EXECUTIVE SUMMARY

Resilient Sites in the Great Lakes and Tallgrass Prairie Region
April 2018

This report presents the results of a 3-year project to identify and map climate resilient sites across the Great Lakes and Tallgrass Prairie region of the United States and Southern Canada. The work was made possible by a grant from the Doris Duke Charitable Foundation, along with matching funds from the many State Chapter and Regional Offices of The Nature Conservancy (TNC) within this geography. It will be followed by a second report on climate corridors and confirmed diversity areas to identify a resilient and connected network of sites.

The Great Lakes and Tallgrass Prairie region includes seven TNC ecoregions, and all or parts of 16 midwestern states and provinces (Figure 1). This fertile region encompasses the entirety of MN, WI, MI, and IA, as well as portions of ND, SD, NE, KS, MO, IL, IN, OH, PA, NY, ON and MB. Scientists and conservation planners from each of these geographies served on our Steering Committee[1], and helped us adapt our methods to the ecological drivers, biodiversity patterns, and land use characteristics that define this region.

Climate change projections suggest that some of the most severe seasonal temperature increases and changes in precipitation extremes in North America will occur here in the "heartland," far away from coastal regions or mountains that might provide climatic refugia for sensitive species. The need to identify climate-resilient sites was further heightened by a century of widespread land cover change across this geography.

Climate Resilient Sites: We defined site resilience as *the capacity of a site to maintain biological diversity, productivity and ecological function as the climate changes.*[2] This means that the character of the existing ecosystem, such as species assemblages and structures, may change even as the core functions and biodiversity of the evolving ecosystem continue to provide the ecosystem services we value. Site resilience differs from the classic definition of resilience in the ecological literature, which holds that an ecosystem demonstrates resilience if it quickly returns to a steady-state equilibrium after a disturbance.[3]

[1] See acknowledgments for full list of contributors
[2] Anderson et al. 2014
[3] Holling 1973

Under changing conditions, however, there is no steady-state to return to. Over time, the definition of resilience in the published literature has evolved to include change—for example Gunderson's (2000) definition, "the capacity for renewal in a dynamic environment."[4] The meaning also varies depending on the object being impacted (e.g., wildlife species, plant communities, human communities). The American Heritage Dictionary defines resilience as "the ability to recover quickly after change or misfortune." Our definition of resilient sites, actual mapped places, revives an idea of land health that originated with Aldo Leopold: "Health is the capacity of the land for self-renewal. Conservation is our effort to understand and preserve this capacity."[5]

Resilient sites will likely change in composition in response to a changing climate, but if adequately conserved they will continue to support a diversity of species into the future that reflect the individual character of the site. Vulnerable sites may also be important to biodiversity and ecosystem services, but are more likely to degrade or lose diversity as the climate changes.

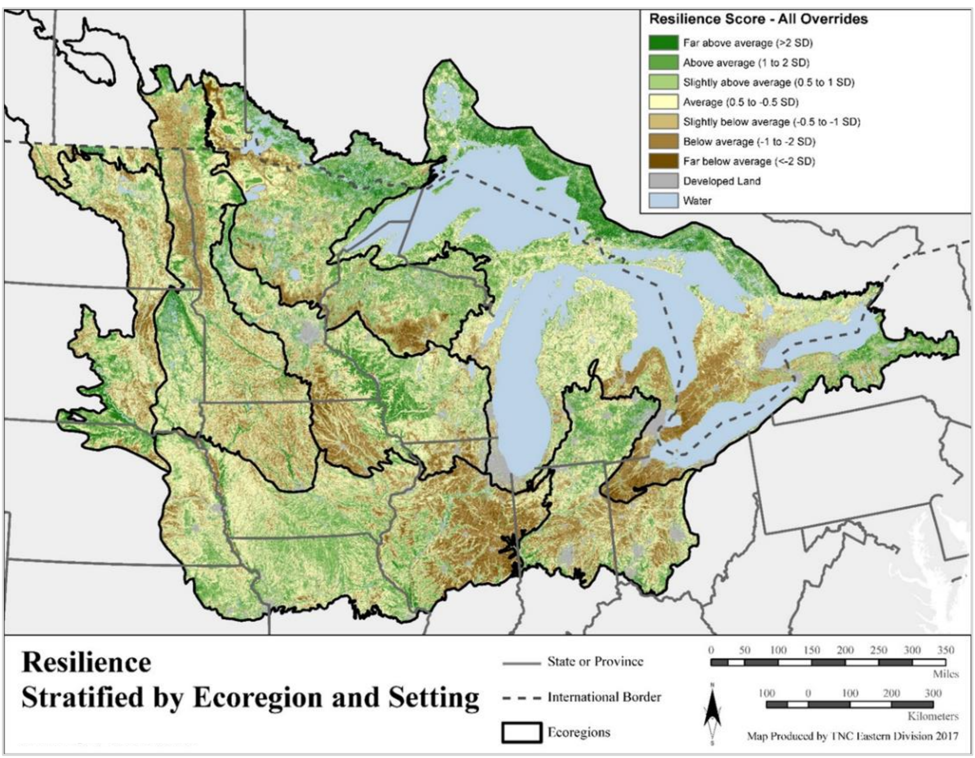

Figure 1. Composite Map of Climate Resilient Sites. The dark outlines are Ecoregions. Areas in green score above average and are estimated to be more resilient relative to ecoregion and geophysical setting. Areas in brown are below average and are considered vulnerable to climate change.

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[4] Gunderson 2000
[5] Leopold 1949

Conserving Nature's Stage (Chapter 2)

Diversity and productivity are relative to a site's physical character because soils and bedrock differ in their inherent qualities. The fertile calcareous loams of the tallgrass prairie region support a diversity of native species quite different from the thin, acidic soils of the northern Great Lakes shoreline. The distinct biotas of these two geophysical settings reflect contrasting site conditions, but both environments are expected to adapt to climate change by incorporating new species adapted to their physical and chemical make-up. Thus, to conserve biological diversity in a changing world, a key step is to conserve the full spectrum of geophysical environments that create diversity in the first place. In this region, that means the loess, silts and calcareous loams of the prairies as well as the sands and bedrock of the forests (Figure 2).

This approach to biodiversity conservation, known colloquially as Conserving Nature's Stage (CNS), is a strategy to account for the uncertainty attendant to climate change[6], and it is supported by extensive evidence[7]. To extend G. E. Hutchinson's 1965 metaphor of the ecological theater and the evolutionary play, we should focus on conserving a variety of geophysical settings as "stages" for the ever-changing cast of actors on the move in the climate change era. The approach provides a framework for conserving current and future biological diversity while allowing species and communities to rearrange in response to change.

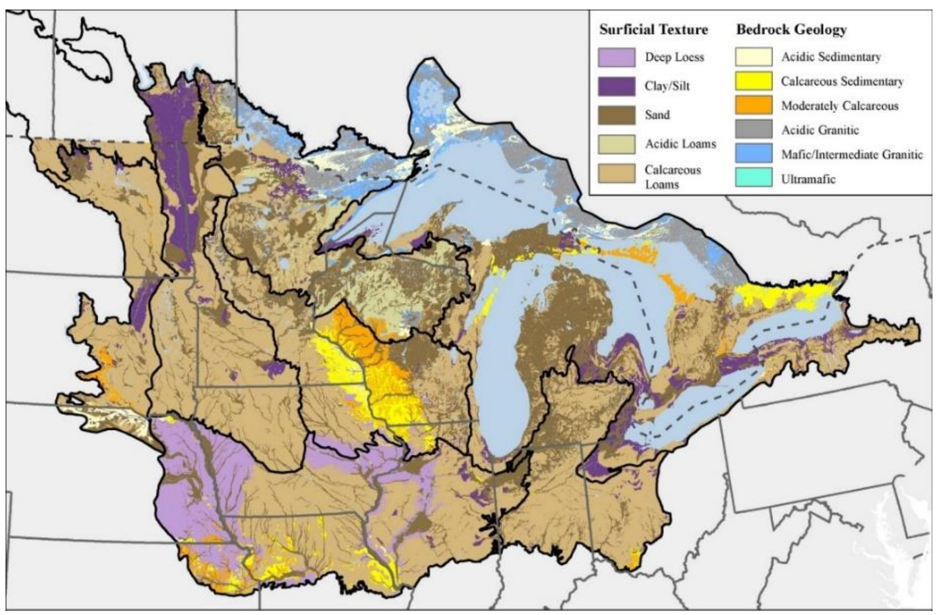

Figure 2. Geophysical Settings of the Great Lakes and Tallgrass Prairie Ecoregion (Chapter 2)

Mapping Resilient Sites (Chapter 3)

The Nature Conservancy and its partners have spent years identifying resilient places as part of a network of sites and linkages that, if conserved, would

[6] Hunter et al. 1988

[7] Bier et al 2015, Lawler et al. 2015, Anderson and Ferree 2010

sustain the diversity of a region[8]. We accomplished this task by studying how species associate with certain geologic settings, how topographic micro-climates buffer species from the regional climate, and how natural cover and riparian corridors connect essential landscape features.

The CNS approach to identifying a network of resilient sites in the Central U.S. and Canada is based on two key observations. First, species diversity is highly correlated with geophysical diversity. Abiotic factors, like soils and topography, shape the region's ecosystems and influence the distribution of biodiversity. Evidence from the past or from other climatic regions suggest that these drivers will continue to influence the distribution and abundance of species, as climatic conditions change. Second, under a changing climate species take advantage of local microclimates to persist in the landscape. Yet, species populations can use microclimates to adjust to change only if the area is permeable and well connected. The core concept of this research lies in protecting examples of all geophysical settings and identifying those sites with the most microclimate diversity and highest landscape permeability.

Chapter 3 describes the site-based characteristics that promote function and diversity and the methods we used to assess and map them. Our estimates of site resilience were based on landscape diversity and local connectedness. These two properties were assessed for every 30-m patch of land and then summed to create a resilience score for each patch.

Landscape Diversity (Figure 3) estimates the number of microclimates available within a given area. It is measured by counting the variety of landforms, and the density and connectivity of wetlands. Microclimate diversity buffers species against regional climatic effects by providing a range of local climates, many of which might be suitable for a species under stress. At a site, we expect high landscape diversity to increase species persistence, and slow the transition to new communities.

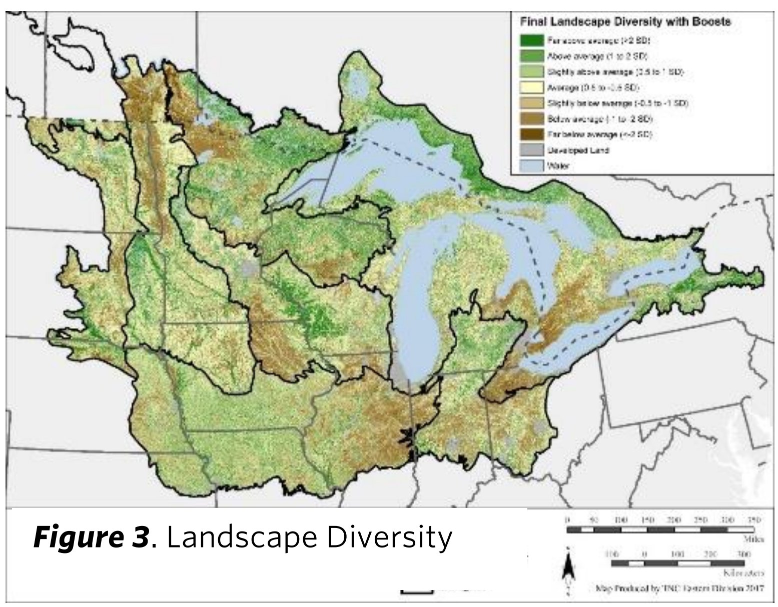

Figure 3. Landscape Diversity

[8] Anderson et al. 2012, 2014, Buttrick et al. 2014

Local connectedness (Figure 4) is defined as the number of barriers and degree of fragmentation within the same area. A highly permeable landscape promotes resilience by facilitating population movements and the reorganization of communities. Roads, development, industrial agriculture, and other structures create resistance that interrupts or redirects movement. Maintaining a connected landscape is the most widely cited strategy for building resilience.

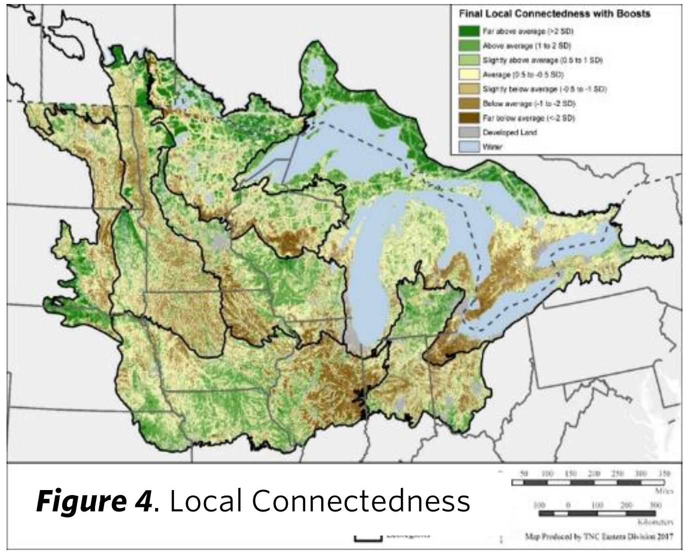

Figure 4. Local Connectedness

Results (Chapters 4 and 5)

Ecoregions

The report provides resilience scores and trends by ecoregion and rolls the ecoregion results up to a composite map of the full study area (Figures 5 & 1). Ecoregions are large contiguous units of land with similar environmental conditions, a roughly similar climate, and a distinct assemblage of natural communities and species. They provide ecological context for understanding landscape-scale conservation. The study area encompassed seven complete TNC ecoregions[9], and the edge of the Aspen Parklands:

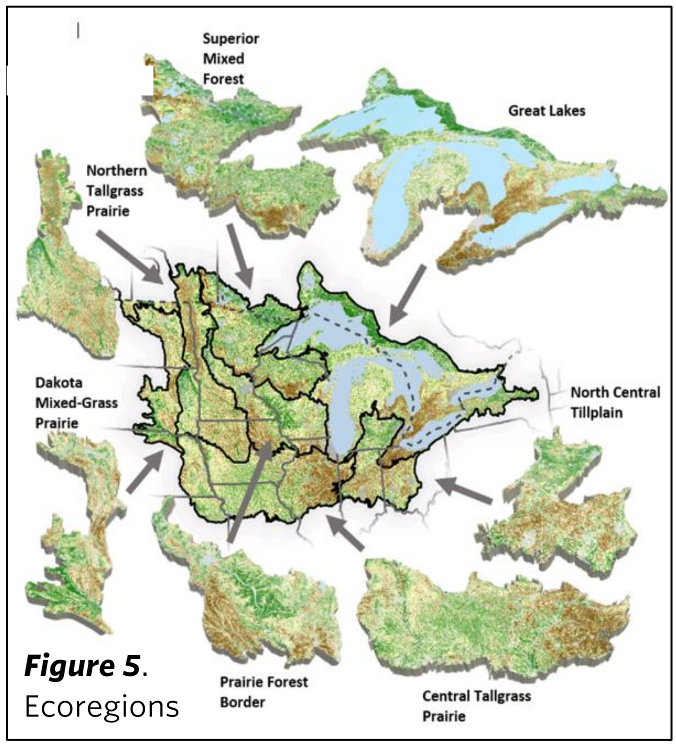

Figure 5. Ecoregions

1. Superior Mixed Forest
2. Great Lakes
3. North Central Tillplain
4. Prairie-Forest Border
5. Central Tallgrass Prairie
6. Northern Tallgrass Prairie
7. Dakota Mixed Grass Prairie
8. Aspen Parkland (in part)

[9] TNC ecoregions are modified from Bailey (1995), and were based on the subsections delineated by the U.S. Forest Service (USDA FS 2007) and the Canadian Provinces (Anderson 1999).

The U.S. portion of the Aspen Parkland ecoregion was included to ensure a comprehensive coverage of North Dakota, which contains a small portion of this mostly Canadian ecoregion.

Resilience Scores

Resilience scores are presented as standard deviations (SD) above or below the mean score for a geophysical setting within an ecoregion. For example, a score of “far above average” for a patch of limestone bedrock in the Prairie Forest Border ecoregion would indicate that the patch scored higher than 98% (+2 SD) of the other limestone patches in the ecoregion. This high score indicates that the patch has more microclimates and is more connected than almost all other patches of limestone bedrock in the ecoregion; as a result, it is considered a “most resilient” site. The legend is interpreted as follows:

Score	***Numeric Value***	***Meaning***	***Interpretation***
Far below average	(<-2 SD)	Below 98%	***Most Vulnerable***
Below average	(-1 to -2 SD)	Below 84%	***More Vulnerable***
Slightly below average	(-0.5 to -1 SD)	Below 69%	***Somewhat Vulnerable***
Average	(-0.5 to 0.5 SD)	Between 31-69%	***Average***
Slightly above average	(0.5 to 1 SD)	Above 69%	***Somewhat Resilient***
Above average	(1- 2 SD)	Above 84%	***More Resilient***
Far above average	(>2 SD)	Above 98%	***Most Resilient***

The composite map is an efficient way to display all the resilience information in a single map, but users should remember that the scores are always relative to setting and ecoregion. A resilience score of 2 SD in the relatively fragmented North Central Tillplain, is not equivalent in an absolute sense to a resilience score of 2 SD in the intact Superior Mixed Forest, because the average score of the latter ecoregion is higher. This relative scale was intentionally used to identify resilient areas across the full range of geophysical settings, and by association, capture the full range of biological diversity. If biological diversity were concentrated only in acidic granite settings, then we could conserve diversity simply by focusing on granite. However, that approach would miss all the inherent diversity of the tallgrass prairies, the limestone slopes of the Driftless area, the rich soils and bluffs of the Loess Hills, and the sandy rivers of the Central Tillplain.

Using the Results for Conservation Decisions

Habitats at Risk

Results from this study can be used to target conservation activities by examining the ratio of conversion to securement (the conservation risk factor), and identifying resilient areas for protection or restoration from among the high-conversion risk settings. Patterns in land securement and conversion correspond surprisingly well to differences among geophysical settings, especially in soil fertility, bedrock structure and groundwater flow. Most human settlement has occurred in gentle landscapes with productive soils, and most conservation areas are located on poor soils with steep slopes. Overall, only 8% of the land in this region is permanently secured against conversion and 60% has been converted to development or agriculture.

The deep loess soils of the prairies along the western edge of the focal region had the highest conservation risk with a ratio of 81 acres converted to every 1 acre secured. Calcareous loams, the widespread fertile soil of the prairie region, also had a large ratio of 25 acres converted to every 1 acre secured, with 75% of these soils converted and only 3% secured (in contrast, the thin acidic bedrock soils of the forested regions were only 4% converted, with 24% secured). Conservation practitioners can focus conservation on at-risk settings by using this map to identify the most resilient areas among the remaining unconverted land. For example, about 10% of the unsecured deep loess soils scored high for resilience, and targeting these areas for protection would begin to address disparities in conservation coverage. Similarly, more than half of the remaining unsecured calcareous loams scored high for resilience, and these areas would make good conservation targets in part because their rougher topography makes them more marginal agricultural land.

Natural Strongholds

More than half of the areas selected for their rare species or exemplary communities in The Nature Conservancy's ecoregional portfolio also scored high (53%) or average (33%) for climate resilience. The high-scoring sites make good targets for land protection or restoration because as natural strongholds for biodiversity, the biota will be buffered from the regional effects of climate change. The inevitable transition to new communities in these places will be slower and more manageable. Additionally, the presence of confirmed diversity suggests that the geophysical properties of these sites are in good condition, and that they are good candidates for sustaining biodiversity into the future.

"Health is the capacity of the land for self-renewal. Conservation is our effort to understand and preserve this capacity." - Aldo Leopold 1949

Key Messages

1) Resilient sites are those we expect to sustain biological diversity and ecological functions even as they change in composition in response to a changing climate.
2) Vulnerable sites may also be important to biodiversity and ecosystem services, but are more likely to degrade or lose diversity as the climate changes.
3) The resilience map shows the estimated climate-resilience of every 30-meter square of land in each ecoregion relative to the soil or bedrock type the land represents. Scores range from +3 (most resilient) to -3 (most vulnerable). http://maps.tnc.org/resilientland/
4) Resilience scores reflect the inherent micro-climate variation and connectedness of the site. They may be improved through restoration, especially when fragmentation is lowering the connectedness of the site.
5) Many resilient sites support rare species or exemplary natural communities as identified and confirmed in the TNC portfolio. These natural strongholds are suitable and essential targets for land protection.
6) The fertile soils of the prairie regions, calcareous loam and deep loess, are largely converted to agriculture and have little protection. The results of this study can be used to identify and prioritize resilient examples of these underrepresented settings to conserve the full spectrum of prairie diversity.
7) In heavily altered ecoregions, such as the North Central Tillplain, even the most resilient examples of fertile soil settings may need restoration and management.
8) Rivers create microclimates, connect wetlands and often remain in natural cover. In this low relief landscape, many rivers and wetlands scored high for resilience, reflecting their vital role in sustaining diversity and function.

Assumptions and Limitations

Site Resilience Only: This analysis estimates the potential resilience of a site based on its physical characteristics because these abiotic features are not expected to change under a changing climate. There are, however, other types of resilience. Ecosystem resilience refers to the likelihood that a system is predisposed to potential future climates. For example, fire dependent oak savannas may expand in areas where temperatures increase and moisture decreases. This study does not address the question: "is oak savanna a resilient ecosystem?" We assume that ecosystems must occur on sites and that sites vary in their ability to sustain diversity. The question addressed here is: "of all the sites that may someday support oak savanna which are most resilient?"

Use the Resilience Information with Other Data to Make Decisions: This analysis does not make decisions. Instead, it provides estimates of resilience that should be integrated and interpreted with additional data to inform conservation decisions. The results can augment local information by providing data on the presence and influence of land characteristics that could improve the long-term persistence of species under a changing climate. USFWS, for example, prioritized areas for conservation in the North Atlantic region based on three characteristics: rare species, intact communities and resilient land. Similarly, sites selected for high climate resilience can be compared to those selected for their biodiversity value in the TNC ecoregional plans (see Chapter 5). Finally, practicing conservationists will still need to prioritize among resilient sites using traditional conservation feasibility factors such as cost, landowner intent or return-on-investment to determine their strategy.

A Coarse Filter Strategy: The Conserving Nature's Stage approach is intended as a 'coarse-filter' for land use decision-making. The approach aims to sustain the maximum amount of biological diversity, but some species may occur largely in climate-vulnerable sites. Sustaining these species will require "fine-filter" conservation strategies aimed specifically at their populations and the management of more vulnerable lands. Finer-scale information may also reveal resiliency considerations and opportunities that were not 'visible' in the coarser-scale datasets. While CNS data can and should be used to inform site-specific decisions, is should not be relied on alone. Ideally, the results should be used in combination with finer-scale datasets and with field validation. The strength of the 30-m scale analysis is that each patch of land is compared to thousands of similar patches to quantify the relative amount microclimates or connectedness. The strength of finer-scale field observations is that there may be subtle microtopographic variation, exemplary species richness, or intact biological legacies present, and this provides information not available in the GIS analysis. These observable characteristics of the biotic community may facilitate resilience at sites and under some circumstances may override the coarse-scale analysis. In general, the resilience data is best used at a landscape-scale, should be combined with finer-scale data to make site level decisions, and will need to be supplemented with detailed population data for individual species that occur predominantly in vulnerable landscapes.

Confidence Considerations: The datasets we used vary in their scale, resolution and accuracy. The 30-m landform models that underlie the microclimate analysis, and the Natural Heritage Program element occurrences had the highest precision and were the most consistently mapped. In contrast, the National land cover, wetland, geology and soil datasets all have known accuracy limits. Although we took steps to integrate finer-resolution data, there are still accuracy and mismatch problems. Users should have higher confidence in high-ranked sites, and realize that lower rankings may result from data gaps or limitations. A takeaway is that users can feel relatively confident about protecting sites ranked as highly resilient, but should look closer before writing off a site because it has a low resilience score to ensure that the rank is not due to a data gap or limitation.

Citations

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