



PINCHOT  
INSTITUTE  
FOR CONSERVATION

Helping your woodland  
adapt to a changing climate









# Woodland adaptation guide

## What landowners need to know

Your woods are always changing. The trees grow and mature — or regrow after agricultural abandonment, natural disturbances, or harvesting activities. Events like storms, droughts, insect and disease outbreaks, or other stressors can damage trees or slow their growth. A changing climate may make your woods more susceptible to the problems these events can cause. Active forest management can help you hedge against these risks, whether you are trying to see more wildlife, have a nicer place to hike, pass the land to your children, or increase your bottom line.

This guide will familiarize you with potential changes on your land and ways you can prepare and respond. Use the resources suggested at the end and at [www.commonwatersfund.org/forest-adaptation](http://www.commonwatersfund.org/forest-adaptation) to find information and people who can help you keep your woods healthy and productive. The guide focuses on the upper portion of the Delaware River Basin, but most of the recommended strategies are applicable across forests of the Northeast.



-  Delaware River Basin
-  Common Waters Focus Area
-  Rivers and Streams
-  Major Cities



# Helping woods adapt

## Forest stewardship and a changing climate

### What is woodland stewardship?

Taking care of your land for the long term while ensuring that it is available for future generations is known as forest stewardship. To become a good forest steward, the first step is to consider what you value about your forest. What do you like about it, and what do you hope to get out of it? For example, do you want to generate income (or reduce your tax burden), or are you more interested in attracting wildlife? Do you like walking to a particular overlook or are you interested protecting endangered plants and animals? Most people are interested in a combination of these objectives; luckily, good forest management can accommodate several goals simultaneously.

The next step is to learn more about your woods, both by spending more time exploring, and through online educational resources (see list on page 17).

The third step is to contact a forester (see links on page 17). Walking the woods with a forester will help you understand the options and opportunities for active management based on your goals. Foresters have experience managing forests for timber, wildlife, water quality, and aesthetics.

A forester can also assist you with the fourth step: developing a forest stewardship plan (or management plan) which serves as the “blueprint” for managing your woods over the next ten or fifteen years. These plans often involve “prescriptions” for guiding the future development of sections of the forest through cutting trees in particular patterns as well as other recommendations to address your goals.

### Your property can make a difference

The upper Delaware River region (which includes the Catskills, Poconos, and Kittatinny Ridge) is about 75% forested. Private landowners currently own 77% of the total land across the region, and they are the first to see any changes in their woods over the years. Keeping an eye out for changes and seeking assistance will help you make wise decisions. Have you noticed trees dying or strange insects? These are only two of many visual clues that may prompt you to learn more about your woods.

The average size of woodland ownership is seven acres in New Jersey, 18 acres in Pennsylvania, and 19 acres in New York. Every property counts—whether large or small—and the cumulative decisions taken by you and hundreds of thousands of other private landowners will determine the future productivity, health, and biodiversity of the region’s forests.

### Manage your woods

#### Step 1

Identify your goals and objectives

#### Step 2

Learn more about your woods

#### Step 3

Contact a forester

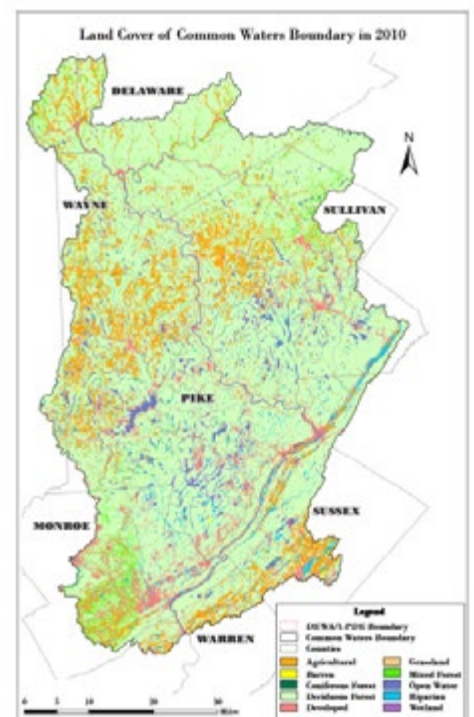
#### Step 4

Develop and implement a forest stewardship plan



Robert L. Anderson, USDA Forest Service, Bugwood.org

A forester can help you identify opportunities to improve the health of your woods.

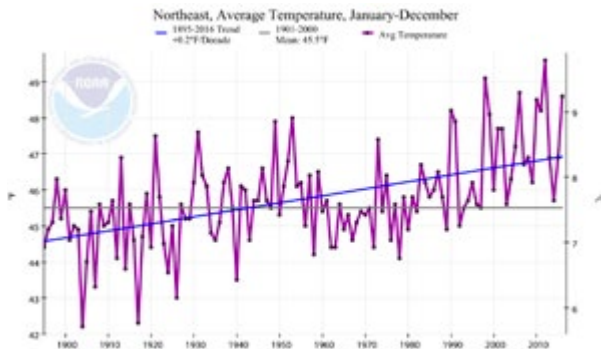


NPS DWGNRA 2013

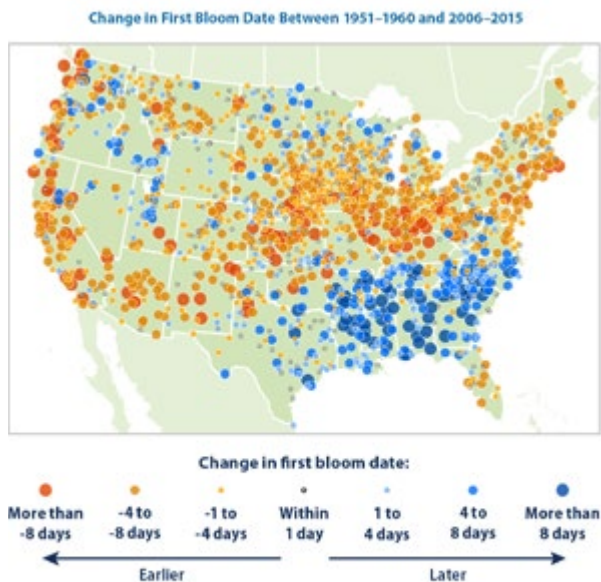
Forests cover 75% of the land in the upper Delaware River Region; private landowners currently own most of that forestland.

# Climate change facts

## The climate is changing



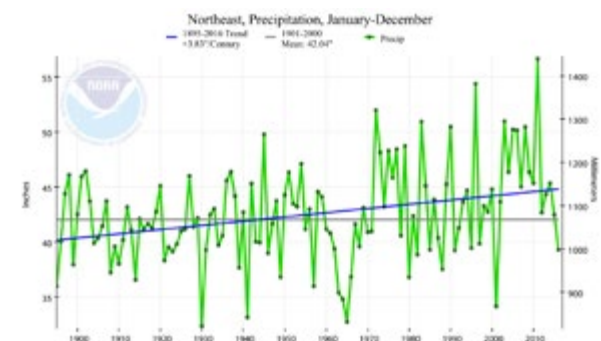
Average air temperatures in the Northeast US have increased ~1.9°F in the century since 1895. (United States National Oceanic and Atmospheric Administration)



Data source: Schwartz, M.D. 2016; update to data originally published in: Schwartz, M.D., T.R. Ault, and J.L. Betanourt. 2013. Spring onset variations and trends in the continental United States: Past and regional assessment using temperature-based indices. *Int. J. Climatol.* 33:2917-2922.

For more information, visit U.S. EPA's "Climate Change Indicators in the United States" at [www.epa.gov/climate-indicators](http://www.epa.gov/climate-indicators).

Lilac and honeysuckle plants tended to flower earlier in the decade ending in 2015 than in the decade ending in 1960. (United States Environmental Protection Agency)



Average annual rainfall in the Northeast US has increased by 3.83 inches over the last century. (United States National Oceanic and Atmospheric Administration)

Within the last 100 years, the northeastern United States has experienced changes in temperature and rainfall patterns that can have future environmental and economic impacts on your land.

### Temperatures are increasing

Temperatures have warmed by two degrees (°F) on average during the year in the Northeast; winter temperatures have warmed as much as four degrees in some places. Warmer winters result in less snow, which is important for storing moisture until the spring. Warmer winter conditions can increase the risk of damage when temperatures drop suddenly. This variability can threaten the health of a woodland. For example, more broken branches create more opportunities for tree pests and diseases to become established.

### The growing season is getting longer

A number of models predict that the frost-free growing season will increase by 20-50 days, with earlier springs and later autumns. This may benefit some species but will also provide opportunities for invasive pest and plant species to spread and grow.

### The timing of natural processes is shifting

Plants flower and birds migrate in response to seasonal weather patterns (this is called phenology). Changes like earlier springs can shift the timing of species' life cycles, which can cause mismatches in the timing of events like leaf-out, insect emergence, migration, and breeding. Asynchronies like these can reduce the growth and survival of wildlife, especially when they impact food availability. The [National Phenology Network](http://www.npn.org) has more information.

### Rainfall patterns are changing

Rainfall has increased over the last century, in part because warmer air is capable of holding more moisture. The region is expected to experience reduced snowpack, more rain-on-snow events, and higher peak spring stream flows, which causes water to run off the land more quickly. Drier summers increase tree stress and the risk of wildfires; and lower base flows combined with warmer temperatures in late summer stress coldwater fish species such as brook trout.

### Extreme weather events are more frequent

The Delaware River Basin is already experiencing more frequent extreme rain and storm events and more flooding; these trends are expected to continue. A growing percentage of the region's annual precipitation is arriving in the form of heavy rain events, which increases the frequency of floods and corresponding damage. Woodlands affected by extreme weather events can take decades to recover after disturbance, and forest ecosystem structure and productivity may change as a result. Of course, change isn't inherently bad, but these changes will be less predictable and harder to mitigate.

# Projected changes

## How will climate change affect your woodlands?

As our climate changes, the projected changes that are most likely to affect woodlands are:

- increasing temperatures,
- changes in rainfall and stream flow patterns (wetter winters, drier summers),
- longer growing seasons,
- drier soil in summer and wetter soil in winter,
- increasing abundance of invasive species, pests, and diseases, and
- more frequent extreme weather events.

Combinations of some or all of these changes will affect the health of your woods and may change what tree species grow best on your property in the future.

### Good management can save you time and money

Your management decisions affect how well your woodland can withstand disturbances or recover after damage. Preparing for these changes now will save you time and money in the long run, improve forest health, increase your enjoyment of your property, and reduce the risk of losses in the future.

There are several things you can do to enhance the ability of your woodland to adapt to climate change and its effects. In most cases, these actions are part of normal woodland management.

### Management Tools

In general, you can do one of three things in the woods: cut something, plant something, or do nothing. Manipulating a section of forest (called a stand) to meet a particular goal is called *silviculture*. For instance, if you have many trees that are crowding each other out, it may make sense to thin them. If trees in a certain stand have reached a large size and you want to begin a new generation, a more dramatic cut may be appropriate. It all depends on what your goals are, and what is possible on the landscape.

Some people think that “selective harvesting” is good, and “clearcutting” is bad. In some cases that’s true, but it depends what you want! If a “selective” harvest only “selects” the largest, most valuable trees, it maximizes short-term income but limits the future value of the forest; several threatened species of wildlife depend on large areas of very young trees that spring up in a clearcut.

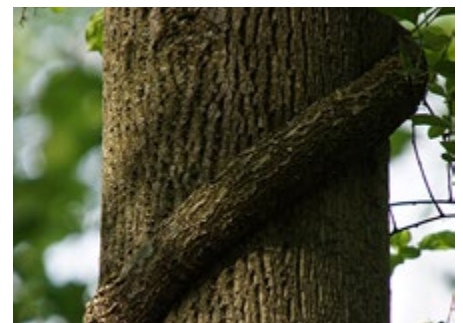
Others may think that planting a tree is the only way to begin a new generation of forest. Planting certainly lets you control the species and placement of a particular tree, but it can also be expensive and time-consuming. Trees naturally create thousands of seeds every year. Many trees will re-sprout from the base. Some forest management strategies involve cutting trees in particular patterns (called “seed tree,” “shelterwood” and “group selection,” among others) that create the right conditions for these seeds to thrive. There are tradeoffs with each method.

The following pages explain the potential impacts of climate change in the upper Delaware River region, how they may affect your forest, and steps that you can take to address them.

In some cases, the best management option may be to take no action, and to allow species composition and structure to change over time.



Minnesota Department of Natural Resources, Bugwood.org



Josh VanBrakle, Watershed Agricultural Council



Nicholas A. Tonelli CC BY 2.0



Steven Katovich, USDA Forest Service, Bugwood.org

Young trees that have died from drought.

Winding vines like bittersweet can strangle trees and increase damage from ice, snow, and wind.

Flooding in Rockland, NY in 2006 occurred when large amounts of rain fell on already-saturated soils.

More variable weather patterns mean the timing of plant life cycles can change.

# Key actions

## Keep your woodlands healthy

- **Manage for a healthy density.** Keep trees vigorous to better resist pests and survive in the face of disturbances. Practices like thinning or timber stand improvement reduce stress and keep forests at reasonable densities for a mix of species.
- **Diversify species.** If planting, consider species likely to thrive in a warmer (and more variable) climate. Some species, like red or white oak, are predicted to adapt well to a changing climate. Some more southerly trees will be able to survive in warmer parts of the Delaware Basin: for example, eastern red cedar is predicted to expand its range north. If you are planning for natural regeneration, consider how trees spread their seeds, and what conditions will make those seeds thrive.
- **Diversify stand ages and structure.** Stands comprised of different ages and species will not all be susceptible to the same damage. Structure refers to the pattern of vegetation across space: Are there leaves and branches at all heights, or just in the canopy? Are there open areas next to dense areas? Or does the forest look the same across the whole property? Timber stand improvement, thinning, regeneration harvests, and planting all provide opportunities to create diversity, both *within* and *between* stands.
- **Build connectivity.** Connected woodland parcels allow tree species and wildlife to move around more easily, which enables greater diversity. Maintaining or establishing forests along streams and rivers is a good way to accomplish this.
- **Learn how to control invasive species.** The species, season, and desired control method all matter if you want to avoid wasting time and money.
- **Control invasive plants, especially vines like bittersweet, honeysuckle, and English ivy.** Vines bring special problems: they can overgrow trees and shade out their canopies. Those with winding growth habits can strangle trunks, and the mass of vines in canopies increases the risk of damage from ice, snow, and wind.
- **Manage deer populations.** Too many deer usually means too few young trees and the loss of the understory in the woods. If you don't hunt, consider a hunting lease on your property to control deer populations.
- **Plan fuel breaks.** Wildfire is always unexpected, but having fuel breaks like well-maintained roads or a thinned area can make it more difficult for fires to spread.
- **Monitor for disease and insects.** A small problem is easier and less expensive to control.
- **Consider future flooding when investing in management or land purchases along rivers.** Official “mapped” floodplains do not necessarily depict all of the areas that may flood; at the same time, larger storms are occurring with greater frequency, raising the probability of floods.
- **Ask your forester** about federal, state, county, or non-profit programs to assist with forest stewardship planning and management costs.



Josh VanBrakle, Watershed Agricultural Council



Eli Roberts, Pinchot Institute



Josh VanBrakle, Watershed Agricultural Council

The shelterwood method is a regeneration strategy that leaves widely-spaced trees that create the light conditions and seed source for a new generation of forest. These pictures were taken in 2008 and 2015.

A healthy forest with diverse species and ages.

Thinning around the most vigorous trees can make them less susceptible to disease and drought, and can increase the future value of a stand.

# Climate change impact

## Shifting species distributions

### Suitable habitat for many species will move further north

The composition of a woodland is largely controlled by past land use history, the impact of deer browsing, and what species are adapted to the climate in the area. Gradual changes in woodland composition are determined by factors like seasonal temperatures, rainfall, soil moisture patterns, the severity of disturbances, deer browsing, and the abundance of pests and diseases. Many of the effects of these changes can be guided through active forest management; some landowners may choose to allow this shift to occur naturally.

It is estimated that the range of some woodland species in the U.S. is migrating northward at a rate of 1–3 miles per year. Ranges are shifting similarly towards higher altitudes. These trends will likely continue, and preferred habitat for many tree species will move—in some cases, faster than some species can handle. As woodland composition changes, the types of wildlife supported will also change, and forest productivity may increase or decrease depending on the species.

Populations of species at the northern limit of their range may increase or expand, whereas those species at the southern limit of their ranges may migrate away from intolerable conditions or die off locally. The mechanisms for these declines vary: problems could affect mature trees, seed dispersal, or saplings competing in a new stand. Forests respond slowly, so the changes may be subtle at first (many forests we see today are the result of decisions made in the 1800s or earlier!).

In the upper Delaware Basin, it is likely that the high elevation northern hardwood forests of sugar maple, yellow birch, and black cherry trees will decline as their suitable habitat decreases in quality and extent; beech, hemlock, and white pine are also expected to decline. Meanwhile white oak, shagbark hickory, and tulip poplar trees are likely to expand their populations and volume, and—eventually—southern species like black hickory and loblolly pine may establish in the region.

(Top) Sugar maple importance values, present-day and projected under high-emissions scenario.

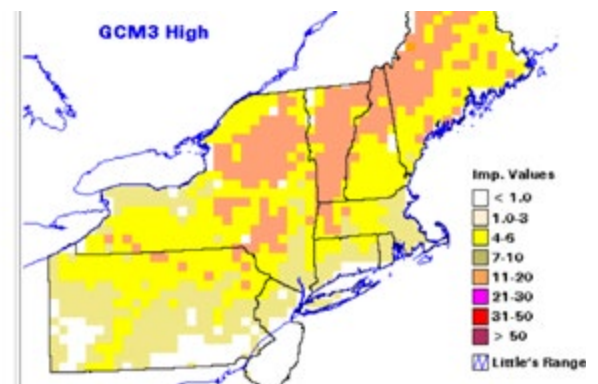
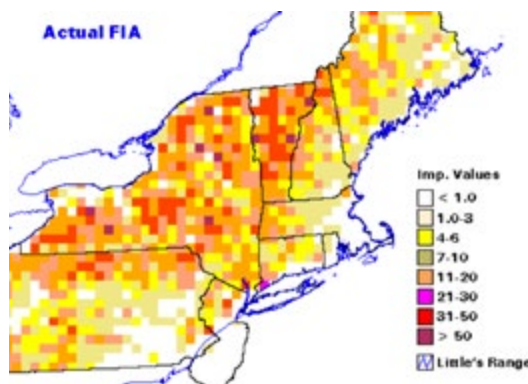
(Bottom) White oak importance values, present-day and projected under high-emissions scenario.

Distribution of sugar maple and white oak in 2000 (left) and projected distributions in 2100 (right) based on the average of three climate change models at high carbon emissions rates.

White oak distribution will expand to the north, while suitable habitat for sugar maple will be reduced.

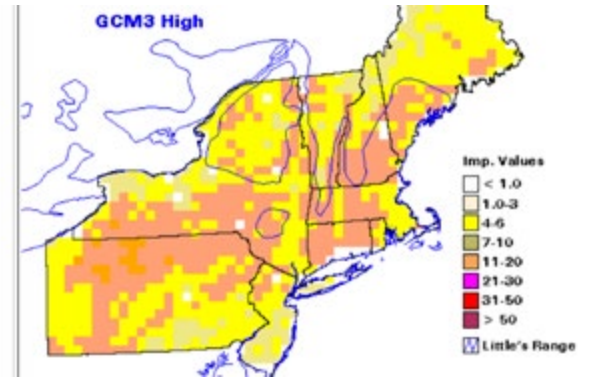
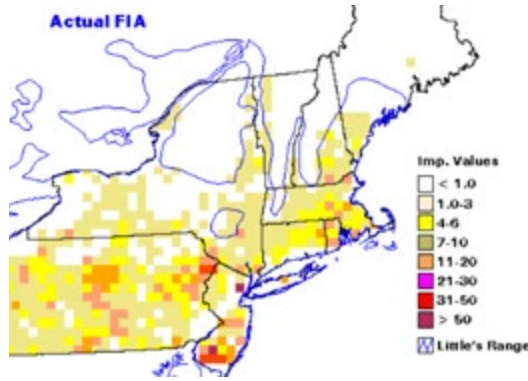
Importance value is defined as the most dominant species by size and abundance in a forest.

Paul Wray, Iowa State University, Bugwood.org



US Forest Service, Northern Research Station

Paul Wray, Iowa State University, Bugwood.org



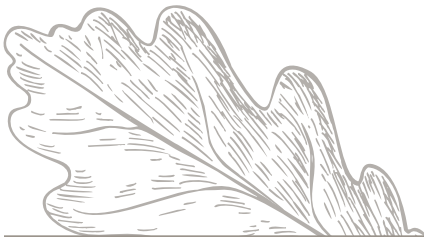
US Forest Service, Northern Research Station



# Management options

## Shifting species distributions

- 1 Consider current conditions for regeneration (planting or natural regeneration) and establishment of native species when harvesting, as well as expected conditions 50 years from now.
- 2 Diversify stand ages and structure through timber stand improvement, thinning, regeneration harvests, and planting. Forests with diverse ages and species have more opportunities to adapt to changing habitat conditions. Think about diversity between stands, too, not only diversity within one stand.
- 3 Plant diverse tree species, choosing native species when possible that are expected to be better adapted to future conditions. In certain cases, non-native species may be a better option—just be sure to discuss your objectives and options carefully with a forester.
- 4 Build connectivity (linkages between patches of forest or other habitat) to allow trees and wildlife to migrate more easily as their preferred habitat changes. Areas along streams are a good place to improve forest connectivity, which provides the added benefits of shade and soil stability for streams.
- 5 Identify and maintain species at the southern extent of their range in cooler and moister microhabitats. For example, areas on north-facing slopes, lake edges, seeps, or wetlands may be suitable for hemlock, sugar maple, and yellow birch.
- 6 Choose drought-resistant species such as eastern red cedar, black oak, black locust, or white pine when planting in areas prone to drought. Techniques like using root gels or providing watering for newly planted seedlings during a dry summer can help improve survival.
- 7 Increase monitoring and control of invasive species to allow native tree species to migrate naturally. Invasive species often gain a competitive advantage as habitat conditions change.



Josh VanBrakle, Watershed Agricultural Council



Eli Roberts, Pinchot Institute



Pinchot Institute

When planting, choose a variety of native species best adapted for projected future conditions.

Deferment cutting promotes a two-age stand structure, improving aesthetics and wildlife habitat.

Forests with diverse ages and structure have more opportunities to adapt to changing habitat conditions.

# Climate change impact

## Flooding, water quality problems, and aquatic habitat degradation

### Heavy precipitation events are more frequent

Heavy rainfall and flooding events are already occurring with greater frequency and magnitude in the upper Delaware River region and northeastern U.S., and this trend is projected to continue through the next half-century. A greater percentage of annual precipitation will come through heavy storms. Of course, more rain in shorter periods of time increases the risk of flooding and associated problems, including damage to infrastructure. Despite increasing rainfall overall, base flows may decrease in summer due to higher rates of evapotranspiration, decreased winter snowpack, and reduced infiltration into the ground during heavy storms.

### Decreasing water quality

Intense rain events create larger amounts of stormwater runoff that carries sediment, nutrients, and other pollutants into streams. Stronger flows after storms contribute to streambank erosion and changes in stream channel structure, such as incision, which can worsen erosion and sediment problems. Channelized streams become disconnected from their floodplains, reducing their ability to mitigate floods and filter sediment and nutrients. Increased nutrient pollution, combined with warmer temperatures, can enhance algae growth in ponds and lakes and reduce dissolved oxygen levels.

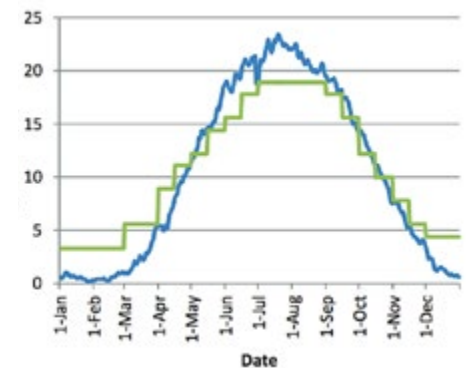
### Habitat degradation and increasing stream temperatures

Cold water fish species such as brook trout are particularly vulnerable to climate change impacts. Warmer air temperatures can raise water temperatures, especially if forest cover is insufficient, making canopy closure an increasingly important objective in riparian (streamside) areas. Earlier snowmelt and peak stream flows in spring could result in lower summer and fall flows. Low summer flows will exacerbate thermal stress problems for trout and potentially cut them off from parts of their habitat where they could seek refuge from warm temperatures.



Flickr user Sanggi, CC BY-NC-ND 2.0

Streams without tree cover have more variable temperatures, which threaten cold-water fish, and fewer kinds of leaf litter, which limits aquatic insect and animal biodiversity.



Pennsylvania Fish and Boat Commission 2011

Callicoon, NY Cold Water Fishes

Mean daily water temperature (°C) values for the Delaware River at Callicoon, NY from October 1974 to September 2008, compared to the PA Chapter 93 criterion for Cold Water Fishes.



Wikimedia User Kuhrfisch CC BY-SA 4.0

Floods often damage streambanks, which will continue to erode and deposit sediment into the stream if not properly restored.



Daniel Case CC BY-SA 3.0

When culverts are overwhelmed by higher-than-expected stream flows, washouts can occur, such as this event in New York caused by Hurricane Irene.

# Management options

## Flooding, water quality problems, and aquatic habitat degradation

- 1 Plant forested buffers where absent along streams and increase the width of forest buffer lands along shorelines and streams on your property.
- 2 Monitor riparian forests closely for forest pests and invasive plant species to catch problems early.
- 3 Develop a plan now for managing hemlock stands in riparian or headwater areas in case of hemlock woolly adelgid infestation. Consider treatments to improve existing hemlocks, or inter-plant with other shade-tolerant evergreens to ensure that streams will remain shaded when the existing hemlocks die. See: [PA DCNR Hemlock Plan](#)
- 4 Retain coarse woody debris like fallen trees on the forest floor and in riparian areas if possible to help slow runoff, filter water, and improve habitat.
- 5 Minimize road networks in your forest by planning ahead, and install best management practices (BMPs) to reduce the impact of existing and new roads on streams.
- 6 Size culverts for increased peak stream flows. Consider fish passage when replacing or installing new stream crossings; these are often better able to withstand peak stream flows than traditional round culverts.
- 7 Restore degraded streambanks using natural stabilization techniques when possible. Work with professionals (from conservation districts, NRCS, or conservation organizations) to improve in-stream habitat and reconnect floodplains where appropriate.
- 8 Resist the urge to “clean out” or straighten streams after floods; such dredging and channelization can destroy habitat and worsen flooding downstream, especially over the long-term. Consult with resource management professionals to address flood damage in ways that enhance natural functions and habitat while still protecting public safety.



Mari-Beth DeLucia/The Nature Conservancy



Walkkill River Watershed Management Group



Chris Smith, US Fish and Wildlife Service  
CC BY-NC-ND 2.0

Forested floodplains can help dissipate the strength of flood waters.

This riparian forest buffer restoration project in northwestern New Jersey aims to improve the stream's quality.

Streambank restoration is one way to prevent further erosion and protect fish habitat after floods.



# Climate change impact

## Increased temperatures, drought, and fire; decreased snow cover

### Less water makes trees more susceptible to pests and disease

Forests generally adjust to natural disturbances such as drought and heat through built-in natural recovery systems. Trees pull water up through the soil when it is available, but a changing climate could bring less water during droughts and prolonged heat stress. Larger trees fare better because of their well-developed root systems; however, seedlings and saplings may not survive. A drought-stressed tree is more susceptible to pests and disease.

### Pests and disease increase fuel sources for wildfires

When trees are already stressed from drought, pests and diseases can further increase the amount of dead leaves and branches on the forest floor. Invasive vines can also serve as “ladder fuels,” allowing wildfires to move from the ground to the canopy, where fire is very difficult to control.

Although wildfires are not a frequent problem in the Delaware River Basin, fires do occur when dry vegetation and debris cover the ground. Increasing temperatures and more droughts, combined with less snowfall, could result in earlier and longer fire seasons, which may affect your woods. As urban development increases in the region, more homes are located near the forest (the Wildland-Urban Interface, or “WUI”), and are at greater risk of damage from wildfire.

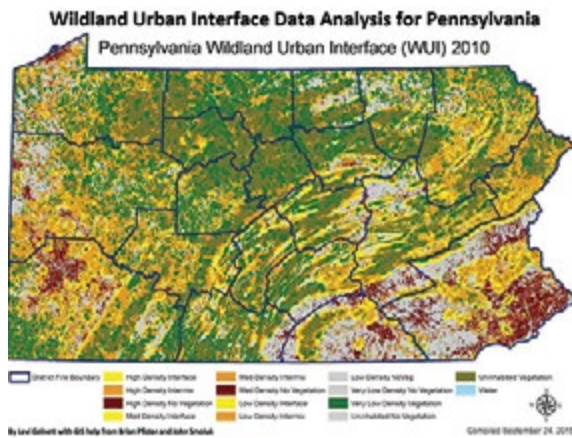
### Warmer, shorter winters

The period of the year without frosts is expected to increase by 20-50 days per year. Winter minimum temperatures will be higher and more precipitation will fall as rain rather than snow. Pests like the hemlock wooly adelgid are likely to respond well to warmer winters. Winter activities such as skiing, snowmobiling, and ice fishing will be hindered, as well.

Robert L. Anderson, USDA Forest Service, Bugwood.org



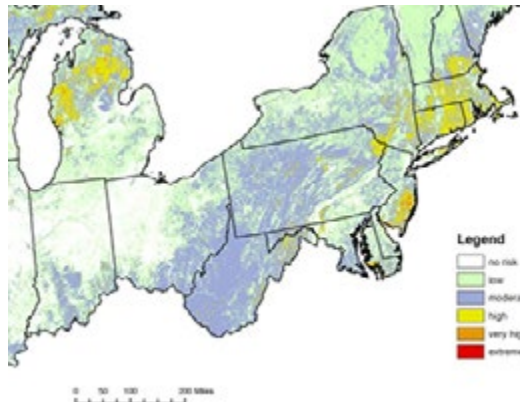
USDA Forest Service - Northeastern Area, Bugwood.org



PA DCNR

The leaves of a sugar maple turn brown due to drought stress.

An expanding Wildland-Urban Interface means that more houses are at risk from wildfires, even though the fires are not especially frequent.



US Forest Service, Northeastern Area

Forest fire.

A map of the relative risk for wildfires across the Northeastern United States

# Management options

## Increased temperatures, drought, and fire; decreased snow cover

- 1 Reduce overcrowding to protect remaining trees and to reduce wildfire risks.
- 2 Increase tree species diversity to reduce risk from pest damage to a single-species stand.
- 3 Monitor woodlands for disease, insects, and invasive plant species.
- 4 Interplant species tolerant of drier, warmer conditions. Make sure to consider the light needs of seedlings.
- 5 Avoid planting in a year that has severe drought predictions, or plant in the fall when precipitation is more frequent.
- 6 Reduce loss of soil moisture by: lengthening regeneration harvest cycles; planting cover crops; or using root dips, gels, and pellets before planting young seedlings.
- 7 Use vented planting tubes to minimize heat stress to newly planted seedlings.
- 8 Plan fuel breaks (e.g., roads, bulldozer lines, thinned areas, or bodies of water) to slow the spread of wildfire and protect areas of high concern or value.
- 9 Practice Firewise landscaping around your home to reduce the threat of damaging wildfires. This can include building non-flammable landscape features, raking leaves, and choosing less-susceptible landscaping plants.  
See: [www.firewise.org](http://www.firewise.org).



USDA Forest Service - Northeastern Area, Bugwood.org



Rob Routledge, Sault College, Bugwood.org

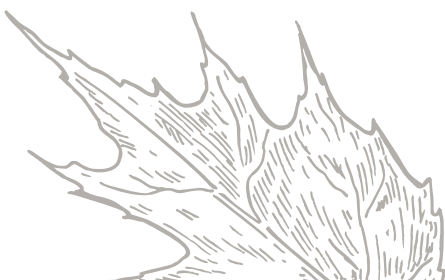


Eli Sagor, Flickr, CC BY-NC 2.0

Reducing overcrowding improves the health of remaining trees and removes fuel, which reduces wildfire risks.

Thinning the canopy while following Best Management Practices often includes harvesting when the ground is frozen to minimize soil compaction.

Dipping bareroot seedlings in a rooting gel helps to preserve moisture around the roots when they're planted.



# Climate change impact

## Invasive species, pests, and disease

### Invasive species compete for light, nutrients, and water

Invasive plants affect forest health and regrowth through competition for light, nutrients, and water. Many of these invasive species were introduced from other regions; the absence of competitors or predators means that they can outgrow many native plants, especially understory species and young trees. This alters the structure of the woods, changing what species grow there—often with a significant loss of biodiversity and reduced habitat for animals.

Especially high deer populations intensify the problem: deer mostly prefer to eat native species, making it easier for invasive species to grow and expand. A changing climate may also intensify the problem in the following ways:

- A longer growing season resulting from a warming climate can give invasive species a bigger advantage in their competition with native species.
- Higher carbon dioxide levels have been linked to a faster spread of invasive plants.
- Shifting species distributions as plant species gradually migrate north provides additional opportunities for invasive species to outcompete natives.

### Climbing vines make trees more likely to break in extreme weather

Invasive species like English ivy, kudzu, and Asiatic bittersweet climb up tree trunks, adding more weight and surface area to the crown of the trees. This stress makes branches more likely to break under the weight of snow and ice. Native grapevines and poison ivy can cause similar problems, but to a lesser extent. Broken trees aren't problematic by themselves, but the invasive plants are likely to crowd out tree seedlings that would occupy the newly-created gap. Some vines may even girdle and kill individual trees.

### Warmer temperatures help pests and disease to overwinter

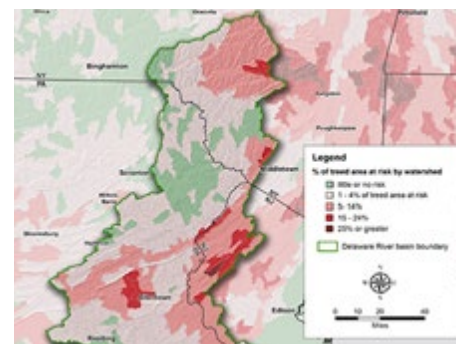
Insect pests and disease can have a significant impact on woodlands, and a changing climate may affect what kind of pests occur in the upper Delaware River region, including insects, fungal pathogens, and diseases. Increasing temperatures may change the distribution and abundance of existing pests and diseases and create opportunities for new invasions.

Many insects and diseases are controlled by cold winter temperatures. As winters get warmer, the number of these pests that survive the winter may increase, expanding infestations. Most forest health problems result from invasive pests that have been transported from other areas by people, including emerald ash borer (ash), gypsy moth (oak), hemlock woolly adelgid (hemlock), and thousand cankers disease (walnut).

Hemlock woolly adelgid can cause hemlocks' death in 4-10 years. The Forest Service and state agencies are testing introducing beetles to control the adelgid, but these are not yet available to private landowners. Watch for developments from your state. Vigorous and healthy hemlocks may be able to withstand infestations; thinning may be appropriate. Individual trees can be treated with insecticides. It may be worthwhile to plant other evergreen species in areas where hemlocks are declining, especially around streams. See the resources on page 17.



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Tom Luther, US Forest Service



Nicholas A. Tonelli CC BY 2.0



US Forest Service

Japanese knotweed spreads by water and can quickly establish along streams.

Tree mortality risk map for the upper Delaware River Region.

Hemlock woolly adelgid populations are usually kept in check by low winter temperatures.

Trees weakened by pests and diseases are more susceptible to wind damage.

# Management options

## Invasive species, pests, and disease

1 Learn about problematic plants in your area, and monitor and remove them from your woods, especially those at the forest edge. Early detection and rapid response to new infestations will save you (and your neighbors) time and money. See resources from [PA DCNR](#) and [NJ ISST](#).

2 Remove or kill unwanted, invasive vegetation before planting tree seedlings or harvesting.

3 Clean your equipment and clothing when leaving an area infested with invasive species, insect pests, or disease to avoid transporting them to a new location. Timber harvest contracts should require operators to power wash their equipment to prevent importing seeds.

4 Reduce deer populations to healthy levels that allow native plant species to grow and compete with invasive species in your woodland. Check out [www.deerandforests.org](http://www.deerandforests.org), and the Deer Management Assistance Programs in NY, PA, and NJ.

5 Monitor for disease and insects. A small problem is easier and less expensive to control. See resources on page 6 from [PA DCNR](#) and [NY DEC](#).

6 Diversify stand ages and structure through timber stand improvement, thinning, regeneration harvests, and planting. Regeneration treatments over large areas (20 acres or so) can produce enough seedlings to survive some deer pressure. You may try to coordinate timber harvests with neighbors to overwhelm the local deer herd. Be sure to leave tops from harvested trees in the woods, which can protect some seedlings.

7 Reduce overcrowding to keep your forest healthy. Healthy woodlands are better at resisting the impacts of invasive species, pests, and diseases. If invasive plants are present in the understory, it is usually appropriate to control those before cutting any overstory trees.



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Livestock can help control some vegetation (“prescribed grazing”), but carefully manage the animals’ nutrition, the plants you wish to maintain, and soil compaction and erosion. See grazing resources from [New York](#) and [Idaho](#).

A forester inspects an insect-damaged tree.

Careful removal of some trees as recommended by a forester provides an opportunity to increase diversity.

# Forests capture carbon

## Storing carbon and filtering water in woodlands and wetlands

### Healthy forests store carbon as biomass and in the soil

Forests naturally capture carbon dioxide from the atmosphere, which is then stored as carbon in live trees, woody debris like fallen branches, and the soil. This carbon can be stored for decades in living trees or in durable wood products like furniture or building frames until it is released when vegetation decays or burns. Maintaining or increasing the amount of carbon that can be stored by your woodland is crucial to help limit the effects of climate change in the future. Oak-hickory forests common to the region can store up to 87 tons of carbon in above ground vegetation and in the soil. Forests in the mid-Atlantic sequester an additional 800-1400 pounds per acre per year of carbon.

When mature forests are harvested sustainably, the carbon that was removed by the forest over time is stored in lumber or other wood and paper products. After a timber harvest, carbon will be removed from the atmosphere at a slower rate at first, but once new forest becomes established the rate of carbon being removed from the atmosphere will increase because young forests tend to have higher tree density and faster growth rates than a mature forest.

If forested land is converted into housing developments, its potential to capture carbon is lost while the construction of roads and buildings and an increased dependence on motor vehicles create new greenhouse gas emissions. Keeping forests as forests is the most important thing a landowner can do to help reduce and capture greenhouse gas emissions. These forests also provide other benefits such as clean air and water, wildlife habitat, and other aesthetic values.

Forests can be managed to store and capture more carbon through sustainable forestry practices. Talk to your forester for more information about opportunities and incentives.

### Wetlands can store carbon for millennia

Wetlands are even more productive at capturing and storing carbon in the soil. In the northeastern United States and the upper Midwest, freshwater wetlands can store on average 193 tons of carbon per acre. This carbon can be stored in the soil for millennia, making these ecosystems very valuable for carbon storage; however, these ecosystems are also at risk of development or conversion.

### Forests as a climate adaptation strategy

One of the most important strategies to help upper Delaware River region communities and natural resources adapt to climate change impacts is to retain existing forests. These forests filter water, recharge groundwater, slow stormwater runoff, keep air and water temperatures cool in summer, and absorb air pollution (including carbon dioxide). They also provide important habitat for a variety of insects and wildlife, which need to retain access to a diversity of interconnected forests and other open space to be able to adapt to change themselves. Protecting open space, managing forests for diversity, and restoring streams and floodplains where degraded are “no-regrets” strategies that will help address current and future problems in the region.



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National Park Service



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Carbon emissions from fossil fuels are directly linked to climate change.

When forests are converted into development, carbon emissions increase.

Trees store carbon until they decay or burn.

Wetlands store carbon and hold and filter runoff from heavy rains.



# Management options

## Storing carbon and filtering water in woodlands and wetlands

- 1 Work with your forester to evaluate carbon storage potential and sustainable forestry practices on your own property. Identify opportunities to work with neighboring forest tracts through cooperatives, limited liability corporations (LLC), or The Nature Conservancy's Working Woodlands program.
- 2 Keep forests as forests—minimizing conversion to other land uses such as housing developments that will increase both carbon emissions and stormwater runoff. Learn about estate planning options for your land and discuss them with your family.
- 3 Plan for longer intervals between regeneration treatments to maximize carbon storage on your property. Timely thinnings are still appropriate; this refers to establishing new generations, or “cohorts” of trees.
- 4 Grow high-quality trees so that more of them can be turned into durable wood products like furniture (which stores carbon), and fewer of them become firewood or pulp (which release carbon). Good silviculture in this region often requires thinning or “timber stand improvement” to favor the growth of the best quality trees.
- 5 Identify locations that do not have trees but could support a forest in the future. Increasing forest cover (through planting or retaining trees) on these lands will help to capture more carbon, as well as other economic and environmental benefits.
- 6 Reduce overcrowding of trees through well-planned thinning to keep your woodland healthy.
- 7 Protect existing wetlands on your property, and restore degraded wetland habitat.



USDA Forest Service - Northeastern Area, Bugwood.org



Tony Fischer, CC BY 2.0



Wing-Chi Poon, CC BY-SA 3.0

You will be more satisfied with a timber sale if it is administered by a forester and carried out by a qualified logger. This is especially important for thinning, where the primary value is the undamaged trees that are left.

Carbon can be stored in durable wood products such as furniture.

Leaving (or placing) fallen trees in streams helps store carbon while providing habitat for fish and slowing down floodwaters.



# Climate change is real

## Take action now to help your woodlands to adapt

Climate change is real and it is happening now. The impacts of climate change in the Delaware Basin are already evident in the form of summer heat waves and more frequent extreme weather events. All of these changes will affect the watershed's citizens, their livelihoods, and the region's economy.

Consider the impacts of climate change outlined in this document as part of your forest stewardship plan. You can make smart environmental and economic decisions and implement the most effective strategies to help your woodlands adapt to climate change. Many of these management options are already good stewardship practices to enhance wildlife, timber values, recreation, and other objectives. You may also want to consider how your forests can play a role to help capture carbon emissions and minimize the impacts of climate change in the future.

None of us will own our forests forever; when planning for the future, it may be useful to think through planning your forest estate. Of course, many people put this off because it is uncomfortable and complicated. There are many options, including transfer through a will, direct sale to your heirs, setting up a conservation easement or limited liability company, selling to a land trust, or, of course, doing nothing. Talk to a local forest owner's group, agency forester, conservation organization, tax lawyer, or land trust. See resources from the [US Forest Service](#) and [Penn State University](#).

Now is the time to get informed, make plans, and implement changes. Woodlands that are well adapted to new and changing conditions will be better able to meet your management goals as you build a more sustainable future for your woodlands. And, don't forget to get out there and enjoy your forest!

### Management choices revolve around

### 3 KEY OPTIONS:

cut something

plant something

or do nothing



Jane Hawkey, IAN Image Library

# Learn more about your woodlands

## About your woodlands

For more information, please visit <http://commonwatersfund.org/forest-adaptation> or the following websites:

## State forestry departments

[New Jersey](#)

[New York](#)

[Pennsylvania](#)

## Forestry extension offices

[New Jersey](#)

[New York](#)

[Pennsylvania](#)

## County Soil and Water Conservation Districts

[New Jersey](#)

[New York](#)

[Pennsylvania](#)

## Online information and planning tools

[LandServer](#) (in PA)

[My Land Plan](#) (PA, NY, NJ)

[Adaptation Workbook](#) (any state, relevant for people with management plans)

## Find a forester

[Pennsylvania](#)

[New York](#)

[New Jersey](#)

[Association of Consulting Foresters directory](#)

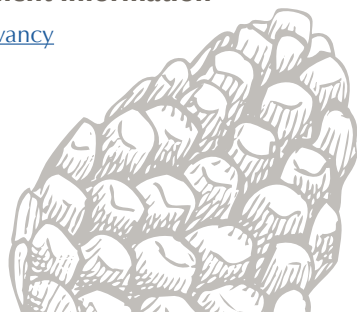
[Society of American Foresters directory](#)

[The Forest Stewards Guild directory](#)

[US Department of Agriculture list of Technical Service Providers](#)

## Land stewardship, estate planning, and conservation easement information

[Delaware Highlands Conservancy](#)



## For more information about Hemlock Woolly Adelgid:

[Pennsylvania DCNR Hemlock conservation plan](#)

[US Forest Service brochure on woolly adelgid](#)

## For more information about Emerald Ash Borer:

[New Jersey: Fact Sheet - Emerald Ash Borer](#)

[Wisconsin: Emerald Ash Borer and Forest Management](#)

[US Forest Service: Managing Ash in Farm Woodlots](#)

[Emerald Ash Borer Information Network](#)

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## On the cover

A healthy forest keeps our water clean. Photo by Flickr user fishhawk CC BY 2.0. Hemlock: Nicholas A. Tonelli CC BY 2.0; Subdivision: Shawn Kashou, Shutterstock; Forest thinning: Eli Roberts, Pinchot Institute.

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