Forest Carbon and Climate Program
Department of Forestry
MICHIGAN STATE UNIVERSITY

NIACS
Northern Institute of Applied Climate Science

Forest Carbon and Climate Change in the Northeast Region of the United States

This white paper summarizes topics such as forest densities and cover types, carbon storage pools, climate considerations, and adaptive management suggestions for the US Northeast region.

In collaboration with the Northern Institute of Applied Climate Science (NIACS), this summary was developed from content found in our FCCP Intensive: US Regions course on the US Northeast, available for purchase on our Professional Development Courses page. Visit our Projects + Research page to learn more about the development of this project.

Forest Carbon and Climate Change in the Northeast Region of the United States

Table of Contents

The Northeast Region Overview 2
Temperature and Precipitation 3
Projected Future Trends in Temperature 4
Forest Density 6
Regional Cover Types 7
Forest Area Over Time 8
Forest Carbon Density 9
Subregional Carbon Pools 9
Carbon Management in the Northeast 11
Introduce Future-Adapted Species or Genotypes 11
Increase Structural Complexity through Retention of Biological Legacies 12
Protect Future-Adapted Trees from Herbivory 13
Resources & References 14

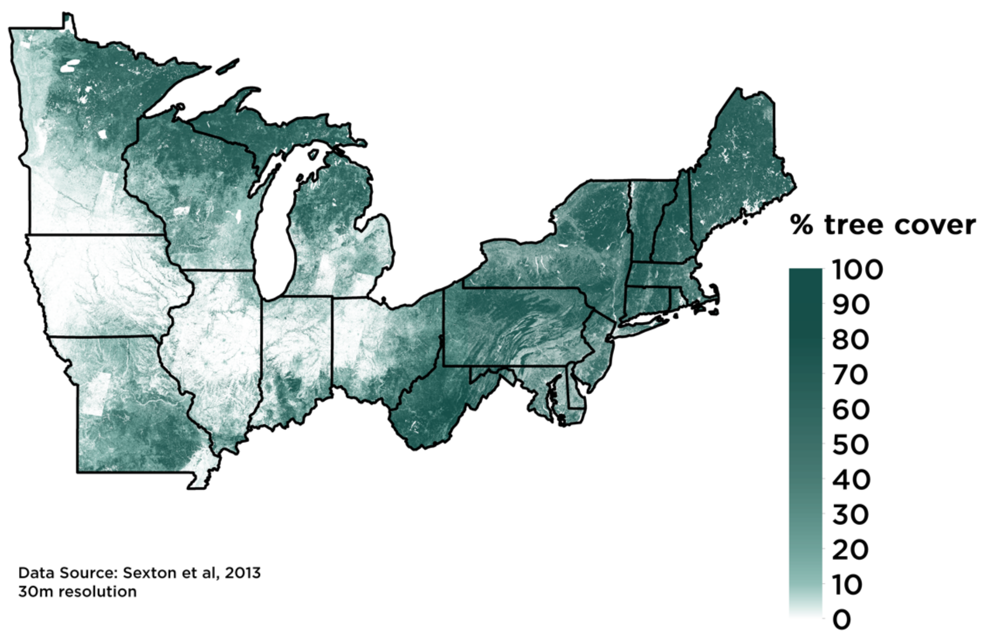
The Northeast Region Overview

For the purposes of this document, the Northeast region of the United States (US NE) includes Connecticut, Delaware, Illinois, Indiana, Iowa, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Vermont, West Virginia, and Wisconsin. The US NE is one of the most populous regions in the United States, with over 40% of the US population residing within its borders. It is also one of the most forested regions in the country, with more than 40% of total land covered by forests and with significant spatial variation in forest type and cover across its landscape.

A map of percent of tree canopy cover across the US NE, can be seen in **Figure 1.** As this map demonstrates, a gradient in coverage exists between the Great Plains region in the west and the more densely forested inland and coastal regions to the east. A notable characteristic of this region is its wide variation in forest types. Because it covers an area stretching from the Mississippi river to the Atlantic coast, the US NE encompasses high levels of biodiversity and climatic variation.

Figure 1

Percent Tree Canopy Cover in the Northeast Region of the United States



Temperature and Precipitation

Two major factors affecting forest carbon and productivity are regional temperature and precipitation. **Figure 2** shows normal mean temperatures throughout the US NE region between 1981 and 2010. Temperatures in the region largely follow latitudinal trends, with warmer temperatures at the southernmost portions of the region, indicated by red shading, slowly giving way to cooler temperatures further north, indicated by blue shading.

Figure 3 shows normal mean precipitation for the same period in centimeters and demonstrates the geographic variation in precipitation trends across the US NE region. Areas that receive lower levels of precipitation (<50 cm) are represented by darker red shading, and areas that receive higher levels of annual precipitation (>120 cm) are indicated by blue shading. The driest climate is found in the northwestern corner of the region, with a large portion of Minnesota receiving <50 cm of average annual precipitation. The highest levels of precipitation occur farther east and closer to the Atlantic coast in states like Maine, Massachusetts, New York, and Pennsylvania. Very high levels of precipitation are also common in the Appalachian Mountains of West Virginia.

Figure 2

Normal Mean Temperature (°C) from 1981–2010 in the Northeast Region of the United States

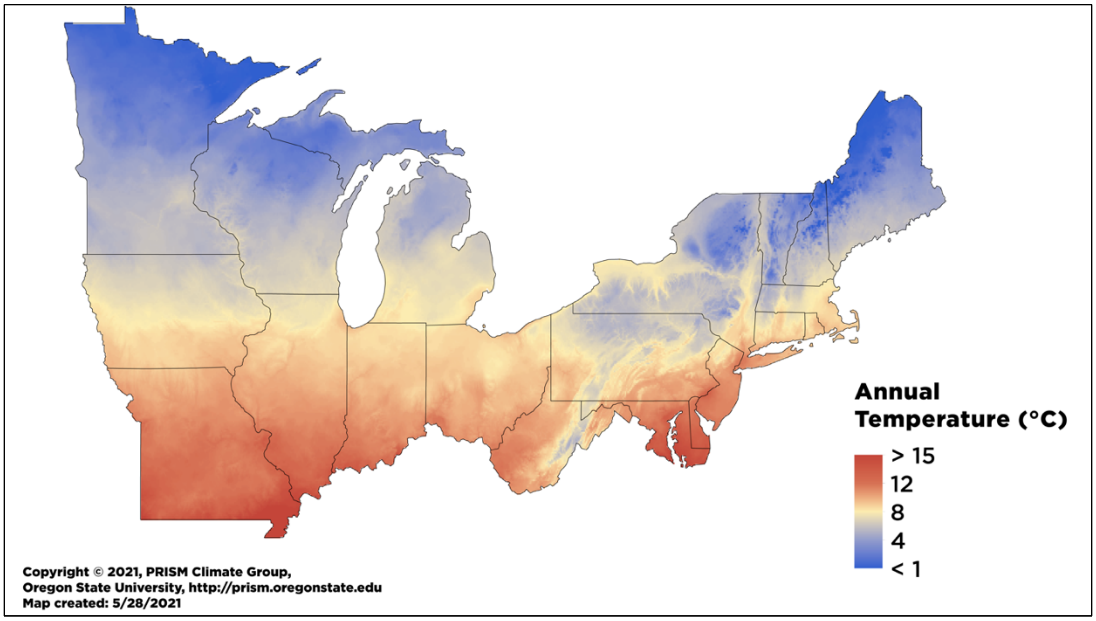
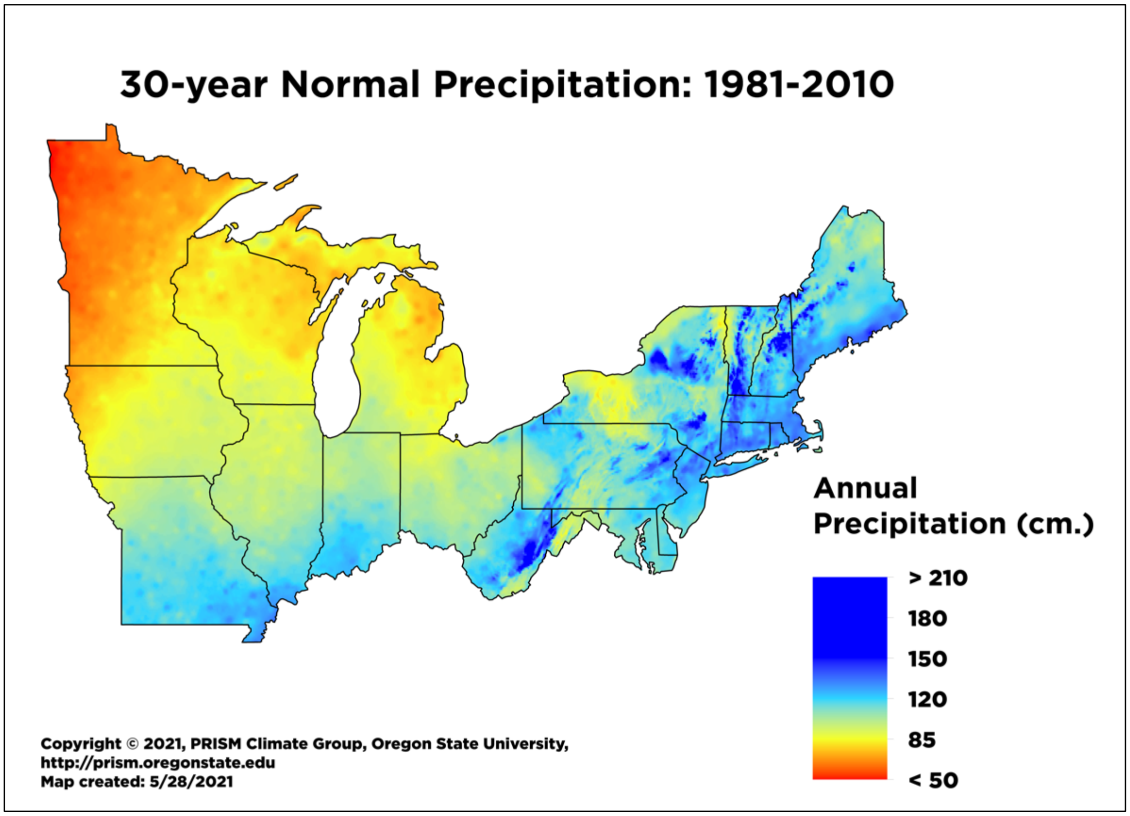


Figure 3

Normal Mean Precipitation (cm) from 1981–2010 in the Northeast Region of the United States

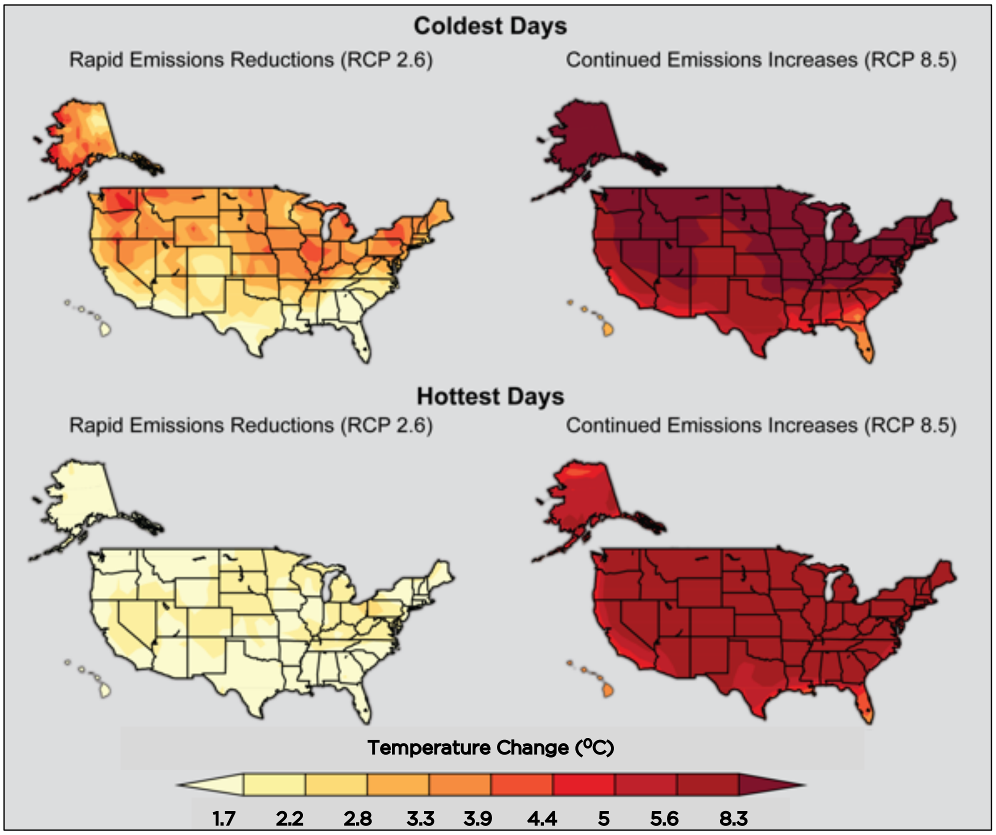


Projected Future Trends in Temperature

Projected future trends in temperature point to shorter and warmer winters across the US NE region. As is shown in **Figure 4,** projected temperature changes—under both low (RCP 2.6) and high (RCP 8.5) emissions scenarios—show that both the coldest and warmest days in the year will get hotter by the end of this century, a trend observed across the United States (Walsh et al. 2014). In New England specifically, a significant increase in the number of days with temperatures surpassing 32 °C is expected by 2070. Some coastal states, such as Maryland, are projected to experience 60 or more additional days per year with extremely high temperatures by 2070 (Horton et al. 2014).

Figure 4

Projected Temperature Change (°C) of Hottest and Coldest Days across the United States



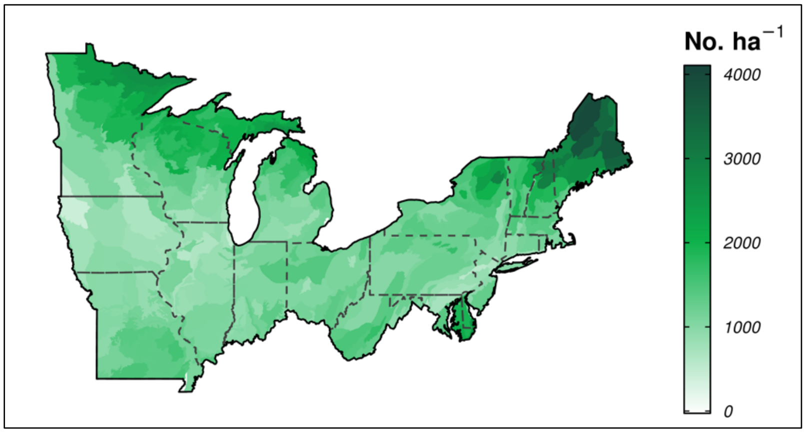
Note. Change in surface air temperature at the end of this century (2081–2100) relative to the turn of the last century (1986–2005) on the coldest and hottest days under a scenario that assumes a rapid reduction in heat-trapping gases (RCP 2.6) and a scenario that assumes continued increases in these gases (RCP 8.5). This figure shows estimated changes in average temperature of the hottest and coldest days in each 20-year period. In other words, the hottest days will get even hotter and the coldest days will be less cold (Walsh et al. 2014). Figure is from NOAA NCDC / CICS-NC.

Forest Density

Forest density is both a structural characteristic of a forest and reflection of forest dynamics. Forest density can be measured as the number of trees per unit area (i.e., trees per hectare, trees per acre, or another spatial unit; **Figure 5**). It can also be measured in terms of tree volume, expressed as basal area (**Figure 6**). Live tree basal area is the amount of ground that is covered by living trees in two-dimensional space. Compare Figure 5, which shows density purely by number of trees, with Figure 6, which shows density by volume of live trees. Note that some areas, like Maine, have a very high density in terms of the number of trees but average density in terms of volume. These are areas with many smaller trees. By contrast, some areas, such as West Virginia, have lower density in terms of number of trees but average density in terms of volume. These are areas with fewer, larger trees. Across the US NE region, forest density is fairly consistent in terms of live tree basal area (**Figure 6**). However, when considering density in terms of the number of live trees per hectare, there are noticeable pockets of denser stands in Maine and in the northernmost zones of the lake states (**Figure 5**).

Figure 5

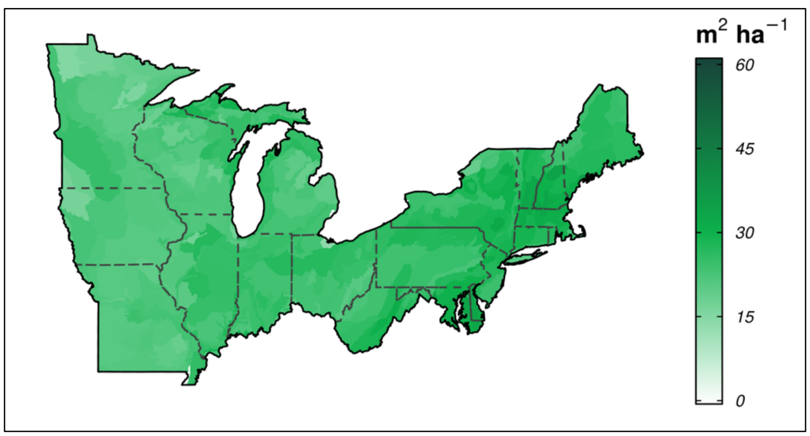
Forest Density as Live Tree Density (No. ha^{-1}) in the Northeast Region of the United States



Note. Created by FCCP, using USFS FIA data accessed 05-08-2021.

Figure 6

Forest Density as Live Tree Basal Area (m^2 ha^{-1}) in the Northeast Region of the United States



Note. Created by FCCP, using USFS FIA data accessed 05-08-2021.

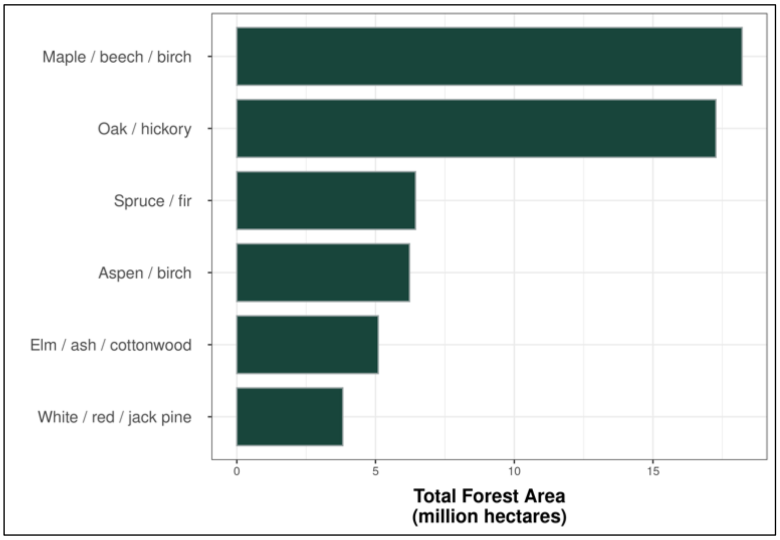
Fire suppression efforts throughout the 20th century have led to altered forest types and an overall increase in forest stand density compared to historical norms. Many Oak/hickory stands have seen compositional changes as fire suppression efforts significantly reduced the occurrence of the low-intensity surface fires that historically thinned smaller understory growth in these ecosystems. Although forests with higher overall densities can hold more carbon, poorly-managed and overstocked stands are often more susceptible to disturbances (e.g., pest and disease outbreaks) and less resilient to climate change.

Regional Cover Types

The Northeast region is dominated by six key forest cover types: Maple/beech/birch, Oak/hickory, Spruce/fir, Aspen/birch, Elm/ash/cottonwood, and White/red/jack pine. **Figure 7** and **Figure 8** show region-level data for total forested area and total forest carbon, respectively, for each of the major cover types. As these figures show, the Maple/beech/birch and Oak/hickory groups dominate the forests of this region, covering roughly 35 million hectares with nearly even coverage across the two types. However, Maple/beech/birch stands hold proportionally more carbon per unit area, >3500 million tons, compared to the Oak/hickory forest type, which holds ~2800 million tons. Across the six cover types, Spruce/fir stands hold the highest proportion of total carbon per unit of area covered. The regional extent of the Spruce/fir cover type is similar to that of the Aspen/birch group, around 6 million hectares; yet it holds roughly 1.5 times the amount of total carbon. Additionally, Spruce/fir stands occupy roughly one-third of the land area covered by Oak/hickory stands in the region but contain nearly two-thirds the total carbon held by Oak/hickory stands.

Figure 7

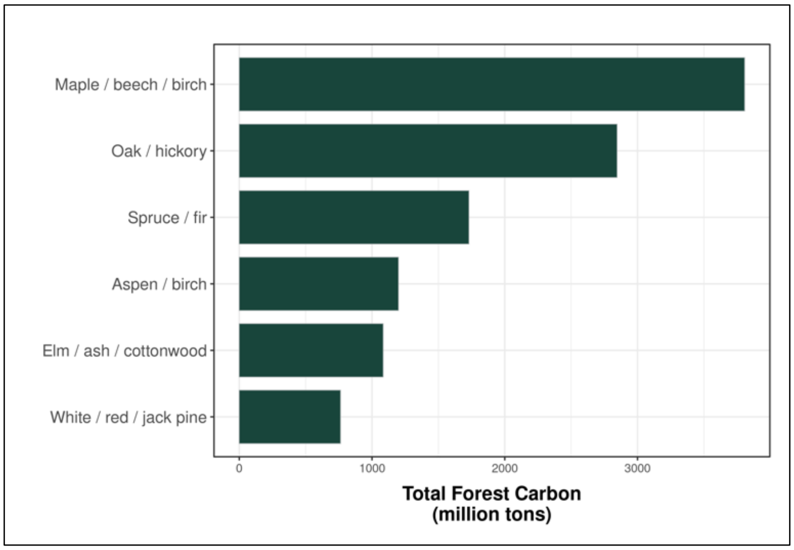
Total Forest Area (million hectares) by Forest Type in the Northeast Region of the United States



Note. Created by FCCP, using USFS FIA data accessed 05-08-2021.

Figure 8

Total Forest Carbon (million tons) by Forest Type in the Northeast Region of the United States



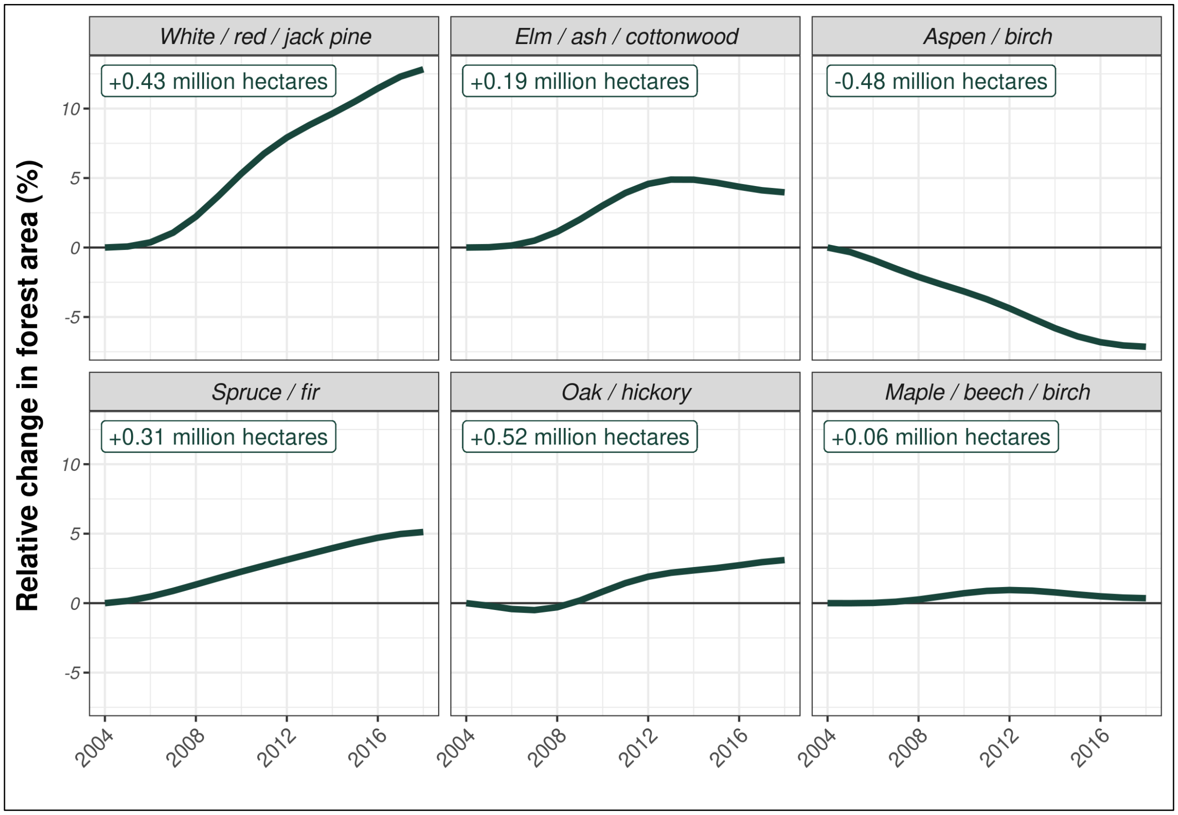
Note. Created by FCCP, using USFS FIA data accessed 05-08-2021.

Forest Area Over Time

Recent trends in forest cover change over time in the US NE show differing shifts depending on forest type. **Figure 9** shows trends in relative change (%) of total forest area from 2004–2018 for key US NE cover types. Over this 14-year period, the White/red/jack pine group saw the highest relative increase in land area, expanding its range by roughly 13%. Although the Oak/hickory group shows a larger *total* gain in land area over this period than White/red/jack pine stands (+0.52 vs. +0.43 million hectares), the *relative* expansion of its regional extent (compared to its regional extent in 2004), is much smaller than that of the White/red/jack pine group (+3% vs. +13%). Maple/beech/birch coverage remained relatively stable on the landscape, while Aspen/birch stands (the only cover type to see reduced coverage from its 2004 levels) declined by roughly 7%.

Figure 9

Relative Change in Total Forest Area (%) between 2004-2018 in the Northeast Region of the United States



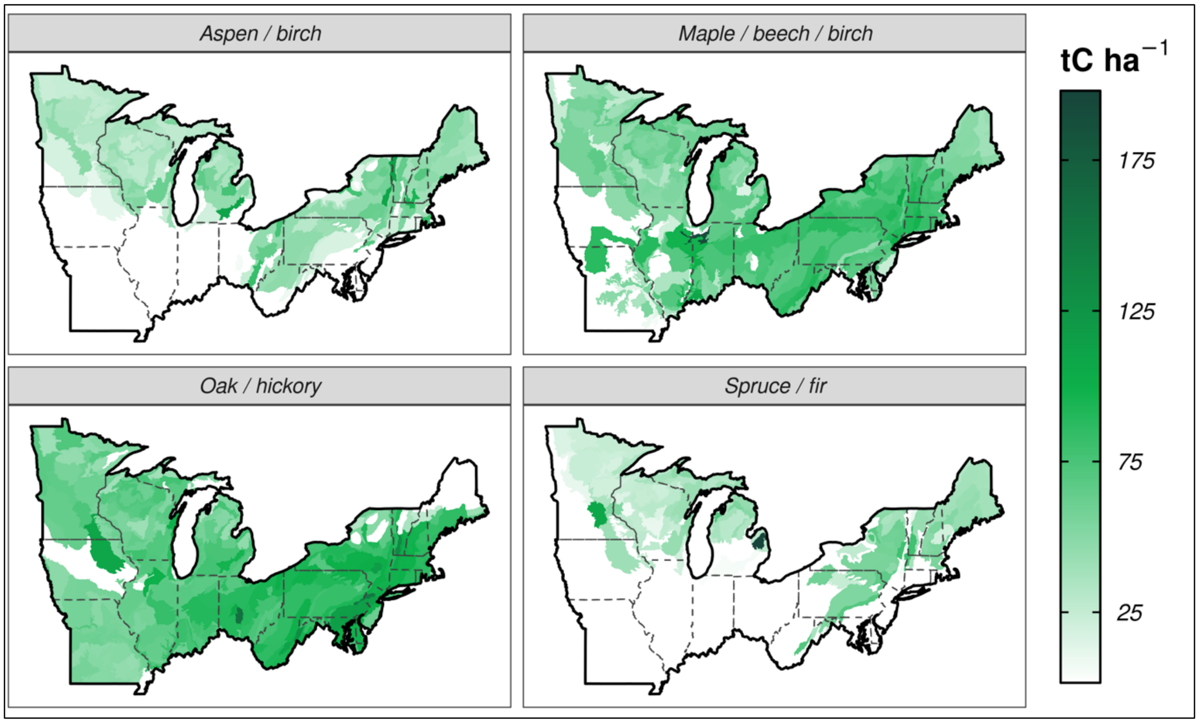
Note. FIA data are smoothed across 5-year increments. Total change values for forest area (million hectares) for the period 2004–2018 are listed in text boxes below each cover type label. Figure created by FCCP, using USFS FIA data accessed 05-08-2021.

Forest Carbon Density

Forest carbon density can be influenced by many ecosystem traits, such as tree density, age, species mix/cover type, soils, and disturbance and management history. In **Figure 10** the carbon density of aboveground (AG) living biomass is shown for four key cover types in the US NE region. Of these, Oak/hickory stands hold the highest levels of living AG carbon per unit area, represented by the deeper shades of green. By contrast, cold-adapted forests that are restricted to high elevations and northern latitudes, such as Aspen/birch and Spruce/fir, store relatively less living carbon per unit area.

Figure 10

Aboveground Live Forest Carbon Density (tC ha^{-1}) by Forest Type in the Northeast Region of the United States



Note. Created by FCCP, using USFS FIA data accessed 05-08-2021.

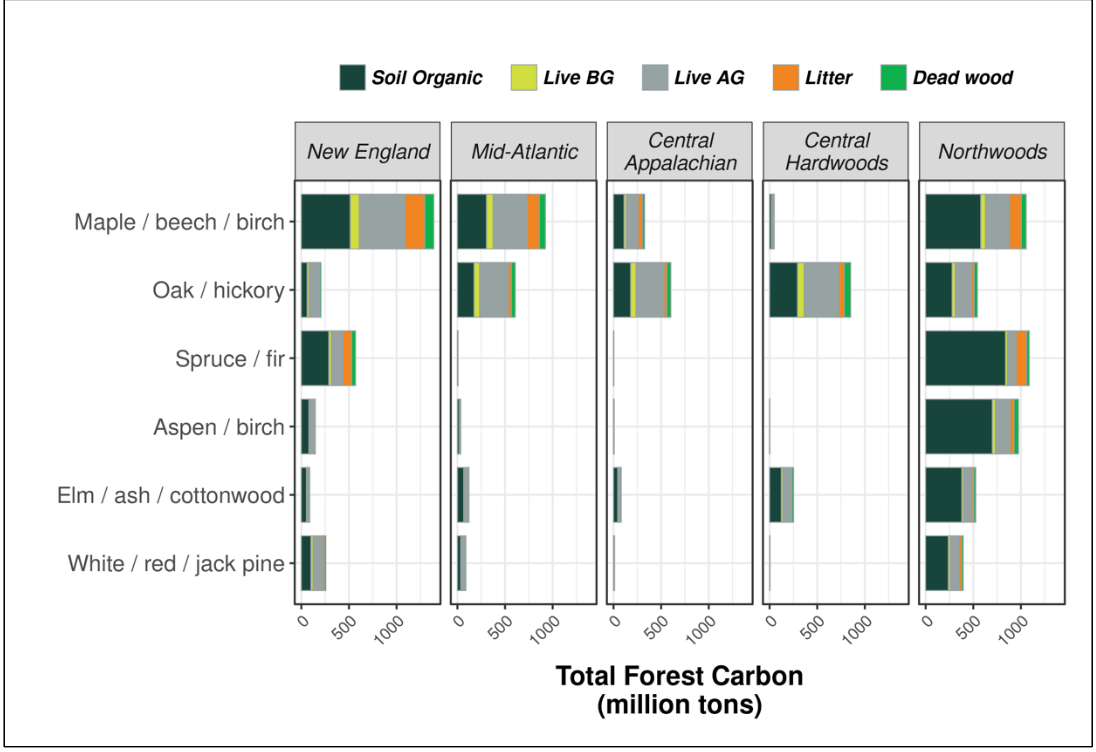
Subregional Carbon Pools

Forest carbon storage can be further assessed by subregion. **Figure 11** shows the amount of carbon stored in different forest carbon pools by key cover types within five subregions of the US NE: New England, Mid-Atlantic, Central Appalachian, Central Hardwoods, and Northwoods. These subregional boundaries are shown in **Figure 12** and each represents a distinct geographic zone based prevailing dominant species, historical trends, and projected climate change impacts. Variations in forest carbon allocation can be observed across cover types within a subregion, as well as across subregions within a given forest type.

Figure 11 shows the amount of carbon allocated to different carbon pools by each forest cover type, showing variations in carbon storage across soil organic matter, live belowground (BG) biomass, live aboveground (AG) biomass, litter, and dead wood pools. For instance, Spruce/fir forests in the Northwoods subregion store most ecosystem carbon belowground in soil organic matter pools. Roughly three-quarters of the total carbon in these stands is stored in soil. By contrast, Spruce/fir that grow in New England store only half of their total carbon in the soil. This geographically-driven trend is also reflected in the Maple/beech/birch forest type, where aboveground carbon pools (composed of living plants, litter, and dead wood) are proportionally larger in New England than in the Northwoods subregion, where more carbon is held in soil organic matter. In the southernmost subregions of the US NE—the Mid-Atlantic, Central Appalachian, and Central Hardwoods—most ecosystem carbon is stored in living plants and trees and aboveground carbon pools are consistently larger than belowground pools.

Figure 11

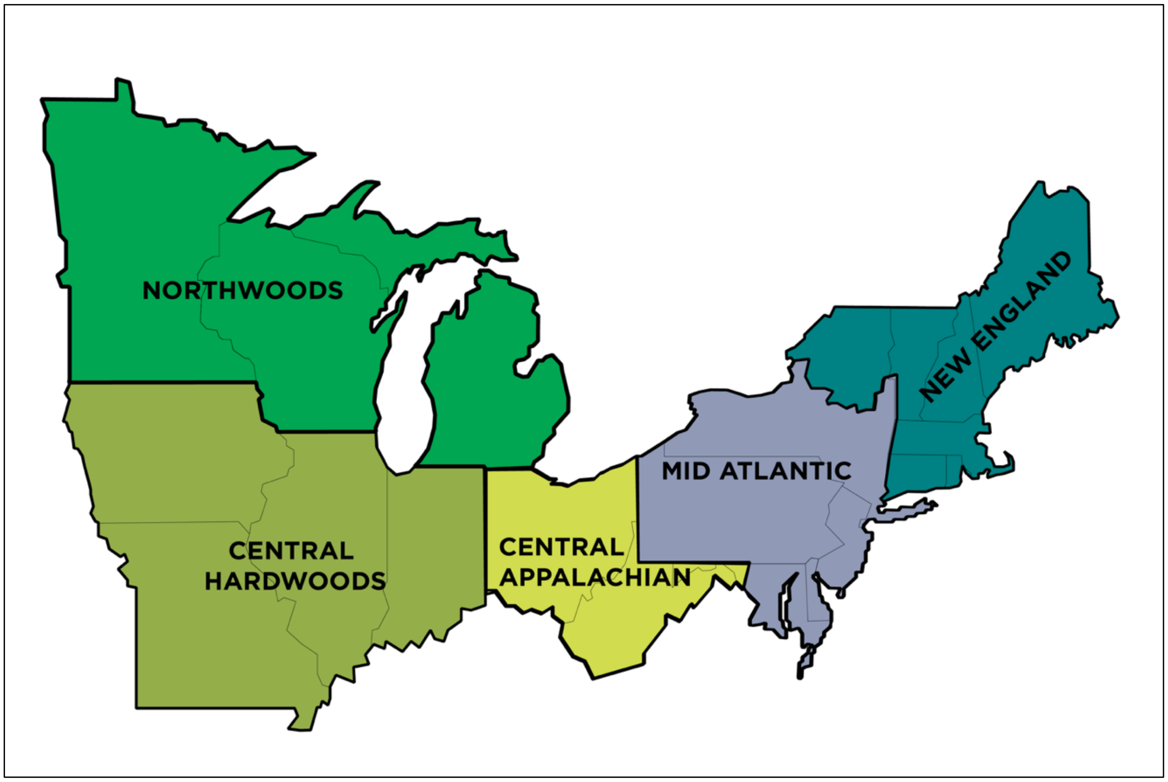
Subregion-level Total Forest Carbon (million tons) by Pool and Forest Type in the Northeast Region of the United States



Note. Created by FCCP, using USFS FIA data accessed 05-08-2021.

Figure 12

Map of Subregions within the Northeast Region of the United States



Note. Created by FCCP, 2021

Carbon Management in the Northeast

Introduce Future-Adapted Species or Genotypes

Managing forests to be better adapted to future climate conditions can also improve long-term carbon sequestration capacity. The human-assisted movement of species in response to climate change is generally described as *assisted migration* and involves the introduction of species or genotypes to areas that they have not historically occupied, but that they are expected to succeed in under future climate conditions. Assisted migration encompasses a variety of potential actions that have substantial differences in terms of risks, ecological implications, and policy considerations. A helpful resource for assisted migration management is the Seedlot Selection Tool, which can be used to match the expected climate at a given site with appropriate locations for sourcing seedling stock. In the context of post-disturbance restoration, this resource can assist in identifying future-adapted planting stock which may increase stand resilience to ongoing climatic changes and expected future conditions.

Increase Structural Complexity through Retention of Biological Legacies

Late-successional and old-growth forests store more carbon compared to young or secondary forests. This is largely due to greater structural complexity and higher densities of carbon stocks in both living and dead trees. Downed logs and coarse woody debris can serve as nurse logs, providing important microclimates for seed germination and seedling establishment, further supporting the ability of species to persist or colonize new habitat as environmental conditions change. Example management actions for promoting structural complexity may include retaining the oldest and largest trees with good vigor as legacy trees, retaining greater amounts of dead wood during forest management (including snags, downed logs, and other coarse woody debris), enhancing dead wood pools using low-quality trees in declining condition (e.g., chop-and-drop), and taking care to retain survivors of disturbance events during salvage operations. Additionally, by avoiding salvage logging altogether on low-risk sites (i.e., stands with low risk of wildfire or forest health issues) higher carbon stocks can be maintained following disturbance.

Figure 13

Forest with Complex Structural Features Including Standing Dead Trees, Downed Logs, and Stems of Diverse Volume, Height, and Age

Note. Image from USDA Forest Service, public domain.

Protect Future-Adapted Trees from Herbivory

Protecting future-adapted seedlings and saplings from herbivory is an approach complementary to many other adaptation and carbon management practices. This approach is concerned with ensuring adequate regeneration of tree species and protecting new plantings. Because seedlings and saplings are more sensitive to herbivory than older trees, the simple act of protecting them can strongly influence future forest composition. Example tactics for protecting young trees from herbivory include:

- Using repellant sprays, bud caps, or fencing to prevent browse of tree species expected to be adapted to future conditions
- Utilizing tree tops or slash from forest harvest operations as a physical barrier to protect natural regeneration from browse pressure (e.g., “slash walls”)
- Partnering with state wildlife agencies to monitor herbivore populations or reduce populations to appropriate levels

Adaptive management approaches such as these can play an important role in species persistence and colonization of new habitat as environmental conditions change. These approaches are potentially appropriate for a variety of forest cover types in the US NE region and, when implemented strategically, encourage increased forest resilience, carbon storage, and ecosystem health.

Resources & References

Horton, Radley M., Yohe Gary, Easterling W., Kates R., Ruth M., Sussman E., Whelchel A., Wolfe D., & Lipschultz F. (2014). Ch. 16: Northeast. In Melillo, Jerry M., Richmond Terese(T. C.), and Yohe Gary (Eds.), *Climate Change Impacts in the United States: The Third National Climate Assessment*. U.S. Global Change Research Program. https://nca2014.globalchange.gov/downloads

Ontl, T. A., Janowiak, M. K., Swanston, C. W., Daley, J., Handler, S., Cornett, M., Hagenbuch, S., Handrick, C., Mccarthy, L., & Patch, N. (2019). Forest Management for Carbon Sequestration and Climate Adaptation. *Journal of Forestry*, *118*(1), 86–101. https://doi.org/10.1093/jofore/fvz062

PRISM Climate Group. (n.d.). Oregon State University. Retrieved December 20, 2022, from http://prism.oregonstate.edu

Seedlot Selection Tool. (n.d.) US Forest Service, Oregon State University, and the Conservation Biology Institute. Retrieved December 20, 2022, from https://seedlotselectiontool.org/sst/

Sexton, J. O., Song, X. P., Feng, M., Noojipady, P., Anand, A., Huang, C., Kim, D. H., Collins, K. M., Channan, S., DiMiceli, C., & Townshend, J. R. (2013). Global, 30-m resolution continuous fields of tree cover: Landsat-based rescaling of MODIS vegetation continuous fields with lidar-based estimates of error. *International Journal of Digital Earth*, *6*(5), 427–448. https://doi.org/10.1080/17538947.2013.786146

USDA Forest Service. (n.d.). Forest Inventory and Analysis National Program. Retrieved December 20, 2022, from https://www.fia.fs.usda.gov/

Walsh, J., D. Wuebbles, Hayhoe, K., Kossin, J., Kunkel, K., Stephens, G., Thorne, P., Vose, R., Wehner, M., Willis, J., Anderson, D., Doney, S., Feely, R., Hennon, P., Kharin, V., Knutson, T., Landerer, F., Lenton, T., Kennedy, J., &. Somerville, R. (2014). Ch. 2: Our Changing Climate. In Melillo, Jerry M., Richmond Terese (T. C.), and Yohe Gary (Eds.), *Climate Change Impacts in the United States: The Third National Climate Assessment*. U.S. Global Change Research Program. https://nca2014.globalchange.gov/downloads