



Forest Carbon and Climate Program  
Department of Forestry  
MICHIGAN STATE UNIVERSITY



# State and Tribal Capacity Building on Forest Carbon

## *Forest Carbon and Climate Change in Rhode Island*

This technical briefing summarizes topics such as forest densities and cover types, carbon storage, and climate considerations for the state of Rhode Island.

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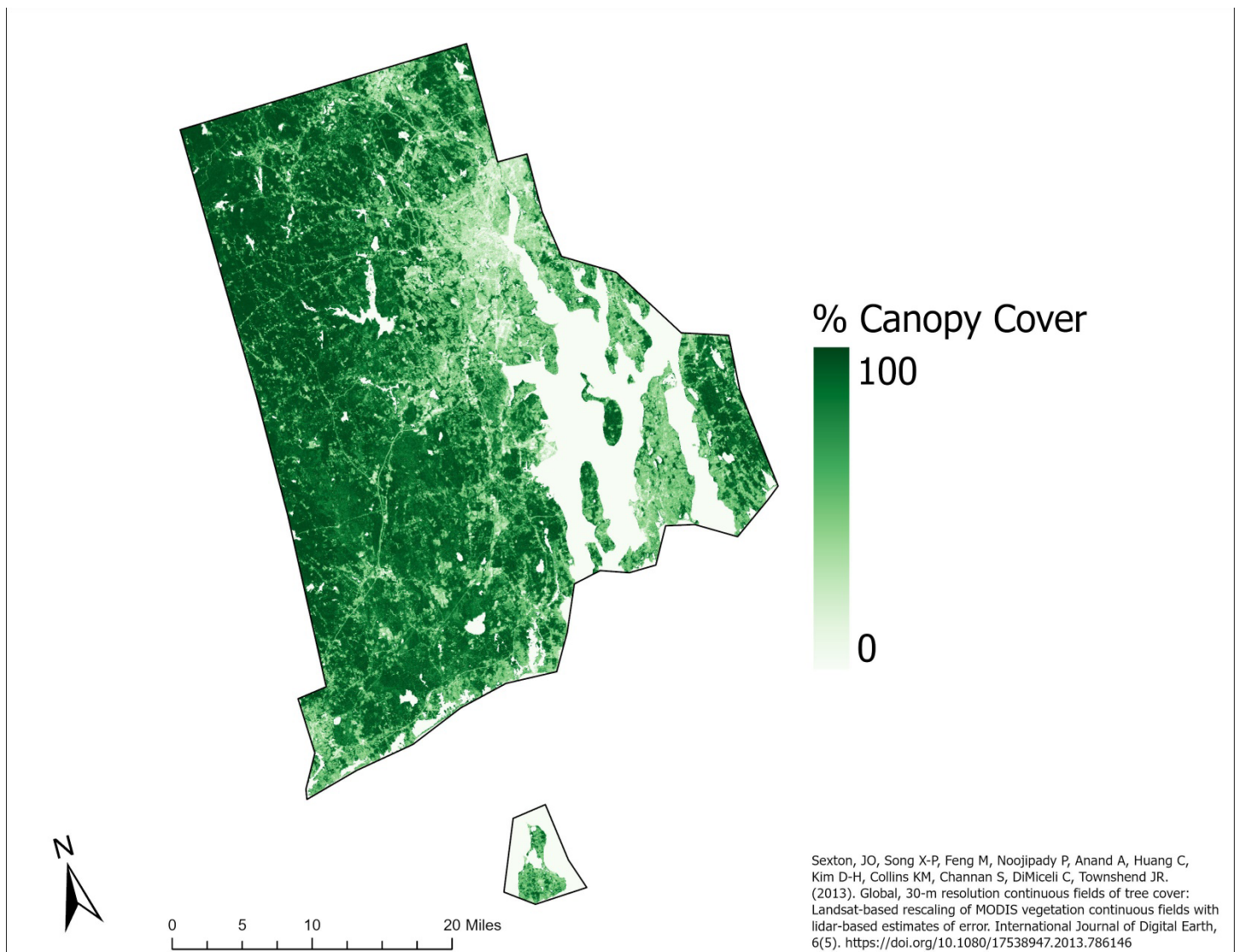
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## Rhode Island Forest Overview

Rhode Island is situated along the east coast of the United States and lies within the US Forest Service's Eastern Region (USFS Region 9). Bordering states include Connecticut to the west, and Massachusetts to the north and east, with the Atlantic coast marking Rhode Island's southern boundary.

A map of percent tree canopy cover in Rhode Island is shown in **Figure 1**. This state has significant forest coverage across much of its extent. Areas of reduced canopy cover coincide with major transportation corridors, urban centers such as Providence and Newport, and surrounding areas of urban sprawl. The heavily-forested eastern portion of the state has a high density of protected lands including state parks, wildlife refuges, and several habitat management areas.

**Figure 1.** Percent tree canopy cover in Rhode Island.

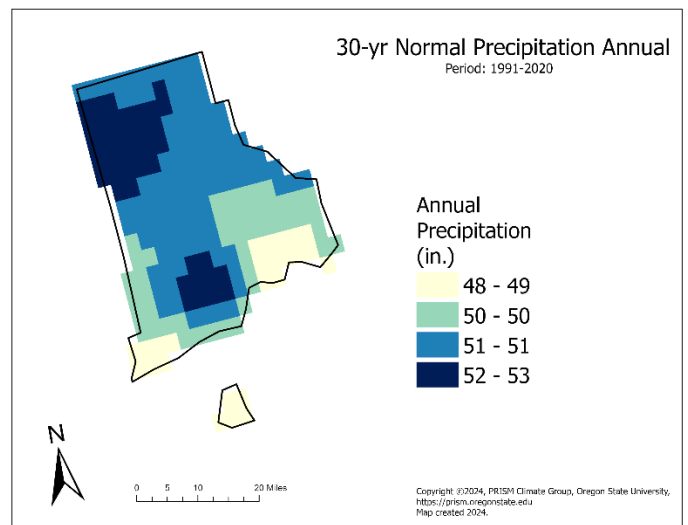
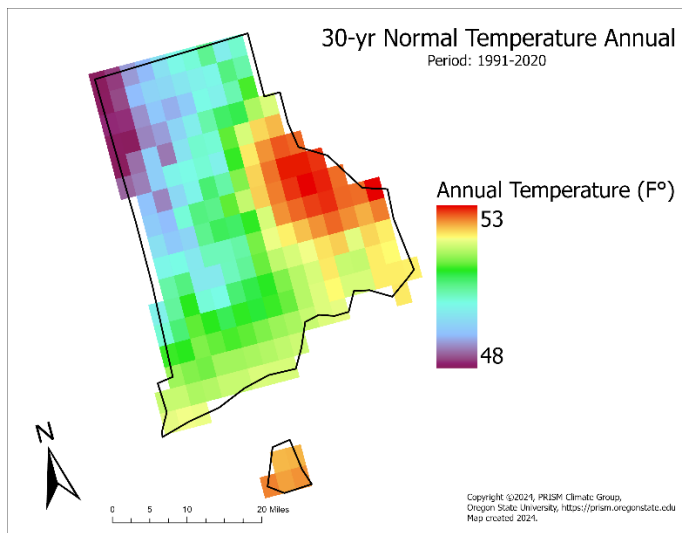


# Temperature and Precipitation

Two major factors affecting forest carbon and productivity are temperature and precipitation. **Figure 2** shows normal mean temperatures throughout Rhode Island between 1991 and 2020. Over this 30-year period, mean annual temperatures varied by about 5 °F across this state. Temperature trends follow a gradient, with warmer mean temperatures occurring in the eastern portion of the state and giving way to cooler temperatures to the northwest. The warmest mean annual temperature is around 53 °F and occurs along Rhode Island’s eastern border, while the coolest mean annual temperature is around 48 °F in the northwest corner of the state and coincides with higher elevations.

**Figure 2.** Normal mean temperature (°F) from 1991–2020 in Rhode Island.

**Figure 3.** Normal mean precipitation (in.) from 1991–2020 in Rhode Island.

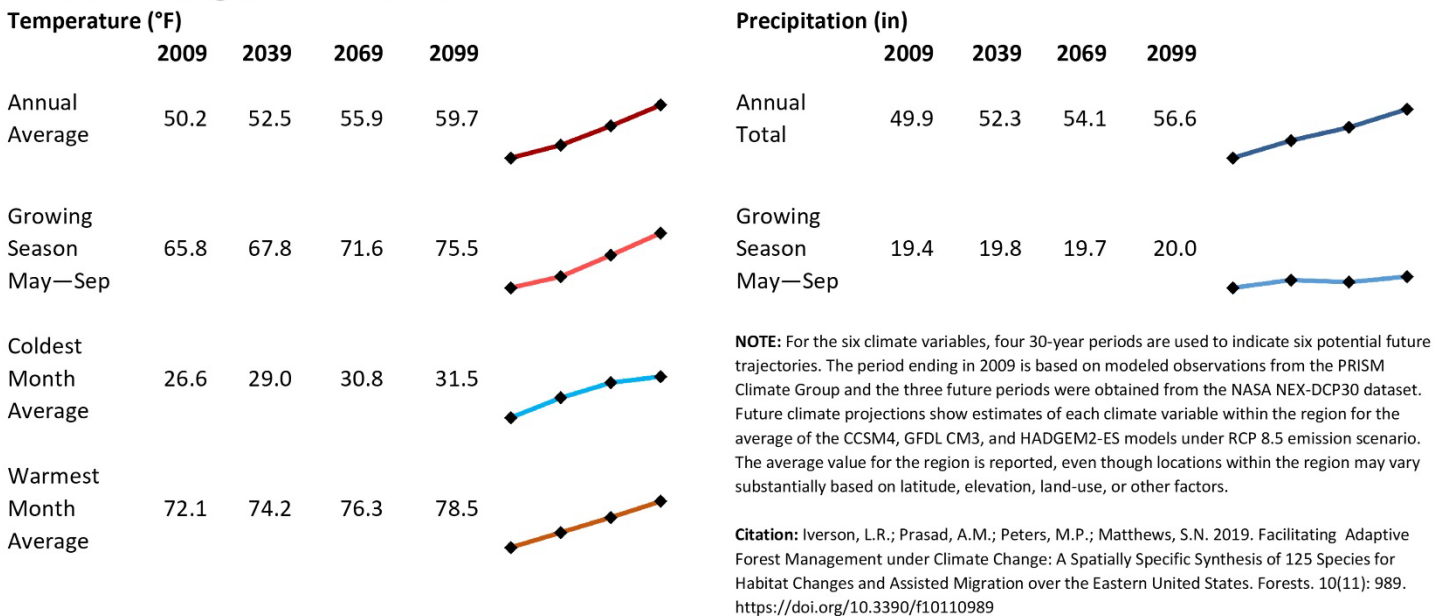


**Figure 3** shows normal mean precipitation throughout Rhode Island between 1991 and 2020 and demonstrates the geographic variation in these trends. Over this 30-year period, mean annual precipitation levels varied by about 5 in. Areas that receive the lowest levels of precipitation (48-49 in.) occur in the southwest and southeast corners of the state, as well as on Block Island. Areas receiving the highest amounts of precipitation (52-53 in.) occur in the northwest corner and south-central portion of the state.

# Projected Future Trends in Temperature / Precipitation

**Figure 4.** Model results for potential changes in temperature and precipitation trends in Rhode Island through 2099 under a high emission scenario (RCP 8.5).

## Potential Changes in Climate Variables



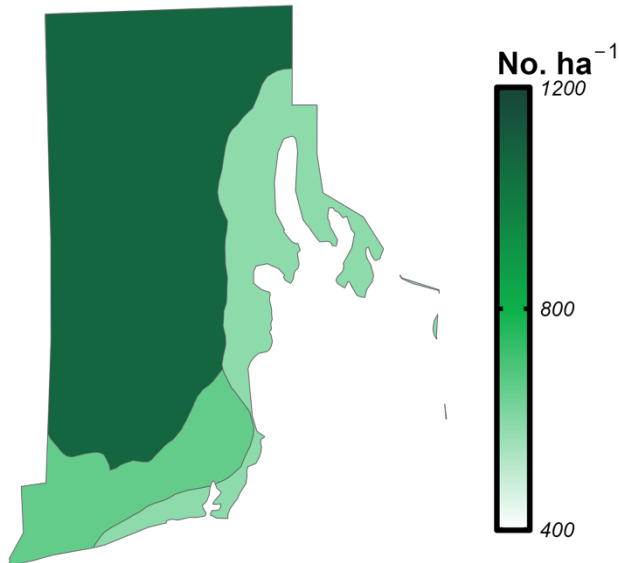
Projected future trends in temperature and precipitation for Rhode Island between 2009 and 2099 are shown in **Figure 4**. Model results suggest average temperatures will continue to increase through the end of the century, a trend which is also projected for the coldest and warmest month averages, as well as throughout the growing season (May – Sep.). Over this 90-year period, average annual temperatures are expected to increase by an estimated 9.5 °F, with the most drastic increases expected to occur during the growing season (+9.7 °F).

Model results of future precipitation in Rhode Island follow variable trends, with totals projected to steadily increase through 2099 (**Figure 4**). Over a 90-year period, annual precipitation is expected to increase by an estimated 6.7 in., which is a higher rate of change than projections for the growing season (+0.6 in.). This suggests that the most significant changes to precipitation in Rhode Island may occur during the winter months (Oct. – Apr.).

# Forest Density

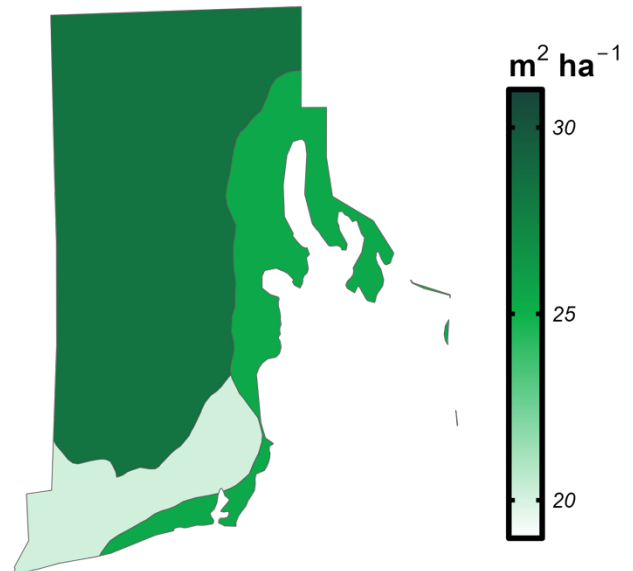
**Figure 5.** Forest density as live tree density (No. ha<sup>-1</sup>) in Rhode Island.

**Forest Density: Live tree number**



**Figure 6.** Forest density as live tree basal area (m<sup>2</sup> ha<sup>-1</sup>) in Rhode Island.

**Forest Density: Live tree basal area**



Forest density<sup>1</sup> is both a structural characteristic of forests and a reflection of forest dynamics. It can be measured as the number of trees per unit area, or it can be measured in terms of live tree area per unit area, known as “basal area”. Live tree basal area represents the amount of ground covered by living trees in two-dimensional space. **Figure 5** shows average forest density in terms of live trees per hectare by ecosection<sup>2</sup> across the state of Rhode Island, while **Figure 6** represents forest density by ecosection in terms of basal area (m<sup>2</sup> ha<sup>-1</sup>).

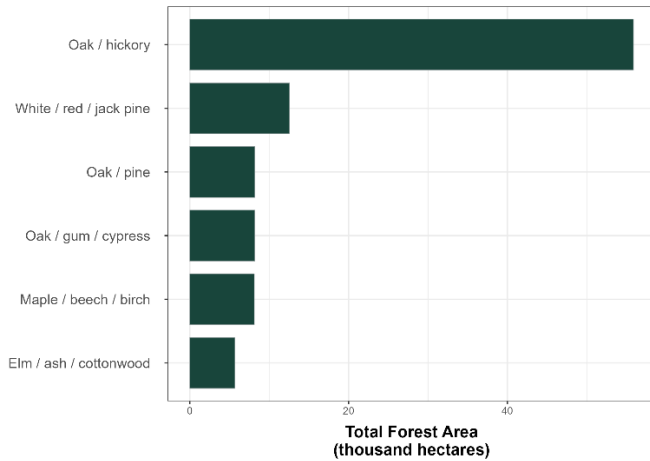
By comparing these figures we can see that the eastern coastal ecosection of the state (which includes the City of Providence) has a relatively low forest density in terms of number of trees per hectare (**Figure 5**), but an average density in terms of basal area (**Figure 6**). This suggests that in this eastern coastal zone, there may be fewer total trees per unit area, but on average, these trees tend to be relatively large. Meanwhile, the ecosection in the southwestern corner of Rhode Island, which borders Connecticut and the Atlantic coast, has lower forest density than other areas in terms of both number of trees and basal area, suggesting a lower overall forest density in this zone.

<sup>1</sup>All forest inventory and carbon data were estimated using data from the Forest Inventory and Analysis (FIA) Program which can be accessed through the FIA DataMart (USDA Forest Service, 2024. *Forest inventory and analysis program*. Available at: <https://www.fia.fs.usda.gov/>) using the rFIA package (Stanke et al, 2020. rFIA: an R package for estimation of forest attributes with the US Forest Inventory and analysis database. *Environ Model Softw.* **127**:104664. <https://doi.org/10.1016/j.envsoft.2020.104664>) in the R programming environment (R Core Team, 2020. *R: A language and environment for statistical computing*, Vienna, Austria: R Foundation for Statistical Computing.

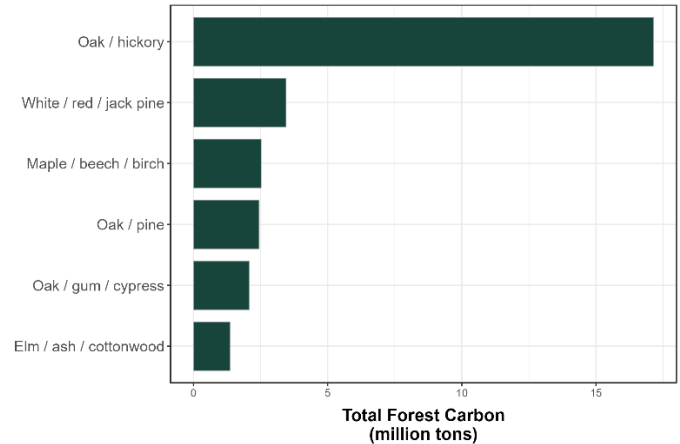
<sup>2</sup>Ecosection definition can be found at Cleland et al, 2007. Ecological Subregions: Sections and Subsections for the conterminous United States. *General Technical Report WO-76D*, Washington Office, USDA Forest Service. <https://doi.org/10.2737/WO-GTR-76D>

# Forest Cover Types and Carbon

**Figure 7.** Total forest area (thousand ha) by forest type in Rhode Island.



**Figure 8.** Total forest carbon (million tons) by forest type in Rhode Island. Total forest carbon is the sum of carbon stored across all aboveground and belowground pools (includes Soil Organic carbon + Live Belowground carbon + Live Aboveground carbon + Litter carbon + Dead wood carbon).

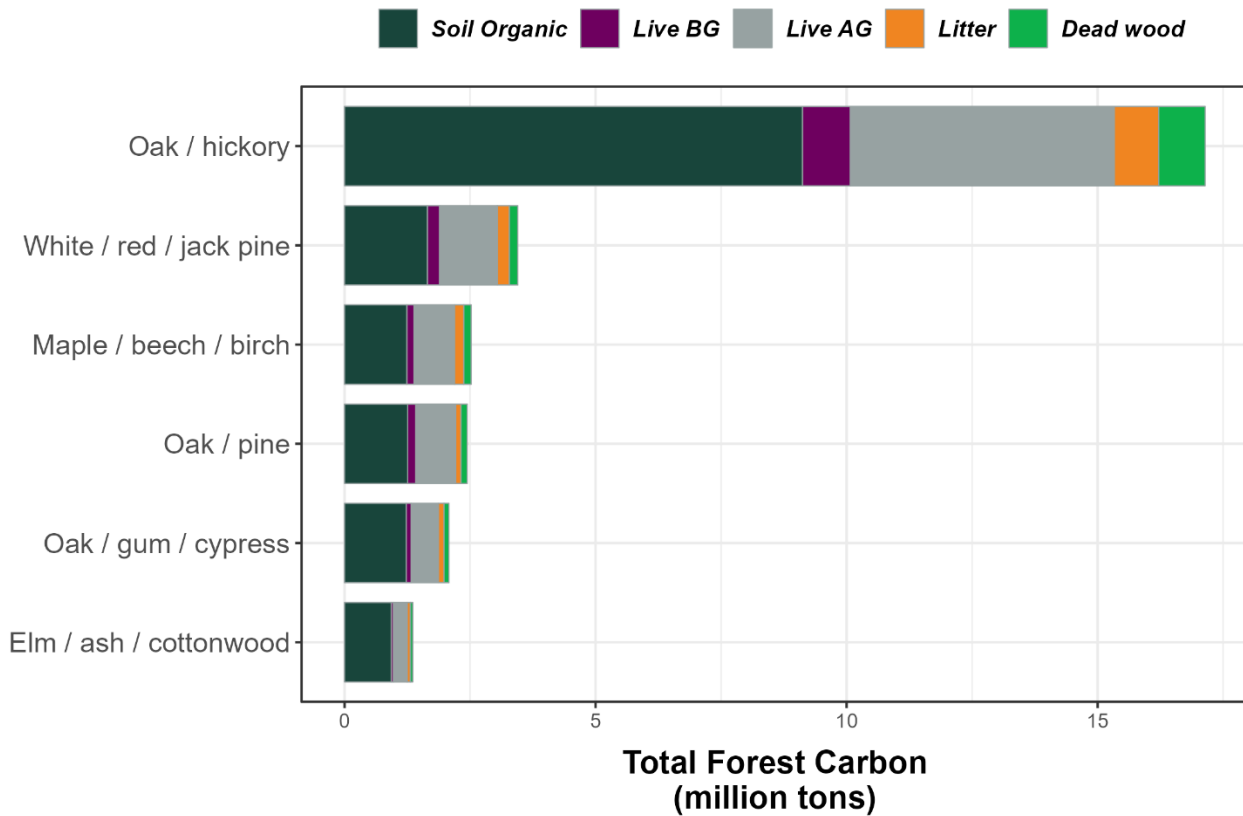


Rhode Island is dominated by 6 key forest cover types: Oak / hickory, White / red / jack pine, Oak / pine, Oak / gum / cypress, Maple / beech / birch, and Elm / ash / cottonwood. **Figure 7** and **Figure 8** show state-level data of total forested area and total forest carbon, respectively, for each of these cover type groups. As these figures show, Oak / hickory is the dominant forest type of Rhode Island, spanning an area upwards of 55,000 hectares and storing roughly 17 million tons of carbon statewide. With coverage levels ranging from ~5,000-12,000 hectares, other forest types in this state are less abundant, yet play an important role contributing to enhanced biodiversity and landscape heterogeneity. Comparing trends from **Figure 7** with those in **Figure 8** demonstrates how carbon storage levels vary by forest cover type. For example, Oak / pine and Oak / gum / cypress forests cover slightly more land area than Maple / beech / birch stands in Rhode Island (**Figure 7**), yet when it comes to carbon, Maple / beech / birch stands store slightly more carbon than their Oak / pine and Oak / gum / cypress counterparts (**Figure 8**).

<sup>3</sup>Forest Types are a classification of forest land based upon and named for the tree species that forms the plurality of live-tree stocking. These forest types used in the briefing align with FIA's definition of Forest type group which are a combination of forest types that share closely associated species and site requirements. Longer definitions of both forest types and forest type groups are found in Appendix D of the Forest Inventory and Analysis Database: Database Description and User Guide for Phase 2 (version 9.1) which can be accessed here: [https://research.fs.usda.gov/sites/default/files/2023-11/wo-fiadb\\_user\\_guide\\_p2\\_9-1\\_final.pdf](https://research.fs.usda.gov/sites/default/files/2023-11/wo-fiadb_user_guide_p2_9-1_final.pdf)

# Forest Carbon Pools

**Figure 9.** Total forest carbon (million tons) by pool and forest type in Rhode Island.



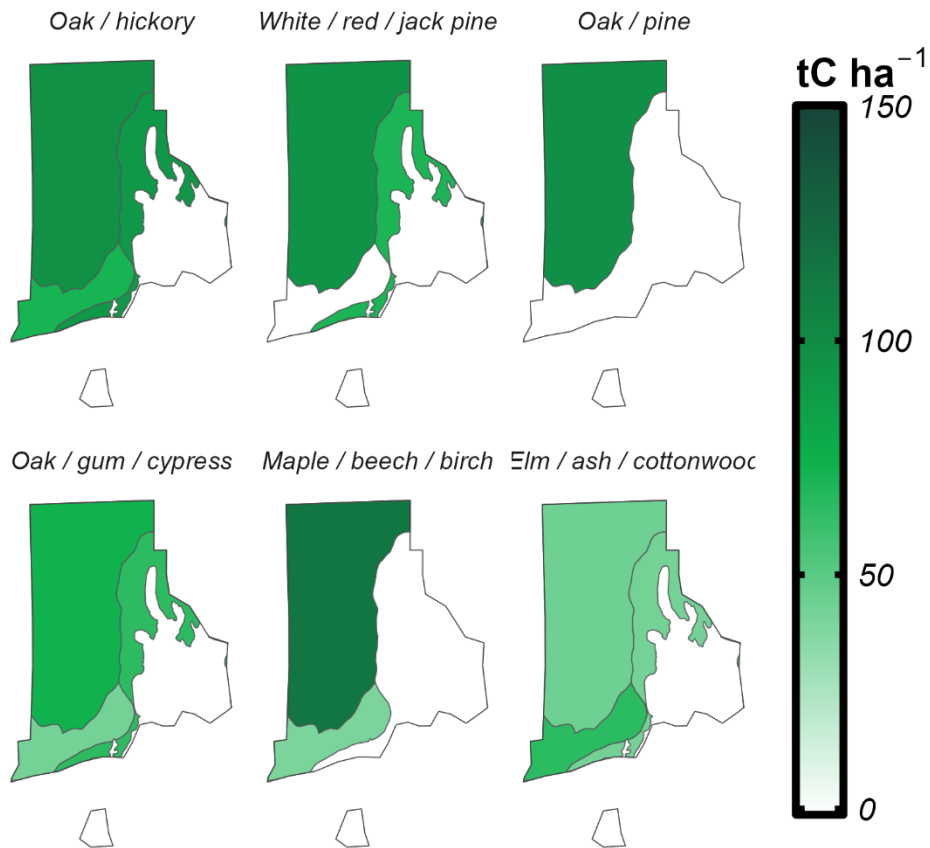
Forest carbon storage can be further assessed by examining how it's distributed across different ecosystem carbon pools. **Figure 9** shows the amount of carbon stored in different carbon pools of key forest cover types in Rhode Island. These values show how different forest types allocate distinct proportions of forest carbon into soil organic matter, live belowground (BG) biomass, live aboveground (AG) biomass, litter, and dead wood pools. Rhode Island forests generally allocate more ecosystem carbon to belowground pools (soil organic matter + live BG biomass) than aboveground pools (live AG biomass + litter + dead wood), yet the proportions in which they do so varies across forest cover types. For instance, Oak / gum / cypress and Elm / ash / cottonwood forests allocate approximately double the amount of carbon to belowground pools than aboveground pools, whereas forest types like White / red / jack pine and Maple / beech / birch distribute carbon more evenly between belowground and aboveground pools. Another noteworthy trait shown in **Figure 9** is the magnitude of carbon storage levels across different pools and cover types. Oak / hickory's dominating presence on this landscape means its statewide carbon pools are outsized compared to other groups. For example, leaf litter and dead wood pools of Rhode Island's Oak / hickory forests on their own contain more stored carbon than the total ecosystem carbon (sum of carbon stored across all pools) contained by the Elm / ash / cottonwood group.



## Forest Carbon Density

**Figure 9.** Aboveground live forest carbon density ( $\text{tC ha}^{-1}$ ) by forest type in Rhode Island.

### Average Forest Carbon Density by Ecosession: Aboveground Live



Forest carbon density can be influenced by many ecosystem traits, such as tree density, stand age, species mix/ cover type, soil fertility, elevation, and a site's management and disturbance history. In **Figure 9**, the carbon density of aboveground living forest biomass is shown for 6 key cover types in Rhode Island. Of these, Maple / beech / birch stands hold the highest levels of aboveground live carbon per unit area, represented by the deep shade of green in the large western ecosession of the state. By contrast, Elm / ash / cottonwood stands have a much lower carbon density per unit area in this ecosession. Across much of their extent, Oak / hickory and Oak / gum / cypress stands exhibit relatively even carbon densities, while cover types like Maple / beech / birch and Elm / ash / cottonwood show higher levels of variability across ecosessions. In these instances, variable carbon densities can be driven by the relative prevalence or absence of each forest type from a given ecosession.

## Species-Specific Considerations for Climate Adaptation

Climate change is expected impact the distribution of species into the future. Predictive modeling of potential future changes that incorporate species interactions, dispersal mechanisms, demography, physiology, and evolution is needed to assist in adaptive forest planning. The USDA Forest Service **Climate Change Tree Atlas, Version 4**, provides modeled potential suitable habitat for 125 species in the eastern US, with an additional 23 species. <https://www.fs.usda.gov/nrs/atlas/tree/>

### Core Climate Change Tree Atlas components:

- DISTRIB-II: Species habitat suitability model
- SHIFT: Migration model (when combined with DISTRIB-II, estimates colonization potential (HQCL) of future suitable habitats)
- Adaptability Ratings: Species adaptability ratings (species traits not included in DISTRIB-II and SHIFT models)

In addition to the modeled potential suitable habitat for individual tree species, the Climate Change Atlas includes Current and potential future habitat, capability and migration for individual tree species and potential changes in climate variables summarized by the following spatial extents:

Geographic Area	Description
National Forest Summaries	Results summarized for 55 national forests
National Park Summaries	Results summarized for 78 national parks
HUC6 Watershed	Results summarized by hydrologic unit codes level 3 (HUC 6) which are hierarchical classifications based on surface hydrologic features in which level 3 maps watershed basins (Seaber et al, 1987) <a href="https://pubs.usgs.gov/wsp/wsp2294/">https://pubs.usgs.gov/wsp/wsp2294/</a>
Ecoregional Vulnerability Assessments (EVAS)	Results summarized by ecoregions used in the USDA Climate Hub Regional Vulnerability Assessments <a href="https://www.climatehubs.usda.gov/assessments">https://www.climatehubs.usda.gov/assessments</a>
USDA Forest Service EcoMap 2007 Sections	Results summarized by ecological sections that delineate ecosystems with distinctive vegetation and other unique ecological characteristics (Cleland et al, 2007, McNab et al, 2007)
National Climate Assessment (NCA) 2015 Regional Summaries	Results summarized by National Climate Assessment Region which include the Midwest, Northeast, Northern Plains, Southeast, and Southern Plains
1 x 1° Grid Summaries	Results summarized by 1x1° latitude and longitude
State Summaries	Results summarized for 38 states
Urban areas	Results summarized for 185 urban areas across the eastern US

Additional background on this tool can be found at: <https://research.fs.usda.gov/centers/ccrc> along with short video tutorials on the Climate Change Atlas website.

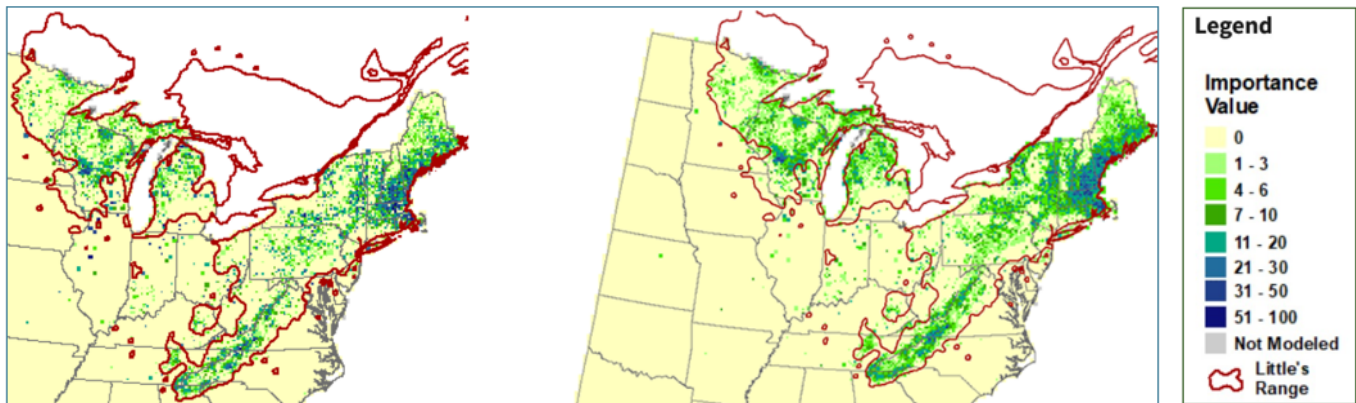
# Habitat Suitability and Migration Models

Model Reliability: **High**

Key Species Example: Modeled potential suitable habitat for Eastern White Pine (*Pinus strobus*) through 2100

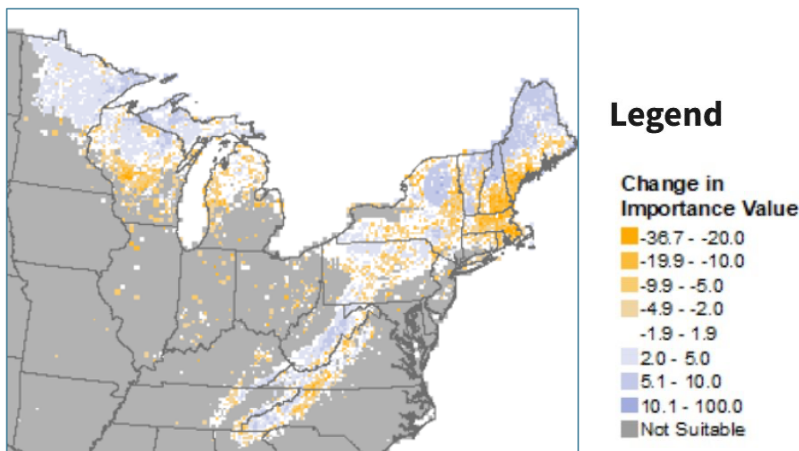
Current habitat quality and distribution (DISTRIB-II)

Potential migration (SHIFT) and colonization likelihood (CL)



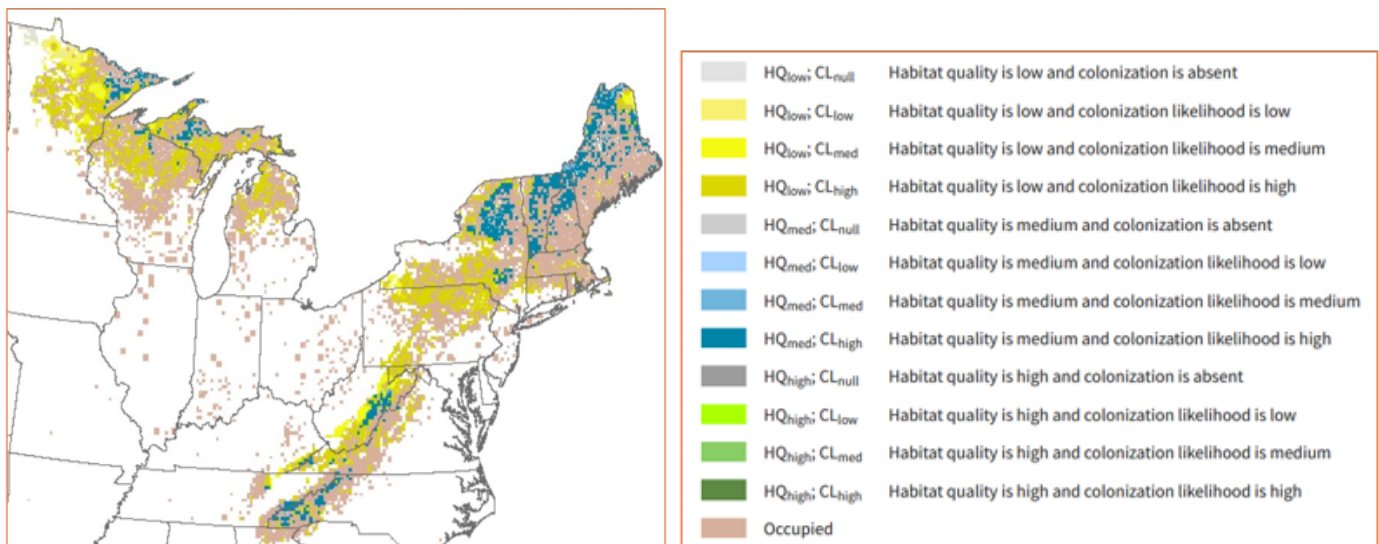
Importance value is a measure of abundance that accounts for both tree basal area and number of stems, ranging from 0-100.

Colonization potential of future habitats under a high emission scenario (RCP 8.5)



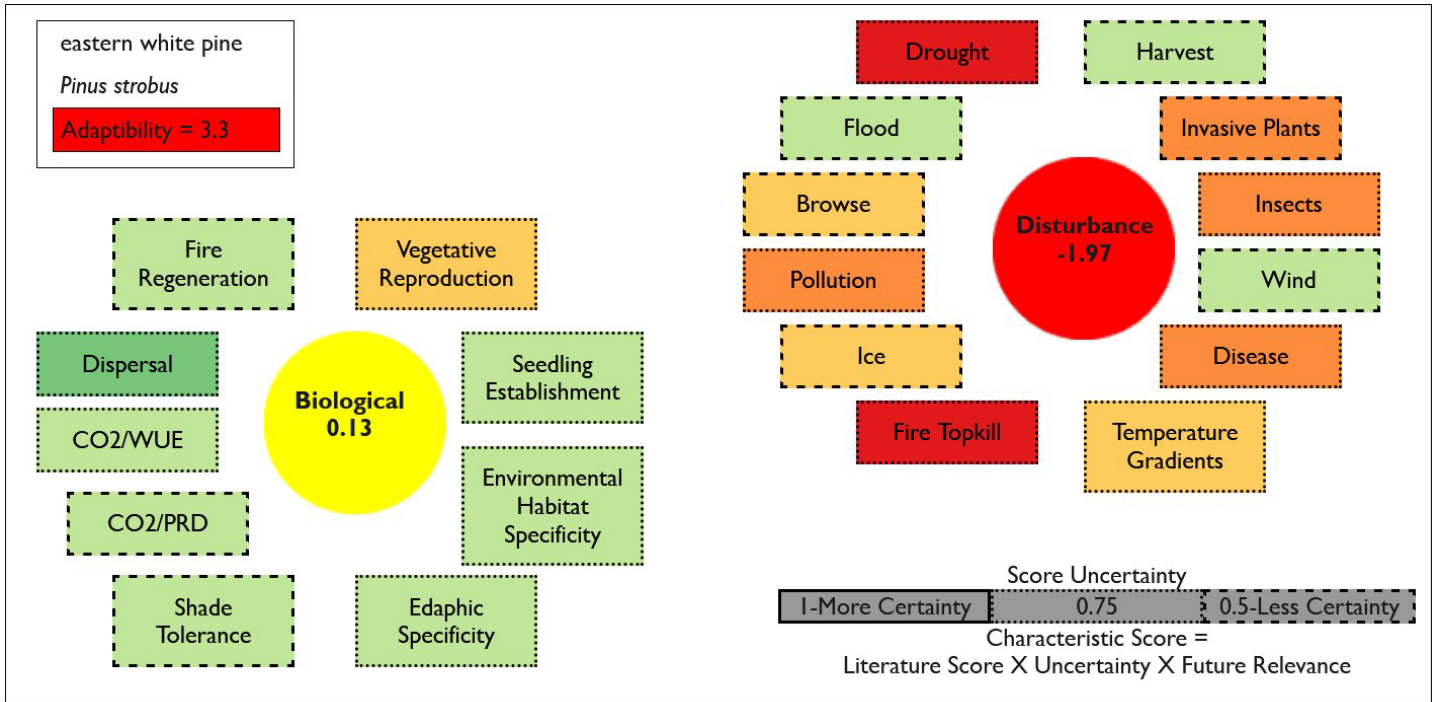
Colonization is limited to range margins and infill (Blue) which is derived from habitat quality (DISTRIB) and migration model (SHIFT) utilizing the colonization likelihood model (CL). Orange shading represents current species' distributions where abundance is predicted to decrease due to loss of habitat suitability.

DISTRIB-II + SHIFT: Habitat quality and colonization likelihood (RCP 8.5)



# Adaptability Ratings

Key Species Example: Eastern White Pine (*Pinus Strobus*)



V Hi Pos +3	High Pos +2	Low Pos +1	Minimal 0	Low Neg -1	High Neg -2	V Hi Neg -3
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The Adaptability score, which assesses 21 variables to assign adaptability ratings to tree species in the eastern US, reflects a species’ potential adaptability to climate change-driven stressors and disturbances at range wide scale. Adaptability ratings provide broad insights into factors that cannot be directly included in the Climate Change Tree Atlas species migration models. Two types of species traits are evaluated: 1) biological and 2) disturbance, each with their own set of factors to help characterize species’ traits and responses to disturbance. Uncertainty is also included for each trait or factor assessed. When coupled with other modeled projections, adaptability ratings can support future planning under a changing climate.

The Adaptability variable is single score derived from the Modification Factors which encompass scores for the 12 disturbance and 9 biological factors. The Adaptability results can be considered relative to other tree species. For example, a species with a low Adaptability variable likely does not have life history characteristics to allow it to thrive under most conditions whereas a high Adaptability variable will likely do better under the climate change outputs from the DISTRIB-II and SHIFT Models.

## Climate Change Atlas Summary for Red Oak

Eastern white pine is a widely distributed (10.6% of area), dense, and high importance northern pine with little modeled change in suitable habitat by 2100. It does, however, suffer from some negative traits (e.g., susceptibility to drought, fire, and insects) which drops it to low adaptability. Because of its high current abundance, we upgrade its capacity to cope to fair. SHIFT shows good infill.

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