by a state agency, the Missouri Department of Conservation (MDC), on an operational scale. Treatments are applied with entries at 15-year intervals over the course of the project's planned 100-year rotation length. To date, MOFEP has produced over 65 publications in peer-reviewed journals from scientists at federal, state, academic, and nonprofit organizations. This project is unique in that it is supported and maintained by a state agency, with keys to success including long-term commitment of resources and personnel, communication of results to scientific and management communities, and collaboration among and within those communities.

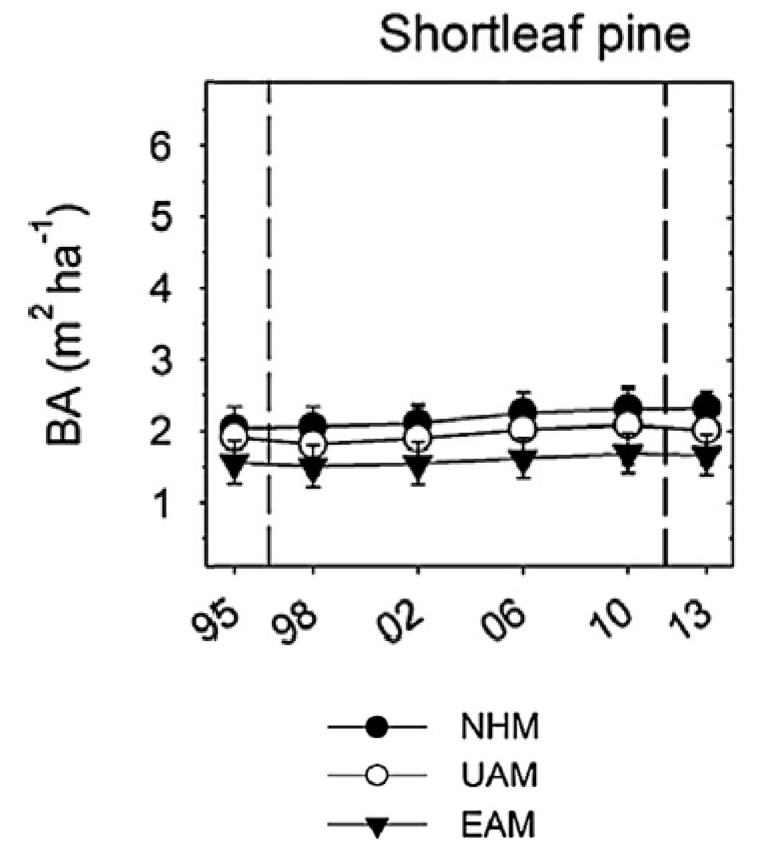
Keywords: even-aged management, MOFEP, silviculture, uneven-aged management

The Missouri Ozark Forest Ecosystem Project (MOFEP) is a long-term, landscape-scale study that was designed to determine the effects of alternative forest management systems on a disciplines. The dynamic character of forest ecosystems is fundamental; they are constantly changing in response to external forces and internal processes that include succession, cycling of resources, and distur-

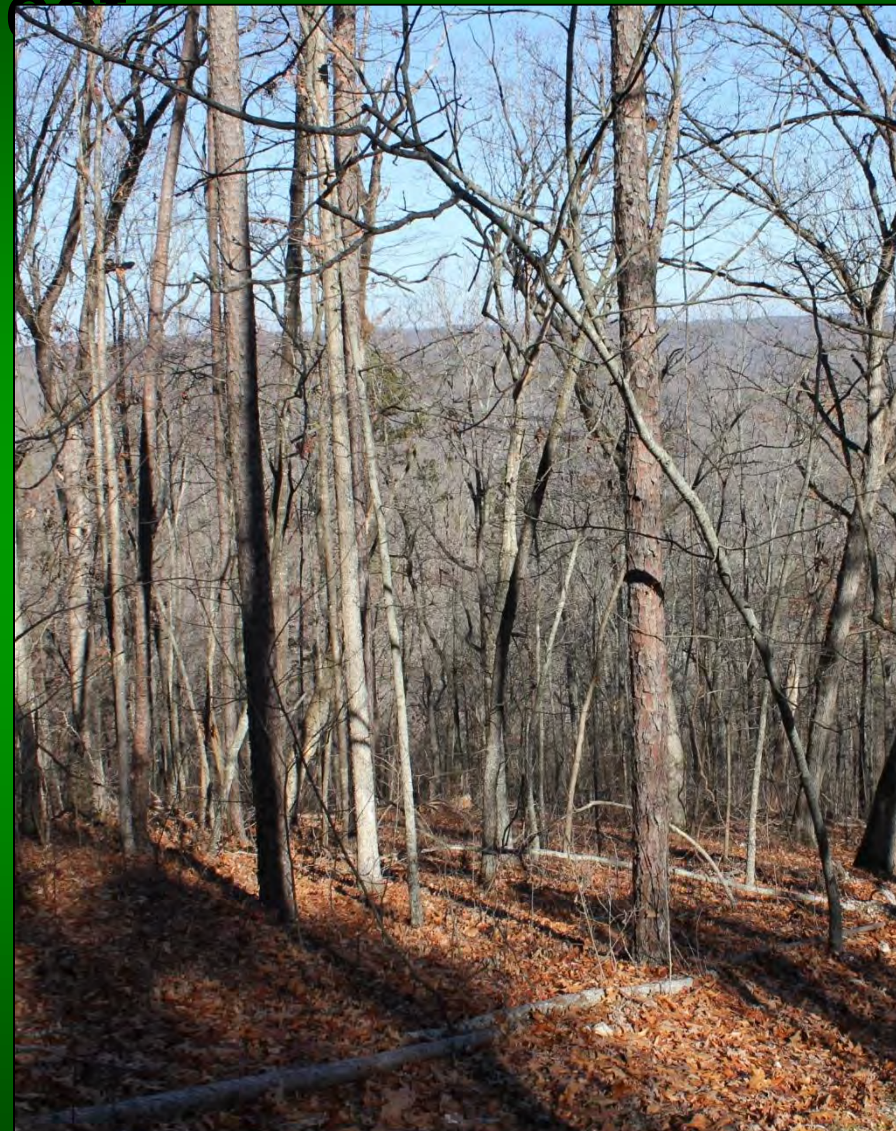
1996). This research model is well-suited for designing detailed investigations of specific questions but is often challenged to adequately study ecological processes that occur over long time scales or across spatial scales or disciplines (Franklin et al. 1990, Magnuson 1990).

The traditional model for field research in ecological sciences generally operates over short time frames and within relatively limited locations (Callahan 1984, Tilman 1989). The reasons for this structure are varied but are in many cases intuitive: Logistically, experimental studies are more feasible if conducted over limited spatial and temporal scales; there is uncertainty in the availability of long-term research funding; the common academic model is that of relatively short-term graduate student projects with an expectation of immediate deliverables; and challenges often exist in coordinating collab-

Missouri Ozark Forest Ecosystem Project



Olson et al. 2016

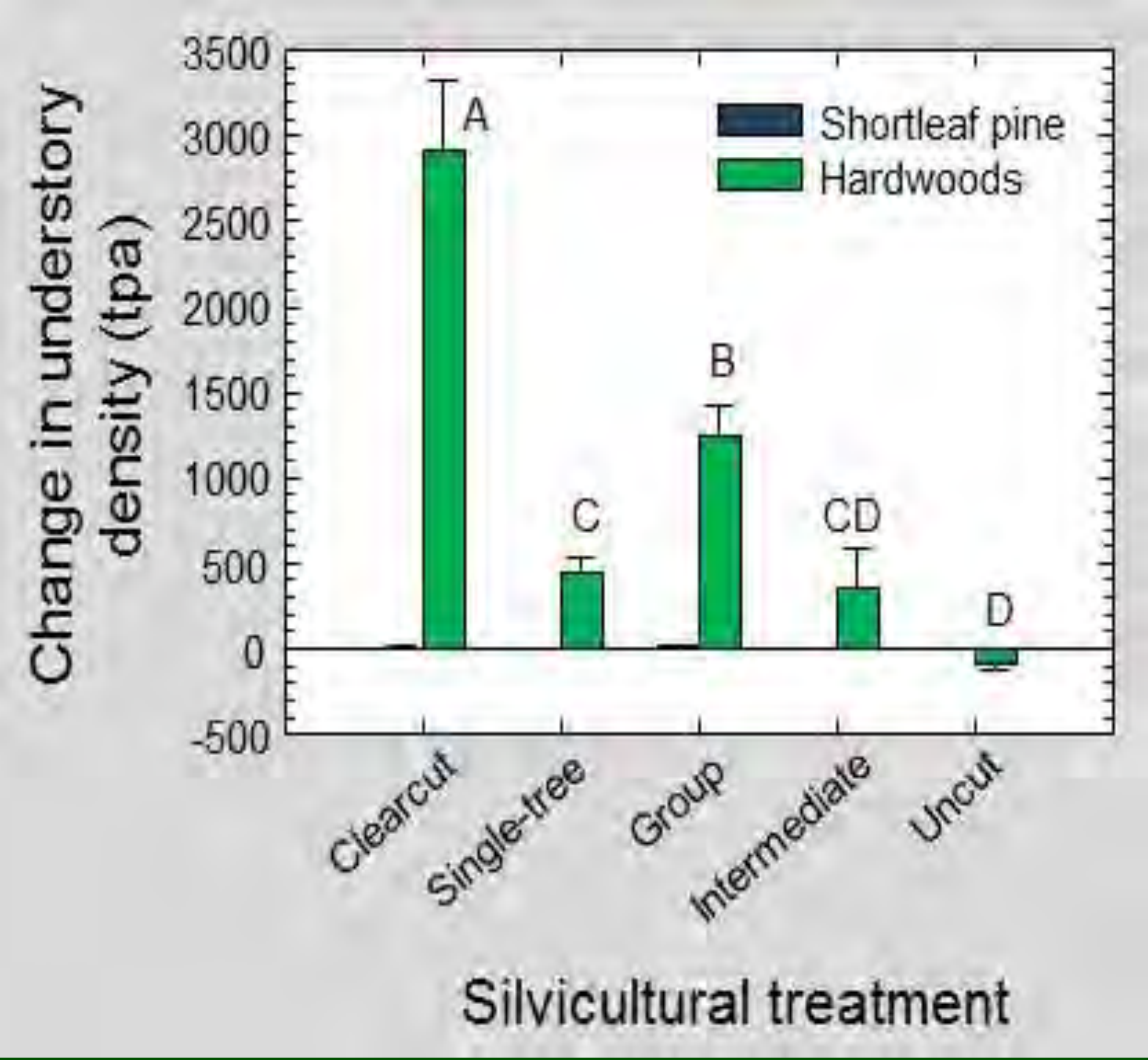


Clearcut with reserves, MOFEP

Missouri Ozark Forest Ecosystem Project

No evidence of shortleaf pine regeneration despite retention of seed trees

- Across silvicultural treatments and forest management treatments



Management recommendations

Underplant shortleaf pine in existing hardwood stands

- Reduce stand density to increase light to planted pines
- Control competition with properly timed fire
- Release pines from hardwood competition with mechanical methods
  - Delay release treatment by 2-4 years

Planted pine in hardwoods

Summary and conclusions

Shortleaf pine-oak mixedwoods of Missouri are transitional without appropriate disturbance regimes

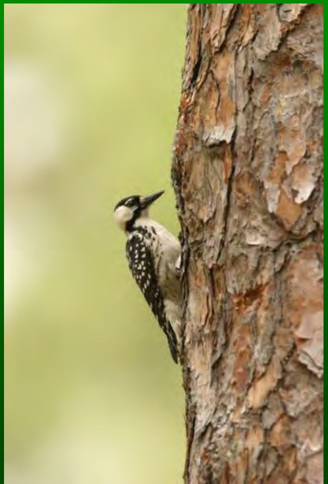
- Common successional trajectory to hardwoods due to challenges with shortleaf pine regeneration

Key management actions for success:

- Regeneration harvests that provide light to forest floor and seed source
- Seedbed for germination (fire) or planting
- Release from competition within first 10 years (fire, herbicide, mechanical)

Ecological significance

- A major component of forest biodiversity
  - Associated with many overstory species (oaks or other pines)
  - Associated with many ground flora (blueberry, huckleberry, deerberry, panic and bluestem grasses)



- Wildlife Habitat
  - Red cockaded woodpecker
  - Coopers, sharp-shined hawks
  - Deer, turkey, quail, squirrel

Economic significance

- Timber production
  - Posts
  - Saw timber
  - Bedding
  - Telephone poles