

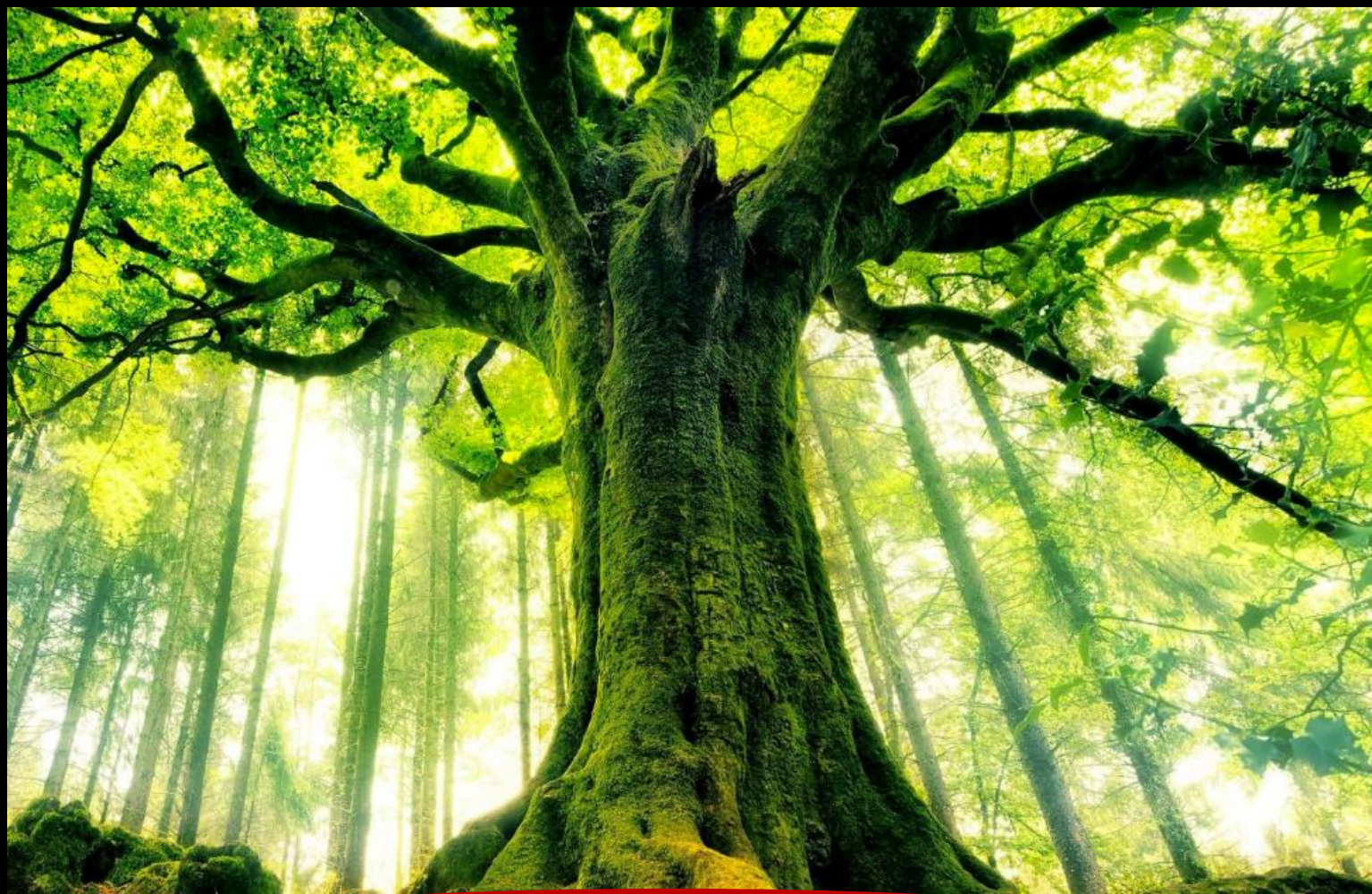
A winter landscape featuring a stream with snow-covered banks and trees. The water is dark and reflects the surrounding snow. The trees are bare and covered in a thick layer of snow. The overall scene is serene and cold.

Natural Solutions for Climate Change

Conservation Data & Tools to Mitigate & Adapt

Forest Service Eastern Region
Climate Change Coordinators Meeting
10 April 2019

Nick Miller, Director of Science & Strategy
The Nature Conservancy in Wisconsin



1. We can help nature adapt
2. Nature can help us adapt
3. Nature can reduce impacts



Conserving Nature's Stage

Resilient and Connected Landscapes

Acknowledgements



**Primary Funder:
Doris Duke Charitable Foundation**

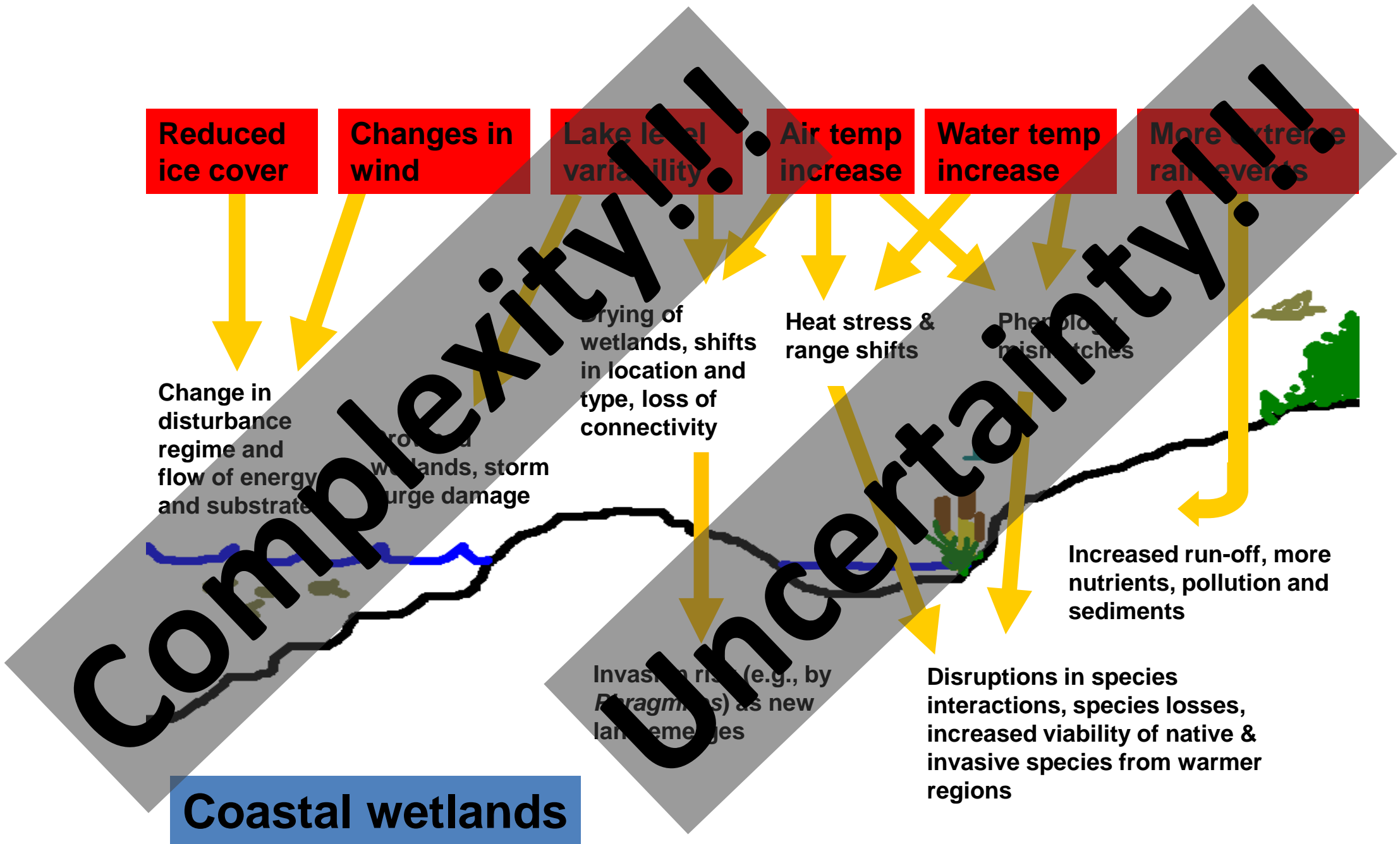


DORIS DUKE
CHARITABLE FOUNDATION

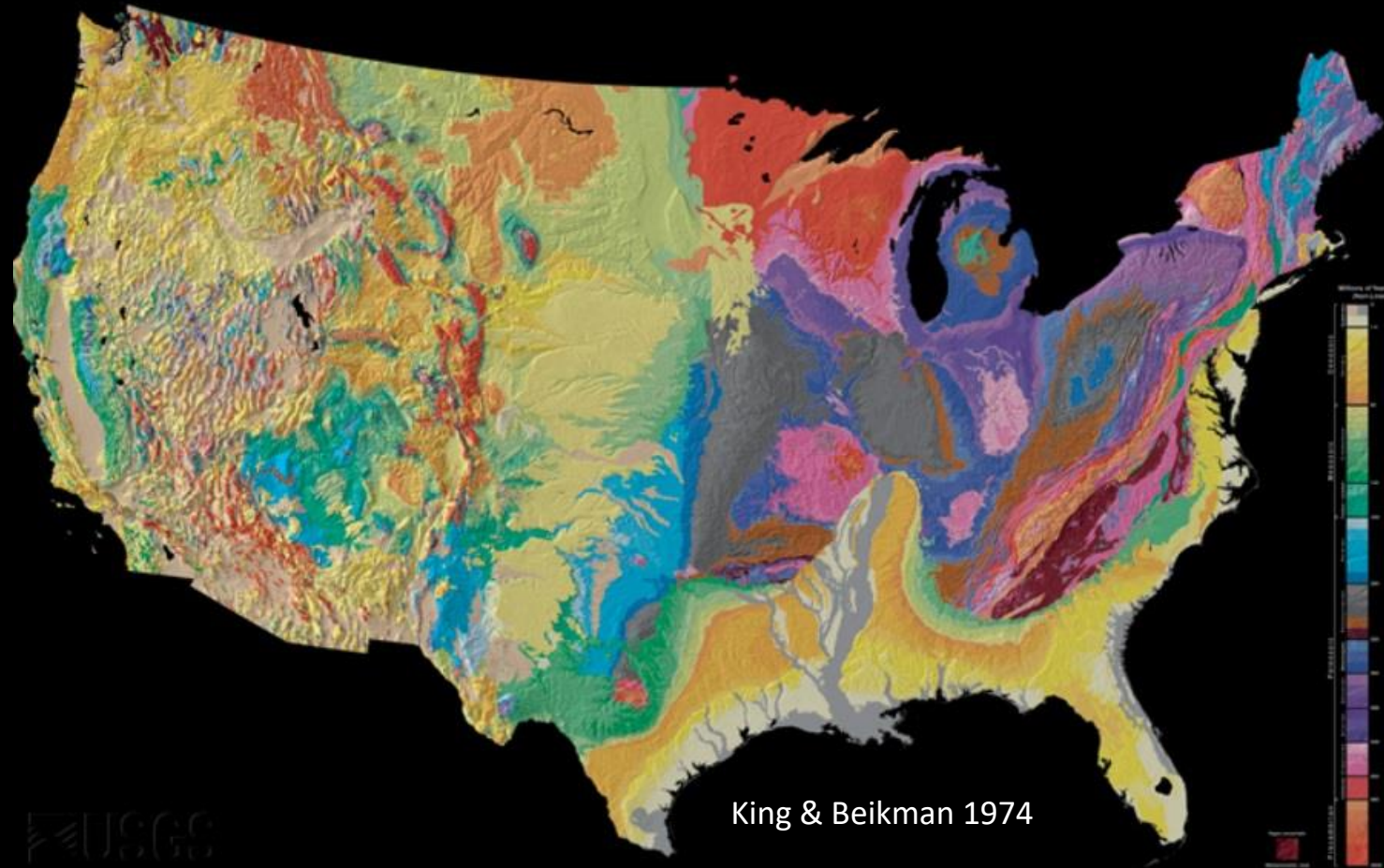
Will our conservation investments withstand the test of time?



Photo © TNC/D. Shaw



Geodiversity... drives patterns of biodiversity



King & Beikman 1974

Resilient Sites



Highly Vulnerable

Disrupted function, low diversity

Few options

Generalist species

Highly Resilient

Sustain function and diversity

Many options

Specialist species

Site Resilience: the capacity of a site to maintain species diversity, productivity, and ecological function as the climate changes.

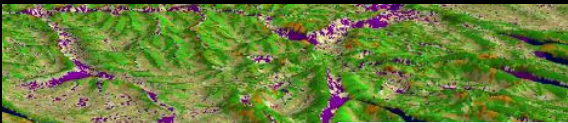
- Anderson et al. 2014

Special Issue on Conserving Nature's Stage

Conservation Biology

Volume 29, Number 3, June 2015

Open Access Papers



The Nature Conservancy
Protecting nature. Preserving life.[™]

Resilient Sites for Terrestrial Biodiversity in the Northeast and Midwest

The Nature Conservancy
Mark G. Anderson, Melissa C. ...

The Nature Conservancy
Mark G. Anderson, Charles E. Ferrer, ...



Physical Settings and Biodiversity in the Eastern United States

Mark G. Anderson, Charles E. Ferrer
Journal of Conservation Science

OPEN ACCESS freely available online

PLUS ONE

Conserving the Stage: Climate Change and the Geophysical Underpinnings of Species Diversity

Mark G. Anderson*, Charles E. Ferrer

The Nature Conservancy, Biology, Molecular and United States of America

Abstract
Conservationists have proposed methods for adapting to climate change that assume species distributions are primarily explained by climate variables. The key idea is to use the understanding of species-climate relationships to map corridors and to identify regions of faunal stability or high species turnover. An alternative approach is to adopt an evolutionary timescale and ask ultimately what factors control total diversity, so that over the long run the major drivers of total species richness can be protected. Within a single climatic region, the temperate area encompassing all of the Northeastern U.S. and Maritime Canada, we hypothesized that geologic factors may take precedence over climate in explaining diversity patterns. If geophysical diversity does drive regional diversity, then conserving geophysical settings may offer an approach to conservation that protects diversity under both current and future climates. Here we tested how well geology predicts the species diversity of 14 U.S. states and three Canadian provinces, using a comprehensive, new spatial dataset. We tested 11 linear regressions of species diversity on all possible combinations of 23 geophysical and climatic variables indicated that four geophysical factors: the number of geological classes, latitude, elevation range and the amount of calcareous bedrock, predicted species diversity with certainty ($R^2 = 0.64$). To confirm the species-geology relationships we ran an independent test using 18,700 location points for 885 rare species and found that 40% of the species were restricted to a single geology. Moreover, each geology class supported 5.95 endemic species and chi-square tests confirmed that calcareous bedrock and extreme elevations had significantly more rare species than expected by chance ($P < 0.0001$), strongly corroborating the regression model. Our results suggest that protecting geophysical settings will conserve the stage for current and future biodiversity and may be a robust alternative to species-level predictions.

Charles E. Ferrer, Mark G. Anderson (2015) Conserving the Stage: Climate Change and the Geophysical Underpinnings of Species Diversity. *Journal of Conservation Science*, 14(3):1-11. doi:10.1080/15230430.2015.1051111

Editor: Justin Wright, Duke University, United States of America

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Competing Interests: The authors have declared that no competing interests exist.

* Email: markanderson@tnc.org

Introduction
As a result of climate change, conservation scientists have been developing a variety of methods for anticipating impacts and identifying priority places to protect in order to maintain biodiversity. The most commonly employed approaches are models that relate species ranges to habitats and climate, and then predict where species are likely to experience extreme turnover or have the highest stability [1]. The latter areas, being regions of low turnover, could be prioritized as refugia for the largest number of species. A second, often advocated approach is to simply provide an abundance of habitat corridors so that species can move around as their range shifts [2]. Overall, many existing conservation plans simply don't account for changes in species distributions and clearly need revision. However, because land protection decisions are long term, require immense, and difficult to reverse, investments need a robust model for identifying reserve networks that is neither rendered obsolete by a changing climate, nor constantly in flux.

Here we explore a contrasting approach, which asserts that rather than trying to protect biodiversity one-species at a time, the key is to protect the climate *diversity* of biodiversity. The world has always experienced some measure of climate change and species ranges are not fixed. Accordingly, we should seek to maintain the landscape features that ultimately control species richness. A longstanding hypothesis in biogeography is that species richness is largely controlled by habitat heterogeneity [3, 4]. If this is true, then the best response to climate change might be the protection of a network of nature reserves that encompasses the maximum habitat heterogeneity [5, 6]. If, for example, geophysical diversity maintains species diversity, independent of climate, then conserving geophysical diversity may offer an approach to conservation that protects diversity under both current and future climates.

To test this hypothesis we used information on species richness, combined with a new comprehensive database of spatial data on geology, elevation, climatic averages and extremes, and over 18,700 rare species locations, to ask how much variation in species richness among 14 U.S. states and three Canadian provinces is explained by geophysical factors.

We chose to focus on geology because geology defines the available environments, determines the location of key habitats, and stimulates diversification [7]. Although climate factors may drive diversity at continental scales, within a single climatic region like the temperate Northeast, geophysical factors may take precedence over climate in explaining diversity patterns [5, 6], and can overwhelm local biotic interactions [8]. In contrast, geology diversity shapes species diversity patterns through its influence on the chemical and physical properties








Resilient Sites

for Terrestrial Conservation
in the Great Lakes
& Tallgrass Prairie Region

Mark Anderson, Melissa Clark,
Meredith Cornett, Kim Hall,
Arlene Olivero Sheldon,
& John Prince.



Resilience Analysis Coverage

-  Ecoregions
-  Great Lakes Expansion
-  Great Plains Expansion
-  Previously Funded
-  Underway



Conserving Nature's Stage: Resilience

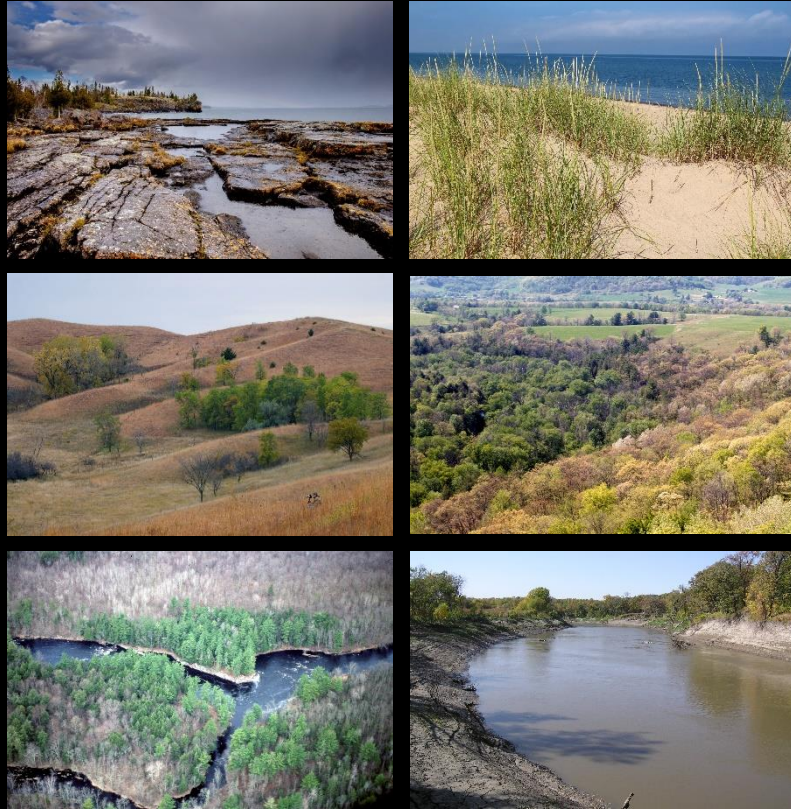
Core Concepts

- Geophysical Setting
- Landform Diversity
- Local Connectedness

Photo © TNC/D. Shaw

Conserving Nature's Stage: *Resilience*

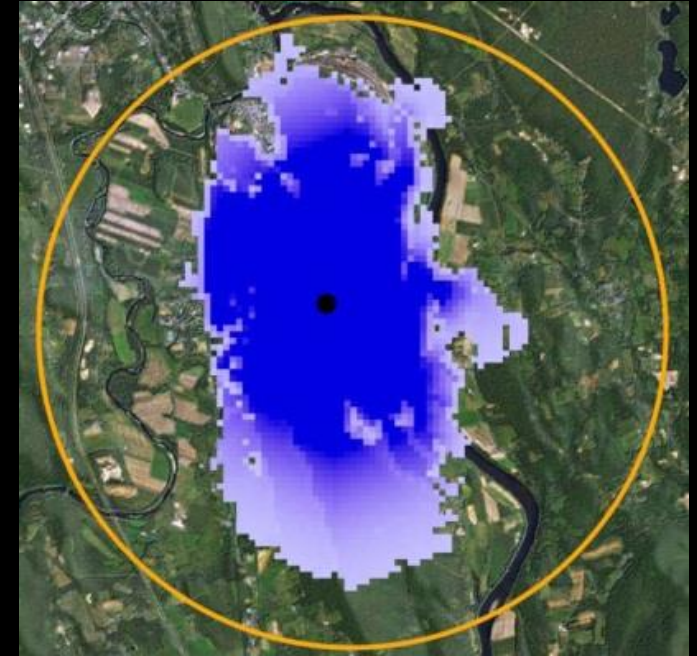
Three Core Concepts



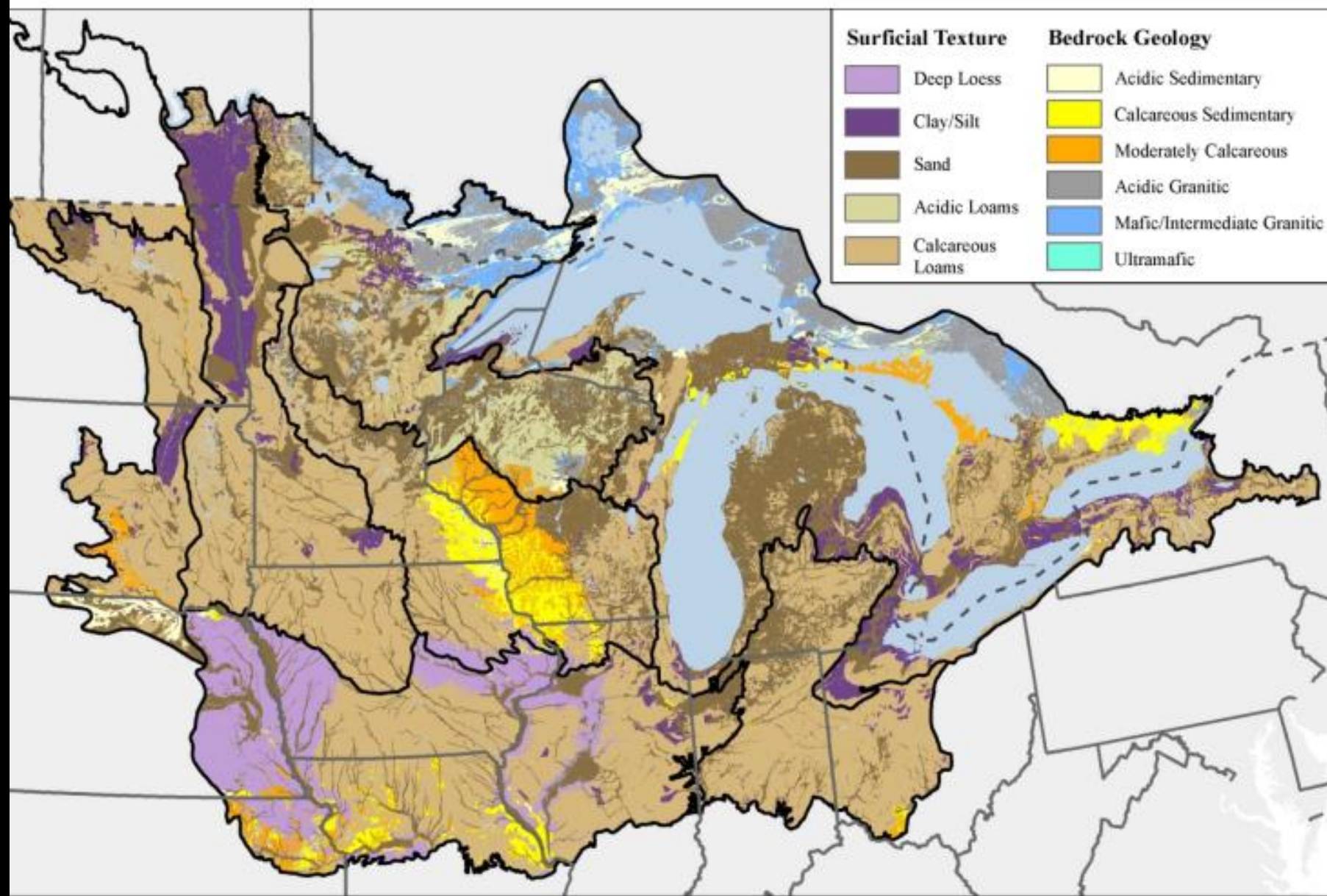
Geophysical Setting
The Stage



Landform Diversity
Niches



Local Connectedness
Access to Niches



Surficial and Bedrock Settings

— State or Province

- - - International Border

□ Ecoregions

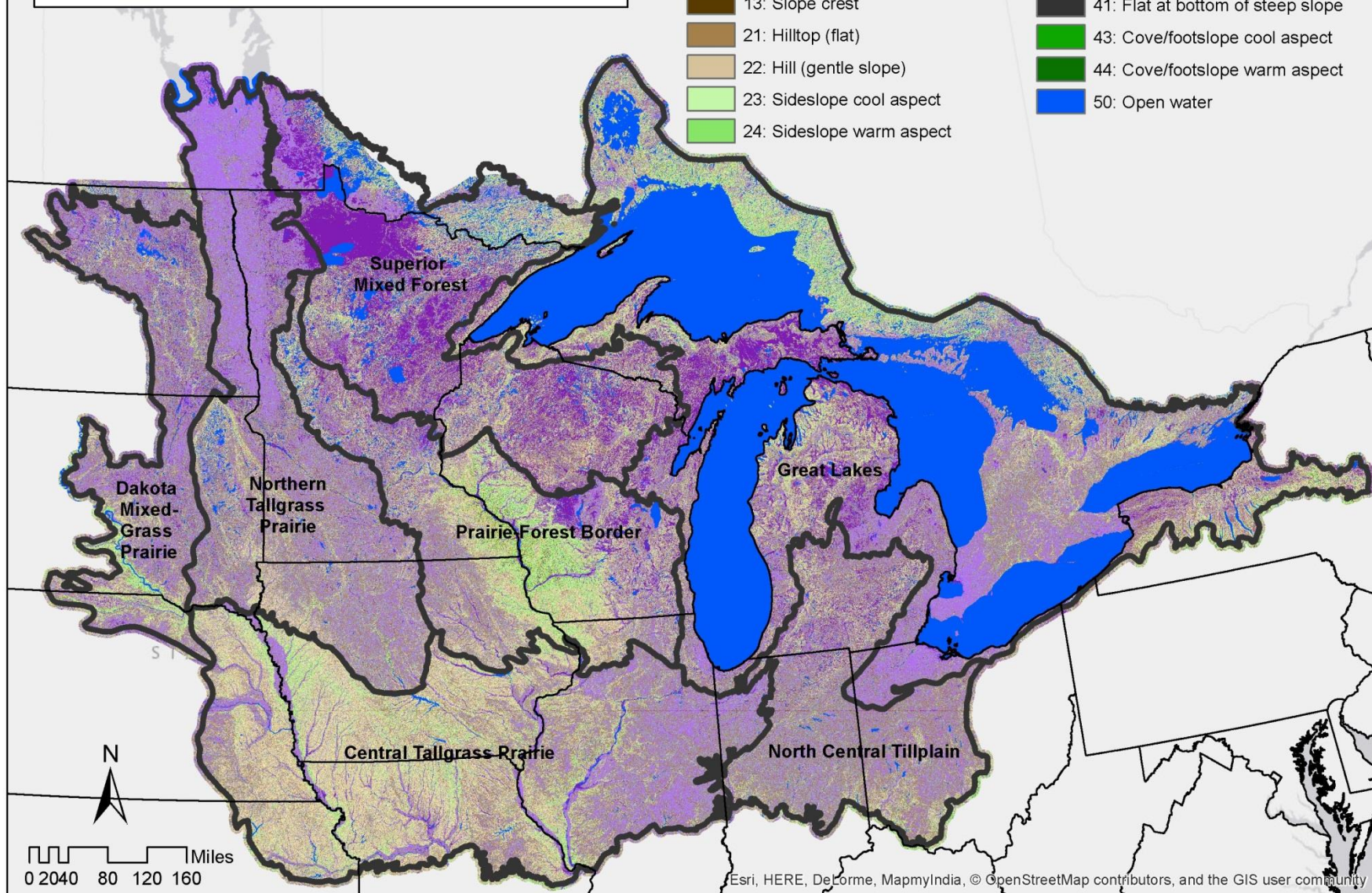
0 50 100 150 200 250 300 350
Miles

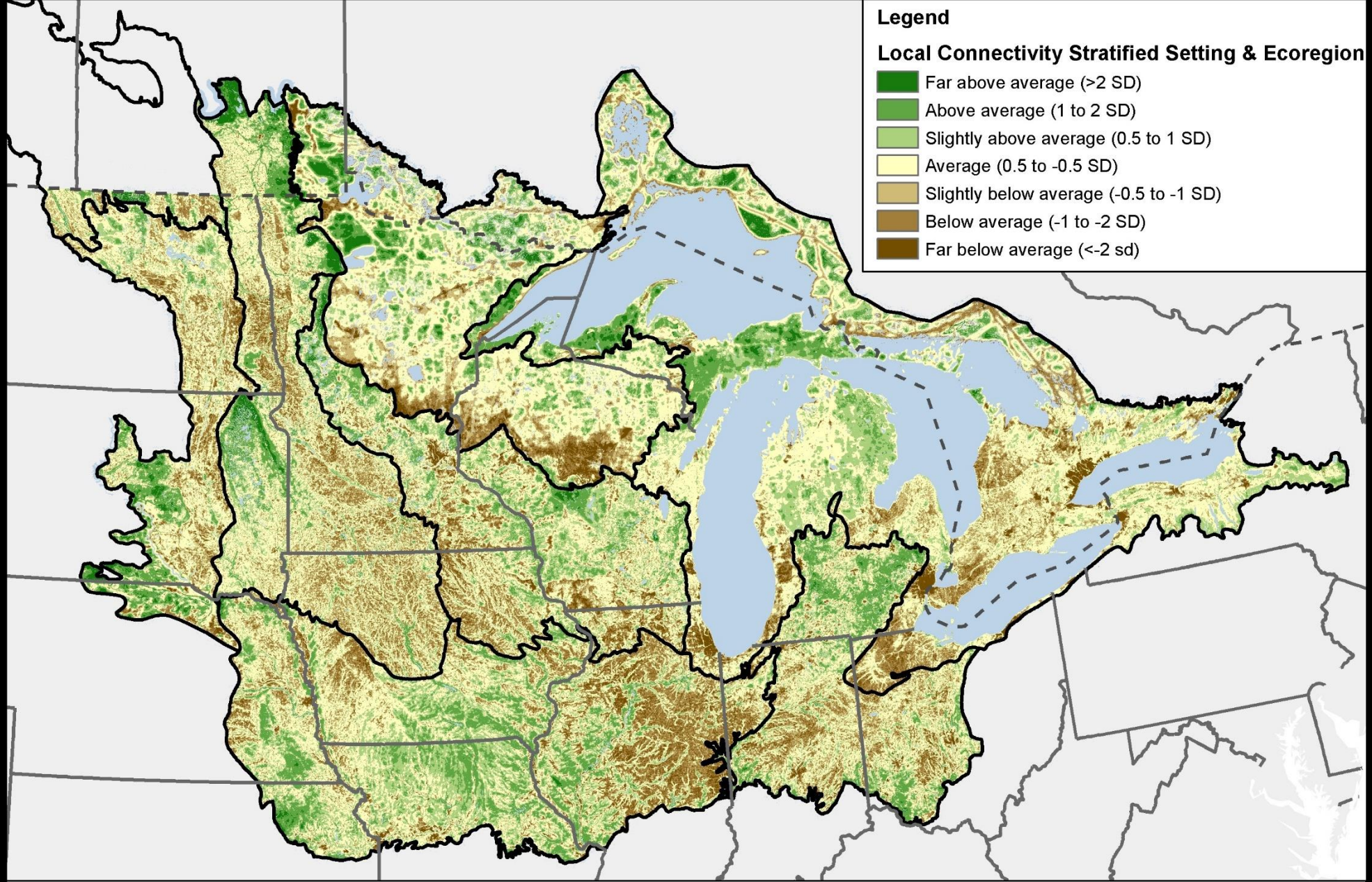
100 0 100 200 300
Kilometers

Map Produced by TNC Eastern Division 2017

Great Lakes Project Area Landforms

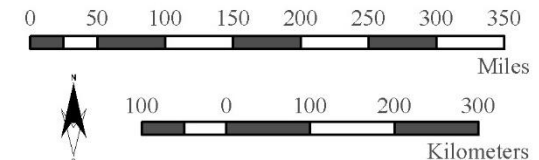
- | | |
|--|---|
|  3: Steep slope cool aspect |  30: Dry flats |
|  4: Steep slope warm aspect |  31: Wet flats |
|  5: Cliff |  32: Valley/toeslope |
|  11: Summit/ridgetop |  39: Moist flats in upland landcover |
|  13: Slope crest |  41: Flat at bottom of steep slope |
|  21: Hilltop (flat) |  43: Cove/footslope cool aspect |
|  22: Hill (gentle slope) |  44: Cove/footslope warm aspect |
|  23: Sideslope cool aspect |  50: Open water |
|  24: Sideslope warm aspect | |

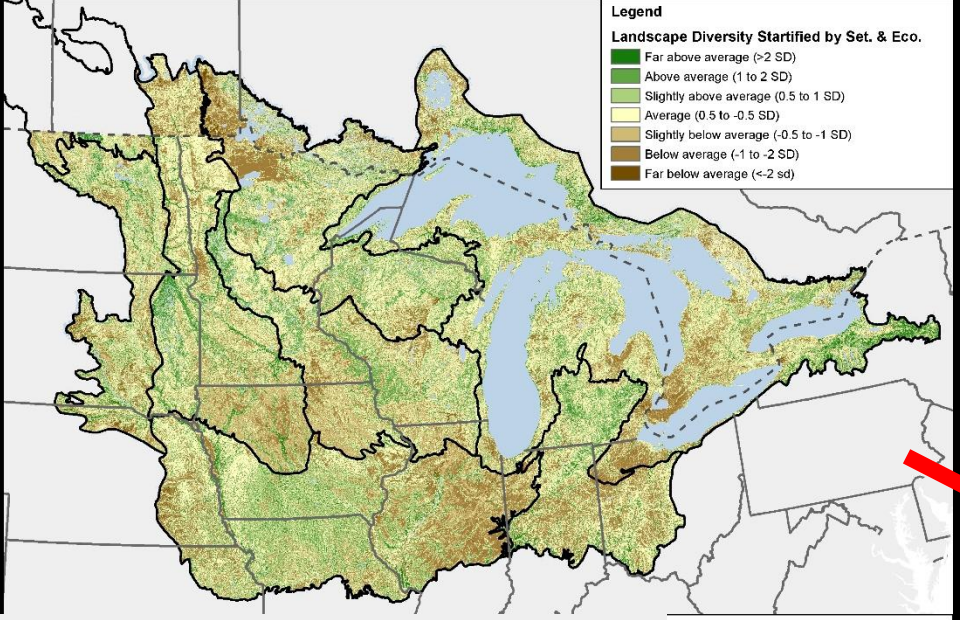




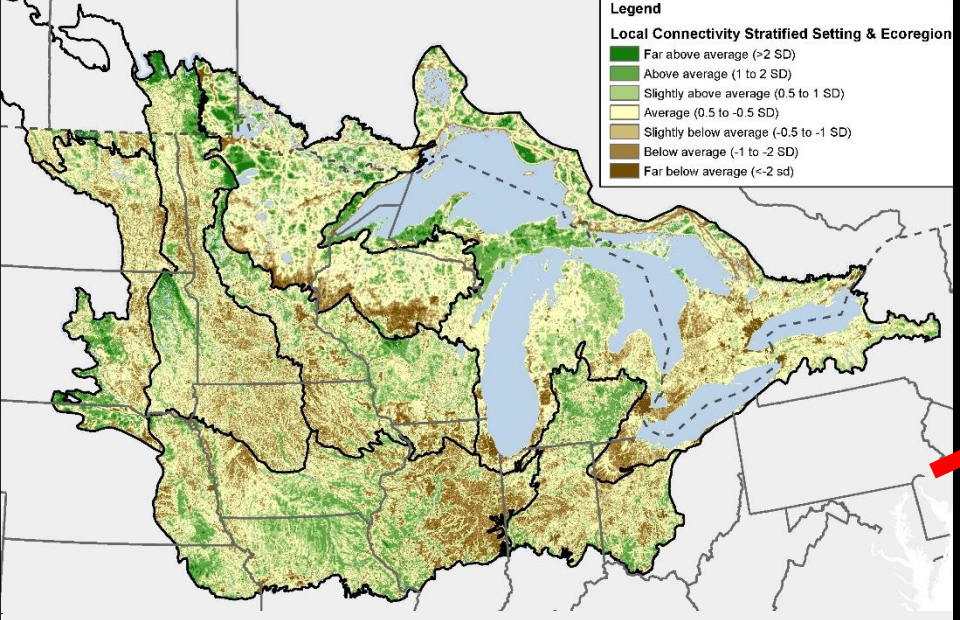
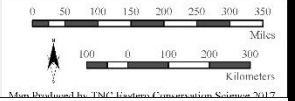
Local Connectivity Stratified by Setting and Ecoregion

— State or Province
 - - - International Border





Landform Diversity



Local Connectedness



Resilience Stratified by Setting and Ecoregion

0 50 100 150 200 250 300 350 Miles
 0 100 0 100 200 300 Kilometers
 Map Produced by TNC Eastern Conservation Science 2017

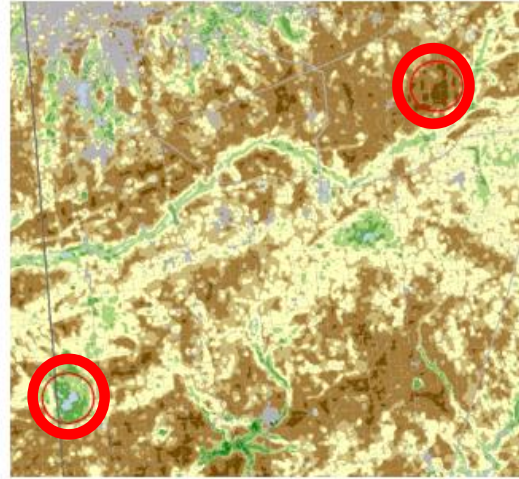
Conserving Nature's Stage: *Resilience*

High Resilience Score



Kankakee Sands

Variety of Landforms and Wetlands
Well Connected



Low Resilience Score

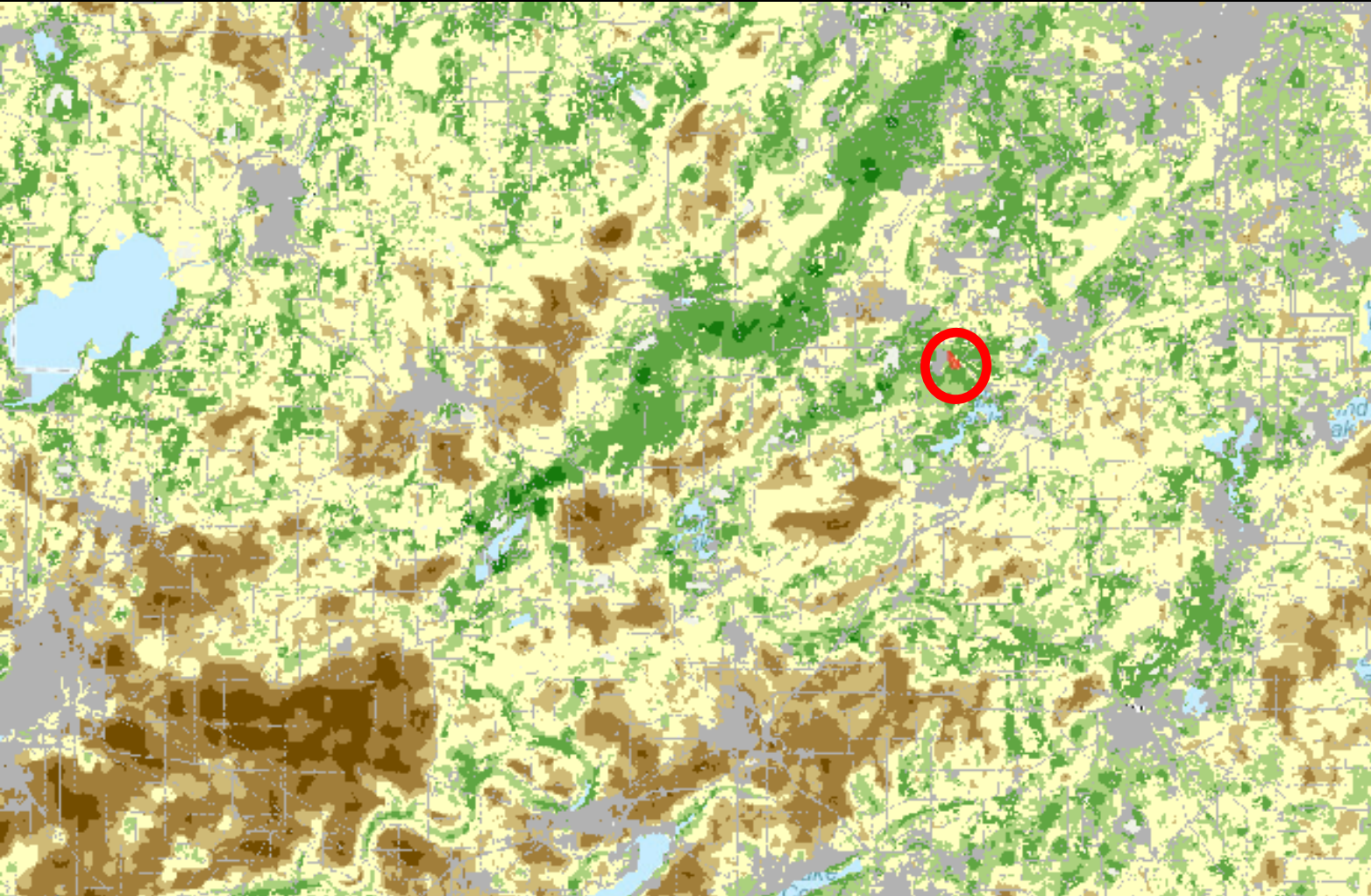


Flat and Dry
Dominated by Corn or Soy Agriculture

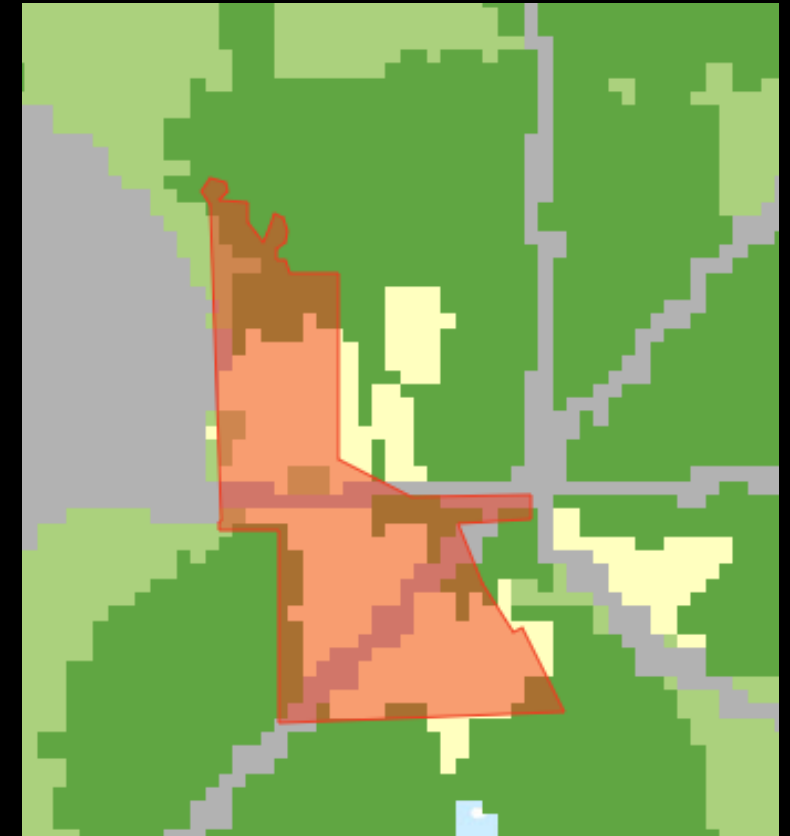


Conserving Nature's Stage: *Resilience*

Regional Scale



Site Scale



Terrestrial Resilience

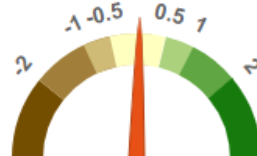
Resilience
Average (0.02 SD)



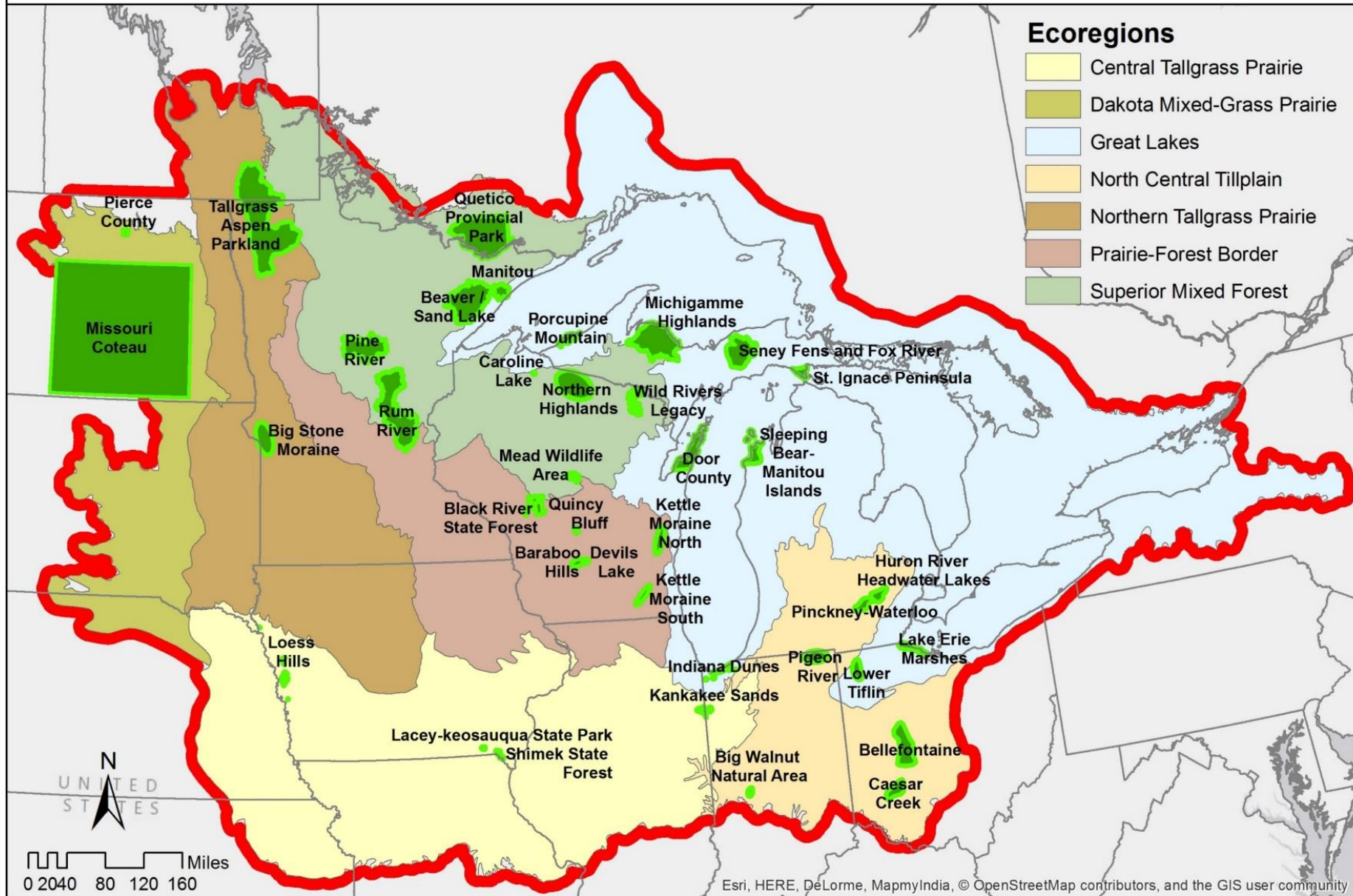
Landscape Diversity
Average (0.39 SD)



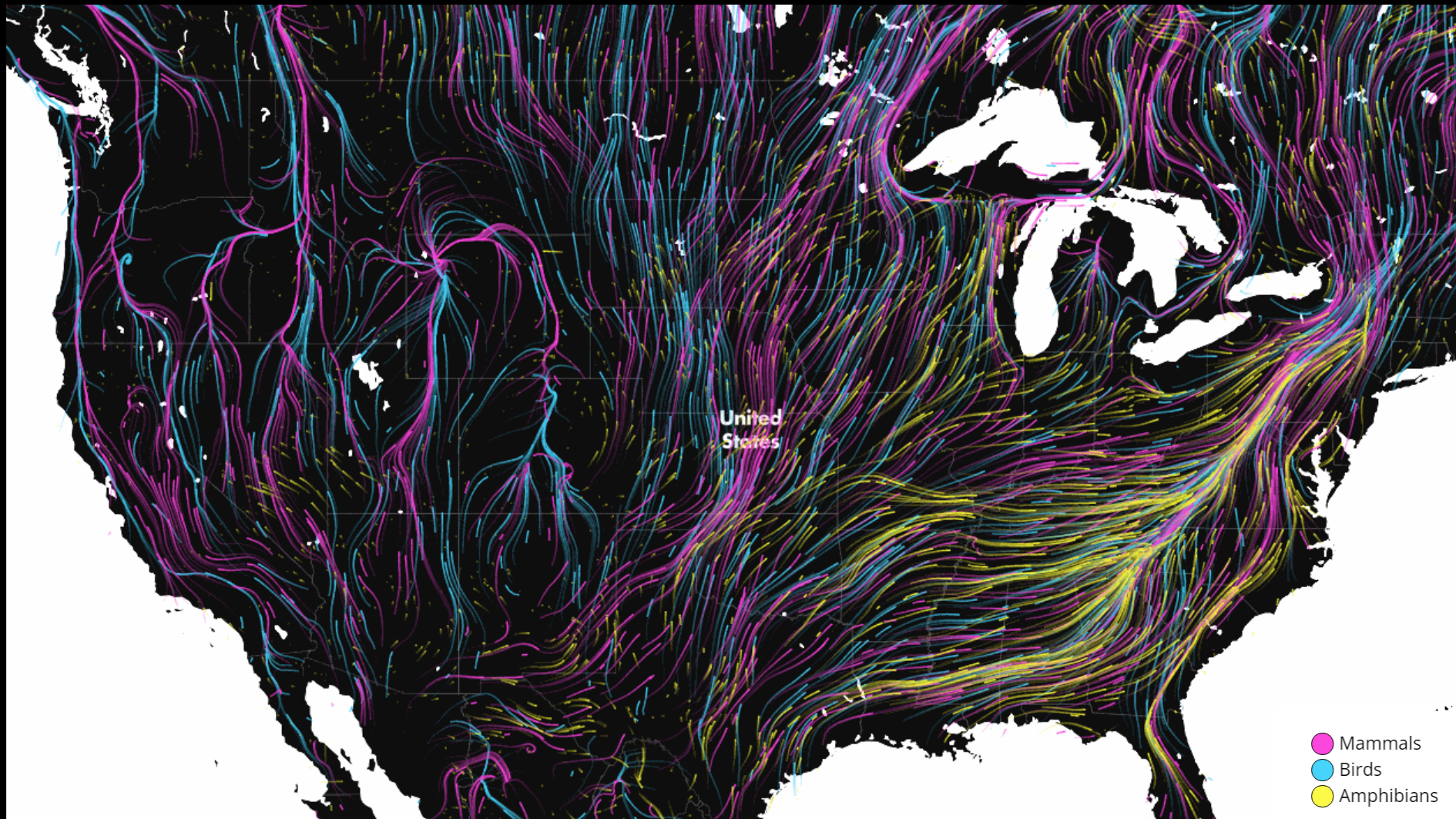
Local Connectedness
Average (0.05 SD)



Test Sites for Great Lakes Terrestrial Resilience Project

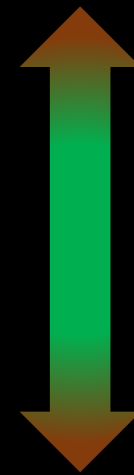
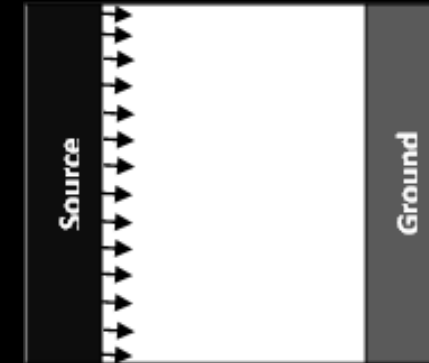
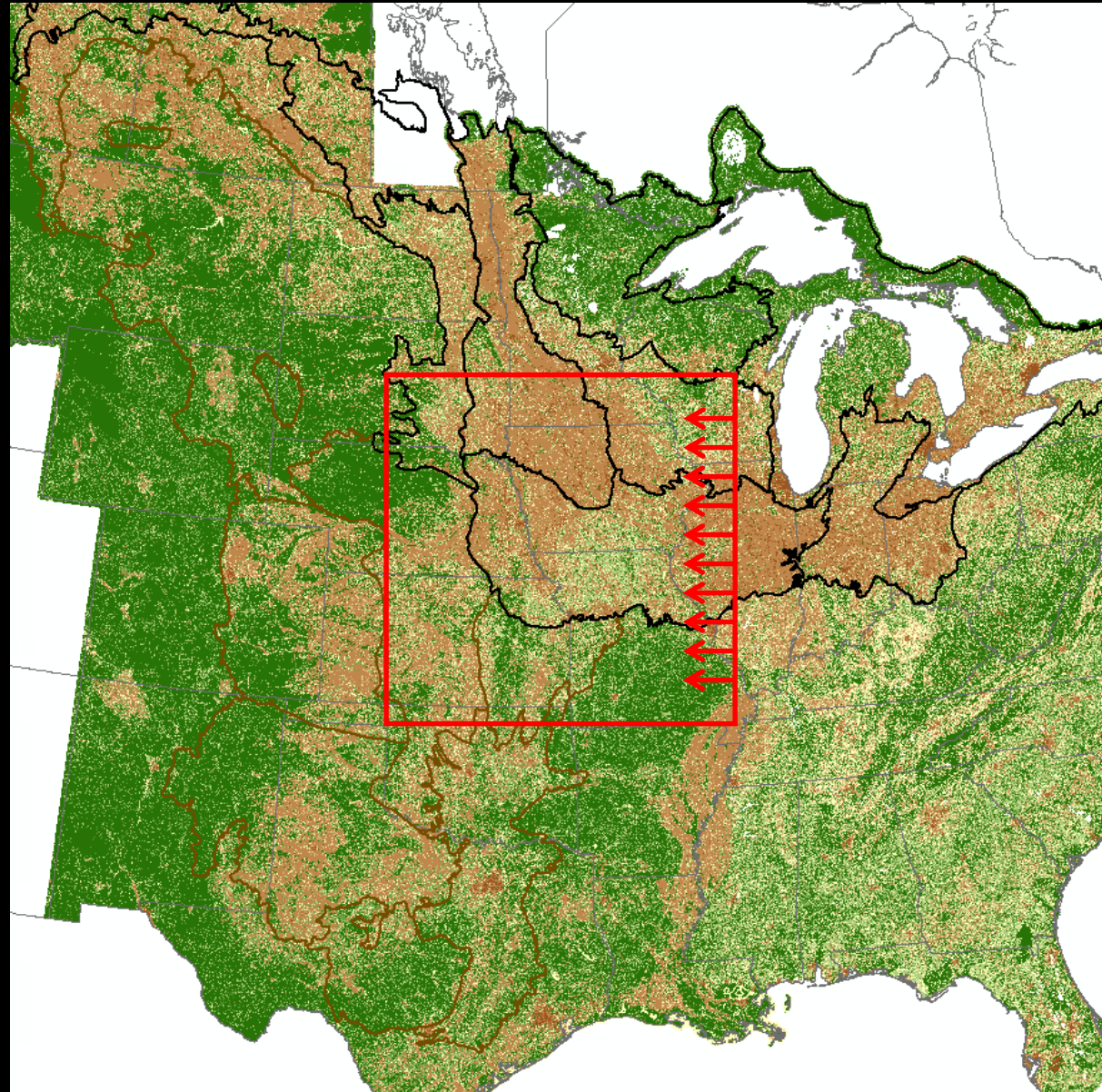


Conserving Nature's Stage: *Regional Connectivity*



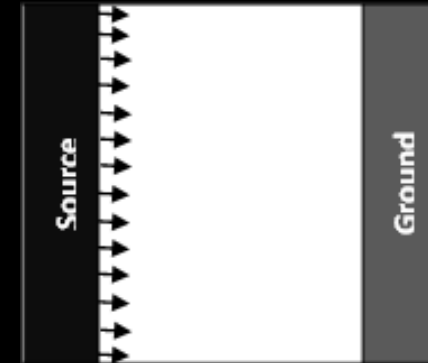
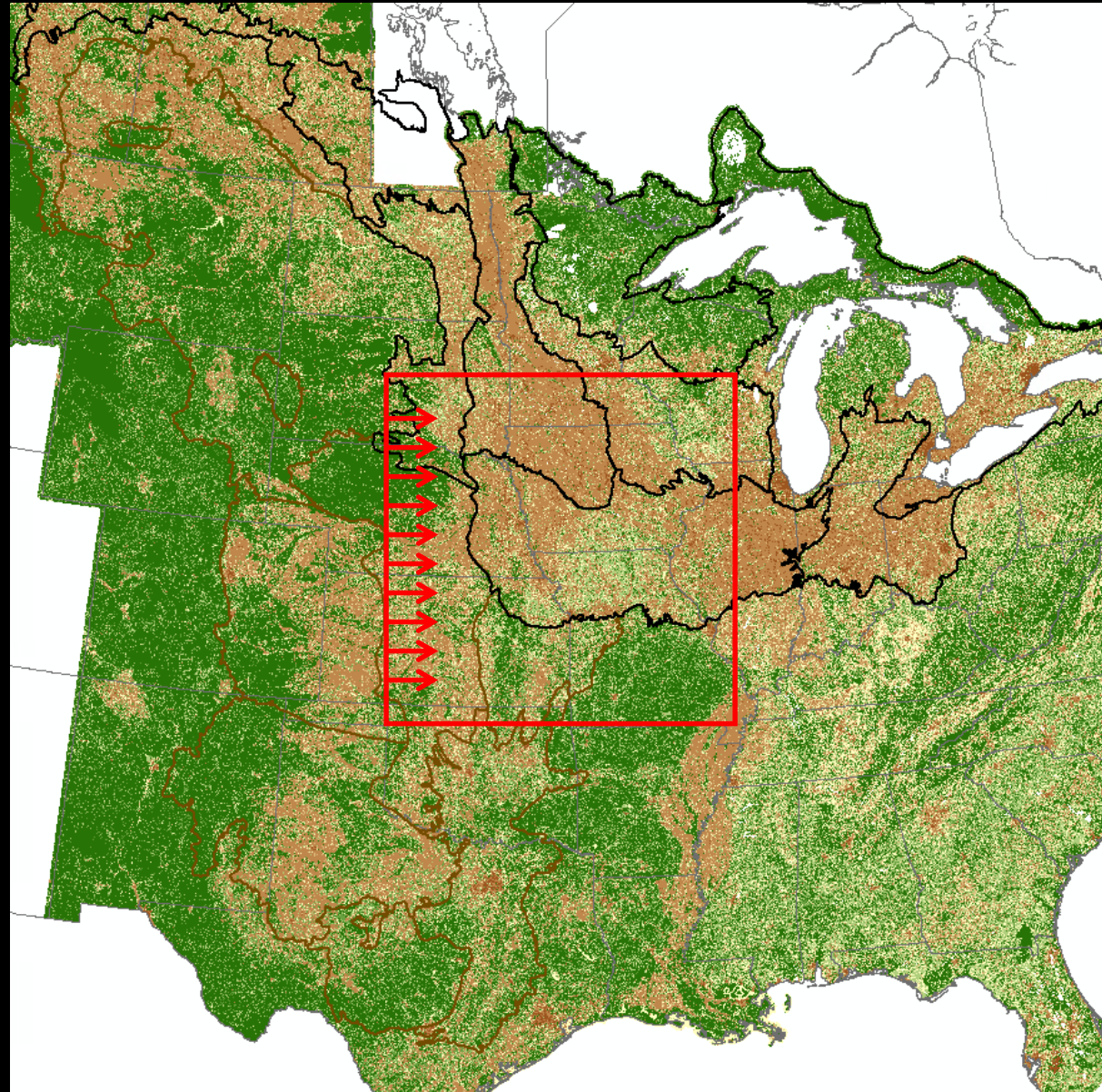
Data source: Lawler et al. 2013; Animation by Dan Majka, TNC

Conserving Nature's Stage: *Regional Connectivity*



- 1 Completely Natural
- 7 Agriculture
- 8 Low Density Development
- 9 Medium Density Development
- 20 High Density Residential

Conserving Nature's Stage: *Regional Connectivity*

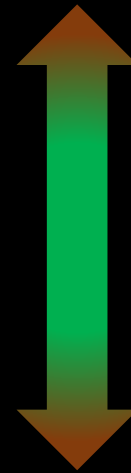
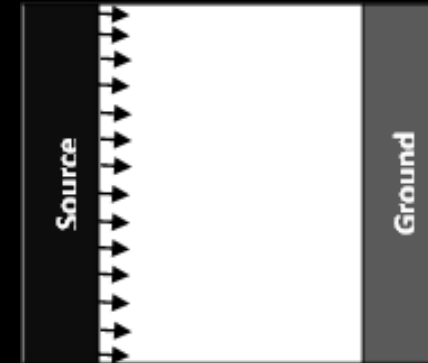


-
- 1 Completely Natural
 - 7 Agriculture
 - 8 Low Density Development
 - 9 Medium Density Development
 - 20 High Density Residential

Conserving Nature's Stage: *Regional Connectivity*



CIRCUITSCAPE



1 Completely Natural

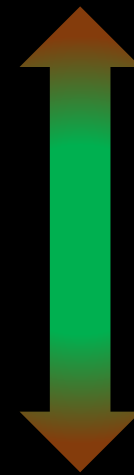
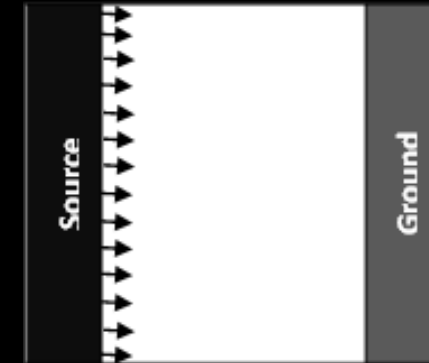
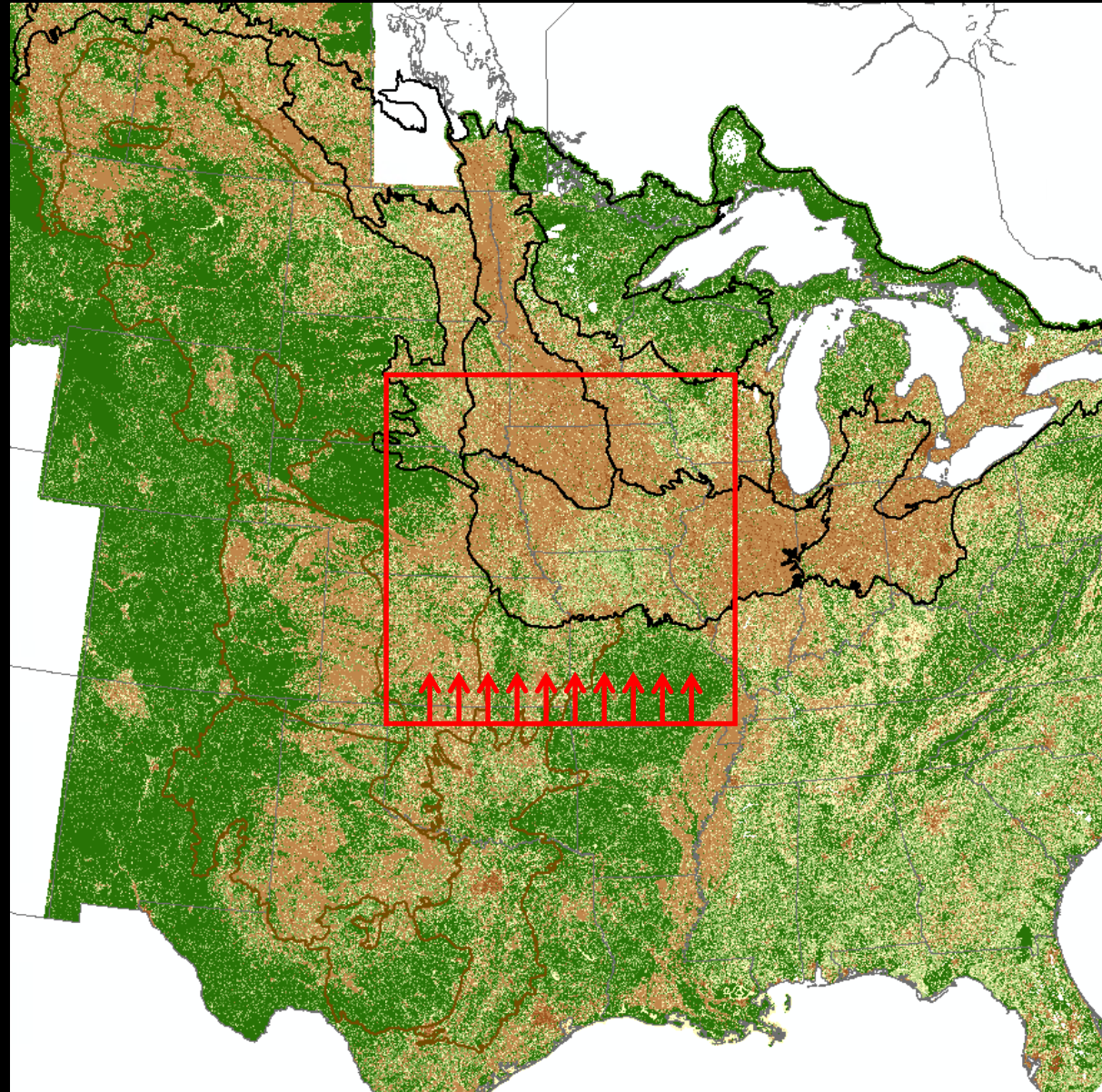
7 Agriculture

8 Low Density Development

9 Medium Density Development

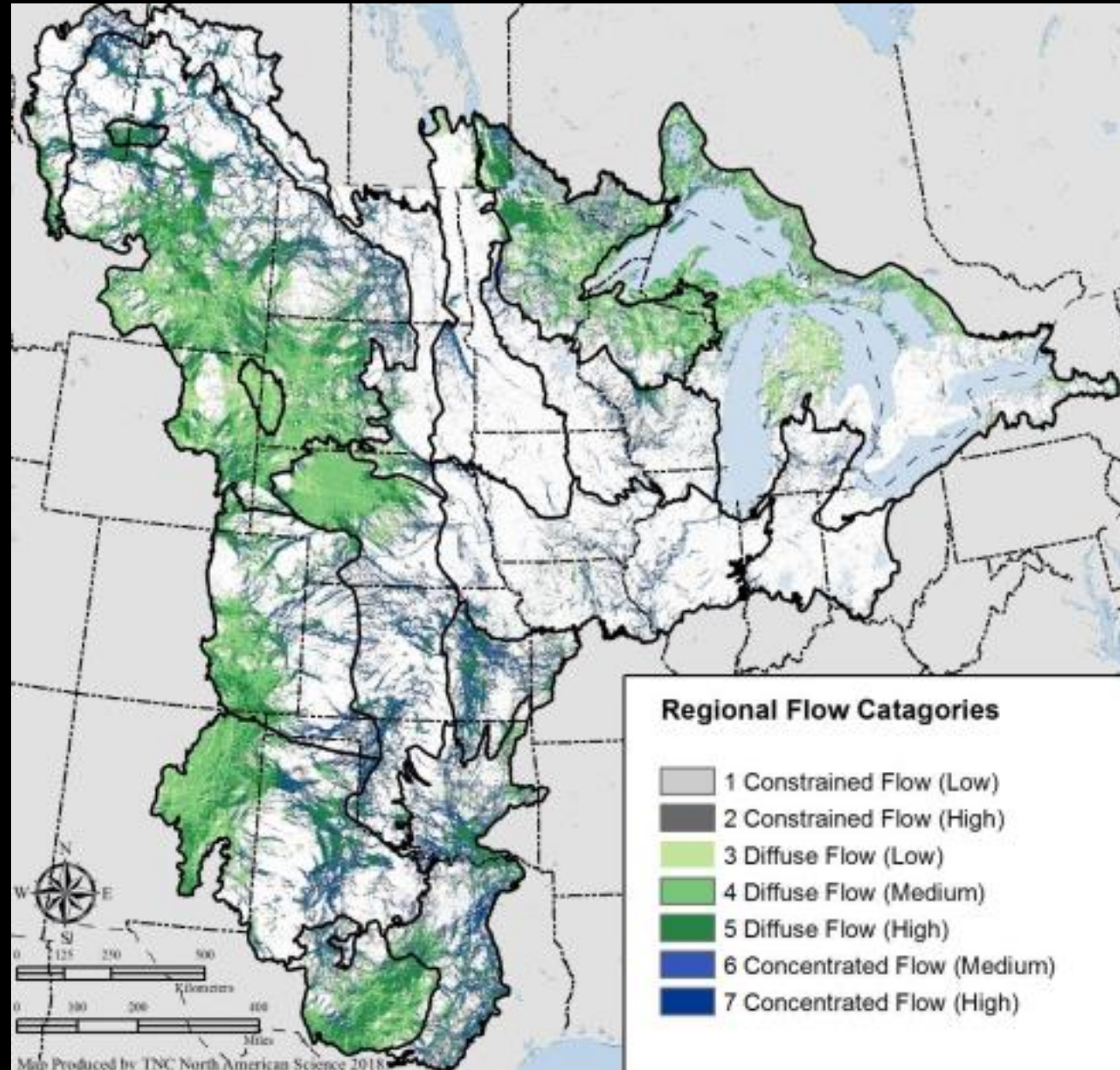
20 High Density Residential

Conserving Nature's Stage: *Regional Connectivity*



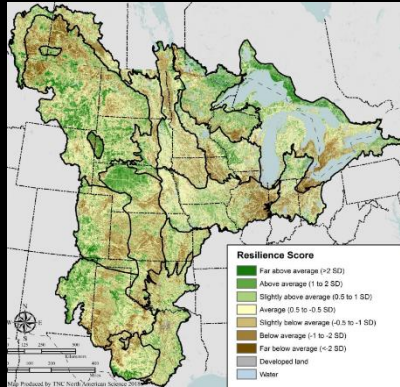
- 1 Completely Natural
- 7 Agriculture
- 8 Low Density Development
- 9 Medium Density Development
- 20 High Density Residential

Conserving Nature's Stage: *Regional Connectivity*

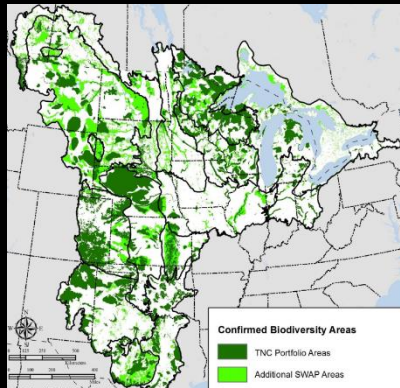


Conserving Nature's Stage: *Resilient AND Connected*

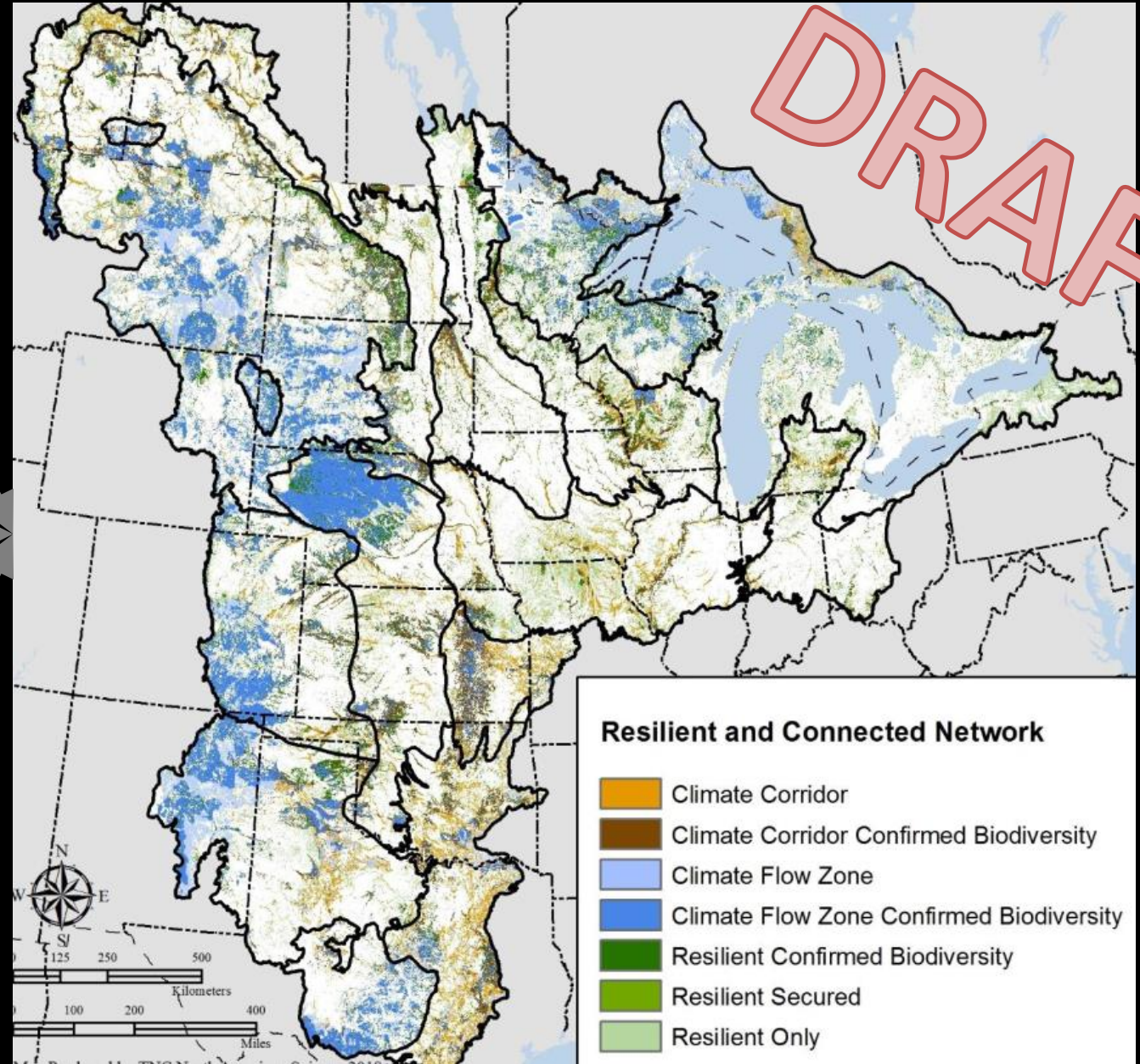
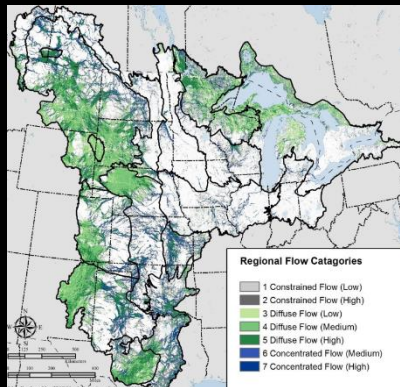
Resilience



Diversity

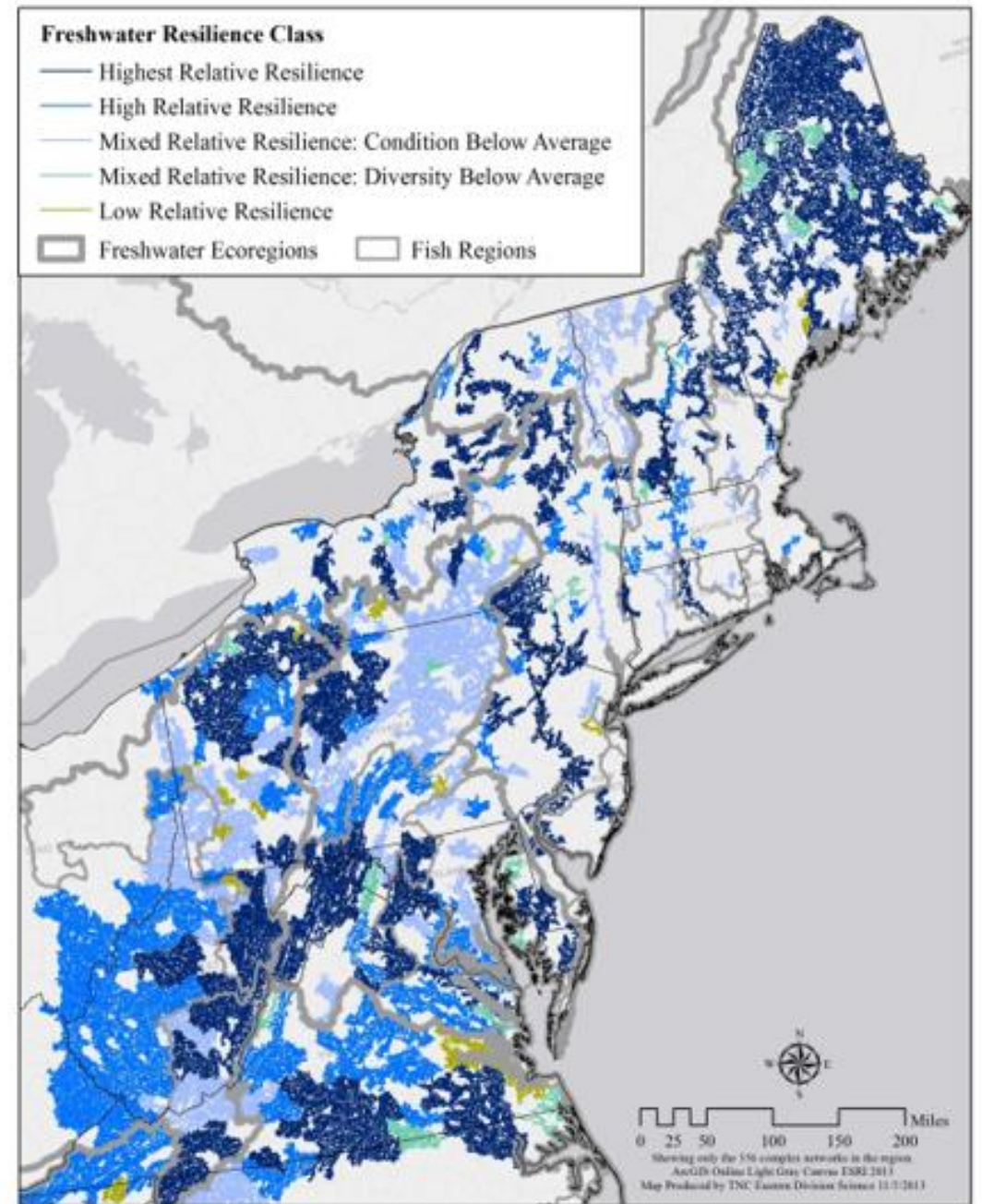


Flow



Next step...

Conserving Nature's Stage *Freshwater Resilience*



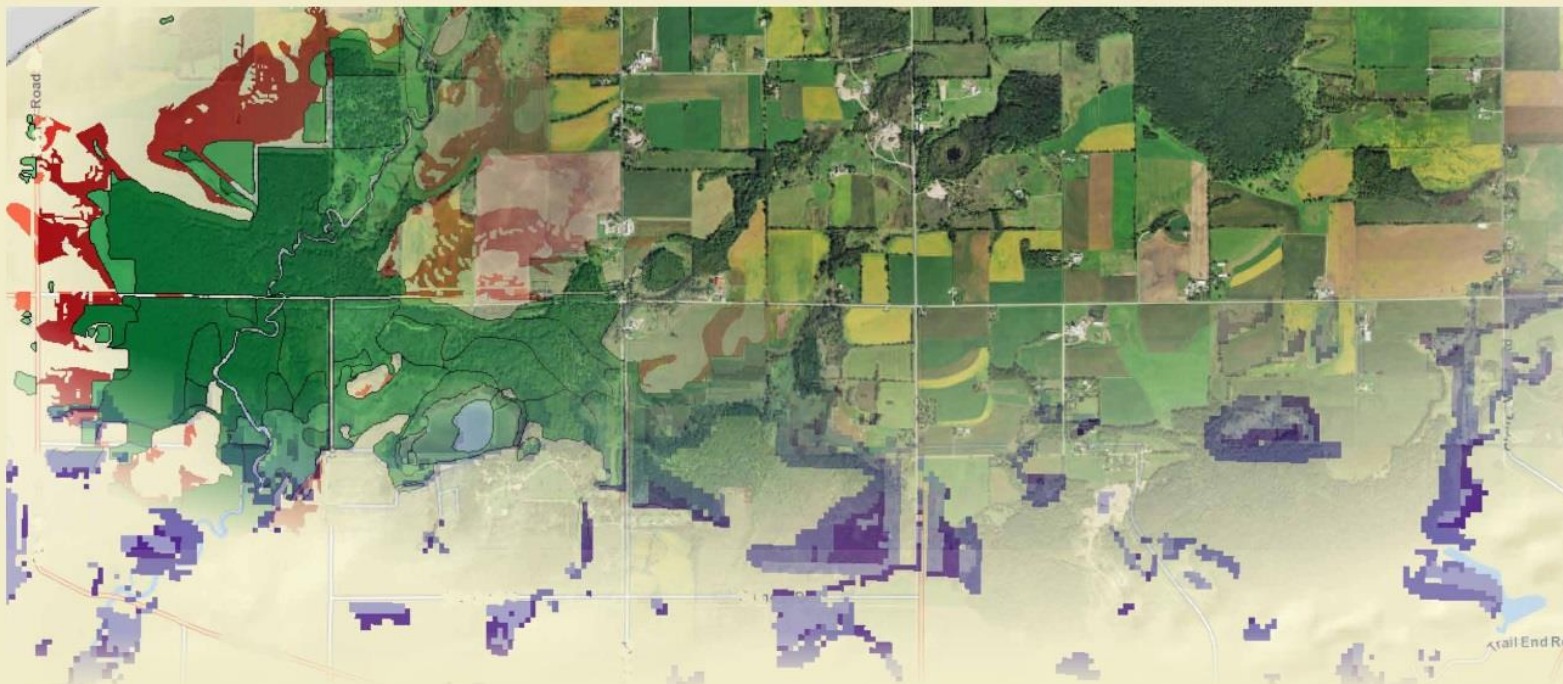
Regional Freshwater Resilience Class

Stratified by Fish Region and Freshwater Ecoregion



1. We can help nature adapt
2. Nature can help us adapt
3. Nature can reduce impacts

2. Nature Can Help Us Adapt



Wetlands by Design

A Watershed Approach for Wisconsin

Wetland Services

Flood abatement

Water quality

- Nitrogen reduction
- Phosphorus reduction
- Sediment reduction

Shoreline protection

Fish & aquatic habitat

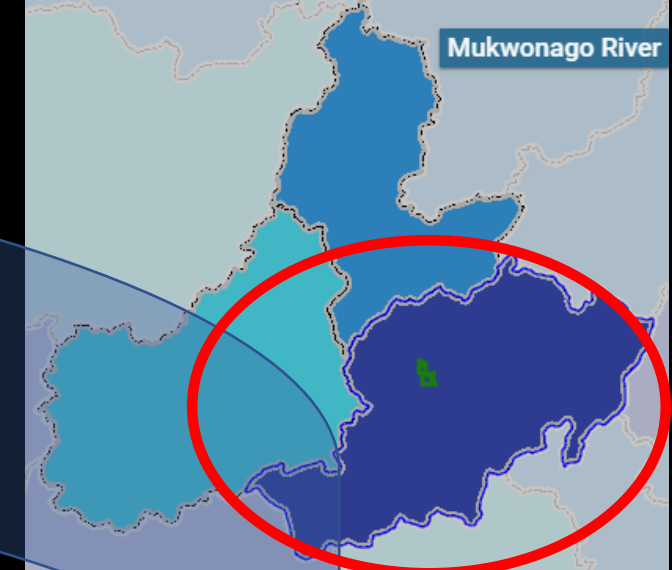
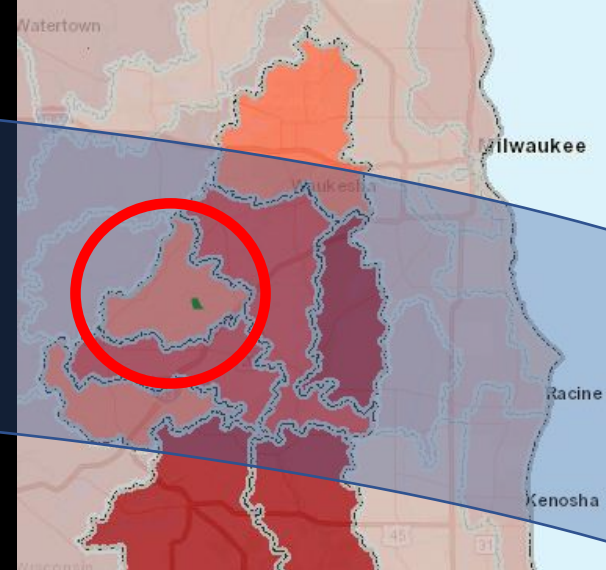
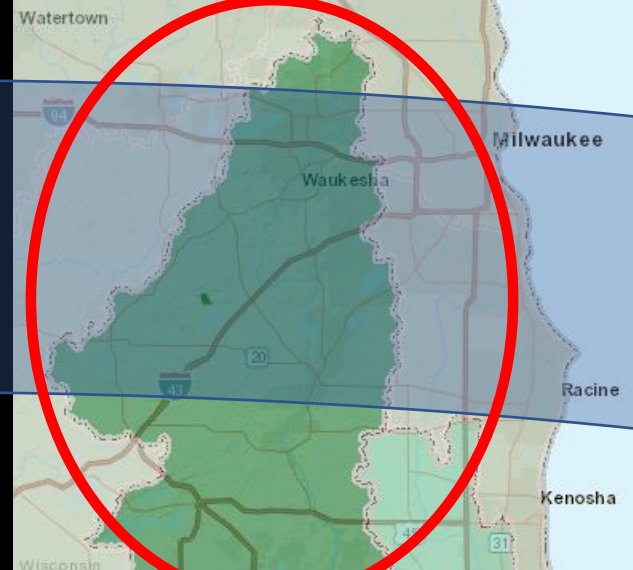
Surface water supply

Carbon storage

Floristic integrity

Wildlife habitat

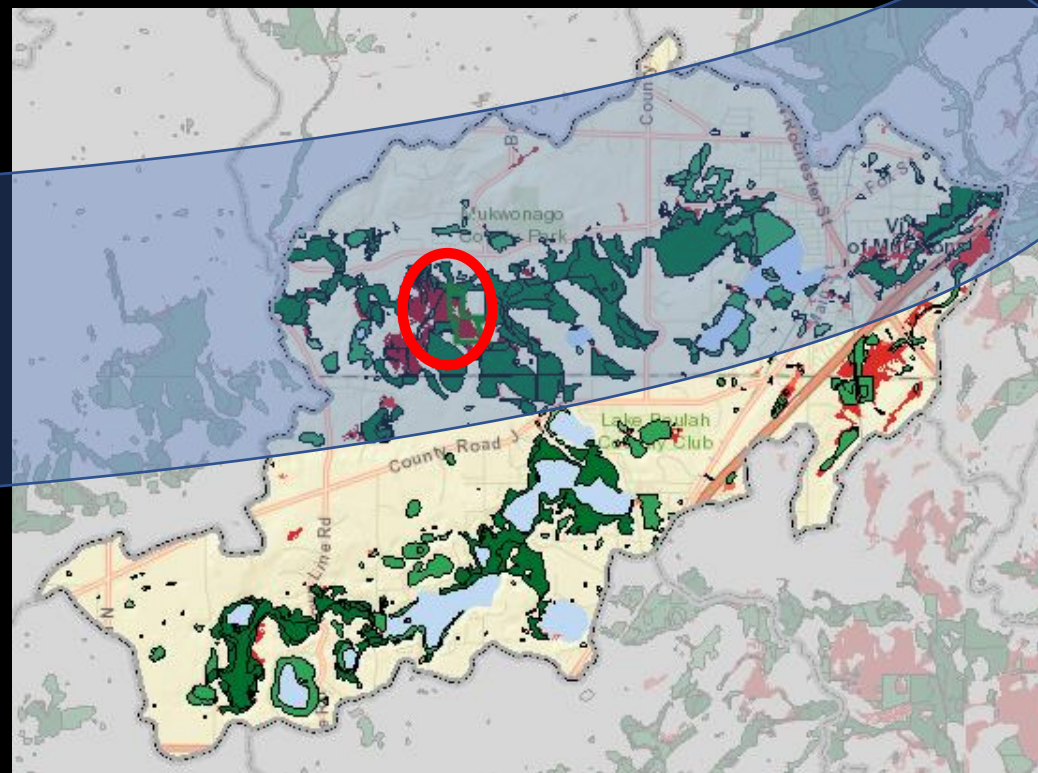


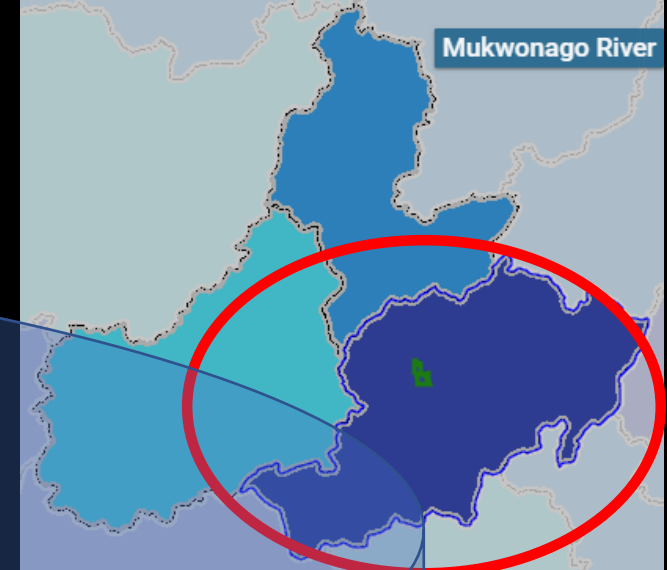
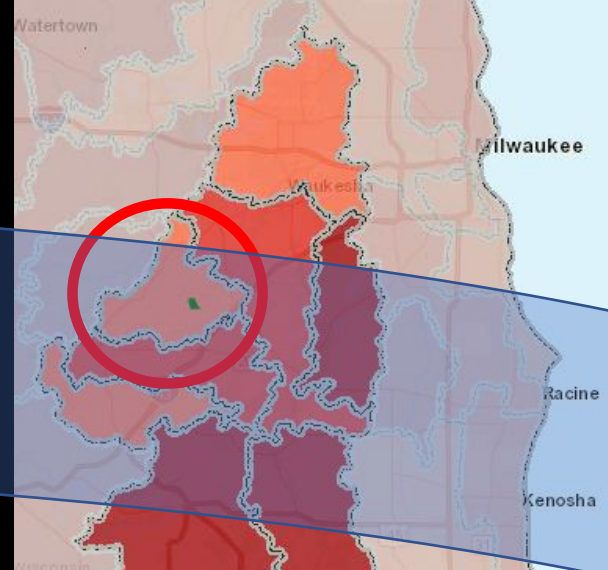
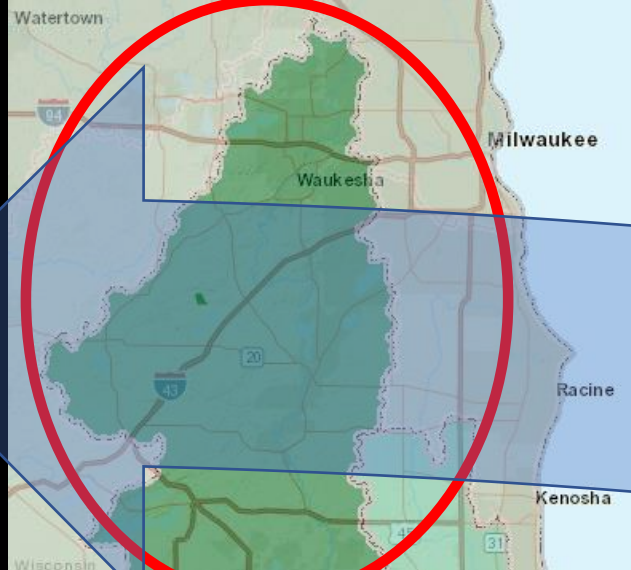


Wetlands By Design

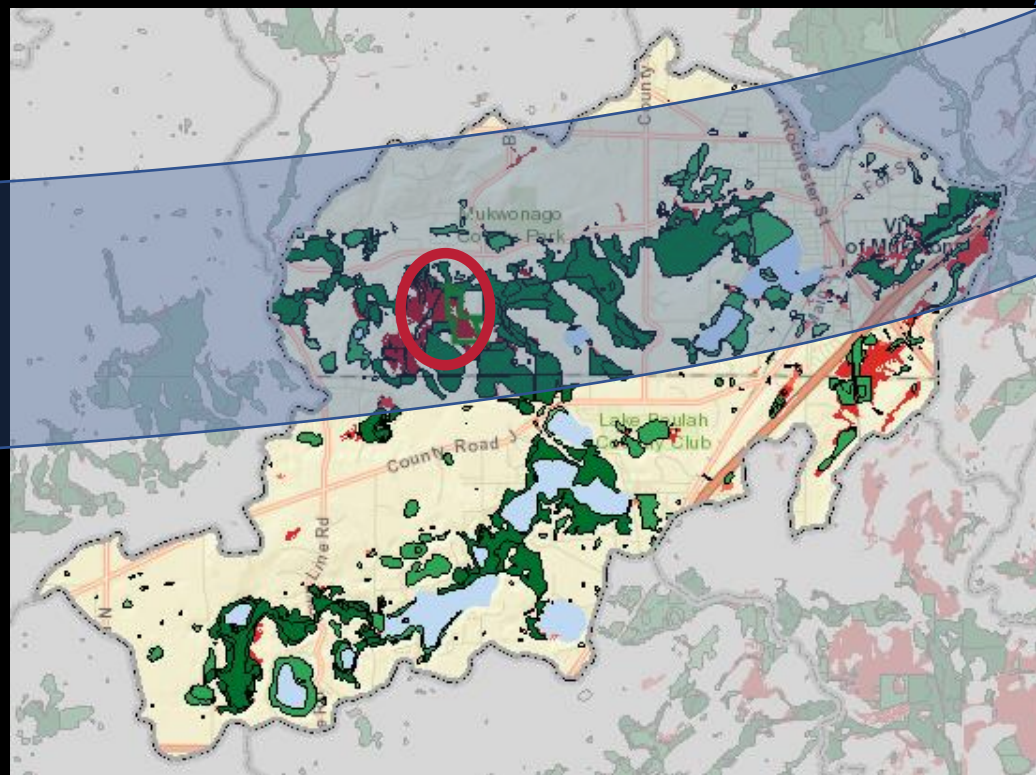
Top-tier site for

- Flood Abatement
- Fish & Aquatic Habitat
- Water Quality (N reduction)
- Surface Water Supply





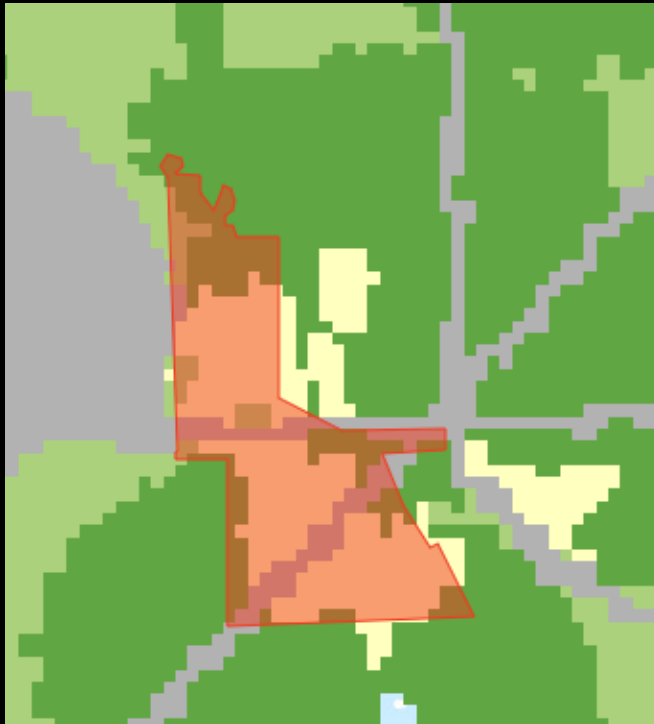
Wetlands By Design



Combining Data

We help nature adapt AND nature helps us adapt

Conserving Nature's Stage



maps.tnc.org/resilientland

Wetlands by Design

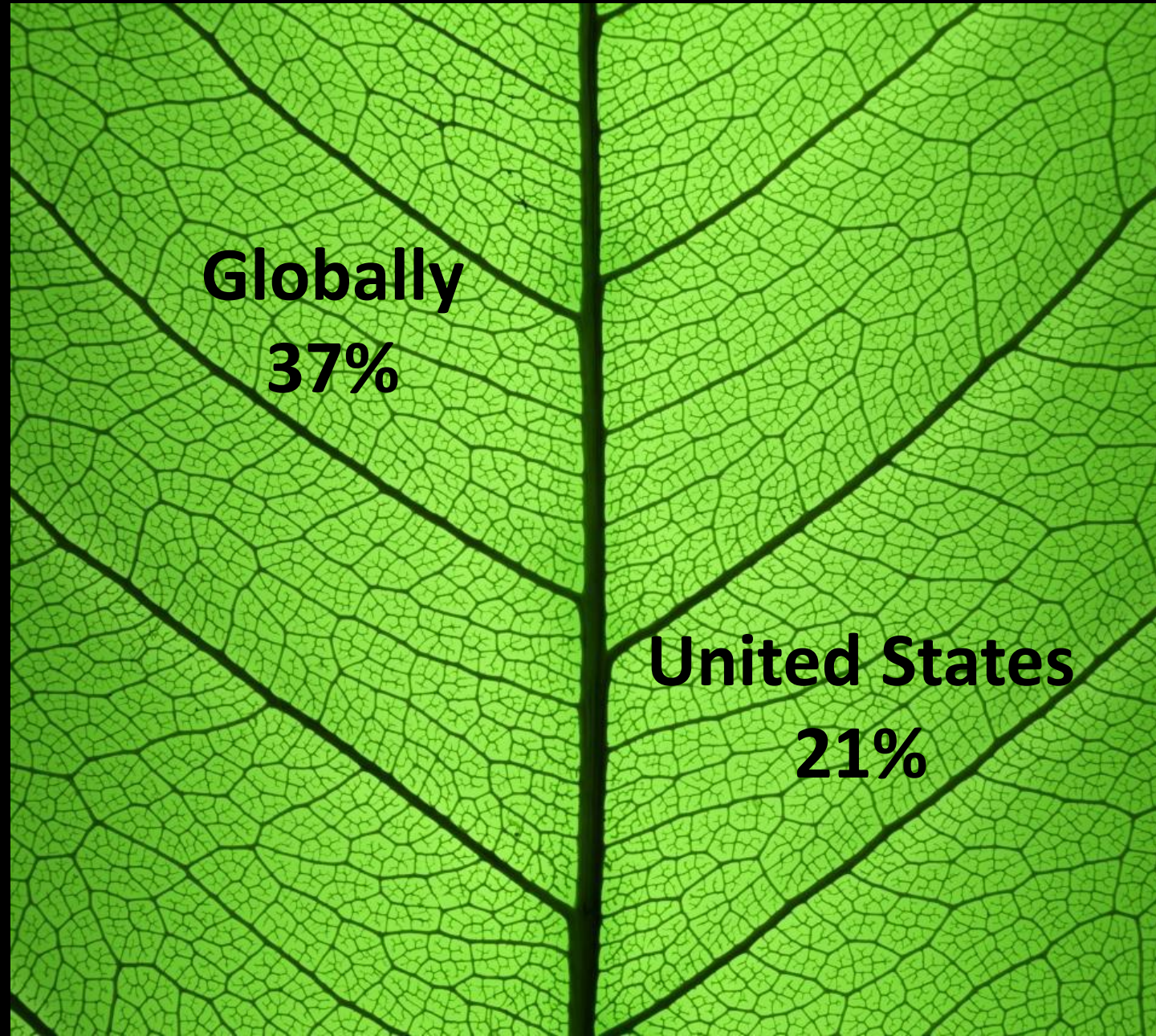


www.WetlandsByDesign.org

Top-tier site for...

- Flood Abatement
- Fish & Aquatic Habitat
- Water Quality (N reduction)
- Surface Water Supply
- Total # of Services

3. Nature Can Reduce Impacts



... of emissions reductions needed to stabilize warming

Natural Climate Solutions for the U.S.

National

State

770

Mitigation potential
Million tons CO₂e per year

5,795

2016 net emissions (U.S.)
Million tons CO₂e per year

Mitigation Pathways ⓘ

Marginal Abatement Cost
\$ per ton of CO₂e 🔒

Reforestation Off \$10 \$50 \$100 Max

Avoided Forest Conversion Off \$10 \$50 \$100 Max

Fire Management Off \$10 \$50 \$100 Max

Urban Reforestation Off \$10 \$50 \$100 Max

Avoided Grassland Conversion Off \$10 \$50 \$100 Max

Grassland Restoration Off \$10 \$50 \$100 Max

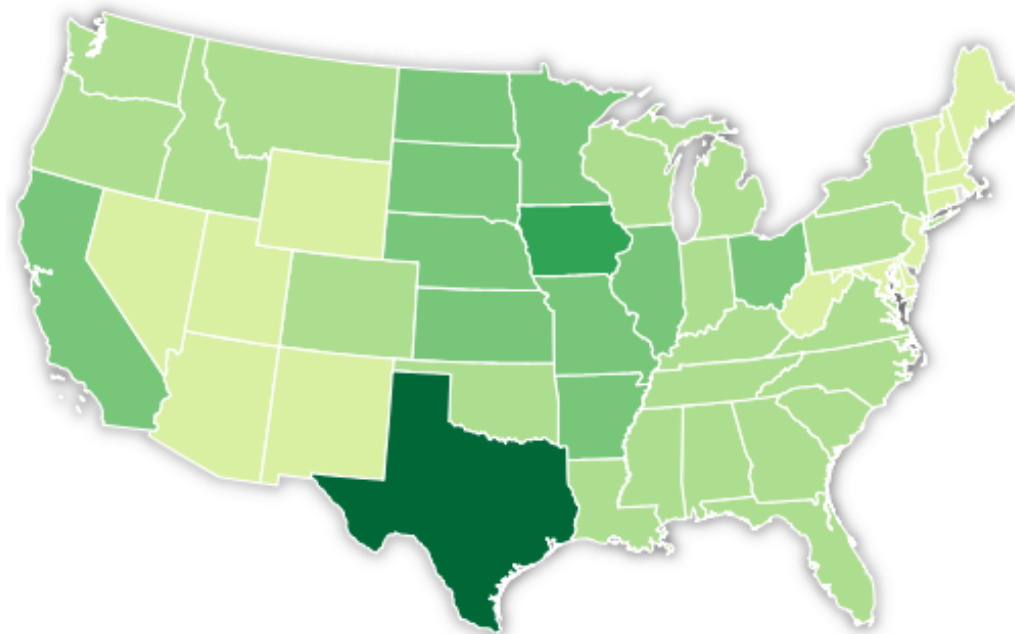
Alley Cropping Off \$10 \$50 \$100 Max

Cover Crops Off \$10 \$50 \$100 Max

Cropland Nutrient Management Off \$10 \$50 \$100 Max

Improved Manure Management Off \$10 \$50 \$100 Max

Improved Rice Cultivation Off \$10 \$50 \$100 Max



State	NCS Mitigation (Mt CO ₂ per year)	Area Available (million acres)
Texas	52.1	26.1
Iowa	35.1	22.6
South Dakota	33	20.9
Kansas	29.9	21.6
Missouri	29.7	15.8
North Dakota	28.6	20.6
Illinois	28.2	21.3
Minnesota	27.5	19.7
California	26.2	32.2
Ohio	24.7	12.4
Nebraska	24.6	18.5

Natural Climate Solutions for the U.S.

National

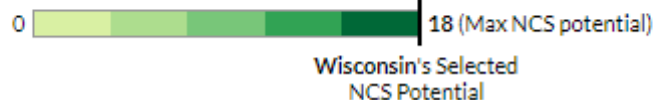
State

18

Mitigation Potential
(Million tons CO₂e per year)

64

2014 net emissions
Million tons CO₂e per year



Wisconsin

Full Extent

Click map to select state



Mitigation Pathways ⓘ

Marginal Abatement Cost
\$ per ton of CO₂e 🔒

Reforestation Off \$10 \$50 \$100 Max

Avoided Forest Conversion Off \$10 \$50 \$100 Max

Fire Management Off \$10 \$50 \$100 Max

Urban Reforestation Off \$10 \$50 \$100 Max

Avoided Grassland Conversion Off \$10 \$50 \$100 Max

Grassland Restoration Off \$10 \$50 \$100 Max

Alley Cropping Off \$10 \$50 \$100 Max

Cover Crops Off \$10 \$50 \$100 Max

Cropland Nutrient Management Off \$10 \$50 \$100 Max

Improved Manure Management Off \$10 \$50 \$100 Max

Improved Rice Cultivation Off \$10 \$50 \$100 Max

Pathway	NCS Mitigation (Mt CO ₂ per year)	Area Available (million acres)
Reforestation	6.8	2.64
Avoided Grassland Conversion	4.02	0.05
Cover Crops	2.57	5.41
Alley Cropping	2.03	0.94
Cropland Nutrient Management	1.36	N/A
Urban Reforestation	0.33	0.14
Grassland Restoration	0.33	0.14
Avoided Forest Conversion	0.28	0.05
Improved Manure Management	0.21	N/A
Fire Management	N/A	N/A
Improved Rice Cultivation	N/A	N/A

Natural Climate Solutions for the U.S.

National

State

4

Mitigation Potential
(Million tons CO₂e per year)

64

2014 net emissions
Million tons CO₂e per year

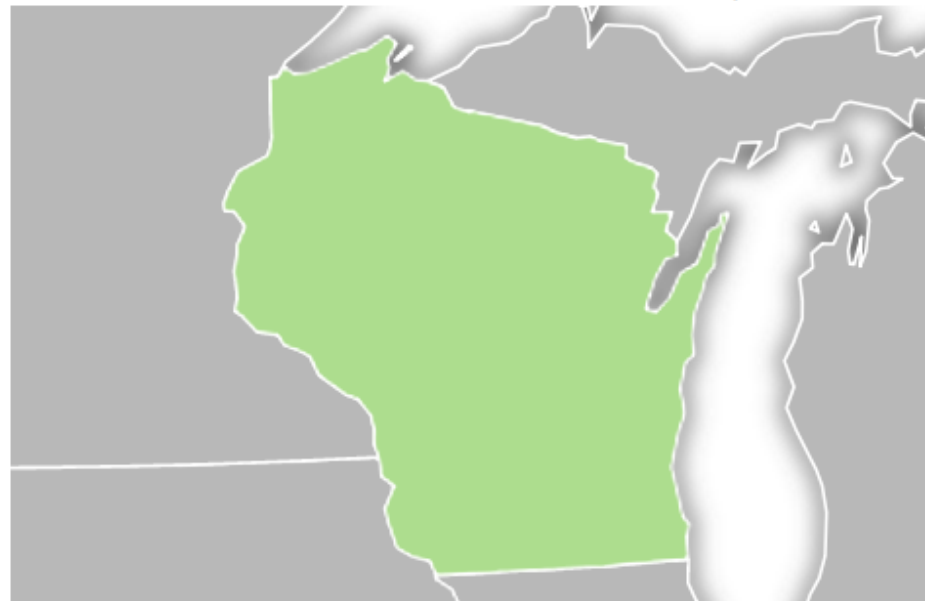


Wisconsin's Selected
NCS Potential

Wisconsin

Full Extent

Click map to select state



Mitigation Pathways ⓘ

Marginal Abatement Cost
\$ per ton of CO₂e 🔒

Reforestation Off \$10 \$50 \$100 Max

Avoided Forest Conversion Off \$10 \$50 \$100 Max

Fire Management Off \$10 \$50 \$100 Max

Urban Reforestation Off \$10 \$50 \$100 Max

Avoided Grassland Conversion Off \$10 \$50 \$100 Max

Grassland Restoration Off \$10 \$50 \$100 Max

Alley Cropping Off \$10 \$50 \$100 Max

Cover Crops Off \$10 \$50 \$100 Max

Cropland Nutrient Management Off \$10 \$50 \$100 Max

Improved Manure Management Off \$10 \$50 \$100 Max

Improved Rice Cultivation Off \$10 \$50 \$100 Max

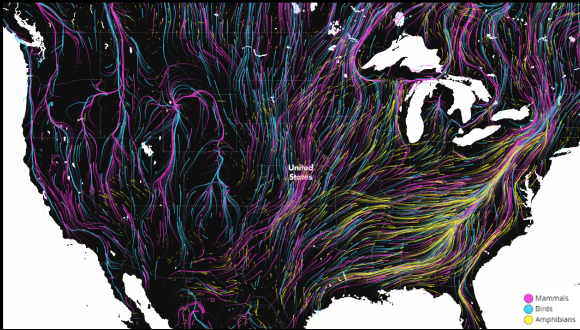
Pathway	NCS Mitigation (Mt CO ₂ per year)	Area Available (million acres)
Cover Crops	2.49	5.24
Cropland Nutrient Management	0.85	N/A
Avoided Forest Conversion	0.27	0.05
Reforestation	0.24	0.09
Avoided Grassland Conversion	0.17	0.01
Alley Cropping	0.1	0.05
Improved Manure Management	0.06	N/A
Grassland Restoration	0.01	0
Urban Reforestation	0	0
Fire Management	N/A	N/A
Improved Rice Cultivation	N/A	N/A

Natural Solutions for Climate Change



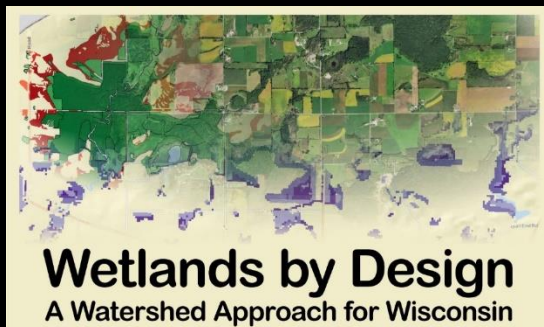
Nature can reduce impacts

<https://nature4climate.org/u-s-carbon-mapper>



We can help nature adapt

maps.tnc.org/resilientland



Nature can help us adapt

www.WetlandsByDesign.org



Floodplain Explorer