Wildfire, Fuels, and Climate Change in Michigan's Jack Pine-Dominated Ecosystems

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Northern Lower Michigan

Northern Lower MI - Grayling Outwash Plain

- High elevation outwash plain
  - Ice-contact features
  - End moraines
  - Glacial meltwater streams
- Inland from Great Lakes
  - Lower winter temperatures
- Excessively drained sands
  - Supports jack pine

Albert et al. 1995

Jack pine

(*Pinus banksiana* Lamb.)

- Grows on dry, infertile soils
- Mature trees:
  - 17-20 m tall, 20-25 cm dbh
- Range:
  - Lake States, Canada
- Adapted to fire
  - Leaf litter flammable, ladder fuels
  - Serotinous cones
  - Germinates on bare mineral soil

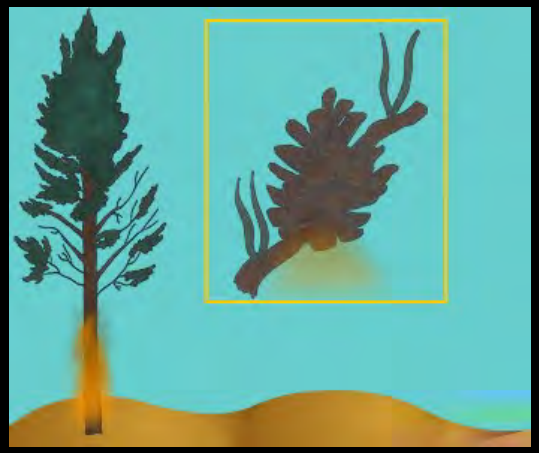


Photo: Michigan Tech

Rudolph, 1958

Background: Fire Regime

Fire Type - level where fire burns: ground, surface, crown

Fire Intensity - length of flame/amount of energy produced

Fire Severity - effect of fire on soil or vegetation

Fire Frequency - how often a burn occurs

From *Forest Ecology,* 4th Edition,
Barnes et al.

Background: Fire Regime

Fire Return Interval - average number of years between fires for a given area

Fire rotation/Fire cycle - length of time required to burn over an area equal to that under consideration

From *Forest Ecology,* 4th Edition, Barnes et al.

Fire Regime of jack pine-dominated ecosystems

- Type: stand-replacing crown fires
- Fire rotation 59 years
  - Cleland et al, 2004
- Fire return interval 12-60 years
  - Simard and Blank, 1982
- Produces typical stand structure in the area

Management for Kirtland's warbler (*Setophaga kirtlandii* Baird) habitat

Figure: Birds of North America database

- Kirtland's warbler breeding habitat
  - 5-23 year old trees
  - 20-60% canopy cover
  - Patchy, with openings

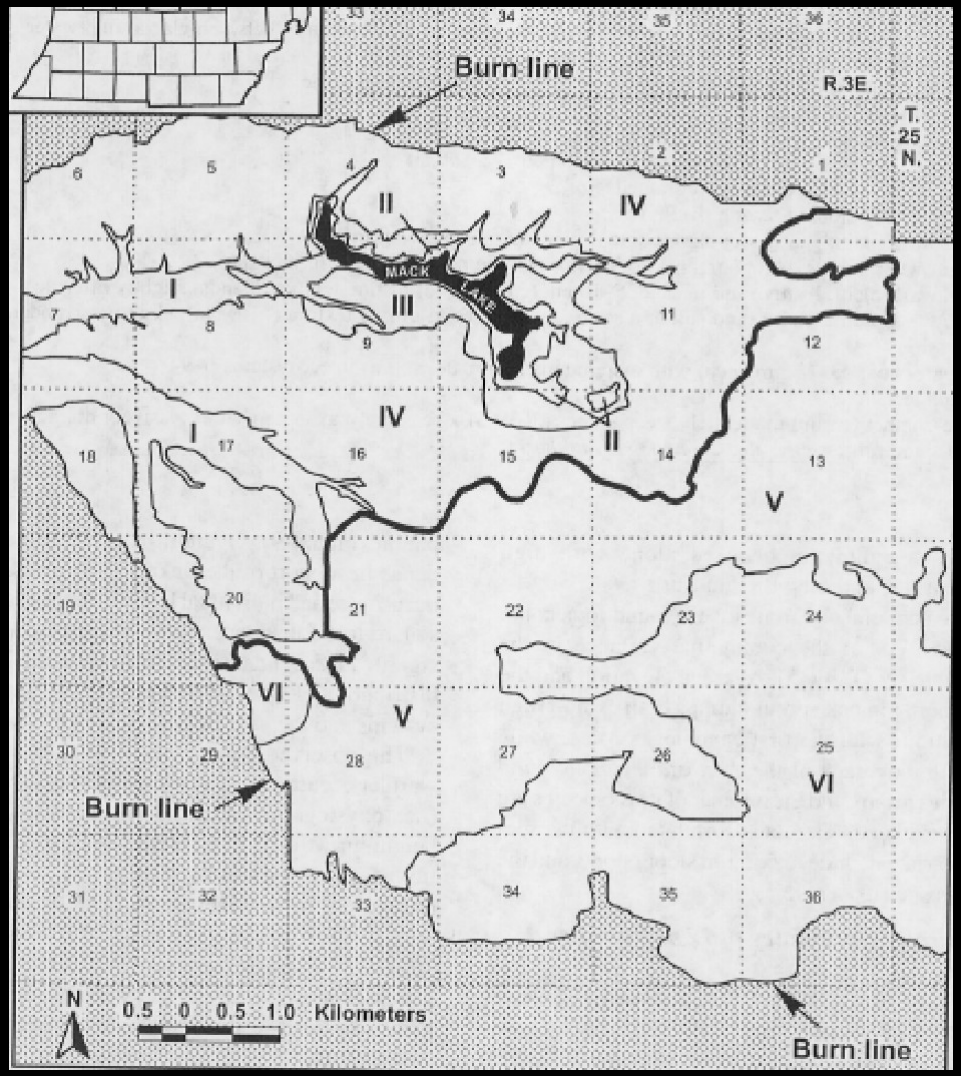
    Probst and Weinrich, 1993
- Management Actions
  - Nearly 80,000 ha
  - Plantations
  - Prescribed fire

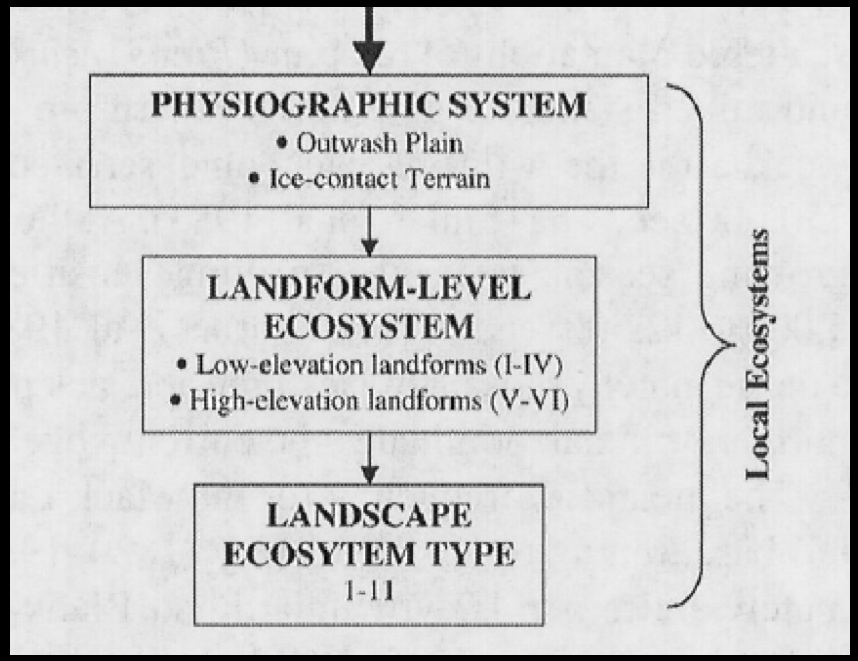
Mack Lake Burn

- May 5, 1980
- Escaped prescribed burn
- 24,000 acres (~9,700 ha)
- Consumed 270,000 tons of fuel
- 1 person killed, 44 buildings destroyed

Simard et al.1983

Landscape Ecosystems of Mack Lake Burn





Walker et al., 2003

Jack pine forests in Mack Lake

Dominant trees:

- jack pine
- northern pin oak

Also:

- red maple, quaking aspen, big-toothed aspen, red pine, white oak

Why study fuels?

- Ecological structure & function
  - Little known how fuels change with succession
- Fuel Management
  - Hazardous fuels reduction
  - Predicting wildfire behavior

Fuel Types

- Fine Woody Debris
  - 1-hr
  - 10-hr
  - 100-hr
- Coarse Woody Debris
  - 1000-hr

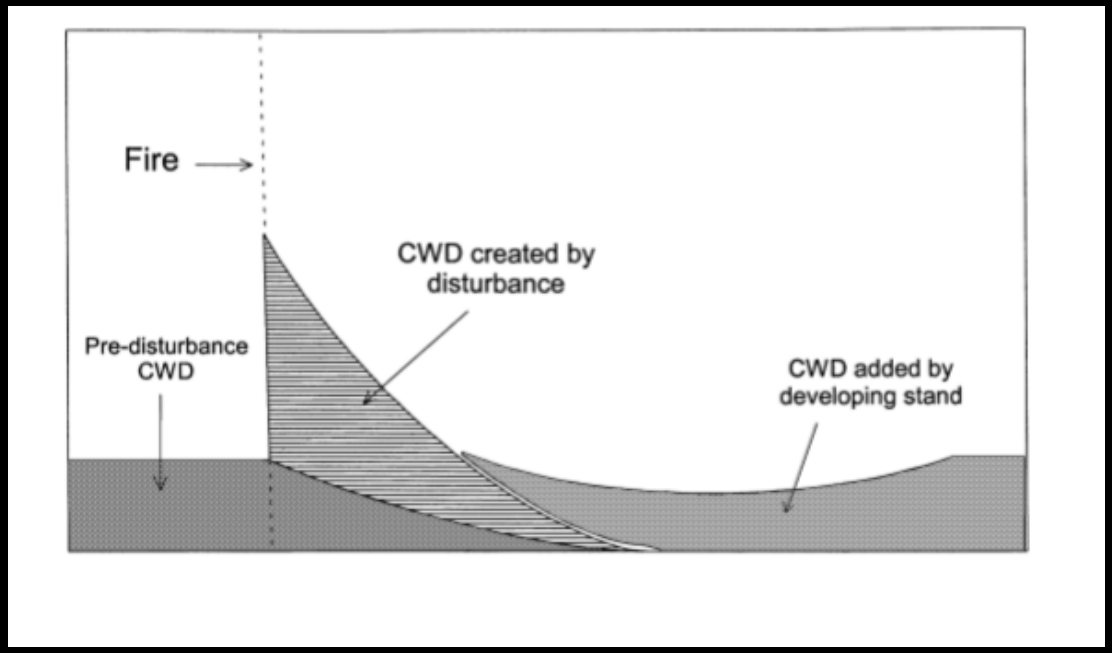
- Litter
- Duff
- Ground Vegetation
- Understory, Overstory Vegetation

Dead woody class			Piece diameter	Piece diameter
			inches	*cm*
DWD				
	FWD	1-hr	0–0.25	0–0.6
		10-hr	0.25–1.0	0.6–2.5
		100-hr	1.0–3.0	2.5–8.0
	CWD	1,000-hr and greater	3.0 and greater	8.0 and greater

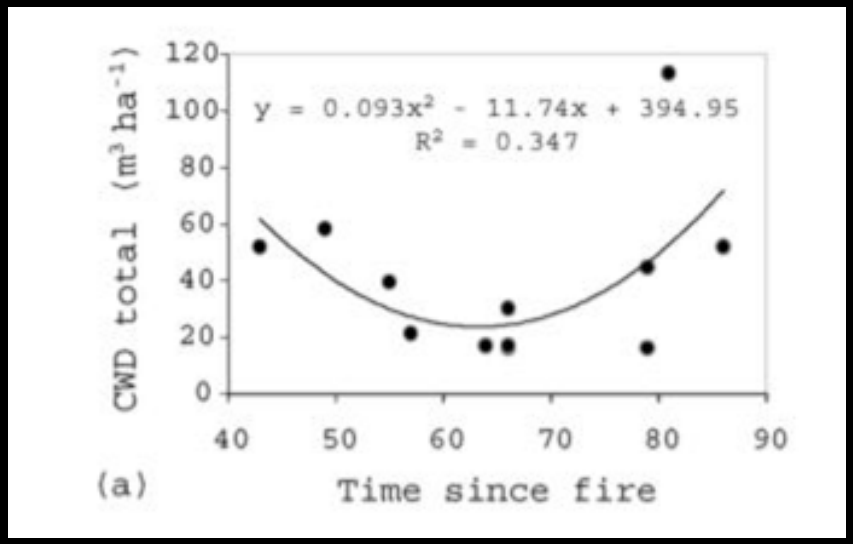
Importance of Coarse Woody Debris (CWD)

- Habitat for insects, bacteria, fungi, invertebrates
- “Nurse logs” for tree seedlings
- Source of carbon to forest floor
- Source of CWD for rivers

Tinker and Knight, 2004



Tinker and Knight, 2004



Brais et al, 2005

Importance of Litter and Duff

- Nutrient-rich
- Habitat for micro and mesofauna
  - Lutes and Keane, 2006
- Unburned, moist duff = layer of insulation
- Thick, dry duff = damage to mineral soil
  - Hartford and Frandsen, 1992

Fuels & Succession in Mack Lake Burn

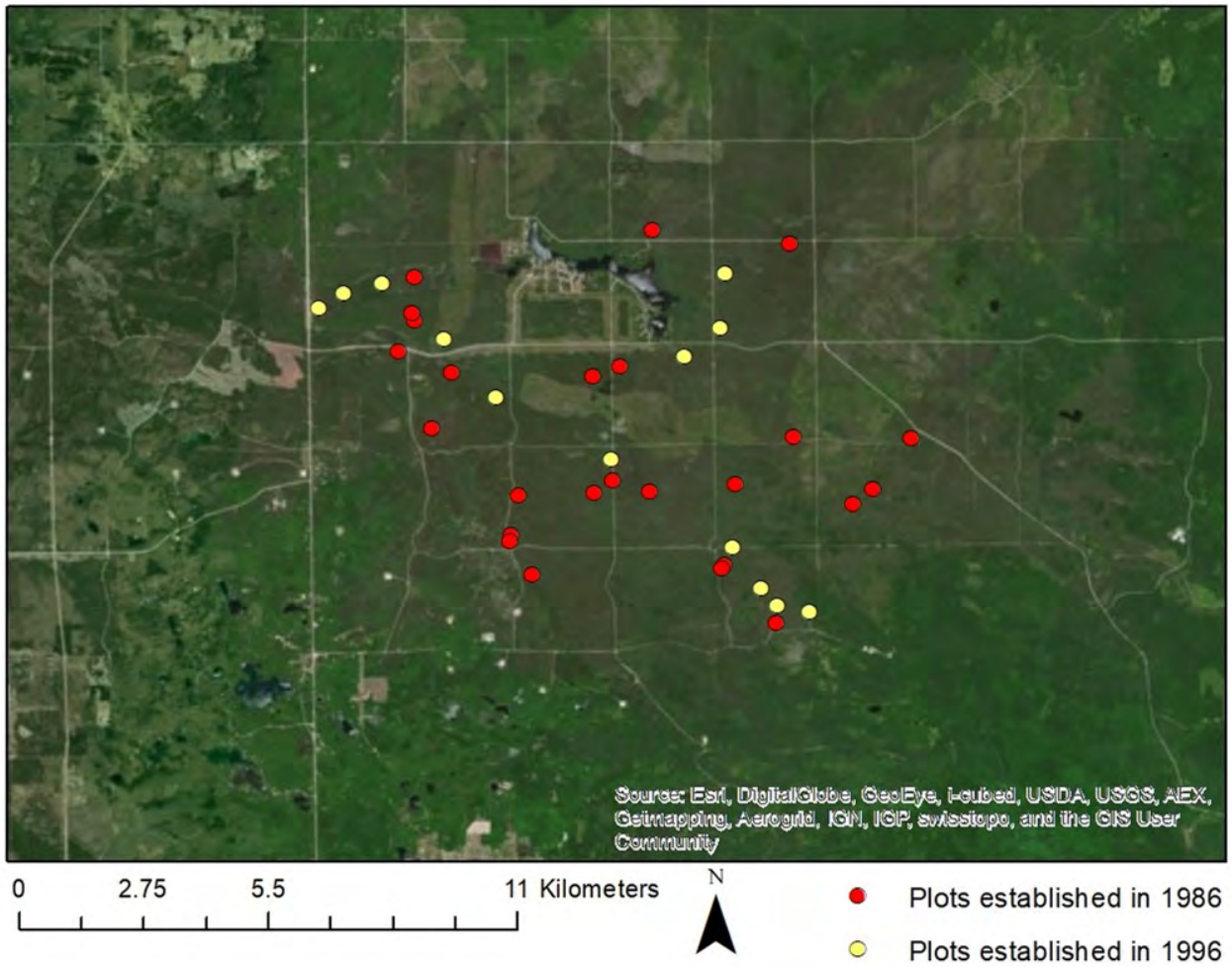
Question:

How will vegetation structure and fuels change throughout post-fire succession?

Hypotheses

- As the forest develops post-burn, we expect
  - More canopy coverage mid-succession
  - Decrease in jack pine density
  - Decrease in coarse woody debris
  - Thicker litter and duff layers

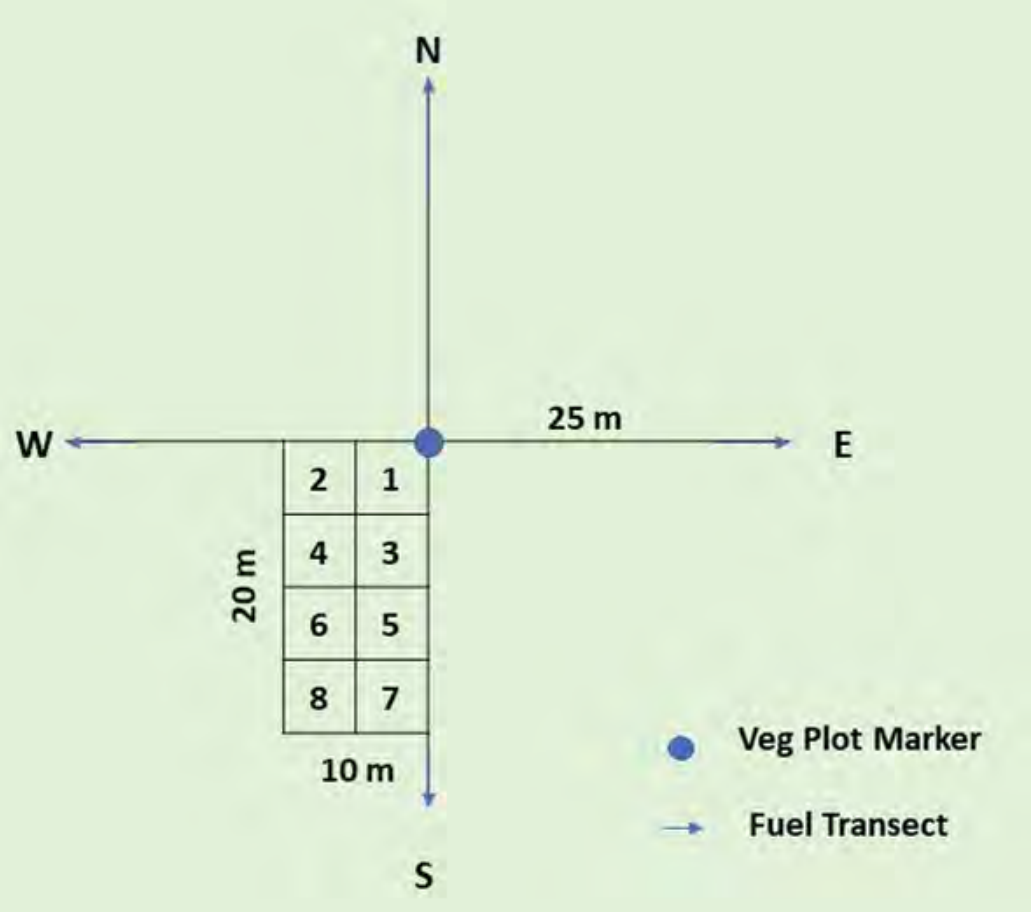
Sampling Sites



Data Collected

- Vegetation Plots:
  - Overstory & Understory Tree Density, DBH & species
  - Groundcover abundance
  - Stand height
- Fuel Transects
  - Modified FIREMON sampling method (Lutes & Keane, 2006)

Sampling Design

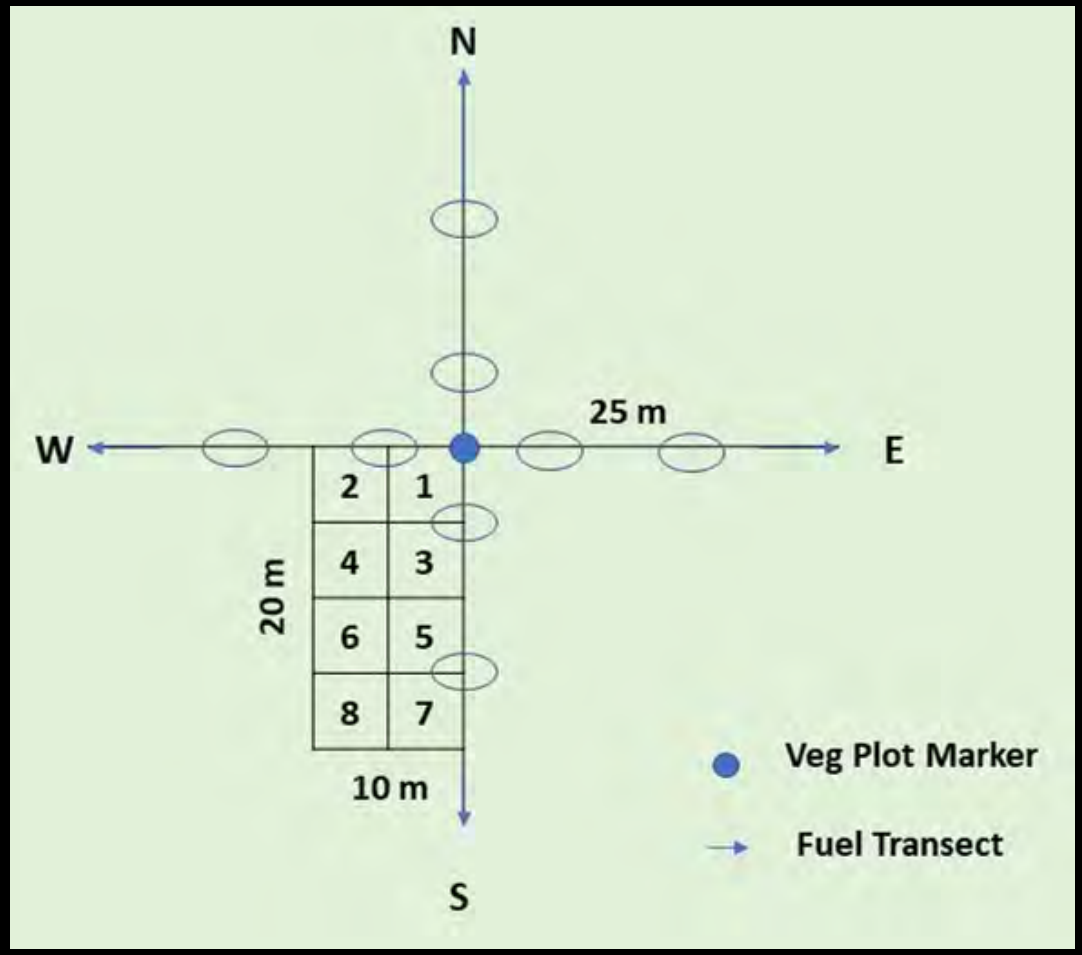


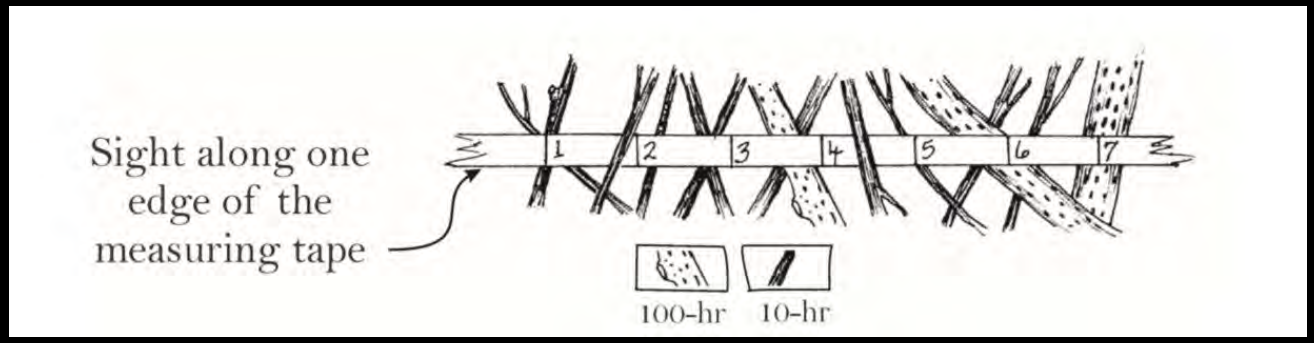
Fuel Data Collected

Along each transect:

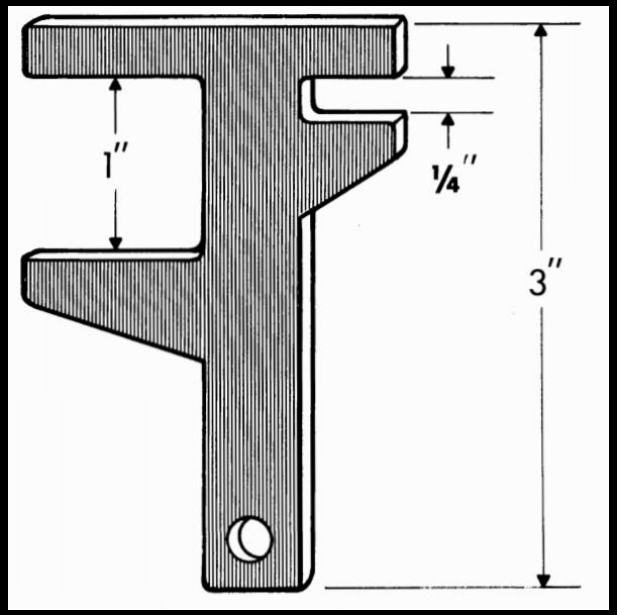
- Aspect & Slope
- 10 & 20 m marks
  - Litter, Duff
  - Ground vegetation
  - Tallest live trees

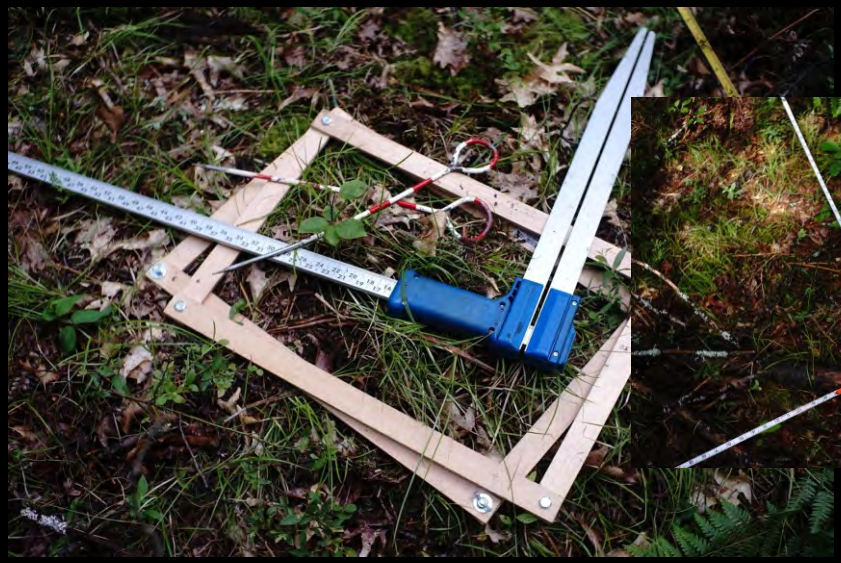
- Fine woody fuels
  - 1-hr
  - 10-hr
  - 100-hr
- Coarse woody fuels (1000-hr)
  - 5-25 m decay class & diameter

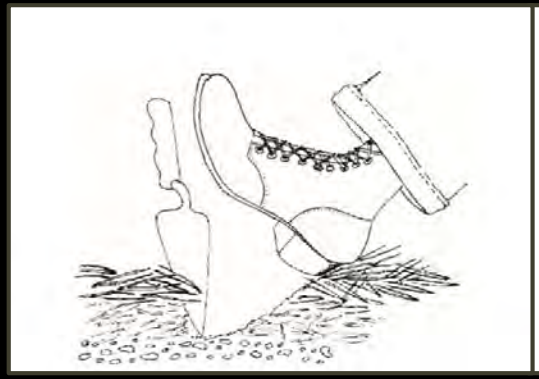

N
W
E
S
25 m
20 m
10 m
2
1
4
3
6
5
8
7
Veg Plot Marker
Fuel Transect

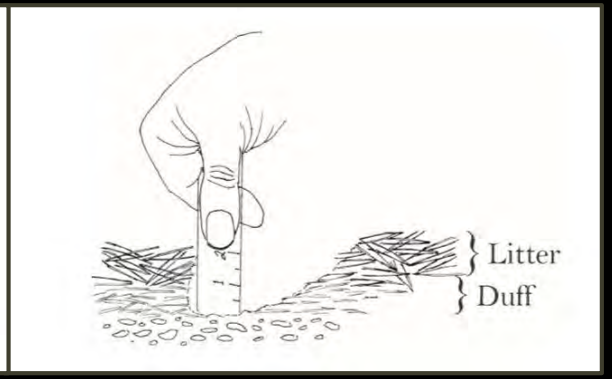

Sight along one edge of the measuring tape
1
2
3
4
5
6
7
100-hr
10-hr

Field Tools

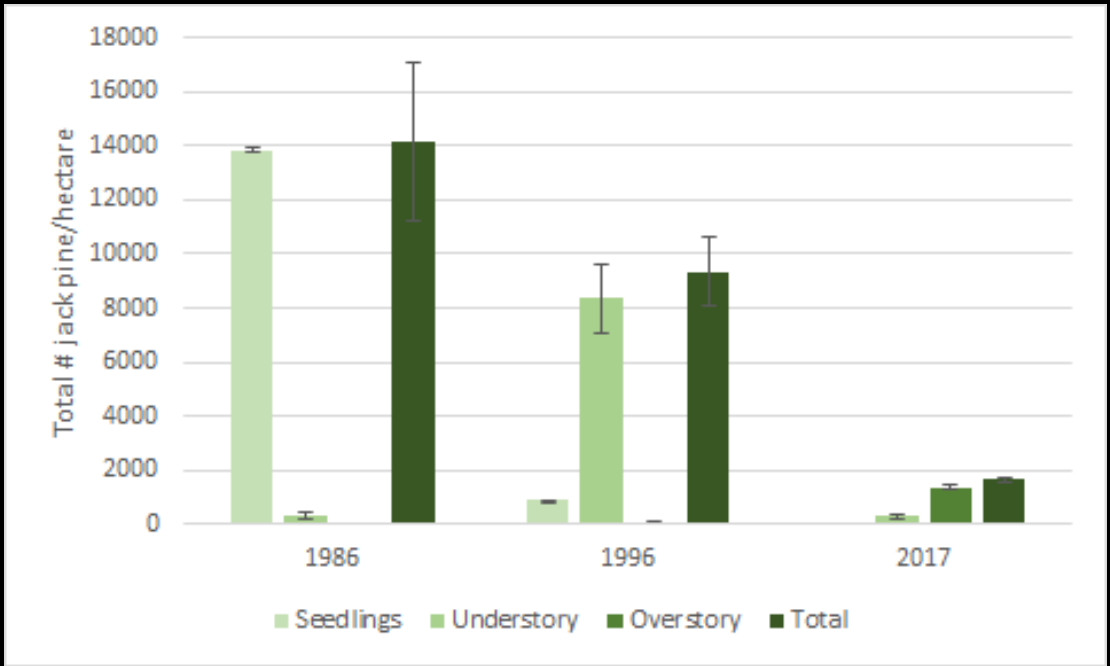




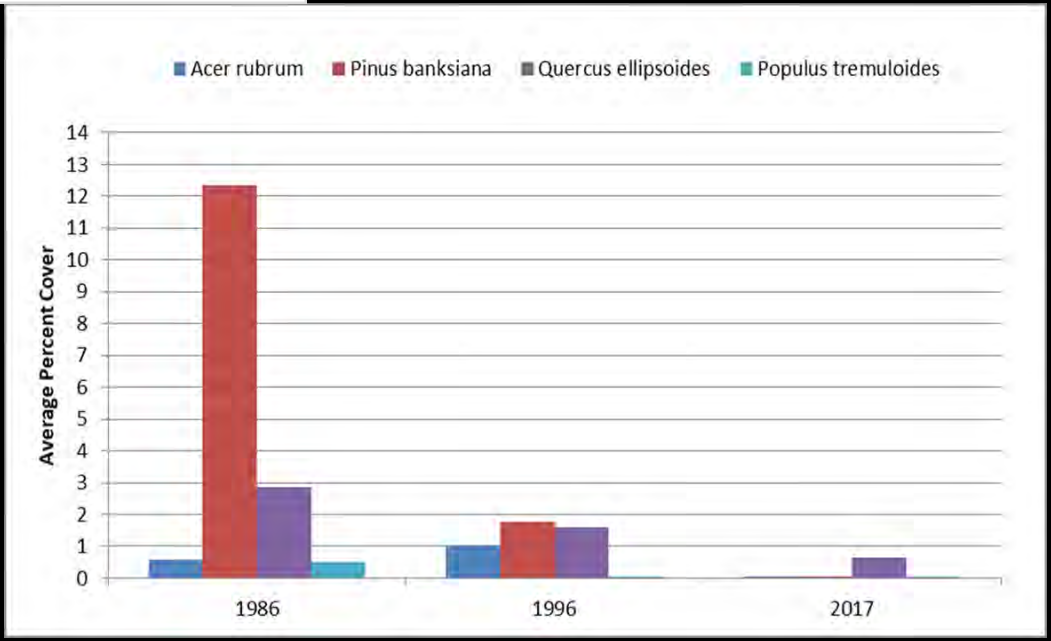




Forest Succession

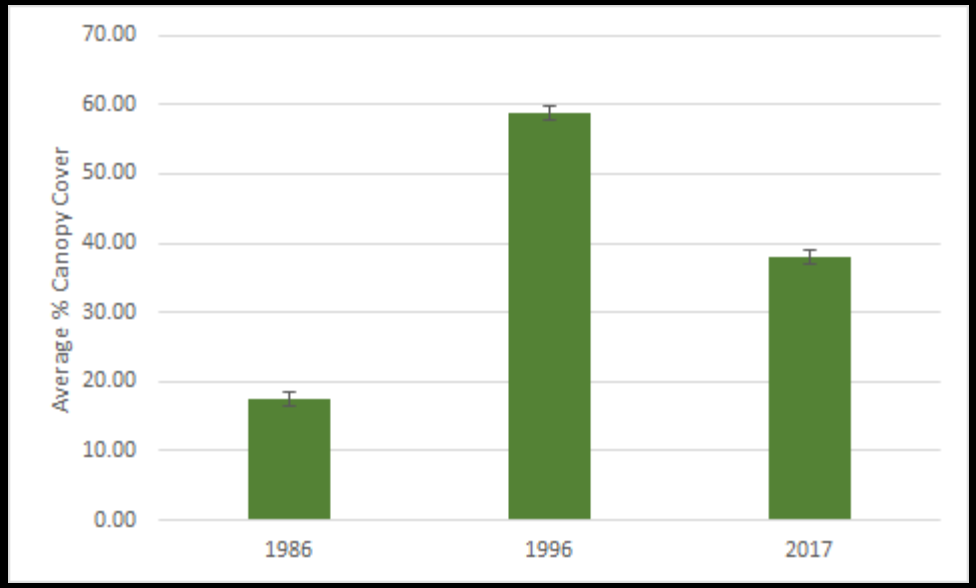


Changes in stand density of jack pine

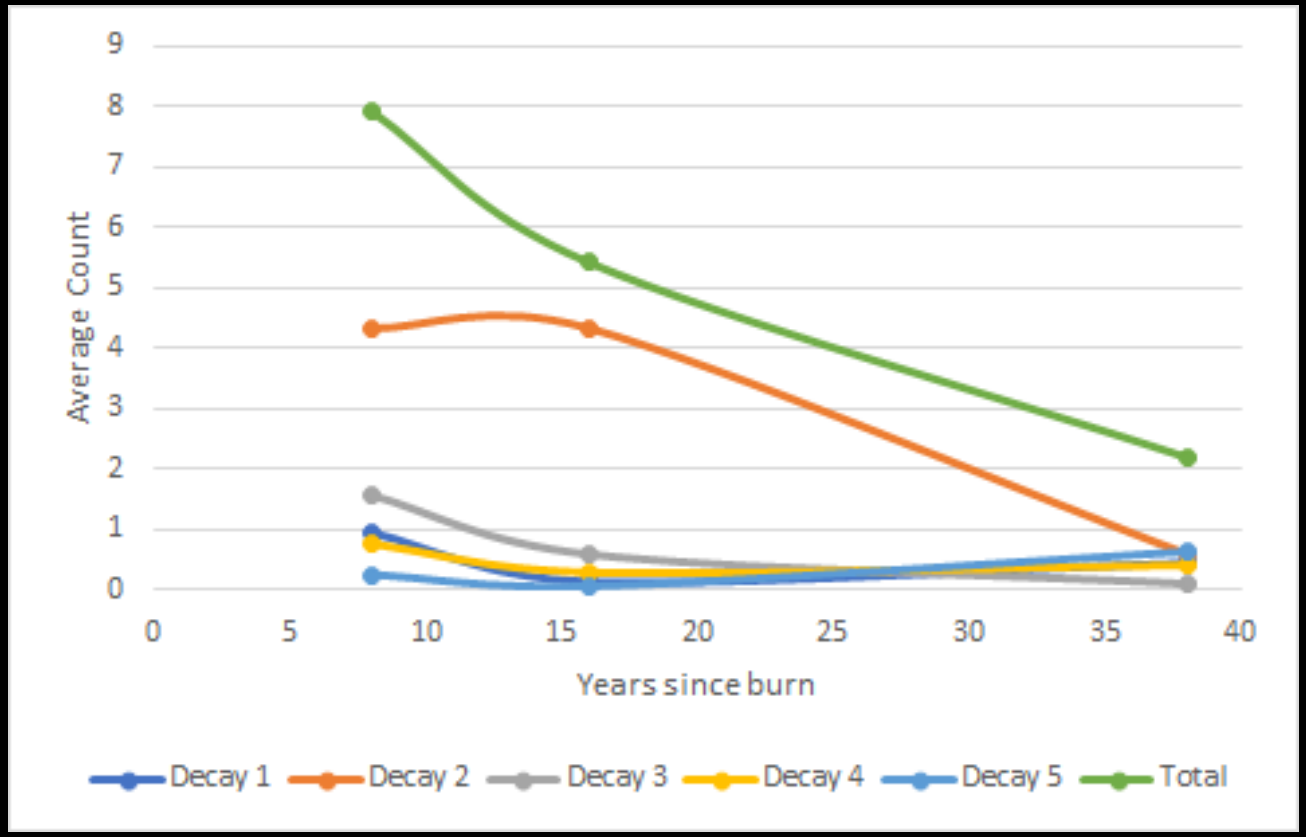


Changes in seedling density of common tree species over time

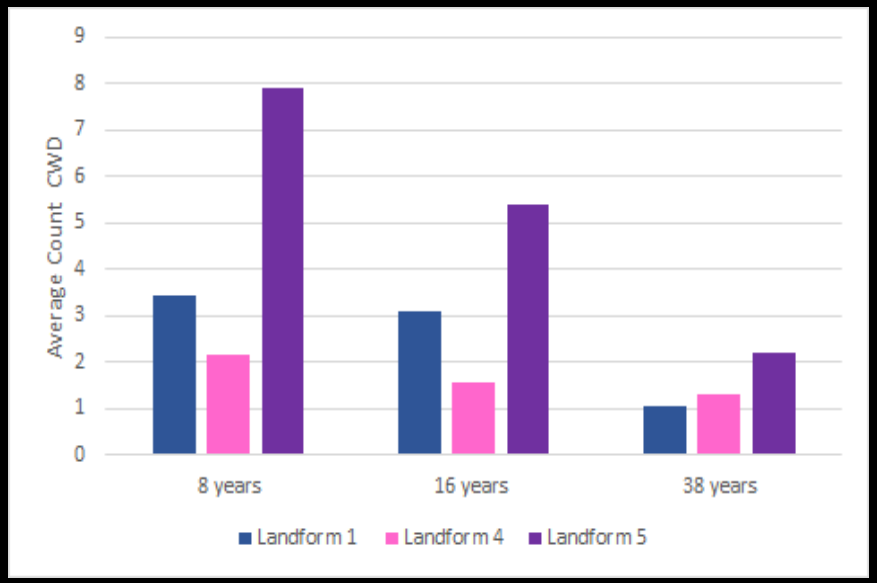
Canopy Cover

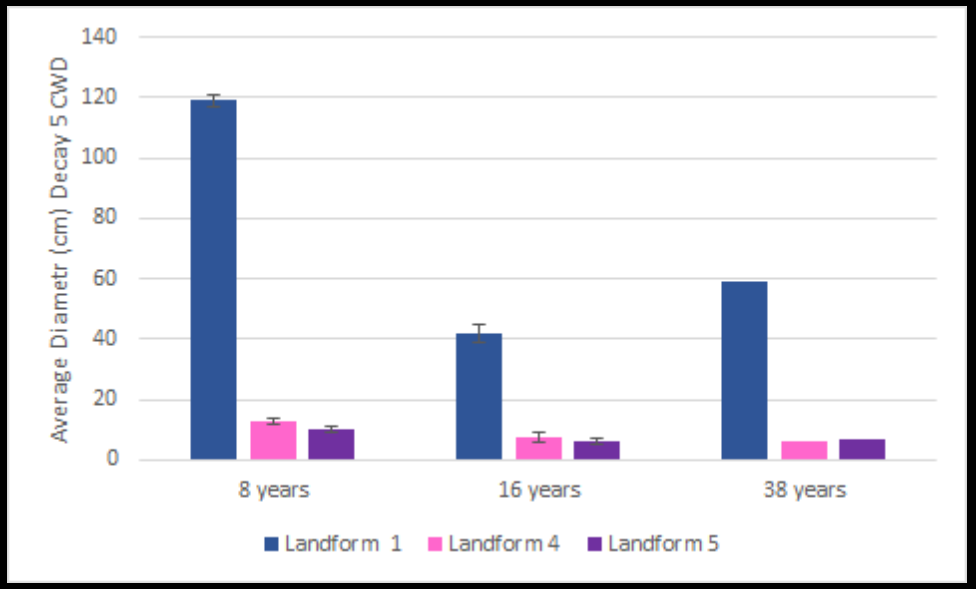


Coarse Woody Debris (CWD)



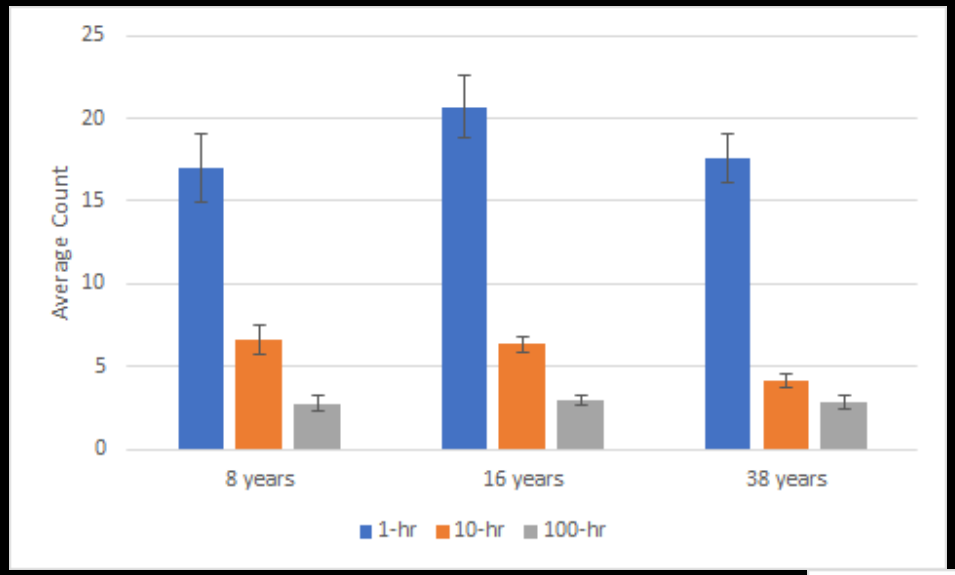
Landform Type and CWD

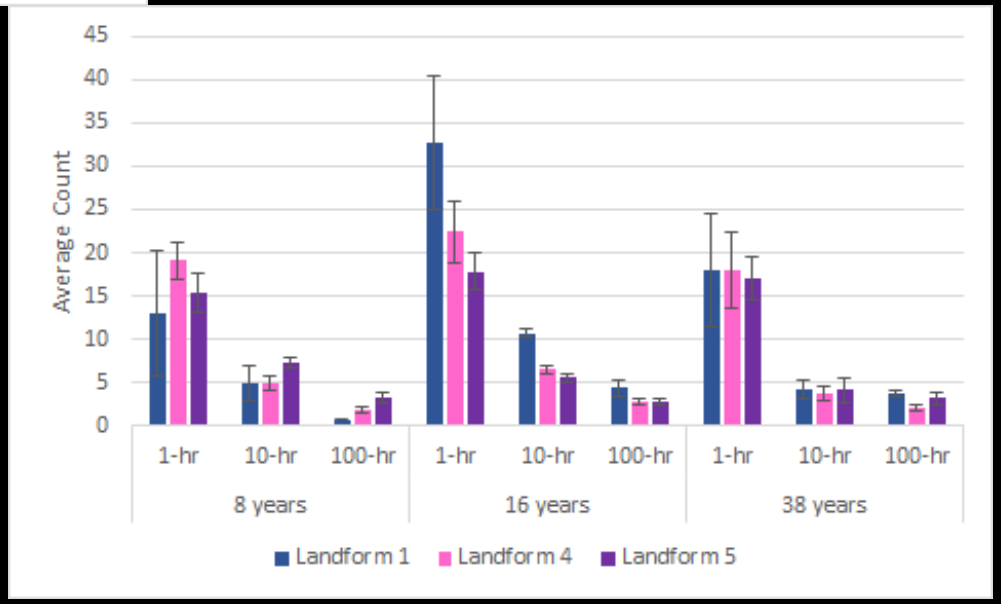




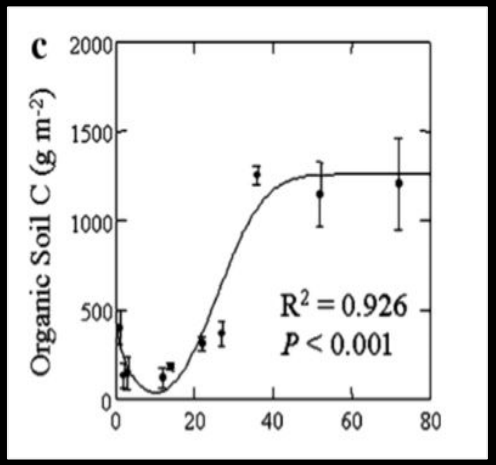
Landform	Description
1	Low elevation; glacial meltwater drainage channels; infertile. (**Very dry, nutrient-poor, very cold**)
4	Low elevation; pitted outwash plains; infertile.(**Very dry and nutrient-poor; cold**).
5	High elevation; outwash plains of varying fertility. (**Moisture and nutrients variable; warmer**).

Fine Woody Debris (FWD)

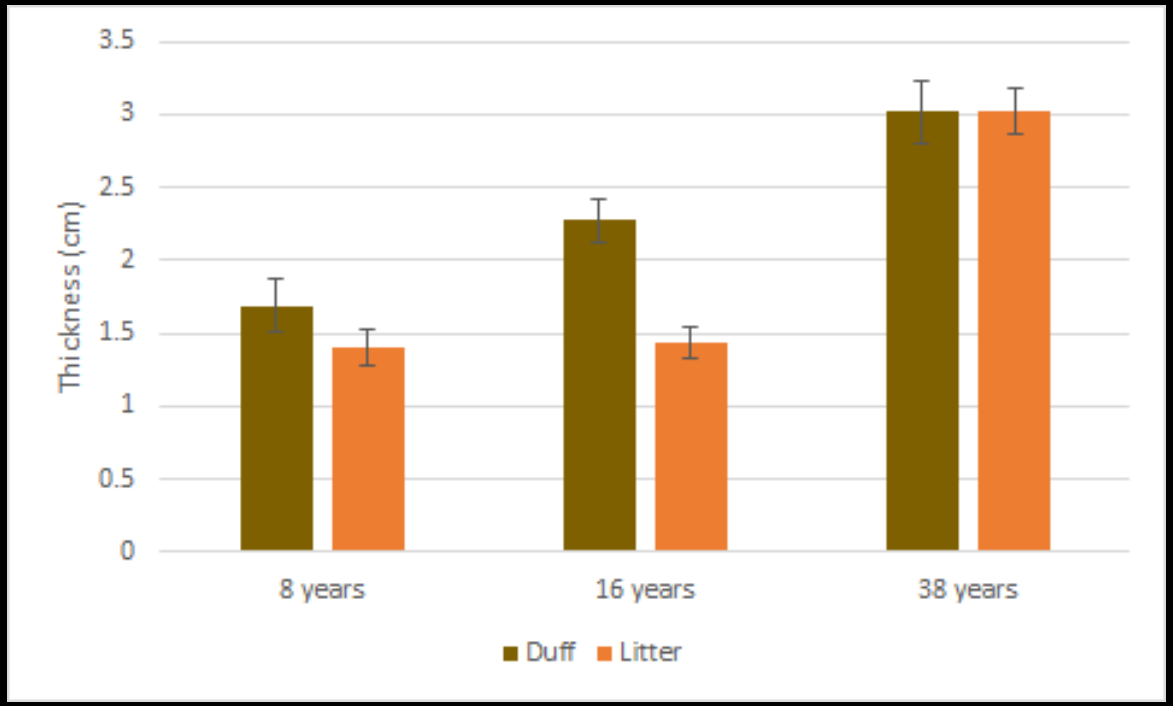




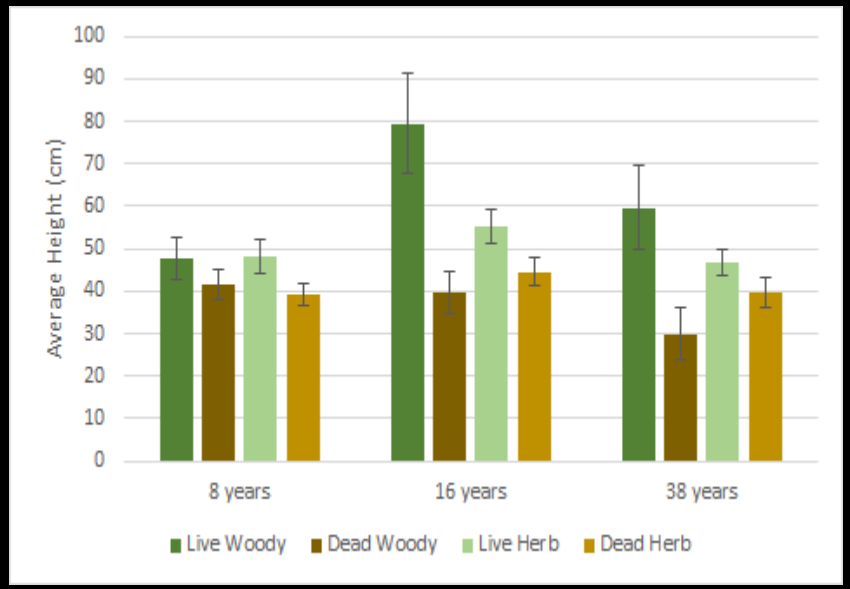
Litter and Duff

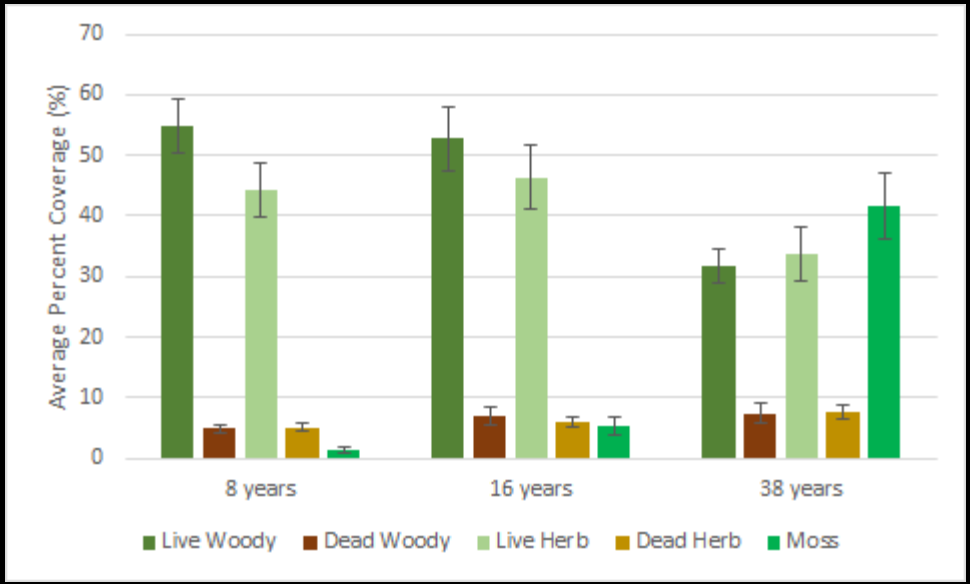


Yermakov and Rothstein, 2004



Height and Cover of Ground Vegetation



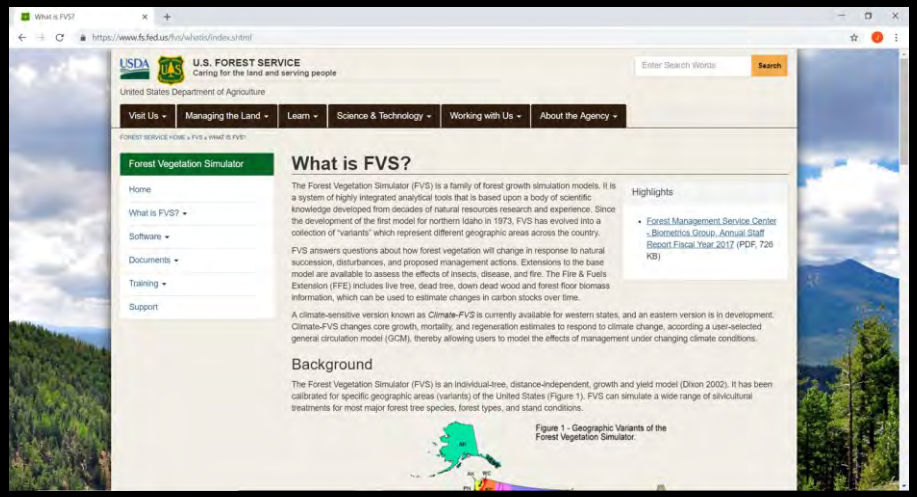


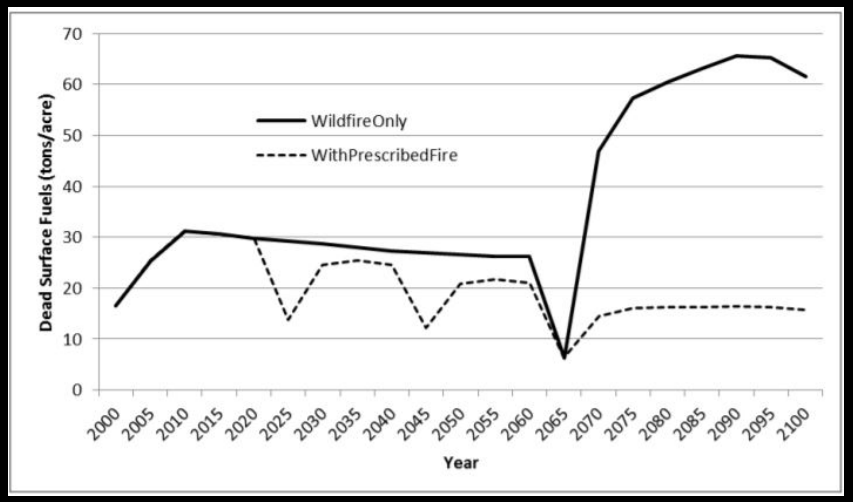
Summary of Mack Lake Fuels

- With time since fire,
  - **Overstory density** *increased*, while **understory density** *decreased*
  - **Overall density** of jack pine *decreased*
  - **Litter and duff** *increased*
  - **CWD** has *decreased*

Forest Vegetation Simulator (FVS)

- Models forest growth
  - due to natural succession, disturbance, or specific management action
- Free and available at https://www.fs.fed.us/fvs/software/complete.php
  - Lake States (LS) geographic variant
  - Fire and Fuels Extension (FFE)





US Forest Service

Comparison to pre-Mack Lake

Table 4b.—*Range of fuel loadings and consumption for jack pine stands (4- to 6-inch d.b.h., 400 to 1,200 trees/acre)*

	Before	After	Consumed
	----------*Tons/acre*----------		
Shrubs, herbaceous	0.0– 2.4	0.0– 0.2	0.0– 2.1
Litter	.2– 5.3	.0	.2– 5.3
Duff	4.2–18.0	1.4–11.7	.8– 7.8
Wood[1]	4.4– 5.0	[4]1.6– 5.3	.0– 2.8
Foliage[2]	1.0– 3.8	.0– 3.8	.0– 3.8
Measured range[3]	11.0–27.2	4.5–16.6	.0–19.1

[1]Average for all species (12 samples).
[2]Based on Brown's (1965) equation (not including branchwood).
[3]Range of individual plots—not the range columns.
[4]The highest woody fuel loading was measured on a burned plot.

Simard et al, 1983

Future Research

- Comparing across ecosystems
  - Effects of soils, landform, elevation, slope, aspect
- Modeling 1986 fuel data in FVS
  - Were fire effects as predicted since fire?
- Modeling future fire behavior

Relationship to slope

Variability in Stand Structure

Can jack pine barrens mediate wildfires under various climate scenarios?

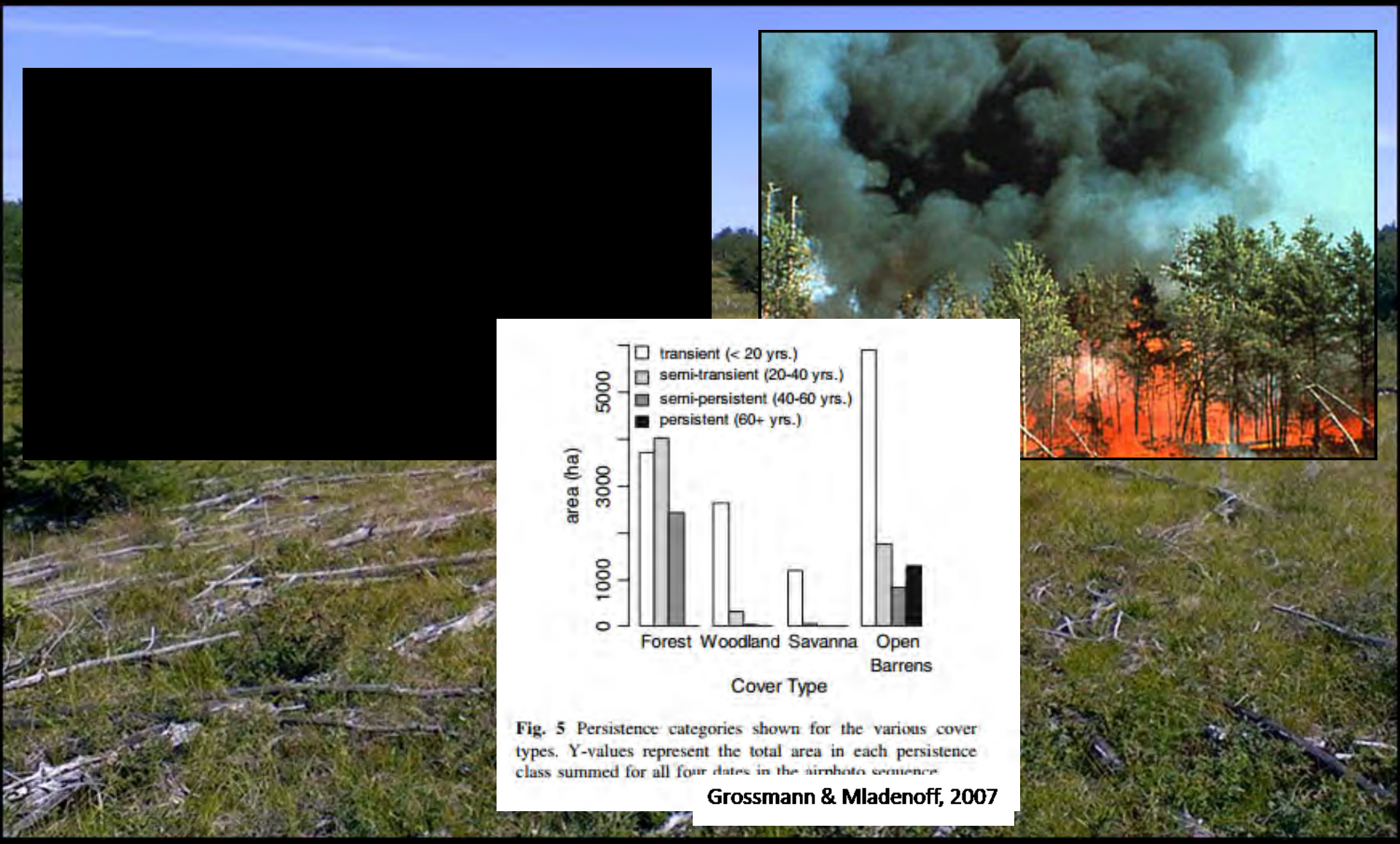


Fig. 5 Persistence categories shown for the various cover types. Y-values represent the total area in each persistence class summed for all four dates in the airphoto sequence

Grossmann & Mladenoff, 2007

Questions and hypotheses

- Q_1: How is jack pine barrens distribution affected by wildfire severity?

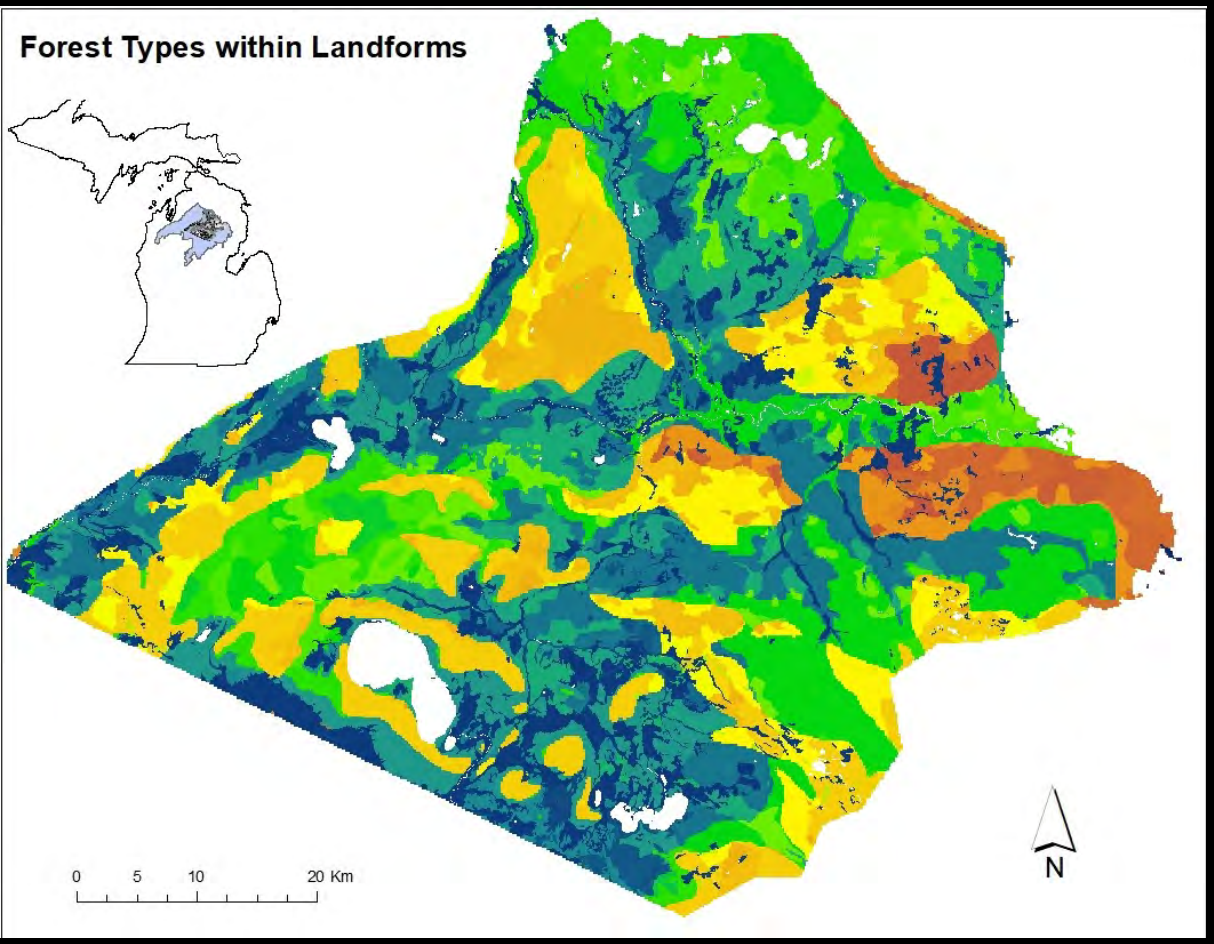
  H_1: Higher severity fires will yield more, larger barrens

- Q_2: How might climate change affect fire severity?

  H_2: Fire severity will increase, and more severe climate scenarios will have greater effects

- Q_3: How might climate change affect the distribution of pine barrens in the region?

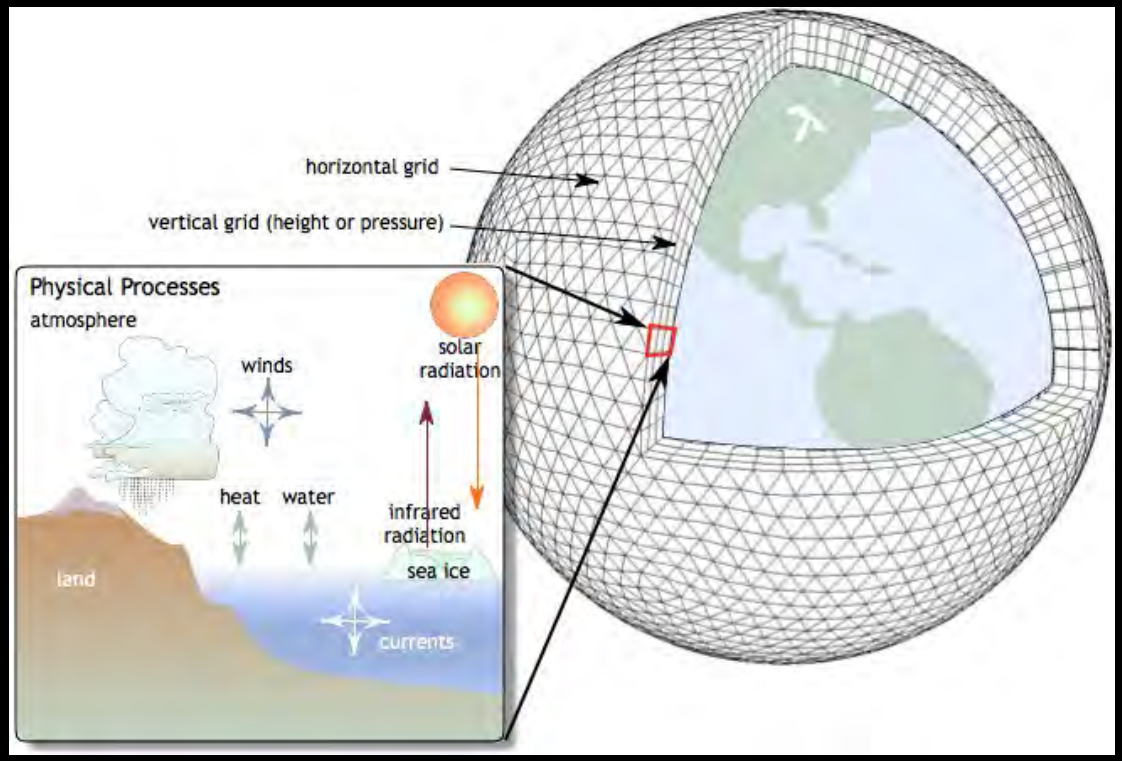
  H_3: Climate change will increase the coverage of barrens, and more severe climate scenarios will have greater effects



LANDIS-II: model fires and resulting cover types to investigate effects of climate change on barrens coverage

Climate Scenarios

- Historical: interpolated data ca. 1900
- Current: averaged 2007-2017
- Future: GCMs projected to 2099
  - CanESM2 - Canadian Centre for Climate Modeling and Analysis
  - CCSM 4.0 - National Center of Atmospheric Research, USA



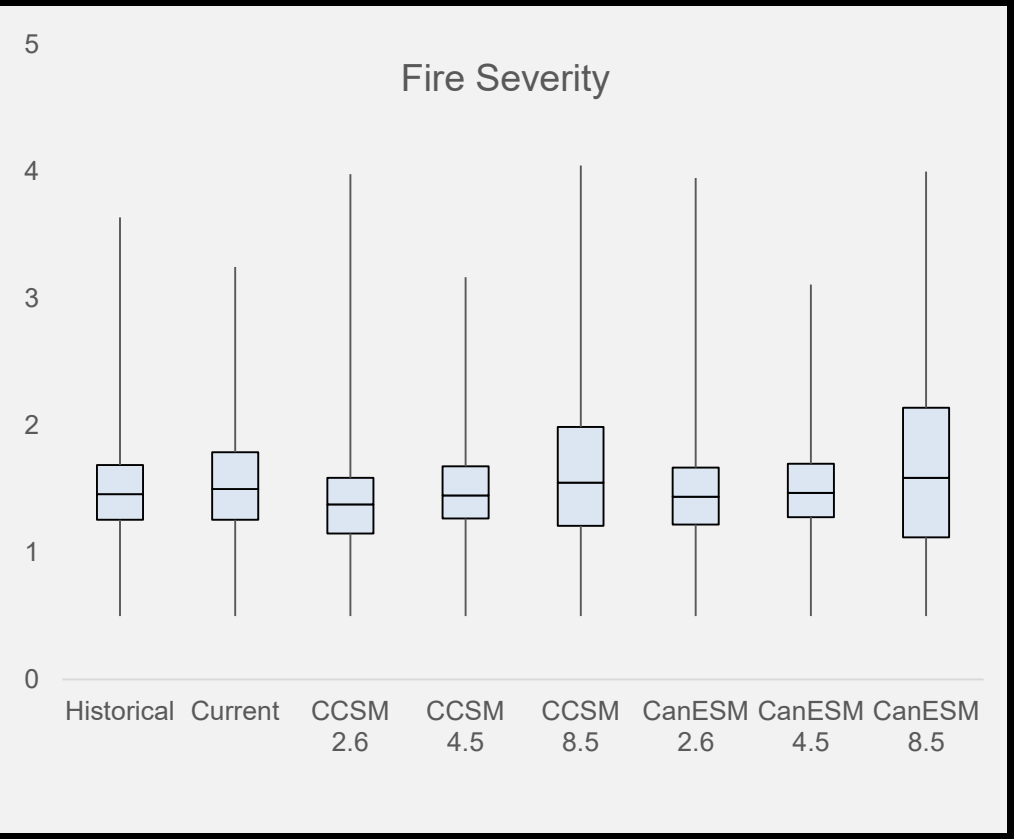
http://kiwi.atmos.colostate.edu/cmmap/learn/modeling/whatIs2.html

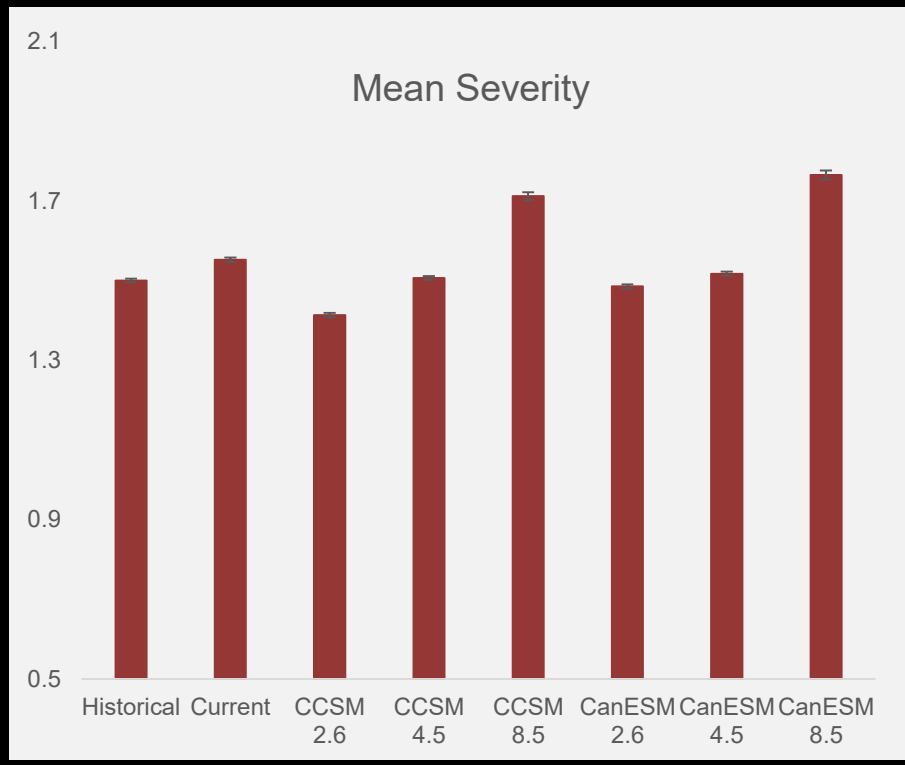
Representative Concentration Pathways

- RCP 2.6 –CO_2 mitigation scenario
- RCP 4.5 – reduced emissions scenario
- RCP 8.5 – business as usual, fossil fuel intensive

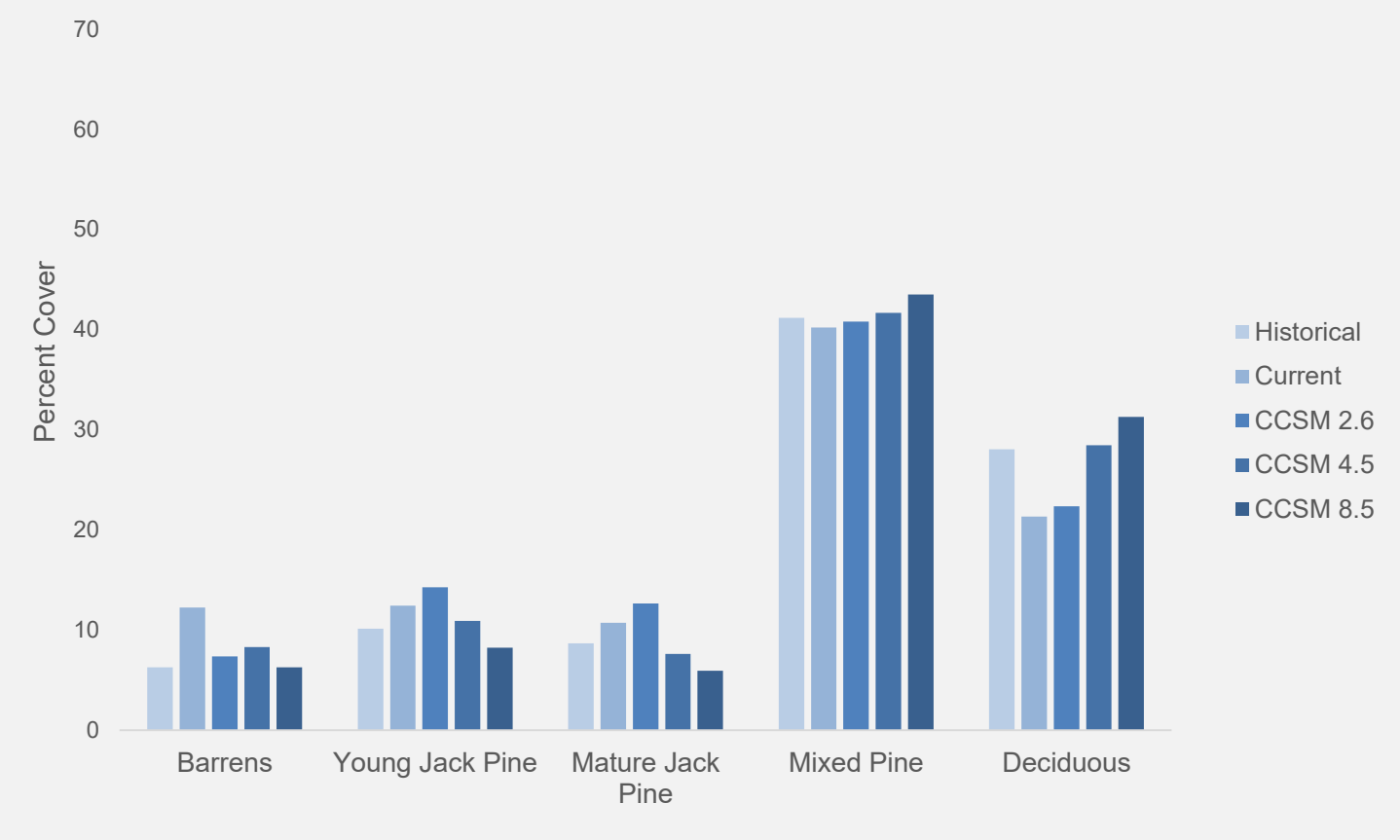
Scenario	Minimum Temperature (C)	Maximum Temperature (C)	Monthly Precipitation (cm)
Historical	-0.5	11.8	6.6
Current	0.3	12.8	5.7
CanESM2 – rcp2.6	3.7	15.0	7.7
CanESM2 – rcp4.5	3.5	15.6	7.4
CanESM2 – rcp8.5	5.9	18.6	8.5
CCSM4 – rcp2.6	1.5	14.0	5.9
CCSM4 – rcp4.5	2.2	15.3	6.7
CCSM4 – rcp8.5	5.5	19.0	6.7

Climate Effects: Fire Severity

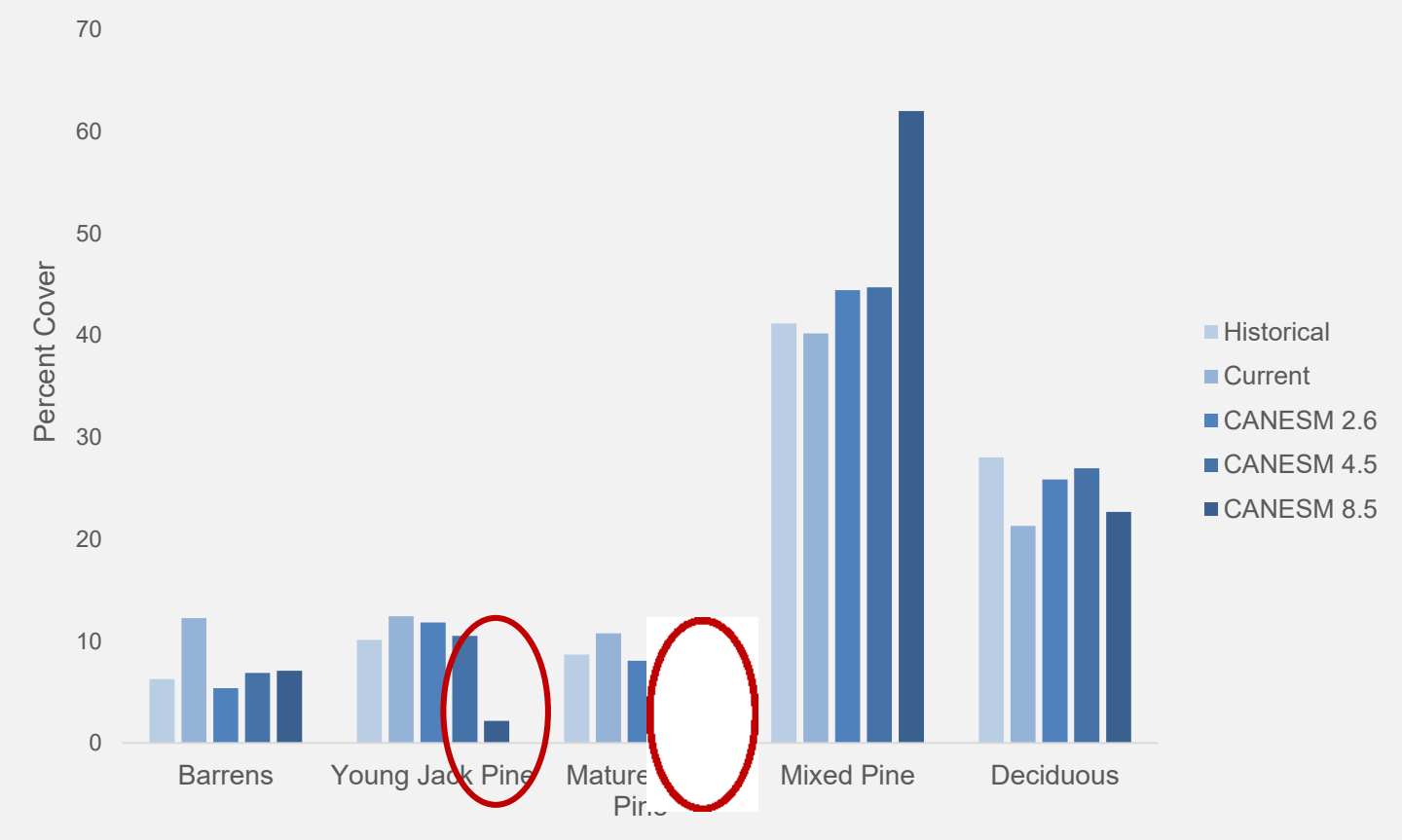




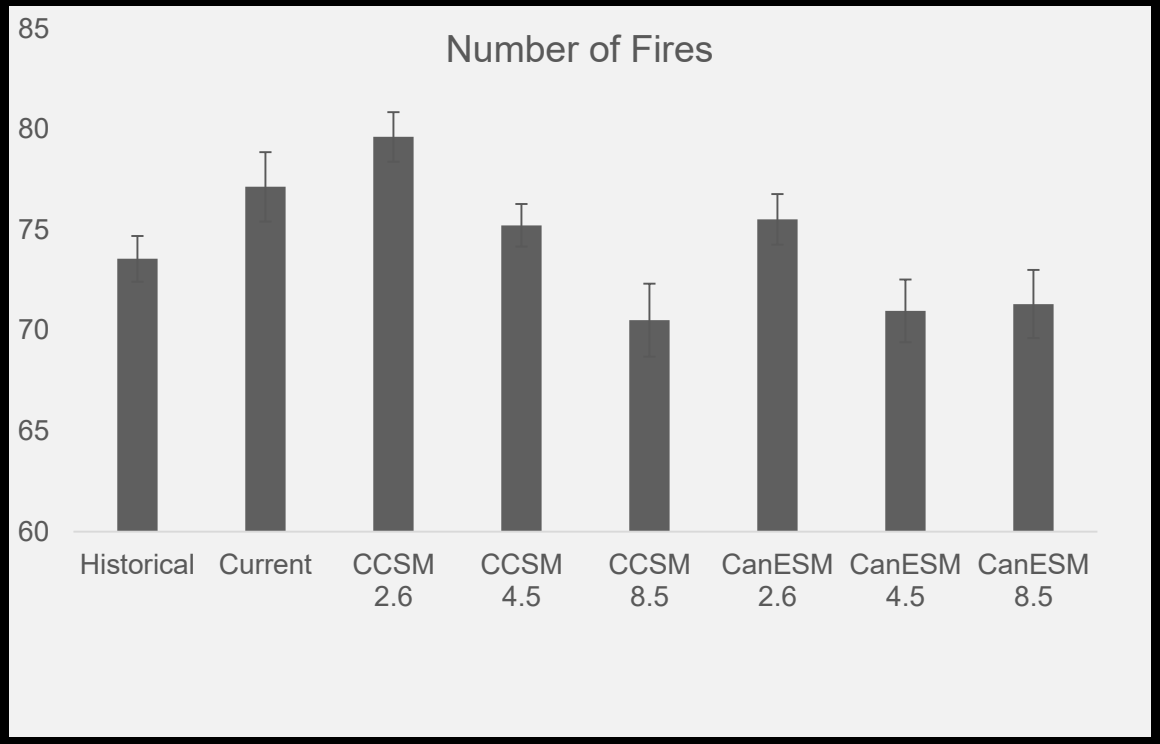
Climate Effects: Cover Type CCSM Model



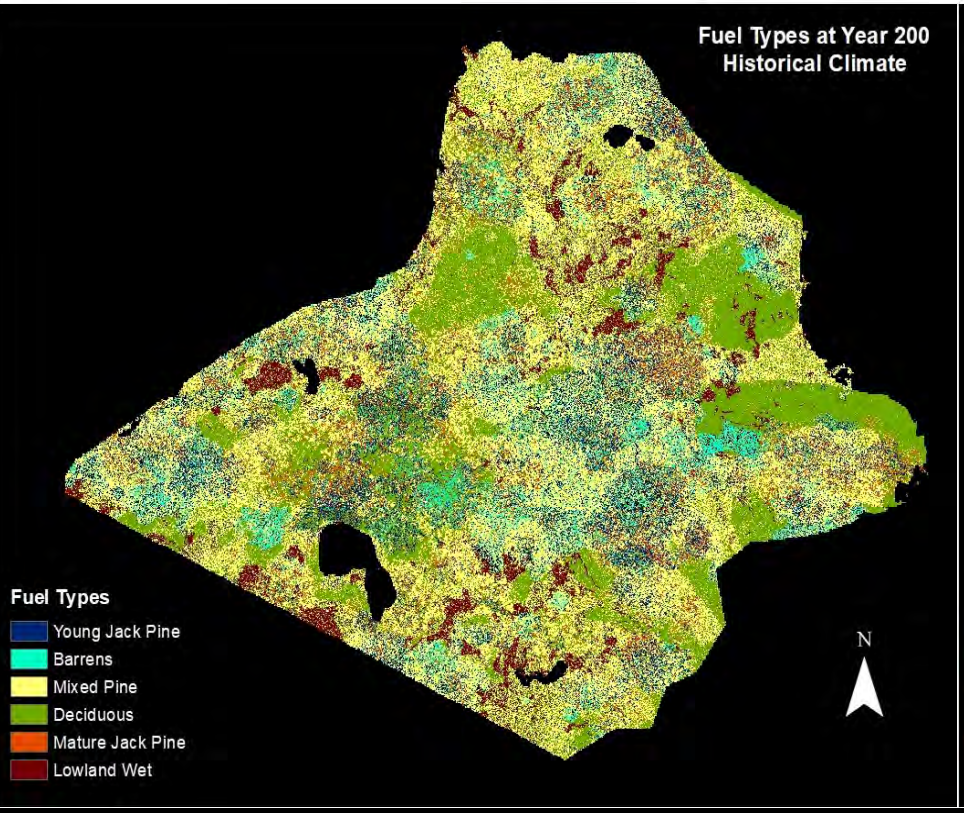
Climate Effects: Cover Type CanESM Model

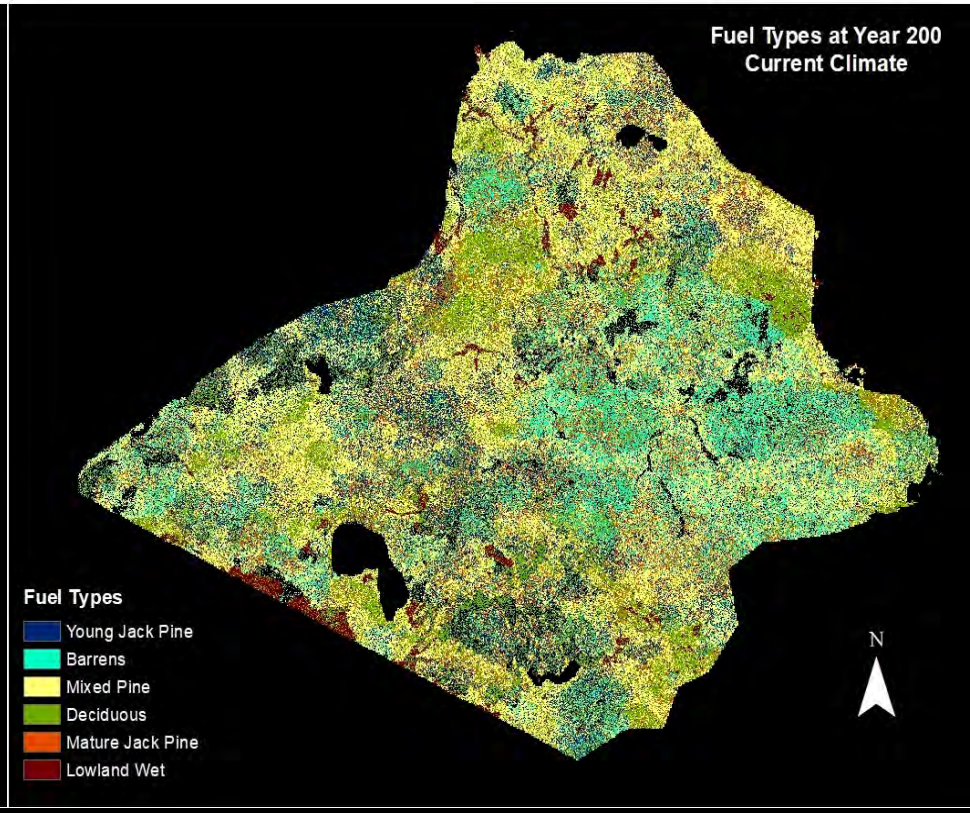


Climate Effects: Fire Regime

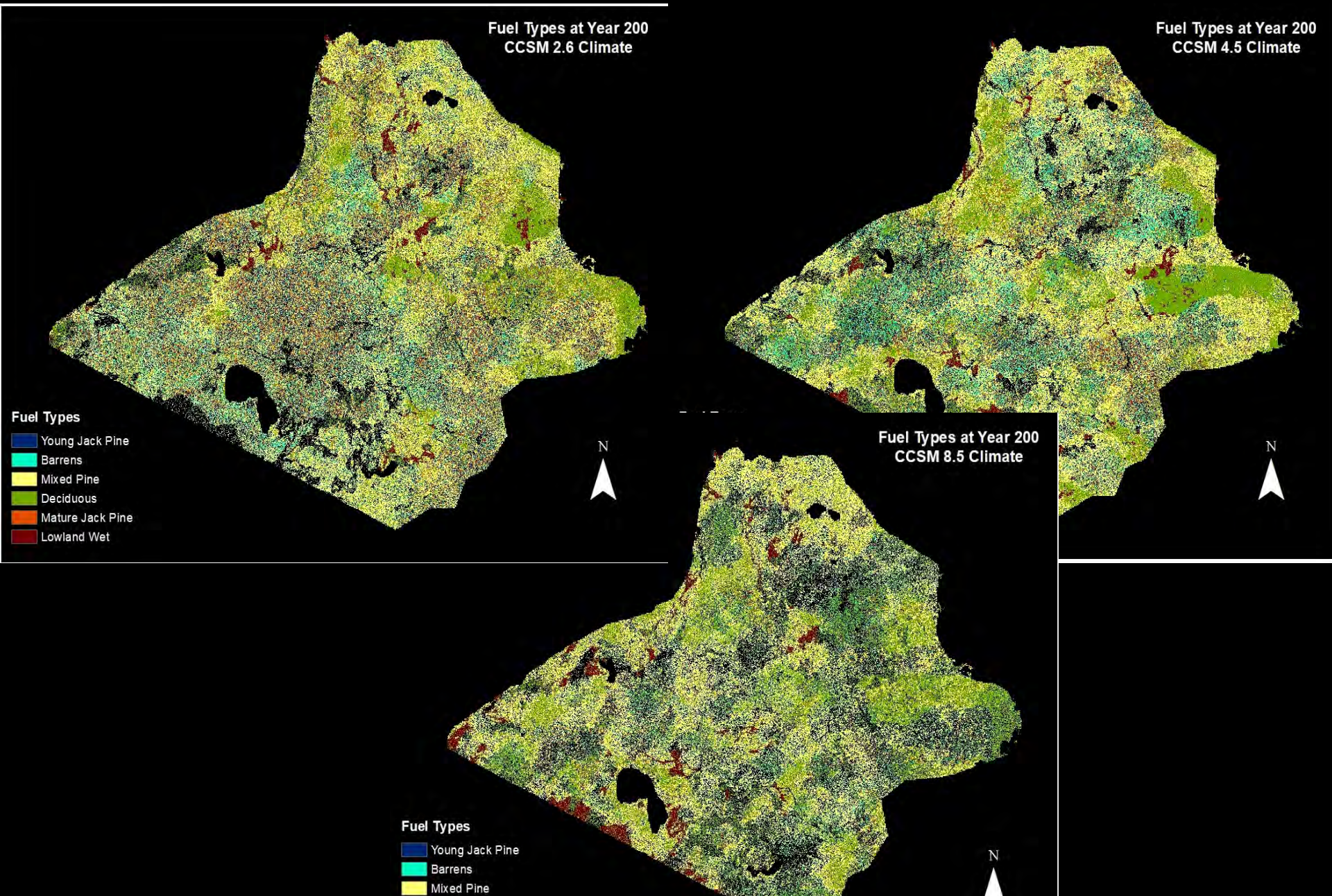


Climate Effects: Barrens Distribution

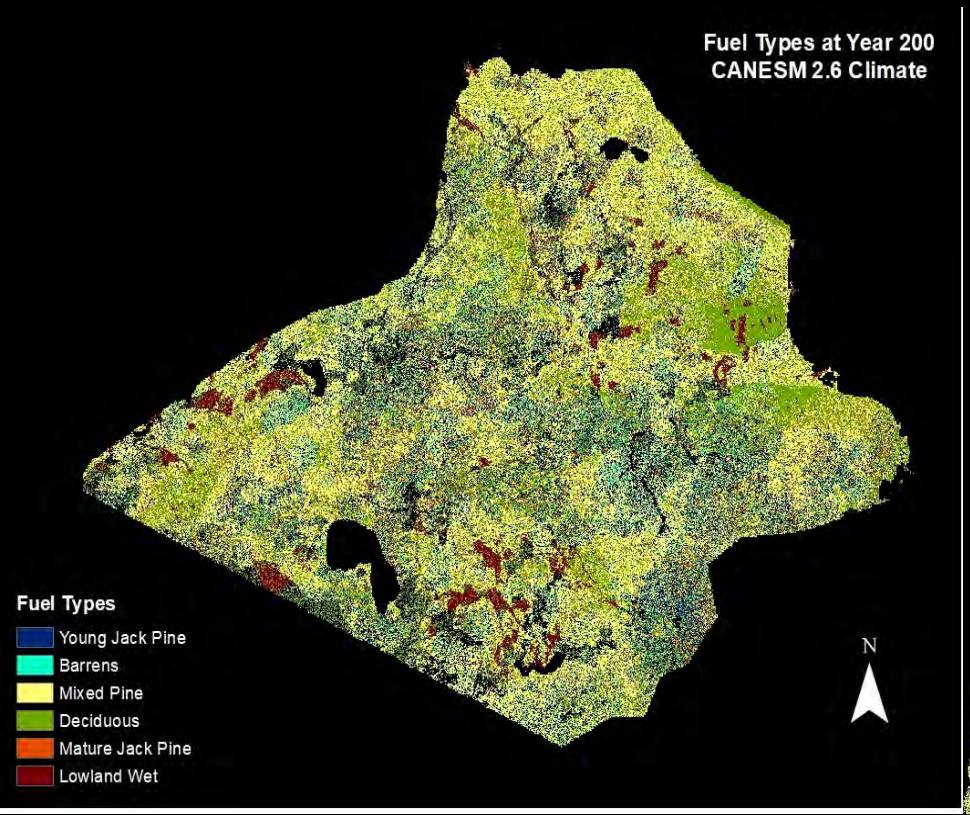


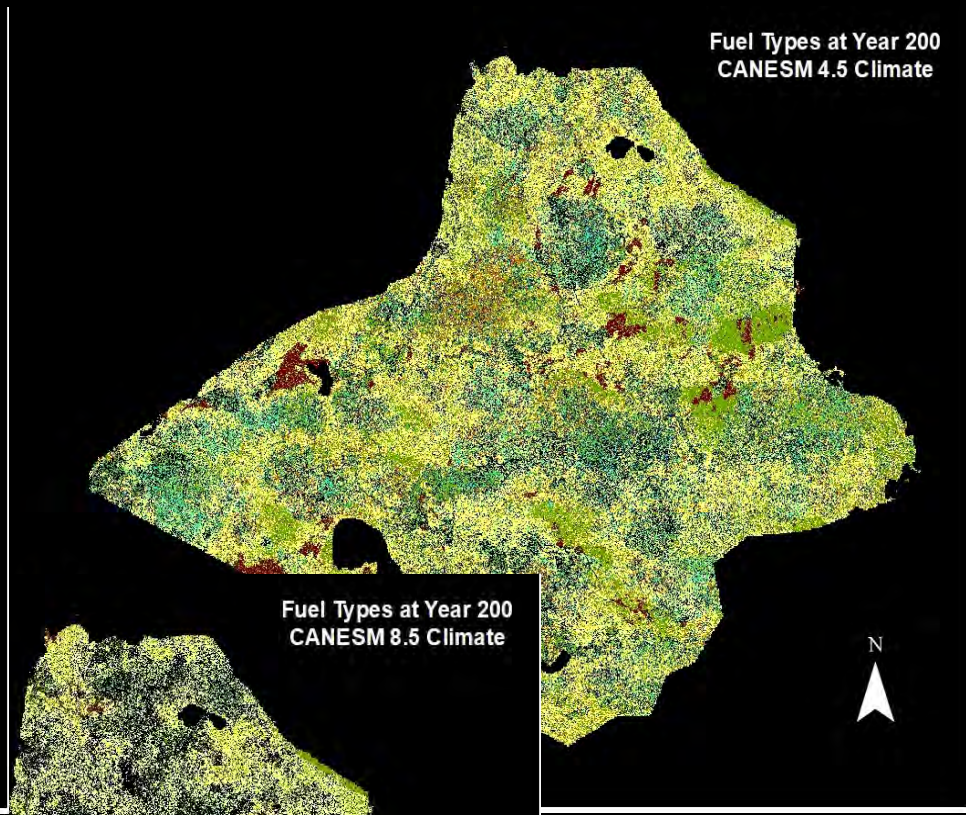


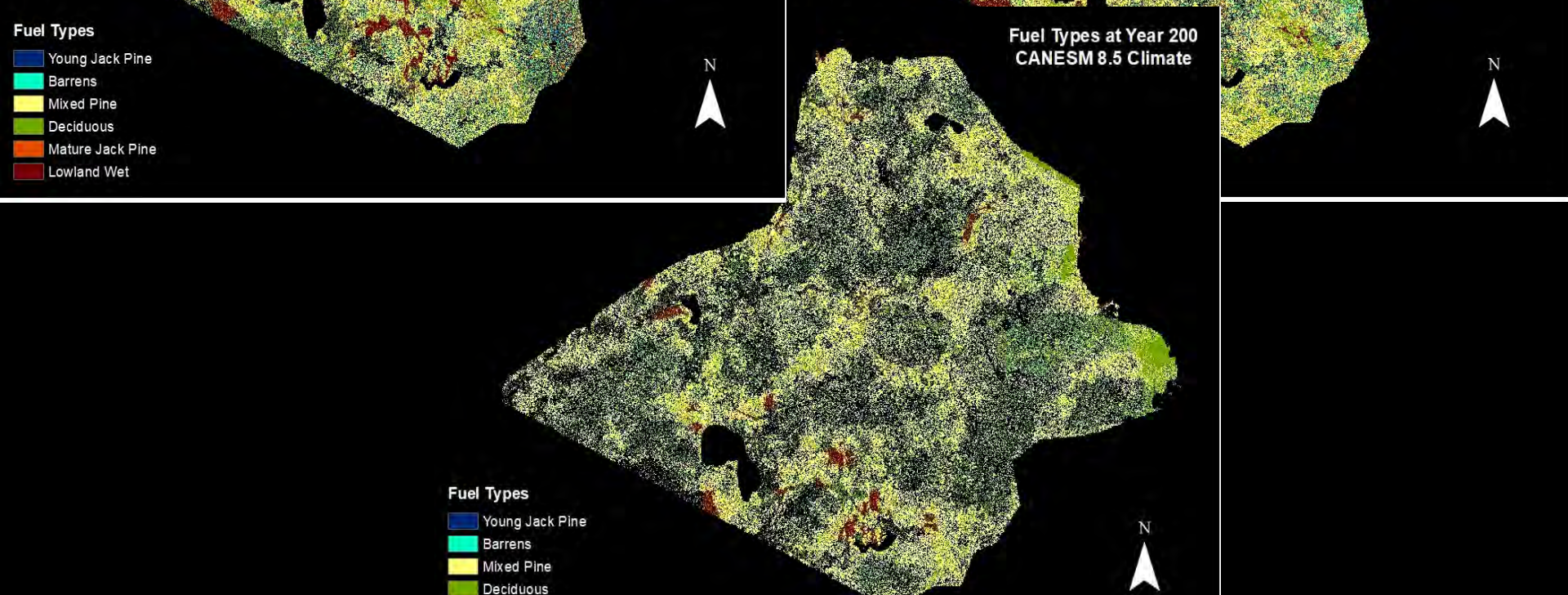
Climate Effects: Barrens Distribution



Climate Effects: Barrens Distribution







- Climate change may cause unpredictable changes in the region
- Severe fires may increase, but barrens may not necessarily

Management Implications

- Barrens are similar in structure to fuel breaks, but may be reduced due to climate change
- Including barrens in management practices may become even more important

Conclusions

- May be difficult to predict future outcomes using historical references
  - Novel conditions imposed by climate change
  - Interactions may be especially difficult to predict
- Highlights importance of long-term, field-based studies

THANK YOU

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