Forest Vulnerability

Climate change will affect different tree species and forest types in different ways. Forest impact models can be combined with manager expertise to assess which species and forest types are at risk and which may benefit from projected changes.

The Earth's climate is changing. Many trends have been tracked, some reaching back tens of thousands of years. Trees and forests are sensitive to a range of environmental conditions, including the climate. In addition to climate, there are other factors to which forests will respond, such as human activities and management, biological relationships, and invasive pests. All of this creates a dynamic within which forests will grow and change.

Scientists have built a variety of tools to help understand complex ecological relationships and how forests might look decades into the future. These tools have evolved with computer technology and a growing body of knowledge. Much of what is included in this bulletin is based on these predictions. Additionally, an increasing body of research investigating empirical, on the ground, change will help refine predictions over time.

For example, a tool used to estimate changes in suitable habitat for tree species is called the "Tree Atlas."[1] Tree Atlas uses climate models to assess future habitat suitability for individual species. Whether or not tree species will follow these patterns is a different question because human choices and other pressures also exert significant influence on forest distribution. Exotic pests and diseases will likely be game-changers for some species, but the Tree Atlas doesn't include these kinds of variables.

In another 50-100 years, climate in the upper Great Lakes is expected to resemble modern-day Arkansas and Missouri.[2] How might Michigan's forests respond to those changes? Boreal tree species are expected to decline. Oaks, hickories, red maple, and white pine are expected to do well. Table 1 lists species that are projected to gain or lose suitable habitat in northern Michigan, and table 2 shows results for the state's most common tree species.[3] In addition to "winners" and "losers," there are tree species currently outside Michigan that will gain new habitat, and species where different models show mixed results.

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Tree species tend to grow with common associations called forest types, forest systems, or natural communities. As the climate changes, forest composition, structure, and function will evolve. There will not likely be a simple direct relationship between climate and forest condition because climate is not the only set of factors influencing forests, and climate will affect different forests in different ways.

Tree species with aggressive dispersal strategies will likely occupy new habitat more quickly than other tree species. Highly fragmented landscapes will be a barrier to natural tree species migration. Planting programs may assist migration of future-adapted species, but would likely be very costly across a large area. As of 2014, there is little evidence of tree species migration tied to climate change.[4]

In the Lake States, there is current research examining this issue.[5] As more information becomes available and forest responses become clearer, assessments will be updated. As scientists learn more about how forests change, foresters will be better able to employ management practices to adapt to those changes.

Vulnerability to Climate Change

"Adaptive capacity" is the ability of a tree species or forest to tolerate stress. Forests with reduced diversity or narrow ecological requirements typically have less adaptive capacity, and are at greater risk to changing conditions. Forests more tolerant of disturbance or with higher diversity will likely be better able to tolerate future stress and change.

"Potential impacts" is a combination of a species' exposure to changes as well as their sensitivity to those changes.

"Vulnerability" is a combination of adaptive capacity and potential impacts.

Table 2. Suitable habitat projections for Michigan's most common tree species (67% of forest volume)[3]

Tree Species	Suitable habitat projections
Sugar maple	Mixed Results
Red maple	Mixed Results
Northern white-cedar	Loser
Red pine	Mixed Results
Northern red oak	Mixed Results
Quaking aspen	Loser
Eastern white pine	Mixed Results
Bigtooth aspen	Mixed Results
Eastern hemlock	Mixed Results
Black cherry	Mixed Results

Table 1. Projected changes in suitable habitat for selected tree species in northern Michigan[3]

"Winners"			Mixed Results	"Losers"	
American elm	Blackgum	Shagbark hickory	American basswood	Balsam fir	Paper birch
Ironwood	Eastern redcedar	Silver maple	Bur oak	Balsam poplar	Quaking aspen
Black locust	Flowering dogwood	Slippery elm	Eastern hemlock	Black spruce	Tamarack
Black oak	Honeylocust	Sycamore	Red pine	Jack pine	White spruce
Black walnut	Sassafras	White ash	Sugar maple	Mountain maple	
Black willow	Scarlet oak	White oak	Yellow birch	Northern white-cedar	

Vulnerability by Forest System

In a recent assessment, researchers and managers from a variety of organizations looked at the vulnerability of northern Michigan's forest systems to climate change (Table 3).[6] The following summaries are from that assessment. The western UP is covered in a companion assessment with northern Wisconsin.[7]

Upland spruce-fir forests are highly vulnerable to climate change (medium to high evidence, medium to high agreement). The boreal species within upland spruce-fir forests are not projected to tolerate warmer temperatures, increased competition from other forest types, and more active forest pests. In Michigan, these forests are generally restricted to lake-effect areas on the landscape.

Jack pine has a high to moderate vulnerability assessment (medium evidence, high to medium agreement). Impact models project declines in suitable habitat and biomass for jack pine, as a species, and pests and diseases may become more damaging under climate change. A high tolerance for disturbance and the current management emphasis increases the adaptive capacity of jack pine types.

Red and white pine forests have a moderate to high vulnerability status (medium to limited evidence, medium agreement). The potential for greater pest and disease activity is a major threat to red pine and white pine forests, along with the potential for interactions among stressors. Tolerance for drought and disturbance increases the adaptive capacity of these forests, and the future fire regime is a primary uncertainty.

Swamp conifer vulnerability to climate change is rated high to moderate (medium evidence, medium agreement). Lowland conifer types have limited tolerance to changes in water tables. Additionally, the dominant species (cedar, black spruce, tamarack) in these forests are expected to decline under a range of climate futures. Low agreement on future precipitation and groundwater levels are the primary uncertainties for these systems.

Aspen forests are moderately vulnerable to climate change (medium evidence, medium agreement). Impact models project substantial declines for aspen as a species in northern Michigan and multiple stressors could interact under climate change, particularly drought and pests. These forests are a management priority, however, and they are adapted to disturbance and exist on a wide range of sites.

Northern hardwoods, Michigan's most common forest type, are moderately vulnerable (medium evidence, medium agreement). Climate change may intensify several major stressors for northern hardwoods, such as drought, invasive species, and forest pests. Higher species diversity may increase resilience to future change. Uncertainty regarding future moisture regimes and potential interactions between stressors limit the confidence in this determination.

Swamp hardwoods, including the different lowland and riparian forest types, have moderate vulnerability (medium evidence, low to medium agreement). Altered hydrology may amplify the effects of pests and invasive species. Higher diversity and the presence of more southern species raise the adaptability of these forests. Future precipitation regimes are the primary uncertainty.

Oak associations have low-moderate vulnerability (medium evidence, medium agreement). Oaks are more tolerant of drought and warmer temperatures. White and black oak, which are projected to increase, already occur in the northern Lower Peninsula. Oak types are less common in the Upper Peninsula.

Barrens have low-moderate vulnerability to climate change (limited-medium evidence, medium agreement). They exist on dry sites with a sparse tree canopy. Barrens are mostly grasslands associated with jack pine, oaks, and a few other species. They may be well-adapted to warmer temperatures and episodic precipitation. More wildfires may benefit this system but an excessive amount could eliminate the tree component.

Table 3. Vulnerability summaries by forest system[6]

Forest System	Potential Impacts	Adaptive Capacity	Vulnerability	Evidence	Agreement
Upland spruce-fir	Negative	Low	High	Medium-High	Medium-High
Jack pine	Moderate	Moderate-Low	High-Moderate	Medium	Medium-High
Red pine/ white pine	Moderate	Moderate-Low	High-Moderate	Limited-Medium	Medium
Lowland conifers	Negative	Moderate-Low	High-Moderate	Medium	Medium
Aspen-birch	Moderate-Negative	Moderate	Moderate	Medium	Medium
Northern hardwoods	Moderate	Moderate-High	Moderate	Medium	Medium
Lowland/ riparian hardwoods	Moderate-Negative	Moderate	Moderate	Medium	Low-Medium
Oak associations	Moderate	Moderate-High	Low-Moderate	Medium	Medium
Barrens	Moderate-Negative	Moderate-High	Low-Moderate	Limited-Medium	Medium

1: Climate Change Tree Atlas, http://www.fs.fed.us/nrs/atlas/
2-3: Handler et al. 2014. Michigan Forest Ecosystem Vulnerability Assessment and Synthesis. GTR-NRS-129. www.nrs.fs.fed.us/pubs/45688
4: Zhu, Kai et al. 2012. Failure to Migrate: Lack of Tree Range Expansion in Response to Climate Change. Global Change Biology. 18(3): 1042-1052.
5: Fisichelli, Nicholas et al. 2013. Temperate Tree Expansion into Adjacent Boreal Forest Patches Facilitated by Warmer Temperatures. Ecography 36: 001-010.
6: Handler et al. 2014.
7: Janowiak et al. 2014. Northern Wisconsin and western Upper Peninsula Ecosystem Vulnerability Assessment and Synthesis. GTR-NRS-136. www.forestadaptation.org/WI-MI-FEVAS.

This bulletin is part of a series about climate change and forests. More detailed information about forest adaptation and climate change can be found in Handler (2014) and Swanston & Janowiak (2012). Three additional Michigan State University bulletins provide climate background "Climate Basics" – E3151, "Greenhouse Gas Basics" – E3148, and "Frequently Asked Questions About Climate Change" – E3150.

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