# Manipulating soil heating patterns to optimize barrens restoration

Sharp-tailed Grouse


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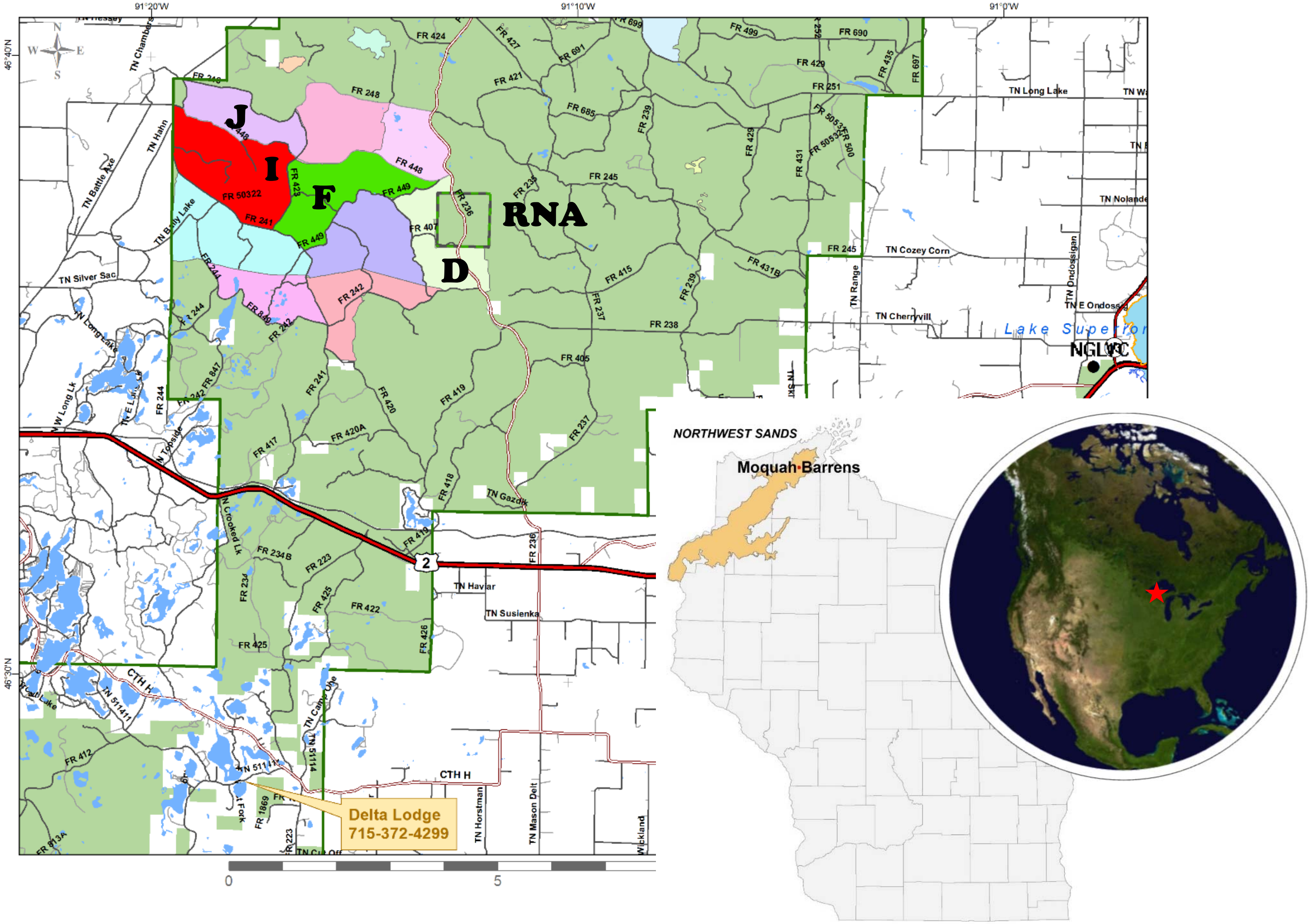
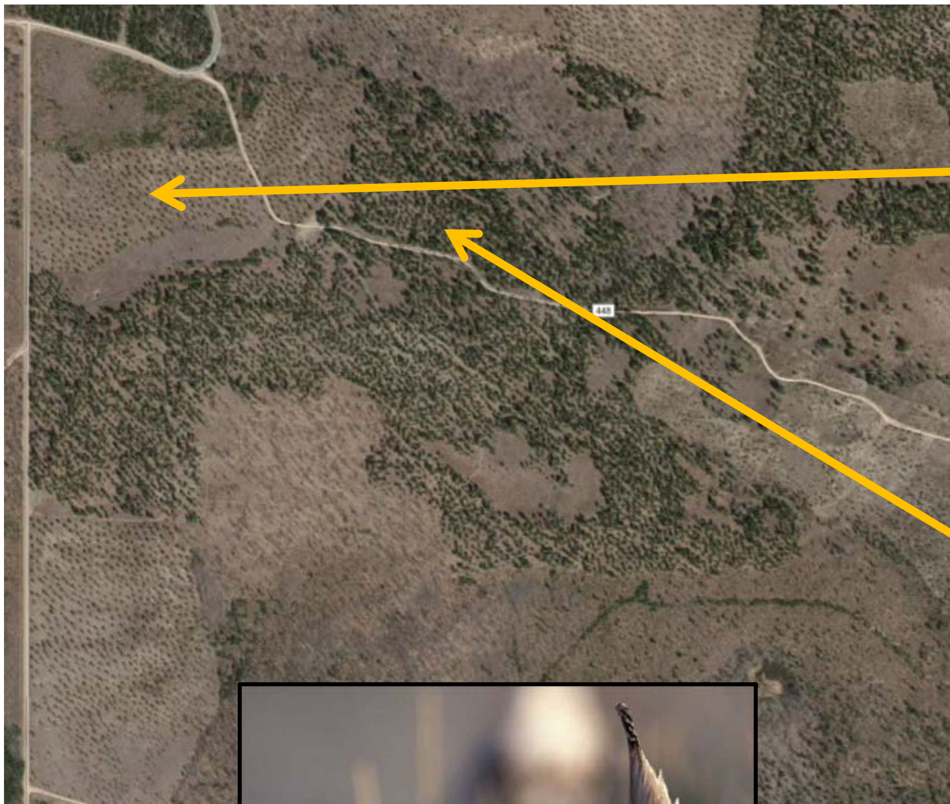
JOINT FIRE SCIENCE PROGRAM

# Moquah Barrens Restoration Area



# Moquah Restoration Goals

## *A mosaic of pine savanna, woodlands, and grasslands*




# Cover type definitions: forest & woodland

**Deciduous forest:**

- Deciduous forest history
- At least pole-sized trees (>4.5” DBH)
- Closed-canopy forest

**Pine woodland treatment**

- Pine plantation history
- Semi-open canopy
  - Minimum tree density = 40 trees/ac
  - Basal Area Target: 30 - 60 $ft^2$/ac
- Recent harvest = 5 years or less (2010 – 2015)

# Cover type definitions: brush & grassland

**Brush**

- Target ≥ 70% woody shrub/sapling cover (Min 50%), excluding short shrub species (sweetfern & *Vaccinium*)
- Stem size ≤ 4.5 in DBH

**Grassland formal definitions**

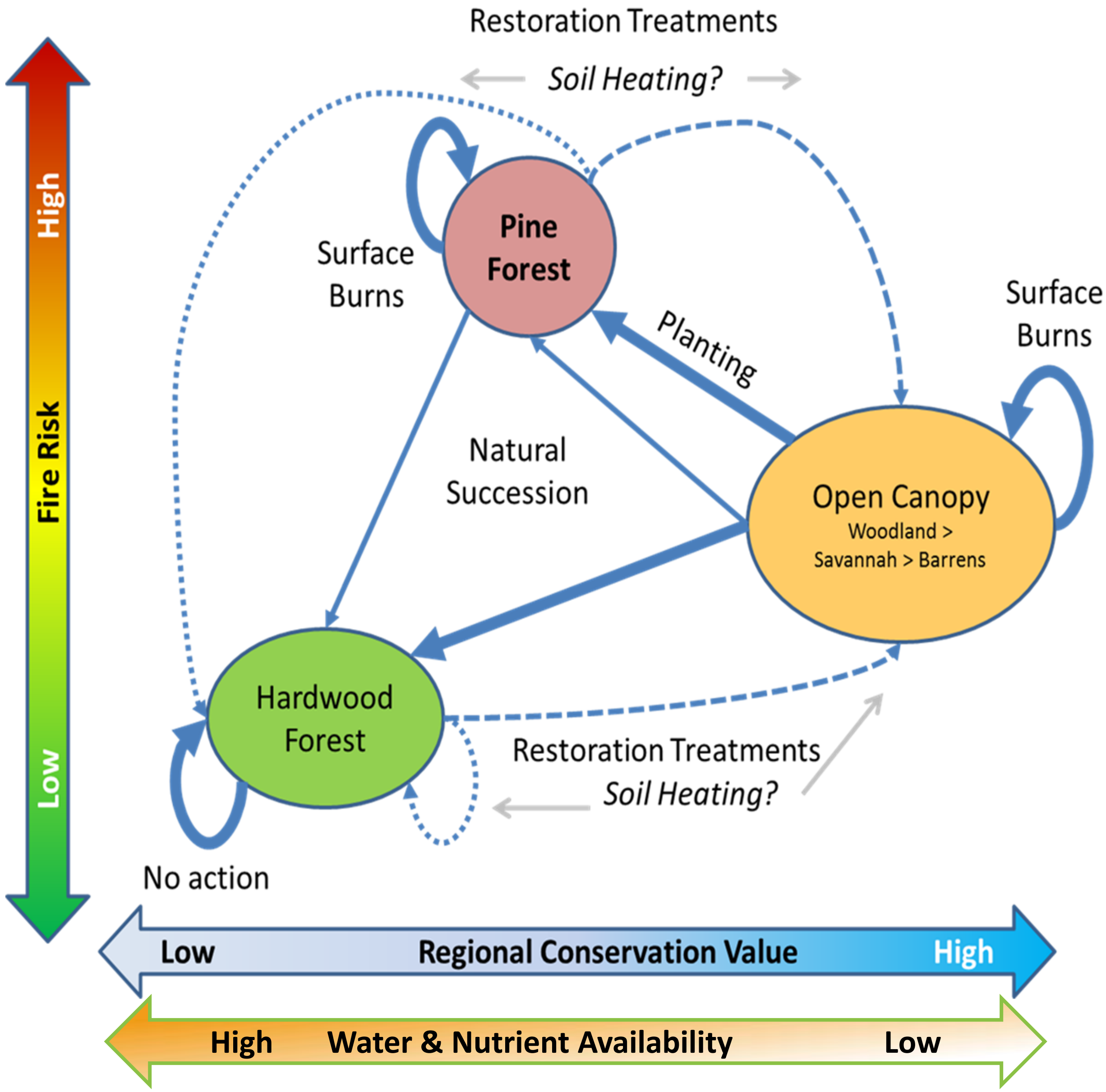
- Tree Density < 50 trees/acre
- Basal Area < 30 ft2 per ac
- Shrub/sapling cover < 30%, excluding short shrub species (sweetfern and *Vaccinium*)

# Example: brush cut-and-leave treatment (~10 tons/ac)

# Can increased soil heating during prescribed burns help improve restoration success?

**Loss of barrens habitat:**
- Plantation establishment
- Fire exclusion

**Barriers to restoration**
- Persistent hardwood “brush”
- Degraded seed source for grasslands
- “Mesophication” – Forest floor development, water & nutrient enrichment



# Project Objectives

- **Provide field validation of the Campbell soil heating model** within sandy soils underlying fire-prone forest and open barren systems of the Lake States region.

- **Investigate second-order relationships between critical ecosystem processes relevant to pine barrens restoration and soil heating,** including:
  - Hardwood stem mortality and re-sprouting response
  - Seed abundance, diversity, and vitality
  - Soil fertility (total carbon, black carbon, nitrogen, cations, pH)

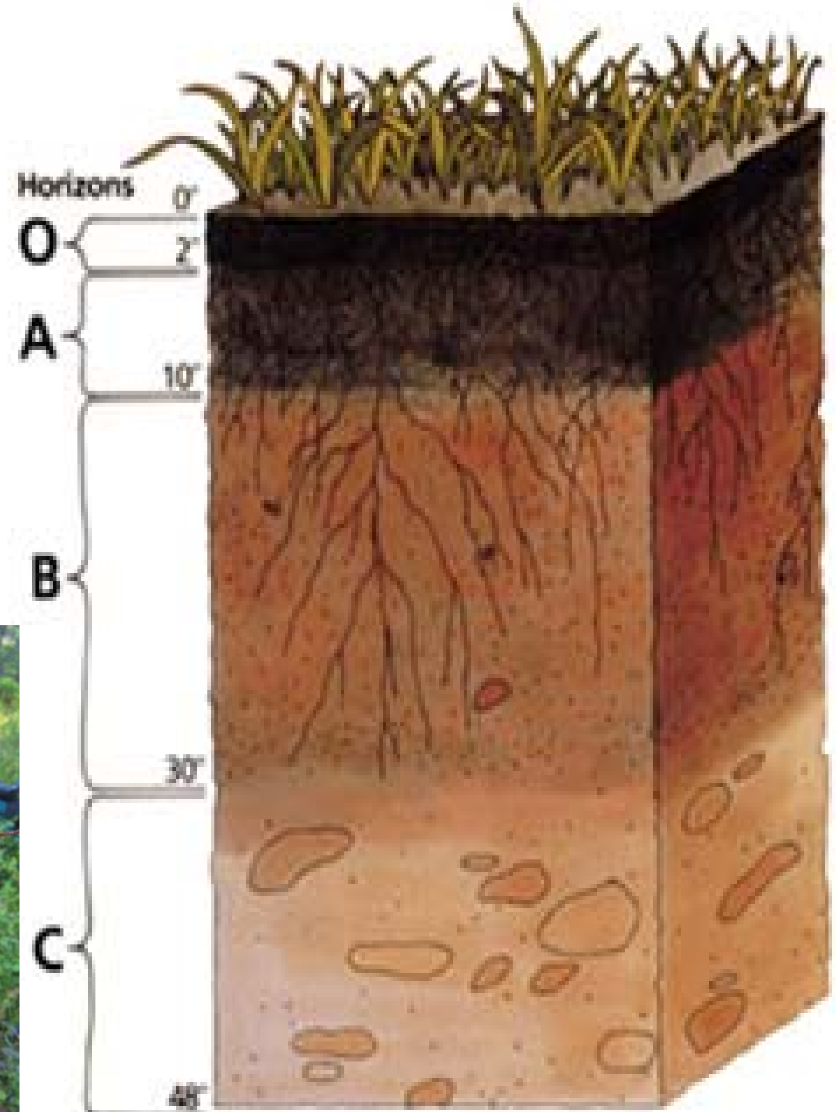
- **Validate and/or adapt existing field-based estimates of post-burn soil impacts** (e.g., Jain et al 2012) to determine relationships between predicted vs actual second-order effects.

# Fire exclusion contributes to mesophication . . . mesophication inhibits fire occurrence & spread

***O** – forest floor (Litter and duff)*

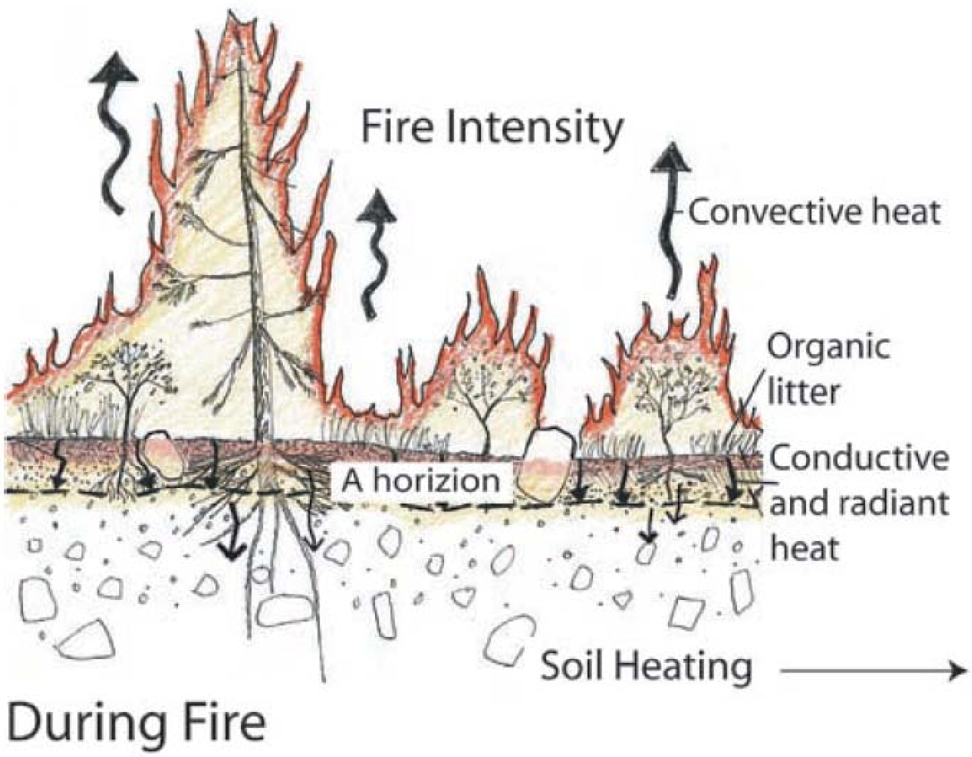
***A** – organic matter mixed with minerals*


https://nsrcforest.org/project/forest-floor-remains-major-source-lead-northern-forest



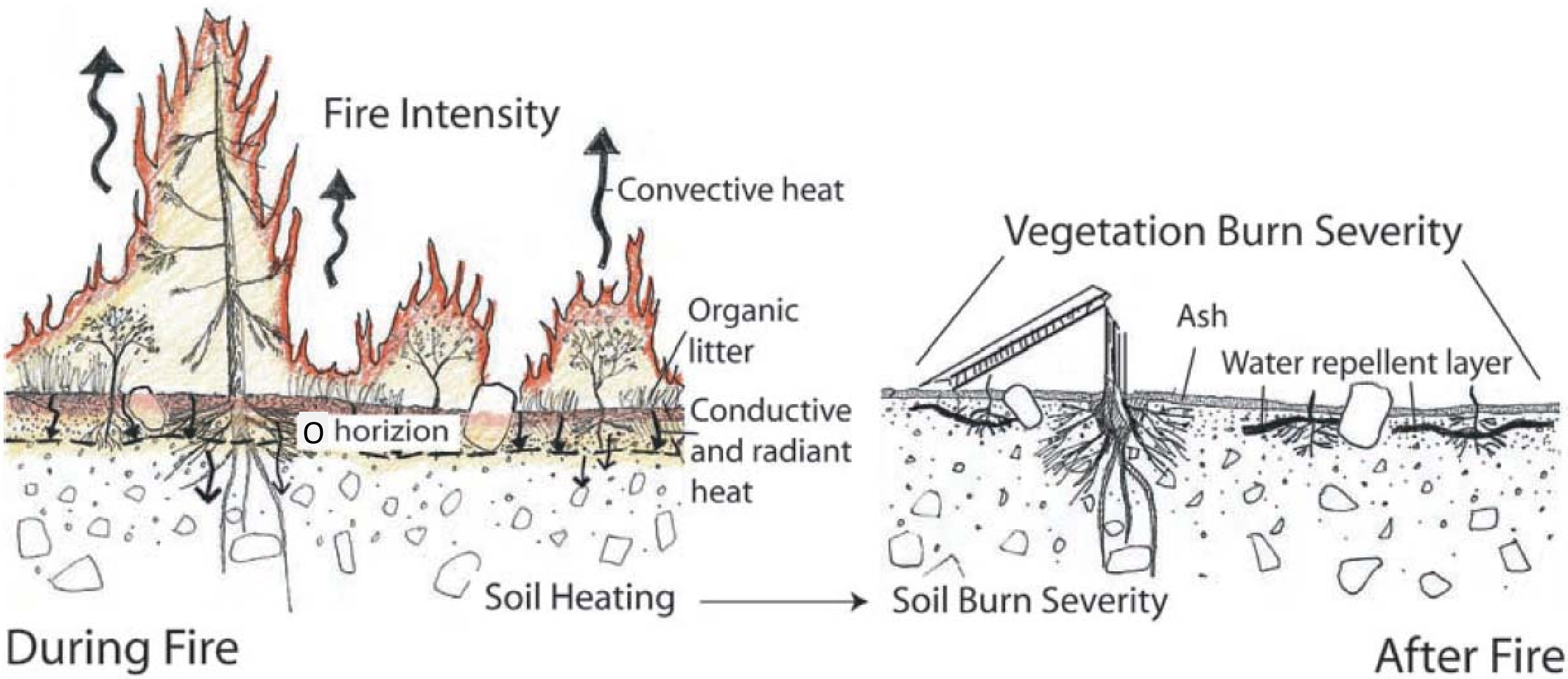

USDA/NRCS

# Why pay attention to soil heating in restoration projects?




Keeley 2009, Parsons et al. 2010

# Why pay attention to soil heating in restoration projects?




**Intense soil heating can:**

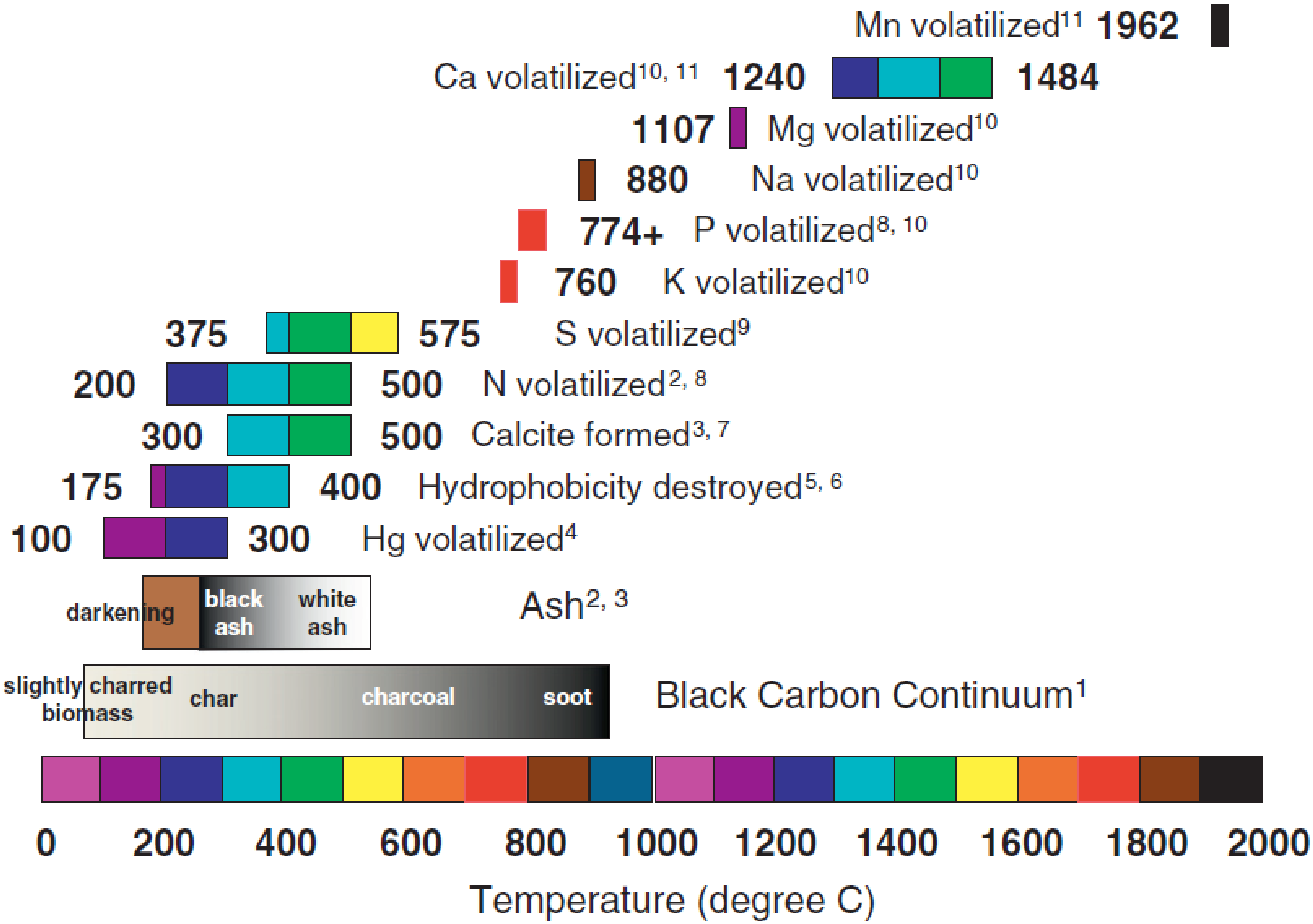
- Decrease duff thickness (consumption)
- Decrease soil moisture & nutrients
- Damage belowground woody tissues
- Favor fire-adapted species in the seedbank

**Dry duff:**
***heat source***

**Moist duff:**
***insulates***

Frandsen & Frandsen 1994, Keeley 2009, Parsons et al. 2010

# Why pay attention to soil heating in restoration projects?




Bodí et al. 2014, Earth Sci Rev

# Manipulating soil heating via woody fuel load

**Brush sites** ***(pine plantation or deciduous history)***

- Brush cut and **leave on site**
- Brush cut and **remove**
- Standing brush (control)

**Pine Woodland** ***(plantation history)***

- Existing (low, biomass harvest)
- Fuel **addition**

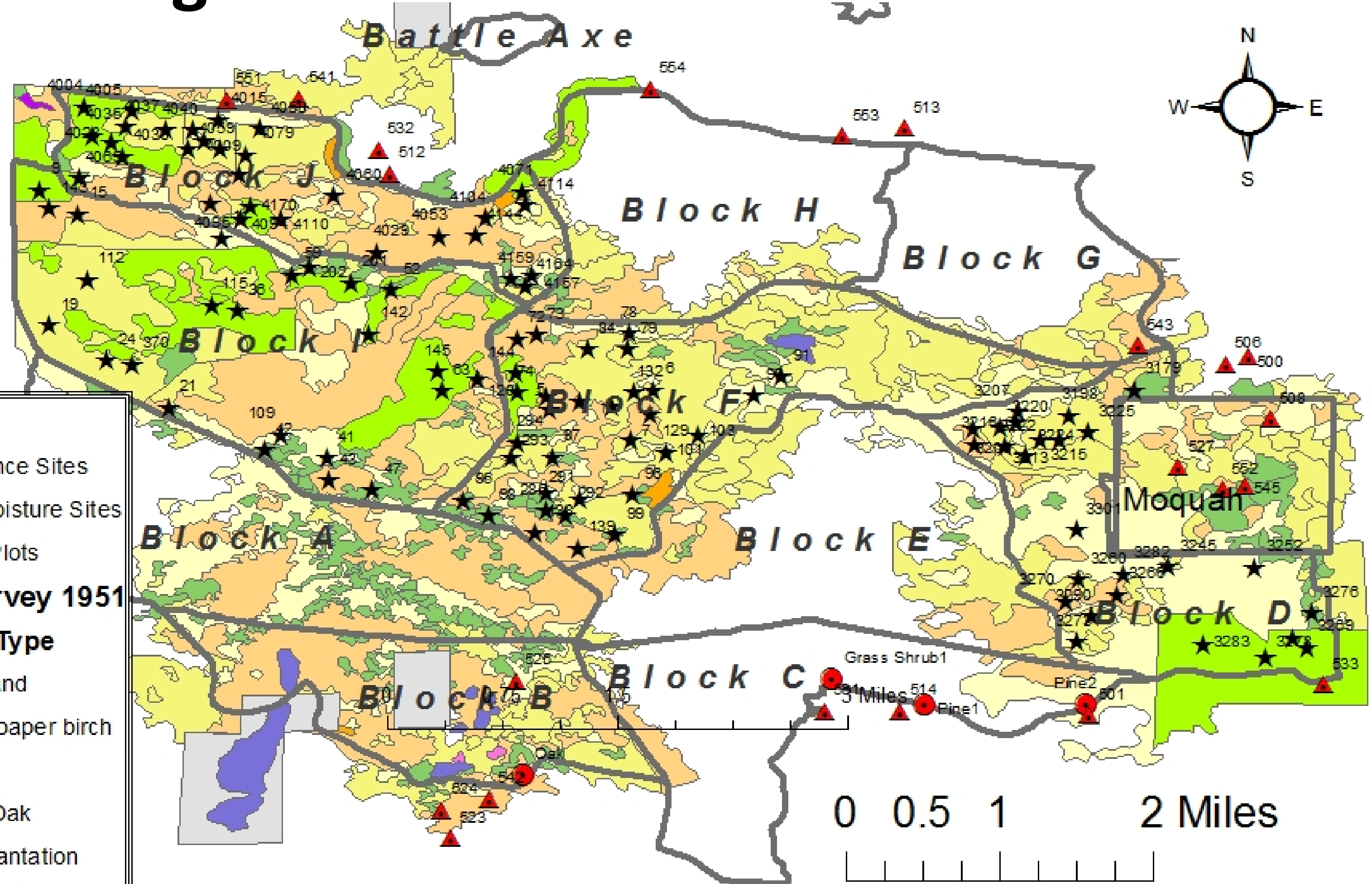
**Grassland** ***(plantation, deciduous, & grassland history)***

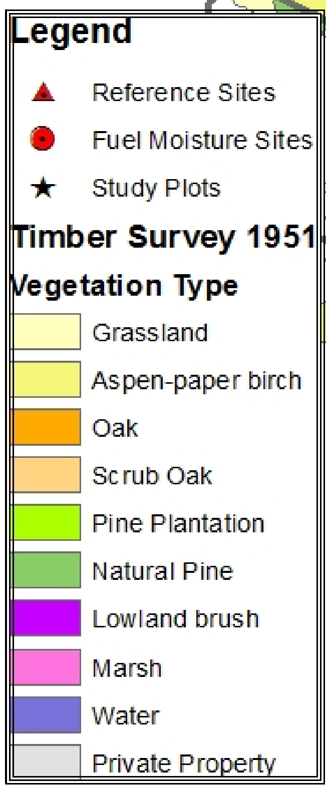
- Existing (low)
- Fuel **addition**



Scale: 20-meter (1 chain) radius plots = 1/3 acre

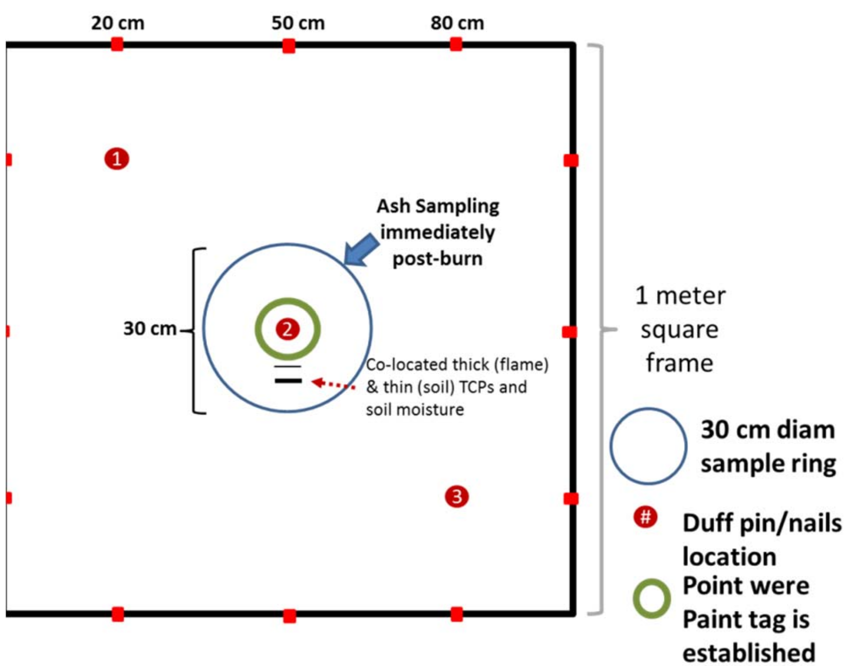
# Moquah Barrens Restoration Area
# Chequamegon-Nicolet National Forest



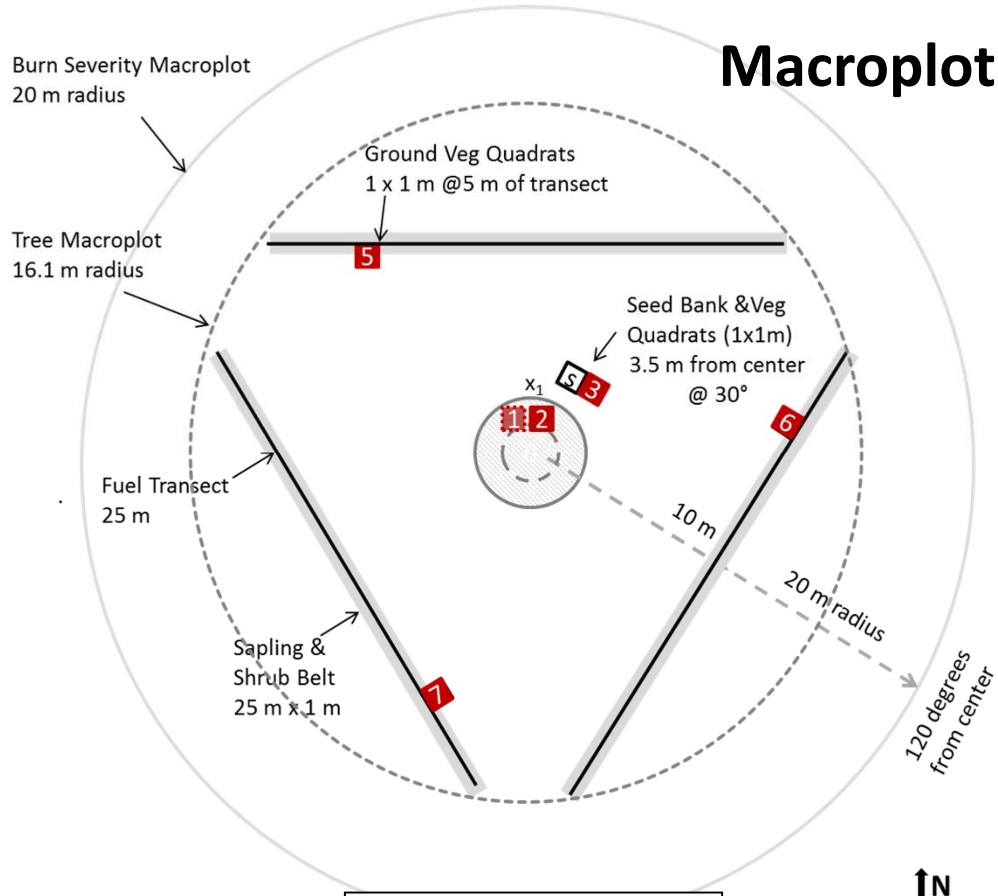



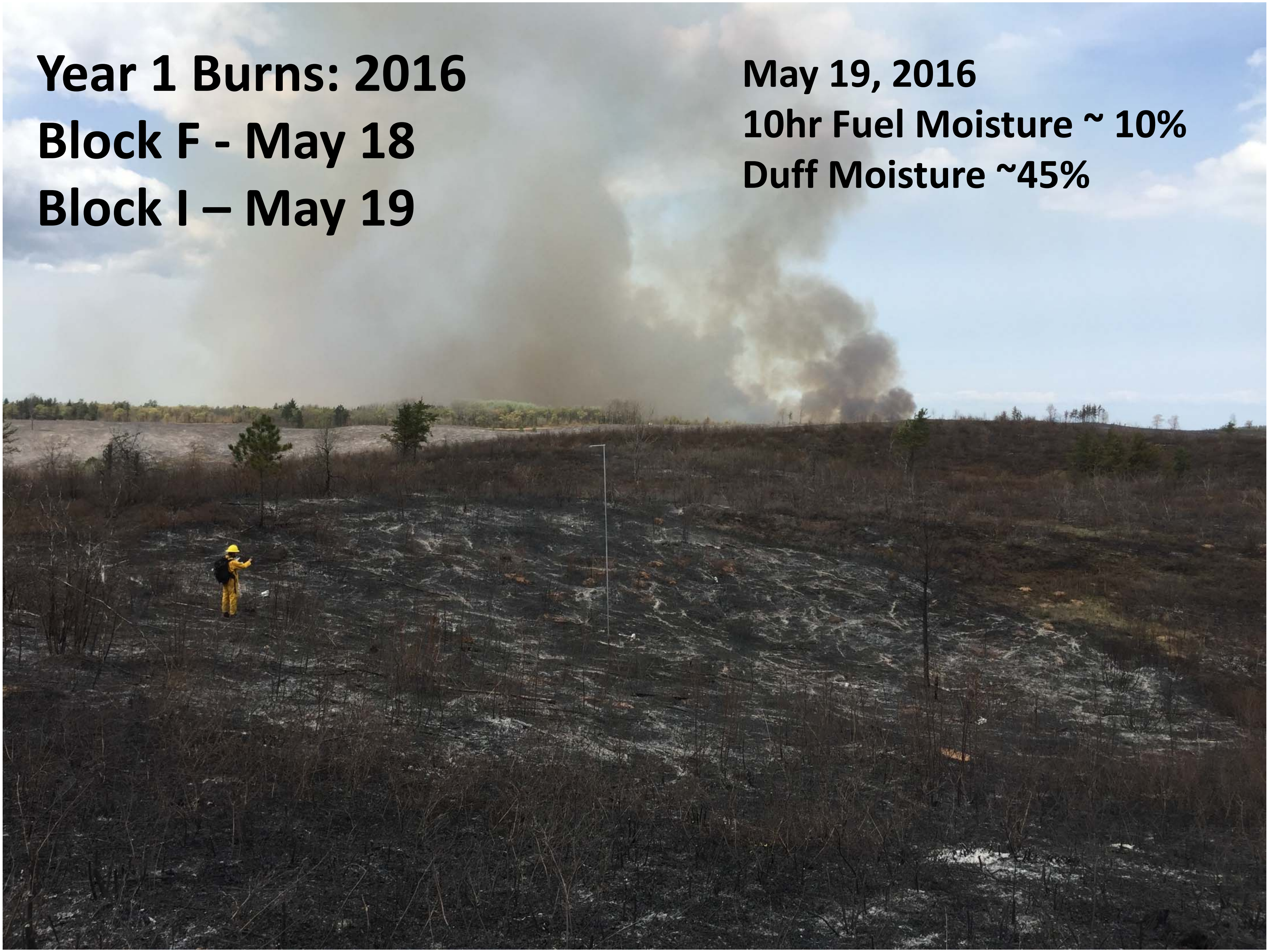

- 112 Burn Plots across 2 Years and 4 Burn Blocks
- 20 Reference Plots
- 4 Fuel Moisture Plots

# Quadrat subplots




# Macroplot

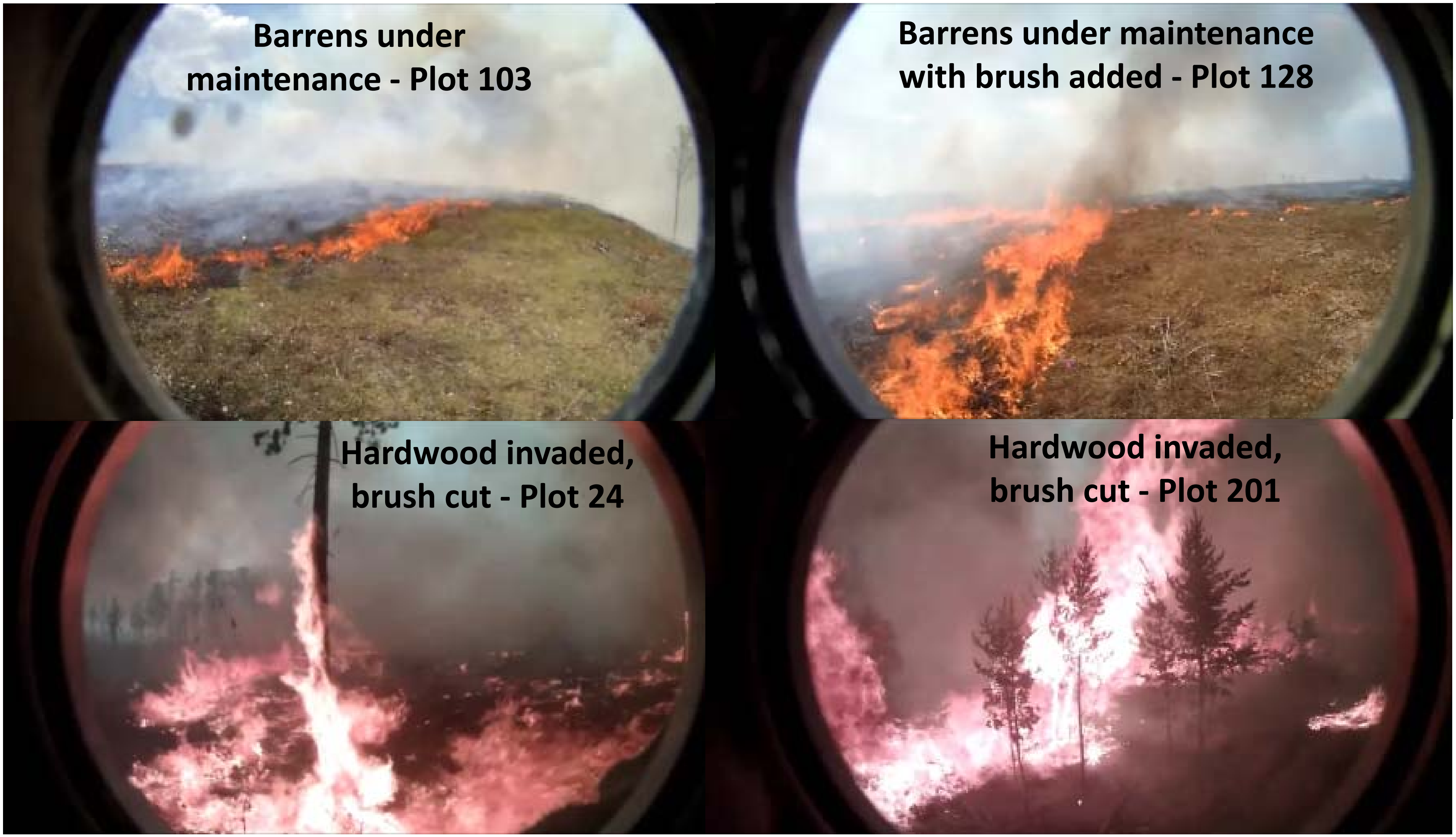




Year 1 Burns: 2016
Block F - May 18
Block I – May 19
May 19, 2016
10hr Fuel Moisture ~ 10%
Duff Moisture ~45%

# How do fuel additions affect fire intensity?

***Aboveground:***

- Low to modest intensity where no woody fuels were cut
- Moderate to high intensity where woody fuels were added or cut on site



*All data here & in following slides are preliminary and have not been peer-reviewed*

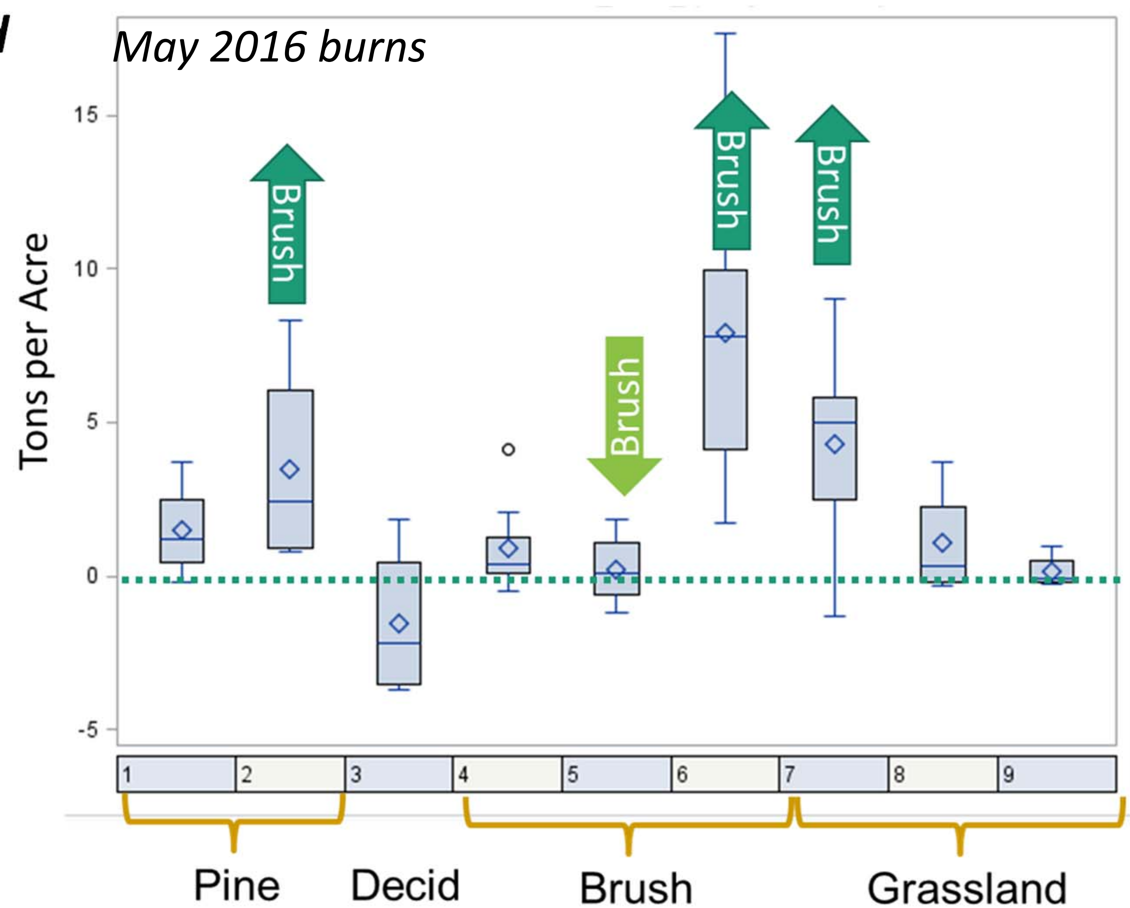
# How do fuel additions affect woody fuel consumption?

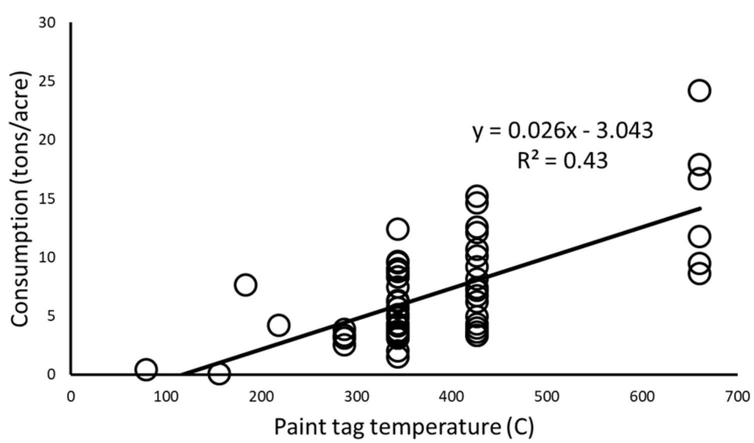
***High fuel loads were associated with greater consumption of woody fuels and duff***

- And, greater burn severity

***Fuel consumption is an indicator of total fire energy release:***

- Aboveground
- Belowground




*Maximum "paint tag" temperature is related to consumption: hotter temps → greater consumption*

# Does duff act as an insulator, or as a heat source?

***There was little to no evidence of independent duff smoldering***

- Spring burns consumed only minimal duff: 0.0 to 1.3 cm
- The relationship between duff thickness & soil heating was not significant: *fire intensity was the best predictor of soil heating.*

Duff (~5 cm) pre-fire

Duff (~3 cm) post-fire

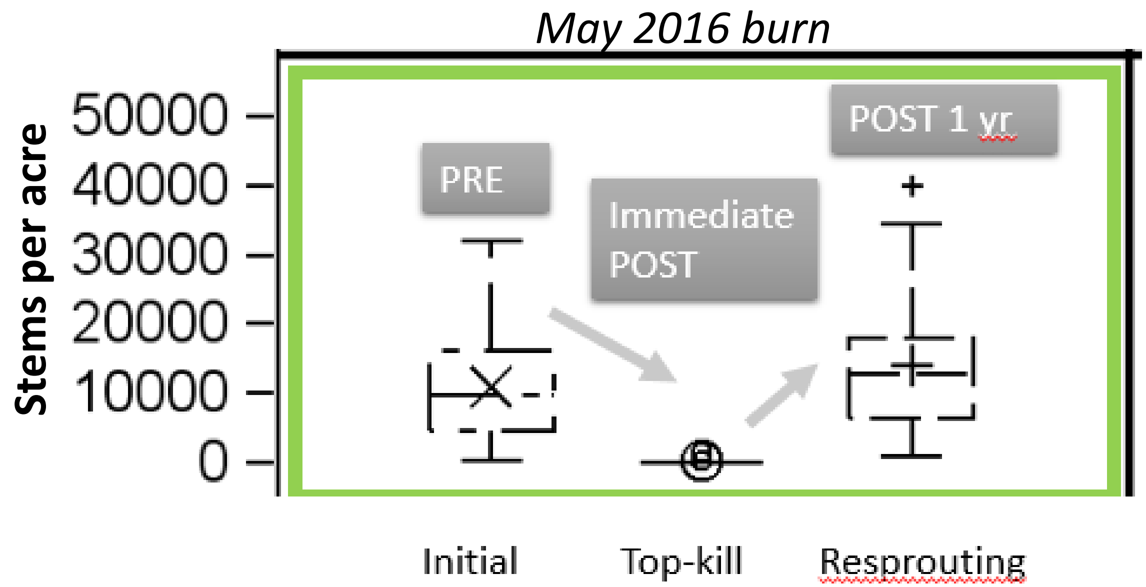
| Variable | Units | N | Mean | Min | Max |
|---|---|---|---|---|---|
| Consumption | tons/acre | 56 | 7 | 0 | 24 |
| Fireline intensity | BTU/ft s | 60 | 192 | 0 | 426 |
| | kW/m | 60 | 663 | 0 | 1472 |
| Duff moisture | % | 24 | 47 | 21 | 84 |
| Duff depth | in | 67 | 0.9 | 0.0 | 2.4 |
| Duff consumption | in | 66 | 0.2 | 0.0 | 1.3 |
| Soil temp. rise* | deg F | 57 | 124 | 3 | 702 |
| | deg C | 57 | 51 | 3 | 372 |

*At/near duff-soil interface.

# How effective are spring burns for decreasing shrub stem density?

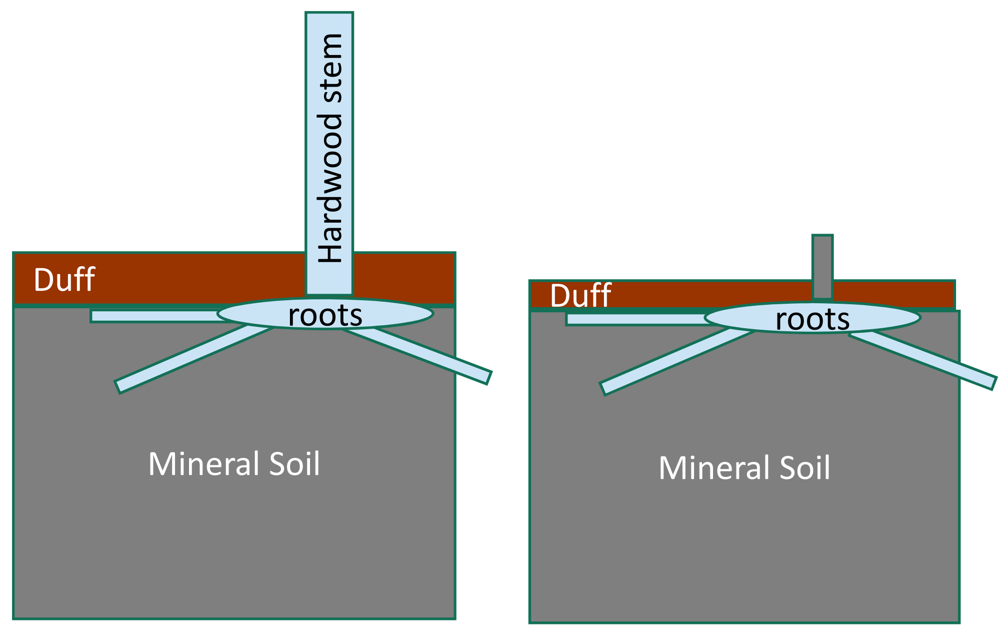
***Not very effective!***

- Fire caused immediate decrease in # of stems
- But, re-sprouting returns to prefire stem densities
- Similar trend where brush was cut




***Why?***

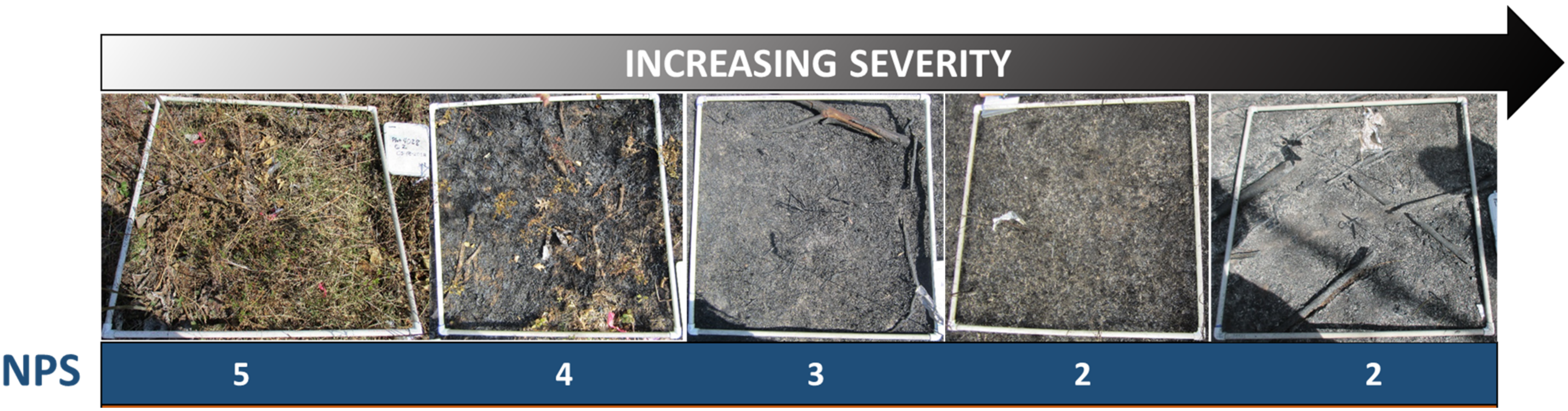
Duff insulates & protects roots when duff moisture content is high

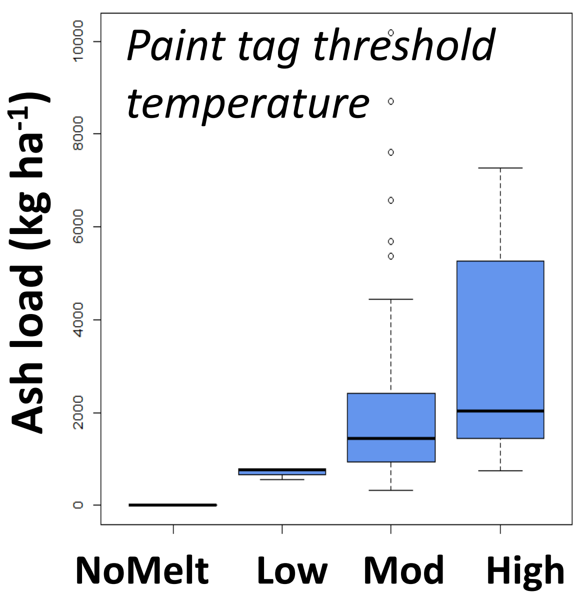


Dormant season burn: Top-kill

Dormant season burn:
Resprouting 1 season later

# What are the consequences of greater fire intensity & burn severity on soil nutrient status?



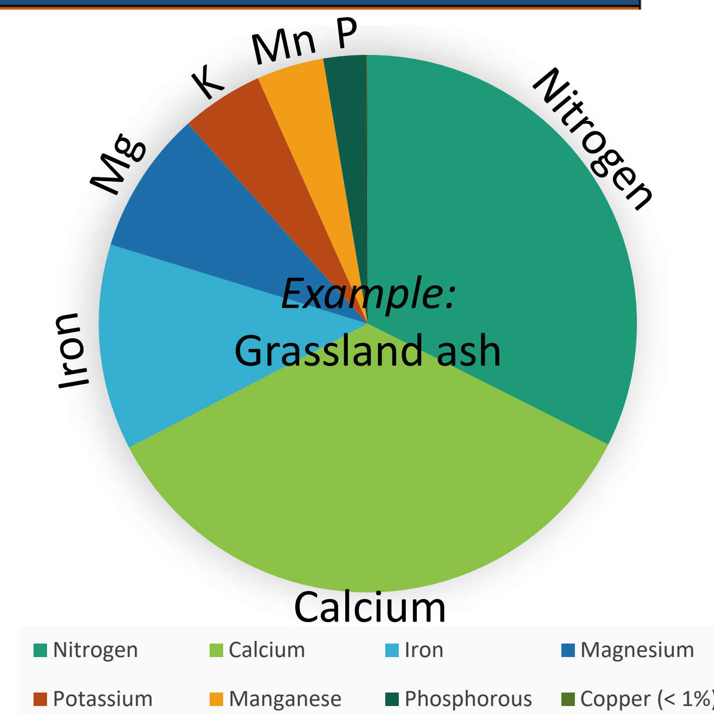




**Higher paint tag temperatures = greater ash production**

**Ash: ~40% carbon + essential plant nutrients**

Nutrients leach to soil

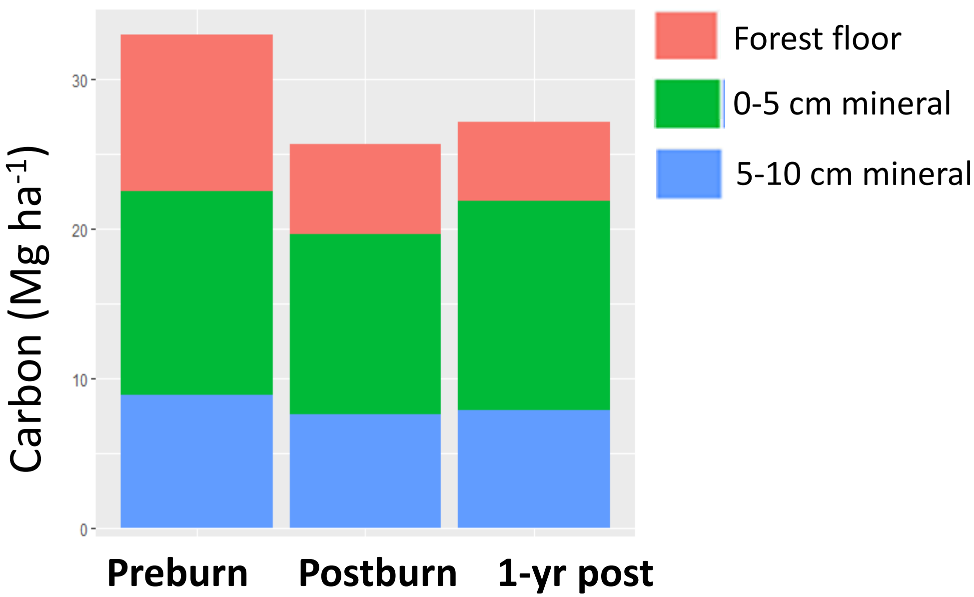
Available for plant uptake, or loss by leaching



# What are the consequences of greater fire intensity & burn severity on soil nutrient status?

***Fire decreases soil carbon stocks***

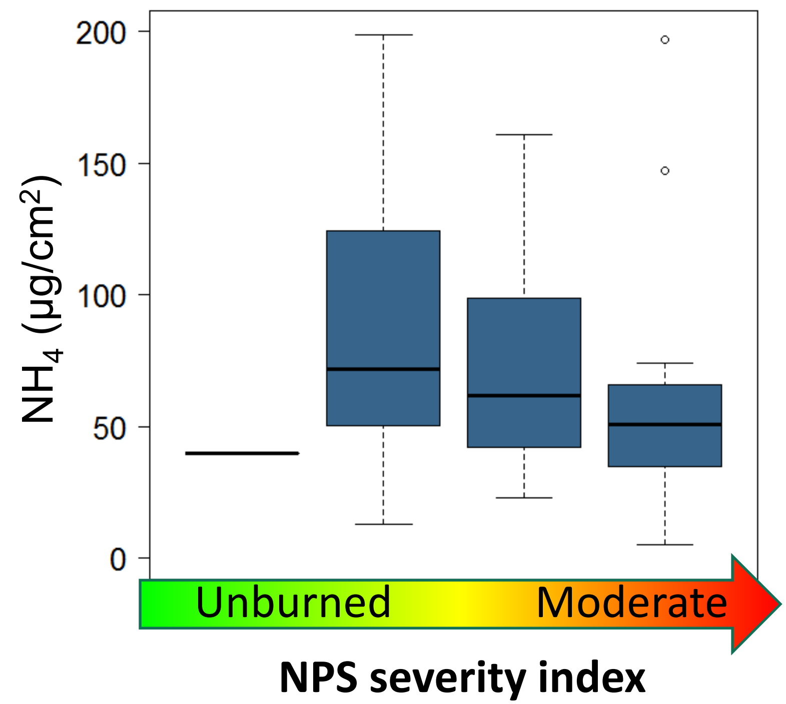
- Removes source of nutrients




***Fire removes nutrients from a site, & removal increases with burn severity***

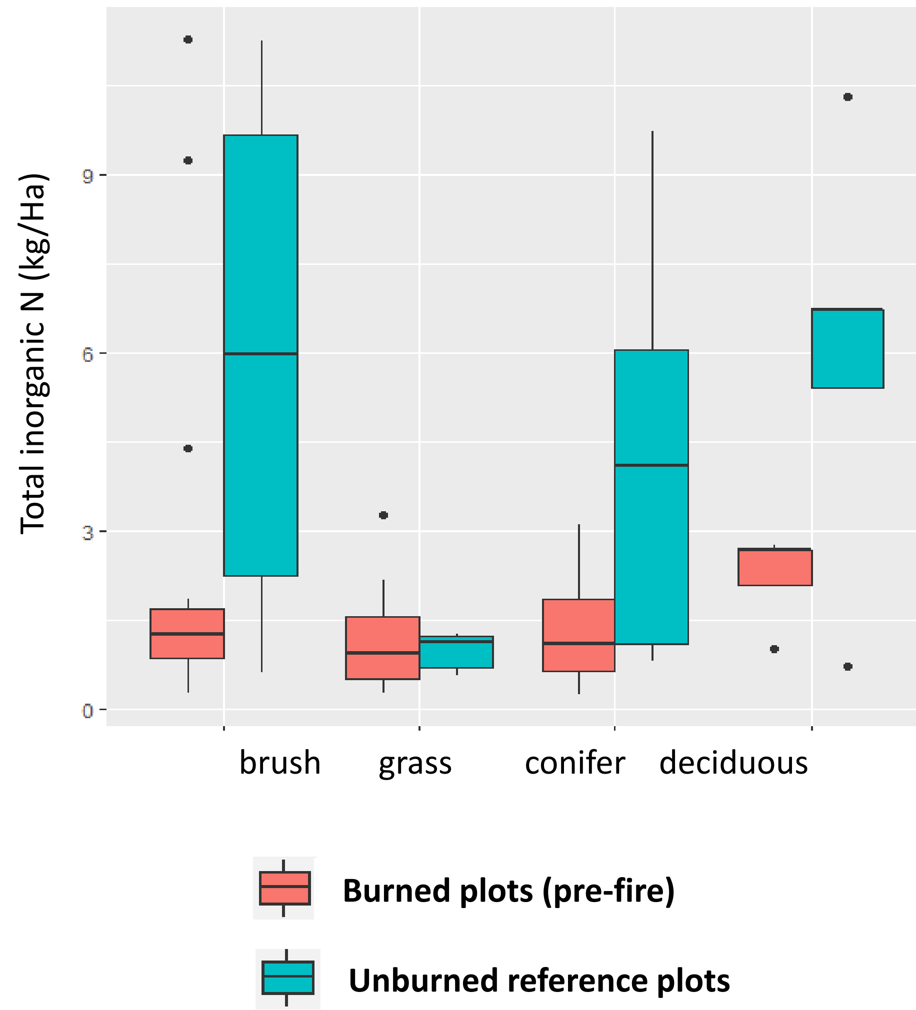
***Fire increased plant-available N***

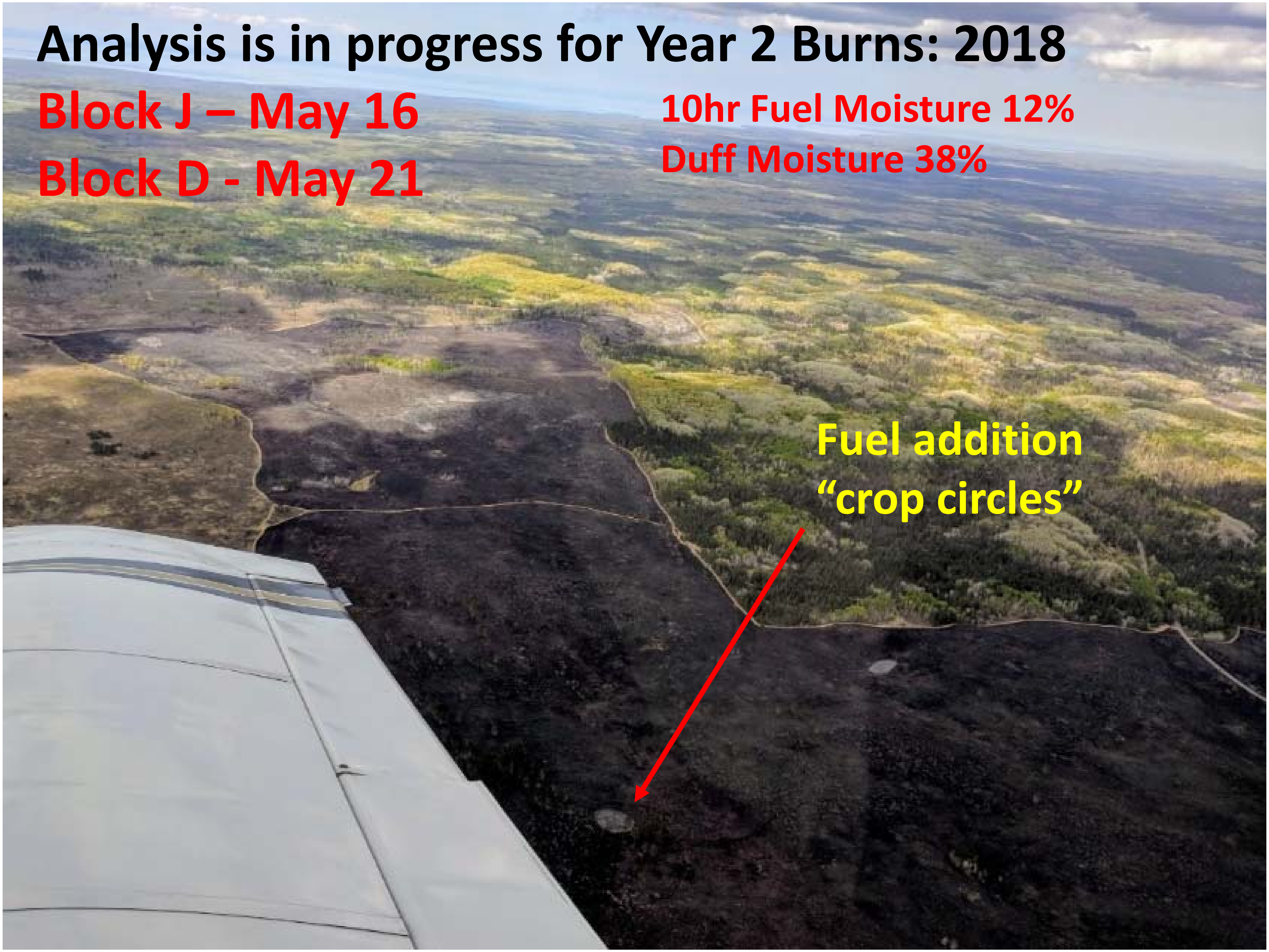
- But effect decreases with severity
- N volatilization increases with severity, leaving less available for plants



# What are the consequences of *long-term* fire exclusion?

- Plots under prescribed fire management have lower nitrogen stocks than long-unburned plots
- *Barrens* historically supported low plant biomass
- Barrens species are adapted to fire and low-nutrient soils




Analysis is in progress for Year 2 Burns: 2018
Block J – May 16
Block D - May 21
10hr Fuel Moisture 12%
Duff Moisture 38%
Fuel addition
“crop circles”

# Summary & implications for management*

**Caveat: based on preliminary results from the 2016 burn*

**Greater fuel load & consumption → greater energy release, higher temperatures, & greater burn severity**

- Leave cut brush on-site to increase impact of restoration burns

**Abundant shrub re-sprouting indicates that spring prescribed fire had minimal effectiveness on woody vegetation**

- Duff accumulates during fire exclusion, and insulates plant roots from heat during burns
- Multiple burns may eventually decrease stem density
- Consider burning when duff is dry(er)

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**Fire removes nutrients from a site & the effect increases with severity**

- Carbon & nutrients are lost via combustion of O horizon, **or** by mineralization during fire followed by uptake or leaching
- Fires of greater intensity & severity are likely most effective for restoring nutrient-poor barrens conditions

# Acknowledgments

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***Check out Moquah webinars!***
***Heeringa 11/29/18***
***Our team 3/12/19***

# It takes a village!