USDA Northern Forests Climate Hub
U.S. DEPARTMENT OF AGRICULTURE

Climate Change Field Guide for Southern Wisconsin Forests:

Site-level considerations and adaptation

FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE

NIACS

The Nature Conservancy
nature.org

Wisconsin Initiative on Climate Change Impacts

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Northern Institute of Applied Climate Science

The Northern Institute of Applied Climate Science (NIACS) is a multi-organization partnership, led by the USDA Forest Service, focused on bridging the gap between research and management in the fields of climate adaptation and carbon science (www.niacs.org). NIACS leads a community effort called the Climate Change Response Framework (CCRF, www.forestadaptation.org) that helps land managers integrate climate change into their work.

NIACS
Northern Institute of Applied Climate Science

USDA Northern Forests Climate Hub

The USDA Northern Forests Climate Hub is also led by NIACS, and was created to deliver locally-relevant information to natural resource managers and landowners (www.climatehubs.usda.gov/hubs/northern-forests). This field guide is an example of how the USDA Climate Hubs are helping people with real-world decisions.

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Wisconsin Initiative on Climate Change Impacts

The Wisconsin Initiative on Climate Change Impacts (WICCI, www.wicci.wisc.edu) is the hub of climate adaptation activity in the state. The WICCI Working Groups on Forestry and Plants and Natural Communities created this field guide.

Wisconsin Initiative on Climate Change Impacts

INTRODUCTION

Climate change is a growing concern for Wisconsin's forests. Foresters and land managers are considering how to prepare for future conditions and evaluate risks in the woods.
This field guide is a quick reference on climate change for southern Wisconsin forests. We hope it will help you consider climate change risks together with local site characteristics, and also that it will help you design adaptation actions that help meet management goals.

There is also a companion field guide for northern Wisconsin forests, available at:
www.forestadaptation.org/northern_WI_fieldguide

This field guide will:

- **Summarize climate change effects on southern Wisconsin's forests**
- **Identify existing site conditions that could increase or reduce risk from climate change**
- **Help you start discussions about potential climate risks and management responses with co-workers, partners, and clients**

This field guide won't:

- **Tell you exactly how to respond to climate change risks**
- **Replace your own planning processes, local knowledge, or management experience**

How to Use this Field Guide

1. **Find your natural community using the key (p. 32)**
   This field guide is organized around 10 forested "natural communities" in southern Wisconsin. Notes and illustrations at the start of each section describe the community.

2. **Review general climate information**
   Each natural community section describes the overall climate change vulnerability, high-level climate change impacts, and important adaptive capacity factors to consider. Pages 22-31 contain tables that show whether the tree species in your stand are generally expected to increase or decrease in suitable habitat.

3. **Consider site-level conditions**
   Some places on the landscape may be more vulnerable, based on their specific conditions. The Site-Level Considerations pages in this field guide (pages 39, 45, 51, etc.) will help you consider local factors such as soils; species diversity; management history; and threats such as pests, diseases, and non-native species.

4. **Brainstorm adaptation actions**
   This guide includes example adaptation actions that could help address any "high risk" conditions in your stand (pages 40-41, 46-47, 52-53, etc.), along with the complete Forest Adaptation Menu (pages 19-21) to help brainstorm appropriate actions.

CLIMATE CHANGE AND SOUTHERN WISCONSIN FORESTS

Climate Change Vulnerability is the susceptibility of a system to adverse effects from climate change. Vulnerability depends on the potential impacts of climate change on a system, as well as the ability of the system to tolerate those impacts without undergoing significant change (adaptive capacity). A forest could be considered vulnerable if it is at risk of composition change or substantial declines in health or productivity.

The WICCI Plants and Natural Communities Working Group led a series of climate change vulnerability assessment workshops in 2014. Those workshops combined the best available information from published research, ecosystem models, and manager expertise (www.wicci.wisc.edu/plants-and-natural-communities-working-group/climate-change-vulnerability-assessments-ccvas/). Participants worked together to reach conclusions about the climate vulnerability of Wisconsin's natural communities by the end of the century.

The authors of this guide re-examined and edited the original vulnerability assessments for forest communities based on updated tree species model results (pages 22-31) as well as new information from literature and field experience.

Climate Change Impacts

The following pages present several impacts that are important to forests in southern Wisconsin. In many cases, climate change acts like a "threat multiplier" by interacting with stressors that already occur. More detailed descriptions and references to support these summaries are available in the WICCI vulnerability assessments mentioned on the previous page.

Key topics in this section include:

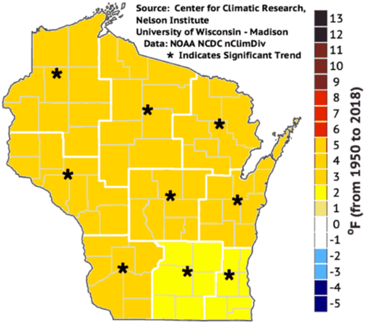
- Temperature increases
- Precipitation changes
- Longer growing season
- Soil moisture and drought stress
- Invasive species
- Forest pests and diseases
- Deer browse damage
- Prescribed fire application

Temperature Increases

Annual temperatures have already increased 2 to 3°F across southern Wisconsin since 1950. Winter is warming about twice as fast as other seasons, and minimum temperatures are increasing faster than maximum temperatures.

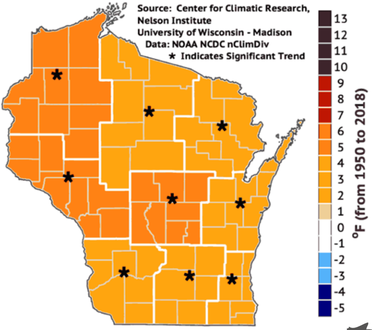
Temperatures are projected to continue to increase by an additional 3 to 4°F across southern Wisconsin by the middle of this century, with winter minimum temperatures continuing to warm most rapidly.

Historical Change in Annual Mean Temp, 1950–2018



Warmer temperatures will have cascading effects on forests, related to hydrology, drought risk, growing season length, germination success, and several other changes.

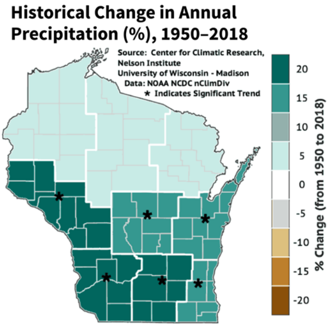
Historical Change in Winter Mean Temp, 1950–2018

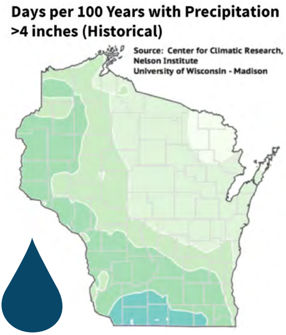


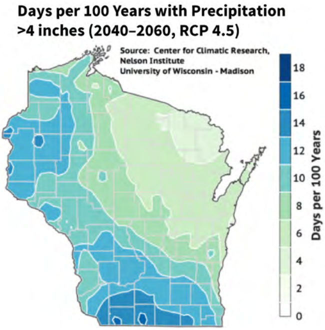
Precipitation Changes

Most of southern Wisconsin now receives about 15 to 20% more annual precipitation than in 1950, and this trend is generally consistent across all seasons. Mean annual precipitation is projected to continue to increase by about 5% by the middle of the century, with larger increases coming in spring and winter.

Perhaps more importantly, a larger share of total precipitation is coming from heavy rainfall events. Extreme precipitation events are projected to occur more frequently as climate change continues. Heavy rainfall has significant impacts on soil moisture, flooding, and erosion.







Longer Growing Season

Wisconsin's growing season has already increased by almost two weeks over the past 70 years. This trend is expected to continue, as some studies have projected that frost-free growing seasons across southern Wisconsin could increase by about 20 days by the middle of the century.

A longer growing season could be a good thing for some tree species, because it means more available time for growth. Native tree species may have limited ability to extend their growing seasons later in the year, and early warm spring conditions also raise the risk of frost damage if trees break bud before the last frost. Non-native species may be better able to take advantage of the longer growing season.

Soil Moisture and Drought Stress

Droughts are major stressors on forests, and they can make trees more vulnerable to insect outbreaks and other impacts. As rainfall has increased over the past century, droughts in Wisconsin have been slightly less common and less severe. Elevated carbon dioxide in the atmosphere may also help some tree species withstand short-term drought stress.

However, a handful of trends may cause drought stress to increase in the future:

- Warmer temperatures will increase evaporative demand on trees and soil (vapor pressure deficit).
- More water will be lost with longer growing seasons.
- More water will be lost to runoff during intense rain events rather than recharging soil moisture, and there may be longer dry periods between rains.
- Warmer winters reduce snowpack and accelerate snowmelt, so water “release” in the spring will be less gradual.

Even if total rainfall increases, these factors may lead to net drier conditions for Wisconsin’s forests.

Joseph O’Brien, USFS

Invasive Species

Invasive species are already a major threat to forests in southern Wisconsin. Humans have contributed to their expansion through disruption of native ecosystem processes triggered by grazing and fire suppression, as well as activities that spread them such as land development and trail maintenance. Invasive plants are expected to benefit from climate change because they readily track environmental changes (e.g., longer growing seasons, increasing precipitation) and rapidly colonize disturbed areas. Woody invasive species and vines (honeysuckle, poison ivy) may also benefit from elevated carbon dioxide in the atmosphere.

While dry, nutrient-poor sites may be less prone to invasion by non-native invasive species, they are still susceptible given projected longer growing seasons and increased precipitation.

Forests Pests and Diseases

Unfortunately, we lack basic information on the climatic thresholds for many forest pests, and we can't predict the pathways of infection, dispersal, and transmission for diseases. Based on our current knowledge, we assume that forest pests and diseases may be more damaging in Wisconsin's forests under climate change. Forest pests and diseases are generally more damaging in stressed forests, so there is high potential for interactions with other climate change impacts. For example, drought stress can weaken a tree's natural defenses to natural pest outbreaks, while new pests such as the southern pine beetle could expand their ranges northward under future climate scenarios.

Additionally, we expect longer growing seasons could allow some insects to complete multiple life cycles. These factors can allow populations to grow rapidly. Furthermore, new pests or pathogens will likely enter Wisconsin during the 21st century.

David Almquist, Bugwood.com

Deer Browse Damage

Climate change is expected to favor white-tailed deer. Warmer winters and reduced snow depth lower energy requirements for deer and increase access to forage during winter months. Milder winters reduce the need for deer to yard up in sheltered areas.

As deer benefit from climate change over the 21st century, they could have even greater impacts on forests across Wisconsin. Deer browsing pressure may limit the ability of forests to respond to climate change, because species like oaks, pines, and red maple are browsed so heavily. Deer herbivory may also favor species which are not browsed heavily, such as ironwood and black cherry, or invasive species like buckthorn or Japanese barberry.

USFS Photo by Ryan Pennesi

Prescribed Fire Application

Fire is an important natural and cultural disturbance for many forests across southern Wisconsin. As fire suppression policies and land conversion have limited the influence of wildfire, land managers now use prescribed fire as a tool in many southern Wisconsin forests.

There's a lot of uncertainty about the effects of climate change on the ability to apply prescribed fire in southern Wisconsin. Warmer, drier conditions may actually support prescribed fire and lengthen the window of opportunity for burning. Conversely, widespread tree mortality, wetter conditions, and on-going mesophication could limit local prescribed fire implementation. Because prescribed fire depends on advanced planning and staff availability, erratic conditions will be a serious challenge.

The Nature Conservancy

CLIMATE CHANGE ADAPTATION

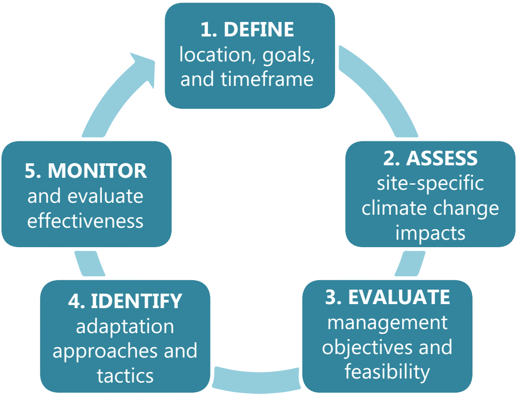
Climate change adaptation means adjusting systems in response to climate change. This is different than genetic or biological adaptation, which is how populations and species undergo genetic changes through time. The overarching purpose of climate change adaptation is to ensure ecosystem integrity and provide environmental benefits to people – in other words, to figure out how to meet your existing management goals despite changing conditions. Sustainable forest management, conservation, and restoration can all contribute to climate adaptation.

There is no "one size fits all" solution for adapting to climate change – each property presents unique conditions and each land manager will have a different set of goals and a different appetite for risk. So adaptation actions will be custom-built each time, and it will take managers with local knowledge and experience to make informed decisions about the future!

Forest Adaptation Resources and the Adaptation Workbook

This guide includes information from *Forest Adaptation Resources: Climate Change Tools and Approaches for Land Managers* (www.nrs.fs.fed.us/pubs/52760). The FAR provides a structured process to help land managers incorporate climate change considerations into management, called the Adaptation Workbook. There is also a "menu" of forest adaptation actions for managers to consider, which is copied on pages 19-21 of the field guide. Learn more about the Adaptation Workbook at www.adaptationworkbook.org.

Adaptation will work best if you generate your own ideas and actions based on local site conditions and management experience. Therefore, this field guide is designed to help you make your own climate-informed decisions for forest management and conservation.



Adaptation Options

Adaptation Options are large concepts that describe the general focus or pathway that land managers might want to take. Think about how each Option might apply to your particular goals and situation – this can help you judge what kind of adaptation choices will be most appropriate for you.

There are three basic Adaptation Options. Consider whether your site and your management goals offer a better opportunity to pursue one or more of these Options:

PERSISTENCE

Resistance: Protect the system from change. Useful when trying to maintain a resource with high economic, cultural, or ecological value in the short-term.

Resilience: Enable the system to rebound to normal conditions after disturbance. Useful with systems and species that can tolerate a wide range of environmental conditions and disturbance.

CHANGE

Transition: Actively encourage change for long-term success. Useful in highly vulnerable systems or when resistance and resilience actions may be too risky or costly.

Adaptation: Common Themes

As we prepared this field guide, it became clear that some over-arching adaptation themes are applicable to many forest management situations in southern Wisconsin. Consider these general ideas and how they might (or might not) apply to your situation:

1. Naturally functioning sites may be more adaptable. For example, fire-dependent communities that have been managed with prescribed fire, or floodplain forests with natural hydrology, may be in a better starting position to cope with stress.
2. Past land-use history and disruptions, such as over-grazing and high-grading, have affected many forests in southern Wisconsin and may make them less resilient to future change.
3. Communities that occur within a large forest matrix may be able to shift across the landscape as conditions change.
4. Conversely, communities that occur in small and isolated locations have a greater vulnerability.
5. Species in most southern Wisconsin community types can tolerate drought relatively well.
6. Red maple is projected to decline in suitable habitat over the next century, which could benefit oak-dominated communities.

Menu of Adaptation Options

The Forest Adaptation Menu can help you brainstorm management tactics for your needs, and it helps connect the dots between your management actions and broader adaptation intentions. For more complete descriptions of the Adaptation Strategies and Approaches listed in the menu, see the full version of the FAR (www.nrs.fs.fed.us/pubs/52760). See NIACS adaptation menus for other topics, including watershed management, wildlife, tribal perspectives, wetlands, and more (www.forestadaptation.org/adapt/adaptation-strategies).

The Forestry menu contains 10 general Adaptation Strategies. Within each Strategy, there are several more specific Approaches. Select Approaches that make sense for your situation, and then add relevant details in order to make them real tactics that you can implement .

Strategies and Approaches are designed to help you **bridge the gap** between big, fuzzy concepts and real management tactics.

Forest Adaptation Menu

Strategy 1: Sustain fundamental ecological functions.

1.1. Reduce impacts to soils and nutrient cycling.

1.2. Maintain or restore hydrology.

1.3. Maintain or restore riparian areas.

1.4. Reduce competition for moisture, nutrients, and light.

1.5. Restore or maintain fire in fire-adapted ecosystems.

Strategy 2: Reduce the impact of biological stressors.

2.1. Maintain or improve the ability of forests to resist pests and pathogens.

2.2. Prevent the introduction and establishment of invasive plant species and remove existing invasive species.

2.3. Manage herbivory to promote regeneration of desired species.

Strategy 3: Reduce the risk and long-term impacts of severe disturbances.

3.1. Alter forest structure or composition to reduce risk or severity of wildfire.

3.2. Establish fuelbreaks to slow the spread of catastrophic fire.

3.3. Alter forest structure to reduce severity or extent of wind and ice damage.

3.4. Promptly revegetate sites after disturbance.

Strategy 4: Maintain or create refugia.

4.1. Prioritize and maintain unique sites.

4.2. Prioritize and maintain sensitive or at-risk species or communities.

4.3. Establish artificial reserves for at-risk and displaced species.

Strategy 5: Maintain and enhance species and structural diversity.

5.1. Promote diverse age classes.

5.2. Maintain and restore diversity of native species.

5.3. Retain biological legacies.

5.4. Establish reserves to maintain ecosystem diversity.

Strategy 6: Increase ecosystem redundancy across the landscape.

6.1. Manage habitats over a range of sites and conditions.

6.2. Expand the boundaries of reserves to increase diversity.

Strategy 7: Promote landscape connectivity.

7.1. Reduce landscape fragmentation.

7.2. Maintain and create habitat corridors through reforestation or restoration.

Strategy 8: Maintain and enhance genetic diversity.

8.1. Use seeds, germplasm, and other genetic material from across a greater geographic range.

8.2. Favor existing genotypes that are better adapted to future conditions.

Strategy 9: Facilitate community adjustments through species transitions.

9.1. Favor or restore native species that are expected to be adapted to future conditions.

9.2. Establish or encourage new mixes of native species.

9.3. Guide changes in species composition at early stages of stand development.

9.4. Protect future-adapted seedlings and saplings.

9.5. Disfavor species that are distinctly maladapted.

9.6. Manage for species and genotypes with wide moisture and temperature tolerances.

9.7. Introduce species that are expected to be adapted to future conditions.

9.8. Move at-risk species to locations that are expected to provide habitat.

Strategy 10: Realign ecosystems after disturbance.

10.1. Promptly revegetate sites after disturbance.

10.2. Allow for areas of natural regeneration to test for future-adapted species.

10.3. Realign significantly disrupted ecosystems to meet expected future conditions.

TREE SPECIES PROJECTIONS

This section shows projections of suitable habitat for tree species in southern Wisconsin for the end of the century. These results are from the Climate Change Tree Atlas model, using two future climate scenarios (Representative Concentration Pathways, or RCPs) to "bracket" a range of plausible futures. On the next pages, the "Low" or mild climate change scenario is RCP 4.5 and the "High" scenario is RCP 8.5. Tree species information is organized by Ecological Section (see following page), which shows how trees are projected to fare in different parts of the state. To conserve space, we are showing results only for 43 species in each Ecological Section. Learn more about the Tree Atlas and get complete results at: https://www.fs.fed.us/nrs/atlas/.

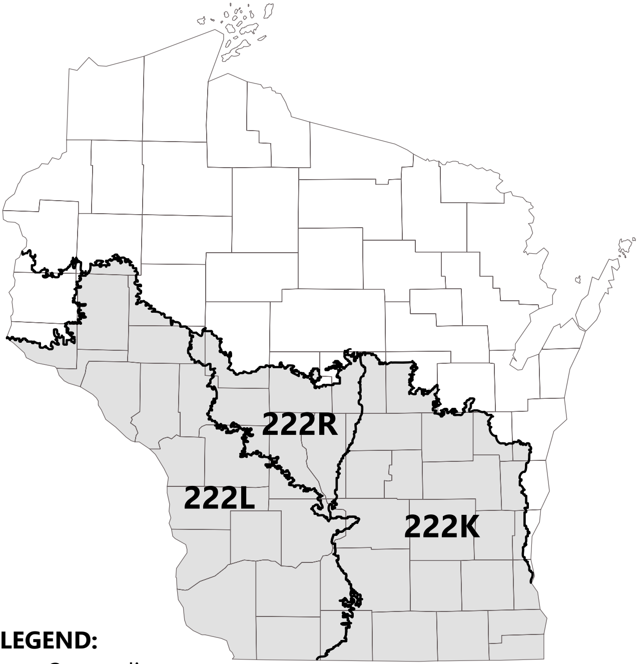
Remember that models are just tools, and they're not perfect. Models don't account for some factors that could be modified by climate change, like droughts, wildfire, and invasive species such as the emerald ash borer. These factors could cause a species to perform better or worse than the model projects. Management choices, such as planting species that are projected to increase, will continue to influence forest trajectories.

Despite these limits, models are useful tools to evaluate future growing conditions. It's probably best to think of these projections as indicators of potential change.

For more tree species projections visit: www.forestadaptation.org/southern_WI_fieldguide

Ecological Sections

In this section, you'll find Tree Atlas results for individual Ecological Sections in southern Wisconsin. The map below will help you determine which Ecological Section to explore. Ecological Sections are similar to Wisconsin DNR's Ecological Landscapes.



LEGEND:

- County lines
- Ecological Section borders
- Laurentian Mixed Forest Province (222)

Using the Tree Species Table

ADAPTABILITY

Factors not modeled, such as disturbance tolerance, may make a species more or less adaptable to future conditions.

- \+ **High:** Species may perform better than modeled
- · **Medium**
- – **Low:** Species may perform worse than modeled

SUITABLE HABITAT CHANGE CLASS

A comparison of future and current "suitable habitat" in an area. Suitable habitat is modeled on 30+ factors, such as soils, topography, and climate.

- ▲ **Increase:** Projected increase of >20% by 2100
- ● **No change:** Little change (<20%) projected by 2100
- ▼ **Decrease:** Projected decrease of >20% by 2100
- ★ **New Habitat:** Tree Atlas projects new habitat for species not currently present

CAPABILITY

A rating of a species' ability to cope or persist with climate change, based on suitable habitat change (statistical modeling), adaptability (lit. review and expert opinion), and abundance (FIA data).

- △ **Good:** Increasing suitable habitat, medium or high adaptability, and common or abundant
- ○ **Fair:** Increasing suitable habitat with low adaptability, decreasing suitable habitat with high adaptability, or other mixed combinations
- ▽ **Poor:** Decreasing suitable habitat, medium or low adaptability, and uncommon or rare

222K Southwestern Great Lakes Morainal

- Flat to rolling topography and various glacial landforms – till and outwash plains, moraines, kettles, etc.
- Many inland lakes and the southern Lake Michigan shoreline

+	high	▲	increase	▼	decrease	△	good
·	medium	●	no change	★	new habitat	○	fair
–	low		**species with low model reliability*			▽	poor

Species	Adapt	LOW CHANGE Habitat Change Class	LOW CHANGE Species Capability	HIGH CHANGE Habitat Change Class	HIGH CHANGE Species Capability
American basswood	·	●	○	●	○
American beech	·	●	▽	▼	▽
American elm	·	▲	△	▲	△
Bigtooth aspen	·	●	▽	▼	▽
Bitternut hickory*	+	▲	△	▲	△
Black ash	–	▼	▽	▼	▽
Black cherry	–	●	▽	▼	▽
Black hickory	·	★		★	
Black oak	·	▲	△	▲	△
Black walnut*	·	▲	△	▲	△
Blackjack oak	+	★		★	
Bur oak	+	▲	△	▲	△
Chinkapin oak	·	★		★	
Eastern cottonwood*	·	▲	△	▲	△
Eastern white pine	–	▼	▽	▼	▽

Species	Adapt	LOW CHANGE Habitat Change Class	LOW CHANGE Species Capability	HIGH CHANGE Habitat Change Class	HIGH CHANGE Species Capability
Green ash*	·	▲	△	▲	△
Hackberry	+	▲	△	▲	△
Ironwood*	+	▲	△	▲	△
Jack pine	+	▼	▽	▼	▽
Northern pin oak	+	▼	○	▼	○
Northern red oak	+	▲	△	▲	△
Ohio buckeye*	·	★		★	
Osage-orange	+	▲	△	▲	△
Pecan*	–	★		★	
Pignut hickory	·	▲	△	▲	△
Post oak	+	★		★	
Quaking aspen	·	●	○	●	○
Red maple	+	●	△	▼	○
Red pine	–	▼	▽	▼	▽
Shagbark hickory	·	●	○	●	○
Shingle oak	·	★		★	
Shumard oak*	+	★		★	
Silver maple*	+	▲	△	▲	△
Slippery elm*	·	▲	○	▲	○
Sugar maple	+	▲	△	▲	△
Sugarberry	·	★		★	
Swamp white oak*	·	●	▽	▲	○
Sweetgum	·	★		★	
Sycamore*	·	▲	△	▲	△
Tamarack (native)	–	▼	▽	▼	▽
White ash	–	▲	○	▲	○
White oak	+	▲	△	●	△
Winged elm	·	★		★	

222L North-Central Driftless and Escarpment

- A dissected plateau with steep bedrock ridges and mounds
- Mississippi River floodplain and narrow valleys in the north and wide drainages in the south

+	high	▲	increase	▼	decrease	△	good
·	medium	●	no change	★	new habitat	○	fair
–	low		**species with low model reliability*			▽	poor

Species	Adapt	LOW CHANGE Habitat Change Class	LOW CHANGE Species Capability	HIGH CHANGE Habitat Change Class	HIGH CHANGE Species Capability
American basswood	·	●	○	▼	▽
American elm	·	●	△	●	△
Bigtooth aspen	·	▼	▽	▼	▽
Bitternut hickory*	+	●	△	●	△
Black ash	–	▼	▽	▼	▽
Black cherry	–	▲	○	●	▽
Black hickory	·	★		★	
Black oak	·	▲	△	▲	△
Black walnut*	·	▲	△	▲	△
Black willlow*	–	▼	▽	●	▽
Blackgum	+	★		★	
Blackjack oak	+	★		★	
Boxelder*	+	●	△	▼	△
Bur oak	+	▲	△	●	△
Chinkapin oak	·	▲	○	▲	○

Species	Adapt	LOW CHANGE Habitat Change Class	LOW CHANGE Species Capability	HIGH CHANGE Habitat Change Class	HIGH CHANGE Species Capability
Eastern cottonwood*	·	▲	△	▲	△
Eastern white pine	–	▼	▽	▼	▽
Green ash*	·	▲	△	▲	△
Hackberry	+	▲	△	▲	△
Ironwood	+	●	△	●	△
Jack pine	+	▼	○	▼	○
Northern pin oak	+	▼	○	▼	○
Northern red oak	+	●	△	▼	△
Osage-orange	+	★		★	
Paper birch	·	▼	▽	▼	▽
Pecan*	–	★		★	
Pignut hickory	·	★		★	
Post oak	+	★		★	
Quaking aspen	·	▼	▽	▼	▽
Red maple	+	▼	○	▼	○
Red pine	–	▼	▽	▼	▽
Scarlet oak	·	★		★	
Shagbark hickory	·	●	○	▼	▽
Shingle oak	·	★		★	
Shumard oak*	+	★		★	
Silver maple*	+	▲	△	▲	
Slippery elm*	·	●	○	●	○
Sugar maple	+	▲	△	▲	△
Swamp white oak*	·	●	▽	●	▽
Sycamore*	·	★		★	
White ash	–	▲	○	▲	○
White oak	+	▲	△	●	△
Yellow-poplar	+	★		★	

222R Wisconsin Central Sands

- Flat to rolling glacial lake plain with scattered sandstone buttes
- Drought-prone outwash sands with small poorly-drained swamps

+	high	▲	increase	▼	decrease	△	good
·	medium	●	no change	★	new habitat	○	fair
−	low		**species with low model reliability*			▽	poor

Species	Adapt	LOW CHANGE Habitat Change Class	LOW CHANGE Species Capability	HIGH CHANGE Habitat Change Class	HIGH CHANGE Species Capability
American basswood	·	▲	△	▲	△
American elm	·	▲	△	▲	△
Bigtooth aspen	·	●	○	●	○
Bitternut hickory*	+	●	△	●	△
Black ash	−	▲	○	●	▽
Black cherry	−	▲	△	▲	△
Black hickory*	+	★		★	
Black oak	·	●	△	●	△
Black spruce	·	▼	▽	▼	▽
Black walnut*	·	▲	△	▲	△
Blackgum	+	★		★	
Bur oak	+	▲	△	▲	△
Eastern cottonwood*	·	★		★	
Eastern redcedar	·	▲	△	▲	△
Eastern white pine	−	▼	▽	▼	▽

Species	Adapt	LOW CHANGE Habitat Change Class	LOW CHANGE Species Capability	HIGH CHANGE Habitat Change Class	HIGH CHANGE Species Capability
Green ash*	·	▲	△	▲	△
Hackberry	+	●	○	▲	△
Ironwood	+	▲	△	▲	△
Jack pine	+	▼	△	▼	△
Mockernut hickory	+	★		★	
Northern pin oak	+	▼	△	▼	△
Northern red oak	+	●	△	●	△
Paper birch	·	▲	△	▲	△
Pignut hickory	·	★		★	
Pin oak*	–	★		★	
Post oak	+	★		★	
Quaking aspen	·	▼	○	▼	○
Red maple	+	▼	△	▼	△
Red pine	–	▼	○	▼	○
Scarlet oak	·	★		★	
Shagbark hickory	·	●	▽	●	▽
Shortleaf pine	·	★		★	
Silver maple*	+	▲	△	▲	△
Slippery elm*	·	●	▽	●	▽
Sugar maple	+	▲	△	▲	△
Swamp white oak*	·	●	▽	●	▽
Sweetgum	·	★		★	
Sycamore*	·	★		★	
Tamarack (native)	–	▼	▽	▼	▽
Virginia pine	·	★		★	
White ash	–	▲	△	▲	△
White oak	+	▲	△	▲	△
Yellow-poplar	·	★		★	

Assisted Migration Considerations

The tree species tables in this field guide include several species that are projected to have new suitable habitat in southern Wisconsin by the end of the century (indicated with a blue star). Though some of these species may already be present but rare, many are unlikely to naturally migrate to the state. **Intentionally planting these species outside of their current range would be considered "assisted range expansion" or "assisted species migration."**

If climate change or other factors may result in the loss of tree species, and if suitable local surrogates aren't available to fill their ecological niche or provide other values, managers might consider planting trees from the Central and Southern United States. Using non-native tree species will ideally be contingent on credible evidence that the species in question is not invasive, will not create significant risks to forest health, is from appropriate provenances that are adapted to the planting site, and is consistent with your organization or agency's guidance. New species will ideally be carefully monitored to determine how they interact with other species.

For more information on Assisted Migration, visit:
www.fs.usda.gov/ccrc/topics/assisted-migration

KEY TO SOUTHERN WISCONSIN FORESTED NATURAL COMMUNITIES

This guide is organized around 10 forested "natural communities" in southern Wisconsin. Natural communities are defined by dominant plant species, physical setting, and disturbance processes (www.dnr.wi.gov/topic/EndangeredResources/Communities.asp). In this field guide, natural communities are cross-walked to related forest cover types. **In some cases, the current cover type of a stand does not reflect the site's historical natural community.**

Other forested natural communities occur in southern Wisconsin, but they are rare and are not usually candidates for active management. Climate change information on all communities is available from the WICCI Plants and Natural Communities Working Group, including rare communities like Pine Relict, Hemlock Relict, Southern Tamarack Swamp, or White Pine-Red Maple Swamp (www.wicci.wisc.edu).

Key 1: Select Your General Forest Cover Type Category

- Oak (Continue on Key 2)
- Bottomland or swamp hardwoods (Continue on Key 3)
- Upland conifer (Continue on Key 4)
- Upland mixed deciduous (Continue on Key 5)

Key 2: Oaks Make Up >50% of the Basal Area, and the Stand Typically Would Contain...

1. Scattered or clumped black oak with native prairie species, blueberry, or huckleberry, on sandy soil. → **Oak Barrens, page 60**
2. Canopy cover < 50% and mostly composed of open-grown bur, white, or black oak with native prairie or savanna species, on loamy soils (not sand). → **Oak Opening, page 66**
3. Canopy cover 50-95%, usually dominated by white oak, but sometimes bur or black oak, with a forest-grown structure and open understory. → **Oak Woodland, page 72**
4. Oak-dominated forest on dry, shallow, or coarse soils and ridgetops. May include shagbark hickory, bigtooth aspen, and black cherry, along with a well-developed shrub layer. → **Southern Dry Forest, page 78**
5. A mix of northern red oak, white oak, basswood, red maple, sugar maple, or hickory species, on loamy, moderately moist soils. Mesic species commonly overtaking the understory. → **Southern Dry-Mesic Forest, page 84**

Key 3: Bottomland or Swamp Hardwoods Stand is Located...

1. Within a river floodplain or river terrace, and vegetation is adapted to periodic flooding. → **Floodplain Forest, page 36**
2. Within an isolated basin, typically saturated in the spring and dry in the summer. → **Southern Hardwood Swamp, page 42**

Key 4: Upland Conifer Stand Would Typically Contain...

1. Dominant white or red pine, with mixed white, black, and northern red oak and the stand is located in the Central Sands region. → **Central Sands Pine-Oak Forest, page 48**

2. Clumped or scattered jack pine on sandy soils, possibly mixed with red pine and oak, with native prairie species. → **Pine Barrens, page 54**

Key 5: Upland Mixed Deciduous Stand Would Typically Contain...

1. Oaks mixed with shagbark hickory, bigtooth aspen, black cherry, red maple, black walnut, or other Central Hardwoods, often with a well-developed shrub layer of dogwood, hazelnut, viburnum, chokecherry, or huckleberry. → **Southern Dry Forest, page 78**

2. Oaks mixed with basswood, red maple, sugar maple, hickory species, bigtooth aspen, black walnut, or other Central Hardwoods. Located on loamy, moderately moist soils. Mesic species commonly overtaking the understory. → **Southern Dry-Mesic Forest, page 84**

3. Canopy dominated by sugar maple, basswood, red maple, American beech, or black walnut. On mesic, loamy, nutrient-rich soils in sheltered locations. → **Southern Mesic Forest, page 90**

Natural Community Climate Change Summaries

Here's what you'll find in the following climate change summaries:

- **Floodplain Forest**
- **Southern Hardwood Swamp**
- **Central Sands Pine-Oak Forest**
- **Pine Barrens**
- **Oak Barrens**
- **Oak Openings**
- **Oak Woodland**
- **Southern Dry Forest**
- **Southern Dry-Mesic Forest**
- **Southern Mesic Forest**

- **Natural Community Description**, including range map and "Related DNR Forest Cover Types" to help crosswalk familiar cover types to natural communities.
- **Climate Change Information**, including a Vulnerability Rating, a Confidence Rating based on amount of available evidence and agreement among that evidence, and a list of Climate Change Impacts for the community.
- **Adaptive Capacity Factors**, or key features that influence the community's ability to cope with climate change.
- **Site-level Factors** that can make an individual stand more or less vulnerable to climate change, including descriptions of "low risk" and "high risk" conditions.
- **Example Adaptation Actions** to use as a starting point for your own brainstorming.

FLOODPLAIN FOREST

222 K, L, R

Related DNR Forest Cover Types:
Bottomland hardwoods

Community Description

Occurs within floodplains and terraces of rivers.

Periodic floods, particularly in the spring, deposit silt and sand, scour streambanks, and create sites for tree establishment.

Vegetation is adapted to tolerate saturated soils, prolonged inundation, and frequent erosion and deposition.

Subtle microtopographic variation supports high plant diversity.

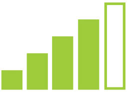
Major tree species: silver maple, green and black ash, American and slippery elm, river birch, hackberry, swamp white oak, cottonwood, black willow.

Climate Change Vulnerability

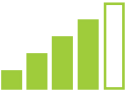
Overall Vulnerability:
Will this community experience declining health, reduced extent, or identity changes by 2100?

Moderate

Confidence:
How much evidence is available from research and observations? Does the evidence tend to agree or conflict?



Medium-high evidence



Medium-high agreement

Climate Change Impacts: Neutral

Emerald ash borer will severely reduce or eliminate ash species in most stands.

Dutch elm disease will continue to limit American elm.

Inundation times have increased with heavy rain events and wetter spring conditions, particularly on large river systems, and prolonged inundation may disrupt tree germination and kill trees.

Large storms increase the risk of excess nutrients, sedimentation, and non-native invasive species.

Adaptive Capacity: Moderate-High

- Floodplain forests are generally tolerant of variable precipitation and periods of high and low flows.
- Moderate increases in flooding and drought may help restore natural variation in flow regimes found in rivers prior to dams and impoundments.
- Floodplain forests contain many species expected to tolerate future climate conditions.
- Floodplain forests tend to have high connectivity and high diversity of species and habitats.
- Riparian areas with flashy hydrology and high land-use conversion will be less adaptable.


Wisconsin DNR

Site-level Considerations

Site-level factors could make a floodplain forest stand more or less vulnerable to climate change. Here are some factors to consider as you visit a particular site.

Factors that increase climate risk	Topic	Factors that decrease climate risk
Ditches, roads, dams, or floodplain alterations have affected natural hydrology.	**Hydrology**	Natural hydrology and stream channel morphology have been maintained. Flood duration and timing within normal range.
Regeneration limited by deer, lack of suitable seedbed conditions, altered disturbance regime, or competition from native or non-native species.	**Regeneration**	Tree regeneration is not limited and satisfies site management objectives.
Site is isolated, surrounded by agricultural or developed land.	**Size and connectivity**	Site is part of a lowland complex, and natural floodplain connectivity is intact.
Site is dominated by a few species and/or species expected to decline due to climate change, pests, or diseases.	**Overstory composition**	Site contains a diverse mix of tree species expected to tolerate future conditions and stressors.

Adaptation Actions

Here are some example adaptation actions to address high-risk conditions in a floodplain forest stand. Use this list as a starting point for your own brainstorming and review the Forest Adaptation Menu (pages 19-21) for more ideas.

High-Risk Condition	**Possible Adaptation Actions** **(Strategy/Approach # from Forest Adaptation Menu)**
Hydrology	• Repair and upgrade culverts or stream crossings that are constricting natural water flow so they can accommodate increased flows. (1.2, 1.3, 10.3) • Ensure that road and trail construction follow best management practices and will not impede the flow of water. (1.2) • Use large woody debris or other materials to dissipate streamflow energy and enhance bank stability during large storms. (1.3) • Re-sculpt functioning ditches in agricultural areas to two-stage designs that mimic a floodplain and slow delivery of water through watershed. (1.2)
Regeneration	• Remove interfering vegetation during regeneration practices (tree planting, regeneration harvesting). (2.2) • Prepare open soil seedbeds for tree regeneration. (5.1/5.2) • Use larger planting stock to enhance seedling survival during intense floods. (1.3)

Adaptation Actions (cont.)

High-Risk Condition	Possible Adaptation Actions (Strategy/Approach # from Forest Adaptation Menu)
Size and connectivity	• Limit runoff of water and nutrients from adjacent lands with filter strips or other means. (1.1/ 1.3) • Restore adjacent lands to natural vegetation. (1.3/ 7.1/ 7.2) • Reconnect natural floodplains and native habitats (such as floodplain forest and sedge meadow). (1.3)
Overstory composition	• Prepare suitable microsites for natural tree regeneration. (5.1/5.2) • As a part of timber management, include patch openings (0.5 to 2 acres) for natural or artificial regeneration, preferably removing species expected to decline. (9.5) • Incorporate southern seed sources or novel species expected to tolerate future conditions into tree planting, following landowner goals or agency guidance. See assisted migration considerations on page 31. (8.1/ 9.7)

SOUTHERN HARDWOOD SWAMP

Related DNR Forest Cover Types:
Swamp hardwoods, Bottomland hardwoods

Community Description

Occurs on poorly-drained isolated basins that are typically inundated in spring and dry in late summer, with a hydrology similar to floodplain forests and swamps in the southern U.S.

Flooding often happens over frozen or saturated ground in the spring, but the timing, duration, and intensity of flooding varies.

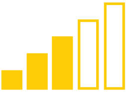
Major tree species: silver and red maple, green ash, American elm, swamp white oak, and occasionally black ash.

Climate Change Vulnerability

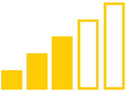
Overall Vulnerability:
Will this community experience declining health, reduced extent, or identity changes by 2100?

Moderate-High to High

Confidence:
How much evidence is available from research and observations? Does the evidence tend to agree or conflict?



Medium evidence



Medium agreement

Climate Change Impacts: Disruptive

Many sites are small, isolated, or adjacent to agricultural land with drain tiles and may be at greater risk from hydrologic changes.

Emerald ash borer will severely reduce or eliminate ash species in most stands.

Dutch elm disease will continue to limit American elm.

Large storms increase the risk of excess nutrients, sedimentation, and non-native invasive species.

Invasive species such as reed canary grass may benefit from nutrient loading and the loss of elm, ash, and red maple.

Adaptive Capacity: Low-Moderate

- Sites already infested with invasive species, adjacent to agricultural or developed land, or affected by EAB and Dutch elm disease will be less adaptable.
- Southern hardwood swamps are adapted to seasonal fluctuations in water levels and may tolerate periods of high and low water.
- These sites tend not to hold flood waters for a long time, so prolonged inundation is less of a risk.
- Silver maple and swamp white oak are expected to tolerate future climate conditions, but red maple is projected to decline.


Wisconsin DNR

Site-level Considerations

Site-level factors could make a southern hardwood swamp stand more or less vulnerable to climate change. Here are some factors to consider as you visit a particular site.

Factors that increase climate risk	Topic	Factors that decrease climate risk
Natural hydrology is disrupted by ditches, roads, drain tile, or other alterations.	**Hydrology**	Natural hydrology has been maintained. Inundation duration and timing within normal range.
Site is small and isolated, surrounded by agricultural or developed land.	**Size and connectivity**	Site is part of a large lowland and upland complex with natural vegetation.
Site is dominated by a limited number of tree species and/or species expected to decline due to climate change, pests or disease. Stocking, vigor, and health are degraded.	**Overstory composition**	Site contains a diverse mix of tree species expected to tolerate future conditions and stressors. Stocking, tree vigor, and health are good.
Invasive species, such as reed canary grass, are common and native vegetation limited.	**Shrub and ground flora composition**	Invasive species not present or limited, while native vegetation is diverse.

Adaptation Actions

Here are some example adaptation actions to address high-risk conditions in a southern hardwood swamp stand. Use this list as a starting point for your own brainstorming and review the Forest Adaptation Menu (pages 19-21) for more ideas.

High-Risk Condition	Possible Adaptation Actions (Strategy/Approach # from Forest Adaptation Menu)
Hydrology	• Repair and upgrade culverts or crossings to accommodate increased flows. (1.2, 10.3) • Upgrade or decommission roads or other infrastructure that is not expected to tolerate increased flows. (1.3) • Remove adjacent drain tile and fill ditches to restore hydrology. (1.2)
Size and connectivity	• Reforest adjacent land where appropriate to increase size of forested wetlands. (7.1) • Limit runoff of water and nutrients from adjacent lands with filter strips or other means. (1.1/ 1.3)

Adaptation Actions (cont.)

High-Risk Condition	Possible Adaptation Actions (Strategy/Approach # from Forest Adaptation Menu)
Overstory composition	• Use intermediate treatments, such as crown thinning, to encourage tree diversity, vigor, and seed production of climate-adapted species. (9.1) • Prepare open soil seedbeds for natural tree regeneration, especially for non-ash species. (5.1/5.2) • Plant a diversity of native tree species, particularly in degraded stands with limited stocking such as underplanting swamp white oak into ash stands. (5.1/5.2/9.2) • Incorporate southern seed sources or novel species expected to tolerate future conditions into tree planting, following landowner goals or agency guidance. See assisted migration considerations on page 31. (8.1/ 9.7)
Shrub and ground flora composition	• Control or contain invasive plants using manual, chemical, or mechanical methods. (2.2) • Monitor sites that are vulnerable to invasions (e.g., areas prone to flooding, inundation, and erosion) and control new infestations early. (2.2) • Promptly revegetate bare soils to prevent establishment of invasives. (2.2)

CENTRAL SANDS PINE-OAK FOREST

222 K, R

Related DNR Forest Cover Types:
Oak, White pine, Jack pine

Community Description

Occurs on dry to dry-mesic outwash and lake plains, dunes, and sandstone ridges.

Soils are dry, coarse-textured and acidic.

Fires naturally maintained the structure and composition of this community (5-20 year interval).

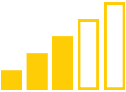
Major tree species: White pine, white oak, black oak, and northern red oak. Rarely red and jack pine and red maple.

Climate Change Vulnerability

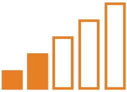
Overall Vulnerability:
Will this community experience declining health, reduced extent, or identity changes by 2100?

Moderate to Moderate-High

Confidence:
How much evidence is available from research and observations? Does the evidence tend to agree or conflict?



Medium evidence



Limited-medium agreement

Climate Change Impacts: Disruptive

White, red, and jack pine are expected to have reduced suitable habitat by the end of the century. Losing white pine (the dominant conifer) would dramatically change this community.

White, black, and northern red oak are expected to maintain or gain suitable habitat under future climate conditions.

Increased drought may favor oak or pine barrens, although conversion might require fire.

Continued lack of fire may make these sites vulnerable to mesophication, although red maple is projected to decline.

Shifting conditions may make it more difficult to apply prescribed fire in this community using conventional approaches.

Adaptive Capacity: Moderate

- White pine is currently increasing in many sites in the Central Sands and promoting this species may help sustain this community.
- Sites that have been managed with fire to remove the duff layer and limit red maple may be more adaptable.
- Sites that occur within a large matrix of forest may be better positioned for species to shift across the landscape as conditions change.
- This is naturally a diverse community that includes elements of southern and northern forests, so particular species may be able to increase or decrease as conditions allow.
- Deer may benefit from climate change and cause more damage to oak and pine regeneration.


Wisconsin DNR

Site-level Considerations

Site-level factors could make a Central Sands pine-oak forest stand more or less vulnerable to climate change. Here are some factors to consider as you visit a particular site.

Factors that increase climate risk	Topic	Factors that decrease climate risk
Dominated by a single species of pine, and oak is limited or absent.	**Overstory composition**	Oak is common; red or jack pine are intermingled throughout the stand or the surrounding area.
Excess shade from trees and shrubs (esp mesic species).	**Understory shading**	Lower woody species dominance, less shading.
Low native plant diversity, or dominated by invasive species.	**Shrub and ground flora composition**	Mostly free of invasive species, and comprised of a diverse native groundlayer.
Landscape context, stand size, and lack of fuels or firebreaks limit the use of prescribed fire.	**Prescribed fire**	Site is well-suited for prescribed fire. Has been managed with prescribed fire in the past.
Site is small and isolated, surrounded by agricultural or developed land.	**Size and connectivity**	Site is part of a large complex of forest and/or savanna.

Adaptation Actions

Here are some example adaptation actions to address high-risk conditions in a Central Sands pine-oak forest stand. Use this list as a starting point for your own brainstorming and review the Forest Adaptation Menu (pages 19-21) for more ideas.

High-Risk Condition	Possible Adaptation Actions (Strategy/Approach # from Forest Adaptation Menu)
Overstory composition	• Enhance oak component and try to enhance oak species diversity. (5.2) • If significant natural red pine or jack pine component, elevate priority and promote these species. (5.2) • Incorporate southern seed sources or novel species expected to tolerate future conditions into tree planting, following landowner goals or agency guidance. See assisted migration considerations on page 31. (8.1/ 9.7)
Understory shading	• Initiate prescribed burns, considering growing season burns to enhance brush control. (1.5) • Conduct mechanical thinning or brush control on the understory. (5.2)
Shrub and ground flora composition	• Initiate prescribed burns. (1.5) • Control invasive plants using manual, mechanical or chemical means. (2.2) • Reduce impacts of invasives where eradication isn't feasible by applying containment measures (restricting activity in infested sites, requiring equipment sanitation, etc.). (2.2)

Adaptation Actions (cont.)

High-Risk Condition	Possible Adaptation Actions (Strategy/Approach # from Forest Adaptation Menu)
Prescribed fire	If prescribed fire is suitable for the site and landowner goals: • Adjust burn unit size to incorporate defensible fire breaks, capture adjacent fire-dependent communities, and increase efficiency. (1.5) • Use silvicultural tools to enhance fire breaks. (3.2) • Consider night-time or growing season burns to expand potential burn windows and reduce fire hazards. (1.5) If prescribed burns are not suitable: • Mimic fire effects with mechanical fuel removal, grazing, or chemical treatments. (1.4) • Manage for the more heavily canopied end of the community spectrum. (9.2) • Manage for a different target community or cover type. (10.3)
Size and connectivity	• Consider cost-efficient management tools such as prescribed fire if the site is surrounded by crops. (1.5) • Restore adjacent lands to natural vegetation. (1.3/ 7.1/ 7.2)

PINE BARRENS

222 K, L, R

Related DNR Forest Cover Types:
Jack pine, Red pine, Oak, White pine

Community Description

Occurs on drought-prone sites with sandy, nutrient-poor soil, typically outwash or lake plains and sandy river terraces.

Trees are scattered or in groves intermingled with shrubs and dry prairie species.

Surface fires and stand-replacing fires were the primary drivers of community structure and composition (5-40 year interval).

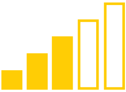
Major tree species: Jack pine is dominant, with possible red pine and bur, northern pin, and black oaks.

Climate Change Vulnerability

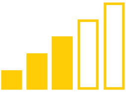
Overall Vulnerability:
Will this community experience declining health, reduced extent, or identity changes by 2100?

Moderate

Confidence:
How much evidence is available from research and observations? Does the evidence tend to agree or conflict?



Medium evidence



Medium agreement

Climate Change Impacts: Neutral

Jack pine and red pine are near the southern edge of their range in Wisconsin and expected to experience declining suitable habitat over the next century.

Warmer conditions and more fire may tend to favor oaks and a conversion to oak barrens.

Forest pests and diseases may be more damaging for pine species under climate change.

Non-native species may benefit from longer growing seasons.

Shifting conditions may make it more difficult to apply prescribed fire in this community using conventional approaches.

Adaptive Capacity: Moderate

- Species in this community can tolerate drought and extreme heat.
- Sites that have been managed with fire more recently may be more adaptable.
- Sites that occur within a large matrix of forest may be better positioned for species to shift across the landscape as conditions change.


Ryan O'Connor

Site-level Considerations

Site-level factors could make a pine barrens stand more or less vulnerable to climate change. Here are some factors to consider as you visit a particular site.

Factors that increase climate risk	Topic	Factors that decrease climate risk
Pines are being replaced by oaks or mesic species. Canopy cover >60%.	**Overstory composition and structure**	Native pines dominate and are healthy. Trees are scattered or clumped.
Low native plant diversity, or dominated by invasive species.	**Shrub and ground flora composition**	Mostly free of invasive species, and comprised of a diverse native groundlayer.
Site is small and isolated, surrounded by agricultural or developed land.	**Size and connectivity**	Site is part of a large complex of forest, savanna, and grassland
Landscape context, stand size, and lack of fuels or firebreaks limit the use of prescribed fire.	**Prescribed fire**	Site is well-suited for prescribed fire. Has been managed with prescribed fire in the past.

Adaptation Actions

Here are some example adaptation actions to address high-risk conditions in a pine barrens stand. Use this list as a starting point for your own brainstorming and review the Forest Adaptation Menu (pages 19-21) for more ideas.

High-Risk Condition	Possible Adaptation Actions (Strategy/Approach # from Forest Adaptation Menu)
Overstory composition and structure	• Use intermediate treatments, such as variable density thinning, to create open and irregular barrens structure. (1.4/ 5.1) • If lacking a viable seed source on site, conduct supplemental seeding or planting with appropriate seed sources/growing stock. (8.1, 8.2) • Favor pine and promote natural pine regeneration with mechanical treatments and prescribed fire. (1.5, 9.1)
Shrub and ground flora composition	• Reduce impacts of invasives where eradication isn't feasible by applying containment measures (restricting activity in infested sites, requiring equipment sanitation, etc.). (2.2) • Revegetate disturbed sites with native species. (3.4) • Control invasive plants using manual, mechanical or chemical means. (2.2) • Experiment with varied burn timing to encourage a mix of species. (1.5/9.1)

Adaptation Actions (cont.)

<table>
<tr><th>High-Risk Condition</th><th>Possible Adaptation Actions
(Strategy/Approach # from Forest Adaptation Menu)</th></tr>
<tr><td>Size and connectivity</td><td>• Consider cost-efficient management tools such as prescribed fire if fuelbreaks exist around the site. (1.5)
• Restore adjacent lands to natural vegetation. (1.3/ 7.1/ 7.2)
• Consider rolling barrens over the long term to create a landscape scale shifting mosaic. (6.1/9.1)</td></tr>
<tr><td>Prescribed fire</td><td>If prescribed fire is suitable for the site and landowner goals:
• Adjust burn unit size to incorporate highly defensible fire breaks and increase efficiency (e.g., tie into a lake or ag field). (1.5)
• Use silvicultural tools to enhance fire breaks. (3.2)
• Consider night-time or growing season burns to expand potential burn windows and reduce fire hazards. (1.5)
If prescribed burns are not suitable:
• Mimic fire effects within a stand with mechanical fuel removal, grazing, or chemical treatments. (1.4)
• Manage for the more heavily canopied end of the barrens spectrum. (9.2)
• Manage for a different target community or cover type, such as a closed jack pine forest or a complex of rolling barrens and short-rotation jack pine. (10.3)</td></tr>
</table>

OAK BARRENS

222 K, L, R

Related DNR Forest Cover Types:
Oak, Jack pine, Red pine, White pine

Community Description

Occurs on drought-prone sites with sandy, nutrient-poor soil, typically outwash or lake plains and sandy terraces or thin soils over bedrock.

Trees are scattered or in groves, supporting sand prairie species, blueberry, or huckleberry.

Regular surface fire was the primary disturbance driving open structure and composition (5-20 year interval).

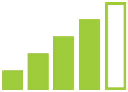
Major tree species: Black oak, with possible white, bur, and northern pin oak.

Climate Change Vulnerability

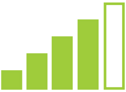
Overall Vulnerability:
Will this community experience declining health, reduced extent, or identity changes by 2100?

Moderate-Low

Confidence:
How much evidence is available from research and observations? Does the evidence tend to agree or conflict?



Medium-high evidence



Medium-high agreement

Climate Change Impacts: Neutral

- The primary tree species in oak barrens (black, bur, and white oak) are expected to maintain or gain suitable habitat over the next century.
- Increasing drought risk may slow or reduce the risk of mesic species encroachment in oak barrens.
- Species such as spotted knapweed, bluegrasses, brambles, or Pennsylvania sedge that can limit overall site diversity may benefit from longer growing seasons.
- Shifting conditions may make it more difficult to apply prescribed fire in this community using conventional approaches.

Adaptive Capacity: High

- Species in this community can tolerate drought and extreme heat.
- Sites that have been managed with fire more recently may be more adaptable.
- Sites that occur within a large matrix of forest may be better positioned for species to shift across the landscape as conditions change.


Armund Bartz

Site-level Considerations

Site-level factors could make an oak barrens stand more or less vulnerable to climate change. Here are some factors to consider as you visit a particular site.

Factors that increase climate risk	Topic	Factors that decrease climate risk
Closed forest structure, canopy cover > 60%, shrub and subcanopy cover > 30%.	**Overstory and subcanopy structure**	Open forest structure, canopy cover 5-60%, shrub and subcanopy cover 0-30%, oak seedlings and sprouts common.
Ground layer diversity is low, or is dominated by aggressive natives or non-native invasive species. Bare soil resulting from anthropogenic disturbance is common.	**Shrub and ground flora composition**	Widespread cover of diverse native herbs, including native grass/ sedges other than Pennsylvania sedge (e.g., Junegrass, little bluestem). Few to no non-native invasives.
Site is small and isolated, surrounded by agricultural or developed land.	**Size and connectivity**	Site is part of a large complex of dry forest and sand prairie.
Landscape context, stand size, and lack of fuels or firebreaks limit the use of prescribed fire.	**Prescribed fire**	Site is well-suited for prescribed fire. Has been managed with prescribed fire in the past.

Adaptation Actions

Here are some example adaptation actions to address high-risk conditions in an oak barrens stand. Use this list as a starting point for your own brainstorming and review the Forest Adaptation Menu (pages 19-21) for more ideas.

High-Risk Condition	Possible Adaptation Actions (Strategy/Approach # from Forest Adaptation Menu)
Overstory and subcanopy structure	• Use repeated prescribed fire to restore or maintain the open character of oak barrens. (1.5) • Use timber harvesting treatments (ex. intermediate treatments, such as variable density thinning) to create open and irregular barrens structure. (1.4/ 5.1) • Target non-oak species for removal, or species not expected to tolerate drought. (9.5)
Shrub and ground flora composition	• Promptly revegetate disturbed soils to prevent non-native species. (3.4) • In low-diversity barrens, interseed following prescribed burns to boost diversity. (5.2) • Control or contain invasive plants and undesirable species using chemical, mechanical, or prescribed fire methods. (2.2)

Adaptation Actions (cont.)

High-Risk Condition	Possible Adaptation Actions (Strategy/Approach # from Forest Adaptation Menu)
Size and connectivity	• Create large block management areas of barrens habitat with adjacent landowners, working to reduce fragmentation. (6.2) • Consider rolling barrens over the long term to create a landscape scale shifting mosaic. (6.1/9.1) • Restore adjacent lands to natural vegetation. (1.3/ 7.1/ 7.2) • Consider cost-efficient management tools such as prescribed fire. (1.5)
Prescribed fire	If prescribed fire is suitable for the site and landowner goals: • Adjust burn unit size to incorporate defensible fire breaks, capture adjacent fire-dependent communities, and increase efficiency. (1.5) • Use silvicultural tools to enhance fire breaks. (3.2) • Burn under moderate conditions to reduce damage to oaks. (1.5) If prescribed burns are not suitable: • Mimic fire effects within a stand with mechanical fuel removal, grazing, or chemical treatments. (1.4) • Manage for the more heavily canopied end of the barrens spectrum. (9.2) • Manage for a different target community or cover type. (10.3)

OAK OPENING

Related DNR Forest Cover Types:
Oak, Central hardwood, Black walnut, Northern hardwood, Red maple

Community Description


Occurs on dry to dry-mesic soils and slopes with hot and dry aspects.


Canopy cover is less than 50% and the ground layer contains prairie and savanna species.


Trees have open grown, horizontal crowns over relatively short trunks.


Frequent fire was the primary disturbance driving open structure and composition (1-10 year interval).

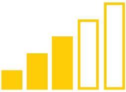

Major tree species: Bur, white, and black oak with occasional shagbark hickory and black cherry.

Climate Change Vulnerability

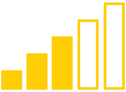
Overall Vulnerability:
Will this community experience declining health, reduced extent, or identity changes by 2100?

Moderate-low

Confidence:
How much evidence is available from research and observations? Does the evidence tend to agree or conflict?



Medium evidence



Medium agreement

Climate Change Impacts: Supportive

The primary tree species in oak openings (black, bur, and white oak) are expected to maintain or gain suitable habitat over the next century.

Invasive species may benefit from longer growing seasons.

Shifting conditions may make it more difficult to apply prescribed fire in this community using conventional approaches.

Soil erosion may increase with heavy rainfall events, particularly in areas following drought, wildfire, or pest outbreaks.

Adaptive Capacity: Moderate

- Oak openings may be most adaptable in large landscapes where mixed with prairie and oak woodlands. Small, isolated woodlots (more common in southeast Wisconsin) will be more vulnerable.
- Sites that have been managed with fire more recently will have a more open understory and may be more adaptable.
- Ground layer species in oak openings occupy a variety of niches and can shift over time in response to changing conditions.
- Deer may benefit from climate change and cause more damage to oak regeneration.


Wisconsin DNR

Site-level Considerations

Site-level factors could make an oak opening stand more or less vulnerable to climate change. Here are some factors to consider as you visit a particular site.

Factors that increase climate risk	Topic	Factors that decrease climate risk
Oak regeneration is limited by deer herbivory, interfering vegetation, or other factors.	**Oak regeneration**	Oak regeneration is well distributed and accumulating in numbers sufficient to maintain the community.
High canopy closure and stand density, few oaks.	**Overstory structure and composition**	Canopy <= 50% cover, and oak predominates.
Shrub layer dominated by invasive and weedy species (buckthorn, honeysuckle, brambles). Herbaceous layer dominated by invasive species or low diversity.	**Shrub and ground flora composition**	Shrub layer of native species, not overly dense. Herbaceous layer with diverse mix of native savanna species, few or no invasives.
Site is small and isolated, surrounded by agricultural or developed land.	**Size and connectivity**	Site is part of a large complex of forest and savanna.
Landscape context, stand size, and lack of fuels or firebreaks limit the use of prescribed fire.	**Prescribed fire**	Site is well-suited for prescribed fire. Has been managed with prescribed fire in the past.

Adaptation Actions

Here are some example adaptation actions to address high-risk conditions in an oak opening stand. Use this list as a starting point for your own brainstorming and review the Forest Adaptation Menu (pages 19-21) for more ideas.

High-Risk Condition	Possible Adaptation Actions (Strategy/Approach # from Forest Adaptation Menu)
Oak regeneration	• Set up small deer exclosures to assess oak regeneration potential. (2.3) • Plant oak seedlings sufficient to recruit new oak saplings on an ongoing basis. (5.2) • Plant oak seedlings in areas with suitable light conditions to succeed. (5.2) • Conduct prescribed burns to reduce interfering vegetation and encourage oak regeneration. On sites where the majority of oaks are old, provide an interval between prescribed burns that allows young oak to grow large enough to withstand fire. (1.5)
Overstory structure and composition	• Reduce canopy closure and stand density by thinning or weeding mesic species. (1.4) • Conduct frequent prescribed burns to reduce non-oak seedlings and saplings. (1.5) • Incorporate southern seed sources or novel species expected to tolerate future conditions into tree planting, following landowner goals or agency guidance. See assisted migration considerations on page 31. (8.1/ 9.7)

Adaptation Actions (cont.)

High-Risk Condition	Possible Adaptation Actions (Strategy/Approach # from Forest Adaptation Menu)
Shrub and ground flora composition	• Control interfering vegetation using manual, mechanical or chemical means. (1.4) • Plant or seed species appropriate for the site and natural community. (5.2) • Use prescribed fire to give native, fire-adapted species a competitive advantage. (1.5)
Size and connectivity	• Improve context by restoring adjacent old fields to prairie or savanna. (6.2) • Created feathered edges into adjacent woodland and oak forest. (3.2/6.2) • Consider cost-efficient management tools such as prescribed fire. (1.5)
Prescribed fire	If prescribed fire is suitable for the site and landowner goals: • Adjust burn unit size to incorporate defensible fire breaks, capture adjacent fire-dependent communities, and increase efficiency. (1.5) • Use silvicultural tools to enhance fire breaks. (3.2) • Burn under moderate conditions to reduce damage to oaks. (1.5) If prescribed burns are not suitable: • Mimic fire effects within a stand with mechanical fuel removal, grazing, or chemical treatments. (1.4) • Manage for the more heavily canopied end of the savanna spectrum. (9.2) • Manage for a different target community or cover type. (10.3)

OAK WOODLAND

Related DNR Forest Cover Types:
Oak, Central hardwood, Black walnut, Northern hardwood, Red maple

Community Description

Occurs most often on dry to dry-mesic soils and slopes with hot and dry aspects, but occasionally on mesic soils if frequently burned.

Tree cover is 50-95%.

Understory is naturally open with few shrubs and saplings.

Frequent surface fire was the primary disturbance (4-16 year interval).

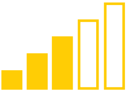
Major tree species: White oak, but sometimes bur and black oak with occasional shagbark hickory, black cherry, northern red oak, and black walnut.

Climate Change Vulnerability

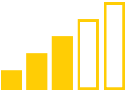
Overall Vulnerability:
Will this community experience declining health, reduced extent, or identity changes by 2100?

Moderate

Confidence:
How much evidence is available from research and observations? Does the evidence tend to agree or conflict?



Medium evidence



Medium agreement

Climate Change Impacts: Neutral

The primary tree species in oak woodlands (white, bur, and black oak) are expected to maintain or gain suitable habitat over the next century.

Oak woodland is more sensitive to change in the absence of fire compared to other oak forests.

Invasive species may benefit from longer growing seasons.

Forest pests and diseases may become more damaging under climate change.

Shifting conditions may make it more difficult to apply prescribed fire using conventional approaches.

Adaptive Capacity: Moderate-Low

- Oak woodland is an extremely rare community.
- Many remnant sites are degraded because they haven't had regular fire. Sites that have been managed with fire may be more adaptable because they will have more favorable conditions to perpetuate oak.
- Site conditions in remnant stands (southern exposure, arid soils) may have slowed the process of mesophication.
- Species in this community are generally tolerant of warm, dry conditions.
- Ground layer species in oak woodlands occupy a variety of niches and can shift over time in response to changing conditions.
- Sites that have been grazed often have degraded understory plant communities.
- Deer may benefit from climate change and cause more damage to oak regeneration.


Wisconsin DNR

Site-level Considerations

Site-level factors could make an oak woodland stand more or less vulnerable to climate change. Here are some factors to consider as you visit a particular site.

Factors that increase climate risk	Topic	Factors that decrease climate risk
Dominated by old oak reaching biological maturity; Oak regeneration is limited by deer, mesic species competition, or other factors.	**Oak status**	Dominated by vigorous, healthy oaks (esp. white oak); Oak is regenerating well.
Woody species create a shady ground environment. Low native plant diversity or dominated by invasive species.	**Shrub and ground flora composition and shade**	Open structure, less shading; mostly free of invasive species and comprised of a diverse native groundlayer.
Landscape context, stand size, and lack of fuels or firebreaks limit the use of prescribed fire.	**Prescribed fire**	Site is well-suited for prescribed fire. Has been managed with prescribed fire in the past.
Site is small and isolated, surrounded by agricultural or developed land.	**Size and connectivity**	Site is part of a large complex of forest and savanna.

Adaptation Actions

Here are some example adaptation actions to address high-risk conditions in an oak woodland stand. Use this list as a starting point for your own brainstorming and review the Forest Adaptation Menu (pages 19-21) for more ideas.

High-Risk Condition	Possible Adaptation Actions (Strategy/Approach # from Forest Adaptation Menu)
Oak status	• Promote natural oak regeneration by removing shading vegetation (targeting invasive shrubs, mid-story non-oaks, and non-white oak species), conducting site preparation burns, or scarifying the soil. (1.4/1.5/5.2) • Plant oak seedlings to replace canopy layer oaks that die. (5.1/5.2) • Protect regeneration from deer browse through seedling protection or fencing. (2.3)
Shrub and ground flora composition and shade	• Initiate prescribed fire, considering growing season burns to enhance brush control. (1.5) • Control invasive plants using manual, mechanical or chemical means. (2.2) • Remove shading vegetation (targeting invasive shrubs, mid-story non-oaks, and non-white oak species) to attain desirable light levels. (1.4)

Adaptation Actions (cont.)

High-Risk Condition	Possible Adaptation Actions (Strategy/Approach # from Forest Adaptation Menu)
Prescribed fire	If prescribed fire is suitable for the site and landowner goals: • Adjust burn unit size to incorporate defensible fire breaks, capture adjacent fire-dependent communities, and increase efficiency. (1.5) • Use silvicultural tools to enhance fire breaks. (3.2) • Burn under moderate conditions to reduce damage to oaks. (1.5) If prescribed burns are not suitable: • Mimic fire effects within a stand with mechanical fuel removal, grazing, or chemical treatments. (1.4) • Manage for the more heavily canopied end of the woodland spectrum. (9.2) • Manage for a different target community or cover type. (10.3)
Size and connectivity	• Consider cost-efficient management tools such as prescribed fire. (1.5) • Improve context by restoring adjacent old fields to prairie or savanna. (7.1/7.2) • Created feathered edges into adjacent woodland and oak forest. (3.2/6.2)

SOUTHERN DRY FOREST

222 K, L, R

Related DNR Forest Cover Types:
Oak, Central hardwoods, Aspen, Red maple, Black walnut, White pine

Community Description


Occurs on drought-prone, slightly acidic soils and on slopes with warm and dry aspects.


Can occur on formerly open sites where fire has been excluded.


Light conditions and intervals between fires permit a well-developed shrub layer.


Regular surface fire maintained oak dominance (10-20 year interval).

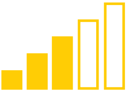

Major tree species: White, bur, and black oak, with shagbark hickory, bigtooth aspen, black cherry, red maple, northern pin oak, and black walnut.

Climate Change Vulnerability

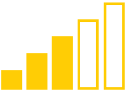
Overall Vulnerability:
Will this community experience declining health, reduced extent, or identity changes by 2100?

Moderate

Confidence:
How much evidence is available from research and observations? Does the evidence tend to agree or conflict?



Medium evidence



Medium agreement

Climate Change Impacts: Neutral

Bur, white, and black oak; shagbark hickory; and black cherry are generally expected to maintain or gain suitable habitat over the next century.

Red maple (a common invader in this community) is expected to decline in suitable habitat, which could benefit this community.

Shifting conditions may make it more difficult to apply prescribed fire using conventional approaches.

Invasive species such as buckthorn and honeysuckle may benefit from longer growing seasons.

Forest pests and diseases may become more damaging under climate change.

Adaptive Capacity: Moderate-Low

- Many dry forests are degraded because they haven't had regular fire. Sites that have been managed with fire may be more adaptable because they will have more favorable conditions to perpetuate oak.
- Past high-grading may have damaged some stands and made them less resilient to future change.
- Sites that have a history of grazing often have degraded understory plant communities.
- Southern dry forests convert to mesic species more slowly than dry-mesic stands.
- Invasive species are slower to occupy these sites than dry-mesic stands.
- Species in this community are generally tolerant of warm, dry conditions.
- Deer may benefit from climate change and cause more damage to oak regeneration.


Ryan O'Connor

Site-level Considerations

Site-level factors could make a southern dry forest stand more or less vulnerable to climate change. Here are some factors to consider as you visit a particular site.

Factors that increase climate risk	Topic	Factors that decrease climate risk
Oak regeneration is limited by interfering vegetation, deer, non-native species, or other factors.	**Oak regeneration**	Oak regeneration is present.
Site is dominated by a single species or tree species expected to decline due to climate change, pests, or diseases.	**Overstory composition**	Site contains a diverse mix of tree species expected to tolerate future conditions and stressors.
Ground layer diversity is low, or is dominated by aggressive natives or non-native invasive species. Bare soil is common.	**Shrub and ground flora composition**	Abundant cover of diverse native herbs (e.g., hog-peanut, bottlebrush grass, wild geranium, tick-trefoils). Few to no non-native invasives.
Site is small and isolated, surrounded by agricultural or developed land.	**Size and connectivity**	Site is part of a large complex of forest, savanna, and grassland.
Landscape context, stand size, and lack of fuels or firebreaks limit the use of prescribed fire.	**Prescribed fire**	Site is well-suited for prescribed fire. Has been managed with prescribed fire in the past.

Adaptation Actions

Here are some example adaptation actions to address high-risk conditions in a southern dry forest stand. Use this list as a starting point for your own brainstorming and review the Forest Adaptation Menu (pages 19-21) for more ideas.

High-Risk Condition	Possible Adaptation Actions (Strategy/Approach # from Forest Adaptation Menu)
Oak regeneration	• Apply repellant or install fences, bud caps, or other barriers to prevent herbivory. (2.3) • Use harvest slash or plantings of unpalatable trees to "hide" desirable species (2.3) • Use prescribed fire to promote suitable conditions for oak regeneration. (1.5) • Use large group selection or patch clearcuts (0.5-5 acres) to favor oak regeneration (5.2)
Overstory composition	• Favor or establish oak species and other drought- and heat-tolerant species on narrow ridge tops, south-facing slopes with shallow soils, or other sites that are expected to become warmer and drier. (9.2) • Underplant a variety of native species on a site to increase species richness and provide options for future management. (9.2) • Manage for Central Hardwoods species if consistent with landowner goals or agency guidance. Potential new species for southern dry forests include black, mockernut, and pignut hickory; shortleaf and Virginia pine; and blackjack, chinkapin, post, scarlet, and shingle oak. (10.2/10.3)

Adaptation Actions (cont.)

High-Risk Condition	Possible Adaptation Actions (Strategy/Approach # from Forest Adaptation Menu)
Shrub and ground flora composition	• Promptly revegetate disturbed soils to prevent new invasive species. (3.4) • Control invasive plants using manual, mechanical or chemical means. (2.2) • Thin trees and shrubs as necessary to remove interfering vegetation and attain desirable light levels. (1.4)
Size and connectivity	• Restore adjacent lands to natural vegetation. (1.3/ 7.1/ 7.2) • Consider cost-efficient management tools such as prescribed fire. (1.5)
Prescribed fire	If prescribed fire is suitable for the site and landowner goals: • Adjust burn unit size to incorporate defensible fire breaks, capture adjacent fire-dependent communities, and increase efficiency. (1.5) • Use silvicultural tools to enhance fire breaks. (3.2) • Consider night-time or growing season/late summer prescribed burns when conditions are more moderate. (1.5) If prescribed burns are not suitable: • Mimic fire effects within a stand with mechanical fuel removal, grazing, or chemical treatments. (1.4) • Manage for a different target community or cover type. (10.3)

SOUTHERN DRY-MESIC FOREST

222 K, L, R

Related DNR Forest Cover Types:
Oak, Central hardwoods, Aspen, Red maple, Black walnut, Northern hardwood

Community Description

Occurs on loamy soils on moderately moist slopes in the Driftless Area and on glacial outwash, moraines, and kames.

Regular surface fire maintained oak dominance (10-20 year interval).

Mesic tree species commonly overtaking the understory, particularly when disturbance is infrequent.

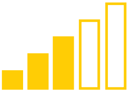
Major tree species: Northern red oak, white oak, red and sugar maple, slippery elm, black cherry, white ash, shagbark and bitternut hickory, and black walnut.

Climate Change Vulnerability

Overall Vulnerability:
Will this community experience declining health, reduced extent, or identity changes by 2100?

Moderate-High

Confidence:
How much evidence is available from research and observations? Does the evidence tend to agree or conflict?



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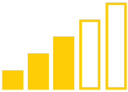


Medium agreement

Climate Change Impacts: Disruptive

Northern red oak, white oak, and shagbark and bitternut hickory are expected to maintain or gain suitable habitat over the next century.

Red maple is currently common but expected to decline in suitable habitat over the next century, while sugar maple is often common and expected to increase slightly.

Disturbances in these forests without fire will likely hasten the conversion to mesic species.

Invasive species such as buckthorn and honeysuckle readily invade dry-mesic stands and may benefit from longer growing seasons.

Adaptive Capacity: Moderate-Low

- Many dry-mesic forests will be degraded because they haven't had regular fire. Sites that have been managed with fire may be more adaptable because they will have more favorable conditions to perpetuate oak.
- Past high-grading may have damaged some stands and made them less resilient to future change.
- Oak regeneration is currently limited by competition with mesic species, deer herbivory, and other factors. Oaks may not be able to capitalize on projected suitable habitat gains.
- Sites that have been grazed often have degraded understory plant communities.
- Stands with several tree species may be more able to adapt to changing conditions.
- Deer may benefit from climate change and cause more damage to oak regeneration.
- Sites with high earthworm activity will have less leaf litter and it will be harder to conduct prescribed burns.


Brad Hutnik

Site-level Considerations

Site-level factors could make a southern dry-mesic forest stand more or less vulnerable to climate change. Here are some factors to consider as you visit a particular site.

Factors that increase climate risk	Topic	Factors that decrease climate risk
Oak regeneration is limited by interfering vegetation, mesic hardwood competition, deer, or other factors.	**Oak regeneration**	Oak is regenerating well; advance oak regeneration present.
Site is dominated by a limited number of tree species and/or species expected to decline due to climate change. Stocking, tree vigor and health degraded.	**Overstory composition**	Site contains a diverse mix of tree species expected to tolerate future conditions. Stocking, tree vigor and health good.
Invasive species, such as buckthorn or honeysuckle, are common, mesic hardwood advance regeneration is dominant, and low native plant diversity.	**Shrub and ground flora composition**	Invasive species are limited, mesic hardwood advance regeneration is limited, and native herbaceous vegetation is abundant and diverse.
Site is small and isolated, surrounded by agricultural or developed land.	**Size and connectivity**	Site is part of a large complex of forest and savanna.
Landscape context, stand size, and lack of fuels or firebreaks limit the use of prescribed fire.	**Prescribed fire**	Surrounding landscape, size, fuel, and firebreaks are sufficient for prescribed fire.

Adaptation Actions

Here are some example adaptation actions to address high-risk conditions in a southern dry-mesic forest stand. Use this list as a starting point for your own brainstorming and review the Forest Adaptation Menu (pages 19-21) for more ideas.

High-Risk Condition	**Possible Adaptation Actions** **(Strategy/Approach # from Forest Adaptation Menu)**
Oak regeneration	• Remove mesic hardwood midstory to create light levels and conditions suitable for oak regeneration. (1.4/5.2) • Encourage suitable seedbeds through chemical, mechanical, or prescribed fire site preparation. • Limit deer herbivory by hunting, barriers, or repellents. (2.3/9.4) • Use high-density oak plantings or deer exclosures to establish regen. in openings. (2.3/5.1)
Overstory composition	• Use intermediate treatments, such as crown thinning, to encourage diversity, vigor, and seed production of target species. (9.1/9.3) • Direct seed or plant a diversity of native tree species, particularly in degraded stands with limited stocking. (5.1/5.2/9.2) • Incorporate southern seed sources or novel species expected to tolerate future conditions into tree planting, following landowner goals or agency guidance. See assisted migration considerations on page 31. (8.1/ 9.7) • Consider transition to mesic hardwoods on north slopes and heavier soils, especially if spring ephemerals exist nearby, if consistent with landowner objectives. (9.6)

Adaptation Actions (cont.)

High-Risk Condition	Possible Adaptation Actions (Strategy/Approach # from Forest Adaptation Menu)
Shrub and ground flora composition	• Control or contain invasive plants using chemical, mechanical, or prescribed fire methods. (2.2) • Consider prescribed fire to control mesic hardwood encroachment where appropriate. (1.5)
Size and connectivity	• Reforest adjacent land where appropriate to increase forest block size. (7.1) • Consider cost-efficient management tools such as prescribed fire. (1.5) • Convert adjacent pine plantations to oak forest. (7.1/9.1)
Prescribed fire	If prescribed fire is suitable for the site and landowner goals: • Adjust burn unit size to incorporate defensible fire breaks, capture adjacent fire-dependent communities, and increase efficiency. (1.5) • Use silvicultural tools to enhance fire breaks. (3.2) • Consider night-time or growing season/late summer prescribed burns when conditions are more moderate. (1.5) If prescribed burns are not suitable: • Mimic fire effects within a stand with mechanical fuel removal, grazing, or chemical treatments. (1.4) • Manage for a different target community or cover type. (10.3)

SOUTHERN MESIC FOREST

222 K, L, R

Related DNR Forest Cover Types:
Northern hardwood, Red maple, Oak, Black walnut, Central hardwood

Community Description

Occurs on rich, loamy soils and in the Driftless Area in cool, moist settings.

Canopy gaps may occur due to windthrow, ice damage, pest outbreaks, or disease.

These forests can develop dense canopies of shade-tolerant trees.

Often an open understory with shade-tolerant plants and spring ephemerals.

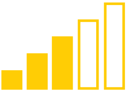
Major tree species: Sugar maple, American basswood, American beech, northern red oak, black walnut, bitternut hickory, red maple, and white ash.

Climate Change Vulnerability

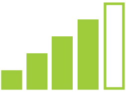
Overall Vulnerability:
Will this community experience declining health, reduced extent, or identity changes by 2100?

Moderate-low to Moderate

Confidence:
How much evidence is available from research and observations? Does the evidence tend to agree or conflict?



Medium evidence



Medium-high agreement

Climate Change Impacts: Disruptive

Sugar maple, bitternut hickory, slippery elm, and ironwood are expected to maintain or gain suitable habitat by the end of the century. Projections for basswood are mixed in different ecological landscapes.

Drought stress may increase as temperatures rise and precipitation becomes more erratic, particularly on gravelly soils in the Kettle Moraine.

Earthworms may intensify drought risk by consuming litter and duff layers.

Invasive species such as garlic mustard readily invade mesic stands and may benefit from longer growing seasons.

Adaptive Capacity: High

- Past high-grading may have damaged some stands and made them less resilient to future change.
- Sites that have a history of grazing often have degraded understory plant communities.
- Mesic forests may expand into dry-mesic sites that aren't managed with fire. Mesophication is already occurring across much of the landscape.
- Southern mesic forests tend to occur on small and isolated locations. This increases the risk of loss and conversion.
- Sites that are in cool microsites and with consistent soil moisture may be buffered from change.
- Deer may benefit from climate change and cause more damage to tree regeneration and understory plants.


Wisconsin DNR

Site-level Considerations

Site-level factors could make a southern mesic forest stand more or less vulnerable to climate change. Here are some factors to consider as you visit a particular site.

Factors that increase climate risk	Topic	Factors that decrease climate risk
Drought risk increased by shallow or coarse soils; earthworms or southern aspect increase the risk of drought on the site.	**Drought risk**	Deep soils, north slope, or landscape position reduce drought risk. Litter and duff layers intact.
Site is dominated by a few species, and/or species expected to decline due to climate change, pests and diseases, or other factors.	**Overstory composition**	Site contains a diverse mix of tree species expected to tolerate future conditions and potential stressors.
Regeneration limited by deer, interfering vegetation, or other factors.	**Tree regeneration**	Regeneration is diverse, seedlings and saplings are well distributed across multiple height classes.
Understory altered by deer, invasive species, earthworms, or past management history.	**Shrub and ground flora composition**	A diversity of native species occupy the site, especially spring ephemerals.
Site is small and isolated, surrounded by agricultural or developed land.	**Size and connectivity**	Site is part of a large complex of mesic and dry-mesic forest.

Adaptation Actions

Here are some example adaptation actions to address high-risk conditions in a southern mesic forest stand. Use this list as a starting point for your own brainstorming and review the Forest Adaptation Menu (pages 19-21) for more ideas.

High-Risk Condition	Possible Adaptation Actions (Strategy/Approach # from Forest Adaptation Menu)
Drought risk	• Favor tree species expected to tolerate warmer, drier conditions. (9.1/9.7) • Plant with a mix of climate-adapted species, including Central Hardwoods, if consistent with landowner objectives. (9.2)
Overstory composition	• Create openings of varying sizes to promote regeneration of a variety of species. (5.2) • Reduce stand density to increase individual tree vigor. (1.4) • Favor retention of climate-adapted species as a part of timber sales. (9.1) • Non-commercially release climate-adapted tree species. (9.1) • Incorporate southern seed sources or novel species expected to tolerate future conditions into tree planting, following landowner goals or agency guidance. See assisted migration considerations on page 31. (8.1/ 9.7)

Adaptation Actions (cont.)

High-Risk Condition	Possible Adaptation Actions (Strategy/Approach # from Forest Adaptation Menu)
Tree regeneration	• Install small deer exclosures to assess herbivory and tree regeneration potential. (2.3) • Plant a diverse mix of current and future climate adapted tree seedlings on an ongoing basis. (9.1/9.7) • Limit deer herbivory through gap/group deer exclusion or locally reducing deer population. (2.3)
Shrub and ground flora composition	• Control invasive plants using manual, mechanical, or chemical means. (2.2) • Reduce impacts of invasives where eradication isn't feasible by applying containment measures (restrict activity in uninfested sites, requiring equipment sanitation, etc.). (2.2) • Plant or seed species appropriate for the site and natural community. (5.2)
Size and connectivity	• Reforest adjacent land where appropriate to increase forest block size. (7.1) • Create large block management areas with adjacent landowners, working to reduce fragmentation. (6.2/7.1)

FOREST CARBON MANAGEMENT

This guide mostly covers adaptation, or helping forests cope with climate change impacts. **But forests also play a critical role in climate change mitigation, because they remove carbon dioxide from the atmosphere through photosynthesis and store carbon in soils and vegetation.**

A growing number of forest managers feel it is important to maintain and enhance carbon storage and sequestration, while also boosting carbon stored in wood products and wood-based fossil fuel substitutes. Many practices to enhance forest carbon align with other benefits, such as managing for wildlife habitat, so the decision may depend on the priorities of your organization and the characteristics of the forest in question. There are usually win-win opportunities where climate adaptation and mitigation can work together. Typically, things that keep forests healthy and prevent large-scale disturbances fulfill both goals.

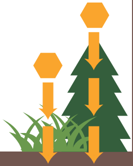
NIACS has released a menu of adaptation actions for Forest Carbon Management. Like the Forestry Adaptation Menu, it is organized into Strategies and Approaches and is designed to be used with the Adaptation Workbook. Review all the ideas and pick those that seem most appropriate to your situation! See: www.forestadaptation.org/focus/forest-carbon-management.

Considerations for Carbon Management

Forests store carbon primarily in soils and in live tree biomass. Along with standing dead trees and down dead wood, these total ~96% of the carbon in Wisconsin's forests. Management can enhance carbon storage by reducing the risk of disturbance to these carbon pools, or increase the rate of sequestration by improving forest health and productivity.

Site-level risks can help determine some of the actions you can take to manage forests for carbon value. In forests with low risk from climate impacts and other stressors, management can help store more carbon in larger trees and forest soils, or increase stocking in understocked stands. For example, designating a reserve stand of long-lived species can provide significant carbon benefits. In forests with increasing risk from climate change, carbon removal from harvest or other actions may ultimately provide long-term benefits compared to no action. Where disturbances such as fire are critical for forest health, it might actually be necessary to reduce carbon storage in the near-term in order to maintain a healthy forest that can act as a carbon sink in the future.

Carbon Storage: The amount of carbon that is retained in a carbon pool within the forest.



Carbon Sequestration: The process of removing carbon from the atmosphere for use in photosynthesis, resulting in the maintenance and growth of plants and trees.

Actions to Increase Carbon in Managed Stands

Soil Carbon

Under climate change, best management practices that protect soils and their large carbon stocks are more important than ever. If site conditions indicate potential risks to soils, you may opt to take additional actions to protect soils.

Topic:	Actions that increase carbon:
Soil Damage: Warmer winter conditions could lead to unreliable frozen ground in the winter, increasing the risk of rutting and compaction.	• Time harvest operations to match site conditions and minimize risk to stands. • Use temporary bridges at stream crossings or timber mats to limit soil impacts during wet conditions.
Flooding and Erosion: Extreme rainfall could strongly affect some locations, such as a floodplain or steep, highly erodible slopes.	• Limit management-related disturbance or widen buffers in areas that may be at risk of erosion, such as steep slopes, riparian zones, and wetlands.


Todd Ontl, NIACS

Live Trees

Older forests that contain abundant large-diameter trees store substantial amounts of carbon in live biomass, while young forest stands with rapidly growing trees have a high rate of carbon sequestration. Consider risks to existing carbon stocks as well as opportunities for enhancing carbon sequestration.

Topic:	Actions that increase carbon:
Tree Health: Damage from insect pests or diseases, or looming threats from pests or diseases could reduce carbon stocks from tree mortality. **Species Diversity and Suitability:** Stands with lower species diversity than expected for the cover type, as well as stands dominated by species near the southern extent of their species range, could have greater impacts from climate stressors. **Structural Diversity:** Mature stands that contain trees that are primarily a single age or size with a simple canopy structure could be more susceptible to disturbance. **Tree Crowns and Spacing:** Trees that are too crowded and competing for growing space may be more impacted by drought.	• Retain healthy, large-diameter trees when harvesting to maintain greater carbon stocks in tree biomass. • Thin around crop trees, retaining carbon in existing healthy trees while improving the ability to sequester additional carbon through enhanced growth. • Enhance future sequestration in young forest stands through harvesting to promote a greater diversity of tree species and promote regeneration. • Plant a variety of native species expected to do well under future conditions to generate resilient sequestration capacity.

Dead Wood

Forests can store significant quantities of carbon in dead biomass, including snags and coarse woody debris that can take decades to decompose. As dead wood decomposes, nutrients are returned to soils to maintain site fertility and future tree productivity. This carbon pool may not be as susceptible to climate stressors as soils and live trees, but foresters can still consider opportunities to enhance carbon storage through accumulation of dead wood.

Topic:	Actions that increase carbon:
Standing Dead Trees and Down Dead Wood: Carbon stocks can be increased with dead wood additions in some situations. For example, foresters can identify stands with few large standing dead trees or stands without coarse woody debris, such as branches and boles.	• Identify several legacy trees per acre, such as trees in declining condition (as long as no serious diseases or pathogens are present), to retain as eventual snags. • Retain low-quality timber on site for down dead wood (e.g. chop-and-drop). • Retain slash, tree tops, and existing snags when present.

Todd Ontl, NIACS

RESOURCES AND LINKS

Wisconsin Initiative on Climate Change Impacts (WICCI): WICCI is the hub of climate information and adaptation in the state. There are many WICCI working groups, including Forestry as well as Plants & Natural Communities. www.wicci.wisc.edu

Climate Change Atlas: Projected suitable habitat for individual tree species under climate change. www.fs.fed.us/nrs/atlas/

Climate Change Response Framework: A collection of NIACS vulnerability assessments, adaptation tools, and real-world adaptation demonstration projects. www.ForestAdaptation.org

Climate Change Resource Center: A national-level website with topic-specific information and a library of online tools. www.fs.usda.gov/ccrc

Great Lakes Silviculture Library: A collection of real-world silviculture case studies, searchable by forest type and keywords. www.silvlib.cfans.umn.edu/silviculture-library

National Climate Assessment: A national-level report with the best available information on observed and projected climate trends. https://nca2018.globalchange.gov/

Online Adaptation Workbook: An interactive, self-guided version of the Adaptation Workbook. www.AdaptationWorkbook.org

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