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 Southeast 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 Southeast 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 Southeast, available for purchase on our Professional Development Courses page. Visit our Projects + Research page to learn more about the development of this project.

Michigan State University Forestry Department
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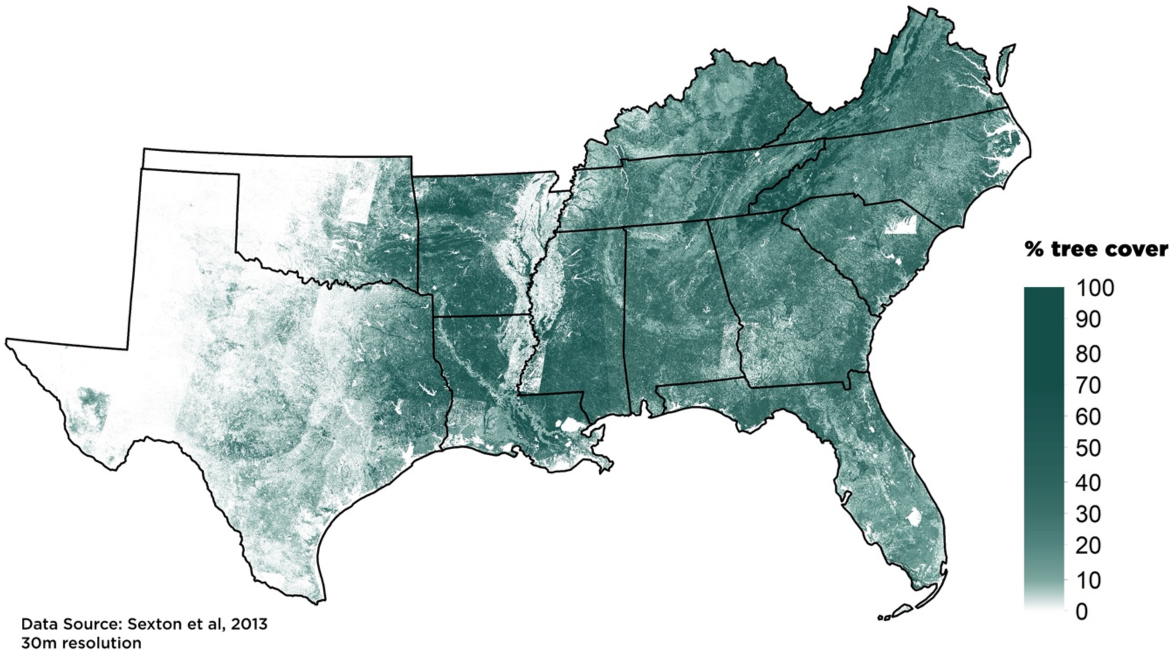
The Southeast Region Overview

For the purposes of this document, the Southeast region of the United States (US SE) includes Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia. Forests in this region are highly productive and supply a significant share of domestic timber. High temperatures and a subtropical climate across much of this range allow trees to develop rapidly.

A map of percent of tree canopy cover across the US SE, can be seen in **Figure 1**. As this map demonstrates, a gradient in coverage exists across the region with more arid and sparsely forested areas in the western portions transitioning to more humid and densely forested portions inland and along coastal regions to the east.

Figure 1

Percent Tree Canopy Cover in the Southeast 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 SE region between 1981 and 2010. Temperatures in the region largely follow latitudinal trends with the warmest mean temperatures, represented by orange and red shading, occurring at the southernmost portions of the region and the coolest mean temperatures, represented by blue shading, found at the northernmost areas and on high-elevation sites in the Appalachian range. Across the region, normal mean temperatures over this 30-year period ranged from <7 °C to >25 °C with the warmest temperatures occurring during the summer months.

Figure 3 shows normal mean precipitation for the same period in centimeters per year and demonstrates the geographic variation in precipitation trends across the US SE region. Note that the western states of Texas and Oklahoma consistently receive less precipitation than the rest of the region, as is shown by the red and yellow shaded zones. Areas receiving the most rainfall, represented by deep blue shading, generally occur along the central Gulf coast, as well as in a small pocket of heavy rainfall in the western Carolinas. Most precipitation occurs during late spring or early fall, but the timing of annual rainfall varies by subregion.

Figure 2

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

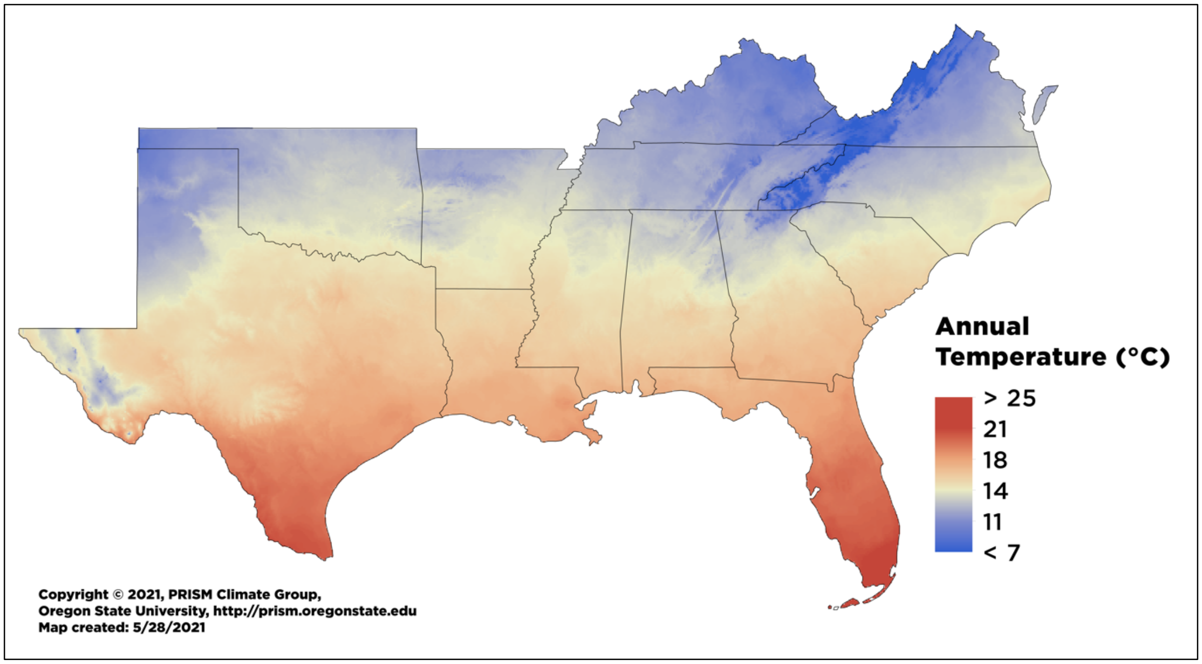
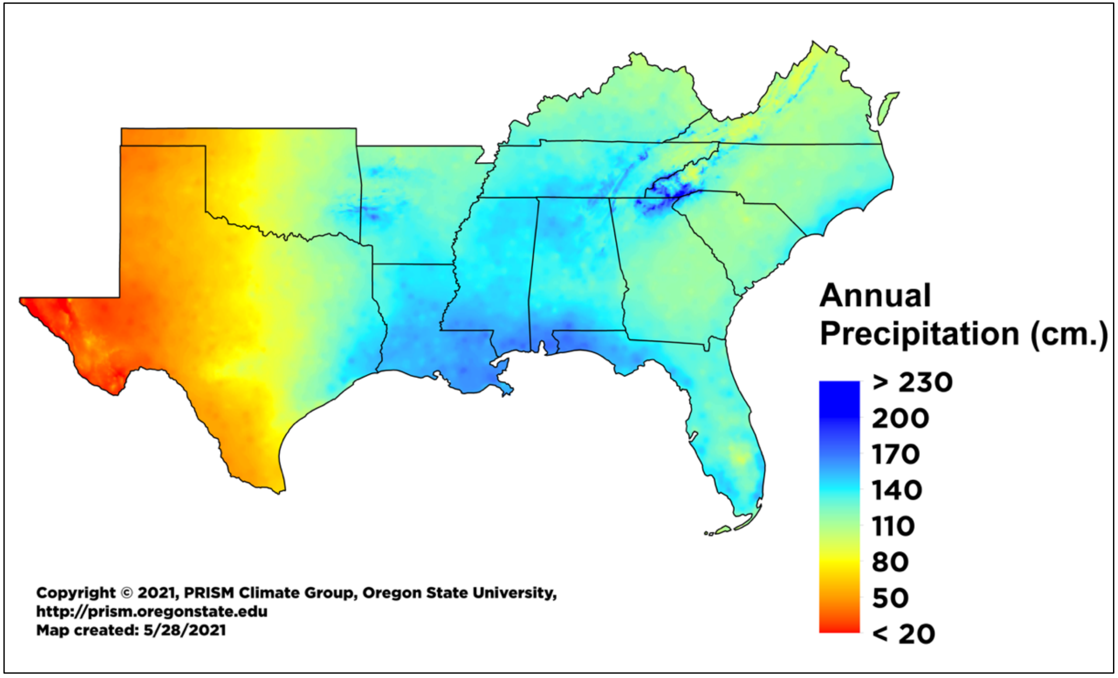


Figure 3

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

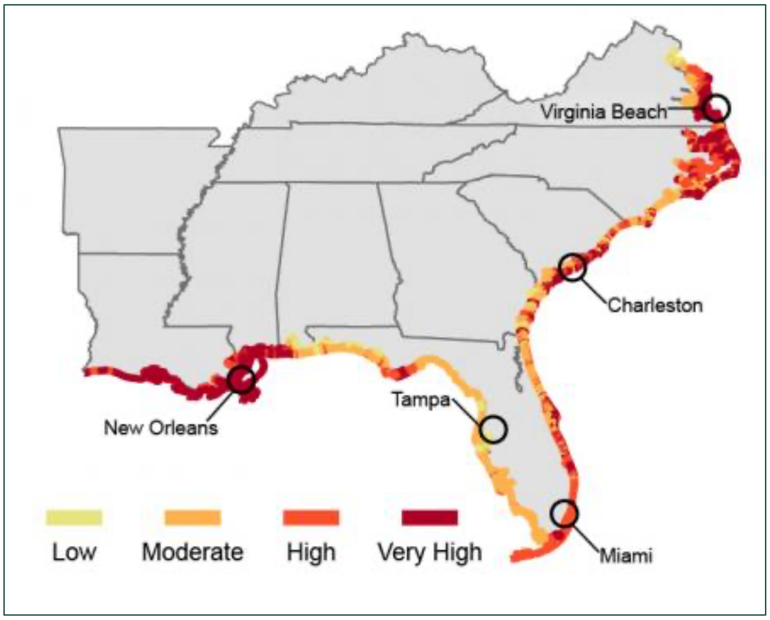


Coastal Climate Change Impacts to Forests

The National Climate Assessment predicts an increase in extreme weather events across the US, with higher storm surges creating more costly impacts (Kunkel et al. 2013). These events could result in the migration of forest species inland from the coast and greater pressure on currently forested areas. In addition to tropical storms, coastal areas of the US SE are vulnerable to rising sea levels and salinization under projected climatic changes. **Figure 4** depicts the vulnerability of coastal areas in the US SE to sea level rise. This projected trend is especially concerning for this region, as many of its most populated and economically productive areas are considered highly vulnerable to the impacts of rising sea levels.

Figure 4

Coastal Vulnerability to Sea Level Rise in the Southeast Region of the United States



Note. Figure from Kunkel et al. 2013

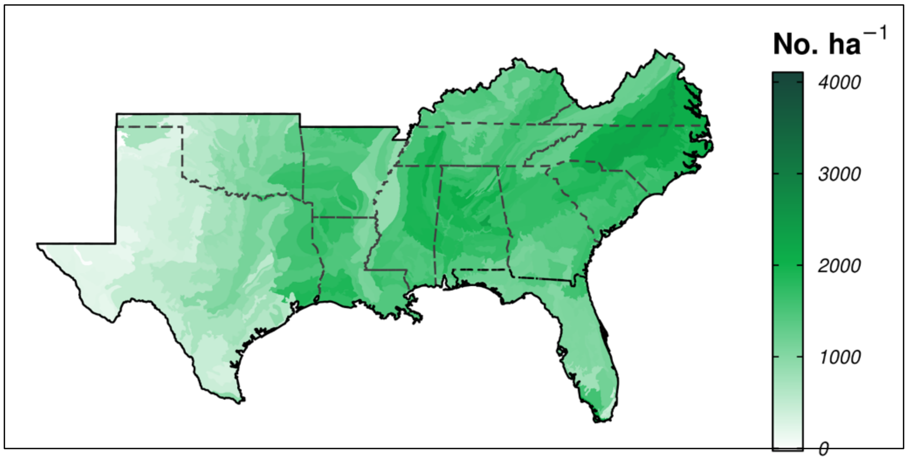
Soil salinization, which can be caused by storm surge flooding and saltwater intrusion into groundwater, is a major concern for coastal forests. Soil salinization can make a site uninhabitable to trees causing the conversion of forest to saltwater marsh.

Forest Density

Forest density is both a structural characteristic of a forest and a 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 live trees in two-dimensional space. As indicated by the darker green shades, forest density is greater along the eastern seaboard than in Texas and Oklahoma. 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 southwestern Louisiana, have a higher density of in terms of number trees than the areas around it, but a relatively equal density in terms of volume. These are areas with many smaller trees. By contrast, some areas, such as central northwestern Mississippi, have lower density in terms of numbers of trees but average density in terms of volume. These are areas with fewer, larger trees.

Figure 5

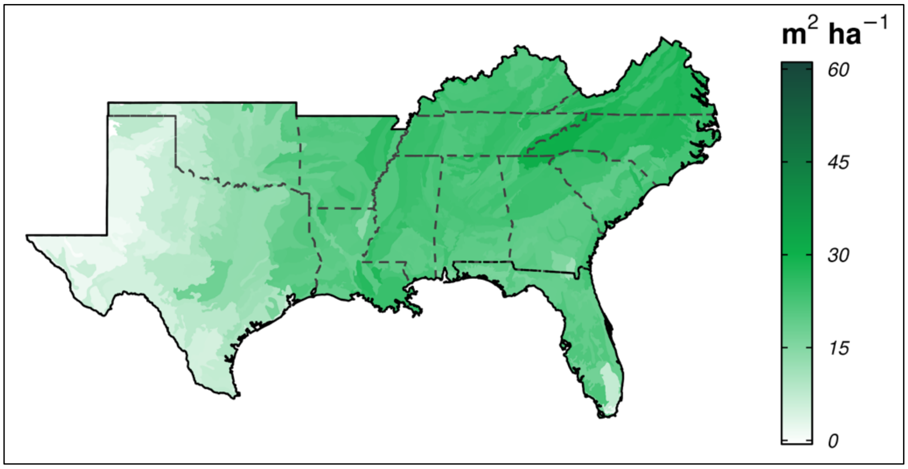
Forest Density as Live Tree Density (No. ha^{-1}) in the Southeast Region of the United States



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 Southeast Region of the United States



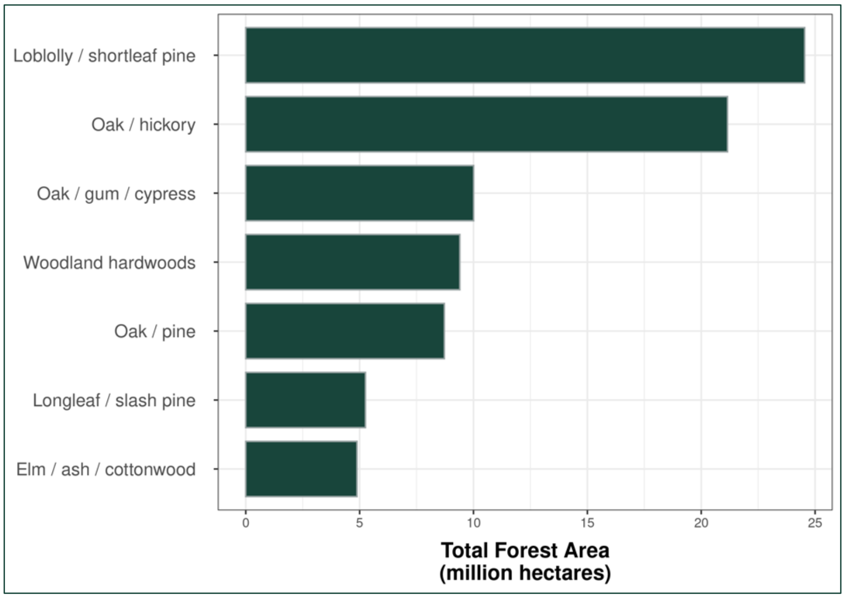
Note. Created by FCCP, using USFS FIA data accessed 05-08-2021.

Regional Cover Types

The Southeast region is dominated by seven key forest cover types: Loblolly/shortleaf pine, Oak/hickory, Oak/gum/cypress, Woodland hardwoods, Oak/pine, Longleaf/slash pine, and Elm/ash/cottonwood. **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, Loblolly/shortleaf pine is the dominant cover type in this region, covering nearly 25 million hectares and storing nearly 3500 million tons of carbon. A comparison of the two figures shows that forest types store different amounts of carbon relative to their forested land area. For example, the Oak/hickory group occupies >20 million hectares in the region, more than double the coverage of the Oak/gum/cypress group, which occupies about 10 million hectares. Yet, when comparing carbon storage between the two, Oak/gum/cypress holds much more carbon per unit area, storing nearly 75% of the total regional carbon held by Oak/Hickory stands. By contrast, some forest types hold proportionally less carbon per unit area. Such is the case for the Woodland hardwoods group. These stands are typically drier and sparser

Figure 7

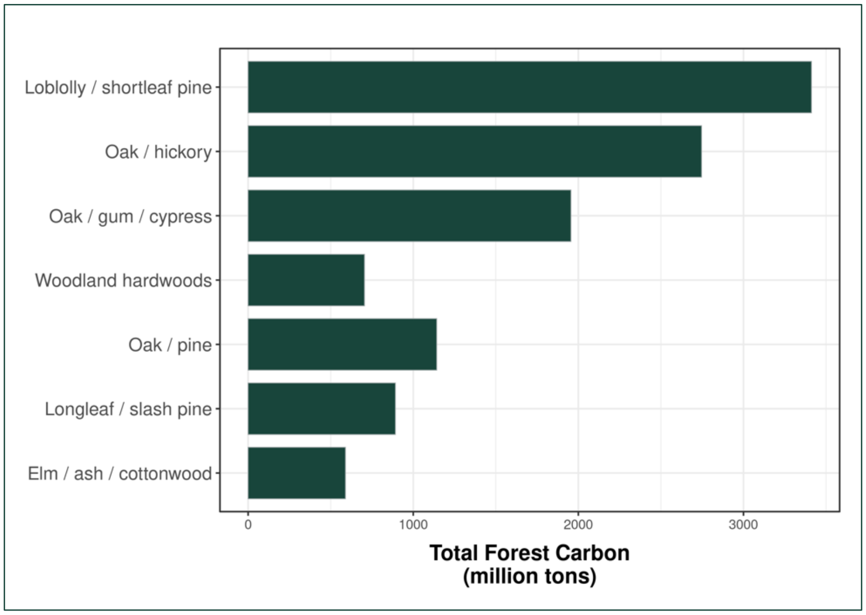
Total Forest Area (million hectares) by Forest Type in the Southeast Region of the United States



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

Figure 8

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



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

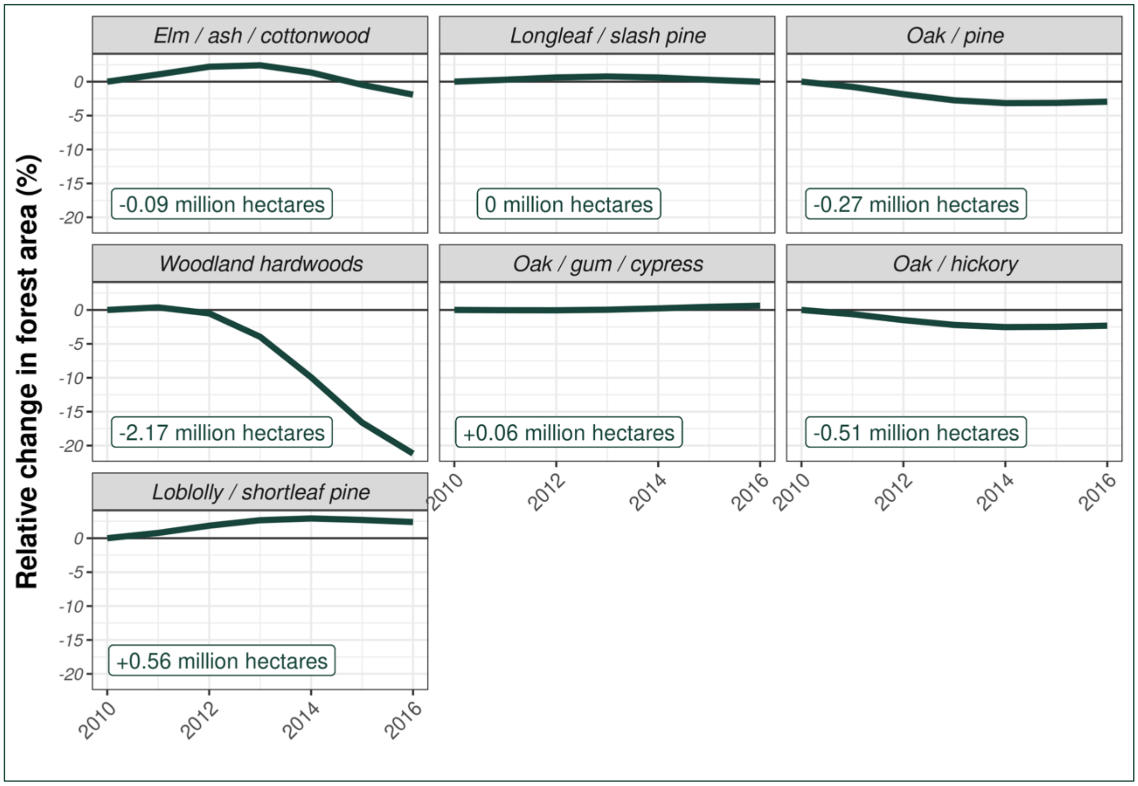
than other cover types. Though they cover more area in the region, Woodland hardwood forests hold less total carbon than the Oak/pine or Longleaf/slash pine groups.

Forest Area Over Time

Recent trends in forest cover change in the US SE show that most regional forest cover types experienced a reduction in total area. **Figure 9** shows trends in relative change (%) of total forest area from 2010–2016 for key US SE cover types. Over this 6-year period, the Elm/ash/cottonwood, Oak/pine, and Oak/hickory forest types all experienced a slight relative decline in cover of <5%. By contrast, the Woodland hardwoods group lost >20% of its extent over a 4-year period from 2012–2016. The Oak/gum/cypress and Longleaf/slash pine groups remained relatively stable on the landscape for the period shown. The Loblolly/shortleaf pine group, which includes timber plantations, was the only cover type to see a relative expansion on the landscape, a roughly 2.5% increase from its 2010 coverage.

Figure 9

Relative Percent Change in Forest Area by Forest Type (million hectares) in the Southeast Region of the United States



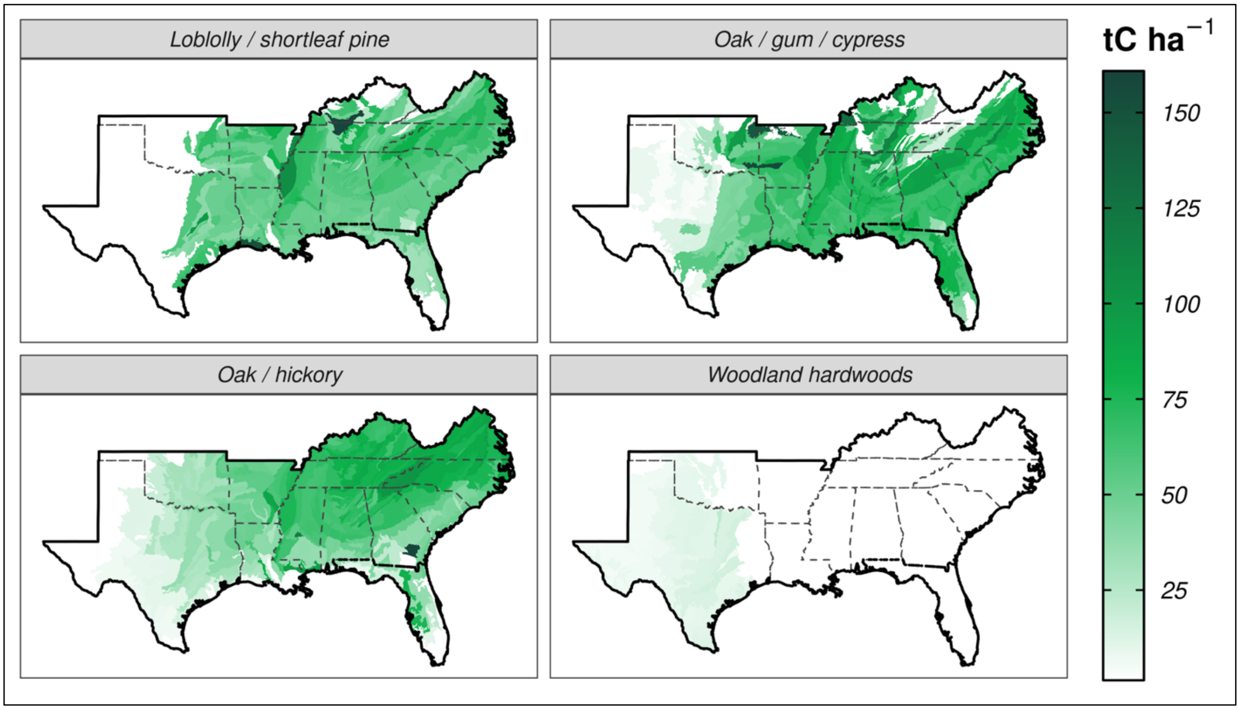
Note. Created by FCCP, using USFS FIA data accessed 05-08-2021.

Forest Carbon Density

Forest carbon density can be influenced by many ecosystem traits, such as tree density, age, species mix/cover type, soils, 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 SE region. Overall, forests found on the eastern side of the region have the highest carbon densities. Of the cover types shown in Figure 10, Oak/gum/cypress forests, which are associated with moist lowland sites, have the highest carbon density per unit area across their range. Conversely, drier forests tend to be less dense and generally hold less living carbon per unit area. This is reflected in the contrast between the carbon density map of the characteristically dry Woodland hardwoods group, which are dominant in western Texas and Oklahoma, to other forest types in the region.

Figure 10

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



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

Subregional Carbon Pools

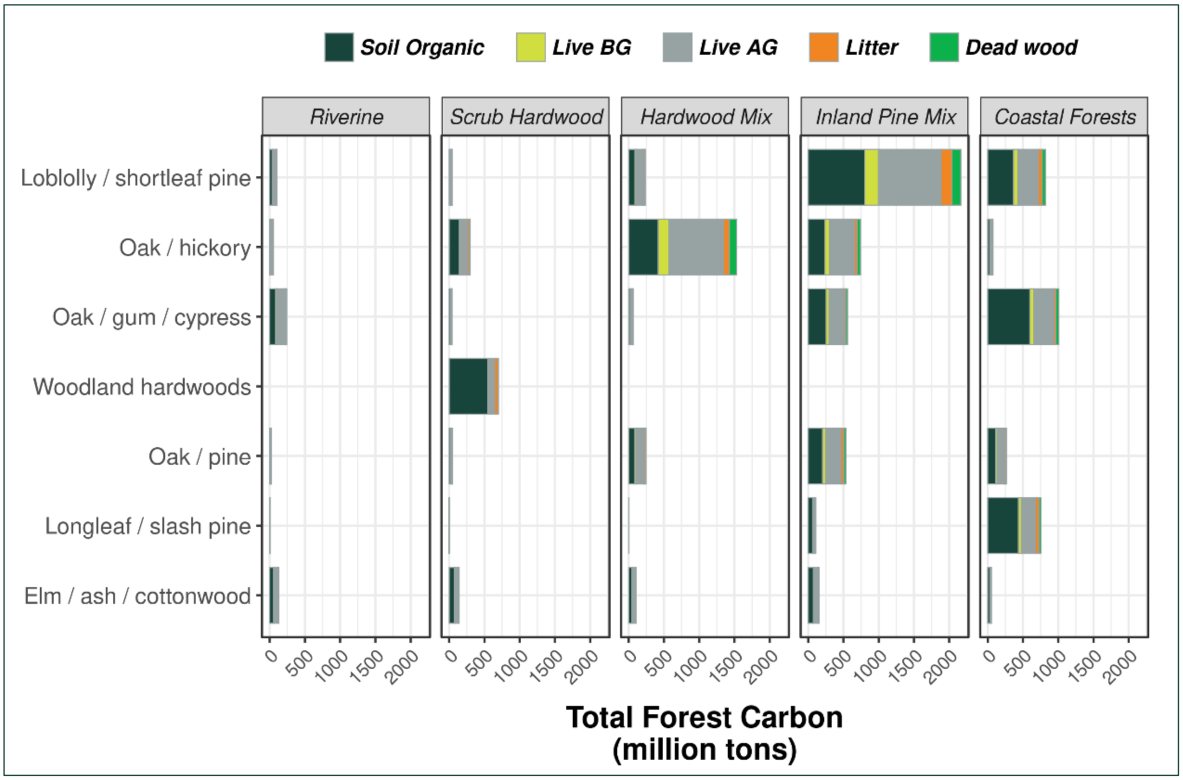
Forest carbon storage can be further assessed by subregion. **Figure 11** shows the amount of carbon stored in different forest carbon pools by key cover types within five subregions of the US SE: Riverine, Scrub Hardwood, Hardwood Mix, Inland Pine Mix, and Coastal Forests. These subregional boundaries are shown in **Figure 12**, and each represents a distinct geographic zone within the US SE based prevailing dominant species, historical trends, and projected climate change impacts. Variations in forest carbon allocation can be seen across cover types within a given 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.

Loblolly/shortleaf pine forests of the Inland Pine Mix subregion are important for regional forest carbon storage, as they store the highest total amount of carbon in every pool across subregions and cover types. The Scrub Hardwood and Coastal Forests subregions are unique from the other zones because they store more total carbon in belowground pools (such as in soil and in living roots) than in aboveground pools of deadwood, litter, and living plants. In the Scrub Hardwood subregion, this trend is primarily driven by the relative abundance of the Woodland hardwoods cover type, which stores more carbon in soil organic pools than other cover types. In the Coastal Forests subregion, which supports very moist forest ecosystems, such as swamps and bayous, large belowground carbon pools accumulate due to slow rates of decomposition in saturated, oxygen-poor soils.

Looking at trends within a single cover type across subregions, the role that geography plays in carbon allocation can be seen. For example, Oak/hickory forests in the Scrub Hardwood subregion store only half of their total carbon in aboveground pools, whereas in the Hardwood Mix subregion, these stands store roughly two-thirds of their total carbon in aboveground pools.

Figure 11

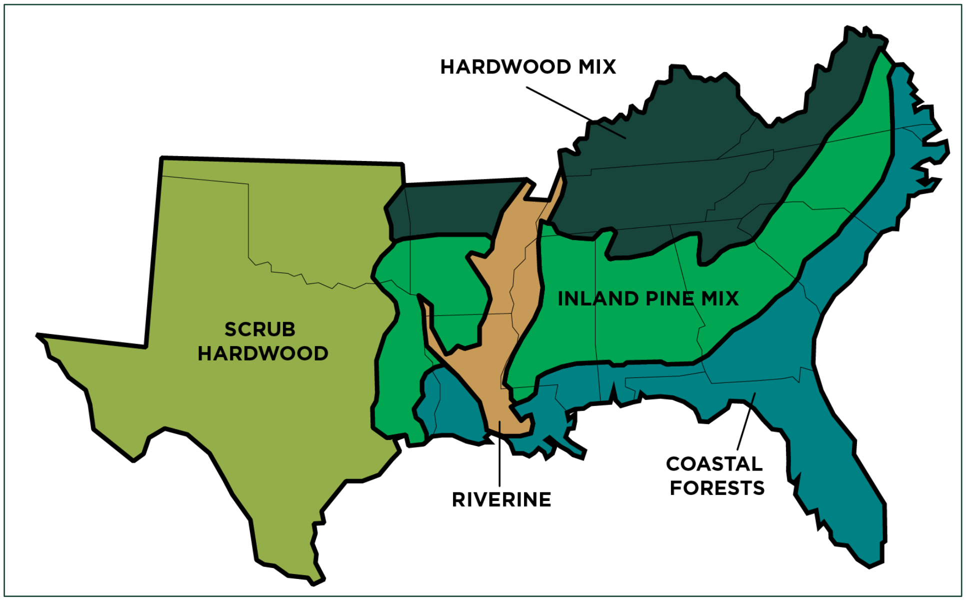
Total Forest Carbon by Forest Type and Subregion (million tons) in the Southeast Region of the United States



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

Figure 12

Map of Subregions within the Southeast Region of the United States



Note. Created by FCCP, 2021.

Carbon Management in the Southeast

Increase Stocking Levels in Understocked Forests

In stands with low to moderate vulnerability, maintaining greater live tree biomass can provide significant carbon benefits over extended periods of time. Increasing stand stocking levels on understocked forests (<60% fully stocked conditions) can increase carbon density in live biomass pools as well as total ecosystem carbon pools. Examples of tactics that can be used to increase stocking levels include:

- Extending rotations to enhance average carbon stocks and store additional carbon in long-lived wood products from larger diameter sawlogs
- Increasing retention of live tree biomass during harvest and thinning treatments
- Protecting forests through the creation or enhancement of reserves, especially for areas with high carbon densities or low vulnerability to climate change
- Extending buffer zones around sensitive sites such as wetlands and riparian areas during harvest

Whether these tactics are appropriate for a given stand is determined by many factors; and before implementing this approach, an assessment of vulnerability to future carbon loss is critical. Forest types that are generally considered to have low vulnerability with increased stocking include those with species that are in the northern portion of their range. These may include Oak/hickory forests as well as some lowland and riparian hardwood forest types.

Enhance Forest Recovery Following Disturbance

Although disturbances are often impossible to predict, land managers can increase the preparedness of ecosystems for large and severe disturbances and prioritize rapid response to mitigate impacts on carbon storage. Adequate planning in advance of disturbance can support an earlier or more flexible response and prevent maladaptive responses that reduce or delay carbon recovery rates. Practices that enhance forest recovery following disturbance can include:

- Retaining biological legacies from damaged areas
- Controlling competition from invasive plant species to enhance tree regeneration
- Promptly revegetating recently disturbed sites (e.g., post-storm rehabilitation) to reduce soil erosion
    - This practice may include strategic planting or promoting of climate-adapted species and genotypes to increase preparedness for future disturbances
- Amending soils when replanting, such as with biochar

Figure 13

Forest Stand Lacking Natural Regeneration Following a Near Stand-Replacing Disturbance

Note. Photo by James M. Gulden.

Prioritize Low-Vulnerability Sites for Maintaining or Enhancing Carbon

Forests that are less vulnerable or possess characteristics that buffer them from disturbance frequency and severity are very important for overall carbon storage at the landscape scale. When managing to retain or increase forest carbon, it is important to prioritize implementation on sites with low vulnerability. This will reduce the risk of those retained and enhanced carbon stores being lost to disturbances such as wildfire, extreme storms, pests, disease, drought, and excessively high or low temperatures. Example characteristics of low-vulnerability forests may include:

- Large, unfragmented forest patches or sites that otherwise minimize exposure to stressors that could increase tree mortality
- Stands that contain species with wide temperature or moisture tolerances
- Sites where hydrology or soil fertility characteristics reduce impacts of drought or nutrient limitations
- Stands with enhanced species or structural diversity which may lower vulnerability or enhance recovery following impacts from pests or pathogens

Example actions to maintain or enhance carbon stocks on low-vulnerability sites may include:

- Promoting old forest conditions by limiting harvest removal
- Increasing retention of large diameter trees on sites with low vulnerability to drought stress
- Protecting large, unfragmented forest areas from forest loss and division

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

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