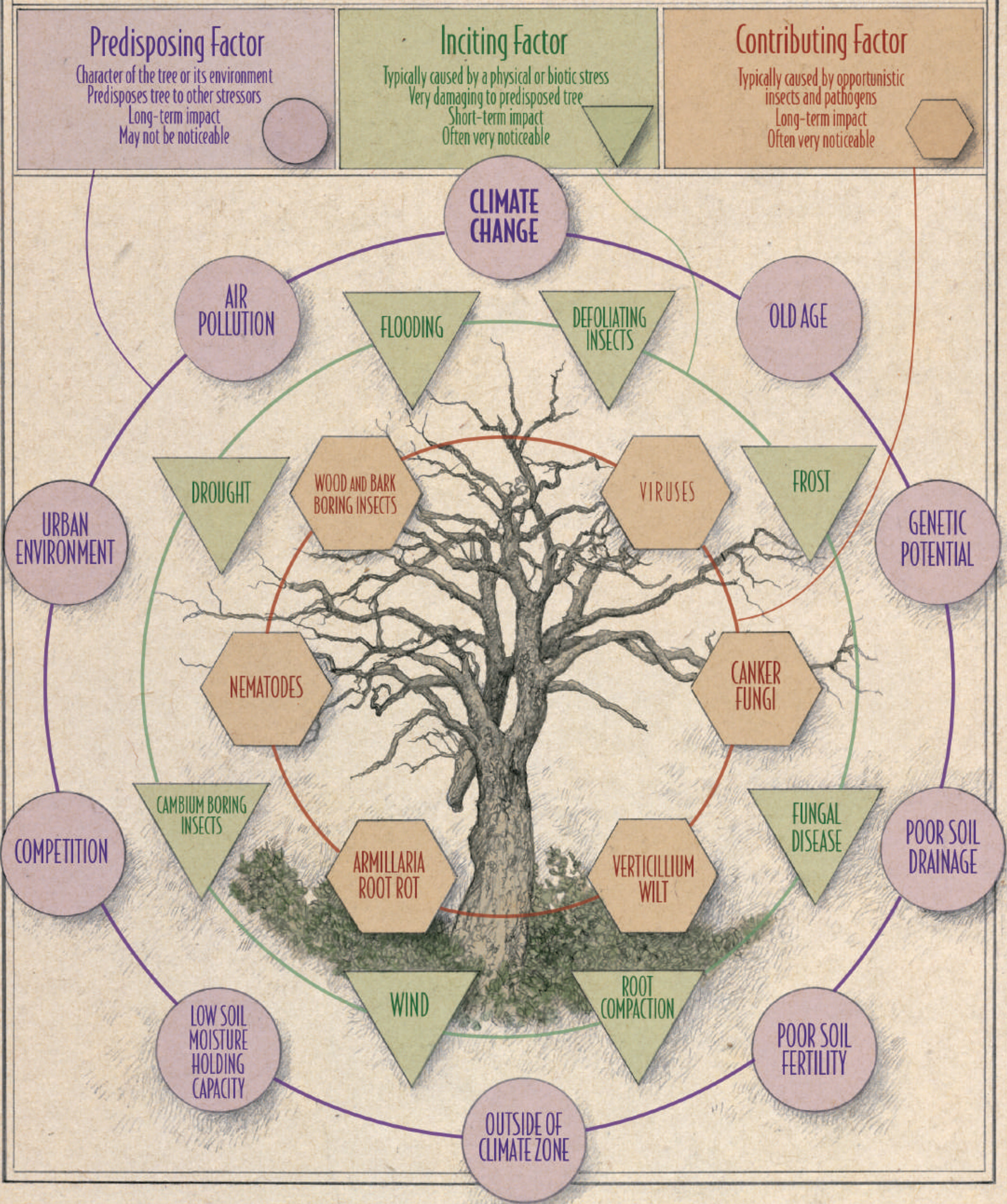
PROCESS OF TREE DECLINE

Multiple, interacting factors often contribute to a tree's decline. Climate change can add to – and intensify – this combination of factors.



CLIMATE CHANGE IMPACTS ON NORTHEASTERN FORESTS

By Alexandra Kosiba. Illustrations by Erick Ingraham.

This article is the first in a four-part series that focuses on climate change impacts and adaptation in forests. A companion series published last year focused on forest carbon. Alexandra Kosiba, a forest ecologist and tree physiologist, is an assistant professor of forestry at University of Vermont Extension. She specializes in climate change impacts to trees and forests and ways that foresters and landowners can incorporate climate change considerations into their decision-making and planning.

It's hard to ignore the changes in the weather we've been experiencing. Winters aren't as cold as they used to be, spring is arriving earlier and fall later, and when it rains, it pours. These changes reflect long-term shifts in the climate. Since 1970, the average annual temperature in the Northeast has risen more than 3 degrees Fahrenheit.[1] This temperature increase is greater than what has been observed for the contiguous United States (2.5 degrees) and the global average (1.7 degrees), but less than for Alaska (4.5 degrees).[2] Depending on future greenhouse gas emissions, climate models predict that the region will experience an additional temperature increase of between 2 and 8 degrees by the end of the century.

As temperatures throughout the world continue to rise, a common pattern is that colder entities are warming faster than warmer ones. For example, Earth's poles are warming faster than the equator, winters are warming more rapidly than summers, and minimum temperatures are increasing faster than maximum temperatures. Because a characteristic of the Northeast's climate has been historically cold and snowy winters, a loss of cold conditions is one of the region's greatest changes.

Predicting the impacts of these changes on forests is complex. Some tree species, in some locations, will benefit, while others will face declines in health and population. For the most part, trees do not die of a single cause, but rather succumb to the combined impact of multiple stressors. A challenge of climate change – and one of the reasons its specific effects can be hard to predict – is that it acts as a "threat multiplier." What this means is that changes in temperature and precipitation can exacerbate other stressors on trees such as insects, diseases, competition from invasive plants, nutrient limitations, and deer browsing.

1 *In this article, the "Northeast" is defined as New York and the New England states. This differs from some larger climate assessments in which the northeast climate region also includes New Jersey, Pennsylvania, Delaware, and Maryland. Climate data retrieved from ncei.noaa.gov/access/monitoring/climate-at-a-glance/statewide/time-series*
2 *nca2023.globalchange.gov*
3 *epa.gov/climate-indicators/climate-change-indicators-length-growing-season*

Lengthened Growing Season

As temperatures rise, the last spring frost arrives earlier than it used to, and the first fall frost comes later. These changes have resulted in a growing season that has lengthened by an average of two and a half weeks in the Northeast since 1895.[3] Some parts of the region have experienced larger increases. For instance, Connecticut has seen the growing season increase by a month.

An extended growing season benefits some tree species by providing more time for photosynthesis. Trees can use this additional energy to grow more, stow away sugars and nutrients, and invest in energy-costly processes, such as making seeds or defense chemicals against pests.

But an extended growing season also introduces challenges. A longer growing season allows some insect species to have more generations per year or to grow larger. When these insects are species that feed on trees, they have the potential to cause unsustainable damage to their hosts. For insects that are beneficial to trees, there is concern that the pace of climate change may lead to phenological mismatches, including divergences between flowering times and the return of pollinators.

Earlier spring conditions and start to the growing season can also elevate the risk of frost damage to newly emerging leaves and flowers. Such an event happened on May 18, 2023 in parts of the region. This freezing event caused noticeable damage to the leaves, flowers, and buds of many trees and shrubs. Whether a tree or shrub suffered from freezing damage depended on both its species and location. Because species leaf out and flower at different times, some late-emerging species, such as beech and oak, were at a more vulnerable developmental stage than earlier emerging species, such as maples. Most frost-damaged trees were able to produce a second set of leaves, although in some cases where leaf buds were also damaged, the new leaves that emerged were small and misshapen, resulting in reduced photosynthesis for the remainder of the growing season. To re-flush a second set of leaves requires use of energy reserves, possibly resulting in less capacity for growth and other important processes. Damage to flowers or flower buds meant that many trees and shrubs did not produce fruit or seeds this past year, which affects not only regeneration potential, but the wildlife that depend on those food sources.

In fall, warmer temperatures, particularly warm nights, can impact trees by delaying the developmental processes that are critical to preparing for winter, including acclimation to below-freezing temperatures. We observe this impact as a late fall foliage season, more muted leaf colors, and unsynchronized timing of peak color among species. Wreath makers are reporting that the timing of needle set in balsam fir, a signal that the tree is preparing for winter dormancy, is occurring later, which can make it more difficult to harvest boughs in time for the holidays.

Milder Winters and Altered Snow Dynamics

Warming in winter has outpaced that of summer, spring, and fall, increasing an average of 4.9 degrees in the Northeast since 1970[4]. This shift alters snow dynamics, leading to more rain than snow, a reduced snowpack, and a shorter snow season. Warmer temperatures may also result in an increase in wet and heavy snow events, which can break tree branches and topple saplings. Although snowfall is variable across the region and from year-to-year, overall snowfall is decreasing, a greater proportion of winter precipitation is falling as rain, and there are more winter days with bare ground.

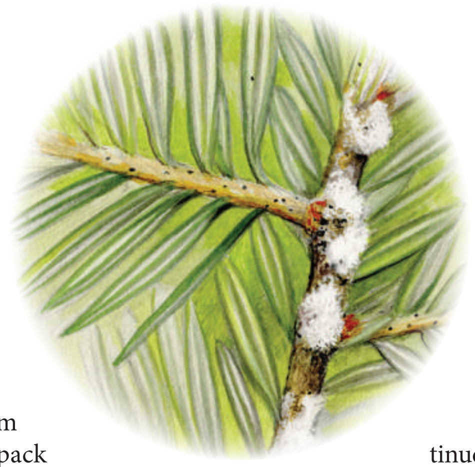
Changes in the snowpack impact forest ecosystems in various ways. Snow insulates soil, minimizing freeze-thaw cycles and freezing depth. More frequent soil freeze-thaw events and deeper soil freezing can damage the fine roots of trees along with other organisms that live in the soil. Because fine roots are responsible for absorbing nutrients and water from the soil, damage to them restricts water and nutrient transport to the branches, which leads to reductions in vigor and growth. Deeper soil freezing and more freeze-thaw cycles can also cause soil nutrient losses, particularly of nitrogen, which is critical for all life in the forest.

Additionally, variations in snowfall affect the subnivean zone – the sheltered area between the forest floor and the bottom of the snowpack. Many wildlife

4 *ncei.noaa.gov/access/monitoring/climate-at-a-glance*

species, such as grouse, mice, and voles, use the subnivean zone as protection from cold temperatures, bitter winds, and predators. Less snow reduces the depth of the subnivean zone, and in some years, it may not exist.

However, for other species of wildlife, a decline in snow may be beneficial. Because white-tailed deer have difficulty traveling in deep snow, deer populations historically have been restricted from the northern parts of the region. If snowpack declines in these locations, it is expected that deer may become more common. Because in winter deer eat tree seedlings and other understory plants, expansion of deer range could cause new impacts to the forests in these locations.



Warmer temperatures in late winter and early spring can also lead to an earlier melting of the snowpack. The melting of the snowpack is an important water source for trees when they are coming out of dormancy and beginning to leaf out. When trees suck up water through their roots, they reduce flood impacts and cycle water back into the forest. Thus, if peak streamflow occurs before trees begin to leaf out, there could be a greater risk of flooding early in spring and a lack of water availability when trees need it most.

Fewer Frigid Cold Winter Nights

Consistent with the pattern that cold entities are warming faster than warm ones, since the 1970s the Northeast's minimum winter temperature has risen a whopping 5.8 degrees compared to a 3.9 degree rise in maximum winter temperature. This means that we are not experiencing the same frigid lows as we did in the past, which has implications for the ecological processes of forests.

Plant and tree species have different abilities to resist injury during exposure to cold temperatures. These differences in cold tolerance limit where each species can grow. For example, balsam fir, one of the region's most cold-hardy trees, can withstand temperatures at least as low as -75 degrees. We can find balsam fir on mountain summits and throughout the coldest parts of the region. In contrast, tulip poplar suffers cold damage when exposed to temperatures below -20 degrees. Tulip poplar grows mostly in the southern part of the region and cannot survive in cold locations in the north. Because the minimum winter temperature at a location is the basis for plant hardiness zone maps, the USDA recently updated the zones to reflect increases in winter low temperatures due to climate change.

As minimum winter temperatures continue to rise, changes in hardiness zones are not limited only to plants. Many insects may be able to expand their ranges. For example, hemlock woolly adelgid is a small, invasive insect in the Northeast that feeds on the needles of hemlock trees, causing declines and mortality. Because the insect is not sufficiently cold hardy to survive in northern New England and New York, its range has been limited to the southern part of the region. However, as the climate warms, it is expected that hemlock woolly adelgid will be able to expand northward.

Warmer Summer Nights and Possibility of Heat Waves

Although winters have warmed faster than summers, the average summer temperature has increased by 2.2 degrees since 1970,[5] and in the future, we'll experience more hot summer days with the potential for longer heat waves. Heat waves can be problematic for trees if they coincide with low water availability, in what are called "hot droughts." Hot droughts dry both the air and the soil. When this occurs, trees can lose water from their leaves, which can cause the collapse of the tree's water-carrying tissues – a process known as "hydraulic failure."

Another trend is that summer nights are warming faster than summer days, which is consistent with the trend of minimum temperatures warming faster than maximum temperatures. Warmer nights mean fewer cool mornings and therefore a smaller diurnal temperature range, which is the difference between the warmest and coolest temperatures experienced in a 24-hour period. In summer, a reduced diurnal temperature range can elevate metabolic demands for trees and increase nighttime water loss, potentially affecting tree growth and overall health.

5 *ncei.noaa.gov/access/monitoring/climate-at-a-glance*

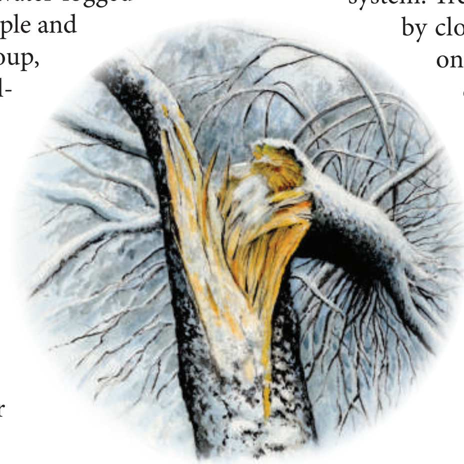
More Rain and Heavier Rain Events

The Northeast has witnessed a 15-percent increase in annual precipitation over the past century, with projections indicating a continuation of this trend. Seasonally, most of this increase is occurring in summer and fall, while winter and spring have seen much less change.[6] As mentioned earlier, a greater proportion of winter precipitation is falling as rain rather than snow due to warmer temperatures.

More rain can benefit trees by increasing water availability, but prolonged periods of cloud cover reduce sunlight and, therefore, a tree's ability to photosynthesize. More wet days can create ideal conditions for the proliferation of foliar fungi and other diseases. Typically, these leaf diseases are not deadly for a tree, but they reduce photosynthetic capacity and often cause premature leaf drop. If foliar diseases persist for multiple growing seasons, and especially if they're coupled with additional stressors, trees may experience health declines or even mortality.

Not only has total precipitation increased, but heavy rainfall events have become more common. Most climate models indicate that this trend will continue. Heavy rainfall events that deposit multiple inches of rain pose challenges to forests, causing different impacts depending on the location and soils. In low-lying and flat areas, heavy rain can lead to more frequent and severe flooding. Following an extreme rain event, soils may remain water-logged because of a high water table or slow draining. Tree species that are adapted to wet areas, such as willows and cottonwoods, can tolerate water-logged soils, but upland species, such as sugar maple and white pine, may suffer. For this latter group, prolonged wet soils can cause root mortality and health declines. Saturated soils can also make trees more susceptible to being knocked over by strong winds.

In sloped terrain, heavy rain may mean that soil cannot absorb water quickly enough, and instead, water flows over the surface of the forest floor. Overland flow accelerates downslope, and in doing so it transports leaf litter, twigs, soil, and nutrients. Loss of leaf litter and soil can expose the fine roots of trees, causing them to be damaged or to dry out after the rain has subsided, in turn affecting the trees' ability to take in nutrients and water. Large amounts of soil erosion and nutrient leaching can lead to sedimentation in streams and lakes, negatively affecting water quality. Heavy rain events can also damage roads and trails, especially where there are culverts or drainages that are not able to accommodate the extreme flows.



Increased Possibility of Drought

Despite the overall increase in rainfall, warmer temperatures and longer periods of time between rain events can lead to drought. Warmer air can hold more water vapor than cooler air, and higher temperatures cause water to evaporate from the surface of leaves and soil more easily. Other site factors, such as the presence of earthworms and a lack of leaves, wood, and other dead organic matter on the forest floor, can further exacerbate soil drying. Because precipitation patterns are highly variable across the region and site conditions strongly affect hydrology, we will likely see that drought affects some areas, while other locations have ample moisture.

Although seasonal droughts are a normal occurrence in our region, if they become more extreme or frequent, they could cause stress to trees and forests. Dry soils are particularly harmful to seedlings that have not yet developed a deep root system. Trees can regulate water loss from their leaves by closing their stomata, which are small pores on the surface of leaves that allow the intake of carbon dioxide and release of oxygen and water. When a tree closes its stomata to reduce water loss on dry days, the tree's ability to capture carbon dioxide and to photosynthesize is also reduced. Trees can withstand dry periods by relying on stored carbohydrates and water, but only as long as their resources last.

Some tree species are more tolerant of drought than others. Thicker, waxier leaves, smaller or needlelike leaves (such

6 *ncei.noaa.gov/access/monitoring/climate-at-a-glance*

as those of pine trees), as well as trees that are shorter in height, are examples of traits that can make certain species more drought tolerant than others.

Drought conditions can also make some trees more susceptible to other stressors, such as insect infestations. For example, drought stress can reduce a tree's ability to produce and transport defense chemicals, which can then make the tree susceptible to wood-boring beetles, whose entry holes may be exploited by opportunistic decay fungi. As discussed earlier, hemlock woolly adelgid may be able to exist in new locations as winters continue to warm. In addition to this climate impact, the occurrence of drought can make hemlock trees more likely to succumb to the adelgid's feeding.

Prolonged droughts may also lead to an increased risk of forest fires. However, fire itself is not always a threat to forests. In fact, some forest types in the Northeast are adapted to fire. This means that many of the tree and plant species that live in these communities rely on fire for reproduction or to be able to compete with other plants. For example, pitch pine has serotinous cones that remain closed until fire melts the resin that holds the seeds inside. Fire also creates ideal conditions on the forest floor for the pitch pine seeds to germinate. But decades of fire suppression have reduced this natural process. While fire can be beneficial to ecosystems adapted to fire, it could have more negative impacts on ecosystems that are not fire adapted or where fire affects human communities.

Possibility of More Wind and Ice Storms

The Northeast may face more severe weather conditions, including ice storms and damaging winds. These events can have detrimental effects to forests, causing limbs to break and trees to topple. These types of events can facilitate forest development, creating complexity and diversity. However, wind and ice storms have different impacts depending on the size and species of the trees. Stands with a single species or trees of similar size can suffer more extensive damage and take longer to recover than a multispecies, multi-aged stand. Wind and ice storms are often most problematic to our infrastructure, such as power lines, roads, trails, and sap lines in sugarbushes.

Adapting to Climate Change

Trees can't, of course, move to more favorable locations when local conditions become stressful. They must adapt to the new conditions or perish. Declines in forest health can have numerous negative secondary effects, including emissions of stored carbon into the atmosphere, loss of wildlife habitat and biodiversity, decreases in wood supply, and reductions in the many ecosystem benefits forests provide, such as controlling soil erosion and regulating water.

Although individual trees are not able to migrate, species of trees can move to more favorable locations through their progeny. Over millennia, forests have adapted to substantial climate changes, but the current rate of change poses special challenges. Climate change is generally expected to outpace the distance that seeds can move through natural migration.

In general, the future climate in the Northeast is anticipated to be more stressful for trees adapted to cold climates, such as balsam fir, northern white cedar, and black spruce, while those trees adapted to warmer conditions, such as red oak, tulip poplar, and bitternut hickory, may be able to grow in new locations. A deeper exploration of differences among tree species, as well as strategies we can take to steward forests under changing conditions, will be addressed in future articles.[7]

Special thanks to our reviewers of this article: Maria Janowiak, Acting Director – USDA Northern Forests Climate Hub, and members of the State Leadership Committee of the Securing Northeast Forest Carbon Program.

7 For more information on climate change and forests, visit uvm.edu/extension/forestry-climate-change.