Forest Fire Ecology & Management

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“Fire is a reaction that synthesizes its surroundings, taking its character from its context, making it a shape-shifter“
Stephen Pyne, Fire Historian

Humans are a fire species

Fire has shaped our culture & our evolution

“Civilized” society has lost connection with nature more broadly including our role as a steward of ecological fire

Indigenous cultural burning (left) vs. **wildland fire suppression (right)**

Catastrophic burns of early 20th century (e.g., Burn Big of 1910) led to a strategy of “fighting" and suppressing all wildland fire

Before fire suppression era (fire-maintained ecosystems)

Decades of fire suppression

Modern fire-suppressed forest

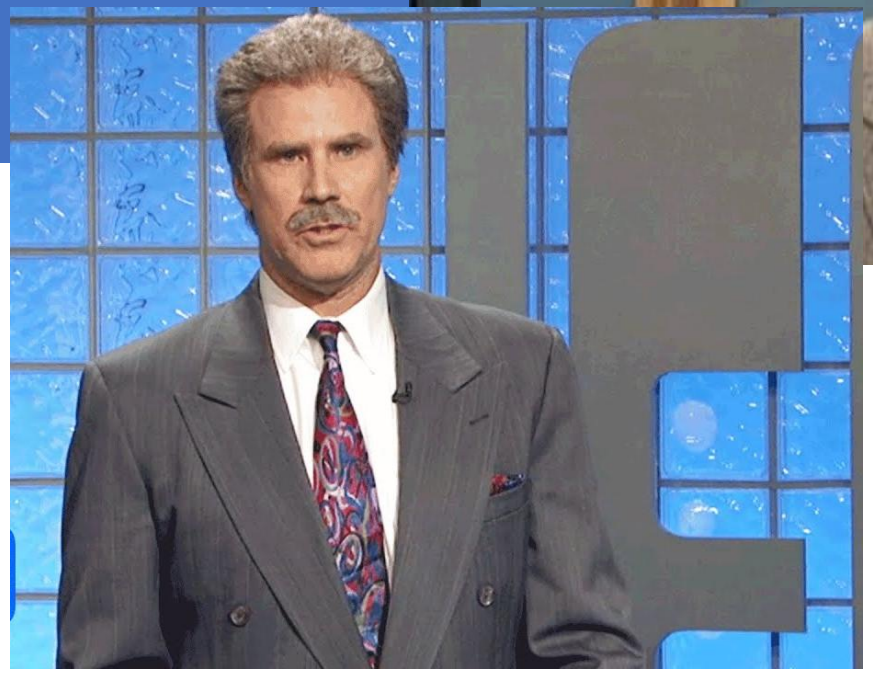
Dense forest, high fuel loading, warming climate, & plenty of ignitions…

Welcome to the *PYROCENE* or age of fire

Megafire: a wildfire ≥ 40k ha (100k ac) in extent with a high percentage classified as “high severity”

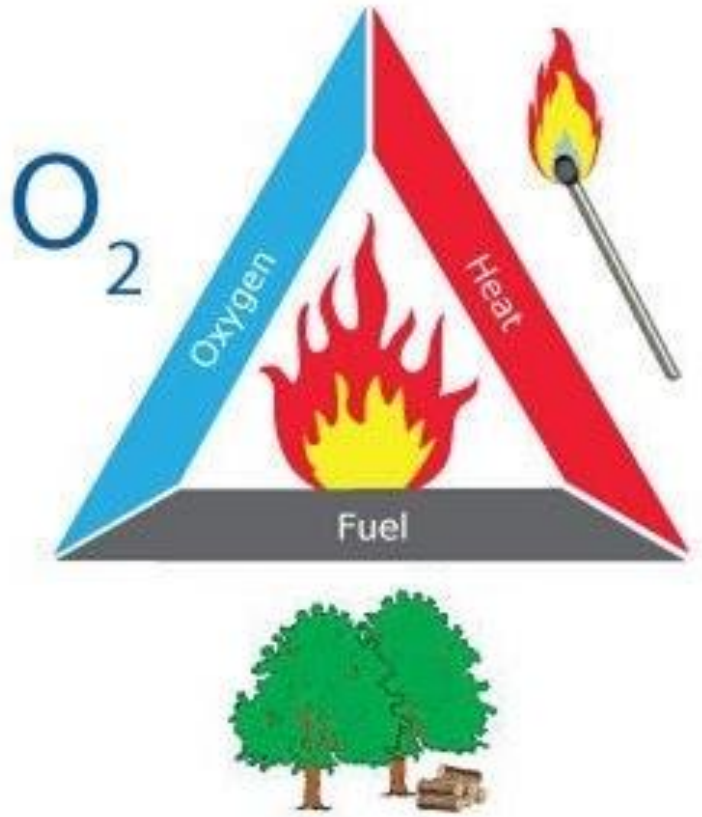
The visible effect of the process of combustion

What is Fire?



Fire is a product of combustion, an exothermic chemical reaction

Fire Triangle



Fire has 3 basic ingredients

- Oxygen
- Fuel
- Heat

Without all 3, fire does not occur

Natural ignition (heat side of the triangle) comes from several non-human sources

Rare & limited geographically

Widespread & common

Life can exist without fire, but fire cannot exist without life

Life produces O_2 & biomass (fuel)

Ecological fire dates back to the Silurian period (~420 MYBP)

What is smoke & what's it made of?

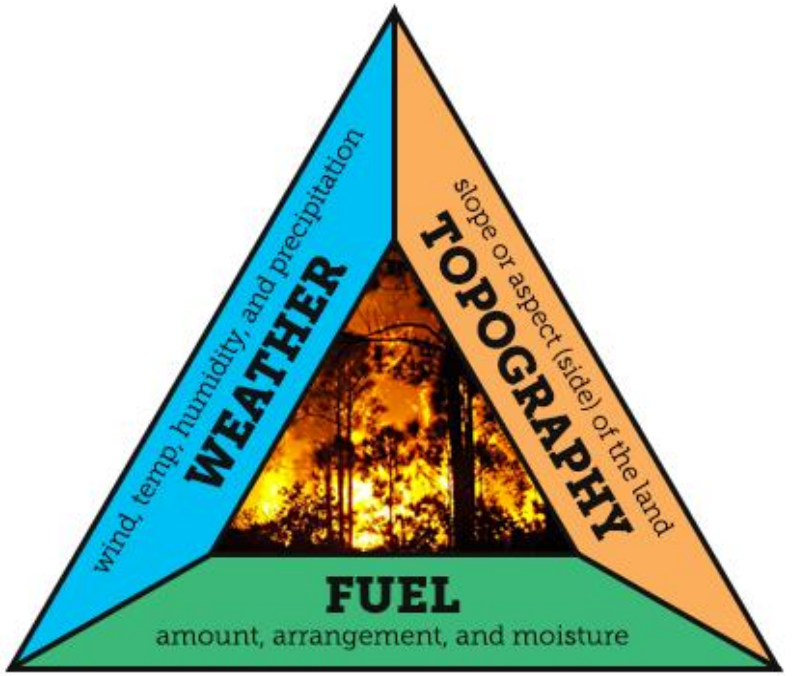
- Smoke is a suspension of airborne particles (aka, particulates) & gases emitted by incomplete combustion
  - CO_2 & H_2O plus many types of gases & particulates (biomass burning)
  - Composition depends on fuels & external conditions
  - Combustion under high oxygen & dry fuel types burn hot, producing less smoke
  - Pathogens? Yes… biotic disease-causing agents detected in smoke

Fire behavior has its own triangle
Assumes a fire has already started

- Factors that influence fire spread & intensity
  - Higher fuel loading, more extreme fire behavior
  - Fire spreads quickly upslope and slowly downslope
  - High wind speeds & low humidity = high fire danger

- Factors interact to effect behavior
  - Shaded slopes are cooler and wetter than sunny slopes leading to higher fuel moisture (less fire prone)

- Fuel is what we can alter through management, managing fuels to moderate future fire behavior
  - A main reason for prescribed burning is <u>fuel reduction</u>



Fire Behavior Triangle

Adapting to fire:
<u>resistance</u>, resilience, avoidance, and promotion

Fire resistance = damage prevention

Thick bark insulates & protects the vascular cambium

ponderosa pine forest (Flagstaff, AZ)

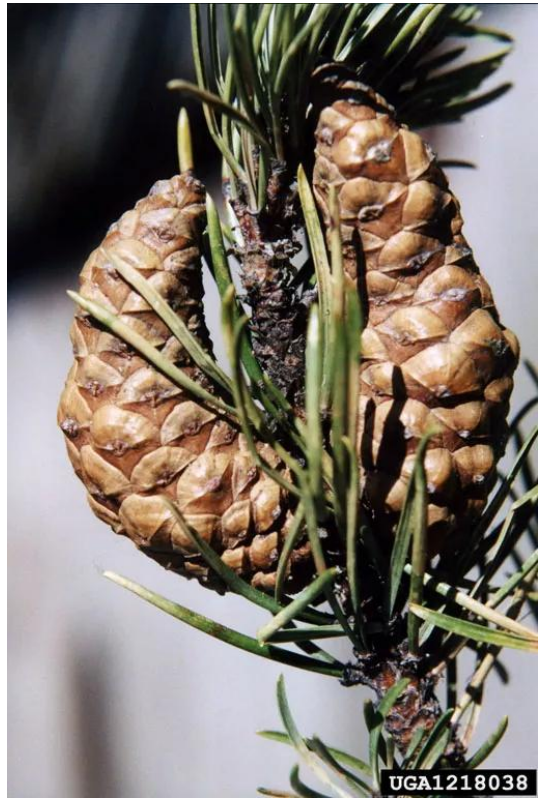
Adapting to fire:
resistance, resilience, avoidance, and promotion

Fire resilience = post-damage recovery

Sprouting after high-severity fire

Canopy-stored seed: *Resilience through offspring*

Serotiny – a botanical term describing late opening of fruits & cones to release viable seed, often after a fire



Serotinous cones (left & center) and fruit (right)

Adapting to fire:
resistance, resilience, avoidance, and promotion

Gopher tortoises dig a burrow to escape fire

Gopher tortoise is a keystone species

Burrow serves as a refuge for other species during a fire

Adapting to fire:
resistance, resilience, avoidance, and promotion

Some plants in fire-prone areas produce flammable biomass
(foliage & fibrous bark)

Eucalypts have oily leaves and shreddy bark that promotes fire spread

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Fire-adapted traits reflect adaptations to patterns in historical fire, or fire regime

- Fire regime can be defined by variation in:
  - Fire type, ignition sources, frequency, intensity, severity, spatial extent or scale, & seasonality or time of year

- Fire regime parameters are correlated:
  - Higher the frequency, lower the intensity
  - Higher the intensity, higher the severity
  - High frequency, lower extent (without human propagation)
  - Winter season burning tends to be lower severity (when plants are mostly dormant)

Fire-adapted traits reflect adaptations to patterns in historical fire, or fire regime

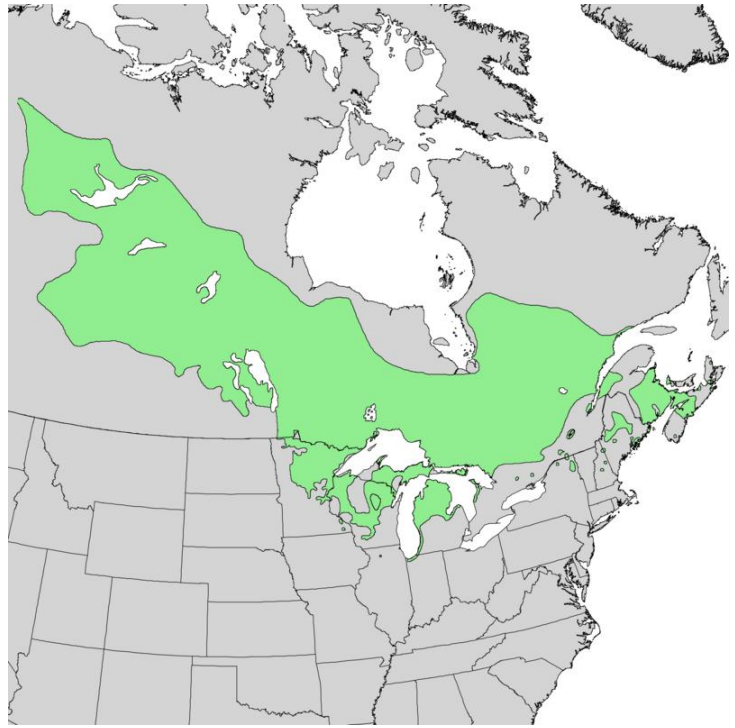
		Frequency	
		Low	**High**
Intensity	**Low**	*None*	Thick bark
	High	Canopy-stored seed (serotinous cones)	Sprouting

Regime: *Low Frequency, High Intensity*

lodgepole pine ecosystem (cone serotiny)

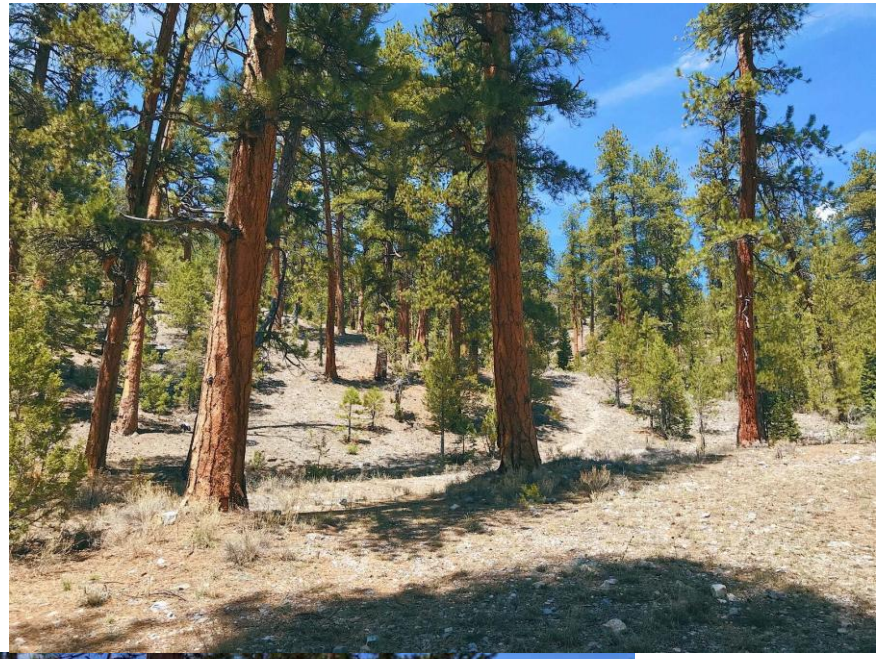
Regime: *Low Frequency, High Intensity*

jack pine ecosystem (similar to lodgepole pine)



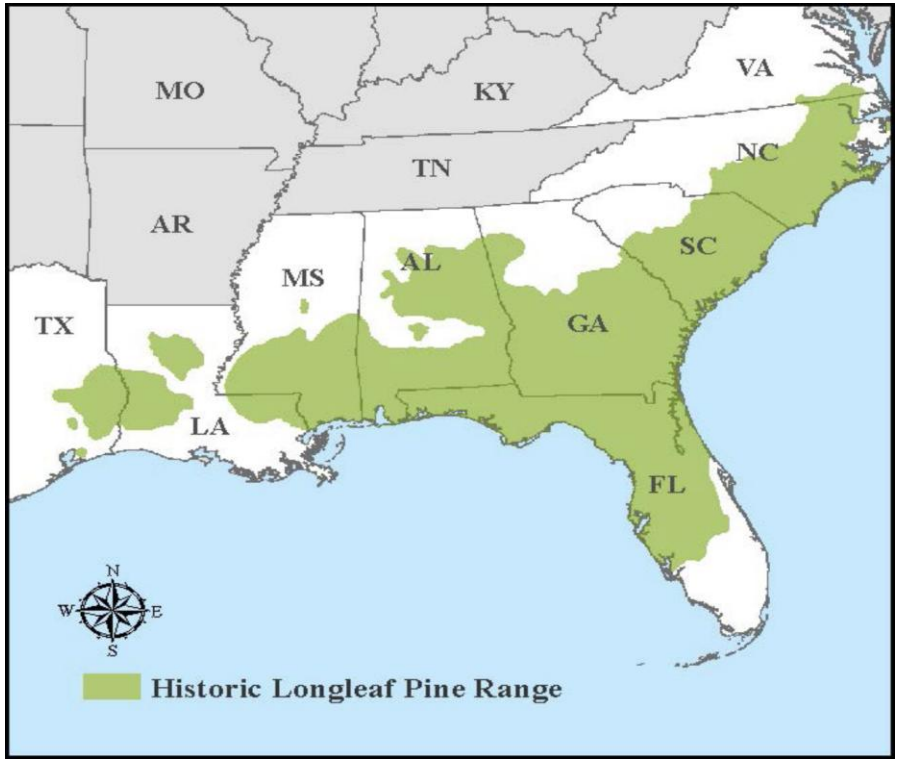
Regime: *High Frequency, Low Intensity*

ponderosa pine ecosystem (thick bark)



Regime: *High Frequency, Low Intensity*

longleaf pine ecosystem – *currently occupies < 5% of its historic range*

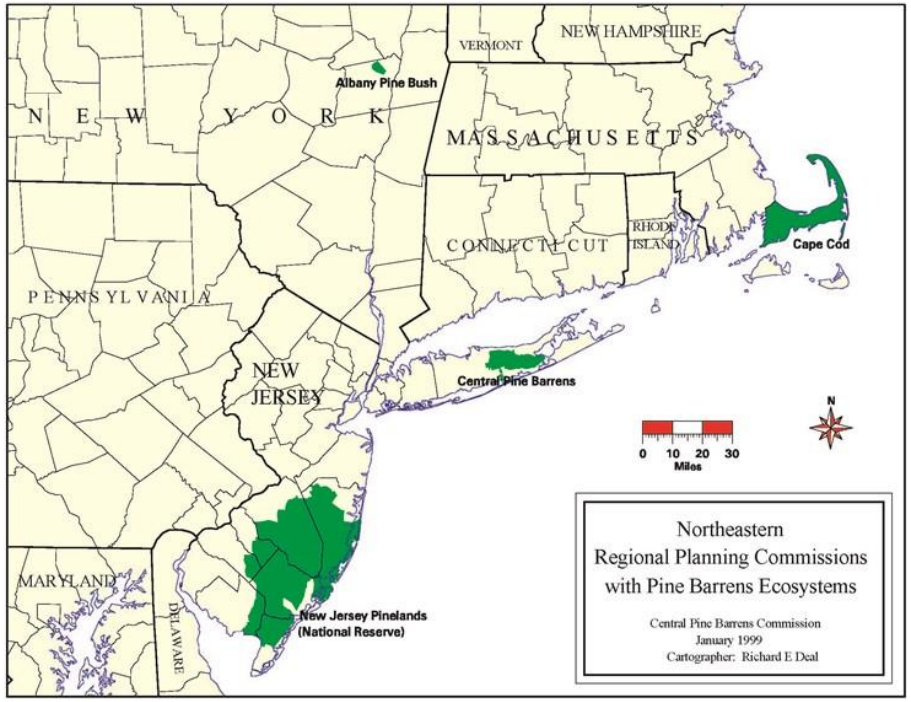


Regime: *High Frequency, High Intensity*

Mediterranean or chaparral shrubland (sprouting)

Regime: *High Frequency, High Intensity*

pine plains ecosystems (aka, pygmy pines)



Forest vs. Woodland – Ecosystems dominated by trees

Mature forest

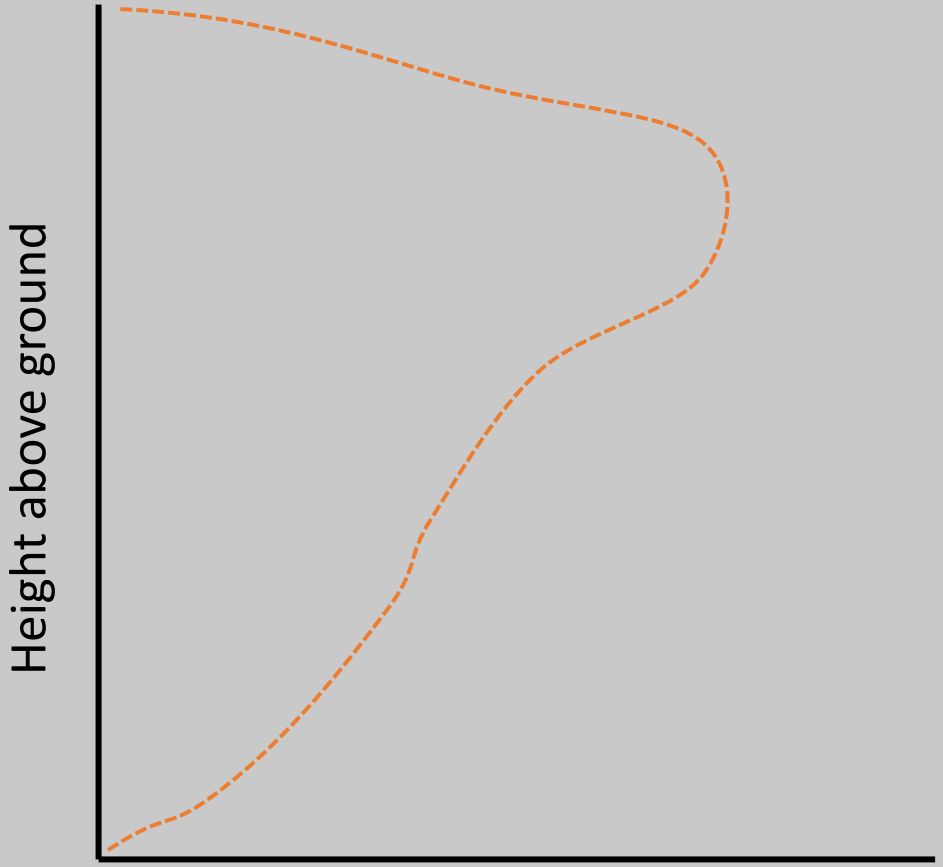
- Canopy cover = 80-100%
- Developed mid- & understory
- Moderate to deep leaf litter
- Scattered herbs on forest floor

Mature woodland

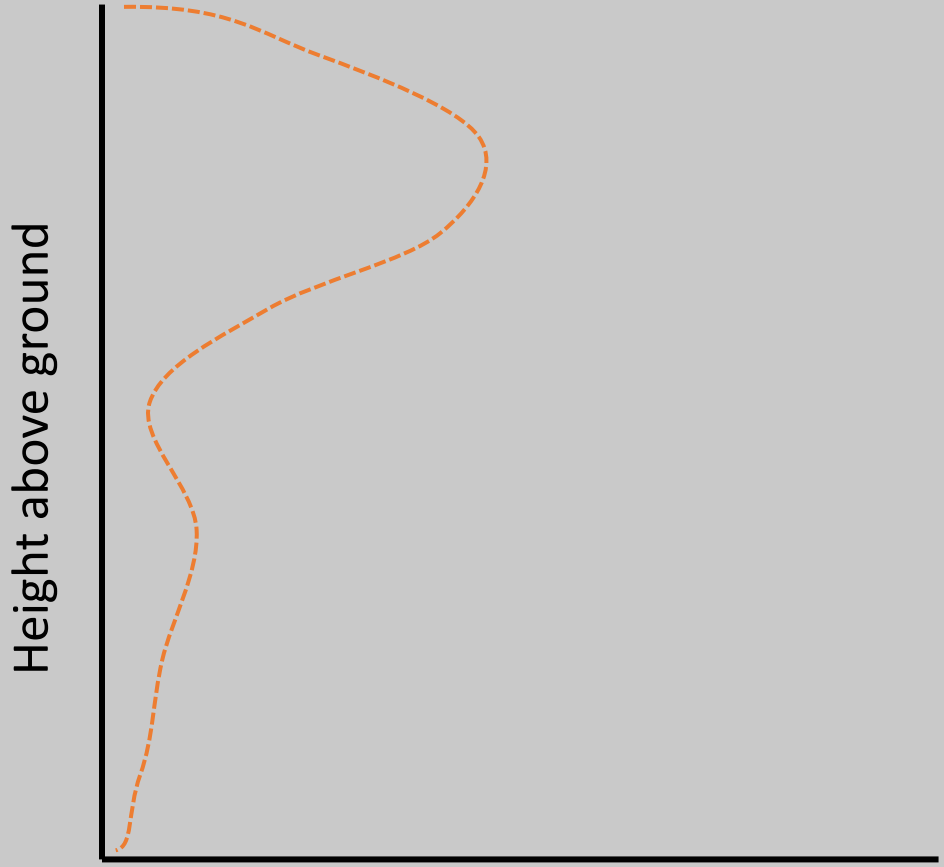
- Canopy cover = 30-80%
- Sparse mid- & understory
- Shallow leaf litter
- Continuous herb cover

Forest vs. Woodland – Ecosystems dominated by trees

Mature forest



Mature woodland



Fire effects in forests – *impact to trees*

- Direct effects from burning & excessive heat
  - Damage to the stem
  - Scorching of foliage
  - Torching of the crown
  - Destruction of seed (embryonic tree)
  - Opening of serotinous cones/fruits

Fire can improve the forest floor “seedbed” for greater seedling establishment

- Light-seeded species are more sensitive to seedbed conditions than heavy-seeded species
- Most seeds (large & small) tend to germinate best where litter is sparse, mineral soil is exposed, & seedbed is moist

Shortleaf pine seedling density decreases exponentially with increasing litter depth.

A sparse, light “litter” cover can enhance initial establishment

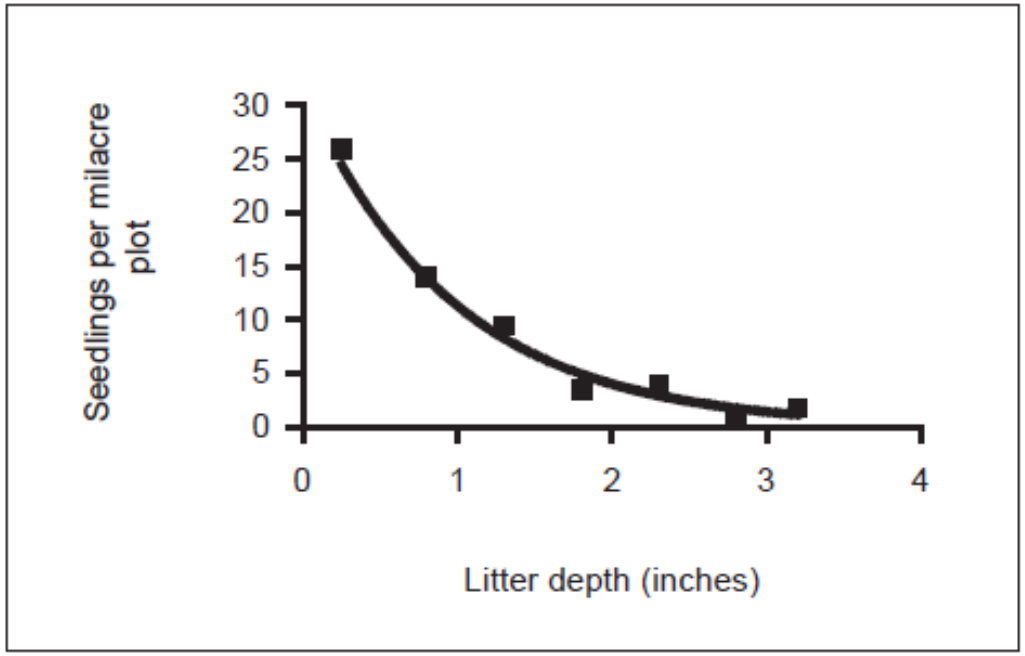
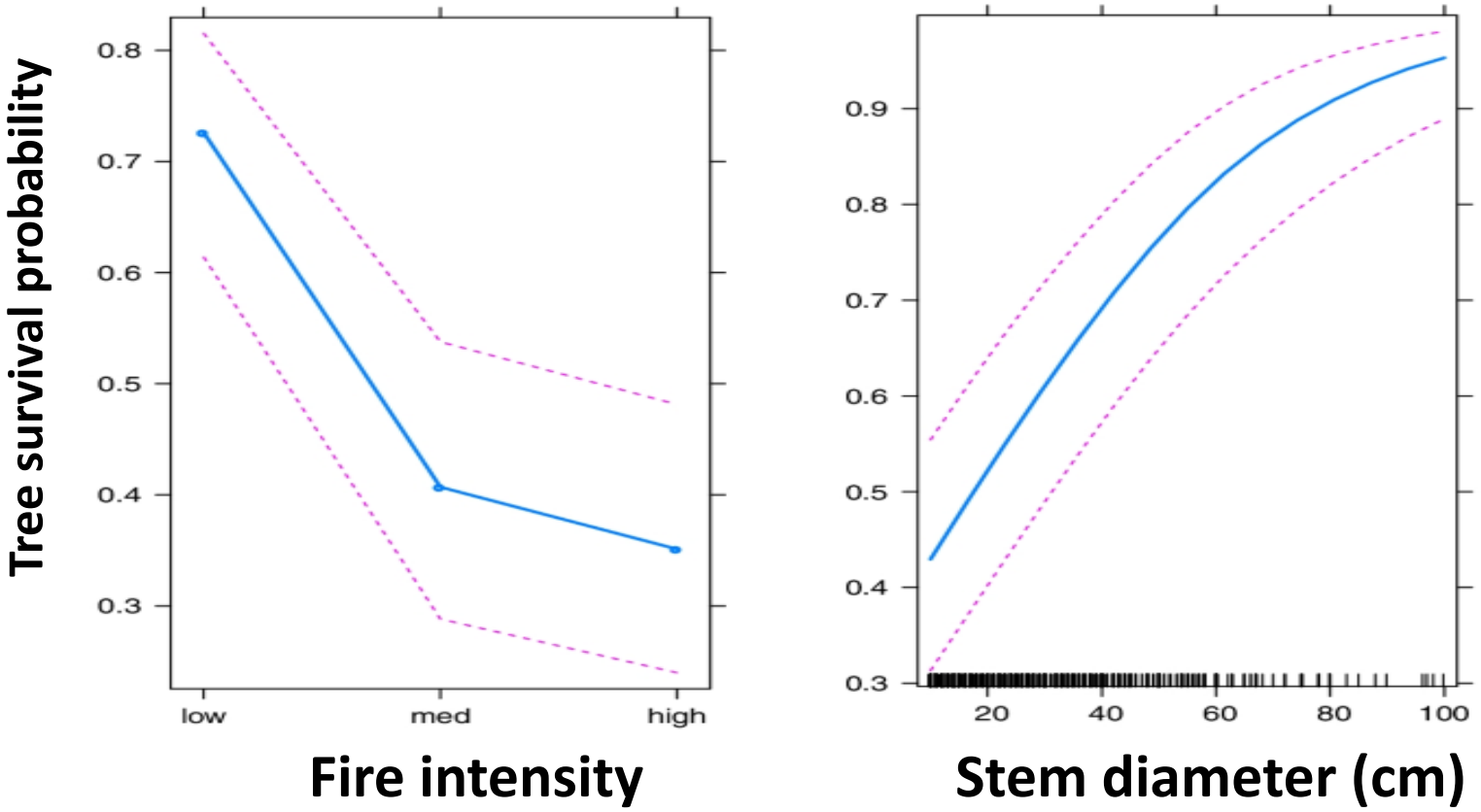


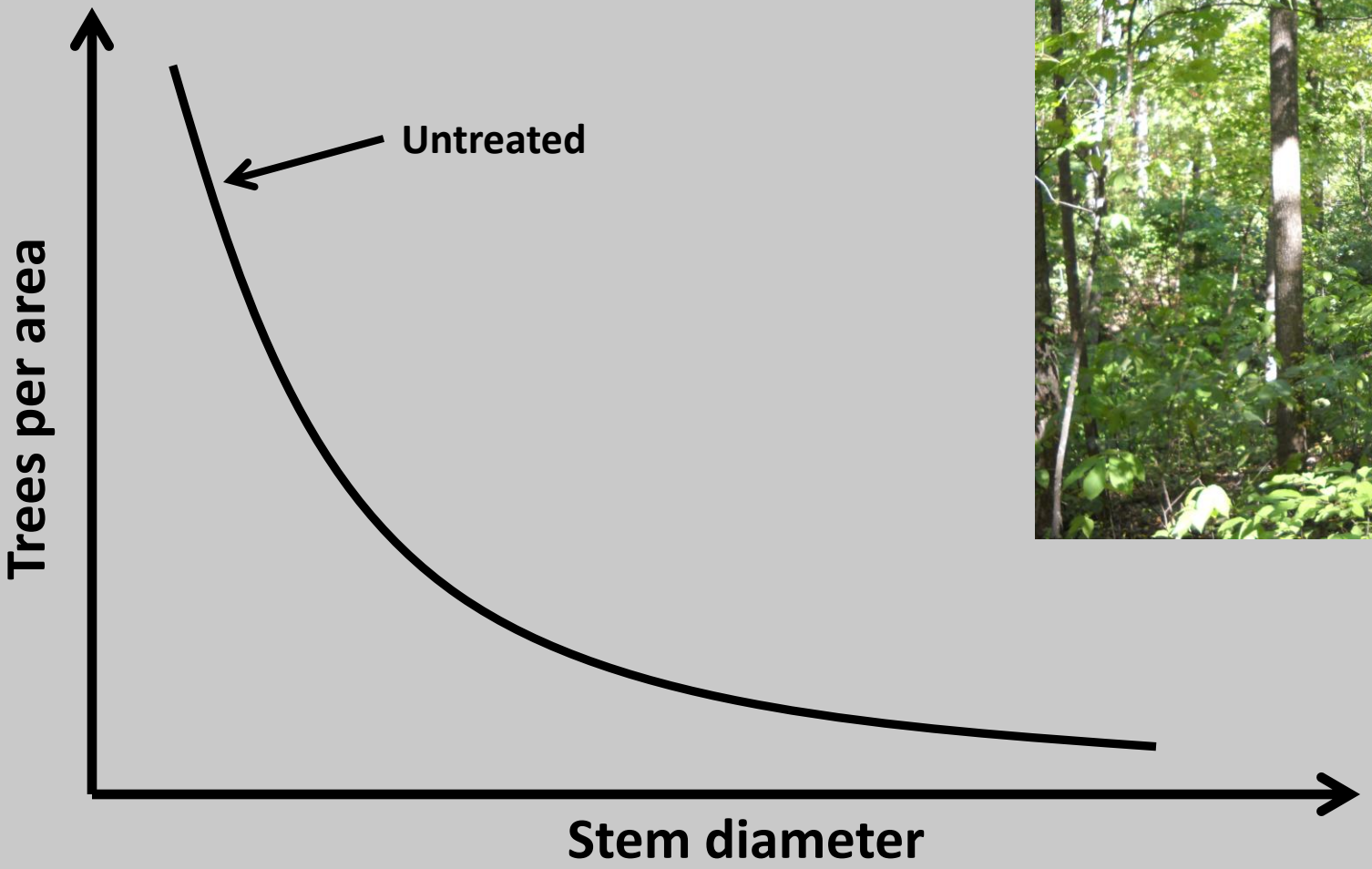
Figure 2.—Relationship between average litter depth and establishment of pine seedlings (adapted from Grano 1949).

Fire effects in forests – *impact to trees*

Tree survival depends fire intensity & tree size (*also species' resistance*)



Stand structural response to a *single prescribed burn*



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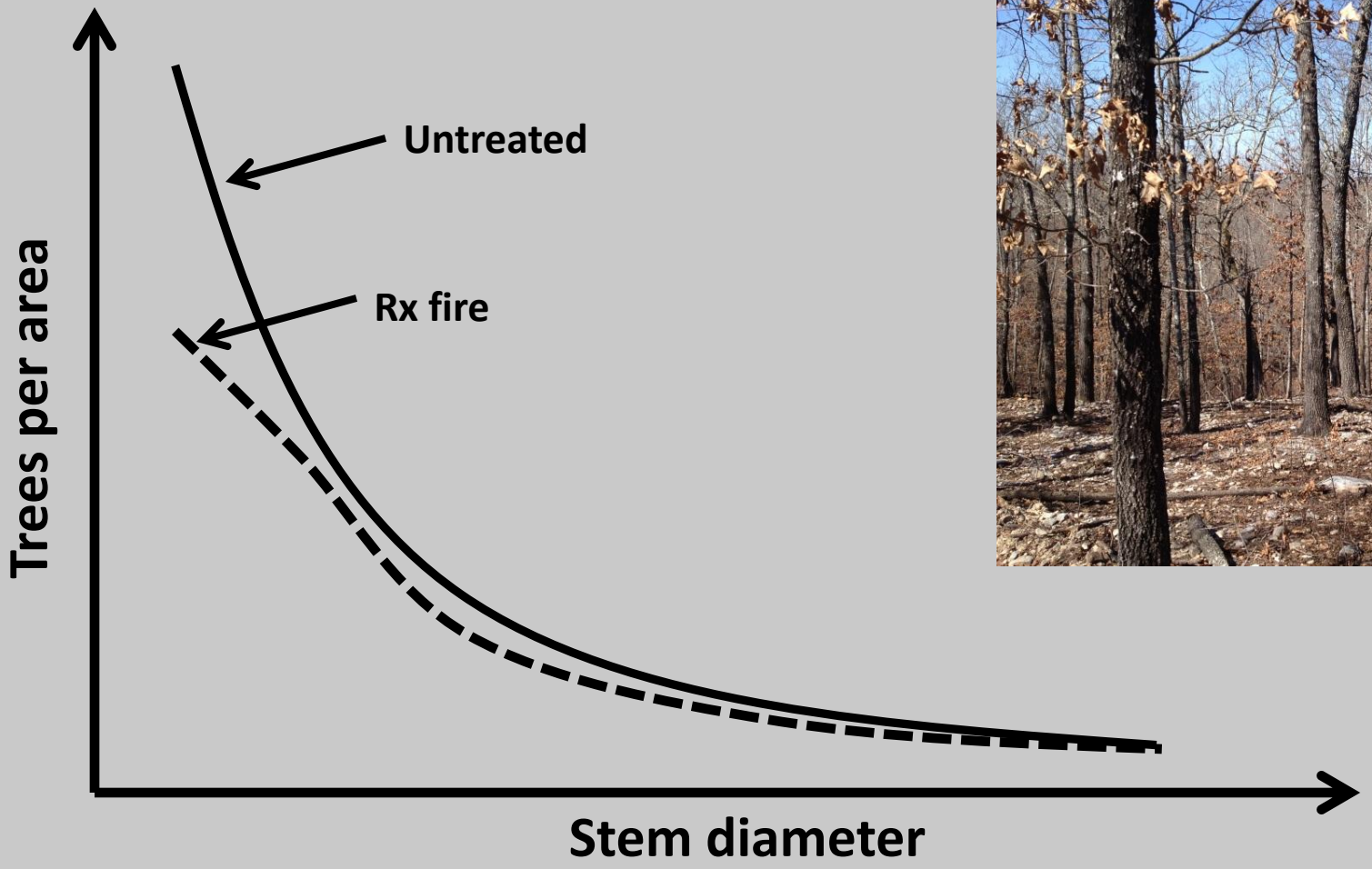
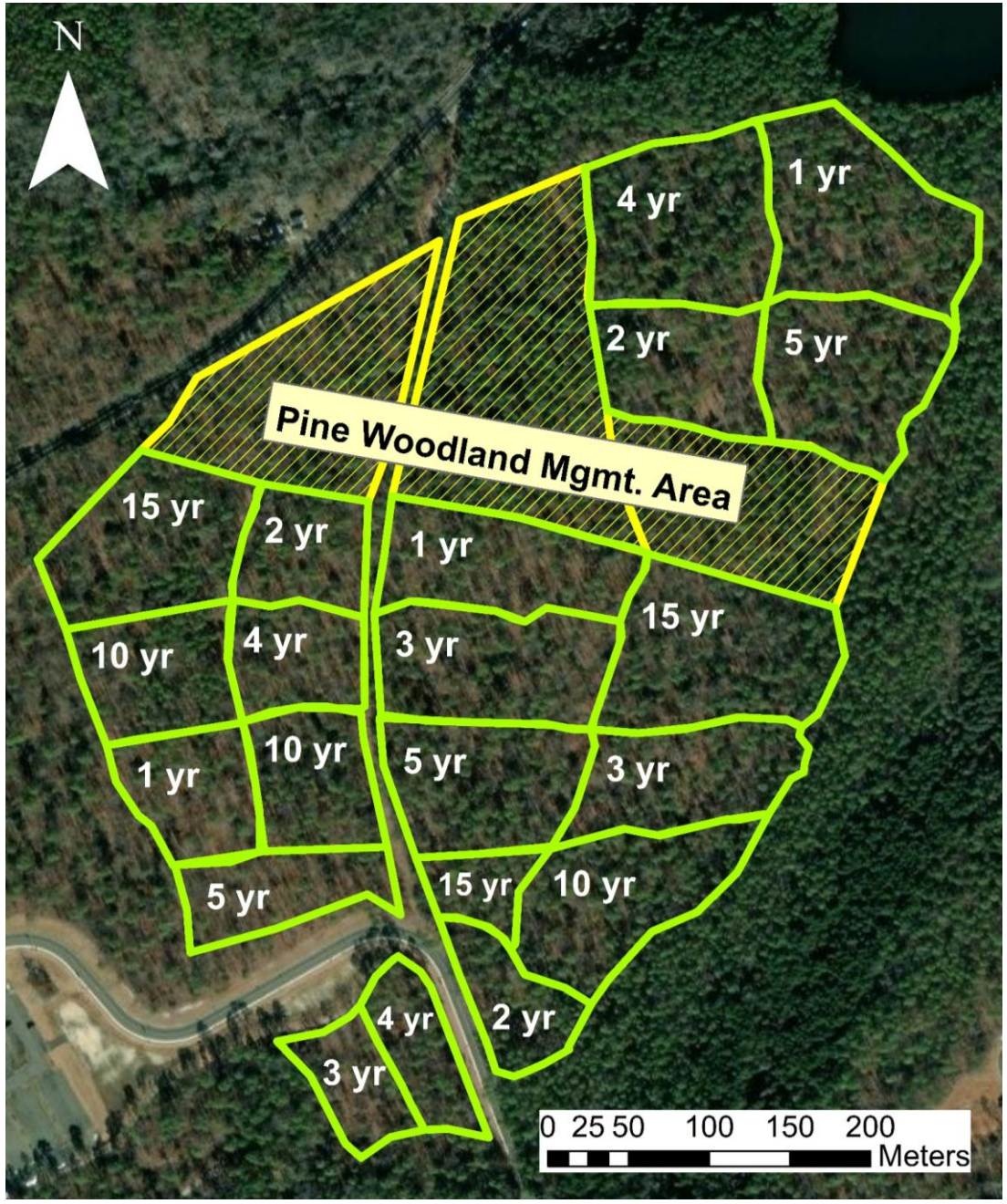


Testing effects of prescribed fire interval

RCBD: 3 blocks x 7 levels = 21 units (0.4-1.0 ha)

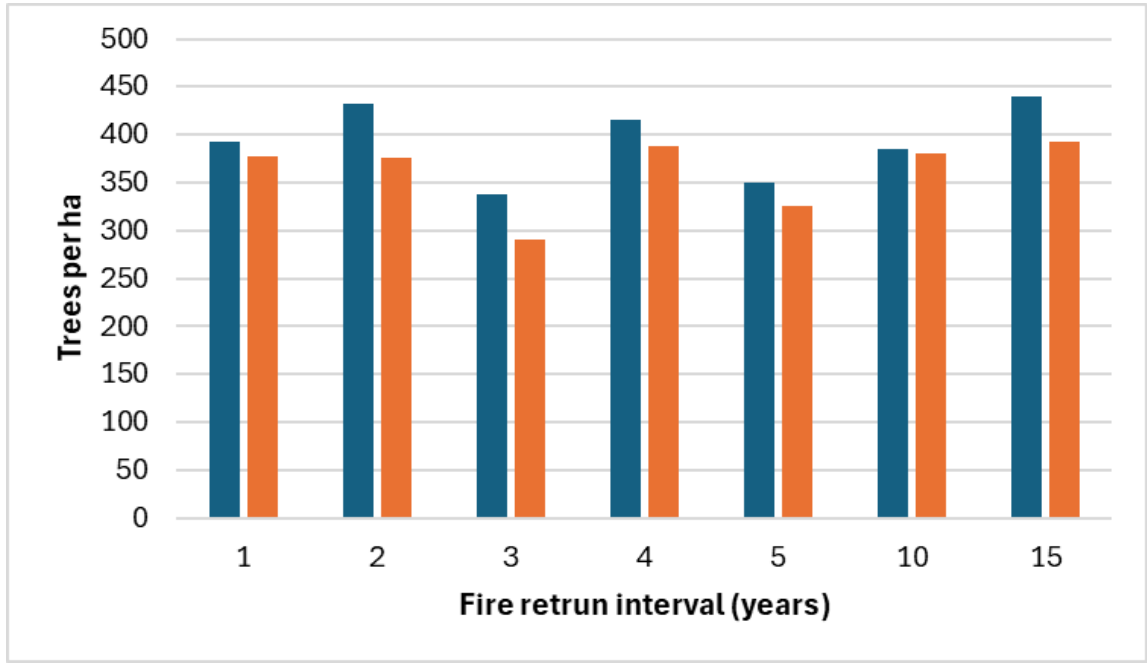
Fire Season	PWMA	1 yr	2 yr	3 yr	4 yr	5 yr	10 yr	15 yr
2015								
2016								
2017								
2018				NB				
2019					NB			
2020								
2021		NB	NB					
2022								
2023								
2024								
2025	NB	NB		NB		NB	NB	

NB = No Burn



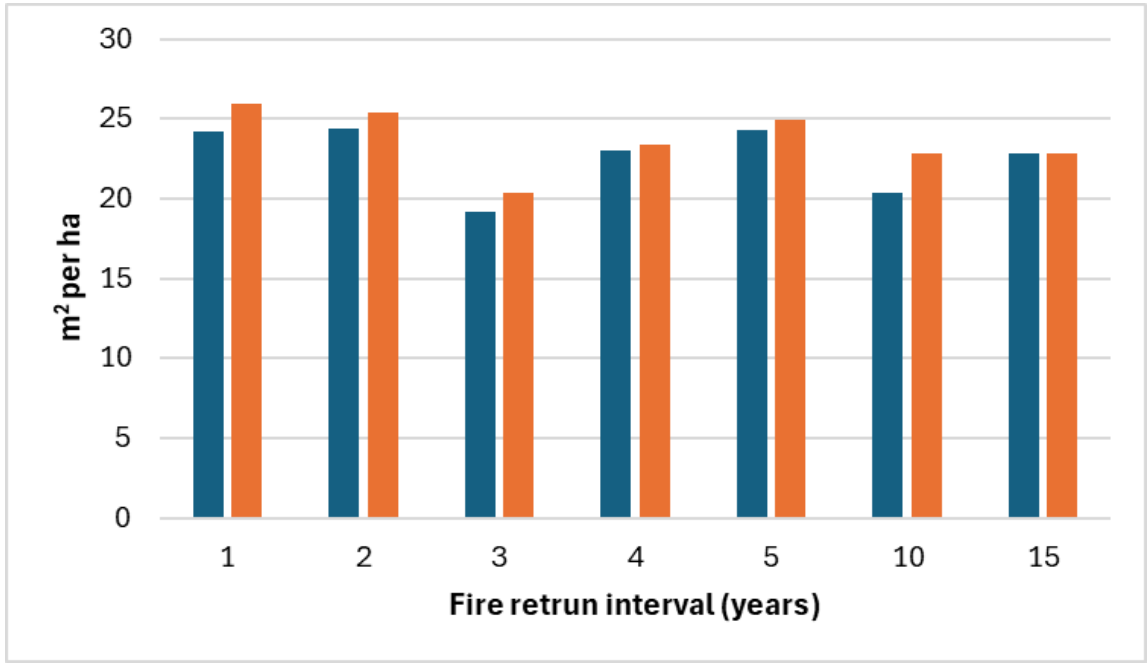
Tree community monitoring

- 0.05-ha circular plots
- All trees ≥ 1.4 m tall
- 2 in each burn unit (n=42)
- Measured 2015-2016 & 2023-24



2015-2016

2023-2024



Tracking understory recovery following March 2024 burning: Summers 2024 (& 2025)

1-yr interval: burned 9/10 yrs

Tracking understory recovery following March 2024 burning: Summers 2024 (& 2025)

2-yr interval: burned 5/10 yrs

Tracking understory recovery following March 2024 burning: Summers 2024 (& 2025)

4-yr interval: burned 3/10 yrs

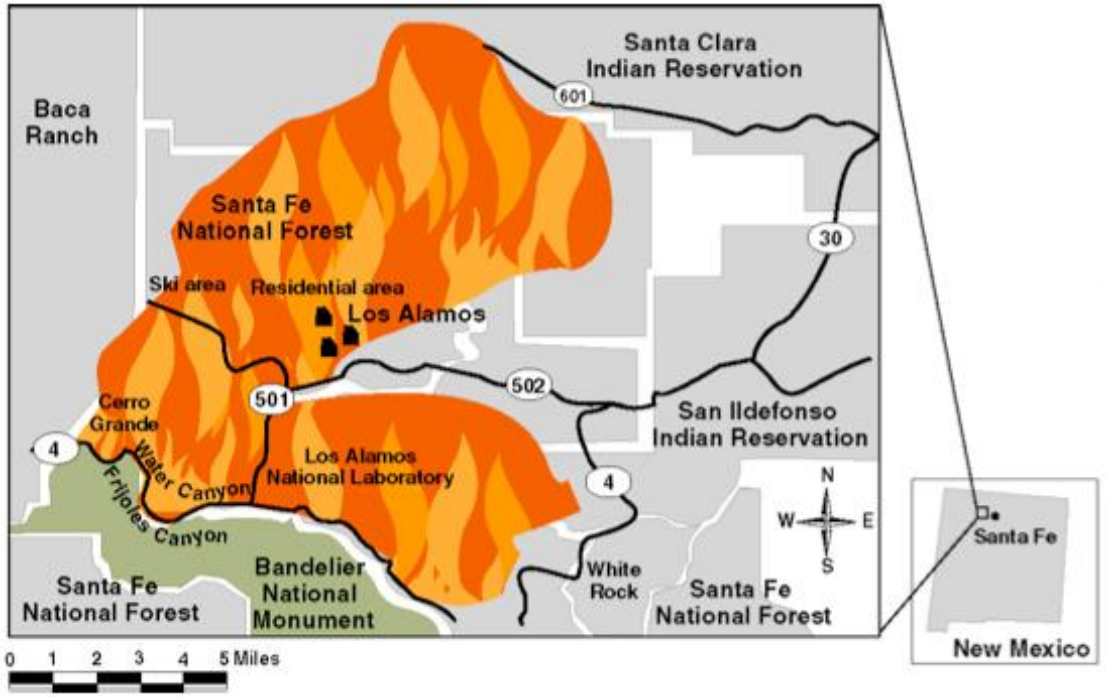
Prescribed Burn (RxB) vs. Wildfire

- RxB: a fire that is deliberately set to achieve one or more objectives for land management
  - Fuel reduction, vegetation mgmt., site preparation, ecosystem restoration
  - Application guided by science and/or traditional (or indigenous) knowledge
  - Affords control over smoke production & dispersion

- Wildfire: a wildland fire (wild-fire); a non-structure wildland fire that is unplanned, or unwanted
  - Wildland – land not designated as agriculture, urban, or mining
  - Unplanned, no control over smoke production & dispersion

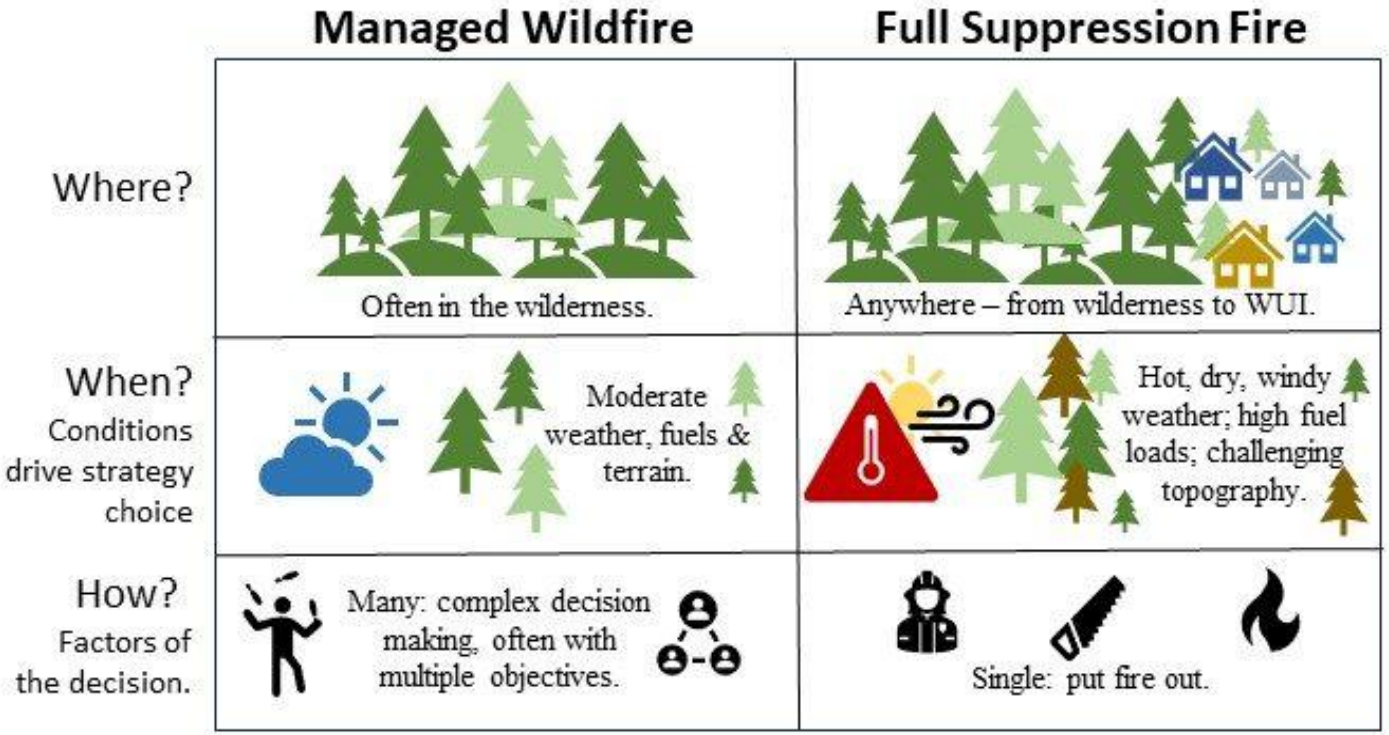
RxB can escape & blowup into a wildfire

- *Example:* 2000 Cerro Grande Fire (Los Alamos, NM)
  - Preventative RxB on a National Park that jumped containment
  - ~60k acres that forced evacuations, destroyed structures, & threatened a nuclear material storage



Managed Wildfire – *increasingly being adopted*

- Allowing wildfires to burn with little to no suppression, usually in remote areas without significant built structures (wilderness)
  - Protecting wildland fire fighters & equipment
  - Land management objectives – fuels reduction & ecological restoration



Thanks for your time!