Forest Service
U.S. DEPARTMENT OF AGRICULTURE

Eastern Region | September 2025

Great Lakes Forests

A Data Synthesis

Cover image: Chequamegon-Nicolet National Forest, photo by Jim Brekke.

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Dedication

This report is dedicated to public service employees past and present.

Citation

Please cite as Khoury, M, Clark, M, Olivero, A, Swaty, R and M.G. Anderson. 2025. Great Lakes Forests: A data synthesis. The Nature Conservancy, Center for Resilient Conservation Science. USA.

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Executive Summary

Foundational to effective forest management is a comprehensive understanding of forest resources. While the Great Lakes region has a rich library of basin-wide assessments, none provide a holistic picture of the region's forests. The Nature Conservancy, working in partnership with staff from the Eastern Region of the US Department of Agriculture's Forest Service, analyzed historic and current data and previous studies to create this synthesis of the region's forests that includes the status and trends of forests in natural, agricultural, and urban landscapes.

The Forest Synthesis covers the US Great Lakes watershed extending from northern Minnesota to the New York state border with Ontario. This 70-million-acre assessment area includes parts of seven states and all of Michigan.

The importance of the Great Lakes cannot be overstated. Together, the lakes hold 20% of the world's freshwater and over 90% of the freshwaters of the United States and provide drinking water for 40 million people in the US and Canada. Integral to the health of the Great Lakes are the region's forests that cover over 50% of the land, capturing and filtering the waters that ultimately reach the lakes, and in doing so supporting remarkable biological diversity and human communities.

Synthesis Contents

- A thorough description of the ecological setting and human factors that have shaped the region's forests (Chapter 2)
- Comprehensive analyses of the region's forests extent, ownership patterns, turnover, and disturbances (Chapter 3)
- The multiple benefits that intact forests provide for water quality, water quantity regulation, wildlife, and the economy through forestry and recreation (Chapter 4)
- The role of trees in agricultural landscapes and resources on agroforestry (Chapter 5)
- The benefits to city dwellers of trees and parks and status of the urban canopy (Chapter 6)

This work was guided by a Forest Service, Eastern Region steering committee. We gratefully acknowledge their help, guidance, and suggestions.

Khoury, M, Clark, M, Olivero, A, Swaty, R and M.G. Anderson. 2025. Great Lakes Forests: A data synthesis. The Nature Conservancy, Center for Resilient Conservation Science. USA.

Key Findings – Chapter 2: The Great Lakes Forest

Of the 75 million acres of US land that drain directly into the Great Lakes, 38 million are forested. These forests are critical for maintaining the water quality of the Great Lakes, which provide drinking water to 40 million people. Forests collect and filter rainfall, regulating the flow of water back into streams and rivers while filtering out excess nutrients and sediments, which protects the lakes.

38 million acres of forests

40 million people

Temperature and precipitation gradients from north to south and geologic variability in the Great Lakes Basin shape the forests. The recently glaciated landscape is covered by deep sands and fertile loams supporting a variety of forest types. The north is dominated by spruce-fir, the central region by mixed hemlock-sugar maple–beech-yellow birch and oak-pine and the south by deciduous beech-maple and oak-hickory. Large expanses of prairies and oak savannahs would have characterized the sandy soils before conversion.

194 bird
63 mammal
21 amphibian
18 reptile
141 fish species

Current forests provide habitat for many species. However, the extent and composition of forest communities has been in flux for centuries and is now changing rapidly. At least 61 forest-dwelling species are at-risk of extinction. Some, like wolverine and mountain lion, are likely extirpated while others, like grey wolf, are recovering.

Whether viewed through the lens of terrestrial ecoregions or freshwater watersheds, the basin naturally divides into distinctly different subregions each with their own ecology, forest types, and conservation issues. The northern half of the basin is more heavily forested, while the southern half is more agricultural, and this land use pattern is reflected in the water quality of the Great Lakes from north to south.

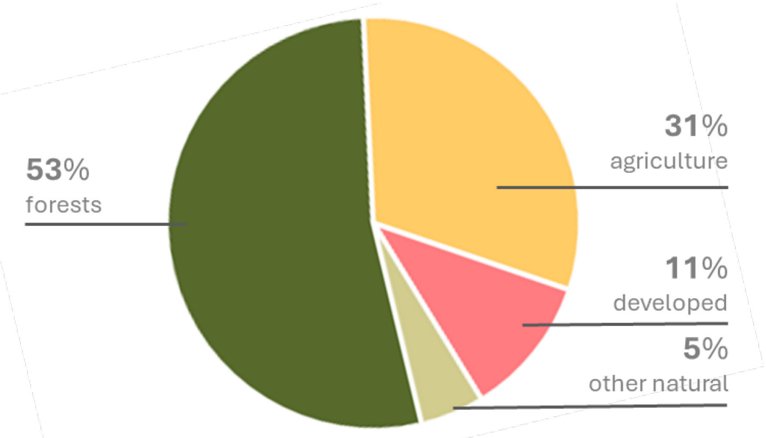
Humans have been a part of the natural systems as early as 14,000 years ago, depending on the forest for food, materials and economic development. Of the 31 federally recognized tribes that reside in the region, most of them have long histories of stewarding the forests for food and materials.

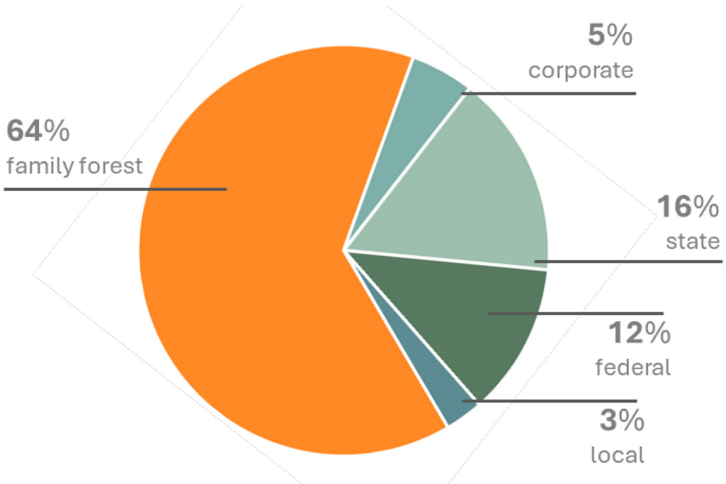
Over the 19th century, the US government's actions resulted in almost all American Indian Tribes ceding territory, and in many cases, being forcibly removed from their lands. Colonists arriving in the late 1800s brought widespread logging that transformed the forests, clogged the rivers, and fueled the development of large cities and towns. Agriculture expansion gave rise to further forest clearing.

Forests are integral to the lives of the people in the Great Lakes assessment area. Over 27 million people rely on them and their connected ecosystems for hunting, fishing, recreation, and employment. In addition to sustaining a substantial forest products industry, healthy forests also underly industries in tourism, fisheries, logging and natural resource management.

Key Findings – Chapter 3: Forest Trends in the Great Lakes Basin

Roughly half of the region remains forested, with the other half split between development and agriculture. Across the basin, development is twice the national average and is concentrated in the south.





Private owners control more forests than any other group. Family forests face challenges like fragmentation, aging ownership, and development pressure, which threaten their ecological integrity and long-term stewardship. Limited access to technical support and financial resources also makes sustainable management difficult for many landowners.

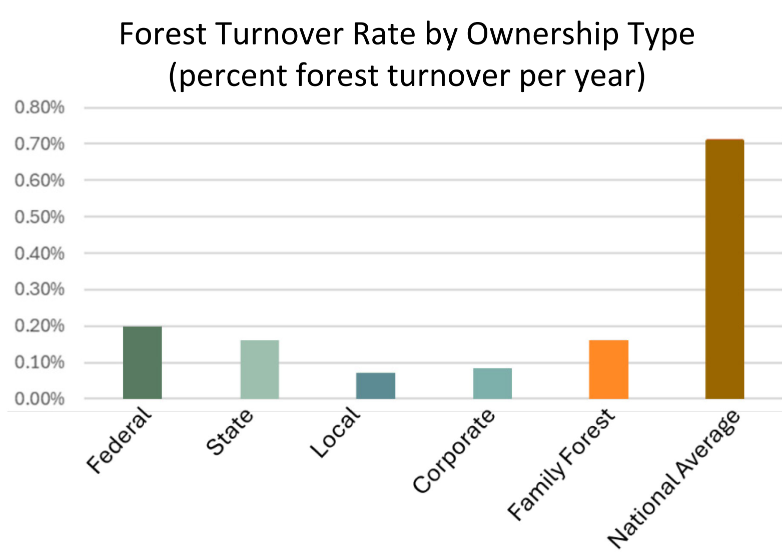
Almost a third of the basin's forests are in public ownership, which is concentrated in the northern part of the basin. National forest land is the largest type of conservation land.

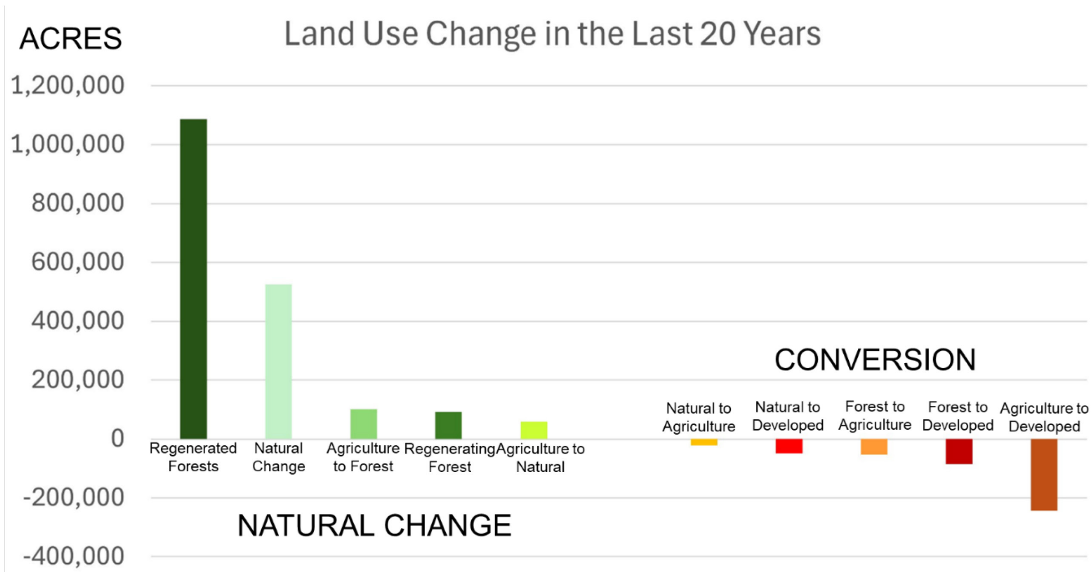
Almost half of the forest (44%) is comprised of Northern Hardwood Forest (30%) characterized by maple, beech and birch, and Alkaline Conifer-Hardwood Swamp (14%) characterized by white cedar, hemlock, maple and ash. The next most common forest type is Plantation and Ruderal Forest (7%) reflecting industrial forest managed for timber-production.

The northern part of the region has large forest blocks as fragmentation by roads is concentrated in the southern part of the region. Road-bounded forest blocks in the north average over 100,000 acres in size and many are over one million acres. The two largest blocks are over a million acres in Superior National Forest in Minnesota. Forest blocks larger than 500,000 acres are also found in northern Wisconsin, the Upper Peninsula of Michigan, northern lower peninsula of Michigan, and the Adirondacks of New York.

Extensive logging in the mid-1800s to early 1900s removed vast old-growth forests, especially white pine and hemlock. This logging and natural regeneration have created ecological shifts where forests have become more homogeneous in both species composition and structure. Forests transitioned from diverse, mature conifer-dominated ecosystems to younger, hardwood-dominated ones. There has been a marked decline in conifer presence—once two-thirds of the forest composition and now about one quarter. Broadleaf deciduous species now dominate, reducing habitat complexity and affecting wildlife. The structural complexity of forests has also declined, with fewer large trees and more uniform tree sizes.

Land use in the Great Lakes region has been remarkably stable over the last twenty years with about 3% of the land changing in cover type during the last twenty years. Half of the change (1.5%) was forest turnover where trees were cut, damaged, or disturbed but then returned to forest. All but a small fraction has already returned to forest. Permanent conversion of forests to development or industrial agriculture accounted for just 0.4% of the total forest area. While the Great Lakes is losing a small amount of forests to development, three times more development is occurring on agricultural land.





Forest logging practices in the Great Lakes region vary significantly by ownership type. Federal lands have the greatest rate of forest turnover (average amount of forest turnover per year/total amount of forests) with more than 0.2% or 500,000 acres per year. While this is the largest rate of forest turnover in the basin, it is still much lower than the national average (0.7% per year).

Insect disturbance is common. In the last five years (2019-2023), spongy moths have been the most prevalent, affecting 4.1 million acres with 6.6 million total acres reported since 1997. Spruce budworm has a similar pattern, 3.2 million acres in the last five years and 4.4 million acres total. Emerald ash borer infestation totaled 3.0 million acres since 1997 but only half a million acres were reported for the last five years. Similarly, forest tent caterpillar extent totaled 27.5 million acres from 1997 to 2023 but decreased to 0.3 million acres in recent years.

Fire has typically been limited in the region, estimated to influence two million acres annually before European settlement. Fire is most prevalent and important to specific ecosystems especially in the central and western part of region. Current fire regimes are altered by suppression or loss of fire-adapted ecosystems.

Weather has always shaped forests in the Great Lakes, particularly wind. The region has warmed 2.3°F in the last 70 years. Changes in weather patterns due to more extreme temperatures and significant changes in the timing and intensity of precipitation, make forests vulnerable to stress and exacerbate the impacts of pests, pathogens, invasive species and altered fire regimes. Many species of importance to human communities have been identified by Ojibwe Tribes in the region to be at risk from these changes.

The forests of the Great Lakes play an essential role in maintaining natural strongholds for biodiversity in the face of more extreme disturbances. Forested lands in the region are more resilient than non-forested land with 64% of the region's forested lands identified as resilient. Eighty percent of national forests within the Great Lakes Basin score are estimated to be resilient.

Key Findings – Chapter 4: Benefits of Forested Landscapes

The connection between forested lands and high water quality is clear. Data from the National Rivers and Streams Assessment show that streams ranked "Poor" for nitrogen had on average 33-48% less forest upstream than streams that ranked "Good." Areas with less forest cover have higher amounts of nitrogen (N), phosphorus (P), and suspended sediments (S).

Using data from the Forest Service's Forests to Faucets (2.0) we found that an area's ability to produce clean water was a function of high forest cover and mean annual water yield, which is a function of precipitation patterns. The areas with the highest ability to produce clean water are in the Upper Saint Lawrence, Lake Superior, and Lake Ontario watersheds. Over 16 million acres of forests (44%) are found in watersheds with high importance for surface drinking water supply. Importance correlates to proximity to population centers.

Combining the Forest to Faucets metrics highlights where increasing and protecting forest cover can boost clean water production. Eight percent of the region's forests have high importance for surface drinking water but are in watersheds with low ability to produce clean water. Forest restoration could improve their ability to produce clean water. Thirty-five percent of forests are in watersheds that have both high importance and medium or higher ability to produce clean water. Almost 80% of this category of forests are unprotected from conversion and would thus be important places to prevent further deforestation.

Another benefit of forest restoration is flood prevention. Areas with little flood prevention provided by forests are concentrated along the coastal and more agricultural areas of the region, particularly the Lake Erie basin.

Hundreds of species depend on Great Lakes forest habitat, which supports especially high species richness for birds, particularly in areas where there is natural variability in forest succession classes. Forests also provide habitat value for Brook Trout, a recreationally important species. In Michigan streams, Brook Trout had the most valuable biomass for stream fishes as a measure of anglers' willingness to spend money to fish.

Timber harvesting is a key forest management tool that helps shape forest structure and composition. Timber harvest is concentrated in a few counties in the northern lower peninsula of Michigan, the Upper Peninsula of Michigan, northern Wisconsin, and northeastern Minnesota and is happening at a volume that allows for regeneration. In the last 20 years, most of this harvest (52%) has occurred on private land, 25% on state land. Twenty-two million acres of forest land are sustainably certified.

In the Great Lakes region, timber harvesting, processing, and manufacturing support thousands of jobs, particularly in rural areas of Michigan, Wisconsin, and Minnesota. In Michigan, the forest products industry supports over 91,000 jobs, many of which are in rural communities. Most of the employment in the timber economy is in the processing of timber into paper (33%) and wood (64%).

In the Great Lakes Basin, Recreation Accounted for:
1 million jobs
$69 billion in wages
¼ of counties with recreation-based economy

National forest user data from five national forests shines a spotlight on recreation with the four most common uses being viewing natural features, viewing wildlife, relaxing, and hiking/walking.

The collection of non-timber forest products, a label that belies the great variety of foods, medicines, and artisanal resources that come from forests, are difficult to track. Best estimates are that the total value of these goods was $645 million from 2013-2022. Game meat is the exception in terms of data and tracking. Forests in the Great Lakes states provided about 94 million servings of meat over five years. Forested land near population centers is especially important for meat products. Mapping deer harvest data provided by state DNR offices shows that the counties and suburbs outside Green Bay, Detroit, Grand Rapids, and Cleveland have the highest amount of harvest. The counties with large blocks of forested land in northern Minnesota, Wisconsin, Michigan, and New York have very low deer harvest.

Key Findings – Chapter 5: The Importance of Forests in Agricultural Landscapes

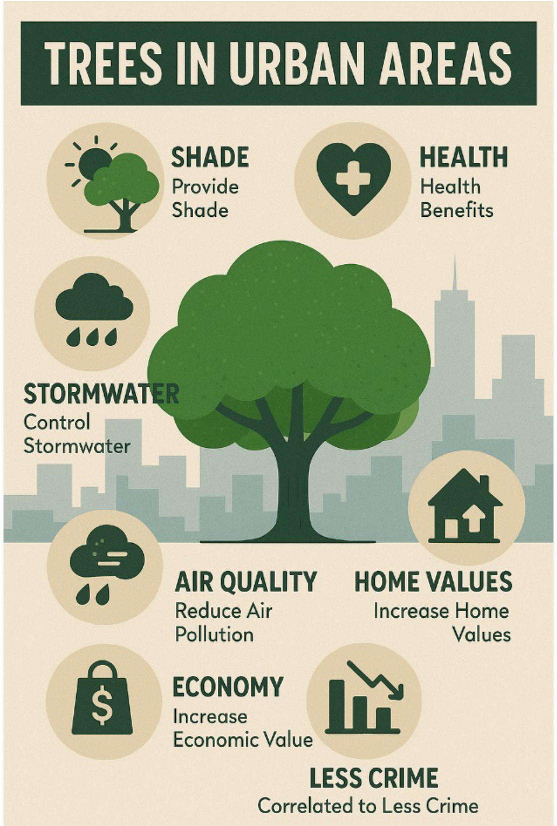
Agriculture covers 30% of the US Great Lakes watershed. These 22 million acres of agricultural land generate about $15 billion annually in livestock, dairy, grain, and corn products. The region's forests are responsible for 83 million metric tons of avoided soil loss annually which protects the critical fertile upper soil layers.

On farms, trees can diversify food production and income, and provide protection for crops and livestock from heat, wind, or extreme weather. Trees also provide critical ecosystem services such as increased soil fertility, erosion control, flood mitigation, and intercepting nutrient runoff.

In the region's agricultural landscapes, over twice as much forest cover is found in the riparian zone than in the local uplands (31% vs. 13%), and the riparian zone offers the best opportunity to improve water quality through increased forest restoration. In addition, restoration of wetland areas could contribute to water quality, flood control, and habitat, particularly in areas such as northwest Ohio's former Black Swamp.

Given the small number of farms reporting agroforestry practices in the Great Lakes (2.3%), significant potential exists to expand these practices.

Key Findings – Chapter 6: The Importance of Forests in Urban Landscapes



People want trees near them and 89% say trees are a necessity. Trees in urban areas provide shade, health benefits, control stormwater, reduce air pollution, increase economic value including attracting people to areas to shop, increase home values and are correlated with crime.

City trees experience extra stresses including improper planting, competition with invasive plants, compacted soil, impervious surfaces limiting air and water flow, excessive heat reflected from pavement, competition with above- and below-ground utilities and other built infrastructure, construction activities, and air pollution.

Gaps exist in canopy cover for most populated parts of the basin. Many tools exist to help focus tree planting to close these gaps and optimize for success and ecosystem services. A survey of 22 cities showed that the residents desired an average 55% increase in canopy cover.

Access to parks benefits people's physical and mental well-being and benefits communities. One indicator of access is being within a 10-minute walk of a park. In about one third of the basin where more than 50,000 people live, 79% of the population is within a 10-minute walk.

Chapter 1: Purpose of the Synthesis

Foundational to effective forest management is a comprehensive understanding of forest resources. Across the Great Lakes, there is a rich library of basin-wide assessments that provide managers and concerned public with information about the status and trends of the Great Lakes and the important ecosystems of this region including S*tate of the Great Lakes 2022 Technical Report* (ECCC & EPA 2022), *Great Lakes Restoration Initiative (GLRI) Action Plan IV* (US EPA 2024a), and *Lakewide Action and Management Plans (LAMP) for the Great Lakes* (US EPA 2024b). Yet, among these documents, none provide a holistic picture of the US Great Lakes Basin's forests. The purpose of this project is to create such a synthesis document that can:

1. Provide a baseline understanding of the conditions, trends, values, threats, and needs for all Great Lakes forests by synthesizing existing data and research;

2. Provide analysis at the appropriate scale with regards to forested watershed conditions and their relation to water resources and water quality; and

3. Inform subsequent US Department of Agriculture, Forest Service and partner efforts for collaborative goal setting and prioritization, such as helping inform future GLRI projects and LAMP development.

Forest Service and The Nature Conservancy (TNC) staff worked cooperatively to develop this Great Lakes Forests Data Synthesis (Forest Synthesis). This project reviews the status and trends of rural and urban forests within the US Great Lakes Basin, with an emphasis on topics relevant to water resources and aquatic life, including topics outside the regular scope of forest assessments (e.g., drinking water protection). The scope for the Forest Synthesis did not include making specific policy or priority recommendations. Rather, the intent was to present the state of knowledge regarding forest conditions in the US Great Lakes Basin. This knowledge is thus now available to inform future project development and priority setting for both the Forest Service and partners.

Forest Synthesis Approach and Area

Together the Forest Service Steering Committee and a core team of TNC staff identified current and historical data relevant to summarizing and characterizing forested lands within the US Great Lakes drainage basin. TNC then analyzed these data to answer questions related to status, trends, and values. In many cases, the TNC team analyzed data, but where possible, relied on previous studies for information. We then presented findings related to each topic to the Forest Service Steering Committee at regular intervals for feedback and alignment.

The Forest Synthesis covers the US Great Lakes watershed extending from northern Minnesota to the New York state border with Ontario. This 70-million-acre area includes parts of seven states and all of Michigan. Within the assessment area, we identified subunits for analysis that capture the key defining characteristics of the landscapes and the waterscapes. For the landscapes, we used the Forest Service Province level classification (ECOMAP 2007), simplifying five provinces into three sub-units for analysis, which are from west to east, the Laurentian Mixed Forest Province, the Midwest and Eastern Broadleaf Forest Provinces, and the Adirondack-New England Mixed Forest-Coniferous Forest-Alpine Meadow/Northeastern Mixed Forest Provinces (Figure 1-1). For the waterscapes, we summarized data and information for the US watersheds of Lake Superior, Lake Michigan, Lake Huron, Lake Erie-Lake St. Clair, and Lake Ontario, as well as the watersheds of the Upper Saint Lawrence River (Figure 1-2). While this report addresses the US portion of the Great Lakes, we at times relied on sources that included the Canadian portion of the Great Lakes. When that was the case, we identified that the information applies to the entire Great Lakes Basin. Note that scientific names of species mentioned in the report can be found in Appendix A and B.

For each of the maps in the report, readers can click on the map for a full-page sized version of the map.

Figure 1-1. US Great Lakes Basin forest synthesis area with ecological subregions.

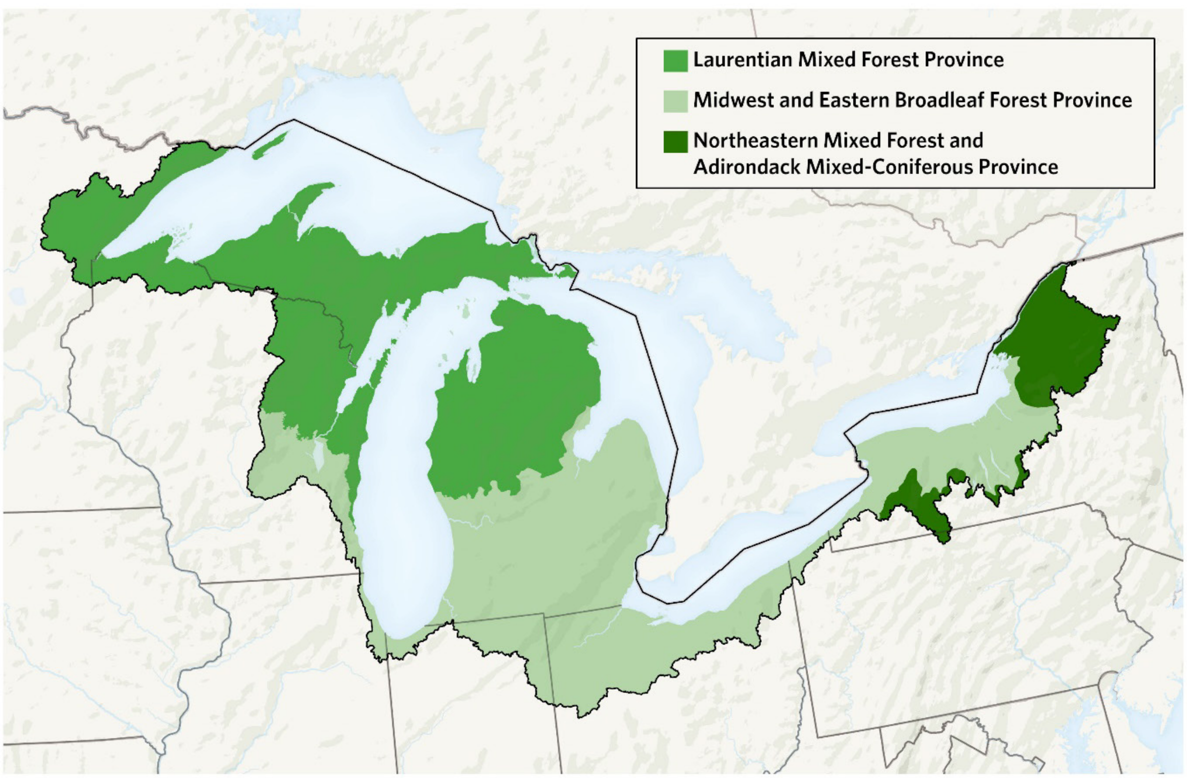
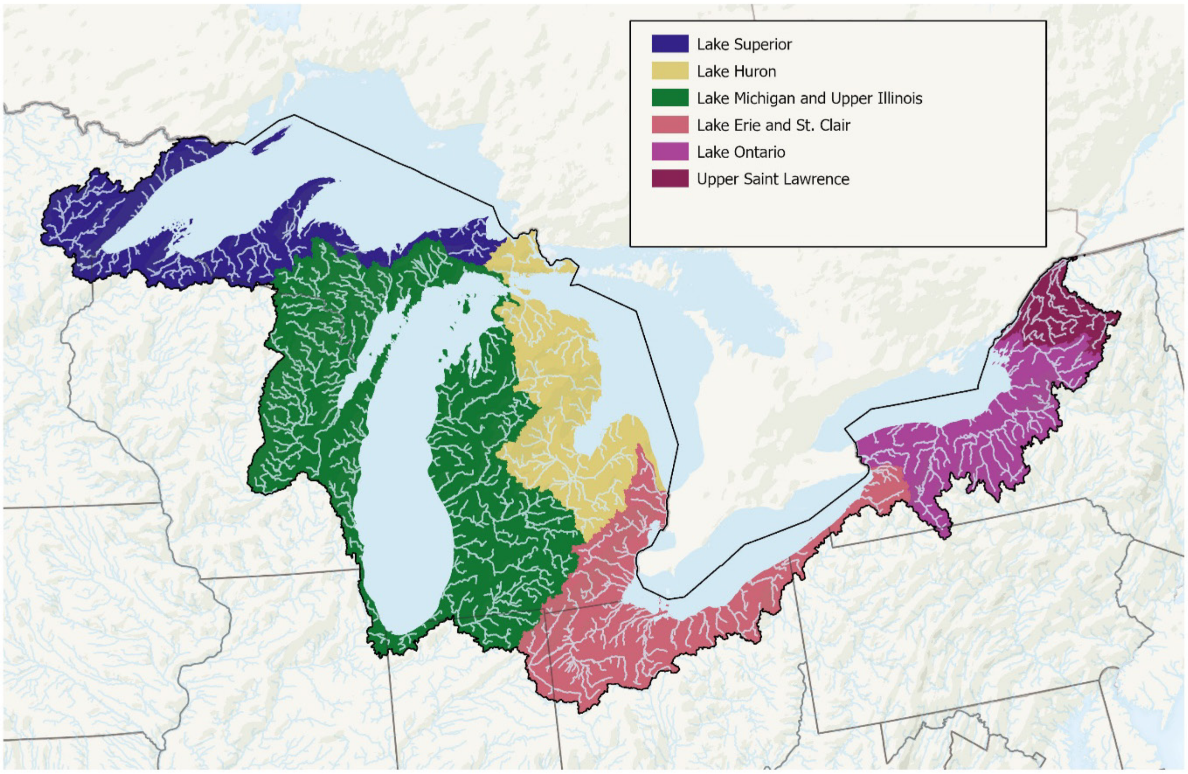


Figure 1-2. Great Lakes watersheds within the assessment area.



Main Topics of the Forest Synthesis

The Forest Synthesis is presented in five chapters in addition to this overview. Chapter 2, "The Great Lakes Forests" describes the ecologic and human factors that shaped the Great Lakes basin forests. Chapter 3, "Forest Trends in the Great Lakes Basin" provides extensive analysis of the basin's forest attributes, how current conditions differ from historical, the role of disturbance, and the consequence of stressors. The remaining chapters catalog the multiple benefits forests provide to people and to nature from three different contexts. Chapter 4, "The Benefits of Forested Landscapes" delves into the relationship between intact forests and water quality and quantity, habitat for wildlife, and the many economic benefits. Chapter 5, "The Importance of Forests in Agricultural Landscapes" explores the benefit of forests to agricultural systems and buffering impact from agricultural practices. Finally, Chapter 6, "The Importance of Forests in Urban Landscapes" looks at the benefits trees provide city dwellers and the status of the urban canopy across the US Great Lakes Basin.

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Chapter 2: The Great Lakes Forests

KEY POINTS

Of the 75 million acres of US land that drain directly into the Great Lakes, **38 million acres are forested**. These forests are critical for maintaining the water quality of the Great Lakes, which provide drinking water to 40 million people. Forests collect and filter rainfall, regulating the flow of water back into streams and rivers as well as filtering out excess nutrients and sediments to protect the lakes.

Temperature gradients from north to south and geological variability in the Great Lakes Basin shape the forests. The recently glaciated landscape is covered by deep sands and fertile loams supporting a variety of forest types. The north is dominated by spruce-fir, the central region by mixed hemlock-sugar maple–beech-yellow birch and oak-pine, and the south by deciduous beech-maple and oak-hickory. Large expanses of prairies and oak savannas would have characterized the sandy soils before conversion.

Current forests harbor over 194 bird species, 63 mammals, 21 amphibians, 18 reptiles, and 141 fish species. However, the extent and composition of forest communities has been in flux for centuries and is now changing rapidly. At least 61 forest dwelling species are at-risk of extinction. Some, like wolverine and mountain lion, are likely extirpated while others, like gray wolf, are recovering.

Whether viewed through the lens of terrestrial ecoregions or freshwater watersheds, **the basin naturally divides into distinctly different subregions, each with their own ecology, forest types, and conservation issues.** The northern half of the basin is more heavily forested, while the southern half is more agricultural, and this land use pattern is reflected in the water quality of the Great Lakes from north to south.

Humans have been a part of the natural systems as early as 14,000 years ago, and have depended on the forest for food, materials, and economic development. Of the 31 federally recognized tribes that reside in the region, most of them have long histories of stewarding the forests for food and materials.

Over the 19th century, the US government's actions resulted in **almost all American Indian Tribes ceding territory and in many cases being forcibly removed from their lands**. Colonists arriving in the **late 1800s brought widespread logging which transformed the forests**, clogged the rivers, and fueled the development of large cities and towns. Agricultural expansion gave rise to further forest clearing.

Forests are integral to the lives of the people in the Great Lakes assessment area. **Over 27 million people rely on forests and their connected ecosystems for hunting, fishing, recreation, and employment.** In addition to sustaining a substantial forest products industry, healthy forests also underly industries in tourism, fisheries, logging, and natural resource management.

The importance of the Great Lakes cannot be overstated. Together, the lakes hold 20% of the world's freshwater and over 90% of the freshwater in the United States and provide drinking water for 40 million people in the US and Canada (NOAA 2025). Integral to the health of the Great Lakes are the region's forests that capture and filter the waters that ultimately reach the lakes, and in doing so support remarkable biological diversity and human communities. The lakes and their entire watershed occupy over 188 million acres in the United States and Canada, reaching from northeastern Minnesota about 1,250 miles east to the tidal waters of the Atlantic Ocean, and 560 miles north to south from Lake Nipigon in Ontario to the Chicago area. Over half of the 74.6 million acres that drain into the Great Lakes from the United States are forested, with the largest contiguous forest over 2.5 million acres in northern Minnesota. This chapter explores the characteristics of Great Lakes forests with a focus on how landscape features, waters, and people have shaped and been shaped by these forests.

Ecological Characteristics of Great Lakes Lands

The watershed of the Great Lakes has been described as one ecoregion given the dominant effects of the lakes themselves, but the gradients of temperature and precipitation and the variability of geologic settings contribute to distinct regional differences that have shaped the forest ecosystems and how human beings interact with these forests. Geology and climate are the primary factors that shape the expression of forested ecosystems in the Great Lakes region. Pre-European settlement, boreal forests dominated by spruce, balsam fir, white pine, white cedar, hemlock, and short-lived species like aspen and birch covered the far north of the assessment area. This conifer-dominated forest transitioned southward into a mixed conifer-hard wood forest, picking up beech, sugar maple, yellow birch where moist and oak where dry, finally grading into deciduous beech-maple and oak-hickory to the south and southeast, and large expanses of prairies and oak savannas where fire occurred or was used by human communities (TNC 1999). Today's forests harbor over 400 vertebrate species, including 21 amphibians, 194 bird species, 63 mammals, 18 reptiles, and 141 fish species in the rivers of the assessment area (see Appendix A for full species list). While Great Lakes forests still reflect the ecological legacy of geology and climate, they have changed greatly in extent and composition in response to human land use and changes in the ambient environment. This chapter will touch on those changes and Chapter 3 will address recent and long-term changes as well as current patterns of forest cover and land use in detail.

Geology

Geologically, because of glaciation, the Great Lakes Basin is young, and the flora and fauna of the region are new arrivals. *The Great Lakes Ecoregional Plan* (TNC 1999) offers a concise geological history of the region in the section, "The Great Lakes region is the geologic child of the Ice Age":

"The glaciers so thoroughly reformed the geography of the region that very little of what we see on the surface today had even remotely similar form 500,000 years ago. The present-day Great Lakes themselves are of very recent origin, having formed only 10,000 years ago. In addition, because of the near total reconstruction of the region by the glaciers, the plants and animals of the Great Lakes are all of recent arrival: biologically it is a "new" region.

The geologic features created include moraines, which are linear mounds of material; till plains, which are flat; and eskers, which are long narrow ridges of coarse gravel. The former basins of the proto-Great Lakes show up in modern days as lake plains, vast flat landscapes still ringed by ancient beach ridges and eroded bluffs now hundreds of feet above lake level.

Both above and below the earth's surface, geologic processes far older than the glaciers are still evident. Perhaps the best known surface feature in the region other than the Lakes, the Niagara Escarpment, was formed out of dolomite over 400 million years ago and is visible as it extends in an arc from Door County, Wisconsin, through Michigan's Upper Peninsula and southern Ontario to western New York state, forming Niagara Falls. But the Niagara Escarpment is only the surface manifestation of a vast bowl of similar-aged rock that circles the basin. And that bowl is one of a dozen or so nesting bowls of gradually advancing age (the farther out the older), the second oldest of which forms the southern shoreline of modern Lake Superior…. Far older than these features, and in fact the bedrock for most of the basin, is the Canadian Shield. This mass of granite and granitic rock formed from the erosion of Precambrian mountain ranges and can still be seen on the surface as gently rolling hills and small mountains in the northern and northwestern Great Lakes region."

Figure 2-1 shows the bedrock and surficial geology of the assessment area today. Sand and loam soils dominate the region. Sandy soils support unique ecosystems like jack pine barrens and coastal dunes, which are home to rare species. Calcareous loam soils, formed from glacial till or lacustrine deposits, support hardwood forests and are fertile and productive for crops. Glacial landforms created rolling hills and flatlands, influencing drainage patterns and microclimates that determine forest types. Poorly-drained glacial basins support wetlands of tamarack, black spruce, and other moisture-loving species, and are a dominant landform in the basin. Figure 2-2 shows the landforms resulting from this geologic history.

Figure 2-1. Great Lakes assessment area bedrock and surficial geology (Anderson et al. 2018).

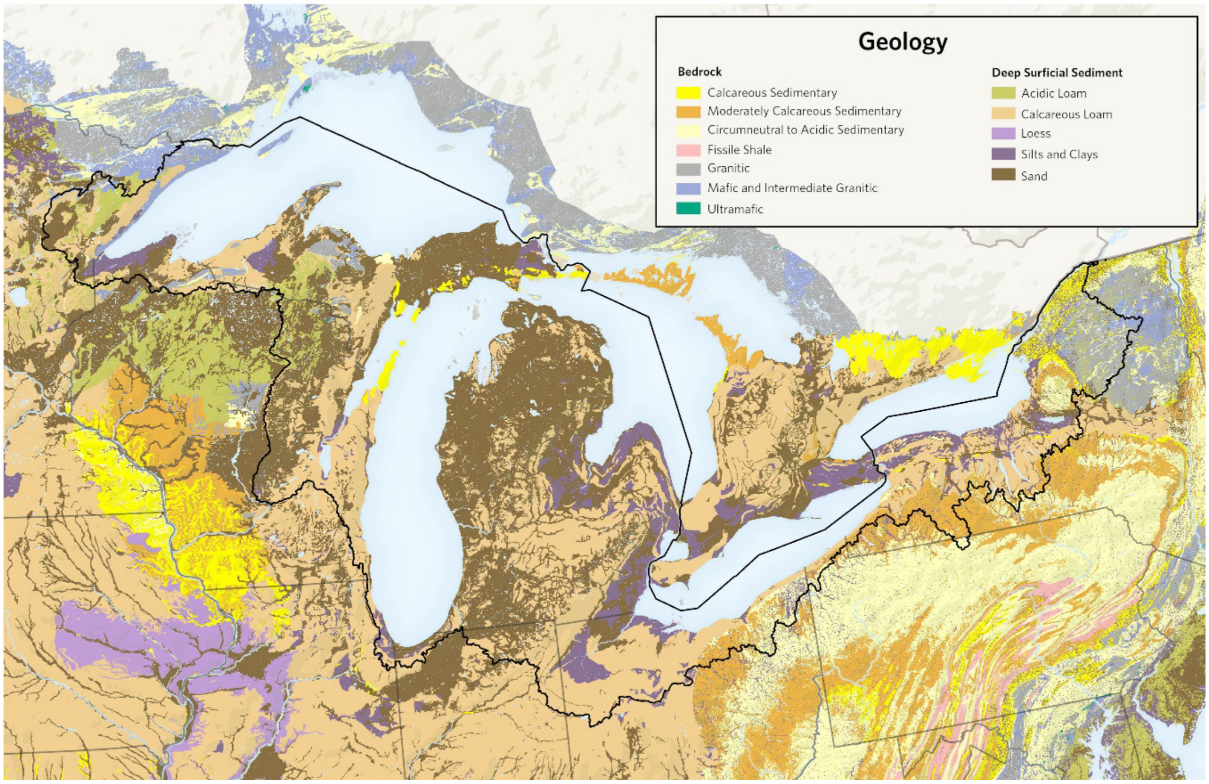
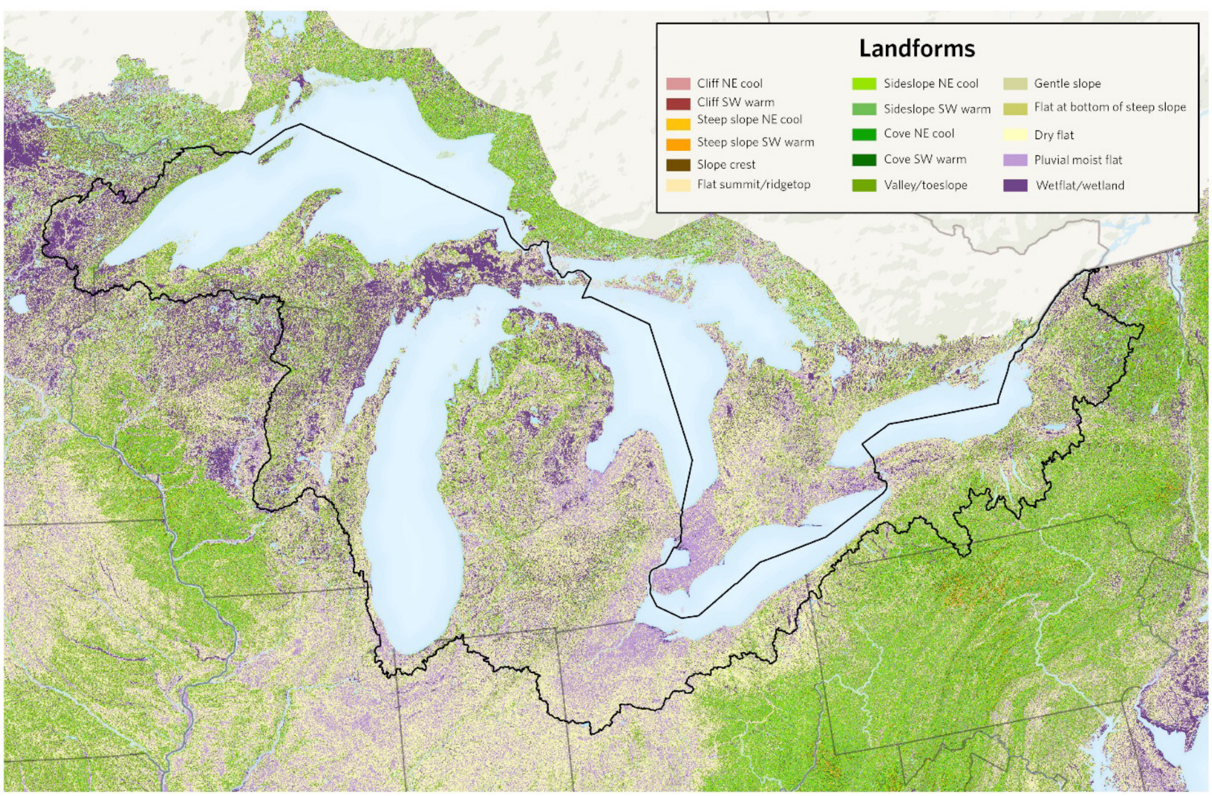


Figure 2-2. Great Lakes assessment area landforms (Anderson et al. 2018).



Climate

The Great Lakes are in a humid, temperate climate zone with wide changes in seasonal temperatures with warm summer days and shorter cold winter days. The lakes themselves exert a significant moderating influence on the region's climate, softening the mid-continental extremes experienced in adjacent regions as the lakes act as heat sinks, providing cooling in the summer and warming in the winter. Precipitation is evenly distributed throughout the year, although not from east to west or north to south, as the predominant winds lead to moisture picked up from the lakes falling on the eastern side of the lakes as "lake effect" snow (TNC 1999).

The climate patterns that have typified the Great Lakes through the 20th century are changing. The pattern of this change is complicated to parse from the major long-term variations in climate, as reflected for example in Great Lakes water levels, which are driven by precipitation (Hayhoe et al. 2010). The water levels of the Great Lakes have been tracked with gages since 1860, revealing decadal cycles from low lake levels to high (Assel et al. 2004). Based on data from NOAA NCEI Climate Divisions and Global Historical Climatology Network Daily Station Observations, the average air temperature has increased 2.3°F from 1951-2017, the frost-free season has increased 16 days, total precipitation has increased 14%, and heavy precipitation events have increased 35% (GLISA 2019). The rise in temperature, especially minimum temperatures, is already affecting vegetation, as evidenced by updates to the USDA Plant Hardiness Zone Map (2023). Species ranges are changing quickly due to altered fire regimes and precipitation variability with heavy rain events and drier conditions in places, as well as the introduction of pests and pathogens and invasive species (GLISA 2019). Given landscape fragmentation, species will be challenged to adapt. For example, boreal species are more sensitive to warming conditions and species like paper birch are already declining on Minnesota's north shore.

Ecological Subregions: Key differences and resulting forest patterns

Across this large region, we describe the variability in forested ecosystems broadly based on province-level descriptions. The Forest Service's Ecological Classification and Mapping Task Team (ECOMAP) created the National Hierarchical Framework of Ecological Units, which classifies the earth into a hierarchy of progressively smaller spatial units that share similar ecological potential, based on climate, physiography, water, soils, air, hydrology, and potential natural communities (ECOMAP 2007). The province is the third level of this classification. As described above, Forest Service defines five ecological provinces that intersect the assessment region, which we simplified into three regions by combining similar provinces together (Figure 1-1). The Forest Service has updated the province-level classification since its last published iteration (Nowacki unpublished). The following sections highlight the key differences and resulting biodiversity patterns among the ecological subregions.

Laurentian Mixed Forest Province

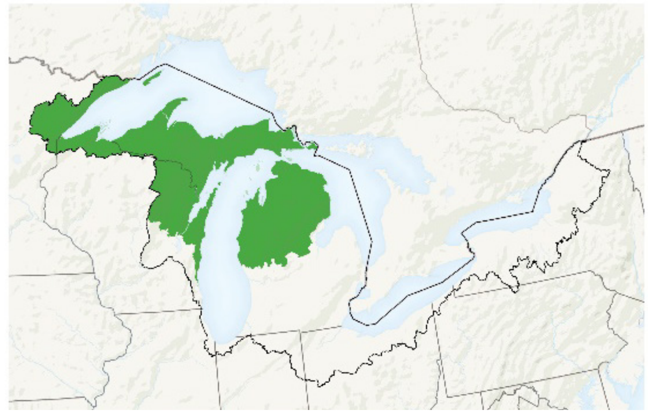


Figure 2-3. Boundary of Laurentian Mixed Forest Province

The northwestern third of the assessment area overlaps most of the Laurentian Mixed Forest Province (Figure 2-3). The dominant landforms in the Great Lakes part of this province were shaped by glaciation that lasted into the Pleistocene, leaving the area with low relief, some rolling hills, glacial features like boggy depressions, morainal hills, and outwash plains. The winters are relatively long and severe, creating a short growing season (less than 150 days), though much of the year is moderate. Snow is present most of the winter, but most of the precipitation happens in the summer. The resulting vegetation reflects this moderate to severe climate and is a transition between boreal forest to the north and broadleaf deciduous to the south (Bailey 1995a).

The trend of warmer winter temperatures is changing the persistence of snow and is having the most noticeable impact at higher elevations and northern latitudes (Demaria et al. 2016). Mammals in the region historically showed winter morphs (ermine and snowshoe hare turning white) but warming winter temperatures (aka brown winters) have caused increased camouflage mismatch for hares suggesting range shifts and decreasing viability of these species (Wilson et al. 2020). This can be significantly ameliorated by forest management for snowshoe hare preferred habitat, described as dense understory and sufficiently large patches of regenerating aspen, which can be maintained through frequent timber harvest (Wilson et al. 2020).

Riparian areas support bald eagles, mink, and otters, as well as aquatic species. The uplands support a diversity of birds, including neotropical migrant songbirds, hawks, eagles, peregrines, cranes, loons, ducks, and the endangered Kirtland's warbler. In the whole province, there are 71 at-risk (defined by NatureServe as species for which the Global Status Rounded Rank is G1-G3 or T1-T3) species of birds, 41 of which use forest habitat (NatureServe 2024).

Freshwater ecosystems are abundant in most areas and include a high frequency of lakes, both isolated and components of stream systems, a variety of wetlands from bogs to spring-fed fens, and mostly low gradient rivers that range from bedrock-controlled to flowing over deep glacial deposits (McNab & Avers 1994). This locally heterogeneous freshwater landscape supports 26 at-risk species of fish including Walleye, Northern Pike, Brook Trout, White Suckers, Sculpin, Smallmouth Bass, Lake Trout, Lake Whitefish, and non-native salmonids; as well as a variety of aquatic macroinvertebrates, including 31 at-risk mussel species (NatureServe 2024).

Midwest and Eastern Broadleaf Forest Provinces

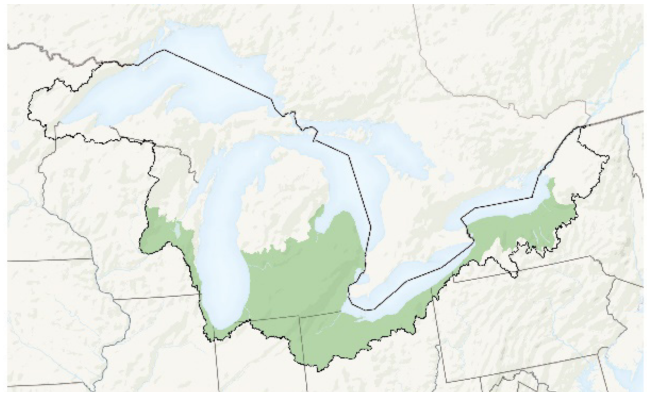


Figure 2-4. Boundary of Midwest and Eastern Broadleaf Forest Provinces.

While it extends from the edge of the Great Lakes across to the Atlantic Coastal Plain, only a small part of the Eastern Broadleaf Province in northwest Ohio occurs in the Great Lakes watershed. Thus, we combined that small slice with the Midwest Broadleaf Forest Province (Figure 2-4). As with the Laurentian Mixed Forest, glaciation shaped the landforms we see today in the Broadleaf Forest Provinces in the assessment area, and this area has less topographic relief than to the north, with rolling terrain and flat areas, comprised primarily of ground moraine and outwash plains and lake plain (Bailey 1995b; Bailey1995c). Average temperatures are higher in both seasons than in the Laurentian Mixed Forest, with an annual average of 40° F to 65° F. Precipitation is greater in the summer, with typically wet springs. The resulting forest is predominantly broadleaf deciduous with abundant oak and hickory but also sugar maple-basswood forests in the north of the province, and beech-maple forests in glaciated areas. Typical fauna associated with the oak-hickory forests include gray squirrel, fox squirrels, eastern chipmunks, whitetail deer, black bear, racoon, and birds including tufted titmouse, blue jays, thrushes, tanagers, grosbeaks, ovenbirds, wild turkey, and a variety of migratory warblers such as the cerulean warbler in beech-maple forests. Over 100 at-risk species of birds are found in the Broadleaf Forest Provinces, 21 of which are globally rare and 62 of which are associated with forest habitats (NatureServe 2024). Forest habitats in this province also support 25 at-risk mammal species, 18 reptiles, and 9 amphibians (NatureServe 2024).

The freshwater features of the Broadleaf Forest Provinces in the Great Lakes include abundant rivers and small lakes, and formerly extensive wetlands in low-lying areas, many of which have been drained for agricultural use. Many of these drainages are flat and shallow, and supplied by precipitation rather than having any significant groundwater and are thus cool to warm water. These aquatic habitats support a great diversity of fish species and other aquatic fauna, specifically 95 at-risk fish species, 56 of which are riverine and thus possibly associated with forested systems, at least 100 aquatic insects, 49 freshwater mussel species, and 8 crayfish, 43 of which are globally rare (NatureServe 2024). Of these species, 37 are on the Forest Service's Eastern Region Regional Forester Sensitive Species list (USFS 2024).

Adirondack-New England Mixed Forest-Coniferous Forest-Alpine Meadow/Northeastern Mixed Forest Provinces

The third provincial subregion combines slices of the Northeastern Mixed Forest Province along the outer reach of Lake Ontario's watershed on the south and the northeastern lands south of the St. Lawrence River with the western draining parts of the Adirondacks that occur in the Adirondack-New England Mixed Forest-Coniferous Forest-Alpine Meadow Province(Figure 2-5).

Figure 2-5. Boundary of Adirondack-New England Mixed Forest-Coniferous Forest-Alpine Meadow/Northeastern Mixed Forest Provinces.

This area is six million acres representing a small part of each province and has a variety of landforms including from southwest to northeast glaciated plateaus with irregular high hills and steep valleys, an incised river valley, mountainous terrain with rolling hills and local steepness, to the terraces and low hills of the St. Lawrence. While the area shares a similar climate, which is continental with distinct seasonality, precipitation throughout the year, moderately long winters with snow cover, as well as generally mixed forest compositions, the higher elevation areas of the Adirondacks are more dominated by conifers and contain many lakes and wetlands (ECOMAP 2017; Bailey 1995d). The mammal fauna is not distinctive, of the few small-bodied mammals found here, all are found in other Great Lakes provinces. As with the other Great Lakes provinces, freshwater is abundant, with many rivers, small lakes and wetlands. Steeper gradients occur in the Adirondacks creating waterfalls and rapids. This diversity of habitats supports 27 at-risk riverine and small lake fish species and 22 at-risk species of freshwater mussels (NatureServe 2024).

Forest Characteristics of each Great Lake Watershed

Another lens through which to consider the forested ecosystems of the Great Lakes is their pattern within each Great Lake watershed and their contribution to maintaining water flows and water quality of the Great Lakes and the tributaries that feed them (Figure 1-2). The Great Lakes watersheds are distinct from each other because of their geology, climate gradients north to south, and patterns of human settlement, all of which in turn shape the forests today and their related freshwater ecosystems (Table 2-1). Rivers, lakes, and wetlands are abundant throughout the assessment area. The watersheds vary in the total length of riverine habitat, with Lake Superior having the most and Lake Ontario the least. Dams built at the mouths of many of these tributaries disconnect the Great Lakes from their upper watersheds. Across the entire Great Lakes

Basin, only about one-third of the stream miles that could be connected are connected. This ranges from 18% of Lake Michigan streams and rivers to 53% of waterways in the Lake Superior watershed (Herbert et al. unpublished data). The lack of connectivity has had a profound impact on fish that migrate from the Great Lakes into the rivers and on the exchange of energy between the tributaries and the lakes. This fragmentation in river and stream continuity inhibits fish passage and alters flow, thermal regimes, sediment transport, and water physiochemistry (Olden & Naiman 2010; Cooper et al. 2017). However, the presence of these dams, in addition to their original purposes for hydropower, water supply, or recreation, provides a barrier to the spread and reproduction of Sea Lamprey, an invasive species in the Great Lakes Basin that kills native fish such as Lake Trout and Lake Whitefish in significant numbers, as well as valued non-native salmonids.

Table 2-1. Land use by Great Lakes watersheds (NLCD 2021; Dewitz et al. 2023).

Lake Watershed	Agriculture	Developed	Forested	Other Natural	Herbaceous Wetland
Lake Superior	3%	4%	88%	3%	2%
Lake Huron	30%	10%	55%	4%	1%
Lake Michigan and Upper Illinois	31%	12%	51%	3%	2%
Lake Erie and St. Clair	54%	22%	22%	1%	1%
Lake Ontario	35%	11%	51%	2%	1%
Upper Saint Lawrence	13%	4%	78%	2%	2%

Ecological Characteristics of each Great Lake Watershed

Lake Superior: The Lake Superior watershed, the most northwesterly lake, features the most forested land of any of the Great Lakes, with forested land comprising 88% of the US portion. (Note that we included forested wetlands in this percentage. See Chapter 3 for more information on land use categories). Only about 7% of the lands are converted to agriculture or human development. Lake Superior deserves its name as the largest Great Lake by area, the deepest and the coldest (Superior Working Group 2015). The US portion features the St. Louis River and estuary, and a series of small drainages along the US north shore that flow over a fault line creating many waterfalls. The Superior, Chequamegon, Ottawa, and Hiawatha National Forests all have lands within the Lake Superior watershed. The amount of forest cover in subwatersheds and within riparian zones is an indicator of the overall health of the Lake Superior nearshore zone and reefs, embayments, coastal wetlands, coastal terrestrial habitats, and tributaries and was rated good in the 2013 *Lake Superior Biodiversity Conservation Assessment*. This assessment also identified tributaries of Lake Superior as being the most vulnerable component of the Lake Superior aquatic ecosystem due to both the impacts of historic logging and the current cumulative impact of dams and barriers, land conversion, and incompatible land management (Superior Working Group 2015).

Lake Huron: Lake Superior meets Lake Huron at Sault Ste. Marie, MI. Called the Sweetwater Sea by French Explorers, Lake Huron has many distinguishing features. The northern lake is dominated geologically by the Niagara Escarpment and the shoreline features over 30,000 islands, including the largest freshwater island in the world, Canada's Manitoulin Island, and has extensive forest and high-quality coastal wetlands. The southern lake features former lake plain and has extensive agriculture both in the United States and Canada (Franks-Taylor et al. 2010). The US portion of Lake Huron is south of the Niagara Escarpment and has had greater land conversion (30% in agriculture) due to more arable soils. Forest covers 55% of the Lake Huron watershed in the US, which includes the Huron National Forest. The remaining matrix of natural lands includes other/barren (5%), herbaceous wetlands (1%), leaving 10% in developed lands. This mosaic supports good water quality in Lake Huron: water quality in the nearshore and coastal wetlands was rated "good" in the 2010 Biodiversity Conservation Strategy (Franks-Taylor et al. 2010). The *State of the Lake Report* in 2022 found that nutrient levels in Lake Huron were "Fair" because of a drop in offshore phosphorous reducing lake productivity and elevated phosphorous in the nearshore (ECCC & US EPA 2022).

Lake Michigan: Lake Michigan and Lake Huron meet under the Mackinaw Bridge, Mackinaw, MI. Entirely within the United States, Lake Michigan stretches north to south about 320 miles, creating an important gradient of ecosystems from north to south. The watershed is forested to the north, grading to agriculturally dominated landscapes in the bottom third, and large cities in the south. The dunes found on its eastern shores form the largest system of freshwater dunes in the world (Pearsall et al. 2012a). The Manistee National Forest and parts of the Hiawatha, Nicolet, and Ottawa National Forests are within the Lake Michigan basin. The forested lands contribute to high water quality in Lake Michigan, but the rivers are not well connected for migrating fish. Overall, forest cover in the watershed is 51%, 3% is in other natural/barrens, 2% is herbaceous wetlands, 30% is in agriculture, and 13% is developed. The northern basin was rated good and very good based on natural cover and direct measurements of nutrients for water quality, while the central and southern basin nearshore zone and coastal wetlands have issues with sedimentation and excessive filamentous algae (*Cladophora sp*.) and reduced water quality (Pearsall et al. 2012a).

Separated from Lake Michigan's central basin by the Door Peninsula, Garden Peninsula and islands, Green Bay is dominated by nearshore habitat, with an array of coastal terrestrial habitats including alvar, cliffs, barrens, dunes, coastal and dunal wetlands, and coastal forests. These habitats provide important stopover habitat for migratory birds and resident habitat for shorebirds and other bird species (Pearsall et al. 2012a). The southern portion of the bay and the Fox River, while rich in biodiversity, are highly disturbed and the mouth of the Fox has been designated as a Great Lakes Area of Concern (US EPA 2025) due to legacy pollution from pulp and paper mills that put PCBs into the Bay in the 50s and 60s. In the mid-20^{th} century, Green Bay had the highest concentration of these mills in the world, fed by the abundant forests. That industry has declined but has been replaced by dairy and crop agriculture that continues to over enrich the waters of the Bay. Forests in the upper watersheds, while important for recreation, would provide more ecological value and water retention if restored to larger patches (GBCP 2021).

Lake Erie: Lake Erie also connects to Lake Huron through two channels, the St. Clair River and the Detroit River, joined in the middle by Lake St. Clair and its freshwater delta. Nowhere in the Great Lakes Basin has the conversion from forest and wetland to agriculture and towns had a more profound impact than on the freshwater ecosystems in the Lake Erie watershed. What was once a mosaic of wetlands and forests and slow-moving clear rivers, called the Black Swamp (Mitsch 2017), is now row-crop agriculture (54%), with channelized and ditched waterways creating a plume of sediment into Lake Erie visible from space (MSU 2016). Forest resources are scant in the Lake Erie drainage comprising 22% of the land cover, but restoration of forests could play a role in slowing water and erosion, bringing shade and wind relief to neighborhoods and capturing carbon. As a result, the overall viability of Lake Erie's aquatic ecosystems including the offshore, nearshore, coastal wetlands, and tributaries is "fair" (Pearsall et al. 2012b).

Lake Ontario: The waters of Lake Erie flow to Lake Ontario through the Niagara River, with the Welland Canal providing passage around the massive waterfalls. Lake Ontario drains 8,525,136 acres of the US, 51% of which is forested. Much of that forest is concentrated in the Tug Hill area and the western Adirondacks. Because of its connection to the Atlantic Ocean via the St. Lawrence River, Lake Ontario has American Eel, and efforts are underway to restore Atlantic Salmon. The Finger Lakes region, including the Finger Lakes National Forest, is also in this watershed. Agriculture comprises 35% of the land use, with developed areas comprising 11%. Non-forested wetlands cover 1%, with some very intact coastal wetlands in the eastern part of the lake. Although certainly not the only driver of viability, these land use patterns have contributed to overall ratings of Lake Ontario's aquatic ecosystems including the nearshore zone, offshore, migratory fish, and coastal wetlands as "fair" (LOBSWG 2009).

Upper St. Lawrence River: The Upper St. Lawrence River watershed is a large drainage basin in New York state that connects the Great Lakes to the North Atlantic, draining over 3.5 million acres. This region is water rich, with over 12,000 miles of rivers and streams and abundant lakes in a matrix of dense forests and peatland complexes to the south (78%), and agriculture (13%) being practiced closer to the St. Lawrence River in its floodplain. The watershed is the home of the Mohawks of the Iroquois confederation. Much of the watershed (44%) is protected by Adirondack State Park. The *St. Lawrence River Watershed Revitalization Plan* (Ecologic 2020) identifies non-point source pollution as challenges to water and habitat quality in the river, noting mercury and acid deposition, nutrients, sediments and road salt from agriculture, contaminated sediment, septic systems and storm water. Priority actions to improve watershed conditions include minimizing forest fragmentation while practicing forestry and timber production with best management practices to protect water quality. About two-thirds of the inland streams and rivers have good water quality, but 75% of lakes were assessed as impaired and not meeting their designated uses, especially due to acidification (Ecologic 2020). The mainstem St. Lawrence River from the outlet of Lake Ontario to Quebec is rated as moderate for water quality overall based on 27 monitoring stations, 33% of which are good, 52% are fair and 15% are poor. The water quality decreases as you move downstream from the Great Lakes (State of the St. Lawrence Monitoring Working Group 2024).

Human Connections with Great Lakes Forests

Forest resources have supported people in the Great Lakes region from the earliest days of human habitation in the region, which followed the recession of glaciers starting about 14,000 years ago (Fond du Lac Band 2022a). It is important to note that the cultural and historical landscape of the Great Lakes region extends beyond the geographic boundary of the Great Lakes Basin, from the eastern Great Plains to New England. Tribes,[1] who have occupied the region since time immemorial, may have ancestral or present-day lands that do not reside strictly within the basin but still have strong ties to all or parts of the Lakes and their forested watersheds.

Prior to European and US colonization, there were no "vacant" lands. Ancestors of the present-day Haudenosaunee, Ho-Chunk, Menominee Potawatomi, Ojibwe, Ottawa, (MPM n.d. a), Assiniboine, Cree, and Dakota Tribes (Fond du Lac Band 2022b) all inhabited the Great Lakes region. The way each Tribe or group of Tribes interacted with the forests of the Great Lakes differed depending on their unique history and lifeways, but many communities hunted, fished, farmed, and gathered forest resources for food and other purposes (e.g., ceremonies, building materials, art, etc.). Tribes have maintained relationships with forest ecosystems through various interactions with culturally significant species such as paper birch, ash, wild rice, and moose to enhance forest products and wildlife habitat, regulation of water and air quality, and maintain lifeways.

The cultural and ecological landscapes of the Great Lakes region shifted with colonialization by Europeans and eventual rule of the US government. US-tribal relations brought changes in patterns of land ownership, land use, and land management that impacted the relationships between humans and the region's forest ecosystems. Through a series of treaties and other agreements, often accompanied by coercive political and military pressure, the vast majority of lands comprising the territorial limits of the United States were ceded by Indian tribes from approximately 1778-1871 (also known as the Treaty-Making Era; BIA 2024). Some Tribes in the Great Lakes region still reserved usufructuary rights to hunt, fish, and gather in the territories ceded in treaties.

[1] Throughout this document the terms Indian, American Indian, Tribe(s), and Tribal Nations, is intended to have the same meaning as "federally-recognized tribe(s)" and federally-recognized tribal members.

The 19th century brought additional change to the ecosystems and people of the Great Lakes region. The Treaty-Making Era gave way to the Removal Era (1830-1850), when the United States removed many tribes from the east, including the Great Lakes southern tier region of Illinois, Indiana, and Ohio, and then to the Reservation System (1850-1891) during which the present-day reservation system was created (BIA 2024). Simultaneously, waves of development and wide-spread logging not only transformed the forests, but also the rivers as "they were gouged out by the transport of logs, spawning beds of fish choked with sawdust, migratory fish unable to access the river" (Egerton 2018). This lumber built large cities in the Great Lakes Basin as well as lumbering towns. The expansion of the railroads followed by the expansion of agriculture led to the clearing of forests in the Lake Erie watershed that have not been allowed to grow back. In contrast, in the northern reaches of the basin, cut-over forests have been allowed to grow back to varying extents (Egerton 2018).

One reflection of this wholesale change in the Great Lakes region was the near loss of large, forest-dwelling mammals during the 19th century that were once abundant including beaver, bison, elk, wolverine, mountain lion, lynx, gray wolf, black bear, and even white-tail deer. Deer, bear, and beavers are now abundant in parts of the basin thanks in part to management efforts to control harvest, and in the case of deer and bear, these animals' ability to adapt to altered landscapes. Deer, which are adaptive and prolific, have expanded beyond historic population levels, and benefit from the greater abundance of early succession classes of trees as a food source (McShea 2012). Black bears are equally adaptive and have proven to thrive through tolerance for food source variability (Garshelis et al. 2022). In fact, black bear populations have risen from 9,000 to 24,000 in Wisconsin between 1989 to the present (WDNR n.d.), but not in their full historic range. Gray wolf populations have recovered from near extirpation by 1970 to stable today at about 4,200 animals in Minnesota, Wisconsin, and Michigan (van den Bosch et al. 2024), due to protected status. Bison, elk, wolverine, mountain lions, and lynx are rare compared to their historic abundances, if present at all (Egerton 2018; NatureServe 2024). More detailed information on the occurrence of wildlife in the Great Lakes forests is presented in Chapter 4.

The forests continue to support numerous Tribal communities and their cultural traditions. There are 76 federally recognized Tribes that have rights and interests in the management of forests in the Forest Service's Eastern Region, and many of these have ties to the forests of the Great Lakes Basin. Currently, 31 federally recognized Tribes reside in the Great Lakes region of the US (BIA n.d.), there are 32 reservations, ranging from 17 acres (Grand Traverse Reservation) to 270,000 acres, the largest belonging to the Oneida Indian Nation (Wikipedia 2025). The New York area of the Great Lakes region is home primarily to the Haudenosaunee (People of the Longhouse/Iroquois). The principal Tribes of the Haudenosaunee are the Seneca, Onondaga, Oneida, Cayuga, Mohawk, and Tuscaro. The lake states of Minnesota, Wisconsin, and Michigan are home to the Anishinaabeg (*pl. Anishinaabe*), of which the principal Tribes are the Ojibwe (Chippewa), Odawa (Ottawa), and the Bodéwadmik (Potawatomi) peoples, as well as the

Menominee, Dakota, Ho-Chunk, and "relocated tribes" such as the Oneida and Stockbridge-Munsee. The Southern Tier of the Great Lakes region includes Illinois, Indiana, and Ohio--Tribes with ancestral ties to these lands were forcibly removed from their homelands and relocated to lands west of the Mississippi River. These Tribes include the Lenape (Delaware), Iowa, Kickapoo, Miami, Munsee, Osage, Otoe-Missouria, Ottawa, Peoria, Potawatomi, Sauk & Meskwaki (Sac & Fox), Seneca-Cayuga, Shawnee, and Wyandotte. Despite removal, they retain contemporary lifeways based on ancestral and cultural links to the Great Lakes region (USFS 2015).

In the Great Lakes Basin, Tribes directly manage 1.1 million acres of land (GIS Nation 2025). However, due to the highly interconnected nature of forest ecosystems that often span multiple jurisdictions, collaborative decision making and land management is needed to ensure that tribal treaty rights, lands, assets, and natural resources are protected.

Many forest resources that were important to Tribes in the past continue to be key to modern lifeways. Ecosystem stressors discussed in detail in this report have impacted these resources and related lifeways. For instance, polluted runoff in waterways damages wild rice (*manoomin* in Ojibwe) and puts the related food and cultural systems of many Ojibwe communities at risk. Similarly, the decimation of black ash trees by the invasive emerald ash borer has ripple effects on cultural practices and arts that traditionally use ash wood, such as basket making. Forest disturbance is addressed further in Chapter 3.

The forests of the Great Lakes Basin continue to support the extensive and growing human population of the region. More than 27 million people reside just within the US boundaries of the basin (US Census Bureau 2024a), while almost 86 million people live in the eight states with a Great Lakes' shoreline (US Census Bureau 2024b). People across the region rely on the forests and their connected ecosystems for hunting, fishing, recreation, and employment (forest products industries, tourism industries, fisheries industries, logging, and natural resource management). Today's forests play a key role in catching and slowing water entering streams and lakes, retaining soil and sediment, and preventing pollution from entering water bodies. Forests also continue to provide and maintain habitat for aquatic and terrestrial plants and animals. Many of these, such as Brook Trout, which rely on shady forests to help maintain cold water streams (Stranko et al. 2008), are important cultural and economic drivers. The value of forests to the water, economy, and wildlife in the Great Lakes Basin is discussed in Chapter 4.

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Chapter 3: Forest Trends in the Great Lakes Basin

KEY POINTS

Although **half of the region remains forested (53%), the other half is split between development and agriculture (43%).** Across the basin, development is twice the national average but is concentrated in the southern portion of the basin.

About two thirds of **forests are in private family ownership (64%)** with another 5% being corporate timber managers (4.7%) and tribes (0.3%). This dispersed ownership can hinder sustainable management and conservation efforts due to the lack of coordination, financial constraints, and lack of forestry experience among owners.

National forest land is the largest conservation ownership type. Almost one-third of the forest (31%) is publicly owned, and these lands are concentrated in the northern part of the region with ownership split across state (16%), federal (12%), and county (3%) governments.

Almost **half of the forests (44%) are comprised of northern hardwood forest** (30%) characterized by maple, beech and birch, and alkaline conifer-hardwood swamp (14%) characterized by white cedar, hemlock, maple, and ash. The next most common forest type is plantation and ruderal forest (7%) reflecting the industrial forest managed for timber-production.

The region has large forest blocks, thanks to fragmentation by roads being concentrated in the southern part of the region. Road-bounded forest blocks in the north average over 100,000 acres in size and many are over one million acres. The two largest blocks are over a million acres in Superior National Forest in Minnesota. Forest blocks over 500,000 acres are also found in northern Wisconsin, the Upper Peninsula of Michigan, northern lower peninsula of Michigan, and the Adirondacks of New York.

Extensive logging in the mid-1800s to early 1900s removed vast old-growth forests, especially white pine and hemlock. This logging and natural regeneration have created ecological shifts where forests have become more homogeneous in both species composition and structure. Forests transitioned from diverse, mature conifer-dominated ecosystems to younger, hardwood-dominated ones. There has been a marked decline in conifer presence—once two-thirds of the forest composition and now about one quarter. Broadleaf deciduous species now dominate, reducing habitat complexity and affecting wildlife. Structural complexity of forests has also declined, with fewer large trees and more uniform tree sizes.

KEY POINTS CONT.

Land use in the Great Lakes region has been remarkably stable over the last 20 years with about 3% of the land changing in cover type. Half of the change (1.5%) was forest turnover where trees were cut, damaged, or disturbed but then returned to forest. All but a small fraction has already returned to forest. Permanent conversion of forests to development or industrial agriculture accounted for just 0.4% of the total forest area. While the Great Lakes region is losing a small amount of forests to development, three times more development is occurring on agricultural land.

Forest logging practices in the Great Lakes region vary significantly by ownership type. Federal lands have the greatest rate of forest turnover, defined as the average amount of forest turnover per year/total amount of forests, with more than 0.2% or 500,000 acres per year. While this is the largest rate of forest turnover in the basin, it is still much lower than the national average (0.7% per year).

Insect disturbance is common. In the last five years (2019-2023), spongy moth has been the most prevalent, affecting 4.1 million acres with 6.6 million total acres reported since 1997. Spruce budworm has a similar pattern, 3.2 million acres in the last five years and 4.4 million acres total. Emerald ash borer infestation totaled 3.0 million acres since 1997 but only half a million acres were reported for the last five years. Similarly, forest tent caterpillar extent totaled 27.5 million acres for the 26 years of the survey but decreased to 0.3 million acres in recent years.

Fire has typically been limited in the region, estimated to be 2 million acres annually before European settlement, but fire is most prevalent and important to specific ecosystems especially in the central and western part of region. Current fire regimes are altered by suppression or loss of fire-adapted ecosystems.

Weather has always shaped forests in the Great Lakes, particularly wind. The region has warmed 2.3 ^{o}F in the last 70 years. **Changes in weather patterns** due to more extreme temperatures and significant changes in timing and intensity of precipitation, **make forests vulnerable to stress, and exacerbate the impacts of pests, pathogens, invasive species and altered fire regimes.** Many species important to human communities have been identified by Ojibwe Tribes in the region to be at risk from these changes.

The forests of the Great Lakes play an essential role in maintaining natural strongholds for biodiversity in the face of more extreme disturbances. Forested lands in the region are more resilient than non-forested land with 64% of the region's forested lands scoring resilient. Eighty percent of national forests within the Great Lakes Basin are estimated to be resilient.

Forest Extent in the Great Lakes Basin

The Great Lakes Basin is home to diverse forests interspersed with a variety of land uses that have evolved over time due to human activity, climate, and ecological factors. Land use in the basin has undergone significant changes due to industrial development leading to urbanization and large-scale agriculture. We explored land use patterns across the basin using the National Landcover Dataset 2021 (NLCD 2021; Dewitz 2023). In broad terms, 43% of the region has been converted to agricultural or developed land (Figure 3-1). The basin hosts 22.5 million acres of agriculture either in hay/pasture or row crop (30% of assessment area). The amount of hay/pasture is similar to the national average, but the percentage of cultivated crops is 50% more than the national average. Additionally, cities like Chicago, Cleveland, Detroit, and their surrounding suburbs have expanded in the last 50 years, leading to deforestation and habitat fragmentation. Currently, 8.7 million acres are in low to high intensity development (13% of the assessment area), this is twice the amount of the national average. The remaining 57% of the land is in natural vegetation, with 53% being forest. Most forest occurs in the northern areas of the region with some notable exceptions in the northeastern Ohio/Pennsylvania/New York portions of the region. Forests in the Great Lakes Basin account for almost 7% of the forests in the United States and the basin contains twice the amount of forest as the national average.

We defined forests as any tree-dominated landscape, recognizing that they often experience disturbances, forest management activities, and other temporary vegetation changes. Stands that have undergone recent changes in surface vegetation due to disturbances but are expected to regain forest cover over a relatively short period (such as recovery from fire or harvest) were considered forest. In the NLCD 2021, this included deciduous forests, evergreen forests, mixed forest, and woody wetlands, totaling 38.4 million acres or 53% of the assessment area (Figure 3-2).

Figure 3-1. Land use in the US Great Lakes Basin.

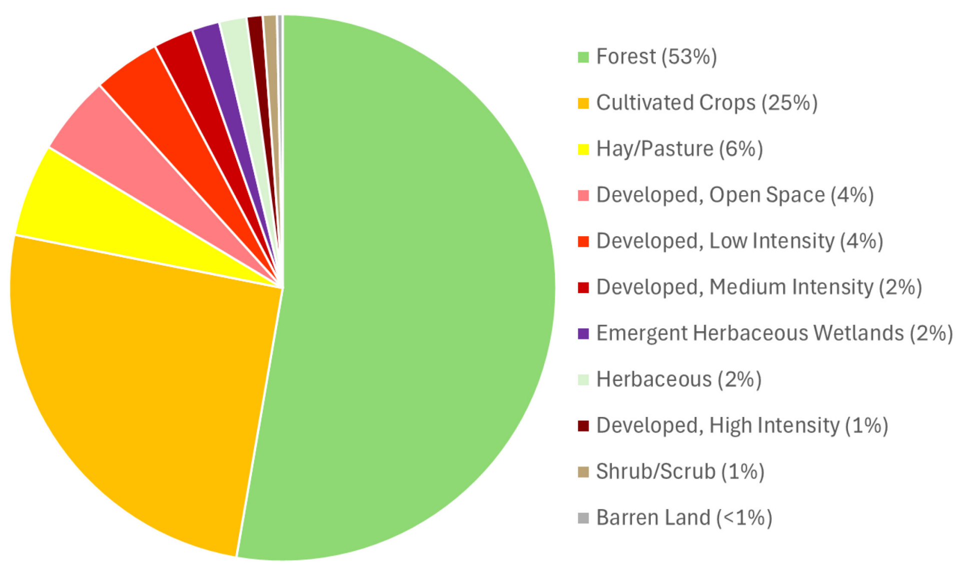
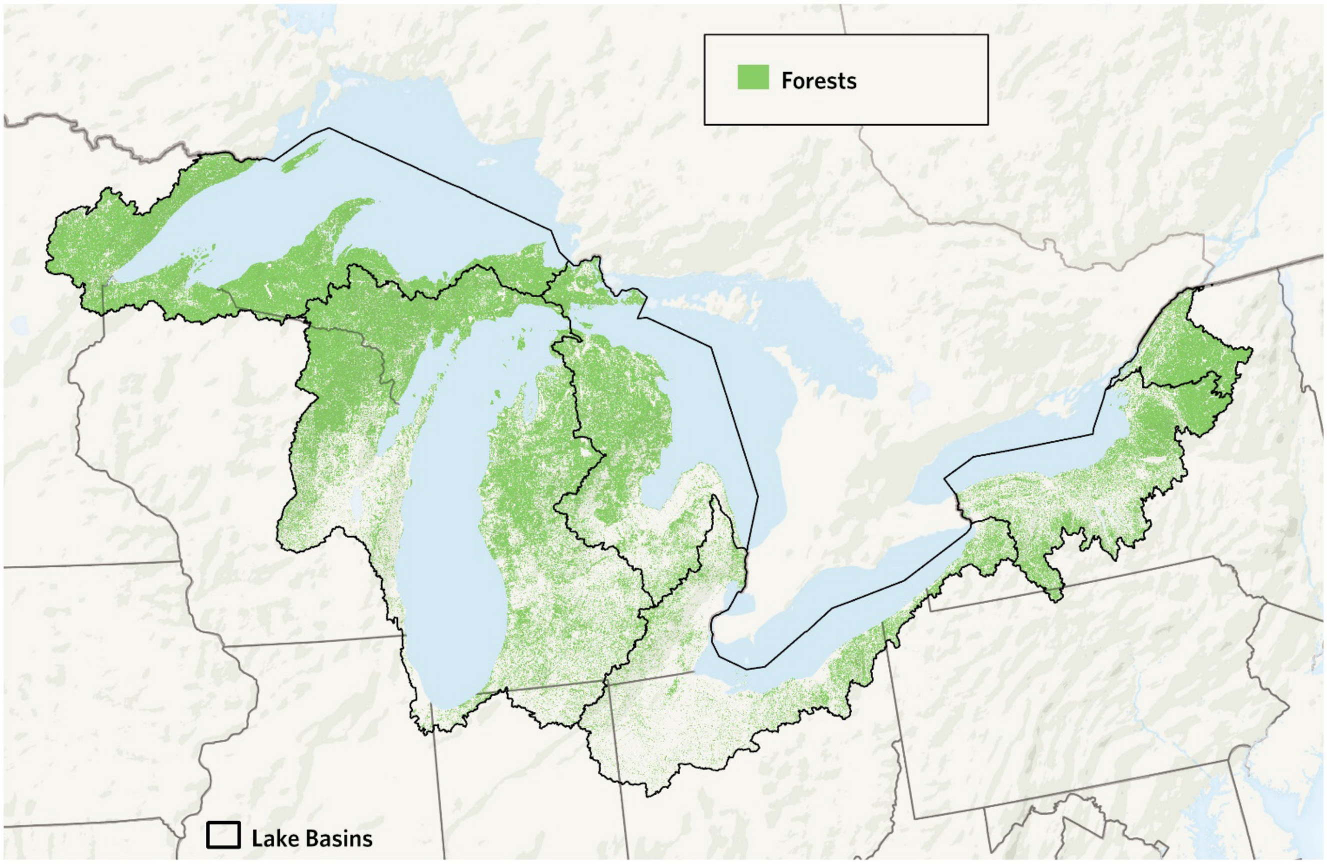


Figure 3-2. Forest extent in the US Great Lakes Basin.



Forest Ownership

The future of forests largely depends on their owners, whose goals, knowledge, resources, and needs, within environmental limits, social expectations, and legal frameworks, shape both conservation and management decisions.

In the United States, approximately 58% of forest land is privately owned by individuals, families, corporations, Tribes, and organizations, while public forests, managed by federal, state, and local agencies, make up less than half of the nation's forested areas (USFS 2025). The Forest Service, though the largest steward of public lands, oversees only a portion of the country's forests. Ownership patterns vary widely across the country, with private forests predominating in the eastern US and public lands more common in the western US. However, historical settlement trends, legislation, land value, and other factors influence ownership, leading to changes over time. Recognizing the complex social dynamics of forest ownership is crucial since the decisions made by landowners, whether private or public, ultimately shape how forests are managed and preserved for future generations. Landowners serve as the critical connection between society and nature, playing a key role in the future of America's forests.

The US portion of the Great Lakes Basin is a mix of public and private lands, containing portions of thirty-one sovereign nations, and eight American states. As a result, hundreds of local, regional, and private non-profit groups have jurisdiction over the management or protection of some aspect of the basin and its forests. To analyze ownership of forests, we combined protected lands data with parcel-based ownership information (CRCS 2024; Regrid 2024). Of the basin's forests, 31% are in public ownership: 16% state, 12% federal, 3% county (Figure 3-3). The remaining forested lands are 69% in private ownership. Of the private owners, only 5% are corporate owners and 0.3% are Tribal (Figure 3-4).

The large amount of family forest ownership (64% being much higher than the national average of 44%) comes with challenges. Financial constraints faced by the owners often hinder sustainable management and conservation efforts. As forests are divided among heirs or sold, fragmentation makes large-scale management more complex. Additionally, some owners lack expertise in forestry practices, which can limit effective stewardship. Landowners with small acreages of forests may also struggle to access carbon credit markets or sell timber profitably, adding to the difficulties of maintaining their forests.

Figure 3-3. Public forest ownership in the US Great Lakes Basin.

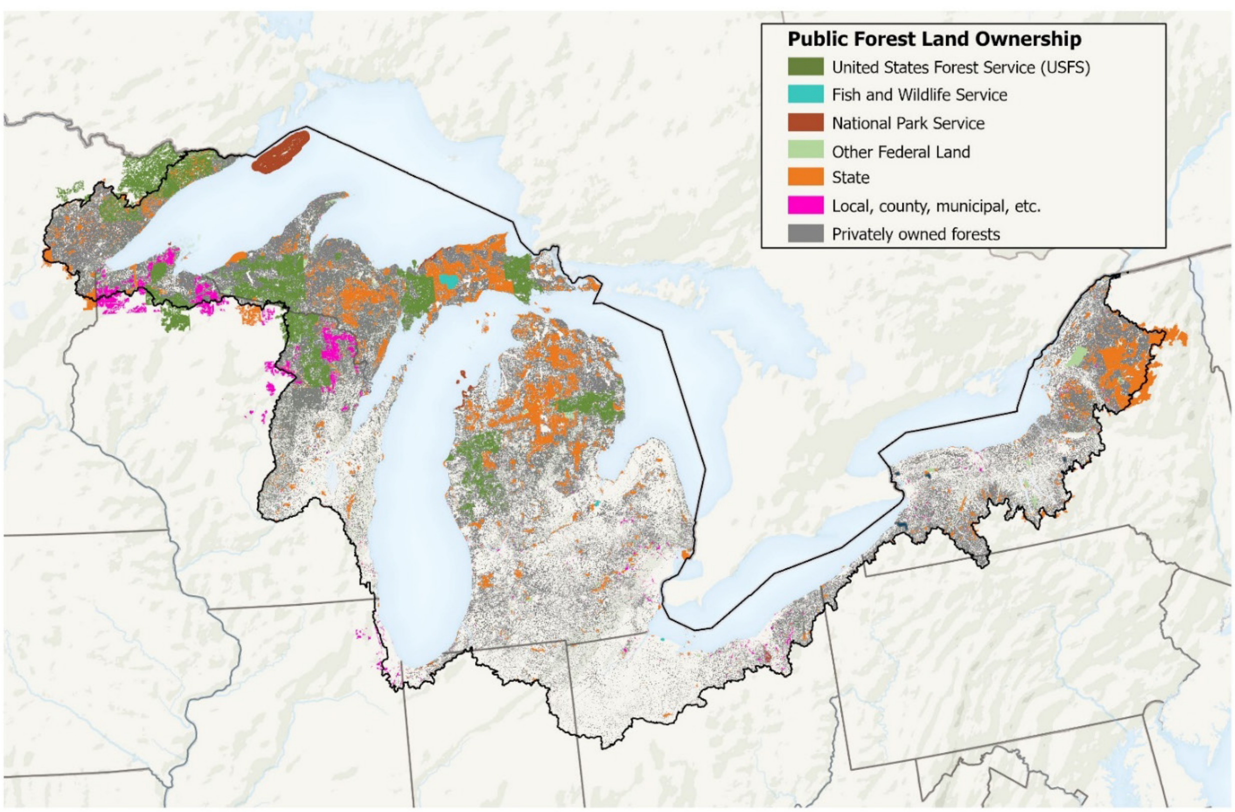
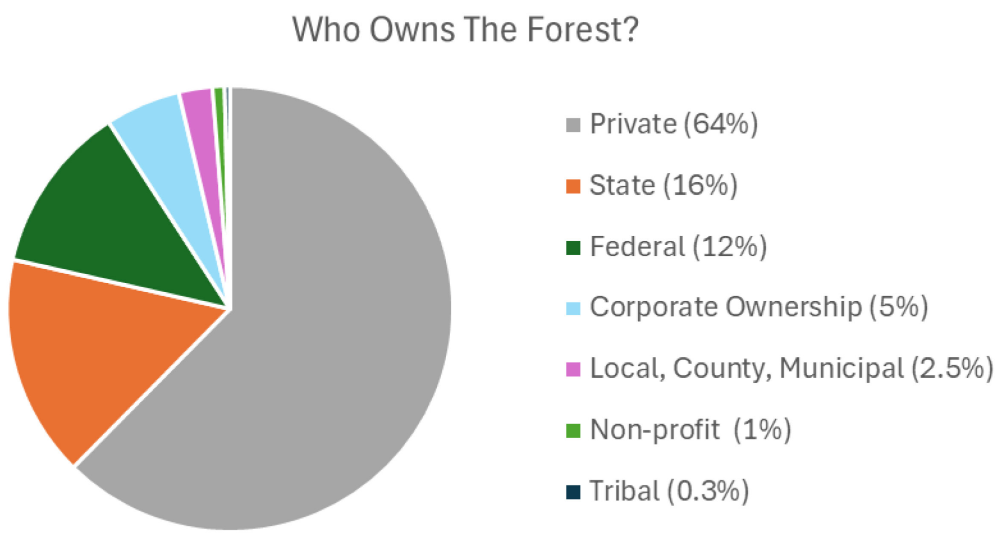


Figure 3-4. Ownership of forests in the US Great Lakes Basin.



Current Patterns of Forested Ecosystems

A starting place to understand forest status and trends is to look at the current patterns of forested ecosystems. Using data from the LANDFIRE Program, we assessed:

- **How much of each forested ecosystem occurs today?**
- **What are the patterns of vegetation cover and height?**

LANDFIRE is a shared program between the wildland fire management programs of the Forest Service Fire and Aviation branch and the US Department of the Interior, that provides more than 20 landscape-scale geo-spatial products, 950 vegetation models, and a suite of tools that support all-lands planning, management, and operations. For the Great Lakes Basin (US), we summarized LANDFIRE's Existing Vegetation Cover, Height, and Type spatial data (LANDFIRE 2023 a-c).

Using the LANDFIRE 2023 Existing Vegetation Type dataset (LANDFIRE 2023c), we found 132 types, with 101 of those types representing more than 1% of the area. The top nine types covered about 74% of the forested area, dominated by Northern Hardwoods (30%), Alkaline-Conifer Hardwood Swamp (14%), Plantation and Ruderal Forest (7%), Aspen Birch (6%), and five other types, each comprising less than 5% of the area (Table 3-1). Geographically, we found that "Hardwood" types were dominant across the region (Figure 3-6). In Wisconsin and Michigan, especially, there were widespread representations of 'riparian' types such as the 'Alkaline Conifer-Hardwood Swamp", and fire-adapted ecosystems such as the 'Jack Pine-Red Pine Forest.'

We also assessed the type of vegetative cover and its height. Vegetative cover is measured by lifeform (tree, shrub, or grass) and the percent cover in the assessment area. Vegetative cover, comprising 60-80% trees, constitutes the largest share of non-agricultural and undeveloped areas (~27% of the entire region). Within the "Tree" lifeform, most fall into the 15 to 20-meter range (~27%). This is based on the average tree height across the assessment area, so individual tree size could be higher than the top of the range suggests (25 m). This indicates that the forests in the basin are primarily even-aged stands (Figure 3-7).

Figure 3-5. Existing Vegetation Types for the Great Lakes forest assessment area. This chart shows the top types in the region in the LANDFIRE 2023 Existing Vegetation Types dataset.

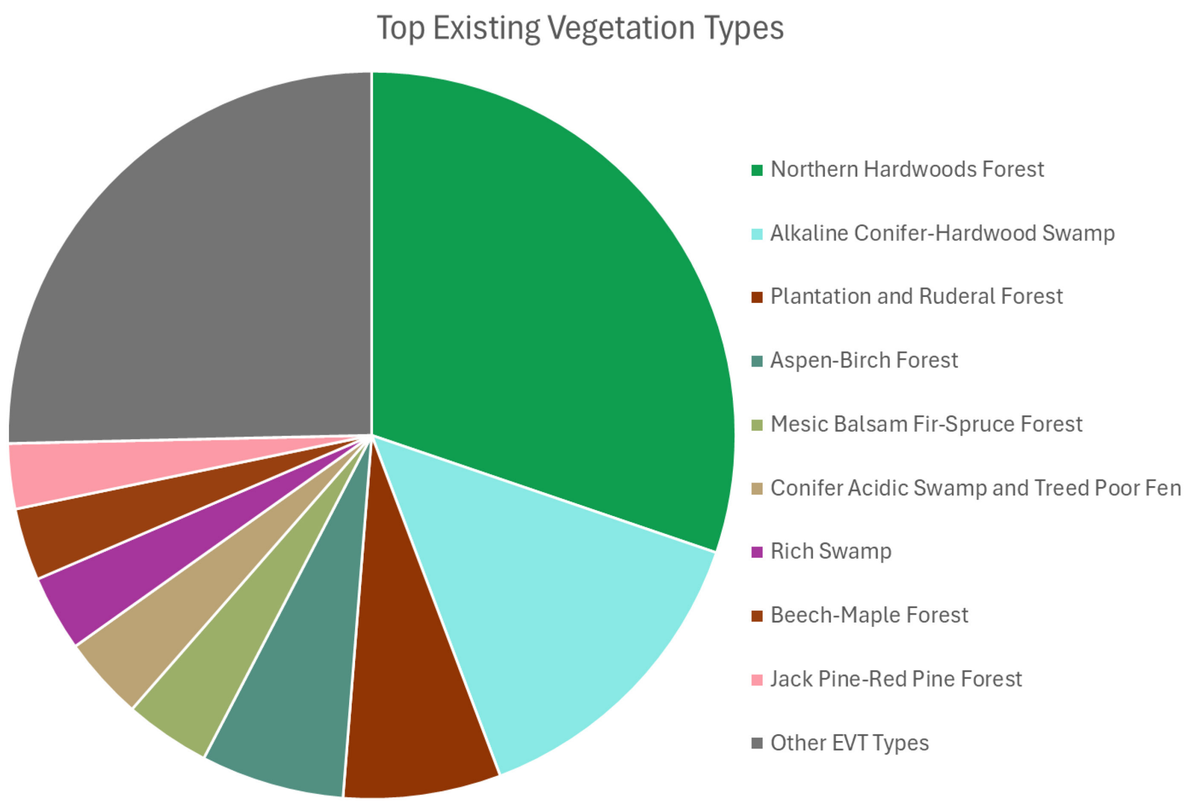


Table 3-1. Ecosystem descriptions of the top nine Existing Vegetation Types (EVT).

Existing Vegetation Type	Ecosystem Description
Northern Hardwoods Forest	Occur in dry-mesic to wet-mesic soils and are dominated by sugar maple, American beech, eastern hemlock and white pine. These forests typically grow on well-drained, fertile soils that are rich in organic matter and nutrients. Blowdowns, heavy snowfalls and/or ice damage are the main disturbance agents.
Alkaline Conifer-Hardwood Swamp	Forested wetland occurring in basins with mineral soil and sometimes some peat. Soils are generally alkaline due to limestone or other calcareous substrates, and the system relies on cold, nutrient-rich ground water. Dominant trees include white cedar, red maple, black ash and also eastern hemlock. Beaver herbivory, windthrow and altered hydrology (e.g., flooding, drought) are main disturbances.
Aspen-Birch Forest	Early successional forest that follows a catastrophic disturbance such as wildfire or a windstorm. Trembling aspen and paper birch are the dominant trees. It often occurs on loamy well-drained soils that may be droughty in late summer. Without disturbance, this type will often transition to coniferous forests.
Eastern Boreal-Sub-boreal Conifer Acidic Swamp and Treed Poor Fen	Characterized by stunted to well-developed black spruce and tamarack trees. The soils are composed of acidic, nutrient-poor peat, which forms a shallow, continuous mat ranging from one to three meters in depth. Natural disturbances include fire, which can influence the composition and structure of the vegetation, and hydrological changes that affect the water table and nutrient availability.
Mesic Balsam Fir-Spruce Forest	This ecosystem is dominated by balsam fir and black spruce and may also include jack pine and red maple. The soils in this forest type are typically well-drained (though can range to somewhat poorly drained), acidic, and rich in organic matter, supporting a diverse understory of mosses, ferns, and shrubs. Natural disturbances in this ecosystem include windthrow, insect outbreaks, and relatively rare fires.

Table 3-1 continued. Ecosystem descriptions of the top nine Existing Vegetation Types (EVT).

Existing Vegetation Type	Ecosystem Description
Rich Swamp	The North-Central Interior and Appalachian Rich Swamp is a diverse ecosystem characterized by hardwood or occasionally mixed swamps. Dominant tree species include red maple and black ash, with conifers such as larch. The soils are primarily mineral-based, often alkaline and can be mucky. This ecosystem occurs at low to mid elevations in poorly drained depressions or stream valley margins. Natural disturbances include hydrological changes, windthrow, and occasional fires.
Jack Pine-Red Pine Forest	The Laurentian Jack Pine-Red Pine Forest is dominated by jack and red pines. The soils are typically sandy and well-drained, often found on outwash plains and dune fields. These soils are moderately dry, and relatively acidic with limited nutrients. Natural disturbances include frequent surface fires and occasional crown fires plus windthrow.
Southern Appalachian Northern Hardwood Forest	The Southern Appalachian Northern Hardwood Forest occurs at higher elevations (>4,500ft) and is characterized by a diverse mix of hardwood species, including sugar maple, American beech, eastern hemlock and yellow birch. The soils are typically well-drained, acidic, and rich in organic matter. The climate is generally cool and moist, with significant precipitation throughout the year. Natural disturbances include windthrow, ice storms, and occasional fires.
North-Central Interior Beech-Maple Forest	This forest is dominated by American beech and sugar maple, which together make up most of the canopy that is typically very dense. The soils are rich loam, formed over glacial till, and are well-drained with high nutrient content. The climate is generally cool and moist, with significant precipitation throughout the year. Natural disturbances include windthrow and ice storms.

Figure 3-6. LANDFIRE 2023 Existing Vegetation Types (EVT) in the US Great Lakes Basin.

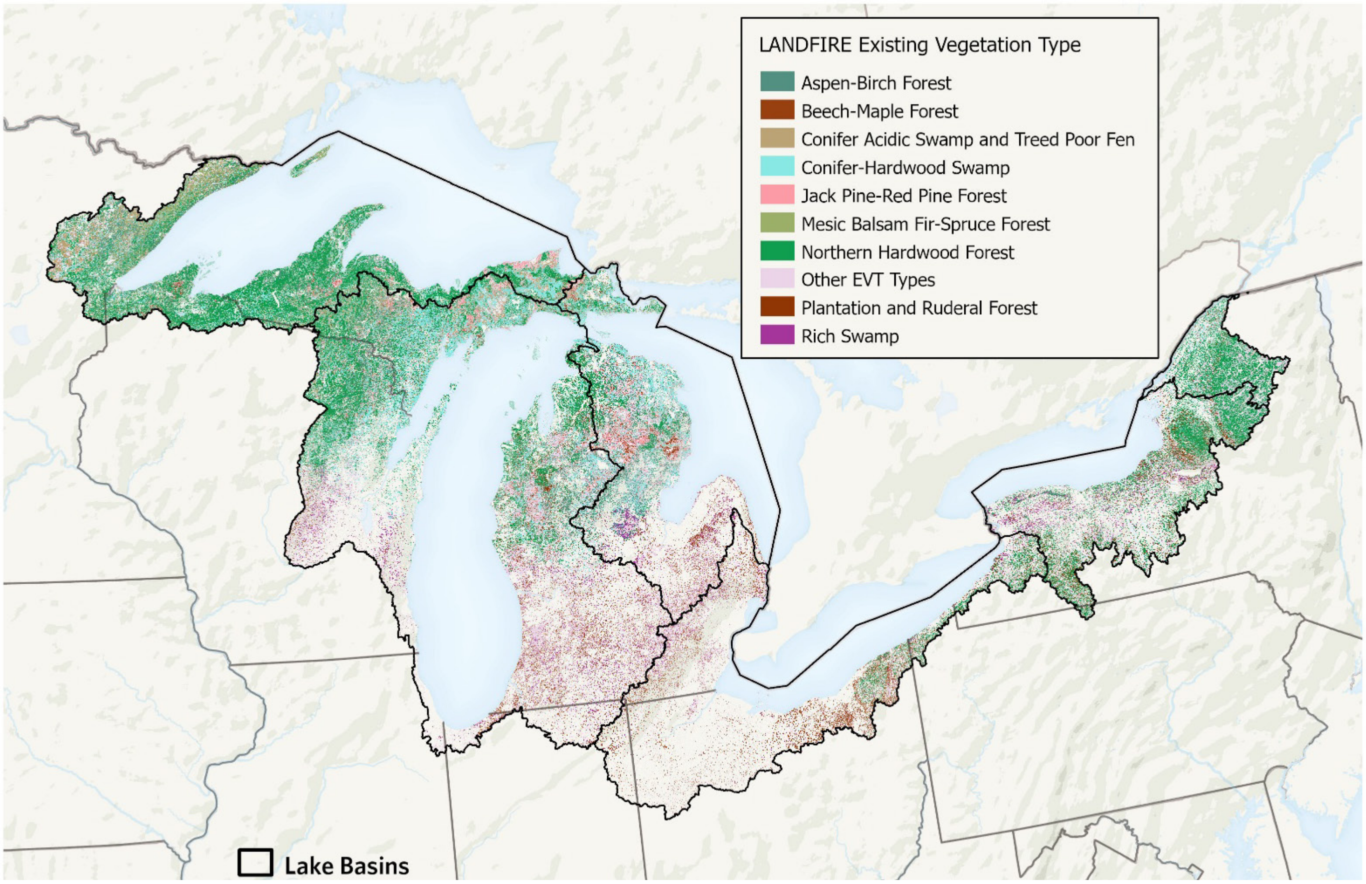
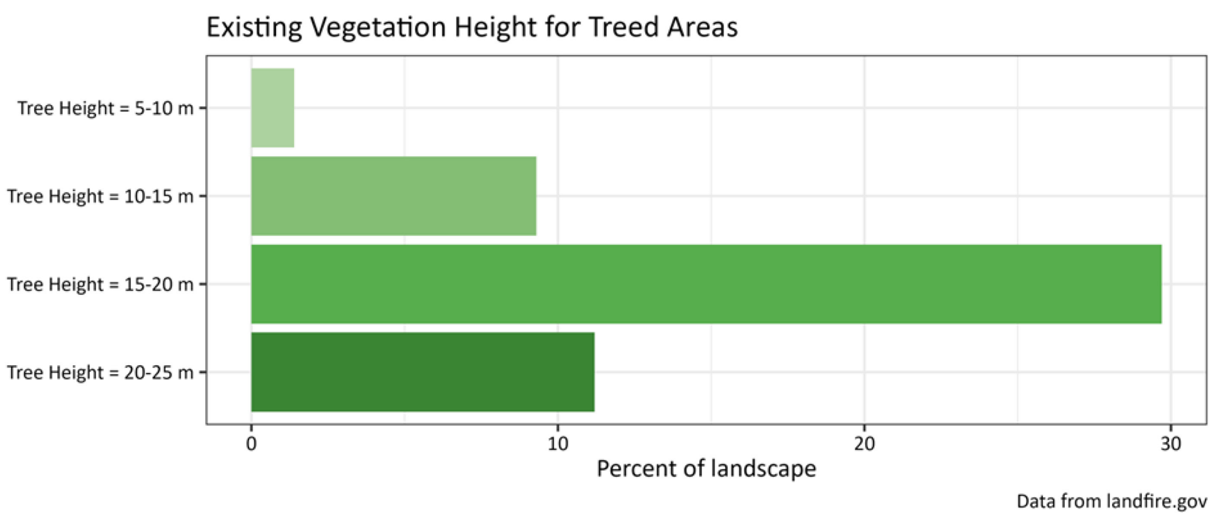


Figure 3-7. Distribution of tree height in the US Great Lakes Basin.



Forest Condition

Forests in the Great Lakes have a long history of human use, from widespread local scale burning by Indigenous people, to extensive clearing for agriculture and forestry by colonists in the 1800s, and now the logging of hardwoods and conifers for forest products. Moreover, as Great Lakes forests recovered from clearing after 1900, other changes transformed the land. These include an increase in the human population from a few hundred thousand to 27 million, and the development of a road network that now includes over 425,000 miles of permanent roads (enough to circle the equator 17 times; US Census Bureau 2024). One effect of these changes has been dramatic shifts in the type and abundance of wildlife; most dramatically, a decrease in forest interior species, a spike in the abundance of open habitat species, and a recent increase in forest generalists and game species. While it is difficult to comprehend the scope of these changes, the aim of this section is to objectively assess the degree of forest fragmentation and its inverse "local connectedness" and determine the rate of change over the last decade.

Forest Block Size

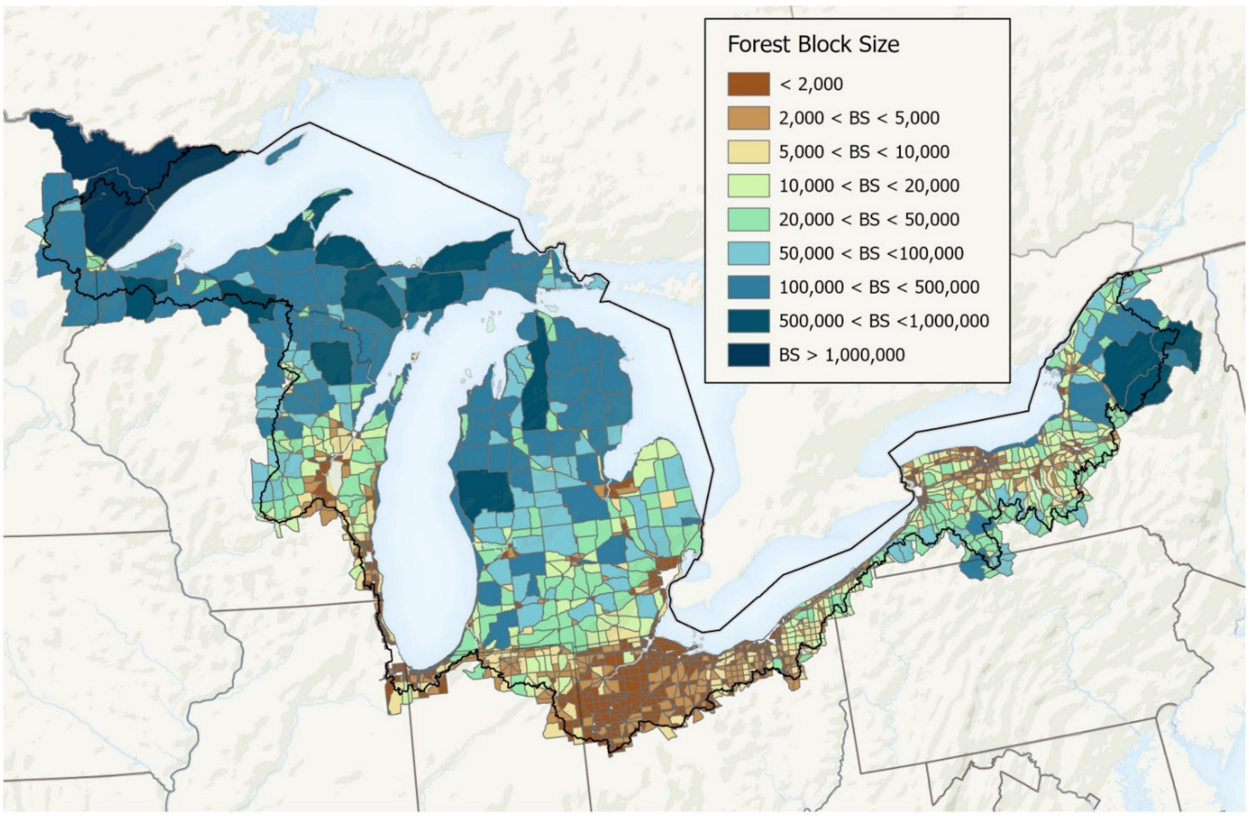
Fragmentation occurs when a contiguous area of forest is subdivided into smaller patches, resulting in each patch having more edge and less interior. Because edge habitat contrasts strongly with interior – drier and more exposed, higher predator densities, greater susceptibility to blowdowns – the surrounding edge habitat tends to isolate the interior region and contribute to its degradation. Thus, the divide-and-conquer effect of fragmentation can lead to an overall deterioration of forest quality and a shift in associated species from interior specialists to edge generalists.

A simple way to measure fragmentation is through the distribution of forest block sizes created by the road network. Roads affect forest systems primarily by providing access into forest interior regions, thus decreasing the amount of sheltered and secluded habitat preferred by many species for breeding. Additionally, heavily used paved roads create noisy edge habitat that many species avoid, and the roads themselves may form movement barriers for small mammals, reptiles, and amphibians.

To evaluate the extent and potential impact of roads on Great Lakes forests, we examined the patterns created when major roads connect to encircle contiguous blocks of forest. To this end, we defined a forest block as a distinct area of forest surrounded by major roads (US Census Bureau 2024; Major Road classes MTFCC = S1100, S1200), and we mapped the major-road bounded blocks comprehensively across the region (Figure 3-8). The highest quality interior habitat is found in the central core of each block and the effects of the fragmenting feature decrease with the size of the blocks.

Most forests in the Great Lakes are in large block sizes (greater than 100,000 acres; Figure 3-8). The most common forest block class is between 100,000 and 500,000 acres. The two largest blocks are over a million acres in Superior National Forest in Minnesota. Forest blocks over 500,000 acres are also found in northern Wisconsin, the Upper Peninsula of Michigan, northern lower peninsula of Michigan, and the Adirondacks of New York. The smallest forest blocks are found around the major urban centers in the basin (Chicago, Detroit, and Milwaukee) and in predominately agricultural areas (Northern Ohio and the I-90 corridor in New York).

Figure 3-8. Forest block size (in acres).

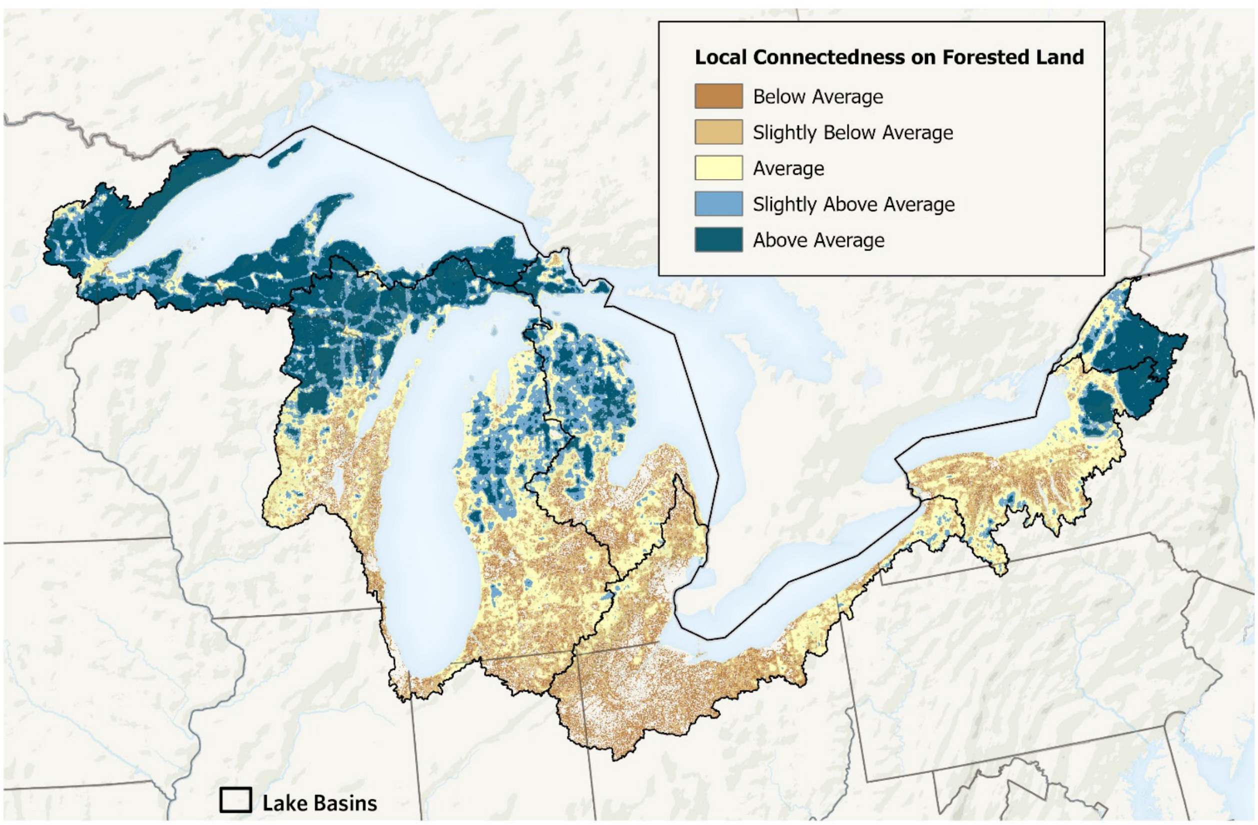


Local Connectedness

One solution to the pervasive problem of fragmentation is to preserve connectivity, which helps maintain the quality of the whole ecosystem. The metric we used to measure connectivity, local connectedness, is related to, but more sensitive than, the forest block analysis in the previous section. We measured local connectedness using a resistant kernel algorithm to account for the impacts of major and minor roads, as well as the density of all nearby roads and the degree of nearby conversion. The method follows Compton et al. (2007) and treats the landscape as having a gradient of permeability where highly contrasting land cover types have reduced permeability between them, and highly similar ones have enhanced permeability. Every point on the landscape is scored based on how connected it is in all directions within its local 3-km neighborhood. In applying the metric, we differentiated between developed lands, agricultural lands, and natural cover, but all forms of natural land cover were combined into one class for the analysis. Our application was run with the 30-m NLCD 2021 (Dewitz & USGS 2023) land cover supplemented with major and minor road information (US Census Bureau 2024).

For every 30-m grid cell in the region, a circular area with a 3-km radius around the cell was evaluated and the amount of resistance /permeability was calculated to create a wall-to-wall grid with cell values ranging from 0 to 100. These scores were adjusted to a standard normal score, to determine the relative position of a value within its distribution. The mean connectedness score for all forest (LC = 0.64 SD) indicates that forests are more connected, on average, than the region in general (LC=0; Figure 3-9).

Figure 3-9. Local connectedness on forested land.

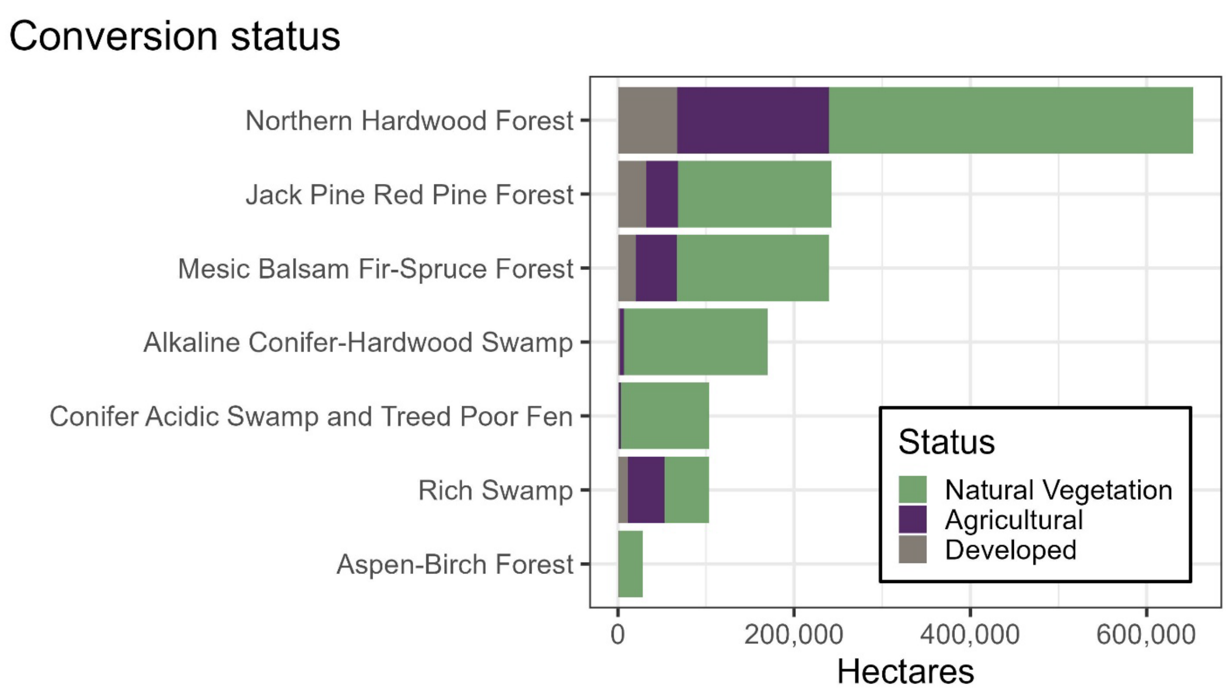


Historical change

Extensive logging in the mid-1800s to early 1900s removed vast old-growth forests, especially white pine and hemlock (National Park Service 2021). The region experienced logging at the time that was globally unprecedented in its speed and intensity, with over 50 million acres deforested in 60 years (Williams 1989). Logging was followed by repeated and often intense slash fires. In the southern Great Lakes basin, oak savanna, prairie, and hardwood forests were often converted to persistent agriculture (Gough 1997). Farming was promoted, but failed in the northern parts of the basin, leading to widespread farm abandonment (Gough 1997). Following successful fire suppression efforts in the 1930s, the region was reforested largely through natural regeneration (Graham et al. 1963).

This extensive logging and natural regeneration have created ecological shifts (Figure 3-10). Forests have become more homogeneous in both species composition and structure. Forests transitioned from diverse, mature conifer-dominated ecosystems to younger, hardwood-dominated ones (Figure 3-11). There was a marked decline in conifer presence, once two-thirds of the forest composition (Schulte 2007), conifers now make up about one quarter of forest composition. Broadleaf deciduous species dominate today, reducing habitat complexity and affecting wildlife. The structural complexity of forests declined, with fewer large trees and more uniform tree sizes (Schulte 2007; Figure 3-7).

Figure 3-10. Change in representation of main forest types from pre-European settlement to the present.



Data from landfire.gov.

Figure 3-11. Bruneau logging camp in the Keweenaw Peninsula of the Upper Peninsula (approx. 1870 to 1900). Notice predominance of conifer trees in the picture and the large diameter of the lumbered trees, indicating their old age. Photo courtesy of A. Olivero.

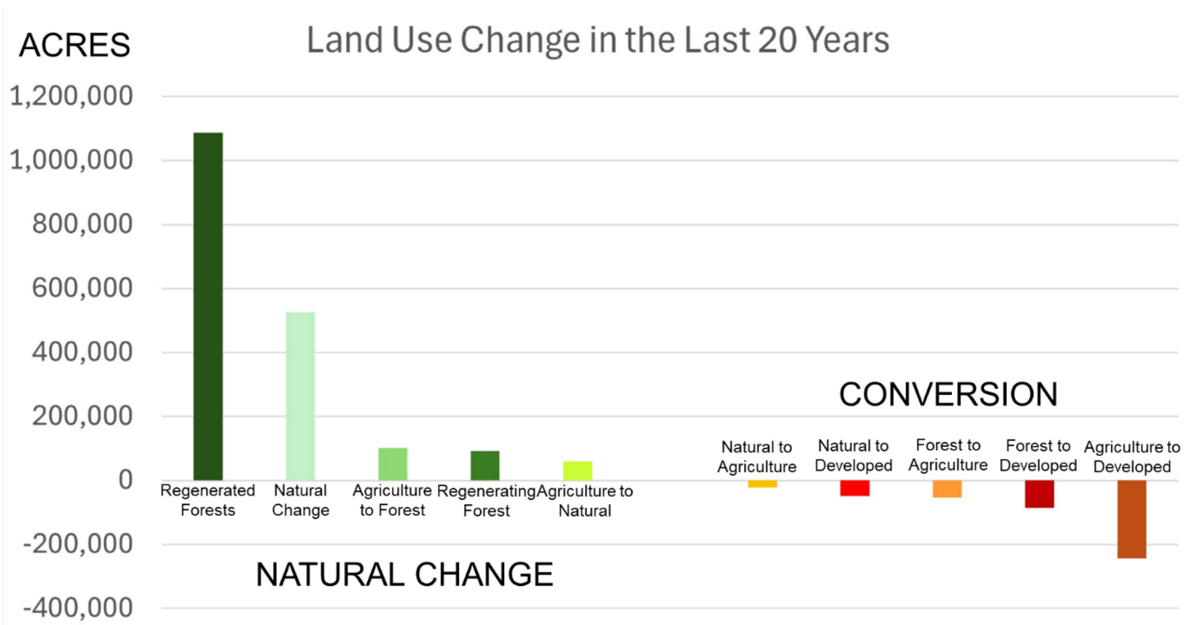
Short-term Forest Trends

Land use Trends

Examining short-term forest change gives us a sharper, real-time view of how landscapes are transforming. To examine recent changes in forests and land use types, we used the Global Forest Change dataset, which provides annual maps of forest cover, loss, and gain from 2000 to 2024 at a 30-m resolution. It is based on Landsat imagery and is widely used for tracking deforestation and reforestation trends globally (Hansen et al. 2013). Within areas identified as forest change between 2001 and 2021, we used the NLCD to provide details on the type of change (e.g., forest turnover, forest conversion to development, or forest conversion to agriculture; Dewitz & USGS 2023; Dewitz & USGS 2001).

Land use in the Great Lakes region has been remarkably stable over the last 20 years with about 3% of the land changing in cover type during that period. Half of the change (1.5%) was forest turnover, of which all but a small fraction has already returned to forest (Figure 3-12). A quarter of the change reflected transitions within the natural systems (i.e., shrub to wetlands). A fair amount of agriculture (100,000 acres) has transitioned back to forest over the last 20 years. The Great Lakes area is gaining more forests from agriculture than it is losing at a ratio of about 2:1 (101,000-acre gain and 54,000-acre loss). Permanent conversion of forests to development or industrial agriculture accounted for just 0.36% of the total forest area with two thirds of that going to development. While the Great Lakes is losing forests to development, three times as much development is occurring on agriculture than forested land. Most of the conversion occurred in counties already predominantly urban, residential or agricultural, but models suggest that conversion could move northward into more forested counties.

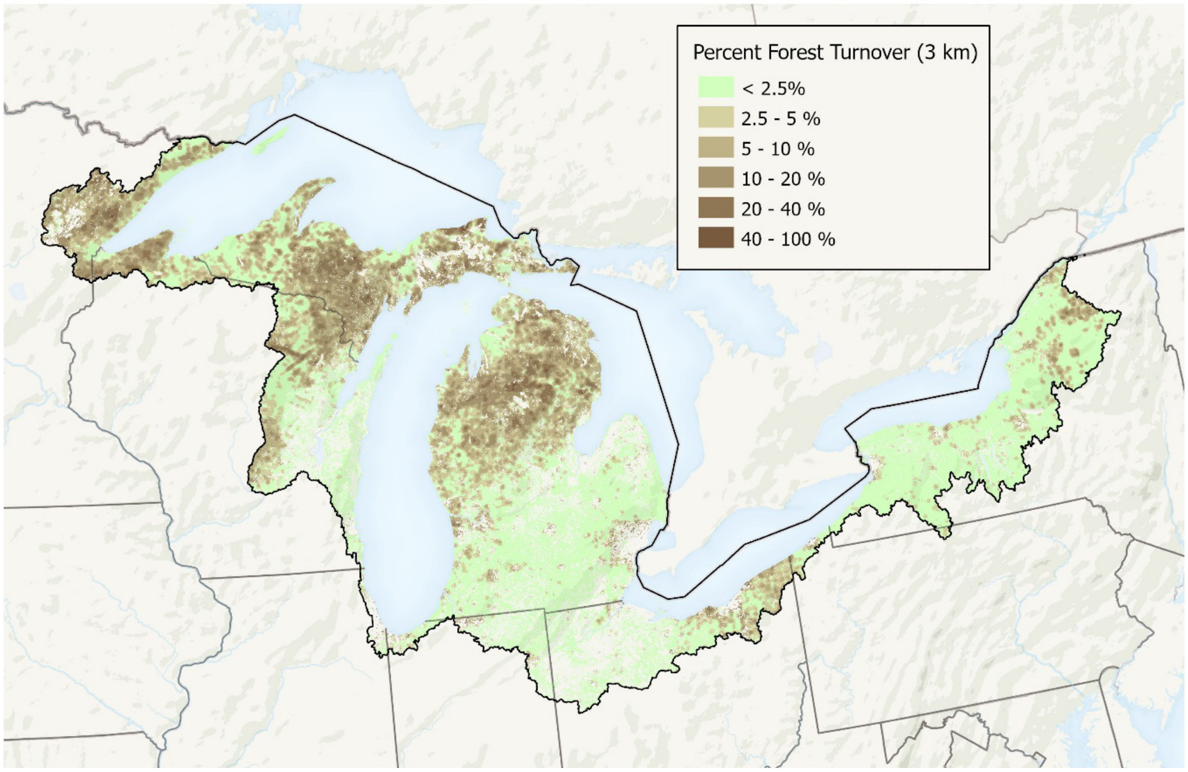
Figure 3-12. Land use trends in the last 20 years.



Trends in Forest Systems

Using the same analysis as above but looking specifically at forests suggests that 25.7 million acres (8%) of forests in the Great Lakes changed to a different landcover type between 2001 and 2020 (Figure 3-13). The primary type of change was turnover, defined as a temporary change from forest to non-forest that returned to forest in the 20-year period. Conversion, a permanent change to development or industrial agriculture, accounted for a small amount of the landcover change. Turnover was concentrated in the northern lower peninsula and Upper Peninsula of Michigan (Figure 3-13).

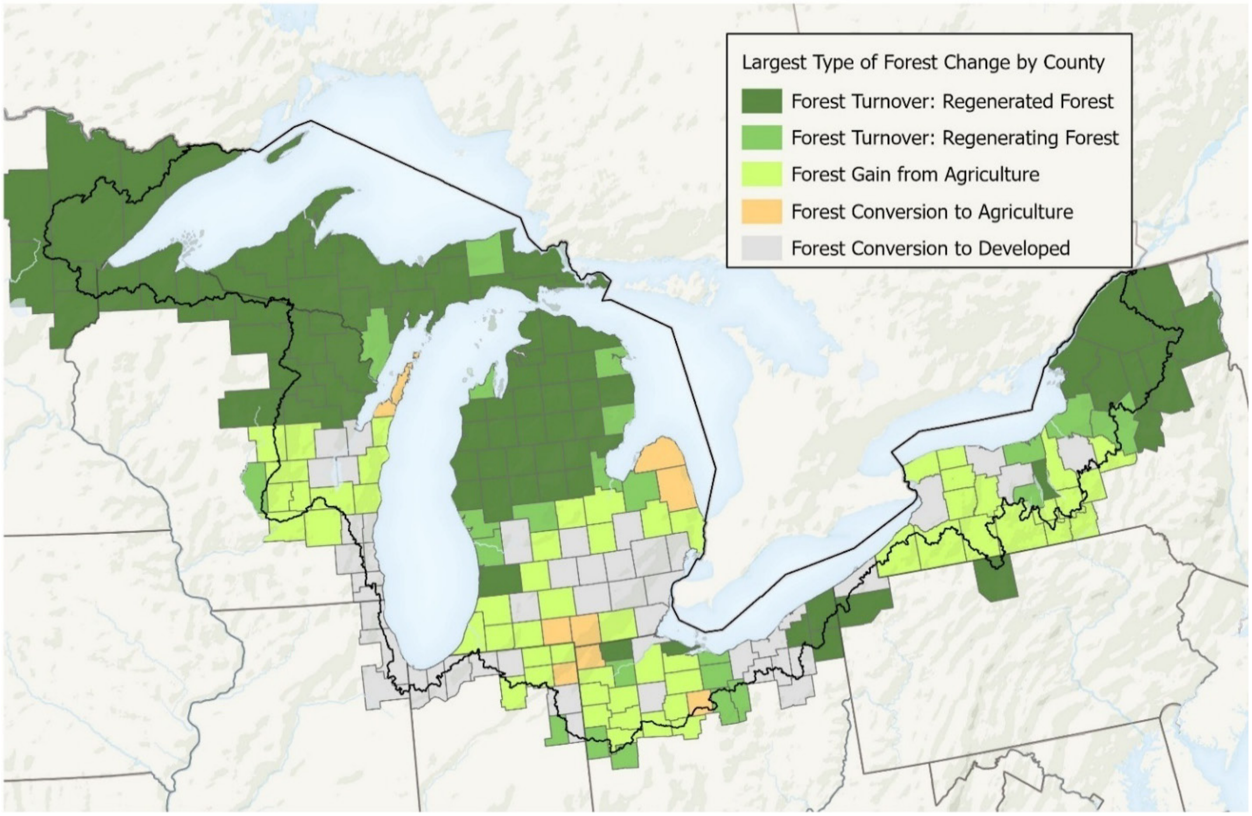
Figure 3-13. Forest change over 20 years. Each cell summarizes the percent forest change in a three-kilometer circle around the cell based on the Global Forest Watch data. Most of the change was turnover, defined as forests that became non-forest and then returned to forest. This change density analysis inflates the spatial extent to make it more visible. The high percentage change around Detroit and Chicago is caused by having fewer trees to begin with.



Of the forests that changed, 74% returned to forests by 2021. Eleven percent of the forests that have experienced forest change appear to be regenerating and are on a trajectory to return to forests. Another 7% began as forest but are now classified as some other form of natural cover such as grassland, herbaceous wetland, woody wetland, or dwarf scrub. Only 6% of the forest change was permanent conversion to anthropogenic uses, with two thirds going to development and one third to industrial agriculture.

Although the forest-land base has remained relatively stable at the state level, there has been substantial change by county. This change has been more pronounced in the southern and northern Lower Peninsula. Almost all the counties with northern forests, including northern Minnesota, Wisconsin, Michigan, and New York, have seen forest cutting, but that cutting has regrown back to forests (dark green in Figure 3-14). Not surprisingly, counties with urban and suburban development saw the largest type of change occurring in the transition of forests to development (gray in Figure 3-14). However, there is also some good news, in 57 counties, the largest type of forest change was the transition from agriculture back to forests.

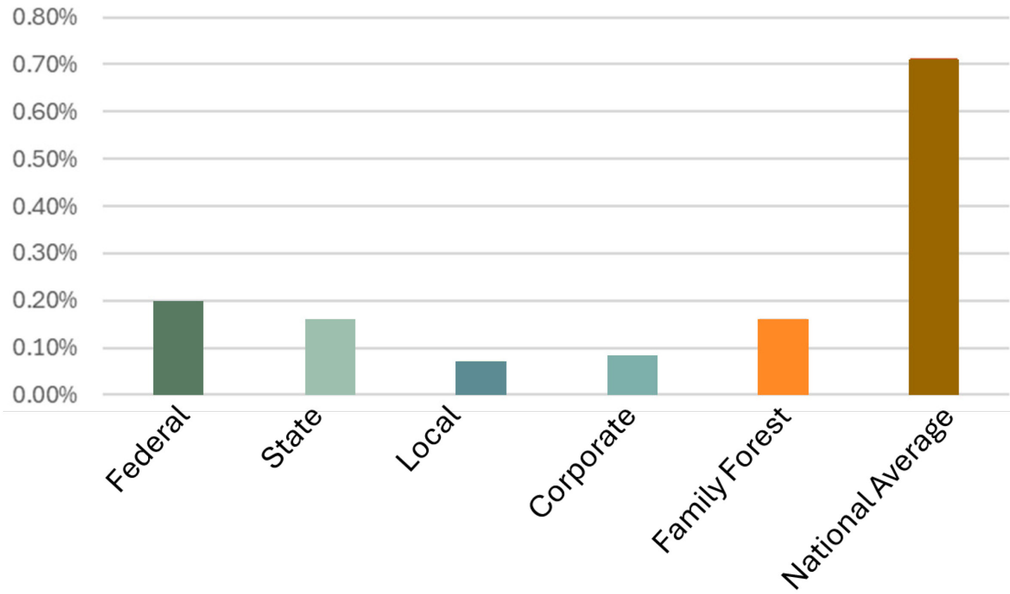
Figure 3-14. Forest change by county over the last 20 years.



Rate of Forest Turnover and Ownership

Forest logging practices in the Great Lakes region vary significantly by ownership type (Figure 3-15). Looking at the *rate of forest turnover*, defined as the average amount of forest turnover per year/total amount of forests, federal lands have the greatest rate per year of the landowner types, with more than 500,000 acres (a rate of 0.2% per year). While this is the largest rate of forest turnover in the basin, it is still much lower than the national average (a rate of 0.7% per year).

Figure 3-15. Forest turnover rate by ownership type as shown by percent turnover per year.



Disturbance of Great Lakes Forests

Forest disturbance refers to any event or process that disrupts the structure, composition, or function of a forest ecosystem. Disturbances play a critical role in maintaining healthy, resilient ecosystems. When extreme, they also pose serious economic and environmental threats to forests and urban landscapes worldwide. This section discusses the impacts of insects and pathogens, fire, and weather disturbances, and characteristics that lend resilience to forest ecosystems.

Insects and Pathogens

Impacts from insects and pathogens can alter the ecosystem services that are derived from forested lands and affect timber, recreation, clean water, energy, wildlife habitat, and jobs.

Detection surveys are the primary method of collecting data on the health of treed areas affected by insects and diseases. The Forest Service's National Insect and Disease Detection Survey records the main disturbances that impact our nation's forests (USFS 2023). The impacts of fungal, insect, and weather-related disturbances on forest health are significant and often interconnected. These disturbances often interact; drought-stressed trees are more vulnerable to insect attacks, insect damage can open pathways for fungal infections, and storm-damaged trees may become breeding grounds for pests.

Over the full survey period (1997-2023), forest tent caterpillar, spongy moth, spruce budworm, and emerald ash borer have affected the most acres (Table 3-2). Following the approach of the US Forest Atlas, we mapped disturbance types for the last five years. From 2019-2023, the same species, spongy moth, spruce budworm, emerald ash borer, and tent caterpillar, were the forest disturbances that affected the greatest area of trees and are all insect agents (Figure 3-16 and Figure 3-17). The highest number of insect disturbance types occurred in northern Minnesota, Wisconsin, and Michigan. Weather events were also sources of forest disturbance. The primary events were flooding/high water, wind/tornado/hurricane, and snow and ice. Fungal damage was the least common damage in the area, with the most prevalent being white pine needle damage, oak wilt, and needle cast. Oak wilt, one of the most devastating diseases for oak species in the eastern United States was especially common in 2023.

Table 3-2. Most prevalent insect pests in the Great Lakes assessment area ordered by extent and reported from 2019-2023.

Pest	Total 2019-2023 (M acres)	Total 1997-2023 (M acres)	Description
Spongy moth *(Lymantria dispar)*	**4.1**	**6.6**	In the US, 1.3 million acres of spongy moth damage were reported in 2023. It is a highly invasive insect that has significant impacts on forests in the Great Lakes region. Wisconsin reported 384,000 acres with defoliation, a state record and more than any other state in 2023. The spongy moth prefers oak, but also feeds on aspen, birch, willow, and even conifers like pine and spruce during heavy infestations. There is one generation per year; caterpillars hatch in the spring and feed voraciously through the early summer. The larvae can strip trees of their leaves, weakening them and making them vulnerable to disease and drought. Repeated defoliation over 2–3 years can kill trees, especially oaks. This alters forest composition by reducing dominant hardwoods and allowing less-preferred species to take over.

Table 3-2 continued. Most prevalent insect pests in the Great Lakes assessment area ordered by extent and reported from 2019-2023.

Pest	Total 2019-2023 (M acres)	Total 1997-2023 (M acres)	Description
Spruce budworm (*Choristoneura fumiferana*)	**3.2**	**4.4**	Spruce budworm is one of the most destructive native insect pests affecting coniferous forests in the Great Lakes region. The spruce budworm primarily targets balsam fir and white spruce, but also affects black spruce, red spruce, and occasionally tamarack and pine. Repeated feeding weakens trees, reduces growth, and increases mortality. Severe outbreaks can kill up to 80% of host trees in affected stands. Severe outbreaks promote hardwood regeneration and reduce conifer dominance.
Emerald ash borer *(Argrilus planipennis)*	**.5**	**3.0**	Emerald ash borer is a highly destructive, invasive beetle that has devastated ash tree populations across the Great Lakes region since its discovery in southeastern Michigan in 2002. The larvae tunnel under the bark, feeding on the tree's vascular tissue, disrupting water, and nutrient flow. Dead ash trees reduce forest canopy, altering light and moisture conditions. With the significant loss of most ash trees, ash-dependent species (e.g., certain insects and birds) have lost significant habitat and food sources.
Forest tent caterpillar *(Malacosoma disstria)*	**.3**	**27.5**	While not as devastating as invasive pests like the emerald ash borer, tent caterpillars can still have noticeable impacts on forest health and appearance. Caterpillars feed on leaves in spring, sometimes stripping entire trees. Tent caterpillars cause stress on trees; while most healthy trees recover, repeated defoliation can weaken them, making them more susceptible to disease and drought.

Figure 3-16. Composite of disturbance types by country across the Great Lakes Basin for the years 2019-2023.

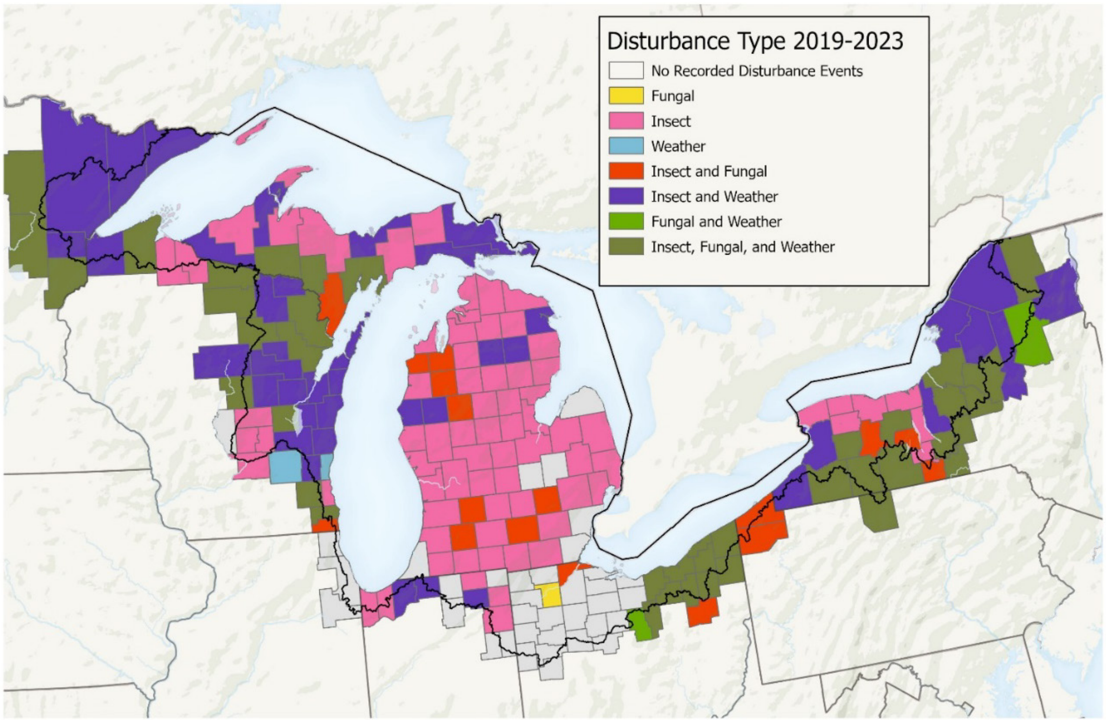
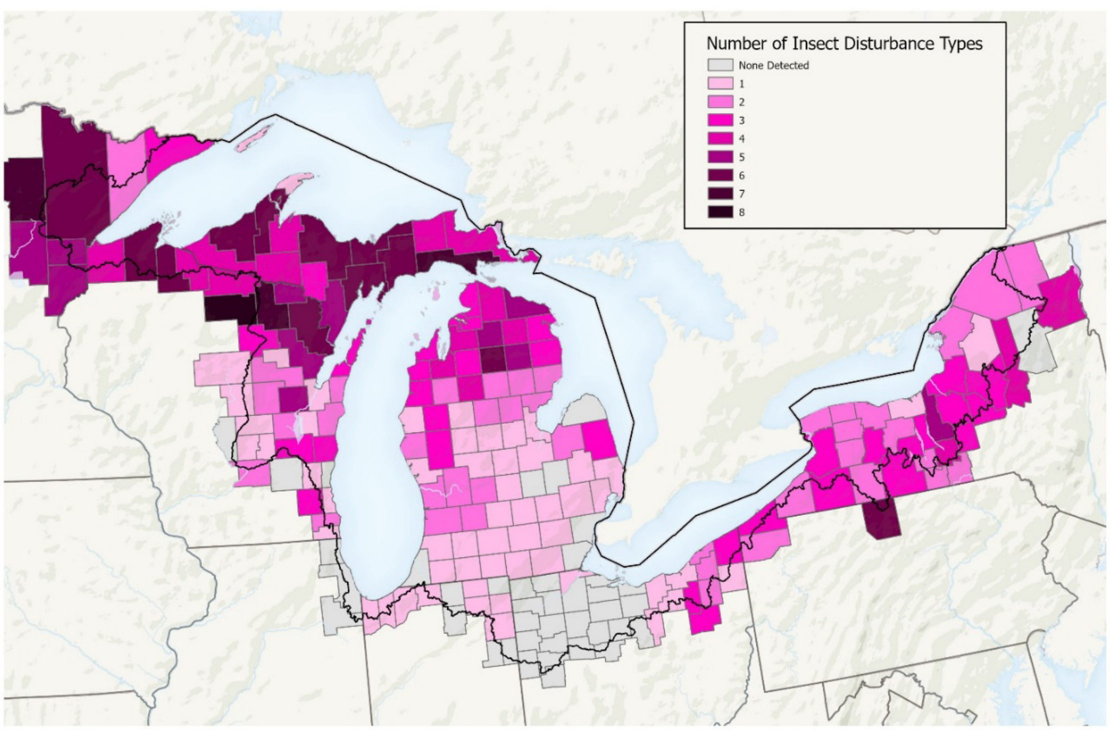


Figure 3-17. Number of insect disturbance types from 2019-2023.



Regional Fires Past and Present

Fire is a natural process in many ecosystems across the Great Lakes. Fire can help reduce the buildup of fuels that can lead to unnaturally severe wildfires, promote regeneration of many oaks and pine, release nutrients, diversify vegetative habitats, boost plant biodiversity, reduce invasive species such as buckthorn, and even reduce ticks and associated tick-borne diseases.

For most of the fire-adapted ecosystems of the region, fires were relatively frequent, happening every 5-10 years and were primarily of the surface type with little to no mature tree mortality. Fire adapted ecosystems of the region include:

- Jack Pine-Red Pine Forest
- Dry-Mesic Oak Forest and Woodland
- Northern Pine-Oak Forest
- Dry Oak Forest and Woodland
- Pine-Oak Barrens

While most of these types are small in area and often do not show up on maps and charts, they have local importance and are home to rare species including Kirtland's warbler (federally endangered), Karner blue butterfly (federally endangered), and Eastern massasauga rattlesnake (federal candidate species).

Historically, we estimate that there would have been over two million acres of fire annually across the region (Figure 3-18). Many of the historical fires would have occurred at an interval of less than 15 years, meaning there would have been a fire at any one place on average every 15 years or less. This would have varied based on climate and landscape position (e.g., northeast facing slopes having longer fire return intervals). Most fires would have been centered in the central and western portions of the region, especially southern Michigan, the sliver of the basin in northern Indiana and northeastern Illinois, and central Wisconsin (Figure 3-19).

Figure 3-18. Cumulative estimate of fire by ecosystem type (historical names) prior to European settlement.

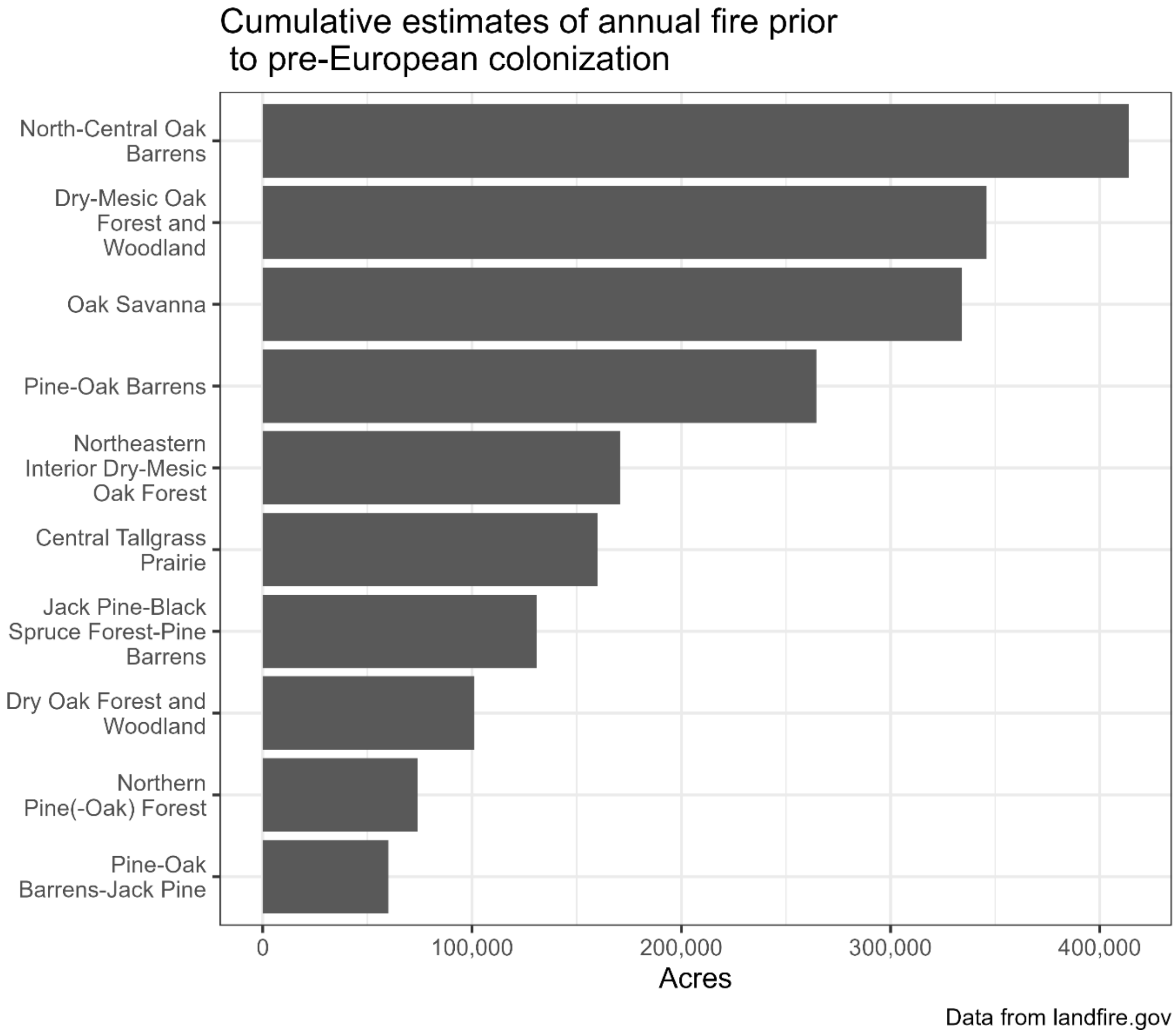
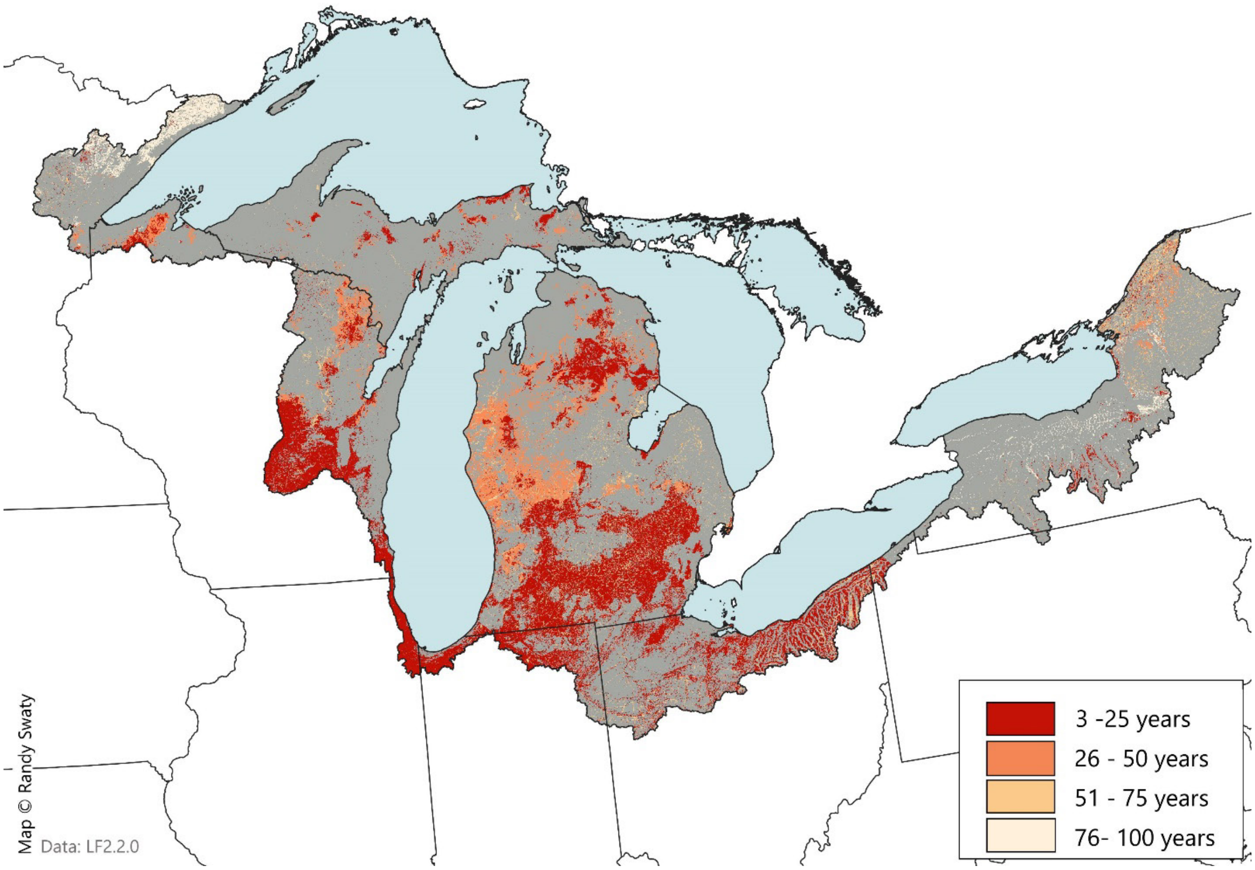


Figure 3-19. The occurrence of fire for the last 100 years is shown by typical time interval.



Today there are still fires, though the amount of area burned is greatly reduced due to many factors including fire suppression and conversion of fire-adapted ecosystems to other land uses such as agriculture. Fire occurrences from 1998-2023 were largely concentrated in Michigan, the arrowhead region of Minnesota, and northern Wisconsin (Figure 3-20). On average, the assessment area has approximately 170 fires per year (Figure 3-21). While fire occurrence on the landscape today is reduced from historical patterns, large wildfires are increasing (Donovan et al. 2023) and further increases in fire numbers and size are predicted in the future due to projected changes in fire weather indices (Kerr et al. 2016), increasing fuel loads, and invasive species such as common buckthorn (see Anfang et al. 2020).

Figure 3-20. Fire occurrences from 1998-2023.

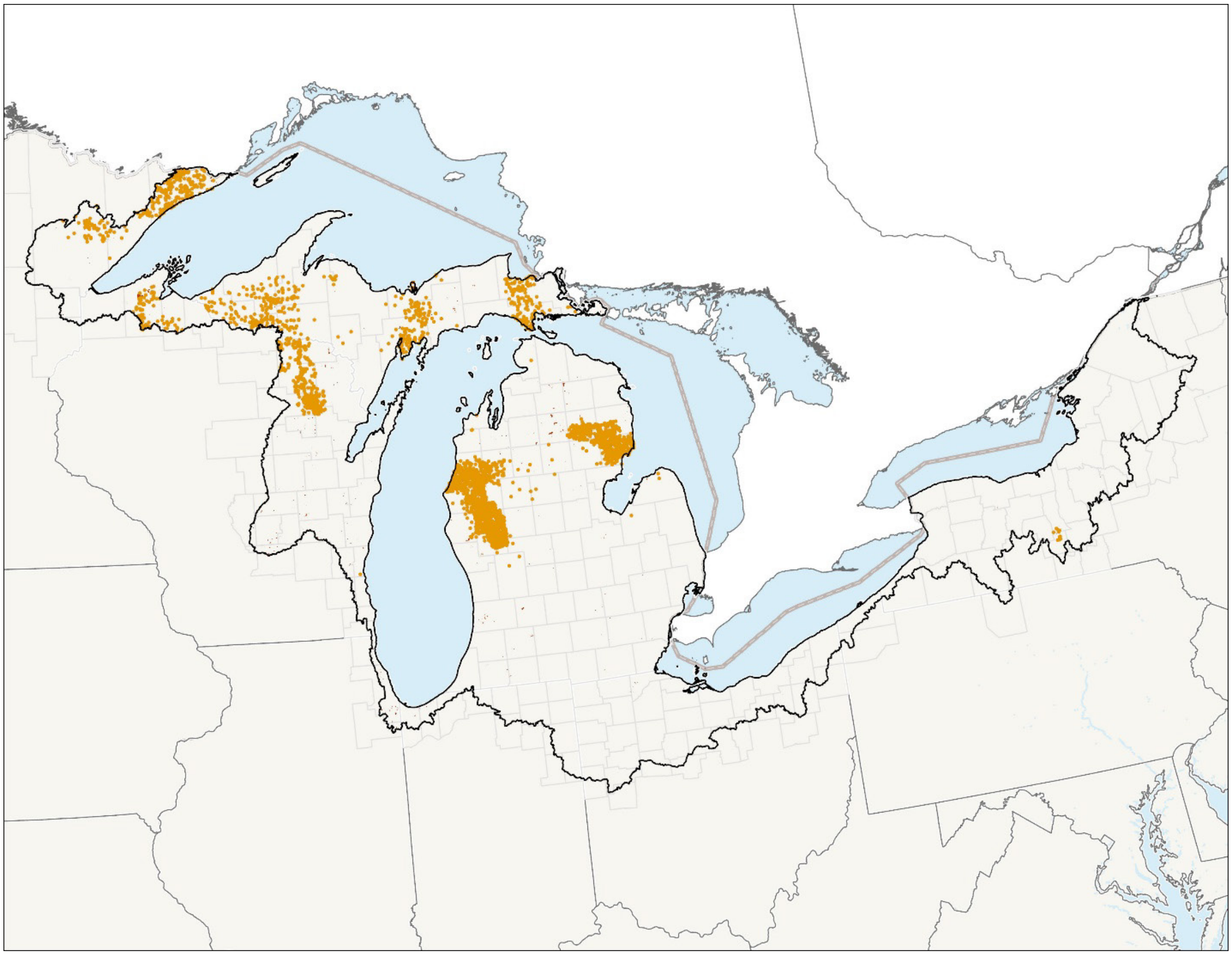
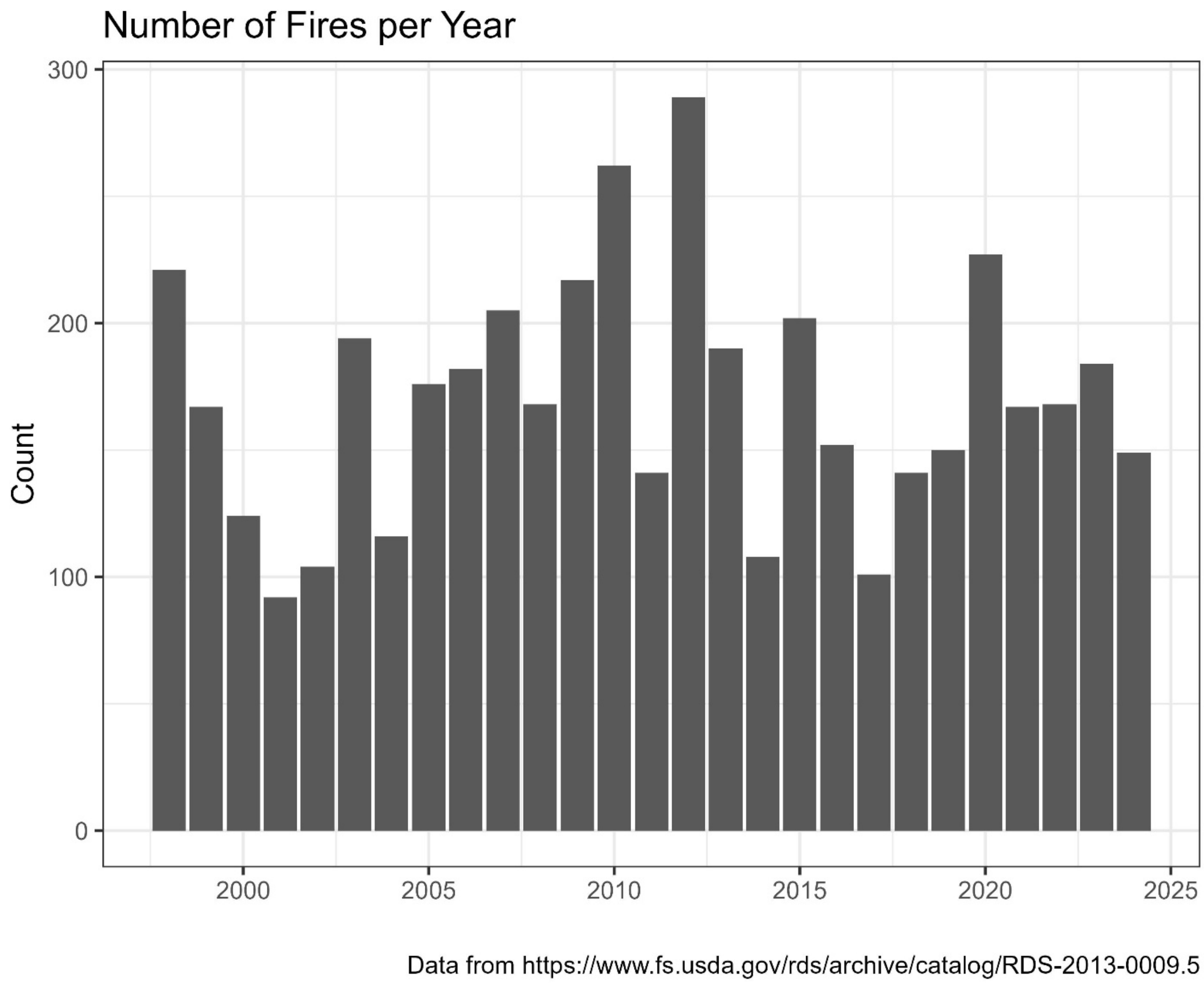


Figure 3-21. Total number of fires per year in the Great Lakes assessment area from 1998-2023.



Case Study: Hiawatha National Forest

Historically the Hiawatha National Forest (HNF) had around 34,000 acres of fire annually, mostly in the jack pine barrens ecosystem. This ecosystem is dominated by the highly fire adapted jack pine species and features red and white pines, blueberry, sweet fern, and grasses such as big bluestem and sedges such as Pennsylvania sedge. Other ecosystems that historically had fires include Pine-Oak barrens, Northern Pine-Oak Forest, and peatlands. The cumulative historical estimates and historical return intervals for the HNF are shown in Figure 3-22 and Figure 3-23, respectively.

Recently, the Hiawatha has increased the acreage of prescribed fire from about 1,000 acres in 2007 to over 10,000 acres in 2024 to reduce wildfire risk from fuel build up, and to improve overall forest health. Additionally, Hiawatha National Forest staff have been working with the Sault Tribe on their "Ishkode" project which aims to integrate western science and tribal knowledge to benefit over 60 species that are valued by the Tribe such as snowshoe hare and ruffed grouse.

Figure 3-22. Cumulative estimate of all fire by ecosystem type (historical) prior to European colonization in the Hiawatha National Forest.

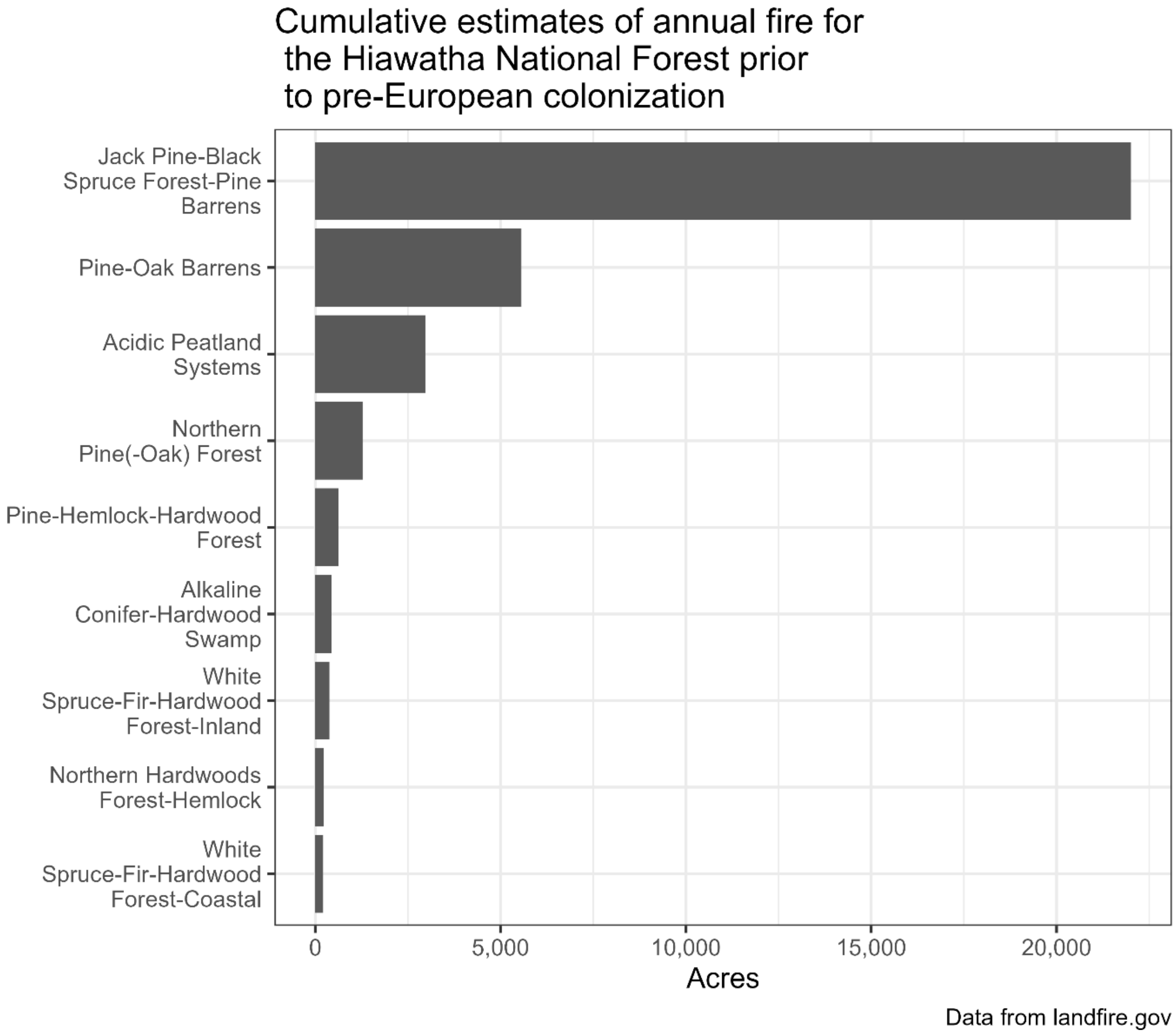
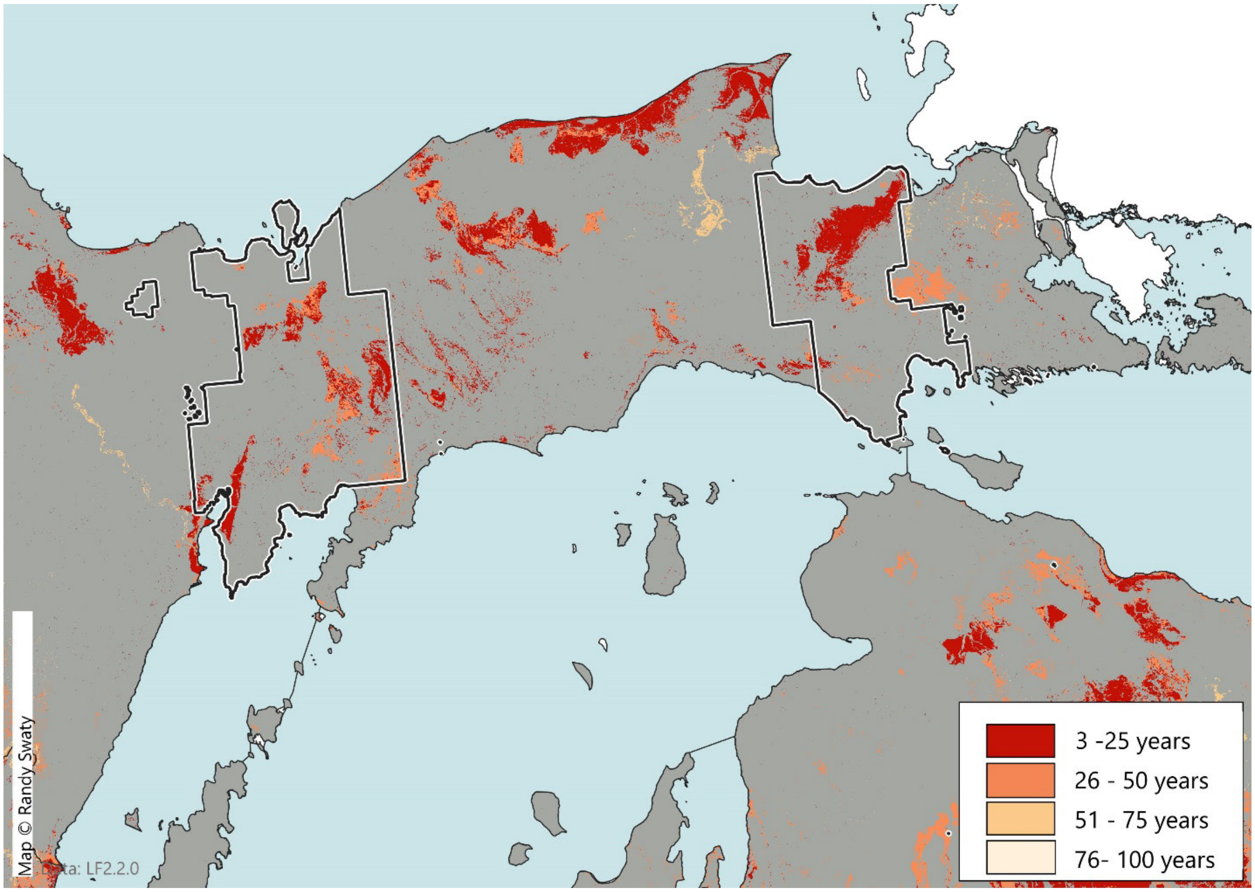


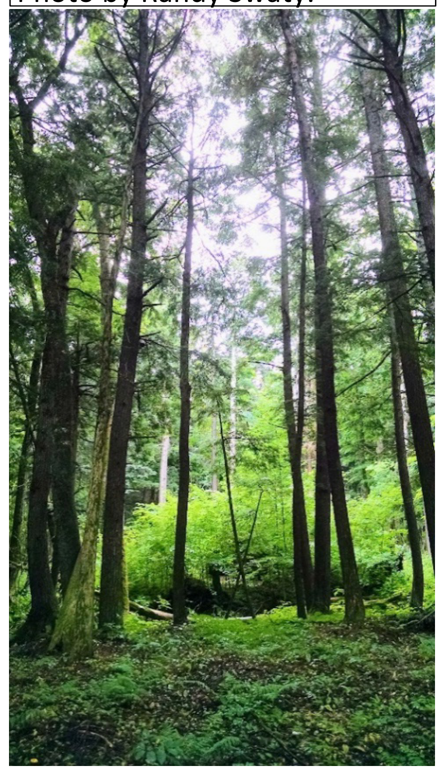
Figure 3-23. The occurrence of fire for the past 100 years, shown by typical time interval for the Hiawatha National Forest (comprises two bounded areas).



Weather Disturbances

Historically, LANDFIRE modeled that there would have been approximately two million acres of 'wind/weather' disturbances every year, about 5% of the forested area in the basin, with most of these disturbances occurring in the Northern Hardwood Forest. These estimates roughly match what was expected for fire disturbances in the basin historically. LANDFIRE did not model different severity classes for this disturbance, but there are accounts in the scientific literature that suggest that most wind disturbances were small, with large catastrophic events being rare (Figure 3-24). For example, Frelich and Lorimer (1991) reported that overall canopy removal was about 6% on average, with most disturbances being small windthrow. Large canopy removal events were rare, occurring on average about 1,900 years apart in Northern Hardwood Forests of the Upper Peninsula of Michigan. Similarly, in northern Michigan, Woods (2004) reported 9% of basal area was removed from storms in Northern Hardwood Forests. Notably, yellow birch suffered the least mortality in storms, while large maples and beech suffered the most. In a study of historical land survey records, Lorimer and White (2003) reported that 2% of New England forests were blown down per year. In New England, there is a higher probability of severe events such as hurricanes and tornadoes, though they are still relatively rare (e.g., tornadoes have a mean reoccurrence interval of 10-20,000 years in the region). Since fire is relatively rare in the Northern Hardwood Forests, these wind events were the main process that would have created canopy gaps and habitat heterogeneity.

Figure 3-24. Post windthrow regeneration in Northern Hardwood Forest in Porcupine Mountains State Park, MI. Photo by Randy Swaty.



As discussed in Chapter 2, forested ecosystems are shaped by climate patterns and ecosystems adapt and evolve to thrive because of periodic cycles of high and low precipitation, its occurrence as snow or rain, and persistent patterns of high and low temperatures. As with the disturbances discussed above, when temperature and precipitation minimums and maximums move beyond historical ranges of variation, ecosystems are less resilient to other disturbances. The measured weather trends in the Great Lakes region are making forest ecosystems, and the ways they benefit people, vulnerable to loss. The average air temperature increased 2.3°F from 1951-2017, the frost-free season has increased 16 days, total precipitation has increased 14%, and heavy precipitation events have increased 35% (GLISA 2019). The rise in temperature is already affecting vegetation and current species ranges are expected to shift while forests will experience greater disturbance from pests and pathogens, invasive species, altered fire regimes, and drier conditions (GLISA 2019). Handler et al. (2012) identified the following as the most likely weather-related vulnerabilities of forests in the Great Lakes region. These changes include:

- Boreal species will face increasing stress, including reduced suitable habitat, biomass, and productivity. These species may be less able to take advantage of longer growing seasons and warmer temperatures than temperate forest species or southern species.

- Forest composition will continue to change as some species decline, others expand, and species ranges shift with changing conditions. This is exacerbated by the current loss of forest species diversity due to emerald ash borer, beech bark disease, and hemlock wooly adelgid. Some species may be unable to migrate to suitable conditions due to habitat loss and fragmentation.

- The decrease in snowfall, snow depth, and duration is expected to affect a variety of ecosystem processes, including decomposition activity, nutrient cycling, the onset of the growing season, and other phenological factors.

- As seasons shift so that spring arrives earlier and fall extends later into the year, risk is greater for species that rely on temperature as a cue for leaf-out, reproductive maturation, and other developmental processes. Longer growing seasons could also result in greater growth and productivity of trees and forest vegetation, but only if sufficient water and nutrients are available.

- Trees and forest vegetation are increasingly exposed to fluctuations in weather extremes, rapidly experiencing periods of intense precipitation and drought, sometimes coinciding with extreme heat. Although some forests are adapting to these types of fluctuations, the increased frequency and intensity may push species beyond their ecological tolerances.

- The potential for interactions among these impacts is also concerning, and interacting stressors can increase susceptibility to invasive species and insect pests and pathogens, as well as disturbance from fire, floods, and wind and phenological mismatches.

Indeed, the Northern Great Lakes are experiencing a fast rate of change because the boreal species are at the edge of their southern range (Duveneck et al. 2014). As a result, the availability of winter recreation, particularly sports like cross-country skiing, snowmobiling, and ice fishing. Not only do warmer temperatures shorten winter recreation seasons, but they also limit the ability to practice sustainable forestry practices such as logging when the ground is frozen to reduce soil damage (MN DNR 2020; WI DNR 2020). Reduced forest productivity for boreal species (Duveneck et al. 2024) will lead to socioeconomic impacts such as loss of employment in the timber industry and increased cost of wood products. Important cultural connections to forests are at risk due to declines in species like paper birch, ash, and white cedar, which are important to Native American Tribes as well as other non-timber forest products including maple syrup (Handler et al. 2012).

Comprehensive work by the Great Lakes Indian Fish and Wildlife Commission (GLIFWC, 2023) sharpens our focus on the impact of changing forest conditions on wildlife and people in the Great Lakes region. They assessed the vulnerability of 66 beings of concern to GLIFWC member tribes, including crawlers (reptiles and amphibians), flyers (birds), four-leggeds (mammals), plants, and swimmers (fishes). These categories are commonly used in Ojibwe culture. Vulnerability integrates exposure, or the amount of change to temperature or precipitation, and sensitivity, which is the ability of a being to tolerate change (Young et al. 2016), with adaptive capacity, which is the ability of a species to adapt or move based both on Traditional Ecological Knowledge (TEK) and Scientific Ecological Knowledge (SEK). Essentially, the authors adjusted the vulnerability score based on knowledge expressed in TEK interviews with tribal members.

The most vulnerable category were the swimmers. However, many of the most vulnerable beings include forest or forest wetland species – including wabooz (snowshoe hare), mooz (moose), mashkiigwaatig (tamarack), giizhikaatig (northern white cedar), waabizheshi (American marten), and ininaandag (northern white cedar), wiigwaasaatig (paper birch) and two other trees, baapaagimaak (black ash) and ziinzibaakwadwaatig (sugar maple). While wildlife and plants may persist if able to shift their range, “Because reservation and Ceded Territory boundaries are legally fixed in place, and treaty rights are limited in geographic scope, Ojibwe tribal members today do not enjoy the same ability to move across the landscape in response to changing environmental conditions that allowed their ancestors to survive and thrive” (GLIFWC 2023).

GLIFWC has observed impacts on treaty resources already. General concerns include:

1. The current and likely expanded impact of bakaan ingoji gaa-ondaadag (Objibwe for non-local beings or invasive species) and manidoonsag (little spirits/pests and pathogens).

2. Indirect effects that cause a cascade of impacts such as the protective effect of snow to reduce browsing on minn (blueberry) or assist animals to hunt.

3. Cultural impacts such as more erratic temperatures that reduce or prevent any ziinzibaakwadwaaboo (maple sap) collection.

4. Direct temperature effects stressing forest beings like mooz (moose).

Maintaining Forest Resilience to Disturbance

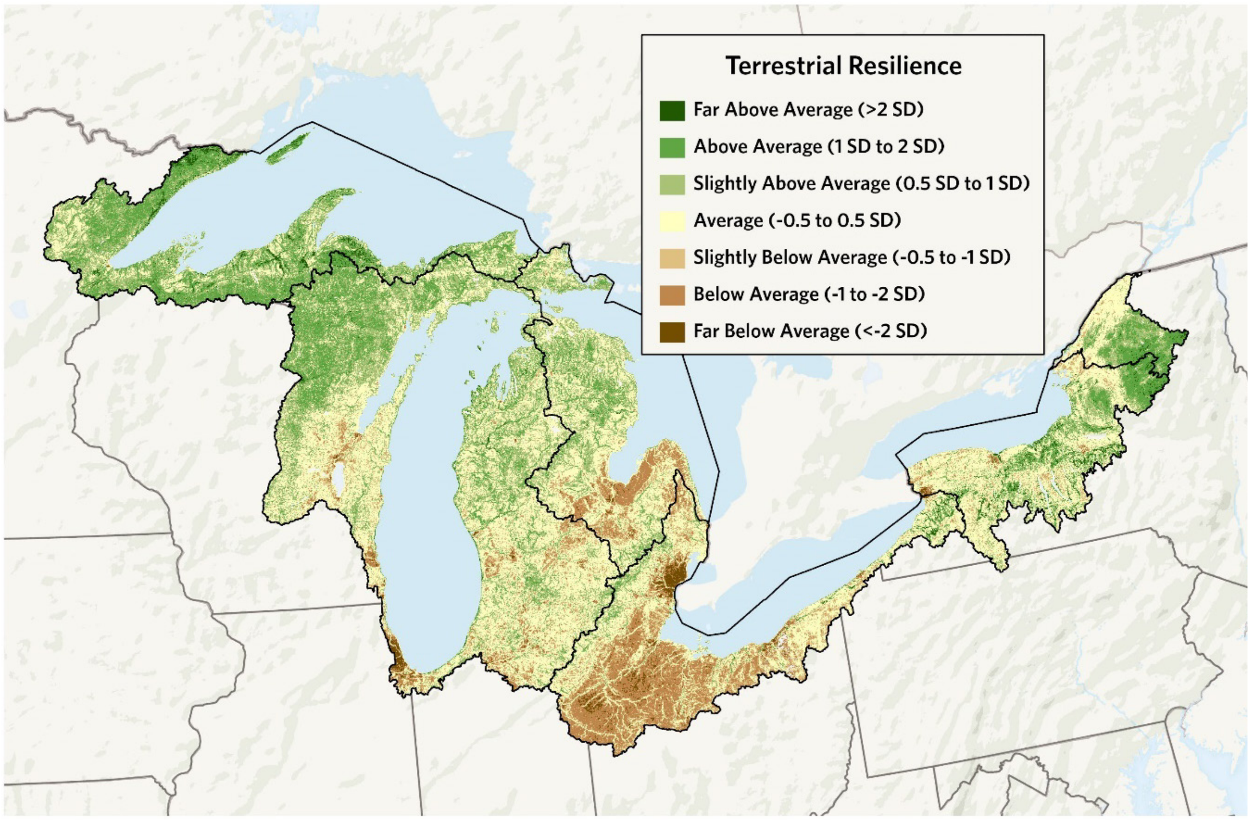
The forests of the Great Lakes play an essential role in maintaining natural strongholds for biodiversity in the face of more extreme disturbances. Lasting conservation depends on identifying and protecting places where long term changes and extreme events are buffered by the natural properties of the site. Natural strongholds are places where the direct effects of temperature and precipitation extremes are moderated by complex topography and connected natural cover, and where the current landscape contains high quality biodiversity features. In these sites, species can find areas of suitable moisture and temperature within their local neighborhood. This allows resident species populations to remain strong and helps ensure that changes in the composition and structure of the communities will be more gradual.

The Nature Conservancy mapped terrestrial resilience using natural stronghold concepts to estimate a site's capacity to maintain species diversity and ecological function as the ambient environment changes (Anderson et al. 2023). The terrestrial resilience score integrates a site's landscape diversity and local connectedness. While landscape diversity is not necessarily related to forest cover, the extent of natural forest is integral to local connectedness. Connected landscapes are places that allow species to move and disperse, and processes like fire or water movement can occur unimpeded. This facilitates the adjustments necessary for the natural world to stay balanced with the climate. Permeable landscapes have an abundance of connected natural cover.

Because the Great Lakes region crosses multiple ecoregions and two major analysis regions of TNC's study (Anderson et al. 2018; Anderson et al. 2016), our standard relative scoring within each ecoregion presents challenges in interpretation and comparison within the Great Lake region. To make scores comparable across the whole geography we used our basic "unstratified" resilience score for the Great Lakes/Tall Grass Prairie region and for the Eastern US. region before it was stratified by ecoregion and setting. We created a single resilience unstratified dataset covering the region with seven classes ranging from "Far Above Average" to "Far Below Average" (Figure 3-25).

Resilient sites are defined as those scoring greater than 0.5 standard deviations (SD) above the mean. Considering all land in the Great Lakes Basin, 42% of the entire area scores resilient, 39% average and 19% below average. Forested lands in the region are more resilient with 64% of the region's forested lands scoring resilient, 34% average, and 2% below average. National forest lands within the Great Lakes Basin score more resilient than other forests, with 80% of national forest lands scoring resilient, 19% scoring average, and only a tiny fraction under 1% scoring less than average. These high scoring national forest lands and other high scoring natural areas could serve as important natural strongholds where the species and ecosystems of this region will be more likely to adapt to change and continue to function into the future.

Figure 3-25. Terrestrial resilience of the Great Lakes assessment area.



By major watershed, the percentage of land that is resilient varies from a high in Lake Superior with 80% of the total area and 82% of the forested land resilient, to a low in Lake Erie-Lake St. Clair where only 10% of the area scores resilient and 24% of the forested land scores resilient (Table 3-3). Lake Erie forests are particularly vulnerable and score far below all other drainages, which could cause Lake Erie to be a strong impediment to the successful exchange and function of forest species and ecosystems throughout the Great Lakes Basin system. In contrast, at least 65% of the forests in Lake Superior, the Upper St. Lawrence, and Lake Ontario are resilient, and about 55% of forests in Lake Huron and Lake Ontario are resilient. These watersheds have many more options for species and a higher likelihood that species and ecosystems will be able to adapt and successfully function into the future.

Table 3-3. Terrestrial resilience by Great Lake watersheds for forested lands and all land cover.

Percent Resilient	Region	Lake Superior	Upper St. Lawrence	Lake Michigan	Lake Ontario	Lake Huron	Lake Erie
Forests	64%	82%	73%	65%	56%	54%	24%
All land cover	42%	80%	63%	44%	42%	37%	10%

Overall, the Great Lakes Basin retains a large amount of resilient land and resilient forests, with over half of the forests scoring resilient in all watersheds except for Lake Erie. It will be important to maintain forest cover and connectivity in these currently resilient forest settings to ensure species and ecosystems will be able to adapt to climate changes in the future. Forests in the Lake Erie watershed are vulnerable to climate disturbance impacts and efforts to improve and restore forests here would be particularly valuable to improve resilience.

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Chapter 4: The Benefits of Forested Landscapes

Trees - - - are always trees - - - with roots deep in earth - - trunks and limbs held high - - -by the texture of the bark – - - the spread of the boughs – - - the sweep of the twigs - - - each kind has a character all its own.

--Gwen Frostic

KEY POINTS

The **connection between forested lands and high water quality** is clear when one compares the distribution of forested land and measurements of nutrients and sediments in rivers. For example, streams that scored "Poor" for nitrogen from the National Rivers and Streams Assessment had on average 33-48% less forest upstream than streams that ranked "Good" for nitrogen.

Using data from the USFS Forests to Faucets (2.0) we found that an area's ability to produce clean water was a function of high forest cover and mean annual water yield, which is a function of precipitation patterns. The **areas with the highest ability to produce clean water** are in the Upper Saint Lawrence, Lake Superior and Lake Ontario watersheds. Over 16 million acres of forests (44%) are found in watersheds with high importance for surface drinking water supply. Importance correlates to proximity to population centers.

Combining the Forest to Faucets metrics highlights where increasing and protecting forest cover can boost clean water production. Eight percent of the region's forests have high importance for surface drinking water but are located within watersheds with low ability to produce clean water. Forest restoration could improve their ability to produce clean water. Thirty-five percent of forests are in watersheds that have both high importance and medium or higher ability to produce clean water. Almost 80% of this category of forests are unprotected from conversion and would thus be important places to prevent further deforestation.

Another benefit of forest restoration is flood prevention. Areas with little flood prevention provided by forests are concentrated along the coastal and more agricultural areas of the region, particularly in the Lake Erie basin.

Hundreds of species depend on Great Lakes forest habitat, which supports especially high species richness for birds, particularly in areas where there is natural variability in forest succession classes. Forests also provide habitat value for Brook Trout, a recreationally important species. In Michigan streams, Brook Trout had the most valuable biomass for stream fishes as a measure of anglers' willingness to spend money to fish.

KEY POINTS CONT.

Timber harvesting is a key forest management tool that helps shape forest structure and composition. Timber harvest is concentrated in a few counties in the northern lower peninsula of Michigan, the Upper Peninsula of Michigan, northern Wisconsin, and northeastern Minnesota and is happening at a volume that allows for regeneration. In the last 20 years, most of this harvest (52%) has occurred on private land, with 25% on state land. Twenty-two million acres of forest land is sustainably certified.

In the Great Lakes region, **timber harvesting, processing, and manufacturing support thousands of jobs,** particularly in rural areas of Michigan, Wisconsin, and Minnesota. In Michigan, the forest products industry provides over 91,000 jobs, many of which are in rural communities. Most of the employment in the timber economy is in the processing of timber into paper (33%) and wood (64%).

Recreation accounts for over a million jobs and $69 billion in wages in the US Great Lakes Basin. About ¼ of all counties have a recreation-based economy, clustered in the forested northern basin and along the lakeshore.

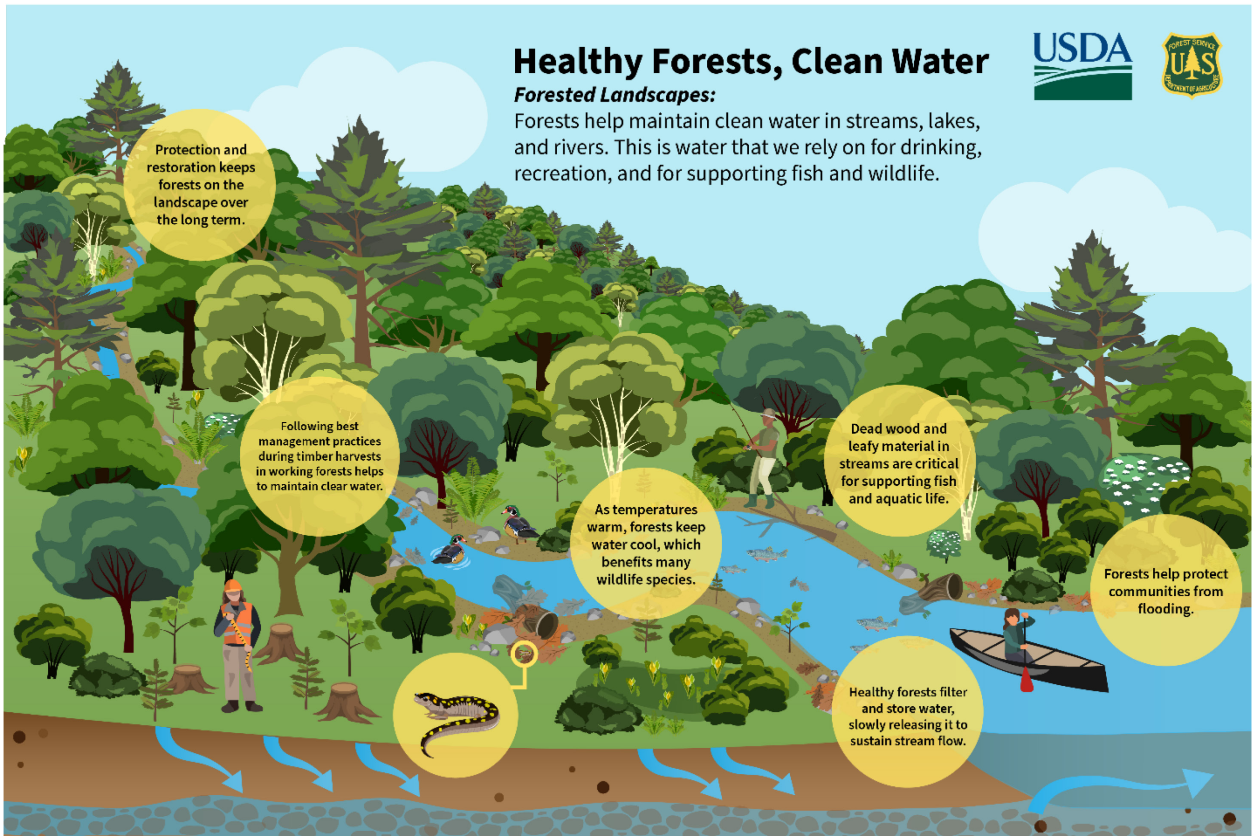
National forest user data shines a spotlight on recreation use: **the four most common uses of the five reporting national forests** are viewing natural features, viewing wildlife, relaxing, and hiking/walking.

The collection of **non-timber forest products**, a label that belies the great variety of foods, medicines and artisanal resources that come from forests, are difficult to track fully but best estimates are that the total value of these goods was **$645 million from** 2013-2022. Game meat is the exception in terms of data and tracking. Forests in the Great Lakes states combined provided about **94 million servings of meat** over five years.

Forested land near population centers is especially important for meat products. From **mapping deer harvest data provided by state DNR offices**, you can see that the counties and suburbs outside Green Bay, Detroit, Grand Rapids, and Cleveland have the highest amount of harvest. The counties with large blocks of forested land in northern Minnesota, Wisconsin, Michigan, and New York have very low deer harvest.

The full range of how forested ecosystems are valued in the Great Lakes Basin is challenging to describe because it encompasses economic, intrinsic, ecological, and spiritual dimensions. This chapter examines some of the key benefits of natural forests, including water supply and quality, wildlife habitat, biodiversity, carbon absorption, and economic opportunities.

Figure 4-1. Benefits of forested landscapes to clean water.



Benefits for Water

Forests provide many benefits and ecosystem services but producing clean and abundant water is one particularly valuable service for nature and people, as all life depends on water (Figure 4-1). As water demand and population increases, these services will be critical to helping maintain the quantity and quality of water and to reduce the costs of water treatment.

Forests are essential to maintaining clean water. Trees collect and filter rainfall, regulating the flow of water back into streams and rivers while filtering out excess nutrients and sediments (Kreye et al. 2014). In naturally forested regions, losses in tree cover are associated with declines in water quality, particularly spikes in nitrogen, while the maintenance of high forest cover ensures healthy aquatic ecosystems can sustain macroinvertebrates such as insect larvae, snails, or worms, which form the base of the food chain and are good indicators of water health. A recent study in an eastern US watershed (OSI 2024) found statistically significant changes in chemistry, macroinvertebrates, and fish between 50 and 80 percent forest cover, well above regulatory or conventional thresholds. These included significant increases in sodium, magnesium, calcium, chloride, nitrate, total nitrogen, and conductivity as forest cover decreased. Brook Trout were more abundant at sites with over 95% forest cover but were replaced by the more thermally tolerant brown trout as forest cover decreased below 60%. The study also found that maintaining forest cover across even a relatively small area of 21,000 acres resulted in the avoidance of an estimated $57 million in total stormwater capital costs and $6 million in annual maintenance costs for projected development (OSI 2024).

Forest Benefits to High Quality Water in the Great Lakes Basin

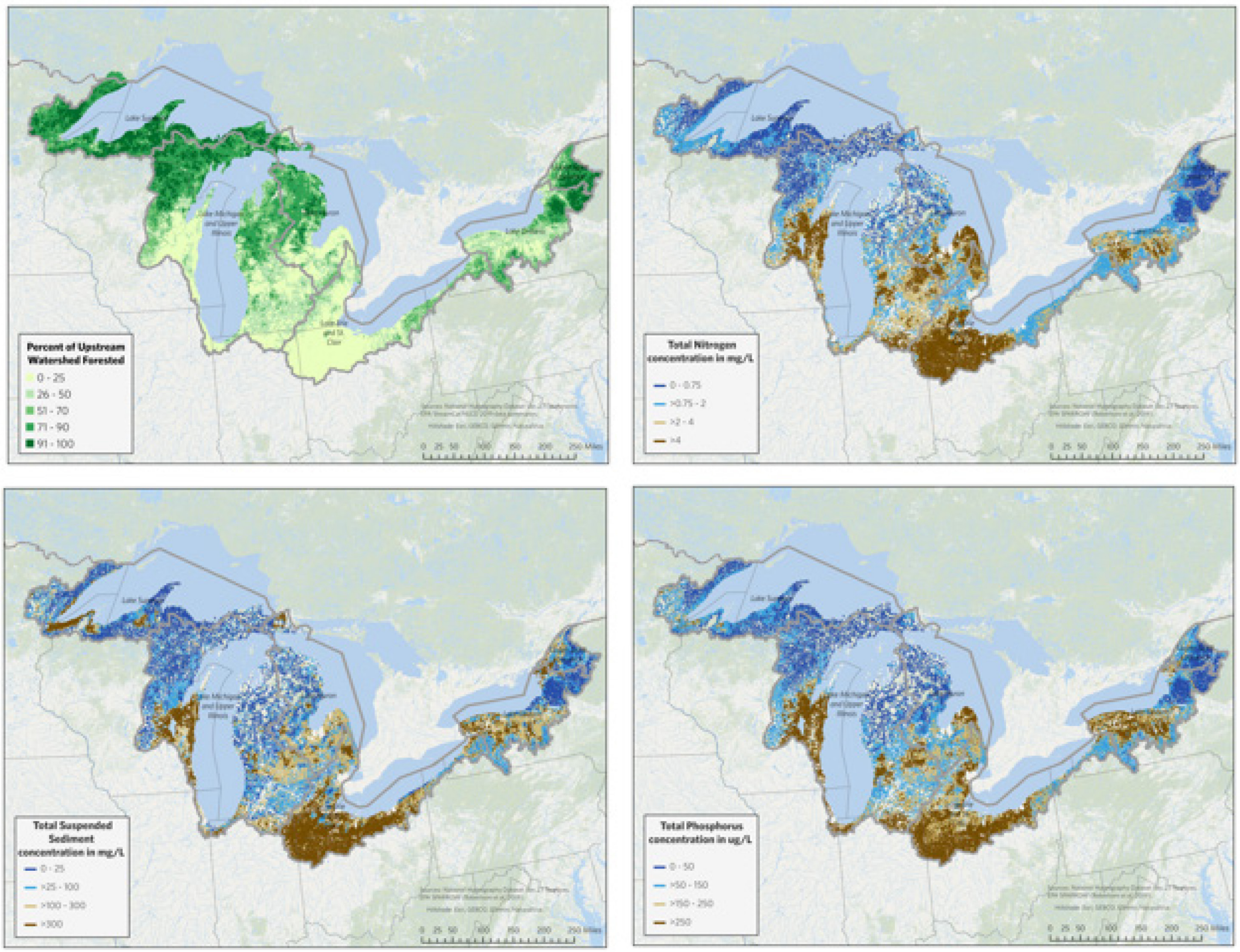
This section looks at watershed measures and riparian indicators of water quality.

In the Great Lakes Basin, a simple visual comparison of forested lands in a watershed (Hill et al. 2016; NLCD 2019) and nutrient levels for nitrogen (Figure 4-2 a & b), phosphorous (Figure 4 a & d), and sediments (Figure 4 a & c; Saad & Robertson 2019) shows a clear correlation between more forested lands and lower nutrient and sediment levels. These values, however, are relative measures and do not tell us how nutrient levels relate to aquatic ecosystem integrity. The National Rivers and Streams Assessment (NRSA), an US EPA, state, and Tribal partnership to assess the condition of rivers and streams across the United States, does just that. The NRSA established thresholds of “Good,” “Fair,” and “Poor” nutrient levels for aquatic ecosystem integrity in streams and rivers, adjusted for Omernik ecoregions (US EPA 2024). Mapping the stream nitrogen and phosphorous concentration (Robertson & Saad 2019) using these NRSA thresholds in appropriate ecoregions (Table 4-1), we can identify streams that have “Good,” “Fair,” and “Poor” aquatic ecological integrity for these nutrients (Figure 4-3, Figure 4-4). Overall, 10% of streams are rated “Good” for nitrogen, 17% are “Fair,” and 73% are “Poor.” For phosphorous, the distribution is very similar, with 16% “Good,” 11% “Fair,” and 73% “Poor.”

If we examine the results by individual Great Lake basin, results are reflective of land cover, with Lake Superior having the highest % of streams in the “Good” category for both nitrogen (38%) and phosphorous (35%), Lake Michigan and Lake Huron with 11% and 8% “Good” for nitrogen, and 21% and 31% for phosphorous. Lake Erie and Lake Ontario scored almost entirely “Poor” for both nitrogen (99% and 93%, respectively) and phosphorous (95% and 84%, respectively).

Figure 4-2. Great Lakes assessment area shown by a. % forest in upstream watershed, b. total nitrogen, c. total suspended sediments, and d. total phosphorous. (Sources: Hill et al. 2016; NLCD 2019; Robertson & Saad 2019)

a. b.



c. d.

Table 4-1. Thresholds from the NRSA for good, fair, and poor levels of nitrogen (N) and phosphorous (P) for three Omernik Ecoregions.

Ecoregion (Omernik)	Total N (ug/L) Good	Total N (ug/L) Fair	Total N (ug/L) Poor	Total P (ug/L) Good	Total P (ug/L) Fair	Total P (ug/L) Fair
Northern Appalachians	<345	345-482	>482	<17.1	17.1-32.6	>32.6
Upper Midwest	<583	583-1,024	>1,024	<36.3	36.2-494.9	>494.9
Temperate Plains	<700	700-1,274	>1,274	<88.6	88.6-143	>143

Figure 4-3. Streams in the Great Lakes assessment area shown by their National River and Stream Assessment (NSRA) nitrogen class.

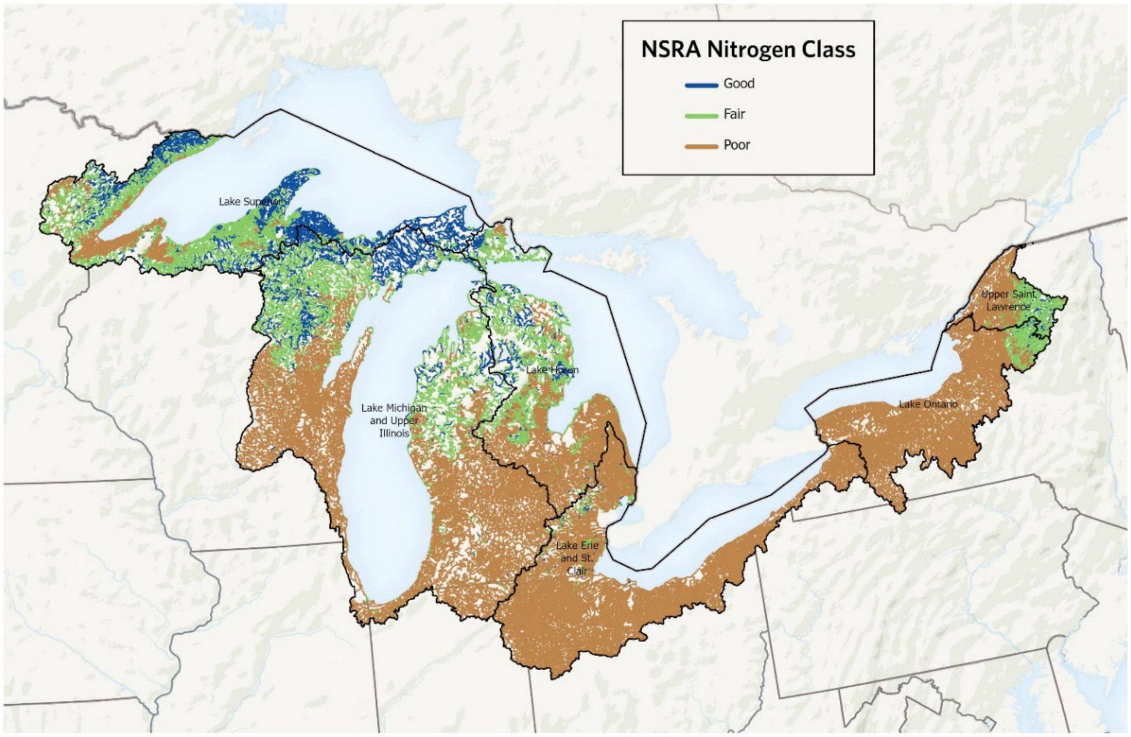
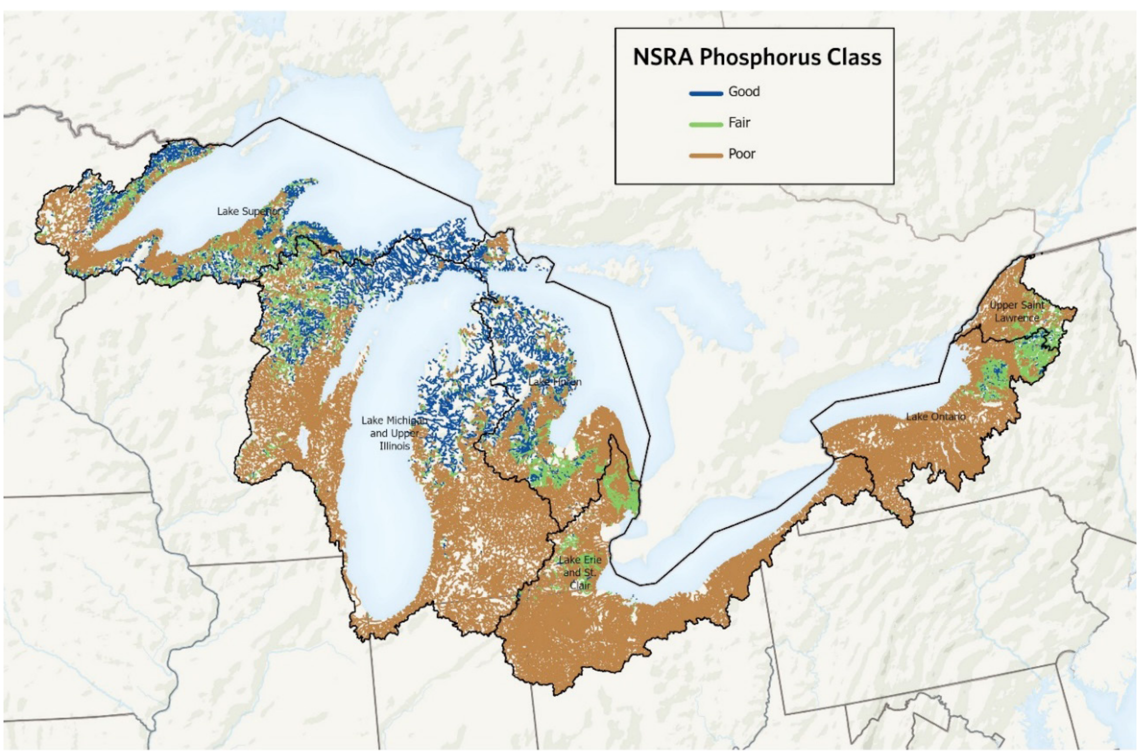


Figure 4-4. Streams in the Great Lakes assessment area shown by their National River and Stream Assessment (NSRA) phosphorous class.



These data further highlight the strong relationship between percent forest in the upstream watershed (Hill et al. 2016) and the nutrient impact class. Using ANOVA, we tested if the NRSA "Good," "Fair," and "Poor" stream classifications had significantly different percentages of upstream forest in the three ecoregions used in NRSA, Northern Appalachians, Upper Midwest, and Temperate Plains. For both nitrogen and phosphorus there was a significant difference in the forest percentage of the upstream watershed between the "Poor," "Fair," and "Good" streams in all three ecoregions (significant $p < 0.01$). Streams that ranked "Poor" for nitrogen (i.e., too much nitrogen) had on average between 33-48% less upstream percent forest than streams that ranked "Good" for nitrogen. Streams that ranked "Poor" for phosphorus had between 19-43% less upstream percent forest than those ranking "Good," depending on region. In the Temperate Plains ecoregion, streams that ranked "Fair" for phosphorus also had 25% less upstream forest compared to streams that ranked "Good" for phosphorus ($p < 0.01$).

Forest cover in riparian zones, the lands immediately adjacent to rivers and lakes, is especially integral to maintaining clean and abundant water. The State of the Great Lakes Report, which covers the US and Canada (ECCC & US EPA 2022), uses forest cover in the riparian zones within each Great Lake sub-basin as the indicator of how well forests are performing hydrologic functions and protecting the physical integrity of the watershed. Each are integral to maintaining high quality water. The authors refer to decades of research and monitoring that have established the relationship between high forest cover and good water quality and water retention by reducing runoff and erosion. The ecosystem objective in the State of the Lakes report is for forest cover in riparian zones "to have a forest composition and structure that reflects natural ecological diversity (i.e., under present climate conditions of the region)." The status of riparian forest cover in the 2022 report was "Good" for Lake Superior, which has 96% of its riparian zones in forest cover; "Fair" for Lake Michigan, Lake Huron, and Lake Ontario, which have 66%, 78%, and 65% forest cover in their riparian zones, respectively; and "Poor" for Lake Erie, which has 35% forest cover in its riparian zones. The importance of riparian forests is further explored in Chapter 5.

Forest Benefits to Drinking Water

To evaluate the provision of clean water by forests in the Great Lakes assessment area, we used the Forest Service's Forests to Faucets 2.0 dataset (Mack et al. 2022). This dataset scored watersheds for their importance to surface water supply and their ability to produce clean water. Forests to Faucets is the only available wall-to-wall spatial analysis linking forests, water, and people across the United States. Its relative scores provide an important standard for comparison across and within our region of analysis.

We focused on two key metrics, the Relative Ability to Produce Clean Water (APCW_R) and the Relative Important Areas for Surface Drinking Water (IMP_R). Both metrics were reported on a relative national scale, which ranged from 0 (lowest relative importance) to 100 (highest relative importance). A watershed's ability to produce clean water was evaluated using an index that integrated five watershed characteristics: percent natural cover, percent agricultural land, percent impervious cover, percent riparian natural cover, and mean annual water yield. The relative importance for drinking water score was based on water supply and water demand for each watershed. Watershed surface public water supply demand was estimated by summing the total number of surface water supply customers in each watershed with a proportion of consumers served by downstream intakes. The water use metric does not incorporate ground water withdrawn for public and private water supply and does not incorporate surface water used for industry, irrigation, livestock, mining, and thermoelectricity (Mack et al. 2022).

Ability to Produce Clean Water

The Great Lakes Basin contains large areas that have a high natural ability to produce clean water: 5.4 million acres of the Great Lakes 38 million acres of forest (14%) are in watersheds that have high ability to produce clean water (relative ability score > 60; Figure 4-5 & Figure 4-6). These forests provide valuable ecosystem services for nature and people by maintaining the ability to produce high quality clean water. Another 27.2 million acres of forest (72%) are within watersheds that have medium ability to produce clean water (relative ability score 30 – 60), while 5.2 million acres of forest (14%) are in watersheds that have low ability to produce clean water (relative ability score <30). Riparian forest (30-m buffer on streams, Lilja et al. 2023), had a larger percentage in the low ability class (25%) compared to all forests (14%). In the Great Lakes Basin, these patterns are reflective of land use where watersheds with less natural cover have less capacity to produce clean water. However, the score is also affected by the mean annual water yield (one of the key inputs to the model). Mean annual water supply varies from lows of 200-300 mm/yr in parts of eastern Wisconsin and eastern Michigan to highs of 800-1,000 mm/yr in parts of the Adirondacks given the dominant precipitation patterns. In comparison to the rest of the country, water yield in the Great Lakes region is in the middle range, so although land use may be highly natural, water yield can still be less than in some other parts of the country.

By lake sub-basin, the Upper Saint Lawrence drainages, Lake Superior, and Lake Ontario have the highest ability to produce clean water with scores over 45 at the HUC12 scale (Figure 4-6). Very high scoring areas (>70) are found in the Adirondack mountains along with some smaller areas in western Upper Peninsula of Michigan draining into Lake Superior. Lake Erie and St. Claire have the lowest ability to produce clean water with scores of 27. Lake Huron, with a score of 30, and Lake Michigan, with a score of 38, are more mixed in their ability to produce clean water. The latter sub-basin contains small watersheds with a wide range of scores, including 11% of its area falling in the higher producing classes (above 50) and a large amount of the area (41%), falling in the mid-range 40-50 score range.

The high scoring sub-basins contain large intact forested areas while the lowest (Lake Erie-St. Clair) has the lowest natural cover and includes large cities such as Cleveland, Detroit, and Toledo, along with agricultural land in northwestern Ohio. Results can be mixed spatially within a single sub-basin. For example, the Lake Michigan basin has higher scores in the northern portion of Michigan's lower peninsula, but lower scores near Milwaukee and Green Bay in Wisconsin and near Grand Rapids, Kalamazoo and Lansing Michigan where again, urban, suburban, and agricultural land use impacts the ability to produce clean water.

Figure 4-5. Ability to produce clean water by HUC12 watershed. This map shows the HUC12 watersheds by their score for relative ability to produce clean water.

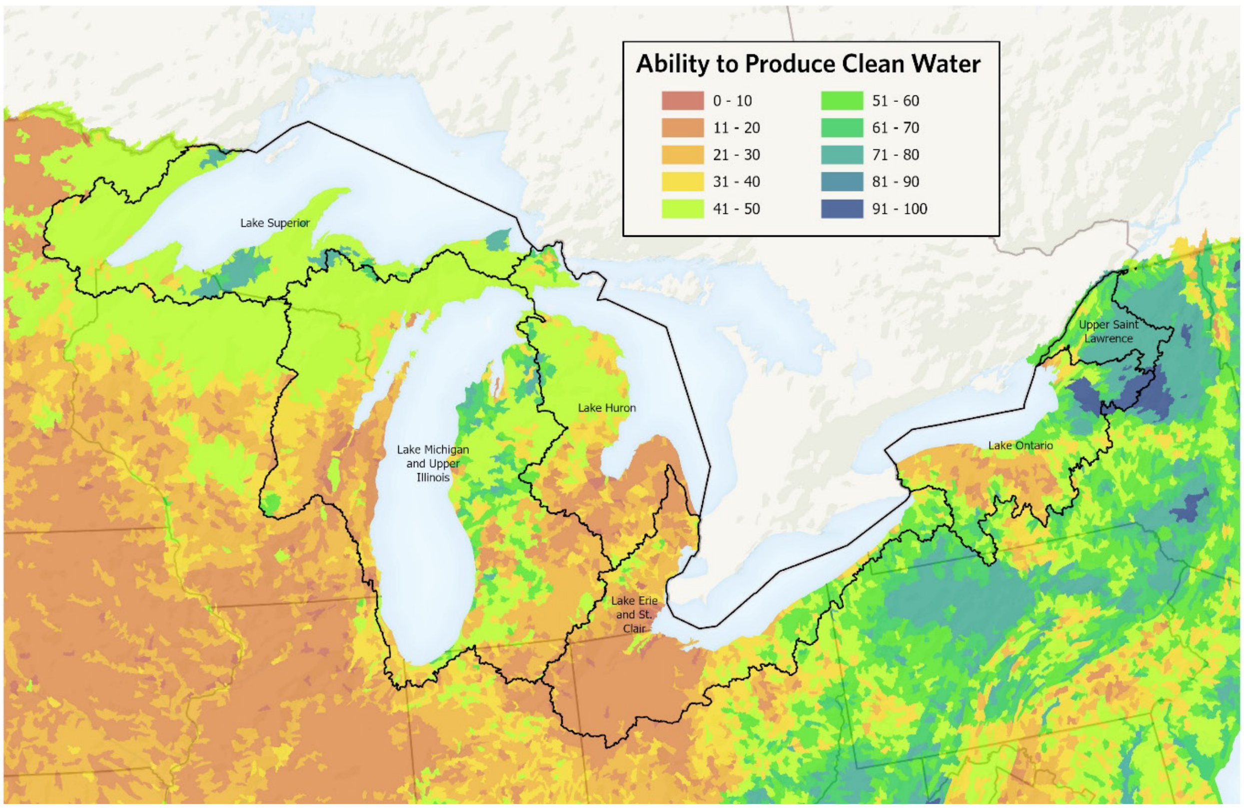
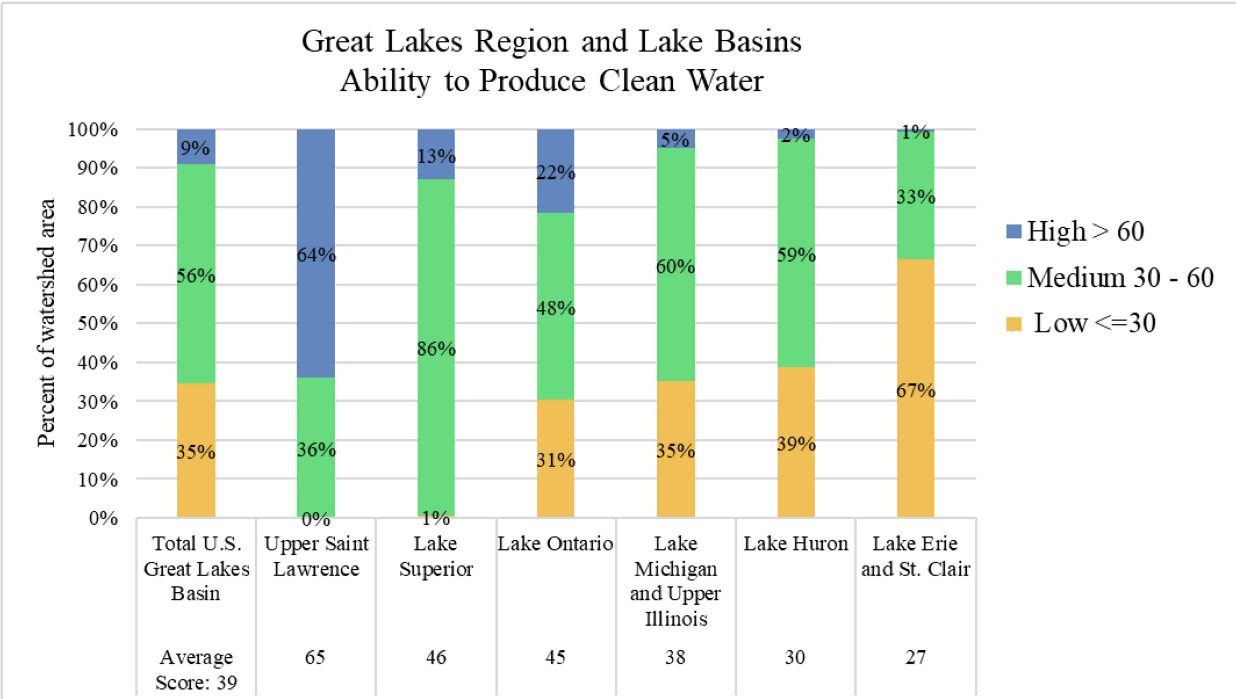


Figure 4-6. Ability to produce clean water summary chart. This chart shows the percentage of each basin falling into each score class along with the overall area-weighted average index score**.**



Important Areas for Surface Drinking Water

The Great Lakes region also contains a high proportion of watersheds that are important for providing surface water to large populations. Watersheds scoring high in the Important Areas for Surface Drinking Water index are defined as those that serve the most people on surface drinking water systems (i.e., high demand) and that provide the most water (i.e., high ability to produce water; USFS 2022). In the Great Lakes region, 55% of the watershed area scored as high importance for surface drinking water supply (relative importance > 60), while 27% of the area scored in the low importance class (relative importance < 30; Figure 4-7).

These results highlight watersheds where forests are contributing to meeting high water demand and where these forests contribute significantly to the watershed's higher ability to produce clean abundant water. For example, 16.6 million acres of Great Lakes forests (44%) are found in watersheds with high importance for surface drinking water supply. Another 8.5 million acres of forest (22%) are within watersheds that have medium importance for surface drinking water supply, while 12.8 million acres of forest (34%) are in watersheds that have low importance for surface drinking water supply (Figure 4-7). When limited to riparian zones (30-m buffer from streams, USDA 2023), 54% of riparian forests are in the highly important surface drinking water supply class.

Because the water demand component of this importance index reflects patterns in population and settlement in the region, the spatial pattern of where the highest scoring watersheds occur is different than the ability to produce clean water metric, which is based on biophysical watershed conditions. In the southern Lake Michigan basin, there are areas with high importance scores around the cities of Lansing and Grand Rapids in Michigan and around Milwaukee and Green Bay in Wisconsin where large populations draw on public surface water systems (Figure 4-8). Lake Superior and Lake Huron have the lowest importance for surface drinking water consumers. Although much of the Lake Superior and Lake Huron basins have moderate to high ability to produce clean water, these basins have much lower population density and number of surface water consumers.

Figure 4-7. Important areas for surface drinking water by HUC12 watershed. This map shows the HUC12 watersheds by their relative importance for surface drinking water score.

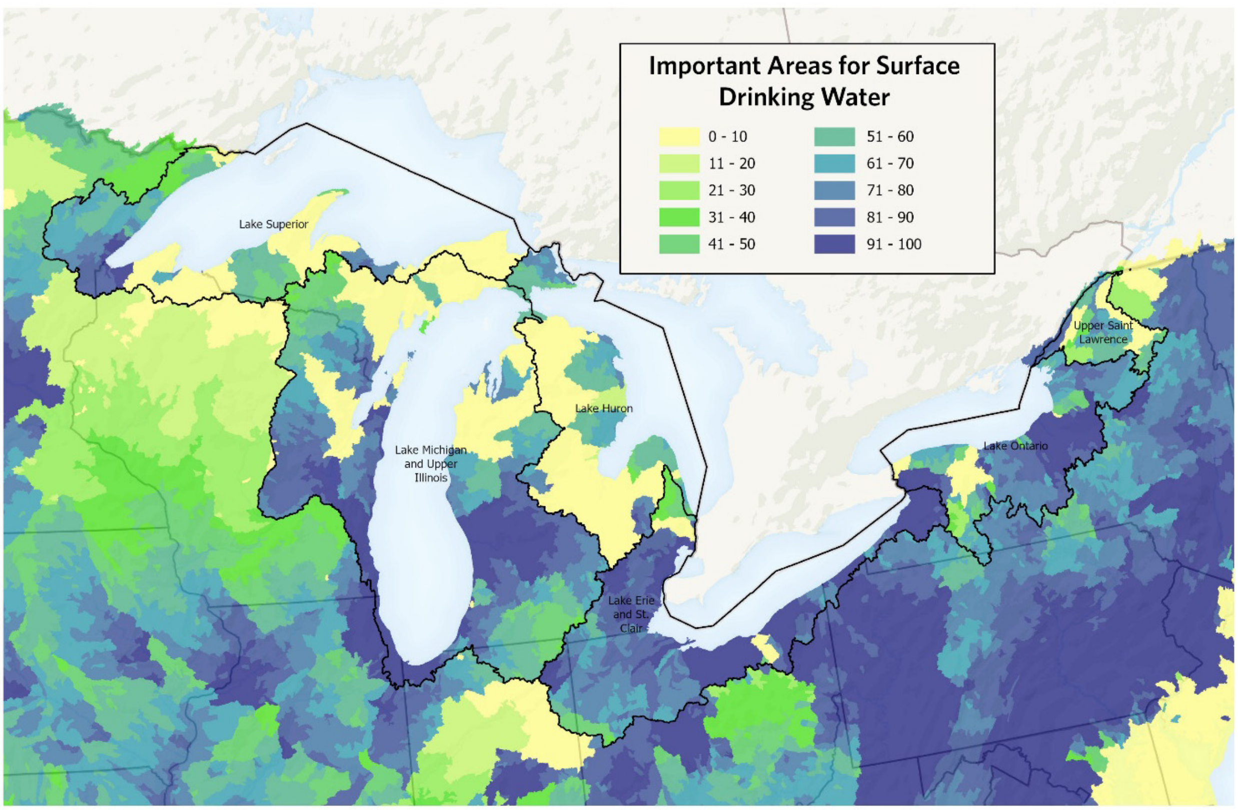
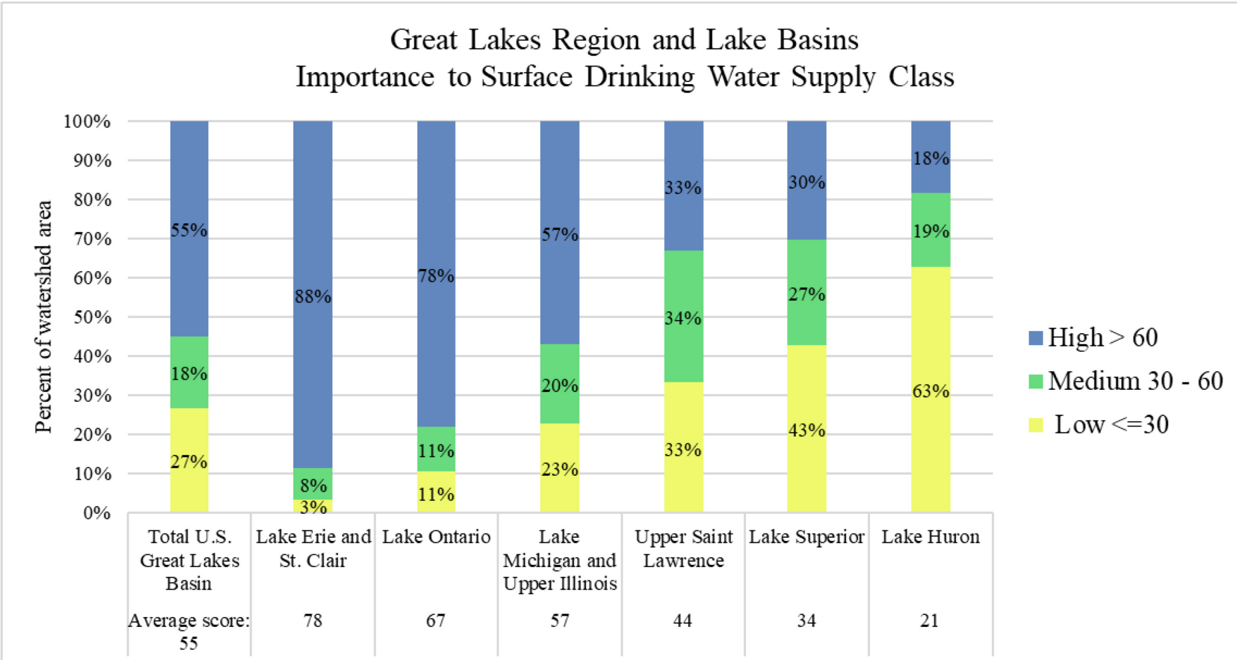


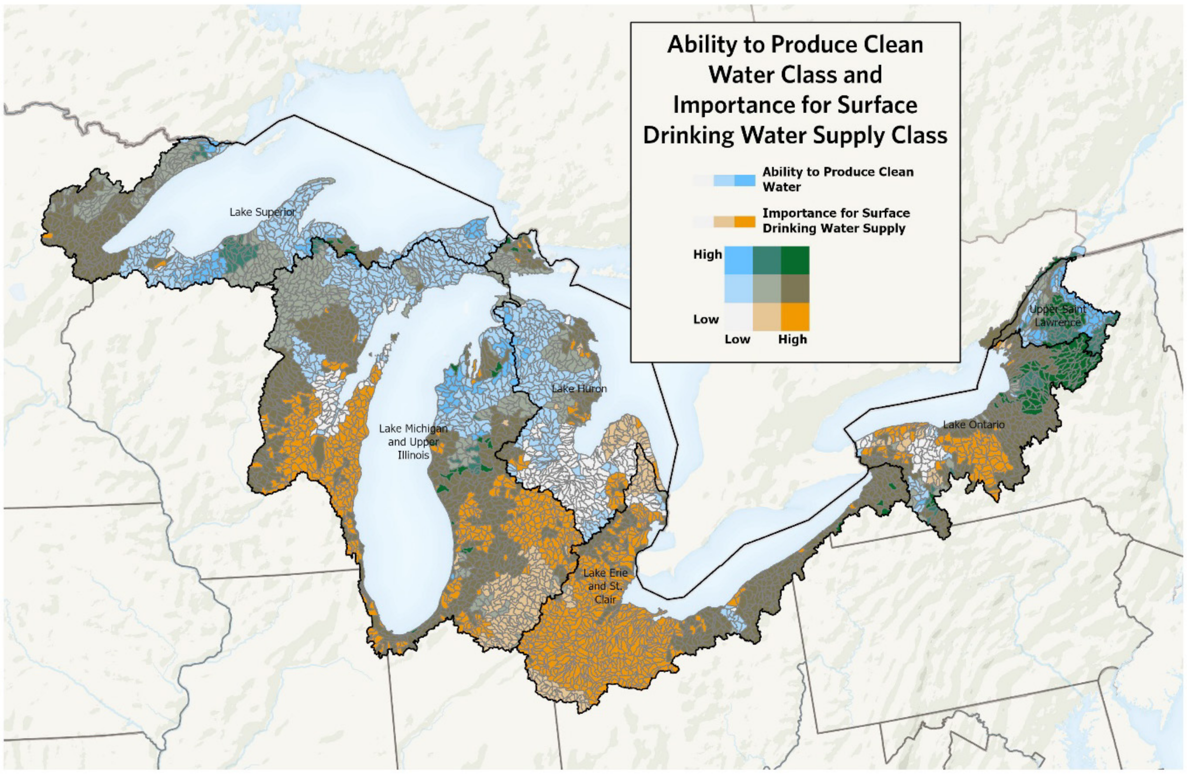
Figure 4-8. Important areas for surface drinking water summary chart. Area-weighted average score and percentage of land falling in each class by lake basin**.**



Integrating Ability to Produce Clean Water and Importance for Surface Drinking Water

When the two metrics from Forests to Faucets are viewed together, for most of the region the scores are mismatched with 75% of watersheds falling into different classes (Figure 4-9). This is because Ability to Produce Clean Water highlights intact forest areas regardless of human population, while in contrast, Importance to Surface Drinking Water is correlated with population size. Considering current forest cover, a total of only 5% of the forests in the Great Lakes have both high importance and high ability to produce water (green watersheds in Figure 4-9). These forests are very critical places in terms of naturally producing high quality clean water which is in high demand as drinking water for people. Another 30% of the forests are high in importance and have a medium ability to produce water (brown watersheds in Figure 4-9). These areas have a high drinking water demand, but only moderate ability to produce clean water. Although watersheds with high importance for drinking water but low ability to produce clean water (orange watershed in Figure 4-9) cover a large proportion of the region (23%), this area is dominated by agriculture and development with little remaining forest. Eight percent of the region's forests have high importance for surface drinking water but are in watersheds with low ability to produce clean water. With forest restoration, these watersheds could improve in their ability to produce clean water for the many people who depend on surface drinking water in these areas. These remaining areas of forest are also important places to protect from further deforestation.

Figure 4-9. Integration of ability to produce clean water and importance for surface drinking water. This map uses a bivariate color ramp to show how HUC12 watersheds score in terms of low, medium, and high classes for the combination of these two key metrics.



Comparison of Water Supply Metrics to Conservation Lands

Long-term forest conservation and management in the Great Lakes region will foster forests' continued ability to produce clean water. We quantified the current level of protection from development for forests that contribute to water supply by summarizing the amount of conservation land within each Ability to Produce Clean Water and Importance for Surface Drinking Water class (Table 4-2). We define conservation land as land that is permanently secured against conversion to development, including public land designated for conservation, but also land with no formal designation where the landowner or easement holder's intent is for permanent conservation. We used the Conservancy's Secured Lands dataset, which is compiled bi-annually from over 60 state, federal, and private sources (CRCS 2024).

Considering both the ability to produce clean water and the importance to drinking water supply class of a watershed, the forests in the small area with both high importance for drinking water and high ability to produce clean water are well conserved, with 44% protected from development. Forests in other areas that have high importance for surface drinking water consumers, but with lower ability to produce clean water, are less protected, with only 18% of medium ability and 6% of low ability forests in high drinking water importance watersheds protected from development. Given the importance of these forests to water supply consumers, these could be places to focus efforts on maintaining, managing, and expanding forest cover for the preservation of the valuable water supply services they contribute.

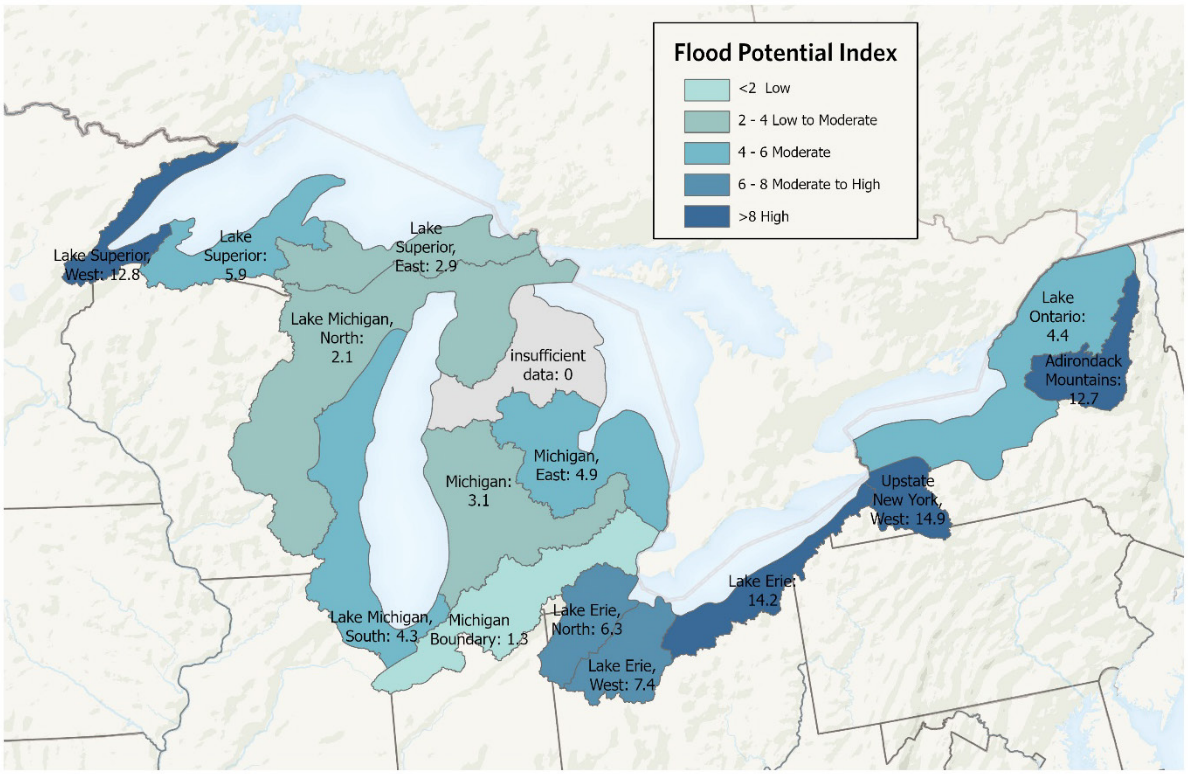
Table 4-2. Conservation land and forest by importance to surface drinking water supply (IMP) and ability to produce clean drinking water. This table subdivides the IMP classes by their ability to produce clean water category and provides conservation status percentage and forest acreage for the groupings.

Importance for Surface Drinking Water Supply (IMP)	Ability to Produce Clean Water	Total Forest Acres in the Region	Percent of all Forest in the Region	Percent Protected from Conversion to Development	Percent Not Protected from Conversion to Development
IMP Low	Low	1,157,796	3%	8%	92%
	Medium	9,773,302	26%	45%	55%
	High	1,910,709	5%	42%	58%
IMP Low Total		***12,841,807***	*34%*	*41%*	*59%*
IMP Medium	Low	904,850	2%	6%	94%
	Medium	6,144,545	16%	49%	51%
	High	1,485,916	4%	53%	47%
IMP Medium Total		***8,535,311***	*22%*	*45%*	*55%*
IMP High	Low	3,224,108	8%	6%	94%
	Medium	11,321,416	30%	18%	82%
	High	2,031,203	5%	44%	56%
IMP High Total		***16,576,726***	*44%*	*19%*	*81%*
Grand Total		**37,953,844**	100%	32%	68%

Benefits for Flood Prevention

Riverine flooding can cause significant damage to human life, infrastructure, and property (Johnson et al. 2020). Although all streams and rivers in the Great Lakes region experience naturally high spring flows, the magnitude of expected floods across the Great Lakes region varies due to differences in topography, soils, and land use. The magnitude of expected floods can be quantified using the Flood Potential Index score from the Forest Service’s Flood Potential Portal (Yochum et al. 2024). These data highlight that within the Great Lakes Basin, areas with relatively higher flood potential include the Adirondack Mountains, upstate New York, Lake Erie coastal zones, and Western Lake Superior (Figure 4-10). The relative index values can also be used to quantify the difference in flood potential between areas. For example, the Lake Superior West zone experiences floods 4.4 times larger, on average, than the floods experienced in the Lake Superior East zone (12.8/2.9 = 4.4).

Figure 4-10. Flood Potential Index (Yochum et al. 2024). Darker blue colors indicate higher flood potential, while lighter blue colors indicate lower flood potential.



Forests are critical to preventing flooding and contribute to flood prevention through the following key processes (Vari et al. 2022):

- **Water Absorption and Infiltration**: Forests act like sponges, absorbing and storing large amounts of rainwater, which delays its passage into streams and rivers thus mitigating flood risk. The complex root systems of trees and other vegetation increase soil porosity, allowing more water to infiltrate into the ground rather than running off the surface.

- **Slowing Water Flow**: The dense vegetation in forests, including trees, shrubs, and leaf litter, slows down the movement of water. Interception by the tree canopy and leaves reduces the speed and volume of runoff, which helps to lower the peak flow of water during heavy rains.

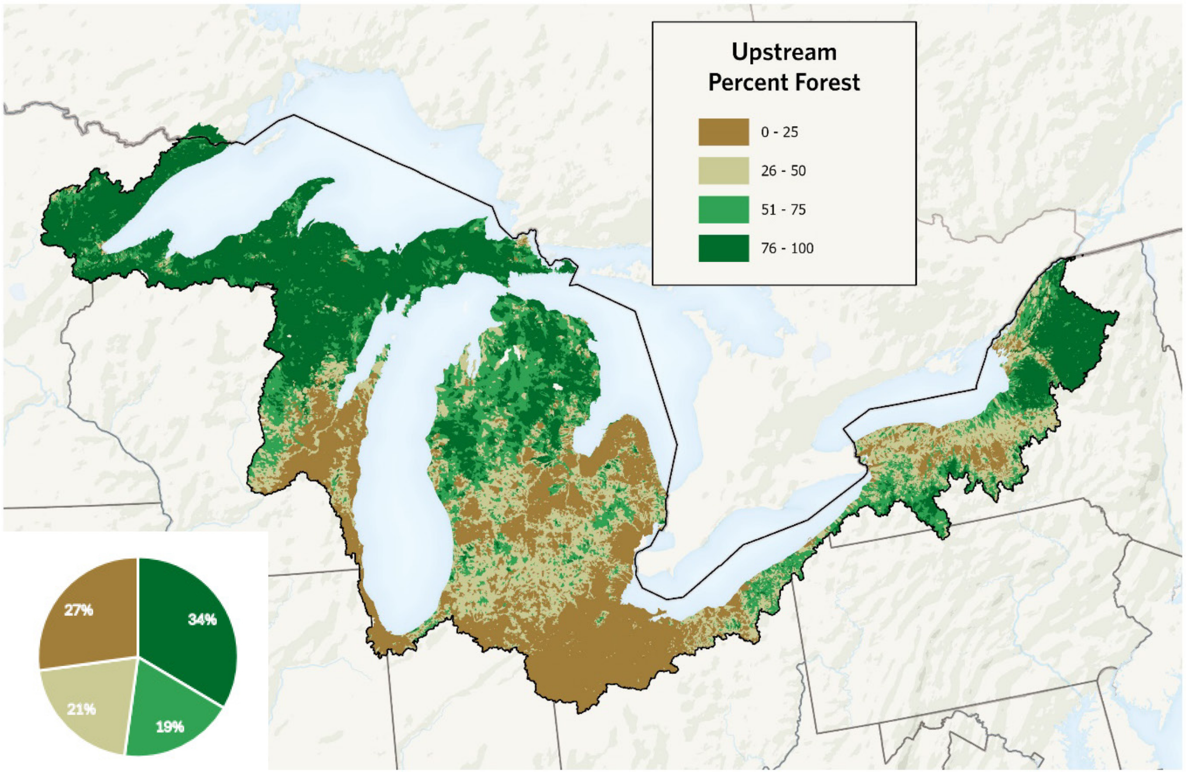
- **Evapotranspiration**: Trees take up water from the soil and release it back into the atmosphere through evapotranspiration. This reduces the amount of water that remains in the soil, thereby increasing its capacity to absorb more water during rainfall

- **Reducing Soil Erosion**: Forests help to stabilize the soil with their root systems, preventing soil erosion and stabilizing stream channels. This is important because eroded soil can clog waterways and reduce their capacity to carry water, leading to increased flooding. Eroded sediment can also be transported via floods and deposited on downstream communities.

Watershed natural vegetation cover has been identified as the most influential flood prevention ecosystem characteristic in a recent survey of flood regulation ecosystem services literature and experts (Vari et al. 2022). By mapping the amount of upstream forest cover across the Great Lakes region, we can identify areas that are expected to receive high flood prevention benefits from their upstream watershed forest cover (Figure 4-11). Results show a similar pattern to overall land use patterns, with areas having the highest flood prevention benefit from forests (green watersheds) concentrated in the forest dominated areas of northern Minnesota, Northern Wisconsin, Michigan's Upper Peninsula, Michigan's Upper Lower Peninsula, and areas of the Adirondacks and Tug Hill mountains of New York. Areas with little flood prevention benefit from forests (brown watersheds) are concentrated along the coastal and more agricultural areas of the region, particularly the Lake Erie basin. Overall, 34% of the region fell in the highest flood prevention class with more than 75% of the upstream watershed forested, while 27% of the region fell in the lowest flood prevention class with less than 25% of their upstream watershed in forest cover.

In addition to watershed forest cover helping reduce high flows and water from accumulating to a flood stage height (flood prevention), once water has accumulated in stream channels, flood damage to downstream communities can be further mitigated by maintaining opportunities for water to spread out and be stored within the floodplain. This floodplain mitigation benefit is primarily determined by the geometrical or topographic characteristics of the broader floodplain which allow water to be stored in deeper depressions and low gradient areas (Vari et al. 2022). In addition to the retention of stored water in floodplains, maintaining or restoring floodplain forest can contribute to decreasing flow velocities and strengthening stream banks which reduces erosion and sediment transport downstream via flood waters (Zukswert & Nislow 2024). Maintaining floodplains in natural cover can also reduce economic losses and damages to human settlements and infrastructure when floodplains are temporarily inundated and store water during floods.

Figure 4-11. Watershed catchments by upstream percent forest. (Sources: USGS NHD V 2.1 Medium Resolution Catchments 2016; USGS StreamCat; NLCD 2023).



Benefits for Wildlife

The forests of the Great Lakes Basin provide a rich tapestry of habitats, supporting a plethora of animals - frogs, toads and salamanders, birds, mammals, snakes and turtles, at least 300 vertebrate species in all. In addition to these forest-dependent vertebrates, across the Great Lakes watershed there are over 1,000 species of fish, mussels, crayfish, freshwater snails, and aquatic insects. We compiled forest vertebrate information from state species lists available from NatureServe Explorer (NatureServe 2024a) and used habitat preferences of forest, forested wetlands, woodland, and savanna to filter out forest vertebrates (NatureServe 2013). Then we used widely available range information to identify those species that occur within the Great Lakes assessment area. In some cases, whether a species occurred in Michigan served as a proxy for being a Great Lakes species. The fish list was compiled from HUC8 fish distributions (NatureServe 2008). The remaining species counts came from a query with NatureServe Explorer Pro for the Great Lakes assessment area (NatureServe 2024b). The full list of forest vertebrate species can be found in Appendix A.

Great Lakes forests are especially rich in birds and are essential to breeding bird communities (Table 4-3). The western Great Lakes region has a notable diversity of bird species for North America (Niemi et al. 2016). As with all forest biota, birds play essential functions in maintaining healthy forest ecosystems, particularly through seed dispersal and controlling pests (MN DNR 2020). About 7% of the species in the US Great Lakes watershed are globally rare, as determined by their NatureServe ranking of Critically Imperiled (G1), Imperiled (G2), or Vulnerable (G3) and 11% appear on the Forest Service's Eastern Regional Forester Sensitive Species (RFSS) list (USFS 2024). The lack of early successional and old growth forests has been linked to the declines of specific bird populations such as the golden-winged warbler, whippoorwill, and others (WI DNR 2020; NY DEC 2020). Where early successional habitat is available in Minnesota, it contains 47% of the breeding population nests for golden-winged warblers in the state (MN DNR 2020).

Table 4-3. Animal species in the Great Lakes assessment area.

Habitat	Taxa Group	Extant Species	Globally Rare (G1-G3)	Forest Service Eastern Regional Forester Sensitive Species
Forest	Amphibians	21		2
Forest	Birds	194	1	13
Forest	Mammals	63	2	5
Forest	Reptiles	18	2	5
Forest	Forest sub-total	296	5	25
River	Fishes (riverine)	141	4	3
River	Mussels	45	11	14
River	Crayfishes	8	0	1
River	Freshwater snails	57	9	0
River	Terrestrial insects	500	68	37
River	Aquatic insects	148	18	52
Forest & River	**Grand total**	**1,195**	**105**	**132**

Brook Trout (*Salvelinus Fontinalis*) provides another example of how essential forested habitats are to species thriving now and for their resilience in the future. Trout Unlimited (TU) analyzed the suitability of Brook Trout habitat patches to support robust populations across the Great Lakes Basin (TU 2021). We compared the "Conserve Strongholds" category, which is the highest value habitat, to forest cover in the basin. Across all land uses (NLCD 2023), "Conserve Strongholds" comprise 24% of the landscape or about 10.5 million acres. Of this land, 90% is forested, reflecting the significant habitat value of forests to Brook Trout. Forests contribute to lower water temperatures through shading, water quality and physical habitat and higher populations of Brook Trout have been documented at sites with relatively more forest cover in their catchments (Stranko et al. 2008). Public lands play a significant role in protecting Brook Trout habitat. State and federal lands make up 43.9% of the total area of the "Conservation Strongholds," with 18.9% National Forest land. Maintenance and restoration of habitat quality for Brook Trout also provides significant economic value. Melstrom et al. (2014) found in Michigan streams that Brook Trout had the most valuable biomass for stream fishes as a measure of anglers' willingness to spend money to fish. Another indicator of this value is the economic output generated by spending on stream restoration activities. In the Great Lakes Basin in 2012, projects funded through the American Recovery and Reinvestment Act (2009), directed $17.5 million to employment generating $28.8 million in output, which is defined as gross output (sales or receipts and other operating income, plus inventory change) minus intermediate inputs (consumption of goods and services purchased from other industries or imported; Samonte et al. 2017).

Benefits for the Economy

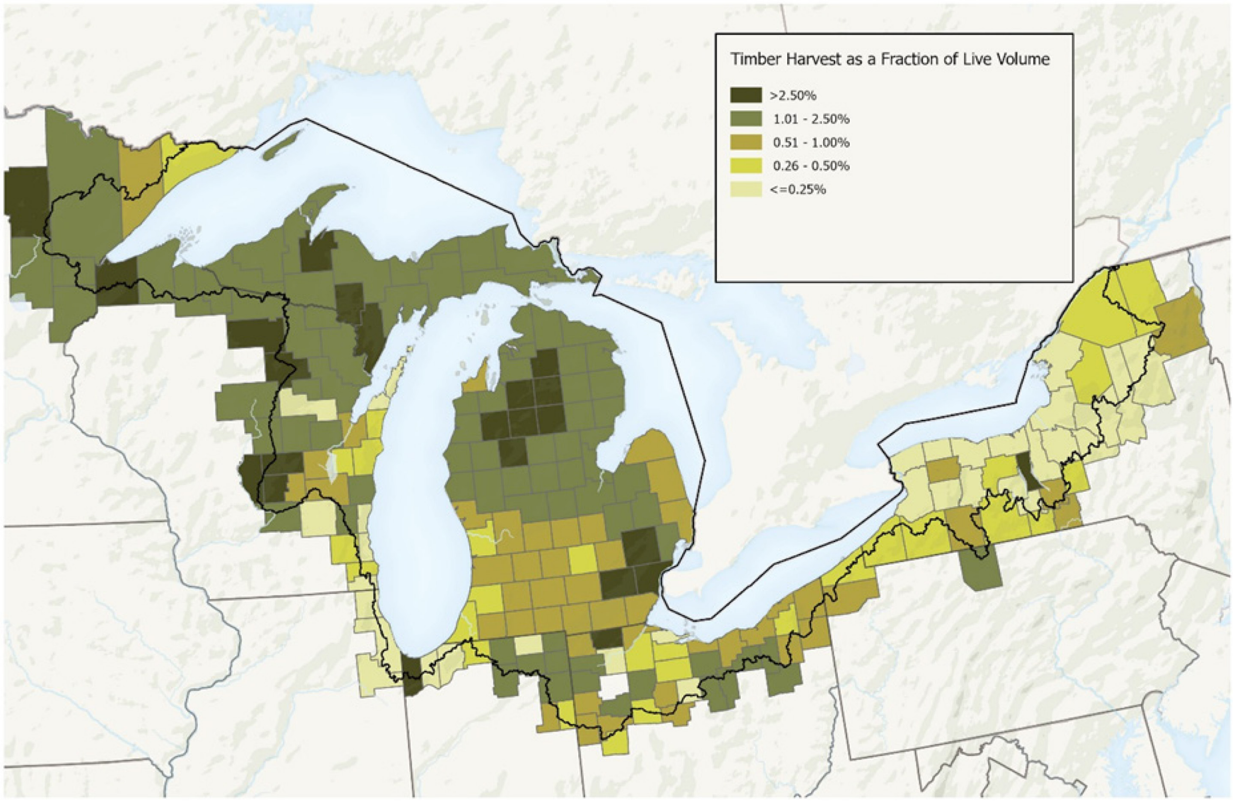
Providing Quality Wood Products while Sustaining Great Lakes Forests

Before wood products can be created, trees must first be harvested and the timber transported to processing facilities. While timber resources and harvesting operations are found across the United States, only a small portion of forests are subject to intensive harvesting. When done responsibly, tree harvesting can be a sustainable practice that supports the regeneration of healthy, resilient forests.

Timber harvesting is a key forest management tool that helps shape forest structure and composition. Through selective cutting, forest managers can guide forest development to meet the needs of both current and future generations. Because trees naturally regrow, they are considered a renewable resource. One of the primary goals of forest management is to ensure that the rate of harvesting and natural tree mortality does not exceed the rate of forest growth. This balance helps maintain a continuous supply of timber while allowing harvested areas to regenerate into thriving new forests. Across the Great Lakes Basin, harvest volume represents low percentages of standing timber volume (Figure 4-12) when measured through FIA plot data summaries (EVALIDator 2025). The higher areas of timber harvest as a percentage of live volume occur in the northern lower peninsula of Michigan, the Upper Peninsula of Michigan, northern Wisconsin, and northeastern Minnesota. The forests of New York have the smallest timber harvest as a fraction of live volume. The high values around Chicago and Detroit reflect the smaller amount of live volume.

Looking only at the total area of forest turnover (the temporary change from forest to non-forest that returned to forest in the 20-year period) which is a result of timber harvesting, when summarized over the last 20 year (for methods and sources see Chapter 3), most forests that had turnover were on private landownership and family forests (52%; Figure 4-13). These lands are owned by individuals or families, often passed down through generations. Management goals vary widely—from income generation to conservation or personal enjoyment. Decisions are more flexible but can be influenced by market conditions and personal values. On privately owned lands, harvesting can be less predictable and more economically driven. Some landowners harvest infrequently or not at all, while others may harvest intensively during high market prices or for

Figure 4-12. Timber harvest as a fraction of live volume by county. Timber volume in forests is constantly in flux, and harvest plays an important role in shaping the future of forests.



land conversion (see Private Owners Value of Woodlands in the Great Lakes States below for more detail). According to a 2024 study, harvest decisions on private lands are highly responsive to timber prices, especially in high-production regions (Wear & Coulston 2024).

State land contributes a smaller but stable share of timber (25%), often used to support local mills and rural economies. Harvesting is guided by long-term forest management plans that include ecological assessments, public input, and sustainability goals. These plans often span 10–20 years and are updated regularly. Many state forests are certified under programs like Forest Stewardship Council (FSC) and Sustainable Forestry Initiative (SFI).

Corporate forests and timber management organizations (TIMOs) manage and harvest a smaller amount of Great Lakes forests. Corporate forests are often more intensively managed than family forests, focusing on timber yield and operational efficiency. Family forest owners control the majority of private forest land, but corporations and TIMOs manage some of the largest contiguous tracts, making them influential in regional timber markets and policy.

Forest certification is a system that ensures forests are managed sustainably, balancing environmental, social, and economic values. It provides a way for consumers to identify wood and paper products that come from responsibly managed forests. Forest certification is a voluntary, third-party process that verifies forests are managed according to defined sustainability standards. Today, 116 million acres of US forestlands are sustainably certified. Forty-four million of those acres (38%) are in the eight Great Lakes states. Today, about 22 million acres in Great Lakes states are FSC certified, and another 22 million are certified under the SFI (Mason 2025; Figure 4-14).

Figure 4-13. Total acres of forest turnover by ownership type, over the last 20 years.

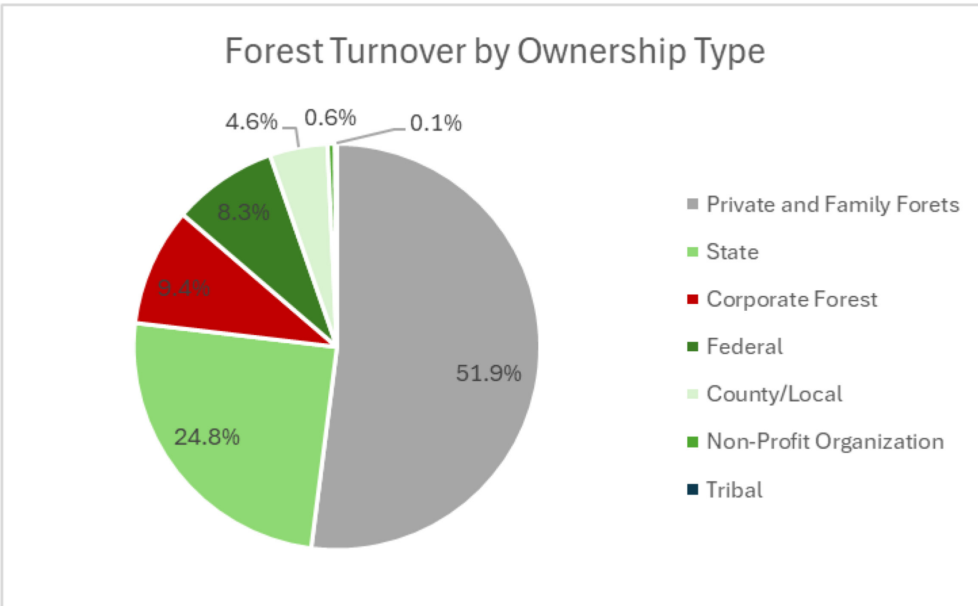
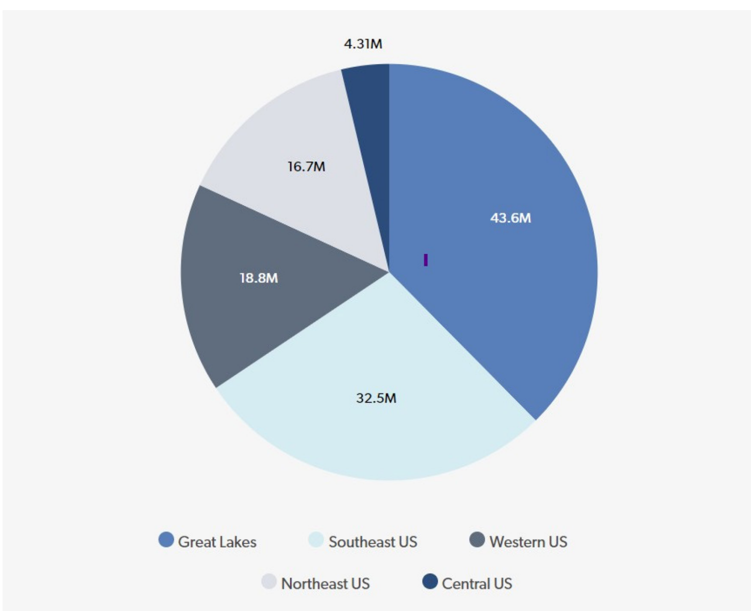


Figure 4-14. The Great Lakes Basin leads the nation in certified forest acres (from Mason 2025).



The Michigamme Highlands Project is a great example of cooperation for sustainable forest management. It is a collaboration between the Michigan DNR and Lyme Great Lakes Timberlands to protect 73,000 acres through a working forest conservation easement (Figure 4-15 ; Michigan DNR 2025). This ensures sustainable forest management, prevents fragmentation, and maintains public access. The conservation easement will ensure that the forest is managed sustainably and keeps the working forest working. The property provides an estimated $4 million in local economic impact and 47 forestry jobs. The property will remain privately owned, maintaining local tax revenue.

Figure 4-15. Michigamme Highlands. © Jason Whalen/Big Foot Media.

Forest Industries Keep America Working

The forest products industry contributes approximately $300 billion annually to the US economy and accounts for 4% of US manufacturing GDP (USFS 2025). In the Great Lakes region, timber harvesting, processing, and manufacturing support thousands of jobs, particularly in rural areas of Michigan, Wisconsin, and Minnesota. In Michigan, the forest products industry supports over 91,000 jobs, many of which are in rural communities (Poudel 2022). In the Great Lakes region, most timber employment is in the manufacturing of wood and paper products, not in logging (Figure 4-16, US Bureau of Labor Statistics 2025). Timber employment by sector varies geographically (Figure 4-17).

Mills that process timber to make wood products provide a major source of employment for forest industry workers in the Great Lakes. Visually comparing Figure 4-17 and Figure 4-18, you can see the overlap with mill locations and timber economy employment. Hardwood mills are prevalent throughout the Great Lakes, with a few mills that process both hardwoods and soft-woods. The mills map shows the variety of types of products produced and varied capacity of the mills with some mills producing several types of products.

Figure 4-16. Timber economy employment by sector in the Great Lakes region.

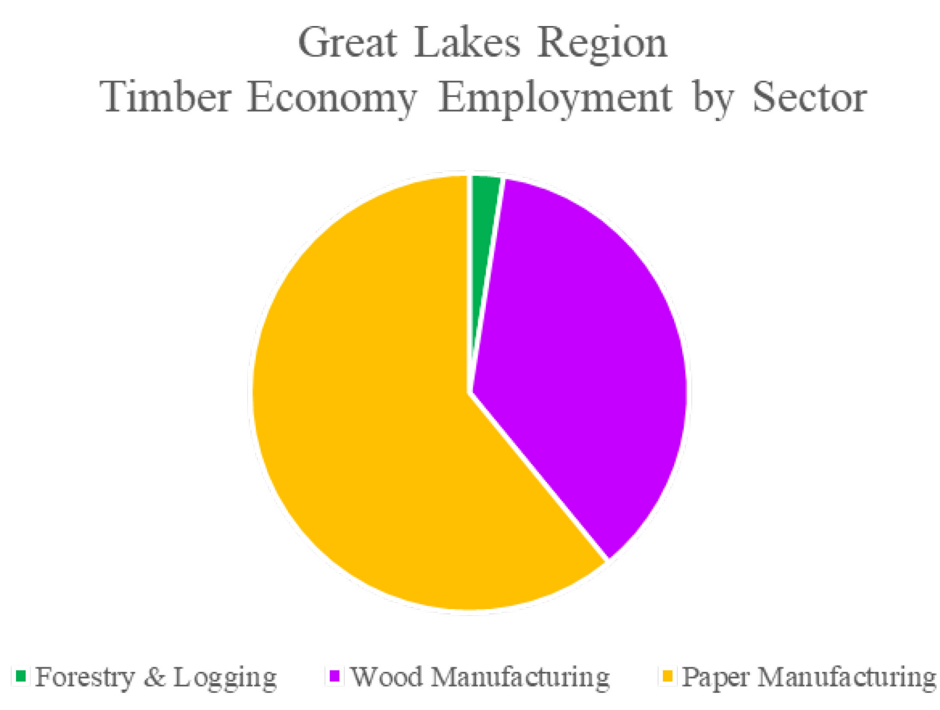


Figure 4-17. Map of timber economy employment by sector in the US Great Lakes Basin.

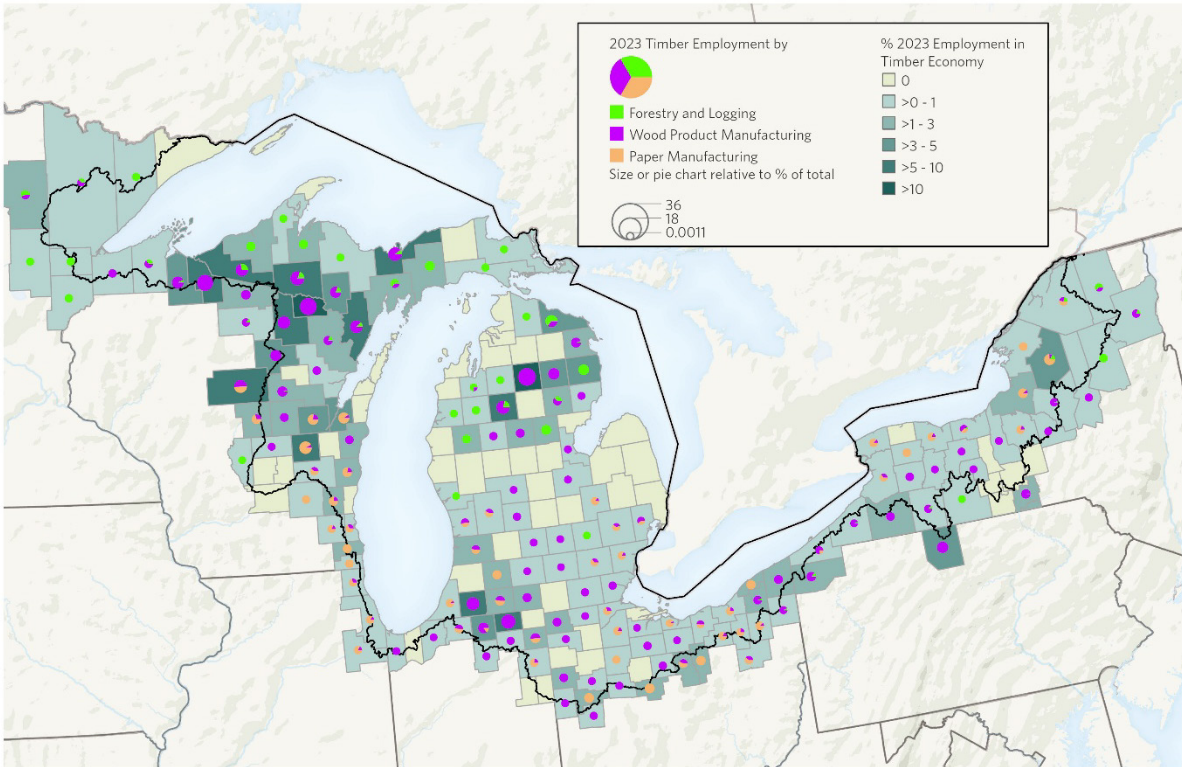
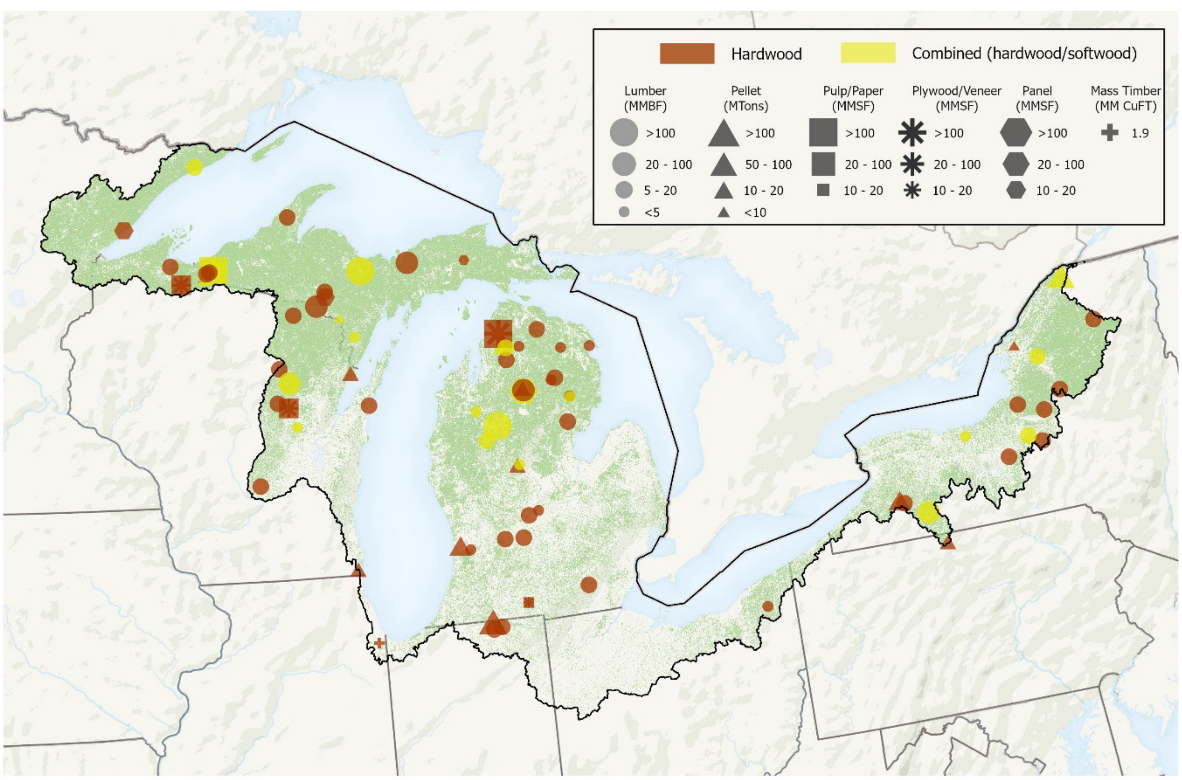


Figure 4-18. Primary wood-producing mills of the Great Lakes. This map shows the myriad locations, types, and sizes of mills in the region (Forisk Consulting 2024).



Carbon Sequestration and Carbon Markets

Private Owners Value of Woodlands in the Great Lakes States

The Forest Service's National Woodland Owners Survey is an annual survey sent randomly to 12,000 private woodlands owners to collect information on forest characteristics, ownership objectives, demographics, and attitudes. In terms of economic value, on average, 17% of woodland owners sell trees from their lands and 48% cut trees for their own use. These survey results also reveal general attitudes towards the importance of forests. The following are the top ten reasons to own woodlands and the average percentage of owners who selected that value across the eight Great Lakes states (USFS 2021a-h):

1. Beauty or scenery 83%
2. Wildlife habitat 81%
3. Nature protection 74%
4. Privacy 73.5%
5. Water protection 67%
6. Family legacy 58%
7. Recreation 56%
8. Hunting 54%
9. Raise family 49%
10. Land investment 45%

Recreational Economies

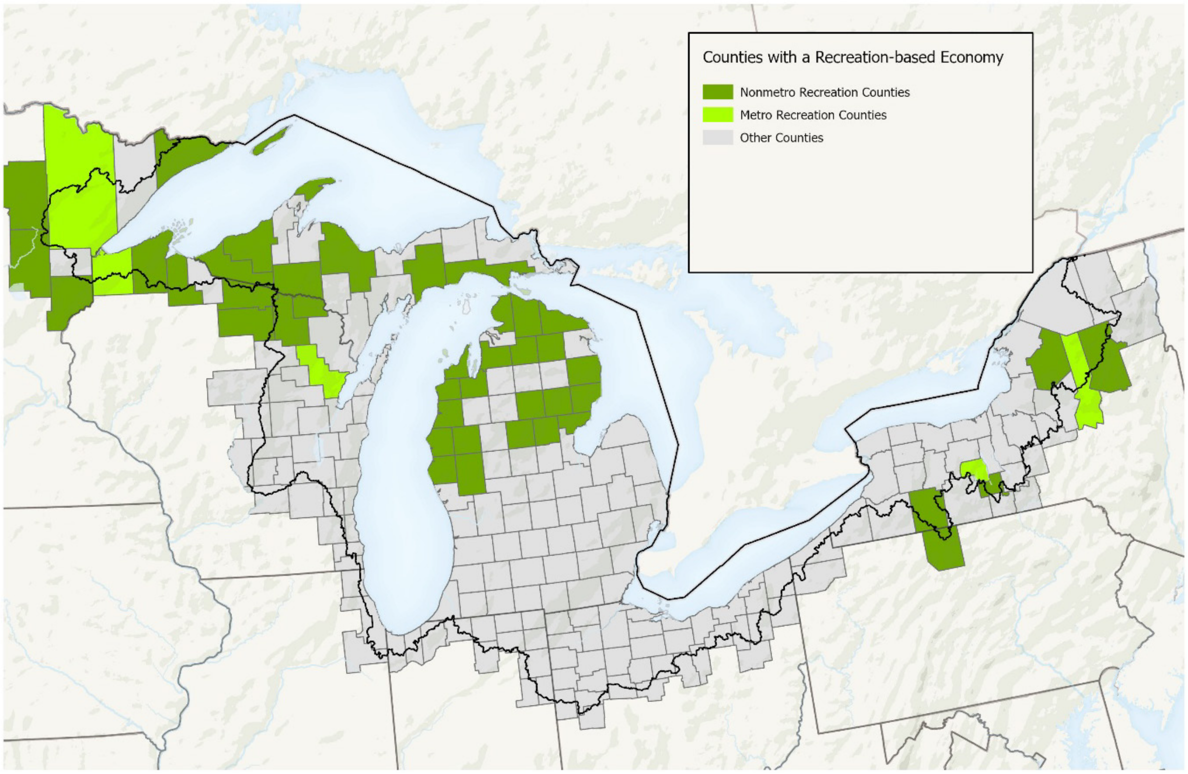
Recreation-based counties, those that prioritize outdoor recreation, parks, and tourism, offer a wide range of economic, social, and environmental benefits to local communities. Forests in the Great Lakes region play a vital role in supporting the recreation economy, contributing through tourism, ecosystem services, and outdoor activities. In the Great Lakes states, when measured by percentage of state GDP recreation, Indiana contributes a high of 3.2%. But, when measured by the total number of jobs and wages, New York state has the highest totals at 247,330 jobs and 17 billion dollars of wages respectively (BEA 2023; Table 4-4). The Forest Service estimates that outdoor recreation on national forests in the US contributes billions of dollars to the US economy annually (Rosenberger et al. 2017). Forests in the region offer year-round activities such as hiking, camping, fishing, hunting, snowmobiling, and birdwatching. Recreation appears to drive varied economic benefits, including short-term support for tourism-related businesses and longer-term support by recruiting new residents who may be business owners, entrepreneurs, or workers, supporting growth in earnings per job across a community (Lawson 2024). Studies have also found that people are more likely to move to recreation counties.

Table 4-4. The contribution of outdoor recreation to the economy of Great Lakes states in 2023 (BEA 2023).

State	Percent of State GDP from Outdoor Recreation	Outdoor Recreation Jobs (thousands)	Outdoor Recreation Wages (billions)
Indiana	3.2	105.08	6.4
Minnesota	2.8	95.9	5.9
Wisconsin	2.6	96.8	5.38
Illinois	2.2	172.89	11.52
Ohio	2.2	147.99	8.02
Michigan	2.1	118.25	6.3
Pennsylvania	1.9	168.32	8.74
New York	1.6	247.33	17.01
Total		**1,152.56**	**69.27**

In the Great Lakes region, out of 213 total counties, 48 counties, of which 43 are non-metro, were identified as having a recreation-based economy by the US Department of Agriculture's Economic Research Service (USDA Economic Research Service 2015). They are largely clustered around the forested northern part of the basin and along the lakeshore. They were identified by calculating the percentage employed; the percentage of total earnings in entertainment, recreation, accommodations, eating and drinking places, and real estate; and the percentage of vacant housing units intended for seasonal of occasional use reported in the 2010 Census of Population. The three variables were converted to a weighted index, and counties scoring at least two-thirds of a standard deviation above the mean were considered to be recreation counties (Figure 4-19).

Figure 4-19. Counties with a recreation-based economy.



Visits to National Forests

The Forest Service's National Visitor Use Monitoring data (English et al. 2002) is available for five national forests in the Great Lakes assessment area (Chequamegon-Nicolet, Hiawatha, Huron-Manistee, Ottawa, and Superior) and provides information for each forest on the demographics of users and attributes of their visits.

Using the available reports for these five national forests from 2006-2021 (USFS n.d.), we determined that the typical visitor is male (64.4%, sd: 6.2) and white (>95%, sd:2.4) and just over half of the respondents travelled over 100 miles to visit the forest. About 45% of the visitors were repeat visitors (more than six visits per year), with an average of 17.4% visiting more than 20 times in a year, and 7% of people visiting the forest more than 100 times in a year.

Visitors were also asked about the purpose of their visit and given 28 choices (see a sample of these survey results in Table 4-5). As a reflection of what people value about forested landscapes, they reported the following four uses as the most common across forest and year (from most to least):

1. Viewing natural features
2. Viewing wildlife
3. Relaxing
4. Hiking/Walking

Apart from hiking/walking, the types of activities people engaged in varied noticeably across forest and year of survey, likely reflecting the different features of the forests, the seasonality of the surveys, and weather variability year to year. For example, hunting was in the top four uses in the Chequamegon-Nicolet National Forest three out of four years, but not in the top four uses in any of the other four forests in any year.

Table 4-5. Activity participation data for the Ottawa National Forest, from the 2017 National Visitor Use Monitoring survey. Note that respondents could select more than one activity.

Activity	% of Participation
Hiking / Walking	50.1
Viewing Natural Features	46.9
Driving for Pleasure	36.1
Relaxing	36.0
Viewing Wildlife	30.6
Hunting	20.6
Fishing	19.6
Picnicking	14.1
Developed Camping	11.5
Motorized Trail Activity	9.9
Nature Center Activity	9.9
Nature Study	8.0
Other Non-motorized	7.4
Non-motorized Water	7.3
Visiting Historic Sites	7.0

Table 4-5 continued. Activity participation data for the Ottawa National Forest, from the 2017 National Visitor Use Monitoring survey. Note that respondents could select more than one activity.

Activity	% of Participation
OHV Use	7.0
Gathering Forest Products	6.4
Primitive Camping	4.2
Snowmobiling	4.0
Motorized Water Activities	4.0
Backpacking	2.9
Bicycling	2.7
Resort Use	2.3
Some Other Activity	0.6
No Activity Reported	0.4
Cross-country Skiing	0.3
Other Motorized Activity	0.2
Downhill Skiing	0.2
Horseback Riding	0.0

Non-timber Forest Products

People value the non-timber forest products (NTFPs) in the Great Lakes region for subsistence, economic opportunity, and cultural significance. Data about these NTFPs is challenging to collect given lack of management, limited tracking, and because harvesters are "diverse, dispersed and often secretive" and are thus difficult to survey (Frey 2011). Chamberlain et al. (2025) present a comprehensive assessment of the food and medicinal value of public forest lands in the United States as is currently available.[2] They found that the total wholesale value of permitted harvest of plant-based food and medicine (bark, nuts, seeds, berries, roots, mushrooms, fungi, and herbs) on just Forest Service and Bureau of Land Management lands exceeded $645 million for the years 2013 to 2022. User survey data for the national forests in the Great Lakes region showed that an average of 10.1% of visitors engaged in gathering forest products as an activity, with a range of 3.5% to 33.2% of visitors.

[2] They were not able to account for harvest by sovereign tribal nations, freshwater habitats within forests, small game and upland birds, nor harvest on private lands nor illegal harvests.

Public forests also supply significant meat protein. Chamberlain et al. (2025) estimated that 437 million servings of wild meat were harvested in a five-year period, in addition to public forests providing grazing land for domestic animals.[3] Great Lakes hunting on forested public lands accounted for 20% of that wild meat, with Michigan having the third highest wild meat harvest by weight (Table 4-6; Chamberlain et al. 2025).

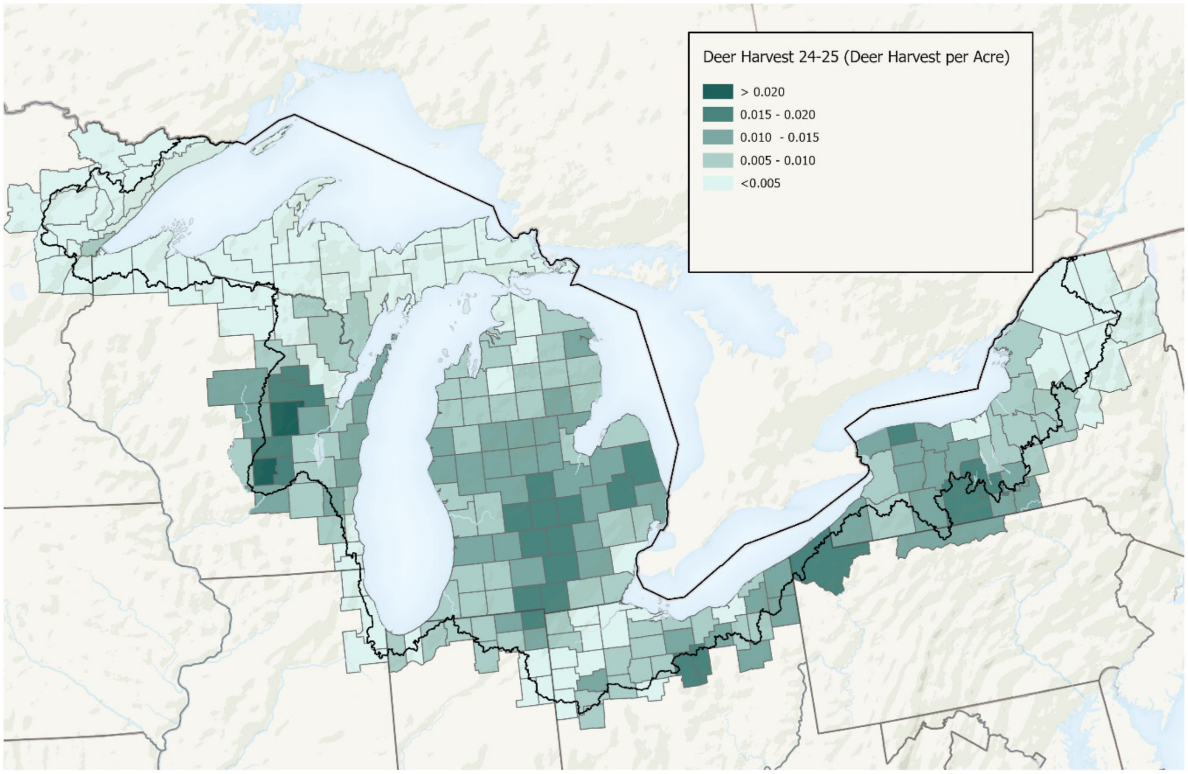
Table 4-6. Harvest of wild meat in the Great Lakes states on public forest land (from Chamberlain et al. 2025).

State	National rank	# animals harvested	Live mass (t)	Dressed mass (t)	Edible mass (t)	Million meal servings (156 g serving)	Percent of public land
Michigan	3	441.75	7.74	5.91	3.49	22.37	22.47
New York	7	244.38	6.88	5.28	3.11	19.92	36.97
Wisconsin	10	332.17	5.42	4.16	2.44	15.63	16.21
Pennsylvania	11	311.35	5.26	4.02	2.37	15.21	14.74
Minnesota	17	266.2	3.17	2.44	1.42	9.13	17.57
Ohio	30	235.63	1.71	1.28	0.77	4.91	2.59
Illinois	32	208.16	1.44	1.09	0.65	4.17	2.35
Indiana	36	48.82	1.01	0.78	0.46	2.94	2.28
Total GL states			32.43			94.28	
Total all states			159.53			437.13	
% of all states			20.3%			21.6%	

Forested lands near population centers are especially important for meat products and perhaps other non-forest timber products. Mapping deer harvest data provided by state DNR offices, shows that the counties and suburbs outside Green Bay, Detroit, Grand Rapids, and Cleveland have the highest amount of harvest (Figure 4-20). The counties with large blocks of forested land in northern Minnesota, Wisconsin, Michigan, and New York have very low deer harvest.

[3] While there is not an estimate specific to forested public land for grazing animals, in total public lands in the US support 1.2 billion servings of protein each year (Chamberlain et al. 2025).

Figure 4-20. Deer harvest in the 2024-2025 season.



Beyond market values, NTFPs are critical to indigenous culture, and traditional ecological knowledge contributes to their sustainable management (Frey et al. 2021). Given the value to many, Chamberlain et al. (2025) suggest that forest management explicitly "enhance availability and access to sustainable harvesting opportunities," which would increase support for public lands and lead to better outcomes for people and nature.

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Chapter 5: The Importance of Forests in Agricultural Landscapes

KEY POINTS

Agriculture covers 30% of the US Great Lakes watershed. These 22 million acres of agricultural land generate about $15 billion annually in livestock, dairy, grain, and corn products. The region's forests are responsible for 83 million metric tons of avoided soil loss annually which protects the critical fertile upper soil layers.

On farms, trees can diversify food production and income, provide protection for crops and livestock from heat, wind, or extreme weather. Trees also provide critical ecosystem services such as increased soil fertility, erosion control, flood mitigation, and buffering adjacent ecosystems from nutrient runoff.

In the region's agricultural landscapes, **over twice as much forest cover is found in the riparian zone as in the local uplands** (31% vs. 13%) and the riparian zone offers the best opportunity to improve water quality through increased forest restoration. In addition, restoration of wetland areas could contribute to water quality, flood control and habitat, particularly in areas such as northwest Ohio's former Black Swamp.

Given the small number of farms reporting agroforestry practices in the Great Lakes (2.3%), **significant potential exists to expand these practices.**

Introduction

Farms and forests play a vital role in the economic, social, and ecological landscape of the Great Lakes Basin. Agricultural land use comprises approximately 30% of the watershed, with 24% in row crop agriculture and another 7% in hay or pasture. This agricultural land covers 22 million acres (USGS 2023) and generates about $15 billion annually in the US from livestock, dairy, grain, and corn products (Kerr et al. 2016). The presence of trees provides significant value to farms – physically and economically, and significant benefits to the people living in agricultural watersheds. On farms, trees improve soil fertility, prevent soil erosion, and improve soil moisture thereby helping to conserve water. Water quality is improved by having trees within agricultural landscapes, especially where they buffer rivers and lakes from water that runs off cultivated fields and animal enclosures. Fruit and nut bearing trees on farms can diversify food production and provide additional income on farms. Trees on farms can provide protection for crops and livestock by moderating heat, wind, and even extreme weather. Trees in agricultural landscapes provide habitat for pollinators and other beneficial insects that prey on insect pests. Trees on farms help maintain habitat and connectivity needed by many other resident and migrating wildlife species (Figure 5-1).

This chapter will discuss the patterns and benefits of trees in agricultural landscapes in the Great Lakes, including riparian forests and the specific practice of agroforestry.

Agricultural Land Use Patterns in the Great Lakes Basin and Impact on Water Quality

Agricultural land is not distributed evenly throughout the Great Lakes Basin. By Great Lake sub-basins, Lake Erie has the highest agricultural use with cropland and pasture covering 54% of the watershed, followed by Lake Ontario with 35%, and Lake Huron and Michigan with 30% agricultural cover. The amount of agriculture is much lower and localized in the Upper Saint Lawrence watershed where it comprises 15% of the subbasin, and in Lake Superior which has only 3% in agricultural use (; USGS 2024). The large amount of agriculture in the Lake Erie watershed is associated with high phosphorus levels that fuel algal blooms in the lake, which at times has led to harmful toxicity to humans and wildlife (ECCC & US EPA 2022). Lake Erie is rated “Poor” for nutrients in the lake, while the other four lakes are rated “Fair” or “Good” (Lake Superior). Regionally, planting trees, especially to buffer agricultural runoff, could greatly enhance environmental stewardship, which is critical to reduce nutrients and sediment that harms the Great Lakes and its tributaries.

Figure 5-1. The ecosystem and economic services provided by trees on farms. (Forest Service illustration by Cheryl Holbrook)

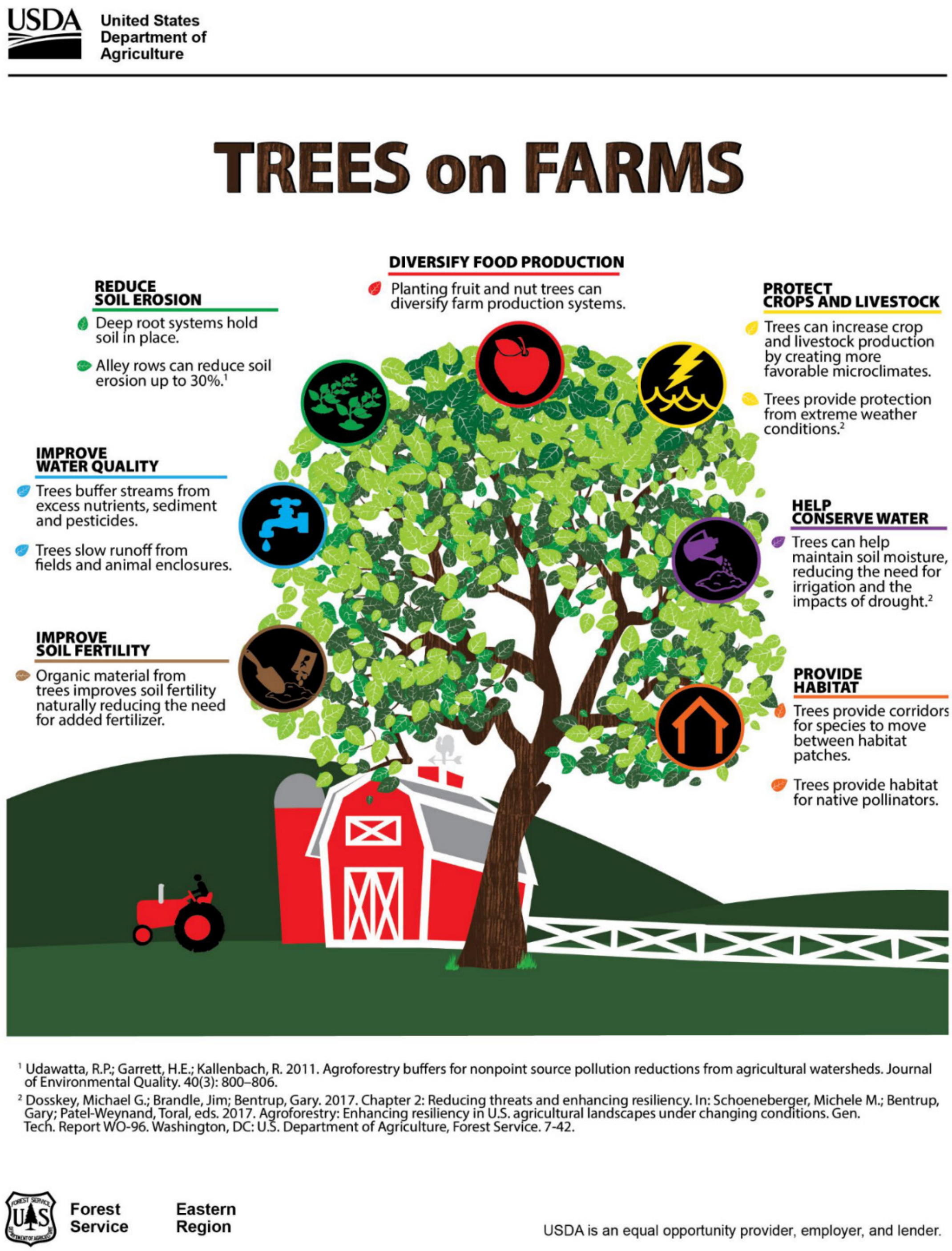
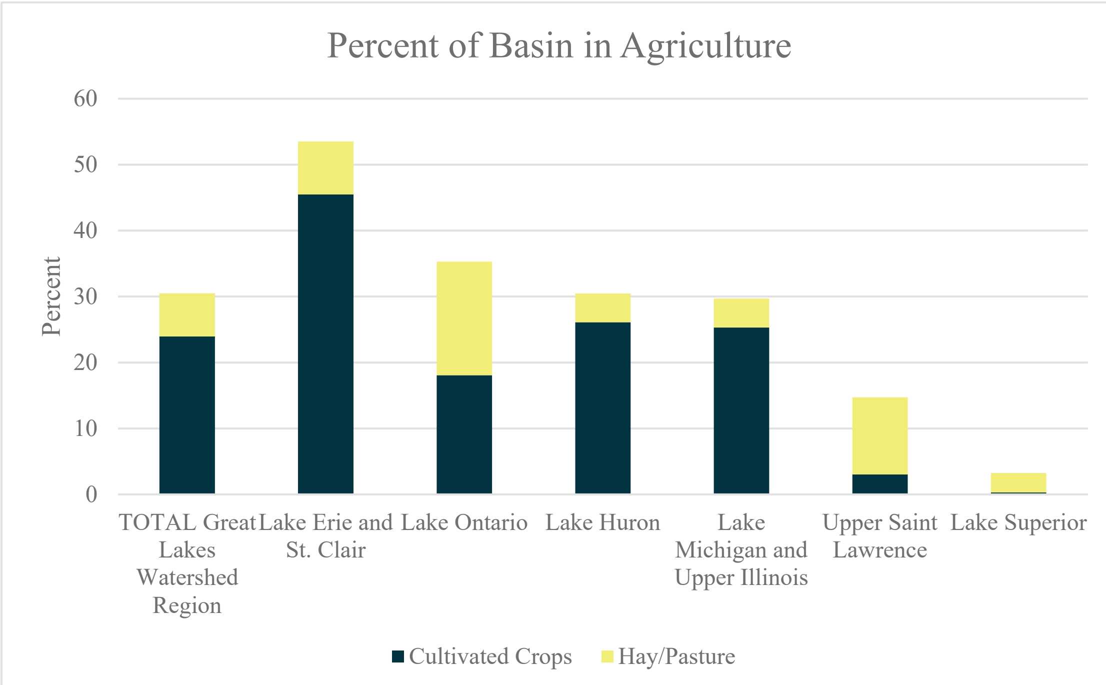


Figure 5-2. Percentage of Great Lakes sub-basins in cultivated crops and hay/pasture agricultural land cover.



Patterns in Soil Erosion

Soil erosion is the movement and removal of topsoil, the most fertile upper layer of soil, by water and wind. This soil loss has a negative impact on soil quality and crop protection and has downstream impacts on water quality, air quality, and biological health. Trees can minimize soil erosion by reducing wind velocity and stabilizing soil with their roots and vegetative cover (Perry et al. 2022). Currently in the Great Lakes Basin, 31 million metric tons of soil are lost per year, with the highest loss per hectare in the most heavily agricultural areas such as the Lake Erie watershed, and parts of western Michigan and southeastern Wisconsin in the Lake Michigan watershed (US EPA 2024; Woznicki et al. 2020; Figure 5-3).

Natural cover in the Great Lakes basin reduces erosion, preventing 91 million metric tons of soil from being lost (US EPA 2024; Woznicki et al. 2020; Figure 5-4). Forested lands provide the greatest value in sediment retention among all the natural land cover types (Woznicki et al. 2020). In the Great Lakes Basin, forests are responsible for 83 million metric tons of avoided soil loss, 91% of all the soil loss being avoided from natural cover (Figure 5-5).

Figure 5-3. HUC12 watersheds by their average annual soil loss under current land cover (US EPA 2024; Woznicki et al. 2020).

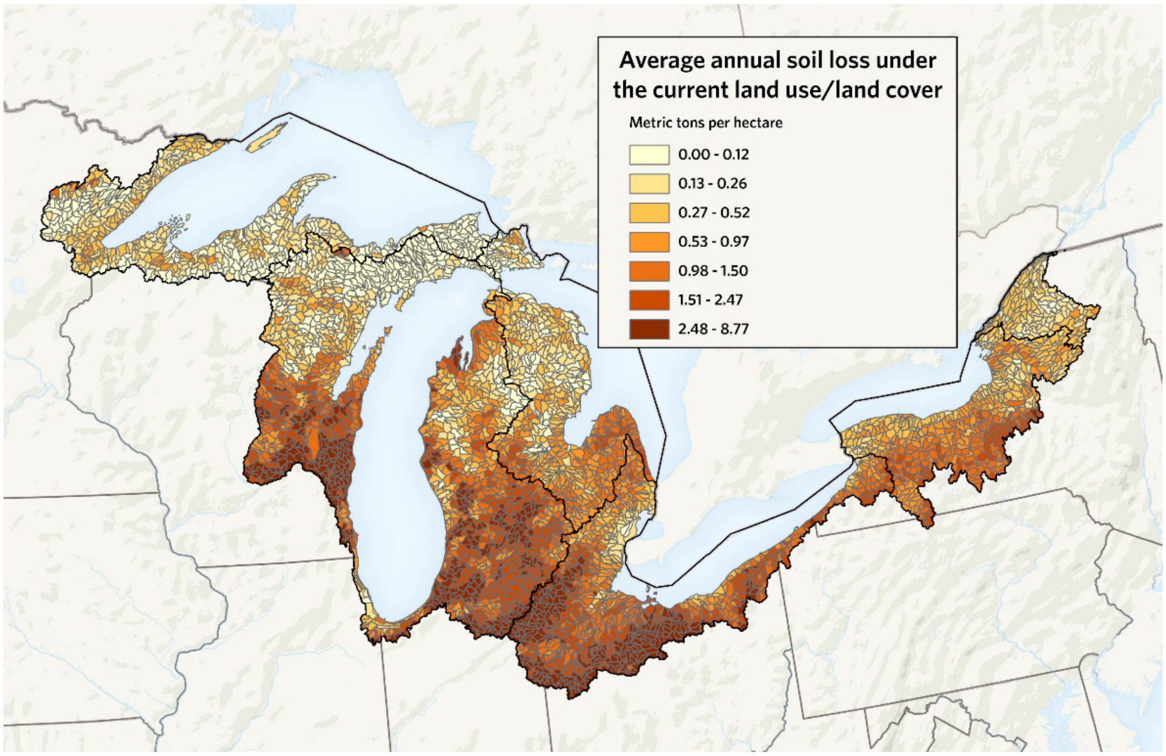


Figure 5-4. HUC12 watersheds by annual soil loss avoided due to current land cover in natural vegetation (US EPA 2024; Woznicki et al. 2020).

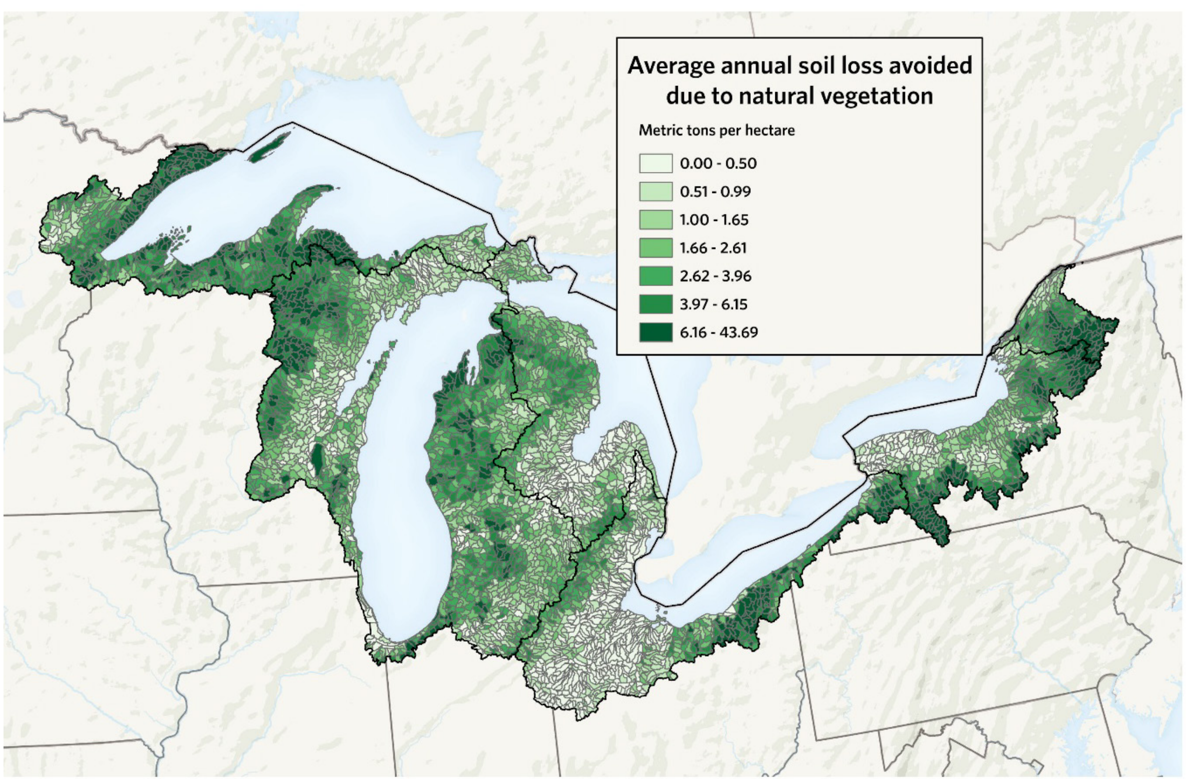
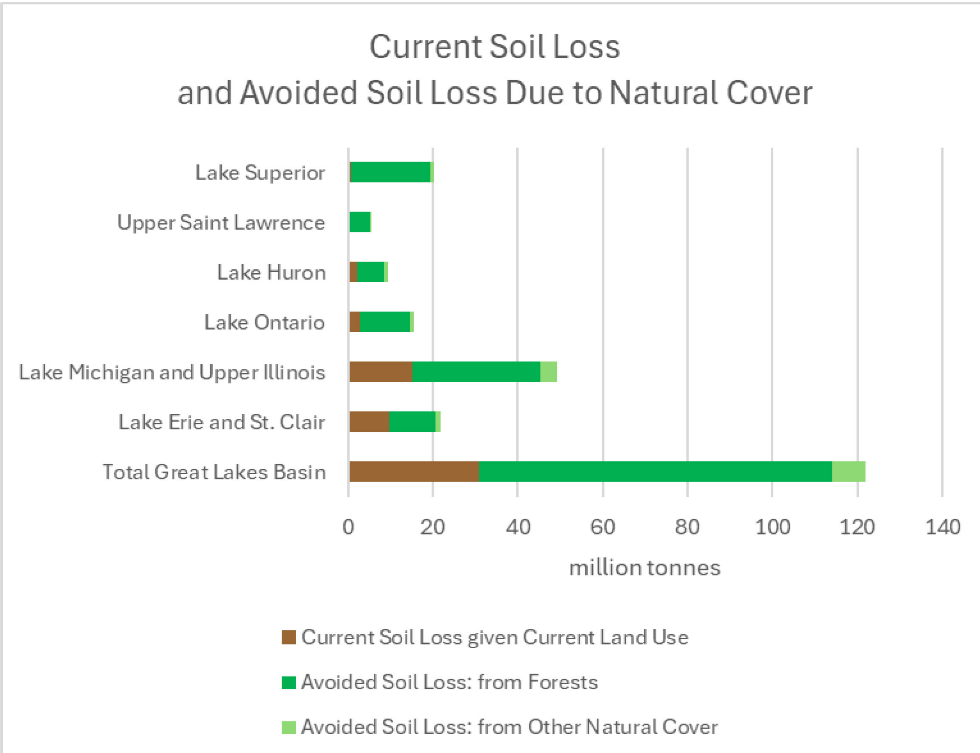


Figure 5-5. Soil loss from land in the Great Lakes watersheds. Current soil loss from existing land cover and avoided soil loss from current forest and other natural land cover. Reported for the total Great Lakes Basin and six subbasins (US EPA 2024; Woznicki et al. 2020).

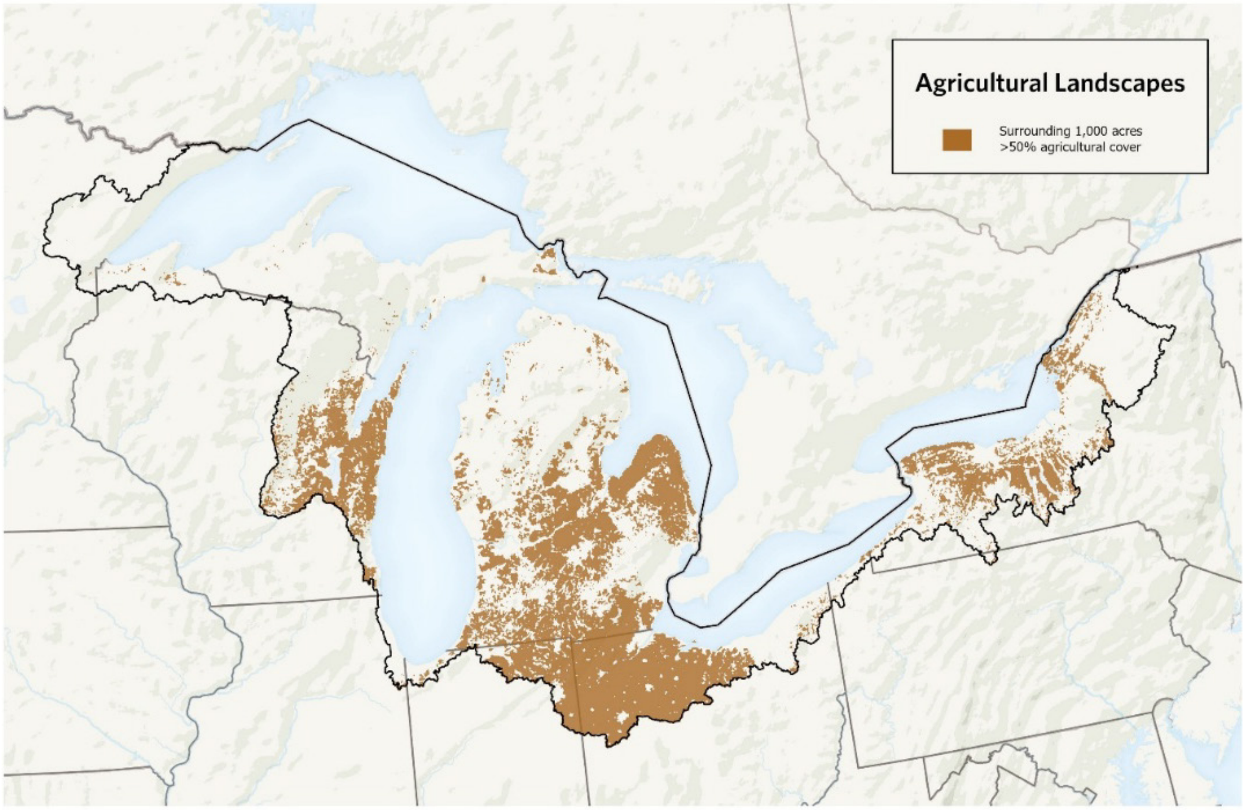


Patterns of Forests in Agricultural Landscapes in the Great Lakes Basin

To analyze more detailed patterns of forest cover within agricultural landscapes, we mapped agriculturally dominated landscapes as those with more than 50% of their 1,000-acre surrounding area in agricultural cover of row crops or hay pasture (NLCD 2021, Dewitz 2023). We determined that 22 million acres of the region were within these landscapes locally dominated by agricultural use (Figure 5-6).

Of the 38 million acres of forest in the Great Lakes watershed, 9% or 3.5 million acres of forest are found within these agriculturally dominated landscape areas. These 3.5 million acres of forest are found in smaller block sizes compared to other parts of the region, with the median forest block size (1,218 acres) three times smaller in agriculturally-dominated landscapes than in non-agriculturally dominated areas of the Great lakes, which average a forest block size of 29,000 acres (Figure 5-6). Although smaller in patch size and connectivity than forests in less developed settings (Figure 3-8), the forests that remain within agriculturally-dominated areas play an important ecological role in terms of protecting soil, air, water quality, and wildlife habitat (Perry et al. 2022).

Figure 5-6. Agriculturally-dominated landscapes (more than 50% of their surrounding 1,000 acres in agricultural land cover) in the Great Lakes Basin.



Riparian Forests in Agriculturally-Dominated Great Lakes Landscapes

Riparian areas are those lands immediately adjacent to rivers, streams, creeks, and lakes (Lilja et al. 2023). The forests in agricultural landscapes are twice as likely to be found in the riparian zone along rivers than away from rivers, reflecting both better conditions for trees where there is a higher water table and the practical considerations of flood risk which reduce the compatibility of agricultural use in riparian areas. As the buffer between croplands and water bodies, trees in riparian areas provide many ecosystem benefits and services for farm enterprises (Lilja et al. 2023) including:

- Filtering nutrients, pesticides, and animal waste from runoff
- Stabilizing banks from erosion
- Filtering sediment from runoff
- Providing shade for temperature moderation, shelter, and food for fish and other aquatic organisms

- Providing wildlife habitat and corridors for terrestrial organisms
- Protecting cropland and downstream communities from flood damage
- Producing income from cropland that would otherwise frequently flood or have poor yields
- Providing space for recreation

In agriculturally-dominated landscapes, riparian areas, when defined using a 50-year flood height (Abood et al. 2012), are made up of 31% forest and 60% agriculture. Forest covers a much lower percentage of the non-riparian areas in agricultural landscapes (13%), while agriculture covers 77%.

Riparian forest benefits can extend far downstream as well. The Forest Service's Buffering America's Waterways tool (Lilja et al. 2023) highlights watersheds where restoration of forest in riparian zones has the greatest opportunity to enhance surface drinking water quality for people. The tool calculates a Riparian Opportunity Index value that scores small watersheds based on the percentage of the riparian area currently in cropland and the number of surface drinking water users. The tool also allows users to zoom in and visually inspect an area of interest and report on acres of potential restoration area per small HUC12 watershed.

A map of the Riparian Opportunity Index for the Great Lakes region shows many high opportunity small watersheds within the agriculturally dominated areas of the Lake Erie watershed, southern Michigan and Saginaw Bay, southern Wisconsin and in much of the Lake Ontario basin in New York (Figure 5-7). In these watersheds, riparian forest restoration would provide much needed water quality benefits to the local communities who depend on surface drinking water (Lilja et al. 2023). Considering those small watersheds with a moderate to extremely high Riparian Opportunity Index (51-100), we find that within the riparian zone (Abood et al. 2012), the amount of cropland totals just over 1.5 million acres, or about 2% of the entire land area in the Great Lakes Basin (US). Much of this cropland, 860,000 acres, is in the Lake Erie watershed (Table 5-1). By restoring this riparian area to forest, these watersheds would gain significant ecosystem services in terms of providing cleaner surface drinking water in areas where this water is in high demand. In addition to riparian restoration, protection of intact wetlands and bottomland forests and their restoration will also contribute to water quality, flood control, and wildlife habitat.

Figure 5-7. Riparian Opportunity Index scores for HUC12 watersheds in the Great Lakes Basin.

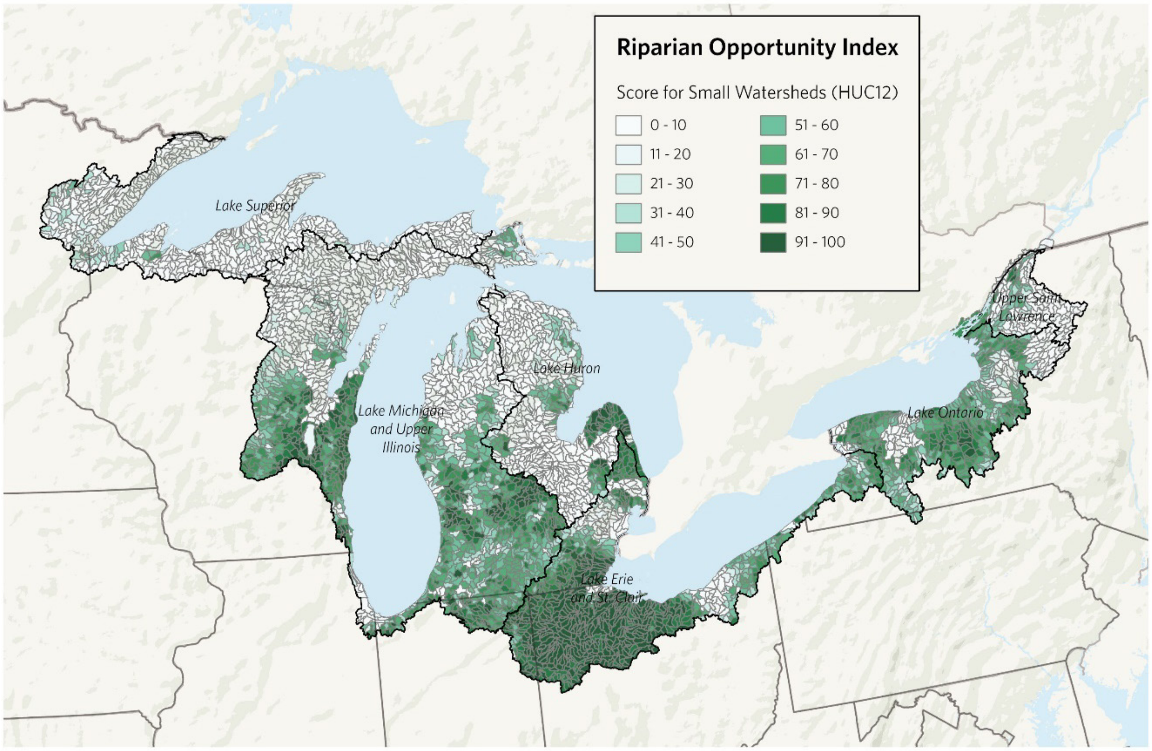


Table 5-1. Acres of cropland in small watersheds with moderate to high Riparian Opportunity Index (ROI) scores. Source: Buffering America's Waterways database (Lilja et al. 2023) which used HUC12 watersheds, a riparian zone defined by the 50-yr. flood height (Abood et al. 2012), and cropland extent from 2020 land use/land cover (Karra et al. 2021).

Major Lake Watershed	Moderate ROI (51-60)	Moderate - high ROI (61-70)	High ROI (71-80)	Very High ROI (81-90)	Extremely High ROI (91-100)	Cropland ROI > 50 Total	Cropland ROI > 50 % Basin
Lake Erie & Lake St. Clair	7,273	10,709	38,025	125,518	668,111	859,636	6.5
Lake Michigan & Upper Illinois	27,387	68,548	80,684	124,122	12,592	443,344	1.6
Lake Ontario	11,502	27,535	48,729	36,929	8,712	133,408	1.6
Lake Huron	4,687	10,163	9,619	47,445	51,475	123,389	1.2
Upper Saint Lawrence	1,836	1,569	2,031	1,944	2	7,383	0.1
Lake Superior	464	42	568			1,063	0.0
Grand Total	**53,150**	**118,565**	**179,655**	**345,960**	**870,893**	**1,568,223**	**2.1**

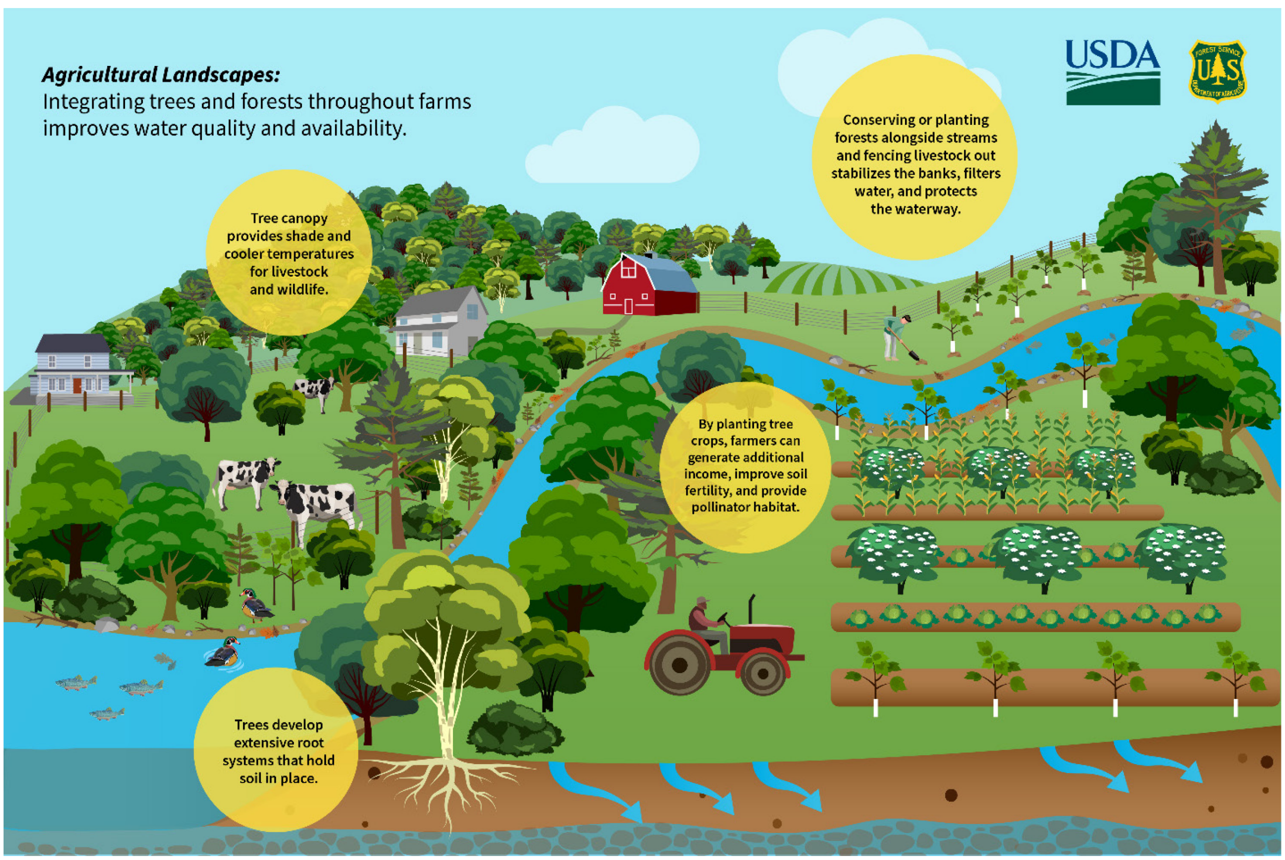
Agroforestry and Riparian Restoration

The US Department of Agriculture (USDA) defines agroforestry as "the intentional integration of trees and shrubs into crop and animal farming systems to create environmental, economic, and social benefits" (USDA 2025). Trees benefit agricultural enterprises in many ways including providing shade, protecting waterways, preventing soil erosion, and providing alternative sources of income (Figure 5-8).

Agroforestry as defined by the USDA (2022) includes the following practices:

> **Alley Cropping** is the growing of annual or perennial crops between rows of trees. The agricultural crop generates annual income while the tree crop matures.
>
> **Silvopasture** combines timber, livestock, and forage production on the land. Trees provide longer-term returns, while livestock generates an annual income.
>
> **Forest farming** is the intentional management of woodlands to grow non-tree crops such as mushrooms, berries, and root crops under trees.
>
> **Windbreaks** are rows of trees and shrubs used to slow wind to protect soil, crop, or livestock, or for visual screening and shade.
>
> **Riparian forest buffers** are natural or planted trees, shrubs, and grasses adjacent to water bodies to protect water resources from non-point source pollution.

Figure 5-8. Benefits of integrating trees and forests into agricultural landscapes.



In addition to the water quality and habitat benefits of riparian areas described above, riparian forest buffers can also produce farm income. Riparian zones could be planted with fruit and nut trees or renewable sources of biomass for energy. The planting and management of riparian forest buffers needs to consider landscape and hydrologic processes and should be combined with best management processes on farms to address farm runoff (Bronson & Claggett 2020). In addition, the intended goals of the buffer will determine its optimal width and configuration. For example, wider buffer widths will be most useful in controlling water soluble nutrients, while narrower buffers can be used to stabilize banks and trap sediment (MacFarland et al. 2017). Bentrup (2008) provides a comprehensive resource for the design of riparian forest buffers for conservation.

Extent of Agroforestry in the Great Lakes Basin

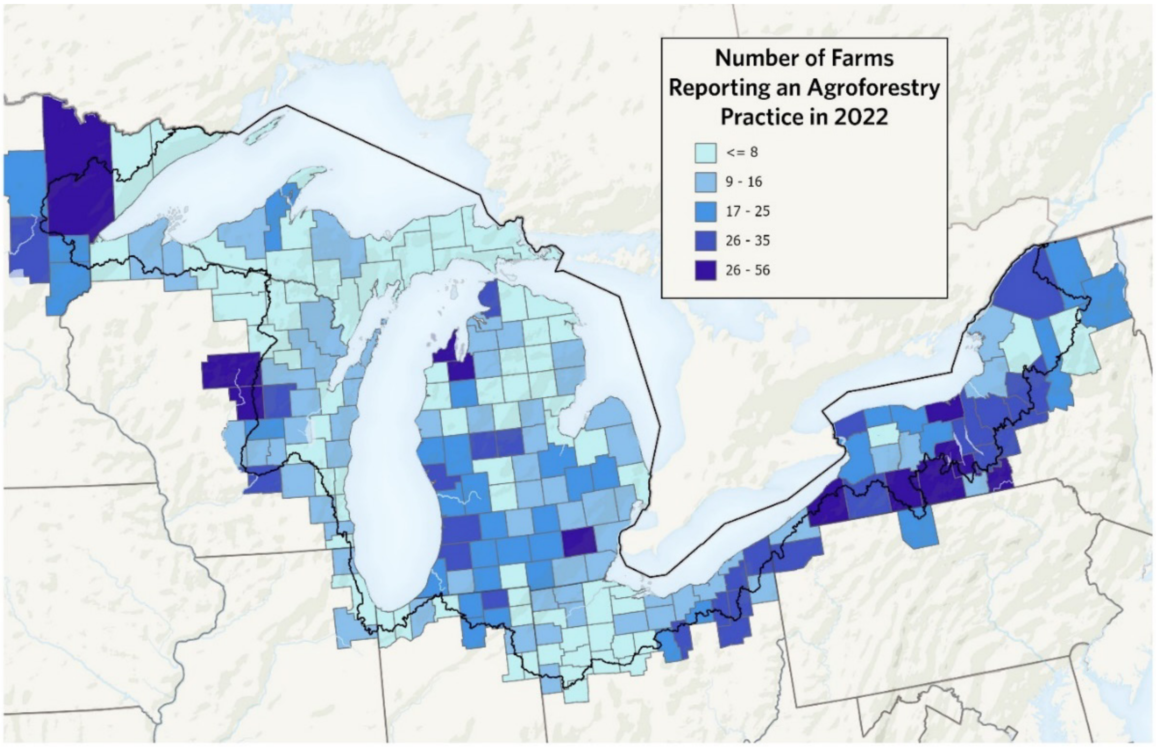
The most consistent information on agroforestry participation comes from the Census of Agriculture (COA), a complete count of farms and ranches taken every five years (Kellerman et al. 2025). In 2007, the COA began asking a single yes/no question about agroforestry, which is whether producers have implemented any one of the five most common agroforestry practices: alley cropping, silvopasture, forest farming, riparian forest buffers, or windbreaks.

The 2022 COA found 3,219 out of 137,273 farms (2.3%) in the Great Lakes region report using an agroforestry practice, which is higher than the national average of 1.7 % (Kellerman & Feibel 2025; Kellerman et al. 2025). Mapping the number of farms using agroforestry by county (Figure 5-9) shows that the practice has considerable spatial variation, with the most participation in southern New York, northeast Ohio, scattered counties in Michigan, central Wisconsin, and northeast Minnesota. We do not have information on what practices are used where, as the COA does not provide that level of detail.

Resources to Expand the Practice of Agroforestry

Given the small number of farms reporting agroforestry practices in the Great Lakes, significant potential exists to expand these practices, which may be a way to both diversify production and improve the water quality of adjacent streams and rivers. There are many resources available to support agroforestry found on the USDA National Agroforestry Center website (https://www.fs.usda.gov/nac/). Tools to assess potential income include the Non-Timber Forest Product Calculator (USFS 2025) and Buffer$ (USFS 2025). The Savanna Institute, working in partnership with the National Agroforestry Center, specifically focuses on growing agroforestry adoption in the Midwest by providing technical assistance (savannainstitute.org).

Figure 5-9. Number of farms by county in the Great Lakes Basin reporting an agroforestry practice in 2022.



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Chapter 6: The Importance of Forests in Urban Landscapes

KEY POINTS

People want trees near them and 89% say trees are a necessity. Trees in urban areas provide shade, health benefits, control stormwater, reduce air pollution, and improve economic value; they attract people to areas to shop, increase home values, and are correlated with less crime.

City trees experience extra stresses including improper planting, competition with invasive plants, compacted soil, impervious surfaces limiting air and water flow, excessive heat reflected from pavement, competition with above- and below-ground utilities and other built infrastructure, construction activities, and air pollution.

Gaps exist in canopy cover for most populated parts of the basin. Many tools exist to help focus tree planting to close these gaps and optimize for success and ecosystem services. A survey of 22 cities showed that they desired an average 55% increase in canopy cover.

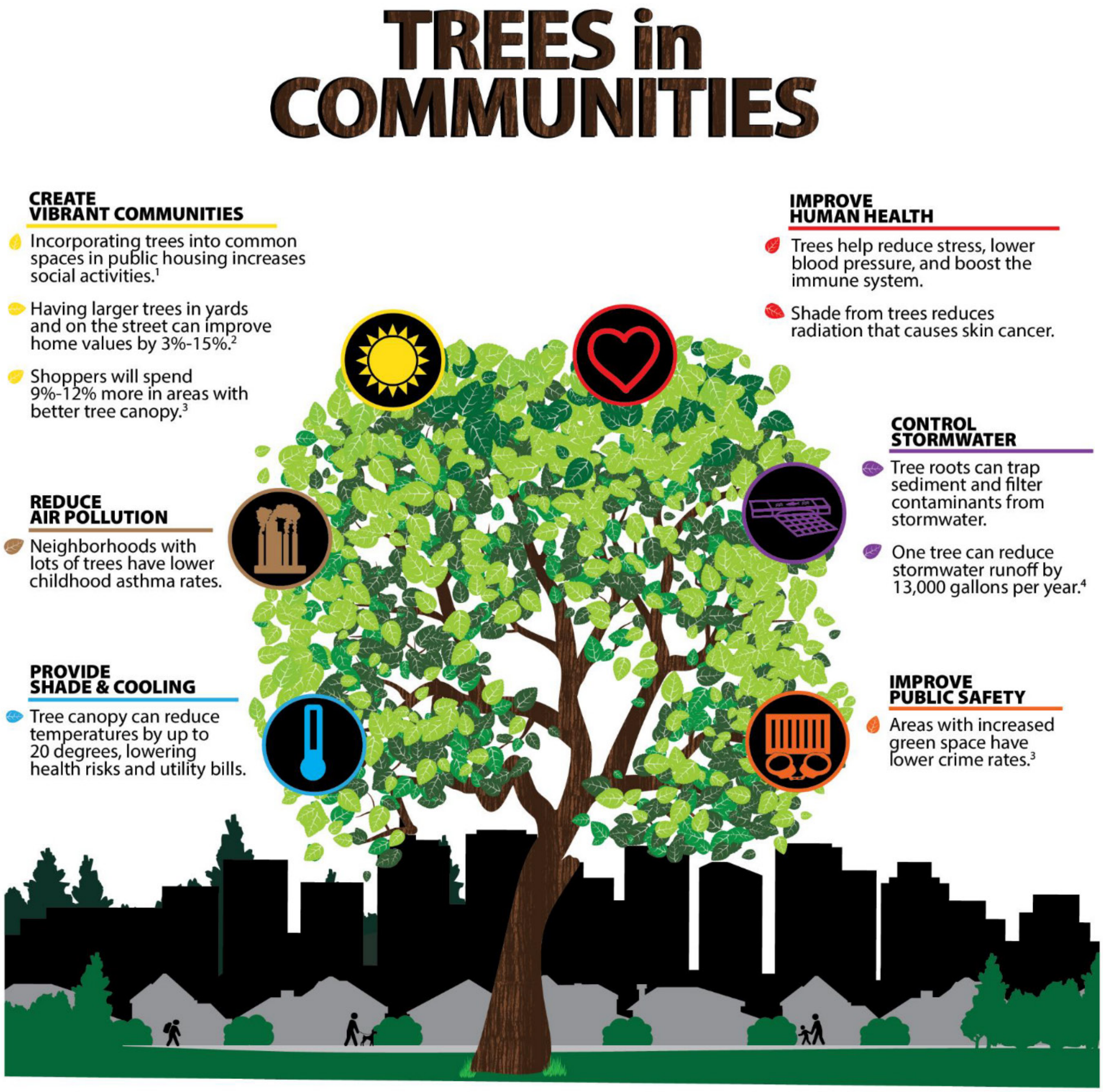
Access to parks benefits people's physical and mental well-being and their communities. One indicator of access is being within a 10-minute walk of a park. In about one third of the basin where more than 50,000 people live, 79% of the population is within a 10-minute walk.

In the temperate climate of the Great Lakes Basin, trees are integral to the quality of life for people from small communities to cities. Trees contribute to so many dimensions of our lives, and their absence creates stress on people and nature. From a utilitarian perspective, trees provide shade and cooling, buffer winter winds, help control stormwater and reduce air pollution. Trees contribute to our physical and mental health, and culturally, areas with more trees have lower crime rates, higher levels of commerce and property values, and more vibrant public spaces (Figure 6-1). The scientific literature is replete with examples of these benefits (e.g., Li et al. 2018; MDCH 2014) and when asked directly, Americans express high value for trees and understand the multiple ways in which trees contribute to their well-being. The Harris Poll found on behalf of the Arbor Day Foundation (ADF & Harris Poll 2024) that:

- 91% of Americans believe that trees are important to the health and well-being of communities
- 91% of Americans agree that we need to replant the trees that get deforested each year

- 88% of Americans agree that our forests and communities need more trees
- 88% of Americans know that trees can slow climate change
- 89% agree that trees are not just a nice-to-have, they're a necessity

Figure 6-1. Trees in communities provide multiple benefits to people and nature (Forest Service illustration by Cheryl Holbrook).



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The Status of Urban Tree Canopy in the Great Lakes Basin

Urban Tree Canopy (UTC) assessment is the method recommended by the Forest Service to measure a community's true canopy cover. UTC is a measure of tree canopy cover expressed as a percentage of total land area. In combination with impervious surface, traffic density, heat island maps, and socio-economic data, UTC can be used to set goals and priorities to expand natural cover in cities (USFS 2019). Urban tree canopy has been measured with national land cover data, aerial imagery, and on-the-ground inventories.

Using the National Land Cover Dataset tree canopy data (USFS 2023), we assessed the tree canopy for urban areas in the Great Lakes Basin, defined as incorporated areas with a population greater than 50,000 people. Twenty-seven urban areas have canopy cover greater than the national average for urban areas (15.4%). Table 6-1 shows the top ten for the Great Lakes Basin. Duluth, MN has the highest percentage canopy cover with 44%. At the other end of the scale, there are 32 urban areas that have canopy cover less than the national average. Table 6-2 shows the bottom ten. The two most populated cities in the basin, Chicago and Detroit, both have some of the lowest urban canopy cover values with less than 10%.

Table 6-1. The top ten incorporated places (>50,000 people) for canopy cover in the Great Lakes Basin.

Incorporated Place	State	Average Percent Canopy Cover
Duluth city	MN	44.29
Cuyahoga Falls city	OH	37.31
Battle Creek city	MI	29.28
Rochester Hills city	MN	26.52
Syracuse city	NY	25.74
Farmington Hills city	MI	25.69
Ann Arbor city	MI	25.10
Akron city	OH	24.96
Kalamazoo city	MI	24.62
Novi city	MI	23.46

Table 6-2. The ten incorporated areas (>50,000 people) with the lowest canopy cover in the Great Lakes Basin.

Incorporated Place	State	Average Percent Canopy Cover
Cicero town	IL	3.94
Oshkosh city	WI	6.36
Chicago city	IL	6.73
Warren city	MI	7.14
Kenosha city	WI	7.28
Tinley Park village	IL	7.56
Oak Lawn village	IL	8.11
St. Clair Shores city	MI	8.54
Racine city	WI	8.79
Buffalo city	NY	9.21

Urban Forest Inventory and Tools

The Urban FIA is a national natural resources inventory system designed to monitor the quality, health, composition, and benefits of trees and forests within our nation's urban land. The program's goal is to monitor the 100 most populous cities. "The Urban Forest Inventory and Analysis program fuses methods and infrastructure of the NFI with the expertise provided by i-Tree, a state of the art, peer reviewed software suite that provides seamless analysis of the NFI and Urban FIA along with tools for assessing the benefits of urban trees" (USFS 2024). These data are available for download through Urban DataMart (USFS 2023) and through online data analysis tools including My City's Trees (Texas A&M Forest Service & USFS 2025), i-Tree (www.itreetools.org), and Urban Forest Stats (Texas A&M Forest Service & USFS 2025). The cities assessed through the Urban FIA program in the US Great Lakes are Chicago and Milwaukee. In progress are Detroit, Toledo, Buffalo, and Rochester.

Through the My City's Trees webtool, users can create customizable reports that characterize the trees in cities relative to land cover, population density, and occurrence of heat anomalies. In Chicago, for example, areas of the city that were 3-20^{o}F warmer than the mean value for the city in the summer of 2022 have 3% of the city's trees with 0.5 trees per person. The areas that were 3-18^{o}F cooler than the mean value for the city have 57% of the trees and 2.6 trees per person. Milwaukee shows concentration of trees when viewed through population density. The highest density areas (>10,000 people per square mile) have 7% of the city's trees, 22% of the area and 60% of the population. The next densest category (5,000-10,000 people per square mile) has 8% of the city's trees, 25% of the area and 31% of the people. So that leaves 76% of the city's trees in the areas of the city with only 9% of the population. My City's Trees also provides information on species, biomass, replacement cost, and other related statistics.

The i-Tree suite of tools was developed through a public-private partnership involving these core partners: Forest Service, Davey Tree Expert Company, Arbor Day Foundation, Society of Municipal Arborists, International Society of Arboriculture, Casey Trees, and SUNY College of Environmental Science and Forestry. The first tool became available in 2006. The overall purpose is to estimate forest structure, ecosystem services, values, and risks related to forests and people so that users can create healthy, sustainable, and resilient forest landscapes across the urban to rural continuum (Nowak 2024). The original focus was urban forests in the US, and the program has expanded to the globe and includes urban and rural lands. The suite of desktop and web-based tools has evolved to include 12 applications maintained by i-Tree and four partner tools that support inventory, planning, planting selections, and even a marketplace for removed trees (Nowak 2024).

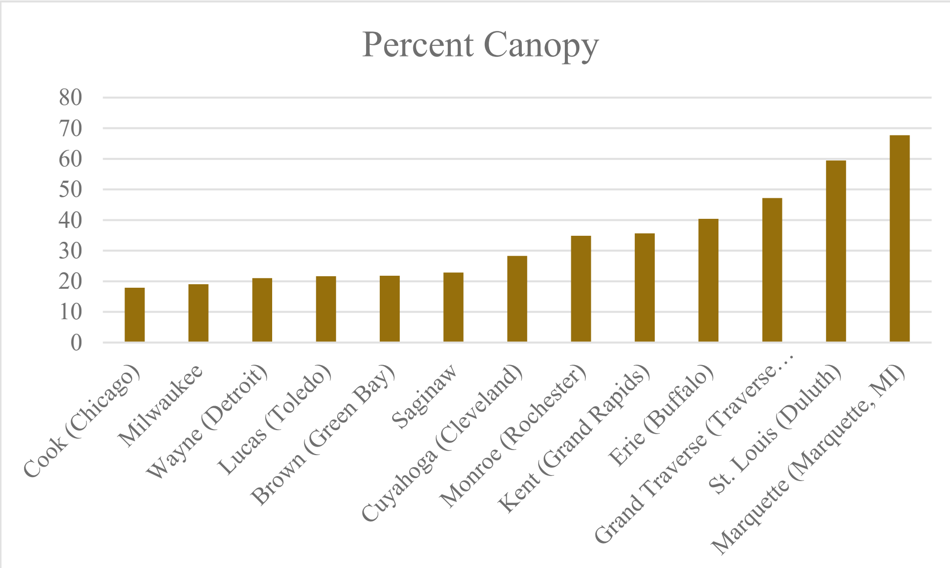
The goals of i-Tree include (Nowak 2024):

- Assess local forest conditions
- Quantify multiple ecosystem services and values derived from forests
- Determine local risks to forests and human health
- Calculate how changes in forest structure will lead to changes and tradeoffs among ecosystem services and values
- Develop best forest management strategies to enhance desired ecosystem services and forest and human health
- Determine the best tree species, locations, and planting rates to optimize ecosystem services and values through time and across space to enhance human health and well-being

The i-Tree Landscape tool (i-Tree 2025), gives users the ability to explore and visualize urban tree canopy information by selecting different spatial units for comparison. For example, we compared canopy cover in large urban counties (>65,000 people) in the Great Lakes Basin. The average urban tree canopy ranges from 17% in Cook County (Chicago, IL) to 68% in Marquette County (Marquette, MI; Figure 6-2). A user can delve further to look at sub-sections of the county as fine as census blocks.

The Forest Service, PlanItGeo, and the Arbor Day Foundation also collaborated on TreesCanopy.US, a software application for the US that provides data to assess and monitor community tree canopy and was released in 2024 (ADF, PlanItGeo, & USFS 2025).

Figure 6-2. Average urban tree canopy for counties with large urban centers in the Great Lakes Basin. Source: i-Tree Landscape (i-Tree 2025)



Stresses to Urban Forests and Trees

Trees in cities contend with a host of stresses beyond those of natural forests. The suite includes improper planting, competition with invasive plants, compacted soil, impervious surfaces limiting air and water flow, excessive heat reflected from pavement, competition with above- and below-ground utilities and other built infrastructure, construction activities and air pollution. All these stresses can be exacerbated by being in heat islands or areas with low soil quality (Brandt et al. 2021). As long-term temperatures have warmed, the hardiness zones for specific species have shifted, benefiting some species at the northern edge of their range, but reducing the growing conditions needed for others (Hellman et al. 2009). As discussed in Chapter 3, the changes in the ambient environment interact, so pests and pathogens may have more impact with higher temperatures, and the longer growing season may also allow for the spread of harmful species (Hellman et al. 2009). Given the dynamism of managing trees in an urban environment, cities may need to make greater financial investments in the short term to ensure that urban trees and forests can provide their many benefits to communities in the long term (Brandt et al. 2017). Some of these impacts can be lessened through thoughtful selection of species to plant and by maintaining species diversity (Brandt et al. 2021).

Expanding Urban Tree Canopy in the Great Lakes Basin

For many communities in the Great Lakes Basin, there is a significant gap between their goals for canopy cover and actual urban canopy. From a recent poll, 77% of Americans wish that their neighborhood had more trees and green spaces (ADF & Harris Poll 2024). Closing these gaps will improve the ecosystem services of trees in cities. While the goals necessarily vary from community to community, based on specific objectives such as stormwater runoff management, access to parks, increasing home values, reducing heat islands through shade, as well as available planting space and other constraints, a survey of 22 cities across the US found that residents desire a 55% increase in canopy cover (Vibrant Cities Lab 2014). Milwaukee has a goal of 40%. Toledo is at 17% and has a goal of 35-40% with their RE-TREE initiative. In New York state, Rochester's Urban Forest Master Plan (2024) calls for 85% stocking across all city quadrants. This means that 85% of plantable sites will have trees by 2025, an increase of 10%. Rochester's plan also sets goals for tree survival.

Tree Equity Score (American Forests 2025) is a webtool that assesses all urban areas as defined by the US Census at the level of census block group, and provides the current canopy value and the gap to a desired canopy based on what would be the minimum tree canopy to support the ecosystem services within a census block group, with adjustments made for the natural biome of that urban area and the building density. Tree Equity's tree canopy goals are assigned at a local scale and "represent a minimum standard of tree cover for all neighborhoods that is considered appropriate to local urban ecologies and are not based on goals set by cities."
Based on the Tree Equity data set, the average tree canopy gap for the entire Great Lakes Basin for all urban areas (as designated by the US Census in 2020) is 16% (SD .11; Figure 6-3). If we leave out areas where the Tree Equity Score is >85 (Figure 6-4), then the average gap increases to .26 (SD .07).

Figure 6-3. Tree canopy gap based on the Tree Equity data set.

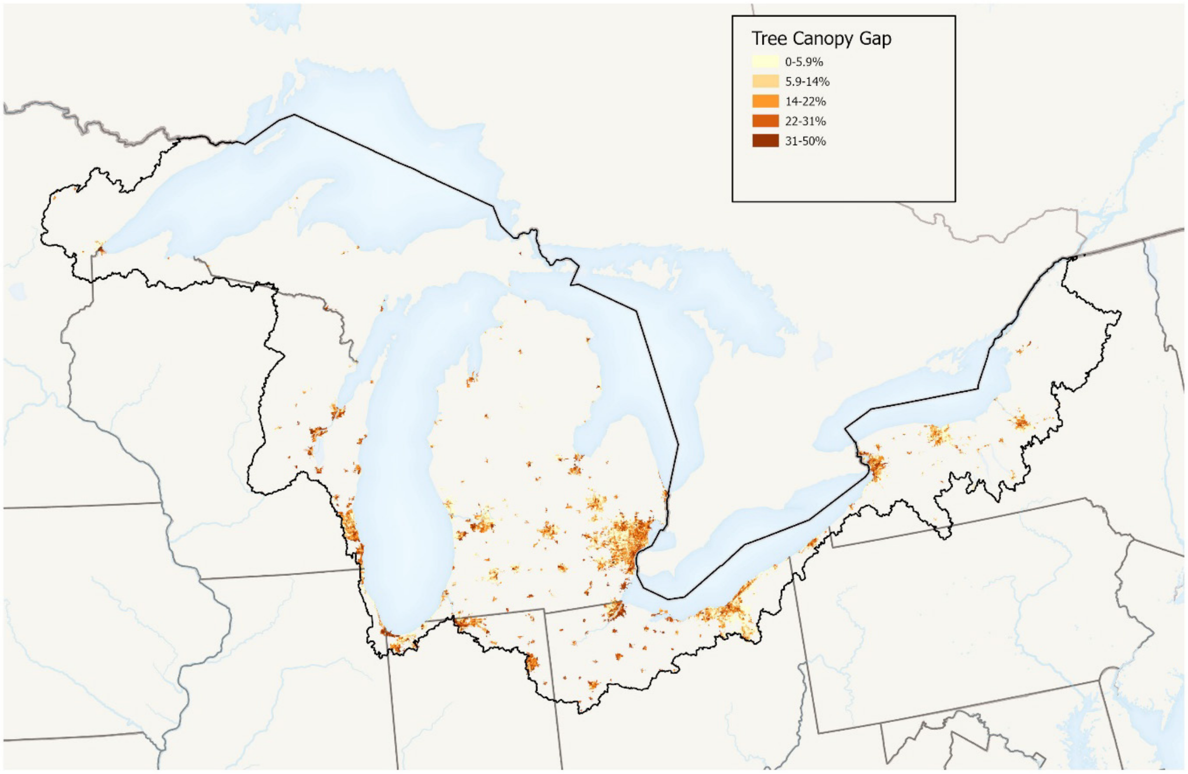
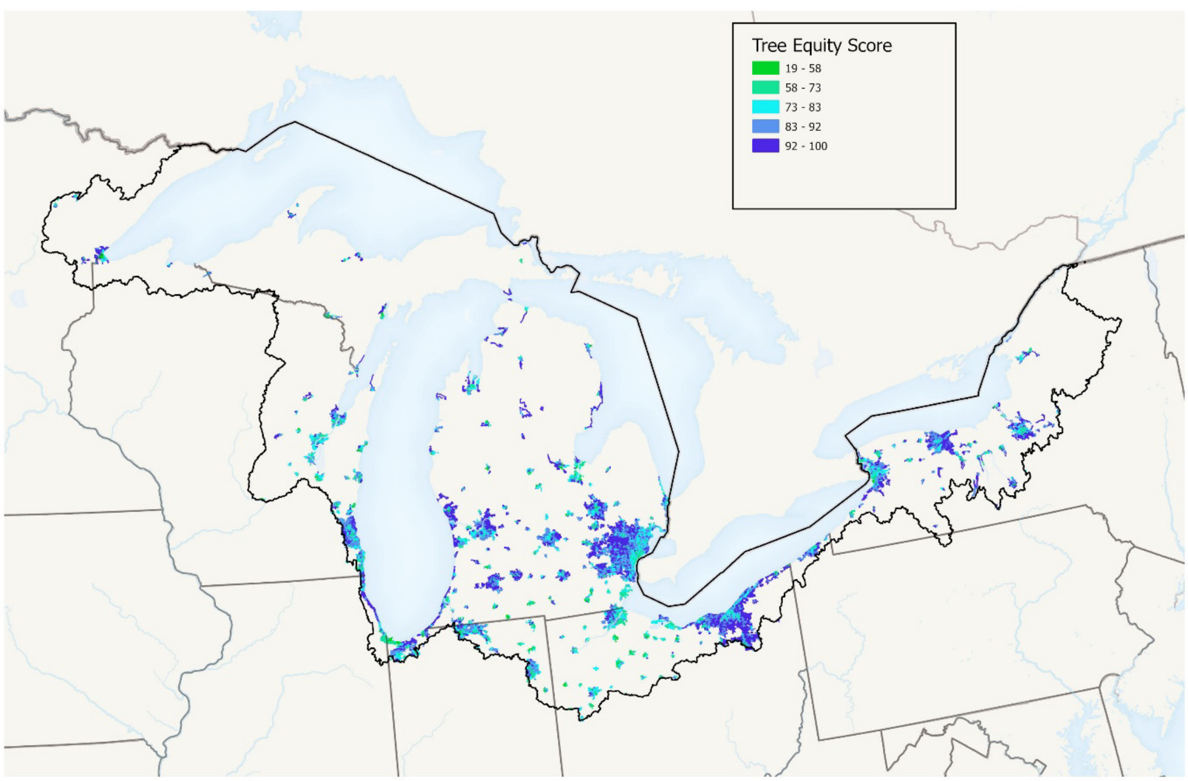


Figure 6-4. Tree Equity score for the Great Lakes Basin.



Initiatives to Increase Tree Canopy

Across the Great Lakes Basin, cities and communities have been working in partnership with the Forest Service and on their own to improve the tree canopy. The City of Rochester's Forestry Division published its Urban Forest Master Plan in 2024 (CRFD 2024). The master plan established a baseline condition of the city's trees based on an inventory, and found that 4% of the 75,000 trees were in poor condition, 42% fair, 40% good, and 12% excellent. Another measure of condition was how well stocked the trees are, in other words, how full are plantable sites. The current value is 81.9% against a goal of 85%. They also use young tree mortality and species diversity as indicators of tree health. For the latter, the goal is not to exceed more than 10% for any one species. As of 2024, the trees were 29% maple. This plan shares Forestry Division management and maintenance policies so that city residents know how the city is addressing uneven tree canopy conditions, pest control, tree protection, removal of dead or damaged trees, and species selection.

In 2024, Michigan's Department of Natural Resources granted more than $1 million to 15 communities statewide to plant trees and manage trees for the benefit of 285,000 people, funded by the Forest Service's Urban and Community Forestry Program. NGO's such as ReLeaf Michigan has been working statewide in Michigan for over 35 years. In that time, they have planted over 33,500 trees on public land in more than 700 communities.

Access to Parks

Another way to measure the benefit of urban trees to people is to look at people's proximity to parks. Parks with trees offer a wide range of benefits for people, enhancing physical health, mental well-being, and community life. There are many health benefits to accessing trees in parks. Time in green spaces lowers stress, anxiety, and depression (Li et al. 2025). Having a park nearby increases physical activities such as walking, jogging, and play which promotes fitness and reduces obesity (Larson et al. 2016). Parks also improve mental health - natural settings are linked to increased happiness and reduced mental fatigue (Li et al. 2025). Parks provide spaces for socializing, reducing loneliness and building community ties (Larson et al. 2025). There are also community benefits for parks. Green spaces are associated with reduced crime and increased community engagement. Homes near tree-filled parks often have higher market values. Parks are venues for events, sports, and cultural activities that enrich community life (The Nature Conservancy n.d.).

The 10-Minute Walk campaign, led by The Trust for Public Land, is a national initiative aimed at ensuring that everyone in US cities has access to a quality park or green space within a 10-minute walk (about half a mile) from home (Trust for Public Land 2016). In the incorporated places in the Great Lakes Basin with a population greater than 50,000 people, which is where over a third of the region's population lives, 79% of the population has a park within a 10-minute walk. The results vary though by city and state. Illinois has the highest amount of walking access to parks with five places having over 95% of their populations being near parks, Evanston, Oak Park, Chicago, Ciero, and Skokie. Michigan has some of the cities with the least amount of park access; Farmington Hills, Troy, Rochester, and Taylor all have less than 25% of their population within a 10-minute walk of parks. Table 6-3 and Table 6-4 show the incorporated areas with the highest ten and lowest ten percentages of people within a 10-minute walking distance to a park.

Table 6-3. Incorporated areas (>50,000) with ten highest percentages of people with a park within a 10-minute walk in the Great Lakes Basin.

Place Name	State	Percent of People with a Park within a 10-Minute Walk
Evanston city	IL	99.82
Oak Park village	IL	99.52
Chicago city	IL	98.04
Cicero town	IL	97.64
Skokie village	IL	96.52
Royal Oak city	MI	92.35
Racine city	WI	91.44
Ann Arbor city	MI	90.90
Oak Lawn village	IL	90.72
Buffalo city	NY	90.40

Table 6-4. Incorporated areas (>50,000) with ten lowest percentages of people with a park within a 10-minute walk in the Great Lakes Basin.

Place Name	State	Percent of People with a Park within a 10-Minute Walk
Taylor city	MI	7.84
Rochester Hills city	MI	16.67
Troy city	MI	16.85
Farmington Hills city	MI	21.73
Elyria city	OH	33.17
Battle Creek city	MI	36.28
Novi city	MI	37.30
Southfield city	MI	40.87
Pontiac city	MI	41.05
Mishawaka city	IN	41.07

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Appendix A: Forest Vertebrate Species in the US Great Lakes Basin.

Appendix Table A-1. Amphibians that occur in forested habitats within the US Great Lakes Basin. Source: NatureServe Explorer state species lists (NatureServe 2024).

Common Name	Scientific Name	Element Code	Global Rank	RFSS	Habitat	IL	IN	MI	MN	OH	NY	PA	WI
Blue-spotted Salamander	Ambystoma laterale	AAAAA01060	G5	X	Forest	X	X	X	X	X	X	X	X
Spotted Salamander	Ambystoma maculatum	AAAAA01090	G5		Forest	X	X	X	X	X	X	X	X
Marbled Salamander	Ambystoma opacum	AAAAA01100	G5		Forest	X	X	X		X	X	X	
Small-Mouthed Salamander	Ambystoma texanum	AAAAA01130	G5		Forest	X	X	X		X			
Eastern Tiger Salamander	Ambystoma tigrinum	AAAAA01146	G5		Forest	X	X	X	X	X	X	X	X
Jeffersonianum x laterale	Ambystoma pop. 2	AAAAA01150	GNA		Forest		X	X	X	X	X		
Northern Dusky Salamander	Desmognathus fuscus	AAAAD03040	G5		Woodland		X	X		X	X	X	
Four-toed Salamander	Hemidactylium scutatum	AAAAD08010	G5		Forested wetland	X	X	X	X	X	X	X	X
Eastern Red-Backed Salamander	Plethodon cinereus	AAAAD12020	G5		Forest	X	X	X	X	X	X	X	X
Eastern Newt	Notophthalmus viridescens	AAAAF01030	G5		Forest	X	X	X	X	X	X	X	X
American Toad	Anaxyrus americanus	AAABB01020	G5		Forest	X	X	X	X	X	X	X	X
Fowler's Toad	Anaxyrus fowleri	AAABB01210	G5		Forest	X	X	X		X	X	X	
Cope's Gray Treefrog	Dryophytes chrysoscelis	AAABC02050	G5		Forest	X	X	X	X	X			X
Gray Treefrog	Dryophytes versicolor	AAABC02130	G5		Forest	X	X	X	X	X	X	X	X
Spring Peeper	Pseudacris crucifer	AAABC05090	G5		Forest	X	X	X	X	X	X	X	X
Boreal Chorus Frog	Pseudacris maculata	AAABC05130	G5		Forest	X	X	X	X		X		X
Western Chorus Frog	Pseudacris triseriata	AAABC05150	G5		Forested wetland		X	X		X	X	X	
American Bullfrog	Lithobates catesbeianus	AAABH01070	G5		Forested wetland	X	X	X	X	X	X	X	X

Common Name	Scientific Name	Element Code	Global Rank	RFSS	Habitat	IL	IN	MI	MN	OH	NY	PA	WI
Green Frog	Lithobates clamitans	AAABH01090	G5		Forest	X	X	X	X	X	X	X	X
Pickerel Frog	Lithobates palustris	AAABH01160	G5		Woodland	X	X	X	X	X	X	X	X
Wood Frog	Lithobates sylvaticus	AAABH01200	G5		Forest	X	X	X	X	X	X	X	X

Appendix Table A-2. Birds that occur in forested habitats within the US Great Lakes Basin. Source: NatureServe Explorer state species lists (NatureServe 2024).

Common Name	Scientific Name	Element Code	Global Rank	RFSS	habitat	IL	IN	MI	MN	OH	NY	PA	WI
Great Blue Heron	Ardea herodias	ABNGA04010	G5		Forest	X	X	X	X	X	X	X	X
Green Heron	Butorides virescens	ABNGA08010	G5		Forested wetland	X	X	X	X	X	X	X	
Wood Duck	Aix sponsa	ABNJB09010	G5		Forested wetland	X	X	X	X	X	X	X	X
American Black Duck	Anas rubripes	ABNJB10040	G5		Forested wetland		X	X	X	X	X	X	X
Mallard	Anas platyrhynchos	ABNJB10200	G5		Forested wetland	X	X	X	X	X	X	X	X
Common Goldeneye	Bucephala clangula	ABNJB18010	G5		Forest	X	X	X	X	X	X	X	X
Bufflehead	Bucephala albeola	ABNJB18030	G5		Forest	X	X	X	X	X	X	X	X
Hooded Merganser	Lophodytes cucullatus	ABNJB20010	G5		Forest	X	X	X	X	X	X	X	X
Common Merganser	Mergus merganser	ABNJB21010	G5		Forest	X	X	X	X	X	X	X	X
Red-breasted Merganser	Mergus serrator	ABNJB21020	G5		Forest	X	X	X	X	X	X	X	X
Black Vulture	Coragyps atratus	ABNKA01010	G5		Woodland	X	X			X	X	X	
Turkey Vulture	Cathartes aura	ABNKA02010	G5		Forest	X	X	X	X	X	X	X	X
Swallow-tailed Kite	Elanoides forficatus	ABNKC04010	G5		Forest	X	X		X				X
Mississippi Kite	Ictinia mississippiensis	ABNKC09010	G5		Forest	X							
Bald Eagle	Haliaeetus leucocephalus	ABNKC10010	G5		Forest	X	X	X	X	X	X	X	X
Sharp-shinned Hawk	Accipiter striatus	ABNKC12020	G5		Forest	X	X	X	X	X	X	X	X
Cooper's Hawk	Accipiter cooperii	ABNKC12040	G5		Forest	X	X	X	X	X	X	X	X
American Goshawk	Accipiter atricapillus	ABNKC12061	G5		Forest	X	X	X	X	X	X	X	X
Red-shouldered Hawk	Buteo lineatus	ABNKC19030	G5		Forest	X	X	X	X	X	X	X	X
Broad-winged Hawk	Buteo platypterus	ABNKC19050	G5		Forest	X	X	X	X	X	X	X	X
Swainson's Hawk	Buteo swainsoni	ABNKC19070	G5		Woodland	X			X				

Common Name	Scientific Name	Element Code	Global Rank	RFSS	habitat	IL	IN	MI	MN	OH	NY	PA	WI
Red-tailed Hawk	Buteo jamaicensis	ABNKC19110	G5		Woodland	X	X	X	X	X	X	X	X
Rough-legged Hawk	Buteo lagopus	ABNKC19130	G5		Woodland	X	X	X	X	X	X	X	X
Golden Eagle	Aquila chrysaetos	ABNKC22010	G5		Woodland	X	X	X	X	X	X	X	X
American Kestrel	Falco sparverius	ABNKD06020	G5		Woodland	X	X	X	X	X	X	X	X
Merlin	Falco columbarius	ABNKD06030	G5		Forest	X	X	X	X	X	X	X	X
Peregrine Falcon	Falco peregrinus	ABNKD06070	G4		Woodland	X	X	X	X	X	X	X	X
Gyrfalcon	Falco rusticolus	ABNKD06080	G5		Woodland			X					
Spruce Grouse	Canachites canadensis	ABNLC09010	G5		Forest			X	X		X		X
Ruffed Grouse	Bonasa umbellus	ABNLC11010	G5		Forest	X	X	X	X	X	X	X	X
Sharp-tailed Grouse	Tympanuchus phasianellus	ABNLC13030	G5		Woodland	X		X	X				X
Wild Turkey	Meleagris gallopavo	ABNLC14010	G5		Forest	X	X	X		X	X	X	X
Northern Bobwhite	Colinus virginianus	ABNLC21020	G4G5	X	Woodland	X	X	X	X	X	X	X	X
Common Gallinule	Gallinula galeata	ABNME13030	G5		Forested Wetland	X	X	X	X	X	X	X	X
American Coot	Fulica americana	ABNME14020	G5		Forested wetland	X	X	X	X	X	X	X	X
Greater Yellowlegs	Tringa melanoleuca	ABNNF01020	G5		Woodland	X	X	X	X	X	X	X	X
Wilson's Snipe	Gallinago delicata	ABNNF18030	G5		Forested wetland	X	X	X	X	X	X	X	X
American Woodcock	Scolopax minor	ABNNF19020	G5		Forest	X	X	X	X	X	X	X	X
Mourning Dove	Zenaida macroura	ABNPB04040	G5		Woodland	X	X	X	X	X	X	X	X
Black-billed Cuckoo	Coccyzus erythropthalmus	ABNRB02010	G5	X	Forest	X	X	X	X	X	X	X	X
Yellow-billed Cuckoo	Coccyzus americanus	ABNRB02020	G5		Forest	X	X	X	X	X	X	X	X
Barn Owl	Tyto alba	ABNSA01010	G5		Savanna	X	X	X		X	X	X	
Eastern Screech-Owl	Megascops asio	ABNSB01030	G5		Forest	X	X	X	X	X	X	X	X
Great Horned Owl	Bubo virginianus	ABNSB05010	G5		Woodland	X	X	X	X	X	X	X	X

Common Name	Scientific Name	Element Code	Global Rank	RFSS	habitat	IL	IN	MI	MN	OH	NY	PA	WI
Northern Hawk Owl	Surnia ulula	ABNSB07010	G5		Woodland			X	X		X		
Great Gray Owl	Strix nebulosa	ABNSB12040	G5		Forest			X	X		X		
Barred Owl	Strix varia	ABNSB12050	G5		Forest	X	X	X	X	X	X	X	X
Long-eared Owl	Asio otus	ABNSB13010	G5		Forest	X	X	X	X	X	X	X	X
Short-eared Owl	Asio flammeus	ABNSB13040	G5	X	Savanna	X	X	X	X	X	X	X	X
Boreal Owl	Aegolius funereus	ABNSB15010	G5		Forest			X	X		X		X
Northern Saw-whet Owl	Aegolius acadicus	ABNSB15020	G5		Forest	X	X	X	X		X	X	X
Common Nighthawk	Chordeiles minor	ABNTA02020	G5		Woodland	X	X	X	X	X	X	X	X
Eastern Whip-poor-will	Antrostomus vociferus	ABNTA07070	G5	X	Forest	X	X	X	X	X	X	X	X
Ruby-throated Hummingbird	Archilochus colubris	ABNUC45010	G5		Woodland	X	X	X	X	X	X	X	X
Belted Kingfisher	Megaceryle alcyon	ABNXD01020	G5		Forested wetland	X	X	X	X	X	X	X	X
Red-headed Woodpecker	Melanerpes erythrocephalus	ABNYF04040	G5	X	Woodland	X	X	X	X	X	X	X	X
Red-bellied Woodpecker	Melanerpes carolinus	ABNYF04170	G5		Woodland	X	X	X	X	X	X	X	X
Yellow-bellied Sapsucker	Sphyrapicus varius	ABNYF05010	G5		Forest	X	X	X	X	X	X	X	X
Downy Woodpecker	Dryobates pubescens	ABNYF07030	G5		Forest	X	X	X	X	X	X	X	X
Hairy Woodpecker	Dryobates villosus	ABNYF07040	G5		Forest	X	X	X	X	X	X	X	X
Black-backed Woodpecker	Picoides arcticus	ABNYF07090	G5		Forest			X	X		X		X
American Three-toed Woodpecker	Picoides dorsalis	ABNYF07110	G5		Forest			X	X		X		
Northern Flicker	Colaptes auratus	ABNYF10020	G5		Woodland	X	X	X	X	X	X	X	X
Pileated Woodpecker	Dryocopus pileatus	ABNYF12020	G5		Forest	X	X	X	X	X	X	X	X
Olive-sided Flycatcher	Contopus cooperi	ABPAE32010	G4		Forest	X	X	X	X	X	X	X	X
Eastern Wood-Pewee	Contopus virens	ABPAE32060	G5		Forest	X	X	X	X	X	X	X	X

Common Name	Scientific Name	Element Code	Global Rank	RFSS	habitat	IL	IN	MI	MN	OH	NY	PA	WI
Yellow-bellied Flycatcher	Empidonax flaviventris	ABPAE33010	G5		Forest	X	X		X	X	X	X	X
Acadian Flycatcher	Empidonax virescens	ABPAE33020	G5		Forest	X	X	X	X	X	X	X	X
Alder Flycatcher	Empidonax alnorum	ABPAE33030	G5		Forested wetland	X	X	X	X	X	X	X	X
Willow Flycatcher	Empidonax traillii	ABPAE33040	G5		Woodland	X	X	X	X	X	X	X	X
Least Flycatcher	Empidonax minimus	ABPAE33070	G5		Woodland	X	X	X	X	X	X	X	X
Eastern Phoebe	Sayornis phoebe	ABPAE35020	G5		Woodland	X	X	X	X	X	X	X	X
Great Crested Flycatcher	Myiarchus crinitus	ABPAE43070	G5		Forest	X	X	X	X	X	X	X	X
Western Kingbird	Tyrannus verticalis	ABPAE52050	G5		Woodland	X		X	X	X			X
Eastern Kingbird	Tyrannus tyrannus	ABPAE52060	G5		Woodland	X	X	X	X	X	X	X	X
Purple Martin	Progne subis	ABPAU01010	G5		Woodland	X	X	X	X	X	X	X	X
Tree Swallow	Tachycineta bicolor	ABPAU03010	G5		Woodland	X	X	X	X	X	X	X	X
Northern Rough-winged Swallow	Stelgidopteryx serripennis	ABPAU07010	G5		Savanna	X	X	X	X	X	X	X	X
Bank Swallow	Riparia riparia	ABPAU08010	G5		Savanna	X	X	X	X	X	X	X	X
Cliff Swallow	Petrochelidon pyrrhonota	ABPAU09010	G5		Savanna			X					
Barn Swallow	Hirundo rustica	ABPAU09030	G5		Savanna	X	X		X		X	X	X
Canada Jay	Perisoreus canadensis	ABPAV01010	G5		Forest			X	X		X		X
Blue Jay	Cyanocitta cristata	ABPAV02020	G5		Forest	X	X	X	X	X	X	X	X
Common Raven	Corvus corax	ABPAV10110	G5		Forest	X	X	X	X	X	X	X	X
American Crow	Corvus brachyrhynchos	ABPAV10170	G5		Woodland	X	X	X	X	X	X	X	X
Black-capped Chickadee	Poecile atricapillus	ABPAW01010	G5		Forest	X	X	X	X	X	X	X	X
Boreal Chickadee	Poecile hudsonicus	ABPAW01060	G5		Forest			X	X		X		X
Tufted Titmouse	Baeolophus bicolor	ABPAW01110	G5		Forest	X	X	X	X	X	X	X	X
Red-breasted Nuthatch	Sitta canadensis	ABPAZ01010	G5		Forest	X	X	X	X		X	X	X

Common Name	Scientific Name	Element Code	Global Rank	RFSS	habitat	IL	IN	MI	MN	OH	NY	PA	WI
White-breasted Nuthatch	Sitta carolinensis	ABPAZ01020	G5		Forest	X	X	X	X	X	X	X	X
Brown Creeper	Certhia americana	ABPBA01010	G5		Forest	X	X	X	X	X	X	X	X
Carolina Wren	Thryothorus ludovicianus	ABPBG06130	G5		Forest	X	X	X	X	X	X	X	
Bewick's Wren	Thryomanes bewickii	ABPBG07010	G5		Woodland	X	X	X	X	X		X	X
House Wren	Troglodytes aedon	ABPBG09010	G5		Woodland	X	X	X	X	X	X	X	X
Winter Wren	Troglodytes hiemalis	ABPBG09100	G5		Woodland	X	X	X	X	X	X	X	X
Golden-crowned Kinglet	Regulus satrapa	ABPBJ05010	G5		Forest	X	X	X	X	X	X	X	X
Ruby-crowned Kinglet	Corthylio calendula	ABPBJ05020	G5		Forest	X	X	X	X	X	X	X	X
Blue-gray Gnatcatcher	Polioptila caerulea	ABPBJ08010	G5		Forest	X	X	X	X	X	X	X	X
Eastern Bluebird	Sialia sialis	ABPBJ15010	G5		Woodland	X	X	X	X	X	X	X	X
Townsend's Solitaire	Myadestes townsendi	ABPBJ16010	G5		Forest			X	X				
Veery	Catharus fuscescens	ABPBJ18080	G5		Forest	X	X	X	X	X	X	X	X
Gray-cheeked Thrush	Catharus minimus	ABPBJ18090	G5		Forest	X	X	X	X	X	X	X	X
Swainson's Thrush	Catharus ustulatus	ABPBJ18100	G5		Forest	X	X	X	X	X	X	X	X
Hermit Thrush	Catharus guttatus	ABPBJ18110	G5		Forest	X	X	X	X	X	X	X	X
Wood Thrush	Hylocichla mustelina	ABPBJ19010	G4		Forest	X	X	X	X	X	X	X	X
American Robin	Turdus migratorius	ABPBJ20170	G5		Forest	X	X	X	X	X	X	X	X
Gray Catbird	Dumetella carolinensis	ABPBK01010	G5		Woodland	X	X	X	X	X	X	X	X
Northern Mockingbird	Mimus polyglottos	ABPBK03010	G5		Savanna			X					
Brown Thrasher	Toxostoma rufum	ABPBK06010	G5		Woodland	X	X	X	X	X	X	X	X
Bohemian Waxwing	Bombycilla garrulus	ABPBN01010	G5		Woodland			X	X		X		X
Cedar Waxwing	Bombycilla cedrorum	ABPBN01020	G5		Woodland	X	X	X	X	X	X	X	X
Loggerhead Shrike	Lanius ludovicianus	ABPBR01030	G4		Savanna			X					
Northern Shrike	Lanius borealis	ABPBR01040	G5		Woodland	X	X	X	X	X	X	X	X
White-eyed Vireo	Vireo griseus	ABPBW01020	G5		Forest	X	X	X		X	X	X	X

Common Name	Scientific Name	Element Code	Global Rank	RFSS	habitat	IL	IN	MI	MN	OH	NY	PA	WI
Bell's Vireo	Vireo bellii	ABPBW01110	G5		Woodland	X	X	X	X				X
Blue-headed Vireo	Vireo solitarius	ABPBW01160	G5		Forest	X	X	X	X	X	X	X	X
Yellow-throated Vireo	Vireo flavifrons	ABPBW01170	G5		Forest	X	X	X	X	X	X	X	X
Warbling Vireo	Vireo gilvus	ABPBW01210	G5		Forest	X	X	X	X	X	X	X	X
Philadelphia Vireo	Vireo philadelphicus	ABPBW01230	G5		Woodland	X	X	X	X	X	X	X	
Red-eyed Vireo	Vireo olivaceus	ABPBW01240	G5		Forest	X	X	X	X	X	X	X	X
Blue-winged Warbler	Vermivora cyanoptera	ABPBX01020	G5		Woodland	X	X	X	X	X	X	X	X
Golden-winged Warbler	Vermivora chrysoptera	ABPBX01030	G4	X	Woodland	X	X	X	X	X	X	X	X
Tennessee Warbler	Leiothlypis peregrina	ABPBX01040	G5		Woodland	X	X	X	X	X	X	X	
Orange-crowned Warbler	Leiothlypis celata	ABPBX01050	G5		Forest	X	X	X	X	X	X	X	X
Nashville Warbler	Leiothlypis ruficapilla	ABPBX01060	G5		Woodland	X	X	X	X		X	X	X
Northern Parula	Setophaga americana	ABPBX02010	G5		Forest	X	X	X	X	X	X	X	X
Yellow Warbler	Setophaga petechia	ABPBX03010	G5		Woodland	X	X	X	X	X	X	X	X
Chestnut-sided Warbler	Setophaga pensylvanica	ABPBX03020	G5		Forest	X	X	X	X	X	X	X	X
Magnolia Warbler	Setophaga magnolia	ABPBX03030	G5		Forest	X		X	X	X	X	X	X
Cape May Warbler	Setophaga tigrina	ABPBX03040	G5		Forest	X	X	X	X	X	X	X	X
Black-throated Blue Warbler	Setophaga caerulescens	ABPBX03050	G5		Forest	X	X	X	X		X	X	X
Yellow-rumped Warbler	Setophaga coronata	ABPBX03060	G5		Forest	X	X	X	X	X	X	X	X
Black-throated Green Warbler	Setophaga virens	ABPBX03100	G5		Forest	X	X	X	X	X	X	X	X
Blackburnian Warbler	Setophaga fusca	ABPBX03120	G5		Forest	X		X	X	X	X	X	X
Yellow-throated Warbler	Setophaga dominica	ABPBX03130	G5		Forest	X	X	X		X	X	X	X
Pine Warbler	Setophaga pinus	ABPBX03170	G5		Forest	X	X	X	X	X	X	X	X
Kirtland's Warbler	Setophaga kirtlandii	ABPBX03180	G3	X	Woodland		X	X		X		X	X

Common Name	Scientific Name	Element Code	Global Rank	RFSS	habitat	IL	IN	MI	MN	OH	NY	PA	WI
Prairie Warbler	Setophaga discolor	ABPBX03190	G5		Woodland	X	X	X		X	X	X	X
Palm Warbler	Setophaga palmarum	ABPBX03210	G5		Woodland	X	X	X	X	X	X	X	X
Bay-breasted Warbler	Setophaga castanea	ABPBX03220	G5		Forest	X	X	X	X	X	X	X	X
Blackpoll Warbler	Setophaga striata	ABPBX03230	G5		Forest	X	X	X	X	X	X	X	X
Cerulean Warbler	Setophaga cerulea	ABPBX03240	G4	X	Forest	X	X	X	X	X	X	X	X
Black-and-white Warbler	Mniotilta varia	ABPBX05010	G5		Forest	X	X	X	X	X	X	X	X
American Redstart	Setophaga ruticilla	ABPBX06010	G5		Forest	X	X	X	X	X	X	X	X
Prothonotary Warbler	Protonotaria citrea	ABPBX07010	G5		Forest	X	X	X	X	X	X	X	X
Ovenbird	Seiurus aurocapilla	ABPBX10010	G5		Forest	X	X	X	X	X	X	X	X
Northern Waterthrush	Parkesia noveboracensis	ABPBX10020	G5		Forest	X		X	X	X	X	X	X
Louisiana Waterthrush	Parkesia motacilla	ABPBX10030	G5		Forest	X	X	X	X	X	X	X	X
Kentucky Warbler	Geothlypis formosa	ABPBX11010	G5		Forest	X	X	X	X	X	X	X	X
Connecticut Warbler	Oporornis agilis	ABPBX11020	G4G5	X	Woodland	X	X	X	X		X	X	X
Mourning Warbler	Geothlypis philadelphia	ABPBX11030	G5		Forest	X		X	X	X	X	X	X
Hooded Warbler	Setophaga citrina	ABPBX16010	G5		Forest	X	X	X	X	X	X	X	X
Wilson's Warbler	Cardellina pusilla	ABPBX16020	G5		Forest	X	X	X	X	X	X	X	
Canada Warbler	Cardellina canadensis	ABPBX16030	G5		Forest	X	X	X	X	X	X	X	X
Yellow-breasted Chat	Icteria virens	ABPBX24010	G5		Woodland	X	X	X	X	X	X	X	X
Summer Tanager	Piranga rubra	ABPBX45030	G5		Forest	X	X	X	X	X		X	
Scarlet Tanager	Piranga olivacea	ABPBX45040	G5		Forest	X	X	X	X	X	X	X	X
Northern Cardinal	Cardinalis cardinalis	ABPBX60010	G5		Woodland	X	X	X	X	X	X	X	X
Rose-breasted Grosbeak	Pheucticus ludovicianus	ABPBX61030	G5		Forest	X	X	X	X	X	X	X	X
Indigo Bunting	Passerina cyanea	ABPBX64030	G5		Woodland	X	X	X	X	X	X	X	X
Dickcissel	Spiza americana	ABPBX65010	G5		Savanna	X	X	X	X	X		X	X
Eastern Towhee	Pipilo erythrophthalmus	ABPBX74030	G5		Forest	X	X	X	X	X	X	X	X
Chipping Sparrow	Spizella passerina	ABPBX94020	G5		Woodland	X	X	X	X	X	X	X	X

Common Name	Scientific Name	Element Code	Global Rank	RFSS	habitat	IL	IN	MI	MN	OH	NY	PA	WI
Clay-colored Sparrow	Spizella pallida	ABPBX94030	G5		Woodland	X		X	X		X	X	X
Field Sparrow	Spizella pusilla	ABPBX94050	G5		Woodland	X	X	X	X	X	X	X	X
Vesper Sparrow	Pooecetes gramineus	ABPBX95010	G5		Savanna			X					
Lark Sparrow	Chondestes grammacus	ABPBX96010	G5		Woodland	X	X		X	X	X		X
Grasshopper Sparrow	Ammodramus savannarum	ABPBXA0020	G5	X	Savanna	X	X	X	X	X	X	X	X
Fox Sparrow	Passerella iliaca	ABPBXA2010	G5		Woodland	X	X	X	X	X	X	X	X
Song Sparrow	Melospiza melodia	ABPBXA3010	G5		Woodland	X	X	X	X	X	X	X	X
Lincoln's Sparrow	Melospiza lincolnii	ABPBXA3020	G5		Woodland	X	X	X	X	X	X	X	X
White-throated Sparrow	Zonotrichia albicollis	ABPBXA4020	G5		Forest	X	X	X	X	X	X	X	X
White-crowned Sparrow	Zonotrichia leucophrys	ABPBXA4040	G5		Woodland	X	X	X	X	X	X	X	X
Harris's Sparrow	Zonotrichia querula	ABPBXA4050	G5		Woodland	X	X	X	X				X
Dark-eyed Junco	Junco hyemalis	ABPBXA5020	G5		Forest	X	X	X	X	X	X	X	X
Lapland Longspur	Calcarius lapponicus	ABPBXA6020	G5		Forested wetland	X	X	X	X	X	X	X	X
Red-winged Blackbird	Agelaius phoeniceus	ABPBXB0010	G5		Forested wetland	X	X	X	X	X	X	X	X
Western Meadowlark	Sturnella neglecta	ABPBXB2030	G5	X	Savanna	X	X	X	X	X			X
Eastern Meadowlark	Sturnella magna	ABPBXB2040	G5	X	Savanna	X	X	X	X	X	X	X	X
Rusty Blackbird	Euphagus carolinus	ABPBXB5010	G4	X	Woodland	X	X	X	X	X	X	X	X
Brewer's Blackbird	Euphagus cyanocephalus	ABPBXB5020	G5		Woodland	X	X	X	X	X			X
Common Grackle	Quiscalus quiscula	ABPBXB6070	G5		Woodland	X	X	X	X	X	X	X	X
Brown-headed Cowbird	Molothrus ater	ABPBXB7030	G5		Forest	X	X	X	X	X	X	X	X
Orchard Oriole	Icterus spurius	ABPBXB9070	G5		Woodland	X	X	X	X	X	X	X	X
Baltimore Oriole	Icterus galbula	ABPBXB9190	G5		Woodland	X	X	X	X	X	X	X	X
Pine Grosbeak	Pinicola enucleator	ABPBY03010	G5		Forest	X	X	X	X		X		X
Purple Finch	Haemorhous purpureus	ABPBY04020	G5		Forest	X	X	X	X	X	X	X	X

Common Name	Scientific Name	Element Code	Global Rank	RFSS	habitat	IL	IN	MI	MN	OH	NY	PA	WI
White-winged Crossbill	Loxia leucoptera	ABPBY05020	G5		Forest	X	X	X	X	X	X		X
Red Crossbill	Loxia curvirostra	ABPBY05050	G5		Savanna	X	X	X	X	X	X	X	X
Common Redpoll	Acanthis flammea	ABPBY06010	G5		Forest	X	X	X	X		X	X	X
Hoary Redpoll	Acanthis hornemanni	ABPBY06020	G5		Woodland				X		X		
Pine Siskin	Spinus pinus	ABPBY06030	G5		Forest	X	X	X	X		X	X	X
American Goldfinch	Spinus tristis	ABPBY06110	G5		Woodland	X	X	X	X	X	X	X	X
Evening Grosbeak	Coccothraustes vespertinus	ABPBY09020	G5		Forest	X	X	X	X	X	X	X	X

Appendix Table A-3. Mammals that occur in forested habitats within the US Great Lakes Basin. Source: NatureServe Explorer state species lists (NatureServe 2024).

Common Name	Scientific Name	Element Code	Global Rank	RFSS	Habitat	IL	IN	MI	MN	OH	NY	PA	WI
Virginia Opossum	Didelphis virginiana	AMAAA01010	G5		Woodland	X	X	X	X	X	X	X	X
Cinereus Shrew	Sorex cinereus	AMABA01010	G5		Forest	X	X		X	X	X	X	X
Eastern Pygmy Shrew	Sorex hoyi	AMABA01050	G5		Forest	X	X		X	X	X	X	X
Smoky Shrew	Sorex fumeus	AMABA01180	G5		Forest		X	X	X	X	X	X	
Arctic Shrew	Sorex arcticus	AMABA01190	G5		Forest				X				X
Northern Short-tailed Shrew	Blarina brevicauda	AMABA03010	G5		Forest	X	X	X	X	X	X	X	X
North American Least Shrew	Cryptotis parva	AMABA04010	G5		Woodland	X	X	X	X	X	X	X	X
Hairy-tailed Mole	Parascalops breweri	AMABB03010	G5		Forest					X	X	X	
Eastern Mole	Scalopus aquaticus	AMABB04010	G5		Forest	X	X	X	X	X	X	X	X
Little Brown Myotis	Myotis lucifugus	AMACC01010	G3G4	X	Forest	X	X	X	X	X	X	X	X
Indiana Myotis	Myotis sodalis	AMACC01100	G2	X	Forest	X	X	X		X	X	X	
Eastern Small-footed Myotis	Myotis leibii	AMACC01130	G4		Forest	X				X	X	X	
Northern Myotis	Myotis septentrionalis	AMACC01150	G2G3	X	Forest	X	X	X	X	X	X	X	X
Silver-haired Bat	Lasionycteris noctivagans	AMACC02010	G3G4	X	Forest	X	X	X	X	X	X	X	X
Tricolored Bat	Perimyotis subflavus	AMACC03020	G3G4	X	Woodland	X	X	X	X	X	X	X	X
Big Brown Bat	Eptesicus fuscus	AMACC04010	G5		Forest	X	X	X	X	X	X	X	X
Eastern Red Bat	Lasiurus borealis	AMACC05010	G3G4	X	Forest	X	X	X	X	X	X	X	X
Northern Hoary Bat	Lasiurus cinereus	AMACC05032	G3G4	X	Forest	X	X	X	X	X	X	X	X
Evening Bat	Nycticeius humeralis	AMACC06010	G5		Forest	X	X	X		X		X	X
Eastern Cottontail	Sylvilagus floridanus	AMAEB01040	G5		Woodland -	X	X		X	X	X	X	X
Snowshoe Hare	Lepus americanus	AMAEB03010	G5		Forest			X	X		X	X	X
Least Chipmunk	Neotamias minimus	AMAFB02020	G5		Forest			X	X				X
Eastern Chipmunk	Tamias striatus	AMAFB02230	G5		Forest	X	X		X	X	X	X	X

Common Name	Scientific Name	Element Code	Global Rank	RFSS	Habitat	IL	IN	MI	MN	OH	NY	PA	WI
Woodchuck	Marmota monax	AMAFB03010	G5		Forest	X	X		X	X	X	X	X
Eastern Gray Squirrel	Sciurus carolinensis	AMAFB07010	G5		Forest	X	X		X	X	X	X	X
Eastern Fox Squirrel	Sciurus niger	AMAFB07040	G5		Forest	X	X		X	X	X	X	X
North American Red Squirrel	Tamiasciurus hudsonicus	AMAFB08040	G5		Forest	X	X		X	X	X	X	X
Southern Flying Squirrel	Glaucomys volans	AMAFB09010	G5		Forest	X	X	X	X	X	X	X	X
Northern Flying Squirrel	Glaucomys sabrinus	AMAFB09030	G5		Forest			X	X	X	X	X	X
American Beaver	Castor canadensis	AMAFE01010	G5		Forest			X		X			
Western Harvest Mouse	Reithrodontomys megalotis	AMAFF02030	G5		Woodland				X				X
North American Deermouse	Peromyscus maniculatus	AMAFF03040	G5		Forest	X	X	X	X	X	X	X	X
White-footed Deermouse	Peromyscus leucopus	AMAFF03070	G5		Woodland	X	X		X	X	X	X	X
Southern Red-backed Vole	Clethrionomys gapperi	AMAFF09020	G5		Forest			X	X		X	X	X
Rock Vole	Microtus chrotorrhinus	AMAFF11090	G5		Forest				X				
Prairie Vole	Microtus ochrogaster	AMAFF11140	G5		Savanna			X					
Woodland Vole	Microtus pinetorum	AMAFF11150	G5		Forest	X	X	X	X	X	X	X	X
Common Muskrat	Ondatra zibethicus	AMAFF15010	G5		Forested wetland	X	X	X	X	X	X	X	X
Southern Bog Lemming	Synaptomys cooperi	AMAFF17010	G5		Forest Har	X	X		X	X	X	X	X
Woodland Jumping Mouse	Napaeozapus insignis	AMAFH02010	G5		Forest			X	X	X	X	X	X
North American Porcupine	Erethizon dorsatum	AMAFJ01010	G5		Forest	X	X	X	X	X	X	X	X
Coyote	Canis latrans	AMAJA01010	G5		Woodland	X	X	X	X	X	X	X	X
Gray Wolf	Canis lupus	AMAJA01030	G5		Forest			X	X				X
Red Fox	Vulpes vulpes	AMAJA03010	G5		Forest	X	X		X	X	X		X
Gray Fox	Urocyon cinereoargenteus	AMAJA04010	G5		Forest	X	X	X	X	X	X	X	X
American Black Bear	Ursus americanus	AMAJB01010	G5		Forest		X	X	X	X	X	X	X
Raccoon	Procyon lotor	AMAJE02010	G5		Forest	X	X		X	X	X	X	X
Fisher	Pekania pennanti	AMAJF01020	G5		forest		X	X	X	X	X	X	X

Common Name	Scientific Name	Element Code	Global Rank	RFSS	Habitat	IL	IN	MI	MN	OH	NY	PA	WI
American Marten	Martes americana	AMAJF01040	G5		Forest			X	X		X		X
Least Weasel	Mustela nivalis	AMAJF02020	G5		Woodland	X	X	X	X	X	X	X	X
Long-tailed Weasel	Neogale frenata	AMAJF02030	G5		Forest	X	X	X	X	X	X	X	X
American Mink	Neogale vison	AMAJF02050	G5		Forested wetland			X		X			
American Ermine	Mustela richardsonii	AMAJF02070	G5		Forest			X	X	X	X	X	X
Wolverine	Gulo gulo	AMAJF03010	G4		Forest			X	X				X
American Badger	Taxidea taxus	AMAJF04010	G5		Savanna			X					
Striped Skunk	Mephitis mephitis	AMAJF06010	G5		Forest	X	X	X	X	X	X	X	X
North American River Otter	Lontra canadensis	AMAJF10010	G5		Forested wetland			X		X			
Canada Lynx	Lynx canadensis	AMAJH03010	G5		Forest			X	X				
Bobcat	Lynx rufus	AMAJH03020	G5		Forest	X	X	X	X	X	X	X	X
Cougar	Puma concolor	AMAJH04010	G5		Forest			X	X				X
Elk	Cervus elaphus	AMALC01010	G5		Forest			X	X				X
White-tailed Deer	Odocoileus virginianus	AMALC02020	G5		Forest	X	X	X	X	X	X	X	X
Moose	Alces alces	AMALC03020	G5		Forest			X	X		X		

Appendix Table A-4. Reptiles that occur in forested habitats within the US Great Lakes Basin. Source: NatureServe Explorer state species lists (NatureServe 2024).

Common Name	Scientific Name	Element Code	Global Rank	RFSS	habitat	IL	IN	MI	MN	OH	NY	PA	WI
Wood Turtle	Glyptemys insculpta	ARAAD02020	G2G3	X	Forest			X	X		X	X	X
American Box Turtle	Terrapene carolina	ARAAD08010	G5		Forest	X	X	X		X	X	X	
Slender Glass Lizard	Ophisaurus attenuatus	ARACB02010	G5		Woodland	X	X						
Coal Skink	Plestiodon anthracinus	ARACH01010	G5		Forest					X	X	X	
Common Five-lined Skink	Plestiodon fasciatus	ARACH01050	G5		Forest	X	X	X	X	X	X	X	X
Six-lined Racerunner	Aspidoscelis sexlineatus	ARACJ02110	G5		Woodland	X	X	X	X				X
North American Racer	Coluber constrictor	ARADB07010	G5		Woodland	X	X	X	X	X	X	X	X
Ring-necked Snake	Diadophis punctatus	ARADB10010	G5		Forest	X	X	X	X	X	X	X	X
Eastern Foxsnake	Pantherophis vulpinus	ARADB13062	G5		Woodland	X	X	X		X			X
Gray Ratsnake	Pantherophis spiloides	ARADB13090	G4G5		Woodland		X	X		X	X		X
Eastern Hog-nosed Snake	Heterodon platirhinos	ARADB17020	G5		Woodland	X	X	X	X	X	X	X	X
Eastern Milksnake	Lampropeltis triangulum	ARADB19080	G5		Woodland	X	X	X	X	X	X	X	X
Dekay's Brownsnake	Storeria dekayi	ARADB34010	G5		Forest	X	X	X	X	X	X	X	X
Red-bellied Snake	Storeria occipitomaculata	ARADB34030	G5		Forest	X	X	X	X	X	X	X	X
Common Gartersnake	Thamnophis sirtalis	ARADB36130	G5		Forest	X	X	X	X	X	X	X	X
Smooth Greensnake	Opheodrys vernalis	ARADB47010	G5	X	Woodland	X	X	X	X	X	X	X	X
Timber Rattlesnake	Crotalus horridus	ARADE02040	G4	X	Forest Har	X			X	X		X	X
Eastern Massasauga	Sistrurus catenatus	ARADE03011	G3	X	Woodland	X	X	X		X	X	X	X

Appendix Table A-5. Fish that occur in forested habitats within the US Great Lakes Basin.
Source: NatureServe 2008

Common Name	Scientific Name	Global Rank	Regional Forester Sensitive Species (RFSS)
Rock Bass	Ambloplites rupestris		
Black Bullhead	Ameiurus melas		
Yellow Bullhead	Ameiurus natalis		
Brown Bullhead	Ameiurus nebulosus		
Bowfin	Amia calva		
Western Sand Darter	Ammocrypta clara		
Eastern Sand Darter	Ammocrypta pellucida		
American Eel	Anguilla rostrata		
Pirate Perch	Aphredoderus sayanus		
Freshwater Drum	Aplodinotus grunniens		
Central Stoneroller	Campostoma anomalum		
Largescale Stoneroller	Campostoma oligolepis		
Quillback	Carpiodes cyprinus		
Highfin Carpsucker	Carpiodes velifer		
Longnose Sucker	Catostomus catostomus		
White Sucker	Catostomus commersonii		
Redside Dace	Clinostomus elongatus	G3	X
Slimy Sculpin	Cottus cognatus		
Spoonhead Sculpin	Cottus ricei		
Lake Chub	Couesius plumbeus		
Brook Stickleback	Culaea inconstans		
Satinfin Shiner	Cyprinella analostana		
Spotfin Shiner	Cyprinella spiloptera		
Gizzard Shad	Dorosoma cepedianum		
Creek Chubsucker	Erimyzon oblongus		
Lake Chubsucker	Erimyzon sucetta		
Redfin Pickerel	Esox americanus		
Northern Pike	Esox lucius		
Muskellunge	Esox masquinongy		

Common Name	Scientific Name	Global Rank	Regional Forester Sensitive Species (RFSS)
Greenside Darter	Etheostoma blennioides		
Rainbow Darter	Etheostoma caeruleum		
Iowa Darter	Etheostoma exile		
Fantail Darter	Etheostoma flabellare		
Spotted Darter	Etheostoma maculatum	G3	
Least Darter	Etheostoma microperca		
Johnny Darter	Etheostoma nigrum		
Tessellated Darter	Etheostoma olmstedi		
Orangethroat Darter	Etheostoma spectabile		
Banded Darter	Etheostoma zonale		
Cutlip Minnow	Exoglossum maxillingua		
Banded Killifish	Fundulus diaphanus		
Starhead Topminnow	Fundulus dispar		
Blackstripe Topminnow	Fundulus notatus		
Threespine Stickleback	Gasterosteus aculeatus		
Mooneye	Hiodon tergisus		
Brassy Minnow	Hybognathus hankinsoni		
Eastern Silvery Minnow	Hybognathus regius		
Bigeye Chub	Hybopsis amblops		
Northern Hog Sucker	Hypentelium nigricans		
Chestnut Lamprey	Ichthyomyzon castaneus		
Northern Brook Lamprey	Ichthyomyzon fossor		
Silver Lamprey	Ichthyomyzon unicuspis		
Channel Catfish	Ictalurus punctatus		
Smallmouth Buffalo	Ictiobus bubalus		
Bigmouth Buffalo	Ictiobus cyprinellus		
Black Buffalo	Ictiobus niger		
Brook Silverside	Labidesthes sicculus		
American Brook Lamprey	Lampetra appendix		
Spotted Gar	Lepisosteus oculatus		
Longnose Gar	Lepisosteus osseus		
Redbreast Sunfish	Lepomis auritus		

Common Name	**Scientific Name**	**Global Rank**	**Regional Forester Sensitive Species (RFSS)**
Green Sunfish	Lepomis cyanellus		
Pumpkinseed	Lepomis gibbosus		
Warmouth	Lepomis gulosus		
Orangespotted Sunfish	Lepomis humilis		
Bluegill	Lepomis macrochirus		
Longear Sunfish	Lepomis megalotis		
Burbot	Lota lota		
Striped Shiner	Luxilus chrysocephalus		
Common Shiner	Luxilus cornutus		
Redfin Shiner	Lythrurus umbratilis		
Silver Chub	Macrhybopsis storeriana		
Pearl Dace	Margariscus margarita		
Smallmouth Bass	Micropterus dolomieu		
Largemouth Bass	Micropterus salmoides		
Spotted Sucker	Minytrema melanops		
White Bass	Morone chrysops		
Silver Redhorse	Moxostoma anisurum		
River Redhorse	Moxostoma carinatum		
Black Redhorse	Moxostoma duquesnei		
Golden Redhorse	Moxostoma erythrurum		
Shorthead Redhorse	Moxostoma macrolepidotum		
Greater Redhorse	Moxostoma valenciennesi		
Hornyhead Chub	Nocomis biguttatus		
River Chub	Nocomis micropogon		
Golden Shiner	Notemigonus crysoleucas		
Pugnose Shiner	Notropis anogenus	G3	X
Emerald Shiner	Notropis atherinoides		
Bridle Shiner	Notropis bifrenatus		
River Shiner	Notropis blennius		
Bigeye Shiner	Notropis boops		
Silverjaw Minnow	Notropis buccatus		
Ghost Shiner	Notropis buchanani		

Common Name	Scientific Name	Global Rank	Regional Forester Sensitive Species (RFSS)
Ironcolor Shiner	Notropis chalybaeus		
Bigmouth Shiner	Notropis dorsalis		
Blackchin Shiner	Notropis heterodon		
Blacknose Shiner	Notropis heterolepis		
Spottail Shiner	Notropis hudsonius		
Silver Shiner	Notropis photogenis		
Swallowtail Shiner	Notropis procne		
Rosyface Shiner	Notropis rubellus		
Sand Shiner	Notropis stramineus		
Weed Shiner	Notropis texanus		
Mimic Shiner	Notropis volucellus		
Stonecat	Noturus flavus		
Tadpole Madtom	Noturus gyrinus		
Margined Madtom	Noturus insignis		
Brindled Madtom	Noturus miurus		
Northern Madtom	Noturus stigmosus	G3	X
Pugnose Minnow	Opsopoeodus emiliae		
Yellow Perch	Perca flavescens		
Logperch	Percina caprodes		
Channel Darter	Percina copelandi		
Gilt Darter	Percina evides		
Blackside Darter	Percina maculata		
Slenderhead Darter	Percina phoxocephala		
River Darter	Percina shumardi		
Trout-perch	Percopsis omiscomaycus		
Suckermouth Minnow	Phenacobius mirabilis		
Northern Redbelly Dace	Phoxinus eos		

Common Name	Scientific Name	Global Rank	Regional Forester Sensitive Species (RFSS)
Southern Redbelly Dace	Phoxinus erythrogaster		
Finescale Dace	Phoxinus neogaeus		
Bluntnose Minnow	Pimephales notatus		
Fathead Minnow	Pimephales promelas		
Bullhead Minnow	Pimephales vigilax		
White Crappie	Pomoxis annularis		
Black Crappie	Pomoxis nigromaculatus		
Round Whitefish	Prosopium cylindraceum		
Ninespine Stickleback	Pungitius pungitius		
Flathead Catfish	Pylodictis olivaris		
Blacknose Dace	Rhinichthys atratulus		
Longnose Dace	Rhinichthys cataractae		
Brook Trout	Salvelinus fontinalis		
Lake Trout	Salvelinus namaycush		
Sauger	Sander canadensis		
Walleye	Sander vitreus		
Shovelnose Sturgeon	Scaphirhynchus platorynchus		
Creek Chub	Semotilus atromaculatus		
Fallfish	Semotilus corporalis		
Central Mudminnow	Umbra limi		

Appendix B: Scientific names of plant, pest and pathogen species.

Appendix Table B-1. Scientific names of plant species in the report.

Common Name	Scientific Name
American beech	Fagus grandifolia
Balsam fir	Abies balsamea
Big bluestem	Andropogon geradi
Black ash	Fraxinus nigra
Black spruce	Picea mariana
Blueberry	Vaccinium angustifolium
Buckthorn	Rhamnus cathartica
Eastern hemlock	Tsuga canadensis
Jack pine	Pinus banksiana
Larch	Larix spp
Maples	Acer spp.
Northern white cedar	Thuja occidentalis
Oak	Quercus spp.
Hickory	Carya spp.
Paper birch	Betula papyrifera
Pennsylvania sedge	Carex pensylvanica
Red maple	Acer rubrum
Red pine	Pinus resinosa
Red spruce	Picea rubens
Sugar maple	Acer saccharum
Sweet fern	Comptonia peregrina
Tamarack	Larix laricina
Trembling aspen	Populus tremuloides
White pine	Pinus strobus
Wild rice	Zizania palustris
Willow	Salix spp.
Yellow birch	Betula alleghaniensis

Appendix Table B-2. Scientific names of pest and pathogen species in the report.

Common Name	Scientific Name
Spongy moth	Lymantria dispar dispar
Spruce budworm	Choristoneura freemani
Emerald ash borer	Agrilus planipennis
Forest tent caterpillar	Malacosoma disstria
White pine needle damage	Lecanosticta acicula, Lophophacidium dooksii (brown spot needle blight), Bifusella linearis, and Septorioides strobi
Oak wilt	Bretziella fagacearum
Needle cast	Rhizosphaera spp.
Beech bark disease	Neonectria spp.
Hemlock woolly adelgid	Adelges tsugae
Sea Lamprey	Petromyzon marinus
Filamentous algae	Cladophora sp.