Landscape Change in the Upper Great Lakes Region Since European Settlement

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Landscapes are made up of interacting local ecosystems

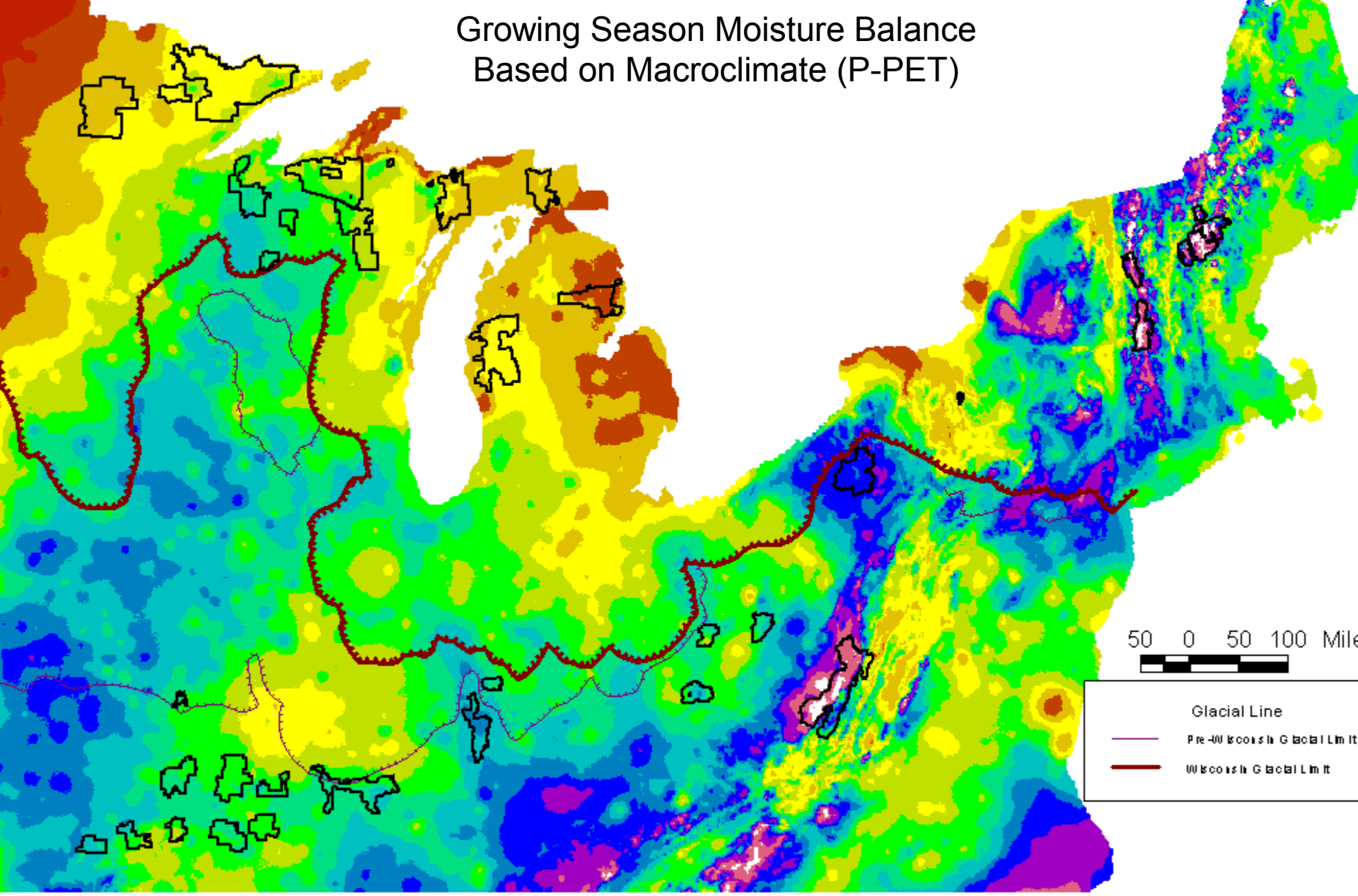
Ecosystem distribution, structure, and function

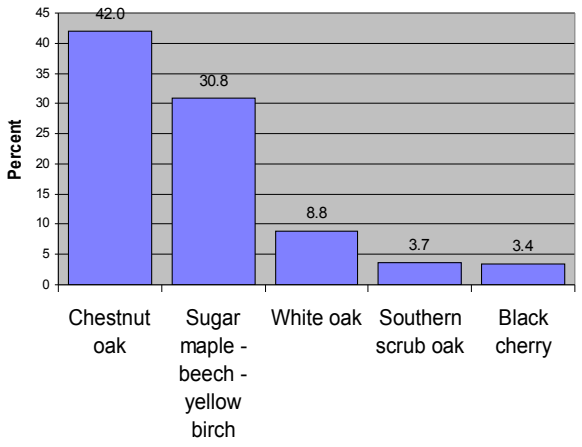
are determined by interactions among biotic & abiotic factors, including:

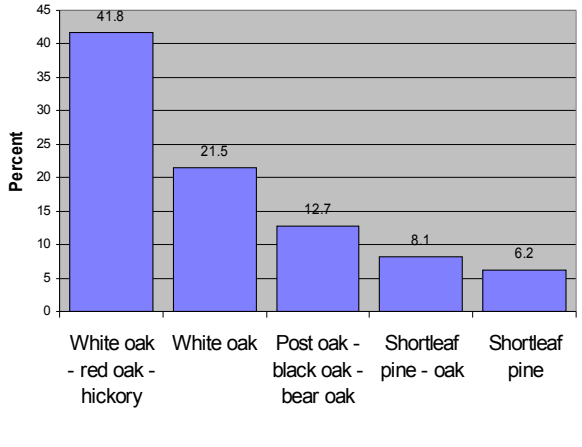
- climate
- landform
- soils
- biotic-mediated processes
- natural & anthropogenic disturbance regimes

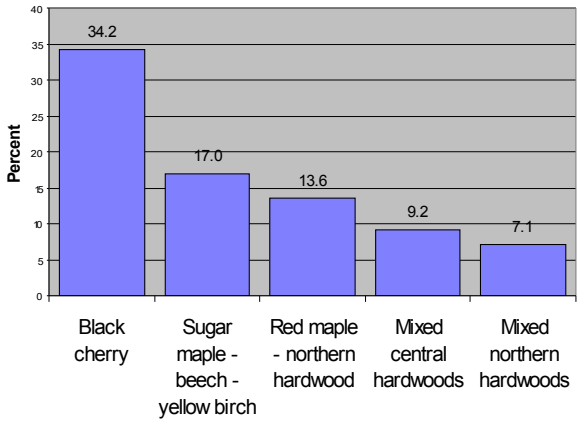
These factors change at different spatial & temporal scales, and, while the association of multiple factors is important in understanding ecosystems, not all factors are equally important at all spatial scales.

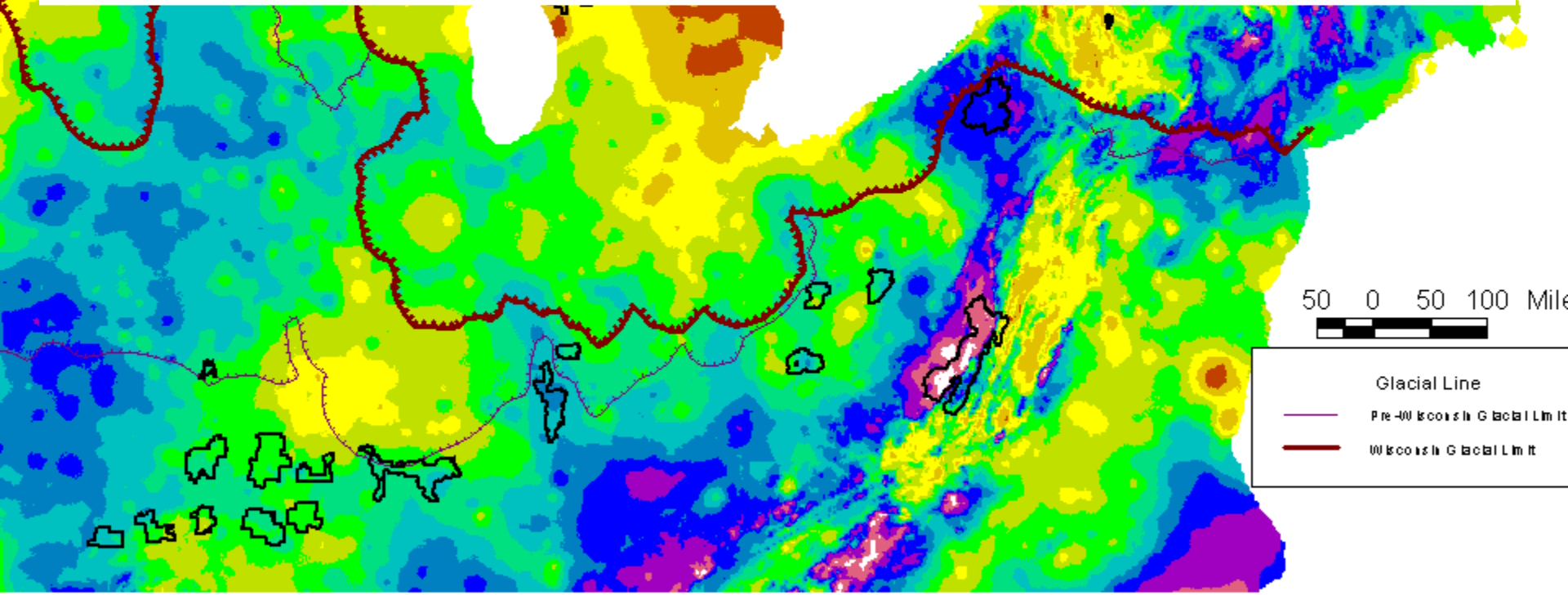
Growing Season Moisture Balance
Based on Macroclimate (P-PET)

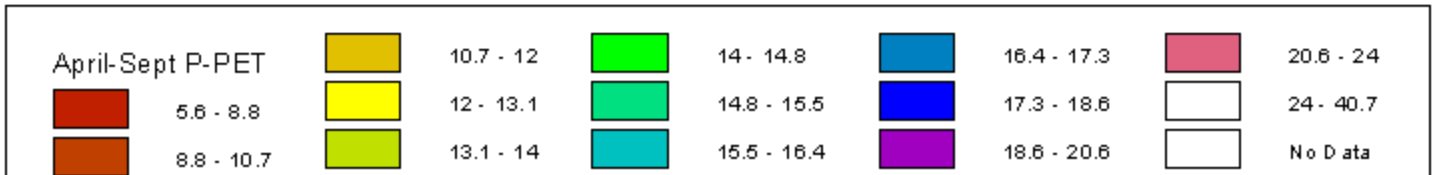


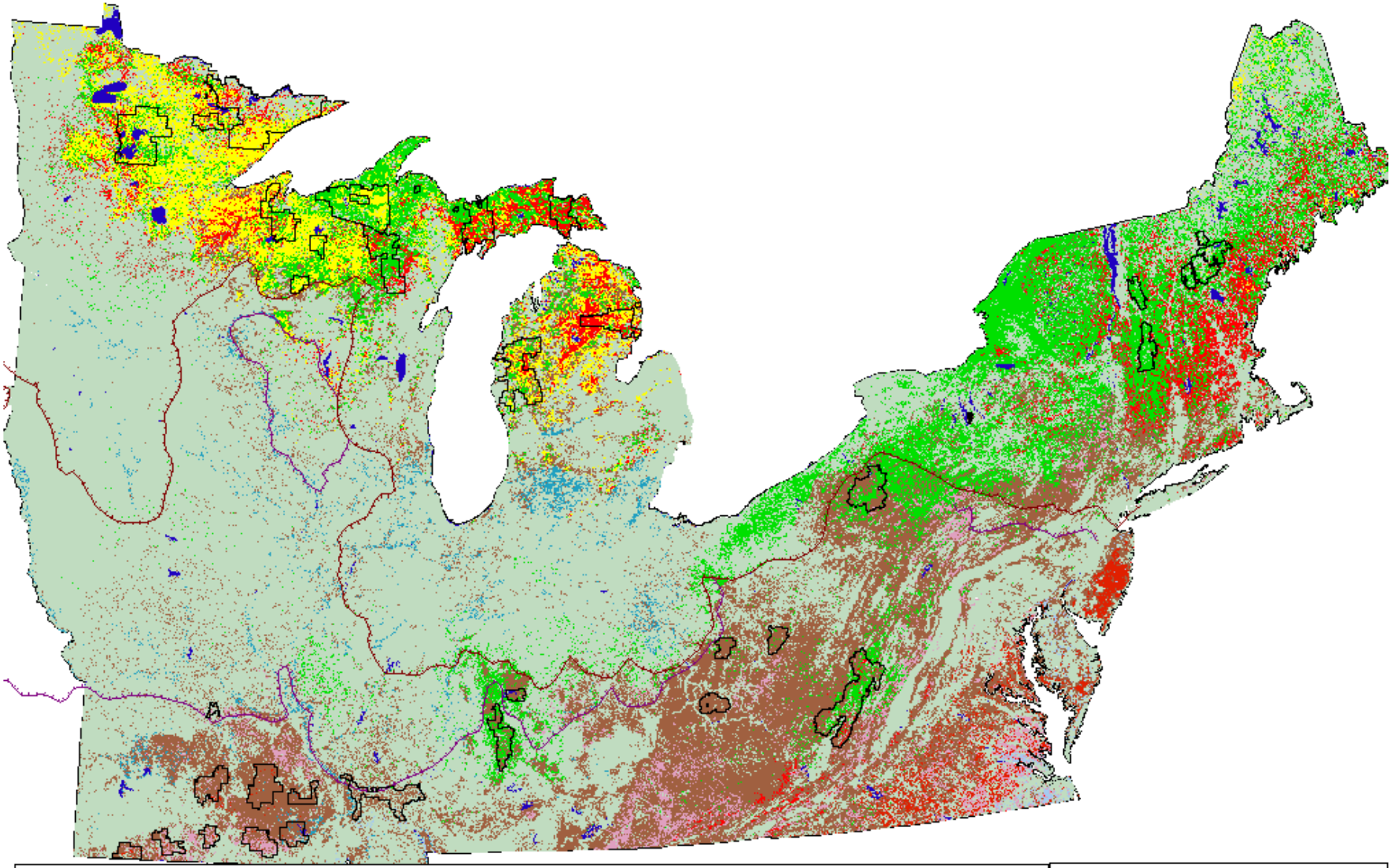

FIA Estimates - Hoosier NF
Percent
42.0
30.8
8.8
3.7
3.4
Chestnut oak
Sugar maple - beech - yellow birch
White oak
Southern scrub oak
Black cherry


FIA Estimates - Mark Twain NF
Percent
41.8
21.5
12.7
8.1
6.2
White oak - red oak - hickory
White oak
Post oak - black oak - bear oak
Shortleaf pine - oak
Shortleaf pine

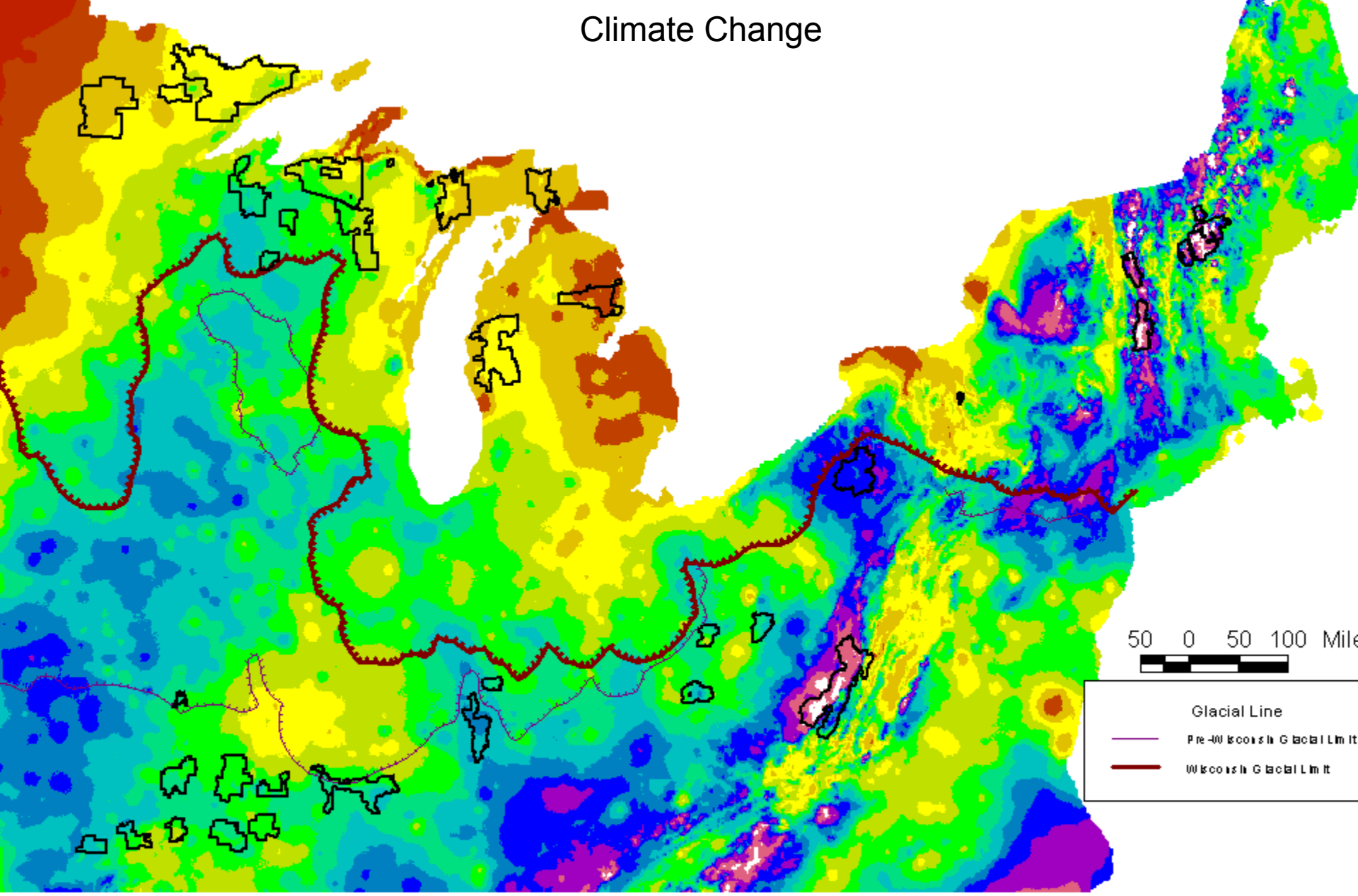

FIA Estimates - Allegheny NF
Percent
34.2
17.0
13.6
9.2
7.1
Black cherry
Sugar maple - beech - yellow birch
Red maple - northern hardwood
Mixed central hardwoods
Mixed northern hardwoods


50 0 50 100 Mile
Glacial Line
Pre-Wisconsin Glacial Limit
Wisconsin Glacial Limit


April-Sept P-PET
5.6 - 8.8
8.8 - 10.7
10.7 - 12
12 - 13.1
13.1 - 14
14 - 14.8
14.8 - 15.5
15.5 - 16.4
16.4 - 17.3
17.3 - 18.6
18.6 - 20.6
20.6 - 24
24 - 40.7
No Data


AVHRR
Aspen-birch
Elm-ash-cottonwood
Loblolly-shortleaf pine
Longleaf-slash pine
Maple-beech-birch
Nonforest
Oak-gum-cypress
Oak-hickory
Oak-pine
Spruce-fir
Water
White-red-jack pine
Glacial Line
Pre-Wisconsin Glacial Limit
Wisconsin Glacial Limit
50 0 50 100 Miles

Climate Change

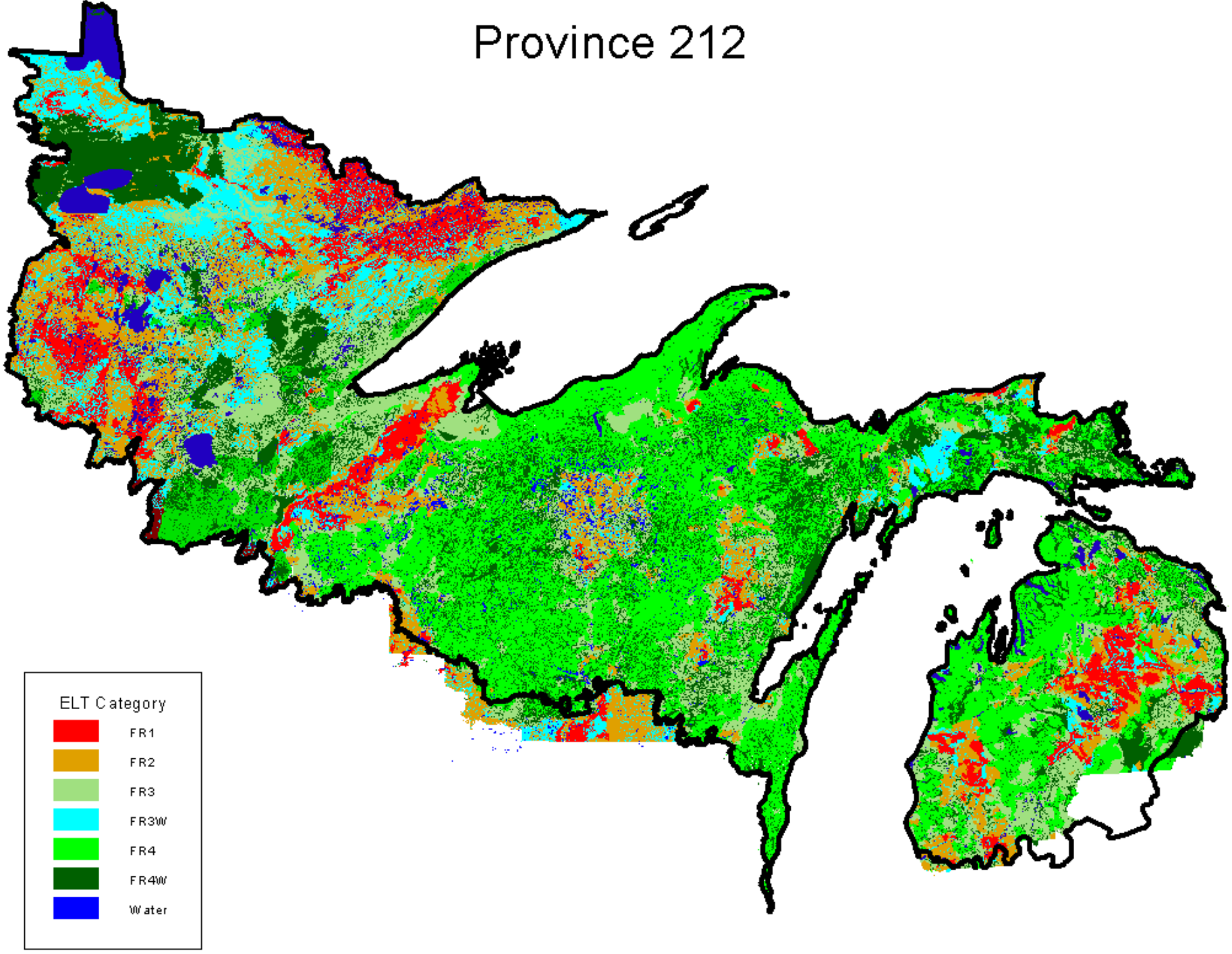



Fire-resistant moist-mesic morainal ecosystems
Moderately fire-prone dry-mesic ice-contact ecosystems
Highly fire-prone xeric outwash ecosystems

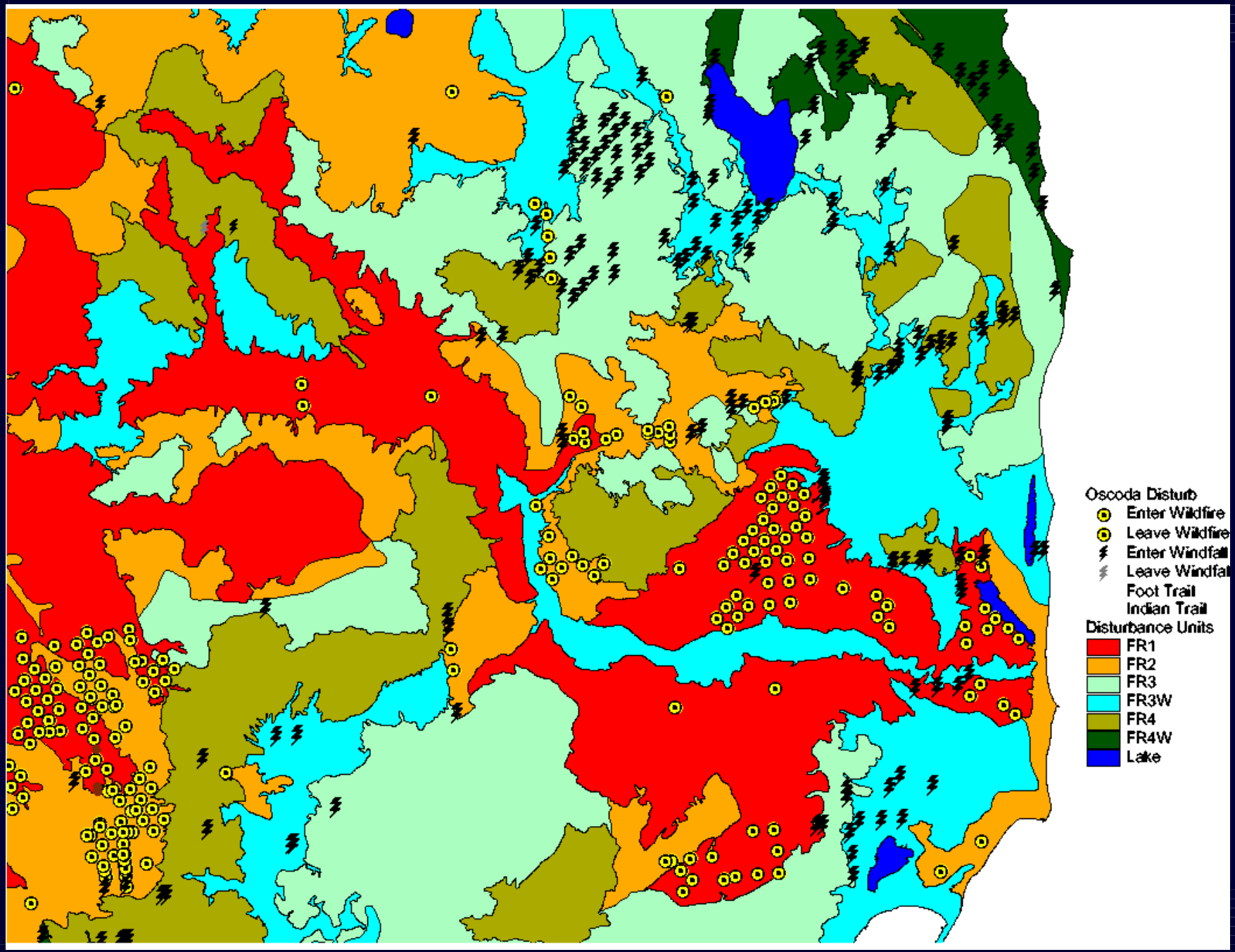
Landscape Ecosystem Forest Replacement (FR) Fire Regime Classes

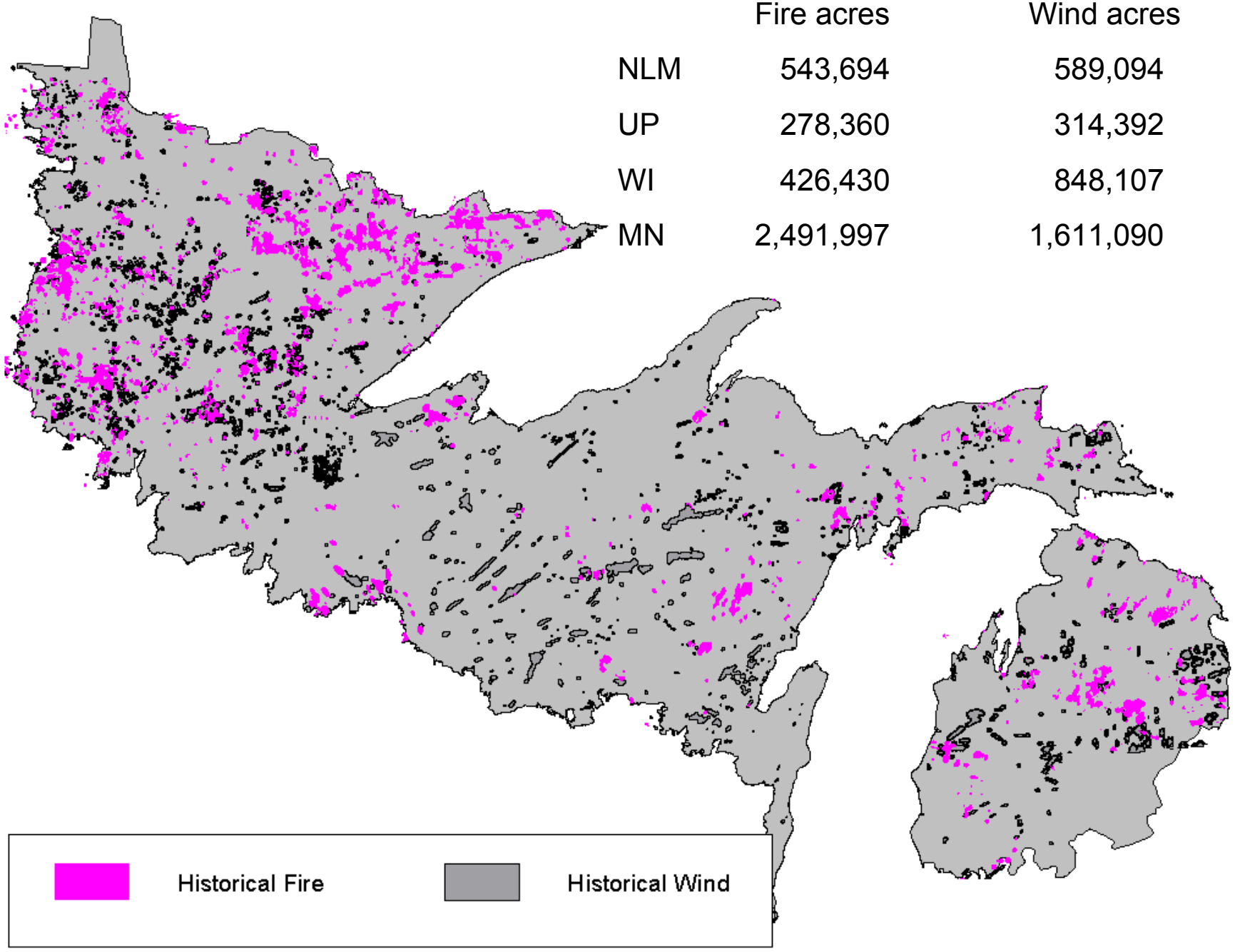
	Typical Landform/Soils	Disturbance Regime	Historic Forest Type
FR1	Very dry, flat outwash plains, sandy soils	Very frequent, large, catastrophic stand-replacing fires	Jack pine, mixed jack-red pine, barrens, savannas
FR2	Dry outwash plains & ice-contact landforms, sandy & loamy sand soils	Frequent surface fires and large, catastrophic stand-replacing fires	White-red pine and mixed red-white-jack pine
FR3	Ice-contact and glacial lakebed landforms, loamy sand to silt loam soils	Relatively infrequent stand-replacing fires	Mixed hemlock-white pine, hemlock-white pine-spruce-fir
FR3W	Poorly & very poorly drained wetlands embedded within or adjacent to fire-prone landscapes	Relatively frequent stand-replacing or community maintenance fires	Wetland conifers (tamarack, spruce, hemlock, cedar)
FR4	Mesic moraines, fine-textured loamy to heavy clay loam soils	Very infrequent stand-replacing or community maintenance fires; fires often assoc. with large-scale severe wind events	Northern hardwood, hardwood-hemlock
FR4W	Wetlands embedded within or adjacent to fire-resistant landscapes (FR4)	Very infrequent stand-replacing or community maintenance fires	Wetland hardwood-conifer (cedar, hemlock, black & gree ash, silver maple, elm)

Province 212

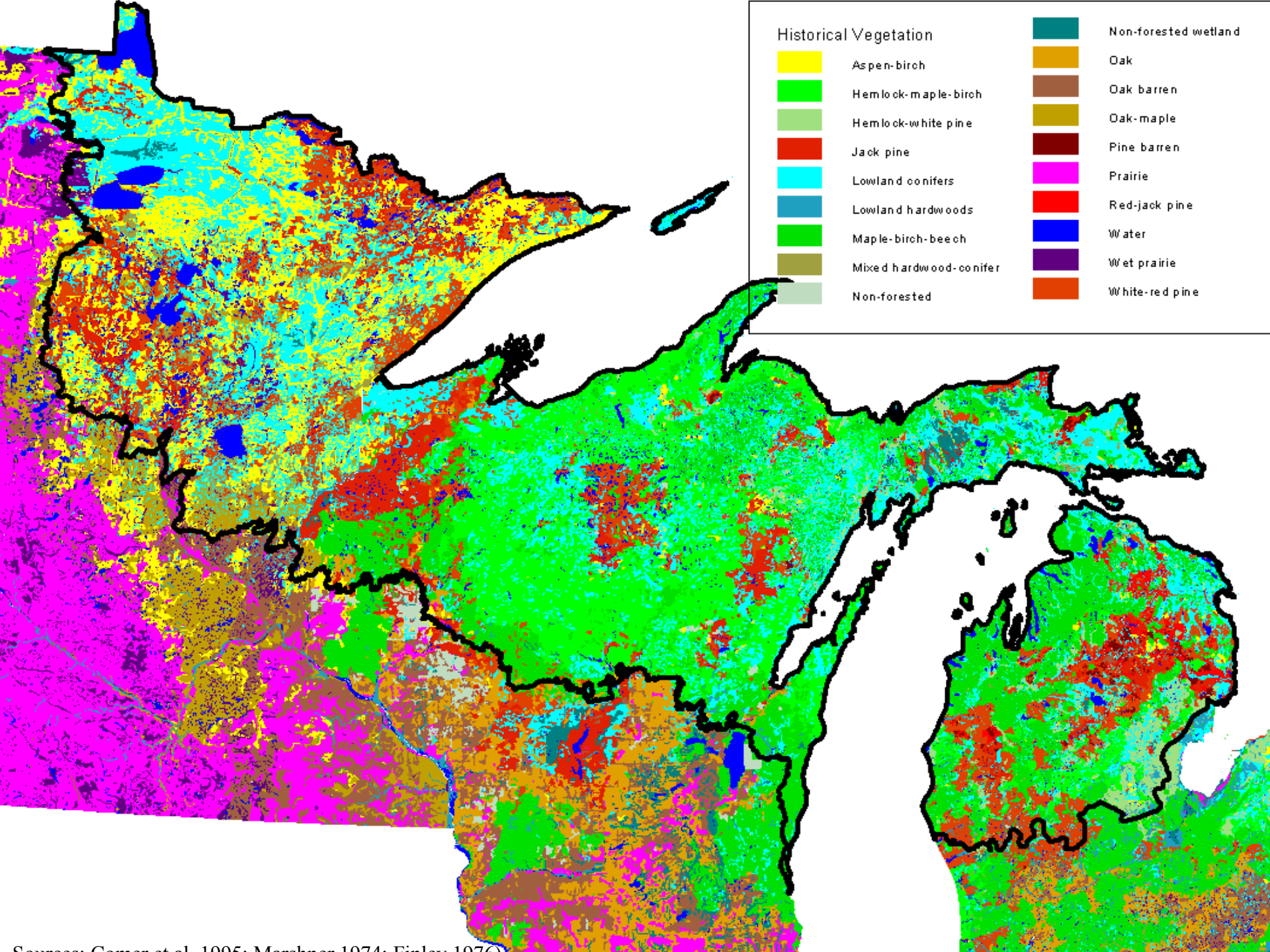


Historical Fire and Wind Locations – Oscoda, Alcona Co, MI (an example)





	Fire acres	Wind acres
NLM	543,694	589,094
UP	278,360	314,392
WI	426,430	848,107
MN	2,491,997	1,611,090



Sources: Comer et al. 1995; Marshner 1974; Finley 1976)

Comparison of Modern and Historical Forest Fire Rotations In Michigan and Wisconsin

Historic Fires	Landscape Ecosystem	NLM Rotation	UP Rotation	WI Rotation
FR1	Xeric LTA's dominated by jack pine and barrens	62	66	62
FR2	Less xeric LTA's dominated by white-red pine	130	170	153
FR3W	Wetland LTA's adjacent to fire-prone LTA's	148	111	246
FR3	Dry-mesic LTA's dominated by hemlock-white pine	520	310	525
FR4	Mesic LTA's dominated by northern hardwoods	1,225	1,871	2,303
FR4W	Wetland LTA's adjacent to mesic hardwood LTA's	738	690	1,873
Total	Study Area Total	271	571	664
	15 year recognition window			
Modern Fires	Landscape Ecosystem	NLM Rotation	UP Rotation	WI Rotation
FR1	Xeric LTA's dominated by jack pine and barrens	870	596	4,350
FR2	Less xeric LTA's dominated by white-red pine	1,162	5,796	8,771
FR3W	Wetland LTA's adjacent to fire-prone LTA's	7,192	2,753	9,931
FR3	Dry-mesic LTA's dominated by hemlock-white pine	4,264	2,010	10,071
FR4	Mesic LTA's dominated by northern hardwoods	19,137	17,543	21,631
FR4W	Wetland LTA's adjacent to mesic hardwood LTA's	9,456	4,093	9,674
Total	Study Area Total	3,606	5,490	12,639
	16 year recognition window			

Landscape Composition

Historical Context

White pine logging began about 1836 and reached a peak between 1890 and 1910, by which time virtually all merchantable pine had been either cut or destroyed by fire.

During the white pine era, hemlock was cut heavily as a source of tannin for processing cow hides into leather, resulting in the extirpation of this species in many of today's forests.

Historical Context

In the mid-1890s, harvesting of hardwoods commenced, continuing into the 1930s, by which time 98% of the Lake States had been clearcut.

The impact of near-total deforestation was amplified by frequent and often catastrophic wildfires burning through slash, as well as smaller fires that were deliberately set to clear land, or started from railroad locomotives.

Historical Context

Due to this history:

Millions of acres formerly composed of flammable conifer species were converted to deciduous forest communities.

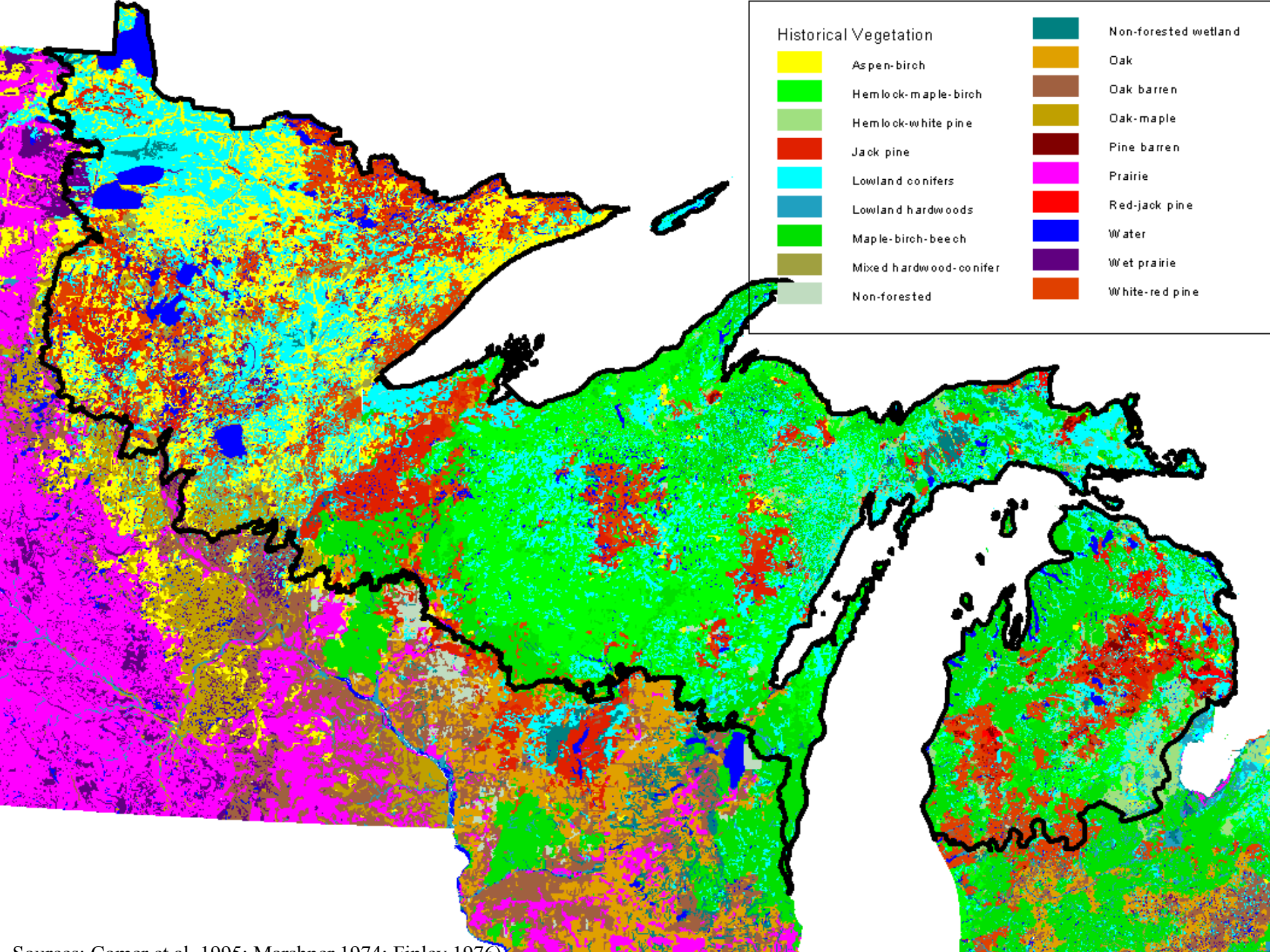
Landscape ecosystems too xeric to support these deciduous communities, or those repeatedly burned, remained unforested due to the absence of seed sources.

Abandoned farms established on infertile sands also remained unforested.

Many of these landscape ecosystems were replanted during the 1930s by the Civilian Conservation Corps, often to the original fire-prone jack or red pine forests.

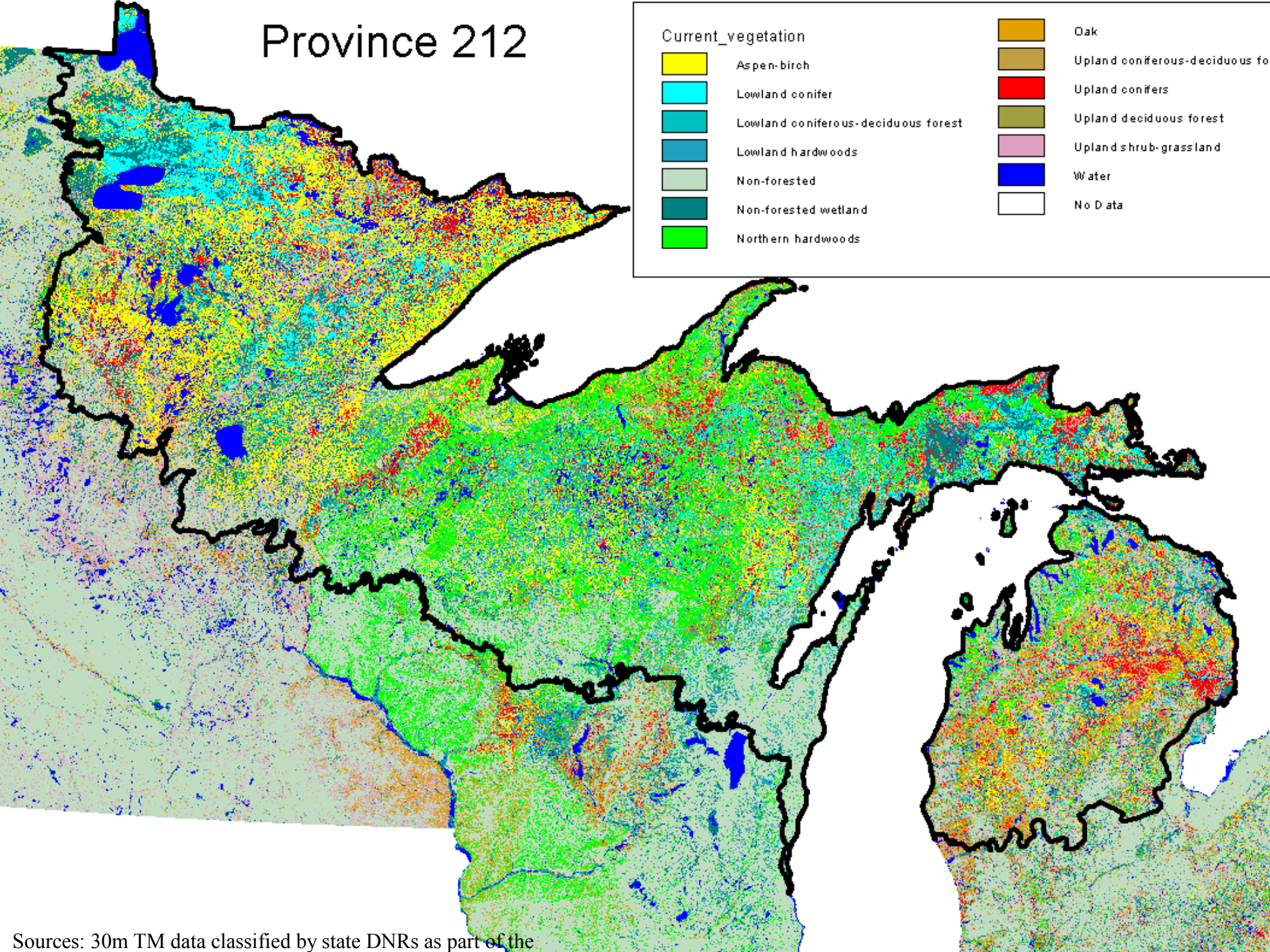
Historical Context

Fire suppression efforts during the past century have also led to a change in the composition and dynamics of fire-prone ecosystems.

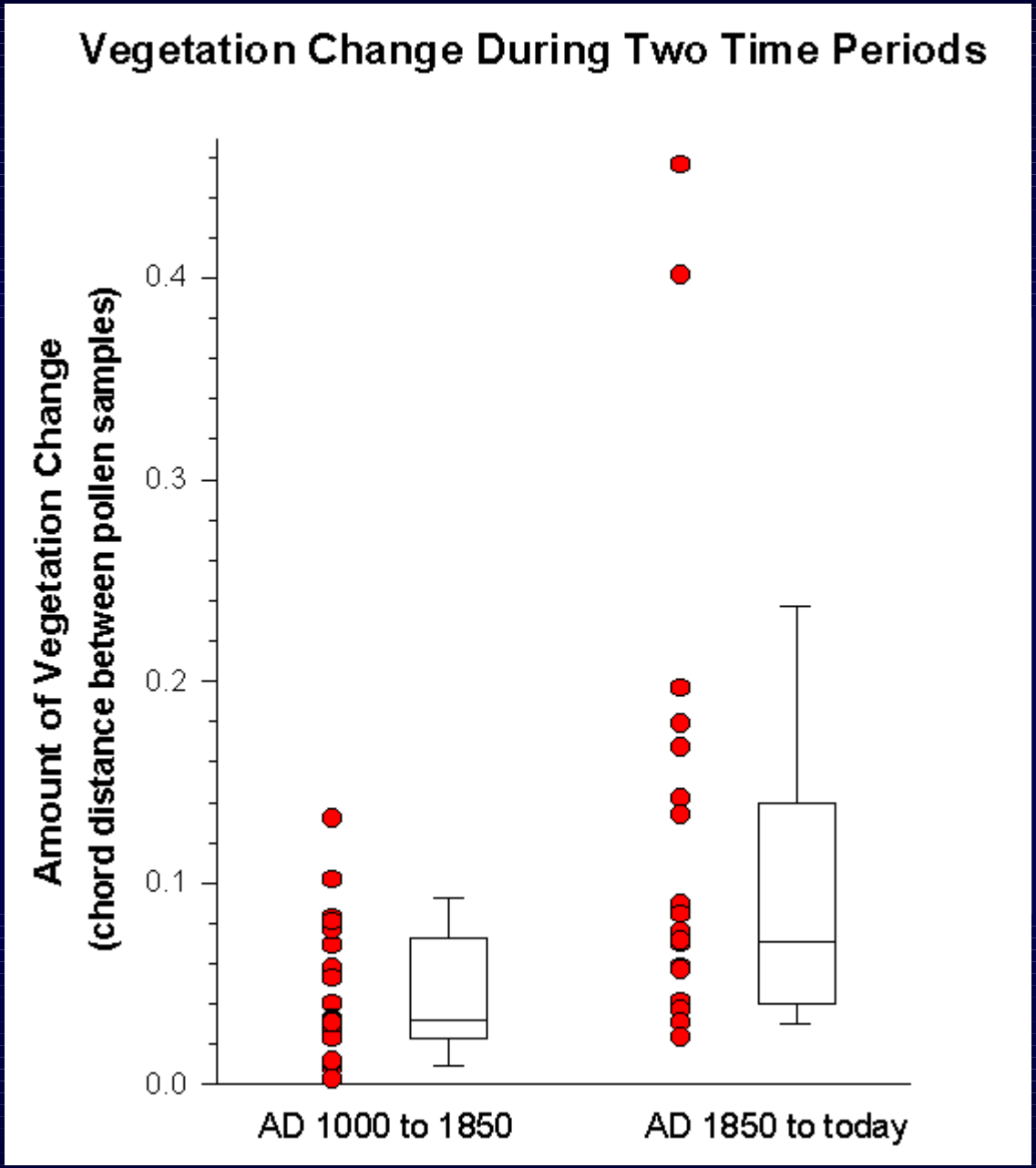


Sources: Comer et al. 1995; Marshner 1974; Finley 1976)

Province 212

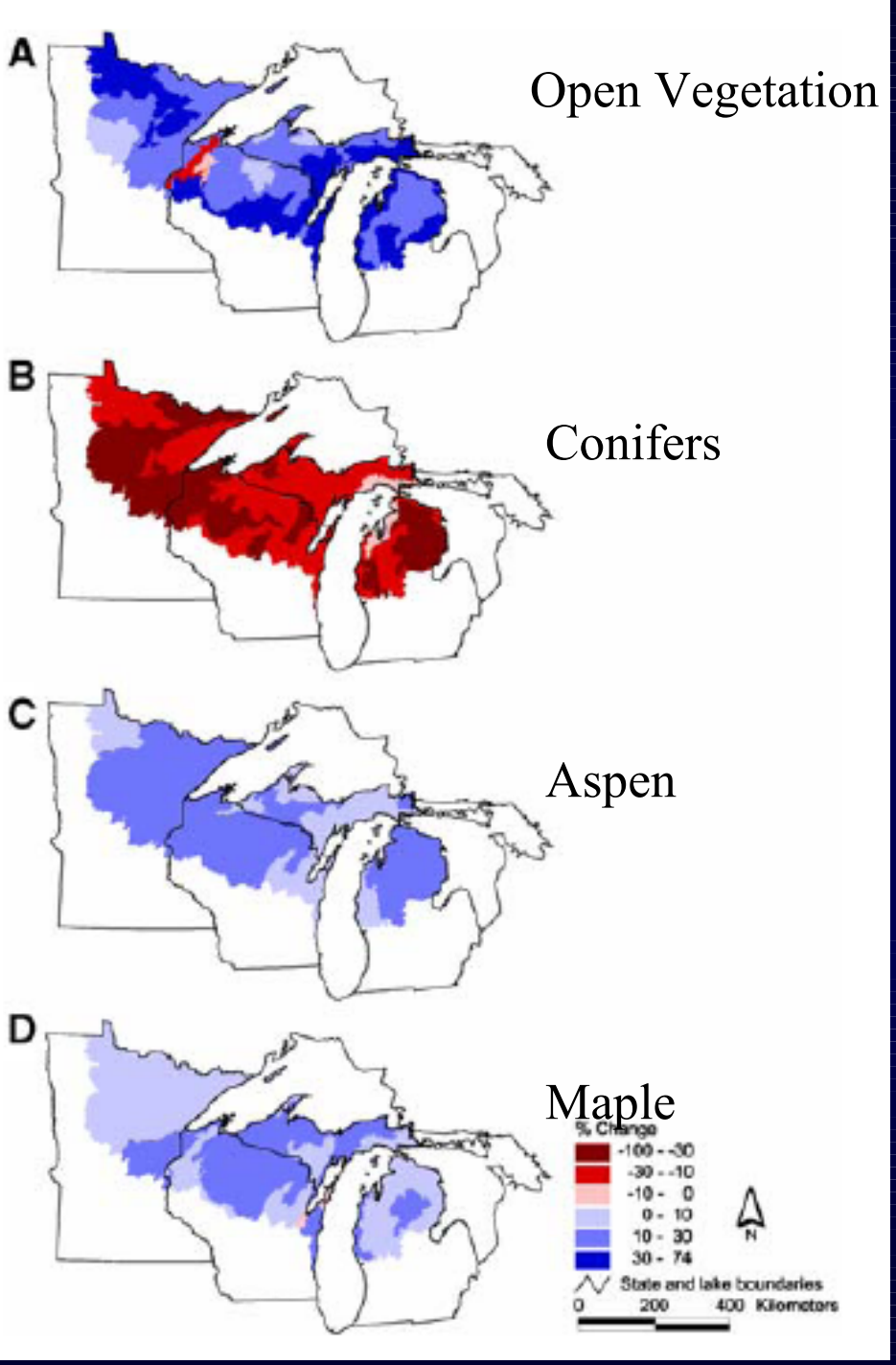


Sources: 30m TM data classified by state DNRs as part of the



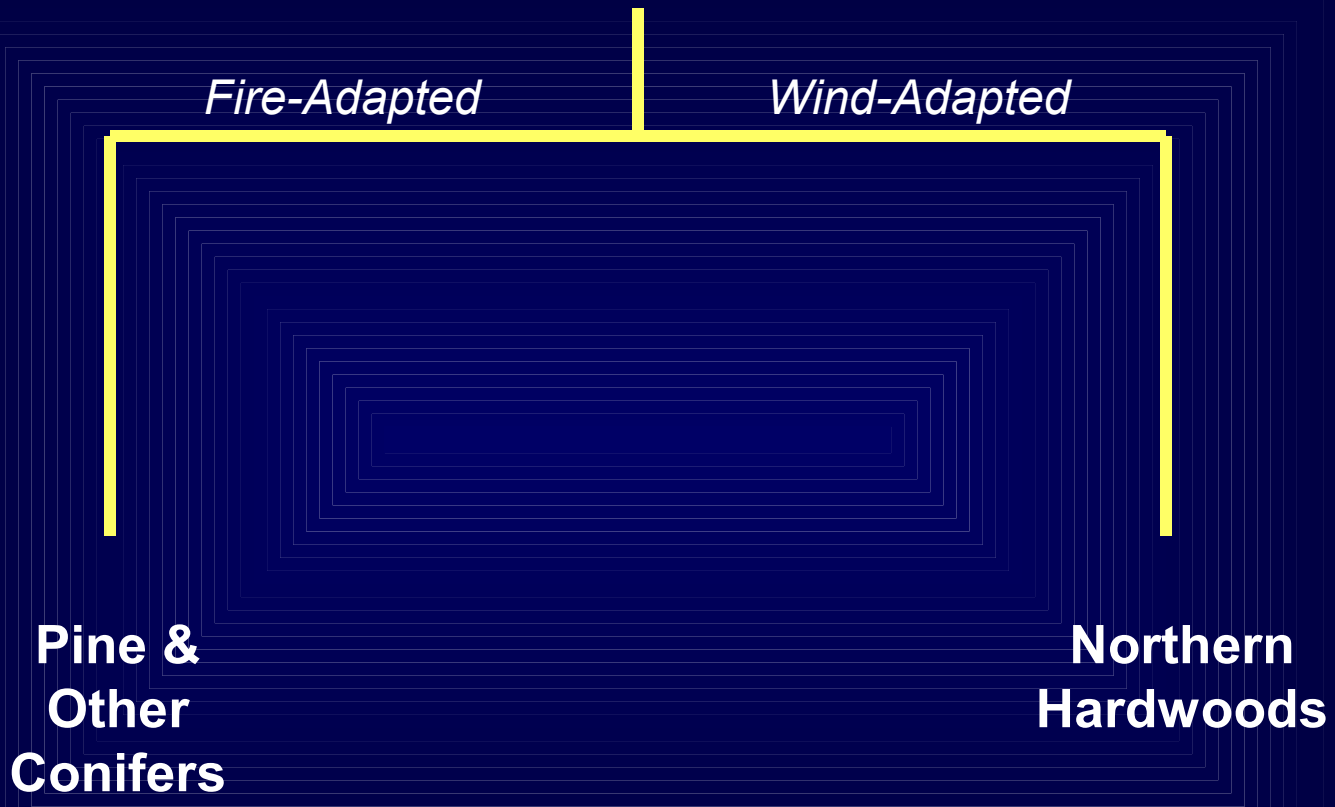
From: Cole et al. 1998. Historical landcover changes in the Great Lakes Region. Chapter 6 in: Land Use History of North America (LUHNA) (online), USGS. URL http://biology.usgs.gov/luhna

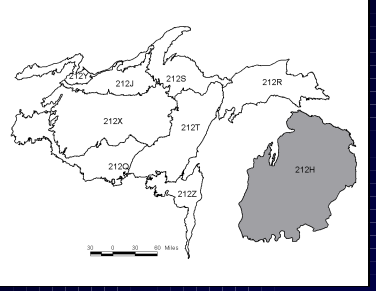
Vegetation Change (pre-Euro to present)



From: Schulte, L..A. et al. 2007. Homogenization of northern U.S. Great Lakes forests due to land use. Landsc. Ecol. 22: 1089-1103.

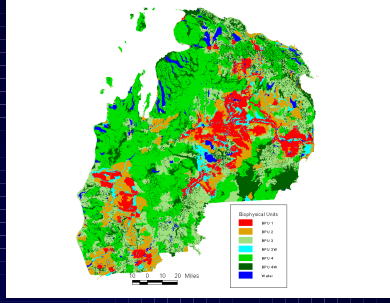
“Maple-ization”



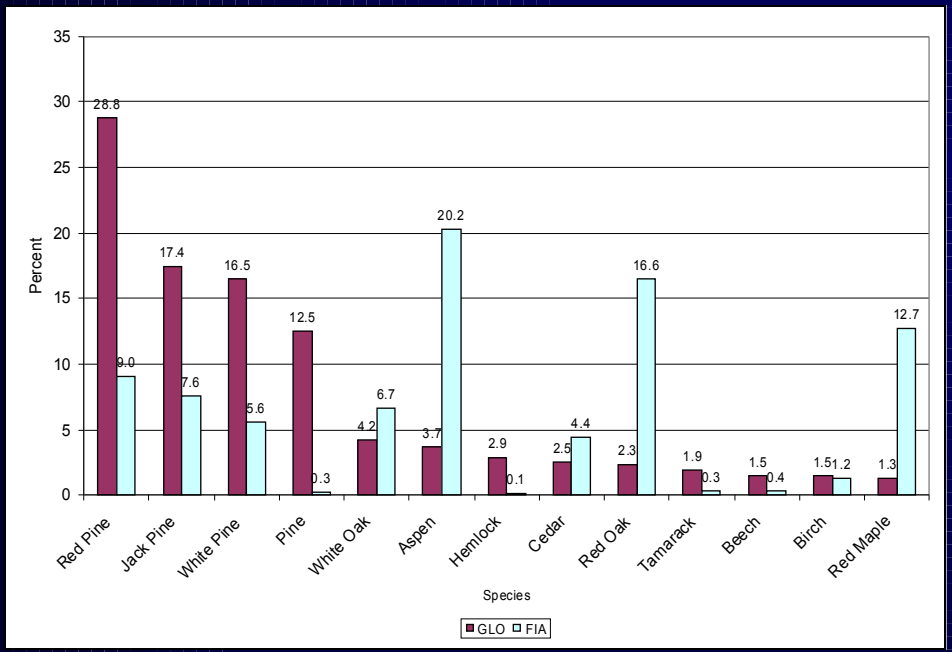


GLO - FIA Comparison

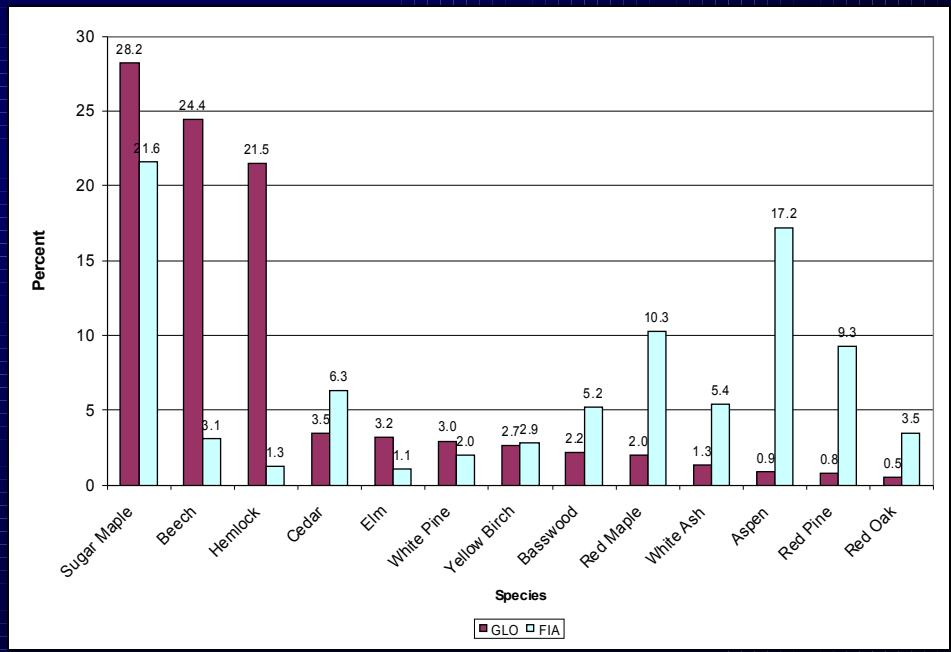
(Northern Lower Michigan)

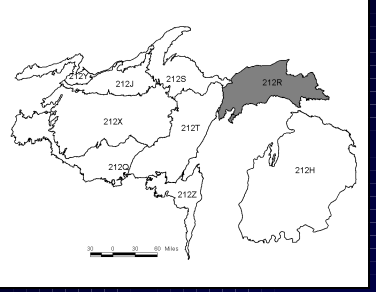


FR2 (fire-prone pine)



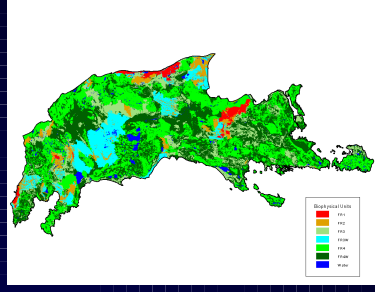
FR4 (mesic n. hardwoods)



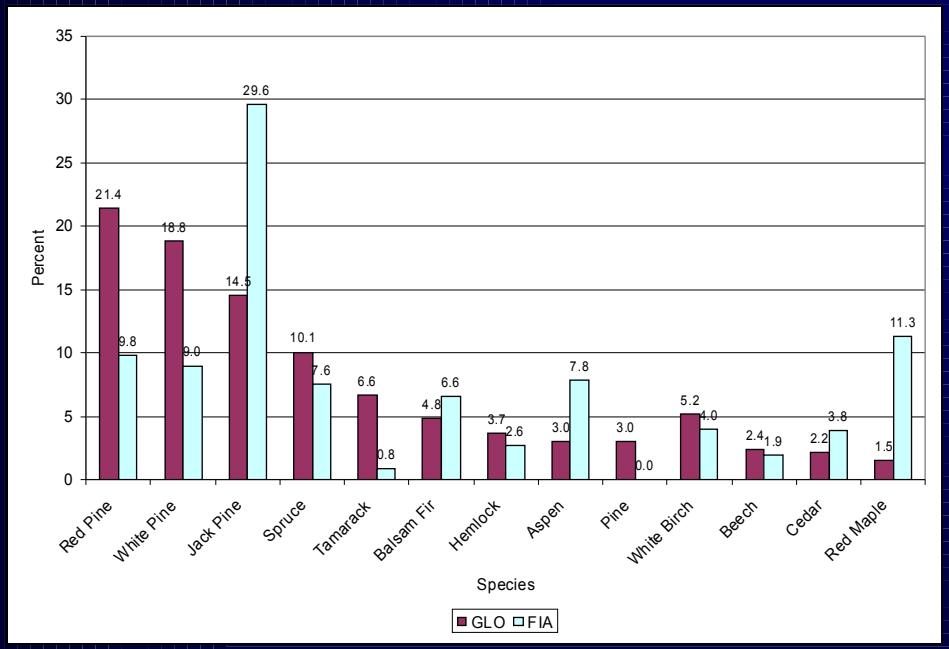


GLO - FIA Comparison

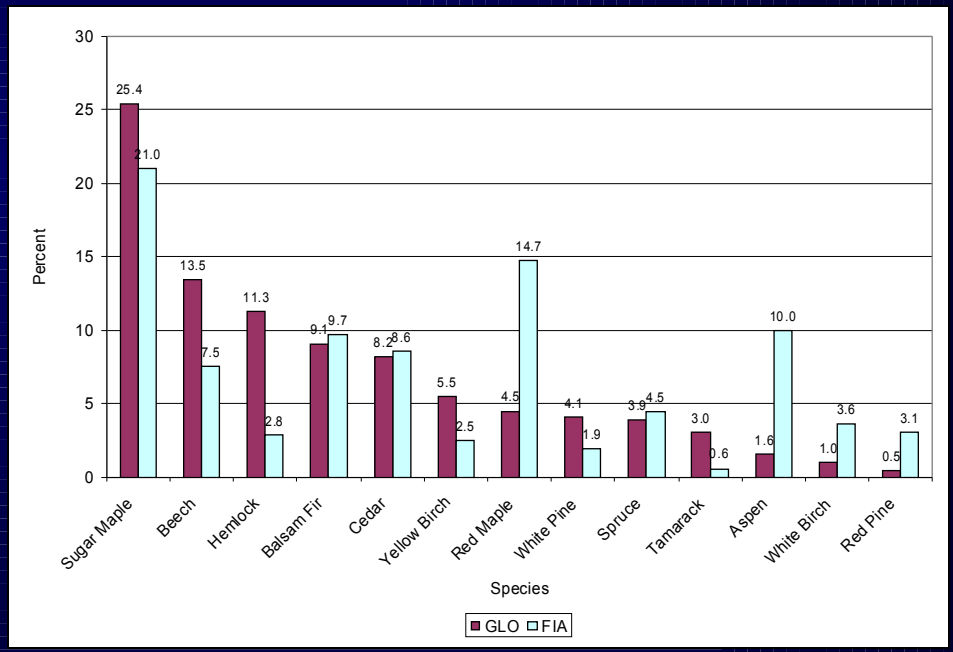
(Eastern Upper Peninsula)



FR2 (fire-prone pine)



FR4 (mesic n. hardwoods)



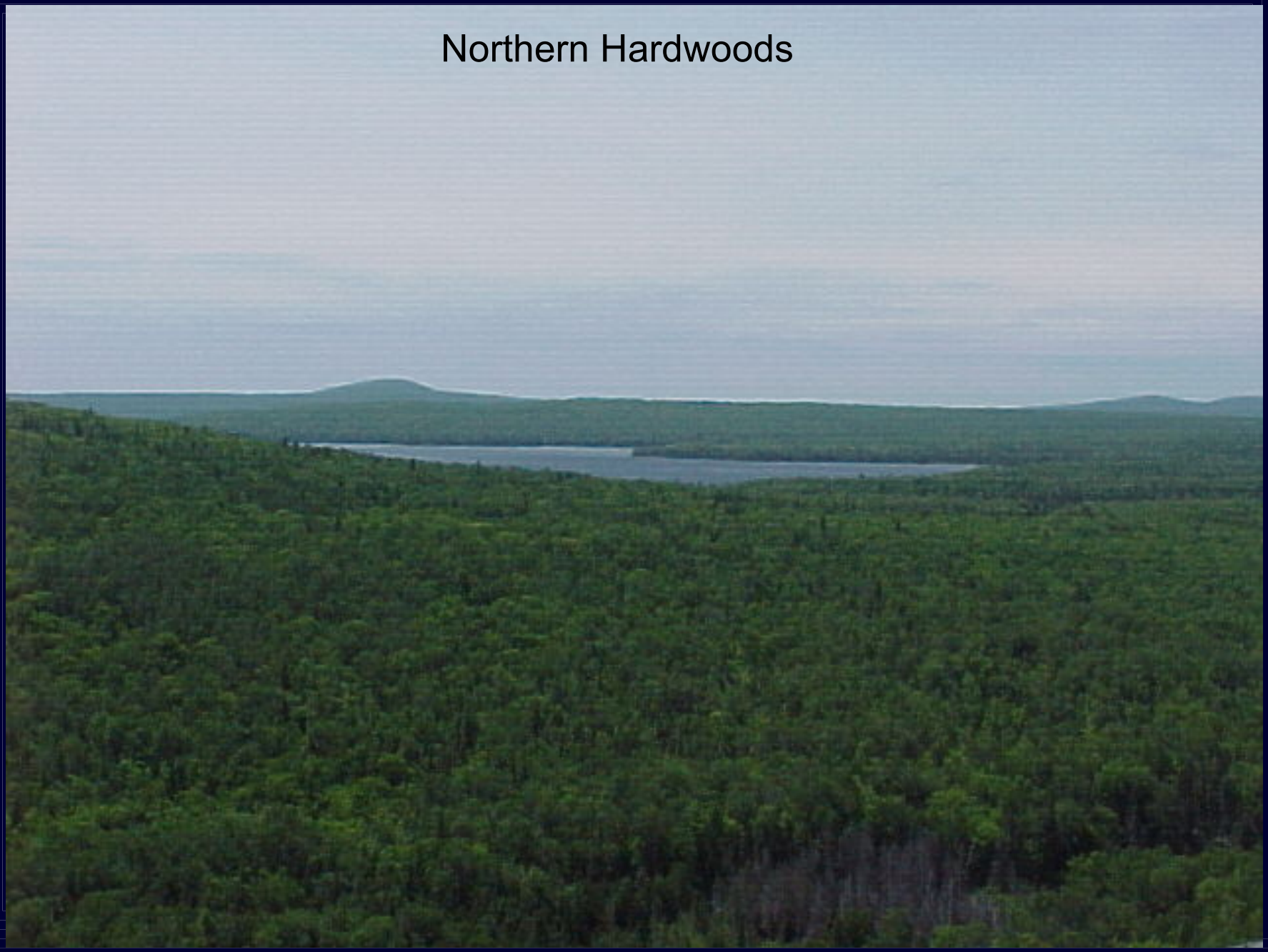
Pine

Historical Red Pine – Large trees; Widely spaced; Crown-fire resistant

Today's Red Pine – Smaller trees; More densely spaced

Today's Jack Pine – Deciduous understory

Northern Hardwoods



Historically – Structurally & compositionally diverse; Gap dynamics & CWD prevalent

Today – Younger & less diverse; Gap dynamics & CWD lacking

Lake States forest landscapes are currently composed of mostly young, second-growth stands.

According to Schmidt et al. (1996), old forests accounted for only 2% of Lake States forests in the mid-90s. The northern hardwoods forest type accounted for the greatest area (37%) of the old forest in the Lake States.

(Schmidt, T.L. et al. 1996. Old and potential old forest in the Lake States, USA. Forest Ecol. Manag. 86: 81-96.)

LANDSCAPE STRUCTURE

Total population within a 500 and 600 mile radius of selected points in the Great Lakes

Gaylord, Michigan

500 miles - **58.8 million**
- Urban 71%
- Rural 29%

600 miles - **86.4 million**
- Urban 70%
- Rural 30%

Wausau, Wisconsin

500 miles - **53.4 million**
- Urban 74%
- Rural 26%

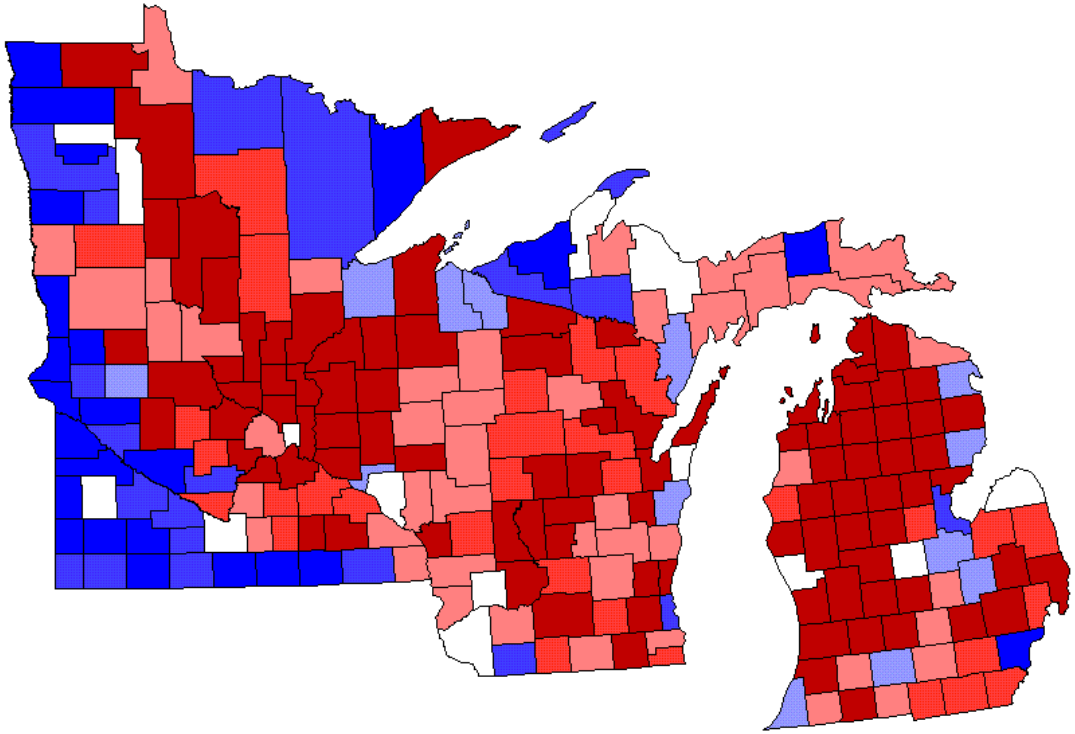
600 miles - **66.3 million**
- Urban 71%
- Rural 29%

Duluth, Minnesota

500 miles - **30.1 million**
- Urban 71%
- Rural 29%

600 miles - **45.9 million**
- Urban 73%
- Rural 27%

Percent Change in Population from 1970 to 1995



200 0 200 400 Miles

N

Great Lakes Ecological Assessment

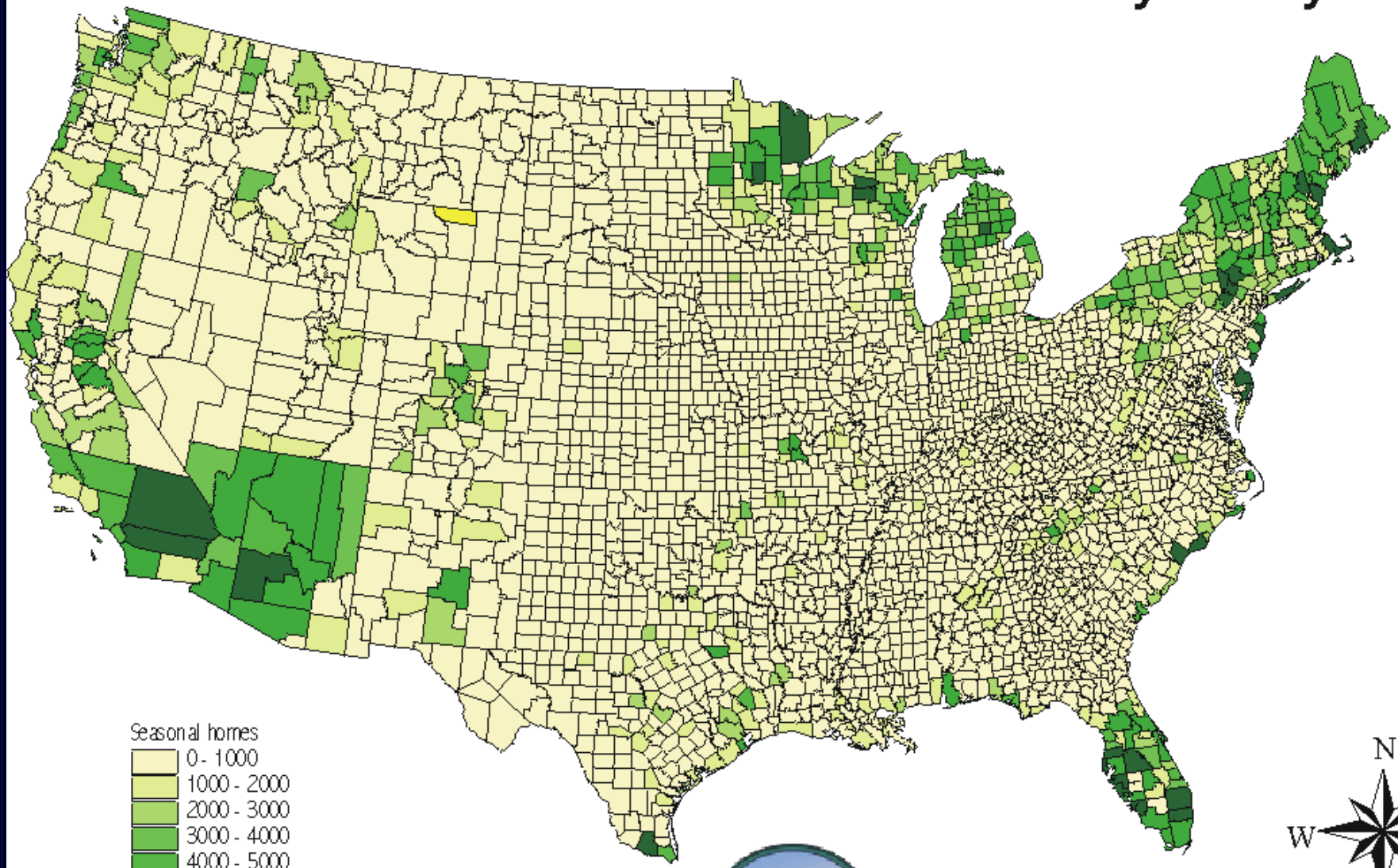
Percent change

- <-15
- -15- -5
- - 5- 0
- 0- 5
- 5- 15
- 15- 25
- > 25

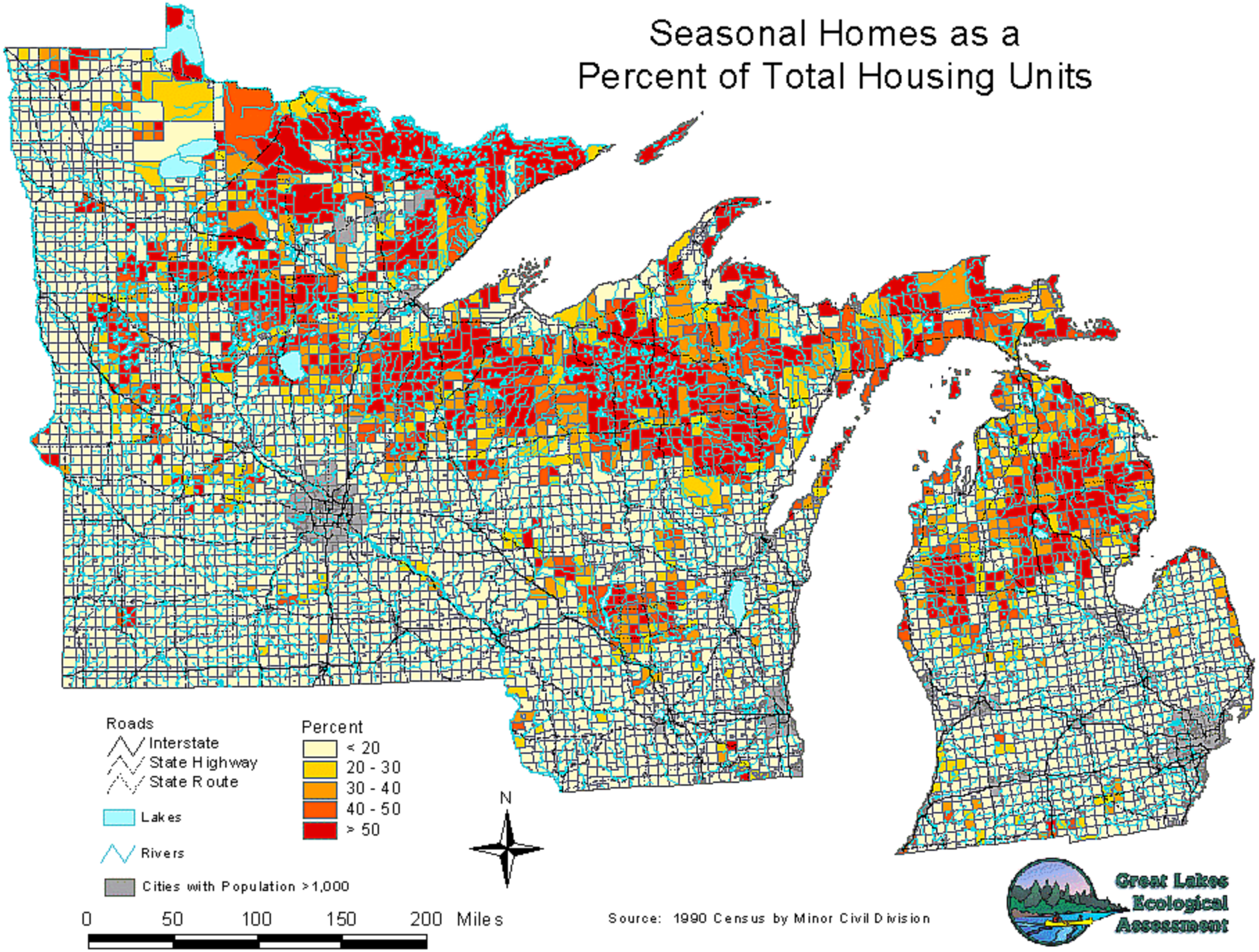
Data are from revised 1970 U.S. Census Bureau Records and 1995 U.S. Census Bureau Projections.


MC6066LG
MC6055LG

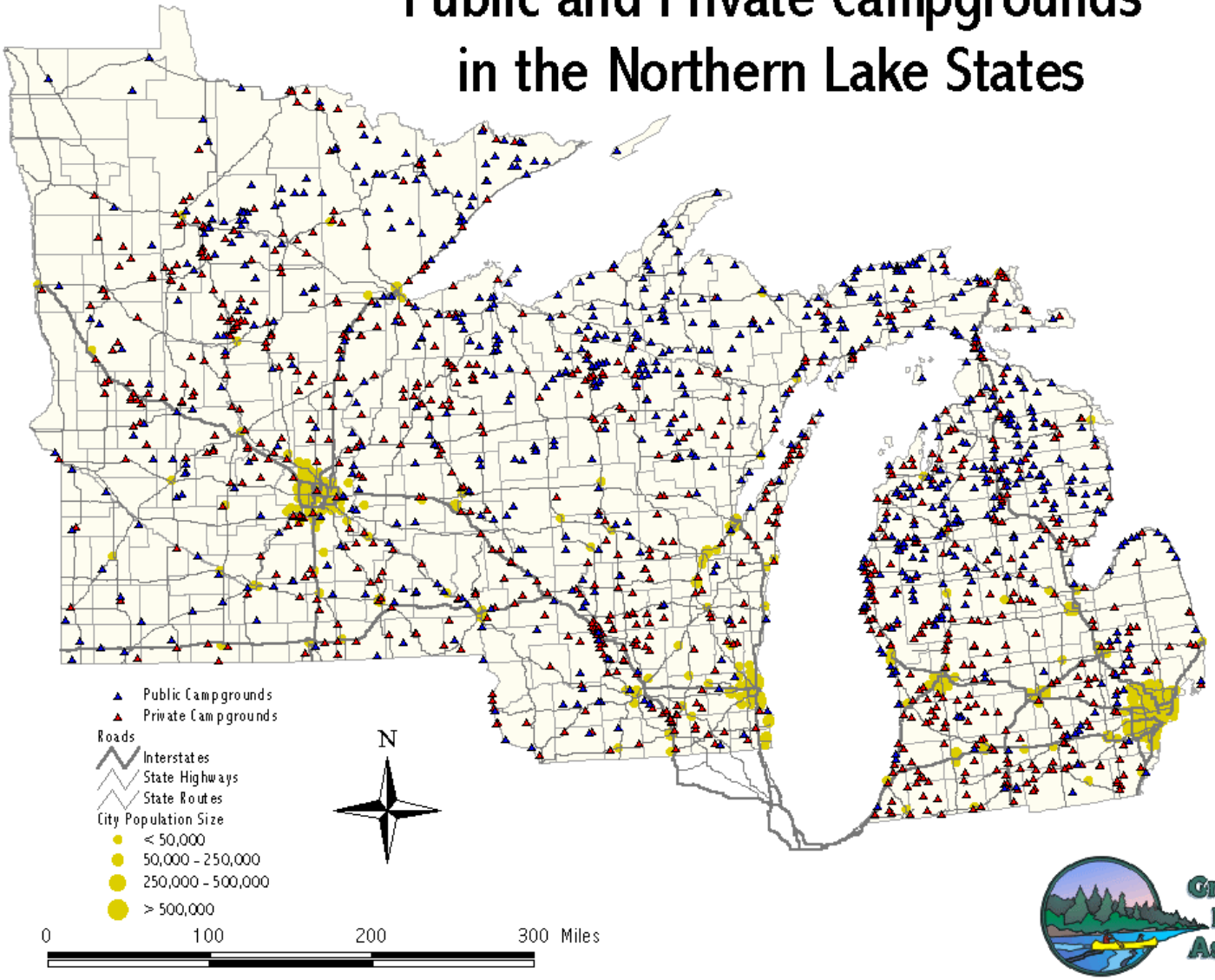
Number of seasonal homes by county



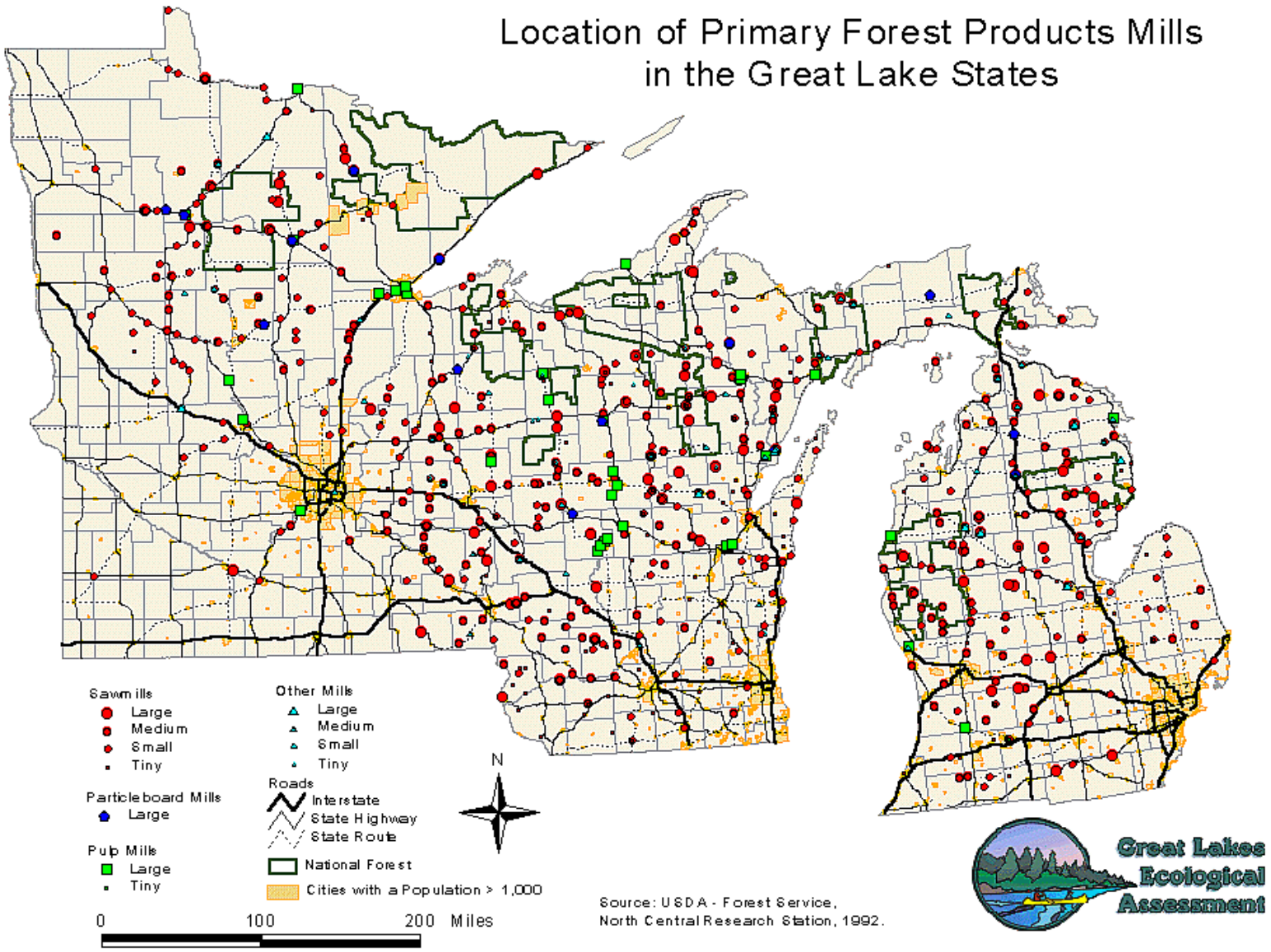
Seasonal Homes as a Percent of Total Housing Units



Public and Private Campgrounds in the Northern Lake States



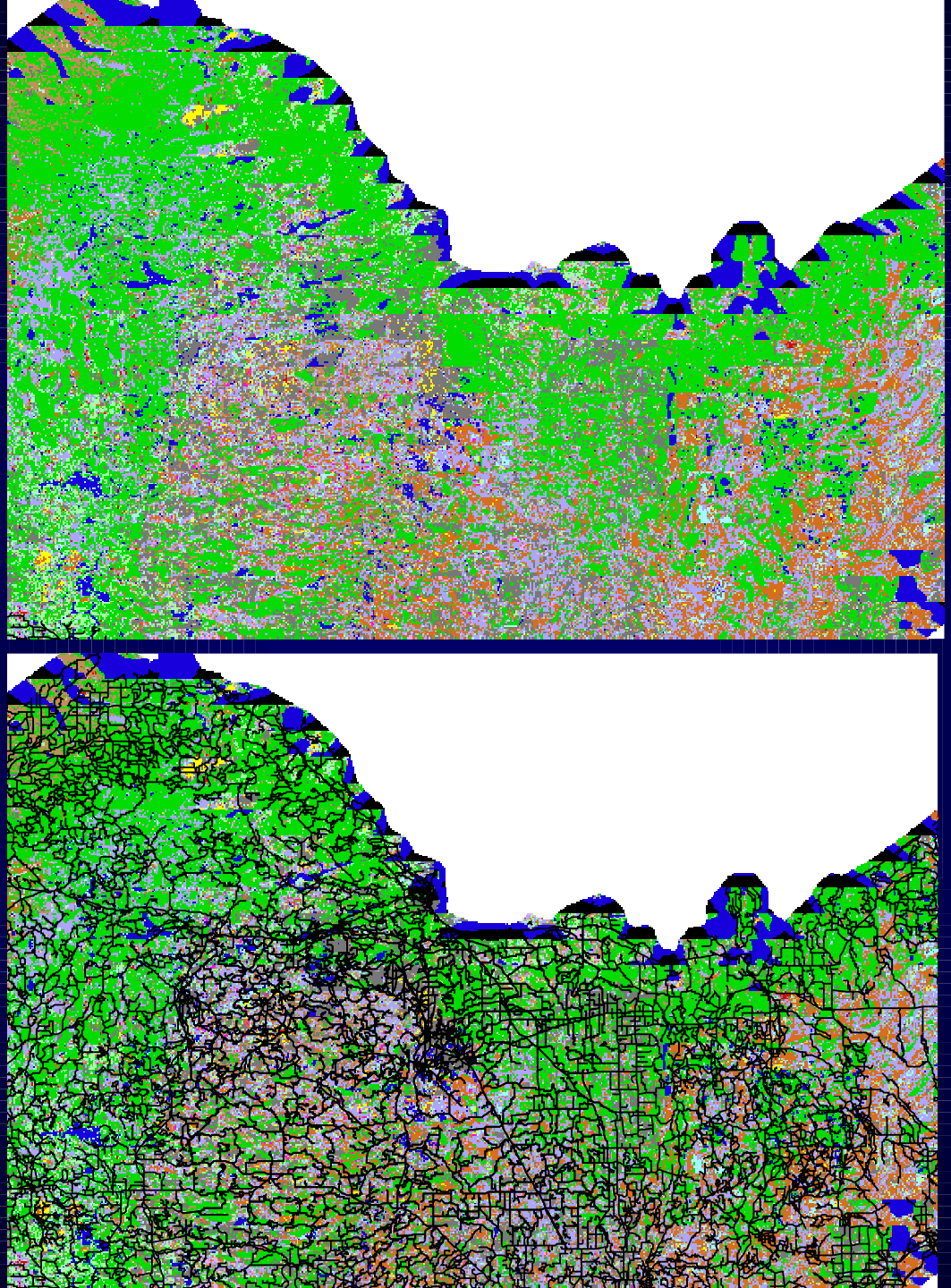
Great Lakes Ecological Assessment


Location of Primary Forest Products Mills
in the Great Lake States
Sawmills
Large
Medium
Small
Tiny
Particleboard Mills
Large
Pulp Mills
Large
Tiny
Other Mills
Large
Medium
Small
Tiny
Roads
Interstate
State Highway
State Route
National Forest
Cities with a Population > 1,000
N
0
100
200 Miles
Source: USDA - Forest Service,
North Central Research Station, 1992.
Great Lakes
Ecological
Assessment

Road Network

Ecological Effects of Roads

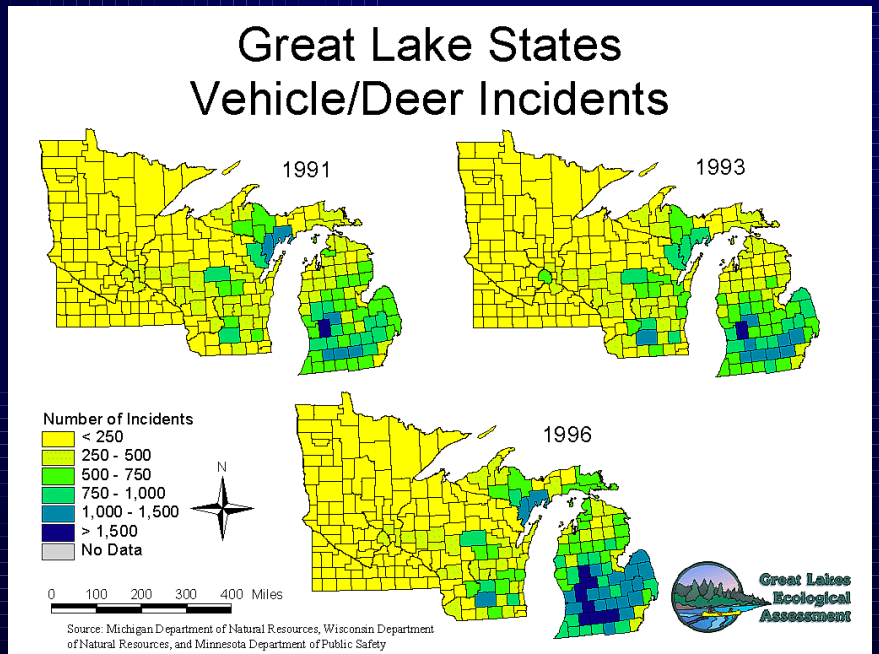
- **Landscape Dissection**
  - Smaller patch size, increased edge effects
  - Habitat loss
  - Habitat isolation



Ecological Effects of Roads

Physical Barrier

- Road avoidance by some species (e.g., amphibians)
- Roadkill
- Fire break
- Interruption of hydrologic flows, etc.
- Population isolation

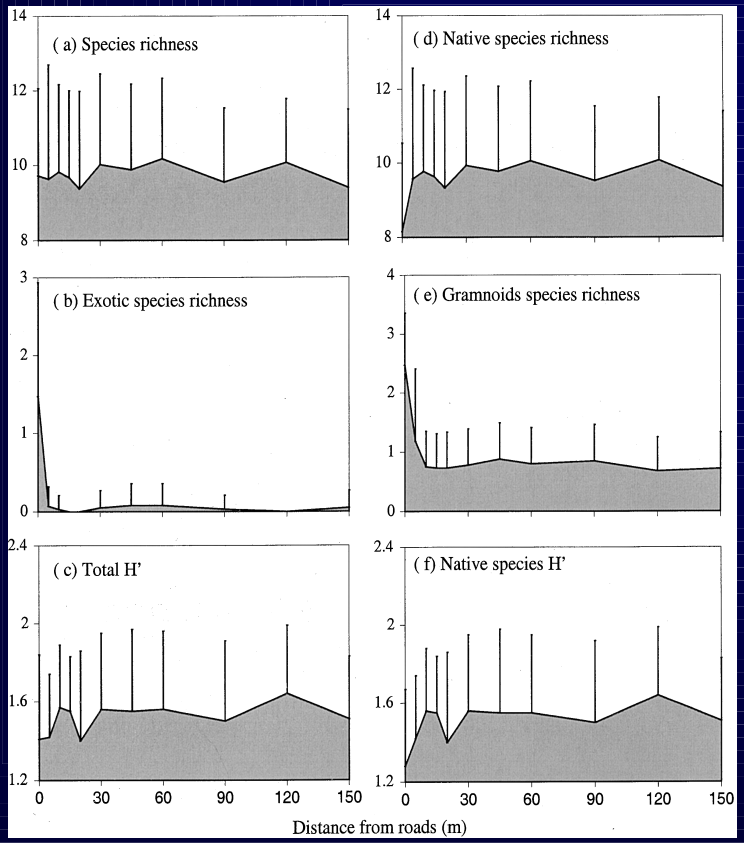


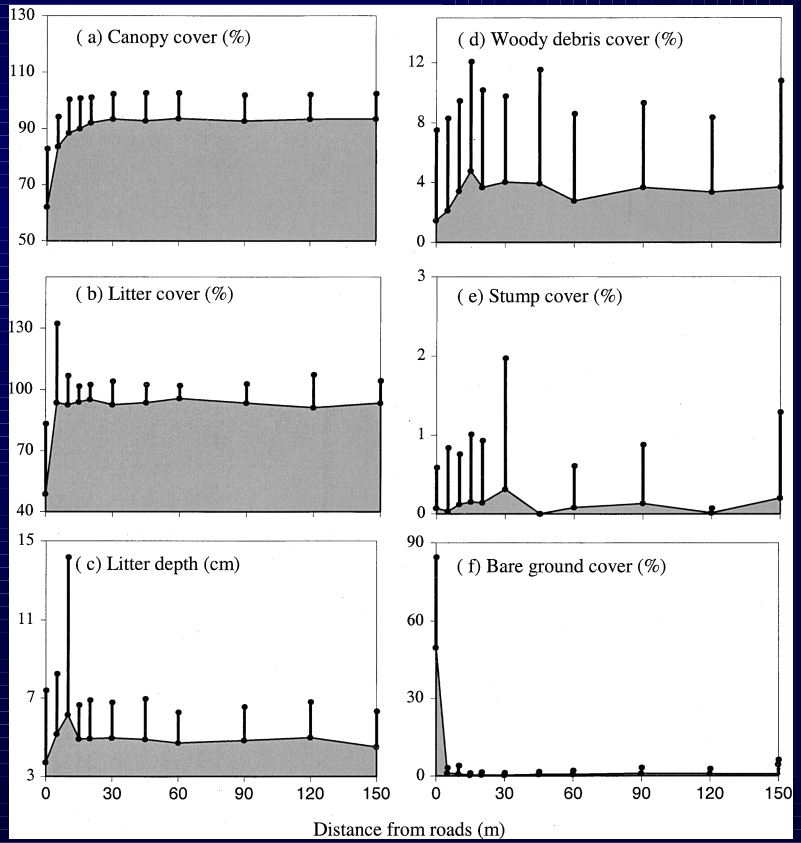
Ecological Effects of Roads

- **Movement Corridor** (e.g., humans, exotic species)
  - Increased hunting, ecosystem damage, etc.
  - More fire ignitions, smaller fire sizes
  - Introduction of exotic species/pests

Ecological Effects of Roads

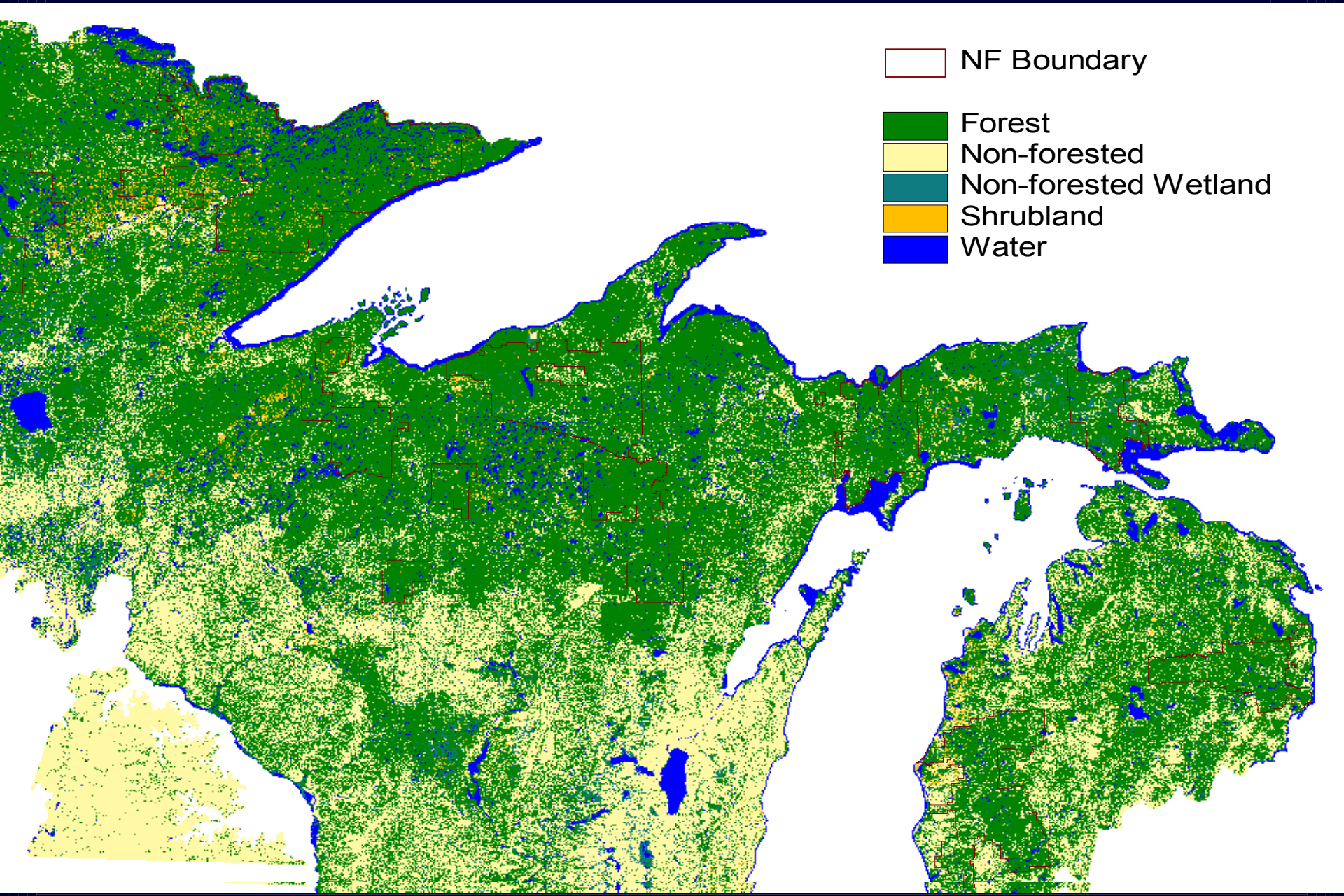
- **Changes in Abiotic & Structural Conditions** (e.g., microclimate, substrate, pollutants, noise, physical disturbance)
  - ➢Vegetation composition changes near roads (more exotics, grasses, etc.)
  - ➢Animal avoidance of roads & near-road areas

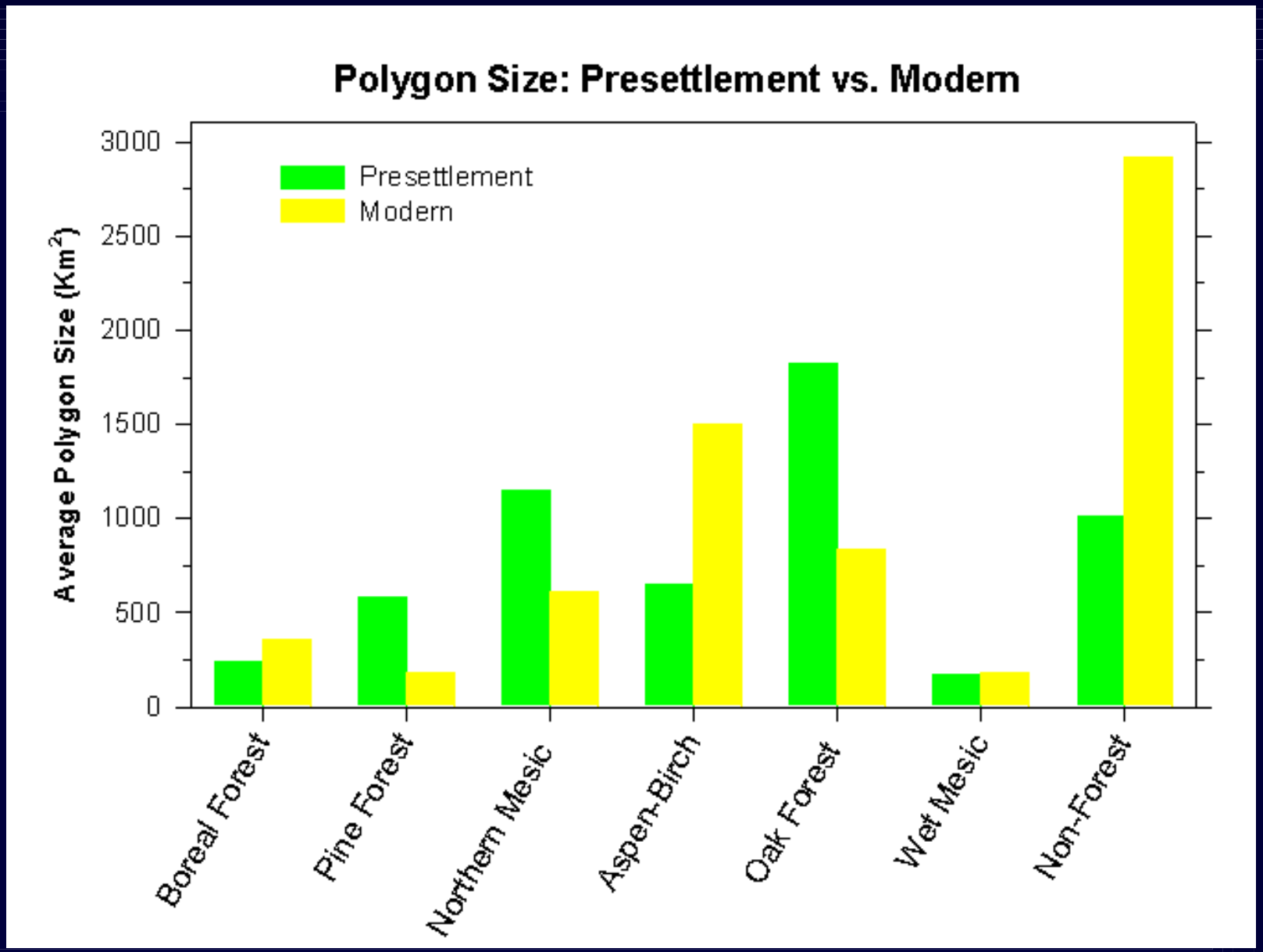




From: Watkins, R., J. Chen, J. Pickens, and K. Brosofske. 2003. Effects of forest roads on understory plants in a managed hardwood landscape. Conservation Biology 17: 411-419.

Forest Fragmentation


NF Boundary
Forest
Non-forested
Non-forested Wetland
Shrubland
Water



From: Cole et al. 1998. Historical landcover changes in the Great Lakes Region. Chapter 6 in: Land Use History of North America (LUHNA) (online), USGS. URL http://biology.usgs.gov/luhna

Edge Effects

Direct effects of edge creation:
- Physical damage
- Exchange of energy, matter, species

1° process responses:
↑ NPP, ET, nutrient cycling, decomposition
↑ Dispersal, pollen flow

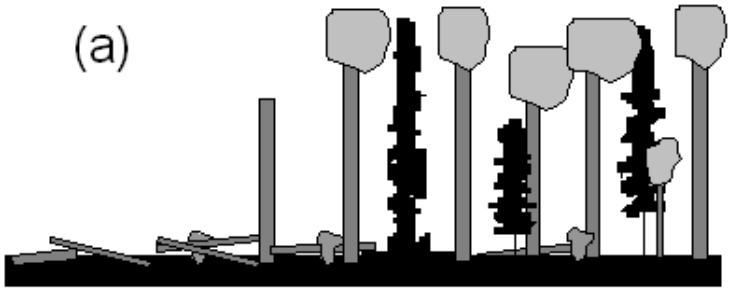
1° structure responses:
↓ canopy cover, tree density, biomass
↑ downed wood

2° process responses:
↑ recruitment, growth, mortality, reproduction

2° structure responses:
↑ sapling density, understory cover

2° composition responses:
- Change in understory composition

(a)



MEI — Abiotic and biotic gradients — DEI

(b)

Edge development:
- 'sealing' MEI ◣ DEI
- 'softening' MEI ◣ DEI
- 'expansion' MEI ◣ DEI

Depth and Magnitude of Edge Influence Depend on:

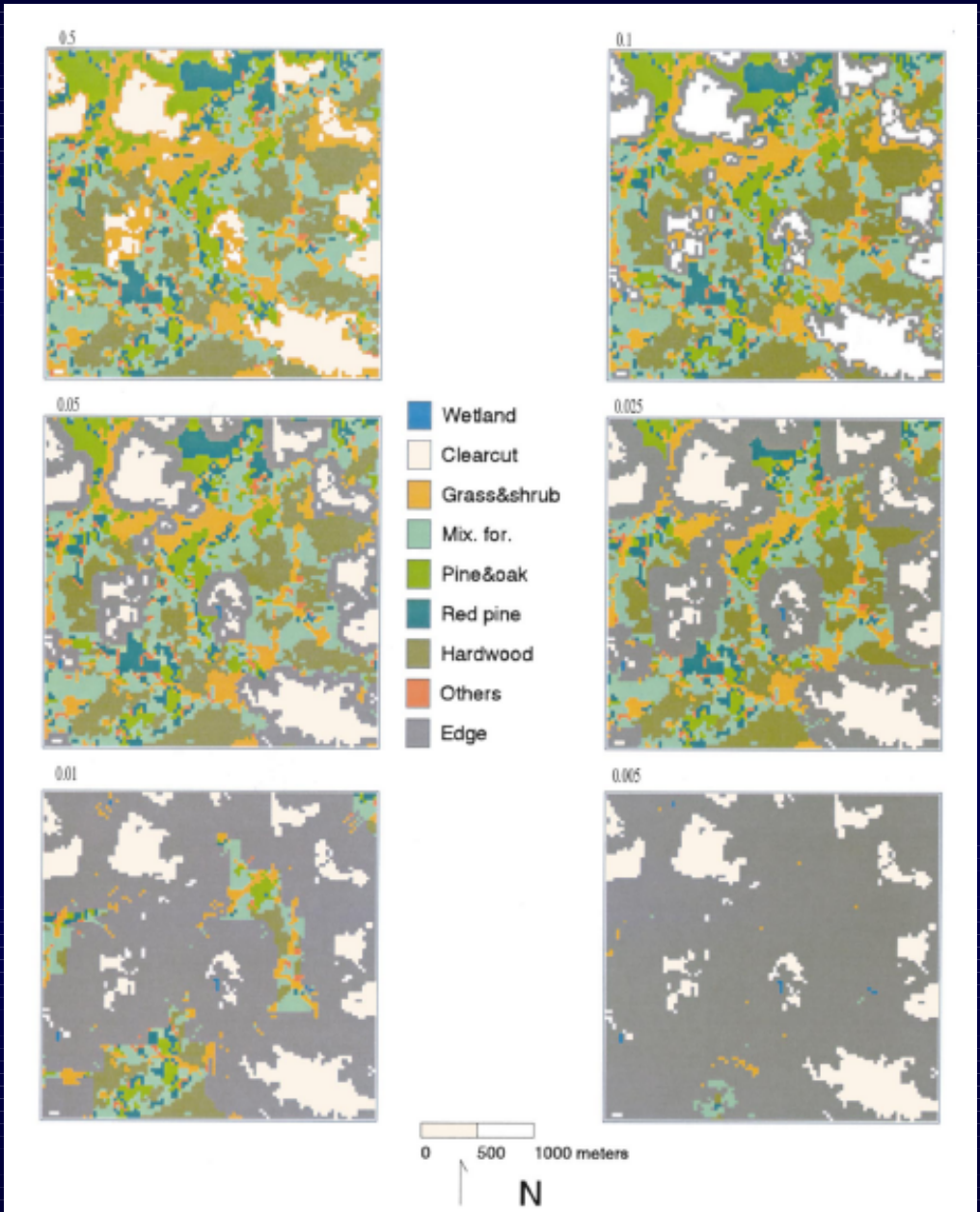
- Variable of interest
- Edge orientation
- Time of day
- Region
- Characteristics of the adjacent patches
- Hardness of the edge

Depth of Edge Influence

- Microclimate (up to 240 m)
- Wildlife poaching/hunting (>2.5 km)
- Vegetation structure & tree mortality (up to 125 m)
- Tree species composition (up to 140 m)
- Understory vegetation (up to 65 m)
- Amphibians (up to 100 m)
- Birds (up to 500 m)
- Small mammals (up to 50 m)
- Wolf habitat use (up to 2 km)
- Bear habitat use (up to 3 km)
- Bald eagle nesting density & reproductive success (up to 300 m)

From: Silva Forest Foundation. 1999. Assessing the ecological impacts of timber management: apparent impacts, actual impacts, and precautionary forest development. URL: http://www.silvafor.org/publications/library/index.htm

D-AEI Model



From: Zheng, D. and J. Chen. 2000. Edge effects in fragmented landscapes: a generic model for delineating area of edge influences (D-AEI). Ecological Modelling 132/3: 175-190.

CURRENT AND EMERGING CONSIDERATIONS

Affecting Landscape Composition:

- Spread of exotic species, pests, & diseases

  (e.g., emerald ash borer, beech bark disease)

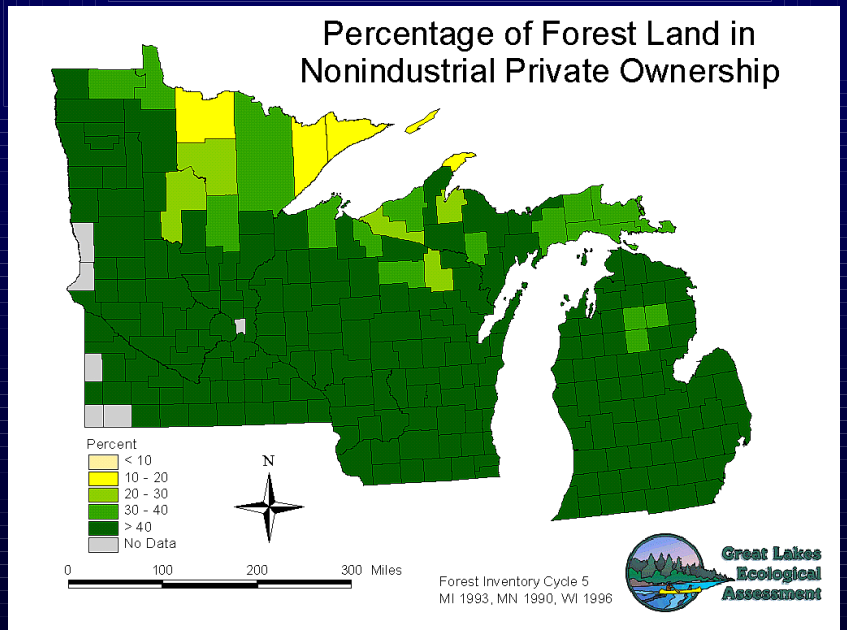
- Climate change

CURRENT AND EMERGING CONSIDERATIONS

Affecting Landscape Structure:

- Parcelization of private lands with unknown outcomes

  (harvest then sell; protect unchanged & keep in the family; conservation easement; multiple-use management with limited harvesting)



Summary

The extensive logging and subsequent fires of the 19th – early 20th centuries in the Lake States have resulted in changes in forest landscape composition.

These compositional changes have included a substantial reduction in conifers accompanied by an increase in aspen and red maple.

Because of the massive deforestation, few old stands are left on the landscape.

Summary

Structural changes in forest ecosystems have occurred as a result of early logging & subsequent fire, followed by other changes in disturbance regimes (e.g., fire suppression).

- *Red pine* – more densely spaced, younger, more prone to crown fire
- *Jack pine* – succeeding to hardwoods where fire is excluded and planting is not undertaken
- *Hardwoods* – younger, less CWD, gap dynamics less influential due to lack of a supercanopy composed of individuals vulnerable to blowdown

Summary

Human population increases, development, and forest management have resulted in:

- dissection of the landscape from the road network and other linear features (e.g., power line corridors);
- reduced forest patch size;
- increased forest fragmentation.

Summary

THUS, Landscape homogenization has occurred in:

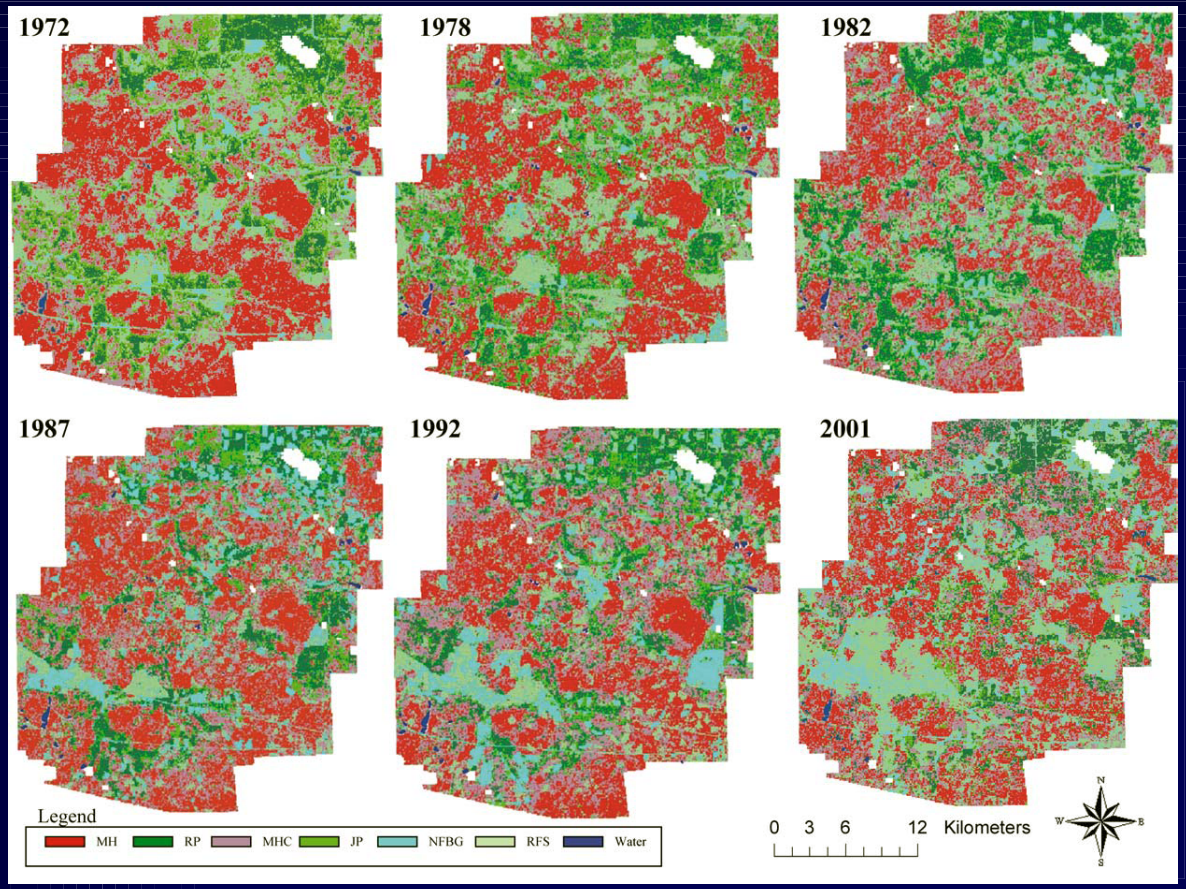
- Forest composition (lower diversity of forest communities, e.g., loss of white pine & hemlock; increase in red maple & aspen)
- Forest stand age and structure (younger stands; even-aged hardwoods; lack of supercanopy & CWD in northern hardwoods)
- Forest patch size (smaller stands)
- Area influenced by edges & roads

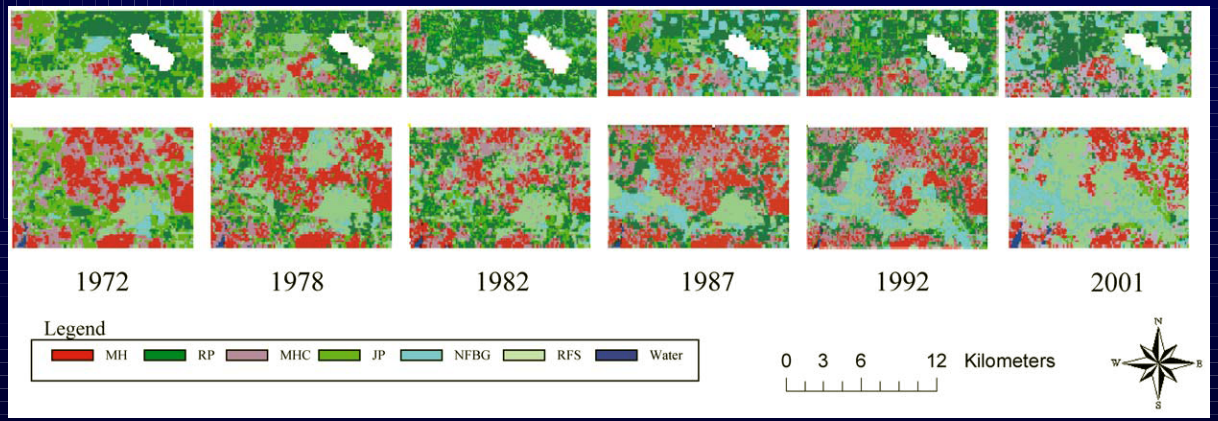
Recommendations

- Landscape perspective
- Maintain a diversity of patch sizes, types, and ages
- Mimic, when possible, historic disturbance regimes (fire rotations for even-aged systems, gap dynamics for uneven-aged, wind-disturbed systems)
- Maintain functional connectivity for organisms and ecosystem processes (e.g., dispersal, material flows)
- Minimize road/edge effects where possible

Thank You!

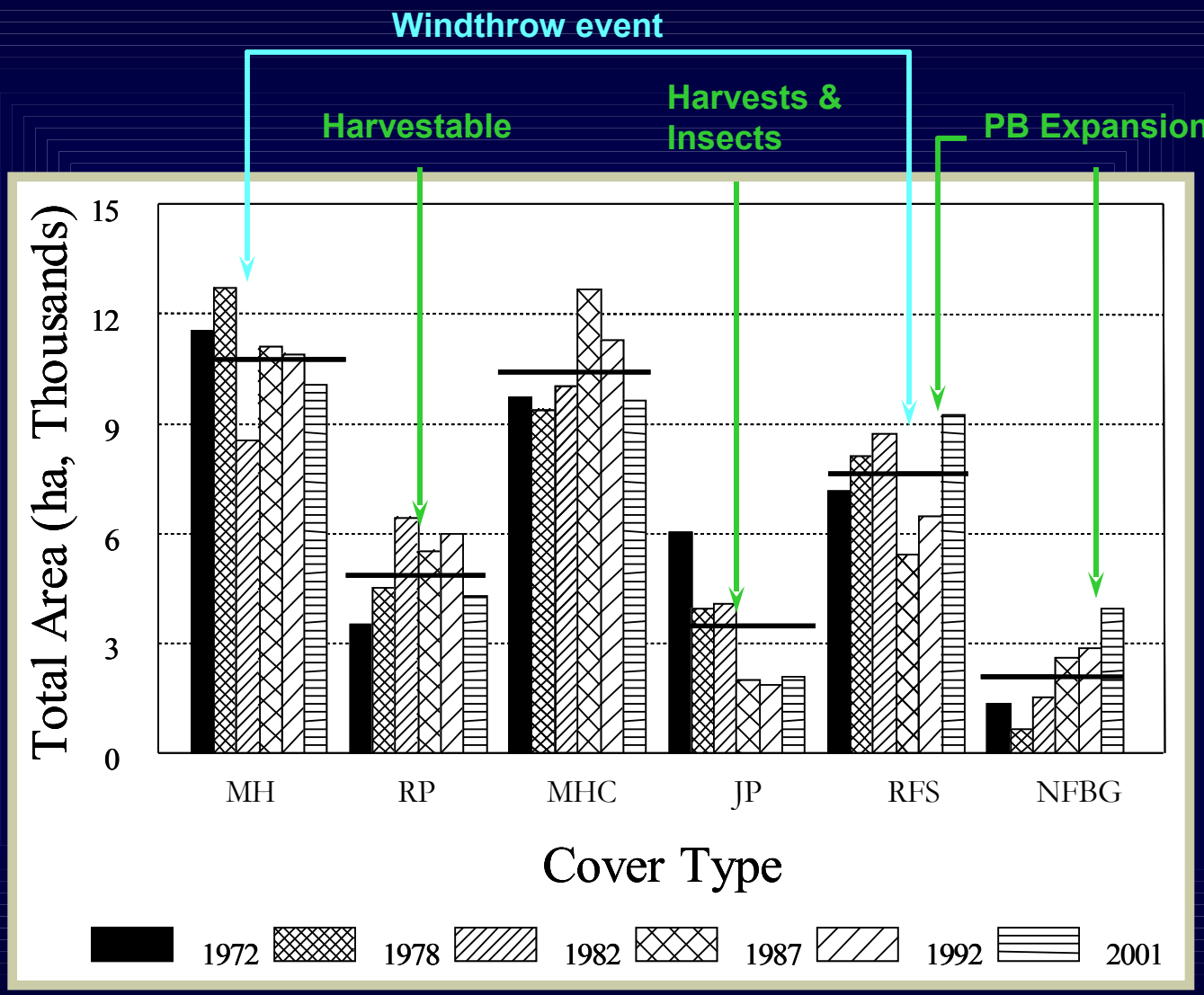
30-Year Landscape Dynamics in Chequamegon NF

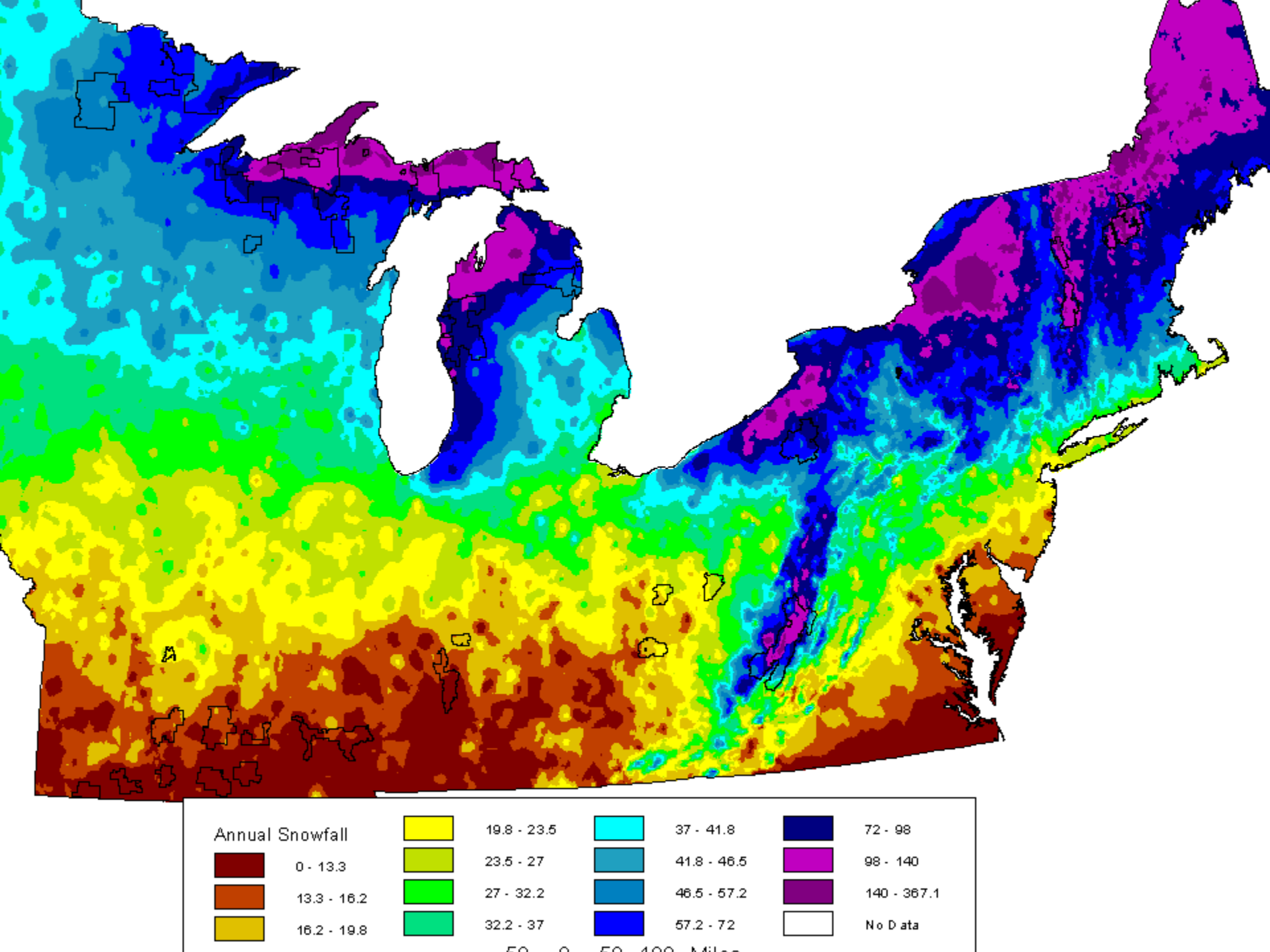


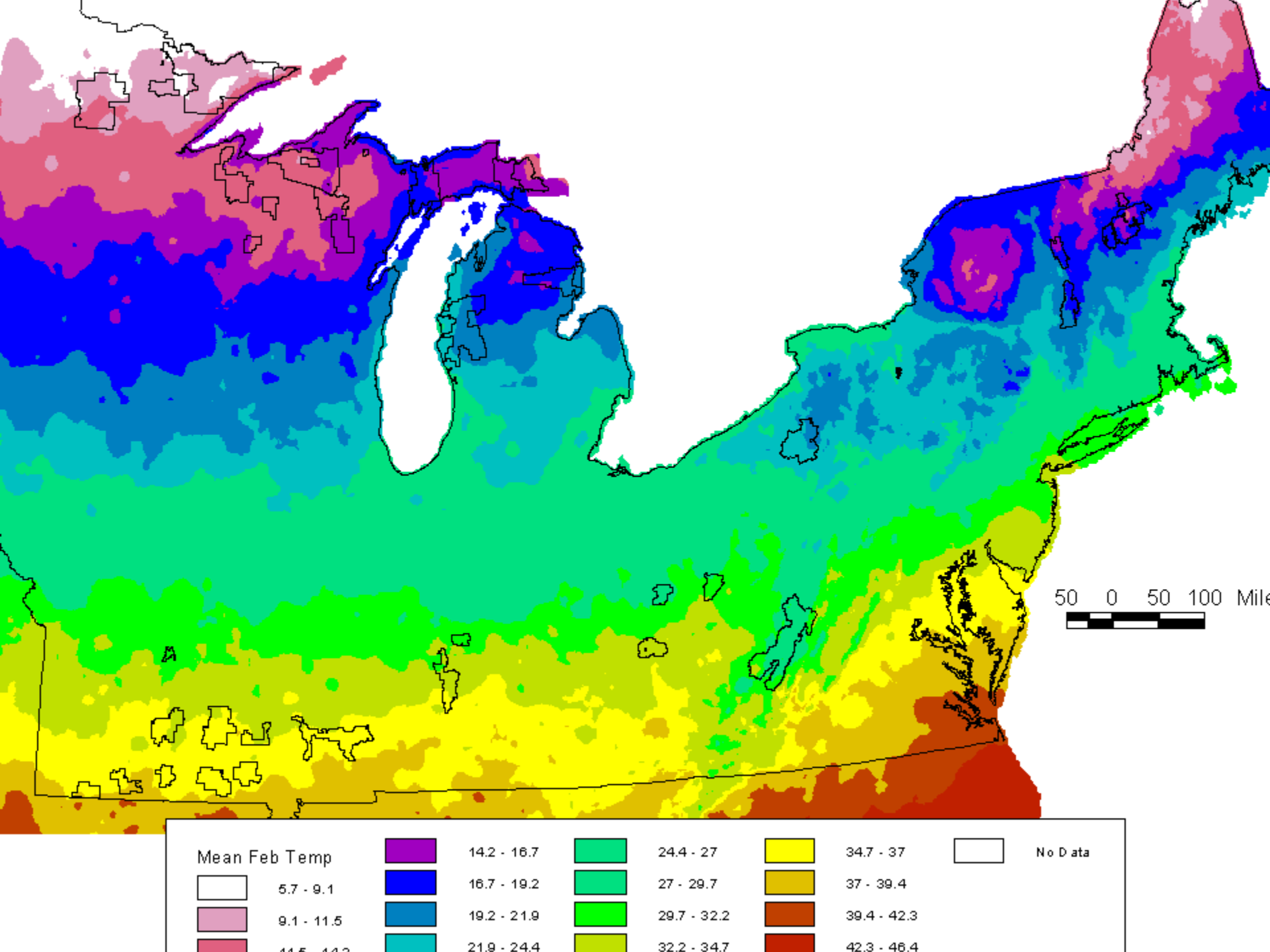


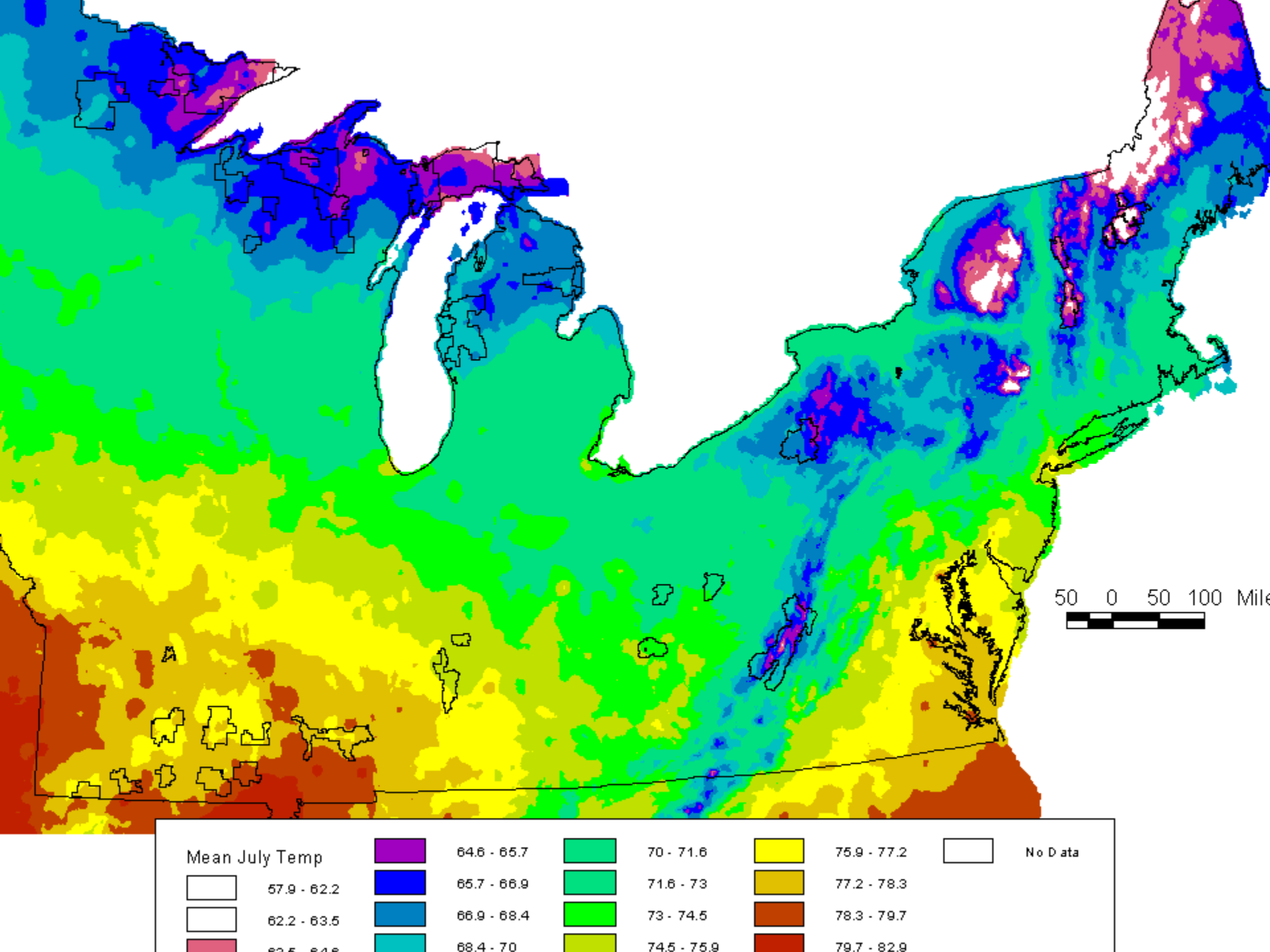
From: Bresee, M.K. et al. 2004. Disturbance and landscape dynamics in the Chequamegon National Forest, Wisconsin, USA, from 1972 to 2001. Landsc. Ecol. 19: 291-309.

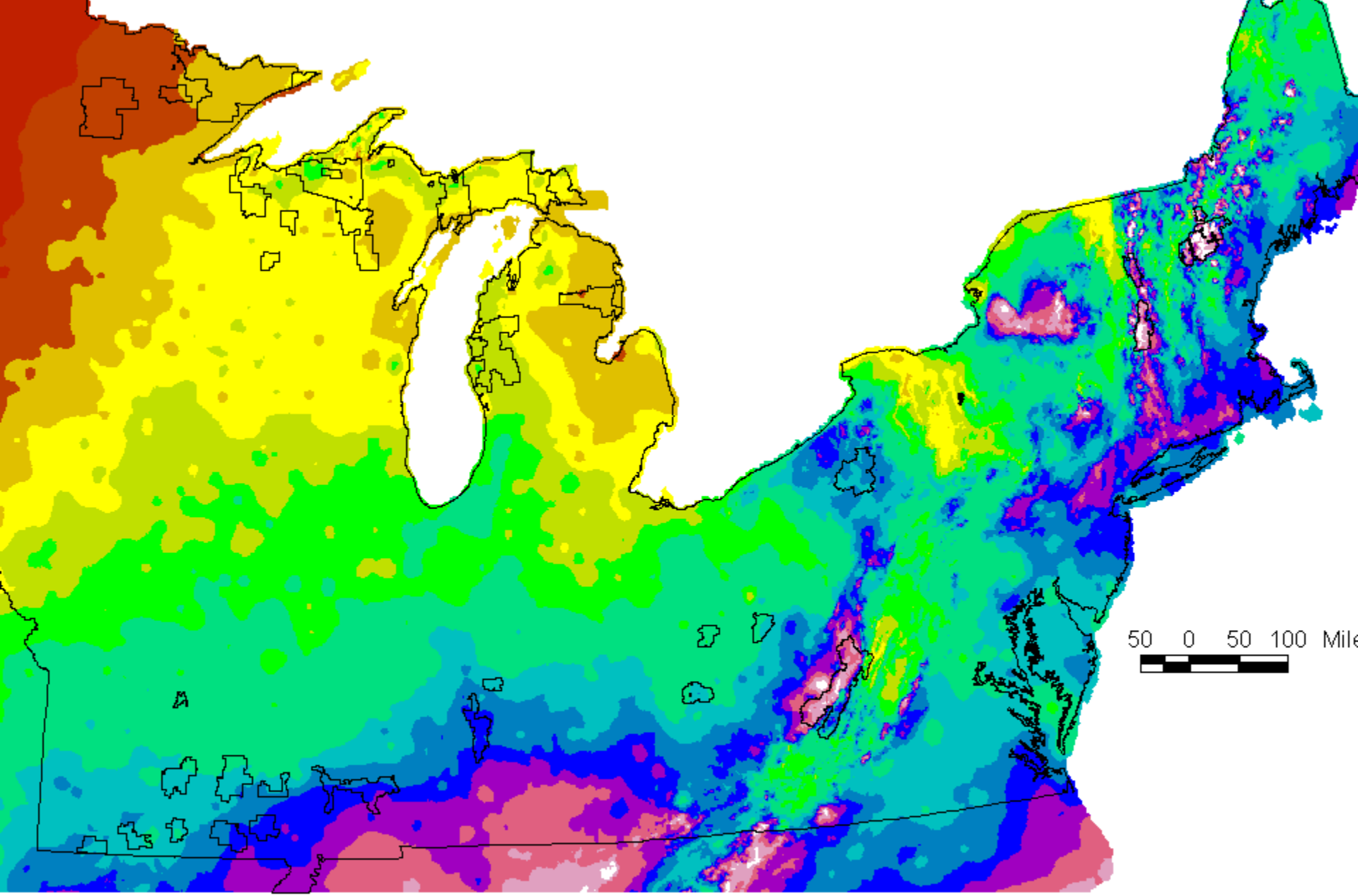
Change in Total Area of Different Patch Types

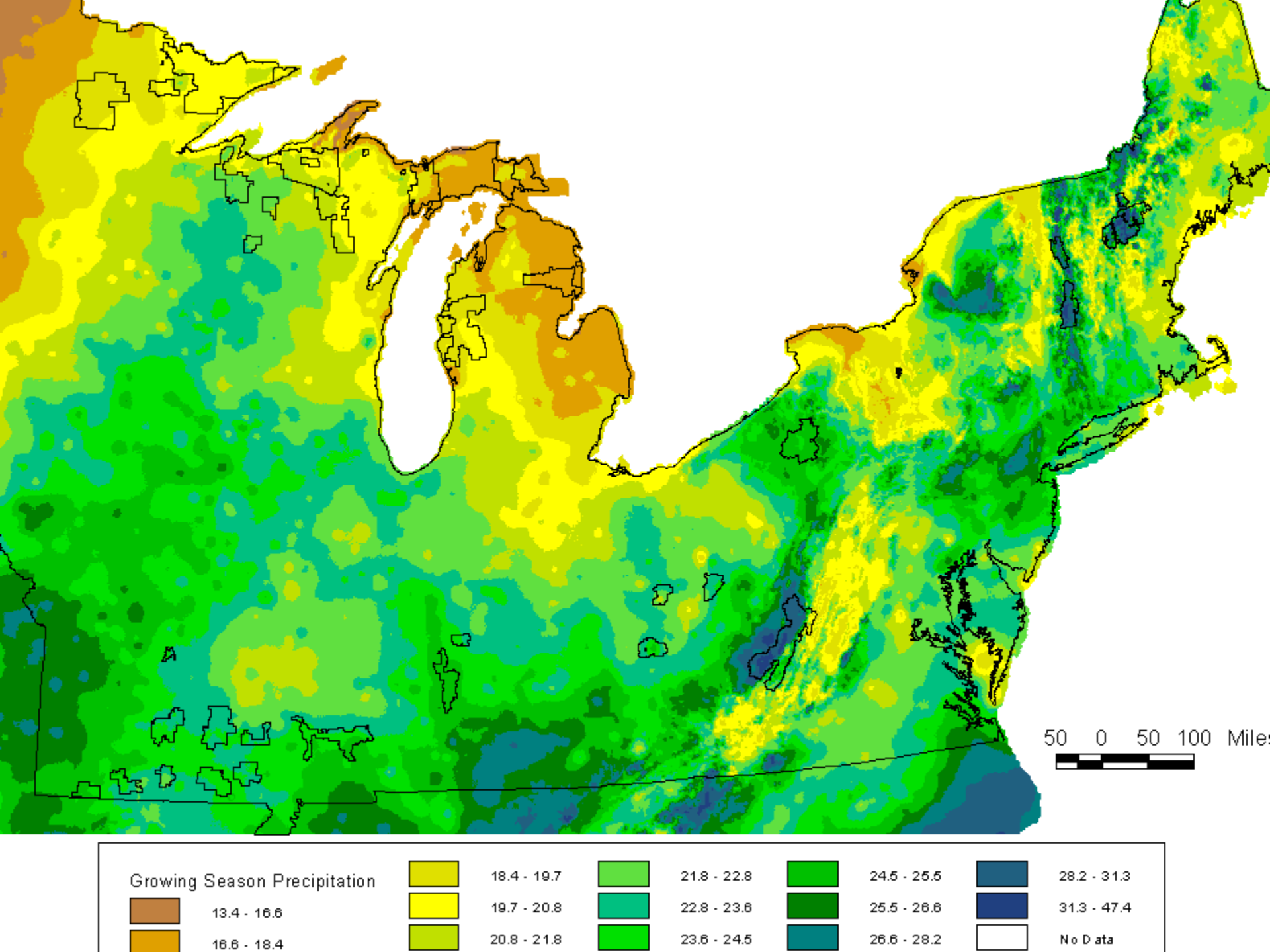


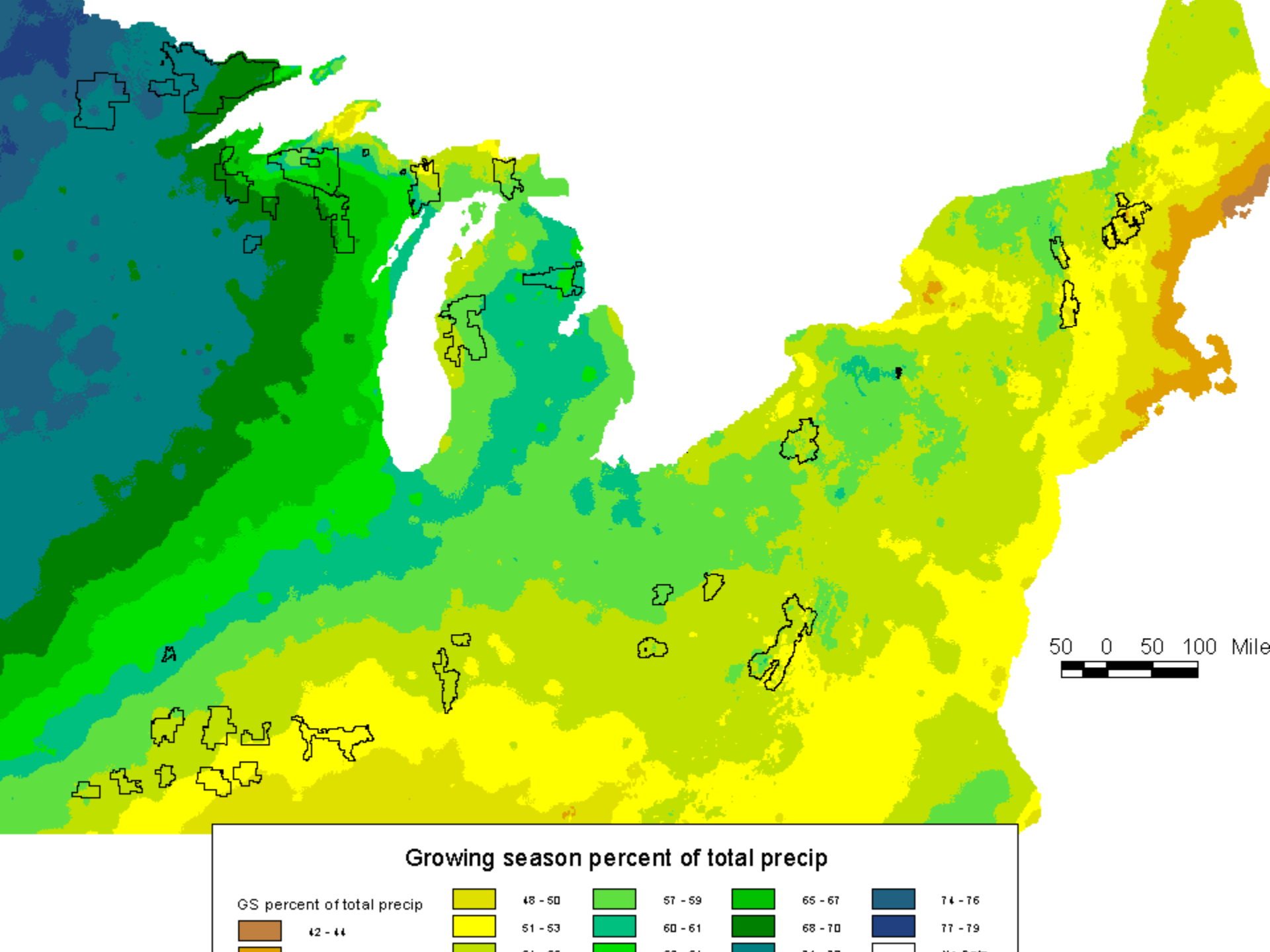

Annual Snowfall
0 - 13.3
13.3 - 16.2
16.2 - 19.8
19.8 - 23.5
23.5 - 27
27 - 32.2
32.2 - 37
37 - 41.8
41.8 - 46.5
46.5 - 57.2
57.2 - 72
72 - 98
98 - 140
140 - 367.1
No Data

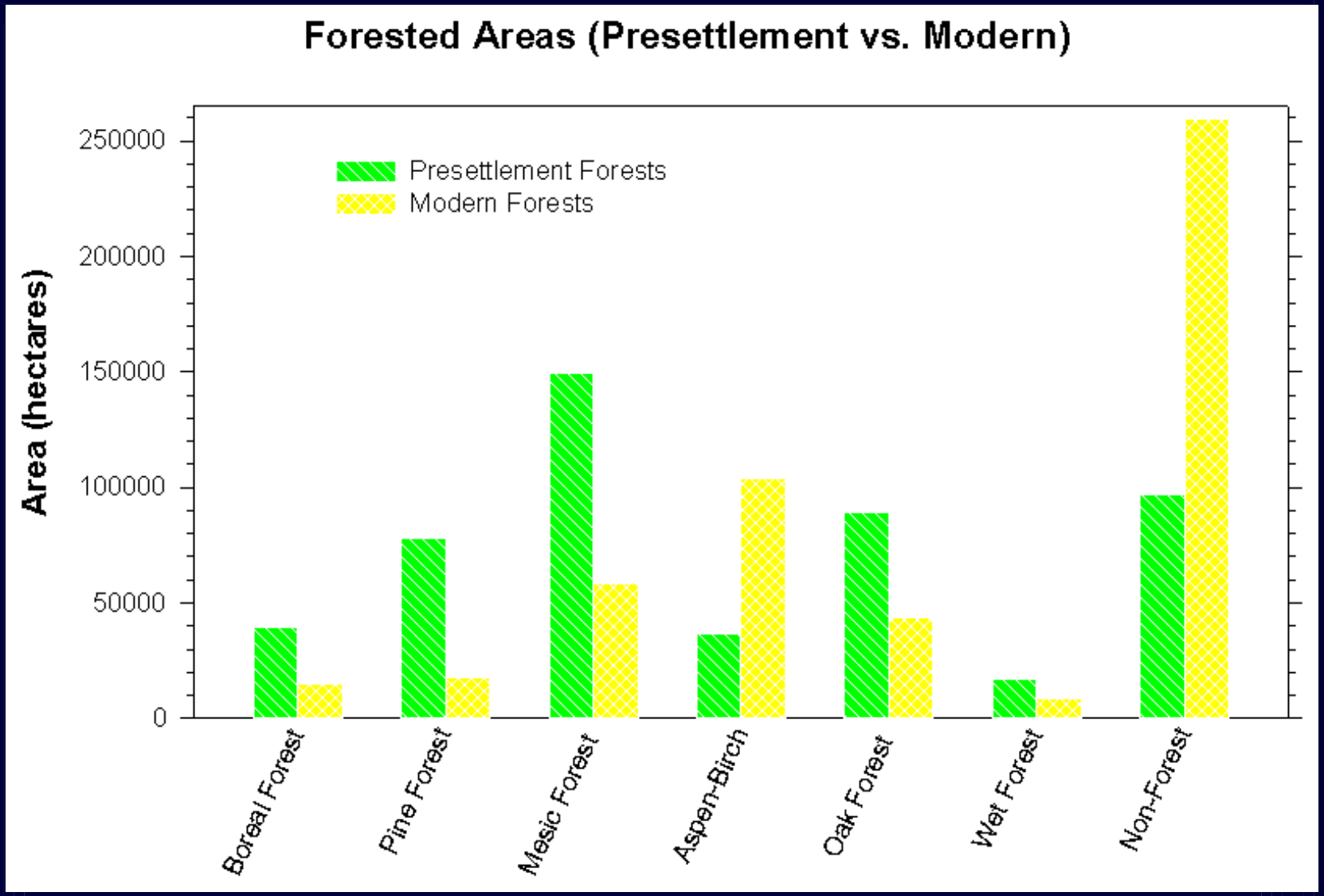

50 0 50 100 Mile
Mean Feb Temp
5.7 - 9.1
9.1 - 11.5
14.2 - 16.7
16.7 - 19.2
19.2 - 21.9
21.9 - 24.4
24.4 - 27
27 - 29.7
29.7 - 32.2
32.2 - 34.7
34.7 - 37
37 - 39.4
39.4 - 42.3
42.3 - 46.4
No Data


50 0 50 100 Mile
Mean July Temp
57.9 - 62.2
62.2 - 63.5
64.6 - 65.7
65.7 - 66.9
66.9 - 68.4
68.4 - 70
70 - 71.6
71.6 - 73
73 - 74.5
74.5 - 75.9
75.9 - 77.2
77.2 - 78.3
78.3 - 79.7
79.7 - 82.9
No Data


50 0 50 100 Mile
Annual Precipitation
17.8 - 23.7
23.7 - 27.8
27.8 - 30.7
30.7 - 33.1
33.1 - 35.4
35.4 - 37.7
37.7 - 39.8
39.8 - 41.9
41.9 - 43.9
43.9 - 45.9
45.9 - 48.2
48.2 - 51
51 - 54.4
54.4 - 60.5
60.5 - 101.9
No Data


50 0 50 100 Miles
Growing Season Precipitation
13.4 - 16.6
16.6 - 18.4
18.4 - 19.7
19.7 - 20.8
20.8 - 21.8
21.8 - 22.8
22.8 - 23.6
23.6 - 24.5
24.5 - 25.5
25.5 - 26.6
26.6 - 28.2
28.2 - 31.3
31.3 - 47.4
No Data


50 0 50 100 Mile
Growing season percent of total precip
GS percent of total precip
42 - 44
48 - 50
51 - 53
57 - 59
60 - 61
65 - 67
68 - 70
74 - 76
77 - 79



From: Cole et al. 1998. Historical landcover changes in the Great Lakes Region. Chapter 6 in: Land Use History of North America (LUHNA) (online), USGS. URL http://biology.usgs.gov/luhna