Healthy Forests for Our Future:

A Management Guide to Increase Carbon Storage in Northeast Forests

The Nature Conservancy

NIACS Northern Institute of Applied Climate Science

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Introduction

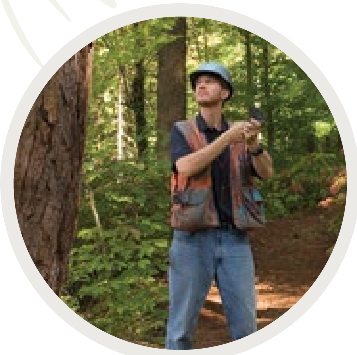
What you do on your land impacts forest resilience and carbon.

As a forest landowner or manager, you know that what you do on your land is important. This is especially true when it comes to climate change. The decisions that you make affect how well your forest can handle droughts, recover from storms, and cope with insect outbreaks, events that are increasing in frequency and severity as the climate changes. This ability to "bounce back" is often called forest resilience. Your decisions also affect climate change by storing more or less carbon in your woods (carbon stocks) and by changing the rate at which carbon is absorbed by your trees (carbon sequestration).

When forests are lost, they can no longer store or absorb carbon. **The most effective thing you can do to impact forest carbon on the land you own or manage is to keep your forest as forest.** This includes planning ahead for what will happen to your forest after you no longer own it.

How you manage your forest is also important. Forests naturally remove carbon from the air. But the amount they store and the length of time they store it largely depends on you. Individual decisions add up, and the collective forest management decisions of people who own and manage private family woodlands are one of the biggest opportunities to remove carbon pollution in the Northeast.

How to use this guide



This management guide, *Healthy Forests for Our Future*, introduces and describes 10 forest management practices designed for hardwood forests in New England and New York. These practices can maintain or increase the carbon that your forest stores within the next two decades, while also increasing your forest's ability to withstand changes in our climate and other threats, such as invasive species. These "climate-smart" forest management practices include practices that:

- Maintain or increase the amount of carbon stored in the forest within a short time frame, and
- Sustain or improve forest resilience (the forest's ability to survive and recover from climate change impacts).

These practices increase the carbon that your forest stores while providing wildlife habitat and increasing your forest's ability to adapt over time.

In this guide, you'll find an explanation of each climate-smart forest management practice; a description of the benefits it provides for storing forest carbon, providing habitat for wildlife, and enabling the forest to adapt; and possible funding sources.

To apply these practices on the ground in your woods, you may want to tap into other resources, including detailed specifications for each practice. To further inform your management decisions and to gain important context, we recommend reading *Forest Carbon: An Essential Natural Solution for Climate Change* and *Increasing Forest Resiliency for an Uncertain Future*, produced jointly by the University of Massachusetts-Amherst and University of Vermont. These excellent resources explain the different carbon pools (places that hold carbon) within forests and the general principles of forest resilience (such as the importance of having a diverse range of tree species and sizes). The list of practices below provides options for you to consider for increasing forest carbon in your forest over the next two decades and helping your forest adapt to climate change, but it is not an exhaustive list.

Forest carbon and wood

Forests have always provided a range of values and benefits to the people, plants, and animals that live in and around them. Two of the important values that forests provide are carbon storage and removal of carbon pollution from the atmosphere. Local, sustainably harvested wood is another important forest value, particularly when it is used instead of more carbon-intensive materials (especially in buildings) or instead of materials transported from far away.

Even after trees are harvested, the carbon that they stored during their lifetimes continues to be stored in their wood. Some of the practices in this guide generate wood in the short term, and others safeguard the future supply of wood products by retaining mature trees of a range of native species or ensuring that new trees grow to take the place of the ones that die or are harvested.

How we built the list

Most of the forests in the northeastern United States are owned by families or individuals. These owners and their forest managers are often interested in managing their woods in ways that increase carbon stocks and build resilience, but there can be an overwhelming amount of advice and information on how to do so.

To help landowners make decisions about their practices, The Nature Conservancy and the Northern Institute of Applied Climate Science led a process to develop a list of climate-smart forest management practices for northern hardwood and oak-hickory forests in southern and central New England and New York, with a focus on carbon benefits. Note that this is not an exhaustive list, and it focuses on developing carbon stocks within a short timeframe of 20 years. We started with a broad set of practices and used the best available science and expert opinions to narrow it to a short list of practices that are most likely to increase carbon stocks within 20 years (and usually much sooner). Input from stakeholders—including foresters, landowners, loggers, scientists, state agencies, and conservation organizations—and carbon modeling were essential to developing the practices you see below. See Appendix A for details on how we developed this list.

Most of the forests in the Northeast United States are owned by families or individuals.

Cost considerations

The practices that follow are grounded in science, informed by stakeholder input, and proven provide carbon and other benefits. They were chosen independently of whether each practice was economically viable, or whether a funding source was available. The practices which involve forest harvest may generate revenue, although retaining more forest carbon may not maximize short-term economic return. However, it is important to note that all of these practices benefit from the help of trained foresters, and several also depend on hiring qualified loggers who might need to spend more time on site to apply best management practices or retain large and diverse trees. Practices such as fencing to keep out deer and moose, planting trees, and removing invasive species also bring costs.

One funding source that can help cover the cost of these practices is the Family Forest Carbon Program, which pays landowners to apply a subset of these climate-smart forest practices on their lands. Forests in the program can range in size from tens to thousands of acres. This program was developed by American Forest Foundation and The Nature Conservancy in recognition of the great capacity of family forests to remove carbon pollution from the air and store it in trees and soils over the next 20 years and beyond. This program is designed for smaller family forest owners who are often unable to access other funding programs that may be more suitable for owners of large forests.

Some of the practices on this list are eligible for payment through programs like the Family Forest Carbon Program that sell carbon credits on the carbon offset markets. If you choose to enter into a carbon offset program, consider the following: 1) Is the payment enabling you to do a different type of forest management than you would have done without it? 2) Are you able to commit to a given practice for the long term? 3) Are you doing the practice exactly as described, and are you willing to have someone come check that this is the case? If the answer to any of those questions is no, you might be better off getting funding from other sources.

Other funds are available from states and the federal Natural Resources Conservation Service to help forest owners carry out good forest management practices. As these costs often vary between states and across forest types, this guide does not list approximate costs of each practice.

Practices such as fencing to keep out deer and moose, planting trees, and removing invasives also bring costs.

Trade-offs

Forests provide many essential benefits, including carbon, but not always in equal proportion. Choosing a strategy for your forest may mean that some benefits are enhanced while others are reduced. These are decisions that every landowner must make, hopefully after a full understanding of the trade-offs.

— *Forest Carbon: An Essential Natural Solution for Climate Change*

Forest management always involves trade-offs. We used multiple lines of evidence—expert opinion, carbon modeling, and field studies—to design these practices to balance the trade-offs between carbon stock benefits and the other values that forest provide. The first eight practices clearly maintain or increase forest carbon stocks within 20 years, while improving forest resilience. The final two practices, *Create gaps to promote regeneration* and *Retain more carbon in a thinning*, involve harvesting trees. Harvesting trees initially reduces the carbon stock in a forest, though this reduction may be somewhat offset by the carbon benefits of the wood that is produced. These two practices can increase forest resilience within 20 years. However, depending on your forest's starting conditions and how much of the forest you harvest, carbon stocks may decrease, stay the same, or increase within this time frame.

Climate-smart forest management practices

Protect forests

1. Avoid forest loss

Grow new trees and forests

2. Green developed areas
3. Reforest
4. Plant trees to increase forest stocking

Reduce stressors

5. Remove invasive vegetation
6. Protect seedlings and saplings from deer browse

Manage forests

7. Increase time between harvests
8. Establish forest reserves
9. Create gaps to promote regeneration
10. Retain more carbon in a thinning

Our hope is that within this list you will find practices that provide climate benefits and fit your forest goals for carbon storage and other values. We recognize that you might want to manage your forest in a way that decreases carbon stocks in the short term, for example to meet a financial need, to produce a certain type of wood product, or to provide habitat for a particular species that interests you. If climate benefits are among your most important goals, Healthy *Forests for Our Future* can help you shape your future forest.

Why planning matters

No matter which practices you choose for your forest, thoughtful, long-term management plans are key to successful forest management. Plans can include information about how you will respond to disturbance (a natural disaster, insect or disease outbreak, drought, or other event that damages or kills many of the trees in the forest), and best management practices to protect soil and water in the forest.

Climate-informed forest access and operations

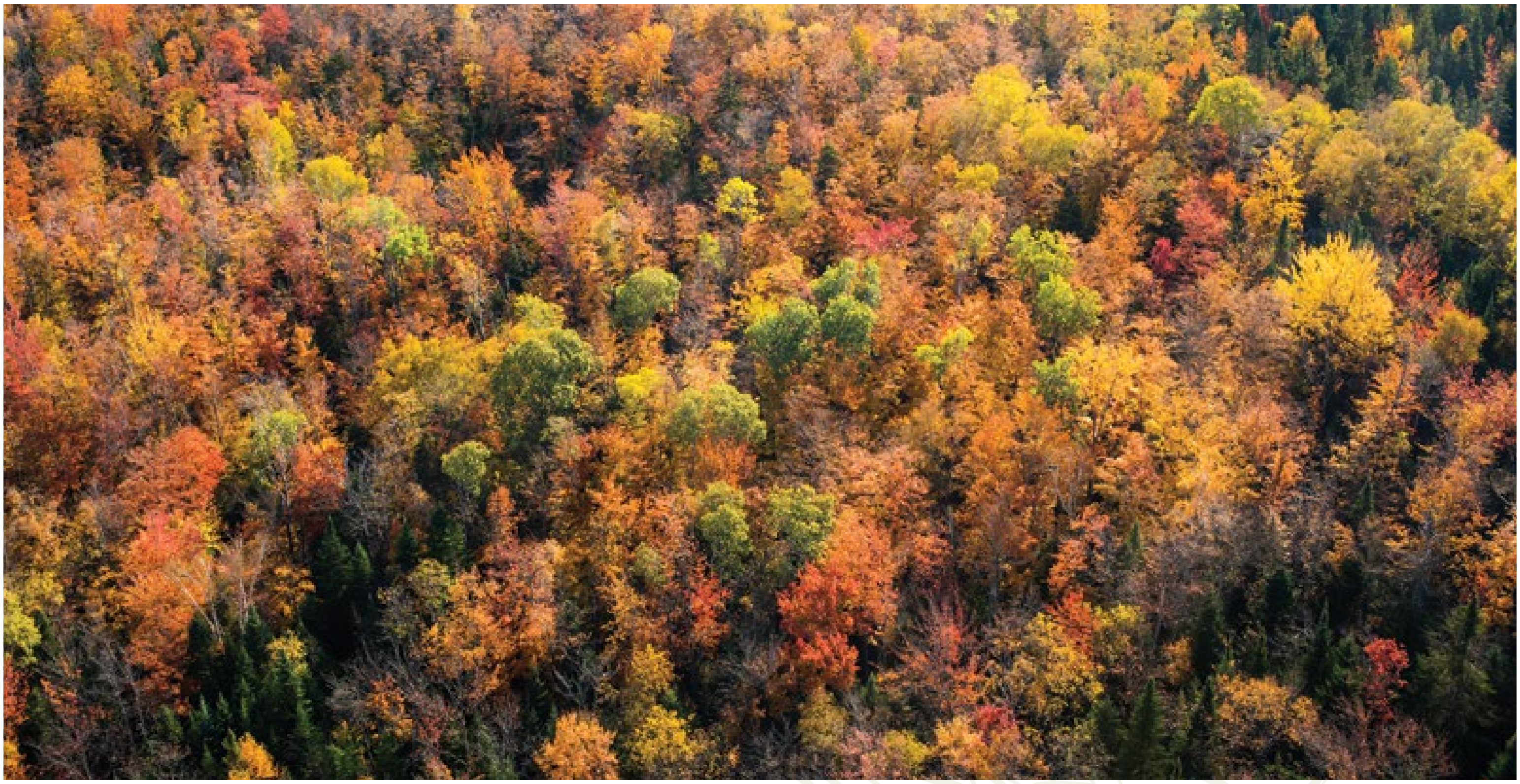
Many forestry practices primarily consider and impact the above-ground portions of forests and trees. It is important to also use best management practices to protect soils and manage the movement of water, no matter what other forest management decisions you make. These practices limit soil disturbance that causes compaction and erosion, and they become even more important given the many effects of climate change. More extreme storms, excessive rainfall, and milder winters with less snow and shorter periods of frozen ground increase the risks of negative impacts to soils that ultimately affect the health and productivity of forests. To take these climate change impacts into account, you can:

- Design forest access roads with larger culverts and additional water bars to accommodate extreme rain events.
- Site access roads so that they are on stable soils, and use timber mats or temporary bridges where appropriate to protect soils during harvests when the ground is not frozen.
- Restore landing sites, temporary roads, and skid trails after harvest—for example, by seeding to stabilize soils and prevent invasive species from growing on the site.
- Retain adequate amounts of slash during harvest (e.g., by leaving at least 25–33% of slash on site).[1] Placement of slash on skid trails during harvest can significantly reduce soil compaction.
- Prevent the introduction and spread of invasive species, for example by washing equipment before and after a forestry operation, and trying not to fill an area with soil taken from another area.

Responding to disturbance

Disturbances shape forests in many important ways. Climate change has increased the frequency, intensity, and duration of natural disturbance events, and this can create significant forest management challenges. As you choose which forestry practices work for you and support your goals for your forest, also consider how you will respond to or plan for a future disturbance such as a windstorm, fire, or insect outbreak that may alter the forest in such a way that it no longer meets your goals. Planning ahead can help you respond quickly, have the needed resources on hand, and manage in a way that bolsters forest resilience. You might also identify trigger points that will cause you to reevaluate and adjust your management goals. For more information about planning ahead for disturbance, see *Forest Adaptation Resources: Climate Change Tools and Approaches for Land Managers*. All of the practices in this guide can help maintain or increase the ability of the forest to bounce back after disturbance.

OPPOSITE PAGE Father and son hiking through the forest and exploring the wonders of nature



PROTECT FORESTS

Avoid forest loss

Description

This practice involves reducing the conversion of forest land to other land uses. Although this practice is focused more on land use than on forest management, we include it here as the first practice in the list because the consequences of forest loss are so significant from a forest carbon and climate adaptation standpoint. In our region, forests are better at storing and absorbing carbon than any other land-based ecosystem, and the loss of forest land each year is a significant source of carbon emissions. Landowners or foresters who are interested in working to avoid loss of a particular forest can consider a range of practices. These might include communicating your intent to keep forest as forest in a management plan or an estate plan, or legally protecting your forest by donating or selling development rights or the land itself to a conservation organization or agency.

Expected Benefits

CARBON: A forest today has taken decades or centuries to store the carbon found within its trees and soils. When forest is converted to another land use, much of this carbon is released into the atmosphere.[2] At least some of this carbon loss is effectively irrecoverable over meaningful time scales.[3] Another reason to avoid forest loss is that it allows forests to continue absorbing carbon each year and storing it in trees and soils.

WILDLIFE: Wildlife species in our region range from being fully dependent on forest habitats to using them at certain times of the year for cover and food. Well-connected forest habitats are a key way to promote biodiversity. Forest loss and fragmentation can reduce habitat quality for wildlife species that depend on large forest areas and reduce the connectivity of forests that allows species to move in response to climate change.

ADAPTATION: Avoiding forest loss sustains the fundamental components of these ecosystems and helps maintains the capacity of forests to adapt to climate change. Healthy, intact forests also help people adapt to changing conditions. For example, forested areas are better able to absorb water from extreme events than developed lands, which helps reduce storm impacts and ensure water quality. Forests also benefit human health by moderating the local climate to reduce the effects of extreme heat, by filtering pollutants from the air, and by promoting mental and social well-being.

Practice Considerations

- Forest protection is a long-term strategy that may continue after you no longer own your land. If you've made the decision to keep a forest you own as forest, communicate this intent in your estate plan and through conversations with family members and any heirs. The *Your Land, Your Legacy* publication can guide these conversations and is available with specific versions for four states: Maine, Massachusetts, New York, and Vermont (see Resources).
- Foresters are often strong advocates for forest protection who manage land across several owners. You can help connect landowners who are interested in this practice to land trusts or land protection agencies, and help them design long-term plans to help the forest remain as forest.
- If you are interested in permanent land protection, contact your local land trust early in the process to find out about opportunities for permanently conserving your land. A list is available from the Land Trust Alliance's site Find a Land Trust.
- It is possible to keep parts of your forest as forest, rather than the whole parcel. For example, if you plan to develop a portion of your land to build a house or other structures, consider whether you could develop a smaller portion of a parcel, or one that is closer to an existing road or structure, and leave the majority of the forest undisturbed.
- Protecting your forest from conversion to another land use protects some, but not all, of the carbon stock from loss. In many ways, making the decision to keep your forest as forest, whether permanently or for the next decade or two, is a first step. Any of the other practices listed in this guide can be done on permanently protected, or unprotected, land.

Potential Funding Opportunities

1. Several Natural Resources Conservation Service practices may support you in avoiding forest loss, including the Healthy Forests Reserve Program (permanent easements, 30-year contracts and 10-year cost-share agreements) and the Conservation Activity Plan Forest Management Plan. Check with your local NRCS technical service provider or Service Center to see what program funds may be available.
2. This practice is included in the New England Forestry Foundation Pooled Timber Income Fund.
3. Each state has its own source of funding and structure for permanent protection of forest land, and many states have current-use tax programs that offer incentives in return for *temporarily* keeping land in forest use. Land trusts or your state forester can help you investigate these programs, which are too numerous to list here.

GROW NEW TREES AND FORESTS

Green developed areas

Description

This practice involves planting and caring for trees or removing barriers to natural forest regeneration (e.g., mowing) to increase the tree cover in developed areas. It is sometimes called urban forestry. Areas where trees can be planted include parks, tree belts along streets, and yards.[4] Unlike the rest of the practices in this document, greening developed areas often involves navigating a complex situation of land ownership, use, and history. This document provides a short summary of benefits, and the Vibrant Cities Lab provides a wealth of resources for working in urban and more developed landscapes.

Expected Benefits

CARBON: Natural ecosystems—including forests, wetlands, and grasslands—contain greater amounts of carbon than paved surfaces, lawns, or other developed land uses.[5] Increasing natural cover increases the carbon storage on the land. Urban trees and forests can have even greater benefits than trees outside urban areas, because they can shade buildings and reduce urban heat, which substantially reduces energy use and the emission of the greenhouse gases that cause climate change.[6,7]

WILDLIFE: Even in densely developed areas, birds, small mammals, and insects use tree cover that is available, and these areas can provide critical areas of refuge within developed landscapes. Urban yards, parks, and forests provide important habitats for many species.

These trees in a park in Brooklyn, New York, offer shade and respite to visitors. © Jonathan Grassi

ADAPTATION: Trees and natural features are increasingly recognized for their ability to absorb and store water, lessening the impacts of extreme rain events and storms across all landscapes and especially in more developed locations. Even small increases in canopy cover can provide shade, reduce urban heat, and reduce damage from extreme events. Importantly, urban ecosystems also improve the physical and mental health of people who live and work nearby, and increase the ability of people to adapt to changing conditions.

Practice Considerations

- When planting, select a diversity of tree species that are adapted for the site.[8] Ensure that trees have adequate soil and room to grow, and use well-trained crews or volunteers to do the planting.
- Plan for long-term care and maintenance of trees, or the benefits may only last a few years.
- As with any forest, plan ahead how to respond to disturbance. Consider when it might be necessary to remove and replant trees, how to handle damage due to a storm or drought, and whether trees will need to be trimmed as they grow larger to avoid damage to power lines and buildings.
- If multiple people or groups own or use the land, engage these community members in urban greening efforts early in the project's development, and integrate their local knowledge and the needs and preferences of the community into the design and implementation of the project.
- Work with the local community to ensure that new trees and green spaces are established collaboratively and in a way that meets the diverse needs of those most impacted by these resources. Community investment throughout the greening process, especially during the planning phase, increases the survival of these trees and green spaces.
- When possible, retain existing healthy trees, since retaining healthy mature trees generally provides greater carbon and adaptation benefits than planting new ones.
- Trees in developed areas can be early indicators of new outbreaks of invasive insects or diseases. If possible, include an annual survey for these novel species in the long-term plan for trees.

Potential Funding Opportunities

1. The Vibrant Cities Lab, a partnership between the U.S. Forest Service, American Forests, and the National Association of Regional Councils, has numerous resources related to finding grants and other funding for greening developed areas.

2. Your state's urban and community forestry program, and your state university extension program, can share information about cost-share and other incentive programs. Most states and some municipalities offer free or low-cost trees to landowners, including the following:

- **Connecticut:** Several cities offer free tree plantings, including New Haven.
- **Maine:** Project Canopy offers funding and sometimes free trees to landowners.
- **Massachusetts:** The Greening the Gateway Cities program offers free tree plantings in 26 cities.
- **New Hampshire:** Free trees are offered to residents of Concord.
- **New York:** New York City residents can request street tree plantings or free trees. Elsewhere in New York state, Trees for Tribs and similar programs offer free trees to landowners.
- **Rhode Island:** Tree cost-share programs are available in Providence.
- **Vermont:** Low-cost trees are sold through community nurseries.

GROW NEW TREES AND FORESTS

Reforest

A volunteer plants a tree at The Nature Conservancy's Neversink Preserve in New York. © TNC

Description

This practice returns tree cover to areas that were historically forested and have the potential to be forest again. Techniques can include planting tree seedlings or saplings, seeding, or changing land management by stopping mowing or other land clearing practices. Successful reforestation is often measured using a performance standard of 350–400 saplings per acre at least 1” in diameter at breast height after 10 years.

Expected Benefits

CARBON: Forests contain greater amounts of carbon than paved surfaces, lawns, or other developed land uses.[9] It takes time for carbon storage to increase due to reforestation, as trees need time to grow. Significant tree growth, and corresponding carbon benefits, may take 10–15 years after seedlings are planted or natural reforestation begins, while soil carbon benefits happen faster. However, with proper site preparation and post-planting maintenance, the benefits to live aboveground carbon pools may be substantial by year 20. Even greater carbon benefits would be expected after this point, as trees accrue carbon above and below the ground, and as leaves and dead wood contribute carbon to the forest floor and soils.

WILDLIFE: Tree planting and natural reforestation in open areas can benefit many different wildlife species over time, first providing habitats to species that rely on young forest. Increases in forest cover can reduce soil erosion and improve water quality, both of which can benefit aquatic species. Depending on which tree species are planted or promoted, there may be benefits for pollinators as well. Over time, planting and reforestation can provide additional benefits to wildlife, particularly forest bird species, by increasing species diversity. Reforested areas that are located adjacent to existing forests increase forest connectivity, which allows for wildlife movement and dispersal across the landscape.

ADAPTATION: Reforestation restores fundamental ecosystem processes that support climate adaptation in the surrounding landscape. Increasing forest vegetation can lessen the impact of extreme storms by intercepting and storing rainfall, thereby reducing flooding, soil erosion, and nutrient runoff into streams. Reforestation activities can also help people adapt to changing conditions since forests moderate temperatures, filter pollutants from the air, and promote mental and social health. Incorporating tree species that have not been historically present but are expanding their range within or into the region can improve adaptive capacity by helping to fill ecological niches that are being vacated by species in decline; this practice is referred to as assisted migration or assisted range expansion.[10]

Practice Considerations

- Engage community members in reforestation efforts on lands that are used by the public early in the project's development, and integrate their local knowledge and the needs and preferences of the community into the design and implementation of the project.
- Consider cost and likelihood of success when deciding whether to use natural reforestation (e.g., stopping mowing), seeding, or tree planting. Plan for annual care and maintenance of trees until they are established.
- For sites where tree planting is the best option, note that tree planting stock comes in many sizes, ranging from plugs to bare-root stock to potted containerized material. In general, larger potted material is more expensive, but has higher survival. Bare-root trees generally need to be planted in spring. Refer to planting guides such as this one from Pennsylvania for more information.[11]
- If you are planting trees, select plants to match management goals and local site conditions, considering both current and anticipated future conditions.
    - Select tree species that are adapted to future climate conditions or that perform well across a wide range of conditions.[8]
    - Obtain trees or seeds locally or from a licensed nursery when possible.
- Prepare sites for planting to ensure success. This may include mowing, cutting brush, or applying herbicide treatments. Manage invasive and competing vegetation as appropriate. (See climate-smart practice #5, *Remove invasive vegetation*.)
- In areas subject to deer browse and other wildlife damage, use tree shelters, fencing, or other methods to protect seedlings from damage. (See climate-smart practice #6, *Protect seedlings and saplings from deer browse*.)
- Consider a performance standard as a way to measure success and create a target for density and height of trees. Vermont's Use Value Appraisal program defines successful regeneration of a forest as having 350 tree seedling stems per acre after five years,[12] while 400 tree seedling stems per acre are often considered a measure of success for forests that have regenerated after a disturbance.[13] Seedling densities are even higher in earlier years. Sapling height of over five feet can also be a useful measure of success, as this is generally above the deer browse line.

Potential Funding Opportunities

1. Several Natural Resources Conservation Service practices may support reforestation efforts, including: tree/shrub establishment, riparian forest buffers, tree/shrub site preparation, and planting for high carbon sequestration rate. Check with your local NRCS technical service provider or Service Center to see what program funds may be available.
2. State programs, such as New York's Trees for Tribs, may provide funding for reforestation in targeted locations (such as riparian areas).

Tree seedlings are planted in the understory of a northern hardwood forest. © Peter Clark

GROW NEW TREES AND FORESTS

Plant trees to increase forest stocking

Description

This practice involves planting climate-adapted tree species in forests that are understocked, have recently been harvested, or do not have sufficient regeneration to replace canopy trees. Climate-adapted tree species are defined here as native tree species that are suitable to the location and have traits that suggest they will grow well across a range of anticipated climate conditions. They are also tree species that may not currently be present locally but are projected to grow well under future climate conditions.

Expected Benefits

CARBON: Increasing the density of trees in understocked forests to levels suitable for that forest type increases aboveground carbon stock as trees grow and mature. Planting seedlings and saplings in the understory also increases carbon stocks by ensuring that there is sufficient regeneration to replace larger canopy trees over time. Note that planting trees in a forest that already has adequate stocking is unlikely to result in carbon benefits, and planted trees may not survive.

WILDLIFE: Increasing stand densities through tree planting adds to the vertical structure of forests, adding to trees in the mid-canopy that provide additional habitat for wildlife. Plantings can also be used to increase tree species diversity, which enhances wildlife diversity. Planting particular tree species, such as species that produce nuts or acorns, can increase food or habitat for a given wildlife species of interest.[10, 14]

ADAPTATION: Forests with greater species and structural diversity generally have greater resilience because there are more pathways for systems to respond in the wake of change and disturbance.[15,16] Incorporating tree species that have not been historically present but are expanding their range within or into the region can improve adaptive capacity by helping to fill ecological niches that are being vacated by species in decline; this practice is referred to as assisted migration or assisted range expansion.[10] Increasing tree density will not have equal benefits in all forests. In particular, forests susceptible to drought or fire may be more resilient at lower densities.[15]

Practice Considerations

- Before applying this practice, determine whether your forest is understocked and may benefit from tree planting.
- Select plants to match management goals and local site conditions, considering both current and anticipated future conditions.
  - Select tree species that are adapted to future climate conditions or that perform well across a wide range of conditions.
  - Use tree species lists to identify species that are expected to persist or increase in a particular region.[8]
  - Consider the shade tolerance of the species you choose.
- Manage invasive and competing vegetation as appropriate. (See climate-smart practice #5, *Remove invasive vegetation.*)
- In areas subject to deer browse and other wildlife damage, use tree shelters, fencing, or other methods to protect seedlings from damage. (See climate-smart practice #6, *Protect seedlings and saplings from deer browse.*)
- Obtain trees through a licensed nursery or locally when possible.
- Tree planting stock comes in many sizes, ranging from bare-root stock, to plugs, to potted containerized material. See climate-smart practice #3, *Reforest,* for a discussion of different survival rates and costs.
- Nursery stock is limited. To make the best use of this limited resource, focus planting in forests that are likely to benefit from the practice. In other words, choose forests that are understocked, have been recently harvested or impacted by a natural disturbance, have insufficient regeneration, or are dominated by species that are in decline or likely to soon decline due to climate changes, insect infestations, or disease outbreaks.
- Avoid planting any invasive species or plants known to be highly competitive/aggressive in natural communities. *The Invasive Plant Atlas of New England (IPANE/EDDMapS)* lists and describes invasive species in this region.

Potential Funding Opportunities

1. Several Natural Resources Conservation Service practices may support planting of trees to increase forest stocking, including tree/shrub establishment and tree/shrub site preparation. Check with your local NRCS technical service provider or Service Center to see what program funds may be available.

REDUCE STRESSORS

Remove invasive vegetation

Description

This practice removes invasive and competing vegetation using physical or chemical treatments. Its goal is to promote tree regeneration and improve the survival and growth of tree seedling and saplings. It should be conducted in areas with moderate to heavy infestations of invasive vegetation, especially areas with over 30% invasive plant cover that have the potential for regeneration failure. The practice is often used to help protect planted trees or ensure regeneration following a timber harvest. By reducing and maintaining the cover of invasive and competing vegetation below a threshold (~10%), it can enable tree seedlings to reach the sapling size class.

Expected Benefits

CARBON: When invasive and competing vegetation is so dense that it prevents the growth or survival of tree seedlings and saplings, there is not sufficient tree regeneration to replace larger trees as they die. An area covered by invasive vegetation likely has a relatively small amount of stored carbon in it, but not as much as if that area was stocked with a diverse mix of seedlings and saplings with the potential to grow into mature trees. This practice increases carbon stock by increasing the density and growth of understory trees. It also increases carbon stocks by ensuring that there is sufficient regeneration to replace larger canopy trees over time. It may take 15 or more years for substantial carbon stock benefits to be realized.[13]

Mile-a-minute vine covers a highly degraded stand. © American Forest Foundation

WILDLIFE: Removal of invasive plants benefits native plant species and increases habitat values for wildlife and pollinators.[17,18] In riparian areas and on slopes, removing invasives and restoring native plant communities can also reduce soil erosion, sedimentation of streams, and degradation of aquatic habitat.[19]

ADAPTATION: Climatic changes such as warmer temperatures, earlier springs, and reduced snowpack are expected to benefit invasive plant species.[20, 21, 22, 23] Forests that have experienced an increase in other disturbances are especially susceptible to high levels of colonization by invasive plant species. Invasive plants can limit or prevent the growth of tree seedlings and saplings, reducing the density and diversity of tree species, and could hinder other management goals.[24, 25] The removal of invasive species can support the growth of seedlings and saplings of a diverse set of tree species, which is essential for maintaining and improving forest resilience over time.

Practice Considerations

- The *Invasive Plant Atlas of New England (IPANE/EDDMapS)* lists and describes invasive species in this region.
- Many invasive and competing plants can out compete native tree species when light and growing space are readily available. For that reason, this practice is often carried out before and/or after timber harvests. Stands with >30% cover of invasive/competing vegetation risk regeneration failure.[26]
- Even if vegetation is controlled, a site with other limiting factors, such as high levels of deer browse, may still suffer regeneration failure.[27] Consider pairing this practice with climate-smart practice #6, *Protect seedling and saplings from deer browse*, if necessary.
- Reduce the cover of invasive/competing vegetation by 85–100% to promote regeneration. You may need to do multiple treatments over consecutive years to achieve the management objective.
- Treatments may include mechanical (e.g., severing the plant at the ground), chemical (e.g., basal spraying of herbicide), and/or a combination of the two ("hack and squirt").
- Chemical treatments can be applied safely, and in some cases may be the most effective treatment available. When you are using herbicides, be sure to apply chemicals according to the chemical label and to follow state and local regulations. If possible, seek the advice of a professional specialized in invasive plant removal or ecosystem restoration. This is particularly important if your forest contains wetlands or streams near the site being treated.
- Minimize damage of native tree species during treatment to advance regeneration. When possible, avoid broadcast applications of herbicide, except where desirable vegetation is non-existent or can be protected by using a selective herbicide or application method.
- Follow best management practices for your state, if they exist (for example, Massachusetts has specific best management practices for invasives).[28]

Potential Funding Opportunities

1. This practice is included in the Family Forest Carbon Program in some but not all regions.
2. Several Natural Resources Conservation Service practices may support removal of invasive and competing vegetation, including herbaceous weed treatment, herbaceous weed treatment to create desired plant communities, brush management, forest stand improvement, woody residue treatment, and prescribed burning. Check with your local NRCS technical service provider or Service Center to see what program funds may be available.
3. This practice is included in New England Forest Foundation's Pooled Timber Income Fund.
4. The Regenerate New York Forestry Cost Share grant program provides funding for this practice in New York. Other states also offer grants as funding allows.
5. Regional groups sometimes called Cooperative Invasive Species Management Areas (CISMAs) or Partnerships for Regional Invasive Species Management (PRISMs), depending on the state] may have funding to help landowners control invasive vegetation. They can offer resources for identifying invasives and determining whether they are a threat to the forest.

Protect seedlings and saplings from deer browse

Description

This practice reduces the impacts of deer and other wildlife browse to promote tree regeneration and growth. Activities include fencing and installing tree shelters to eliminate or reduce seedling and sapling damage and mortality from deer browsing. The goal is to enhance the survival and growth of desired tree and planted seedlings, generally aiming to establish 400 saplings with a 1" diameter at breast height per acre, 10 years after trees are planted or begin to grow.

Expected Benefits

CARBON: Protecting regenerating tree seedlings and saplings from deer long enough for them to grow too tall to be browsed increases carbon stocks in the understory. It also increases carbon stocks by ensuring that there is sufficient regeneration to replace canopy trees as they die. It may take 20 years for regeneration to reach larger size classes[13] and for measurable carbon benefits to be realized. In areas with heavy deer browse, failing to protect regeneration can reduce or even eliminate these seedlings and saplings from the forest.

WILDLIFE: Herbivory can reduce understory plant diversity and simplify forest structure, which reduces the number of habitats available to birds and other species.[29,30]

ADAPTATION: Because herbivores preferentially browse on particular species, protecting regeneration from deer browse, especially tree species that are expected to do well under future climate conditions, may increase tree species diversity. Herbivory can affect forest composition and structure and may generally limit the ability of forest ecosystems to respond to climate change[29] and recover from disturbances. Thus, reducing the impacts of deer herbivory also reduces the impacts of other ecosystem stressors on trees, such as drought, non-native earthworms, and invasive species.[30, 31]

Practice Considerations

- Assess browse intensity and level of impact to forest regeneration to determine whether this practice is needed. There are several methods and protocols to assess impact[32] and seedling growth.[33] Generally, tree seedlings in areas with moderate to high browse impact will benefit from protection from herbivory to meet forest stocking objectives.

Deer fencing © Chris Zimmerman/TNC

- Assess impacts both on tree species that are preferred by deer, and on less-preferred species. Consider the density and height of these seedlings and saplings.
- It is especially important to assess browse impact prior to a timber harvest or treatment that will create gaps in the forest canopy.
- This practice involves the use of tree shelters, exclusion fencing, or small cages. These methods reduce browse damage from deer and improve the growth of hardwood forest regeneration.[34]
    - Generally, tree shelters are more cost effective for smaller areas (<3 acres), while deer exclusion fences are more effective for larger areas (>3 acres).[35] It depends on the cost of tree shelters, fencing, installation, and maintenance.[36]
    - Tree shelters can be solid-walled shelters or fabric/mesh sleeves. Tree shelters should be at least 4 feet tall and can be secured with a stake.
    - A mesh sleeve, wrap, or cage may be most effective for larger seedlings that are more than 2 or 3 feet tall.[37]
    - Note that if rodent (rabbit, mouse, etc.) browse is problematic in your forest, it may be best to use solid tree shelters.
    - Woven wire or polypropylene (plastic) fencing should be 8 feet tall and secured with posts.[38] Electric fencing can also be effective.
- When you are placing tree shelters around existing seedlings, try to protect a diversity of tree species, and include species that are projected to do well under future climate conditions.
- Monitor the success of seedling and sapling growth and density over time. Generally, by year five there should be ~2,000 tree seedlings per acre, and by year 10, there should be about 400 saplings of about 1" in diameter at breast height per acre.[13]
- There are other methods to address deer browse and damage, but they are outside the scope of this document. Deer hunting programs can be an economical way to control and prevent deer damage, but their effectiveness varies depending on deer populations and the scale and intensity of the program. Slash walls use low-value or non-merchantable trees and branches to form barriers around regenerating stands; early studies suggest that they are capable of excluding deer for a decade or more while the young trees grow beyond their reach.[39]

Potential Funding Opportunities

1. Several Natural Resources Conservation Service practices may support efforts to protect seedlings and saplings from deer browse, including tree/shrub establishment and riparian forest buffers These generally only cover part of the cost for tree shelters for planted seedlings, not natural regeneration. Tree/shrub site preparation and fencing are additional relevant practices. Check with your local NRCS technical service provider or Service Center to see what program funds may be available.
2. The Regenerate New York Forestry Cost Share grant program provides funding for this practice in New York. Other states also offer grants as funding allows.

MANAGE FORESTS

Increase time between harvests

Description

This practice delays the harvest of commercially viable stands of trees, allowing them to grow for at least 10 additional years, during which they continue to store carbon. After this time, they are harvested using techniques designed to maintain those carbon gains. This approach is often referred to as extended rotation because it increases the time between harvests, resulting in a longer than typical rotation length. This practice requires developing or modifying a forest management plan. The decision about when to harvest influences carbon stock, resilience, and composition of the next forest.

Expected Benefits

CARBON: Delaying harvesting promotes the growth of large trees and increases the amount of carbon in the live, aboveground carbon pool over time.[40] This carbon stock increase can be temporary, if the same amount of wood is removed later, or long term, if some trees are retained permanently or if the delay in harvest allows them to grow into larger, higher quality trees that are used in long-lived wood products such as furniture. As trees die and fall, delaying harvest also can increase the downed wood carbon pool.

Mature trees form a canopy overhead. © Todd Ontl, NIACS

WILDLIFE: Many forests in the Northeast region lack large-diameter trees, snags, and large downed logs. A number of bird species and other cavity-dwelling wildlife use snags for nesting, while large downed logs are habitat for salamanders and other wildlife species. This practice grows large-diameter trees, retains snags, and recruits large downed logs, benefiting many species that are dependent on mature forest conditions.

ADAPTATION: Extending the time between harvests may maintain or increase the resilience of forests that are already healthy, particularly where there are few current or expected stressors. Over time, forests tend to develop a more complex and diverse structure and include areas at various stages of forest succession that add to the overall species diversity. These increases in structural and species diversity may bolster resilience by offering more pathways for ecosystems to respond to disturbances.[15,41] Increases in downed wood and litter may retain soil moisture and nutrients.

Practice Considerations

- Consider the starting condition of your forest. If it is degraded and dominated by trees with poor growth form, or if it is severely under- or overstocked, this practice may not yield the desired benefit. Consider how your forest scores on various resilience checklists[42] and forest health scorecards to decide whether this practice is a good fit.[43]

- Forests that are heavily impacted by forest pests or pathogens, or that are near heavily impacted forests, may benefit from a more active form of management.

- Forests that are highly vulnerable to disturbance (e.g., on a ridgetop), composed of trees that are nearly all the same age or size, or dominated by short-lived tree species may also not yield the desired benefit from this practice.

- A forest management plan should contain specific management objectives for the stands where this practice is being applied. In other words, because this practice is not appropriate for all stands, it works best when it is part of a deliberate, long-term plan, rather than taking the form of benign neglect. In particular, design any future harvest so that it does not reverse the carbon stock increases that resulted from this practice.

Potential Funding Opportunities

1. This practice is included in the Family Forest Carbon Program.

2. The Natural Resources Conservation Service Conservation Activity Plan forest management plan may provide funding for writing a plan for a given conservation need that includes delaying harvest, in certain situations. Check with your local NRCS technical service provider or Service Center to see what program funds may be available.

3. Many states' current use tax programs (e.g., Massachusetts) allow for a delay in harvesting if necessary to improve the forest condition.

4. Many states have forest stewardship programs or other programs that help cover the cost of writing a management plan and considering the right timing of a harvest.

MANAGE FORESTS

Establish forest reserves

Description

This practice avoids the harvest of trees and allows indefinite continued tree growth and carbon storage. Establishing reserves is defined here as the long-term or permanent setting aside of areas without commercial timber harvest; it is different from practice #7, *Increase time between harvests,* which involves avoiding harvest for a single management cycle (10 years).

It is important to mark reserve areas, communicate the intent to create a reserve through a management plan and even to heirs to the land, and allow exceptions for tree removals in response to novel forest pest and pathogen outbreaks. Reserves can cover an entire parcel, or they can be part of a forest parcel where the desired future condition is to have older, larger trees and complex features such as abundant downed wood.

Expected Benefits

CARBON: In forest reserves, existing live carbon stocks are left to grow. This practice increases stocks in the aboveground carbon pool as the forest continues to grow each year, and increases carbon pools such as downed wood and soil carbon as trees die and fall.

WILDLIFE: Many forests in the Northeast region are lacking large-diameter trees, snags, and large downed logs. A number of bird species and other cavity-dwelling wildlife use snags for nesting, while large downed logs are habitat for salamanders and other wildlife species. This practice grows large-diameter trees, retains snags, and recruits large downed logs, benefiting many species that are dependent on mature forest conditions.

This forest reserve is in New Hampshire's Great Bay Region © Joanne Glode

ADAPTATION: Forgoing forest harvests may maintain or promote resilience in forests that are already healthy, particularly where there are few current or expected stressors. Over time, forest reserves tend to develop a more complex and diverse structure and include areas at various stages of forest succession that add to the overall species diversity. These increases in structural and species diversity may bolster resilience by offering more pathways for ecosystems to respond to disturbances.[15,41] Increases in downed wood and litter may retain soil moisture and nutrients.

Practice Considerations

- Forest reserves are sometimes referred to as being under "active passive management" to reflect that this was a deliberate decision to eliminate harvest, and to continue that practice for many years, rather than to simply not harvest for a decade or two.
- The decision to establish reserves means that the forest will not produce wood products, which has carbon and other consequences, detailed in the introduction to this guide.
- Forests that are dependent on fire, or are unhealthy and in need of restoration (for example, old plantations, forests with no advanced regeneration, or forests heavily impacted by pests and pathogens), are not the best fit for this practice.
- Many states have conservation maps or plans that suggest areas which may be appropriate for forest reserves, such as existing old-growth forests, untilled forest soils, land that is adjacent to an existing, permanently protected forest reserve, or climate refugia (lands relatively buffered from climate change impacts, where valued species and natural communities can persist over time).
- If part of the reason for establishing a reserve is to reach a future condition that includes old trees and other characteristics of older forests, consider siting forest reserves in areas that already contain some of these features (e.g., multiple large-diameter trees of at least 25" in diameter at breast height,[44] well-developed understory with sufficient regeneration to replace the overstory, or an abundance of snags, especially those of at least 10" in diameter at breast height).[1]
- Forest reserves generally prohibit harvesting except in certain circumstances. It is important to identify and include these circumstances in your management plan. They may include treatment of invasive plants, harvesting to control a novel pest or a pathogen outbreak that is new to the area, or removal of trees that are a hazard to recreational users of the reserve. Salvage logging is generally not included in this practice.
- Clearly mark boundaries and consider other marking systems (such as "L" for legacy) to help ensure that a reserve is not inadvertently harvested. It is important to communicate the intent to manage a forest as a reserve in a management plan and potentially an estate plan.

Potential Funding Opportunities

1. Several Natural Resources Conservation Service practices may support the establishment of reserves, including the Healthy Forests Reserve Program (permanent easements, 30-year contracts, and 10-year cost-share agreements) and the Conservation Activity Plan Forest Management Plan. Other relevant practices may include restoration of rare or declining natural communities, fencing, brush management, and access control. Check with your local NRCS technical service provider or Service Center to see what program funds may be available.
2. Land trusts in the region may be interested in protecting land and managing it as reserve in certain areas. For example, the Northeast Wilderness Trust focuses on forest reserves.

MANAGE FORESTS

Create gaps to promote regeneration

Description

This practice creates gaps in the forest canopy by harvesting groups or patches of trees to promote regeneration while retaining large-diameter trees in the harvested areas. In general, this practice is applied to mature stands. To maintain carbon stocks over the 20-year period following implementation, no more than 20% of a stand is harvested, and intact forest is retained in the remaining 80%. Gaps in the canopy mimic natural disturbance and provide sufficient light to promote rapid seedling and sapling growth into larger size classes, while retention zones and retained large-diameter trees, snags, and downed wood in gaps limit impacts to carbon stocks following harvest.

Expected Benefits

CARBON: This practice results in a short-term decrease in forest carbon stocks, but it is generally expected to regain the carbon removed during harvest within 20 years in healthy forests. Importantly, carbon stocks may increase by only a small amount, or may even decrease overall if this practice is not sited and applied carefully. Creating gaps to open up light and growing space increases the density and growth of understory trees in the aboveground carbon pool, and ensures that there is sufficient regeneration to replace larger trees as they die. Retaining large-diameter trees, snags, and downed wood throughout the stand retains much of the existing above-ground carbon stock and allows for continued increases in the downed wood and soil carbon pools over time.

WILDLIFE: Gap creation increases structural complexity by creating a range of tree size and age classes, which helps provide a more diverse array of habitats for many birds and other wildlife species. For example, the increased sunlight in gaps allows more vegetation to grow in the forest understory and midstory, which provides more forage opportunities for herbivores and increases cover for many forest bird species. In many forests in the region, the downed wood pool is comparatively small. This practice retains large-diameter trees, snags, and downed wood that adds habitat for a number of bird species and other cavity-dwelling wildlife over time.

ADAPTATION: Forests with greater species and structural diversity generally have greater resilience because there are more pathways for systems to respond to change and disturbance.[15,16] Larger forest

Gaps (~1 acre in size) were created at the Nature Conservancy's Tug Hill Conservation Area. © Brian Roat/TNC openings allow a greater variety of light conditions and can foster regeneration of a greater diversity of tree and plant species. Gaps can create the conditions that some tree species need to grow (naturally or through planting), such as oak and hickory species.

Practice Considerations

- Gap or patch size generally ranges up to 2 acres, to help a diversity of tree species grow while maintaining sufficient seed sources.[45, 46] In some circumstances, patches may be larger.
- Within gaps, retain at least four of the largest diameter live trees per acre (ideally trees that are at least 14" in diameter at breast height). Retain trees that maintain or increase tree species diversity within the forest. The larger the gap, the more important it is to retain some of the live trees.
- Retain snags and downed wood, even in gaps.
- This practice may be most appropriate in relatively mature forest stands with low browse impact and invasive/competing vegetation cover.
- Assess the density of advanced regeneration pre-harvest, and if advanced regeneration is lacking, make a plan to promote or plant tree seedlings of desirable species.
- Protecting regeneration can be important in forest stands that have moderate to high deer or moose browse impact. In some instances, even moderate browse can move the regeneration toward higher proportions of beech, striped maple, and ferns and can possibly cause regeneration failure. (See climate-smart practice #6, *Protect seedlings and saplings from deer browse.*)
- It is especially important to control invasive or competing vegetation before (and, if needed, after) doing this practice. Stands with more than 30% cover of invasive/competing vegetation risk regeneration failure.[26] (See climate-smart practice #5, *Remove invasive vegetation.*)
- The *Silvicultural Guide for Northern Hardwoods in the Northeast* provides parameters for marking the location of gaps or patches in the stand.[47] Consider locating the harvested patches in areas where trees have poor growth form or are impacted by a disease or pest.

Potential Funding Opportunities

1. This practice is commercially viable in many stands, generating income through the sale of the removed wood.
2. This practice is included in the Family Forest Carbon Program.
3. Several Natural Resources Conservation Service practices may support creating gaps to promote regeneration, including the Conservation Activity Plan forest management plan, forest stand improvement, forest stand improvement to rehabilitate degraded hardwood stands, creating structural diversity with patch openings, woody residue treatment, reduce forest stand density to create open stand structure, increase on-site carbon storage, and crop tree management for mast production. Check with your local NRCS technical service provider or Service Center to see what program funds may be available.
4. This practice is compatible with (but not funded by) New England Forestry Foundation's Exemplary Forest standards, and Massachusetts, Vermont, and New York Audubon's Foresters for the Birds program.

MANAGE FORESTS

Retain more carbon in a thinning

Description

This practice involves thinning a forest to produce carbon benefits by retaining and improving the growth of the larger diameter trees, limiting the number of trees removed, retaining snags and downed logs, and leaving a portion of the forest unharvested (retention zones). Several intermediate thinning treatments could be applied under this practice, including thinning from below by removing mostly suppressed and intermediate trees, and crop tree release that frees up growing space on three or four sides around the best trees. Forests that are understocked are generally not suitable for thinning. Thinning reduces stand density and results in an initial reduction in carbon stock, but when sited and applied carefully, it can maintain or increase carbon stock over a 20-year period.

Expected Benefits

CARBON: This practice results in a short-term decrease in forest carbon stocks, but is generally expected to regain the carbon removed during harvest within 20 years in healthy forests. Importantly, carbon stocks may increase by only a small amount, or may even decrease overall if this practice is not sited and applied carefully. Removal of the poorest quality trees increases growing space for the remaining trees and allows increases in the aboveground carbon pool. Retaining large-diameter trees, snags, and downed wood throughout the stand retains much of the existing above-ground carbon stock and allows continued increases in the downed wood and soil carbon pools over time.

This thinned forest is in Amherst, Massachusetts. © Anthony D'Amato

WILDLIFE: Thinning increases the growth and size of the remaining trees, creating a range of tree size and age classes, which helps provide a more diverse array of habitats for many birds and other wildlife species. In many forests in the region, the downed wood pool is comparatively small. This practice retains large-diameter trees, snags, and downed wood that adds habitat for a number of bird species and other cavity-dwelling wildlife over time.

ADAPTATION: This practice can improve the overall health of the forest by removing diseased trees and reducing tree competition for resources in overly dense forests. Thinning can improve forest resilience to drought and increase wind firmness to reduce the risk of damage from extreme events. Thinning may increase resilience by improving growth of the residual larger trees, and increasing vigor and health of the stand including resistance to pests and pathogens.[48] Depending on what species are available, this practice can also promote tree species that are expected to be better adapted to future conditions.[41]

Practice Considerations

- It is important to understand the current forest stocking level before applying this practice. Generally, this practice is most appropriate for stands that are neither understocked nor overstocked. One guideline is to apply this practice in stands that are no lower than 90% of the A line using the stocking guide in the appropriate silvicultural guide.[47]
- Remove no more than 25% of the current basal area over a 20-year timeframe. The basal area removed should include both dead and live trees. This removal is roughly equivalent to reducing stand stocking to halfway between the A and B line for a fully stocked stand.[47]
- Aim to increase the average stand diameter and improve the quality of the post-harvest stand.
- Retain the largest diameter trees (of a diverse mix of species) and downed logs and snags.
- Generally, mark trees for vigor, quality, species composition, and the potential for regeneration, using the appropriate silvicultural guide.[47]
- Retaining 25–50% of the forest stand in unharvested retention zones will help to increase carbon stocks over a 20-year period. If it is critical to make up carbon losses within 20 years, remove less than 25% of the current basal area in harvested areas and retain a significant portion (50%) of the stand in no-harvest retention zones. However, if the goal is to balance carbon with other benefits, such as short- and long-term income and forest resilience, then retention zones may not be necessary.

Potential Funding Opportunities

1. This practice is commercially viable in many stands, generating income through the sale of the removed wood.
2. This practice is included in the Family Forest Carbon Program.
3. Several Natural Resources Conservation Service practices may support retaining more carbon in a thinning, including the Conservation Activity Plan forest management plan, forest stand improvement, forest stand improvement to rehabilitate degraded hardwood stands, increase on-site carbon storage, and crop tree management for mast production. Check with your local NRCS technical service provider or Service Center to see what program funds may be available.

RESOURCES

A pdf version of this document with hyperlinks to many of the listed resources and funding programs is available at nature.org/climatesmartforestsne.

This page also contains supplemental information, including carbon modeling data and updated lists of funding opportunities.

In addition to the many documents and websites cited in this guide, we recommend the following resources, which provide valuable additional context for applying climate-smart forest management practices in your woods.

FOREST CARBON

These two documents by the University of Massachusetts-Amherst and University of Vermont Extension programs are valuable starting points when thinking about managing forests for carbon and resilience, or when learning more about these forest values.

“Forest Carbon: An Essential Natural Solution for Climate Change”
https://masswoods.org/sites/masswoods.org/files/Forest-Carbon-web_1.pdf

“Increasing Forest Resiliency for an Uncertain Future”
https://masswoods.org/sites/masswoods.net/files/Forest-Resiliency.pdf

This Massachusetts Department of Conservation and Recreation publication walks landowners through the basics of forest carbon, general ways to increase carbon storage, and how to make decisions about their land.

“Caring for Your Woods: Managing for Forest Carbon”
www.massaudubon.org/content/download/48719/1280285/version/1/file/DCR5_CARBON_MANAGEMENT_61521.pdf

This U.S. Forest Service technical report explains carbon pools and cycles, tradeoffs in carbon management, and the general practices that can increase carbon in forests.

“Considering Forest and Grassland Carbon in Land Management”
https://www.fs.usda.gov/treesearch/pubs/54316

 OPPOSITE PAGE Dave Long Media/Getty Images

KEEPING FOREST AS FOREST

The Land Trust Alliance provides a partial listing of national, state, and local land trusts lists that are Alliance members. It is a good starting point if you are interested in contacting a land trust to learn more about or beginning the process of permanently protecting your forest land. www.findalandtrust.org

To learn more about protecting your land for the future, read *Your Land, Your Legacy*, available in versions for four different states.

- Maine: www.mainewoodlandowners.org/legacy-planning
- Massachusetts: www.masswoods.net/legacy
- New York: www.yourlegacyny.org
- Vermont: https://ourvermontwoods.org/resources/your-land-your-legacy-planning-every-vermont-landowner

CLIMATE-SMART FOREST MANAGEMENT

The Climate Change Response Framework is a collaborative, cross-boundary approach among scientists, managers, and landowners to incorporate climate change considerations into natural resource management. Resources include climate-informed tree species lists, vulnerability assessments, and an Adaptation Workbook to support planning. www.forestadaptation.org

This journal article explores how various types of forest management can be climate-smart.

> "Improved Forest Management as a Natural Climate Solution: A Review"
> https://www.fs.fed.us/nrs/pubs/jrnl/2021/nrs_2021_kaaeakka_001.pdf

Many states and organizations are in the process of developing climate-smart forest practices for their region, such as New England Forestry Foundation's Exemplary Forestry.

> https://newenglandforestry.org/learn/initiatives/exemplary-forestry/

This publication describes planning ahead for disturbance.

> "Forest Adaptation Resources: Climate Change Tools and Approaches for Land Managers"
> https://www.fs.usda.gov/treesearch/pubs/52760

The Northeast Regional Invasive Species and Climate Change Management site provides information about the intersection between climate change and invasive species.

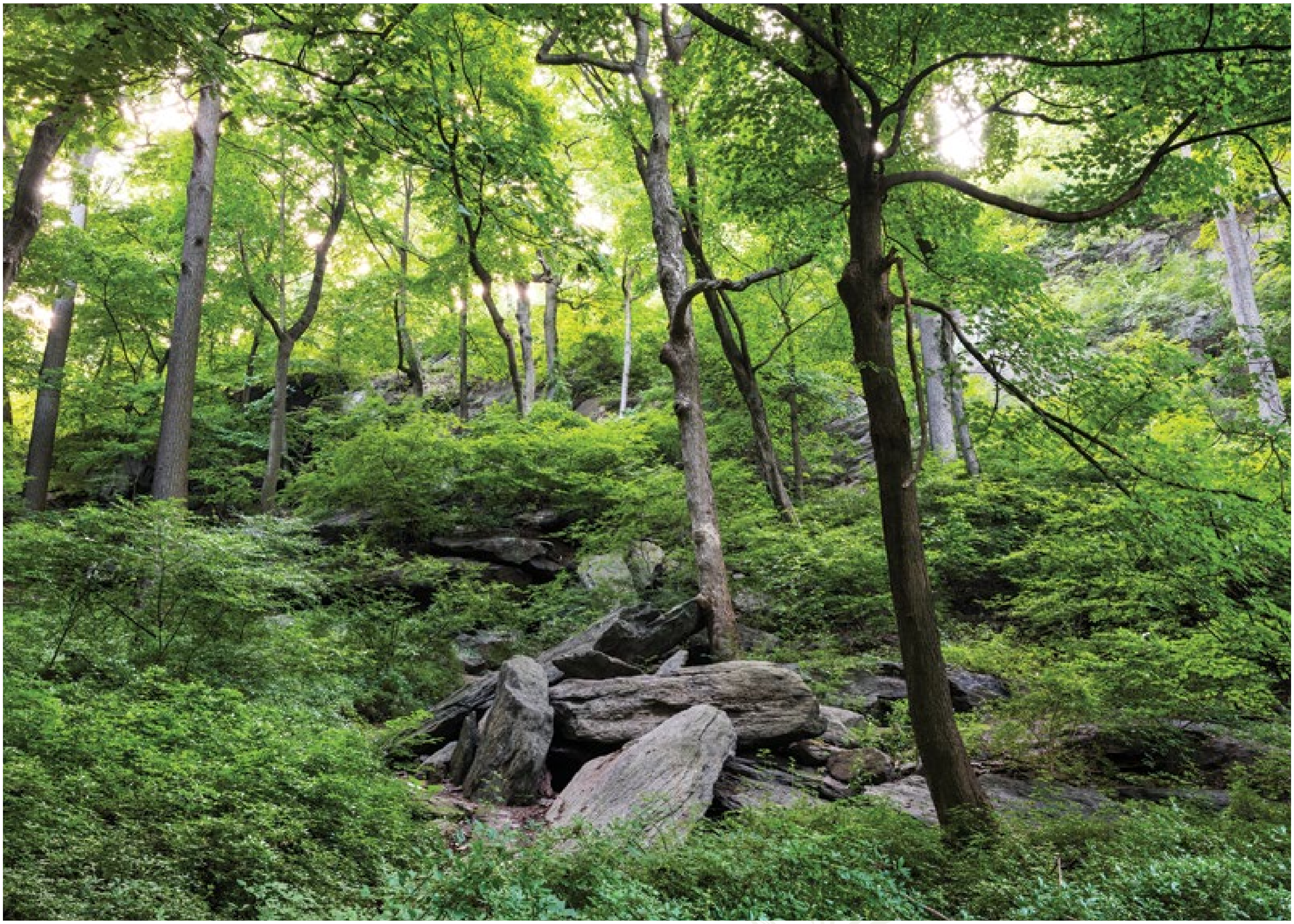
> https://www.risccnetwork.org/management-challenges

The Brandywine Conservancy in Pennsylvania has prepared a helpful planting guide for reforestation or other tree planting projects.

> https://www.brandywine.org/sites/default/files/media/BrandywineConservancy-RiparianBufferGuide.pdf

This article was one of the starting points for our list of practices, and covers additional forest types and regions.

> "The Practitioner's Menu of Adaptation Strategies and Approaches for Forest Carbon Management"
> https://forestadaptation.org/focus/forest-carbon-management



APPENDIX

How we created the list

This list was a joint effort among staff from The Nature Conservancy in Massachusetts and Vermont, and staff from the Northern Institute of Applied Climate Science (NIACS). We selected the practices included in this guide over the course of 18 months, during 2019–21.

We started by conducting a literature review of sources. These sources included the NIACS Forest Carbon Management Adaptation Menu, university extension publications from New England and New York, practices from the Natural Resources Conservation Service's cost-share programs, practices included in Massachusetts and Vermont Audubon's Foresters for the Birds program, and New England Forestry Foundation's Exemplary Forestry program. This initial list included any practice that met our criteria of maintaining or increasing carbon stocks within a short timeframe, while also maintaining or increasing forest resilience. We chose practices that, if applied in forests with the appropriate starting conditions, would be expected to increase carbon stocks within 20 years.

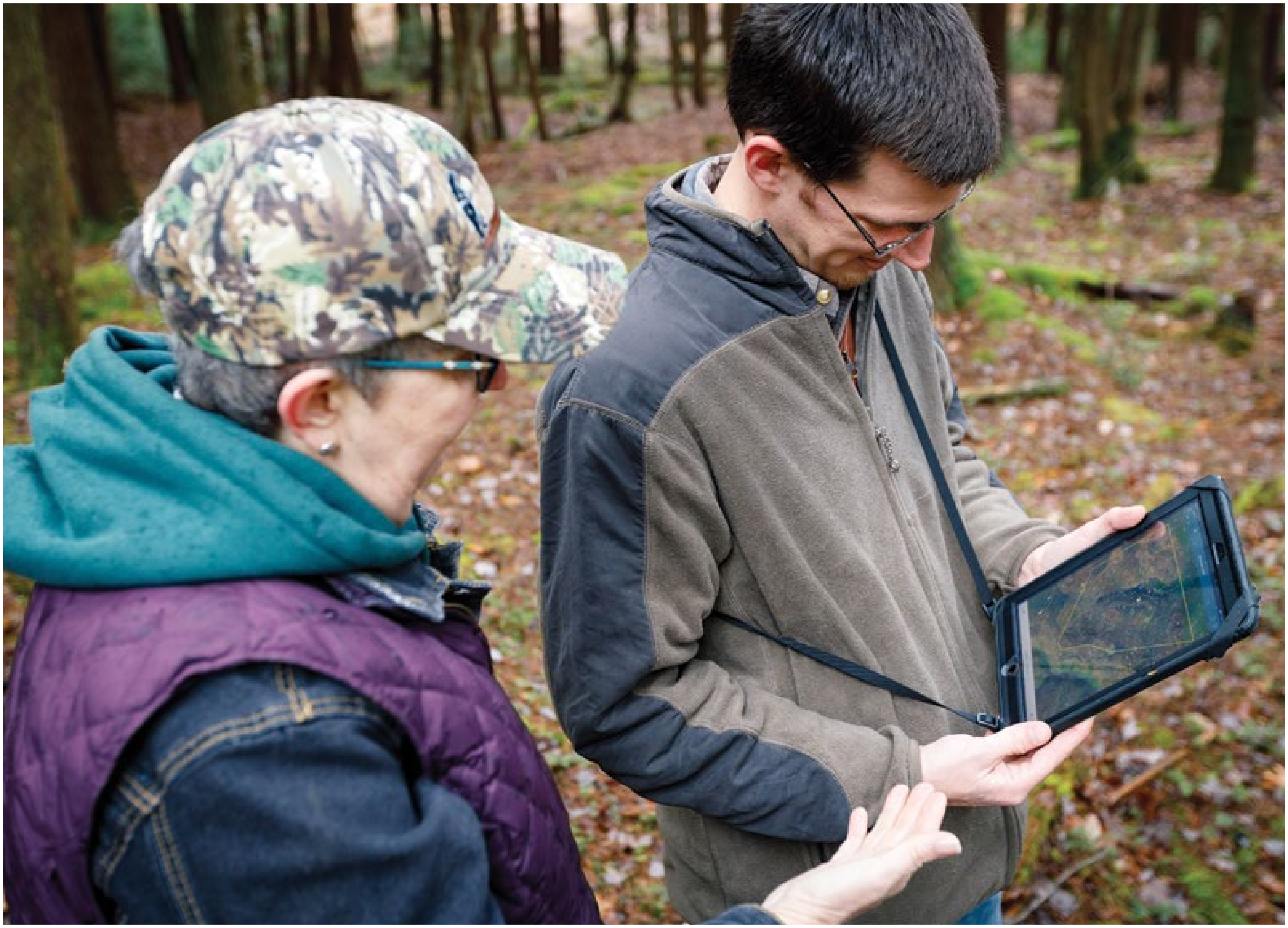
Caves of Inwood Hill Park in Upper Manhattan, New York. © Diane Cook and Len Jenshel

The 20-year timeframe for carbon benefits was selected because one of our goals was to identify a subset of practices that could be incorporated into the Family Forest Carbon Program, a new landowner incentive program developed by the American Forest Foundation and The Nature Conservancy. This also kept our focus primarily on aboveground carbon, and less on soil carbon. Note that two of the practices in our list—*Create gaps to promote regeneration* and *Retain more carbon in a thinning*—initially reduce carbon stock and must be carefully sited and applied in order to see carbon benefits within 20 years.

Some of the practices on our list had been studied extensively, and the carbon benefits were supported in published scientific literature and white papers. For others, we needed expert opinion to understand what specific practices and conditions would lead to carbon stock benefits. Through two day-long workshops in 2020, and follow-up discussion and surveys, we consulted with local and regional scientists, foresters, loggers, landowners, conservation organizations, and state and federal agency staff to refine and narrow our practices. If these stakeholders did not agree that a practice would be expected to lead to carbon benefits in mixed hardwood or oak-hickory forests in New England and eastern New York, we removed it from the list of practices. When stakeholders agreed that there was some carbon benefit to the practice, but that it depended on how the practice was done (e.g., how much wood was removed in a thinning, how much area was cleared in forest gaps), we used carbon modeling to develop quantitative estimates of carbon benefit and adjusted the practices to ensure that they were carbon-beneficial under a wide range of typical forest conditions in the region.

As there is increased interest in using forests to address climate change, there are many lists like this one and there will likely be more in the future. The names of practices and the specifics of each practice vary across lists, but the general categories of actions that impact carbon stock are fairly similar. In general, you can increase carbon stocks in the short term by reducing threats to tree growth and survival, removing less carbon stock than the forest adds (harvesting less intensively or less frequently), or creating new forests and trees (by planting or creating the conditions for natural regeneration).

As noted in the introduction, this list is not an exhaustive list of practices that have carbon benefits, and it leaves out a number of forest management practices that have important adaptation benefits and longer-term carbon outcomes. If you are looking for carbon benefits in 100 years rather than 20, you may want to consider additional practices. If your forest is in need of restoration to address poor past management, disease outbreaks, or natural disasters, then the assumptions we made in our carbon modeling about what happens in a "typical" forest when it grows may not apply to your forest. In addition, these practices also do not include the carbon benefits of wood products, which can be substantial, especially when wood is used to substitute for building materials such as steel and concrete. Some of these practices reduce short-term economic gain in order to retain greater carbon stocks in the forest, which may not be possible or desirable for all forest owners. We encourage you to consider this guide as a starting point and as one piece of information to inform a discussion between landowners and foresters about the right choice for your forest.



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