A comparison of different stages of forest development. At the top is a forest that lacks variation in tree size, species, and structure, and may be vulnerable to climate change impacts, disturbances, and other stressors. In the lower image, management interventions have created a more diverse and complex forest, with protections to soil, water, and biodiversity that can help build resilience.

MANAGING FORESTS FOR RESILIENCE

By Alexandra Kosiba. Illustrations by Erick Ingraham.

This article is the third 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.

As we consider how to best steward forests in a changing climate, it is important to recognize that there is no one-size-fits-all approach. Each forest has unique characteristics and conditions that influence its vulnerability to disturbances and stress. The current community, age, and structure of a forest reflect specific soil and site conditions, its elevation and climate, and the type and timing of past land uses. Understanding where your forest sits along a developmental pathway can help you incorporate climate-focused strategies to advance resilience in an uncertain future.

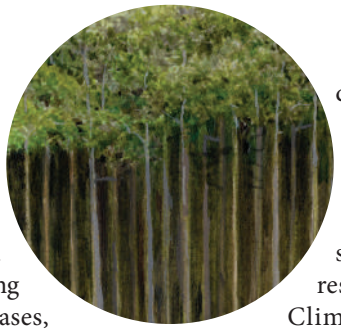
The Importance of Land Use History

Between the 1600s and late 1800s, more than 50 percent of forestland in the Northeast was cleared for agriculture and settlements. Many of the remaining forests were also subject to timber extraction. When people began to move westward and abandon farms, many fields began to revert to forestland. However, these second-growth forests did not possess the same characteristics as their predecessors. In some areas, livestock grazing caused soil compaction, while in other locations, plows had tilled and leveled soils. Although trees grew back, the species that dominated were those that easily established on open land, such as white pine and paper birch.

In subsequent decades, additional timber harvesting occurred in these second-growth forests as well as in forests that had never been fully cleared. Often, these practices were unsustainable. For example, *high-grading*, the practice of harvesting the largest, healthiest, and most valuable trees, simplified the mix of species, reduced the variety of tree sizes, and removed important sources of seeds for the next generation. Another common practice was "cleaning" the woods by removing and burning any dead trees and downed branches, which degraded biodiversity, reduced stormwater retention, and deprived soils of nutrients. This practice has left a legacy of deadwood deficiencies in many forests today.

Overall, the land use history in the Northeast has resulted in a forested landscape that is younger, less diverse, and less structurally complex than the forests that once dominated the region. Today, more than 80 percent of the region's forests are between 40 and 120 years old. While seemingly old to us, from an ecological perspective, these forests are young to middle-aged. Some of these forests may also have other evidence of past land uses, such as old roads or trails.

Climate Change and Forest Resilience



The impacts of climate change on forests will be both direct, through increases in temperature, rainfall, and extreme weather events, and indirect, through increased stress on trees, shifting disturbance patterns, and effects on pests, diseases, and invasive plants. Forests that are relatively uniform in tree age, species type, and canopy structure – and those with degradation from past land uses – may be more vulnerable to greater impacts under this pressure. *Vulnerability* is the degree to which a forest is susceptible to and unable to recover from climate change.

Conversely, forests with more diverse communities and complex structures are likely to fare better because they have more options for recovery. *Resilience* is the capacity of a forest to recover or adapt following disturbance or stress. Resilient forests typically have a diversity of tree species and ages, which allows them to accommodate change and to continue as forests after experiencing disturbances or stress. Different species and ages of trees have varying stress tolerances and disturbance susceptibilities. Although a resilient forest may not retain the same species or appearance as it did before a disturbance, it will continue to provide essential services such as clean air and water, wildlife habitat, recreational opportunities, timber resources, carbon sequestration and storage, and flood prevention.

Other features of resilient forests, as seen in old-growth forests, include the presence of large trees, ample deadwood in various stages of decay (both standing dead trees and downed logs), and intermittent gaps in the forest canopy. These canopy gaps support a wide diversity of regenerating trees and a broad wildlife community and food web. For example, canopy gaps promote plant species such as shrubs and brambles that can enhance the diversity of forest birds that, in turn, help regulate insect populations.

Due to the region's past land use, many forests are at a developmental stage with a dense, uniform overstory canopy and few sun-filled gaps. Without variation in the canopy, there are limited opportunities for a diverse community of new trees to establish if the current overstory trees decline from climate stress or other disturbances. These forests may also have other characteristics that increase vulnerability, such as a lack of deadwood to slow and retain stormwater, invasive plants that hinder tree regeneration, or old access roads that can cause soil erosion on steep slopes.

Recognizing the importance of land use history on forest development, we can make stewardship decisions that enhance forest resilience to climate change through adaptation. Climate adaptation involves preparing for and responding to anticipated climate change impacts by reducing vulnerabilities and advancing forest resilience through restoration, planned enhancements, and avoided degradation. For all forest types, promoting and maintaining resilience over time requires a clear appraisal of the risks and opportunities presented by climate change and other stressors, including an understanding of how local site conditions and management history might make a particular forest more or less vulnerable to climate change impacts.

Assessing Risks and Vulnerabilities

A critical step in long-term planning is to assess possible vulnerabilities to climate change and other stressors to guide which management strategies might be best to lessen possible impacts. One helpful way to do this is to look at the forest in three horizontal layers: the overstory, the area between the ground and overstory, and the forest floor.

Start by looking up at the overstory trees. Are the trees of similar size or species? Do the trees have small, narrow canopies? Are they growing very close together such that little light reaches the forest floor? These are some conditions that may increase your forest's vulnerability to extreme events and disturbances.

Next look at the area between the ground and the overstory trees. Do you see only a few tree saplings, or only one or two different species? Do you see invasive plants or extensive evidence of animal browsing on twigs and stems? These are some conditions that may affect the ability of your forest to remain a forest in the future.

Last, look at the forest floor and consider what's damaged or missing. Are there areas of soil erosion or rutting? Is there an absence of logs and other deadwood on the ground? Do roads and trails lack water diversion structures, such as water bars, dips, or culverts? These are some conditions that can affect the soils

and water quality of your forest. Take the time to go to different areas of your forest and repeat this three-layer assessment. Once you've evaluated the condition of these layers in different areas of your forest, you can begin to consider actions that you might take to improve resilience.

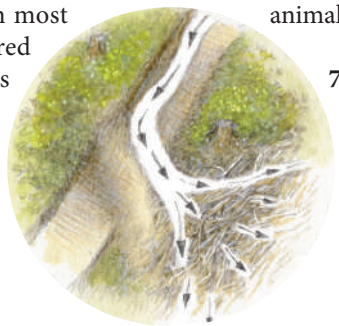
Managing Forests for Resilience and Adaptation

Where you identify possible vulnerabilities, you can take steps to advance the resilience of your woods. A toolbox approach is highly effective, allowing you to prioritize and combine different strategies. Here are 10 key strategies to promote resilience and to support the goal of managing forests for carbon benefits, as detailed in last year's forest carbon series:

1. Keep forests as forests. The Northeast loses forestland to other land uses every year. Connected forests allow species to move as conditions change, promoting biodiversity. Preserve your forest through estate planning, conservation easements, or other methods.

2. Slow, spread, and sink water. Climate change is bringing more rain and stronger storms, which can cause soil erosion and nutrient loss. Use water diversion structures such as water bars or dips on roads and trails, and ensure culverts or bridges can handle extreme flows. Minimize water channelization by diverting water into depressions or flat areas where the water can be absorbed more slowly. Deadwood on the forest floor can also help slow down and retain water, especially when positioned perpendicular to the slope. Close out old, unused roads or trails to prevent erosion. Walking in your woods during or after heavy rainfall can help you see where water travels to identify problem areas.

3. Protect soils and water quality. Soil and water quality are crucial for long-term forest health. Plus, in most northeastern forests, more than half of the stored carbon is in the soil. Avoid traveling on wet roads to prevent soil rutting, compaction, and erosion. When using equipment in the woods – whether for logging, trail building, or recreation – minimize impacts by using equipment designed to reduce damage, working when the ground is dry or frozen, or using bridges and logs on trails. Pay particular attention to minimizing impacts of soil near waterbodies. Protect water sources and sensitive soils, such as areas that are wet, clayey, or mucky. A good strategy is to maintain plants and trees along waterways, wetlands, and steep slopes to stabilize soils.



4. Enhance species diversity and structural complexity. As noted previously, forests that have uniform age and a simple canopy structure are less well positioned to adapt to change, and are more vulnerable to single, forest-wide disturbance events. You can use forest management, including timber harvests and noncommercial cutting, to increase the number of species present in the woods and to create more variation in the forest's structure. When considering complexity, analyze the larger landscape: Are there similar or different conditions in adjacent areas to your property? For example, if the surrounding area is mostly mature forest, creating a few canopy gaps can help create landscape diversity and act as steppingstones for certain species.

5. Increase deadwood. Standing dead trees and downed logs promote resilience by protecting soils, retaining water, and cycling nutrients. Plus, deadwood provides food and shelter for many organisms. Try to keep dead trees and logs where they are. Although the best deadwood comes from trees that die of natural causes, you can create more deadwood by felling trees and leaving them in place, pushing them over with equipment to create tip-ups, or girdling them (cutting a ring around the trees but not felling them) if they're situated where they do not pose a hazard to passersby or future management. Think about ways to increase deadwood across a range of species, sizes, and conditions.

6. Manage other stressors. Climate change may make other stressors more impactful. Control or eliminate invasives, and pay special attention to preventing invasives' expansion to new areas. Use dead tree branches or fences to protect young trees from animal browsing, or consider promoting deer hunting.

7. Encourage successful regeneration. Key to forest resilience is ensuring that there are multiple generations of trees in the woods. Retain a diversity of large, healthy trees as a source of pollen and seed for the next generation. Promote

tree regeneration by creating canopy gaps and other conditions necessary for successful seedling establishment. Consult with a forester to select a gap's size based on the forest type, site characteristics, and desired species and consider whether you need to provide certain ground conditions to promote the establishment of some species. If you are struggling to get natural regeneration, you may consider planting trees. If so, talk to a professional about which species to grow and how to acquire them.

8. Promote future-adapted species. As described in the previous article in this series, climate change will affect tree species differently. Consider maintaining and promoting species that are projected to be adapted to future climate conditions. For example, on warm, dry sites, favor species adapted to warmer conditions, such as oaks, hickories, and pines. Retain healthy, vigorous trees already adapted to your site and able to withstand its projected climate impacts. If planting trees, consider including species that might be better adapted to the future conditions of your woods.

9. Protect the rare, unique, and important. In addition to climate change, we are also facing a biodiversity crisis due to habitat degradation and loss. Help to promote biodiversity by protecting rare species, natural communities, or unique landscape features that you have in your woods. You can also use forest management techniques to improve wildlife habitat.

10. Monitor and reevaluate. Climate change will continue to bring more unexpected and extreme events. Keep track of changes in your woods by noting shifts in seasonal events, stressors, and management outcomes. Consider taking photos of certain locations to monitor changes. Utilize available resources and technical assistance, and keep your forest management plan updated or create one with a forester's help.

Conclusions

We live in uncertain times, but there are ways to make decisions that foster forest resilience and adaptation. Adapting forests to climate change involves understanding and managing the unique conditions and characteristics of each forest. By enhancing diversity and complexity in our forests, we can help them continue to provide essential ecosystem services and mitigate climate change impacts. Prioritizing adaptation actions that provide co-benefits to both people and ecosystems will help ensure the sustainability and health of our forests in the face of a changing climate. A growing number of resources are available to support you as you steward your forest into the future.

Special thanks to our reviewer of this article: Samantha Myers, Fellow – USDA Northern Forests Climate Hub and Forest Adaptation Specialist – Northern Institute of Applied Climate Science and the University of Vermont.

Resources

Kosiba AM. 2024. 12 Steps for Climate Resilience: Managing Your Forest with Climate Change in Mind. www.uvm.edu/sites/default/files/UVM-Extension-Cultivating-Healthy-Communities/forestry/Climate_12Steps_Flyer_2024.pdf

Northern Institute of Applied Climate Science. Adaptation Workbook https://adaptationworkbook.org

Keeping Your Woods Healthy in the Years Ahead. 2021. www.uvm.edu/sites/default/files/UVM-Extension-Cultivating-Healthy-Communities/forestry/resources/KeepingYourWoodsHealthy_VT.pdf

Catanzaro P., D'Amato A., and Huff E.S. 2016. Increasing Forest Resiliency for an Uncertain Future. www.uvm.edu/sites/default/files/UVM-Extension-Cultivating-Healthy-Communities/forestry/resources/IncreasingForestResiliency.pdf