Climate Change and Forests in the Northeast Landscape

28 February 2013

Overview

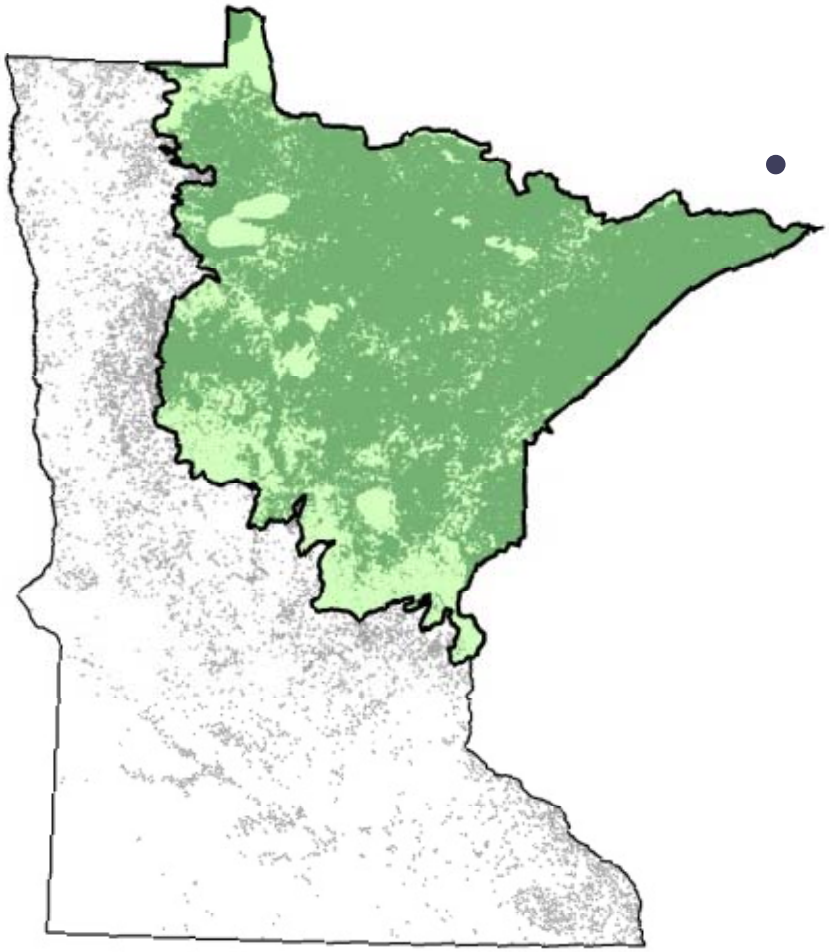
- Northwoods Climate Change Response Framework
- Tree species vulnerability assessments
  - Emissions scenarios, GCMs, and downscaling
  - Projected changes in climate
  - Modeling impacts to tree species
  - Tree Atlas results
- Impacts to Native Plant Communities

Northwoods Climate Change Response Framework

A collaborative approach among scientists, managers, and landowners to incorporate climate change considerations into forest management

Stephen Handler and Chris Swanston
Northern Institute on Applied Climate Sciences
Northern Research Station, US Forest Service

Northwoods CCRF



Objectives:

- **Assess the vulnerability of forests in Province 212 to climate change**
- **Provide advice to forest managers on maintaining forests and the ecosystem services they provide**

Northwoods CCRF Products

Ecosystem Vulnerability Assessment and Synthesis

Forest Adaptation Resources: Climate Change Tools and Approaches for Land Managers

- An integrated set of tools, partnerships and actions to support climate smart conservation and management

Demonstration Projects

- Real-world examples of adaptation forestry
- Variety of landowners and objectives

Northwoods CCRF

Ecosystem Vulnerability Assessment and Synthesis

Contents

1) The Contemporary Landscape
2) Climate Change Primer
3) Observed Climate Change
4) Future Climate Change
5) Impacts on Forests
6) Forest Ecosystem Vulnerability
7) Implications for Forest Management

Tree species vulnerability assessments

- Emissions scenarios, GCMs, and downscaling
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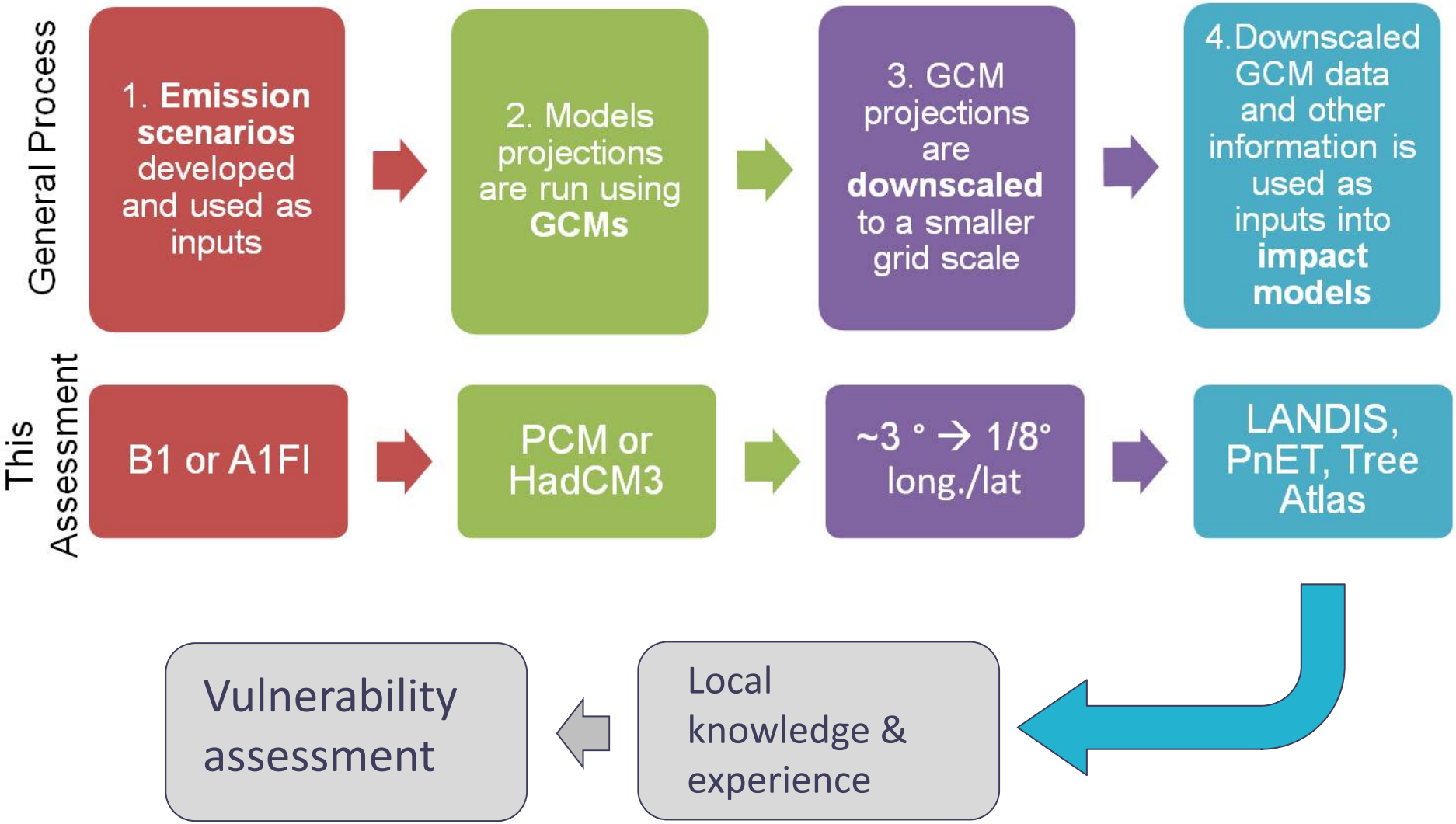
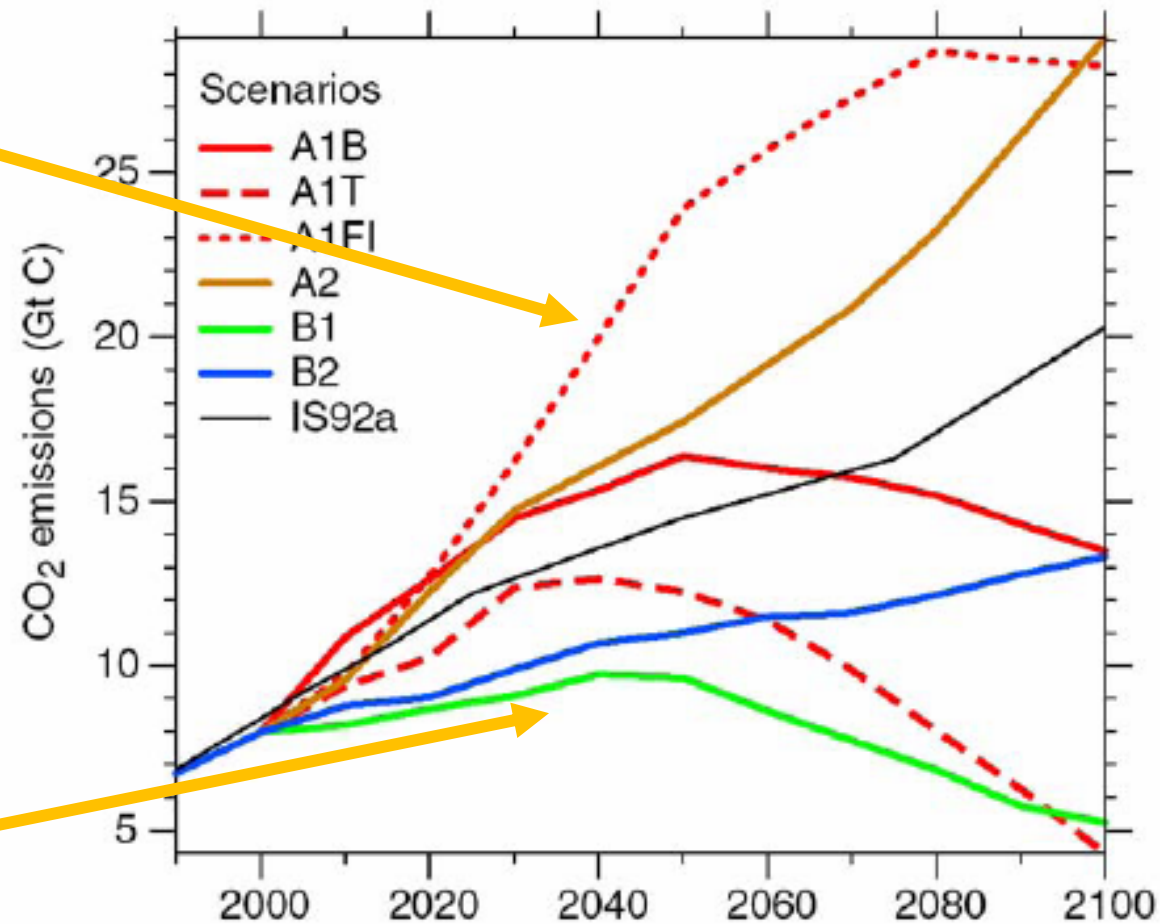
Northwoods CCRF process for assessing vulnerability

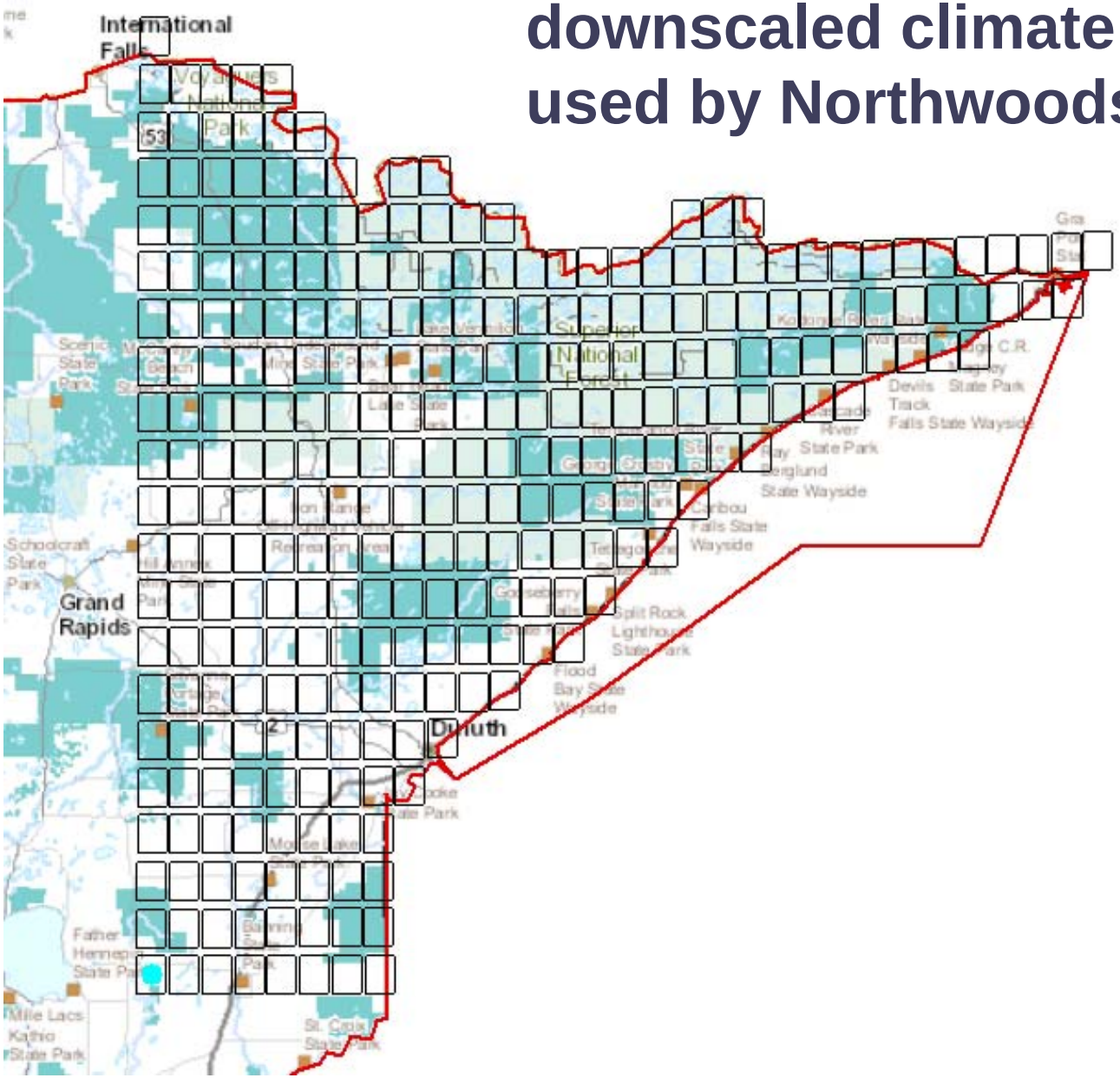


Emissions of CO_2 – range of scenarios over next 100 years

- A1fi (high)-fossil fuel intensive until later century
- B1 (low)-shift to resource efficient technology



Approximate spatial resolution of downscaled climate projections used by Northwoods CCRF



Tree species vulnerability assessments

- Emissions scenarios, GCMs, and downscaling
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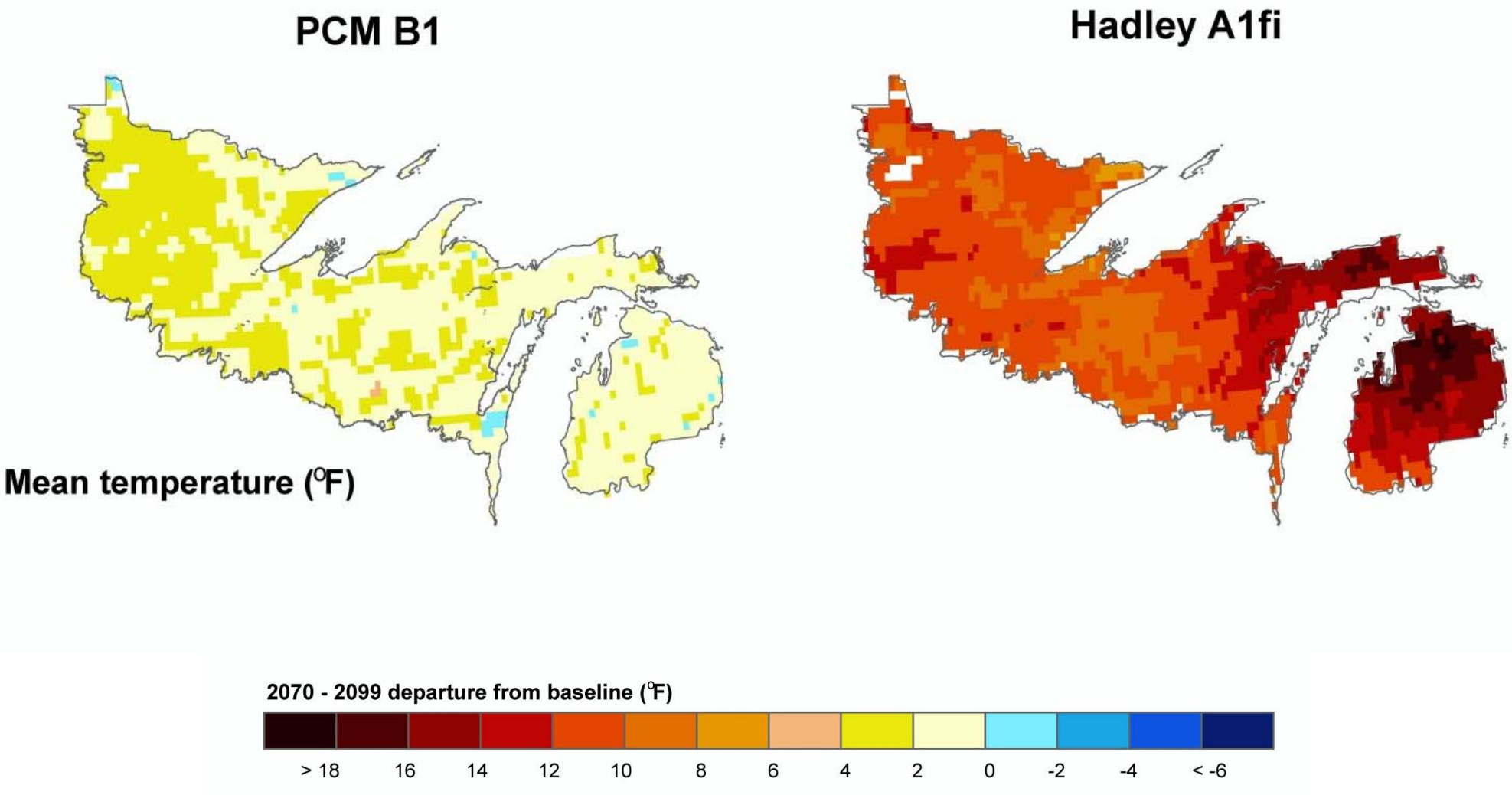
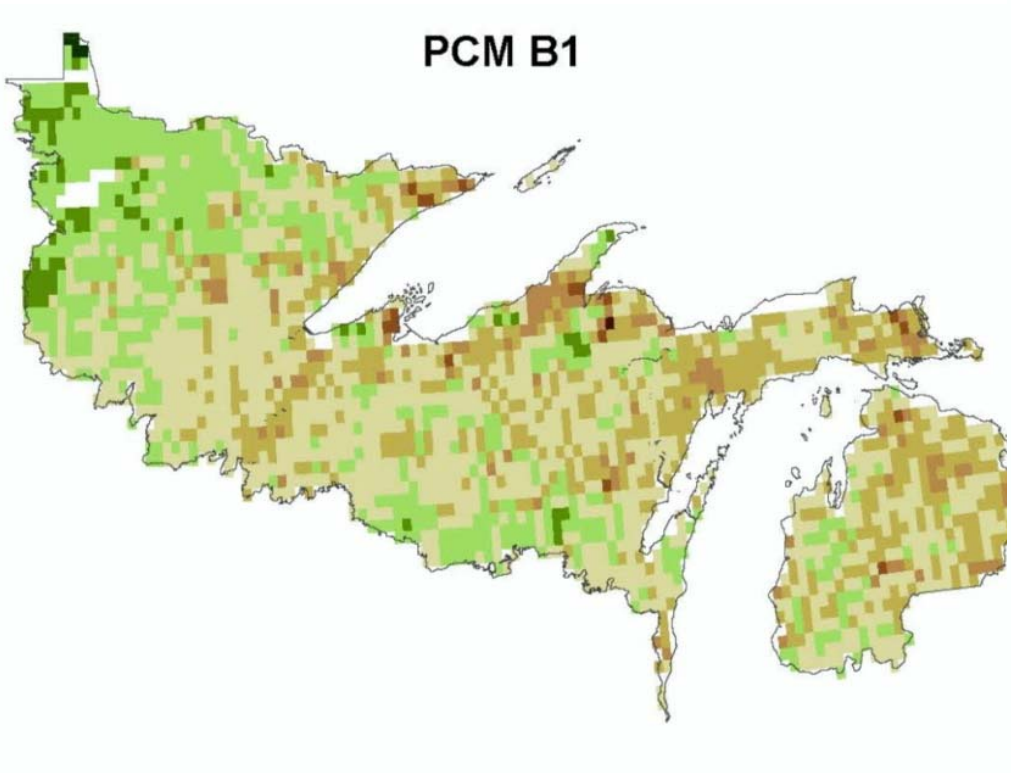
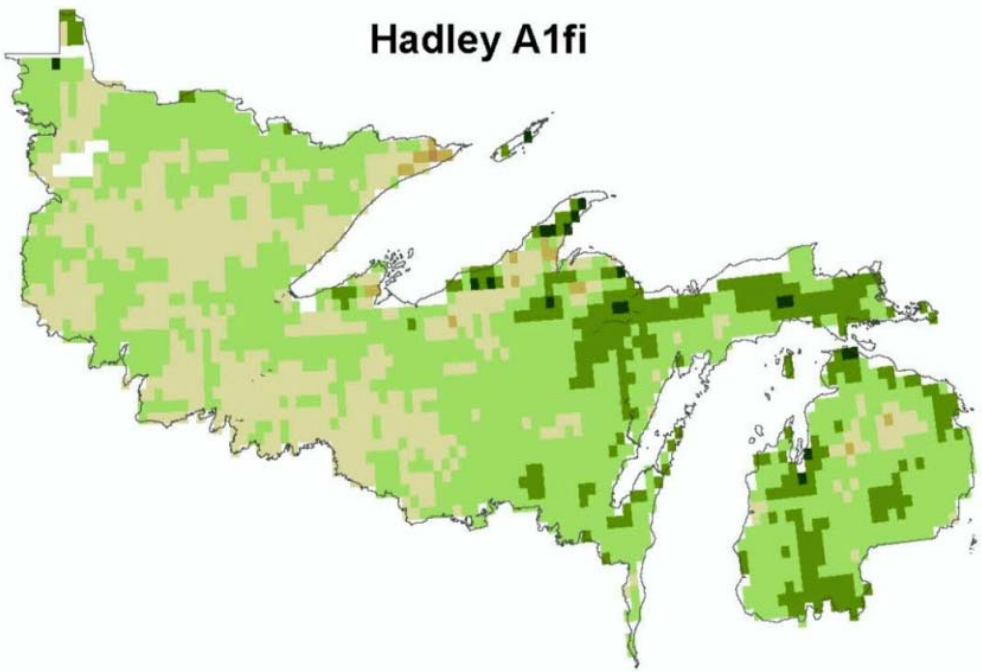
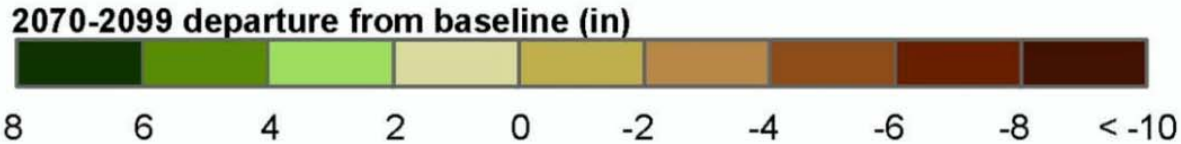
2070-2100 Projected Annual Temperature Departure from Baseline (°F)



2070-2100 Projected Annual Precipitation Departure from Baseline (in)







Summary of anticipated changes in climate for the Laurentian Forest Province in Minnesota

- Average annual temperature is projected to increase between 2.17 °F to 7.96 °F with winter warming by the end of the century (4.7 °F to 10.6 °F) much more than spring (1.36 °F to 4.51 °F).
- Changes in annual precipitation are less clear. GCM-scenarios combinations suggest an annual increase of as much as 3 inches or a decrease of about 0.5 inches.
- Changes in the seasonal distribution of precipitation in combination with higher temperatures suggest that moisture stress at the end of the growing season may be significant.
- Severe weather will be more frequent and intense.

Tree species vulnerability assessments

- Emissions scenarios, GCMs, and downscaling
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Comparison of impact models

	Model		
Feature	**Tree Atlas**	**LANDIS-II**	**PnET-CN**
Description	**Statistical niche model (Species distribution model)**	**Spatially explicit, dynamic process model**	**Ecosystem-level carbon, water, and nitrogen process model**
Primary outputs	**Maps of suitable habitat and relative importance values by species**	**Biomass and distribution maps by species**	**Productivity, transpiration and runoff, N mineralization, etc.**
Migration	**Yes**	**Yes**	**No**
Competition, survival, and reproduction	**No (implied via historic pattern)**	**Yes**	**No**
BAU and new management scenarios	**No**	**Yes**	**No**
Disturbances	**Yes (via modifying factors)**	**Yes (harvest, fire, wind)**	**Yes (harvest, fire, wind)**
Tree physiology feedbacks	**No**	**No**	**Yes**
Succession or ecosystem shifts	**No (implied via historic pattern)**	**Yes**	**No**
Ozone, N-deposition, CO2 fertilization	**No**	**No**	**Yes**
Confidence estimates	**Yes**	**Yes**	**Yes**

Tree Atlas approach

- **Describe the habitat of individual tree species using statistical models; identify where those habitats occur under future climate conditions.**

- **Predict how much of the future habitat will be occupied by those species.**

- **Account for other factors known to influence species success.**

Factors used to describe the current habitat and locate future habitat of individual tree species (20 km cells)

Climate
Mean annual temperature
Mean January temperature
Mean July temperature
Mean May-September temperature
Mean May-September precipitation
Annual precipitation
Difference temperature (January-July)

Elevation
Elevation coefficient of variation
Maximum elevation
Average elevation
Minimum elevation
Range of elevation

Land Use and Fragmentation
Percent cropland
Percent forestland
Fragmentation index
Percent non-forestland

Soil Order and **Soil Properties**
% Alfisol, Aridisol, etc.
Soil bulk density
Percent clay
Soil erodibility
Percent coarse soil
Percent fine soil
Organic matter content
Potential soil productivity
Soil permeability
Soil pH
Depth to bedrock
Percent weight of rock fragments
Soil slope
Total available water capacity

Factors used to predict how much of the future habitat will be occupied by those species (over 100 year period).

Current abundance in surrounding cells
Habitat quality
Distance

Factors known to influence species success.

Biological
Fire regeneration
Dispersal ability
Water use efficiency
Productivity
Shade tolerance
Edaphic specificity
Vegetative regeneration
Seedling establishment
Environmental habitat specificity

Disturbance
Drought
Flood
Browse
Pollution
Ice
Fire topkill
Harvest
Invasive plants
Insect
Wind
Disease
Temperature gradients

Tree species vulnerability assessments

- Emissions scenarios, GCMs, and downscaling
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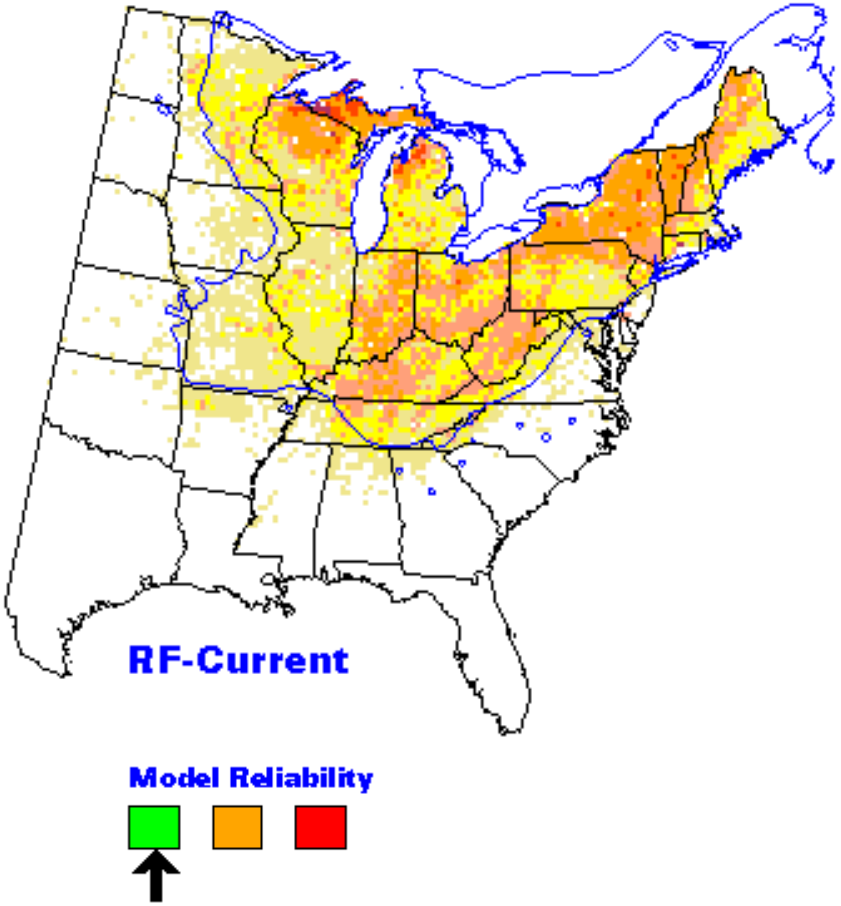
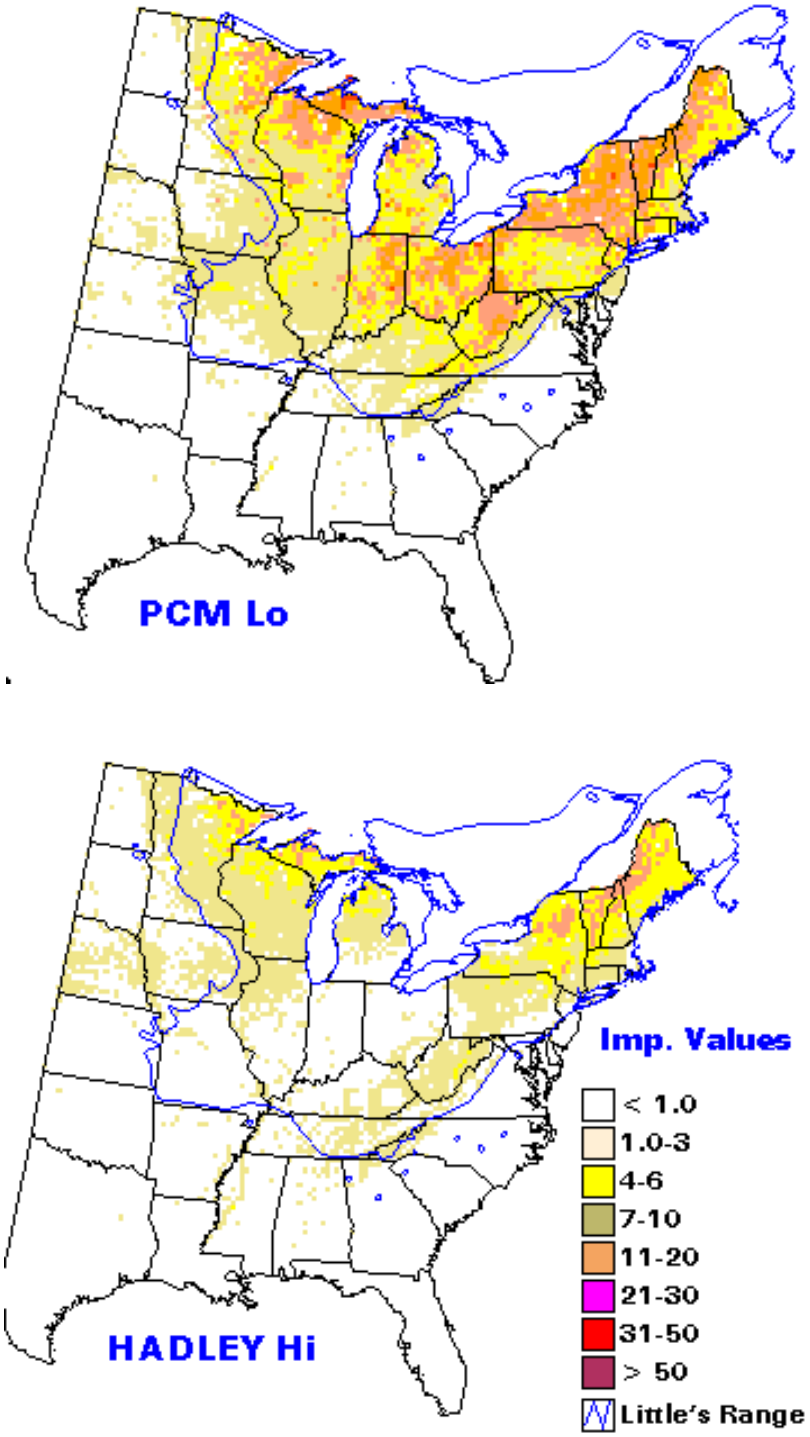
Sugar Maple



Low

?

High



In the following slides

Current and future habitat is measured by Importance Value.

For current conditions, IVs are calculated from FIA data.

IV(x) = 50 * BA(x) / BA (all species) + 50 * NS(x) / NS(all species)

For future conditions, IV is predicted based on relationships between IVs and environmental variables quantified via regression analysis.

In the following slides

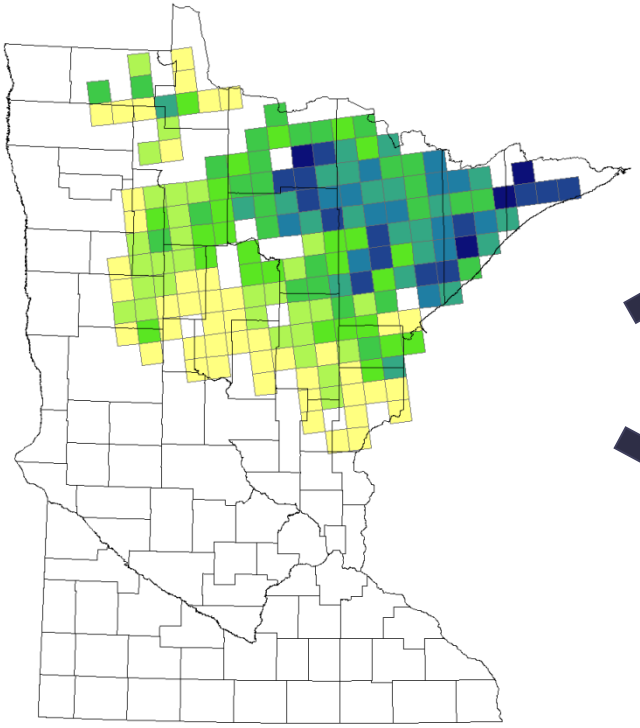
IVs tend to be lower in the future than the present.

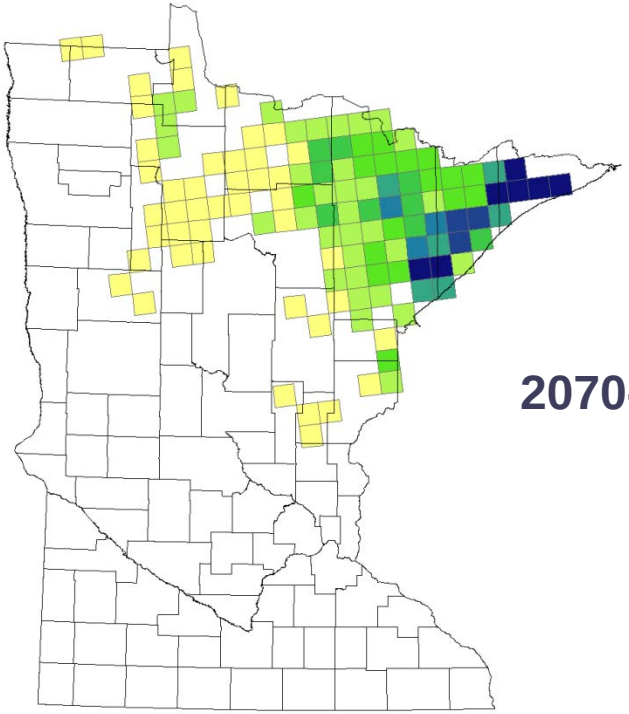
IVs between 0 and 1 were rounded to 1.

Color schemes emphasize the difference between current and future habitats for individual species and should not be used to compare different species.

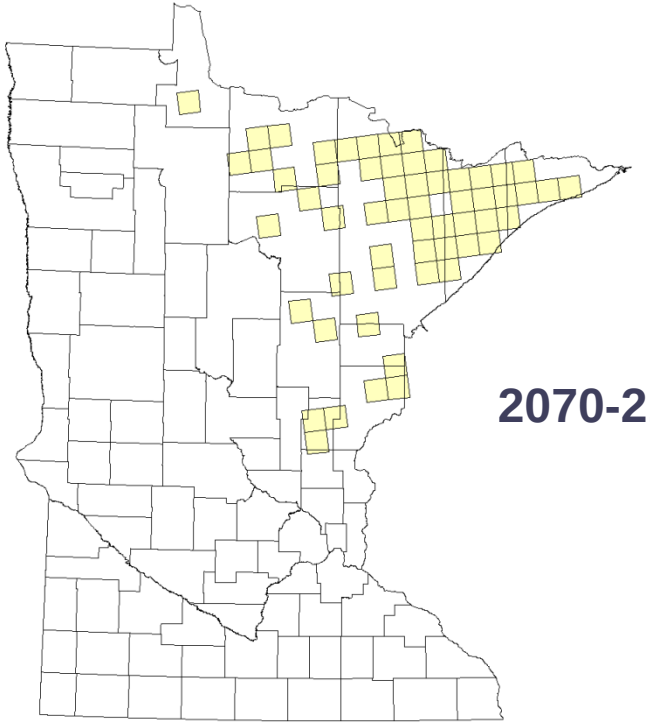
Balsam fir

Current FIA





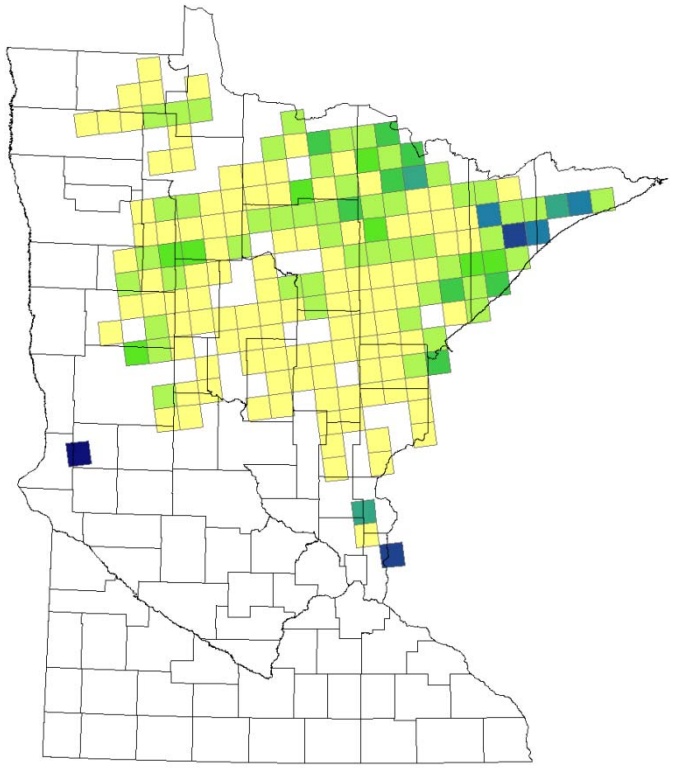
2070-2100 Low

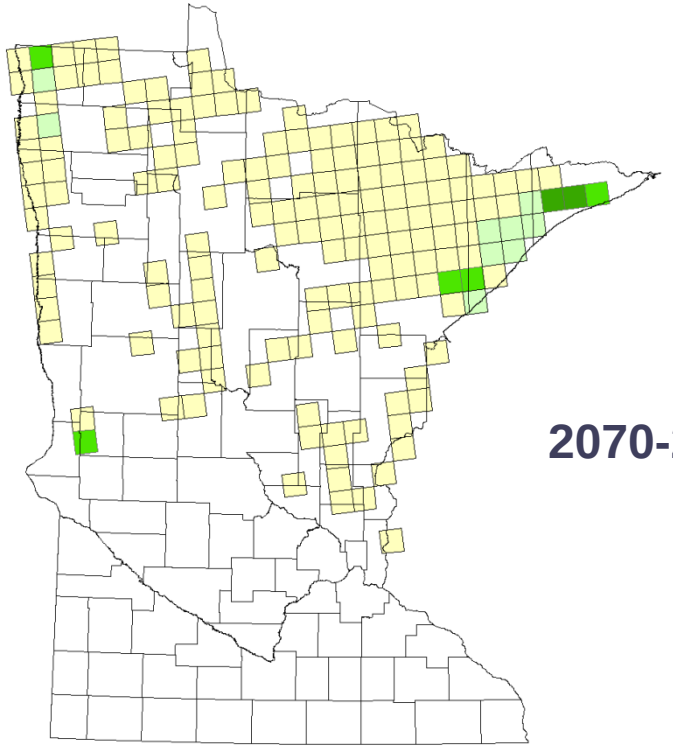


2070-2100 High

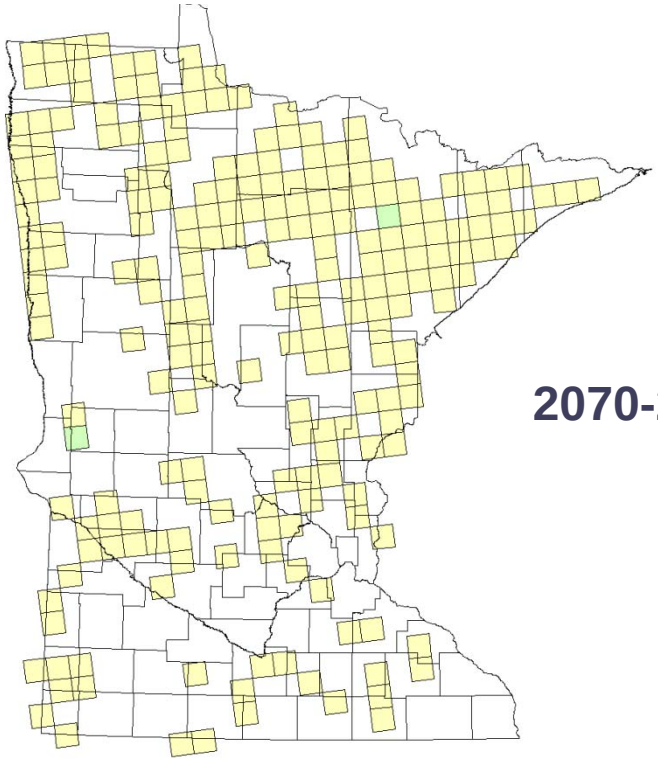
Black spruce

Current FIA





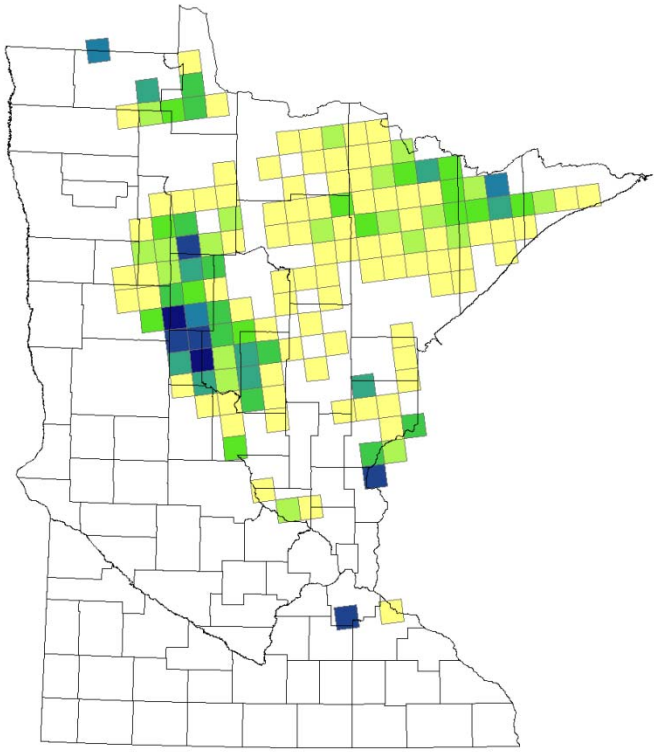
2070-2100 Low

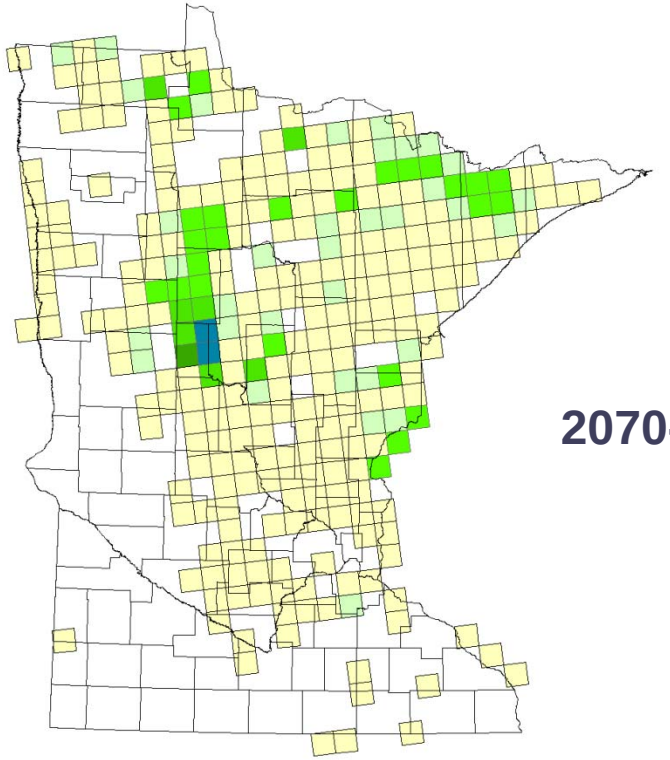


2070-2100 High

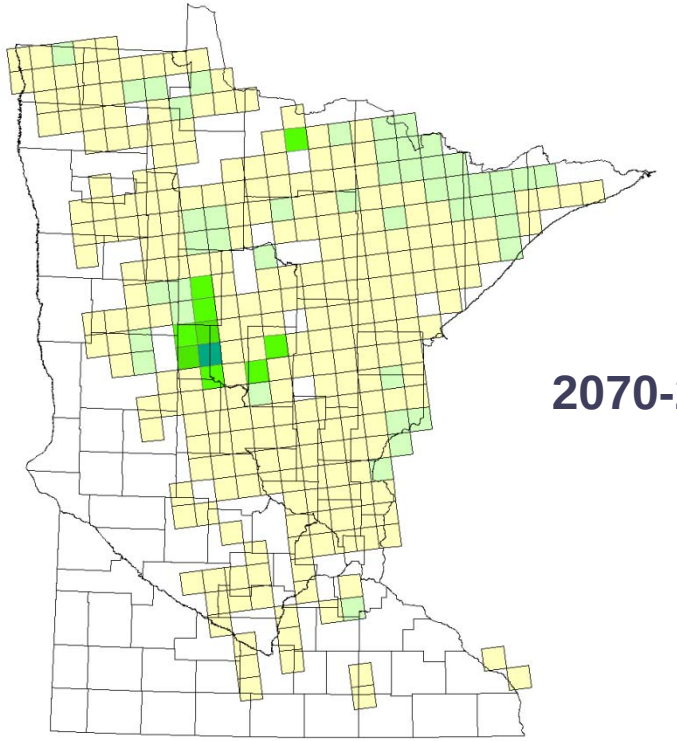
Jack pine

Current FIA





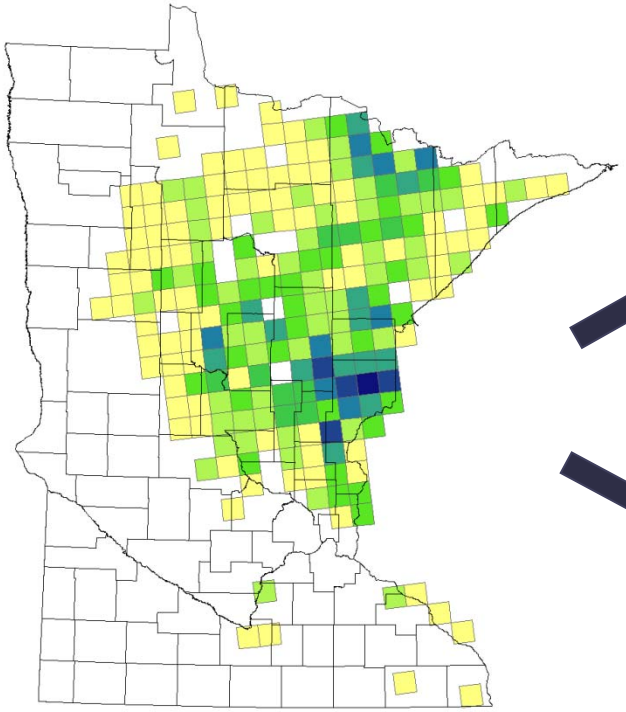
2070-2100 Low

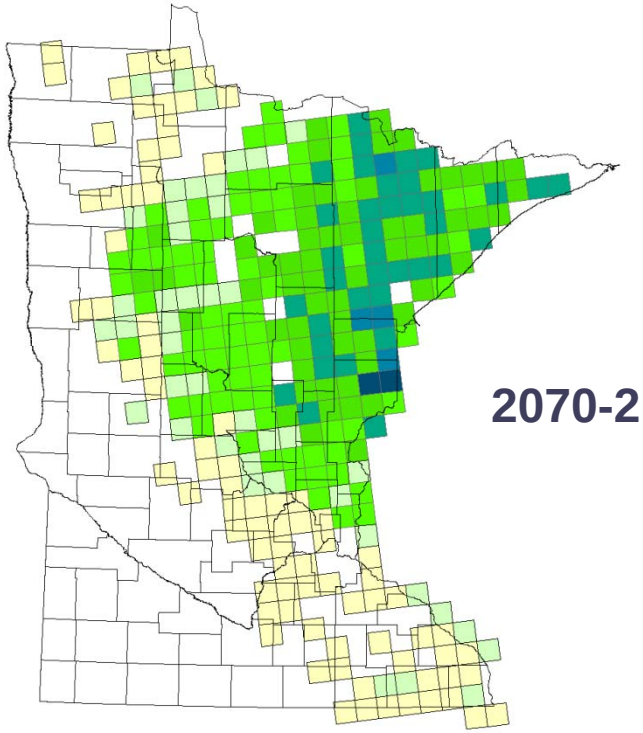


2070-2100 High

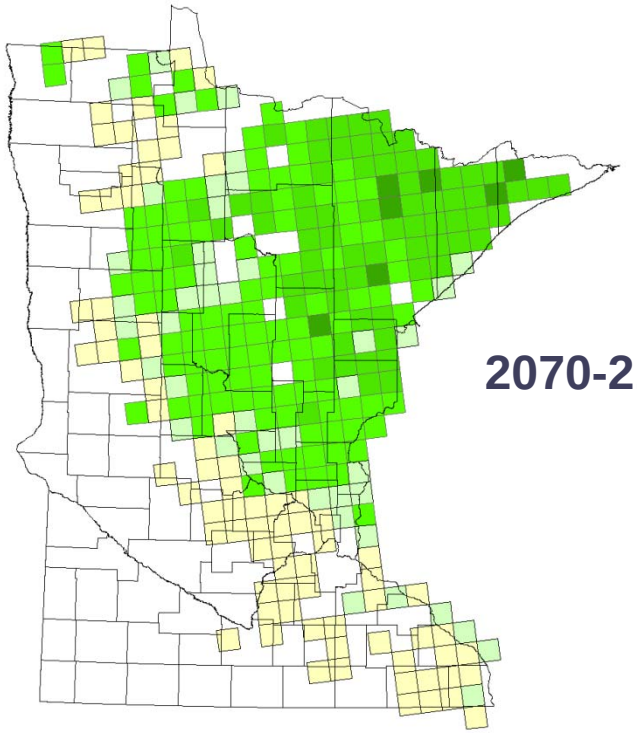
Red maple

Current FIA





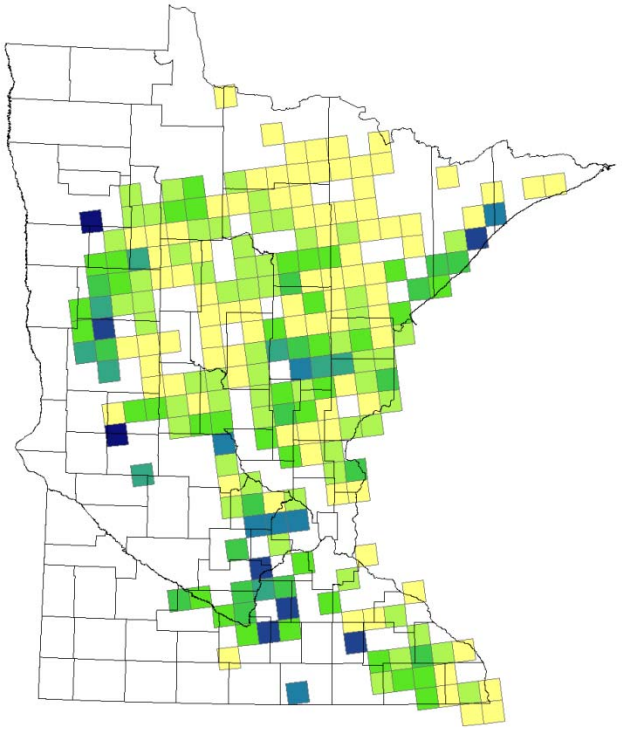
2070-2100 Low

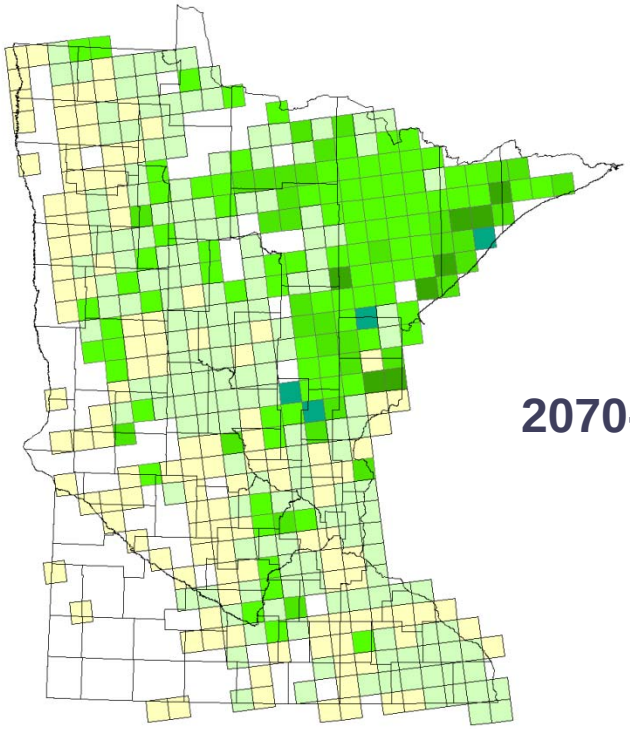


2070-2100 High

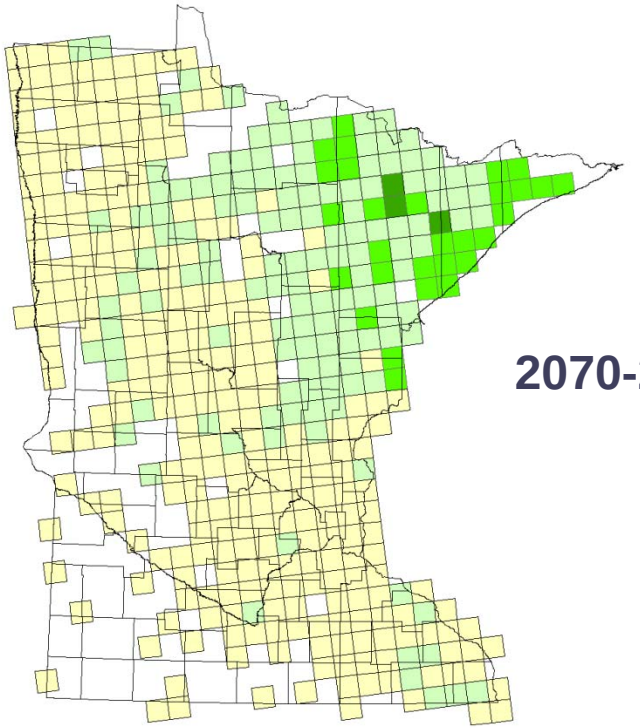
Sugar maple

Current FIA





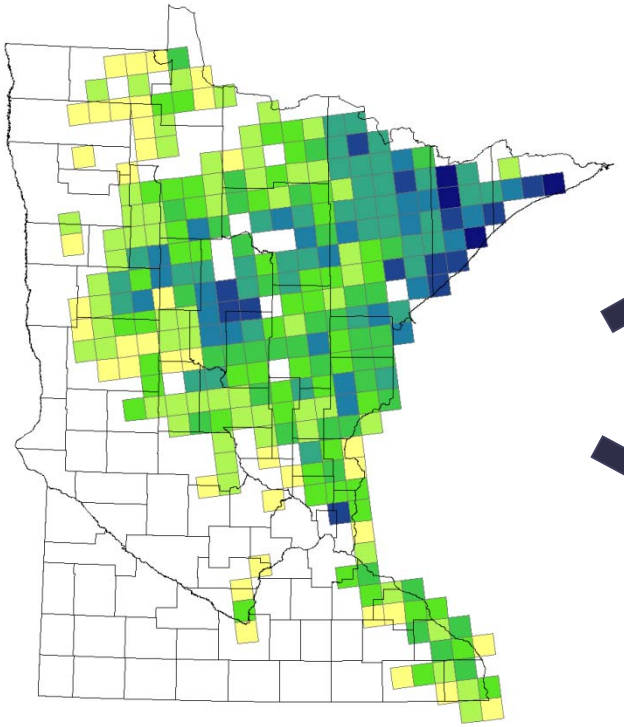
2070-2100 Low

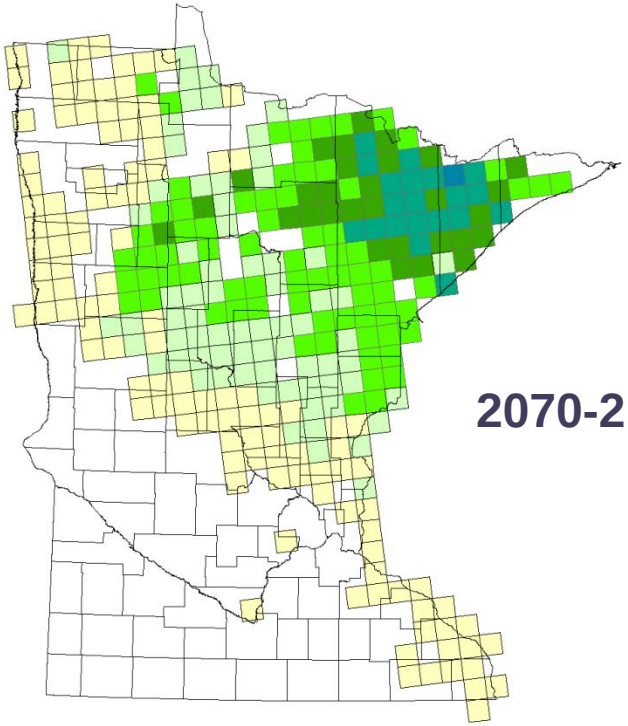


2070-2100 High

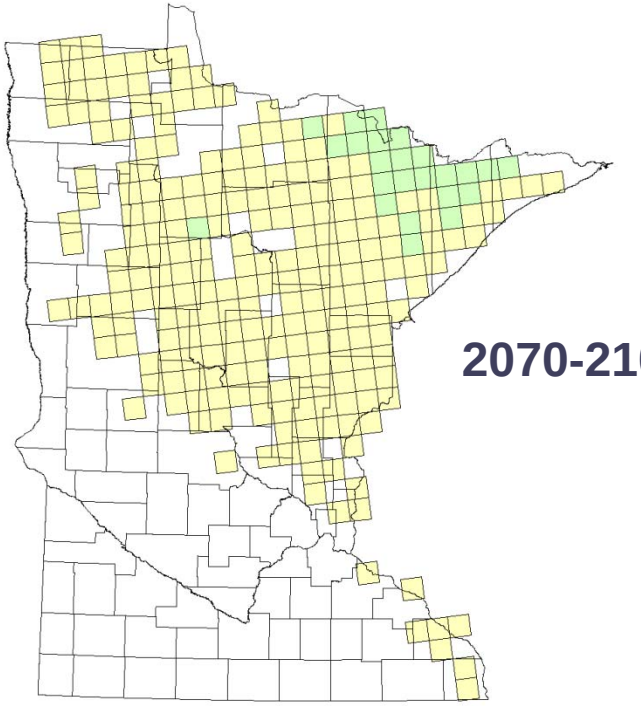
Paper birch

Current FIA





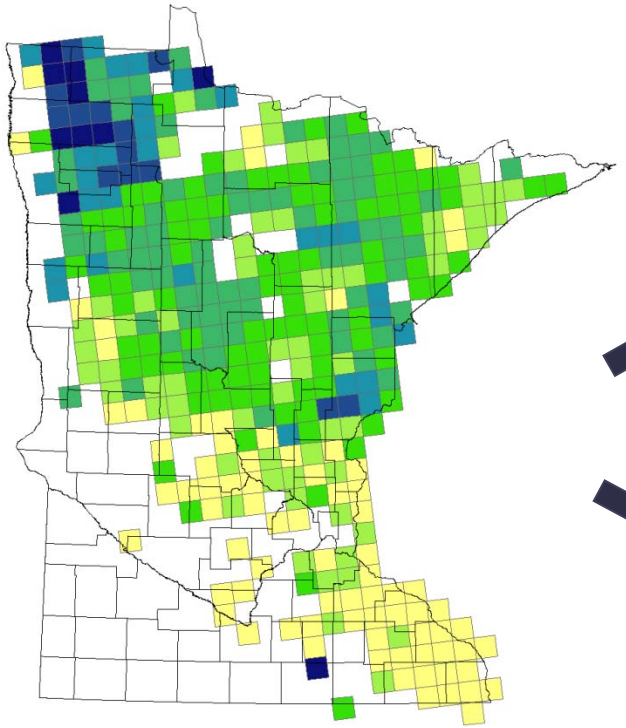
2070-2100 Low

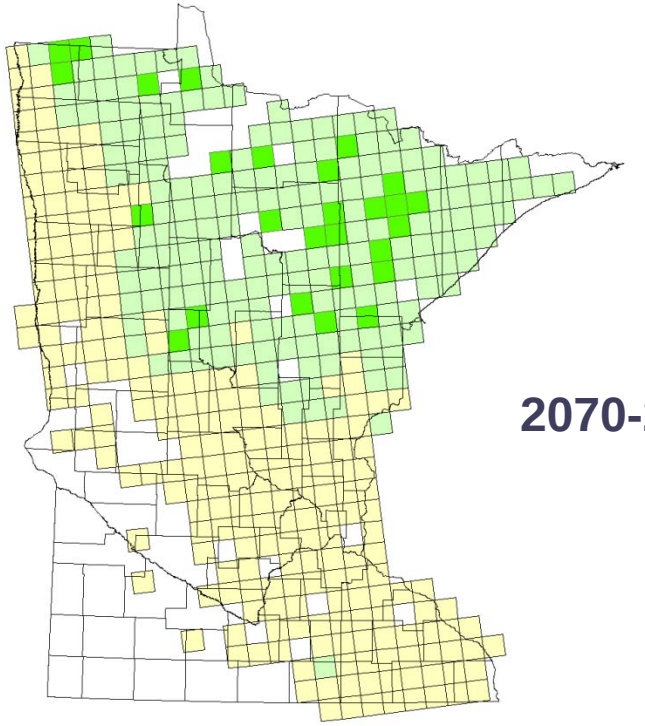


2070-2100 High

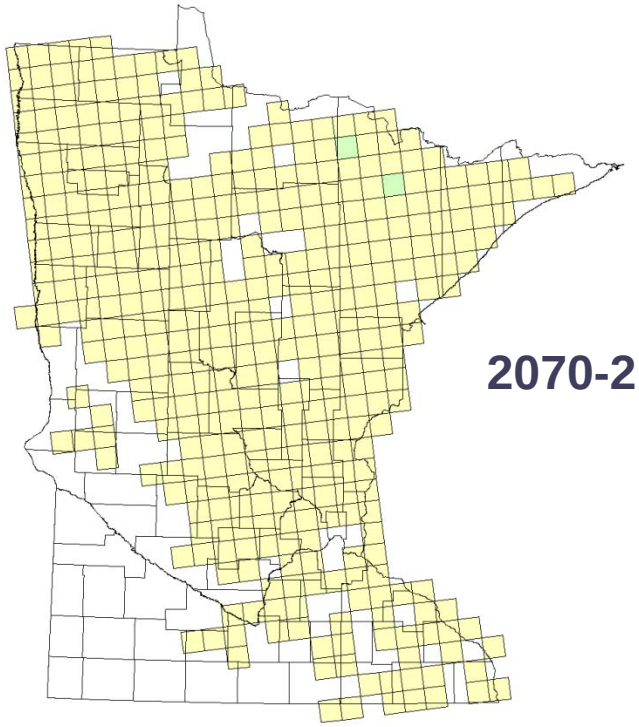
Quaking aspen

Current FIA





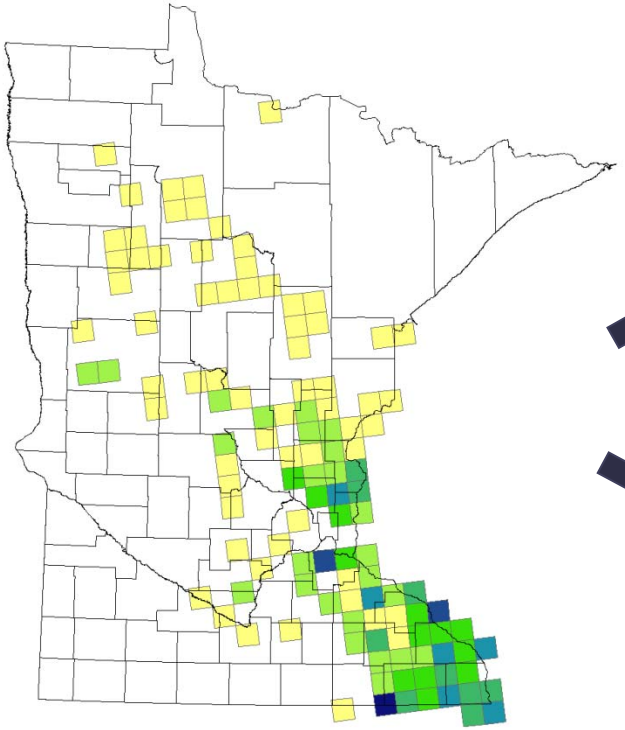
2070-2100 Low

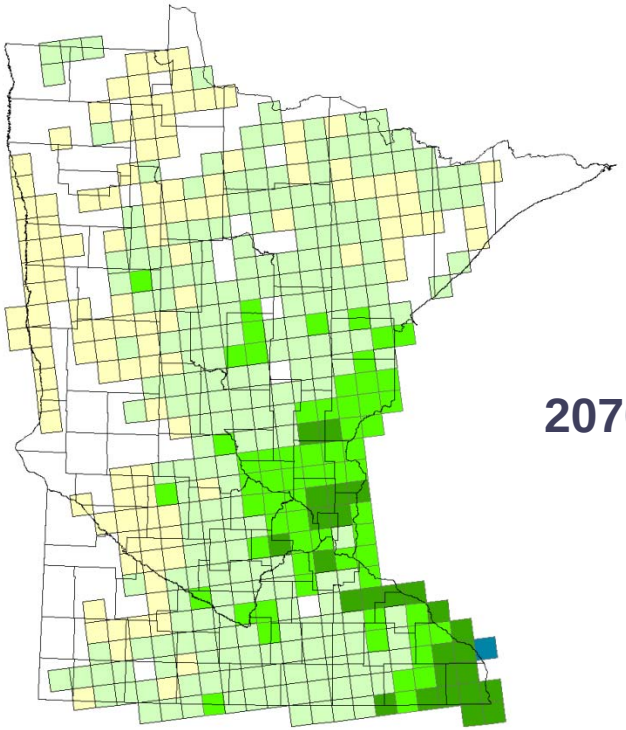


2070-2100 High

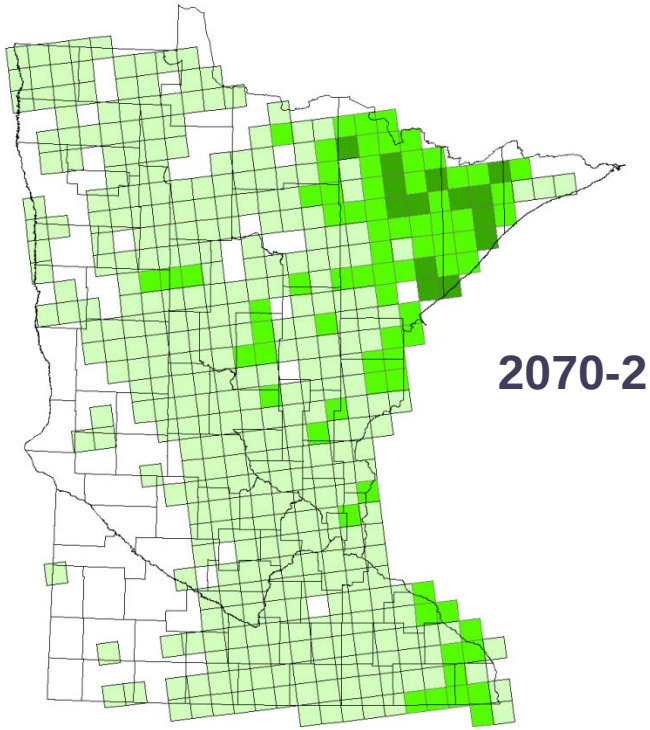
White oak

Current FIA



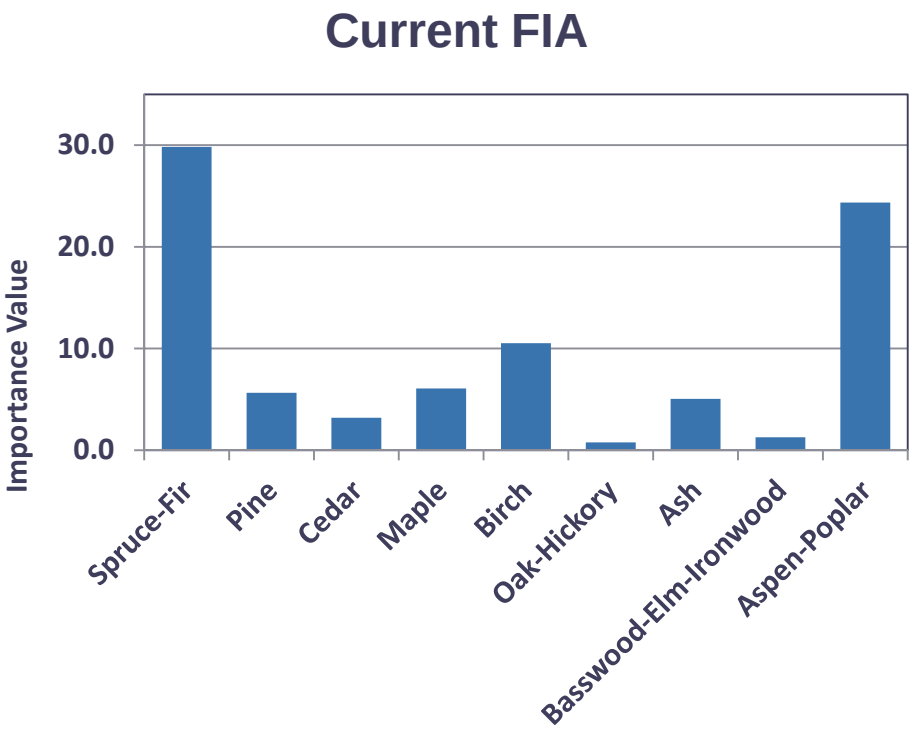


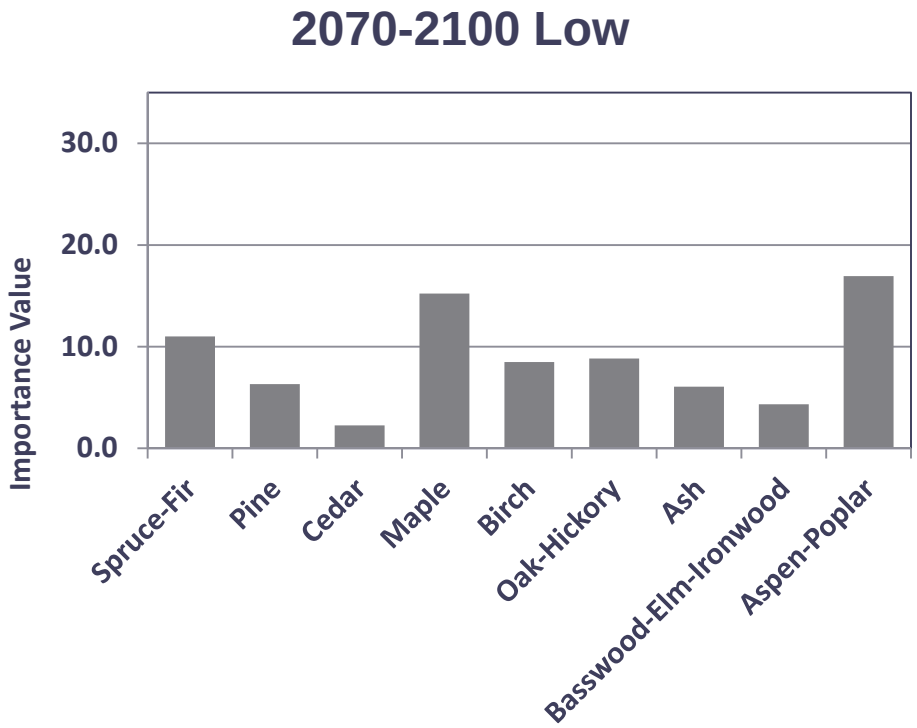
2070-2100 Low

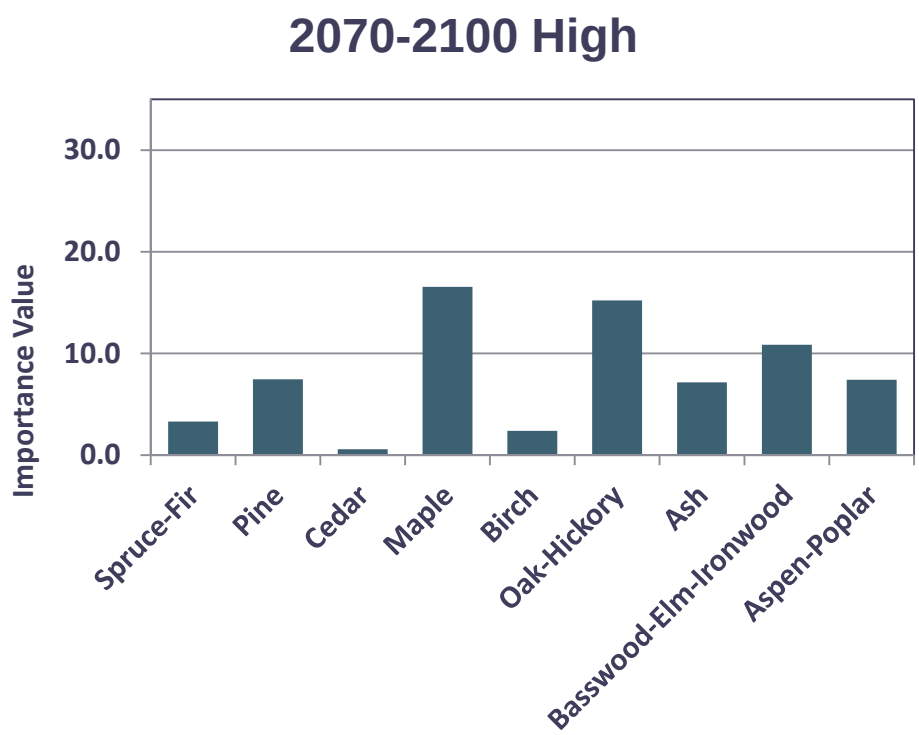


2070-2100 High

Current and projected tree species habitat in the Northeast Landscape







Summary of potential changes in tree species habitat in the NE landscape

	Area-weighted mean IVs in NE landscape			Change	
Species group	**Current**	**Hadley High**	**PCM Low**	**Hadley High**	**PCM Low**
Spruce-Fir	29.8	3.3	11.0	Large decrease	Large decrease
Pine	5.6	7.5	6.3	Increase	Increase
Cedar	3.2	0.6	2.3	Large decrease	Decrease
Maple	6.1	16.6	15.2	Large increase	Large increase
Birch	10.5	2.4	8.5	Large decrease	Decrease
Oak-Hickory	0.8	15.2	8.8	Large increase	Large increase
Ash	5.1	7.2	6.1	Increase	Increase
Basswood-Elm-Ironwood	1.3	10.9	4.3	Large increase	Large increase
Aspen-Poplar	24.4	7.4	16.9	Decrease	Decrease

Northwoods Climate Change Response Framework

Tree species vulnerability assessments

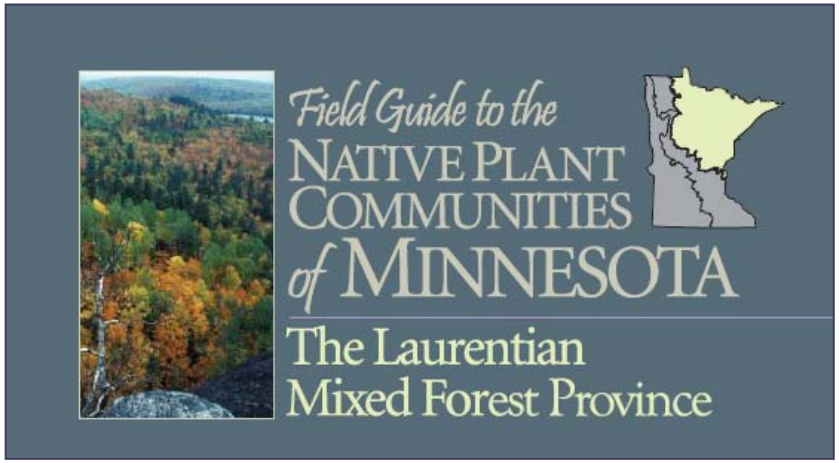
- **Emissions scenarios, GCMs, and downscaling**
- **Projected changes in climate**
- **Modeling impacts to tree species**
- **Tree Atlas results**

Impacts to Native Plant Communities

Forest Systems Addressed:

Native Plant Community Systems:

- Fire Dependent Forests
- Mesic Hardwood Forests
- Wet Forests
- Floodplain Forests
- Forested Rich Peatlands
- Acid Peatlands



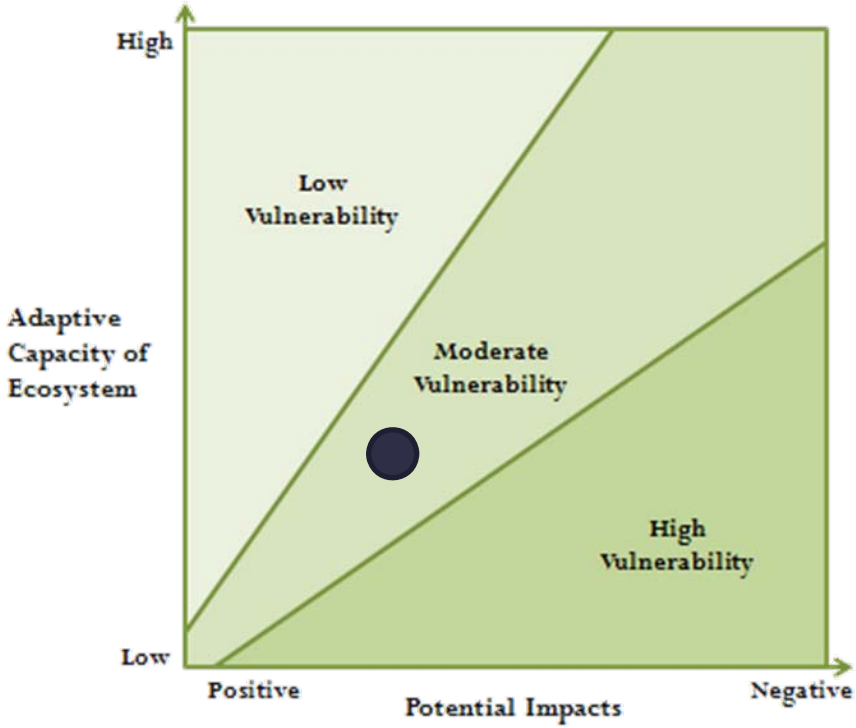
Managed Forest Systems

- Aspen
- Red Pine

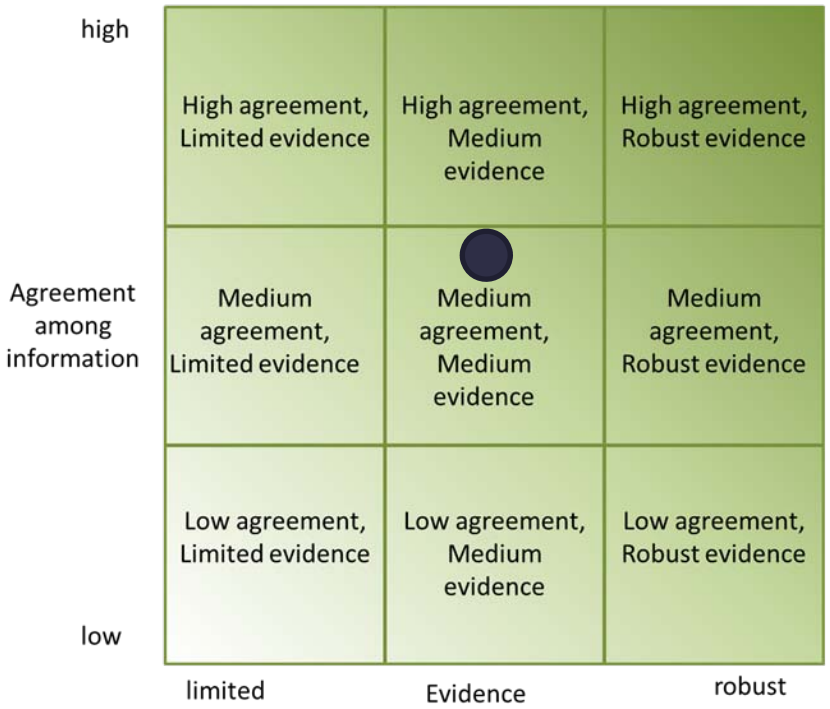
Expert Panel Workshop

Vulnerability & Confidence

1. Determine vulnerability individually



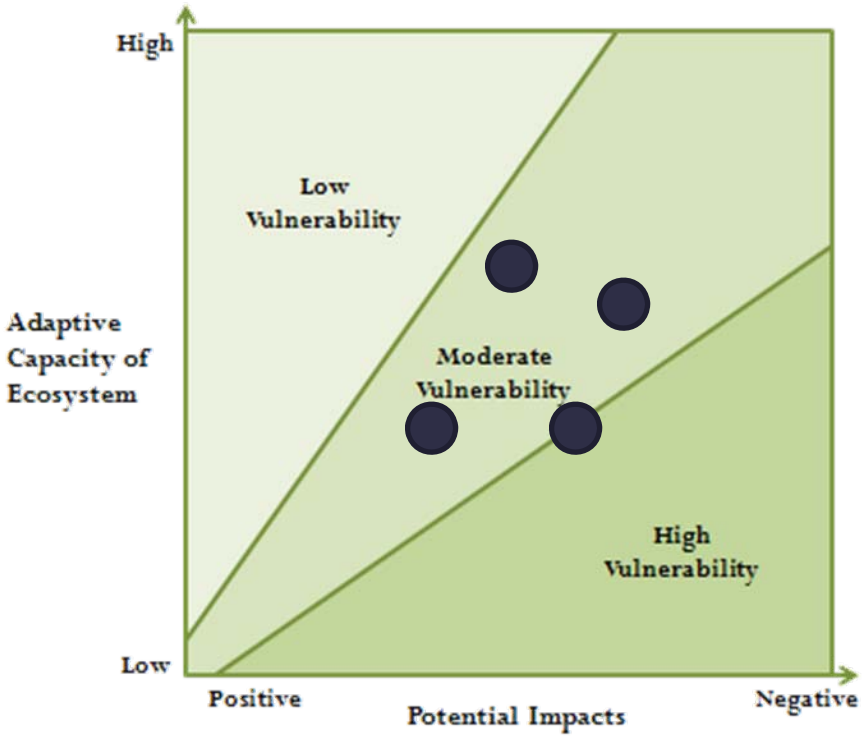
2. Rate confidence individually



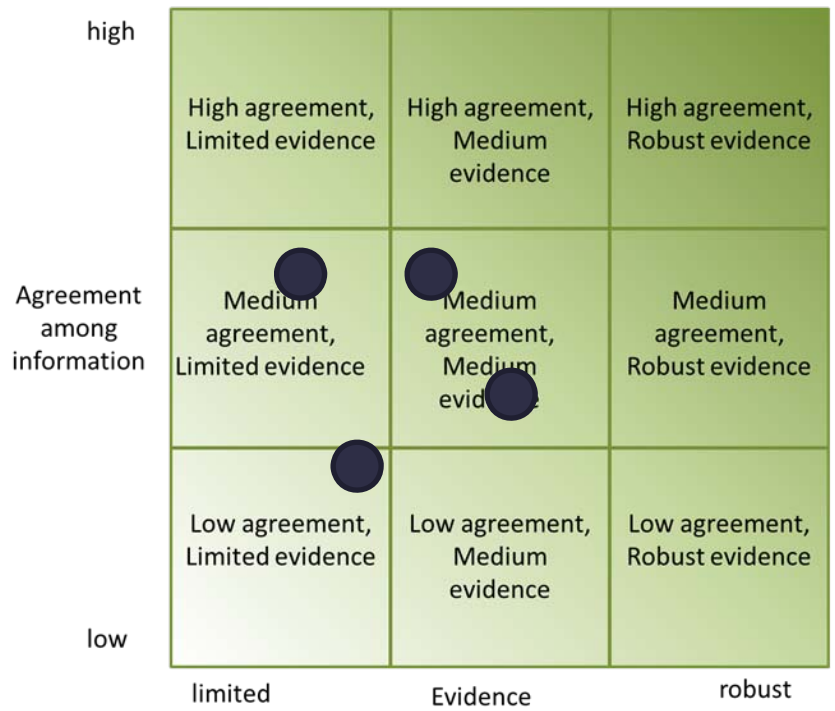
Following structured discussion

Vulnerability & Confidence

3. Vote on vulnerability as a group



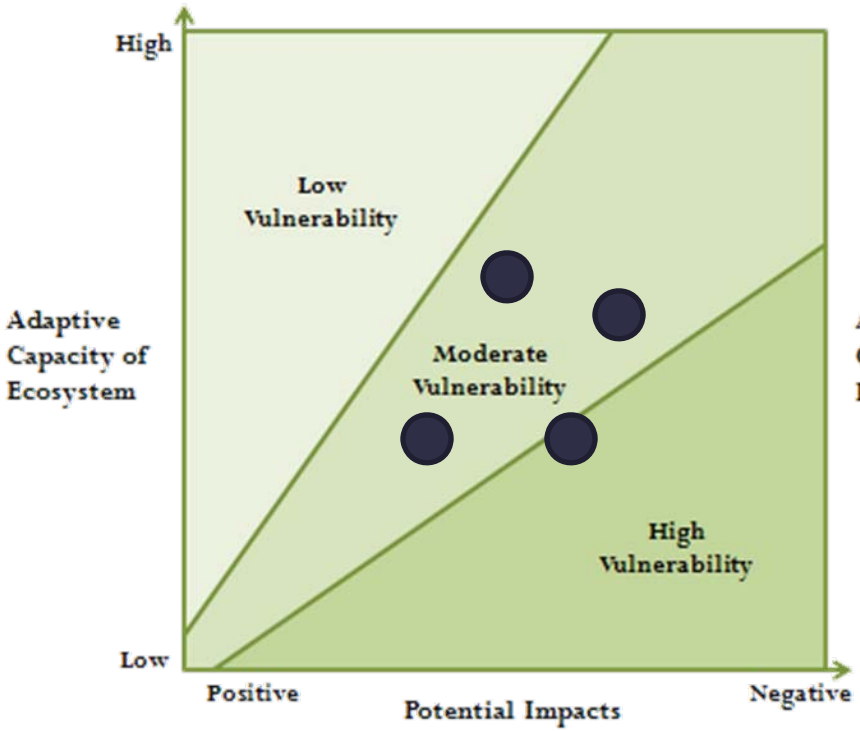
4. Vote on Confidence as A group



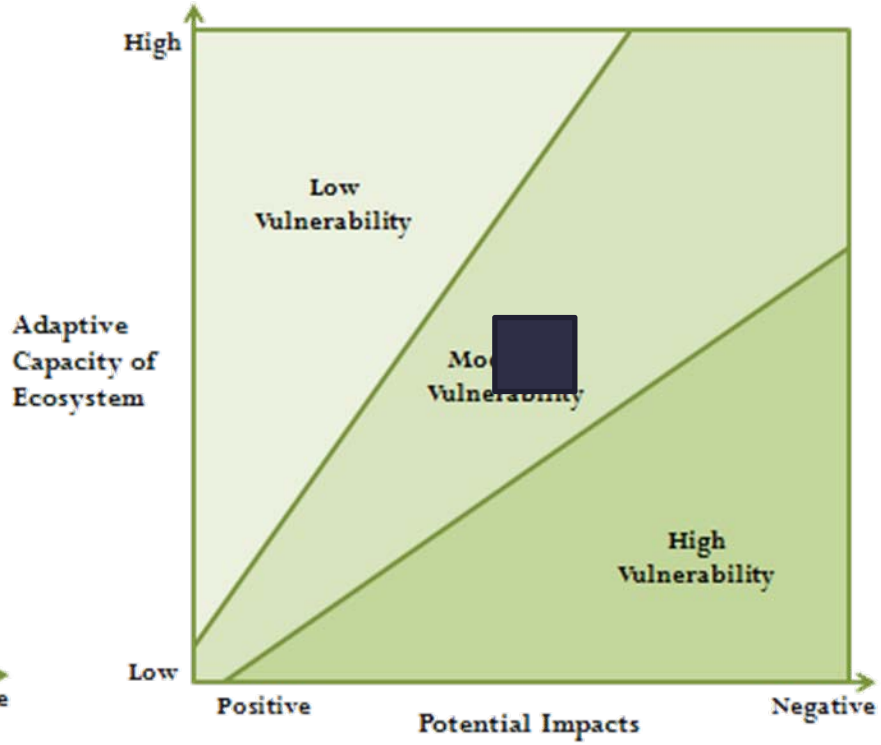
On Large Poster

Vulnerability & Confidence

5. Discuss Vulnerability Votes



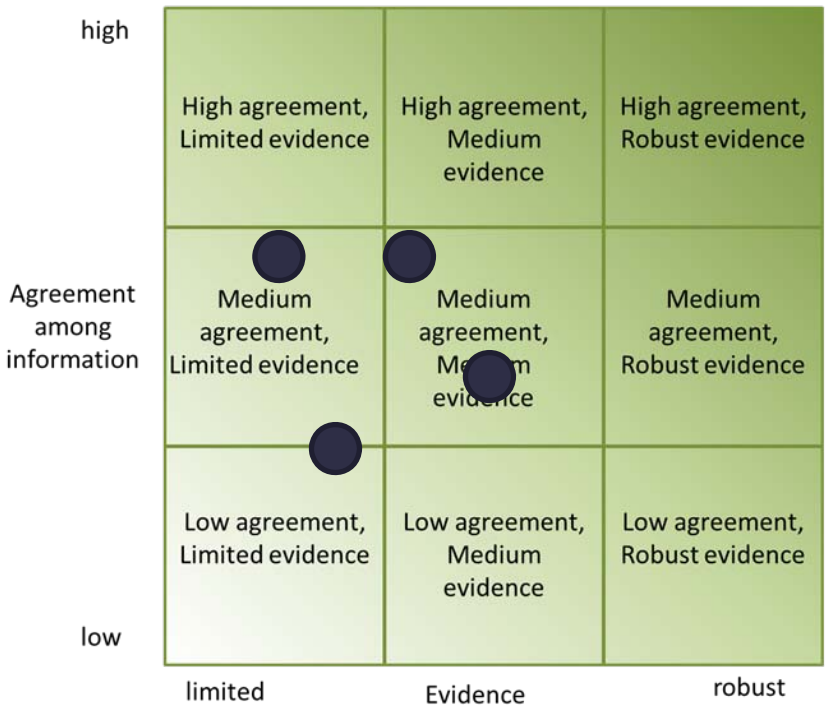
6. Determine Group Vulnerability



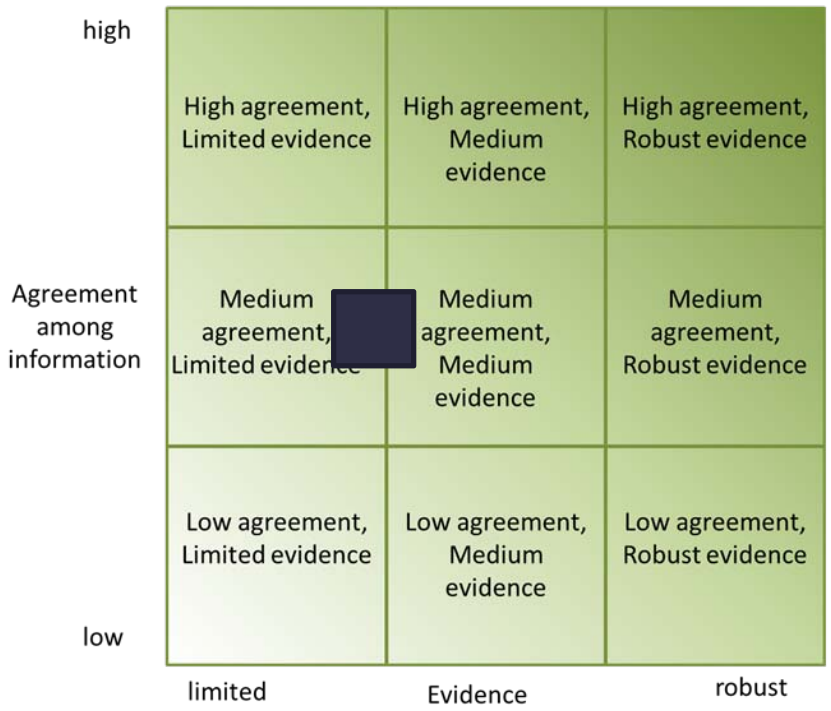
On Large Poster

Vulnerability & Confidence

7. Discuss Confidence Votes



8. Determine Group Confidence



On Large Poster

Summary of vulnerability determinations for Minnesota system-level Native Plant Communities

Community	Potential Impacts	Adaptive Capacity	Vulnerability	Agreement	Evidence
Fire-Dependent Forest	Negative	Moderate-High	Moderate	Medium	Medium
Mesic Hardwood Forest	Moderate	Moderate-High	Moderate	Medium	Medium
Floodplain Forest	Moderate-Positive	Moderate	Low-Moderate	Medium	Limited-Medium
Wet Forest	Negative	Low	High	Medium	Limited-Medium
Forested Rich Peatland	Negative	Low	High	Medium-High	Medium
Acid Peatland	Negative	Low	High	Medium-High	Medium
Managed Aspen	Moderate-Negative	Moderate	Moderate-High	High	Medium
Managed Red Pine	Moderate-Negative	Moderate-Low	High-Moderate	Medium	Medium

Fire-Dependent Forest System

Moderate Vulnerability (medium agreement, medium evidence)

Changes to the fire regime for northern Minnesota are particularly threatening for this system, in addition to the loss of suitable habitat for many key species and the potential for greater pest and diseases activity. A high tolerance for disturbance increases the adaptive capacity of this system.

Negative Potential Impacts

Drivers: Fire-Dependent Forests are generally found on coarse-textured or shallow soils, and may be able to tolerate the projected shift toward drier soils during the summer months. Evidence suggests that wildfires may burn larger areas in northern Minnesota under climate change, and that the fire season may shift later into the growing season. Blowdown-causing wind events could also provide more fuel buildup for large fire events. Greater wildfire activity could be a positive impact for these forest types, but it is possible that too much change to the fire regime would hamper regeneration.

Dominant Species: Considering the range of possible climate futures, the majority of dominant species that make up Fire-Dependent Forests are expected to decline in suitable habitat and biomass across the assessment area according to ecosystem modeling projections (jack pine, quaking aspen, paper birch, balsam fir, and black spruce). The same modeling studies suggest red pine and white pine will remain relatively constant or experience slight increases across the assessment area, and that minor components of Fire Dependent Forests like northern red oak, bur oak, and red maple will also increase across the assessment area.

Stressors: Climate change is expected to intensify several key stressors for Fire-Dependent Forests. Insect pests and diseases may become more virulent and damaging under a warmer climate, and the possibility exists for new pests such as western bark beetles to arrive in the assessment area. The continued mesification of Fire Dependent Forests may be encouraged by climate change if fire suppression activities remain constant and broadleaf species like red maple continue to increase. White-tailed deer populations are also anticipated to increase with warmer winters, so herbivory on preferential species may continue to hinder regeneration.

Moderate-High Adaptive Capacity

Fire-Dependent Forests are generally tolerant of drought and disturbances and contain a diversity of species, which lends these forests greater adaptive capacity to climate change. Additionally, these forests can persist on poor soils, so the possibility exists that Fire-Dependent Forests could "retreat" to favorable locations on the landscape even if overall conditions change. Southern portions of the assessment area may be more prone to shift to Mesic Hardwoods because fragmentation and broadleaf species will likely limit fire activity.

Potential Changes in Habitat of Trees by NPC system

		Native Plant Community					
Species	Predicted change	Forested Rich Peatland	Mesic Hardwood Forest	Fire-Dependent Forest	Floodplain Forest	Wet Forest	Acid Peatland
Quaking aspen	Large decreaser		↓	↓		↓	
Paper birch	Large decreaser	↓	↓	↓	↓	↓	
Balsam fir	Large decreaser	↓	↓	↓	↓	↓	
Black spruce	Large decreaser	↓		↓		↓	↓
Black ash	Small decreaser		↘		↘	↘	
Balsam poplar	Large decreaser		↓			↓	
Bur oak	No change		→	→	→	→	
Northern red oak	Small increaser		↗	↗			
Jack pine	Small decreaser			↘			
Red maple	Small increaser		↗	↗		↗	
Tamarack	Small decreaser	↘				↘	↘
White cedar	Large decreaser	↓	↓	↓		↓	
Basswood	No change		→	→	→	→	
Sugar maple	Small increaser		↗			↗	
Red pine	No change		→	→			
American elm	Large increaser		↑		↑	↑	
Green ash	Small increaser		↗		↗	↗	
Big-toothed aspen	No change		→	→			
White spruce	Large decreaser	↓		↓		↓	
White pine	Small increaser		↗	↗		↗	↗
Ironwood	Small increaser		↗				
Boxelder	Large increaser				↑	↑	
Northern pin oak	Large increaser			↑			
Yellow birch	Small increaser		↗			↗	
White oak	Large increaser		↑				
Silver maple	Large increaser				↑		
White ash	Large increaser		↑				
Butternut	Small increaser		↗				
Red elm	New					New	
Bitternut hickory	Large increaser		↑				

Fire-Dependent Forest

Key Drivers:

- Coarse soils or shallow soils over bedrock
- Drought-prone
- Severe stand-replacing and mild surface fires

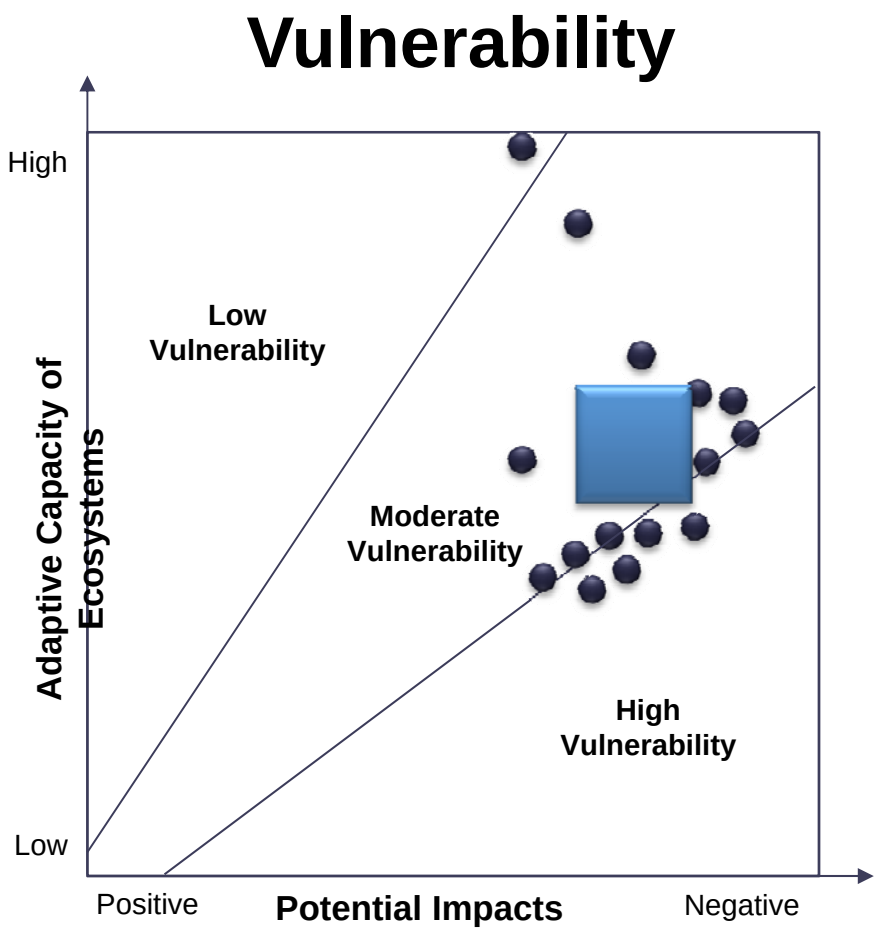
Dominant Species:

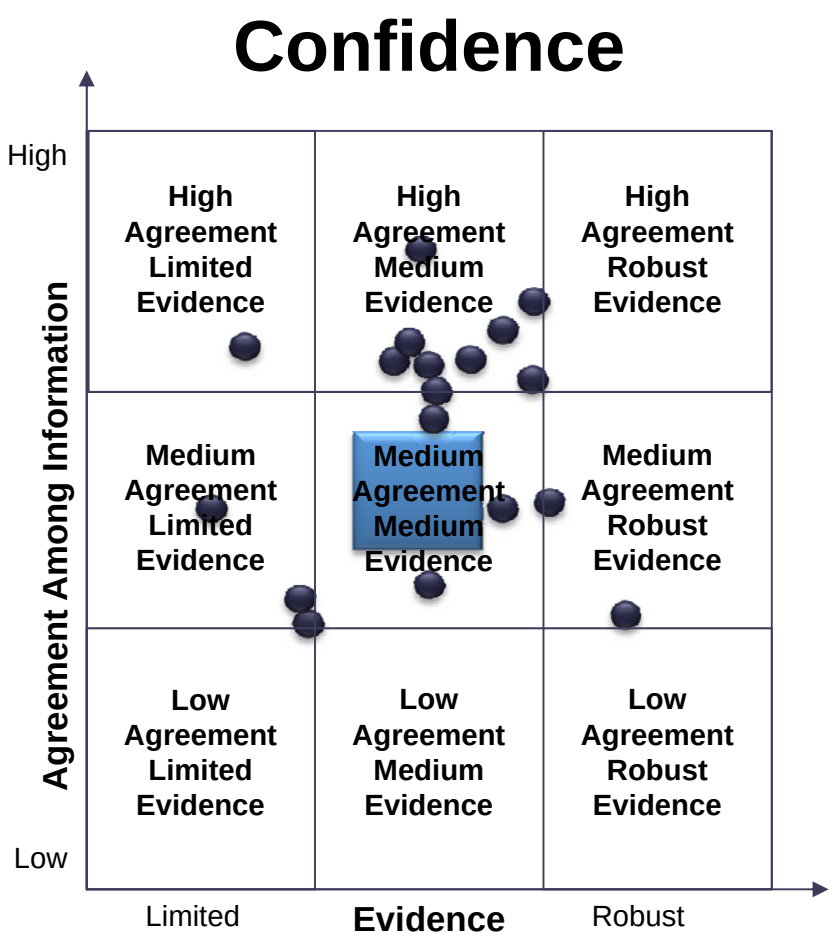
Red pine
Jack pine
Quaking aspen
Paper birch
White pine
Balsam fir
Black spruce

Threats:

- Fire suppression
- WP blister rust, RP shoot blight, armillaria
- Spruce budworm, jp budworm, tent caterpillar, wp tip weevil
- Deer herbivory
- Hazel

Fire-Dependent Forest





Mesic Hardwood Forest

Key Drivers:

- Mesic soils – consistent water and nutrients
- Small canopy gaps – wind, disease, etc
- Large-scale windthrow or fire uncommon
- Constrained by cold temperatures

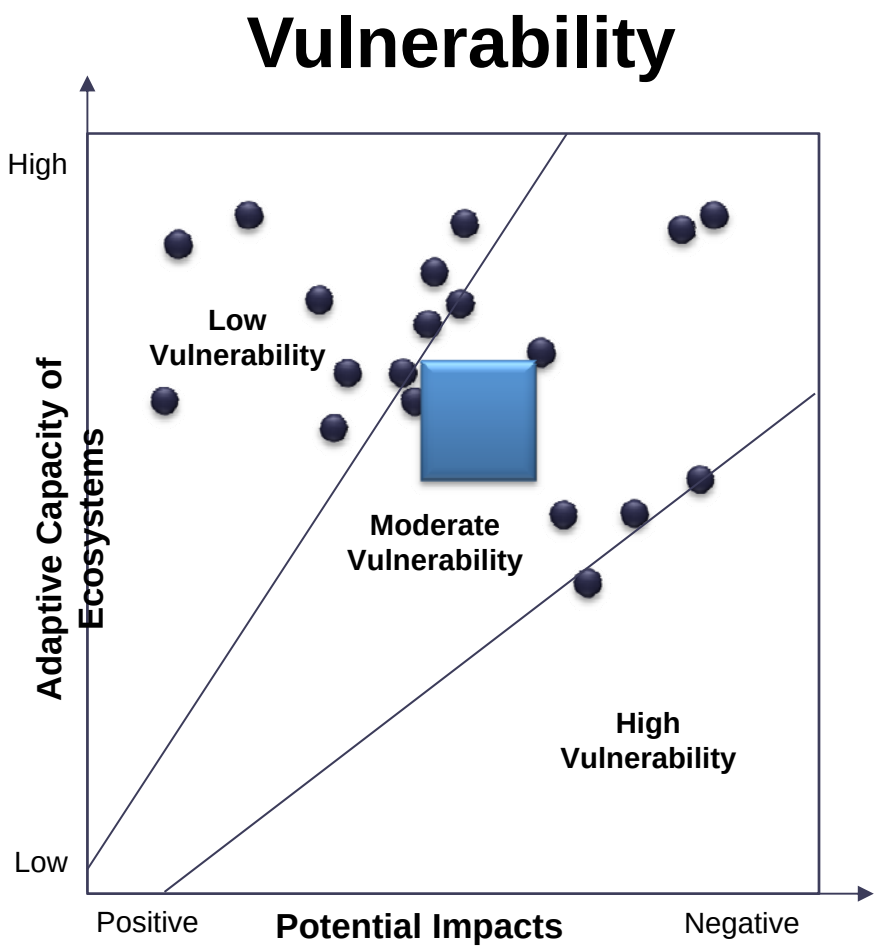
Dominant Species:

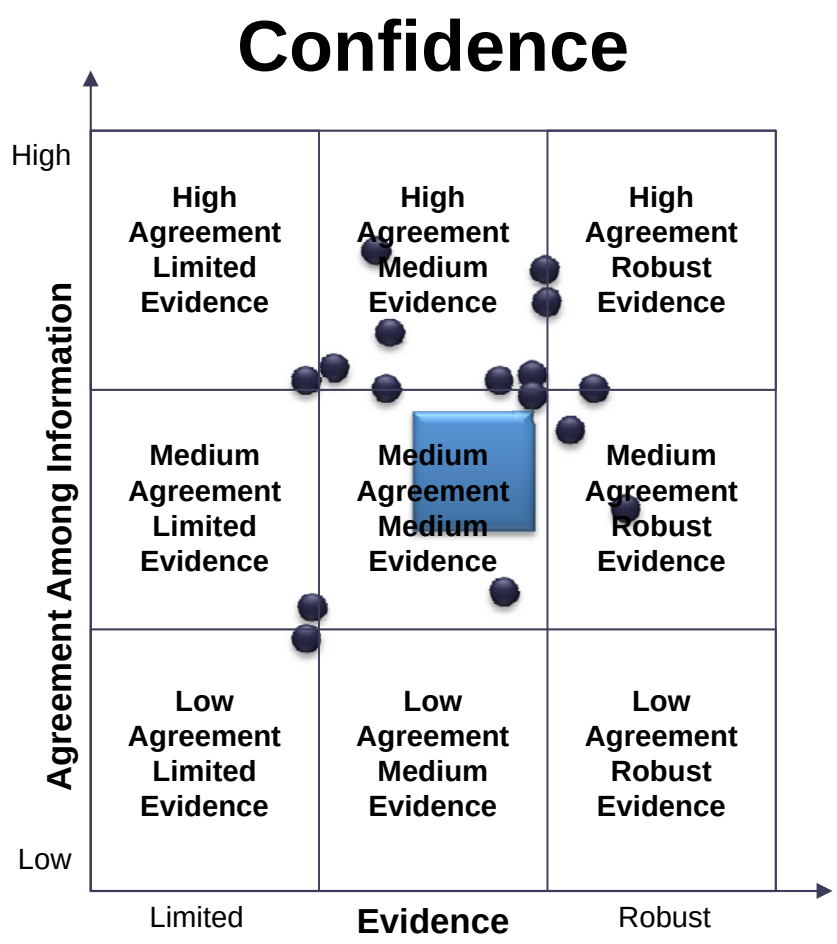
Sugar maple	Bur oak
Basswood	Green ash
Paper birch	Black ash
Quaking aspen	Yellow birch
Northern red oak	White cedar
Red maple	White spruce

Threats:

- Deer herbivory
- Exotic species
- Insect pests
- Earthworms
- Drought
- Root frost

Mesic Hardwood Forest





Floodplain Forest

Key Drivers:

- Terraces or floodplains of rivers and streams
- Silt or sand alluvium
- Occasional or annual flooding, ice damage, erosion

Dominant Species:

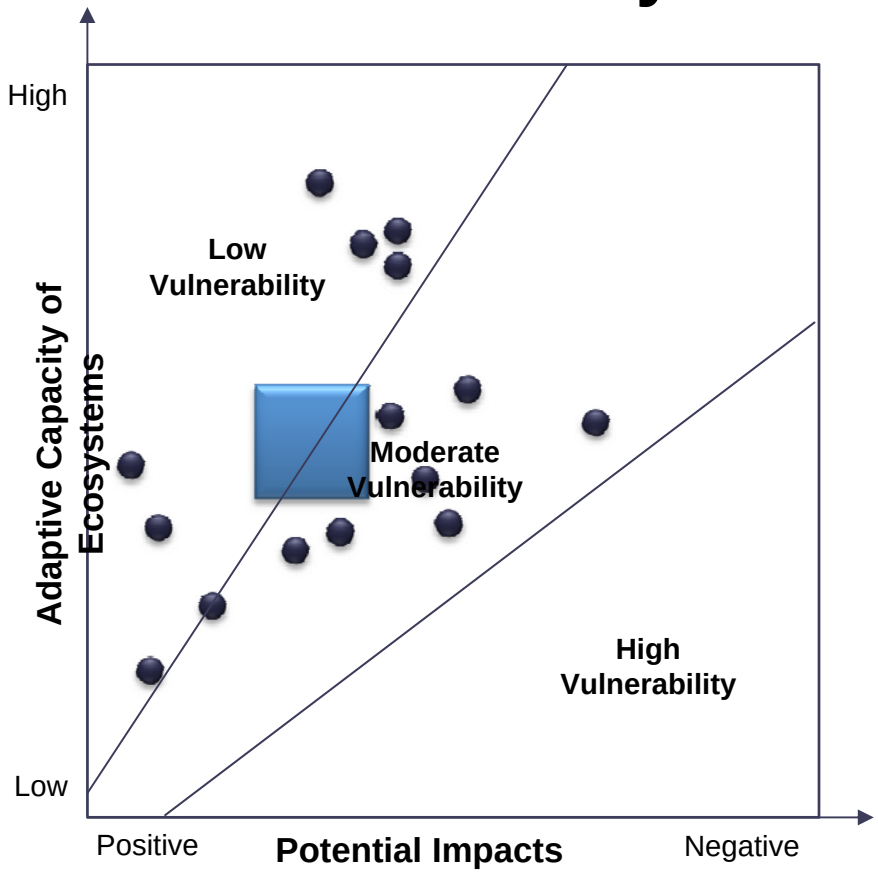
Silver maple
Black ash
Green ash
Black willow
American elm
Basswood
Cottonwood

Threats:

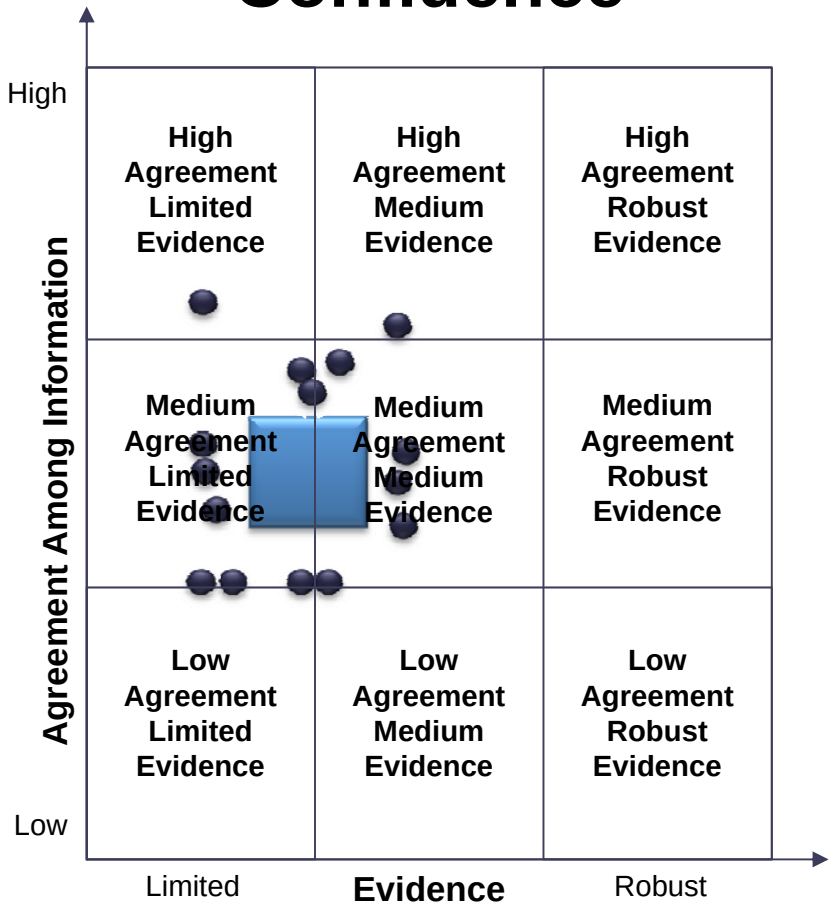
- Invasive species
- Flood regime changes
- Deer herbivory
- Erosion/ sedimentation changes

Floodplain Forest

Vulnerability



Confidence



Wet Forest

Key Drivers:

- Wet mineral soils, nutrient rich
- Saturated seasonally, flooding
- Dry periods for establishment
- Deeper soil layers saturated & anaerobic

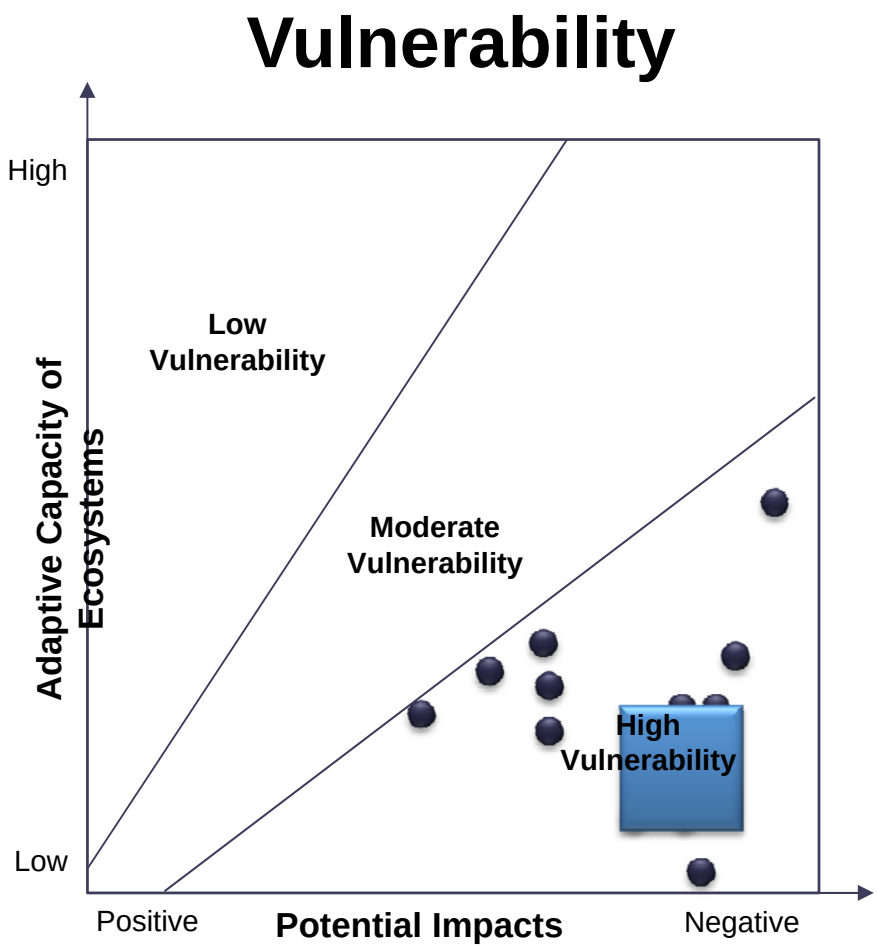
Dominant Species:

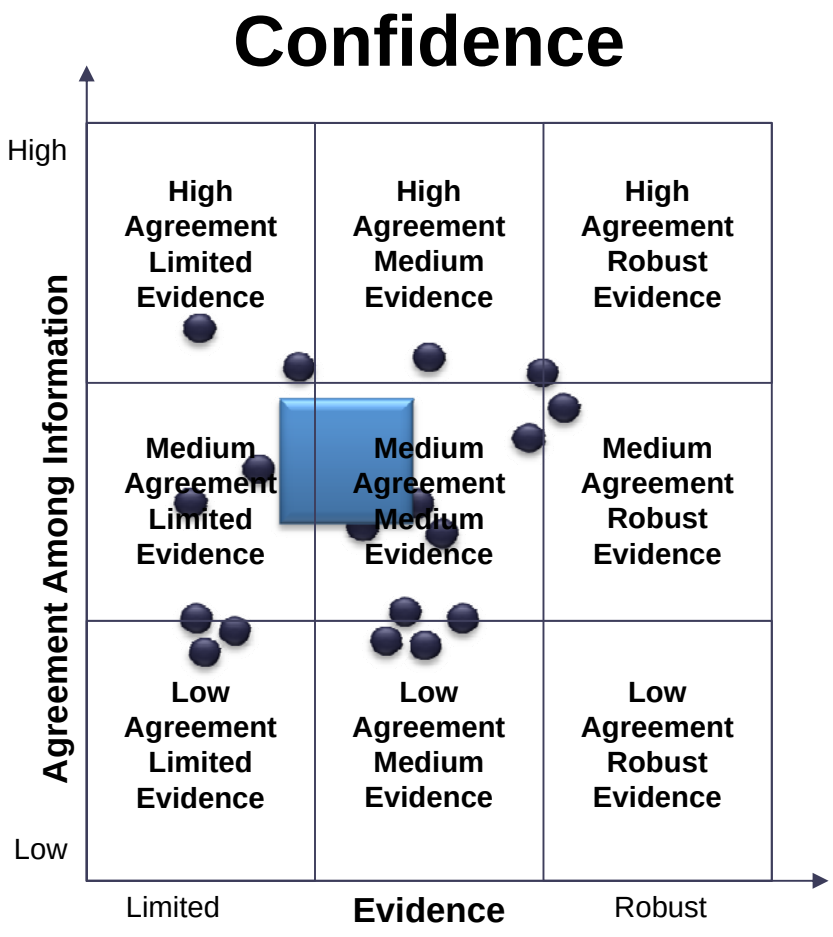
Black ash
White cedar
Balsam fir
Balsam poplar
Red maple
Black spruce

Threats:

- Black ash decline
- Invasive plants
- Excessive drought or waterlogging
- Insect pests (spruce budworm, EAB and gypsy moth)

Wet Forest


Vulnerability
High
Low
Low Vulnerability
Moderate Vulnerability
High Vulnerability
Adaptive Capacity of Ecosystems
Positive
Potential Impacts
Negative


Confidence
High
Low
High Agreement Limited Evidence
High Agreement Medium Evidence
High Agreement Robust Evidence
Medium Agreement Limited Evidence
Medium Agreement Medium Evidence
Medium Agreement Robust Evidence
Low Agreement Limited Evidence
Low Agreement Medium Evidence
Low Agreement Robust Evidence
Agreement Among Information
Limited
Evidence
Robust

Forested Rich Peatland

Key Drivers:

- Deep, actively forming peat
- Saturated, anaerobic soils
- Lower water table than open peatlands
- Moisture through groundwater and precip

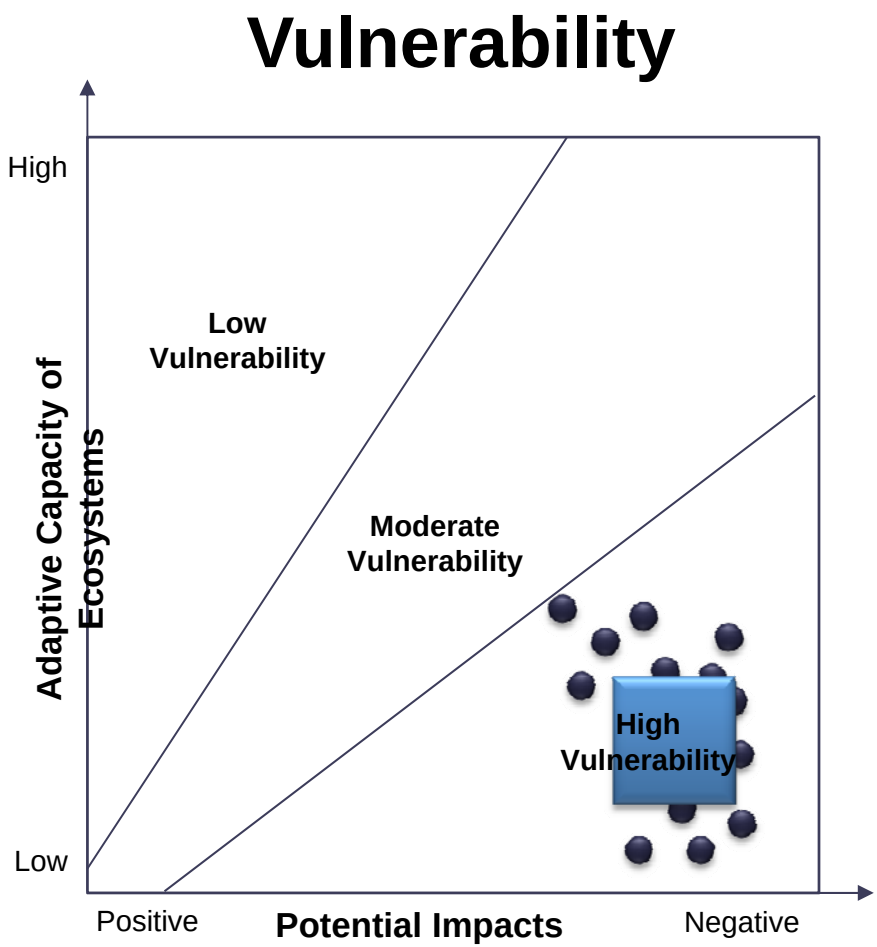
Dominant Species:

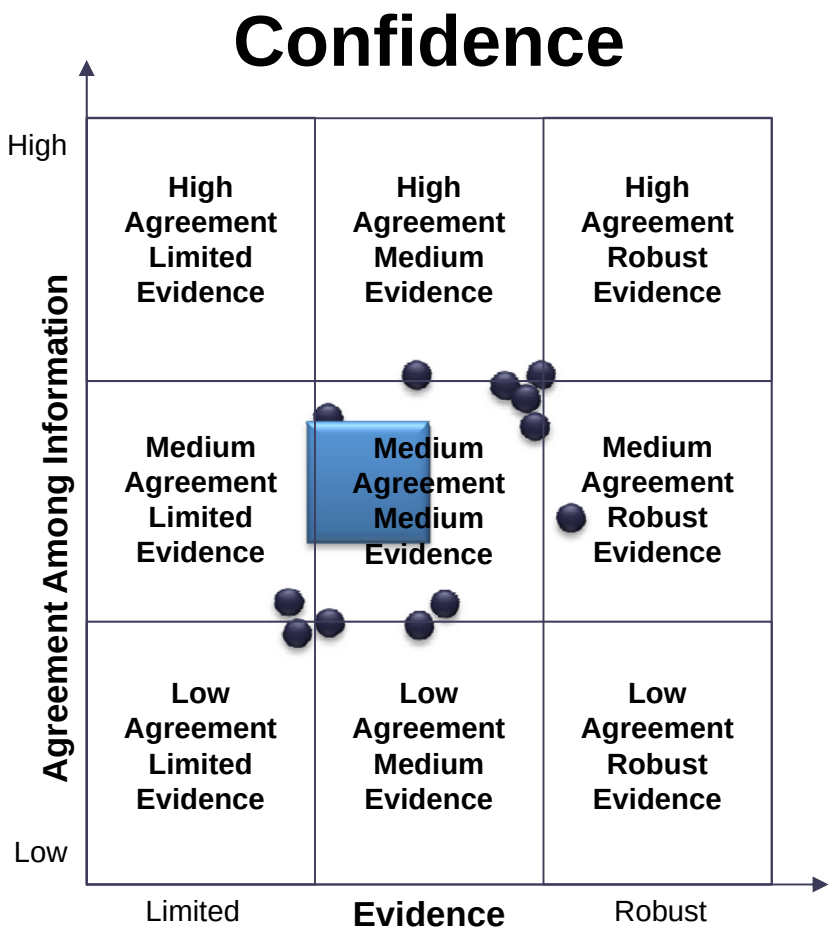
Tamarack
Black spruce
Paper birch
Balsam fir
White spruce
Red maple
Yellow birch

Threats:

- Changes to flood regime – timing and water level
- Road building/draining
- Mistletoe
- Tamarack sawfly
- Winter burn

Forested Rich Peatland





Acid Peatland

Key Drivers:

- Deep, actively forming peat
- Saturated, anaerobic soils
- Lower water table than open peatlands
- Moisture through precip only
- More acidic and FRP
- Smaller and more isolated, but more common than FRP

Dominant Species:

Tamarack

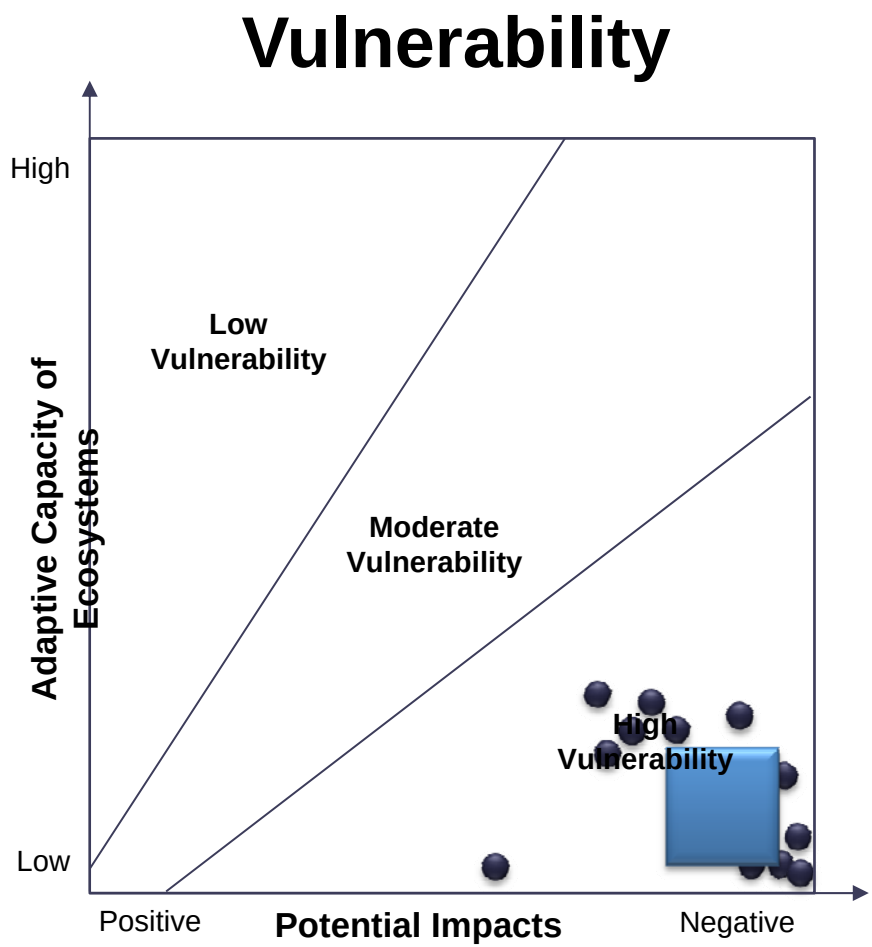
Black spruce

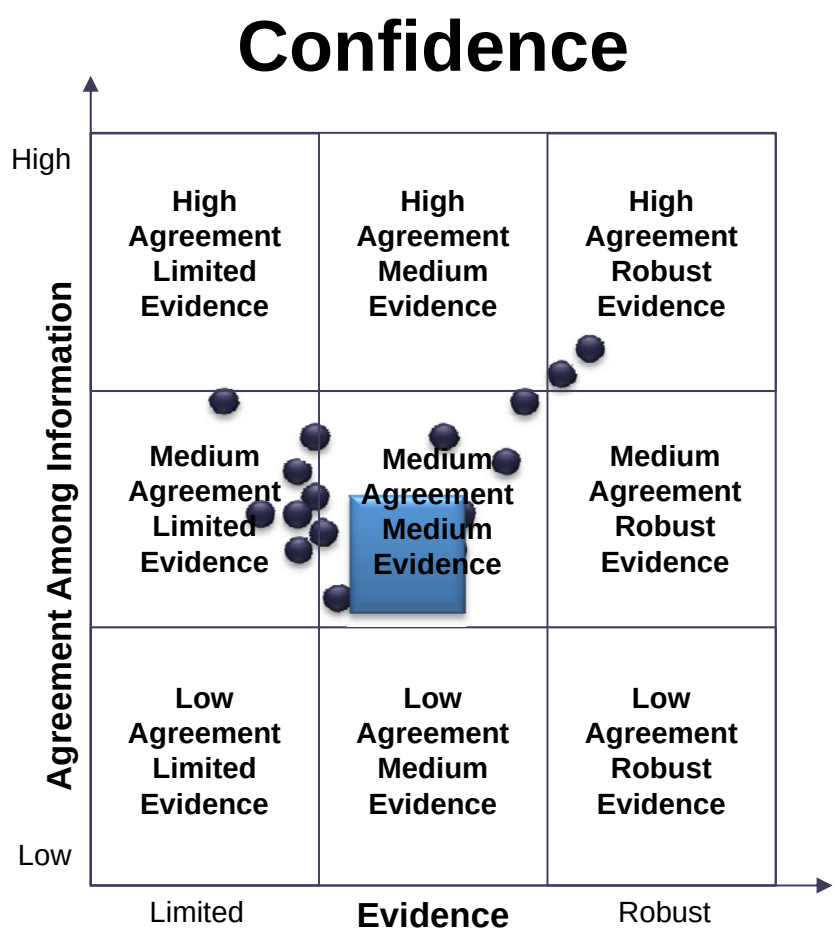
Bog birch

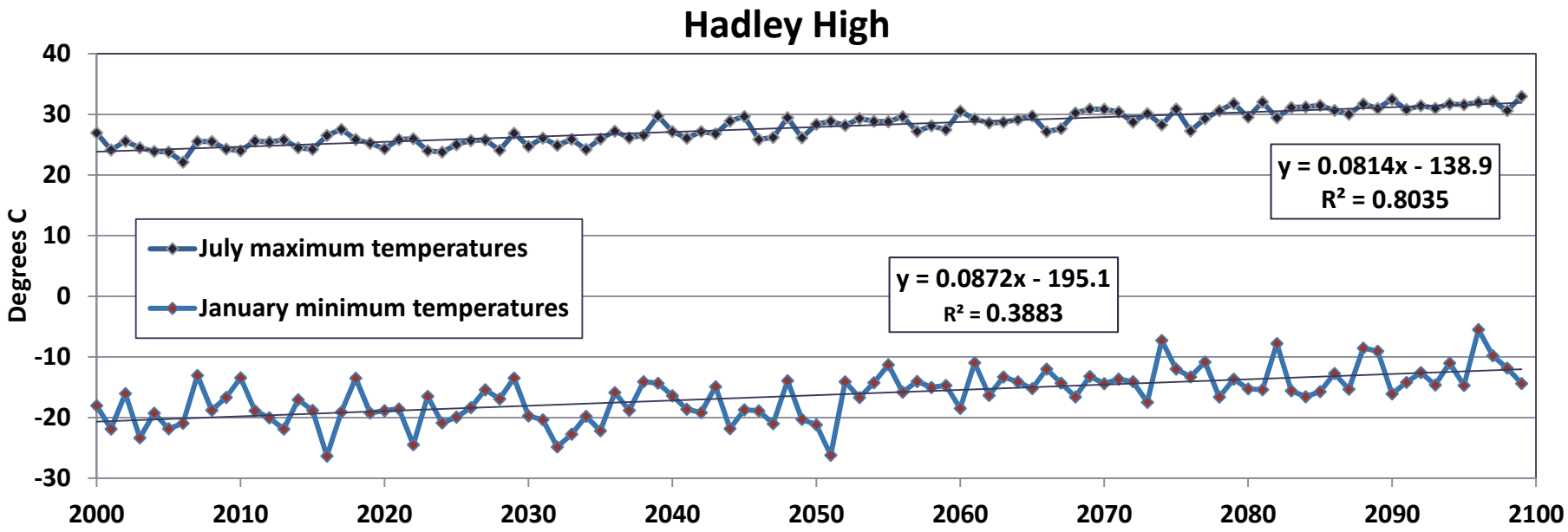
Threats:

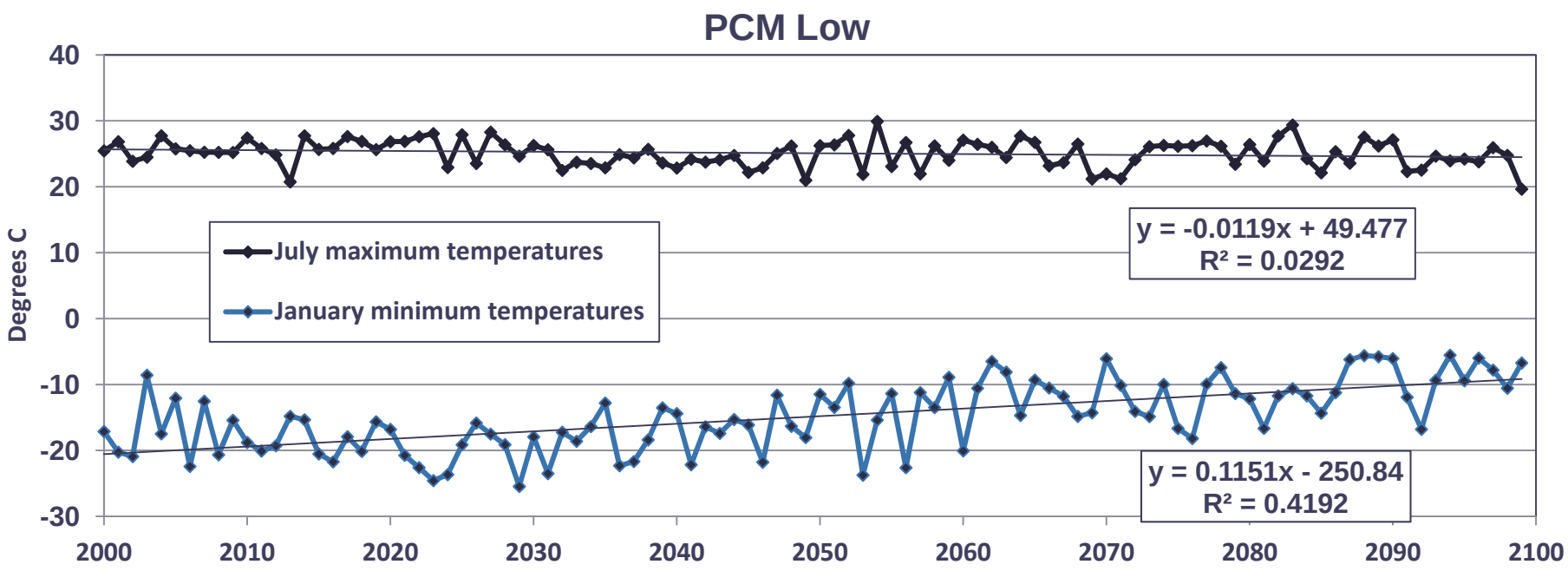
- Changes to flood regime – timing and water level
- Road building/draining
- Mistletoe
- Tamarack sawfly
- Winter burn

Acid Peatland






Hadley High
Degrees C
40
30
20
10
0
-10
-20
-30
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
July maximum temperatures
January minimum temperatures
y = 0.0814x - 138.9
R² = 0.8035
y = 0.0872x - 195.1
R² = 0.3883


PCM Low
Degrees C
40
30
20
10
0
-10
-20
-30
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
July maximum temperatures
January minimum temperatures
y = -0.0119x + 49.477
R² = 0.0292
y = 0.1151x - 250.84
R² = 0.4192