Open Forest Restoration
Practical considerations for long-term maintenance of woodlands

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Applied Ecological Silviculture
Webinar Series

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Roadmap

Contemporary oak woodland management in the central/east often focuses on restoration – what happens when you get there?

- Woodland overview
- Restoration vs maintenance
- Management considerations
- Approaches to long-term woodland management

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What are woodlands?

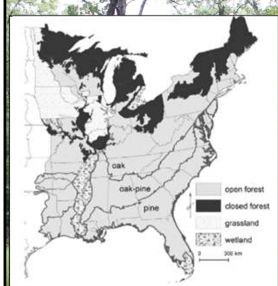

Fig. 1. Estimated historical extent of open forests in the eastern United States (modified from Hanberry and Thompson 2019 using Hanberry et al., 2014; Hanberry and Dey, 2019; Hanberry, 2020). Finer scale variation occurred due to firebreaks or fire exposure, resulting in closed forests within open forests or open forests within closed forests.

Hanberry, B.B., Bragg, D.C., Alexander, H.D. 2020. Open forest ecosystems: an excluded state. Forest Ecology and Management 472: 118256

Structure
- Relatively open canopy (cover < 100%)
- Open vertical structure

Composition
- Fire-adapted species
- Rich/diverse herbaceous ground flora

Site factors
- Gradient of edaphic control

Management
- Combinations of thinning and prescribed fire

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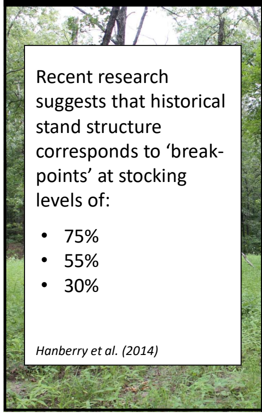
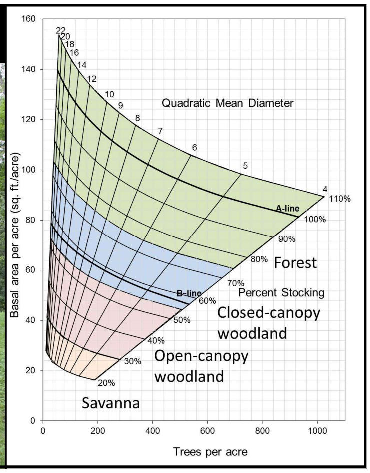
Woodlands



Recent research suggests that historical stand structure corresponds to 'break-points' at stocking levels of:

- 75%
- 55%
- 30%

Hanberry et al. (2014)



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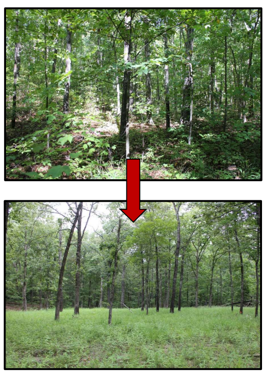
Woodland management



<u>Restoration phase</u>: mechanical, chemical, and fire methods to reduce stocking, open vertical structure, enhance ground flora

- Known targets for canopy structure/composition
- Represents a short-term objective for management

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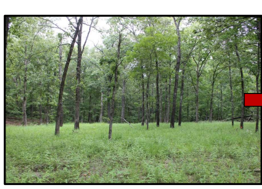
Woodland management

<u>Maintenance phase</u>: frequent fire used to maintain open vertical structure associated with woodlands

- Do we expect the woodland condition to remain through time?
- How do we balance long-term dynamics with desired conditions?



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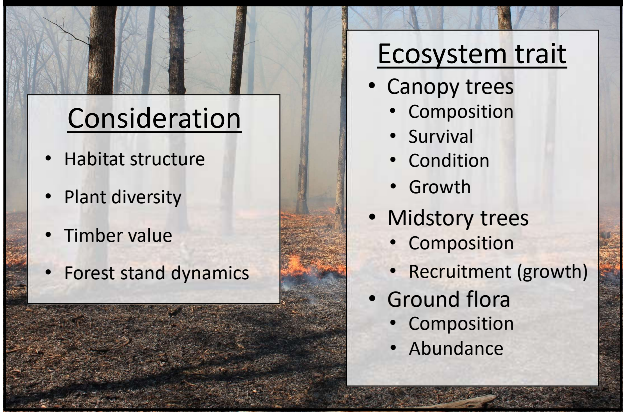
Long-term considerations



Consideration
- Habitat structure
- Plant diversity
- Timber value
- Forest stand dynamics

Ecosystem trait
- Canopy trees
  - Composition
  - Survival
  - Condition
  - Growth
- Midstory trees
  - Composition
  - Recruitment (growth)
- Ground flora
  - Composition
  - Abundance

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Habitat structure

- Structure is inherent to the current definition of 'woodland'
- In most eastern forests, frequent fire is necessary to maintain the structure

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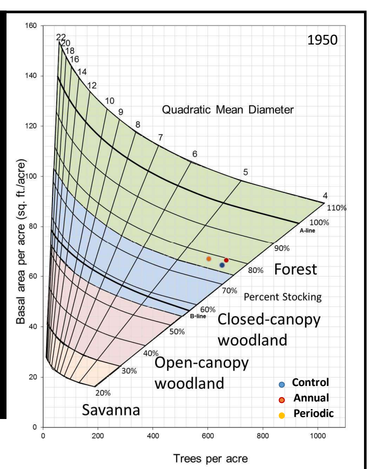
Fire and structure

Through time, repeated burning was found to create and maintain structure associated with woodlands



Knapp, B.O., Hullinger, M.A., Kabrick, J.M. 2017. Effects of fire frequency on long-term development of an oak-hickory forest in Missouri, USA. Forest Ecology and Management 387: 19-29

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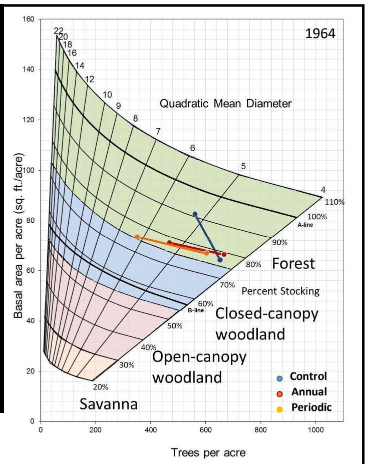

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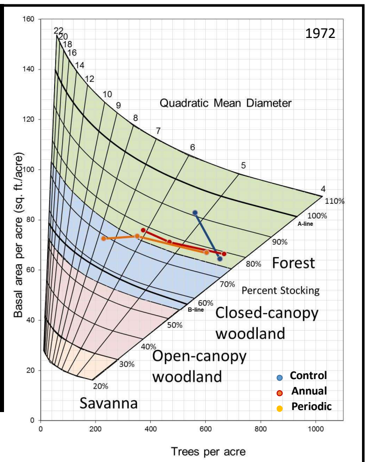

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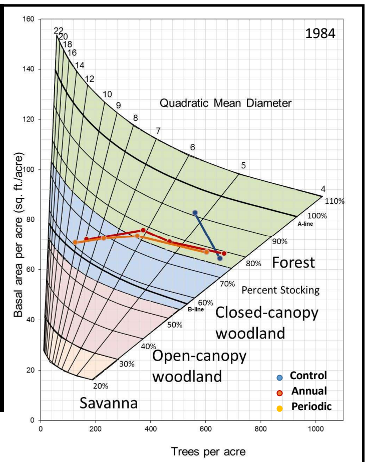

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Fire and structure

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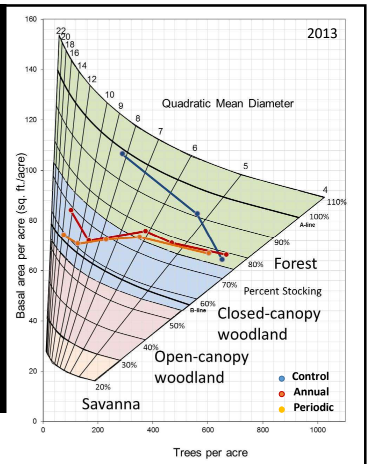

Knapp, B.O., Hullinger, M.A., Kabrick, J.M. 2017. Effects of fire frequency on long-term development of an oak-hickory forest in Missouri, USA. Forest Ecology and Management 387: 19-29

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Long-term considerations

Consideration

- Habitat structure: created with frequent burning
- Plant diversity
- Timber value
- Forest stand dynamics

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Long-term considerations

Consideration

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Plant diversity

Where is the plant diversity?

- Woodland ecosystem: support high levels of diversity in the ground flora

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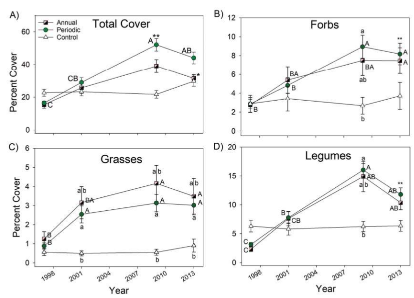
Plant diversity

Repeated burning increases ground flora abundance and diversity

- Increased light availability
- Reduced forest floor accumulation



Maginel, C.J., Knapp, B.O., Kabrick, J.M., Muzika, R.M. 2019. Landscape- and site-level responses of woody structure and ground flora to repeated prescribed fire in the Missouri Ozarks. Canadian Journal of Forest Research. 48: 1004-1014

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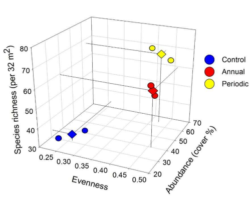
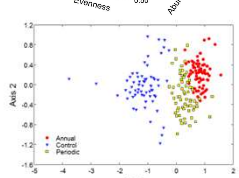
Plant diversity

Through 60 years of prescribed burning, metrics of plant diversity increased with fire

- Annual burning reduced presence of woody species to reduce overall diversity and cover
- Plant community shifts to more fire-adapted species
- Edaphic variation important consideration for response





Knapp, BO, Stephan, K, Hubbart, JA. 2015. Structure and composition of an oak-hickory forest after over 60 years of repeated prescribed burning in Missouri, USA. Forest Ecology and Management 344: 95-109

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Long-term considerations

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Timber value

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Fire damage effects on red oak timber product value

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ABSTRACT

Land managers use prescribed fire for a variety of resource objectives on sites containing merchantable trees. We analyzed how fire-caused injuries (i.e., fire scars) affect lumber volume and value in 88 red oak (*Quercus velutina, Quercus rubra, and Quercus coccinea*) butt logs from trees harvested from three sites in southern Missouri. Trees with varying amounts of external fire damage, time since fire, and diameter were harvested and milled into dimensional lumber. We tracked lumber grade changes and volume losses due to fire-related injuries on individual boards ($n = 1298$, 18.3 cubic meters (7754 board feet)). Most analyses considered value loss to the individual butt log. We identified threshold values for fire-scar height and percent basal circumference injured, beyond which value loss is expected. Our analysis produced two models to describe how butt log value loss relates to fire-scar dimensions and residence time (timespan between damage occurrence and tree harvest). Overall, value and volume losses due to fire damage were low. If fire damage is less than 50 cm in height and 20% of basal circumference, our study suggests little value loss is to be expected within 14 years of injury. If these thresholds are exceeded, value loss is likely, and increases over time. Value loss is very low if trees are harvested within approximately five years after fire damage, regardless of scar size. These findings are applicable for red oak trees which are at least 20 cm diameter at breast height at time of fire damage and with fire-scar residence times not greater than fourteen years.

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Value loss

Attributed value loss due to two factors:

1) **Damage from scarring**
2) Changes in composition and structure

Factor 1: Calculate estimated timber value loss to the butt log using equations developed for red oaks (Marschall et al. 2014)

$$PVL = 0.51 + (13.5 * FDI)$$

$$FDI = \frac{(SH * SD)}{TBA}$$

PVL = Percent value loss

FDI = Fire Damage Index

SH = scar height (in)

SD = scar depth (in)

TBA = tree basal area (in^2)

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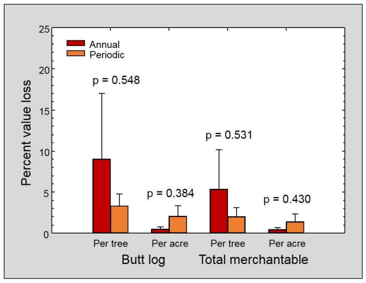
Value loss

Less than 5% value loss at the stand-level due to external fire scars



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Value loss

Attributed value loss due to two factors:

1) Damage from scarring
2) **Changes in composition and structure**

Factor 2: Calculate treatment effect on stumpage value due to composition and structure

Species	Control	Annual	Periodic
hickories	367	26	0
post oak	2539	3984	3510
red oaks	4173	1886	2133
white oaks	349	491	178
total	7428	6387	5821

Merchantable volume (bd ft/acre)

$/bd ft
0.21
0.13
0.29
0.26

Species	Control	Annual	Periodic
hickories	77	5	0
post oak	330	517	456
red oaks	1210	547	619
white oaks	91	128	46
total	1708	1198	1121

Stumpage value ($/acre)

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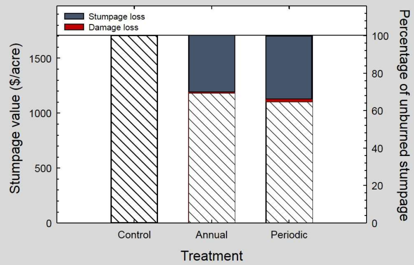
Value loss

Attributed value loss due to two factors:

1) **Damage from scarring (<5%)**
2) **Changes in composition and structure (~30%)**



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Long-term considerations

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- Habitat structure: created/maintained with frequent burning
- Plant diversity: increased with repeated frequent burning
- Timber value: most value loss due to composition change
- Forest stand dynamics

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- **Forest stand dynamics**

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Forest stand dynamics

Repeated burning affects several aspects of forest stand dynamics:

- Tree mortality
- Tree growth
- Tree recruitment

→ Structure and composition

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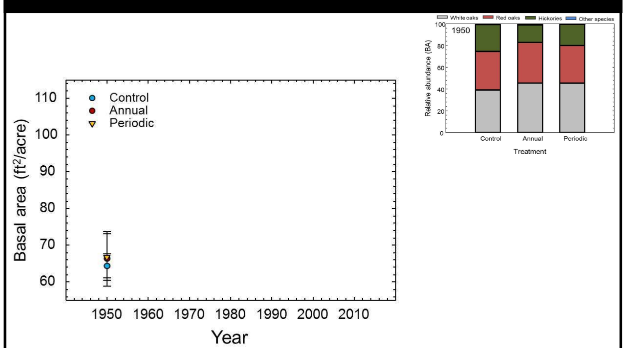
Basal area - 1950



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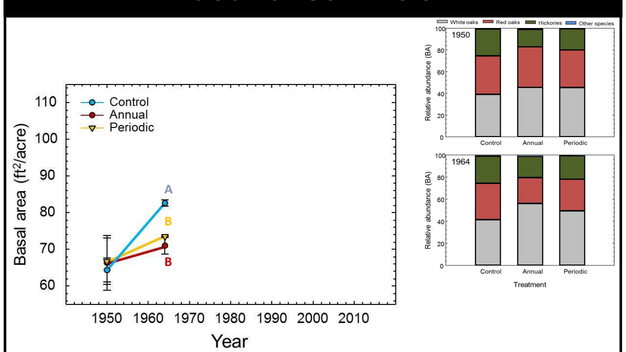
Basal area - 1964



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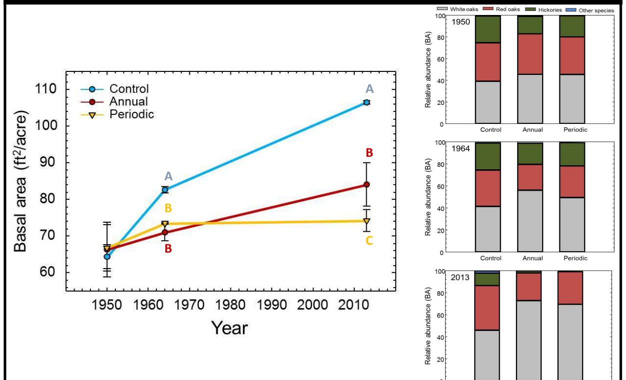
Basal area - 2013



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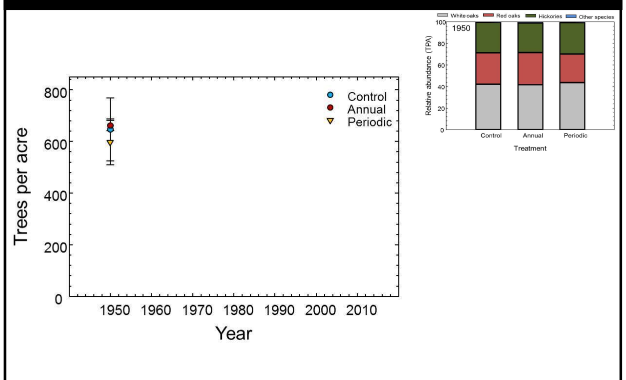
Stem density - 1950



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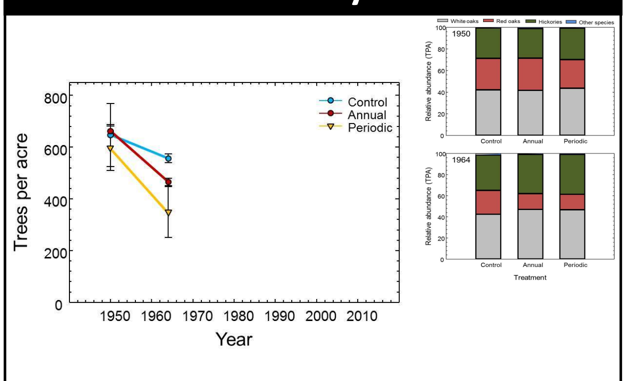

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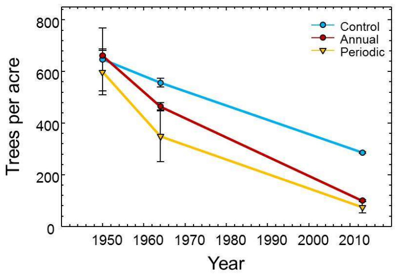

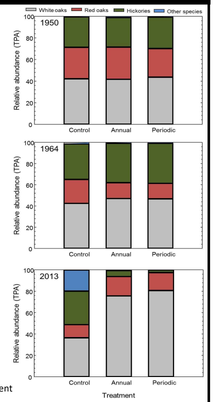

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Tree mortality

Repeated prescribed burning kills small diameter stems, performing a 'thin from below'

Through time, species-specific tree mortality patterns emerge among larger trees

Post oaks favored as canopy trees through time

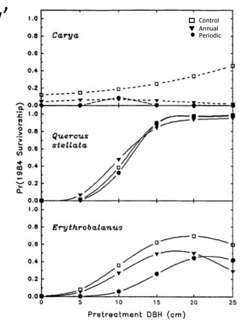

Figure 18: Probabilities of survivorship until 1984 given pretreatment DBH for Carya spp., Q. stellata and Erythrobalanus species. Curves calculated from logistic

Huddle, J.A. 1995. The effects of fire on species of maple and oak. University of Missouri, Dissertation. 255 p.

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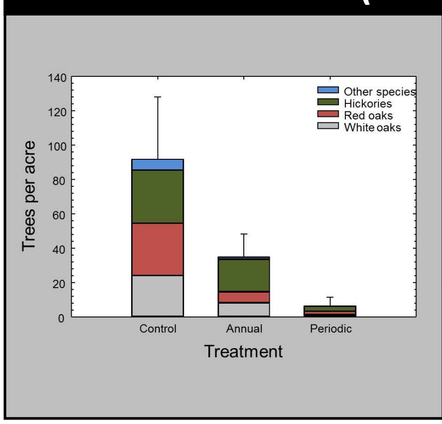
Tree recruitment (1950-1964)



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Long-term considerations

Consideration

- Habitat structure: created/maintained with frequent burning
- Plant diversity: increased with repeated frequent burning
- Timber value: most value loss due to composition change
- Forest stand dynamics: canopy mortality without replacement presents a problem

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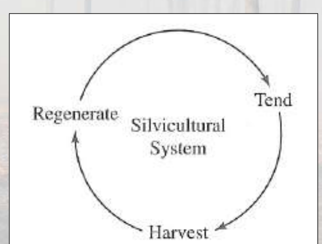
Approaches to long-term management

Forest stand dynamics: canopy mortality and no replacement presents a problem

- Consider the silvicultural system
- How does woodland management fit?



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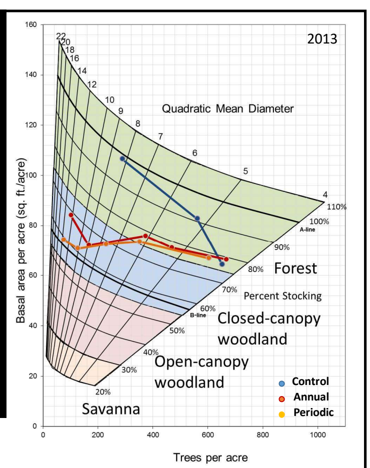
Tending stage

Can be argued that 'restoration' approaches to woodland management are tending



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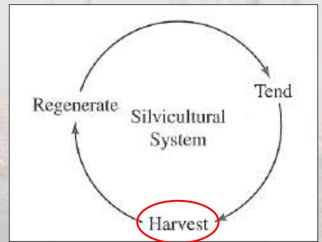
Approaches to long-term management

The harvest stage may or may not be necessary, depending on structure of the woodland

- Does maintaining woodland structure imply continuous cover?



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Harvest

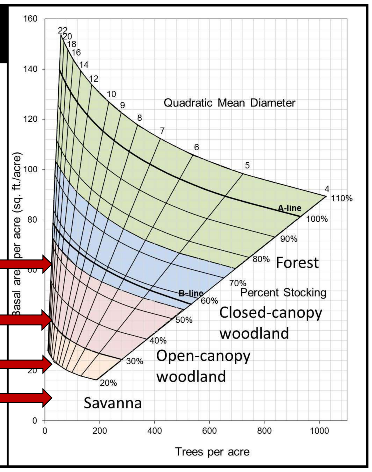
Depending on structure, regeneration harvest may not require much removal

Selection (single-tree or group)

Shelterwood

Seed tree

Clearcut



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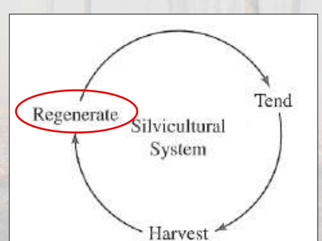
Approaches to long-term management

The harvest stage may or may not be necessary, depending on structure of the woodland

- Does maintaining woodland structure imply continuous cover?
- Deliberate focus on regeneration success



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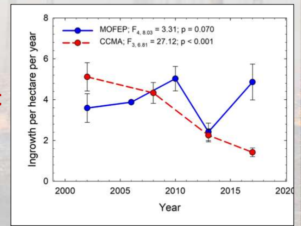
Approaches to long-term management

Can regeneration occur with frequent fire?

- Overwhelming evidence that oaks require fire-free period for recruitment

Does variability in fire behavior allow for regeneration/recruitment with frequent fire?

How much recruitment is enough?



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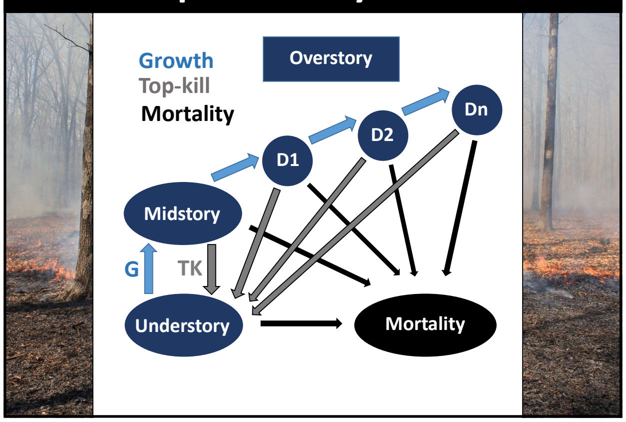
Population dynamics



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Transition matrix

DBH class in 2017

DBH class 1998

DBH	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	D	N
12	0.07	**0.21**	0.12	0.05	0.02	0.01																		0.52	2257
14		0.08	**0.19**	0.14	0.09	0.03	0.02	0.01																0.44	2084
16			0.05	**0.19**	0.19	0.11	0.04	0.02	0.01															0.37	1474
18				0.06	**0.19**	0.19	0.11	0.08	0.03	0.01	0.01													0.30	1386
20					0.06	0.17	**0.19**	0.16	0.09	0.04	0.01	0.01												0.26	1084
22						0.04	0.15	**0.19**	0.15	0.11	0.05	0.03	0.02	0.01										0.23	946
24							0.03	0.14	**0.18**	0.17	0.11	0.07	0.03	0.02	0.02	0.01								0.22	746
26								0.02	0.15	**0.19**	0.14	0.12	0.08	0.04	0.02	0.01	0.01							0.21	681
28									0.02	0.12	0.15	**0.19**	0.13	0.05	0.04	0.02	0.01	0.01						0.26	596
30										0.02	0.05	0.20	**0.20**	0.15	0.07	0.04	0.02	0.01	0.01					0.22	542
32											0.02	0.08	0.17	**0.20**	0.14	0.06	0.06	0.02	0.02					0.23	424
34												0.00	0.10	0.17	**0.18**	0.15	0.07	0.04	0.03	0.01				0.24	458
36													0.01	0.07	0.20	**0.20**	0.14	0.06	0.05	0.01	0.01	0.01		0.23	416
38														0.01	0.03	0.17	**0.20**	0.20	0.10	0.04	0.03	0.02	0.01	0.21	357
40															0.02	0.05	0.11	**0.21**	0.16	0.11	0.05	0.02	0.01	0.25	248
42																0.01	0.07	0.11	**0.23**	0.14	0.12	0.06	0.05	0.20	177
44																	0.01	0.04	0.08	**0.20**	0.13	0.19	0.13	0.22	113
46																		0.01	0.05	0.09	0.15	0.15	**0.27**	0.24	74
48																			0.00	0.06	0.00	0.16	**0.41**	0.31	32
50																				0.00	0.06	0.10	**0.71**	0.13	31
52																					0.00	0.10	**0.60**	0.30	10
54																						0.00	**0.62**	0.38	13
56																							0.50	0.50	18

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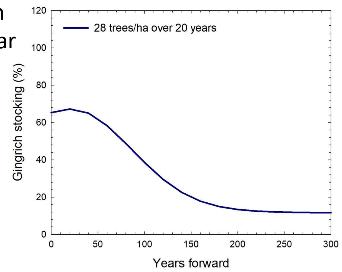
Structure through time

Generated transition matrix over 20-year period with frequent burning (CCMA) and unburned (MOFEP)

Rate of recruitment with fire was 1.4 trees/ha/year

Assuming no changes in growth or mortality rates through time, population stabilizes at 11% stocking



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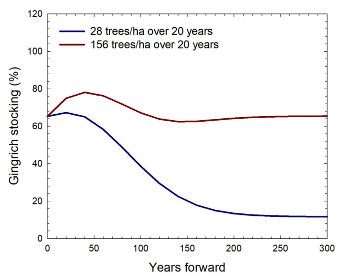
Structure through time

Generated transition matrix over 20-year period with frequent burning (CCMA) and unburned (MOFEP)

Stability of stand stocking from starting condition (65%) requires recruitment rate of 7.8 trees/ha/year



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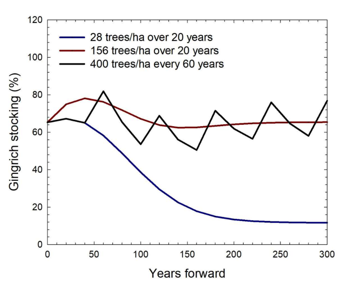
Structure through time

Generated transition matrix over 20-year period with frequent burning (CCMA) and unburned (MOFEP)

Stability reached with episodic recruitment with background rates of 1.4 trees/ha/year and pulse of 400 trees/ha every 60 years



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Approaches to long-term management

Can regeneration and frequent fire mix?

- Overwhelming evidence that oaks require fire-free period for recruitment
- “Get lucky approach” – allow natural variability in fire behavior to dictate regeneration success
- “Even-aged approach” – remove fire from entire stand to allow regeneration to occur

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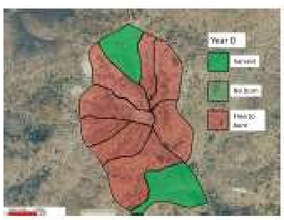
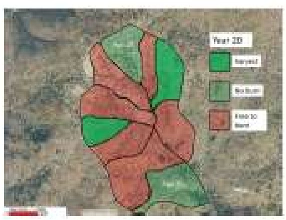
Area-based woodland regeneration



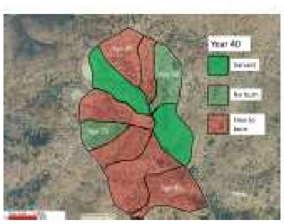


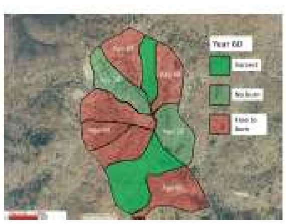
Within a larger woodland management compartment, schedule harvest and regeneration (no fire) treatments at the stand level

Kabrick, J.M., Dey, D.C., Kinkead, C.O., Knapp, B.O., Leahy, M., Olson, M.G., Stambaugh, M.C., Stevenson, A.P. 2014. Silvicultural considerations for managing fire-dependent oak woodland ecosystems. Proceedings of the 19th Central Hardwood Forest Conference. GTR-NRS-P-142.

50

Area-based woodland regeneration





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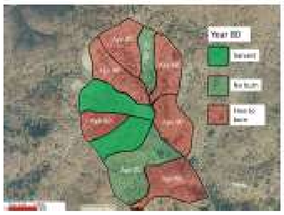
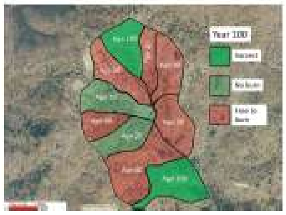
Area-based woodland regeneration





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Habitat structure

- Structure is inherent to the current definition of ‘woodland’
- Perhaps need to shift thinking towards temporally dynamic woodland structure

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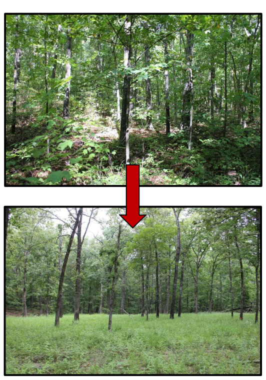
Conclusion



Long-term woodland management requires realistic objectives that may be dynamic through time

Framework of the silvicultural system can be used for developing sustainable prescriptions

Need for additional research on long-term trade-offs, benefits, and challenges

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Acknowledgements

- Funding from Joint Fire Science Program; McIntire Stennis; MU Research Council
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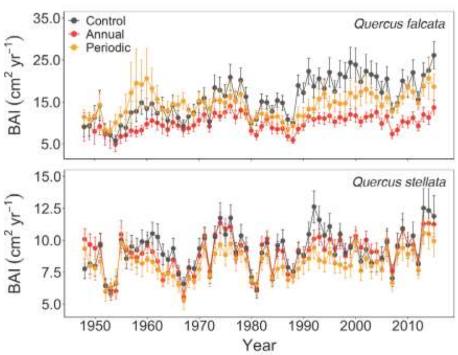
Tree growth



Refsland, T., Knapp, B.O., Stephan, K., and Fraterrigo, J. 2020. Sixty-five years of fire manipulation reveals climate and fire interact to determine growth rates of *Quercus* spp. Ecosphere 11: e03287.

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