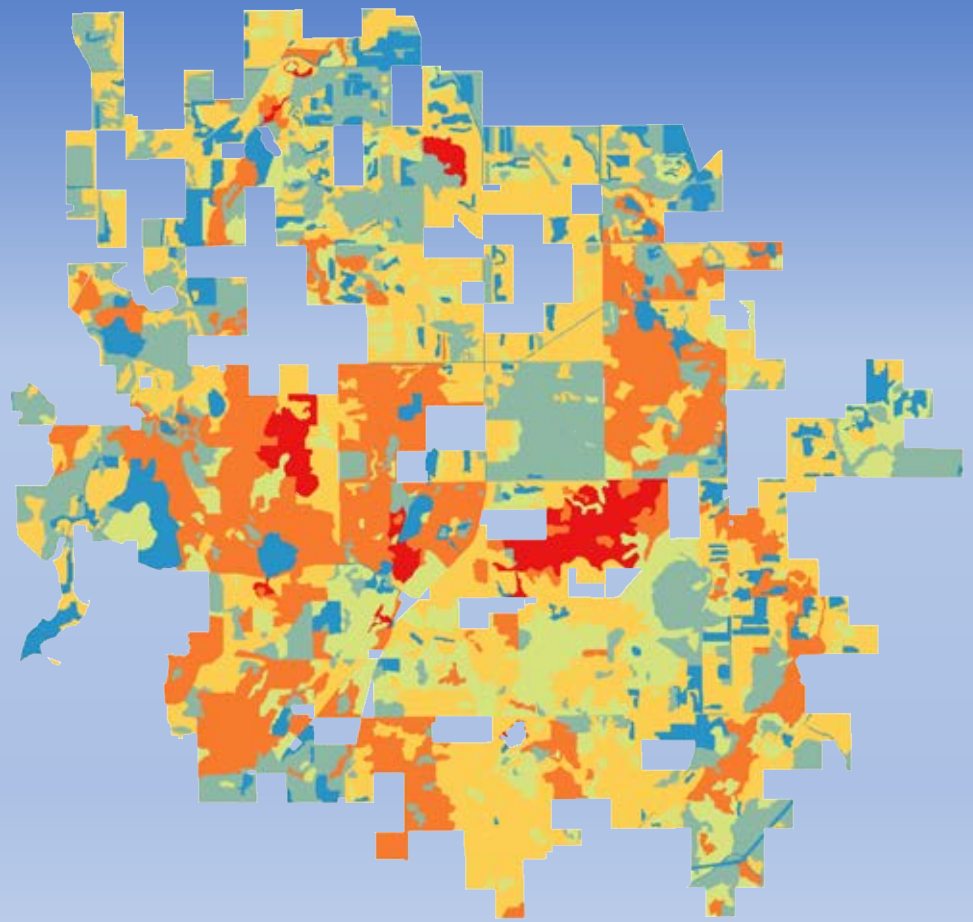
Using GIS-based multicriteria decision analysis to prioritize invasive plant treatment



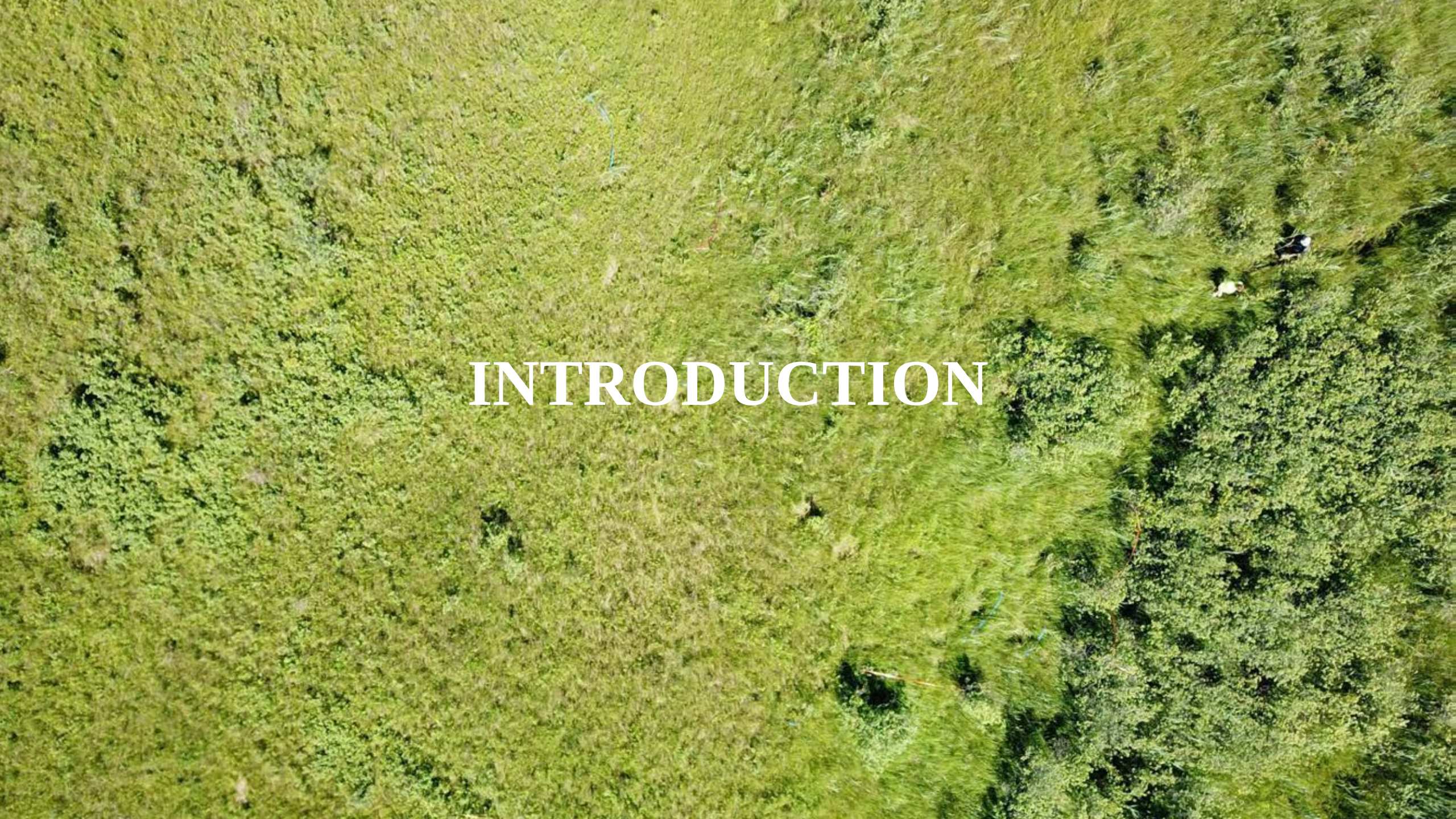
Joshua Cohen, Helen Enander, Clay Wilton, Tyler Bassett, Courtney Ross, and Ashley Cole-Wick
Michigan Natural Features Inventory
Michigan State University Extension

2026 Cal-IPC Symposium
Geospatial Technologies and Approaches
Berkely, California
October 21, 2026

MICHIGAN STATE UNIVERSITY | Extension



Michigan Natural Features Inventory's Mission - To guide the conservation of Michigan's biodiversity by providing the highest quality scientific expertise and information.



INTRODUCTION





- Invasives degrade native biodiversity by altering fundamental composition, structure, and function
  - Displace critical habitat
  - Interrupt food webs
  - Alter soils, hydrology, and disturbance regimes
  - Compromise pollinator services
- Impact local economies



Environmental damages from invasive species are estimated to be over $120 billion per year



Invasive impacts projected to increase as landscapes are fragmented and the climate changes



Invasive plant infestations are characterized as rapid and extensive, occurring at regional scales as species disperse over long distances.



The rate of spread often outpaces land managers' ability to effectively detect and control infestations.



The unprecedented rate of spread of pernicious invaders across landscapes demands tools that can match the pace and scale of invasive infestations and help prioritize control efforts in the most ecologically important areas.

Introduction

- Problem

  Currently no systematic statewide prioritization for invasive species treatment.

- Solution

  Inform invasive species management with best available ecological information.

- Method

  Use GIS-based multicriteria decision analysis to prioritize invasive species treatment across state lands.

- Outcome

  Facilitate implementation of invasive species management in the ecologically most important areas.


METHODS

GIS-Based Multicriteria Decision Analysis

- Combines spatially referenced data and multi-attribute criteria in a problem-solving environment (Malczewski 2006, Malczewski and Jankowski 2020)
- Excellent means for harnessing institutional and expert knowledge as well as stakeholder input to answer spatially explicit questions to inform conservation decisions.

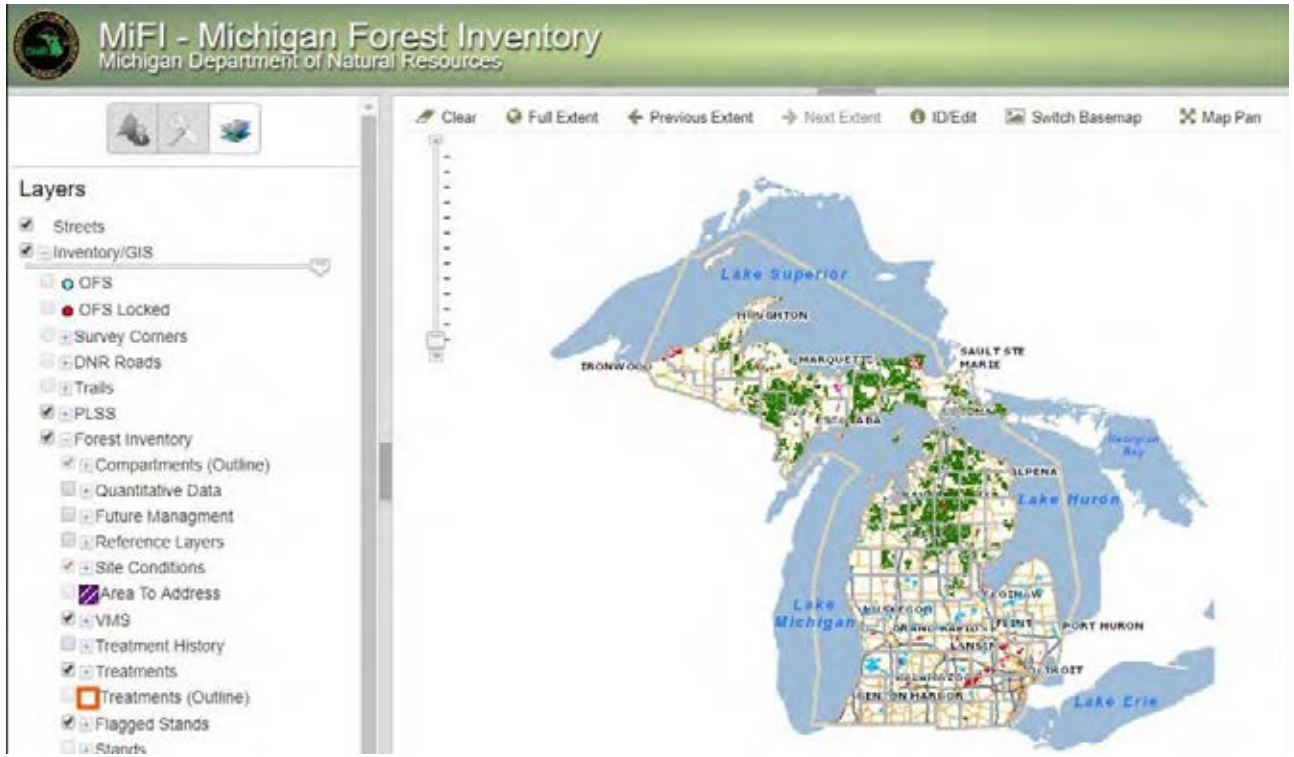
GIS-Based Multicriteria Decision Analysis

- Incorporate multiple spatially explicit variables, score them, and weigh them to efficiently and effectively answer critical “Where should we?” questions
- Excellent means for engaging multiple knowledge systems
- Readily iterative








MiFI - Michigan Forest Inventory
Michigan Department of Natural Resources
Clear
Full Extent
Previous Extent
Next Extent
ID/Edit
Switch Basemap
Map Pan
Layers
Streets
Inventory/GIS
OFS
OFS Locked
Survey Corners
DNR Roads
Trails
PLSS
Forest Inventory
Compartments (Outline)
Quantitative Data
Future Managment
Reference Layers
Site Conditions
Area To Address
VMS
Treatment History
Treatments
Treatments (Outline)
Flagged Stands
Stands
Lake Superior
Lake Huron
Lake Michigan
Lake Erie
MARQUETTE
SAULT STE MARIE
PORT HURON

The Model

- Used stands as the fundamental unit for the model: 20,110 in SLP (173,549 ha), 91,820 in NLP (851,807 ha), and 69,091 in UP (803,708 ha)
- Generated intersection of stands with spatial data and crosswalked stands to natural community type
- Identified four factors critical for determining a site's priority for invasive species treatment:
  - Integrity
  - Biodiversity
  - Resiliency
  - Ecosystem Services
- For each factor developed variables to score on a scale of 0 to 5 (with 0 being no priority and 5 being the highest priority).
- For each stand these multiple input variables were evaluated, scored, and weighted to generate an overall priority score.

Invasive Species Treatment Prioritization Model

Invasive Species Prioritization =

$12a_i + 2b_i + 10c_i + 2d_i + 1e_i + 1f_i + 12g_i + \ldots$

INTEGRITY INVASIVE
- Invasive Species — $w_i = 8$
- Invasion Density — $w_i = 6$

INTEGRITY LANDSCAPE
- Land Use Index — $w_i = 8$
- Invasion Risk — $w_i = 1$
- Management — $w_i = 2$
- Temporal Continuity — $w_i = 1$
- Buffer — $w_i = 2$

INTEGRITY STAND
- Natural Community Rank — $w_i = 12$
- Stand Age — $w_i = 2$

BIODIVERSITY RARITY
- Natural Community Rarity — $w_i = 10$
- Rare Species — $w_i = 4$

BIODIVERSITY RICHNESS
- NC Species Richness — $w_i = 14$

RESILIENCY
- TNC Resilience — $w_i = 10$
- MNFI Resilience — $w_i = 4$

SERVICES
- Ecosystems Services — $w_i = 14$

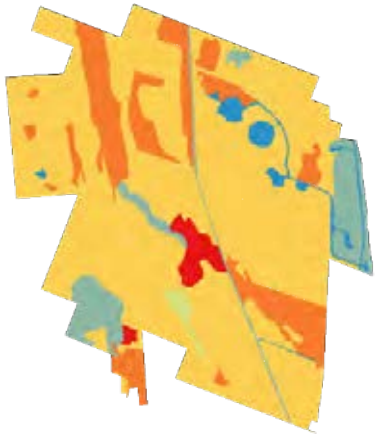
X

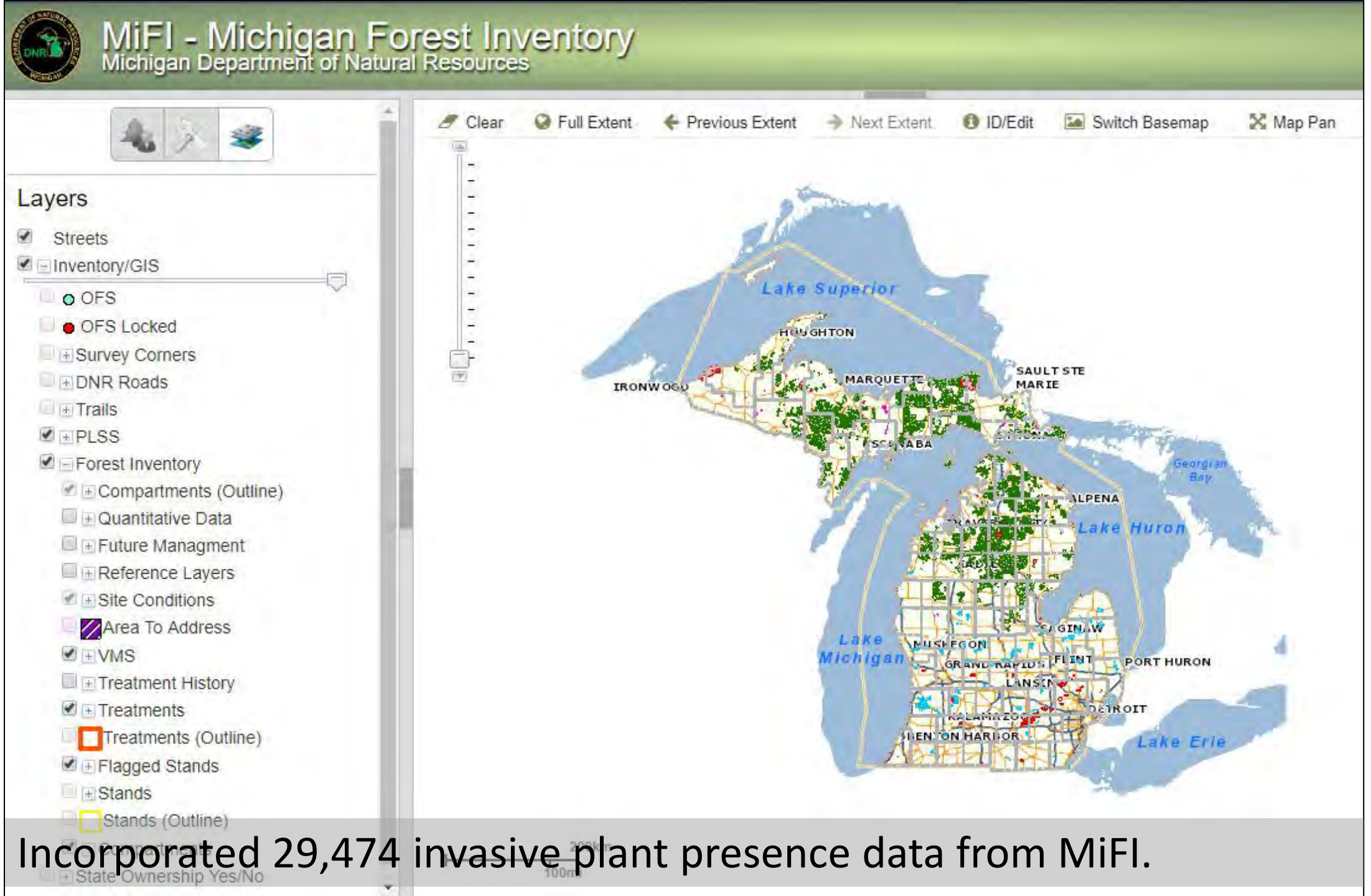
Invasive Score:
0 = None
1 = Low
2 = Moderate
3 = High
4 = Very High
5 = Highest

=

Stand-level Invasive Species Prioritization Database

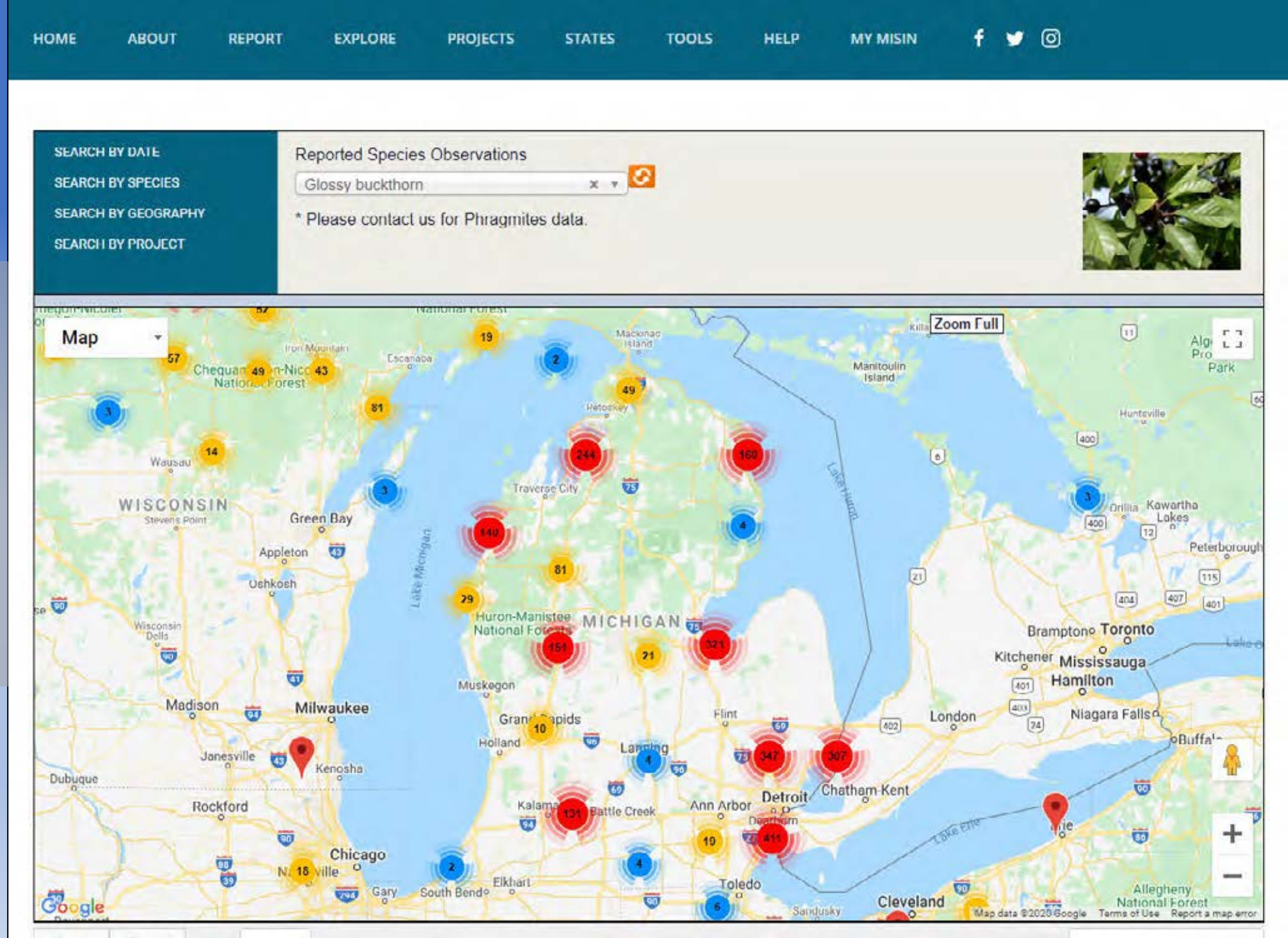
GIS Functionality



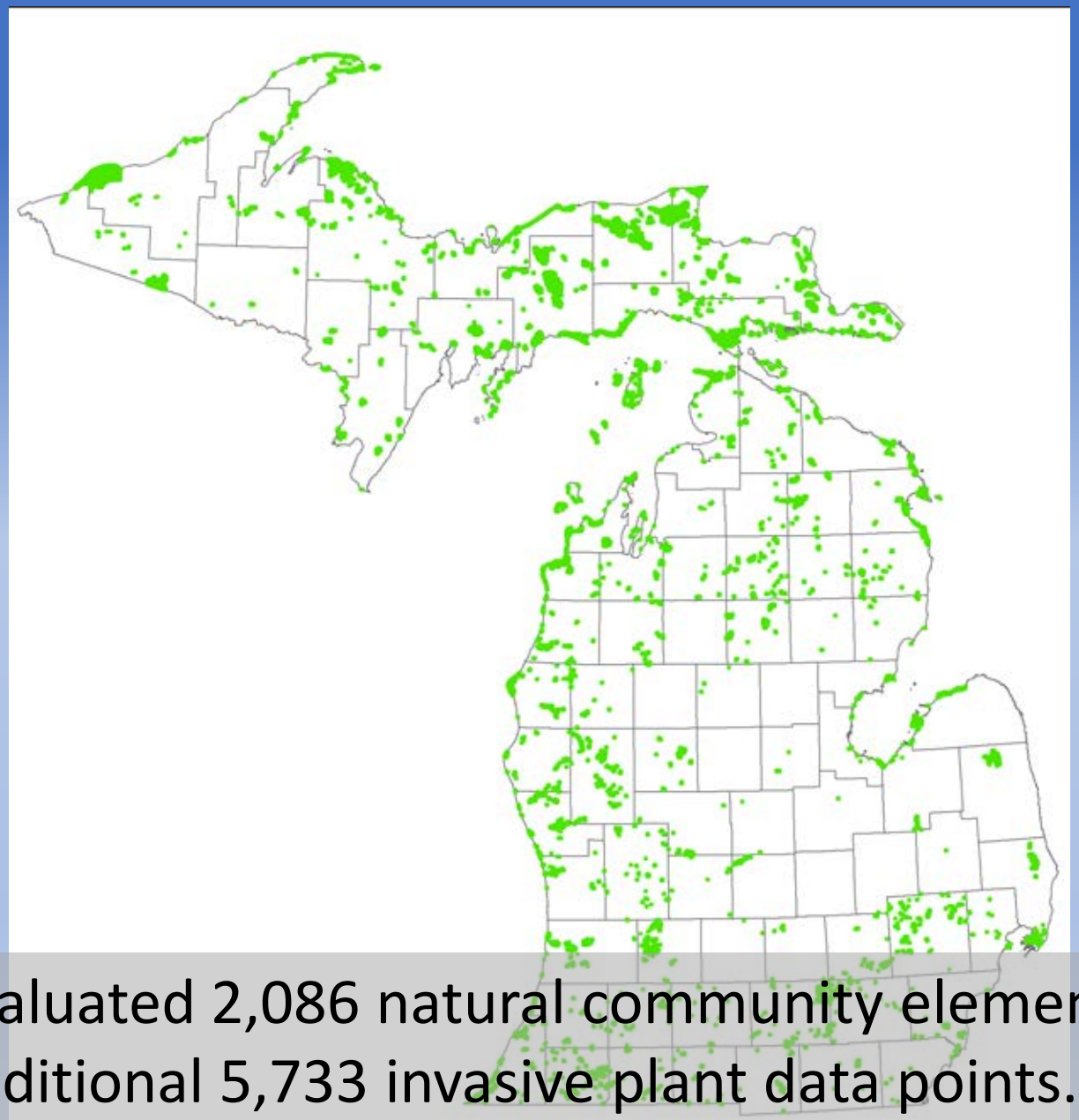


Incorporated 29,474 invasive plant presence data from MiFI.

Incorporated 27,696 invasive plant data points from Midwest Invasive Species Information Network (MISIN).



Natural Heritage Database



Element Occurrence Report

EO ID 20638 | Subnational Scientific Name *Lakeplain Wet-mesic Prairie* | Shape_ID 101987

Source Feature ID	Descriptor	Locator	Conceptual Feature Type	Uncertainty Type	Uncertainty Distance	Unit	Location Use Class	Digitizing Base
56402			Polygon	Delimited				2 - 1:24,000 Quad
56583			Polygon	Delimited				2 - 1:24,000 Quad
56584			Polygon	Negligible				2 - 1:24,000 Quad
56587			Polygon	Delimited				2 - 1:24,000 Quad
56588			Polygon	Delimited				2 - 1:24,000 Quad
56589			Polygon	Delimited				2 - 1:24,000 Quad
56629			Polygon	Delimited				2 - 1:24,000 Quad

Survey Information

Survey Type

Survey Type: Qualitative ground survey

EO Survey Note: Joshua G. Cohen, Mike Penskar, Jesse Lincoln, and Bradfor

Surveyor

Surveyor:
Joshua G. Cohen (2016-05-19, -20, -24 and -25)
Jesse Lincoln (2016-05-12 and 2016-05-13)
Bradford Slaughter (2016-06-03)
Joshua G. Cohen and Mike Penskar (2016-07-28)
Joshua G. Cohen and Mike Penskar (2016-08-03)

Survey Date 2016-07-28

Last Observation Date 2016-08-03 **First Observation Date** 2016-05-12

EO Data

The lakeplain wet-mesic prairie is dominated by graminoids and forbs with prevalent graminoids including big bluestem (Andropogon gerardii), little bluestem (Schizachyrium scoparium), Indian grass (Sorghastrum nutans), and switch grass (Panicum virgatum). Tall prairie grasses reach over two meters and many forbs are over one meter tall. Prevalent forbs include marsh blazing-star (Liatris spicata), common mountain mint (Pycnanthemum virginianum), tall coreopsis (Coreopsis tripteris), wild-bergamot (Monarda fistulosa), balsam ragwort (Packera paupercula), whorled loosestrife (Lysimachia quadriflora), Missouri ironweed (Vernonia missurica), culvers-root (Veronicastrum virginicum), northern bog violet (Viola nephrophylla), swamp-betony (Pedicularis lanceolata), swamp milkweed (Asclepias incarnata), common milkweed (A. syriaca), yarrow (Achillea millefolium), Canada anemone (Anemone canadensis), showy tick-trefoil (Desmodium canadense), star-grass (Hypoxis hirsuta), black-eyed Susan (Rudbeckia hirta), and golden alexanders (Zizia aurea). In addition, sedges (Carex stricta, C. buxbaumii, and C. granularis), goldenrods (Solidago altissima, S. canadensis, and S. juncea), marsh wild-timothy (Muhlenbergia glomerata), and golden-seeded spike rush (Eleocharis elliptica) are common throughout the prairie and prairie cordgrass (Spartina pectinata) is locally abundant. Reed (Phragmites australis subsp. australis) occurs scattered throughout the lakeplain wet-mesic prairie.

Scattered trees and shrubs include pin oak (Quercus palustris), quaking aspen (Populus tremuloides), cottonwood (Populus deltoides), gray dogwood (Cornus foemina), red-osier dogwood (C. sericea), willows (Salix spp.), prickly-ash (Zanthoxylum americanum), and glossy buckthorn (Frangula alnus). Shrubs occur as scattered individuals and also in scattered clumps. Glossy buckthorn occurs both scattered within the lakeplain wet-mesic prairie and as a dominant in localized shrub thickets. Areas along the margin of the prairie especially bordering the adjacent uplands have a higher density of shrubs. Low shrubs include meadowsweet (Spiraea alba), Kalm's St. Johns-wort (Hypericum kalmianum), and blackberry (Rubus allegheniensis). Additional invasive shrubs within the lakeplain wet-mesic prairie include autumn olive (Elaeagnus umbellata), Japanese barberry (Berberis thunbergii), and honeysuckles (Lonicera spp.). Compared to the adjacent lakeplain wet prairie, shrubs are more prevalent in the lakeplain wet-mesic prairie remnants.

MNFI ecologists and botanists visited this site nine times over the 2016 field season. The floristic data was compiled into the Michigan Floristic Quality Assessment (Rezmerek et al. 2014). A total of 136 plant species were documented with 112 native species and 19

Evaluated 2,086 natural community element occurrences and generated an additional 5,733 invasive plant data points.

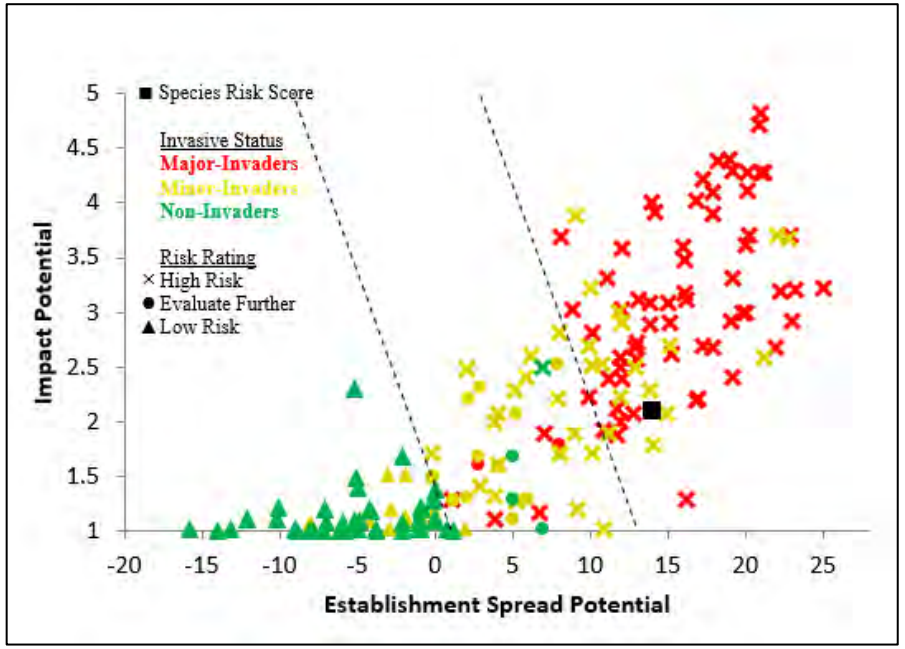
Invasive Species Impact

- Non-native species noted in MiFI, MNFI, and MISIN databases systematically evaluated/scored
- Utilized weed risk assessment tool developed by U.S. Department of Agriculture
- Series of questions researched and answered to evaluate each species'
  - Establishment Potential
  - Spread Potential
  - Impact Potential
- Categorized each species into 3 categories
  - Major-Invader
  - Minor-Invader
  - Non-Invader
- Based on this analysis assigned each species a treatment priority ranking with 0 as "No Priority" and 5 as "Critical"

Invasive Species Scoring – USDA PPQ WRA

Question ID	Question	Answer	Uncer-tainty	Score
Establishment / Spread Potential				
ES-1	What is the taxon's establishment and spread status outside its native range? Choose one: (a) Introduced elsewhere =>75 years ago but not escaped; (b) Introduced <75 years ago but not escaped; (c) Never moved beyond its native range; (d) Escaped/Casual; (e) Naturalized; (f) Invasive; (?) Unknown.	f	negl	5
ES-2	Is the species highly domesticated? (y, n, or ?)			???
ES-3	Are there any congeners that are considered significant weeds? (y, n, or ?)			???
ES-4	Is it shade tolerant at some stage of its life cycle? (y, n, or ?)	y	negl	1
ES-5	Is the plant a vine or scrambling plant, or does it form tightly appressed basal rosettes? (y, n, or ?)			???
ES-6	Does the taxon form dense thickets, patches, or populations? (y, n, or ?)	y	negl	2
Impact Potential				
General impacts				
Imp-G1	Is the taxon allelopathic? (y, n, or ?)	n	negl	0
Imp-G2	Is the taxon parasitic, and does it have potential hosts in the WRA area? (y, n, or ?)			???
Impact to Natural areas (national parks, wildlife/conservation				
Imp-N1	Does the taxon change ecosystem processes and parameters? (y, n, ?)	y	negl	0.4
Imp-N2	Does the taxon change habitat structure? (y, n, ?)	y	negl	0.2
Imp-N3	Does the taxon change species diversity? (y, n, ?)	y	negl	0.2
Imp-N4	Is the taxon likely to affect Federal Threatened & Endangered species? (y, n, ?)	y	negl	0.1
Imp-N5	Is the taxon likely to affect any U.S. globally outstanding ecoregion? (y, n, ?)	y	negl	0.1

Risk Score Summary				
	Establishment/Spread Potential		#N/A	14
	Impact Potential		#N/A	2.1
	General			0
	Natural Areas Impact			1
	Anthropogenic Impact			0.1
	Production Impact			0
	Geographic Potential		N/A	N/A
	Entry Potential		#N/A	0
	Number of questions remaining to be answered:	65		
	Number of missing or incorrect uncertainties:	56		
	Secondary Screening Score	8		
	Probability (Major-Invader) =	0.605		
	Probability (Minor-Invader) =	0.375		
	Probability (Non-Invader) =	0.019		



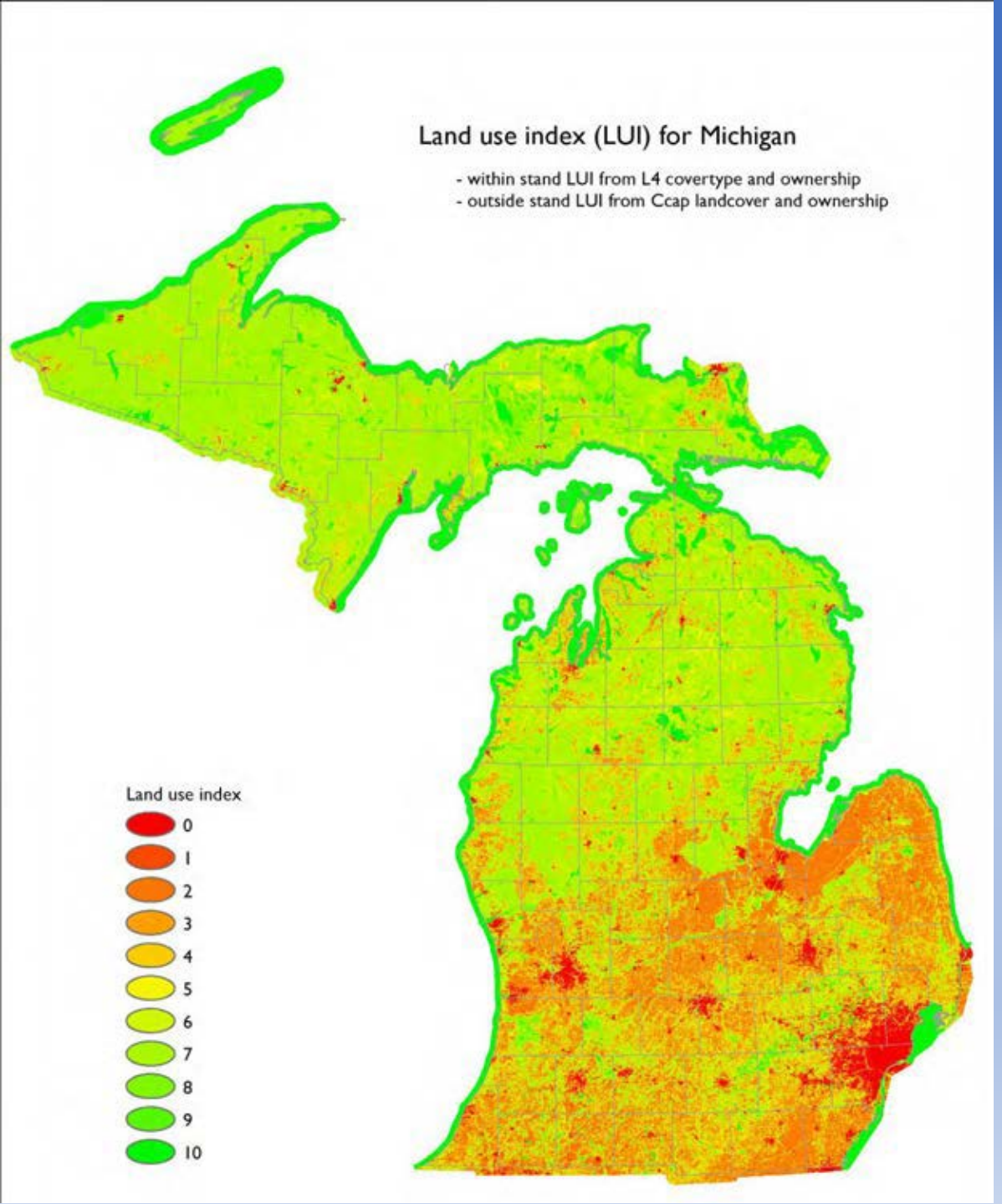


Table 12. Land Use Index Table.

Worksheet : Land Use Categories	Weight	% Area (0 to 1.0)	Score
Paved roads / parking lots	0		
Domestic, commercial, or publicly developed buildings and facilities (non-vegetated)	0		
Gravel pit / quarry / open pit / strip mining	0		
Unpaved roads (e.g., driveway, tractor trail, 4-wheel drive, logging roads)	1		
Agriculture: tilled crop production	2		
Intensively developed vegetation (golf courses, lawns, etc.)	2		
Vegetation conversion (chaining, cabling, roto-chopping, clearcut)	3		
Agriculture: permanent crop (vineyard, orchard, nursery, hayed pasture, etc.)	4		
Intense recreation (ATV use / camping / popular fishing spot, etc.)	4		
Military training areas (armor, mechanized)	4		
Heavy grazing by livestock on pastures or native rangeland	4		
Heavy logging or tree removal (50-75% of trees > 30 cm DBH removed)	5		
Commercial tree plantations / holiday tree farms	5		
Recent old fields and other disturbed fallow lands dominated by ruderal and exotic species	5		
Dam sites and flood disturbed shorelines around water storage reservoirs and motorized boating	5		
Moderate grazing of native grassland	6		
Moderate recreation (high-use trail)	7		
Mature old fields and other fallow lands with natural composition	7		
Selective logging or tree removal (< 50% of trees > 30 cm DBH removed)	8		
Light grazing or haying of native rangeland	9		
Light recreation (low-use trail)	9		
Natural area / land managed for native vegetation	10		
A = ≥ 9.5, B = 8.0-9.4, C = 4.0-7.9, D = < 4.0 Total Land Use Index			

Metric is based on the proportion of land use in a surrounding buffer



Biodiversity Variables

- Natural Community Rarity– Natural community state and global ranks used to assign rarity score for stands
- Rare Species– Rare species element occurrences within stands also contribute to biodiversity score
- Natural Community Species Richness – Score of natural community based on average species richness of natural community type and diversity of ecosystem processes.

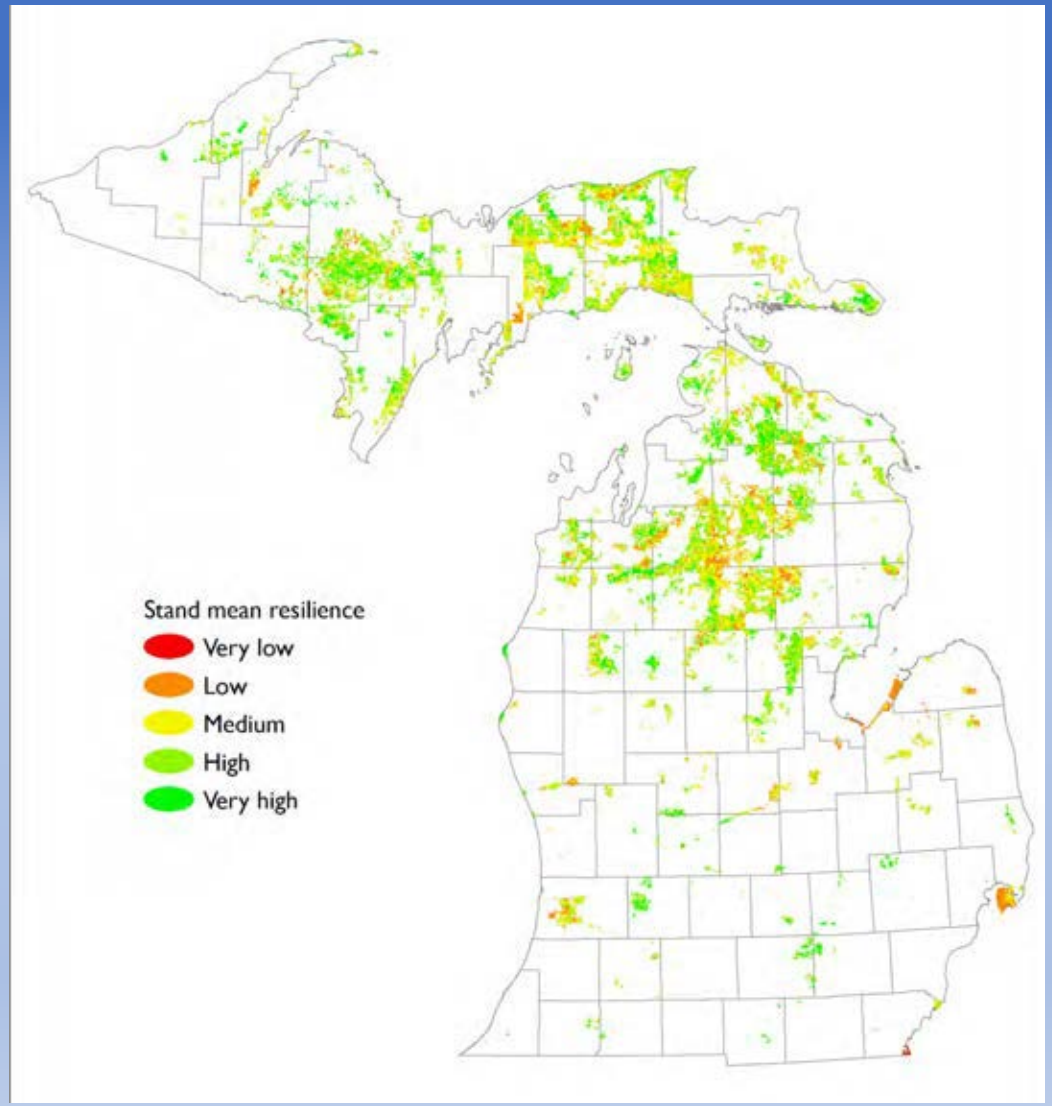






Resilience

- TNC Resilience Analysis – incorporated areas identified as being resilient to climate change into model
- These areas are characterized by a diversity of landforms and high habitat connectivity.

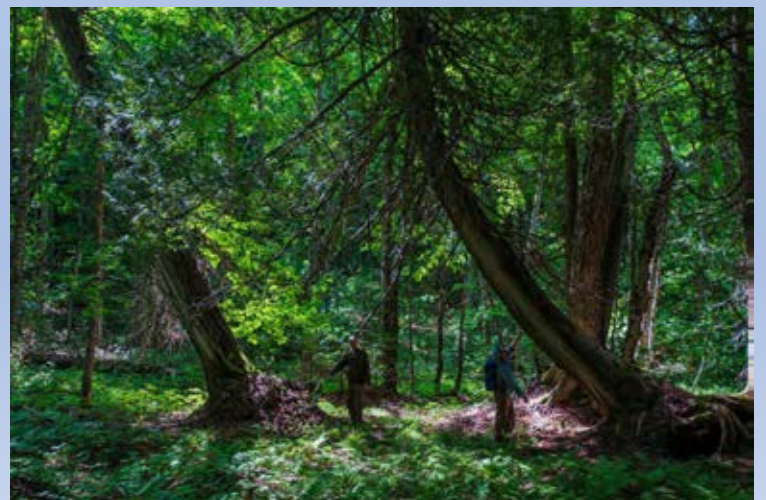


Ecosystem Services

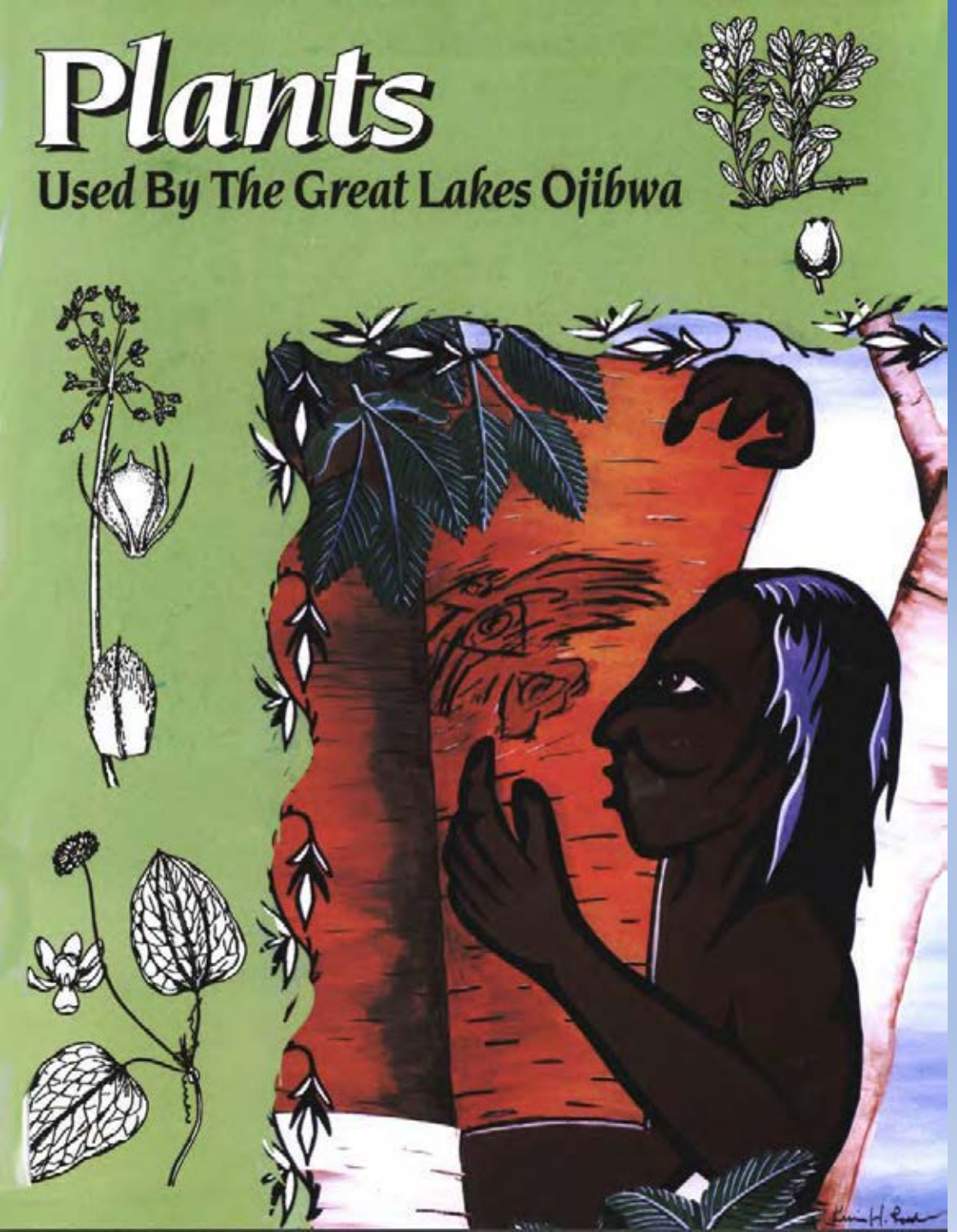
Each natural community type assigned an ecosystem services score based on 10 factors that gauge contribution to provisioning, regulating, supporting and cultural services.

- Water filtration
- Carbon Sequestration
- Pollinator Habitat
- Recreation
- Subsistence Foraging
- Coastal Shoreline Buffer
- **Cultural Value**
- Flood Protection
- Nutrient Cycling
- Regulation of Climate/Air Quality







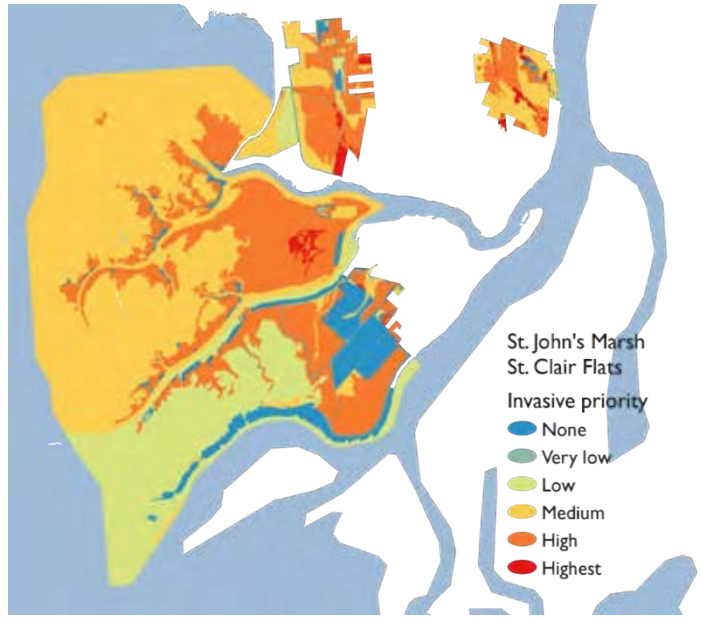

Plants
Used By The Great Lakes Ojibwa

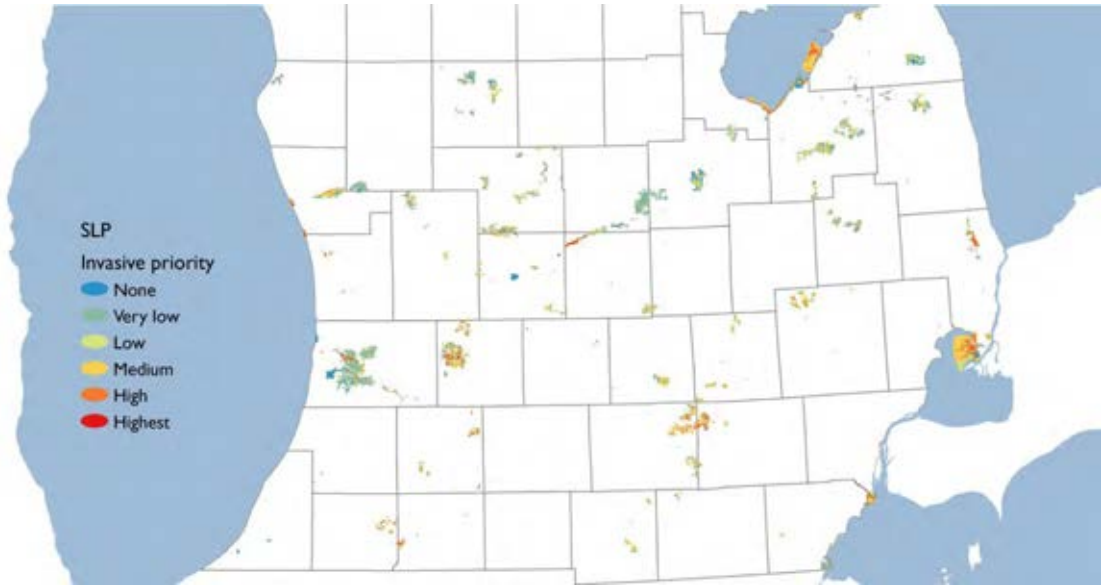


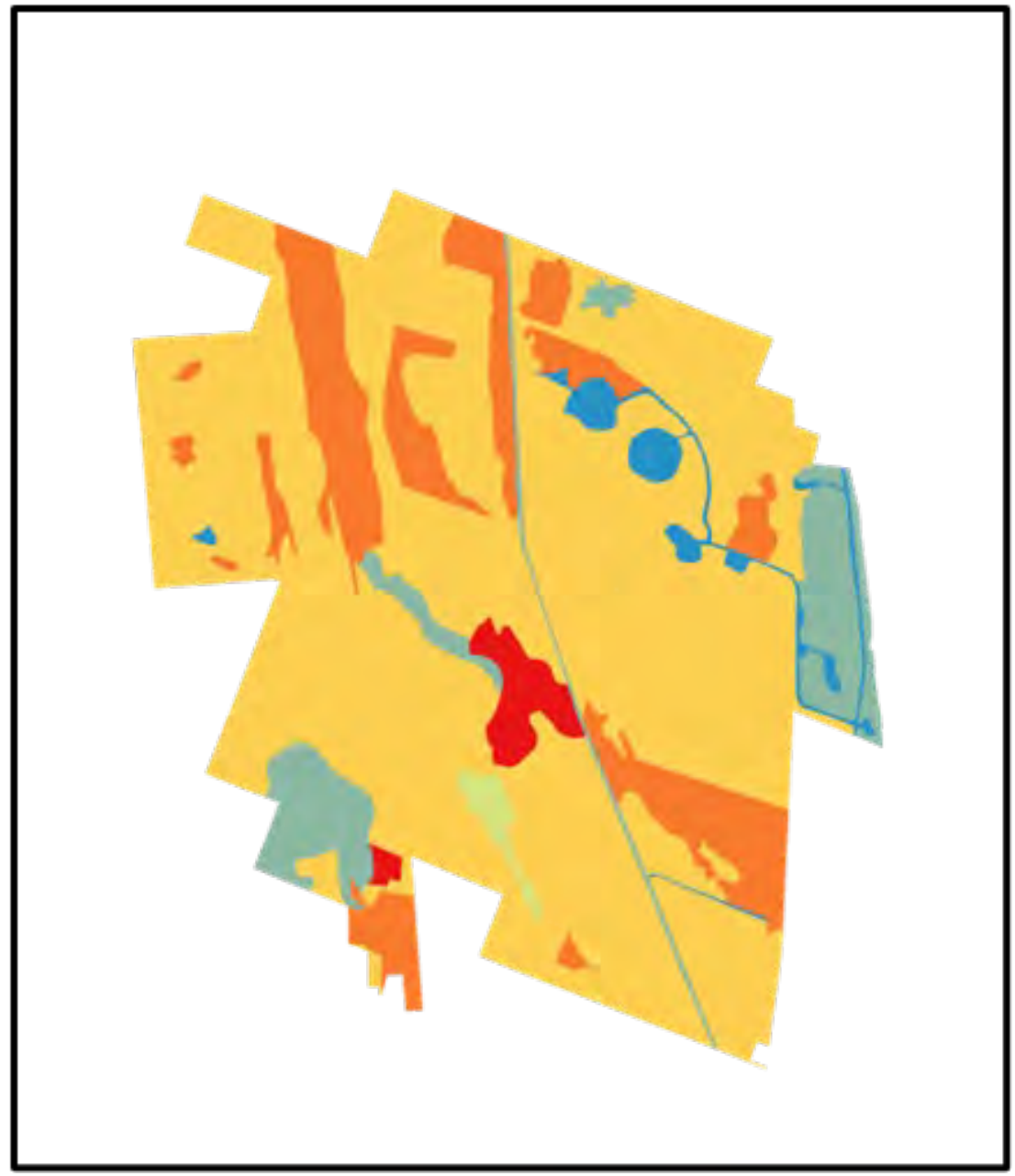
The Script

Variable Weight	Variable	Rule for Invasive Species Prioritization Formula
12	WRA P(Major invader)	IF Translated P(Maj inv) = 0, THEN Score = + 0
12	WRA P(Major invader)	IF Translated P(Maj inv) = 1, THEN Score = + 1
12	WRA P(Major invader)	IF Translated P(Maj inv) = 2, THEN Score = + 2
12	WRA P(Major invader)	IF Translated P(Maj inv) = 3, THEN Score = + 3
12	WRA P(Major invader)	IF Translated P(Maj inv) = 4, THEN Score = + 4
12	WRA P(Major invader)	IF Translated P(Maj inv) = 5, THEN Score = + 5
5	Nat com resiliency	IF Nat Com Resiliency = Granite Lakeshore Cliff, THEN Score = + 5
5	Nat com resiliency	IF Nat Com Resiliency = Limestone Cliff, THEN Score = + 5
5	Nat com resiliency	IF Nat Com Resiliency = Limestone Lakeshore Cliff, THEN Score = + 5
5	Nat com resiliency	IF Nat Com Resiliency = Lakeplain Oak Openings, THEN Score = + 1
12	Nat com rarity	IF Nat Com Rarity = Alvar, THEN Score = + 4.75
12	Nat com rarity	IF Nat Com Rarity = Poor Conifer Swamp, THEN Score = + 2
10	TNC Climate Resiliency	IF TNC Climate Resiliency = Slightly Above Average, THEN Score = + 1
10	TNC Climate Resiliency	IF TNC Climate Resiliency = Above Average, THEN Score = + 3
10	TNC Climate Resiliency	IF TNC Climate Resiliency = Far Above Average, THEN Score = + 5
10	Landuse Integrity Index	IF Ecological Integrity Assessment = 0-10, THEN Score = + (0-10)/2, respectively
5	Invasion risk - distance to vector	IF Invasion risk - distance to vector = 0.000000 - 10, THEN Score = + 0
5	Invasion risk - distance to vector	IF Invasion risk - distance to vector = 10.1 - 152.970581, THEN Score = + 1
5	Invasion risk - distance to vector	IF Invasion risk - distance to vector = 152.970582 - 458.911743, THEN Score = + 2
5	Invasion risk - distance to vector	IF Invasion risk - distance to vector = 458.911744 - 920.271729, THEN Score = + 3
5	Invasion risk - distance to vector	IF Invasion risk - distance to vector = 920.271730 - 1717.352661, THEN Score = + 4
5	Invasion risk - distance to vector	IF Invasion risk - distance to vector = 1717.352662 - 5610.080078, THEN Score = + 5
2	Stand age	IF Stand age >= 100 yrs, THEN Score = + 5
2	EO (species)	IF EO (species) = TRUE, THEN Score = + 5
2	DNR Focal Areas	IF DNR Focal Areas = TRUE, THEN Score = + 5
12	EO (nat com)	IF EO (nat com) = A or AB, THEN Score = + 5
12	EO (nat com)	IF EO (nat com) = B, THEN Score = + 4
12	EO (nat com)	IF EO (nat com) = BC, THEN Score = + 3
12	EO (nat com)	IF EO (nat com) = C or CD, THEN Score = + 2
12	EO (nat com)	IF EO (nat com) = D, THEN Score = + 1
1	Bufferedge %(EIA)	IF buffer/edge > 0.8 THEN Score = + 5
1	Bufferedge %(EIA)	IF buffer/edge > 0.6 AND <= 0.8, THEN Score = + 3
1	Bufferedge %(EIA)	IF buffer/edge > 0.4 AND <= 0.6 THEN Score = + 1
1	Bufferedge %(EIA)	IF buffer/edge <= 0.4 THEN Score = + 0

RESULTS

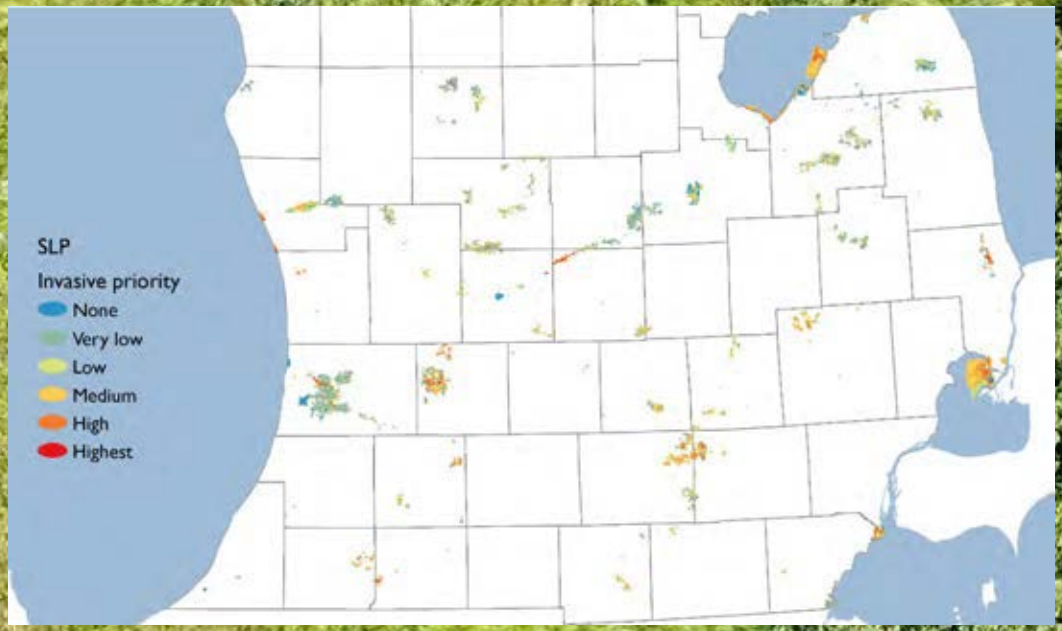

St. John's Marsh
St. Clair Flats
Invasive priority
None
Very low
Low
Medium
High
Highest

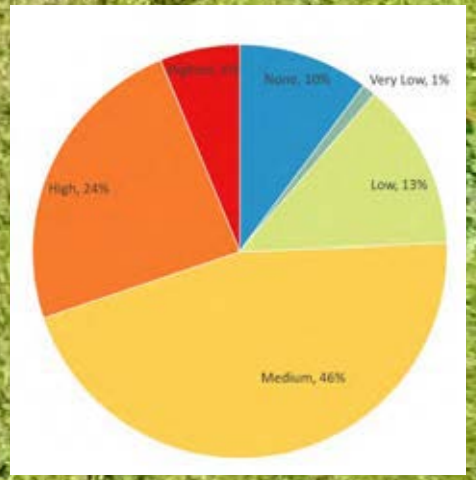

SLP
Invasive priority
None
Very low
Low
Medium
High
Highest

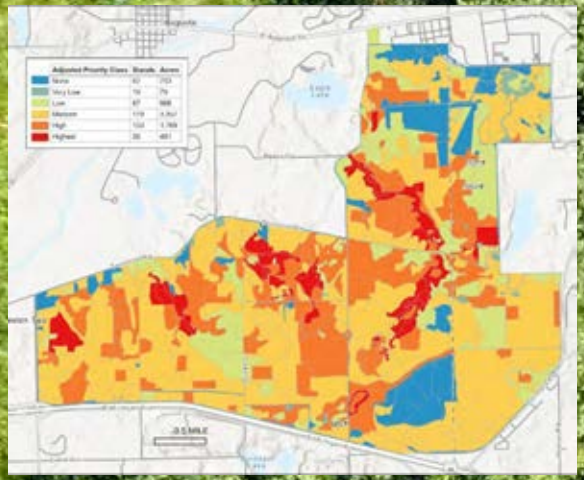


Model Products

- Stand-level data files attributed with ecological data and priority score
- Spatial representation at multiple scales
- Summary graphics and statistics by areas of interest
- ArcGIS Online tool and user's handbook







MiFI Stands Invasive Treatment Prioritization

Overview



Web map of the MNFI invasive treatment prioritization model for MiFI stands.

Web Map by enanderh

Item created: Dec 23, 2022 Item updated: Feb 4, 2024 View count: 859

Open in Map Viewer

Open in ArcGIS Desktop

Open in ArcMap

Open in ArcGIS Pro

Description

The MNFI model for invasive species treatment prioritization on Michigan state lands is based on 15 scored metrics in categories of Biodiversity (rarity and richness), Resiliency (climate and natural community type), Integrity (stand, landscape, and invasive), and Ecosystem services. Invasive species locations are from MiFI canopy and subcanopy, and MISIN point data (as of 08/12/2022). Prioritization scores (0-5, lowest - highest) are categorized into six classes: None, Very Low, Low, Medium, High, Highest.

Details

Size: 9.1 KB

ID: f53c22327ad545688f11ecfcd69750b1

Layers

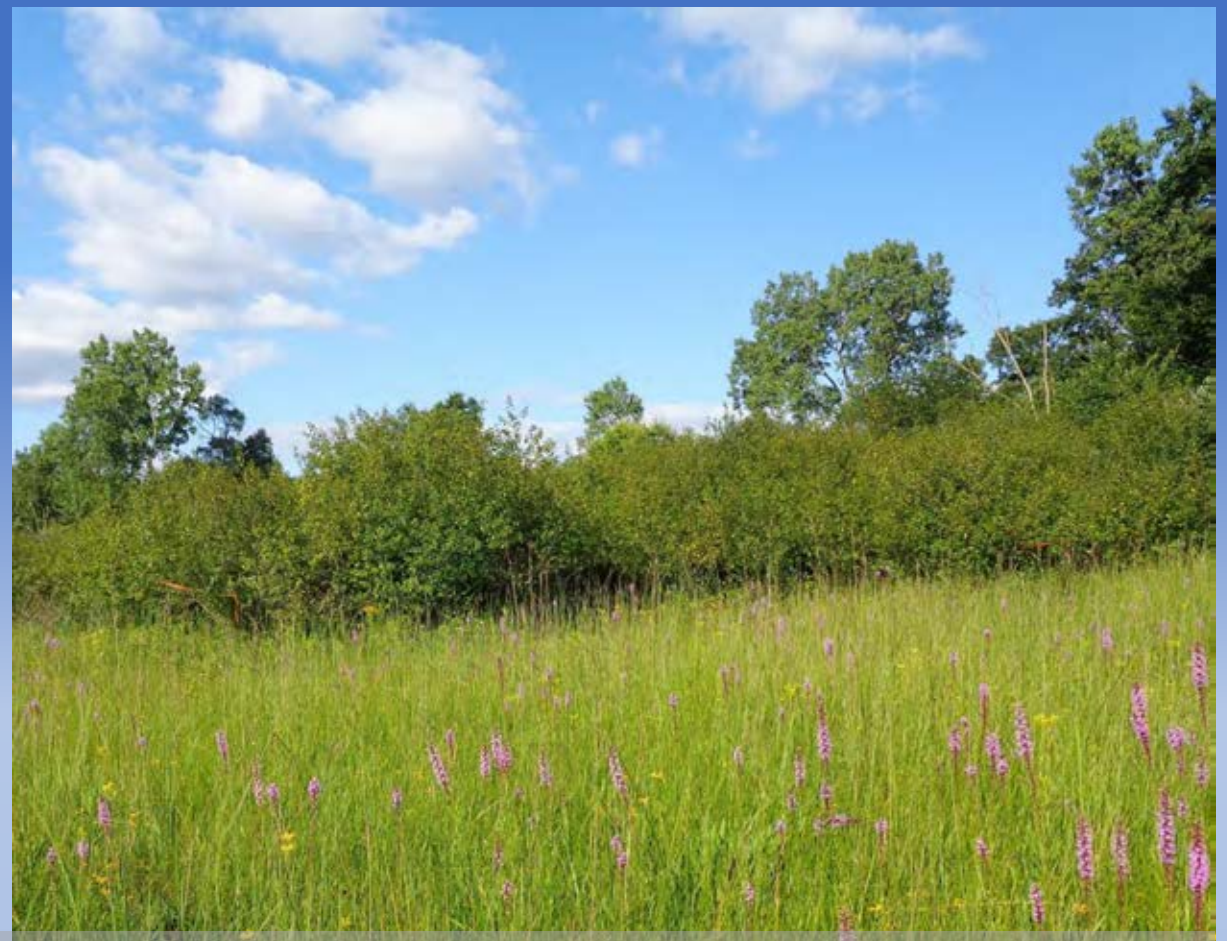
Natural Communities
Feature layer

Landscape Ecoregions
Feature layer

Vegetation c1800

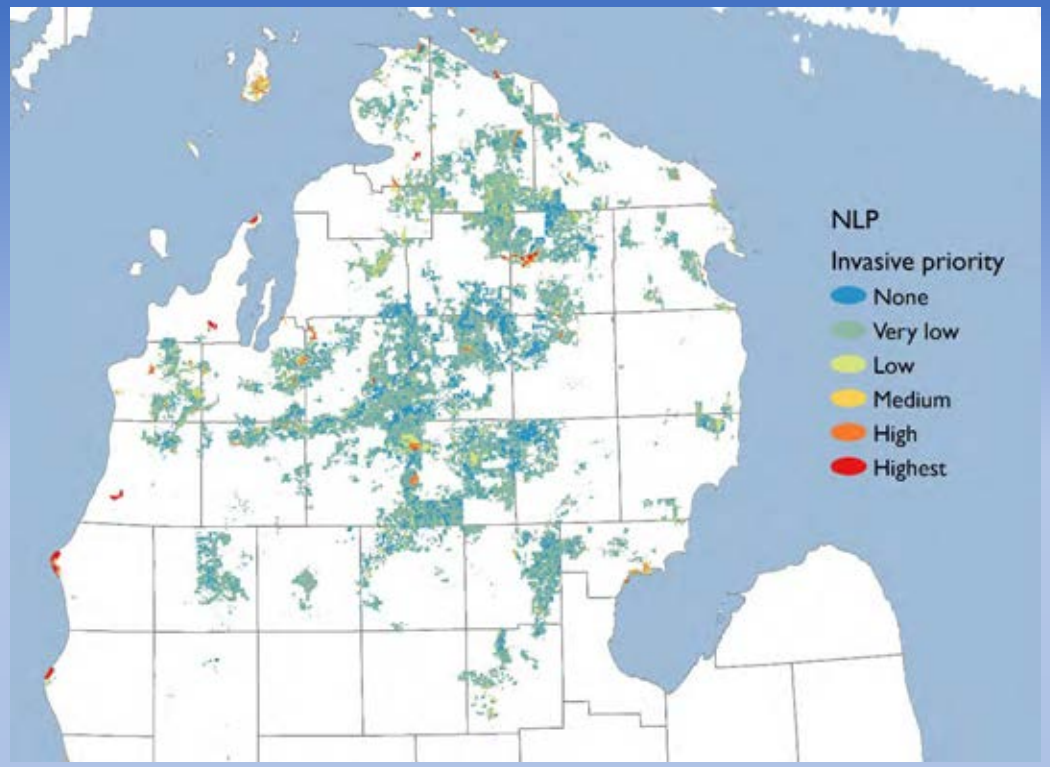
https://mnfi.maps.arcgis.com/home/item.html?id=f53c22327ad545688f11ecfcd69750b1

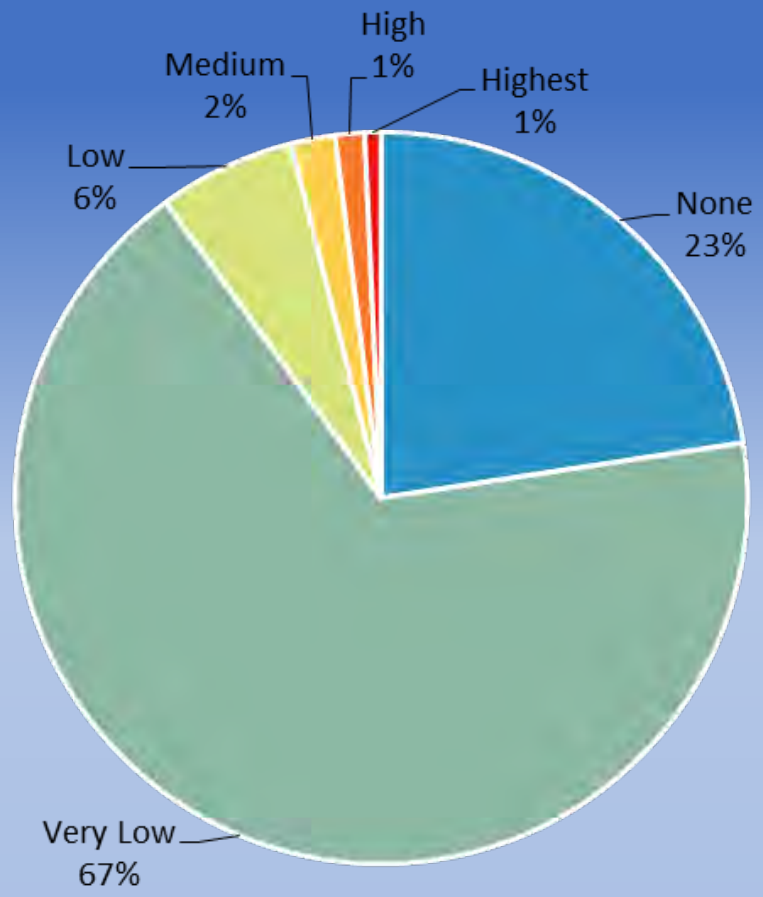




Priority scores are high in Southern Michigan in ecosystems such as lakeplain prairie and prairie fen that are rare, characterized by high native biodiversity and numerous rare species, provide critical ecosystem services, and are threatened by invasive species such as invasive reed and glossy buckthorn.

Northern Lower Peninsula





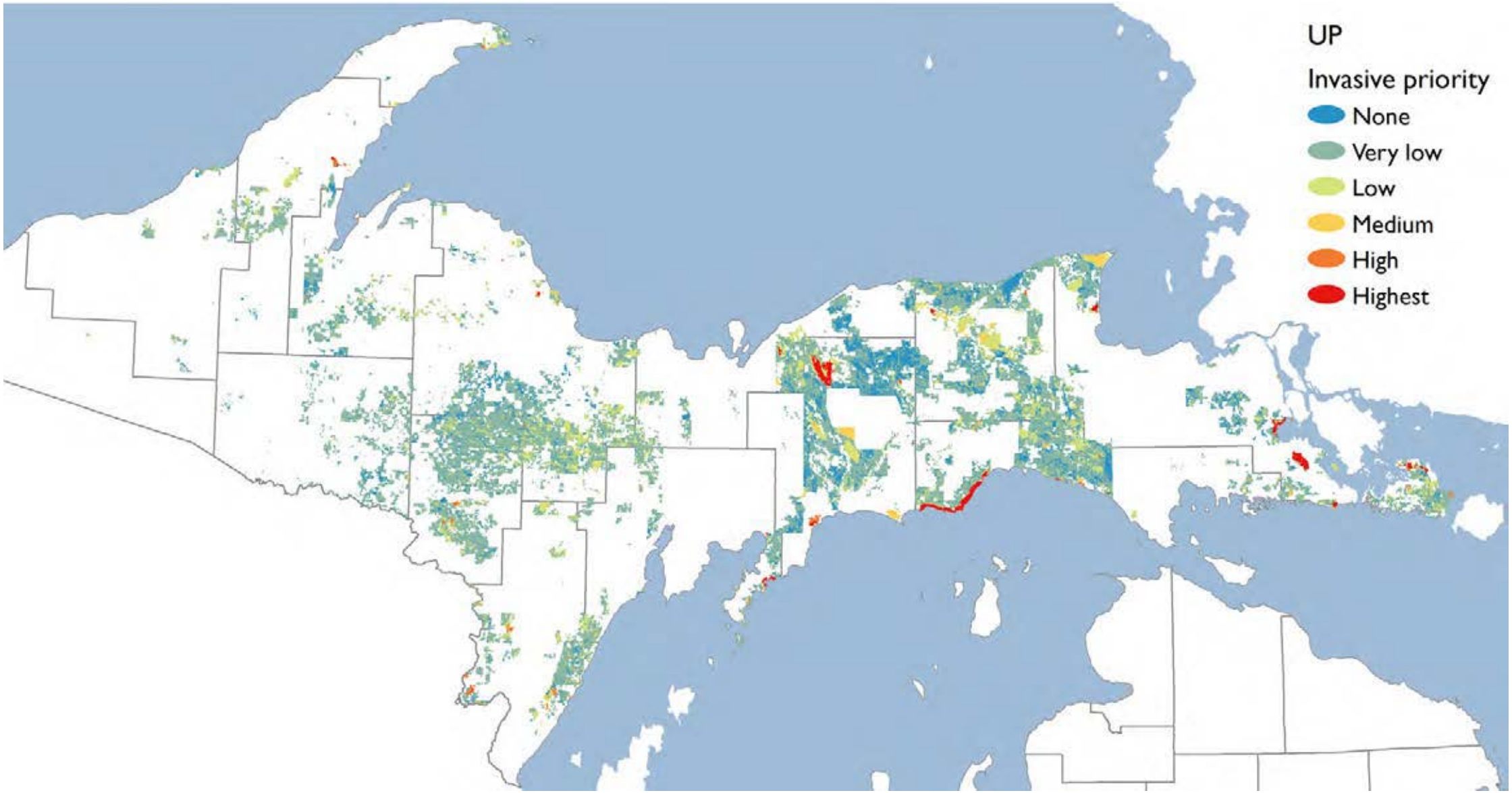
Priority	Acres
None	471,679
Very Low	1,407,156
Low	126,349
Medium	40,699
High	27,140
Highest	15,009
Total	**2,088,032**

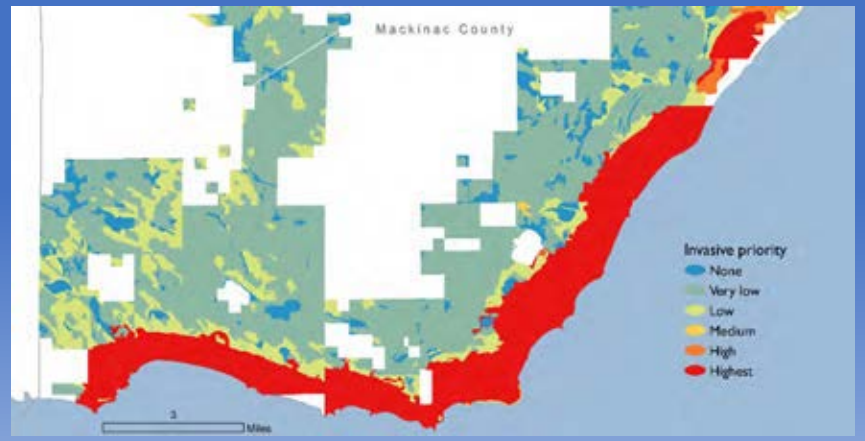




In NLP, high priority scores for Great Lakes Marsh and open dunes.

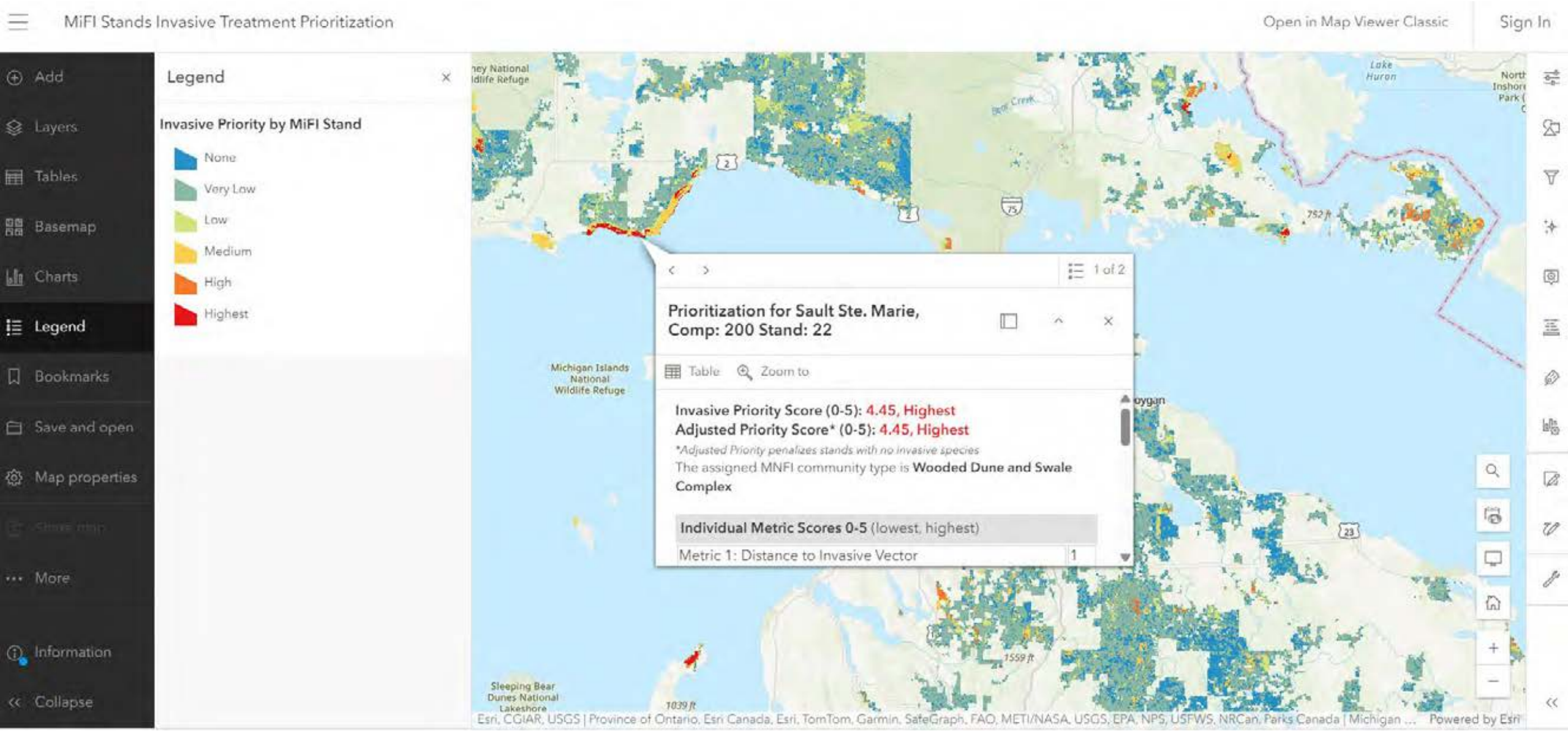
- Endemic to the Great Lakes.
- Characterized by high native biodiversity and numerous rare species
- Provide critical ecosystem services (e.g., coastal shoreline buffering, spawning and pollinator habitat).
- Threatened by invasive species (e.g., invasive reed and spotted knapweed).


UP
Invasive priority
None
Very low
Low
Medium
High
Highest


Mackinac County
Invasive priority
None
Very low
Low
Medium
High
Highest
3
Miles






MiFI Stands Invasive Treatment Prioritization
Open in Map Viewer Classic
Sign In
Add
Layers
Tables
Basemap
Charts
Legend
Bookmarks
Save and open
Map properties
More
Information
Collapse
Legend
Invasive Priority by MiFI Stand
None
Very Low
Low
Medium
High
Highest
1 of 2
Prioritization for Sault Ste. Marie, Comp: 200 Stand: 22
Table
Zoom to
Invasive Priority Score (0-5): 4.45, Highest
Adjusted Priority Score* (0-5): 4.45, Highest
*Adjusted Priority penalizes stands with no invasive species
The assigned MNFI community type is Wooded Dune and Swale Complex
Individual Metric Scores 0-5 (lowest, highest)
Metric 1: Distance to Invasive Vector
1
Michigan Islands National Wildlife Refuge
Sleeping Bear Dunes National Lakeshore
Lake Huron
752 ft
1559 ft
1039 ft
Esri, CGIAR, USGS | Province of Ontario, Esri Canada, Esri, TomTom, Garmin, SafeGraph, FAO, METI/NASA, USGS, EPA, NPS, USFWS, NRCan, Parks Canada | Michigan ...
Powered by Esri



Contents lists available at ScienceDirect

Ecological Modelling

journal homepage: www.elsevier.com/locate/ecolmodel

Using GIS-based multicriteria decision analysis to prioritize invasive plant treatment: A creative solution for a pernicious problem

Joshua G. Cohen *, Helen D. Enander, Tyler J. Bassett, Clay M. Wilton, Ashley A. Cole-Wick

Michigan Natural Features Inventory, Michigan State University Extension, PO Box 13036, Lansing, MI 48901-3036, USA

ARTICLE INFO

Keywords:
GIS based multicriteria decision analysis
Invasive plant species
Biodiversity
Resilience
Integrity
Ecosystem services

ABSTRACT

Invasive plant infestations are projected to rapidly increase with continued habitat fragmentation and climate change. The rate of spread often outpaces land managers' ability to effectively detect and control infestations. Land stewards need tools that can match the rapid pace and scale of invasive infestation and help prioritize control efforts in the most ecologically important areas and optimize resource allocation. It is imperative that proposed control be informed by the best available ecological information. We present a spatially explicit modeling framework for prioritizing invasive plant treatment. In our case study from Michigan, we employ a multicriteria decision analysis model that synthesizes four critical factors for prioritizing invasive plant stewardship: integrity, biodiversity, resilience, and ecosystem services. Data for quantifying these factors were compiled from several state, federal, university, and non-governmental data sources. The model uses a geographic information system (GIS) to identify places that are impacted by invasive plant infestations that threaten to degrade ecosystem composition, structure, and function; are characterized by high ecosystem integrity; support high biodiversity; are resilient to disturbance; and provide ecosystem services. While specific to Michigan, our modeling framework is broadly applicable. This type of integrated analysis can help inform decisions about allocation of limited resources for numerous biodiversity stewardship and landscape-level conservation planning needs, regardless of geographic location.

1. Introduction

Invasive plants affect ecosystem processes through their patterns of resource acquisition and growth and degrade native biodiversity by altering fundamental structures and functions and even triggering trophic cascades (Ehrenfeld, 2010). Invasive plants displace critical habitat for native species, interrupt food webs, alter soils, hydrology, and disturbance regimes, compromise pollinator services, change microclimates, despoil recreational resources, jeopardize human health, and degrade local economies (Zavaleta, 2000; Pimentel et al., 2005; Huang and Asner, 2009; Ehrenfeld, 2010; Vila et al., 2011). The spread of invasive plant species is projected to increase with anthropogenic global change, in particular, continued habitat fragmentation and climate change (Dukes and Mooney, 1999; Vila and Ibanez, 2011; Bradley et al., 2012). Environmental damage caused by invasive species within the United States is estimated to cost between $21 and $120 billion per year (Pimentel et al., 2005; Fantle-Lepczyk et al., 2022). Invasive plant infestations are characterized as rapid and extensive, occurring at regional scales as species disperse over long distances with the rate of spread often outpacing land managers' ability to effectively detect and control infestations (Lass et al., 2005; Lass et al., 2005; Mullerova et al., 2013; Mullerova et al., 2017). The rapid spread of a diverse array of invasive plants across landscapes demands dynamic tools that can help land stewards match the pace and scale of infestations and prioritize control efforts in the most ecologically important areas while maximizing the allocation of finite resources for biodiversity stewardship.

In the field of conservation biology, the criteria used to identify the ecologically most important places for conservation have evolved. Preservation and biodiversity stewardship efforts initially focused on areas that support high concentrations of biodiversity, often with an emphasis on rare species and ecosystems and endemism (Wilcox, 1982; Myers et al., 2000). As our understanding of biodiversity expanded beyond species to include multiple scales of diversity (e.g., from genetic diversity within populations to ecosystem diversity across landscapes) as well as driving ecological processes, the coarse-filter approach to conservation gained momentum, and emphasis was placed on protecting areas characterized by ecological integrity (Noss, 1990; Noss and

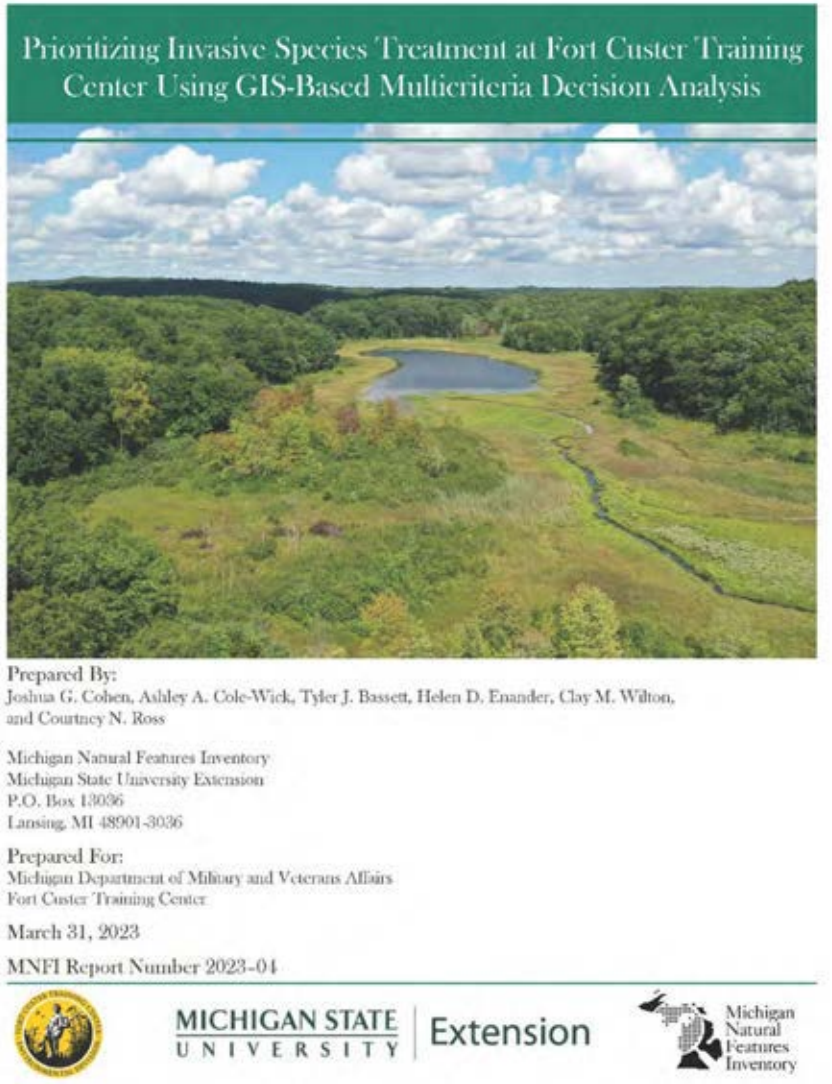
* Corresponding author at: Michigan Natural Features Inventory, PO Box 13036, Lansing, MI 48901-3036, USA.
E-mail address: cohenj@msu.edu (J.G. Cohen).

https://doi.org/10.1016/j.ecolmodel.2024.110807
Received 20 December 2023; Received in revised form 3 April 2024; Accepted 16 July 2024
Available online 25 July 2024
0304-3800/© 2024 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

https://doi.org/10.1016/j.ecolmodel.2024.110807



https://storymaps.arcgis.com/stories/1243c098a45a4f4db11082fbcb16e0f6



https://mnfi.anr.msu.edu/reports/MNFI-Report-2023-04.pdf



https://doi.org/10.1016/j.ecolmodel.2024.110807





https://mnfi.anr.msu.edu/reports/MNFI-Report-2023-04.pdf



https://doi.org/10.3390/d13030100

diversity

MDPI

Article

Assessing the Ecological Need for Prescribed Fire in Michigan Using GIS-Based Multicriteria Decision Analysis: Igniting Fire Gaps

Joshua G. Cohen *, Clay M. Wilton, Helen D. Enander and Tyler J. Bassett *

Michigan Natural Feature Inventory, Michigan State University Extension, Lansing, MI 48933, USA; wiltonc@msu.edu (C.M.W.), enander@msu.edu (H.D.E.)

* Correspondence: cohenj@msu.edu (J.G.C.); bassett7@msu.edu (T.J.B.); Tel.: +1 517 284 6161 (J.G.C.); +1-517-284-6220 (T.J.B.)

Abstract: In fire-suppressed landscapes, managers make difficult decisions about devoting limited resources for prescribed fire. Using GIS-based multicriteria decision analysis, we developed a model assessing ecological need for prescribed fire on Michigan's state-owned lands, ranging from fire-dependent prairies, savannas, barrens, and oak and pine forests to fire-intolerant mesic forests, and including a diversity of wetlands. The model integrates fine-scale field-collected and broad-scale GIS data to identify where prescribed fire needs are greatest. We describe the model's development and architecture, present results at multiple scales, introduce the concepts of "fire gaps" and "fire sink", and rate the fire needs of more than 1.8 million hectares into one of six fire needs classes. Statewide, fire needs increase with decreasing latitude. The highest and lowest needs occur in southwestern Michigan and the Upper Peninsula, respectively, but actual fire application rates for these regions are inverted. The model suggests burn rates should be increased 2.2 to 13.4 times to burn all lands with greater than high fire needs. The model identifies regional patterns, highlights specific sites, and illustrates the disparity of fire needs and fire application. The modeling framework is broadly applicable to other geographies and efforts to prioritize stewardship of biodiversity at multiple scales.

Keywords: fire; needs assessment; multicriteria decision analysis; prescribed fire; fire suppression; fire frequency; prioritization; biodiversity; Michigan; upper Midwest

check for updates

Citation: Cohen, J.G.; Wilton, C.M.; Enander, H.D.; Bassett, T.J. Assessing the Ecological Need for Prescribed Fire in Michigan Using GIS-Based Multicriteria Decision Analysis: Igniting Fire Gaps. *Diversity* **2021**, *13*, 100. https://doi.org/10.3390/d13030100

Academic Editors: Michael Wink and Brian R. Lindberg

Received: 7 February 2021
Accepted: 18 February 2021
Published: 24 February 2021

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Copyright: © 2021 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

Fire is a key ecological process in many ecosystems worldwide that determines a wide range of ecosystem attributes, from nutrient cycling rates to vegetation structure to patterns of biodiversity at multiple scales [1]. Modern land managers use prescribed fire to restore or maintain desired ecosystem structure and species composition, particularly in grasslands, savannas, and woodlands [2,3], ecosystems that are critical habitats for a wide array of wildlife including many game species. However, the resources (time, money, and labor) available to conduct prescribed fire are limited. Where those resources are directed has profound implications for conservation and may determine the fate of many wildlife species and the ecosystems on which they depend. Using GIS-based multicriteria decision analysis, we developed a robust model for assessing the ecological need for fire at multiple spatial scales in Michigan, USA. Conceptualization and development of the model were informed by interactions with natural resource managers and fire ecology experts. The goal of developing this prescribed fire needs assessment model is to enhance the application of fire in the ecologically most important landscapes and ecosystems and thereby restore or maintain a critical ecosystem process; increase the integrity of fire-dependent systems; and improve habitat for native biodiversity, including a diverse array of both game and non-game species. While the model is focused on evaluating the ecological need for fire on state lands in Michigan, it is not a comprehensive needs assessment in that it focuses on



https://doi.org/10.3390/d13030100

diversity

MDPI

Article

Assessing the Ecological Need for Prescribed Fire in Michigan Using GIS-Based Multicriteria Decision Analysis: Igniting Fire Gaps

Joshua G. Cohen *, Clay M. Wilton, Helen D. Enander and Tyler J. Bassett *

Michigan Natural Feature Inventory, Michigan State University Extension, Lansing, MI 48933, USA; wiltonel@msu.edu (C.M.W.), enander@msu.edu (H.D.E.)

* Correspondence: cohenj@msu.edu (J.G.C.); bassett7@msu.edu (T.J.B.); Tel.: +1 517 284 6161 (J.G.C.); +1-517-284-6220 (T.J.B.)

Abstract: In fire-suppressed landscapes, managers make difficult decisions about devoting limited resources for prescribed fire. Using GIS-based multicriteria decision analysis, we developed a model assessing ecological need for prescribed fire on Michigan's state-owned lands, ranging from fire-dependent prairies, savannas, barrens, and oak and pine forests to fire-intolerant mesic forests, and including a diversity of wetlands. The model integrates fine-scale field-collected and broad-scale GIS data to identify where prescribed fire needs are greatest. We describe the model's development and architecture, present results at multiple scales, introduce the concepts of "fire gaps" and "fire sink", and rate the fire needs of more than 1.8 million hectares into one of six fire needs classes. Statewide, fire needs increase with decreasing latitude. The highest and lowest needs occur in southwestern Michigan and the Upper Peninsula, respectively, but actual fire application rates for these regions are inverted. The model suggests burn rates should be increased 2.2 to 13.4 times to burn all lands with greater than high fire needs. The model identifies regional patterns, highlights specific sites, and illustrates the disparity of fire needs and fire application. The modeling framework is broadly applicable to other geographies and efforts to prioritize stewardship of biodiversity at multiple scales.

Keywords: fire; needs assessment; multicriteria decision analysis; prescribed fire; fire suppression; fire frequency; prioritization; biodiversity; Michigan; upper Midwest

check for updates

Citation: Cohen, J.G.; Wilton, C.M.; Enander, H.D.; Bassett, T.J. Assessing the Ecological Need for Prescribed Fire in Michigan Using GIS-Based Multicriteria Decision Analysis: Igniting Fire Gaps. *Diversity* 2021, *13*, 100. https://doi.org/10.3390/d13030100

Academic Editors: Michael Wink and Brian R. Lindberg

Received: 7 February 2021
Accepted: 18 February 2021
Published: 24 February 2021

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

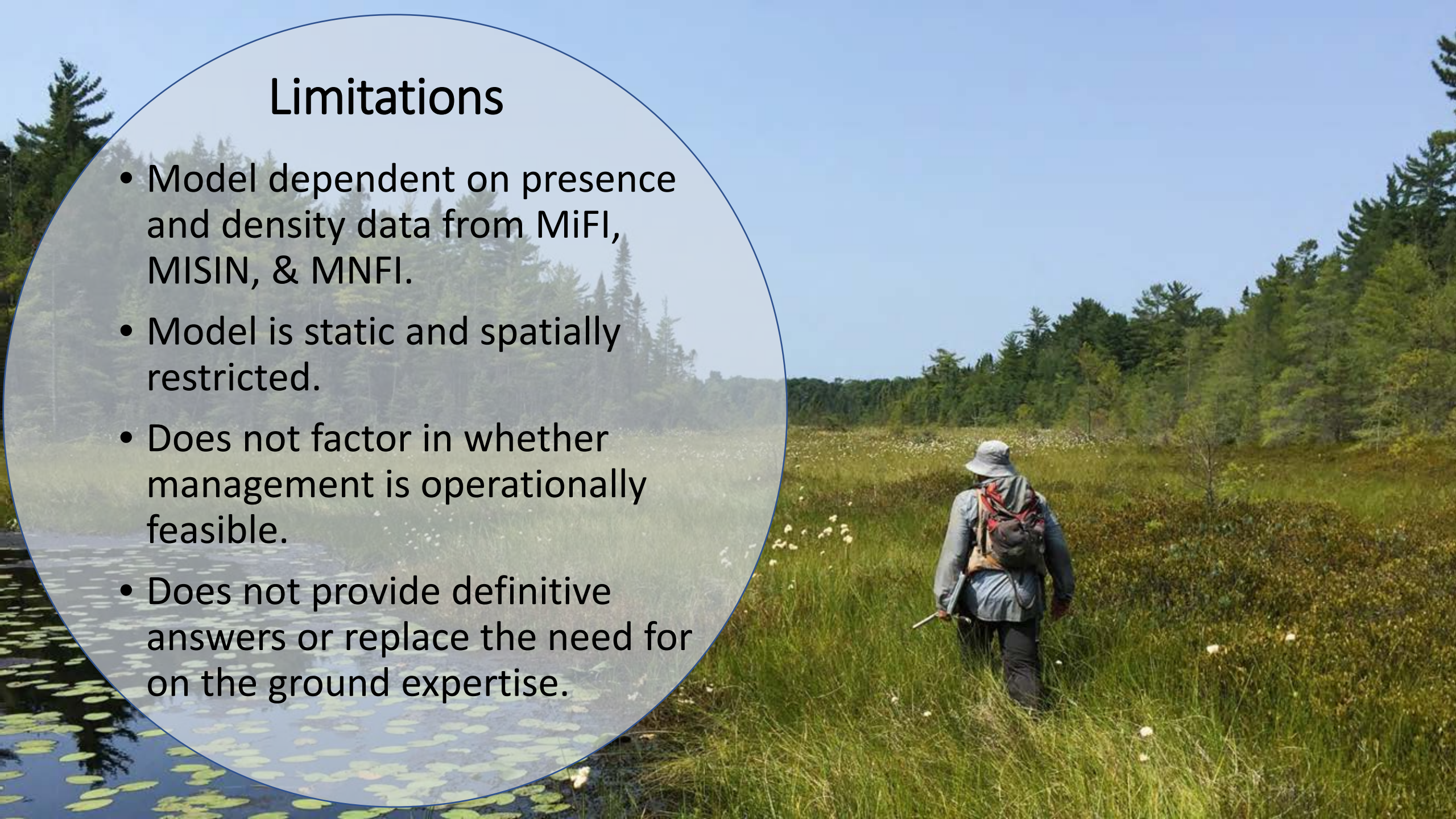
Copyright: © 2021 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

Fire is a key ecological process in many ecosystems worldwide that determines a wide range of ecosystem attributes, from nutrient cycling rates to vegetation structure to patterns of biodiversity at multiple scales [1]. Modern land managers use prescribed fire to restore or maintain desired ecosystem structure and species composition, particularly in grasslands, savannas, and woodlands [2,3], ecosystems that are critical habitats for a wide array of wildlife including many game species. However, the resources (time, money, and labor) available to conduct prescribed fire are limited. Where those resources are directed has profound implications for conservation and may determine the fate of many wildlife species and the ecosystems on which they depend. Using GIS-based multicriteria decision analysis, we developed a robust model for assessing the ecological need for fire at multiple spatial scales in Michigan, USA. Conceptualization and development of the model were informed by interactions with natural resource managers and fire ecology experts. The goal of developing this prescribed fire needs assessment model is to enhance the application of fire in the ecologically most important landscapes and ecosystems and thereby restore or maintain a critical ecosystem process; increase the integrity of fire-dependent systems; and improve habitat for native biodiversity, including a diverse array of both game and non-game species. While the model is focused on evaluating the ecological need for fire on state lands in Michigan, it is not a comprehensive needs assessment in that it focuses on

Limitations

- Model dependent on presence and density data from MiFI, MISIN, & MNFI.
- Model is static and spatially restricted.
- Does not factor in whether management is operationally feasible.
- Does not provide definitive answers or replace the need for on the ground expertise.



Conclusions

- Useful tool to provide managers with information about where to manage for invasive species.
- Allows managers to evaluate invasive species control at multiple scales
- Developed to foster informed discussion and facilitate difficult decisions about allocation of finite resources.

Questions?



Joshua Cohen: cohenj@michigan.gov

Acknowledgments

- Michael Donovan (DNR WLD)
- Greg Norwood and Robert Clancey (DNR PRD)
- Glenn Palmgren (DNR FRD)
- Anthony Koop (USDA)
- Claire Peterson (MISIN)
- Jesse Lincoln, Aaron Kortenhoven, Phyllis Higman, Rachel Hackett, Tyler Bassett (MNFI)
- Photo Credits
  - Joshua Cohen (MNFI)
  - Jesse Lincoln (MNFI)
  - Clay Wilton (MNFI)
  - Aaron Kortenhoven (MNFI)
  - Matt Lewis (Michigan Aerospace Corporation)