# Forest Resource Considerations for A New Jersey Natural and Working Lands Strategy

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Prepared By
Amanda O'Lear, Rutgers University
Marjorie Kaplan, Rutgers University
Richard Lathrop, Rutgers University
Christopher Idell, Rutgers University
Lucas Marxen, Rutgers University
Pam Zipse, Rutgers University

Prepared for the New Jersey Climate Change Alliance (https://njadapt.rutgers.edu/)
Natural and Working Lands Group Co-Chairs:
Russell Furnari, PSEG
Tom Gilbert, NJ Conservation Foundation

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## Introduction

The New Jersey Climate Change Alliance (The Alliance) is a network of diverse public, private, non-governmental and academic organizations from across New Jersey facilitated by Rutgers University. The Alliance's goal is to advance science-informed climate change strategies in New Jersey. The Alliance's Natural and Working Lands Workgroup (NWLWG) focuses on identifying opportunities to advance natural and working land strategies helpful to climate mitigation.

In Spring 2021, the Full NWLWG convened a Forestry Workgroup to identify strategies for enhancing New Jersey's ability to store and sequester carbon within forests.[1] (Organizations whose representatives participated in this process are provided in Appendix A).

As a complement to this effort, the Forestry Workgroup was briefed by the Rutgers University developers of the NJForestAdapt tool: a data visualization and mapping tool that provides geospatial and other information on climate change and New Jersey forests (including forest carbon). The Rutgers team also elicited feedback from the Forestry Workgroup for expansion of NJForestAdapt to provide analytical capacity for understanding forest vulnerability as well as opportunities for forest resources to act as a carbon sink. The NJForestAdapt team's final report by Lathrop and Idell (2022) is appended to this report.

This report summarizes the process and resultant strategy options for storing and sequestering carbon in New Jersey's forest resources. These options for consideration can help inform the New Jersey Department of Environmental Protection's Forestry component of a Natural and Working Lands Strategy.

## Forests and Carbon

The global carbon cycle involves storing and moving carbon compounds such as carbon dioxide between carbon pools found in carbon sinks and sources. Carbon pools are reservoirs of carbon capable of storing or releasing carbon. Carbon sinks remove carbon from the atmosphere and store it in a carbon pool, absorbing more carbon than they emit (Janowiak et al., 2017). Conversely, carbon sources release carbon into the atmosphere, releasing more carbon than they absorb. Expanding carbon sinks while limiting the increase of carbon sources reduces the amount of carbon in the atmosphere, helping with carbon management goals and combatting climate change.

Trees and forests play a significant role in the carbon cycle because of their ability to sequester, store and release carbon. Forest plants absorb carbon dioxide from the atmosphere during photosynthesis to produce food for growth, releasing oxygen and storing carbon in woody biomass and the soil (Janowiak et al., 2017). Some carbon is released back into the atmosphere during plant respiration and decomposition (Janowiak et al., 2017). Forests store and release additional carbon through decaying organic matter. When plants die, they stop sequestering carbon and begin releasing carbon into the atmosphere during decomposition. However, some carbon is transferred into the soil where it can reside for extended periods (United States Department of Agriculture [USDA], n.d.a). These processes are constantly underway in the forest ecosystem.

Through the absorption and release of carbon, forests have the potential to be carbon sinks or carbon sources. Globally, forests are the largest terrestrial carbon sink on earth, with carbon stored in five carbon pools:

1. Live tree aboveground biomass
2. Live tree belowground biomass
3. Dead wood

[1] In this context, street trees are considered part of an urban or community forest.

4. Litter
5. Soil organic carbon (Domke et al, 2018).

In New Jersey, forests act as a carbon sink as well. Approximately 40% of the state's total land area is forested and stores an estimated 141 million metric tons of carbon in the five pools (USDA, 2018). This estimate does not include trees in urban and community forests that sequester an additional 1.03 million metric tons of carbon annually (NJDEP, 2020b). However, forests are not guaranteed carbon sinks and can become net emitters of carbon (NJDEP, 2020a). Disturbances like drought, wildfire, harvesting, and invasive species, can quickly release carbon stored in soils and forest biomass (Vose et al., 2018). Proper management practices can reduce stress thereby enhancing and protecting carbon storage in addition to other benefits provided by forests. This report includes stakeholder-identified options from the Forestry Workgroup (representing organizations noted in Appendix A) to maintain New Jersey's forests as carbon sinks by continuing to store existing and future carbon.

## Methodology For Strategy Identification

The Natural and Working Lands Forestry Workgroup reviewed the New Jersey Global Warming Response Act 80 x 50 Report (herein referred to as the 80 x 50 Report) to understand the existing strategies that seek to protect forest carbon sequestration capacity and storage already in place for forests and carbon sequestration in New Jersey (NJDEP, 2020a). The 80 x 50 Report estimates NJ's natural lands store the equivalent of 8% of the state's annual greenhouse gas emissions, and the forest strategies within the report aim to maintain and enhance those carbon stores found in the state's forests (NJDEP, 2020a). The group developed an initial list of key forest-related issues absent from the state's list of strategies for achieving New Jersey's 2050 greenhouse gas reduction target. These issues helped inform the stakeholder options presented below.

Reports produced in over a dozen states[2] and by federal and non-governmental organizations (NGOs) were also reviewed for identification of additional strategies for forest resources, yielding over 65 unique strategies related to forestry not included in the 80 x 50 Report addressing numerous aspects of carbon storage and sequestration and forest management. This crosswalk between the 80 x 50 Report and extant strategies from state, NGO, and federal resources identified a series of additional forest actions that New Jersey could consider. Appendix B shows this comparison.

The Workgroup held a June 2021 stakeholder meeting with two dozen participants to discuss the crosswalk and also to explore strategies in the New Jersey State Forest Action Plan (NJ SFAP) which at the time was not publicly accessible as it was undergoing final review by the U.S. Forest Service. However, representatives from the New Jersey Forest Service graciously provided the Workgroup with a presentation on the NJ SFAP. The presentation outlined the organizational framework and central focus of the NJ SFAP. The NJ SFAP analyzes forest conditions and trends, organizes strategies under the U.S. Forest Service's national priorities, and outlines guidance for stakeholders. Following the meeting, attendees received a survey asking for additional input on potential topics and strategies for a forestry component to the New Jersey Natural and Working Lands Strategy. The final NJ SFAP was released in late August 2021 (NJDEP, 2020b), enabling the Workgroup to compare its initial list of strategies not in 80 x 50 Report with the NJ SFAP and use the NJ SFAP to help further refine the stakeholder options. The comparison with the NJ SFAP identified approximately a dozen strategies that were indeed included in the NJ SFAP but absent from the 80 x 50 Report.

A September 2021 meeting provided additional opportunities for input, as well as provided progress updates regarding the NJForestAdapt tool. As NJForestAdapt is further improved and expanded, it can

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[2] California, Colorado, Connecticut, Maine, Massachusetts, Maryland, New Hampshire, New Mexico, New York, North Carolina, Oregon, Pennsylvania, and Washington

inform many of the stakeholder options put forth in this report. The tool creates a snapshot of New Jersey's forest carbon storage and provides information on areas with high potential for carbon loss due to pest, disease and wildfire risk, and helps prioritize candidate areas for afforestation, reforestation, and forest management. In return, as strategies are implemented and monitored, they will inform the continued development of NJForestAdapt. These stakeholder options may identify additional capacity desired in NJForestAdapt, fill knowledge gaps, and meet New Jersey's forest resource goals in the NJ SFAP.

The NJDEP released its 2021 Natural and Working Lands Strategy Scoping Document in December of 2021. The scoping document was shared with the Workgroup and considered in the Workgroup's stakeholder options.

## Stakeholder Identified Options for a New Jersey Natural and Working Lands Strategy for Forests

The options presented below are a synthesis of key Forestry provisions that the Workgroup has identified for a New Jersey Natural and Working Lands Strategy through its literature review, survey, and stakeholder working sessions. Multiple options are identified in four key areas: characterizing climate change and its impacts on New Jersey's forests; establishing a baseline for a strategy to establish a vision and goals; identification of actions New Jersey can take to enhance forest carbon sinks; and considerations for implementing the strategy.

### Key Area 1: Characterizing Climate Change and its Impacts on New Jersey Forests

1. *Understanding climate impact on New Jersey forests.* The strategy could include details on the impact of climate change. Climate change brings a range of impacts to New Jersey's forests including drought, heat waves, more intense precipitation, and the spread of invasive species. Properly managing forests in the face of climate change requires understanding the extent and intensity of these impacts under current conditions and under various climate projections. This can inform what actions the state can take in forest and carbon management.
2. *Understanding the current state of New Jersey's forest carbon and future sequestration potential*. The strategy could include an overview of current forest carbon and sequestration summarizing forest and carbon characteristics, including carbon pool stability, canopy cover, forest density, and projected successional changes. The NJForestAdapt tool provides data in the forest stands, county forest statistics, and pest and disease risk datasets from the USDA's Forest Inventory and Analysis Program. Additional capabilities could be in implementing a decision support function to identify future sequestration potential based on current and potential stocking rates and canopy cover. It is important to note that no single tool is likely to meet all planning and scenario needs. Comprehensive literature reviews and analyses will be required, including Lathrop et al. (2011) as a New Jersey specific resource, in addition to the report developed for this Workgroup by Lathrop and Idell (2022).
3. *Understanding regional differences across New Jersey***.** Incorporating regional approaches to carbon sequestration and storage in the strategy could aid in addressing the unique characteristics, threats, and forest carbon dynamics found across the state in areas including coastal forests, Highlands, Pinelands, and Sourlands. For example, coastal forests are highly vulnerable to sea-level rise. Rising groundwater tables inundate soils, limiting root oxygen, and storm-induced saltwater intrusion creates saline soil conditions (Sacatelli et al., 2020; Carleton et al. 2021). These conditions are unique to the state's coasts. Understanding these differences can inform what forest management strategies the state pursues in different locations. A regional approach

will need to identify critical differences between forests characteristic of the various physiographic provinces and ecoregions of New Jersey, including historic land use change and associated soil alterations. Differences in physiography or historic land use will have important impacts on carbon sequestration potential, native species regeneration, ability to accumulate organic carbon, and resistance to alien species invasion.

4. *Understanding management strategies for minimizing impacts and maximizing carbon.* The strategy could include both carbon defense and carbon offense strategies to address the greatest threats and opportunities facing the state's forests. Carbon defense strategies look to protect the carbon already stored in forests by identifying and addressing risks such as disease, pests, non-native vegetation, and lack of forest regeneration due to deer overpopulation, sunlight regimes, and catastrophic wildfire (Moghaddas et al., 2018; Seidl et al., 2018; NJDEP, 2020b). These include strategies targeting avoided emissions and avoided forest conversion to non-forest land use to prevent carbon loss and maintain and/or restore forest function, diversity, and resilience (NJDEP, 2020b). Carbon offense strategies focus on expanding the existing carbon pool and increasing sequestration rates. These strategies include afforestation, reforestation, forest restoration, proforestation, and enhancing urban and community forests (NJDEP, 2020b). Afforestation is planting trees in areas where there were no forests before, and reforestation re-establishes forest cover to restore forest function (USDA, n.d.b). Forest restoration looks to improve and maintain the health and resilience of the forest ecosystem (USDA n.d.c). Proforestation is a strategy to allow forests to reach their ecological potential by keeping them intact, thereby enhancing carbon sequestration through preserving and/or increasing biodiversity and ecological function (NJDEP, 2020b; Moomaw et al., 2019; Bashir et al., 2019). New Jersey's many ecosystems can benefit from diversifying management through different combinations of these strategies as opposed to prioritizing one strategy over another (NJDEP, 2020b).

## Key Area 2: Establishing the Baseline for a Strategy

1. *Develop objectives and a vision for the strategy incorporating forest carbon sequestration*. The strategy can include a vision to articulate the goal for New Jersey's natural and working lands, including specific objectives within the plan for New Jersey's forest resources. Baseline inventories and actionable management plans at the project level are critical to achieving enhanced biological carbon sequestration. In a broader context, carbon sequestration benefits should be considered within the context of critical habitat and potential trade-offs (e.g., pursuing afforestation on functioning grasslands could involve trade-offs).
2. *Establish goals to store and defend carbon.* The strategy can include numeric and qualitative goals for the state's forests. States such as California and Connecticut have numeric goals to increase the amount of forest cover.[3] North Carolina's Natural and Working Lands Action Plan has a broad carbon-focused goal to "enhance the ability of NWL to sequester carbon and mitigate GHG emissions" (North Carolina Department of Environmental Quality, 2020). The goals can consider harvesting implications on carbon dynamics and encourage the implementation of practices that retain/store carbon. One method suggested by stakeholders for constructing numeric goals is running an optimization model whereby the State can examine multiple scenarios for forest strategies under different assumptions over multiple time horizons. The optimization model can show the potential impacts for each scenario and help identify preferred pathways. Some

[3] California's goal for urban forest expansion is a 20% increase in canopy cover by 2030 (California Environmental Protection Agency et al., 2019). One of Connecticut's goals for forest cover is to increase forest cover in the state from 59% to over 60% by 2040 (GC3 Governor's Council on Climate Change, 2021; Forests Sub-Group, 2020).

stakeholders also noted that an optimization model or approach should also consider critical wildlife habitat and water resources (e.g., evapotranspiration and tree species composition impacts in forests) to fully assess potential trade-offs for each scenario and help holistically identify preferred pathways.

## Key Area 3: Actions to Enhance New Jersey's Forest Carbon Sinks

1. *Develop a protocol for afforestation and reforestation criteria*. A protocol can identify criteria for what qualifies as afforestation and reforestation while establishing recommended practices for success, such as measures to minimize deer impacts.
2. *Consider forest utilization pathways in forest management.* In some instances, harvesting snags, logs, and coarse woody debris provides opportunities for long-term carbon storage and reduced emissions through the production of wood products in forest product markets. Using wood in durable goods such as construction materials and furniture can store carbon for decades. However, it is important to understand the carbon dynamics of any particular forest stand, as harvesting trees can affect carbon in positive or negative ways depending on the circumstances. For example, harvesting mature forests sequestering large amounts of carbon would be counterproductive to forest carbon goals. Any forest utilization pathways should consider urban wood utilization. Urban wood is often underused and costly to dispose of, while it has potential to become new products and to create jobs and income for cities (Nowak, Greenfield, & Ash, 2019). Some examples of urban wood utilization programs for the state include the Urban Wood Network (n.d.) that partners with Illinois Urban Wood (n.d.), Wisconsin Urban Wood (n.d.), and Michigan Urban Wood (n.d.) and the Baltimore Wood Project (n.d.).
3. *Explore the benefits of starting a New Jersey state chapter of the Urban Wood Network. S*uch a network in New Jersey could be adapted from those in the several states mentioned above that have created chapters with success.
4. *Manage forests and forest health threats to protect forest carbon sequestration.* A strategy can include actions to obtain well-balanced forest management to promote long-term forest health and good carbon management. Forest management can include specific actions to address a variety of forests threats including wildfires, disease and pest outbreaks, deer, sunlight suppression and marsh transgression (movement of wetlands inland invading low-lying land areas (Fagherazzi, 2019)), to protect the carbon sequestration potential of the state's forests. Stakeholder options for forest management and addressing forest health threats include the following items.
    a. Pursue a diversity of habitat types using the NJ State Wildlife Action Plan as a guide while pursuing carbon sequestration and storage. Biodiversity is critical for healthy and productive forests (NJDEP, 2020b).
    b. Prioritize soil health to promote overall forest health, especially for urban forests and street trees. Poor soil health can impact tree growth and in turn, impact the carbon storage and sequestration of forests (NJDEP, 2020b).
    c. Pursue forest restoration in forests where regeneration is not occurring to optimize carbon sequestration potential. Forest regeneration is the process of sustaining a forest through the survival and growth of seedling and saplings that replace trees as they die (National Park Service, 2021). Forest restoration would include identifying the mechanism of recruitment failure to better restore these forests and build resilience in a changing climate.
    d. Use prescribed burning to reduce wildfire risk in the hopes of reducing overall forest and carbon losses (Forest Management Task Force, 2021). A study on fire management in the Pine Barren ecosystems found stands lost carbon during the year of a prescribed burn, but this carbon was recovered within two to three years of the burn (Clark et al., 2015). Additionally, prescribed burning can reduce fuel loads to reduce atypically large fires helping maintain biodiversity and other ecosystem services (Gillson et al., 2019).
    e. Actively manage forest diseases and pest outbreaks.

f. Pursue deer management. Over-population of white-tailed deer presents one of the largest threats to forest regeneration in the state of New Jersey and thus jeopardizes future biological carbon sequestration in forested ecosystems. The state should pursue reasonable paths to expand population management programs to address this threat.
g. Pursue invasive species management. Invasive plants and pests threaten the health of New Jersey forests. Forest Stewardship Plans can be encouraged to assess the extent of this threat on individual tracts and to outline strategies to manage these threats. The State could consider incentivizing invasive species management for private-landowners. This management could also include management of farm corridors such as wind breaks and hedgerows (woodland strips that separate farm fields).
h. Adopt a specific and actionable definition of 'proforestation' applicable to New Jersey as well as decision criteria, evaluation methods to assess efficacy, and adaptive management approaches to intervene if monitoring demonstrates that 'proforestation' areas are not developing along a desired trajectory. With those clarified definitions, the State can then identify mature, intact forests storing large amounts of carbon where additional carbon gains and ecological benefits can be achieved.
i. Consider the spatial distribution of forest management and planning efforts and assess the evenness of investment at the watershed scale-- a headwaters to estuary confluence approach. This ensures that groundwater resources and precipitation interception (both key components of forest ecosystem services) remain resilient to climate change across an entire watershed. This could also serve as a systematic assessment to ensure investment equity is obtained (i.e., find areas with historically low investment that can be interpreted as environmental injustices). This may be essential in poor, minority dominated coastal communities that could benefit the greatest from coastal/low-lying forest services.

5. *Promote urban and community forestry throughout the state.* Urban and community forests possess significant carbon sequestration and storage potential quality (NJDEP, 2020b). Additional benefits include improved air and water quality, lowered building energy use, mitigating runoff and flooding, mitigating heat island effects, and strengthened human health and social well-being (Nowak & Greenfield, 2018). Promoting urban and community forests would bring additional trees and co-benefits to New Jersey communities. Listed below are different programs and projects that could help promote and expand urban and community forests.
   a. The NJ Forest Service Urban & Community Forestry Program works to encourage, promote, and support the local stewardship and effective management of trees and forest ecosystems in New Jersey's communities. Participating municipalities and counties gain access to training programs, grant opportunities, and liability protection related to the management of their local tree resource. Incorporating other topical areas such as the Connecting Habitat Across New Jersey (CHANJ) plan to build corridors that connect spaces both urban to urban and urban to broader natural areas can add additional value to these efforts be used to develop a sense of stewardship in urban communities.
   b. Brownfield restoration projects can incorporate afforestation and reforestation efforts to grow the urban tree canopy. One example is the Harrison Avenue Landfill project in Camden, NJ turning 62 acres of the former landfill into a waterfront park with freshwater tidal wetlands, a living shoreline, fishing pond, habitat conservation island, playground, and amphitheater with trees and shrubs planted over 50% of the site (NJDEP, 2021).
   c. Pocket forests offer potential in urban redevelopment strategies. Pocket forests involve planting small biodiverse forests in urban and community settings using native plants (Stuntz, 2017). These forests require minimal space, so they provide an opportunity for communities lacking available space. For example, the organization SUGi built a 400-square-meter pocket forest in Cambridge, MA on the site of an old landfill (SUGi, 2021). Pocket forests can build on efforts by academic institutions, conservation organizations

and urban communities to map existing tree canopy and identify potential open spaces that can be utilized for this purpose.

d. Engage previously redlined communities and overburdened communities to assess where and what types of tree planting projects would benefit community members best. Research has shown these communities including Camden, NJ and Trenton, NJ experience higher land surface temperatures than non-redlined areas, and additional trees can help lower land surface temperatures (Hoffman et al., 2020).

e. The state's maritime and other coastal forests are currently threatened by sea level through rising groundwater and saltwater intrusion mentioned earlier and increased flooding events due to more severe precipitation. The Blue Acres Program purchases flood-prone homes and demolishes them to restore the floodplain and reduce risk. The restoration of the floodplain can include restoring forests, including maritime forests. In Linden, NJ, a recent project involved multiple organizations, including the Blue Acres Program restoring a floodplain ecosystem. The project includes an ecological restoration project within the acquired properties, restoring native coastal floodplain forest, marsh, and wetlands (Princeton Hydro, 2020). Another example is the Forested Wetland Floodplain Restoration currently underway in Woodbridge, NJ. This project incorporates Blue Acres acquisitions to restore a flood prone neighborhood back into a natural forested wetland with nature trails that will provide opportunities for local residents to experience natural areas close to home. Pursuing similar projects elsewhere can help expand urban and community forests

6. *Explore voluntary carbon markets with emphasis on state lands.* Voluntary carbon markets present a potential carbon and economic opportunity to the state. State forests can potentially generate hundreds of thousands of offset credits in the coming years, generating revenue from their sale that could be reinvested into forest management to defend and enhance carbon stores. For example, Michigan developed it's Bluesource/Michigan DNR Big Wild Forest Carbon Project, a pilot project to create a portfolio of carbon offset credits from forest management activities on state lands (Michigan Department of Natural Resources, n.d.). For New Jersey, the Regional Greenhouse Gas Initiative has a mechanism for forestry or afforestation offset allowances (Regional Greenhouse Gas Initiative, n.d.). The state can also explore voluntary carbon market feasibility on urban, county, municipal and private lands.
7. *Develop and communicate guidelines and best management practices for maximizing sequestration on private and public land.* The State could consider private, county, and municipal lands along with State owned and managed lands already considered in the 80 x 50 Report. BMPs can consider management practices identified in the NJSFAP as well as the Montreal Process for Sustainable Forest Management to address sequestration as well as forest health and resiliency (The Montréal Process, 2015).
8. *No net loss legislation can be explored for its impact to carbon storage.* The New Jersey No Net Loss Compensatory Reforestation Act (N.J.S.A. 13:1L-14.1 et. seq.) requires State entities submit a compensatory reforestation plan to the NJ Forest Service for each project that results in deforestation of one-half acre or more for projects (that are not standard forestry, wildlife management, arboricultural or active utility easement management practices) (NJDEP, 2016). The goal of each plan shall be no net loss of existing forested area. The State could explore and evaluate the carbon storage implications of the compensatory reforestation mitigation obligation under this program.

## Key Area 4: Considerations for Implementing the Strategy

1. *Evaluate the projected resource needs for afforestation, reforestation and urban tree programs and the local capacity to sustainably source these needs.* A recent study analyzing the reforestation potential in the United States projected a necessary two-fold increase in nursery production and additional investments in the reforestation process starting from seed collection through post-planting practices (Fargione et al., 2019). Developing seeding plans can help manage these restoration efforts and aid in sharing outcomes and best available knowledge (Shaw

et al., 2020). Expanding plant breeding efforts can also help, particularly for native plant material more tolerant of disturbed sites, disease, and invasive species. Pursuing these strategies and programs in New Jersey will require additional resources in the number of trees available for planting along with the funding and human capital to grow, plant and care for the trees. Understanding project expenses and resources will dictate what strategies are feasible in the short and long-term. The State could also incentivize bedding plant producers to grow native plant material (e.g., understory trees) in short supply for conservation efforts.

2. *Engage in research and monitoring.* Monitor the implemented strategies to measure progress and success over time. Identify and fill existing research gaps, including but not limited to those mentioned below.
    a. Quantify the carbon pools and fluxes in different forest types in New Jersey.
    b. Conduct comprehensive research to estimate the net carbon effect of harvesting activities in New Jersey forests. Analyze different harvesting methods and their impact on carbon pools such as mechanical versus hand (saws) treatments, leaving slash and tops compared to whole tree harvesting, and impact of different forestry movers on soil compaction and soil carbon storage. Compare the carbon impacts of different harvesting activities with not harvesting.
    c. Understand how to incorporate potential future forest assemblages for the various candidate areas for reforestation while determining appropriate afforestation species mixes and corresponding suitable soil characteristics and water requirements. Forest assemblages are species sharing an attribute of habitat or taxonomic similarity (Pyron, 2010). These efforts should include consideration of future climatic conditions, given that trees planted today would need to persist in the climate expected 100 years hence.
    d. Identify the challenges in current and future transition areas between forested land and other land types including urban areas, tidal marshes, and meadowlands. Understand how the interaction between areas may change and the corresponding impact on carbon potential.

## Prioritizing Strategies

Feedback from the Workgroup included criteria to prioritize strategies in a Natural and Working Land Strategy for New Jersey. The feedback suggested by the Workgroup is listed below in no particular order. Possible criteria to prioritizing strategies include:

- Quantifiable carbon defense or offense gains relative to no-action scenarios;
- Greatest ability and impact when sequestering carbon;
- Co-benefits as well as potential risks;
- Probability of success;
- Equity benefits to meet the needs of all community members;
- Benefits to overburdened communities that may experience disproportionate environmental harms and risks (U.S. Environmental Protection Agency, 2021); and
- Economic feasibility and funding avenues for implementation.

The Workgroup also identified lessons for New Jersey for creating criteria. The California Air Resources Board (CARB) developed quantification methodologies for agencies to measure greenhouse gas emissions and co-benefits from various programs (CARB, 2021a). One such methodology is the Climate Adaptation Co-Benefit Assessment used to determine if a project causes positive or negative changes to a community's vulnerability to the impacts of climate change.[4] The assessment is not specific to forestry, but it can provide insights into New Jersey's measurement of co-benefits and the development of criteria.

The Workgroup identified California's recent outreach process as a potential resource to the state when considering additional plan outreach for New Jersey. The California Natural Resources Agency (CNRA) conducted a series of workshops to inform its Natural and Working Lands Climate Smart Strategy[5] and 30x30 Initiative.[6] Eight Regional Workshops invited the public to answer eight questions posed by the CNRA. Four Topical Workshops had experts share their recommendations for specific aspects of the strategy, and the public provided feedback. New Jersey could follow California's approach in its outreach for a Natural and Working Lands Strategy.

[4] The impacts of climate change included in the assessment are extreme heat, drought, sea level rise and inland flooding adaptation, agricultural productivity and conservation, species habitat, and wildlife.
[5] The first statewide natural and working lands strategy for California meant to build climate resilience and help reach carbon neutrality for the state.
[6] The 30x30 Initiative is a strategy to meet the state goal of conserving 30% of California's land and coastal waters by 2030. Approximately 22% of California's land is already conserved. In contrast, NJ has conserved more than 34% of its land according to the NJ SFAP.

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## Appendix A: Organizations Represented in the Natural and Working Lands Workgroup

***Denotes those Whose Representatives Participated in the Forestry Working Group**

American Littoral Society
Barnegat Bay Partnership*
C-Change Conversations*
Drexel University*
Duke Farms*
Honey Brook Organic Farm*
Hunterdon Land Trust*
Isles, Inc.*
Mercer County Park Commission*
NJ Audubon*
NJ Conservation Foundation*
NJ Department of Agriculture*
NJ Farm Bureau*
NJ Food Democracy Collaborative*
NJ Forest Service*
NJ Future*
NJ Highlands Coalition*
NJ Shade Tree Federation*
NJ Tree Foundation*
NJDEP Bureau of Climate Resilience*
NJDEP Community Forestry*
NJDEP Bureau of Climate Change & Clean Energy*
NJDEP Division of Science and Research*
NJDEP Office of Natural Lands Management*
NJDEP Office of Natural Resource Restoration*
Northeast Organic Farming Association of NJ*
North Jersey Resource Conservation & Development*
NY-NJ Harbor Estuary Program
Partnership for the Delaware Estuary*
Pew Charitable Trusts*
Pinelands Preservation Alliance*
PSEG*
Raritan Valley Community College*
Rutgers University*
Terhune Orchards*
The Nature Conservancy - NJ
USDA Natural Resource Conservation Service*

## Appendix B: Comparison of New Jersey Strategies with Strategies of Other States and NGOs

| NJ (80 x 50 Report) | Other State, Federal, and NGO |
|---|---|
| Urban/Community Forests | Urban/Community Forests |
| NJ: Expand the Urban and Community Forestry program by considering requiring municipal and board of education accreditation through the New Jersey Shade Tree and Community Forest Assistance Act | CA: Protect and enhance the carbon sequestration potential and related benefits of urban forests by protecting existing tree canopy through policies/programs, increasing urban tree canopy statewide, assisting local governments and others in locating optimal sites, and providing resources and technical assistance (Forest Climate Action Team, 2018) |
| | CA: Pursue urban reforestation by planting trees through programs like the Urban Greening Program that funds projects reducing GHG emissions by sequestering carbon and decreasing energy consumption (part of the state's Urban Greening Grant Program funded by the state's cap-and-trade revenues) (Chamberlin et al., 2020) |
| | CA: "Develop a comprehensive needs assessment for urban forests, looking at threats and overall conditions statewide, as well as coordinated monitoring and pest detection" (Forest Climate Action Team, 2018) |
| | CA: Provide support and technical assistance for counties, cities, and regions in assessing policies and regulations for green infrastructure and urban forestry and when integrating forest conservation priorities into plans (Forest Climate Action Team, 2018) |
| | MD: Increase urban trees to capture carbon through tree planting assistance programs: - Lawn to Woodland Program: State partnership with the Arbor Day Foundation targeting lots with 1-5 acres of plantable surface and provides free tree planting<br>- Marylanders Plant Trees Program: Provides a coupon of $25 off the purchase of a tree with a retail value of $50 from a participating nursery. Funded by a settlement for Clean Air Act violations and participating tree vendors who absorb $5 of the coupon.<br>(Maryland Department of the Environment, 2021) |
| | NY: "Establish and measure baseline urban canopy metrics and continue measuring metrics" (Hart et al., 2020) |
| NJ: Provide Municipal Tree Inventory and Assessment Tools to collect better data on trees throughout New Jersey. This would be a free tool for municipalities and counties to collect data and inform their management and maintenance. | |

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| State Goals | State Goals |
| NJ: Set a statewide carbon sequestration target for 2030 and 2050. | CT: Set statewide goal to permanently protect at least 50% of core forests greater than 250 acres by 2040 (GC3 Governor's Council on Climate Change, 2021; Forests Sub-Group, 2020) |
| NJ: Set reforestation, wetland revegetation and urban reforestation goals for the state. Explore the potential to reforest less agriculturally productive lands (agricultural modified wetlands) on preserved farms. | CT: Adopt a forest cover goal and develop an Action Plan to increase the statewide forest cover from 59% to over 60% by 2040, building on the state's proposed no-net loss policy (GC3 Governor's Council on Climate Change, 2021; Forests Sub-Group, 2020) |
| NJ: Develop and adopt minimum forest cover objectives for land development, including performance of requirements for forest stand delineations and implementation of forest conservation. (Modeled after Maryland's Forest Conservation Act) | CA: Work with local and regional agencies to establish regional targets for local tree canopy goals (Forest Management Task Force, 2021) |
| | CA: By 2030, increase the area reforested annually by 25 percent above the current level. (Forest Climate Action Team, 2018) |
| | MD: Maryland's Forest Conservation Act established minimum standards for developers when designing projects that will impact forested areas on land that is 40,000 square feet or greater. It has two main components:<br>- Forest Stand Delineation: an inventory of forest cover and environmental features of the site<br>- Forest Conservation Plan: the plan for protecting and retaining forested areas and planting and maintaining new trees (Chesapeake Bay Foundation, 2004) |
| State Lands (Public Lands) | State Lands (Public Lands) |
| NJ: Develop guidelines and best management practices for maximizing sequestration on state owned and maintained properties, including specifications for plantings and management. | |
| | MA: Increase natural carbon stocks by pursuing afforestation and reforestation on public lands (Thompson et al., 2020.) |
| Private Lands | Private Lands |
| NJ: Offer a Private Woodland Conservation Program. | |
| | CA: Develop a Consolidated Forest Conservation Program: "a consolidated program and grant application process for forest conservation… will align federal conservation programs to the extent feasible." to conserve working forests (Forest Management Task Force, 2021) |

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| | ME: Develop new and maintain existing incentives for adopting climate-friendly practices and technologies in forestry that increase carbon storage. (Maine Climate Council, 2020) |
| | NY: "Work with NGOs and municipalities to promote private land conservation when land is not suited for direct protection by the State. Continue and strengthen forest conservation efforts to avoid forestland conversion." (Hart et al., 2020) |
| | NY: Encourage reforestation on private land by providing funding (Regenerate NY) and technical assistance<br>- Regenerate NY is a cost-share program for reimbursing costs of forest regeneration practices including tree planting and maintenance, deer fencing, site preparation, tree protection funded by NYS Environmental Protection Fund. The state legislature created the fund in 1993, and it is funded mostly through a portion of real estate transfer taxes.<br>(Hart et al., 2020) |
| | WA: Work with partners to expand use of the Forest Legacy Program. This is a conservation program administered by the U.S. Forest Service with state agencies to protect forestland with conservation easements or land purchases. The program is funded by the Land and Water Conservation Fund. (Washington State Department of Natural Resources, 2020a) |
| Regulatory | Regulatory |
| NJ: Integrate tree, woodland and forest protection in existing land use permits and the CAFRA regulations. | CA: Advance coordination among state agencies, grant programs and guidelines to eliminate inconsistencies in varying prioritization of forestry and restrictions on using funds (Chamberlin et al., 2020) |
| | OR: "Implement log utilization standards that enhance carbon storage in durable wood products" (Oregon Department of Forestry, 2019) |
| | WA: Reduce barriers to infill and incentivize infill development to reduce risk of conversion and enhance retention of forestland; Can be done by the Washington Chamber of Commerce, the Puget Sound Regional Council, and other nearby jurisdictions (Washington State Department of Natural Resources, 2020a) |
| State Policy | State Policy |
| NJ: Develop a New Jersey Carbon Sequestration Plan | CO: Plans to create a statewide carbon plan for sequestration (Colorado State Forest Service, 2020) |
| NJ: Update Executive Order 215 (1989) to include consideration of climate change and carbon sequestration | |

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| NJ: Sign onto the U.S. Climate Alliance Natural and Working Lands Challenge | |
| NJ: Expand the No Net Loss Program to projects under one half acre. The current No Net Loss Act only requires state entities to replant trees when projects are one-half acre or more. | MA: Explore creating and funding incentive-based programs to achieve no net-loss of forestland and farmland by 2030 (Executive Office of Energy and Environmental Affairs, 2020) |
| NJ: Update the Municipal Land Use Law to encourage and facilitate green infrastructure including green streets. Prioritization should be given to infrastructure that accommodates trees. | NM: "Integrate urban forestry into all scales of city and state-scale master plans, emphasizing the role of the urban forest as green infrastructure to mitigate heat and manage stormwater" (pg. 88) (New Mexico Energy, Minerals and Natural Resources Department, Forestry Division, 2020) |
| NJ: Evaluate establishing forest carbon markets in New Jersey. | CA: As part of the state's Cap-and-Trade Program there is the Compliance Offsets Program that serve as a compliance mechanism other than direct emissions reductions. There are six compliance offset project types including forest projects and urban forest projects. (California Air Resources Board, 2021b) |
| NJ: Evaluate adopting climate considerations in state lease agreements and easements to ensure carbon pools are protected. | |
| NJ: Create an incentive program to encourage reforestation of 5+ acre parcels. | |
| | CA, OR: Prevent forestland conversion through land use planning<br>CA: Promoting regional transportation and development plans that recognize the climate mitigation impacts of land use and forest conditions and work to conserve forestland (Forest Climate Action Team, 2018)<br>OR: (Cloughesy & Hall, 2020) |
| | CA, CT, NH, WA: Prevent forestland conversion through conservation easements and acquisitions<br>CA: (Forest Climate Action Team, 2018)<br>CT: (Peracchio, 2020; GC3 Governor's Council on Climate Change, 2021)<br>NH: (Hackley et al., 2020)<br>WA: (Natural and Working Lands Carbon Sequestration Advisory Group, 2020) |
| | NC: Expand legislative funding for the state's land conservation programs (North Carolina Department of Environmental Quality, 2020) |
| | CT: Increase the amount of forest protected from development following priority criteria based on core forest areas, forest legacy potential, and vulnerability (Peracchio, 2020) |

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| | ME: Increase permanent protection of forestland by creating a sustained funding source for conservation easements and fee acquisition<br>(Natural and Working Lands Work Group, 2020) |
| | MA: Update land use policies to encourage denser development near existing cities and redevelopment. Also, update energy facility siting policies, so they encourage maximum density and utilization of already developed land when and where available.<br>(Ismay et al., 2020) |
| | ME, NY, OR: Property tax incentives to encourage landowners to maintain forests and prevent forestland conversion<br>- ME: Update the state's Open Space Current Use Taxation Program and maintain the Tree Growth Tax Law to serve as incentives to maintain land as forest. Both programs provide a reduction in the property's assessed value. (Maine Climate Council, 2020)<br>- NC: The state's current use laws tax forested land upon current usage as forestland rather than "highest and best use" to reduce tax costs for landowners. Reinstate the state's Conservation Tax Incentives for landowners who donate land or easements for conservation purposes (North Carolina Department of Environmental Quality, 2020)<br>- OR: Uses preferential tax programs to prevent forestland conversion. Oregon's Forestland Program and Small Tract Forestland Program serve as special tax assessments to recognize the importance of forestland. The state designated some forestland as "highest and best use forestlands" qualifying the land for special assessment that is lower than the real market value used for taxing properties. Landowners of forestland can apply for the "highest and best use" designation to obtain this special assessment. (Cloughesy & Hall, 2020) |
| | WA: "Retain and seek to improve the current land use taxation system that encourages longterm forest management. Create tax incentives for intergenerational transfers or transfers to tree farmers that qualify under certain conditions." (Washington State Department of Natural Resources, 2020a) |
| Forestry Products/Markets | Forestry Products/Markets |
| NJ: Expand the “NJ Fresh” and “Jersey Grown” marketing program to better promote forestry products from the Garden State | CT: Support a viable forest products industry that provides marketable products from renewable and diverse forest resources by advertising and promoting forest product markets.<br>(Peracchio, 2020) |
| | CT: "Build a market for creative re-use of urban wood waste to store carbon while simultaneously creating education, employment, and stewardship opportunities."<br>(Forests Sub-Group, 2020) |

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| | CT & NY: Support the use of forest products from local forests<br>CT: (Forests Sub-Group, 2020)<br>NY: (Hart et al., 2020) |
| | CA, MA: Encourage and incentivize forest biomass utilization in long-lived products and as wood and biomass substitutions (replacing fossil fuel energy and certain materials with wood and biomass fuels) to reduce emissions<br>CA: (California Environmental Protection Agency et al., 2019)<br>MA: (Ismay et al., 2020) |
| | NY: Promote local wood markets to remove and use unhealthy trees and create more resilient forests on private land (Hart et al., 2020) |
| Forest Management/Health Threats | Forest Management/Health Threats |
| NJ: Provide additional incentives and technical tools to assist communities in forestry management and climate friendly agricultural practices. | |
| NJ: Expand deer population management, including by allowing depredation permits for forestry management on private lands. Adopt Carbon Sequestration criteria as part of the Community Based Deer Management Plans. | |
| NJ: Implement selective thinning in the Pine Barrens to prevent carbon loss from southern pine beetle infestation. | |
| | CA: Increase prescribed burning and sustainable timber harvest to enhance net forest carbon accumulation, reduce high-severity fire, and reduce forest fuel (California Environmental Protection Agency et al., 2019) |
| | NM: "Support the development of legislation to expand the use of prescribed fire"<br>(New Mexico Energy, Minerals and Natural Resources Department, Forestry Division, 2020) |
| | CA & OR: Minimize the risk of fire and emissions through fuel reduction projects<br>CA: (California Air Resources Board, 2017)<br>OR: (Oregon Department of Forestry, 2019) |
| | CA & OR: Change to less intensive forest management to enhance carbon in forested ecosystems [uneven-aged management (partial cut) or areas of no harvest management; increasing rotation age]<br>CA: (California Environmental Protection Agency et al., 2019)<br>OR: (Cloughesy & Hall, 2020) |

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| | CA: Increase incentives for timber harvests that improve forest resilience "which may include improved permitting, landscape-scale projects across multiple ownerships, and incentives for multi-age stands, increased carbon storage, and biodiversity" (Forest Management Task Force, 2021) |
| | CT: Provide support and funding for the prevention and management of forest pests (Forests Sub-Group, 2020) |
| | CT: Increase funding for forest management planning (Forests Sub-Group, 2020) |
| | CO: Retain dead trees (standing and fallen) to maintain carbon storage stocks (Colorado State Forest Service, 2020) |
| | OR: Use incentive programs to encourage specific forest management practices that increase carbon sequestration<br>- One such program is the Family Forest Carbon Program by the Nature Conservancy and American Forest Foundation where investors provide funds for the program to pay forest owners to use sustainable forest management practices that retain carbon. The carbon benefits of these practices are then verified, and companies can then purchase these carbon credits. The proceeds from selling the credits are used to repay investors.<br>(Cloughesy & Hall, 2020) |
| | OR: "Implement harvest practices that minimize soil disturbance" (Oregon Department of Forestry, 2019) |
| Outreach and Education | Outreach and Education |
| NJ: Enhance education and outreach around the Conservation Reserve Enhancement Program. | |
| NJ: Create a clearinghouse for information on sources of funding, and regulatory processes for carbon sequestration/forestry restoration projects and management applications. | |
| | CT: Dedicate resources to educating landowners of the value of protecting their forests and using mitigation-focused forest management (Forests Sub-Group, 2020) |
| | ME: "Engage in regional discussions to consider multistate carbon programs that could support Maine's working lands and natural resource industries, and state carbon neutrality goals." (Maine Climate Council, 2020) |

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| | NH: Increase technical assistance provided to municipal staff for urban tree assessments, management plans, and tree ordinances (Hackley et al., 2020) |
| | NH: Support municipalities, volunteer groups, and professional organizations in the planning, management and maintenance of urban and community forests (Hackley et al., 2020) |
| | NC: Facilitate voluntary participation in carbon offset markets by creating new state-level program to encourage and coordinate participation (North Carolina Department of Environmental Quality, 2020) |
| | NC: Advocate for reforestation on public and private lands (North Carolina Forest Service, 2020) |
| | WA: Conduct outreach and share educational and technical information with small forest landowners to enhance retention of forestland (Washington State Department of Natural Resources, 2020a) |
| | WA: "Develop urban and community education materials and engagement opportunities… to assist with climate-informed natural area restoration and maintenance" (Washington State Department of Natural Resources, 2020a) |
| Scientific Assessment, Monitoring and Research | Scientific Assessment, Monitoring and Research |
| NJ: Refine sequestration estimates in the Greenhouse Gas Inventory. | CA, WA: Complete forest carbon inventories (stocks, emissions, flux)<br>CA: (Forest Climate Action Team, 2018)<br>WA: (Washington State Department of Natural Resources, 2020a) |
| | MA: Update statewide biogenic emissions (emissions from land use change, forest sequestration, and combustion of plant or animal material) inventory as needed to track verified carbon sequestration allowing the state to verify the annual removal and storage of carbon. (Executive Office of Energy and Environmental Affairs, 2020) |
| | CT: Invest in scientific monitoring to track progress toward increasing overall forest cover in the state (Forests Sub-Group, 2020) |
| | WA: Work to create inventories of "harvested wood products, sawmill energy use, wildfire, and land management" to help guide sequestration efforts (Washington State Department of Natural Resources, 2020b) |
| | ME & CT: Create the framework and begin pilot for a coordinated, comprehensive monitoring system of carbon sequestration over time<br>ME: (Maine Climate Council, 2020)<br>CT: (Forests Sub-Group, 2020) |

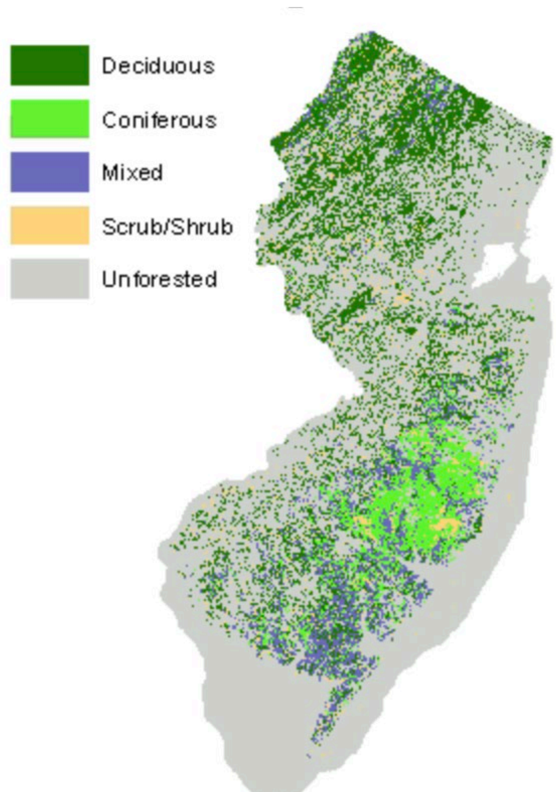
| | |
|---|---|
| | CA: Develop a system to track implementation activities in a standardized way that includes cost and other elements allowing for improvement in cost-efficiency and overall effectiveness over time (Forest Climate Action Team, 2018) |
| | MA: Commission additional forest carbon sequestration research to assess long-term impacts of practices (Executive Office of Energy and Environmental Affairs, 2020) |
| | ME: "Establish a “coordinating hub” with state and non-state partners for key climate change research and monitoring work to facilitate statewide collaboration by 2024." (Maine Climate Council, 2020) |
| | NM: "Provide and develop data and information on both tree survival and climate models to improve the likelihood that trees planted in the next decade will survive and thrive throughout their lifetimes" to inform reforestation (New Mexico Energy, Minerals and Natural Resources Department, Forestry Division, 2020) |
| | WA: "Evaluate the long-term carbon storage and sequestration potential associated with landscape resilience in fire-prone forests" (Washington State Department of Natural Resources, 2020a) |
| | WA: Conducted a "legislatively mandated study to assess and improve the retention of working forestlands held by small forest landowners" (Washington State Department of Natural Resources, 2020b) |
| | NGO: Conduct forest product research on new uses for wood to establish new carbon pools for mitigation-focused management (Forest-Climate Working Group, 2018) |

# Appendix C: Assessing the Status of New Jersey's Forest Lands: Identifying Risks to Forest Carbon Stocks and Opportunities for Enhanced Carbon Sequestration

Report to the NJ Climate Change Alliance Natural and Working Lands (NJCCA-NWL) Forest Working Group by Professor Richard Lathrop and Chris Idell, Rutgers University

# Assessing the Status of New Jersey's Forest Lands: Identifying Risks to Forest Carbon Stocks and Opportunities for Enhanced Carbon Sequestration

Report to the
NJ Climate Change Alliance Natural Working Lands (NJCCA-NWL)
Forest Working Group




Rick Lathrop and Chris Idell
Center for Remote Sensing & Spatial Analysis
Rutgers University
January 2022

## Introduction

Forests account for the most land cover of any ecosystem type in the state of New Jersey, covering over 40% of the state's total landscape (New Jersey Department of Environmental Protection, 2021). New Jersey forests provide several ecosystem services valued at $2.6 billion/year including recreation, water filtration, carbon sequestration, wildlife habitat, cultural services, timber products, and local climate resiliency (Costanza et al. 2006). Land use and climate change are affecting the health and viability of New Jersey's forest resources. Reduced canopy cover in our urban areas whether due to the conversion of remaining undeveloped forested open space or loss of street and yard trees has possible negative implications for such ecosystem services as local climate resiliency (i.e. heat island effects) and downstream water quality (due to increased runoff). Increasing temperatures and frequency of extreme events (storm and drought) may affect urban and rural forest alike, leading to increased pest, disease, invasive species and storm damage. Changing climate is expected to result in range shifts in tree species with cascading effects on the community composition of our urban and rural forests. These escalating climate pressures will likely result in the reduction or loss of ecosystem services provided by New Jersey's forests (Shifley et al. 2016). In short, New Jersey's forests are in a state of flux and in many cases, decline.

Starting from the premise that New Jersey should sustain, if not enhance, the productivity of our forest land and its attendant natural resources, we as a society can either adopt a "hands-off" approach and let Nature and climate change take its course or take a more proactive approach to steward our forest resources. In considering the latter option, we find it useful to adopt the following terminology:

- Carbon Defense strategies: proactive management of forest lands to protect their existing "bank" of carbon storage and reduce greenhouse gas emission;
- Carbon Offense strategies: increase carbon dioxide storage by increased carbon sequestration in soils and woody vegetation through tree planting (afforestation and reforestation).

Determining which carbon defense or offense strategies are relevant and appropriate is a local decision-making challenge and is going to require site-specific remedies. In addition to statewide goals, forest stewardship plans also need to factor in the long-term goals of the participating landowner or agency for the property in question.

The NJ Climate Change Alliance Natural Working Lands (NJCCA-NWL) Forest Working Group is working to develop sustainable forest management strategies aimed at increasing forest resilience in the face of these changes and preserve forest ecosystem services. Any forest sustainability planning effort focused on carbon sequestration needs a baseline estimate of existing forest lands and their carbon stocks (i.e., carbon stored in plant biomass and soils) before an assessment of the potential for enhanced carbon sequestration (i.e., additional carbon stored above and beyond the baseline) can be undertaken. In collaboration with the NJ Climate Change Alliance Natural Working Lands (NJCCA-NWL) Forest Working Group, we have undertaken a geospatial analysis employing existing credible, authoritative mapped sources of information complemented by USFS Forest Inventory Analyses data where appropriate and available to establish this baseline. We undertook a geospatial approach to identify the location and to determine the amount of land that might represent opportunities to enhance sequestration across the state. More specifically, our main objectives were to:

1) Map and characterize New Jersey's forests in terms of the physiognomic/species community type and canopy cover. Further delineate by publicly owned conservation lands vs. private ownership.

2) Quantify the potential carbon stocks and classify the Forest class types into High-Medium-Low Carbon Storage.

3) Map and characterize areas of high carbon forests at risk due to important pests and wildfire.

4) Identify and map candidate areas for afforestation and/or reforestation based on criteria set out by the NJCCA-NWL group.

This report summarizes several geospatial analyses that have been carried out to support and inform these efforts by the NJCCA-NWL group, particularly in increasing forest carbon sequestration and reducing greenhouse gas emissions. The resulting maps and tables can aid conservation decision-making and reveal areas where either carbon defense or carbon offense strategies are appropriate and necessary for maintaining and increasing forest carbon pools in New Jersey.

The following report documents the methods, data sets employed and the results (including maps and data tables). In several cases we have included several different data sets for the same parameter (e.g., forest types). These different data sets may provide slightly different quantitative results as they are based on different classification systems/definitions and/or different underlying data sources (i.e., different remotely sensed imagery and/or forest inventory plot data). We provide these multiple results as the end user might prefer one agency data set vs. another to address their particular question. The Results and Discussion section includes a short summary of the underlying objectives for each set of analyses and along with some of the key results including tables and maps. This section delves a bit more deeply to interpret the results and possible management implications. For a more complete documenting of all the analysis outputs refer to Appendix A. Please refer to Appendix B for greater detail on the data sets (including links to original sources) and methods employed.

This report is part of Rutgers Climate Resource Center's broader climate adaptation planning program. One component is the NJForestAdapt web-based interactive map and visualization tool developed to facilitate natural resource managers and land use "decision-makers" (i.e., government agency, non-governmental organization personnel and forest land-owners) in accessing and understanding relevant geographic information concerning New Jersey's forest resources and strategies for adapting to a changing environment. As part of the ongoing development of NJForestAdapt, we are committed to further developing and refining this platform to better meet the needs of our targeted user community, in this case forest landowners, managers and decision-makers. Where appropriate the outputs of this project will be incorporated into NJForestAdapt (www.njforest.adapt).

## Results And Discussion

1. **Status of New Jersey's forests: Forest Type and Canopy Cover**

Objectives:

A. Map NJ forest lands by forest type. Depending on the particular classification schema employed, forest type is based on tree physiognomic/structural type (e.g., evergreen vs. deciduous) or general tree species composition/community type. Scrub/shrub is a type of forest land dominated by woody multi-stemmed shrubs or small status trees. In our analysis, we mapped and quantified by forest acreage using several different authoritative datasets including Land Use/Land Cover of New Jersey 2015 (LU/LC1 2015) produced by the New Jersey Department of Environmental Protection (NJDEP), the National Land Cover Database Land Use 2016 (NLCD 2016) produced by the US Geological Survey, and the United States Forest Service (USFS) Forest Inventory Analysis (FIA) Continental US (CONUS) Forest Group 2002-2003.
B. Forest canopy cover represents how much of a unit area of land is covered by tree canopy on an areal percentage basis. Datasets employed: NJ LULC 2015, USGS NLCD 2016 and USFS Landfire 2014. Canopy cover was mapped into the following 2 categories:
   i. >50% canopy cover for upland or wetland forest
   ii. Sparse forest canopy (10-50% cover) or Scrub/Shrub.

   In some cases, the 50% threshold was what was available in the original dataset (i.e., NJ LULC 2015) whereas the NLCD 2016 data set includes a more continuous gradient of cover but was classed using the same thresholds for comparability. The amount of canopy cover may reflect environmental restrictions (i.e., poorer growing conditions) or past disturbance (i.e., insect infestations, drought or wildfire). The canopy cover may also influence possible management actions such as with forest stands that have >50% canopy cover for upland or wetland forest the focus might be on maintaining the existing forest as is and protecting against forest pests/diseases/invasive plants and deer overbrowsing; or in other words on Forest Health Defense. Alternatively, a sparse forest canopy (10-50%) or Scrub/Shrub conditions might reflect past disturbance where forest management actions that focus on Reforesting to increase forest cover might be feasible and of long-term benefit.

C. Enumerate forest type and canopy cover by Publicly owned conservation land vs. privately owned land area. Using the USGS Protected Areas Database of the United States (PAD-US), NJ forest land was divided by land ownership and classed broadly as public or private land. Fee simple and conservation easements were lumped into a single category for each land ownership type. These mapped data were then overlaid and cross-tabulated with forest-type and canopy-cover maps.

Statewide forest management requires baseline estimates of quantities, locations, and composition of existing forest lands. The US Forest Service estimated that there is approximately 2 million acres of forest in New Jersey (Crocker and Nelson, 2017). In our analysis, we mapped and quantified by forest acreage using several different authoritative datasets including NJ LU/LC1 2015, the USGS NLCD 2016 and the USFS CONUS Forest Group. Forest data in the LU/LC 2015 and NLCD 2016 layers were broken out by deciduous, coniferous, mixed, and scrub/shrub forest. LU/LC 2015 breaks out each of these classes by wetland/upland. NLCD 2016 lumps all forested wetlands into one broad category.

Deciduous forest throughout New Jersey dominates the central and northwest parts of the state while coniferous forest is dominant in the south-central Pine Barrens region (Figure 1). Table 1 summarizes the acreage of each forest class provided by the three datasets. Note that the differences in Table 1 reflect the differences in the classification and mapping criteria. The NLCD maps over 2.3 million acres of forest as compared to 2.1 million for NJ LULC and 1.8 for the USFS (Table 1). The NLCD uses the most liberal definition of forest land (i.e., includes small areas of forest within an otherwise urban matrix), while the USFS uses the most restrictive definition of forest land. The areal amount of coniferous and mixed forest acreage vary in each dataset, likely due to differing definitions and means of obtaining forest data. LULC 2015 includes 284,181 acres of upland coniferous forest while NLCD 2016 shows 194,804. CONUS Forest Group provides a species group-specific breakdown of forests. USFS CONUS Group data shows 535,335 acres of Loblolly/shortleaf Pine within the state. It is likely that much of this acreage is classed as mixed forest in the other datasets, given the relatively low acreage of mixed forest derived from USFS CONUS Group data. Mapped USFS CONUS data show northwest regions dominated by Oak/Hickory Forest and southern-central Pine Barrens regions dominated by loblolly/shortleaf pine forest group types.

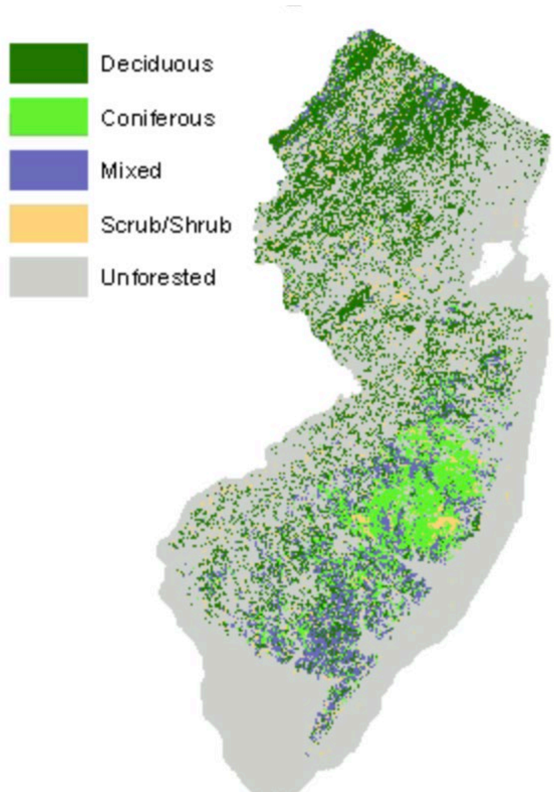



Figure 1. Map of Forest Type derived from NJ LULC15 dataset

Table 1. New Jersey Forest Types (area in acres) as mapped by three different government agencies.

| LU/LC 2015 | | acres | NLCD 2016 | acres | | USFS CONUS Group | acres |
|---|---|---|---|---|---|---|---|
| **Upland** | Deciduous | 767,255 | Deciduous | 1,002,273 | **Deciduous** | Oak/Hickory Group | 1,069,553 |
| | Conifer | 284,181 | Conifer | 194,804 | | Elm/Ash/Cottonwood | 57,818 |
| | Mixed | 303,344 | Mixed | 269,542 | | Maple/Beech/Birch | 82,299 |
| | Shrub | 117,380 | Scrub/ Shrub | 32,942 | | Aspen/Birch Group | 525 |
| **Wetland** | Deciduous | 342,687 | Woody Wetland | 811,801 | **Coniferous** | White/Red/Jack Pine | 92 |
| | Coniferous | 114,512 | | | | Loblolly/Shortleaf Pine | 535,335 |
| | Mixed | 132,716 | | | | Pinyon/Juniper | 10,910 |
| | Shrub | 66,485 | | | | Oak/Pine Group | 50,878 |
| | | | | | | Oak/Gum/Cypress | 33,145 |
| | | | | | **Mixed** | Exotic Softwoods | 46 |
| Total | | 2,128,560 | | 2,311,362 | | | 1,840,601 |

Forest canopy cover can provide insights into overall forest health (Henyen and Lindsay, 2003). Forest canopy cover was mapped using several forest data from several datasets including the NLCD 2016 USFS Tree Canopy Cover dataset, LANDFIRE's (LF) Forest Canopy Cover (CC), and LU/LC 2015 (Table 2). Canopy cover was broken out by sparse cover (<50%) and high cover (>50%). Maps produced from these datasets show strips of high canopy cover that follow the forested ridges of the Kittatiny Mountains and the Highlands (Figure 2). High canopy cover is also concentrated in the central/southeastern Pine Barrens region. Low canopy cover is dotted sparsely throughout the north/northwest deciduous forests. Large patches of low cover appear in the Pine Barrens where forest fires occur regularly. Note that the NLCD 2016 categorizes over 3 million acres of canopy cover as it uses a different definition of forest land that includes other land use types (i.e., urban lands that may be partially to fully tree covered). LU/LC 2015 and Landfire datasets show over 1.7 million acres of high canopy cover. LU/LC 2015 shows 348,955 acres of sparse canopy cover.

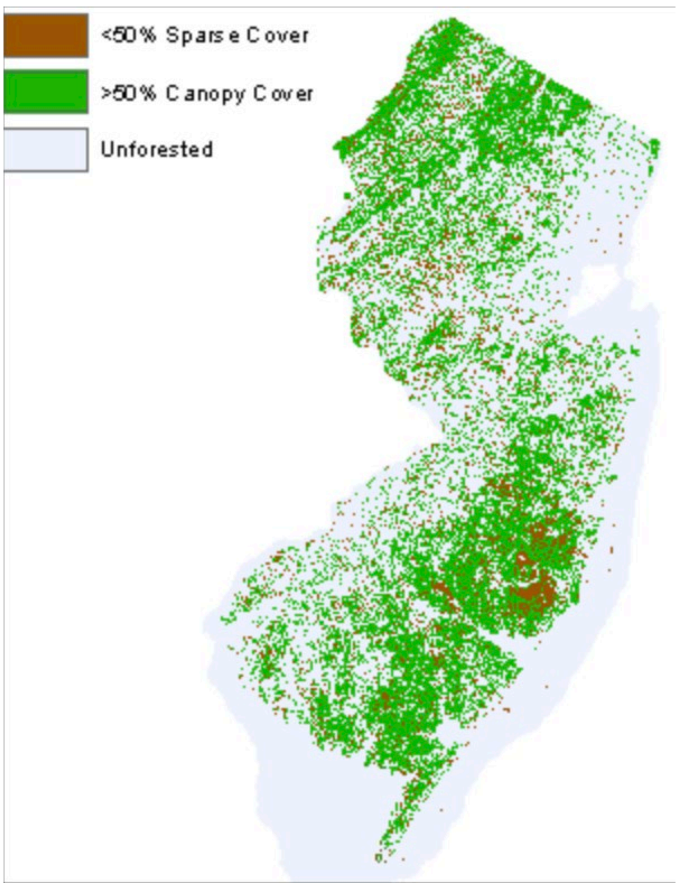



Figure 2. Map of New Jersey Forest Canopy Cover as classed into Sparse (< 50%) vs. High (>50%).

Table 2. New Jersey forests classified by canopy cover (area in acres) as defined three different government agency maps.

| | **NLCD 2016** | **LU/LC 2015** | **Landfire** |
|---|---|---|---|
| **<50% Sparse Cover** | 942,515 | 348,955 | 681,568 |
| **>50% Canopy Cover** | 2,224,720 | 1,737,692 | 1,784,539 |

LU/LC 2015 forest data cross-tabulated with PAD-US data suggests that New Jersey's forests are nearly evenly split between Private (1,095,322 acres) and Public/Preserved Farm Easement (1,033,238 acres) ownership (Table 3). Privately owned land is not generally managed at the same level of intensity within the state of New Jersey as publicly owned land (Oehler, 2003). Concentrations of public forest land occur in the deciduous-dominated north-central and northwestern edges of the state. There are large portions of public coniferous-dominated forest land in the south-central pine barrens region. Low canopy cover public forest or scrub/shrub land occurs largely in the Pine Barrens presumably due to the higher incidence of wildfire disturbance. Note that though forest management activities (such as harvesting timber or thinning trees) or natural disturbances may temporarily reduce forest canopy cover, the lands are still considered as forest lands.

Table 3. LULC15 Forest type broken out by ownership class (PAD-US)

| Forest Type | Ownership | Acres |
|---|---|---|
| Upland | Public | 668,968 |
| | Preserved Farmland | 37,528 |
| | Private | 765,663 |
| Wetland | Public | 301,657 |
| | Preserved Farmland | 25,083 |
| | Private | 329,659 |
| Total | | |

2. Carbon Stocks

Objective: Classify New Jersey forest lands into High-Medium-Low carbon stocks.

This analysis was based on the USFS Forest Inventory & Analysis (FIA) Total forest ecosystem carbon density imputed from forest inventory plots, 2000-2009 and includes above- and belowground live trees, downed dead wood, forest floor, soil organic carbon, standing dead trees, understory above- and belowground pools. Imputed Carbon density maps reclassified into Quartiles by total carbon (Megagrams/hectare). Units were converted from MG/ha to MG/ac. The USDA Natural Resources Conservation Service (NRCS) Gridded Soil Survey

Geographic (gSSURGO) Soil Organic Carbon (SOC) Data provides an additional source for a baseline estimate of soil carbon across the state of New Jersey.

The US Forest Service FIA Imputed Carbon Density Maps provide estimates of forest carbon concentrations in live aboveground biomass, live belowground biomass, down dead wood, forest litter, forest soil, standing dead, and understory carbon (Woodall et al., 2013). High-carbon areas occur in the northwest region of the state and in the Pine Barrens across the mid-southeastern parts of the state (Figure 3). Lowest total carbon occurs across northeastern, central, and southwestern parts of New Jersey. These areas generally match up with areas of sparse canopy cover (Figure 3). Tabulated data shows that nearly 1.6 million acres in New Jersey forests (based on the LULC15 mapping) contain medium-high (27-47 MG/ac) to high (47 – 96 MG/ac) levels of total carbon (Table 4).

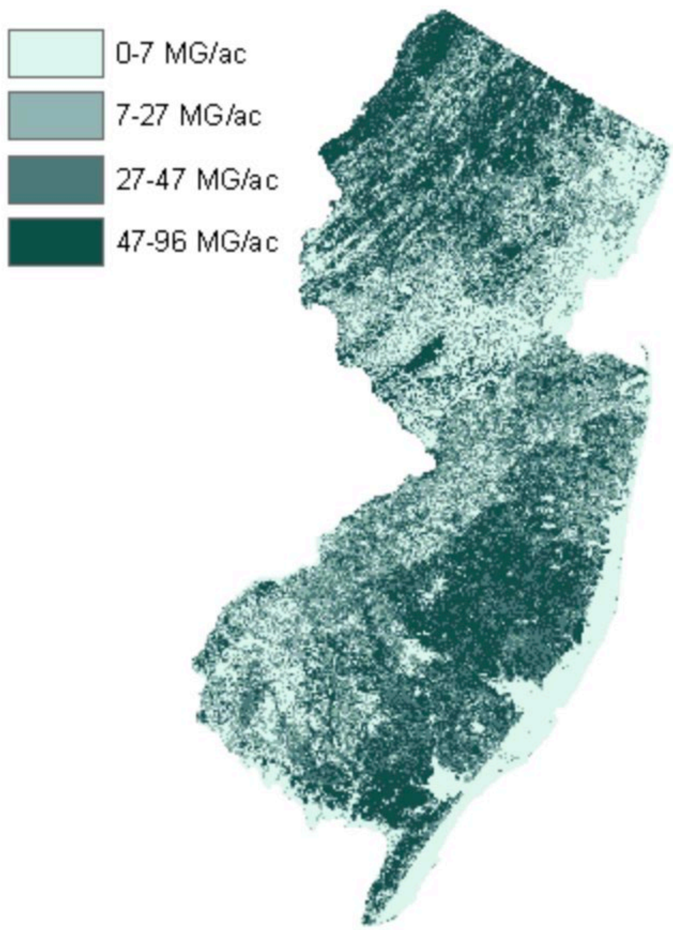



Figure 3. Map of Forest Carbon stock (MG/ac) derived from USFS FIA imputed carbon mapped data. Note that this map does not exclude non-forest lands (i.e., an urban or agricultural area with a low amount of tree cover is still mapped but would most likely fall in the lowest quantile (0-7 MG/ac)).

Table 4. Forest Type Acreage per Quartile of total carbon

| Dataset | Forest Type | Q1 (0-7 Mg/Ac) | Q2 (7-27 Mg/Ac) | Q3 (27-47 Mg/Ac) | Q4 (47-96 Mg/Ac) |
|---|---|---|---|---|---|
| **LULC15** | Deciduous | 96,880 | 231,815 | 327,429 | 452,047 |
| | Coniferous | 7,305 | 29,544 | 132,849 | 229,189 |
| | Mixed | 12,602 | 48,278 | 148,124 | 228,602 |
| **NLCD16** | Deciduous | 82,116 | 212,865 | 302,780 | 402,857 |
| | Coniferous | 3,583 | 13,436 | 67,490 | 110,981 |
| | Mixed | 13,019 | 39,197 | 98,054 | 115,290 |
| **USFS Groups** | Deciduous | 54,904 | 179,321 | 376,170 | 599,027 |
| | Coniferous | 8,278 | 29,066 | 173,992 | 334,657 |
| | Mixed | 3,459 | 9,622 | 30,734 | 40,510 |

Gridded USDA-NRCS Soil Survey Geographic (gSSURGO) Soil Organic Carbon (SOC) Data provides an additional source for these baseline estimates of carbon in New Jersey. 2.4 million acres within the state contain medium-high (27-43 MG/ac) to high (>43 MG/ac) levels of soil organic carbon. High SOC areas occur across northwest NJ in Sussex and Warren Counties, marsh/swamp areas in northeast parts of the state including Essex County, sporadically across the Pine Barrens, and around most of the coastline up into the Delaware Bay (Figure 4). Unlike total carbon mapping, high SOC mapping does not necessarily match up with areas of high forest canopy cover. Wetland Forest and Scrub/Shrub types have nearly 3 to 5 times as much soil organic carbon pools as compared to upland forest types (Table 5).

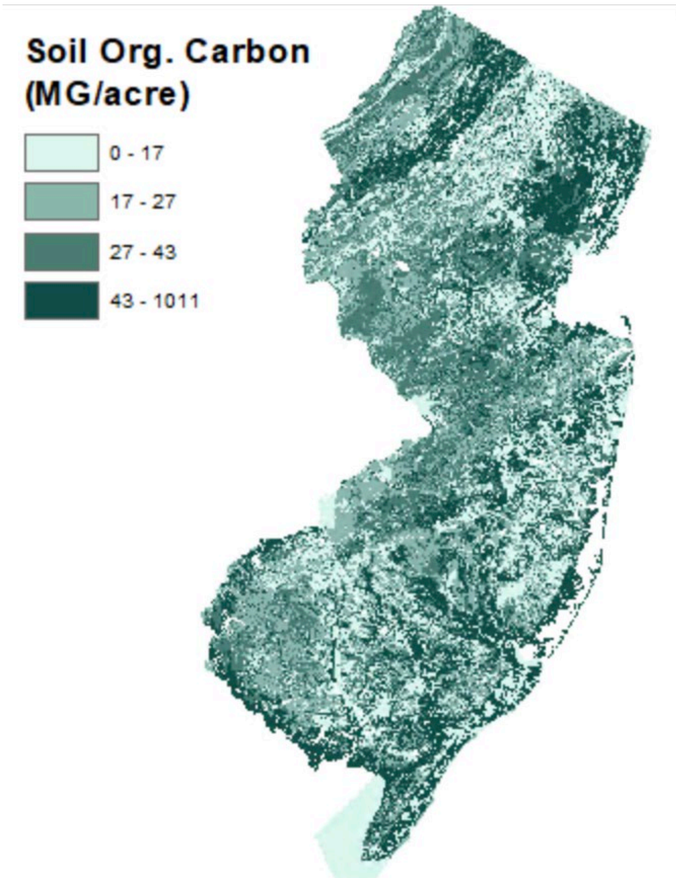



Figure 4. Map of Soil Organic Carbon (MG/ac) derived from NRCS gridded SSURGO.

Table 5. Soil organic carbon statistics in each forest category derived from NJ LULC data

| Type | Area (acres) | Median | | Mean | | Sum |
|---|---|---|---|---|---|---|
| | | g/m^2 | MG/ac | g/m^2 | MG/ac | MG |
| **Unforested** | 2,726,686 | 6,515 | 26 | 20,364 | 82 | 24,186,718 |
| **Upland Deciduous** | 763,143 | 5,702 | 23 | 7,466 | 30 | 2,482,031 |
| **Upland Coniferous** | 280,335 | 4,625 | 19 | 6,840 | 28 | 835,268 |
| **Upland Mixed** | 301,207 | 4,428 | 18 | 6,921 | 28 | 908,123 |
| **Upland Scrub/Shrub** | 113,553 | 5,803 | 23 | 8,196 | 33 | 405,379 |
| **Wetland Deciduous** | 340,044 | 11,044 | 45 | 25,537 | 103 | 3,782,602 |
| **Wetland Coniferous** | 113,941 | 12,695 | 51 | 36,594 | 148 | 1,816,277 |
| **Wetland Mixed** | 132,223 | 12,695 | 51 | 27,614 | 112 | 1,590,471 |
| **Wetland Scrub/Shrub** | 64,612 | 12,695 | 51 | 34,906 | 141 | 982,442 |

### 3. Risks to Carbon Stocks: Pests and Wildfire

Objective: Map the areas of high potential carbon loss due to Pest and Wildfire Risk
Recognizing that other endogenous or exogenous processes may affect the health of forests and their ability to store carbon in the long term, it is imperative to identify those forests where proactive Carbon Defense Strategies should be prioritized. While there are a number of potential risks to forest land, two of the major forest insect pests were selected for further analysis:

- Southern Pine Beetle which negatively affects pitch and shortleaf pine forests that dominate the NJ Pinelands; and,
- Emerald Ash Borer which infests and kills white and green ash (a deciduous tree) in Central and Northern portions of the state.

The projected basal area (BA) Loss rate due to these two pests over the 2013-2027 time frame was obtained from the USFS 2012 National Insect and Disease Risk Map (NIDRM) Project. These maps were cross-referenced with the USFS FIA Imputed Carbon maps (described in the section above) to estimate potential carbon stocks at risk. The wildfire risk was based on mapping/modeling undertaken by the NJ Forest Fire Services using 2002 LULC data modified by digital elevation data.

The 2012 National Insect and Disease Risk Maps (2012 NIDRM) models projected basal area (BA) loss expected between 2013 and 2027 that will occur due to insect pests without remediating management. Southern pine beetle-associated BA loss in high-carbon forests is expected to occur across the coniferous-dominated Pine Barrens, while Ash borer-associated BA loss in high-carbon forest is projected across central and northern New Jersey (Figure 5). BA loss due to southern pine beetle is projected in over 340,000 acres of high-carbon forest with nearly 50,000 acres projected to lose over 15% (Figure 6). BA loss due to emerald ash borer is projected in over 200,000 acres of high-carbon forest with over 15% BA loss in over 80,000 high-carbon acres (Figure 7). Management of southern pine beetle and emerald ash borer is complex and generally requires site-specific remediating action (Heuss et al., 2018, McCullough 2019). These maps and tables can help land managers decide where to focus pest-related carbon defense strategies. There are a number of other possible diseases and pests such as hemlock wooly adelgid and oak wilt that deserve further scrutiny. We chose southern pine beetle and emerald ash borer as examples of this approach to assessing risks to existing forest carbon stock.

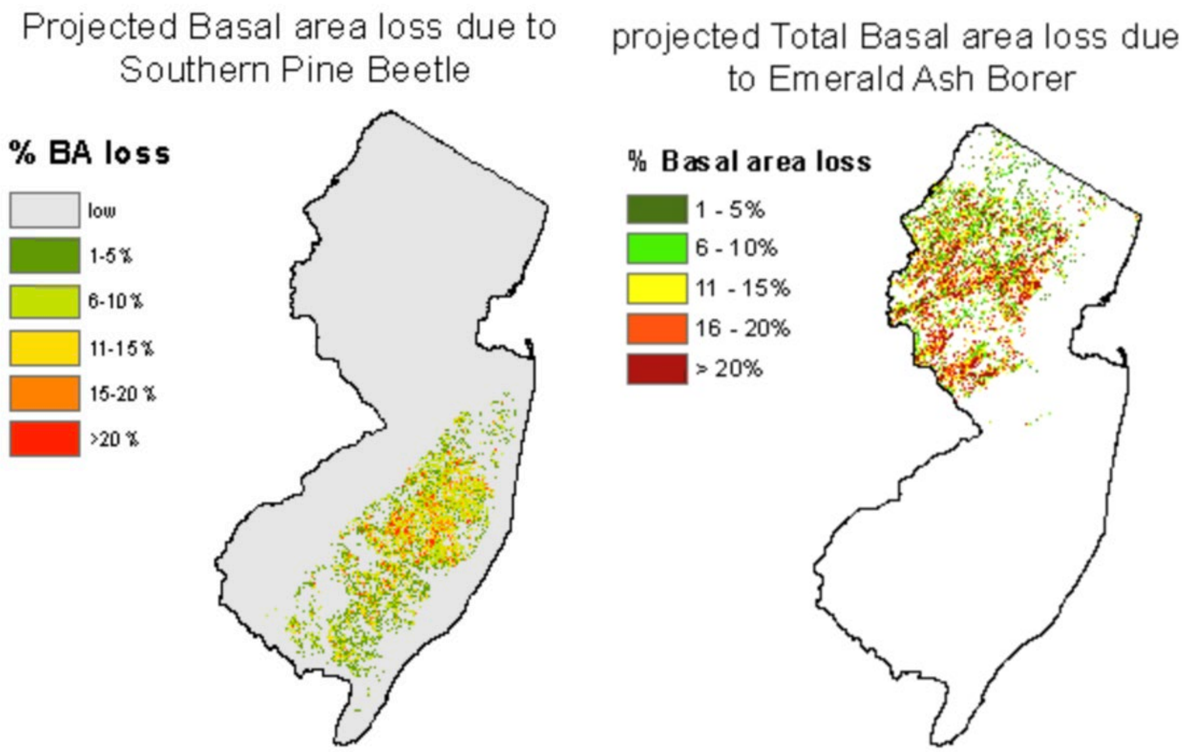



Figure 5. Map of projected basal area loss due to Southern Pine Beetle and Emerald Ash Borer.

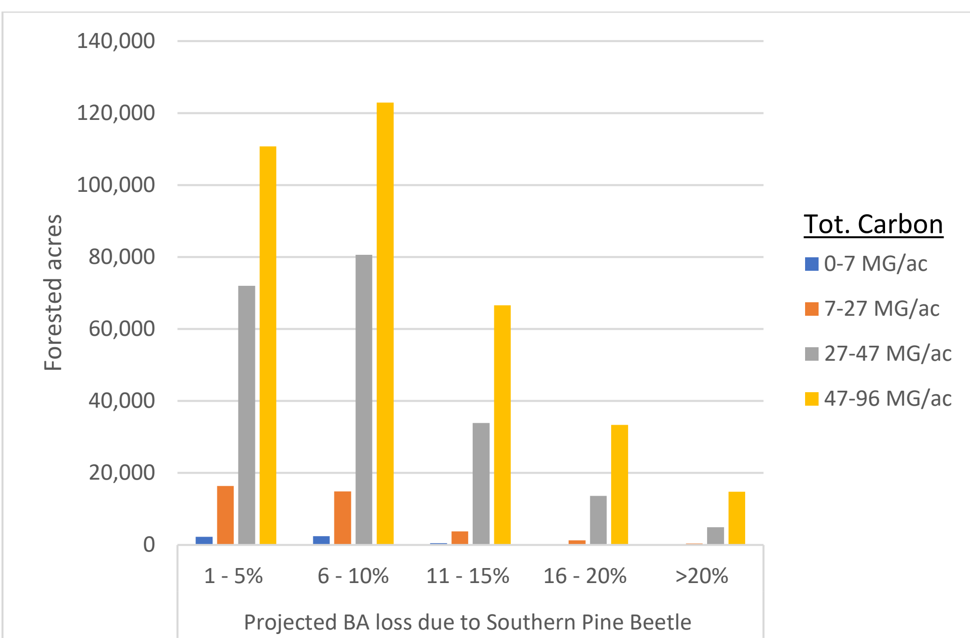


Figure 6. Map of projected basal area loss due to Southern Pine Beetle.

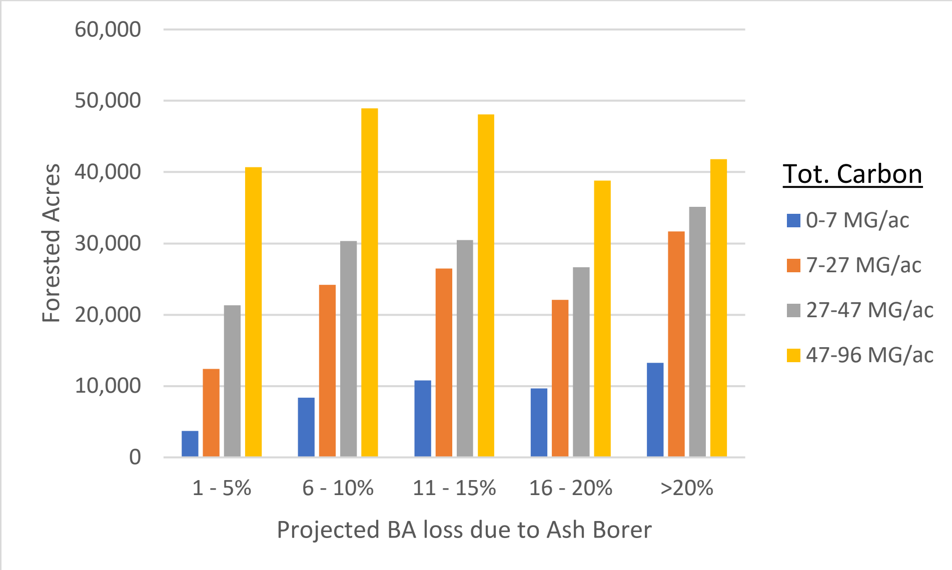



Figure 7. Map of projected basal area loss due to Emerald Ash Borer

The New Jersey Forest Fire Service's (NJFFS) Wildfire Fuel Hazard dataset models statewide forest fire risk. Risk categories range from low to extreme. For areas of Wildfire Fuel Hazard 1 to 4 (i.e., Low to Very High) that were coincident with areas of 30% or greater slope, the Wildfire Fuel Hazard Ranking was increased by 1 value (i.e., Low was increased to Moderate, Moderate to High, etc.). This spatial data was overlaid with the FIA imputed carbon maps to reveal where wildfires may reduce forest carbon pools (Figure 8). The resulting map shows the spatial distribution of forest wildfire risk across the state, and where it falls within high-carbon pools. Risk is generally low across northern deciduous-dominated forests, though there are areas at extreme risk within these forests in the northwestern-most portions of the state. Extreme wildfire risk occurs largely in high-carbon pools located in the Pine Barrens where fires occur frequently (Figure 8). Statewide, over 200,000 acres of high-carbon forest fall within areas of extreme wildfire risk (Table 6).

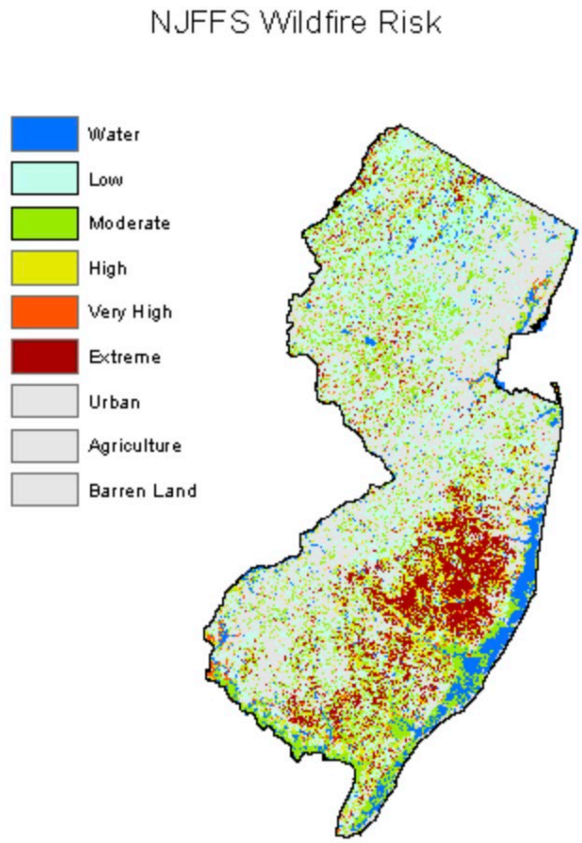



Figure 8. Map of the New Jersey Forest Fire Service Fire Risk.

Table 6. Area by wildfire risk based on the NJFFS risk mapping.

| **Risk** | **Acres** |
|---|---|
| None | 3,556,640 |
| low | 449,727 |
| moderate | 174,095 |
| high | 148,391 |
| very high | 25,420 |
| extreme | 220,764 |

### 4. Mapping Afforestation Candidate Areas

Objective: Identify and map candidate areas that might be suitable for Afforestation to re-establish forest cover. These potential target area types were identified by the NJCCA-NWL

a. Formerly Agricultural lands. These were identified from the NJ LULC 2015 maps under the categories of Former Agricultural Wetlands and Old Fields (wetland

and uplands areas, respectively, that were formerly used for agriculture but at the time of mapping appear to no longer be actively cultivated).

b. Urban Brown field. The NJ Department of Environmental Protection mapped Brownfield Development Areas (i.e., blocks or lats within urban areas that were no longer in active use and suitable for redevelopment).
c. Existing Agricultural land with lower soil productivity (i.e., non-prime farmland soils). The Natural Resources Conservation Service (NRCS) Soil Survey Geographic Database (SSURGO) classifies soils types as to whether they represent Prime Farmland soils (soil types of statewide/local/unique importance) or Not Prime Farmland soils. While farmland of lower soil productivity may still find valuable use for agricultural purposes (e.g., as pasture) under some situations they might also serve as potential sites for afforestation.
d. Areas of Depleted Soil Carbon. Edwin Muniz of the New Jersey Office of NRCS (these data were provided to us for this analysis) has undertaken an analysis to identify areas of New Jersey's farmland where the soils appear to be depleted in soil carbon as compared to areas nearby with a similar soil type. These higher soil carbon depleted soils may serve as candidate target areas for afforestation as a means of increasing the potential stock of carbon in the soils.

New Jersey forest area continues to lose forest area. Between 2012 and 2015, 11,459 acres of forest land were converted to other land uses resulting in an approximately 479,585 MG loss of total carbon storage (Lathrop and Hasse, 2020). Further, New Jersey's forests are aging and not being replaced by younger age classes of forest. Healthy, resilient, and diverse forests should include a range of various age classes (New Jersey Forest Service, 2020). One way to help achieve this goal is through afforestation: planting new trees and thereby cultivating new forests, introducing young forest-age classes. Possible target areas for afforestation that were identified included: former Agricultural Wetlands, abandoned Old Field areas and urban Brownfields. Brownfields and former agricultural wetlands make up a relatively small area for potential foresting at just over 1,000 acres (Table 7, Figure 9). While comparatively small in area there may be a host of other benefits associated with planting trees in brownfields and increasing tree cover in urban areas. Old Field areas present high potential for afforestation with 15,000 acres on public lands and another 25,000 acres on private lands (Table 7).

Table 7. Former Agricultural Wetlands, urban brownfields, and old field areas
In New Jersey from LULC15 and Urban Brownfields of NJ that may serve as potential candidate afforestation sites.

| Land Use/Cover type | Private Ownership (acres) | Public Ownership (acres) | |
|---|---|---|---|
| Urban Brownfield | 2,547 | 256 | 2,803 |
| Former Ag. Wetland | 1,777 | 1,171 | 2,948 |
| Old Field | 25,191 | 15,085 | 40,276 |
| Total | | | 46,027 |

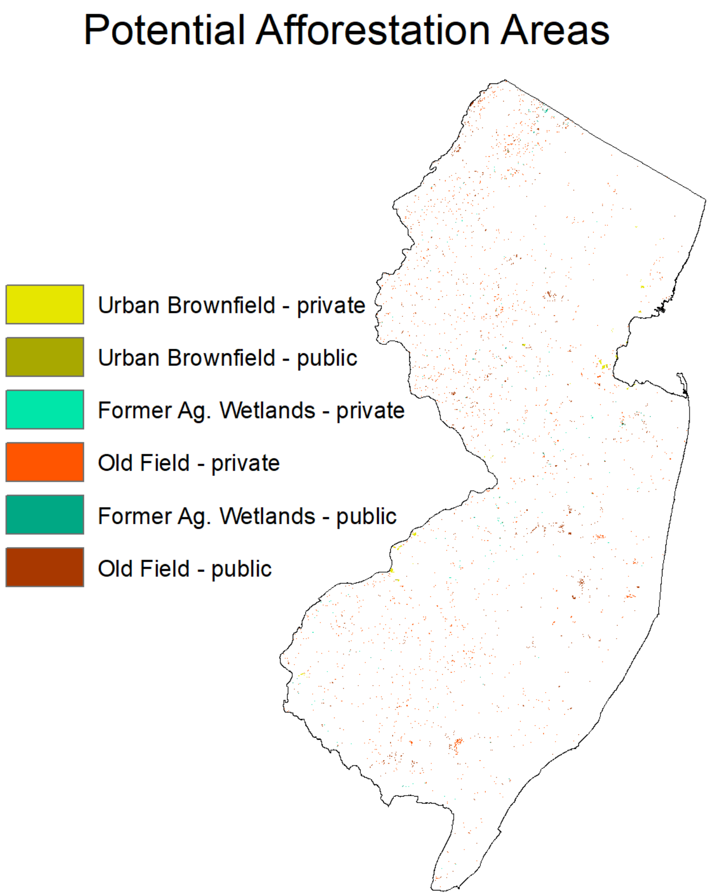



Figure 9. Map of areas identified as potential candidate afforestation sites.

Removing active agricultural land from production and planting trees represents a tradeoff. There may be some agricultural areas, especially areas where the soils may be more marginal for agricultural production (i.e., non-prime farmland soils) that could be candidate sites for afforestation. SSURGO soil data was used to differentiate between areas of prime and non-prime farmland soils. LU/LC 2015 Agricultural areas were overlaid with this farmland map and further broken into private/public land with open space data. Over 25,000 acres of publicly owned agricultural land are on non-prime farmland (Figure 10, Table 8). These areas are spread across the state with relatively high concentrations in central and northwestern regions (Figure 10). Any decisions on the advisability of converting active agricultural land to forest land needs to factor in the long-term goals of the participating landowner or agency for the property in question.

Table 8. Existing Agricultural areas that fall within non-prime farmland areas

| Land Use/Cover | Private (acres) | Farmland Preservation Easement (acres) | Public (acres) | Total (acres) |
|---|---|---|---|---|
| Crop/Pastureland | 5,745 | 2,509 | 1,661 | 9,915 |
| Orchards/Vineyards | 38,365 | 14,712 | 5,691 | 58,768 |
| Ag. Wetlands | 3,439 | 1,151 | 254 | 4,844 |
| Other Ag. | 7,861 | 1,453 | 271 | 9,585 |
| Total | 55,410 | 19,826 | 7,877 | 83,113 |

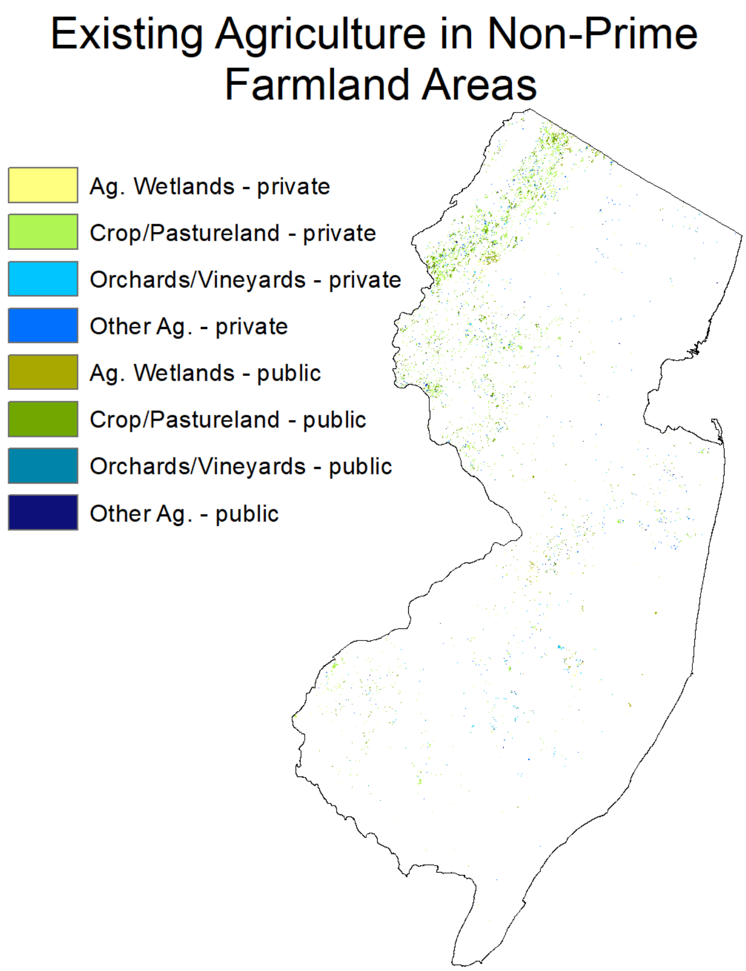



Figure 10. Map of non-prime farmland areas identified as potential candidate afforestation sites.

Farmland exhibiting higher soil carbon depletion may represent an opportunity for afforestation as one means of restoring soil organic carbon. This soil carbon depletion analysis was broken out by public/private land to identify candidate areas and acreage for possible afforestation. There are 70,120 acres of farmland with highly depleted soil carbon on public land (Table 9). These acres are generally spread across western portions of the state ranging north to south (Figure 11).

Table 9. Area of New Jersey farmland soils classed by soil carbon depletion.

| C Depletion | Private (acres) | Farmland Preservation Easement (acres) | Public (acres) | Total (acres) |
|---|---|---|---|---|
| Low 0 - 0.30 | 117,992 | 43,739 | 20,791 | 182,522 |
| Medium 0.30 - 0.44 | 116,814 | 52,020 | 12,023 | 180,857 |
| High 0.44 - 0.68 | 109,177 | 59,120 | 11,000 | 179,297 |

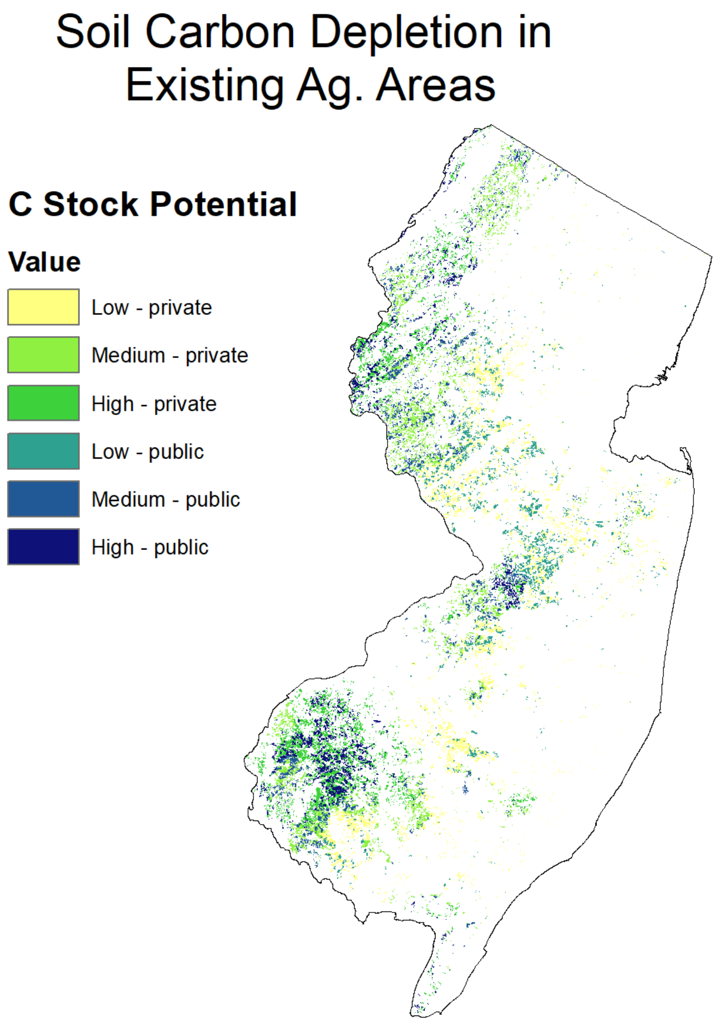



Figure 11. Map of farmland areas classed into Low-Medium-High soil carbon depletion.

5. **Mapping Reforestation Candidate Areas**

Forest lands where forest canopy has decreased may be suitable candidates for proactive reforestation to a more fully stocked forest and thereby increase carbon sequestration. The analysis of Forest Canopy Cover change based on NLCD 2011-2016 canopy cover data sets may help direct attention to areas that have experienced a decline in canopy cover and would benefit from management interventions to further minimize canopy loss. Over 30,000 acres have seen over 20% canopy decrease between 2011 and 2016 (Table 10). The change maps should be interpreted with caution as the mapping techniques were not consistent between the two time periods. In general, these areas that have decreased canopy cover by over 20% may be of interest to land managers for further conservation actions. Unsurprisingly, a good portion of canopy reduction occurs in the Pine Barrens where wildfires occur most frequently (Figure 12).

**Table 10. NLCD Canopy change 2011-2016**

| Canopy Change | ACRES |
|---|---|
| 40-100% decrease | 20,158 |
| 20-40% decrease | 14,060 |
| 5-20% decrease | 539 |
| No change | 35 |
| 5-20% increase | 415 |
| 20-40% increase | 11,202 |
| 40-100% increase | 2,611 |

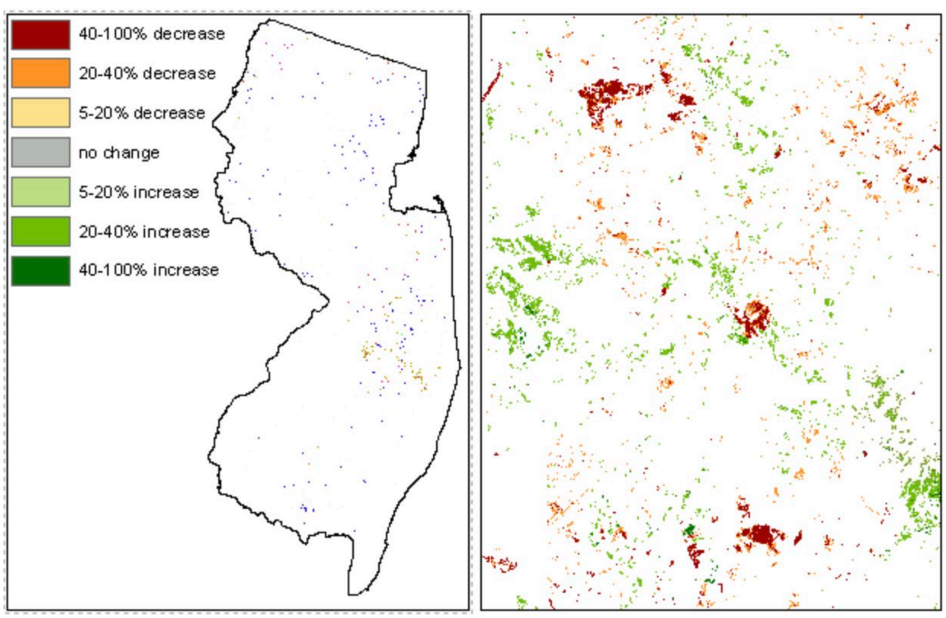



Figure 12. Map of forest lands classed into Low-Medium-High canopy cover loss or gain. Mapped Results zoomed in on Pine Barrens

The NJ Land Use/Land Cover datasets show a loss of 122,541 acres of forest land between 1986 and 2015 (Lathrop and Hasse, 2020). Despite this relatively significant net loss of forest land, Land Use/Land Cover datasets show other areas that have converted from some other land use to forest between the years 1986 and 2015. Often abandoned farmland areas that are starting to reestablish as forest through natural succession, these areas may present opportunities to speed up or redirect the successional process. For example, protection from deer browsing or strategic plantings of desired species might be an option. To aid in identifying potential areas for afforestation or reforestation, a history of New Jersey forests was derived from Land Use/Land Cover datasets going back to 1986 (Figure 13, Table 11). This analysis provides the approximate year in which areas became newly forested. It also shows the previous land use type of newly forested areas. These forest areas may be suitable candidate sites for proactive management to increase their afforestation/reforestation potential. Table 12 show the results of a land-use change analysis of non-forest land converting to forest land between 1986 and 2015 through versions of the LU/LC dataset. It is important to note that this forest age analysis includes both wetland and upland forest. Notably, since 1986, 44,645 acres of Cropland and Pastureland, 28,312 acres of herbaceous wetland, and 17,572 acres of Old Field have converted to forest (Table 12).

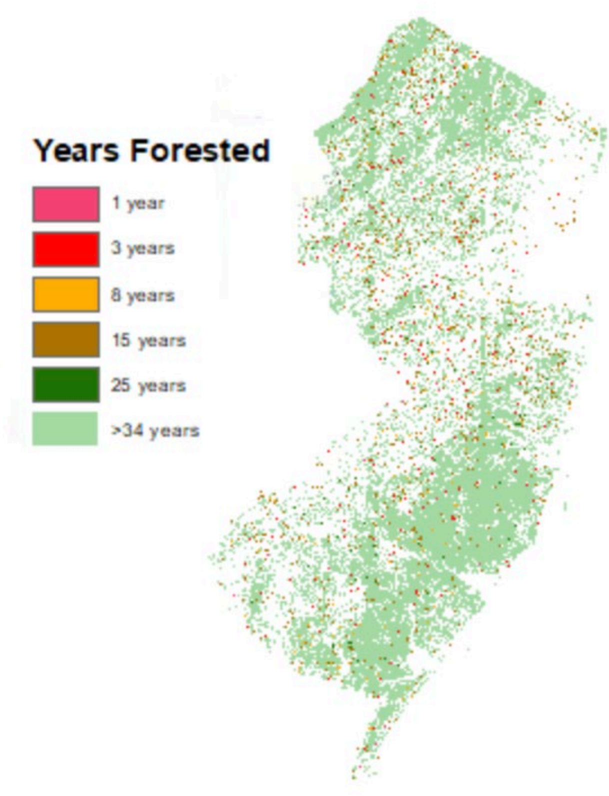



Figure 13. Map of recently reforested lands classed into approximate age of the existing forest.

Table 11. LULC derived forest age acreage

| Years Forested | Acres |
|---|---|
| 1 | 5,402 |
| 3 | 27,458 |
| 8 | 23,792 |
| 13 | 117,631 |
| 25 | 14,951 |
| >34 | 1,930,168 |

Table 12. Land use type in 1986 and 1995 that are of forested in 2015 from NJ LU/LC data. (Only LU types with over 9,000 acres of afforestation are included)

| LULC 1986 | Acres |
|---|---|
| Unforested | 3,356,132 |
| AGRICULTURAL WETLANDS (MODIFIED) | 9,749 |
| CROPLAND AND PASTURELAND | 44,645 |
| HERBACEOUS WETLANDS | 28,312 |
| OLD FIELD (< 25% BRUSH COVERED) | 17,572 |
| OTHER URBAN OR BUILT-UP LAND | 9,055 |
| RESIDENTIAL, RURAL, SINGLE UNIT | 10,272 |
| Forested 86-15 | 1,963,850 |

| LULC 1995 | Acres |
|---|---|
| Unforested | 3,356,132 |
| AGRICULTURAL WETLANDS (MODIFIED) | 6,446 |
| CROPLAND AND PASTURELAND | 28,239 |
| HERBACEOUS WETLANDS | 26,022 |
| OLD FIELD (< 25% BRUSH COVERED) | 31,413 |
| OTHER URBAN OR BUILT-UP LAND | 9,597 |
| RESIDENTIAL, RURAL, SINGLE UNIT | 12,643 |
| RESIDENTIAL, SINGLE UNIT, LOW DENSITY | 6,164 |
| Forested 95-2015 | 1,959,388 |

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**Appendix A.  Entire Suite of Results**

**1.A. Forest Type**

Dataset: Land Use/Land Cover (LULC) of New Jersey 2015

Table 1. Forest Type Acreage in New Jersey derived from LULC15 dataset

| Forest Type | Acres |
|---|---|
| Deciduous | 1,109,941 |
| Coniferous | 398,693 |
| Mixed | 436,059 |
| Scrub/Shrub | 183,865 |
| Total Forest | 2,128,558 |
| | |
| Unforested | 3,755,256 |

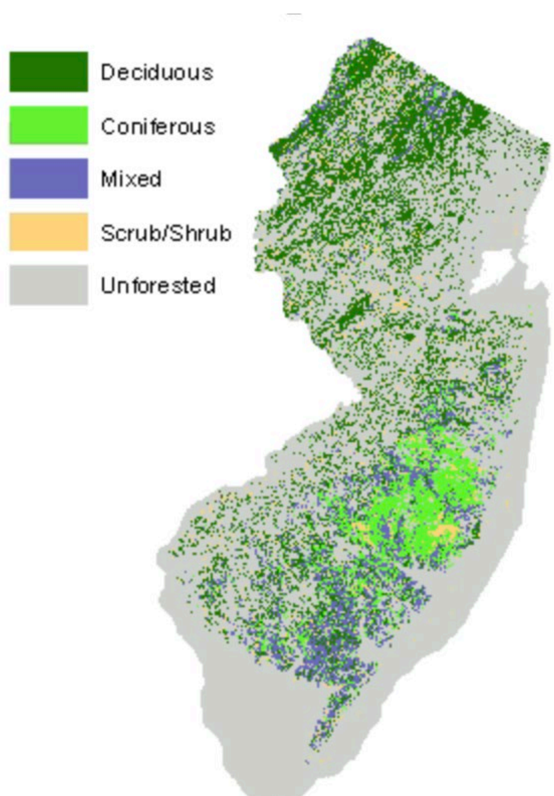
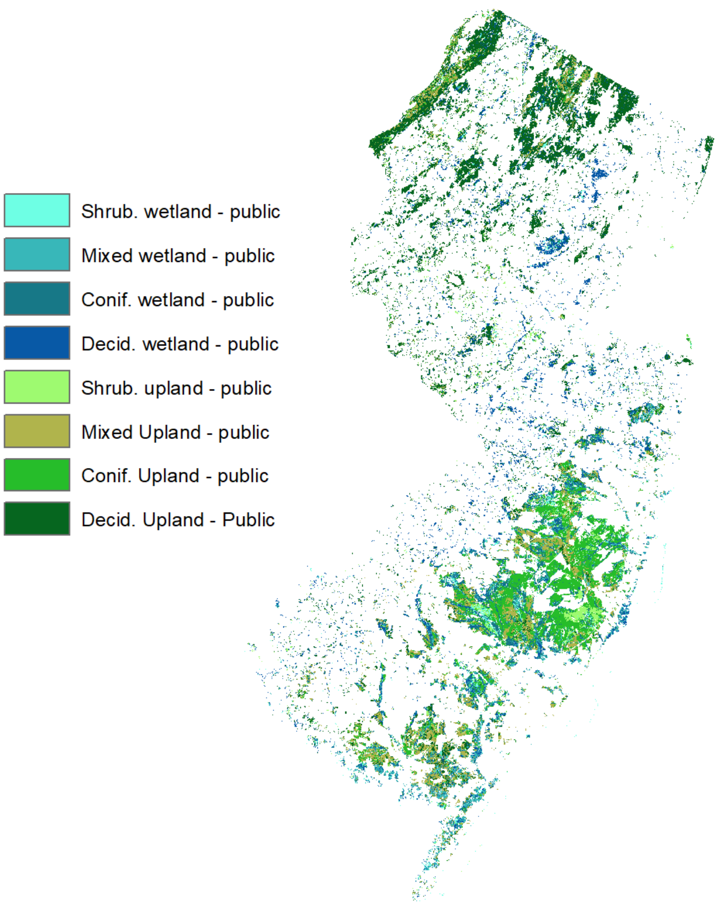



Figure 1. Map of Forest Type derived from NJ LULC15 dataset

Table 2. LULC15 Forest type broken out by wetland/upland and ownership class (PAD-US)

| Type | Upland/Wetland | Owner | acres |
|---|---|---|---|
| Deciduous | Upland | Private | 444,371 |
| Coniferous | Upland | Private | 97,340 |
| Mixed | Upland | Private | 154,548 |
| Scrub/shrub | Upland | Private | 69,404 |
| Deciduous | Wetland | Private | 198,390 |
| Coniferous | Wetland | Private | 39,761 |
| Mixed | Wetland | Private | 60,149 |
| Scrub/shrub | Wetland | Private | 31,359 |
| Deciduous | Upland | Public | 322,884 |
| Coniferous | Upland | Public | 186,841 |
| Mixed | Upland | Public | 148,796 |
| Scrub/shrub | Upland | Public | 47,976 |
| Deciduous | Wetland | Public | 144,297 |
| Coniferous | Wetland | Public | 74,751 |
| Mixed | Wetland | Public | 72,567 |
| Scrub/shrub | Wetland | Public | 35,126 |

## LU/LC15 Public Land Forest Classes




Dataset: National Land Cover Data 2016 (NLCD16)

Table 3. Forest Type Acreage in New Jersey derived from NLCD16 dataset

| NLCD_Land | ACRES |
|---|---|
| Unforested | 2,654,227 |
| Deciduous Forest | 1,002,273 |
| Evergreen Forest | 194,804 |
| Mixed Forest | 269,542 |
| Shrub/Scrub | 32,942 |
| Woody Wetlands | 811,801 |

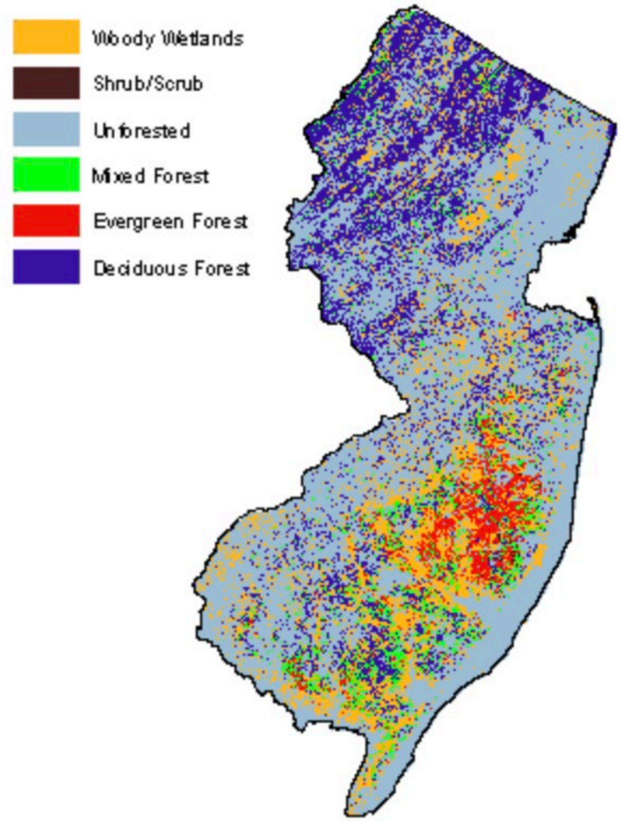



Figure 3. Map of Forest Type derived from National Land Cover Data 2016 Land Cover Dataset: US Forest Service (USFS) Continental US (Conus) Forest Group

Table 4. USFS Forest Group Acreage in NJ

| Forest Group | Acres |
|---|---:|
| Unforested | 3,129,346 |
| White/Red/Jack Pine Group | 92 |
| Loblolly/Shortleaf Pine Group | 535,335 |
| Pinyon/Juniper Group | 10,910 |
| Exotic Softwoods Group | 46 |
| Oak/Pine Group | 50,878 |
| Oak/Hickory Group | 1,069,553 |
| Oak/Gum/Cypress Group | 33,145 |
| Elm/Ash/Cottonwood Group | 57,818 |
| Maple/Beech/Birch Group | 82,299 |
| Aspen/Birch Group | 525 |

Table 5. USFS Forest Group Reclassed to broad forest type in NJ

| Type | Acres |
|---|---|
| Unforested | 3,128,691 |
| Deciduous | 1,210,804 |
| Coniferous | 545,991 |
| Mixed | 84,353 |

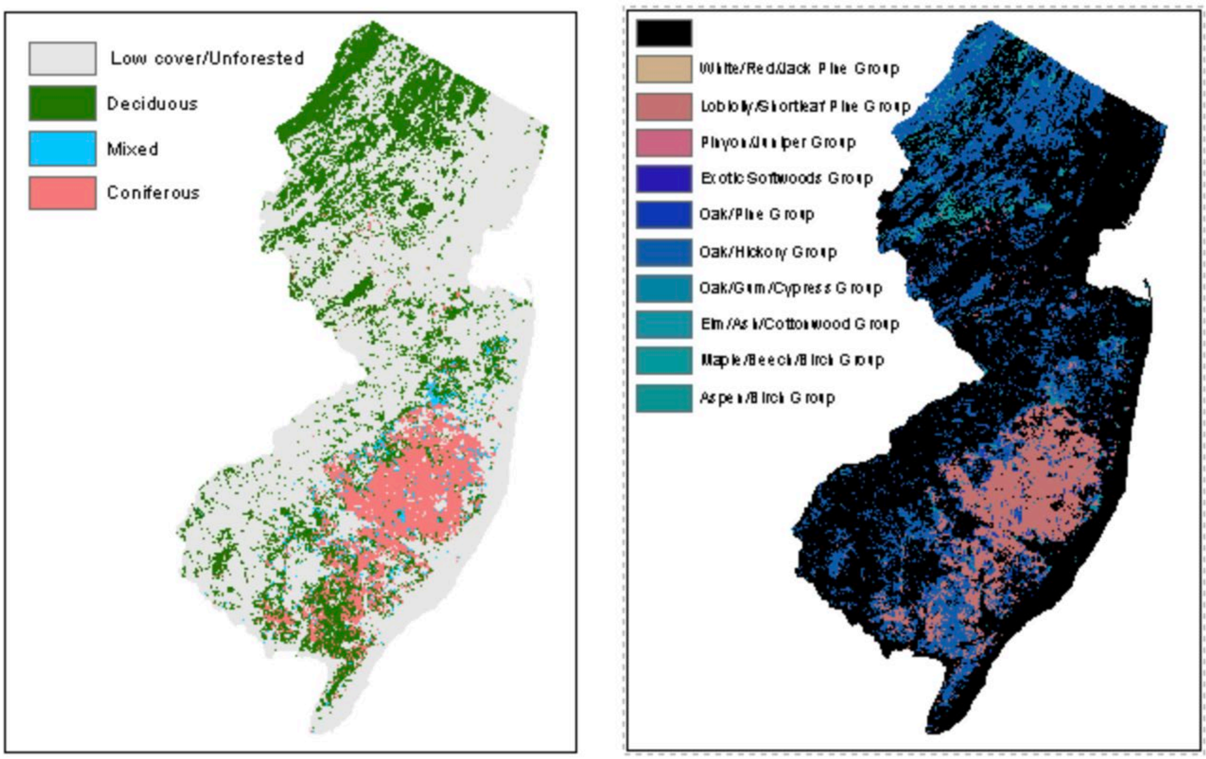



Figure 4. Map of USFS CONUS Forest Type. 4a. Simplified. 4b. All categories.

**1.B. Canopy Cover**

Dataset: Land Use/Land Cover of New Jersey 2015

Table 6. LULC15 derived canopy cover types in NJ

| % Cover | ACRES |
|---|---|
| <50% Sparse Cover | 348,955 |
| >50% Canopy Cover | 1,737,692 |
| Unforested | 3,797,167 |

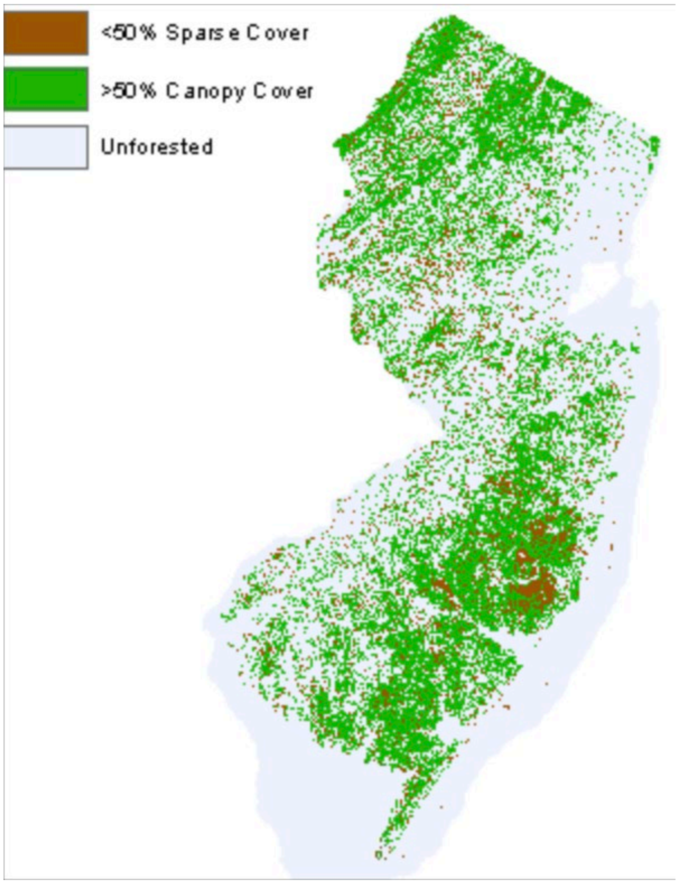



Figure 5. Map of Forest Canopy Cover type derived from LULC15 dataset

Dataset: NLCD 2016 USFS Tree Canopy Cover (CONUS)

Table 7. NLCD16 derived canopy cover type in NJ

| Canopy Cover | ACRES |
|---|---|
| Unforested | 1,799,714 |
| under 50% Cover | 942,515 |
| Over 50% Cover | 2,224,720 |

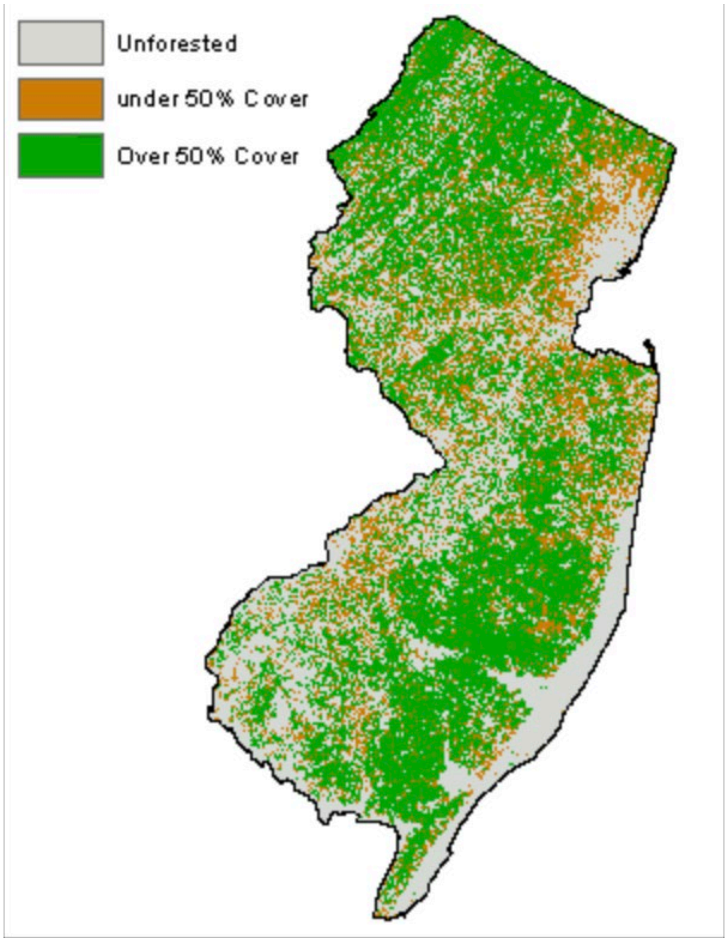



Figure 6. Map of Forest Canopy Cover type derived from NLCD 2016

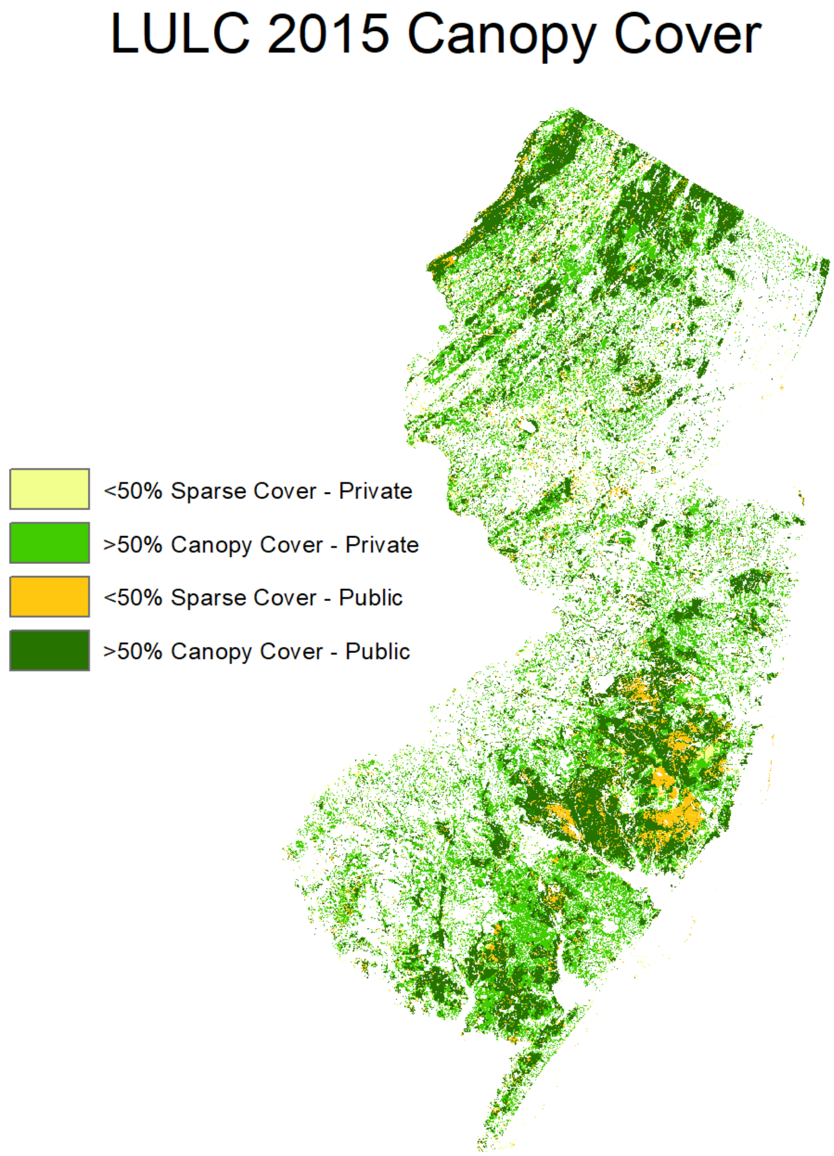



Figure 7. Map of Forest Canopy Cover type derived from LULC15 dataset
Broken out by land ownership class (PAD-US)

Dataset: US Forest Service Landfire Canopy Cover

Table 8. LANDFIRE derived Canopy Cover in NJ

| CC_PERCENT | acres |
|---|---|
| Unforested | 2,503,763 |
| <50% Sparse Cover | 681,568 |
| >50% Canopy Cover | 1,784,539 |

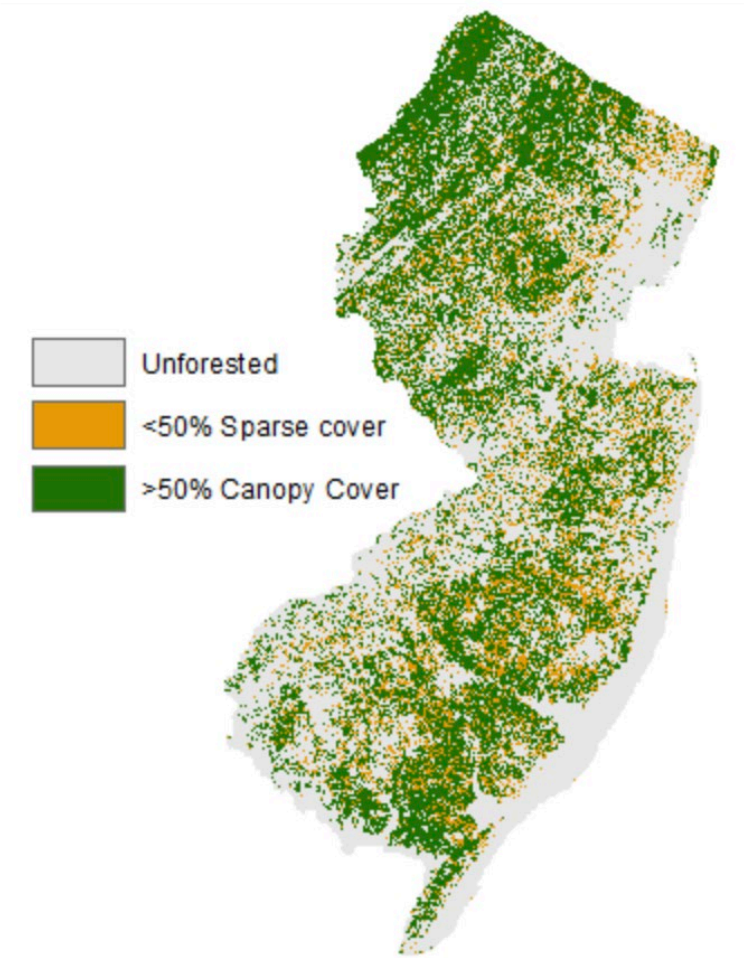



Figure 8. Map of Forest Canopy Cover type derived from USFS Landfire

**3. Baseline Forest Carbon Stocks**

**2.A. Total carbon distribution**

**Dataset:** USFS Forest Inventory & Analysis (FIA) Imputed Carbon density maps reclassified into Quartiles by total carbon (Megagrams/hectare). Units were converted from MG/ha to MG/ac.

Table 9. Carbon quartiles in NJ (USFS FIA imputed Carbon density maps)

| Carbon Stock | Mg_Acres | Acres |
|---|---|---|
| Lowest quartile | 0-7 MG/ac | 1,244,626 |
| Low-Medium | 7-27 MG/ac | 1,244,796 |
| Medium-High | 27-47MG/ac | 1,245,676 |
| Highest quartile | 47-96 MG/ac | 1,243,267 |

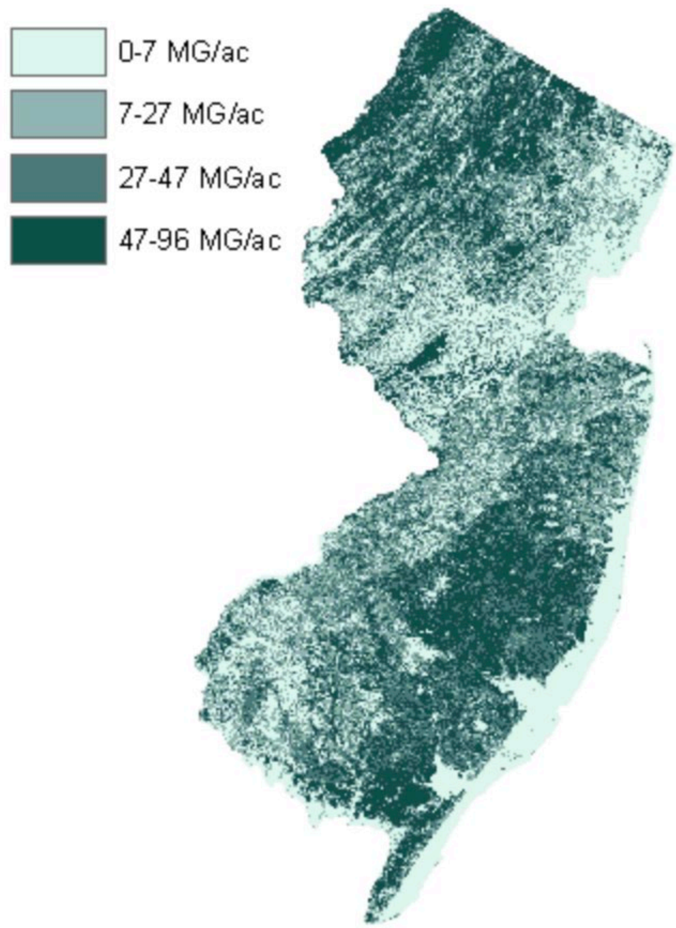



Figure 9. Map of Forest Carbon stock (MG/ac) derived from USFS FIA imputed carbon mapped data.

**2.B. Carbon Stock by Forest Type:**

Table 10. Forest Type Acreage per Quartile of total carbon

| Dataset | Forest Type | Q1 (0-7 Mg/Ac) | Q2 (7-27 Mg/Ac) | Q3 (27-47 Mg/Ac) | Q4 (47-96 Mg/Ac) |
|---|---|---|---|---|---|
| **LULC15** | Deciduous | 96,880 | 231,815 | 327,429 | 452,047 |
| | Coniferous | 7,305 | 29,544 | 132,849 | 229,189 |
| | Mixed | 12,602 | 48,278 | 148,124 | 228,602 |
| **NLCD16** | Deciduous | 82,116 | 212,865 | 302,780 | 402,857 |
| | Coniferous | 3,583 | 13,436 | 67,490 | 110,981 |
| | Mixed | 13,019 | 39,197 | 98,054 | 115,290 |
| **USFS Groups** | Deciduous | 54,904 | 179,321 | 376,170 | 599,027 |
| | Coniferous | 8,278 | 29,066 | 173,992 | 334,657 |
| | Mixed | 3,459 | 9,622 | 30,734 | 40,510 |

**2.C. Carbon Stock by Canopy Cover:**

Table 11. Canopy Cover Class Acreage per carbon quartile

| Dataset | Canopy Cover | Q1 (0-7 Mg/Ac) | Q2 (7-27 Mg/Ac) | Q3 (27-47 Mg/Ac) | Q4 (47-96 Mg/Ac) |
|---|---|---|---|---|---|
| **LULC15** | **high** (over 50%) | 100,973 | 276,139 | 543,645 | 816,417 |
| | **Low** (under 50%) | 43,614 | 76,139 | 108,757 | 121,683 |
| **NLCD16** | **high** (over 50%) | 164,911 | 394,734 | 690,008 | 973,375 |
| | **Low** (under 50%) | 223,135 | 312,247 | 261,436 | 144,062 |
| **Landfire** | **high** (over 50%) | 102,888 | 286,394 | 559,738 | 834,178 |
| | **Low** (under 50%) | 80,046 | 178,471 | 232,155 | 194,286 |

**2.D. Soil Organic Carbon**

Dataset: gridded SSURGO NJ Soil Organic Carbon

Table 12. Soil organic carbon quartiles in NJ (gSSURGO)

| Value | Count | **acres** | **SOC (g/m^2)** | **SOC (MG/acre)** |
|---|---|---|---|---|
| 1 | 528676617 | 1213675 | 0 - 4233 | 0 - 17 |
| 2 | 527166354 | 1210207 | 4233 - 6719 | 17 - 27 |
| 3 | 532239503 | 1221854 | 6719 - 10,643 | 27 - 43 |
| 4 | 519686766 | 1193037 | 10,634 - 249,682 | 43 - 1011 |

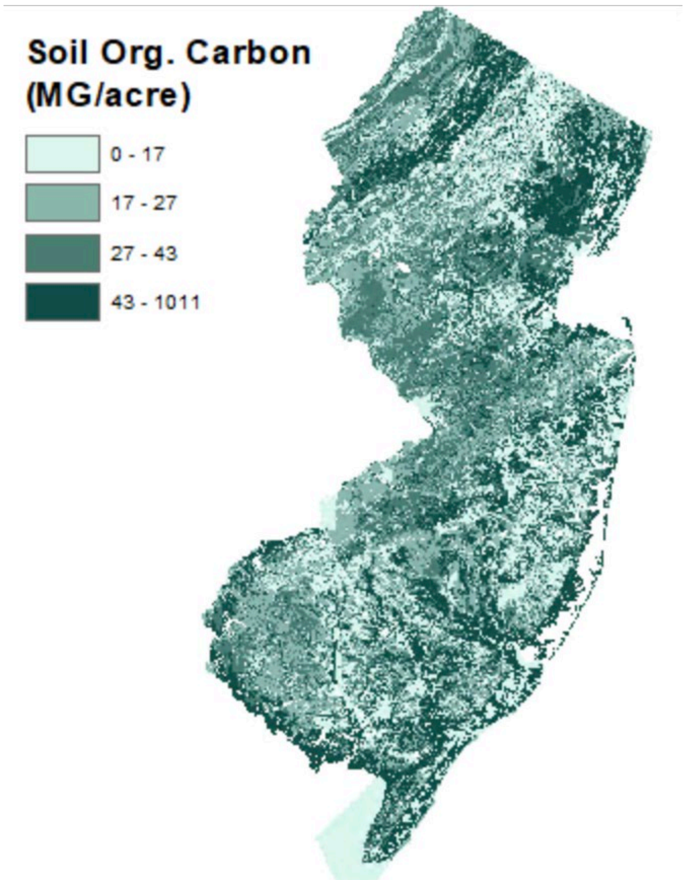



Figure 10. Map of Soil Organic Carbon (MG/ac) derived from NRCS gridded SSURGO.

Table 13. Soil organic carbon statistics in each forest category derived from NJ LULC data

| Type | Area (acres) | Median | | Mean | | Sum |
|---|---|---|---|---|---|---|
| | | g/m^2 | MG/ac | g/m^2 | MG/ac | MG |
| **Unforested** | 2,726,686 | 6,515 | 26 | 20,364 | 82 | 24,186,718 |
| **Upland Deciduous** | 763,143 | 5,702 | 23 | 7,466 | 30 | 2,482,031 |
| **Upland Coniferous** | 280,335 | 4,625 | 19 | 6,840 | 28 | 835,268 |
| **Upland Mixed** | 301,207 | 4,428 | 18 | 6,921 | 28 | 908,123 |
| **Upland Scrub/Shrub** | 113,553 | 5,803 | 23 | 8,196 | 33 | 405,379 |
| **Wetland Deciduous** | 340,044 | 11,044 | 45 | 25,537 | 103 | 3,782,602 |
| **Wetland Coniferous** | 113,941 | 12,695 | 51 | 36,594 | 148 | 1,816,277 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Wetland Mixed** | 132,223 | 12,695 | 51 | 27,614 | 112 | 1,590,471 |
| **Wetland Scrub/Shrub** | 64,612 | 12,695 | 51 | 34,906 | 141 | 982,442 |

## 3. Pest and Wildfire Risk

### 3.A. Pest Risk

**Southern Pine Beetle**

**Dataset:** Projected BA Loss rate due to Southern Pine Beetle over the 2013-2027 time frame from the 2012 National Insect and Disease Risk Map (NIDRM) Project

Table 14. Pine Beetle risk class acreage

| Class | Acres |
|---|---|
| Low/no Ba Loss | 4,374,141 |
| 1 - 5% BA loss | 201,365 |
| 6 - 10% BA loss | 220,907 |
| 11 - 15% BA loss | 104,725 |
| 15 - 20% BA loss | 48,391 |
| >20% BA loss | 20,211 |

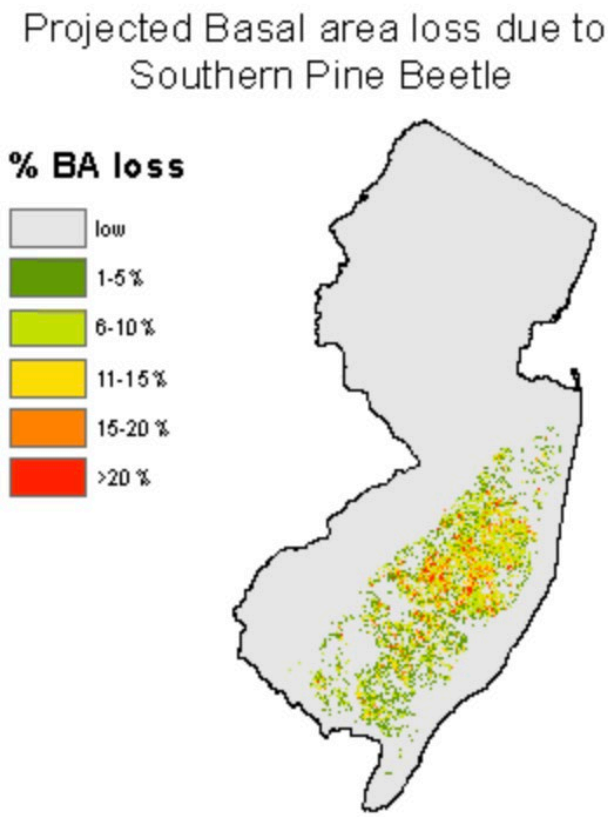



Figure 11. Map of projected basal area loss due to Southern Pine Beetle.

Table 15. Acres of forest in each total carbon class and the projected BA loss due to the Southern pine beetle. For example, there are 14,802 acres of forest that is estimated to have high carbon amount (4th quantile) and expected to lose more than 20% of its basal area.

| | Projected BA loss due to Southern Pine Beetle | | | | |
|---|---|---|---|---|---|
| **Total Carbon** | **1 - 5%** | **6 - 10%** | **11 - 15%** | **16 - 20%** | **>20%** |
| 0-7 MG/ac | 2,235 | 2,434 | 470 | 100 | 43 |
| 7-27 MG/ac | 16,382 | 14,873 | 3,772 | 1,324 | 399 |
| 27-47 MG/ac | 72,004 | 80,657 | 33,902 | 13,649 | 4,967 |
| 47-96 MG/ac | 110,745 | 122,943 | 66,581 | 33,319 | 14,802 |

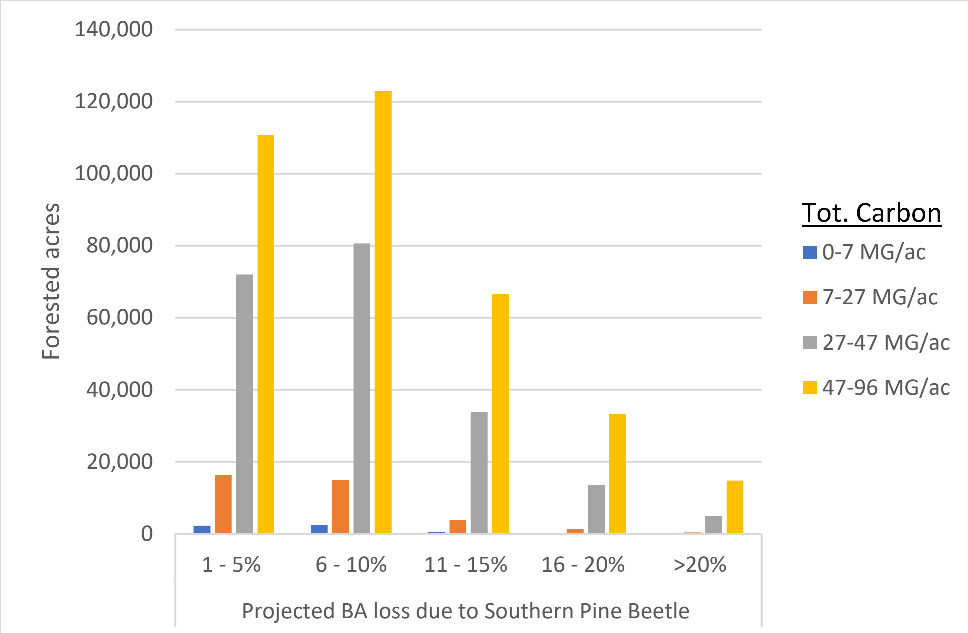



Figure 12. Projected total Basal area loss due to Southern Pine Beetle cross-tabulated with total carbon quartiles.

Table 16. Pine Beetle Risk Classes in 4th Carbon Quartile (High Quartile: 47-96 MG/ac)

| %BA loss | Acres |
|---|---|
| 1-5% | 110,745 |
| 6-10% | 122,943 |
| 11-15% | 66,581 |
| 16-20% | 33,319 |
| >20% | 14,802 |

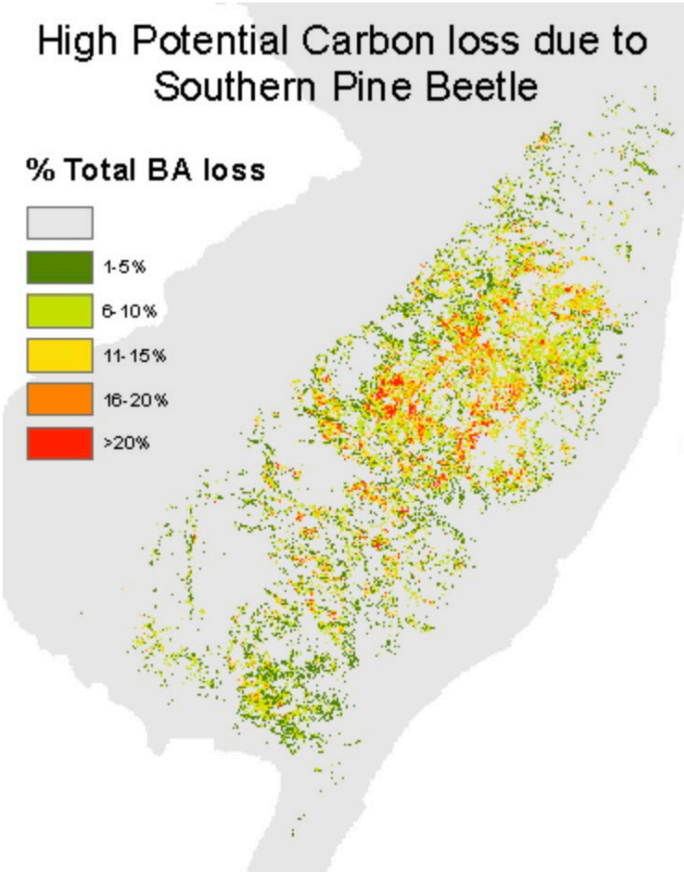



Figure 13. Map of the southern New Jersey pinelands high carbon stock forests classed by projected Southern Pine Beetle risk

**Emerald Ash Borer**

**Dataset:** Projected Total BA Loss rate due to Emerald Ash Borer over the 2013-2027 time frame from the 2012 National Insect and Disease Risk Map (NIDRM) Project

Table 17. Emerald Ash Borer risk class acreage

| Risk Class | Acres |
|---|---|
| Low/no loss | 4,444,466 |
| 1 - 5% BA loss | 78,280 |
| 6 - 10% BA loss | 111,941 |
| 11-15% BA loss | 115,883 |
| 16 -20% BA loss | 97,267 |
| >20% BA loss | 121,904 |

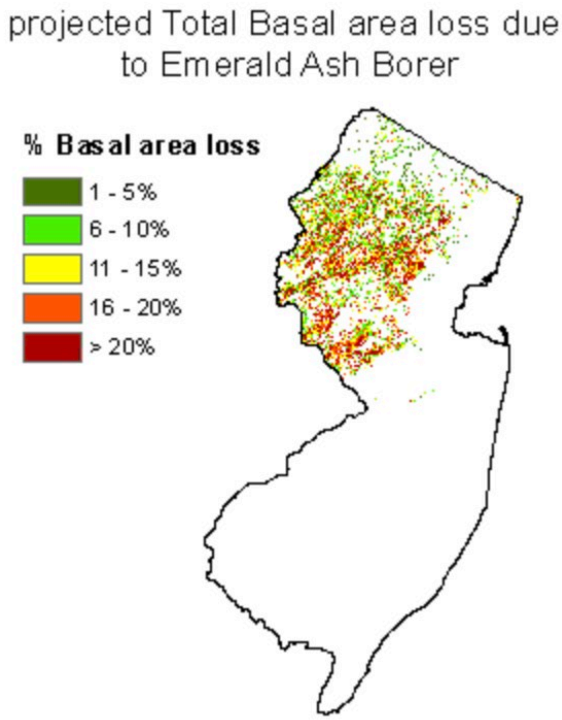



Figure 14. Map of projected basal area loss due to Emerald Ash Borer

Table 18. Acres of forest in each Ash Borer BA loss class and total carbon class. For example, there are 41,830 acres of forest that is estimated to have high carbon amount (4th quantile) and expected to lose more than 20% of its basal area.

| | Projected BA loss due to Ash Borer | | | | |
|---|---|---|---|---|---|
| **Total Carbon** | **1 - 5%** | **6 - 10%** | **11 - 15%** | **16 - 20%** | **>20%** |
| 0-7 MG/ac | 3,729 | 8,383 | 10,803 | 9,678 | 13,236 |
| 7-27 MG/ac | 12,425 | 24,181 | 26,473 | 22,089 | 31,696 |
| 27-47 MG/ac | 21,349 | 30,344 | 30,472 | 26,672 | 35,141 |
| 47-96 MG/ac | 40,691 | 48,961 | 48,093 | 38,799 | 41,830 |

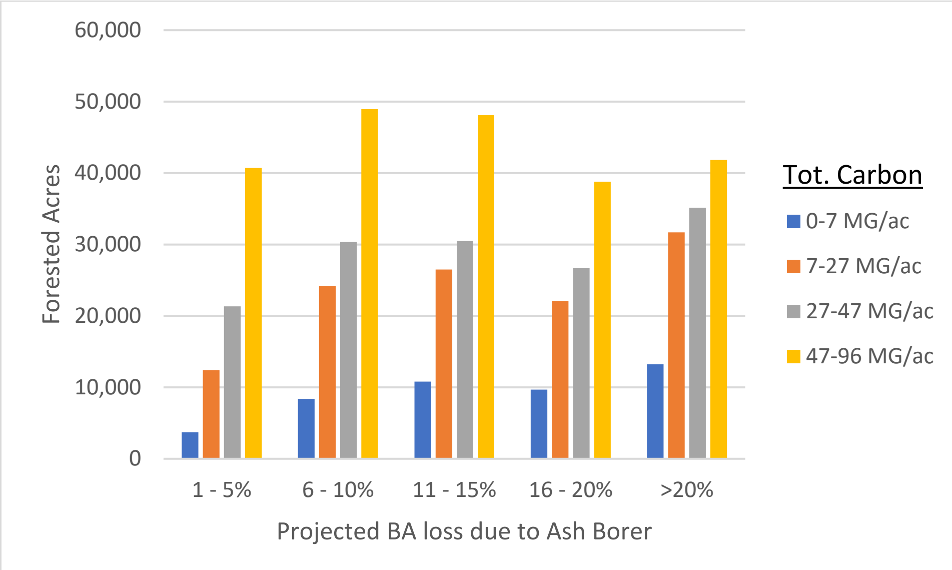



Figure 15. Projected total Basal area loss due to Emerald Ash Borer cross-tabulated with total carbon quartiles.

Table 19. Ash Borer Risk Classes in 4$^{th}$ Carbon Quartile (High Quartile: 47-96 MG/ac)

| %BA loss | Acres |
|---|---|
| 1-5% | 40,691 |
| 6-10% | 48,961 |
| 11-15% | 48,093 |
| 16-20% | 38,799 |
| >20% | 41,830 |

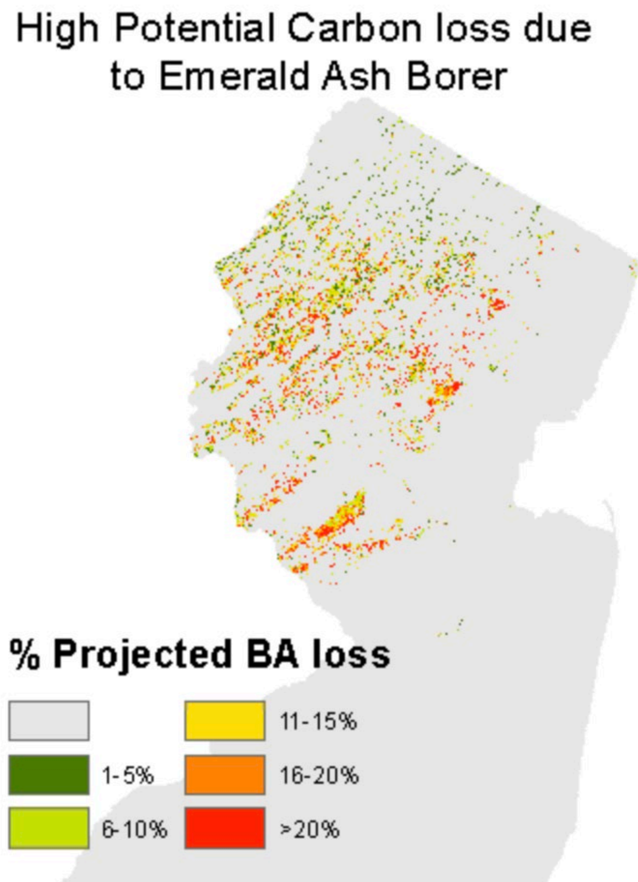



Figure 16. Map of the New Jersey high carbon stock forests classed by projected Emerald Ash Borer risk

### 3.B. Wildfire Risk

**Dataset:** New Jersey Forest Fire Service (NJFFS) based on 2002 LULC data

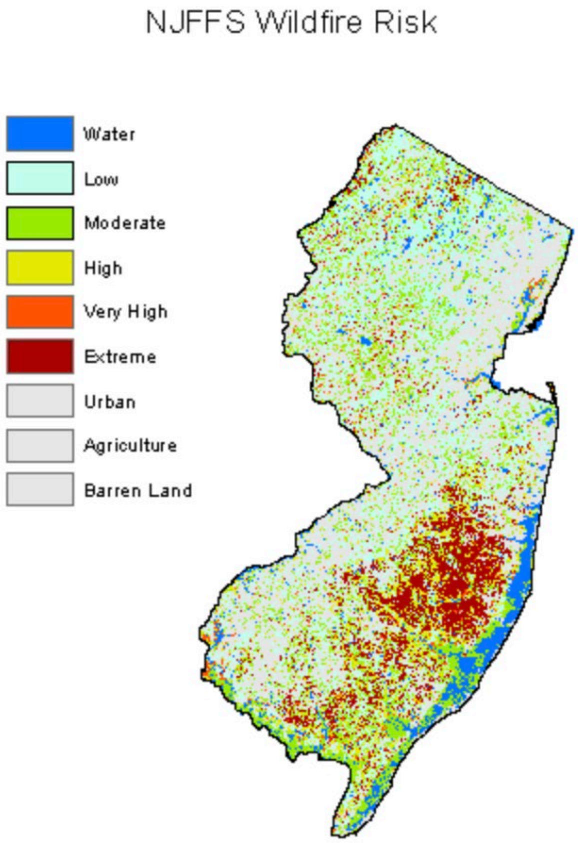



Figure 17. Map of the New Jersey Forest Fire Risk.

Table 20. NFFFS wildfire risk in high-carbon areas

| **Risk** | **Acres** |
|---|---|
| None | 3,556,640 |
| low | 449,727 |
| moderate | 174,095 |
| high | 148,391 |
| very high | 25,420 |
| extreme | 220,764 |

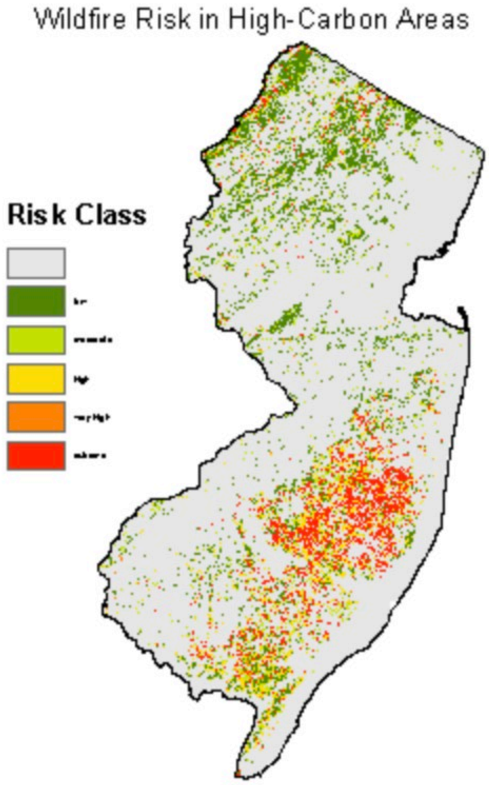



Figure 18. Map of New Jersey high carbon stock forest classed by NJFFS Wildfire risk classes

### 4. Mapping Afforestation Candidate Areas

#### 4.A. Prime/Non-Prime Farmland:

Dataset: Natural Resources Conservation Service (NRCS) Soil Survey Geographic Database (SSURGO). From gridded SSURGO the MUPOLYGON data layer Farm Class field was reclassified into: **Prime Farmland (of statewide/local/unique importance); 1, Not Prime Farmland; 2.**

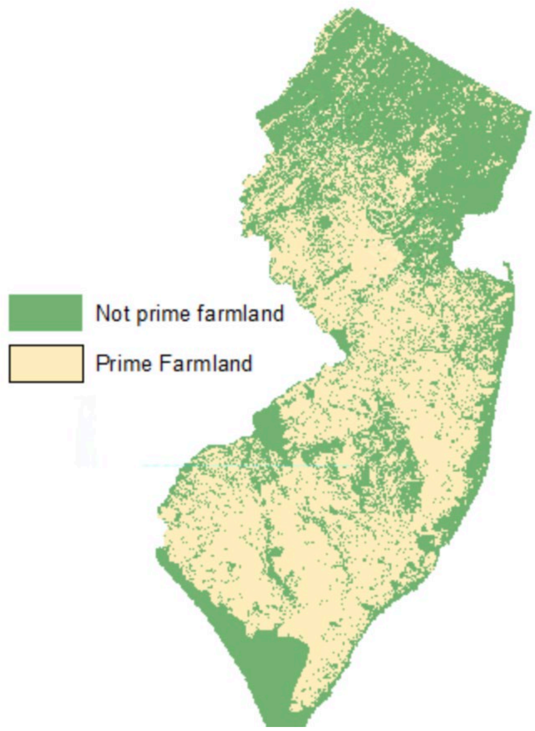



Figure 19. Map of New Jersey Prime vs. non-prime farm soil areas.

**4.B. Brownfields**

**Datasets:** Land Use/Land Cover of New Jersey 2015, Brownfield Development Areas (Blocks and Lots) of New Jersey, PAD-US V 2.1 (USGS)

Table 21. Former Agricultural Wetlands, urban brownfields, and old field areas
In New Jersey from LULC15 and Urban Brownfields of NJ that may serve as potential candidate afforestation sites.

| Land Use/Cover | Owner | Acres |
|---|---|---|
| Urban Brownfield | | 2,547 |
| Former Ag. Wetland | | 1,777 |
| Old Field | private | 25,191 |
| Urban Brownfield | | 256 |
| Former Ag. Wetland | | 1,171 |
| Old Field | public | 15,085 |

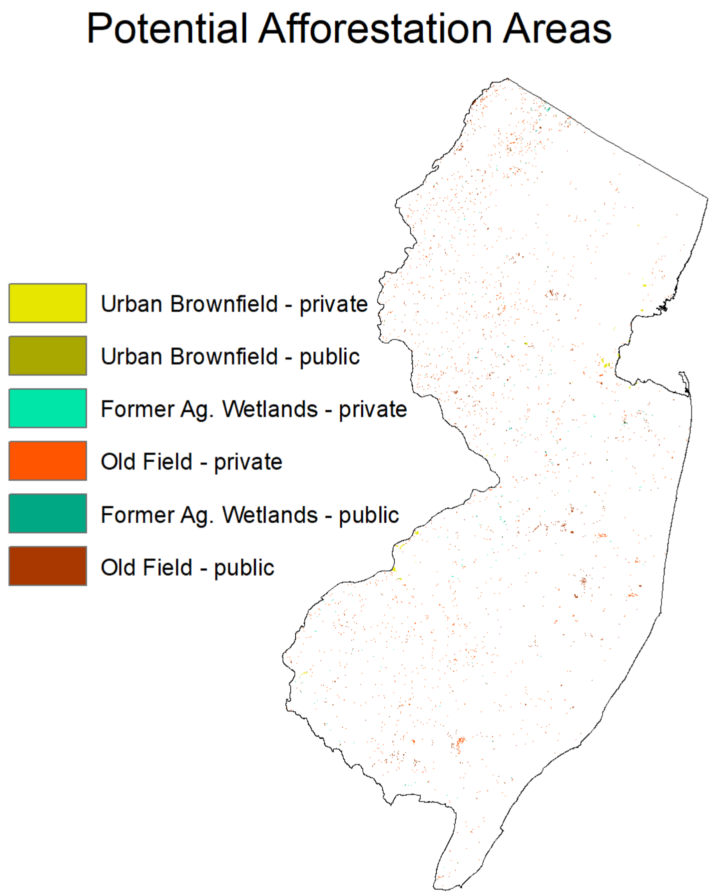



Figure 20. Map of areas identified as potential candidate afforestation sites.

### 4.C. Existing Agriculture in Non-Prime Farmland Soil Areas

Dataset: NJLULC 2015 and NRCS SSURGO Non-prime farmland.

Table 22. Existing Agricultural areas that fall within non-prime farmland areas

| Land Use/Cover | | Owner | Acres |
|---|---|---|---|
| Ag. Wetlands | | | 5,745 |
| Crop/Pastureland | | | 38,365 |
| Orchards/Vineyards | | | 3,439 |
| Other Ag. | | private | 7,861 |
| Ag. Wetlands | | | 4,170 |
| Crop/Pastureland | | | 20,403 |
| Orchards/Vineyards | | | 1,405 |
| Other Ag. | | public | 1,724 |

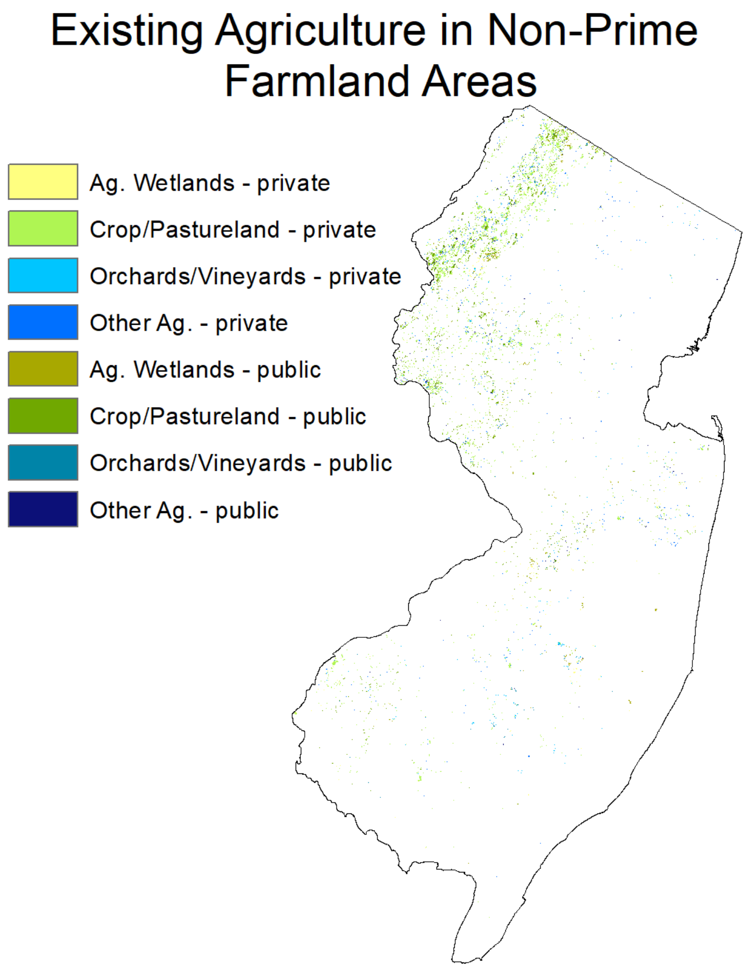



Figure 21. Map of non-prime farmland areas identified as potential candidate afforestation sites.

### 4.D. Depleted Soil Carbon Areas

Dataset: Edwin Muniz of the New Jersey Office of NRCS has undertaken an analysis to identify areas of New Jersey's farmland where the soils appear to be depleted in soil carbon as compared to areas nearby with a similar soil type. These high soil carbon depleted soils may serve as candidate target areas for afforestation as a means of increasing the potential stock of carbon in the soils.

Table 23. Area of New Jersey farmland soils classed by soil carbon depletion.

| C Depletion | Land Owner | Acres |
|---|---|---|
| Low 0 - 0.30 | | 117,992 |
| Medium 0.30 - 0.44 | | 116,814 |
| High 0.44 - 0.68 | Private | 109,177 |
| Low 0 - 0.30 | | 64,530 |
| Medium 0.30 - 0.44 | | 64,223 |
| High 0.44 - 0.68 | Public | 70,120 |
| | | |

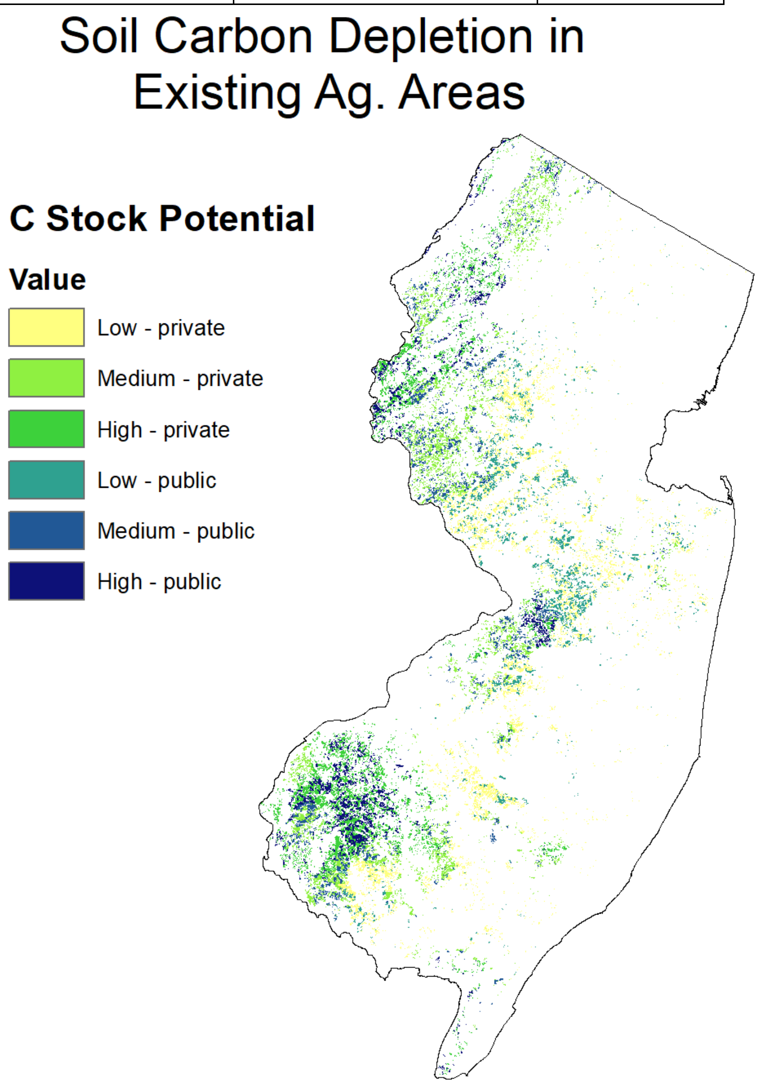



Figure 22. Map of farmland areas classed into Low-Medium-High soil carbon depletion.

## 5. Mapping Reforestation Candidate Areas

### 5.A. Canopy Cover Change

**Dataset:** NLCD 2011 to 2016 Percent Tree Canopy Change (CONUS)

Table 24. NLCD Canopy change 2011-2016

| Canopy Change | ACRES |
|---|---|
| 40-100% decrease | 20,158 |
| 20-40% decrease | 14,060 |
| 5-20% decrease | 539 |
| No change | 35 |
| 5-20% increase | 415 |
| 20-40% increase | 11,202 |
| 40-100% increase | 2,611 |

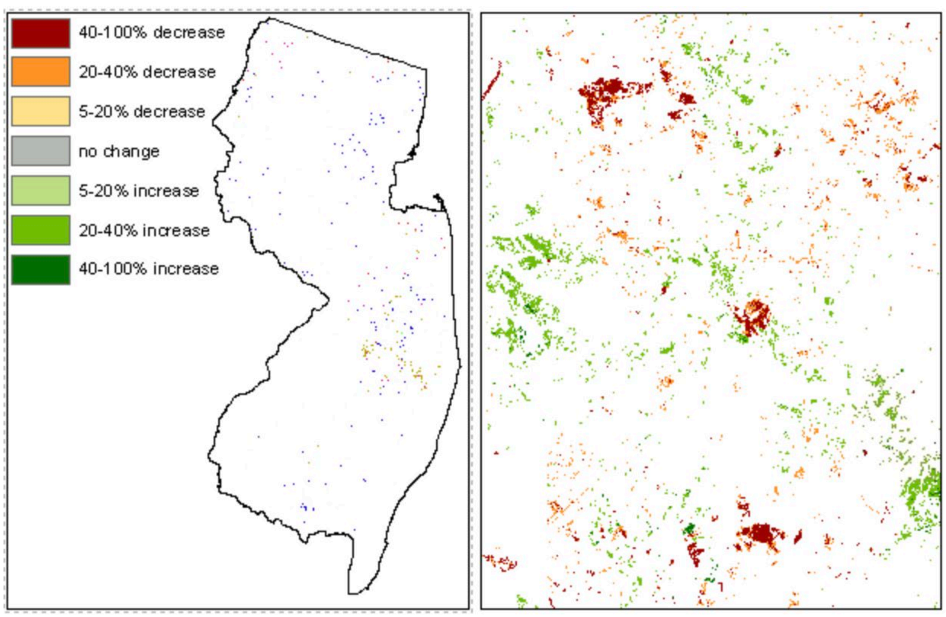



Figure 23. Map of forest lands classed into Low-Medium-High canopy cover loss or gain.
Mapped Results zoomed in on Pine Barrens

### 5.B. Recently Abandoned Farmland Areas

Table 25. LULC derived forest age acreage

| Years Forested | Acres |
|---|---|
| 1 | 5,402 |
| 3 | 27,458 |
| 8 | 23,792 |
| 13 | 117,631 |
| 25 | 14,951 |
| >34 | 1,930,168 |

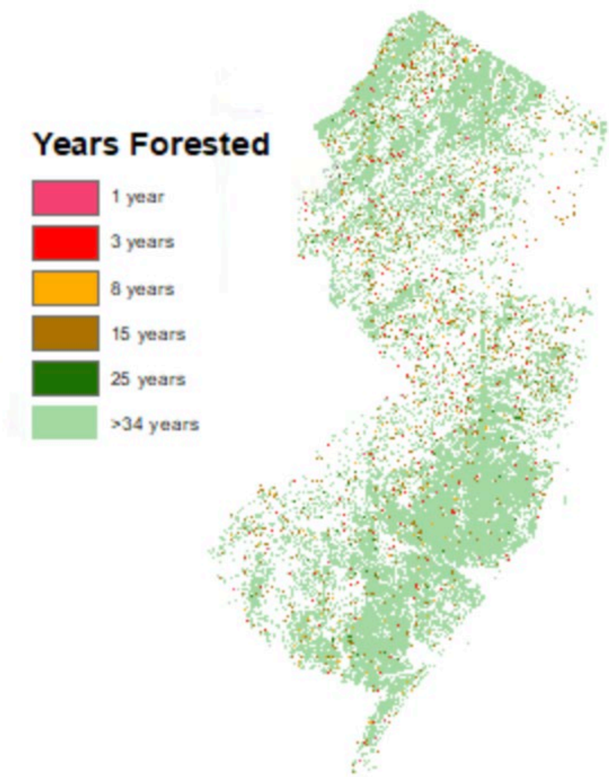



Figure 24. Map of recently reforested lands classed into approximate age of the existing forest.

Table 26. Land use type in 1986 of afforested areas in 2015 from NJ LU/LC data layers (Only LU types with over 9,000 acres of afforestation are included)

| LULC 1986 | Acres |
|---|---|
| Unforested | 3,356,132 |
| AGRICULTURAL WETLANDS (MODIFIED) | 9,749 |
| CROPLAND AND PASTURELAND | 44,645 |
| HERBACEOUS WETLANDS | 28,312 |
| OLD FIELD (< 25% BRUSH COVERED) | 17,572 |
| OTHER URBAN OR BUILT-UP LAND | 9,055 |
| RESIDENTIAL, RURAL, SINGLE UNIT | 10,272 |
| Forested 86-15 | 1,963,850 |

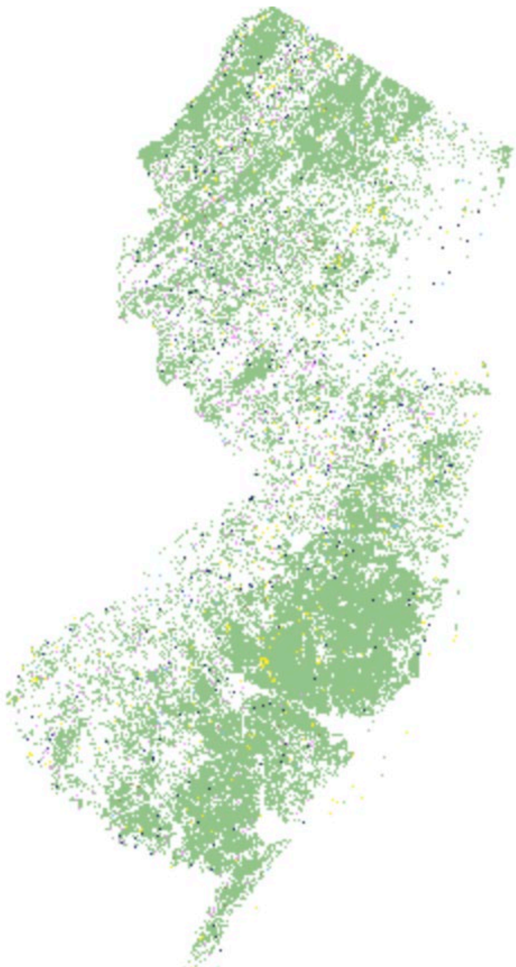


Figure 25. Map of recently reforested areas (mapped forest as of 2015) and the prior land use of each forested area as of 1986

Table 27. Land use type in 1995 of afforested areas in 2015 from NJ LU/LC data layers (Only LU types
with over 6,000 acres of afforestation are included)

| LULC 1995 | Acres |
|---|---|
| Unforested | 3,356,132 |
| AGRICULTURAL WETLANDS (MODIFIED) | 6,446 |
| CROPLAND AND PASTURELAND | 28,239 |
| HERBACEOUS WETLANDS | 26,022 |
| OLD FIELD (< 25% BRUSH COVERED) | 31,413 |
| OTHER URBAN OR BUILT-UP LAND | 9,597 |
| RESIDENTIAL, RURAL, SINGLE UNIT | 12,643 |
| RESIDENTIAL, SINGLE UNIT, LOW DENSITY | 6,164 |
| Forested 95-2015 | 1,959,388 |

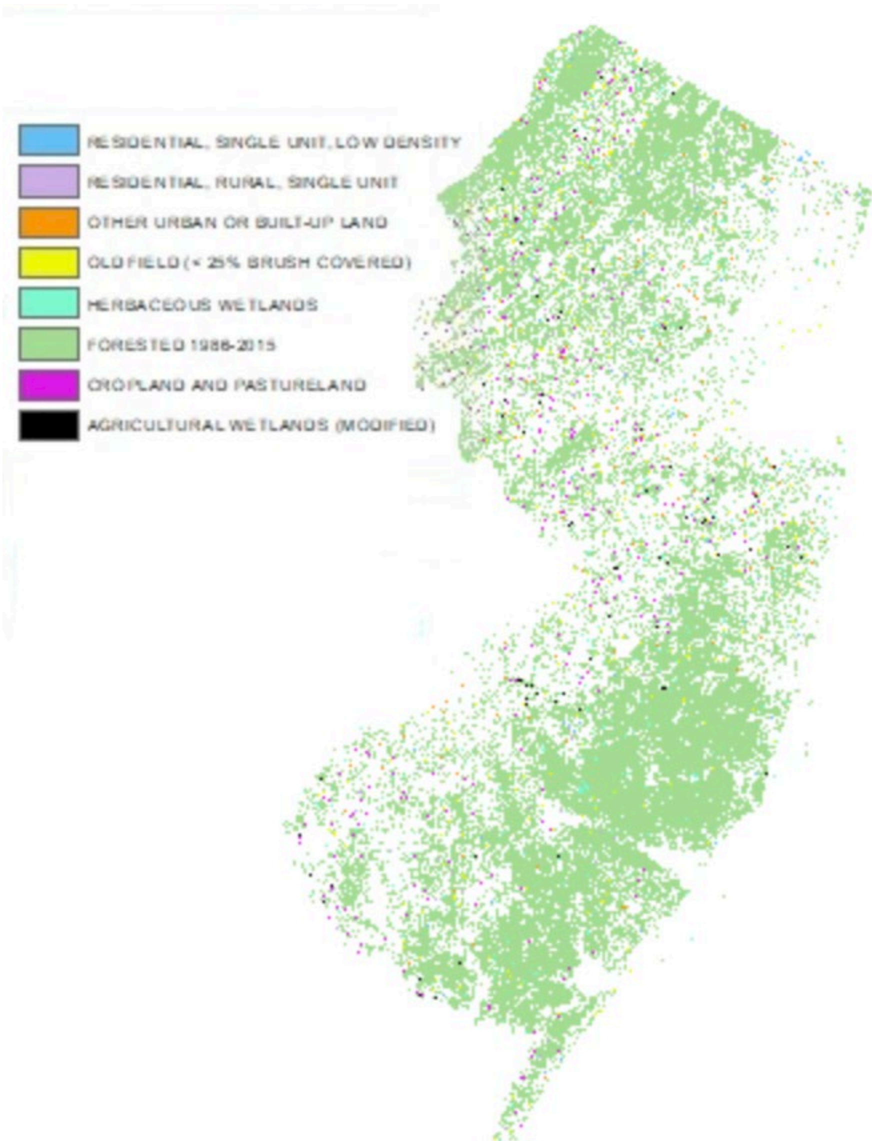



Figure 26. Map of recently reforested areas (mapped forest as of 2015) and the prior land use of each forested area as of 1995

**Appendix B. Processing and Analysis methods**

## 1 Mapping Forest Type/Canopy Cover

### A. Forest Type

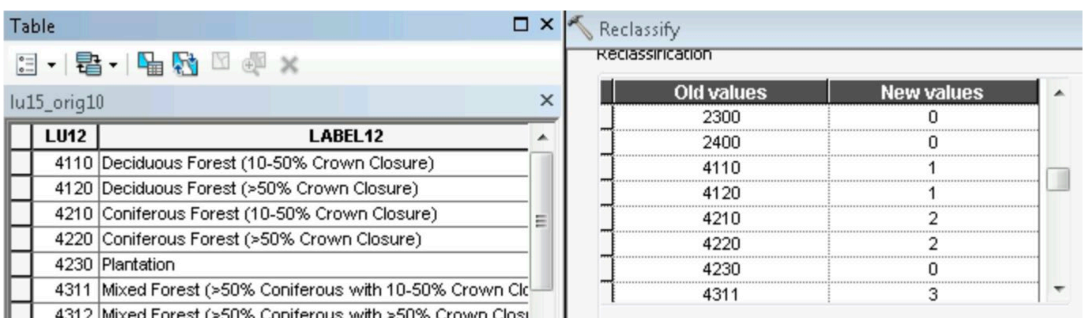
LULC15

**Dataset:** Land Use/Land Cover of New Jersey 2015
https://gisdata-njdep.opendata.arcgis.com/documents/6f76b90deda34cc98aec255e2defdb45/about
**Source:**
X:\projects\lri\LULC2012\raster_99_2015\lu15_orig10
*This is a gridded version of the dataset

**Projection:** NAD_1983_StatePlane_New_Jersey_FIPS_2900_Feet
**Extent:**
West -75.592929 East -73.890364
North 41.357576 South 38.855875

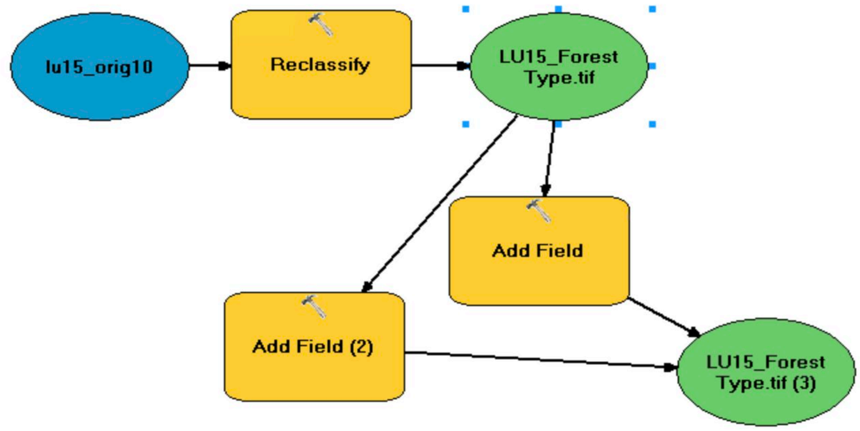
**Raster Resolution:** 10ft

**Data Processing:** The gridded LULC15NJ dataset was reclassified to map general forest type.




| LU12 | LABEL12 |
|---|---|
| 4110 | Deciduous Forest (10-50% Crown Closure) |
| 4120 | Deciduous Forest (>50% Crown Closure) |
| 4210 | Coniferous Forest (10-50% Crown Closure) |
| 4220 | Coniferous Forest (>50% Crown Closure) |
| 4230 | Plantation |
| 4311 | Mixed Forest (>50% Coniferous with 10-50% Crown Clc |

| Old values | New values |
|---|---|
| 2300 | 0 |
| 2400 | 0 |
| 4110 | 1 |
| 4120 | 1 |
| 4210 | 2 |
| 4220 | 2 |
| 4230 | 0 |
| 4311 | 3 |



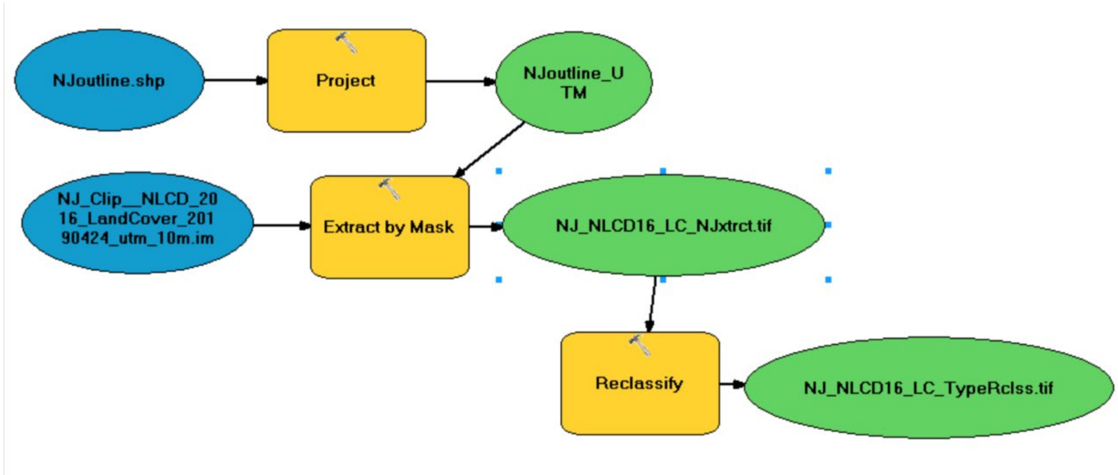

NLCD16

**Dataset:** NLCD 2016 Land Cover (Conus)
https://www.mrlc.gov/data/nlcd-2016-land-cover-conus
**Source:**
X:\databank\usgs2\landcover\NLCD2016\Data_LandCover\CRSSA_Subsets\
NJ_Clip__NLCD_2016_LandCover_20190424_utm_10m.img

**Projection:** NAD_1983_UTM_Zone_18N
**Extent:**
West -75.574206 East -73.896387
North 41.358106 South 38.923635

**Raster Resolution:** 10m

**Data Processing:**
NJoutline, derived from NJ_munis, was projected to UTM. Extract by Mask was used with NJ_Clip_NLCD16_LandCover_UTM as input Raster and NJoutline_UTM as feature Mask. The resulting raster was reclassified into Deciduous Forest, Evergreen Forest (Coniferous), Mixed Forest, Shrub/Scrub, Woody Wetlands, and Unforested space.

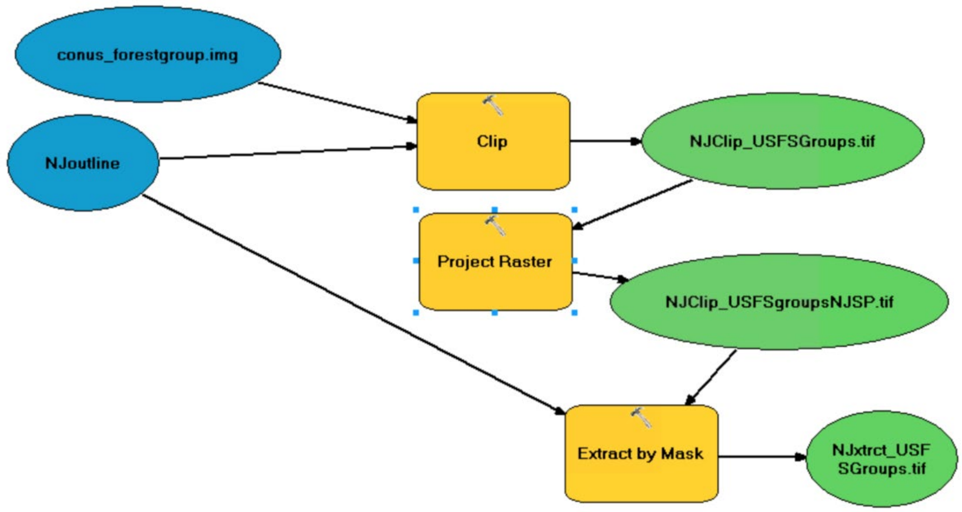



USFS CONUS Type/Group

**Dataset:** USFS Conus Forest Group
https://data.fs.usda.gov/geodata/rastergateway/forest_type/conus_forest_type_group_metadata.php
**Source:**
X:\projects\forestry\forestcarbon\Data\Task1data\USFSConusTypeGroup\conus_forestgroup\

**Projection:** Albers_Conical_Equal_Area
**Raster Resolution:** 250m

**Data Processing:** conus_forestgroup.img was clipped with NJoutline as the Output extent. The resulting raster was projected to NAD_1983_StatePlane_New_Jersey_FIPS_2900_Feet. Extract by Mask was used with this projected Raster as input feature and NJoutline as feature Mask.




**Further Processing:** This NJ extracted USFS Conus Forest Group raster was reclassified into four groups by tree species: Low cover/Unforested, Deciduous, Coniferous, Mixed.

**Resulting Projection:** NAD_1983_StatePlane_New_Jersey_FIPS_2900_Meters
**Resulting Extent:**

West -75.588529 East -73.897419
North 41.359997 South 38.923416

**Resulting Raster Resolution:** 250m

B. Canopy Cover

LULC15

To map broad Canopy Cover, lu15_orig10 was reclassified via label12 field as follows:

**>50% canopy cover**
'Coniferous Forest (>50% Crown Closure)', 'Coniferous Wooded Wetlands', 'Deciduous Forest (>50% Crown Closure)', 'Deciduous Wooded Wetlands', 'Mixed Forest (>50% Coniferous with >50% Crown Closure)', 'Mixed Forest (>50% Deciduous with >50% Crown Closure)', 'Mixed Forested Wetlands (Coniferous Dom.)', 'Mixed Forested Wetlands (Deciduous Dom.)',

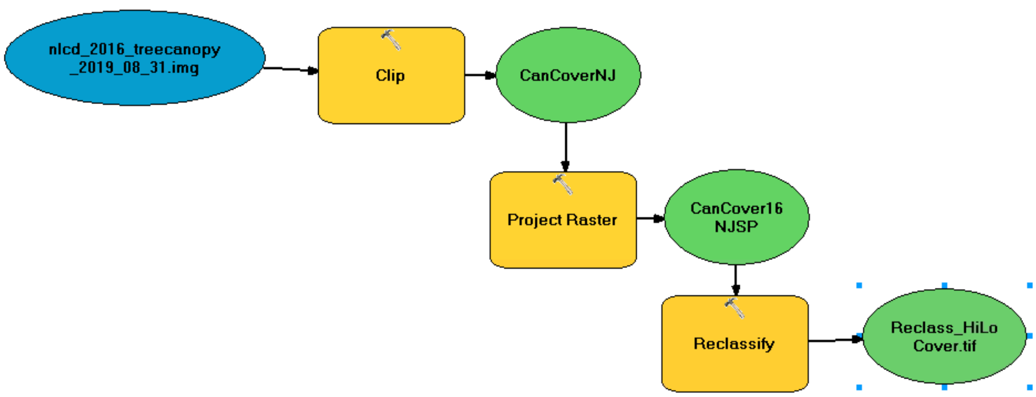
**<50% sparse cover:**
'Coniferous Brush/Shrubland', 'Coniferous Forest (10-50% Crown Closure)', 'Coniferous Scrub/Shrub Wetlands', 'Deciduous Brush/Shrubland', 'Deciduous Forest (10-50% Crown Closure)', 'Deciduous Scrub/Shrub Wetlands', 'Mixed Deciduous/Coniferous Brush/Shrubland', 'Mixed Forest (>50% Coniferous with 10-50% Crown Closure)', 'Mixed

Forest (>50% Deciduous with 10-50% Crown Closure)', 'Mixed Scrub/Shrub Wetlands (Coniferous Dom.)', 'Mixed Scrub/Shrub Wetlands (Deciduous Dom.)'

NLCD16

**Origin Dataset:** NLCD 2016 USFS Tree Canopy Cover (CONUS)
https://www.mrlc.gov/data/type/tree-canopy
**File Name**: nlcd_2016_treecanopy_2019_08_31.img
**CRSSA Databank path:** X:\databank\usgs2\landcover\NLCD2016\Data_TreeCanopy\

**Raster Processing:**
Clipped to area of interest (New Jersey and surrounding area)
Projected to NAD_1983_StatePlane_New_Jersey_FIPS_2900_Meters
Reclassified to 1-49% Canopy Cover, 50-100% Canopy Cover, and no cover




Landfire

**Origin Dataset:** LANDFIRE Forest Canopy Cover
https://www.arcgis.com/home/item.html?id=190522f9c81646038f3af80ff40b8130
**File Name**: us_210cc_21
**CRSSA Databank path:** X:\projects\forestry\forestcarbon\Data\1_ForestMapping\LFFCC

**Raster Processing:**
Clipped to area of interest (New Jersey and surrounding area)
Projected to NAD_1983_StatePlane_New_Jersey_FIPS_2900_Meters
Reclassified to 1-50% Canopy Cover, 50-100% Canopy Cover, and no cover

## 2. Carbon Mapping

### New Jersey Carbon Distribution

**Dataset:** USFS FIA Imputed Carbon density maps
https://www.fia.fs.fed.us/forestcarbon/
**Source:** X:\projects\forestry\Carbon_data.gdb
**Data Processing**: tot_mg_ha_NJ was reclassified into Quartiles by total carbon (Megagams/hectare). Units were converted from MG/ha to MG/ac.

This NJ total carbon breakdown was used to tabulate each resulting forest type and canopy cover class into carbon quartile classes. This raster was used as the input zone to Tabulate Area for each mapped result from task 1 (Mapping forest Type/Canopy Cover). The tabulated results below show how many acres of each forest type and canopy cover class fall within each carbon quartile.

**Dataset:** gSSURGO NJ Soil Organic Carbon
https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/home/?cid=nrcs142p2_053628
**Source:** X:\projects\forestry\forestcarbon\Data\2_CarbonAnalysis\SSURGOCarbon\
**Data Processing**: tot_ soc0_999_10ftwas reclassified into Quartiles by total carbon (Megagams/hectare). Units in this data layer are g/m^2. A field was added with units converted to MG/ac.

## 3. Wildfire/Pathogen Risk

### A. Pest Risk

Southern Pine Beetle

**Dataset:** Projected BA Loss rate due to Southern Pine Beetle
https://www.fs.fed.us/foresthealth/applied-sciences/mapping-reporting/national-risk-maps.shtml
https://www.fs.fed.us/foresthealth/technology/pdfs/2012_RiskMap_Exec_summary.pdf

**Source:** X:\projects\forestry\forestcarbon\Data\3_PestFireRisk\SthnPineBeetle\
**Projection:** NAD_1983_Albers

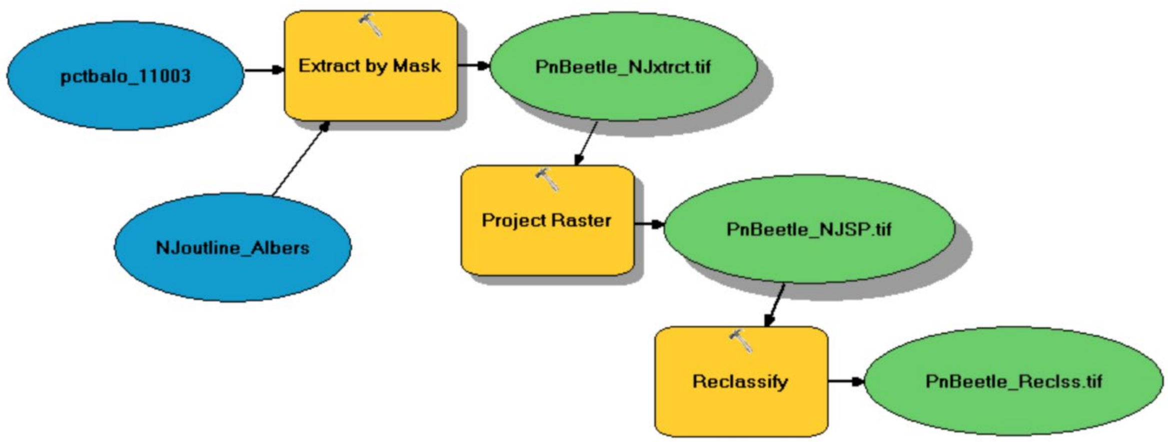
**Extent:**
West -75.592929 East -73.890364
North 41.357576 South 38.855875

**Raster Resolution:** 240m

**Description:** This raster dataset shows the percent of projected BA loss relative to overall total BA from Southern Pine Beetle, assuming no remediating management, over the 2013-2027 time frame. The 2012 National Insect and Disease Risk Map (NIDRM) Project integrates 186 individual risk models constructed within a common, consistent framework that accounts for regional variations in forest health conditions. These 186 models are built to portray the expected loss of host basal area for each pair of damage agents and hosts over each unique landscape where they coexist.

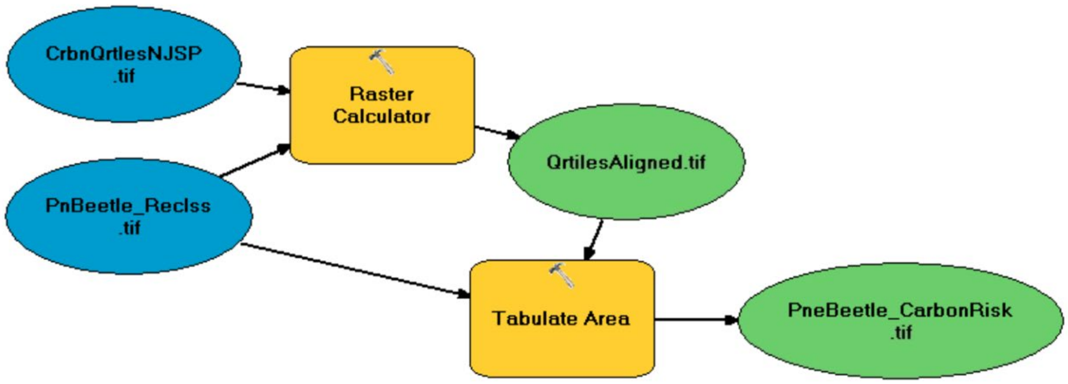
These estimates do not include hazard due to projected climate changes, although this NIDRM report includes an examination of future climate impacts on insect and disease hazards. While future climate change is not modeled within NIDRM, the USDA expect that the climate changes projected over the next 15 years will significantly increase the number of acres at risk and will include elevated risk from some already highly destructive pests.

**Data Processing:** Dataset was extracted to New Jersey shapefile, projected to NJ State Plane (m), and reclassified into risk classes by projected Basal area loss. Classes were as follows: Low/no risk (<1% projected BA loss), 1-5%, 6-10%, 11-15%, 16-20%, and >20% BA loss.




**Carbon Risk Analysis:**

The Carbon quartiles raster from task 2 was prepared for cross-tabulation with the above results as follows: Raster Calculator was used with processing extent, snap raster, and cell size set to match PnBeetle_Reclss.tif. Map Algebra Expression was set as **"CrbnQrtlesNJSP.tif"**. The resulting carbon quartiles raster cells and extent matched PnBeetle_Reclss.tif raster. The resulting aligned carbon quartile raster was used as Input Raster Zone Data for Tabulate Area function with PnBeetle_Reclss.tif set as Input Raster Data.




**Mapping Risk to High-Carbon Pools:**

Risk of loss to high-carbon pools due to Southern Pine Beetle was mapped as follows: The aligned carbon raster from the previous step (QrtlesAligned.tif) was reclassified with quartile values set to intervals of 10. Quartile 1 set to 10, 2 to 20, 3 to 30, and 4 to 40. The resulting raster was used in a Raster Calculator function with the following Map Algebra Expression: **"QrtilesAligned.tif" + "PnBeetle_Reclss.tif".** The resulting raster contained the breakdown of Pine Beetle risk classes within each carbon quartile. Risk classes within the highest quartile are tabulated and mapped below.

**Emerald Ash Borer**

**Dataset:** Projected Total BA Loss rate due to Emerald Ash Borer
https://www.fs.fed.us/foresthealth/applied-sciences/mapping-reporting/national-risk-maps.shtml
**Source:** X:\projects\forestry\forestcarbon\Data\3_PestFireRisk\AshBorer
**Projection:** NAD_1983_Albers
**Extent:**
West -75.592929 East -73.890364
North 41.357576 South 38.855875

**Raster Resolution:** 240m
**Description:** This raster dataset shows the percent of projected BA loss relative to overall total BA from Emerald Ash Borer, assuming no remediating management, over the 2013-2027 time frame.
The 2012 National Insect and Disease Risk Map (NIDRM) Project integrates 186 individual risk models constructed within a common, consistent framework that accounts for regional variations in forest health conditions. These 186 models are built to portray the expected loss of host basal area for each pair of damage agents and hosts over each unique landscape where they coexist.

**Processing:** Risk Mapping and Carbon Risk Analysis for Emerald Ash Borer were done following the same steps used for Southern Pine Beetle.

**Carbon Analysis:**

Risk of Carbon Loss was analyzed as for Southern Pine Beetle, cross tabbing carbon quartiles with mapped Emerald Ash Borer Risk. Largest Forest Carbon pools at risk due to Emerald Ash Borer were mapped and tabulated in the same way as was done for the Southern Pine Beetle.

B. Wildfire Risk

**Dataset:** NJFFS Wildfire Risk
The New Jersey Forest Fire Service (NJFFS), a division of the New Jersey Departmental of Environmental Protection (NJDEP), has developed this Wildfire Fuel Hazard data based upon NJDEP's 2002 Land Use/Land Cover (LU/LC) datasets and NJDEP's 2002 10-meter Digital Elevation Grid datasets. The NJFFS took the NJDEP Modified Anderson Land Use/Land Cover Classification System 2002 and assigned Wildfire Fuel Hazard Rankings to it. The ranking system is as follows: 0 = Water, 1 = Low, 2 = Moderate, 3 = High, 4 = Very High, 5 = Extreme, 6 = Urban, 7 = Agriculture, 8 = Barren Land. The NJFFS used NJDEP's 2002 10-meter Digital Elevation Grids and calculated areas of 30% or greater slope throughout New Jersey. For areas of Wildfire Fuel Hazard 1 to 4 (i.e. Low to Very High) that were coincident with areas of 30% or greater slope, the Wildfire Fuel Hazard Ranking was increased by 1 value (i.e. Low was increased to Moderate, Moderate to High, etc.). For areas of Wildfire Fuel Hazard 0, and 5-8, the Wildfire Fuel Hazard Ranking remained the same.

**Source:** X:\projects\forestry\forestcarbon\Data\3_PestFireRisk\NJFFSFire\
**Projection:** NAD_1983_StatePlane_New_Jersey_FIPS_2900_Feet
**Extent:** West -75.587298 East -73.889327
North 41.357074 South 38.924819

**Raster Resolution:** 240m
**Data Processing:** Combined and Rasterized County Shapefiles

**Carbon Risk Analysis:**
At-risk carbon stocks were mapped as they were for insect pathogens in the previous step.

**Mapping Prime/Non-Prime Farmland:**

From gSSURGO_NJ.gdb, MUPOLYGON was rasterized with extent and resolution set to match the gridded Land Use/Land Cover 2015 data layer. The attribute table was joined with the mapunit table from the above gridded SSURGO geodatabase by MUKEY. This mapunit table contains the field "Farm Class". The rasterized MUPOLYGON data layer was reclassified by the Farm Class field as follows:

> **"'Not prime farmland' 1;'Farmland of unique importance' 2;'Farmland of statewide importance' 2;'All areas are prime farmland' 2;'Farmland of local importance' 2;'Farmland of statewide importance, if drained' 2"**

This classification is based on
https://www.nrcs.usda.gov/wps/portal/nrcs/detail/nj/soils/?cid=nrcs141p2_018874

Farmlands of statewide importance include those soils in land capability Class II and III that do not meet the criteria as Prime Farmland. These soils are nearly Prime Farmland and economically produce high yields of crops when treated and managed according to acceptable farming methods. Some may produce yields as high as Prime Farmland if conditions are favorable.

https://www.nrcs.usda.gov/wps/portal/nrcs/detail/nj/soils/?cid=nrcs141p2_018873
Farmland of local importance includes those soils that are not prime or statewide importance and are used for the production of high value food, fiber or horticultural crops.
Unique farmlands :
https://www.nrcs.usda.gov/wps/portal/nrcs/detail/nj/soils/?cid=nrcs141p2_018880
(If being used for special crops)

The resulting raster contains two records: **Prime Farmland; 1, Not Prime Farmland; 2.**

## 4. Mapping Afforestation Candidate Areas

**Datasets:** Land Use/Land Cover of New Jersey 2015,
PAD-US V 2.1 (USGS) https://www.sciencebase.gov/catalog/item/5f186a2082cef313ed843257
Brownfield Development Areas (Blocks and Lots) of New Jersey,
https://njogis-newjersey.opendata.arcgis.com/datasets/ae54f6a6e87140aba675fe0412b8bc01/explore?location=40.243800%2C-74.759900%2C9.38
**Projection:** NAD_1983_StatePlane_New_Jersey_FIPS_2900_Feet
**Extent:**

West -75.592929 East -73.890364
North 41.357576 South 38.855875

**Raster Resolution:** 10ft

**Raster Processing:**
The Brownfields dataset was rasterized to match extent and resolution of LULC15.

LULC15 was Reclassed, isolating Former Agricultural Wetlands (2150 **"Former Agricultural Wetlands- Becoming Shrubby not Built-up") and Old Field (4410 "Old Field"). The Extract By Mask Tool was used to identify areas where PAD-US (public lands) overlaps with Brownfield Development areas, Former Agricultural Wetlands, and Old Fields.

Mosaic to New Raster was used to combine all Old field, Brown Field, and Former Ag. Wetlands with those on Public Lands derived in the previous step. The Mosaic tool was set so that the layer containing Public Lands would overwrite areas of overlap. The result of this process is a data layer containing Old Field, Former Ag. Wetlands, and Brownfields on private or public lands.

**Existing Ag in Non-Prime Farm Soil Areas**

**Datasets:** Land Use/Land Cover of New Jersey 2015, gSSURGO (Prime/Non-Prime Farmlands) PAD-US V 2.1 (USGS)

**Projection:** NAD_1983_StatePlane_New_Jersey_FIPS_2900_Feet
**Extent:**
West -75.592929 East -73.890364
North 41.357576 South 38.855875

**Raster Resolution:** 10ft

**Raster Processing:**
The gSSURGO (Prime/Non-Prime Farmlands) data layer was reclassified such that Non-Prime areas were assigned a value of 1 and all other values were set to "NoData".

LULC15 was reclassified isolating 'AGRICULTURAL WETLANDS (MODIFIED)', 'CROPLAND AND PASTURELAND', 'ORCHARDS/VINEYARDS/NURSERIES/HORTICULTURAL AREAS', and 'ORCHARDS/VINEYARDS/NURSERIES/HORTICULTURAL AREAS'.

Extract by Mask tool was used with the Non-Prime Data Layer as mask and the LULC Agriculture data layer set as input Raster. The resulting layer contains these LULC15 derived agricultural areas in Non-Prime Farmland.

To locate which of these areas fall in public land, Extract By Mask tool was used with PAD-US as Mask Layer and the Ag in Non-Prime areas from the previous step used as input raster.

Mosaic to New Raster was used to combine the total Ag in Non-Prime Areas with Public areas derived in the previous step. The Mosaic tool was set so that the Layer containing Public Lands would overwrite areas of overlap. The result of this process is a data layer containing existing Agricultural areas in non-prime farmland on private or public lands.

### Soil Carbon Depletion Analysis.

**Datasets:** PAD-US V 2.1 (USGS), Priority Carbon Areas based on Edwin Muniz, NJ NRCS, Carbon Depletion Analysis.

**Processing.** Priority Areas based on SSURGO carbon depletion analyses were broken out into 3 quantiles (low, medium, high) by area potential to increase Carbon Stock. This layer was further broken out into Public vs. Private lands based on PAD-US in the same way as done in the previous analysis.

### 5. Mapping Reforestation Candidate Areas

### Canopy Change

**Dataset:** NLCD 2011 to 2016 Percent Tree Canopy Change (CONUS)

**File Name:** nlcd_2011_to_2016_treecanopy_change_2019_08_31_u8.img
**XY Coordinate System:** Albers_Conical_Equal_Area
**Resolution:** 30m
**Extent:** West -130.232828 East -63.672192
North 52.877264 South 21.742308
**Source:** X:\databank\usgs2\landcover\NLCD2016\Data_TreeCanopy\

**Raster Processing:**

nlcd_2011_to_2016_treecanopy_change_2019_08_31_u8.img was clipped using NJ_outline Shapefile as Output Extent. "Use Input Features For Clipping Geometry" was checked and the output raster extent matches state borders.
The resulting raster attribute table contains a Value field with values ranging from -98 to 97, representing percent canopy loss (negative values) and percent canopy gain (positive values). This raster was reclassed with Value 0 set to NoData to eliminate extraneous non-forested data spanning the entire state. Further Reclassification grouped forested areas into Hi-Med-Low Increase; No change; Hi-Med-Low decrease with change classes as follows: Hi: 40-100% change, Med: 20-40% change, Low: 5-20% change, and No Change: 0 – 5% change.

### Recently Abandoned Farmland

To aid in identifying potential areas for afforestation, a history of New Jersey forests was derived from Land Use/Land Cover datasets going back to 1986. This analysis provides the approximate year in which areas became newly forested. It also shows the previous land use type of newly forested areas.

The results of this analysis can provide insights into which land use types make good afforestation.

LU/LC of New Jersey Shapefiles from 1986, 1995, 2002, 2007, 20012, and 2015 were Dissolved by Label-year (i.e., label15) and then rasterized to match extent and resolution of gridded Land Use/Land Cover of New Jersey data layer.

(example of resulting attribute table)

| OID | Value | Count | LABEL15 |
|---|---|---|---|
| 0 | 1 | 30175810 | AGRICULTURAL WETLANDS (MODIFIED) |
| 1 | 2 | 2116168 | AIRPORT FACILITIES |
| 2 | 3 | 5699008 | ALTERED LANDS |
| 3 | 4 | 31020222 | ARTIFICIAL LAKES |
| 4 | 5 | 7208047 | ATHLETIC FIELDS (SCHOOLS) |
| 5 | 6 | 143391609 | ATLANTIC OCEAN |

Each newly created raster was reclassified into Forest and Non-forest. From "Label" field, any record containing Deciduous, Coniferous, Mixed, Scrub/Shrub, and severely burned; both Upland (TYPE(year) = FOREST) and Wetland (TYPE(year) = WETLAND), was assigned as Forested. Every other attribute was reclassed as non-forest. Forested cells were classified as 1 and Non-forested cells were classified as 0 in each LULC raster.

(example of resulting attribute table)

| OID | Value | Count | LABEL15 | FORESTCLSS |
|---|---|---|---|---|
| 0 | 0 | 1635789516 | AGRICULTURAL WETLANDS (MODIFIED)/ | Non-Forest |
| 1 | 1 | 927199937 | ATLANTIC WHITE CEDAR WETLANDS/CO | Forest |

As a result, each LULC layer from each was now gridded and contained only a two-record attribute table, Forested (1) and Non-forested (0).

To Calculate Forest age, A Raster Calculation was done with the following statement:

**Con(("LU15_ForestReclass.tif" == 1) & ("LU12_ForestReclass.tif" == 1) & ("LU07_ForestReclass.tif " == 1) & ("LU02_ForestReclass.tif " == 1) & ("LU95_ForestReclass.tif " == 1) & ("LU86_ForestReclass.tif " == 1),34, Con(("LU15_ForestReclass.tif" == 1) & ("LU12_ForestReclass.tif" == 1) & ("LU07_ForestReclass.tif " == 1) & ("LU02_ForestReclass.tif " == 1) & ("LU95_ForestReclass.tif " == 1) & ("LU86_ForestReclass.tif " == 0),25, Con(("LU15_ForestReclass.tif" == 1) & ("LU12_ForestReclass.tif" == 1) & ("LU07_ForestReclass.tif " == 1) & ("LU02_ForestReclass.tif " == 1) & ("LU95_ForestReclass.tif " == 0),13, Con(("LU15_ForestReclass.tif" == 1) & ("LU12_ForestReclass.tif" == 1) & ("LU07_ForestReclass.tif " == 1) & ("LU02_ForestReclass.tif " == 0),8, Con(("LU15_ForestReclass.tif" == 1) & ("LU12_ForestReclass.tif" == 1) & ("LU07_ForestReclass.tif " == 0),3, Con(("LU15_ForestReclass.tif " == 1) & ("LU12_ForestReclass.tif" == 0),1,))))))**

Starting from 2015 and working backwards, this statement finds the first LU/LC year when grid cells were assigned a forested value, giving the approximate forest age as it appears within these NJ LULC data layers.

**Mapping Previous Land Use**

**Non-Forested LU Types 1986 to Forested in 2015:**

The Following analyses were performed to identify the predominant land types that have become Forested across the LULC data layers used above.

To Identify which Land Types have moved from unforested to forested, the following Raster Calculator statement was run:

**Con(("forested15.tif" == 1)&("forested86.tif" == 0),"GridLabel86.tif",Con(("forested15.tif" == 1)&("forested86.tif" == 1),80,0))**

This statement locates Forested areas in 2015 and Non-Forested areas in 1986. It then designates each newly forested grid cell to the LU Label it had in 1986, showing which Land Use Types have transitioned to Forest.

(sample of resulting attribute table)

| OID | Value | Count | acres | Label86 |
|---|---|---|---|---|
| 0 | 0 | 1461931194 | 3,356,132 | Unforested |
| 1 | 1 | 4246456 | 9,749 | AGRICULTURAL WETLANDS (MODIFIED) |
| 2 | 2 | 343502 | 789 | ALTERED LANDS |
| 3 | 3 | 860564 | 1,976 | ARTIFICIAL LAKES |
| 4 | 4 | 98870 | 227 | ATHLETIC FIELDS (SCHOOLS) |
| 5 | 7 | 30365 | 70 | BARE EXPOSED ROCK, ROCK SLIDES, ETC. |
| 6 | 8 | 6078 | 14 | BEACHES |
| 7 | 10 | 666790 | 1,531 | COMMERCIAL/SERVICES |
| 8 | 11 | 26914 | 62 | CONFINED FEEDING OPERATIONS |
| 9 | 19 | 2295 | 5 | CRANBERRY BOGS |

This analysis was repeated with each NJ LULC layer from 1995 – 2012.