Climate Change and Adaptation: Mid-Atlantic Forests

Forests are a prominent feature of the landscape across the Mid-Atlantic region. Sweeping from the Atlantic coastal plain to the Catskill Mountains, forests cover approximately half of the 60-million-acre assessment area. These forests provide many benefits to residents of this region, including clean air and water, fish and wildlife, and places for families to spend time outdoors. Working forests also give us lumber, maple syrup, ginseng, and other products that support the local economy.

Foresters, biologists, and land managers are working hard to preserve these forests for future generations, as part of the Mid-Atlantic Climate Change Response Framework. Understanding how our forests are changing now and how they will continue to change in the future is the key to making sustainable choices. To help with these decisions, the **Mid-Atlantic Forest Ecosystem Vulnerability Assessment and Synthesis: a report from the Mid-Atlantic Climate Change Response Framework** summarizes the best available information about these forests from published research and local knowledge. The first three sections of this story map highlight key themes from the report and describe the general effects of anticipated changes across the region. The final section shows what foresters and land managers are doing to protect these forests and all of the benefits they provide for us.

Changing Climate

Our climate is changing more rapidly than we've seen in previous climate record. Some of these changes are obvious while others may take several decades to become apparent. Sea level rise is already contributing to coastal erosion and flooding. Winters are getting warmer, with fewer opportunities to ski, snowshoe, ice fish, or enjoy other winter sports. Spring is getting wetter, with more issues related to road maintenance, accessibility, as well as erosion and flooding. Understanding how the climate is changing provides the foundation for understanding how forests and people will be affected, and how we can safeguard these forests for future generations.

Explore observed and expected changes in the Mid-Atlantic region in the following impacts:

- Warmer Temperatures
- Longer Growing Seasons
- Shorter, Warmer Winters
- Rising Sea Levels
- Changing Precipitation
- More Extreme Precipitation
- Changes to the Water Cycle
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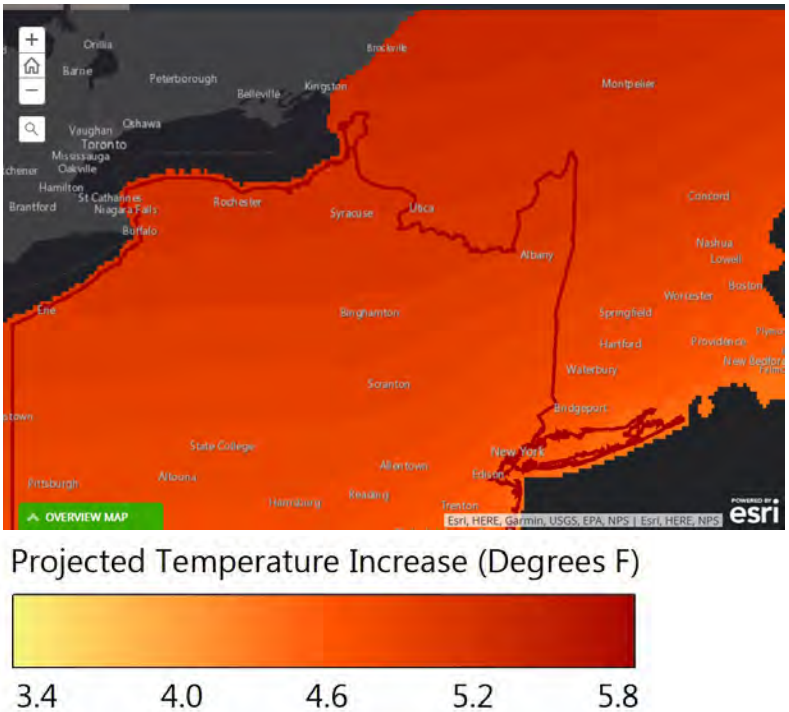
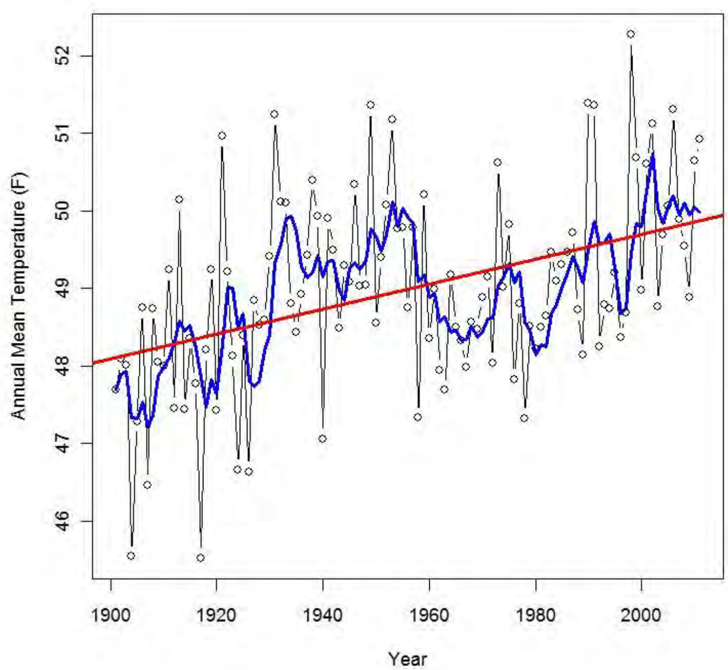
Warmer Temperatures

Since 1901, temperatures rose by an average of 1.8° F across the region, with hotspots in New Jersey and New York warming by up to 6°F. Temperatures are projected to increase another 3.4 to 5.8 degrees or more by 2100. The exact amount of warming will depend on the amount of future greenhouse gas emissions from energy use and other human activities.

During the next century, the number of hot days (exceeding 90 °F) in the Mid-Atlantic region is expected to increase by up to 60 days per year in some locations while the number of extremely cold days is expected to decrease. Warmer temperatures will have cascading effects related to snowfall, frozen ground, growing season length, and drought stress.



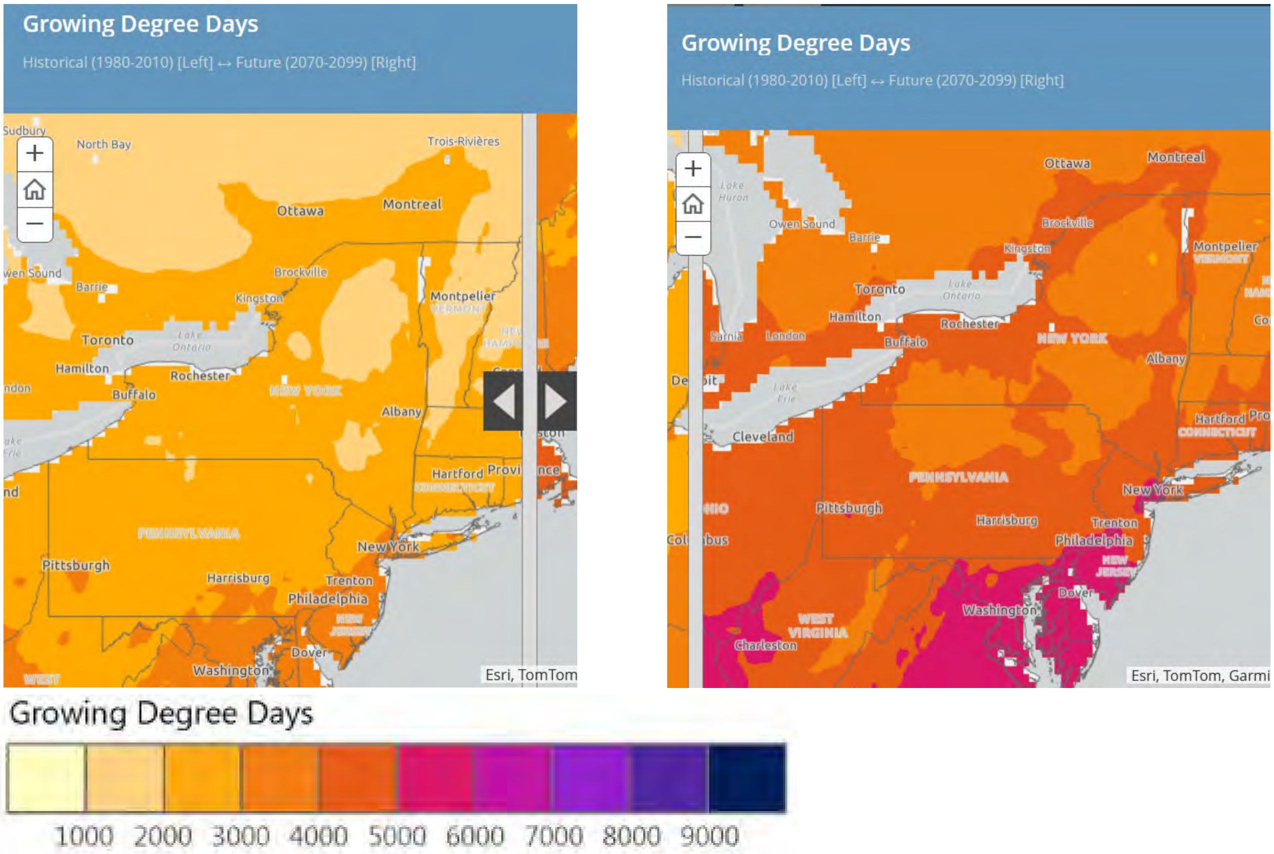
The map displays projected increases in average annual temperatures (º F) for the end of the century (2070-2099) using a high greenhouse gas emission scenario (RCP8.5; no climate policy and high population).



Average annual temperatures across the region rose by about 1.8 degrees F between 1901 and 2011. Open circles represent the average for each year. The blue line represents the 5-year average, while the red line shows the trend across the entire time period (an increase of 0.16 °F per decade). Figure produced by Climate Wizard © University of Washington and The Nature Conservancy, 2009. Base climate data from the PRISM Group, Oregon State University, Http://www.prismclimate.org

Longer Growing Seasons

Rising temperatures are increasing the length of the growing season, which describes the season available for plants to grow and mature. The growing season has already shifted earlier by about 10 days over the past 50 years, resulting in earlier leaf out and flowering times, and later leaf drop in the fall. By the end of this century, growing degree days are expected to increase substantially in all areas of the region, marking continued increases in the growing season and potential for improved plant growth when adequate water is available. However, higher temperatures or water deficits could limit growth effects on plants.



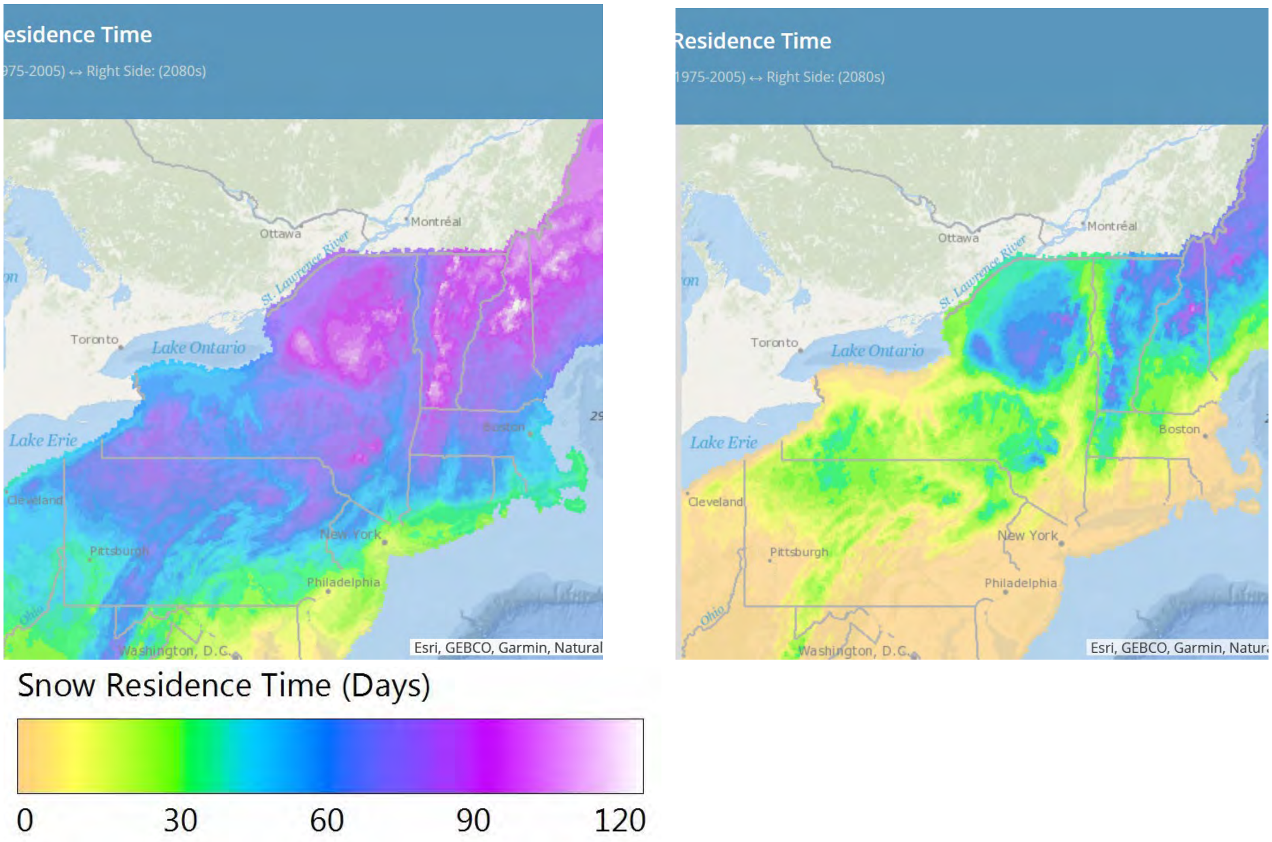
Growing degree days were modeled for two time periods, 1980-2010 and 2070-2099. The future projection uses a high greenhouse gas emission scenario (RCP8.5; no climate policy and high population). Growing degree days are calculated by 1) finding the average daily temperature for each day in the year; 2) summing for all the days of the year the average number of degrees above 41 ⁰ F.

Shorter, Warmer Winters

Cold and snowy winters are characteristic of much of the region, but winters are becoming shorter and milder. Winter temperatures increased 3.5 degrees Fahrenheit since 1900, about twice the amount of warming observed in other seasons. This has caused important changes in snow patterns and freeze-thaw cycles.

Although winter precipitation has generally increased in the region in recent decades, shorter winters and warmer temperatures mean that a greater proportion of that precipitation is falling as rain rather than snow. The number of days with snowfall and with snow cover have decreased across the region, and these trends are expected to continue.

All parts of the region are expected to have many fewer days with snow each year by the end of the century, with the greatest reductions in the south. Snow cover is important in many forests for protecting tree roots and storing water. Snow is also an essential part of the culture of the region, and is important for those who enjoy winter recreation, from skiing and sledding to building a snowman with their family.



*[**Snow residence time**](), the average length of time that snow will remain on the ground in days, was analyzed for two time periods, 1975-2005 and the 2080s. The future projection uses a high greenhouse gas emission scenario ([**RCP8.5**](); no climate policy and high population). Snow residence time is measured by the number of days per year with snow on the ground.*

Rising Sea Levels

Sea levels have increased by 12 inches across since 1900 along the Atlantic coast, rising faster than the global average due to regional development, land subsidence, and the behavior of ocean currents. A number of studies estimate the regional sea level to rise by an additional 4.3 feet in the Mid-Atlantic region. The area of land exposed to inundation is also projected to increase: 14.5 percent more land in Washington, DC, 11.4 percent in Delaware, and 10.2 percent in Pennsylvania.

Increases in sea-level rise directly and immediately influence storm surge and erosion potential of low-lying areas. Natural habitats and developed areas will continue to be increasingly exposed to sea-level rise and storms

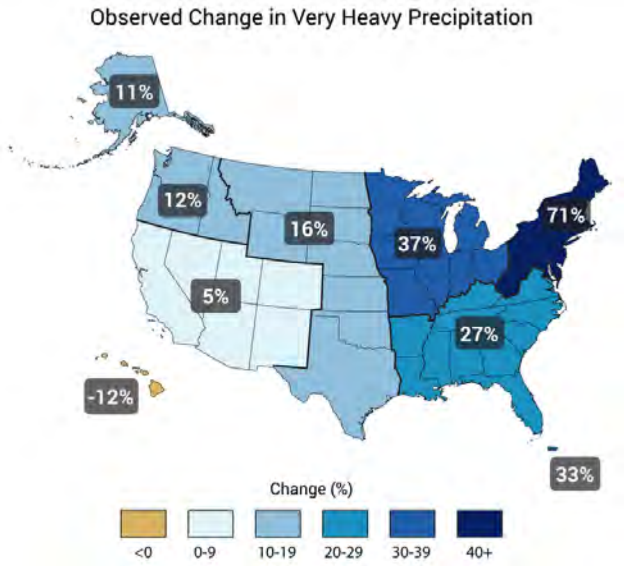
Changing Precipitation

Many places in the region receive several inches more rainfall throughout the year than they did in the early 1900s. Annual rainfall totals increased 4.5 inches during 1901 to 2011, with fall providing most of that precipitation (3.2 inches).
Most models project annual precipitation to continue increase slightly during the next century, with much of the increase shifting to winter and spring. There is greater variability among projections of precipitation during other seasons, particularly during summer and fall. Model results from several studies suggests that there is the potential for reduced growing season precipitation in at least some parts of the region during the next century.

More Extreme Precipitation

Perhaps even more important than changes in seasonal averages, the region is getting a larger share of total precipitation from heavy rainfall events. Intense rainstorms are happening much more frequently in recent decades, with the Mid-Atlantic and New England seeing greater increases in extreme precipitation events than any other part of the country.

Intense rainfall will continue to become more frequent in the Mid-Atlantic region. As more rain falls during any one event, there may also be longer dry periods between events, increasing the risk of moisture stress for vegetation.



The map shows percent increases in the amount of precipitation falling in very heavy events (defined as the heaviest 1% of all daily events) from 1958 to 2012 for each region of the continental United States.

Changes to the Water Cycle

Warmer temperatures, earlier snowmelt, and increases in winter and early spring rainfall have resulted in changes to the water cycle. Lakes are freezing less, and melting 9 to 16 days earlier in the spring than when record-keeping began in the mid-1800s.

Streams typically flow at their highest levels in late winter or early spring, but the date of that peak flow is shifting to earlier in the year. This shift in the timing means that summer stream flows are lower on average, but still subject to extreme events that can increase the risk of flooding, erosion, and sedimentation. Changes in precipitation patterns and reduced snowpack is expected to affect the quality and quantity of water resources for ecosystems, domestic use, agriculture, industry and recreational rivers and lakes.

Effects on Forests

Forest ecosystems in the Mid-Atlantic region will respond to climate change in a variety of ways. These responses can be positive or negative. Beneficial impacts can improve forest health and productivity or increase forest distribution. Negative impacts disrupt ecosystems by impairing forest health or productivity, reducing forest cover, or causing a forest to shift to a substantially different composition. This section describes how changes in climate may lead to various changes in regional forests. Forests in a particular location will be affected in unique ways depending on the local site conditions and on past and future management decisions.

- More Variable Soil Moisture
- Increased Risk of Drought
- Stress from Forest Pests and Diseases
- Competition from Invasive Plants
- Changes in Suitable Habitat
- Changes in Tree Establishment
- Changes in Tree Growth
- Changes in Forest Composition
- Sea-Level Rise and Saltwater Intrusion

More Variable Soil Moisture

Soil moisture will change in response to changes in temperature and precipitation. Seasonal and geographic differences are expected, such that some areas may become wetter in some seasons and drier in others. Increases in precipitation during the winter and colder parts of the year may cause seasonal increase in soil moisture. Larger and more frequent heavy precipitation events can also create wet and saturated soil conditions. However, increased temperatures combined with similar or reduced amounts of rainfall may lead to drier soil conditions during other times of the year. Soils may become drier during the growing season where warmer temperatures drive increases in evaporation and transpiration that are not offset by corresponding increases in precipitation, potentially leading to drought.

Increased Risk of Drought

A drought occurs when conditions are dry relative to long-term averages in a particular place, often causing moisture stress on plants adapted to that place. Moisture stress and drought can occur when increases in evapotranspiration are not offset by a corresponding increase in precipitation and soil moisture. As growing season temperatures rise to new extremes, the frequency of moisture stress is expected to increase from warmer, drier air as a result of increases in vapor pressure deficit and changing patterns of precipitation. Increasingly episodic rain events may result in greater stress on tree species and could lead to the decline of moisture-sensitive species.

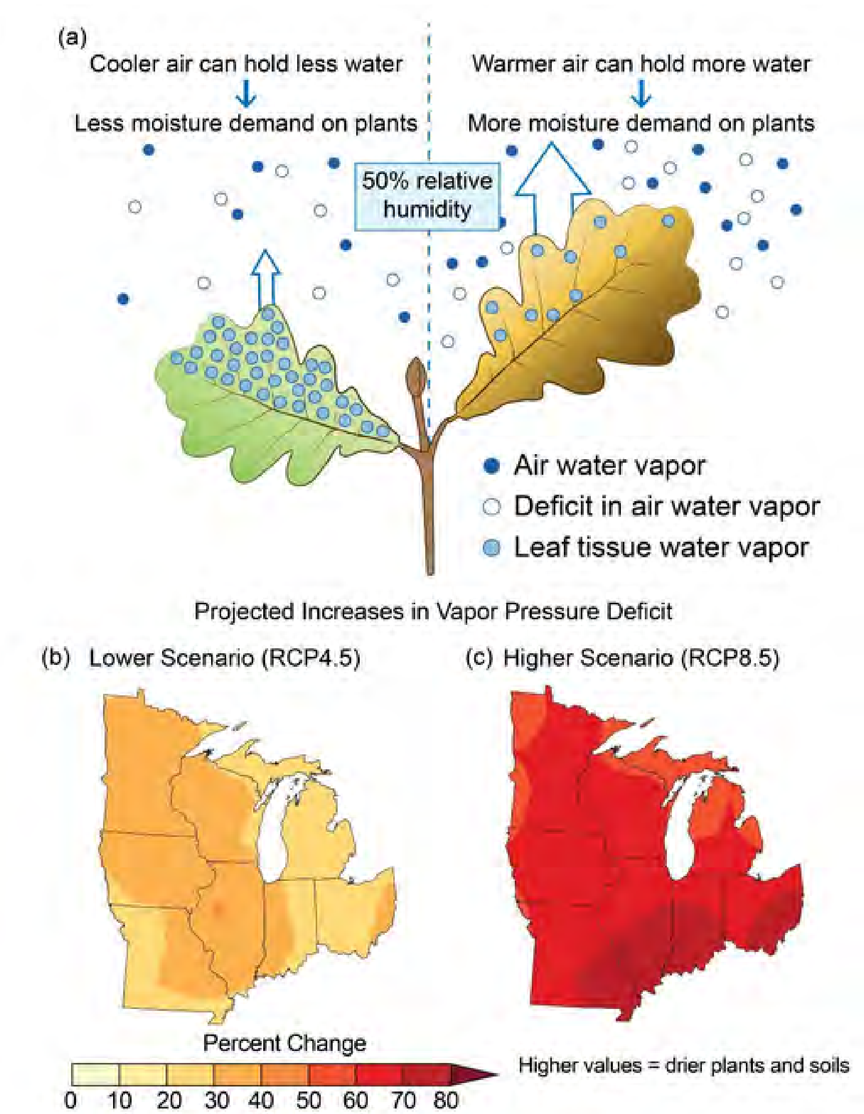


Figure at left: As air temperature increases in a warming climate, vapor pressure deficit (VPD) is projected to increase. VPD is the difference between how much moisture is in the air and the amount of moisture in the air at saturation (at 100% relative humidity). Increased VPD has a drying effect on plants and soils, as moisture transpires (from plants) and evaporates (from soil) into the air. (a) Cooler air can maintain less water as vapor, putting less demand for moisture on plants, while warmer air can maintain more water as vapor, putting more demand for moisture on plants. (b, c) The maps show the percent change in the moisture deficit of the air based on the projected maximum 5-day VPD by the late 21st century (2070–2099) compared to 1976–2005 for (b) lower and (c) higher scenarios (RCP4.5 and RCP8.5).

Stress from Forest Pests and Diseases

The response of forest pests and pathogens to a warmer future will vary widely by modes of infection, transmission, survival, and tree response. Based on current knowledge, it is expected that that many forest pests and diseases will be more damaging under climate change. Forest pests and diseases are generally able to adapt more quickly to new climatic conditions, migrate more quickly to suitable habitat, and reproduce at faster rates than host tree species.

Mild winters allow some insect pests to expand northward, such as the hemlock woolly adelgid and southern pine beetle. Additionally, forests pests and diseases are generally more damaging in stressed forests. For example, drought can weaken a tree's natural defenses and make it more susceptible to infestation. Furthermore, new pests or pathogens may enter the region during the next century.

Competition from Invasive Plants

Non-native invasive species are already a major threat to some forests in the region and this threat is expected to worsen as the climate shifts. Invasive plants are expected to "disproportionally benefit" under climate change, because they have traits that allow them to exploit changed environments and aggressively colonize disturbed areas. Increases in carbon dioxide increase growth for many plant species, including some of the most invasive weeds in the U.S.

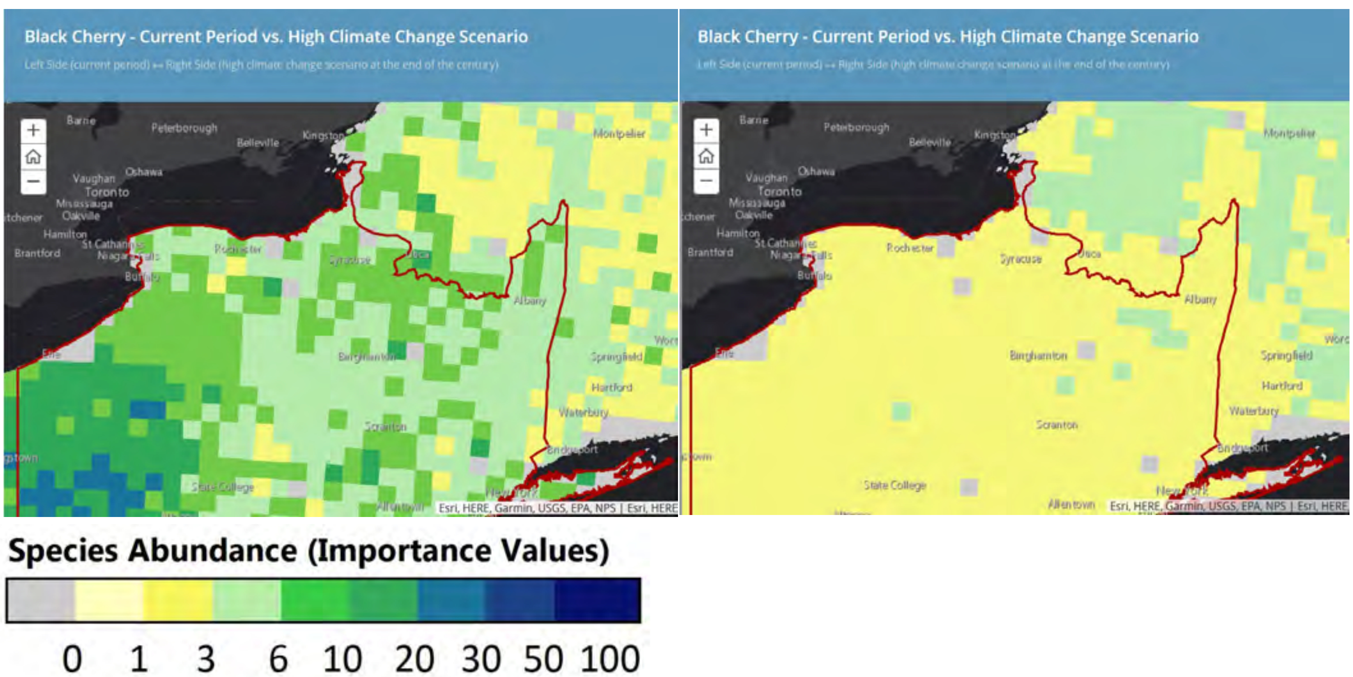
The region may lose some of the protection offered by a traditionally cold climate and short growing season, and warmer conditions may allow invasive plant species to expand their ranges northward. Increases in disturbances such as drought, fire, or flooding are likely to benefit invasive plants that are able to establish quickly and out compete native vegetation on disturbed sites. Unfortunately, there is a lack of information regarding the climatic thresholds that apply to many of these plants, which limits the ability to predict how well individual species may spread, or predict which new invasive species may enter the region during the next century.

Changes in Suitable Habitat: Decreases in Tree Species Abundance

Trees and other plant species have responded to past climate change in a number of ways, with the ranges of tree species in eastern North America shifting dramatically since the last ice age. As the climate warms and changes, the distribution of suitable habitat will change again for individual species.

Many northern tree species will face increasing stress as habitat conditions become less favorable in a warmer climate. Some of these species are present in the region as boreal remnants of a cooler climate and include black spruce, red spruce, northern white-cedar, paper birch, quaking aspen and white spruce. These species are expected to decline with even a slight amount warming and will lose substantial habitat as temperatures continue to increase.

Other species, such as bigtooth aspen, black cherry, sugar maple, and yellow birch are projected to have declines in habitat under scenarios of greater warming, particularly farther south in the region. Many of these species are currently common across the landscape; these species play an important role in many forests, and the decline of these species can have important consequences for forest ecosystems.

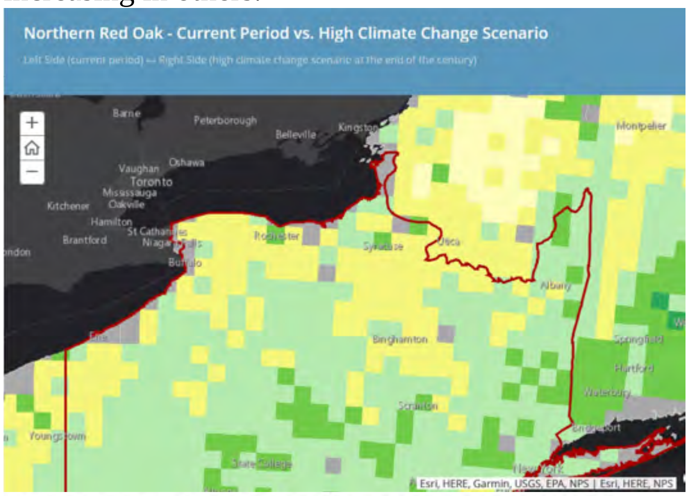


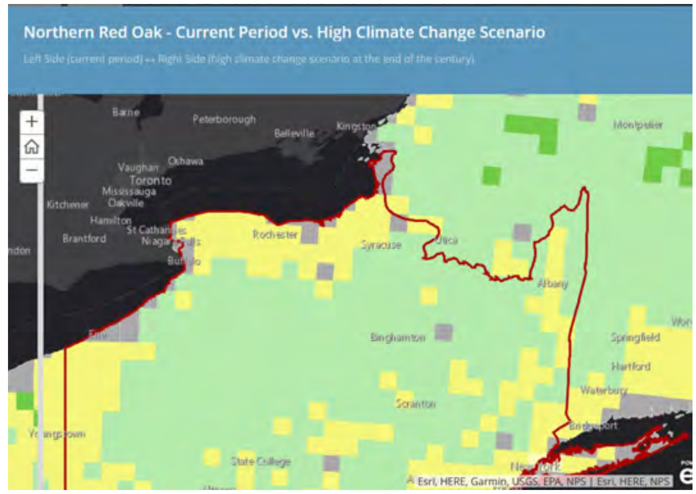
Importance values represent the relative abundance of a given species within a stand and are calculated by averaging its trees-per-acre and basal area values.

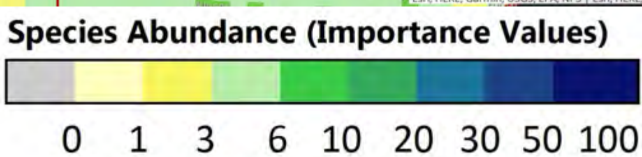
The map to the right displays the range of suitable habitat for black cherry within the eastern United States. Slide the horizontal bar left and right to compare current modeled habitat (left) to modeled future habitat projected for the end of the century using a high greenhouse gas emissions scenario and sensitive climate model (GFDL A1FI). Current and future suitable habitat is presented using importance values, which represent the relative abundance of a given species in a particular location.

Changes in Suitable Habitat: Shifts in Tree Species Distribution

Even though the suitable habitat is projected to decrease for some northern tree species, this does not mean that those species will disappear from the landscape. Trees are often slow to respond to change, and the conditions in some locations may remain suitable for quite some time. Northern species may persist in the assessment area through the next century, although they may have reduced vigor where conditions become less suitable. Additionally, species that are widely distributed across the landscape may decrease in some areas, while increasing in others.







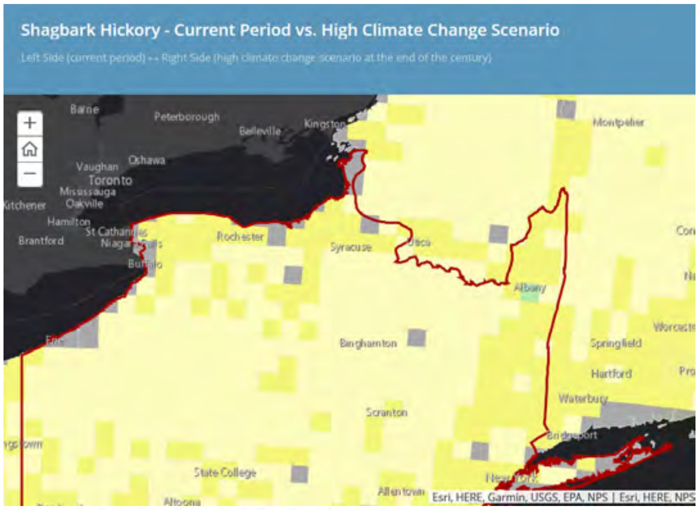
Importance values represent the relative abundance of a given species within a stand and are calculated by averaging its trees-per-acre and basal area values.

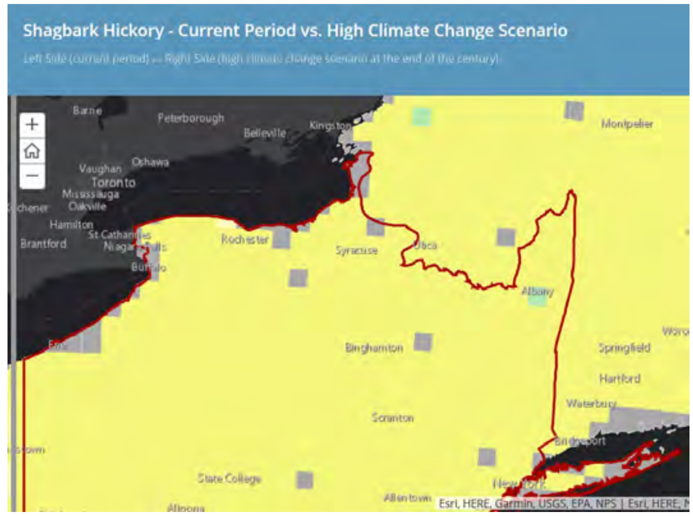
The map to the right displays the range of suitable habitat for northern red oak within the eastern United States. Slide the horizontal bar left and right to compare current modeled habitat (left) to modeled future habitat projected for the end of the century using a high greenhouse gas emissions scenario and sensitive climate model (GFDL A1FI). Current and future suitable habitat is presented using importance values, which represent the relative abundance of a given species in a particular location.

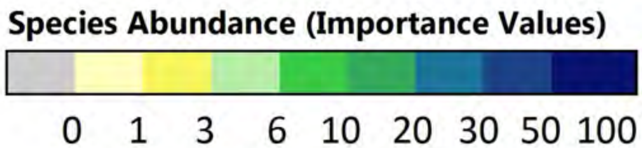
Changes in Suitable Habitat: Increases in Tree Species Abundance

Many species, including several oak and hickory species, may have increased habitat due to changing conditions. Some of these species are currently present in the warmer parts of the region, such as scarlet oak, black walnut, shagbark hickory, pin oak, and southern red oak.

Other species are rare in the region currently but may have new habitat in the future, such as post oak and chinkapin oak. These species generally have more southerly distributions, and changes in climate are generally projected to extend the range of these species northward. Although suitable habitat may increase for many species, landscape fragmentation and the dispersal limitations of individual species could hinder the colonization of these species into newly available habitats.







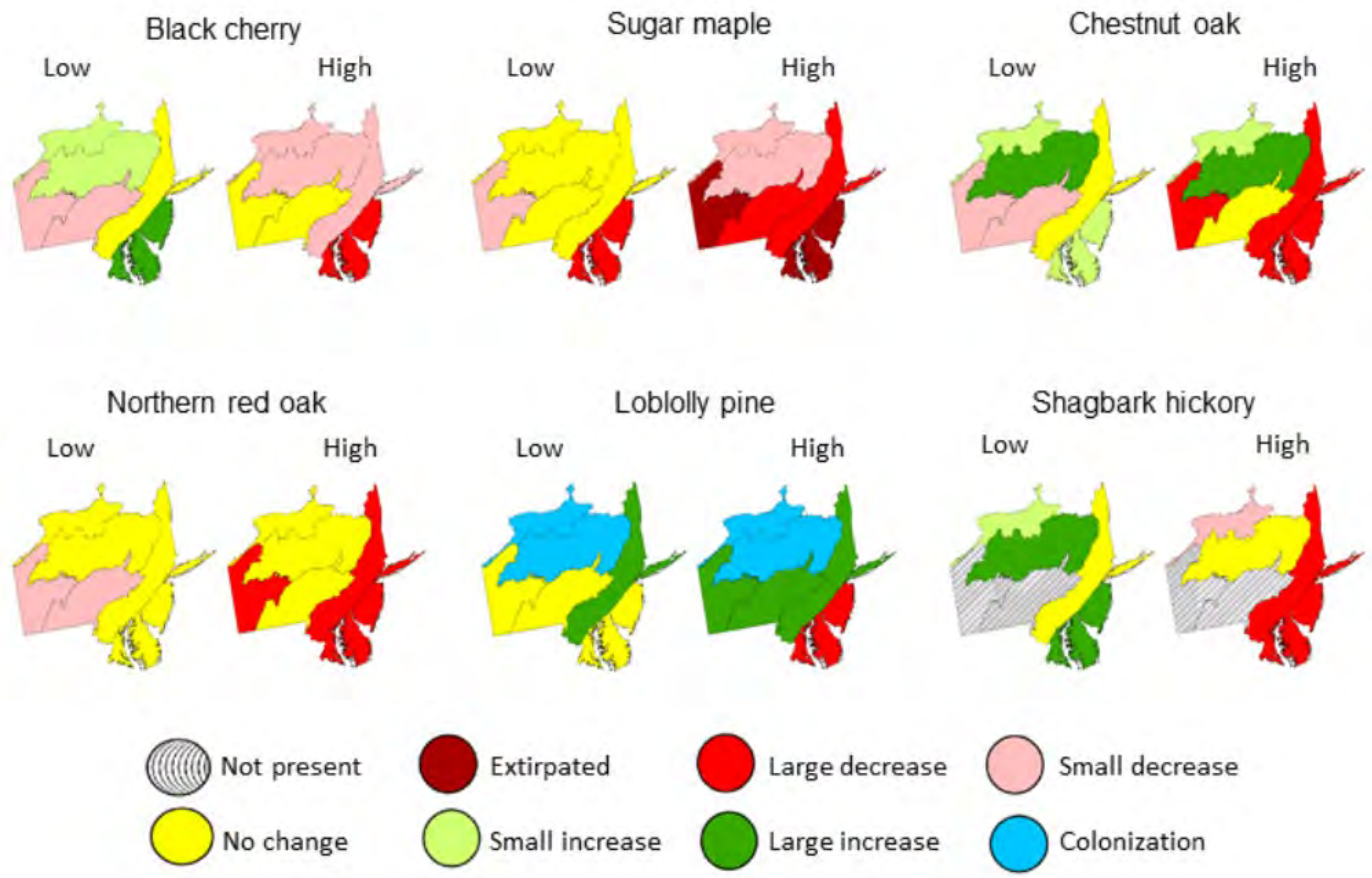
Importance values represent the relative abundance of a given species within a stand and are calculated by averaging its trees-per-acre and basal area values.

The map to the right displays the range of suitable habitat for shagbark hickory within the eastern United States. Slide the horizontal bar left and right to compare current modeled habitat (left) to modeled future habitat projected for the end of the century using a high greenhouse gas emissions scenario and sensitive climate model (GFDL A1FI). Current and future suitable habitat is presented using importance values, which represent the relative abundance of a given species in a particular location.

Changes in Tree Establishment

Changes in the establishment of new trees are expected to be one of the first signals of climate change in forests, because seedlings are more sensitive to environmental conditions than larger trees. Changes in temperature, precipitation, growing season, and soil moisture could all affect seedling germination, establishment, and growth.

Each species has unique requirements for establishment, which means that some species will fare better and others worse as conditions change. Both local conditions—including site and climate factors—and forest management actions will influence how well trees are able to establish in a particular place. Because seeds need to germinate and start to grow before they can become the future forests of the region, changes at the early stage of their growth can have major impacts on the species and structure of tomorrow's landscapes.



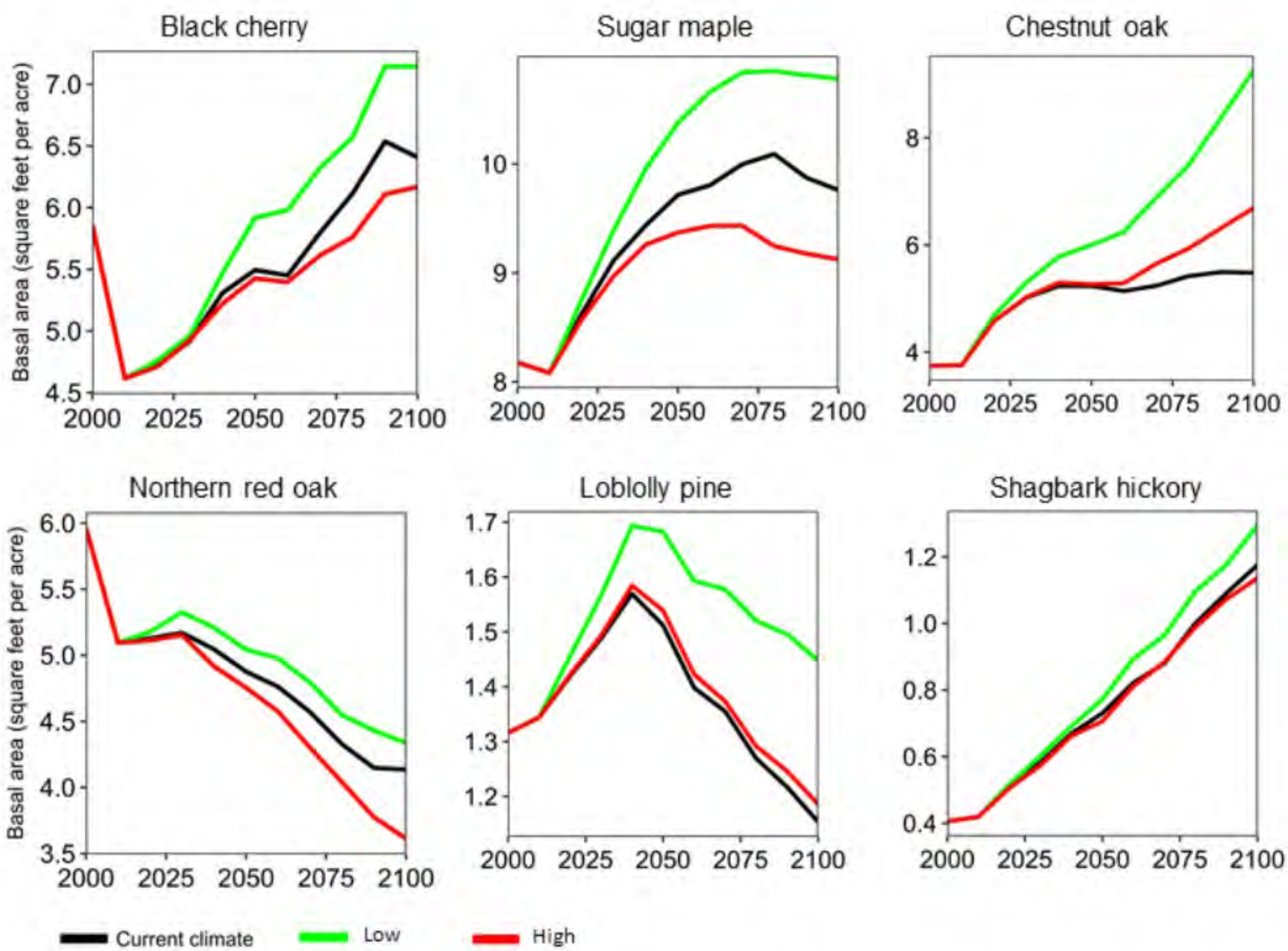
The figure shows future changes in tree species establishment for six tree species, as modeled by the end of the century by the LINKAGES model. Results are shown for a low change (PCM B1) and a high change (GFDL A1FI) climate scenario.

Changes in Tree Growth

The factors influencing the growth of forests are complex. Regional forests are still recovering from past disturbances, which will affect how they respond to future changes.

Local factors, such as soil conditions, prior disturbances, and past or current forest management, will continue to exert a strong influence on tree growth and forest productivity in the coming decades. At the same time, climate change will affect whether individual species are able to thrive in a particular place by increasing the risk of damage from drought, storms, invasive species, forest pests, and other threats. Forests near the ocean will face increasing risk of saltwater intrusion from storm surge, spray, and salt water expansion into freshwater habitats.

For these reasons, changes in tree growth and forest productivity will vary from place to place. Some tree species, particularly cold-adapted northern species like balsam fir, quaking aspen, red spruce, and yellow birch, are generally expected to decline as the climate warms over the next century and beyond, even with a low amount of change. Other tree species, such as northern red oak, black cherry, and sugar maple, are expected to decline only under the high emissions scenario, suggesting that future changes in temperature and soil moisture may not be tolerable to seedlings and young saplings. Loblolly pine, which is currently present in coastal Maryland, is the only species expected to become more abundant.



The figure shows changes relative density for six tree species, measured in basal area and modeled by the end of the century by the LANDIS PRO model. Results are shown for a low change (PCM B1) and a high change (GFDL A1FI) climate scenario.

Changes in Forest Composition

Forests are constantly changing in response to environmental conditions, and the climate is changing much more quickly now than it had after the retreat of the glaciers more than 10,000 years ago. Because species respond individually to changes in climate, new forest communities may emerge over time, with new mixes of tree species. In the absence of major disturbances, shifts in tree species are expected to be relatively subtle until well into the 21st century because of the long time periods associated with many forest processes. Climate-related changes can interact with other changes that are occurring within forests, such as the shift from oak to maple forests that is currently happening in parts of the region. Changes are likely to be more apparent along the boundaries of different types of forests, where southern species are at the northern edges of their ranges, and vice versa.

Apart from the slow shifts in forests that result from gradual changes in climate, other climatic changes increase the risk of many disturbances and spark more rapid shifts. These disturbances, including extreme storms, drought, pests, and invasive species, can change forests quickly and dramatically.

Sea-Level Rise and Saltwater Intrusion

Forest ecosystems along coasts will be affected by climate change. Mid-Atlantic coastal ecosystems—including wetlands, salt marshes, estuaries, and forests—provide a number of benefits, such as water filtration, habitat for fish, carbon storage, and recreation for some of the most populated areas in the country. Forested wetlands, swamps, and adjacent marshes are sensitive to changes in sea level. Freshwater tree species can tolerate low chronic levels or acute episodes of moderately increased salinity, but may suffer during periods of higher exposure. However, low amounts of salinity can have severe effects on freshwater systems that are not usually reached by saltwater. Salinity levels can remain high for months or longer, especially in situations where soil salinity is increased, and may result in suppression of tree regeneration. Increased salinity can also affect nitrogen inputs, ultimately impeding forest growth. And even a relatively small increase in salinity can cause a freshwater swamp forest to transition to marsh.

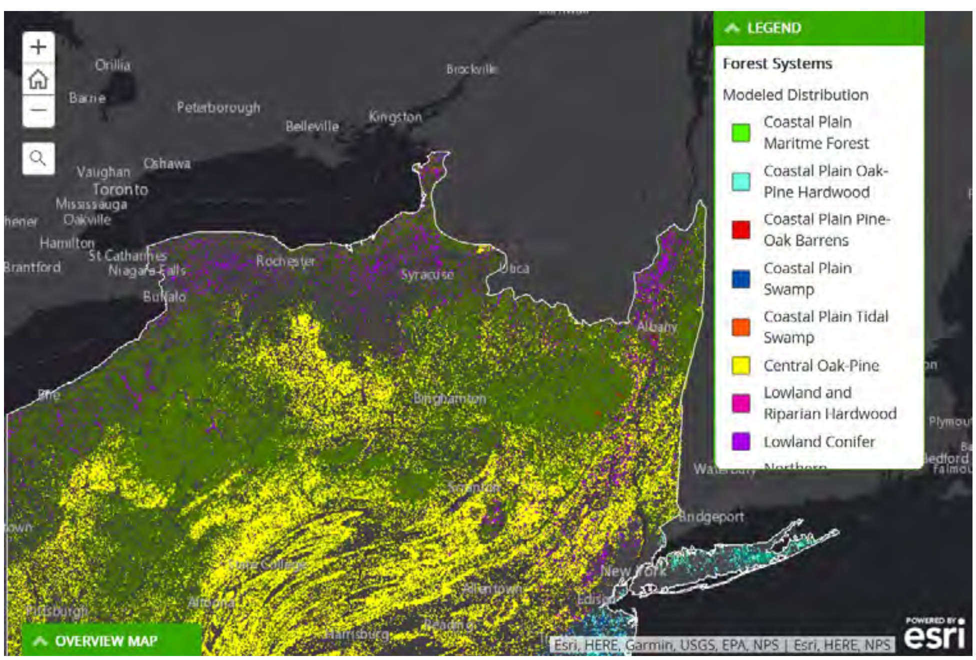
Drought can also influence saltwater intrusion; as streamflow decreases during a drought, saltwater is able to move farther upriver. Drought-induced salinity stress has caused widespread mortality and long-term negative effects on tree growth in forests along the Atlantic coast.

Forest Vulnerability

The region contains a diverse mix and gradient of forest communities, each defined by micro-climate, soil, landscape position, hydrology, and other local factors. Each of these communities has a level of risk from the negative effects of climate change. The vulnerability of a particular forest community depends on the impacts of climate change, as well as the ability of the system to tolerate those impacts without undergoing major changes.

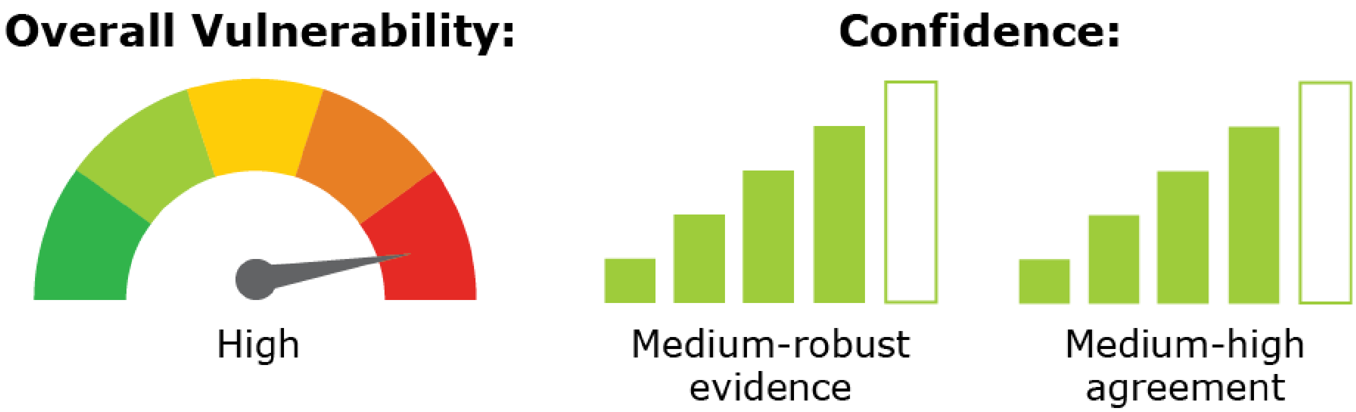
Two teams of scientists and managers assessed the vulnerability of eleven regional forest systems to climate change: 6 interior forest types and 5 coastal forest types. These determinations can provide a starting point for land managers and woodland owners to consider how climate change is going to affect their forests, recognizing that local site conditions and management strongly influence the ways in which forests change.

- Coastal
    - Maritime Forest
    - Oak-Pine-Hardwood
    - Pine-Oak Barrens
    - Swamp
    - Tidal Swamp
- Interior
    - Central Oak-Pine
    - Lowland Conifer
    - Lowland and Riparian Hardwood
    - Montane Spruce-Fir
    - Northern Hardwood
    - Woodland, Glade, and Barrens

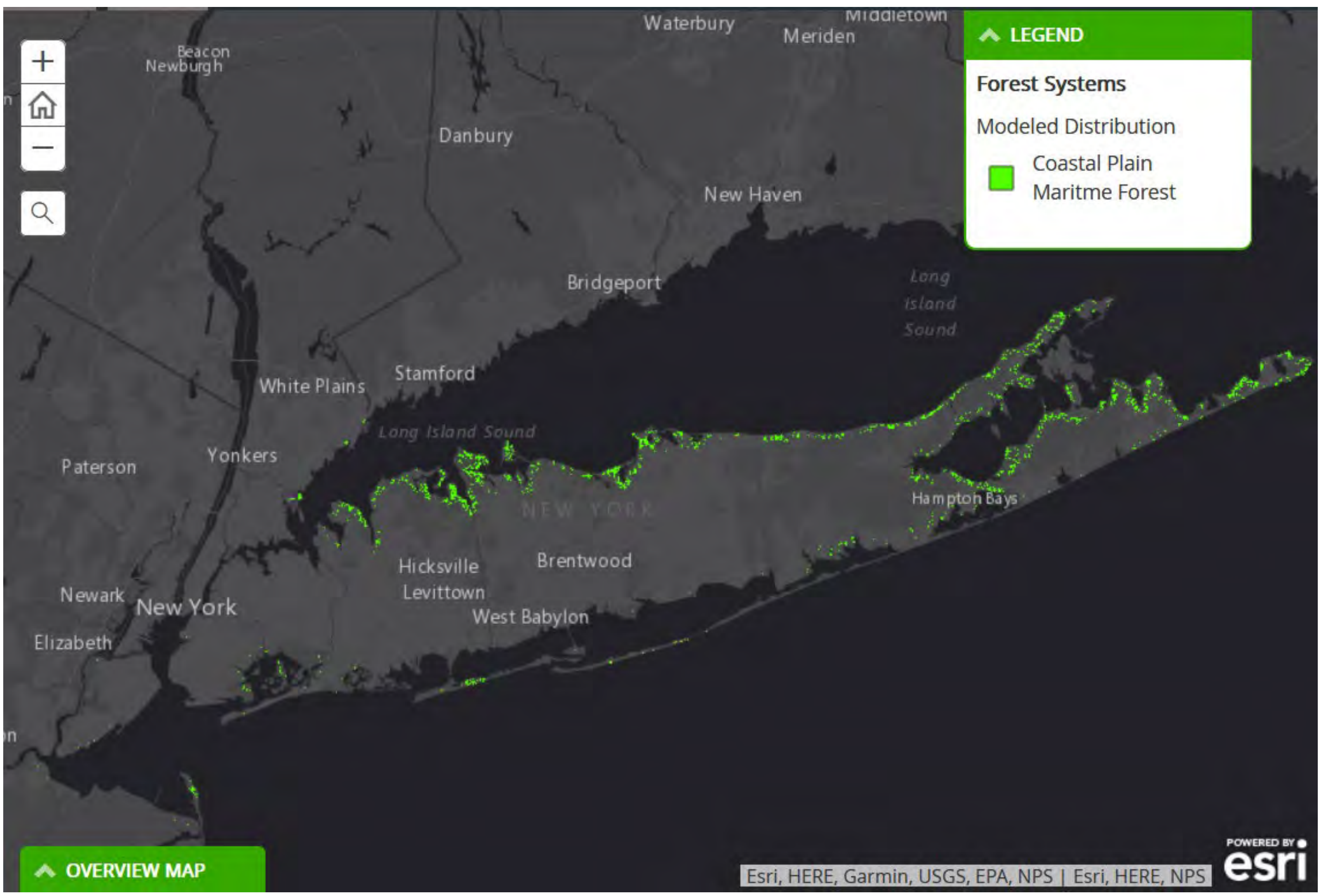


This map displays the approximate distribution of forest systems that were used in this assessment. Forest systems shown in this map are aggregations of terrestrial habitats that have been mapped for the Northeast U.S. and Atlantic Canada.

Maritime Forest

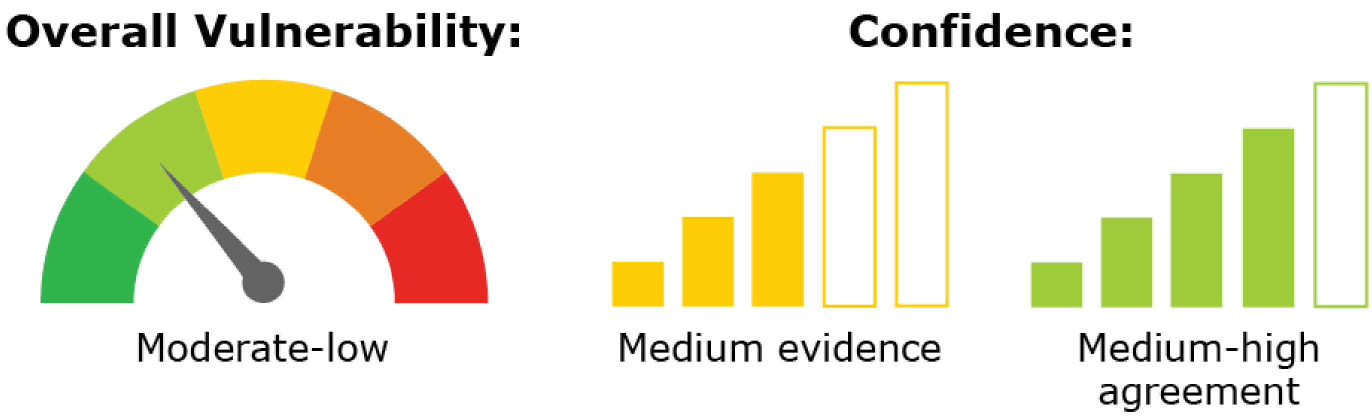


Maritime forests cover a relatively small area on the coastal plain, existing on barrier islands or in narrow bands near estuaries, islands, and other coastal zones. The proximity of this forest community to ocean coasts means that changes in coastal dynamics – such as rising sea levels, more severe storm surges, and more frequent flooding - are greater drivers of species composition than changes in temperature and precipitation.



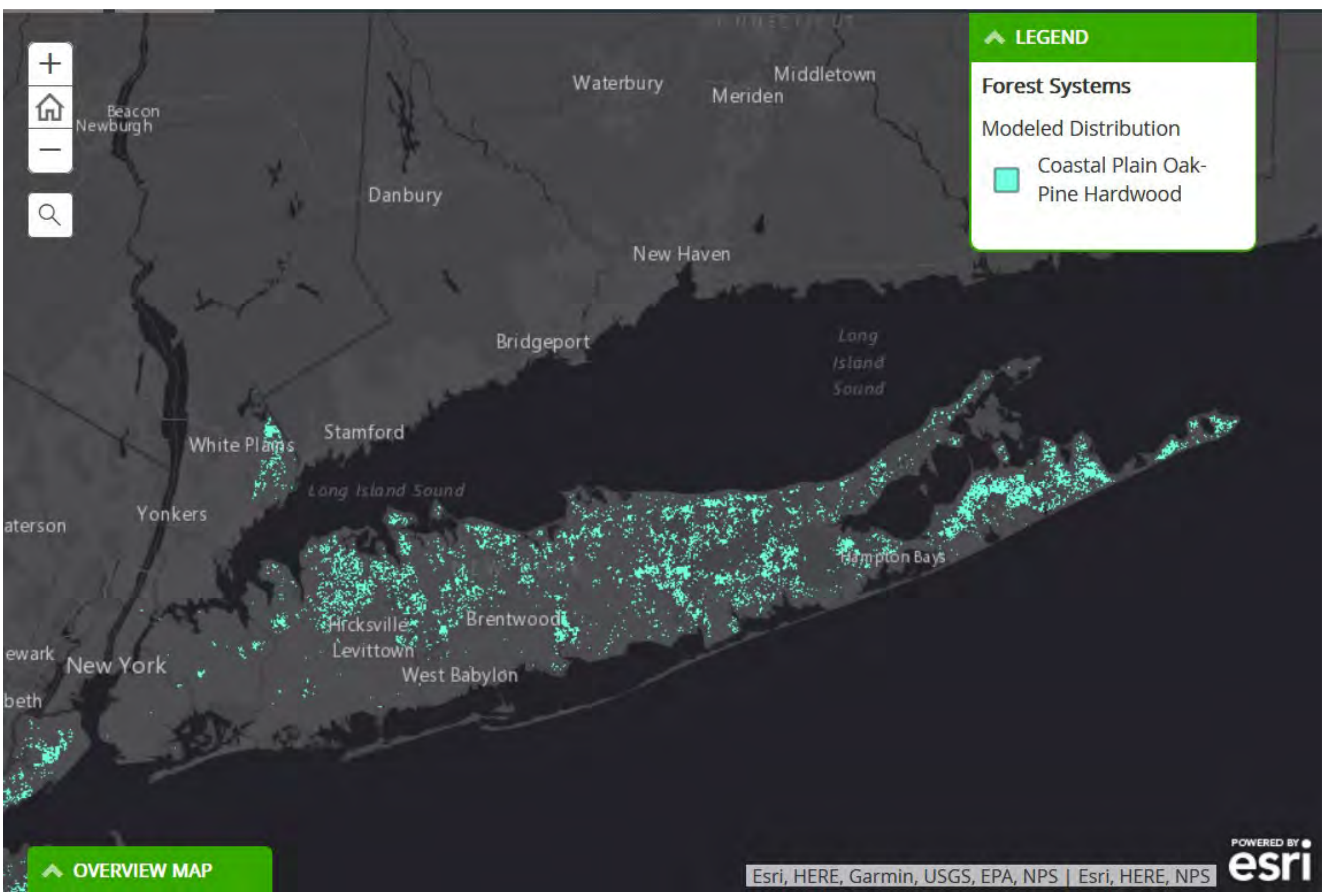
Prolonged inundation with saltwater may cause stress or mortality of trees, depending on the tolerance of individual species to salt and inundation. Salt tolerance is expected to influence how species respond to the changing environment. Salt-tolerant species include pitch pine, red oak, white oak, black cherry, and eastern redcedar, and forests containing these species may be better able to tolerate future changes.

Oak-Pine-Hardwood



Oak-pine-hardwood forests in the coastal plain often occupy dry sandy areas conducive to periodic fire. They can also occupy moist sites on lower slopes and along rivers and streams; these sites afford natural protection from fire and favor mesic hardwood species. For these mesic species, changes resulting in moisture stress may reduce regeneration potential and seedling establishment, especially during hot periods. Drought may also stress mature trees, leading to mortality of mesic species and shifting the species composition to oaks and pines.

Many species are projected to increase, including shortleaf pine, southern red oak, shagbark hickory, bitternut hickory, willow oak, post oak, loblolly pine, and pitch pine. Species projected to decrease include chestnut oak, Virginia pine, and bigtooth aspen. The occurrence of fire is expected to strongly influence whether oak or pine species are dominant in the future, with fire likely to favor pine species, particularly in drier sites.

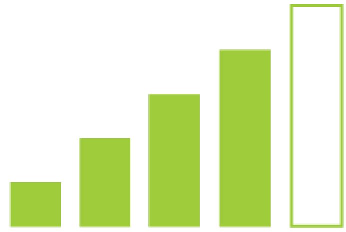


Pine-Oak Barrens

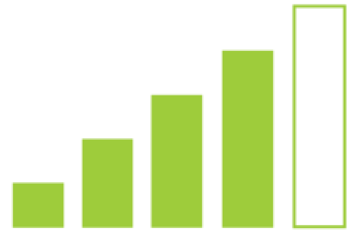
Overall Vulnerability:

Moderate-low

Confidence:



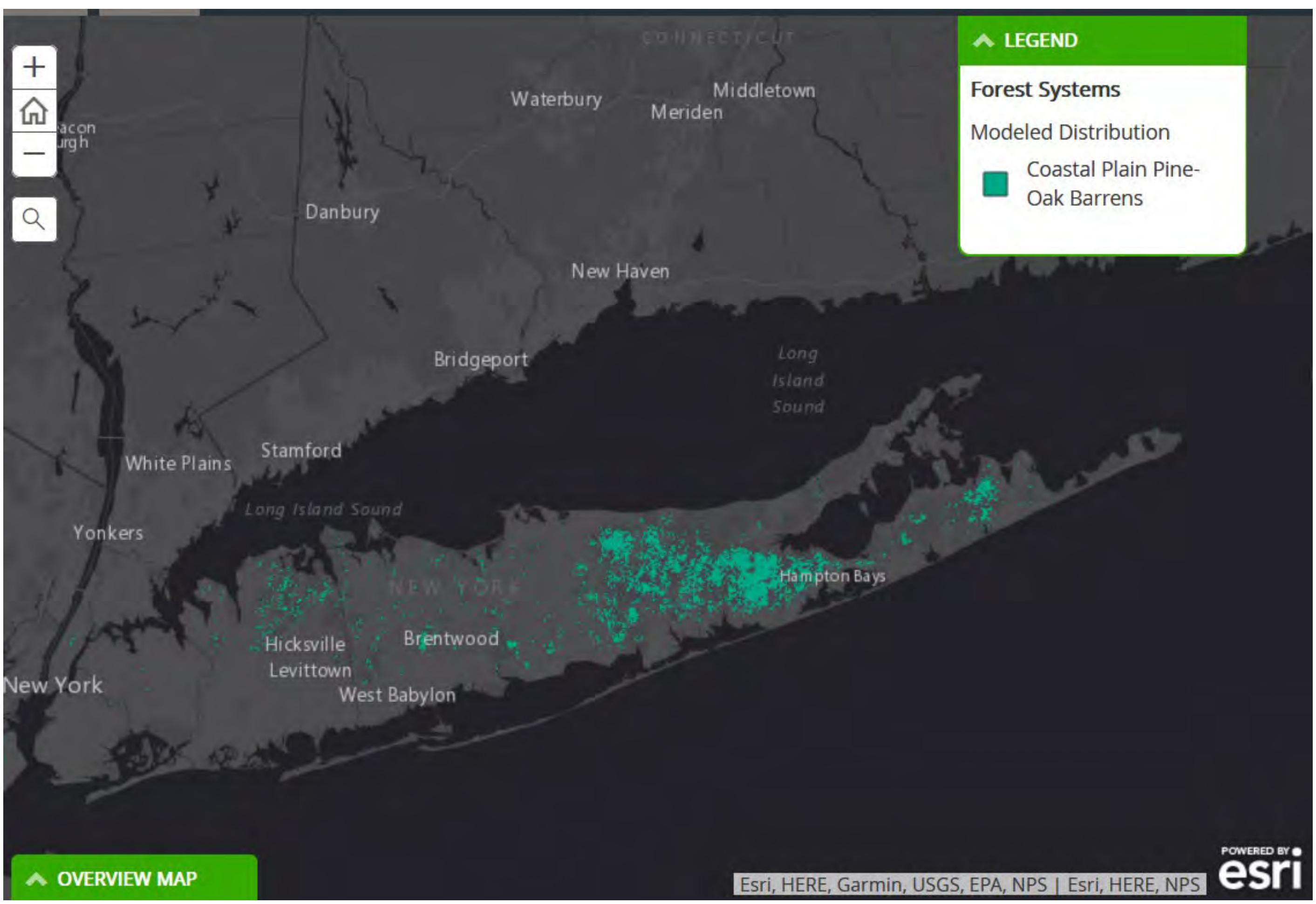
Medium-robust evidence



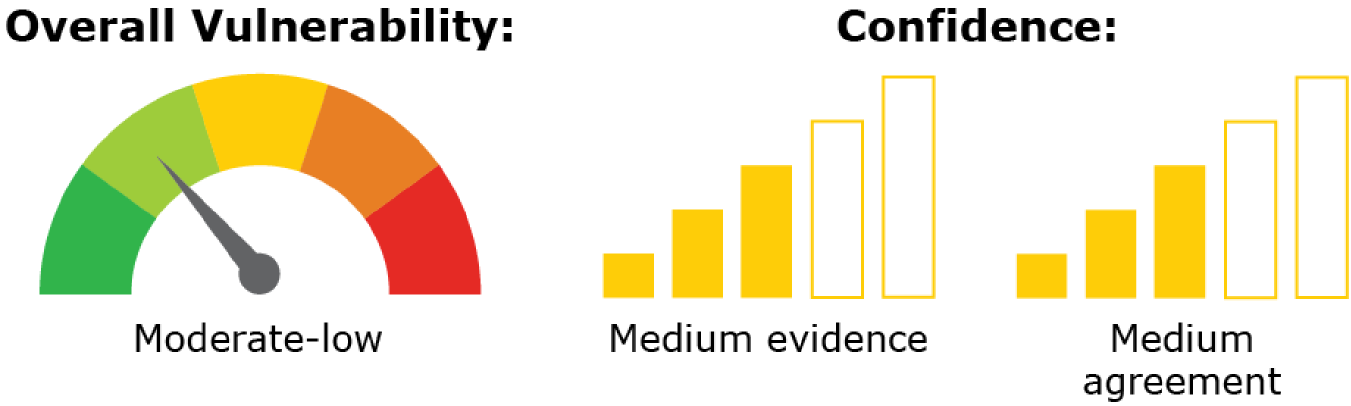
Medium-high agreement

Fire is a major driver of species composition and dominance in coastal pine barrens. Long fire return intervals favor oak species while short fire return intervals tend to favor pitch pine. This forest would benefit from increased drought and fire, although very hot droughts or very hot fires can damage roots and prevent resprouting.

Pitch pine, blackjack oak, and post oak are projected to increase, while common associates including black oak, chestnut oak, scarlet oak and white oak are projected to decrease. Warmer winter temperatures have also contributed to the northward expansion of southern pine beetles, which can result in greater than 90 percent mortality of overstory pines in infested stands; periodic outbreaks of this insect pest may create management challenges.



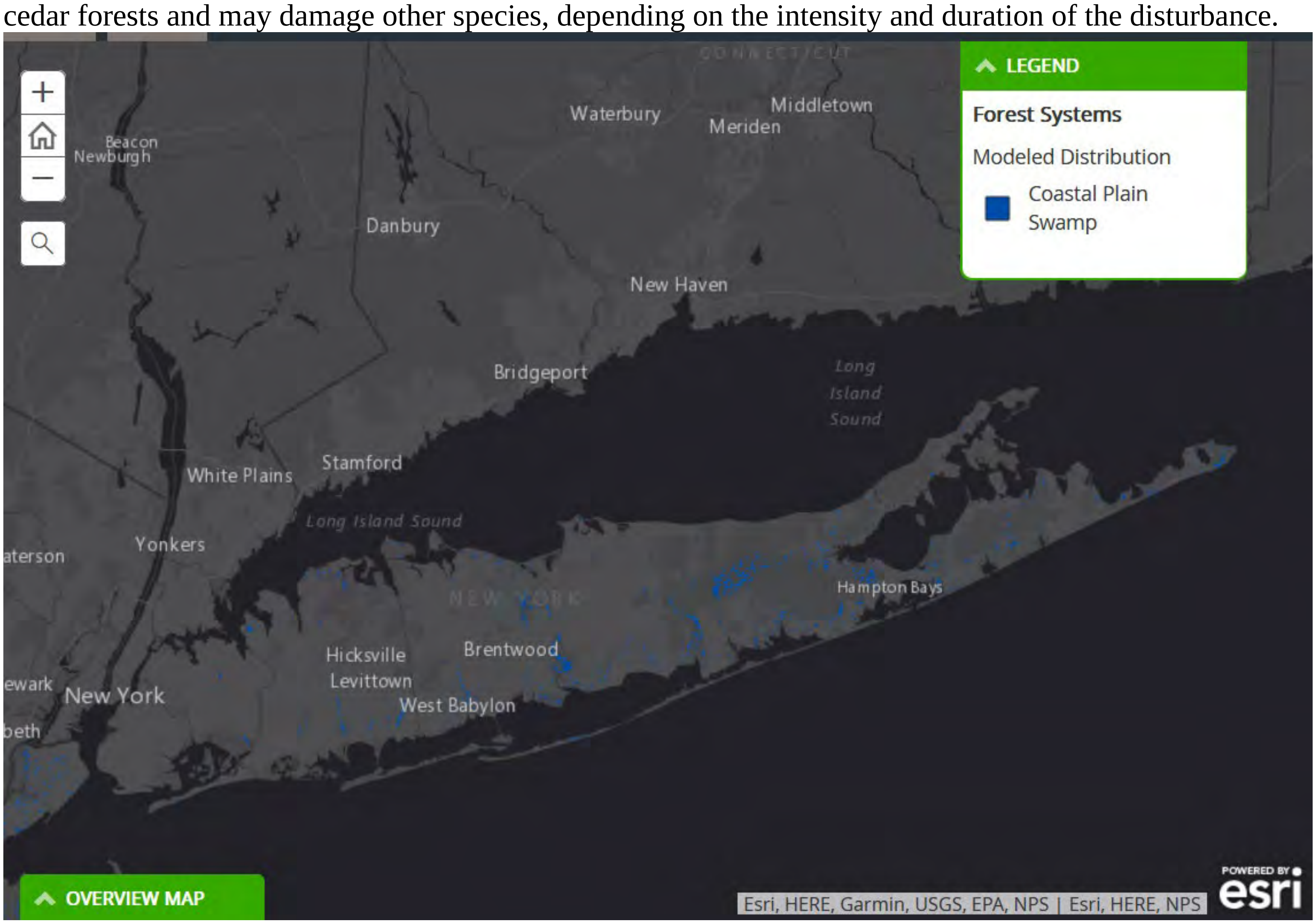
Swamp



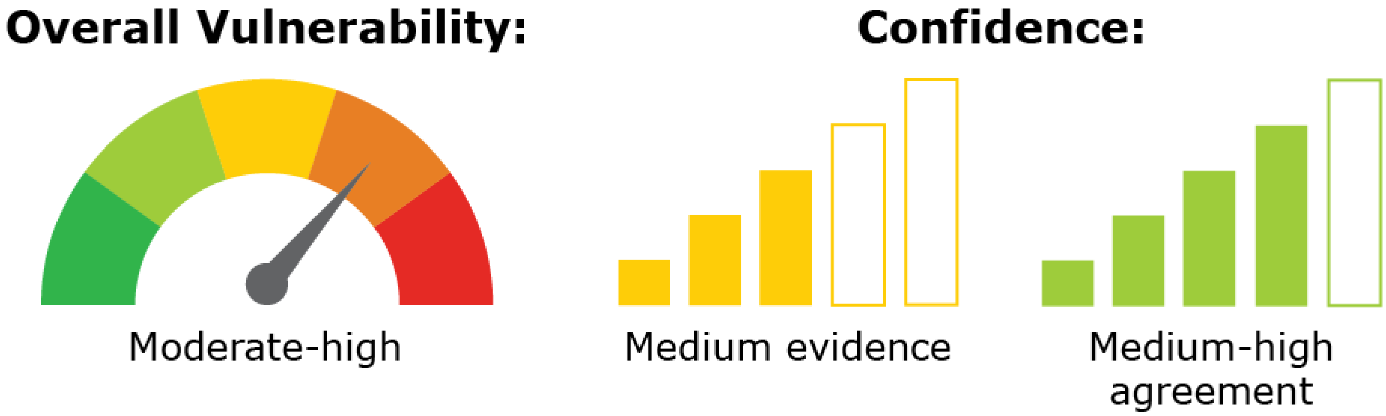
Although surface water within the coastal swamps is largely derived from groundwater, precipitation can lower or raise standing water levels. Warmer temperatures may lead to greater evapotranspiration and increased risk of moisture deficits between precipitation events. Hot droughts, even of short duration, can result in mortality of swamp trees.

Many species are projected to persist including baldcypress, green ash, pin oak, pitch pine, sweetgum, loblolly pine, and willow oak, however, ash species are highly susceptible to damage by emerald ash borer. Atlantic white-cedar, blackgum, and swamp white oak are projected to decline. Red maple is expected to become more competitive.

Continuing sea-level rise is projected to permanently flood areas where elevation is close to sea level, compounding the effects of storm surge, flooding, and salt spray. Saltwater intrusion can kill Atlantic white-cedar forests and may damage other species, depending on the intensity and duration of the disturbance.

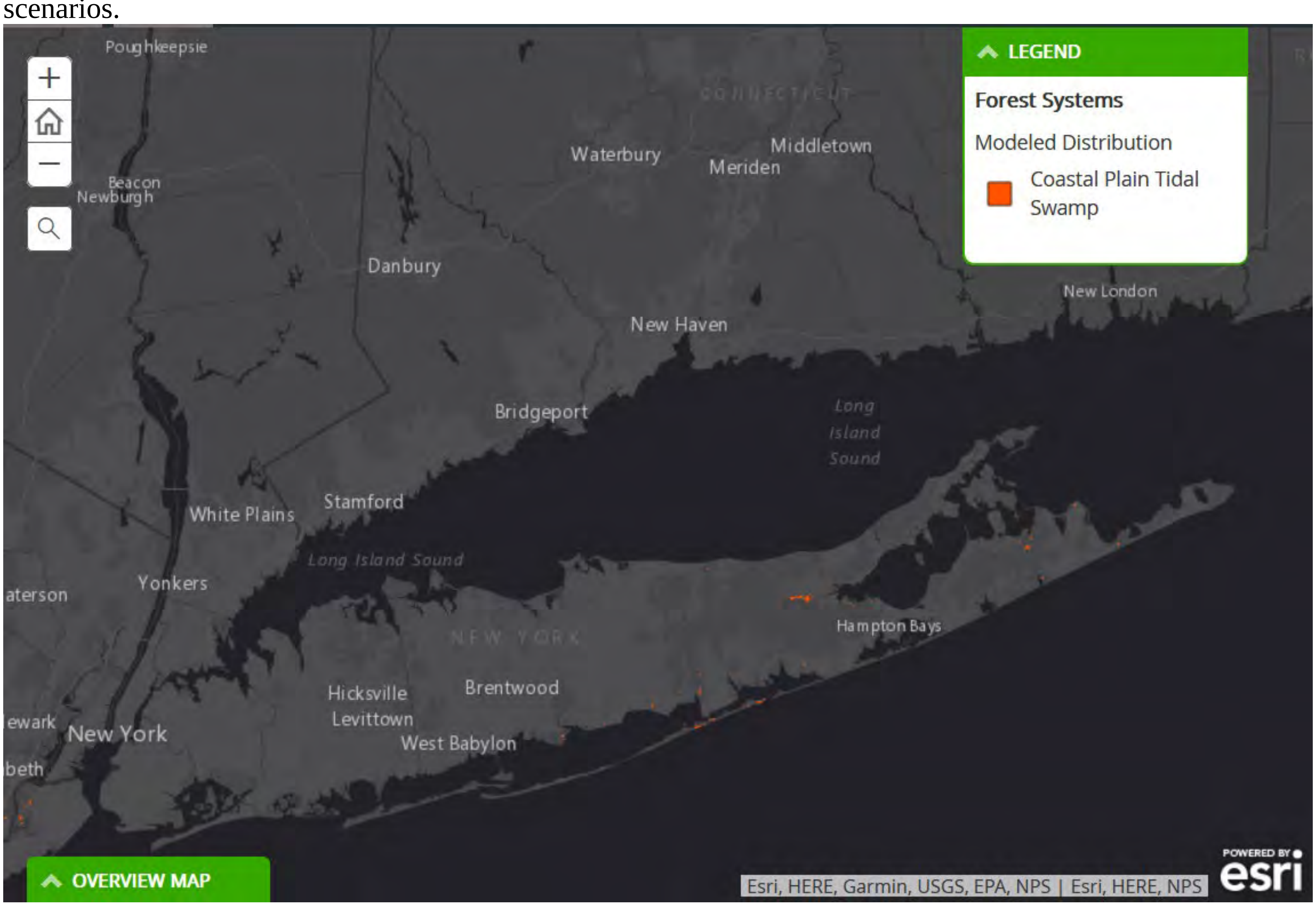


Tidal Swamp



Diverse hydrologic conditions result in many variations of the coastal tidal swamp. Precipitation can cause changes in salinity through dilution with fresh water, while drought can allow saltwater to migrate farther upstream. As sea level rises, salinity levels may interact with other stressors, and the salt tolerance of individual trees may factor into tree response. Salt-tolerant species include pitch pine, red oak, white oak, black cherry, and eastern redcedar, and these species may be better able to tolerate future changes. Sea-level rise is expected to inundate some areas, resulting in a net loss of tidal swamp forests.

Many species are projected to increase or remain steady including American elm, baldcypress, water tupelo, loblolly pine, and green ash. However, ash species are susceptible to emerald ash borer and may face high mortality rates in the next few decades. Red maple is expected to become more competitive under both climate scenarios.

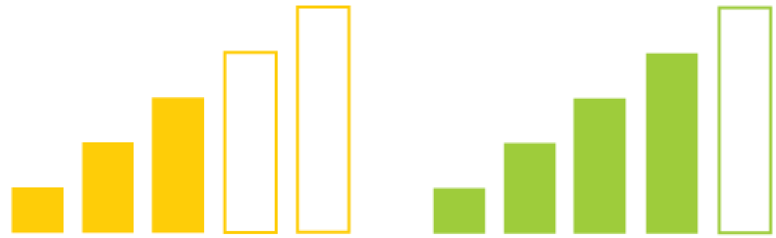


Central Oak-Pine

Overall Vulnerability:

Moderate-low

Confidence:

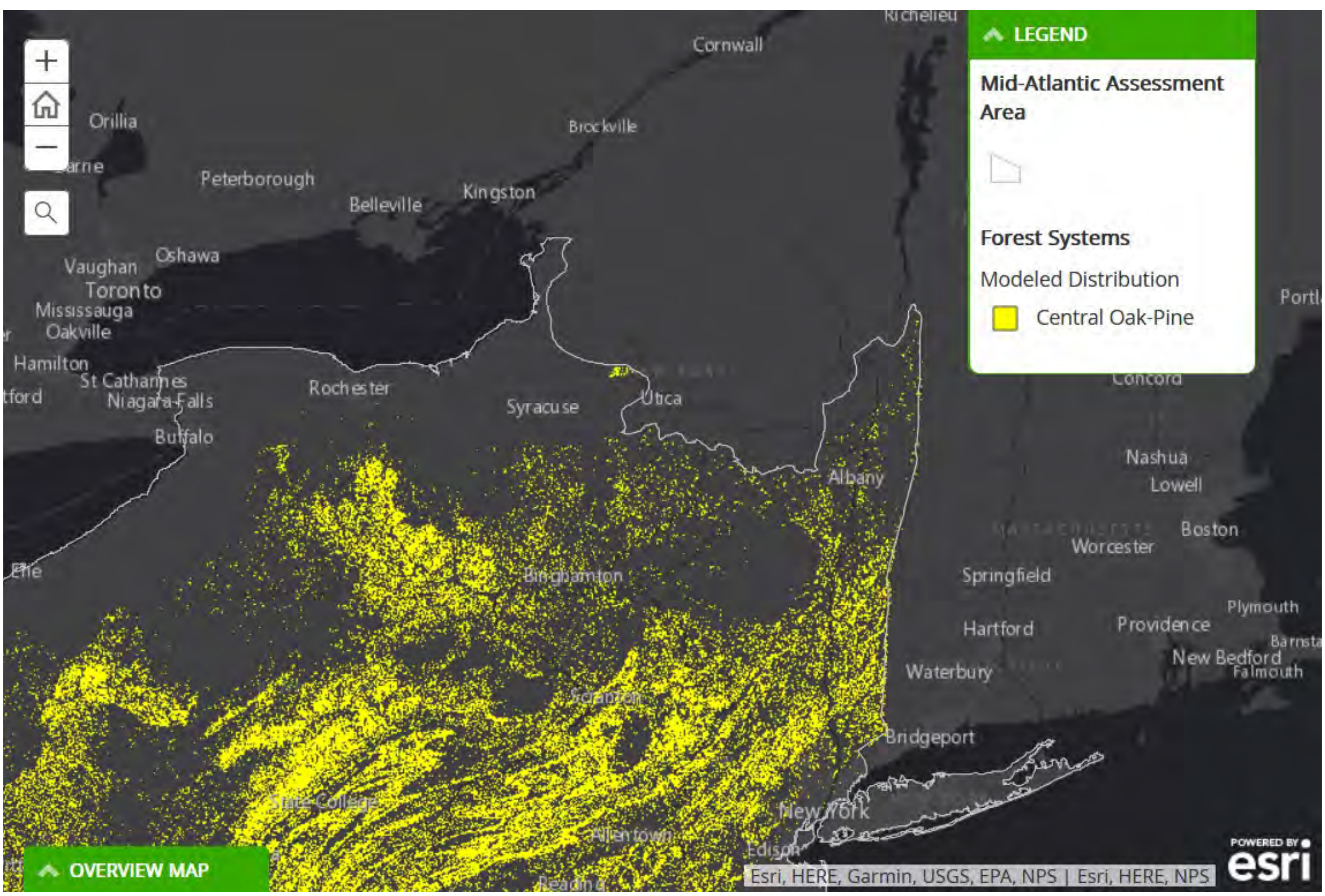


Medium evidence

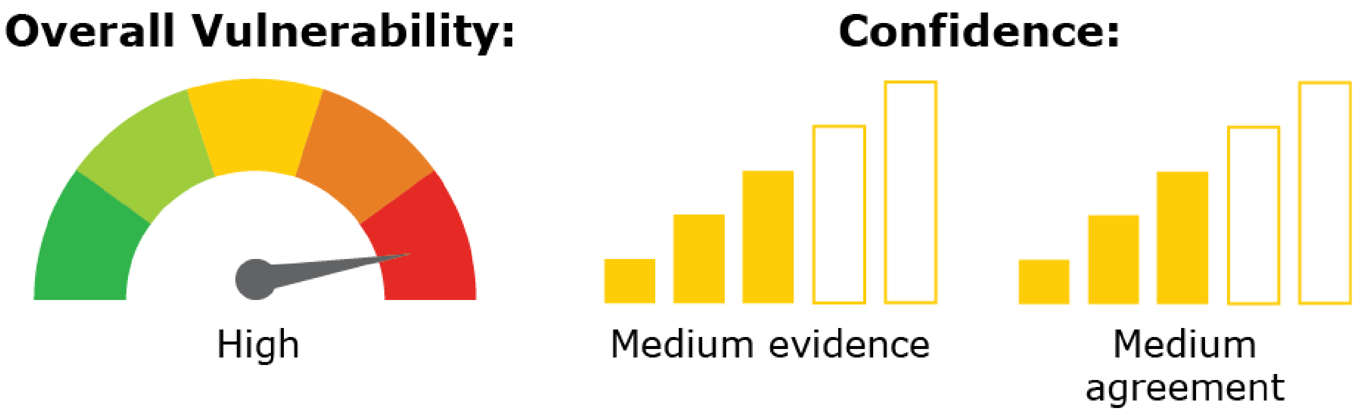
Medium-high agreement

Central oak-pine forests are widespread and common throughout the Mid-Atlantic region. Increased precipitation in spring and early summer may reduce fire risk while increasing vegetation growth. Late summer and fall moisture deficits and prolonged higher temperatures may increase fire risk, especially in places where dry fuels exist. Low to moderate fire intensity may benefit oak and pine species, but high-intensity fire can be fatal to trees. Moisture stress combined with pests such as the two-lined chestnut borer may increase the risk of oak decline or sudden oak death.

Many species are project to increase, including black oak, chestnut oak, mockernut hickory, northern red oak, pignut hickory, pitch pine, scarlet oak, shortleaf pine, Virginia pine, and white oak. Others including eastern white pine, red pine, and sassafras are projected to decline. Where mesic conditions have developed, regeneration of oak and pine species has become a notorious management challenge.

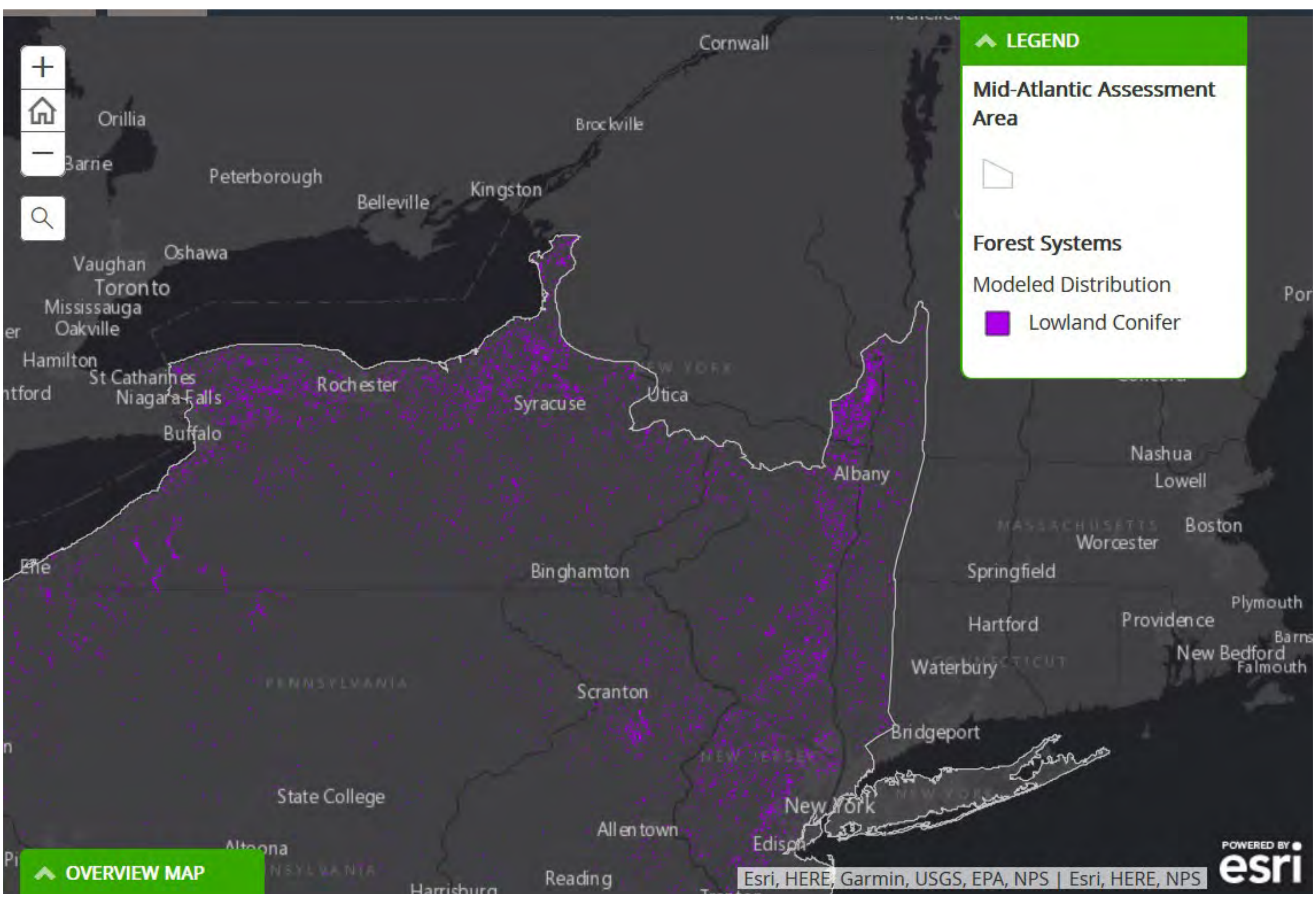


Lowland Conifer

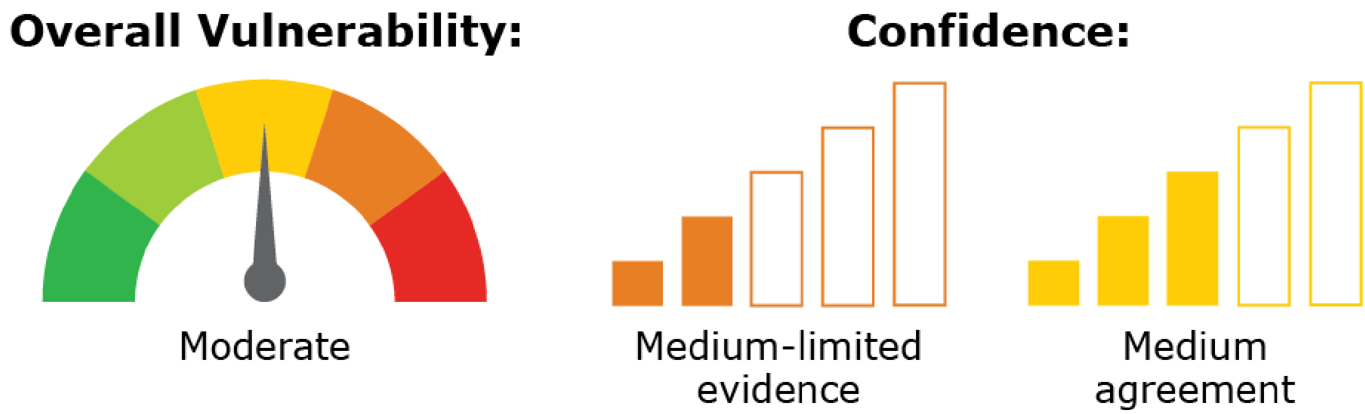


Impacts on lowland conifer forests are expected to be closely linked to site conditions related to hydrology, soils, and other factors. Although prolonged flooding may exceed the saturation tolerance of some species, an increased risk of drought is also a serious threat to many species. Reduced precipitation in the summer and fall may result in drier conditions, which can negatively affect rain-fed ecosystems. Tree susceptibility to insect infestations is expected to increase as trees become moisture-stressed.

Fewer than a dozen species make up the lowland conifer community, and most are projected to decline, including balsam fir, black ash, black spruce, eastern hemlock, eastern white pine, red spruce, tamarack, and northern white-cedar. The physical structure and function of conifer communities create the shady, cool microclimates where they thrive, and there are relatively few native conifers to fill this functional role. As the keystone conifers decline, the identity of this forest community may be severely compromised.



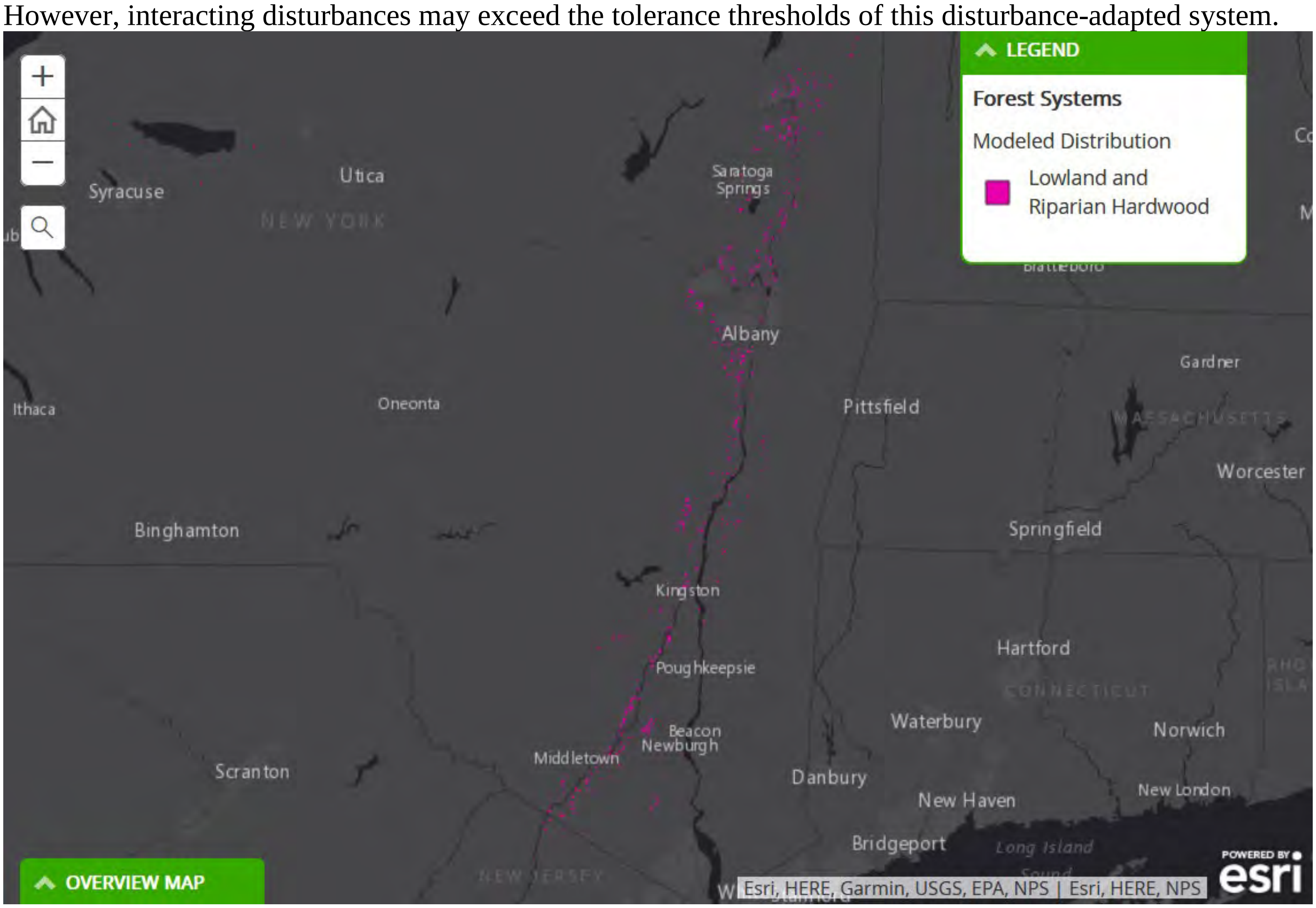
Lowland and Riparian Hardwood



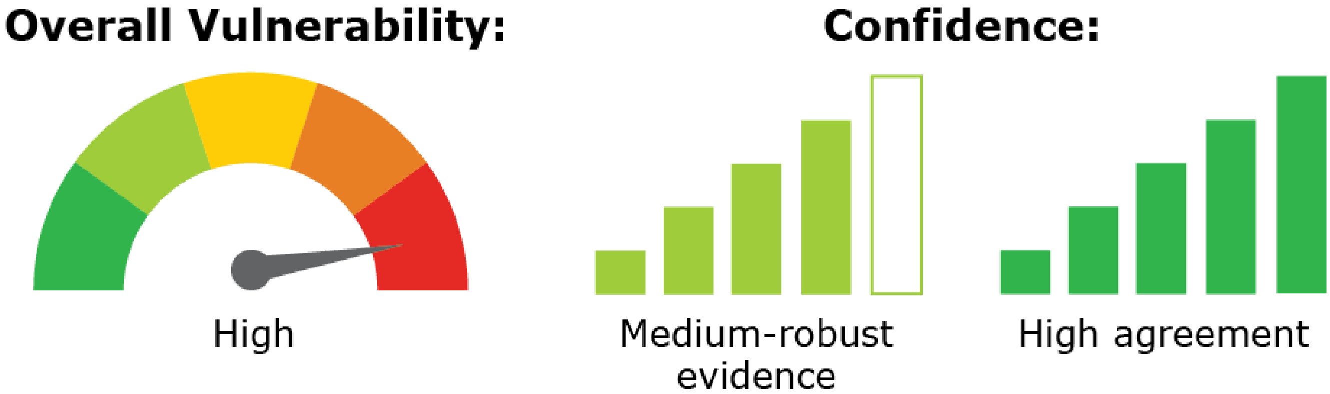
Lowland and riparian forests are threatened by changes in the timing and intensity of precipitation events, which are expected to result in increased flooding, erosion, and sedimentation, as well as increased risk of drought between precipitation events. Prolonged flooding during the growing season may increase mortality in some tree species. Hotter and drier periods may reduce water available to trees; those trees with shallow roots, on droughty soils, or already stressed may be most at risk.

Many species are expected to increase, including hornbeam, blackgum, boxelder, bur oak, cottonwood, green ash, pin oak, shagbark hickory, swamp white oak, sweetgum, and sycamore. Only black ash and eastern hemlock are expected to decline.

These forests can cope with a high level of natural variability and disturbance and are expected to tolerate some additional disturbance, with the exception of extreme drought, extreme erosion, or prolonged flooding. However, interacting disturbances may exceed the tolerance thresholds of this disturbance-adapted system.



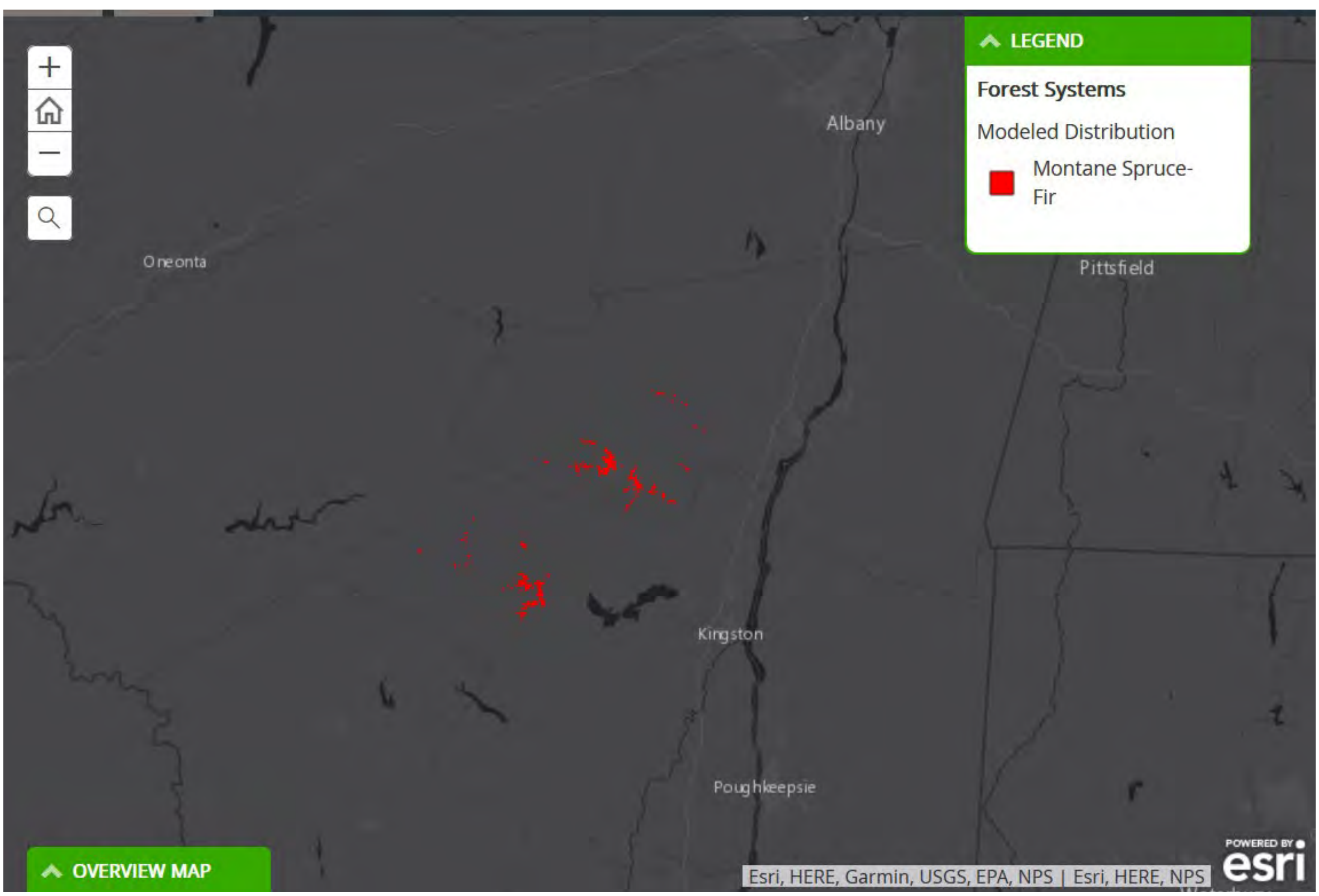
Montane Spruce-Fir



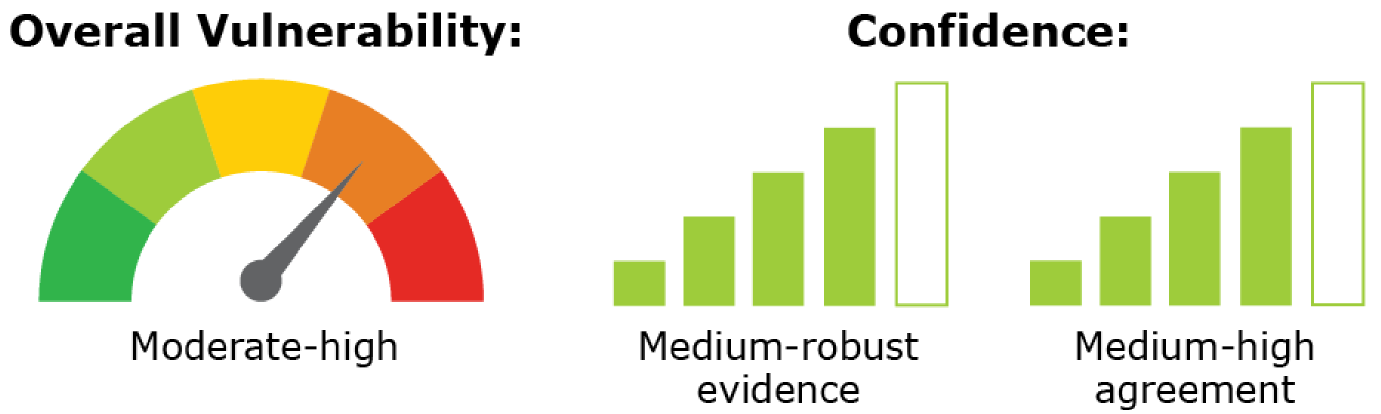
Montane spruce-fir forests are adapted to cold temperatures and abundant moisture, and thus are isolated at the highest elevations in the region. There is relatively low species and genetic diversity in these forests and most species are projected to decline including balsam fir, red spruce, mountain-ash, and paper birch. Further, balsam fir and red spruce seeds and seedlings will not tolerate hot, dry conditions and may fail to regenerate.

Winter snowfall and snowpack are projected to decrease, which may lead to less water storage and lower moisture levels in winter and spring. Warmer winter temperatures could result in higher insect mortality from spruce budworm outbreaks, which occur in periodic natural cycles in mature spruce-fir, causing individual mortality after one or more years of heavy defoliation.

Spruce-fir forests are still slowly recovering from the impacts of historical acid deposition and logging. This current recovery may mask climate-induced migration or decline of the system in coming decades.

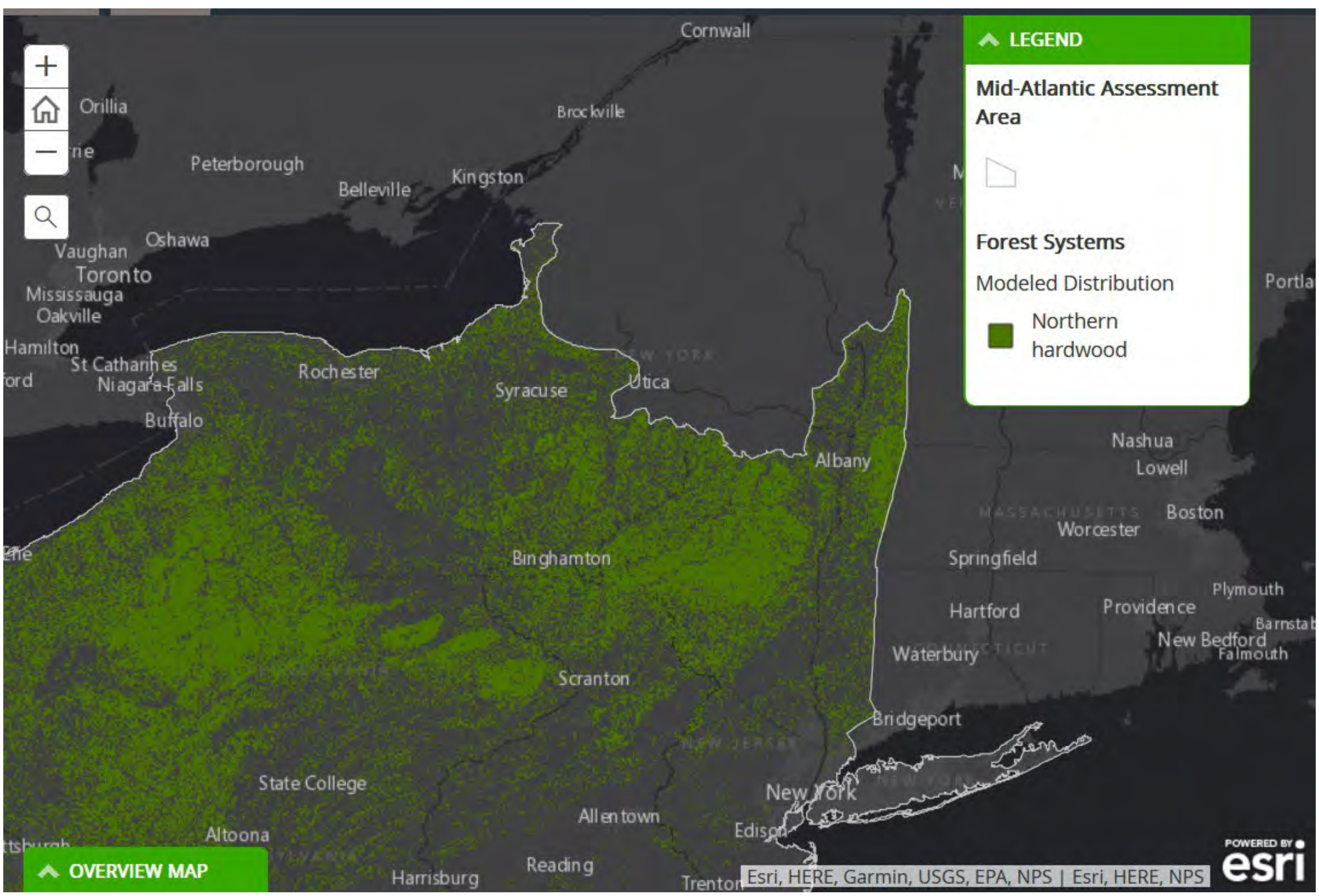


Northern Hardwood

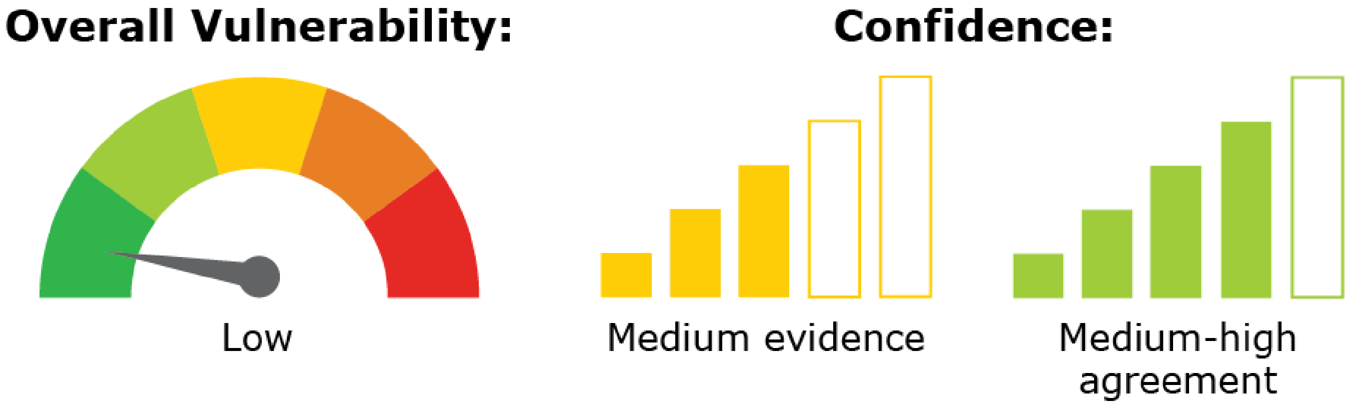


Northern hardwood forests are diverse and widely distributed across the Mid-Atlantic region. Northern Hardwoods species are sensitive to reduced soil moisture. Disturbance dynamics may also change. For example, eastern hemlock, beech, and ash species have already declined due to hemlock woolly adelgid, beech bark disease, and emerald ash borer. Interactions between insect pests and drought may result in decline of other species in the near term, with the Asian longhorned beetle posing a serious threat.

Northern hardwoods are composed of numerous tree species. Some are projected to decline, including basswood, beech, black cherry, eastern hemlock, eastern white pine, sugar maple, sweet birch, and tulip. However, even as some species decline, others are well established to fill in the new gaps on a variety of sites. Valley bottoms and other cooler, moister sites may be buffered from some of the effects of climate change.

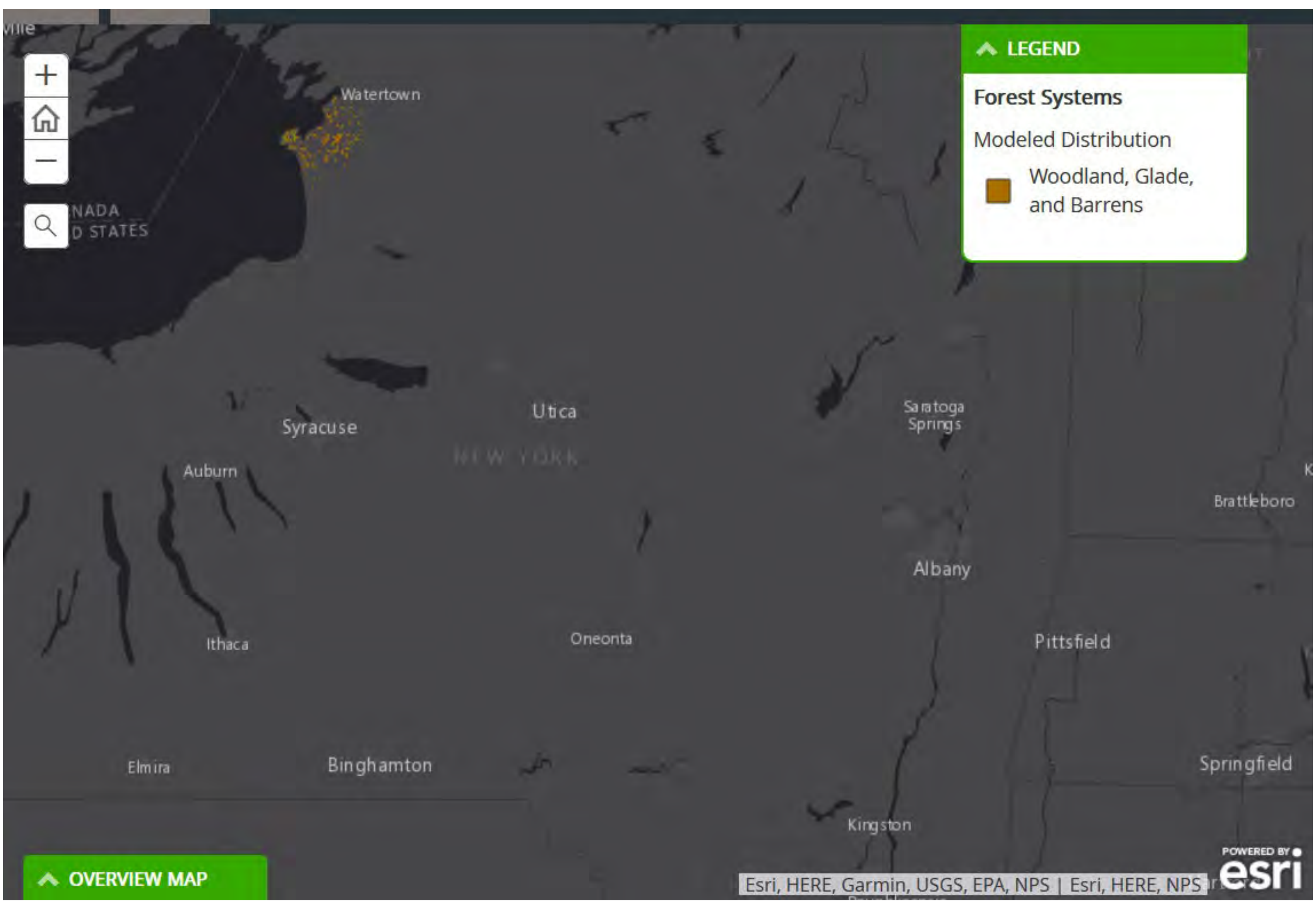


Woodland, Glade, and Barrens



Woodland, glade, and barrens systems thrive in the hottest, driest, and most exposed sites, including steep slopes of shale and limestone. Warmer, drier summers are likely to increase the risk of drought and fire in these locations, which could help maintain open conditions. However, longer or more extreme drought can delay germination or kill seedlings and mature trees.

This community is characterized by fewer than a dozen species, which vary based on the presence of shale or limestone bedrock. Most dominant species are projected to increase or remain stable, including eastern redcedar, eastern redbud, hackberry, northern red oak, pignut hickory, pitch pine, scrub oak, Virginia pine, and white oak. Sugar maple is projected to decline, and would be the species most likely to disappear from this community type due to moisture deficit.



THANK YOU

This story map was produced by the USDA Forest Service Eastern Region, State and Private Forestry and the Northern Institute of Applied Climate Science (NIACS). State and Private Forestry, Eastern Region helps family landowners and communities keep trees and woodlands in their lives. NIACS is a multi-organization partnership focused on bridging the gap between research and management in the fields of climate adaptation and carbon science. NIACS leads a community effort called the Climate Change Response Framework (CCRF) that helps land managers integrate climate change into their work. The CCRF has created numerous tools and resources for forest managers, as well as a growing network of real-world adaptation projects across the Midwest and Northeast.

The recommended citation for referencing this story map is: Butler-Leopold, P.R.; Q. Chavez, C. Swanston. Climate Change and Adaptation: Mid-Atlantic Forests. USDA Forest Service.

The information presented in the sections on changes in climate, effects on forests, and the vulnerability of different forest ecosystems was largely summarized from the vulnerability assessment and should reference the source report:
Butler-Leopold, P. R. I., Louis R.; Thompson, Frank R., III; Brandt, Leslie A.; Handler, Stephen D.; Janowiak, Maria K.; Shannon, P. Danielle; Swanston, Christopher W.; Bearer, Scott; Bryan, Alexander M.; Clark, Kenneth L.; Czarnecki, Greg; DeSenze, Philip; Dijak, William D.; Fraser, Jacob S.; Gugger, Paul F.; Hille, Andrea; Hynicka, Justin; Jantz, Claire A.; Kelly, Matthew C.; Krause, Katrina M.; La Puma, Inga Parker; Landau, Deborah; Lathrop, Richard G.; Leites, Laura P.; Madlinger, Evan; Matthews, Stephen N.; Ozbay, Gulnihal; Peters, Matthew P.; Prasad, Anantha; Schmit, David A.; Shephard, Collin; Shirer, Rebecca; Skowronski, Nicholas S.; Steele, Al; Stout, Susan; Thomas-Van Gundy, Melissa; Thompson, John; Turcotte, Richard M.; Weinstein, David A.; Yáñez, Alfonso (2018). Mid-Atlantic forest ecosystem vulnerability assessment and synthesis: a report from the Mid-Atlantic Climate Change Response Framework project. Gen. Tech. Rep. NRS-181, U.S. Department of Agriculture, Forest Service, Northern Research Station: 294.
We want to thank Erik Johnson and Nathan Walker for their technical assistance. This story map was adapted from the “Climate Change and Adaptation: New England and Northern New York Forests” created by Maria Janowiak, Jesse Nett, Erik Johnson, Nathan Walker, Stephen Handler, and Chris Swanston. Kailey Marcinkowski provided assistance with graphic design. We also appreciate the assistance of Matt Peters and Jacob Fraser in providing datasets and technical support that made this project possible.
Several people graciously contributed photographs for this work. Credits have been listed next to the photos whenever possible. Photographs were also provided by Greg Czarnecki for the home page and Patricia Leopold for the credits page.

For more information on climate issues, how they affect Forest Service lands and how the Forest Service is dealing with these issues, see the USFS Office of Sustainability and Climate's Climate Gallery and Climate Tools and Data page, for collections of maps, data, and other resources.