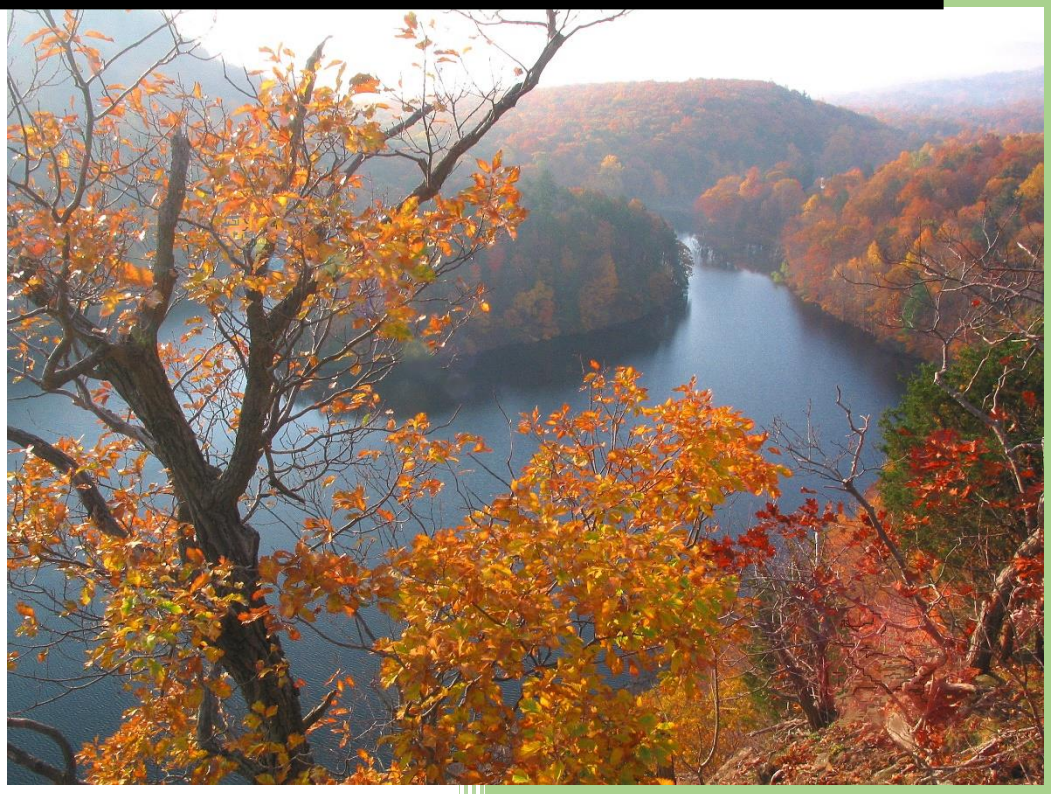
2020

Forests Sub-Group Final Report



Forests Sub-Group

Working and Natural Lands Working Group

11/6/2020

Acknowledgements

Over the course of 5 months, the Forests Sub-Group held 9 public meetings, organized 20 presentations from experts on various issues related to forests and climate change, built a resource catalog of over 40 peer-reviewed journal articles, and kept up an enthusiastic pace thanks to the wisdom, expertise, and commitment of its members.

The following members of the Forests Sub-Group who all contributed to this report are listed below with their organizational affiliations:

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- Charles Leigus, Supreme Forest Products, Inc.
- Amy Paterson, Connecticut Land Conservation Council
- Herb Virgo, Keney Park Sustainability Project

The CT Department of Energy and Environmental Protection also deserves enormous credit for supporting the efforts of this Sub-Group in addition to their "day jobs." In particular, the Sub-Group wants to thank Commissioner Katie Dykes for enabling Rick Jacobson, Chris Martin, Cary Lynch, and Jaimeson Sinclair to be so engaged and helpful throughout this process.

We also want to recognize the other Sub-Groups of the Working and Natural Lands Working Group – Agriculture/Soils, Rivers, Wetlands – as well as the Equity and Environmental Justice Working Group, the Science & Technology Working Group, and the Progress on Mitigation Strategies Working Group for their partnership on forest issues and to make our Sub-group and process as inclusive as it should be.

Lastly, we thank Governor Lamont for re-energizing the Governor's Council on Climate Change through Executive Order #3 which gave our Sub-Group its overall charge to create this report.

In the following report, the Forests Sub-Group endeavors to give you a better understanding of Connecticut's forests and the important role they play in helping Connecticut to adapt, become more resilient, and mitigate the many challenges we face due to climate change.

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Executive Summary

Background

In its 2018 report, Building a Low Carbon Future for Connecticut: Achieving a 45% GHG Reduction by 2030,[1] the Governor's Council on Climate Change (GC3) recognized natural and working lands as important carbon sinks that could help mitigate emissions from the electricity generation, transportation, and building sectors which together produce almost 60% of Connecticut's greenhouse gas (GHG) emissions.[2]

The GC3 recommended that Connecticut continue to work with non-governmental organizations like the U.S. Climate Alliance in efforts to regionally develop carbon sequestration and storage practices.[3] The council also recommended that "DEEP should work with land trusts, forest owners, and working lands managers to help adopt carbon accounting methodologies that further support sustainable land-use practices."

In 2018, Connecticut joined with over 25 states in accepting the U.S. Climate Alliance's Natural and Working Lands Challenge[4] with a commitment to the following actions:

- Improve inventory methods for land-based carbon flux;
- Identify best practices to reduce GHG emissions and increase resilient carbon sequestration;
- Advance programs, policies, and incentives to reduce GHG emissions and enhance resilient carbon sequestration;
- Undertake actions that will support a collective, Alliance-wide goal to maintain natural and working lands as a net sink of carbon and protect and increase carbon storage capacity, while balancing near- and long-term sequestration objectives; and
- Integrate priority actions and pathways into state GHG mitigation plans within two years of joining this challenge.

Although none of these actions are "completed" at this time, Connecticut continues to work toward these goals both individually and in partnership with neighboring states, academia, and nonprofit organizations as well as the private sector. Many of the recommendations in this report are tied to furthering the commitments Connecticut made in 2018.

Introduction

The Intergovernmental Panel on Climate Change (IPCC) is widely regarded to be the international scientific authority on climate change. We include here as a reference, summary statements for policymakers from a 2019 IPCC report on "Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems."[5] Not surprisingly, there were several statements in this IPCC special report related to forests, and our goal in this report is to be similarly grounded in the best available science.

The headings at the beginning of each of the following statements are references to sections of the full report, and the relative confidence levels of each statement based upon available science are also included.

A.1: Land provides the principal basis for human livelihoods and well-being including the supply of food, freshwater and multiple other ecosystem services, as well as biodiversity. Human use directly affects more than 70% (*likely* 69–76%) of the global, ice-free land surface (*high confidence*). Land also plays an important role in the climate system.

A.1.1: People currently use one quarter to one third of land's potential net primary production for food, feed, fibre, timber and energy. Land provides the basis for many other ecosystem functions and services, including cultural and regulating services that are essential for humanity (*high confidence*).

B.5: Sustainable land management, including sustainable forest management, can prevent and reduce land degradation, maintain land productivity, and sometimes reverse the adverse impacts of climate change on land degradation (very high confidence). It can also contribute to mitigation and adaptation (*high confidence*). Reducing and reversing land degradation, at scales from individual farms to entire watersheds, can provide cost effective, immediate, and long-term benefits to communities and support several Sustainable Development Goals (SDGs) with co-benefits for adaptation (*very high confidence*) and mitigation (*high confidence*).

B.5.3: Reducing deforestation and forest degradation lowers GHG emissions (*high confidence*), with an estimated technical mitigation potential of 0.4–5.8 $GtCO_2\ yr^{-1}$. By providing long-term livelihoods for communities, sustainable forest management can reduce the extent of forest conversion to non-forest uses (e.g., cropland or settlements) (*high confidence*). Sustainable forest management aimed at providing timber, fibre, biomass, non-timber resources and other ecosystem functions and services, can lower GHG emissions and can contribute to adaptation (*high confidence*).

B.5.4: Sustainable forest management can maintain or enhance forest carbon stocks, and can maintain forest carbon sinks, including by transferring carbon to wood products, thus addressing the issue of sink saturation (*high confidence*). Where wood carbon is transferred to harvested wood products, these can store carbon over the long-term and can substitute for emissions-intensive materials reducing emissions in other sectors (*high confidence*). Where biomass is used for energy, e.g., as a mitigation strategy, the carbon is released back into the atmosphere more quickly (*high confidence*).

C.4.1: Successful implementation of sustainable land management practices requires accounting for local environmental and socio-economic conditions (*very high confidence*). Sustainable land management in the context of climate change is typically advanced by involving all relevant stakeholders in identifying land-use pressures and impacts (such as biodiversity decline, soil loss, over-extraction of groundwater, habitat loss, land-use change in agriculture, food production and forestry) as well as preventing, reducing and restoring degraded land (*medium confidence*).

We introduce the Forests Report with these authoritative, science-based statements from the IPCC because there has been considerable debate leading up to this final report to the Governor's Council on Climate Change. Topics such as the respective roles of forest management, forest reserves, long-lived wood products, old growth and young forests, and other issues may continue to be debated. However, we put forward the recommendations in this report that have the broadest consensus based upon available science, the expertise and experience of members of the Forests Sub-Group, and considerable input from credible experts provided during the public comment period.

Summary of Report

Climate change is an enormous threat to Connecticut's forests and people, and we must respond boldly with urgent action.

This report recommends policy, funding, conservation, research, and stewardship actions which would both make forests more resilient and enhance their potential for sequestering and storing carbon as a significant and growing offset for GHG emissions from other sectors. Following is a summary of the major recommendations and findings in this report:

We are all forest dwellers. Connecticut's dominant land type is "forest" which covers approximately 59% of the state. Go here for more on the Status of Connecticut's forests.

Resilient forests provide many benefits to people and nature, such as reducing heat stress and lowering energy bills by providing shade; improving air quality and providing physical and mental health benefits; supporting local wood products, jobs, and economic benefits; sustaining wildlife habitats and more livable communities for people; storing and sequestering carbon; and much more. Go here for the benefits forests provide to Connecticut.

Forest resiliency is threatened by various factors. Although forests are an important carbon sink in Connecticut, our forests may become less resilient and effective at adapting to and mitigating climate change due to a mix of factors (invasive plants and forest pests; over-browse by deer impacting forest regeneration; forest conversion to other uses creating more vulnerable forest edges; air pollution; more intense weather events; etc.). Go here for threats to forest resiliency.

Connecticut's forests are valuable for carbon storage. Connecticut's forests are the most "carbon dense" (most above-ground carbon stored/acre), oldest (~16% of our forests are 100+ years old), and have the highest annual net growth in forest biomass in the Northeast (net growth exceeds net removals from timber harvests or salvage operations by more than 500%). In addition, significant carbon is stored in long-lived wood products. Go here for forests as mitigation to climate change.

Keep forests as forests. Being responsible stewards of forests and preventing the conversion of forestland to non-forest uses are likely the most important things we can do to allow forests to both adapt to and mitigate climate change. Recommendations in the report include setting a goal for increasing Connecticut's forest cover, protecting and connecting core forests, and dedicating more resources to work with private landowners (who own ~71% of Connecticut's

forestland). Go here for recommendations on forest adaptation/resiliency, and go here for recommendations on mitigation.

Retain large trees in forests and residential areas. Large trees store a significant amount of the carbon and other benefits that trees provide in both urban/residential and rural settings. Retaining large healthy trees and forest cover whenever possible should be actively encouraged. Go here for recommendations on large trees.

Climate change is impacting vulnerable people the hardest, and there are significant inequities both in the locations where trees are, and are not, currently providing benefits to people. These inequities are most apparent in our cities where communities with the highest poverty rates and health inequities tend to also have the lowest tree canopy cover and direct connections to green spaces. Go here for impacts of climate change on vulnerable populations.

Energize a Youth Conservation Corps for another "tree planting army" like the original Civilian Conservation Corps (CCC) to provide outdoor jobs, build trust and cultural understanding of green spaces at the community level, clean-up/plant-up open spaces to benefit both urban and rural environments, support ongoing forest stewardship, and at the same time encourage conservation career opportunities for people of color. Go here for supporting community interest in trees and green spaces.

Vulnerable forest types require focused protection and management. There are a number of specialized forest types (freshwater forested wetlands, pitch pine-scrub oak, riparian forests alongside cold-water streams and headwaters, lowland Atlantic white cedar, and other forest types) that should be priorities for protection and management as appropriate. Go here for the impacts of climate change on special forest types.

Establish forest carbon baseline and goals for Connecticut. Under the Global Warming Solutions Act (GWSA), Connecticut has established significant goals for reducing emissions from the transportation, energy, and building sectors to combat climate change. Connecticut should establish quantitative scientific studies on carbon dynamics to add similar goals to the GWSA for carbon storage and ongoing "negative emissions" (carbon and other greenhouse gas sinks) that forests and forest products, wetlands, soils, and other natural climate solutions can provide. Go here for the need for Connecticut's forest carbon baseline and goals.

Commitments to funding, programs, and resources are critical. Enhancing existing funding programs, funding long-term research initiatives, establishing new sources of revenue, and providing tax incentives for acquisition and stewardship must be priorities. Go here for recommended funding, programs, and resources.

Adopt a "No Net Loss of Forest" policy to support all of the recommendations above by:

(1) Keeping forests as forests to retain the multiple benefits of carbon storage, biodiversity, public health, green infrastructure, etc.

(2) Protecting healthy, intact forests to ensure that impacts upon forests, sensitive habitats, and other natural climate solutions are considered at every level of planning.

(3) Offsetting all planned or permitted forest losses through a combination of compensatory mitigation requirements and other tools.

(4) Providing financial incentives for stewardship, forest retention, and forest resiliency on privately-owned forestlands; and

(5) Protecting urban forests, building more parks, and planting more trees and gardens to maximize the benefits to people of trees and green spaces. Go here for more on a "No Net Loss of Forest" policy for Connecticut.

There are many factors to consider simultaneously with forests which makes any single recommendation on their future insufficient. It will likely require a full suite of conservation strategies working together to manage for a variety of values and uses on a long-term timescale using peer-reviewed science and a holistic understanding of forest systems.

In addition, any comprehensive climate policy solutions for forests should strive to address the challenges of 1) the *longevity* of the approach, 2) *additionality* (that the action would not have taken place anyway), 3) *leakage* (that the mitigation action is not pushing the activity elsewhere where it may cause more damage), and 4) *substitution*, the carbon implications of using one material instead of another compared to keeping carbon stored in the forest.[6,7] This kind of approach can help ensure that southern New England forests continue to capture and store carbon, maintain ecosystem functions and services, and decrease global deforestation.[8]

Before getting into the status of Connecticut's forests and recommendations of this report, we want to thank the Connecticut certified forestry practitioners who play such a critical role in managing forests. These professionals work with landowners to develop forest management plans and lead the implementation of silvicultural practices to achieve multiple on-the-ground results in addition to carbon storage and sequestration. Maintaining high standards and a commitment to using best practices amongst forest practitioners is perhaps the most critical element of ensuring forests on private and public lands are well- and sustainably-managed.

Status of Connecticut's Forests

Connecticut's forests and trees add immensely to the quality of life for the people of the state. They filter the air that is breathed, safeguard private and public drinking water sources, produce locally grown forest products, provide essential habitat for wildlife, and moderate summer and winter temperatures near homes and businesses. They also have the potential to absorb and store atmospheric carbon which is currently increasing beyond historic and naturally occurring levels.

Carbon Storage in Connecticut's Forests

The most recent national Forest Carbon Inventory published by the USDA Forest Service documents 191 million metric tons (MMT) of Carbon in Connecticut's forests in 2019, which has increased by ~9 MMT over the past decade. Of note, these Forest Service figures do not include individual trees or groups of trees that may not fit the standard definition of "forest." The Forest Service's definition of forest land is at least one continuous acre of forest canopy cover.[9]

A different type of carbon pool exists in the urban forest. Connecticut is a heavily urbanized state. According to Forest Service analysis, 36.4% of the land area of the state is urban (1.13 million acres), with 87.7% of the population, nearly 3 million people, living in these urban areas (FIA). Despite the high population concentration in these areas, these same lands have a fairly high degree of tree cover, with tree canopy cover estimated at nearly 50%. These urban trees are storing about 22.5 million tons of carbon and continue to sequester carbon at the rate of about 744 thousand tons per year (FIA). The importance of urban trees is magnified by their proximity to people and co-benefits for health, energy savings, flood retention, and more.[10]

Forest Quantity is Good but Highest Quality Forests are Getting Fragmented

Approximately 59% of Connecticut is "forested" and this percentage has remained relatively flat since 2010.[11]

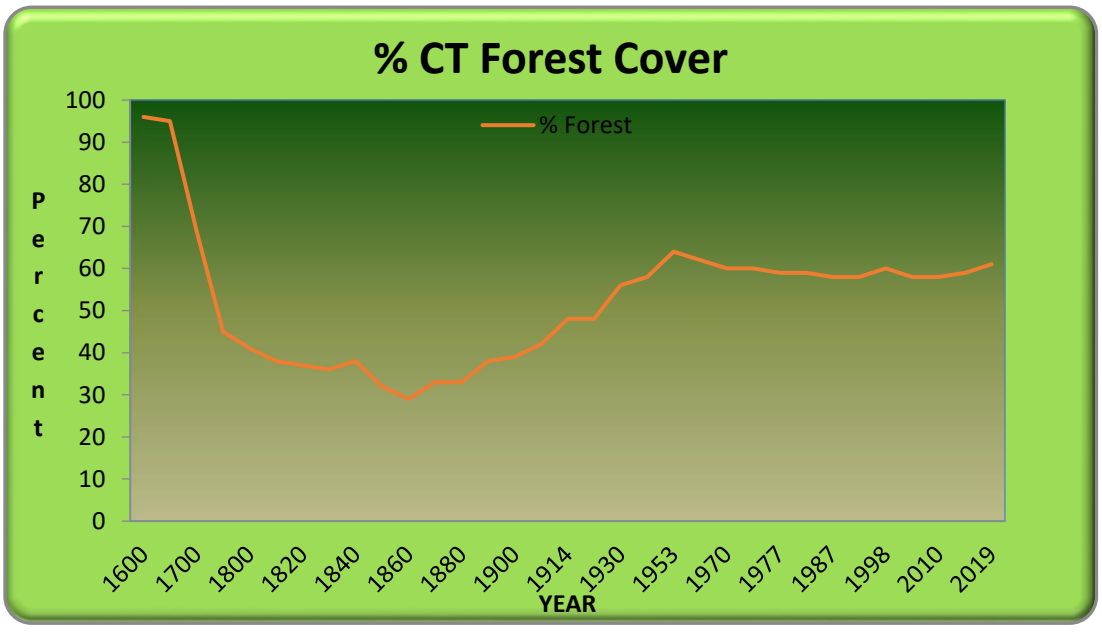

Figure 1. Historic Forest Cover in Connecticut.[12]

Connecticut's forests have made a remarkable comeback after being cleared, primarily for agriculture, starting in the 1700s. At the low point in ~1860, only 30% of Connecticut's forests remained (approximately half of the forest cover we enjoy today). As the forests grew back they were repeatedly cut for charcoal fuel that fed the industrial age until about 1920 when coal and petroleum replaced wood-based fuel.

Of the 59% forested area, preliminary findings show ~53% of Connecticut's forest are defined as core forest, larger blocks of forest that are generally more important for wildlife habitat, drinking water supply protection, ecological resilience, and a sustainable supply of lumber and other forest products.

Larger core forests of 500+ acres have been the fastest declining forest type losing approximately 120,000 acres over 30 years from 1985 to 2015.[13] In fact, 1985 to 2015, Connecticut lost about 465 km2 of forest cover to development—about 5.8% of the forest that existed in 1985. Loss of core forest during that period was about 719 km^2, a relative change of 15.7% from 1985 levels. In fact, core forest was lost at a pace (24 km^2 per year) more than 1.5 times the pace of the loss of total forest (15 km^2 per year).[14]

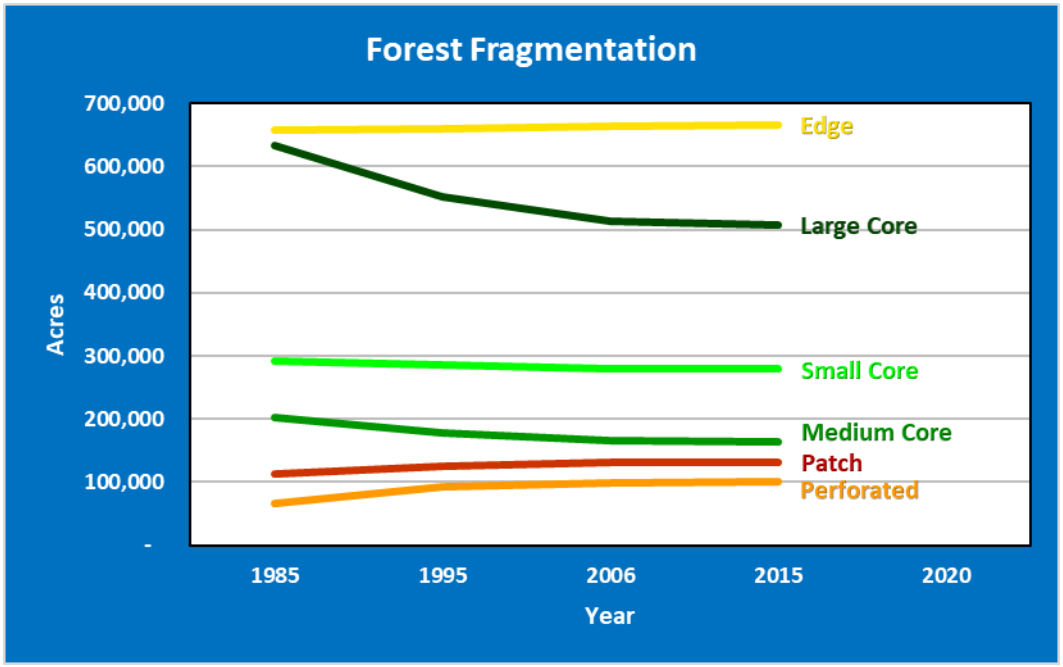

Figure 2. Forest fragmentation by forest category. Source: 2015 CT Forest Action Plan. **Note that Connecticut's 2020 Forest Action Plan is due to be published at the end of 2020.

Dominant Forest Types and Age Structure

Oak/Hickory is the most common forest type with red maple being the most common tree. Regarding tree age and forest demographics, Connecticut's forests are growing older with less age diversity. Despite significant tree mortality between 2013 and 2018 due to Gypsy moth and Emerald ash borer infestations, net annual growth in aboveground forest biomass continued to exceed annual removals by more than five times.[15]

The following figures provide a quick snapshot of Connecticut's forest types and age structure:

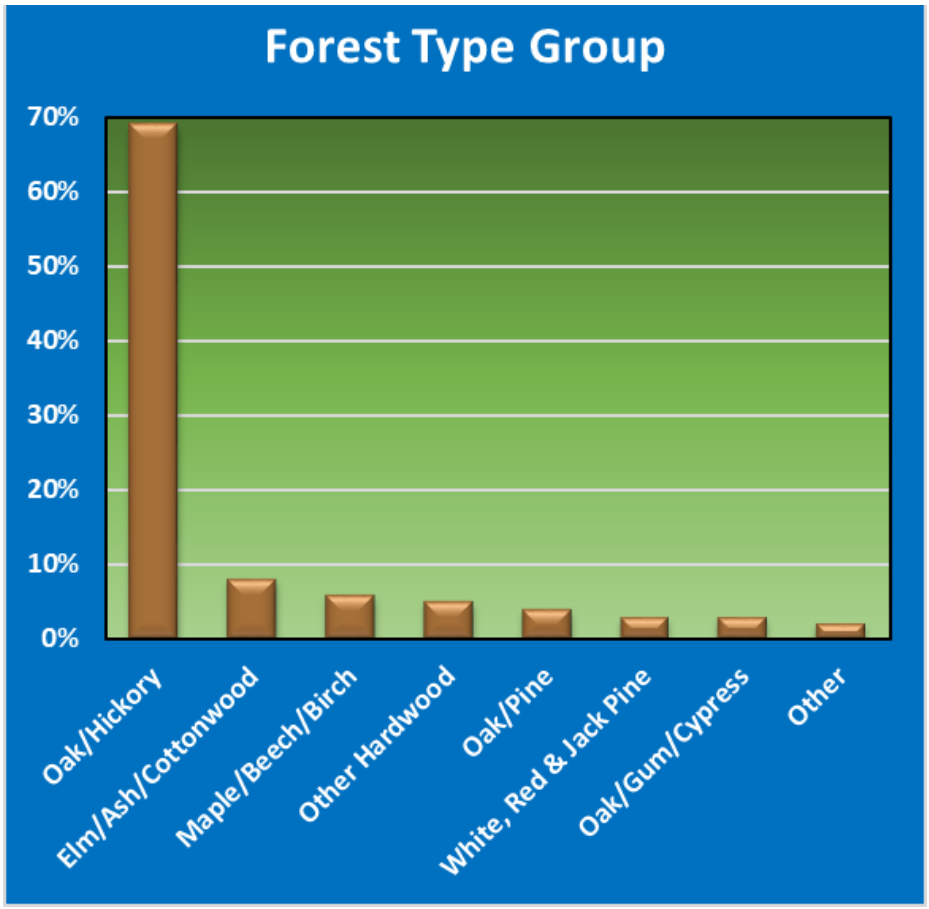

Figure 3. Percentage of forest cover in Connecticut by forest type. Source: 2015 CT Forest Action Plan.

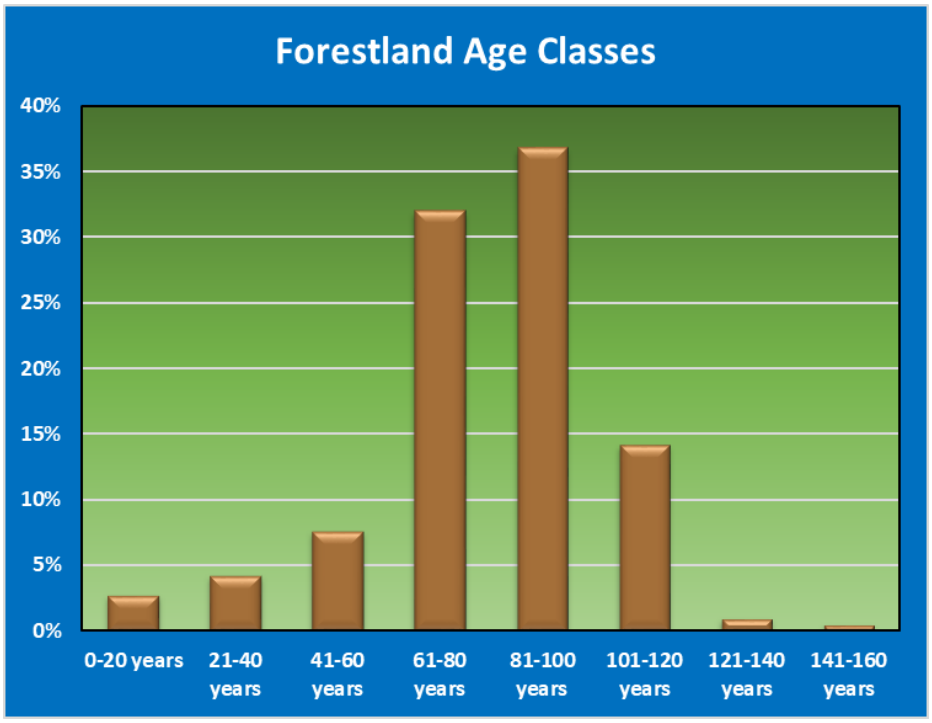

Figure 4. Forest cover in Connecticut grouped by age classes. Source: 2015 CT Forest Action Plan.

Who Owns the Woods?

Of Connecticut's approximate 1.8 million acres of woodlands, 71% is owned by private individuals, corporate landholders (including private water companies), and land trusts. The remaining forestland is owned by the state (17%), municipalities (11%), and minimal federal lands (1%).

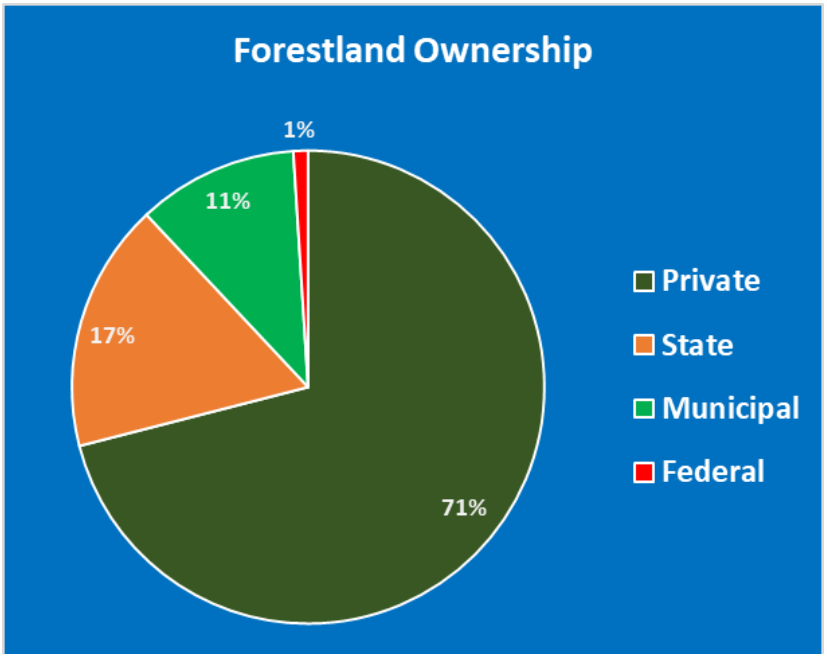

Figure 5. Forestland in Connecticut with percentage of ownership. Private includes individuals/families, land trusts, private water companies, and corporate landowners. Source: USDA Forest Service FIA Program (2018).

Likely contributing to an aging forest is the low interest in active forest management by most individual forest landowners. A 2015 Connecticut Woodland Owners (CWO) Survey report documented that the primary ownership objectives tend to be beauty/scenery, privacy, wildlife viewing, and nature protection, with only 21% having cut trees at some time during their ownership. 59% of these landowners have cut trees for their personal home heating purposes. Many woodland owners believe that "hands off, let nature take its course" is the best approach.[16]

The 2015 CWO Survey also showed these owners believe conserving their woodlands is extremely important - they almost unanimously say they would like their land to stay wooded (95%). Hence there exists considerable opportunity to retain Connecticut existing forests as forest. However, most woodland owners would require financial compensation to permanently protect their forests.

These same woodland owners are also discouraged and deeply concerned with invasive plants and insects which are disrupting their woodlands. Fortunately, the USDA Natural Resources Conservation Service has invested millions of dollars in Connecticut annually for several years through federal assistance programs such as the Environmental Quality Incentives Program and Regional Conservation Partnerships Programs. These USDA Farm Bill-funded programs encourage property owners to engage and invest in the health, diversity and sustainability of

their woodlands. DEEP's Cooperative Forestry Program also offers technical assistance to these woodland owners supported by the USDA Forest Service. DEEP Service Foresters direct woodland owners to these resources and qualified professional foresters and wildlife biologists to make informed decisions. The more programs and professionals that engage with landowners on stewardship of their woods, the more likely these landowners will continue as long-term, dedicated stewards of their woodlands.

Because the vast majority of Connecticut's forests are privately owned, engaging family forest landowners, corporate landholders, and land trusts is critical to maintain and increase resilient sequestration and storage of forest carbon in Connecticut.

Management of Forests on DEEP Properties

The concept of a State Forest system in Connecticut was conceived by foresters and other conservationists in the late 1800s. These visionaries were dismayed by the poor condition of privately-owned woodlands that were repeatedly cut over and burned with no regard for the future.

In 1903, the first Connecticut State Forest was established in 1903 to serve as a demonstration area for sound forestry practices.[17]

Connecticut has 33 State Forests on about 175,000 acres that are managed for the sustainable growth of wood products, forest health, watershed protection, carbon sequestration and storage, diverse wildlife habitat, and recreation compatible with these uses.

These lands are well protected from development. In 2018, an amendment to the State's Constitution was passed which requires a public hearing and a 2/3 vote by the General Assembly before DEEP lands can be transferred, sold, or otherwise conveyed.[18]

Forest Management Plan Status

Forest Management Plans are developed by DEEP's State Lands foresters. The Plans are based on data from extensive inventory plots and receive input from other DEEP Divisions such as Wildlife, Fisheries, Parks, Natural Diversity Database, local officials, and organizations such as historical societies and conservation groups. The plans are due to be updated every 10 years. It has been challenging for DEEP to keep its Forest Management Plans up-to-date due to inadequate staff resources. All active Forest Management Plans are posted online by DEEP.[19]

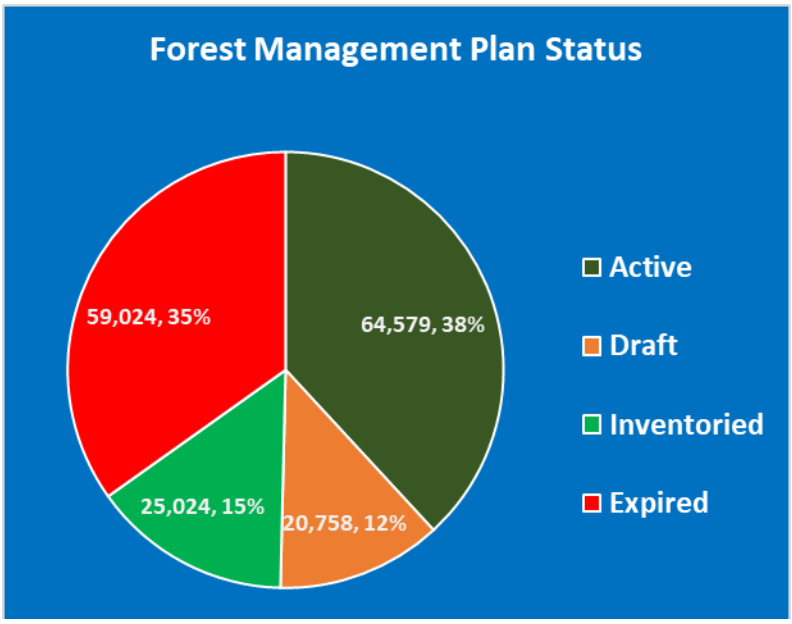

Figure 6. Status of Forest Management Plans with acres and percentages as of June, 2020. Source: DEEP Forestry.

Forest Management on DEEP Properties

State Forests and Wildlife Management Areas (WMAs) are subject to periodic forest and wildlife habitat management with the goals of improving forest health and augmenting conditions for wildlife.

State Forests

There are 33 State Forests on approximately 175,000 acres (because not all DEEP land records have been added to the GIS DEEP Property Layer to date, the figure of 168,960 acres of State Forests will be used); 162,379 acres are forestland.[20]

All DEEP forested land can be classified as either "actively managed" or "passively managed" (see glossary of terms at the end of this report). Actively managed lands may support periodic forest or wildlife habitat management through commercial sales of forest products or other tree and vegetation removal treatments. Active management uses silviculture that promotes both horizontal and vertical structural complexity. Durable wood products from timber harvests, such as lumber and railroad ties, store carbon and substitute for more carbon intensive products such as concrete, aluminum, and steel.[21]

Planning guidelines allow for designed passive management, or forest reserve areas in the State Forests, called Old Forest Land Management Sites (OFLMS). They are selected to be subject to the forces of nature with minimal or no human intervention.

As shown in Figure 6, 64,579 acres of State Forests (~37% of the total) have current management plans.

Active management: 28,150 acres (~44% of acres with forest management plans) are currently classified as being under active management.

On average, DEEP conducts active management on 1,000 – 1,500 acres/year (less than 1% of all State Forest lands) based upon forest management plan prescriptions.[22]

All timber harvests on DEEP lands are administered by DEEP State Lands foresters and use Best Management Practices. The draft 2020 Forest Action Plan written by the Division of Forestry states that from 2015-2019, an average of 17.3% of the annual growth on State Forests was harvested each year.

Passive management: 36,429 acres (~56% of acres with forest management plans) are currently classified as being under passive management. For DEEP, passive management falls into the following categories:

- **Old Forest Management Sites** (planned Forest Reserves): **14,077 acres**
- **Inoperable Sites** (land perpetually passively managed due to site conditions, such as abundant surface stones, excessive soil moisture, steep slopes, etc.): **16,864 acres**
- **Inaccessible Sites** (land which cannot currently be accessed to be managed): **5,488 acres**

In addition, 59,024 acres of State Forests that have expired Forest Management Plans and another 45,782 acres of State Forests that are in the process of developing Forest Management Plans are essentially being passively managed at this time. There are exceptions when a State Forest without a forest management plan may have to be managed in response to an emergency situation, but in general, State Forests are not actively managed unless they have active forest management plans.

Wildlife Management Areas

There are 34,000 acres of Wildlife Management Areas; 19,812 acres are considered to be forest land using GIS analysis and CT Land Cover Assessment data.

State WMAs are managed to provide habitat for both common and uncommon wildlife and to provide for wildlife-based recreation (hunting, fishing, trapping and wildlife viewing) in support of the Division's overall mission of conserving the state's wildlife resources for the use and appreciation of the public. The vast majority of the funding to manage these lands comes from the U.S. Fish and Wildlife Service Wildlife and Sport Fish Restoration (WSFR) program. WSFR funding is provided to restore, conserve, manage and enhance wildlife habitat and to provide wildlife based recreation. Activities, uses or encumbrances which interfere with the purpose of the WSFR funding are not allowed.

The desirability for old forest management areas would be determined at the site specific level and would take into consideration existing physical and biological natural resource conditions and the management objectives for the property. Opportunities to designate no management or reserve areas to function as old forest management areas would vary widely, due to the diversity of habitat types found on our WMAs. If it was determined that a particular wildlife species required it and/or it would enhance overall biological diversity, the Wildlife Division would consider passive management (or potentially active management) to set the stage for well–developed old forest management areas. Ideally old forest management areas would either provide for or be able to grow into areas characterized with large trees, a diversity of

tree species and complex multi-layered structure, canopy gaps, standing dead trees, fallen trees and trees with cavities. At this time, no codified or intentional passive management in WMAs for forests is shown in Table 1 below.

Forest Management Acreage by DEEP Land Classifications

Except for State Forests and WMAs, the DEEP Land Classifications on the following table generally receive no planned forest management. The forested-acreage numbers attributed to each classification are derived based on Land Cover analysis. Any forestry activity implemented on lands other than State Forests or WMAs would be in response to an immediate public safety issue or large-scale forest health concerns.[23]

Table 1. DEEP Land Classifications by total Acreage, Forested Acreage, and Passively Managed Acreage.

DEEP Land Classification (does not include water bodies)	Total Acres	Forested Acres	Passive Forest Management Acres	Percentage of Total Forested Acres
State Forest	168,960	162,379	36,429	22%
Wildlife Mgmt. Area	34,000	19,812	0	0%
State Park	34,115	27,167	27,167	100%
Fish Hatchery	744	393	393	100%
Flood Control	4,434	2,627	2,627	100%
Natural Area Preserve	2,508	2,452	2,375	97%
Other	1,498	1,063	1,063	100%
Water Access	1,588	900	900	100%
Wildlife Sanctuary	1,500	1,280	1,280	100%
Total	**249,347**	**218,073**	**72,234**	**33%**

As stated earlier, 64,579 acres of State Forests have management plans. Table 1 shows that 36,429 of these acres, or 56%, are classified as passive forest management.

Benefits of Forests to Ecosystems and Society

Forests are one of nature's most powerful solutions to human-caused climate change.

Whether we live near a forest or not, our human communities are intricately connected with the services they provide. These natural benefits include homes and food for wildlife, pumping oxygen into the air we breathe, filtering runoff that helps clean the water we drink, and delivering nutrients to the soil when leaves and branches decompose.[24]

Forests benefit wildlife

Healthy forest landscapes often include a variety of tree species of varying age classes. Tall, canopy-layer trees grow above smaller sub-canopy trees, with a shrub layer and diverse plants on the forest floor. This suite of vegetation supports wildlife, from bear and moose to resident and migratory birds. Butterflies and insect pollinators help ensure that same vegetation produces the next generation of life-supporting trees. Many of Connecticut's wildlife species rely on forest habitats. With greater biodiversity comes forest resilience and a greater ability to adapt to changing conditions related to climate change.

Forests mitigate climate change and clean the air

By doing what they naturally do, the trees in Connecticut's forests – covering an estimated 1.8 million acres, about 59% of the state's land cover[25] – provide innumerable benefits to people, including removing heat-trapping carbon emissions our activities release into the atmosphere. The U.S. Climate Alliance estimates that "within Alliance states [including Connecticut], natural and working lands offset 16% of the GHG emissions from energy, transportation, and other sources in 2016."[26]

The ability of trees to take in or sequester and store carbon dioxide, turning it to wood and other forest components including soil, provides significant potential to mitigate climate change by retaining existing forests and improved forest management. A study in the Proceedings of the National Academy of Sciences finds that "natural climate solutions" could offset land-based emissions and store additional carbon equivalent to more than a third (37%) of needed emissions reductions to keep global temperatures at or below 2 degrees Celsius through 2030, although benefits decrease beyond that date due to saturation of natural systems among other factors. Among the strategies found to deliver the most benefit, according to the paper, are "reforestation" (conversion of non-forest to forest) and "avoided forest conversion" that along with "natural forest management" (i.e., managing forests with carbon processes in mind), represent easily available and effective solutions. [27]

Trees are also effective air filters, removing pollution and particulate matter, with studies showing significant reduction of asthma and improved respiratory health in urban areas with more tree cover.[28] Roadside trees could reduce nearby air pollution by more than 50%,[29] but the potential for air pollution reduction varies among species and as a function of tree size and landscape position[30] and there are significant ongoing costs of managing roadside trees to consider.

Forests protect water resources

Forests are also indispensable in production of our drinking water. Approximately 85% of Connecticut residents get their drinking water from public water systems.[31] Forests that surround public water supply reservoirs and private wells improve water quality and can greatly reduce costs for treatment by filtering surface water and maintaining groundwater reserves, ensuring this vital natural resource is not degraded. Forested wetlands and floodplains along rivers retain and slow the movement of vast quantities of water during storm events, protecting nearby municipalities from flooding and reducing stormwater runoff.

Forests provide wood products and economic benefits

In Connecticut, the Land of Steady Habits, generations of families have harvested trees from their land to heat their homes, to build the post and beam barns on their farms and perhaps sell some timber to generate income. The vistas of forested hills and fields along country roads, and tree-lined suburban streets are part of our New England cultural identity.

Trees are a renewable resource – and in New England, where conditions usually allow seeds to take root and regenerate, working forests can also supply a local source of wood products. Connecticut consumes an estimated 80.4 million board feet of roundwood each year.[32] For a relative measure, building a typical 2,000 square foot home would require about 16,000 board feet of roundwood.[33]

Depending on the goals and desired outcomes of private or public owners of forests, cutting some trees according to a variety of silvicultural practices or prescriptions, can enhance the health and vigor of remaining trees, generate income from the sale of timber to produce wood products for human needs, and silviculture can be employed to create a wide variety of habitat conditions and specific habitat features to benefit various wildlife species.[34]

Harvesting timber grown sustainably in Connecticut and as locally as possible in our own region can help to reduce transport emissions, global deforestation, and poor management practices by avoiding a shift of pressure to harvest primary forests in other nations with less stringent environmental policies. In its 2015 report, the North East State Foresters Association estimated Connecticut's forest products and forest recreation industries produce an annual gross output of $3.38 billion and almost 13,000 jobs (figure below).[35] Please note that some of the gross output and products shown below are based on production from forests outside Connecticut.

Gross State Output (sales), Forest-based Manufacturing & Recreation, Connecticut, 2013

		millions of $	jobs
Forestry & logging		25	450
Wood products manufacturing		154	1,300
Furniture and related product manufacturing		418	2,802
Paper manufacturing		1,573	3,550
Wood energy		7	40
Christmas trees and maple syrup		4	58
Total Forest Products		2,181	8,200
Forest Recreation sales		1,200	4,600
	Total	$ 3,381	12,800

Long-lived wood products – from your grandmother's antique desk to the cabinets in your renovated kitchen – also lock up and store carbon until the wood decomposes. From paper to plywood and barrels to baseball bats, some wood products are well known; other forest products such as rayon, mulch, medicines, fiber, gums, resins and tannins (such as witch hazel) are less obvious.[36,37] Lumber can also be reclaimed from old structures and recycled into new uses for furniture or building materials, keeping carbon out of the atmosphere longer.

Forests support recreation and health

Connecticut's forests provide recreational settings for people to get outside to exercise and enjoy nature through countless activities, such as hiking, mountain biking, horse riding, bird watching, camping, hunting and fishing, and serve as attractions that support tourism and natural resource-related businesses that generate economic benefits to Connecticut.

Forests also offer solace and spiritual renewal to people seeking to unplug from hours of "screen time" spent for work and entertainment. Particularly during the 2020 pandemic, forest trails and open space available for public access has provided physical and mental health benefits. One study on the Japanese practice of forest bathing (shinrin-yoku), found that pulse rate, systolic and diastolic blood pressure were significantly lower among a group of 128 people (ages 45-86) after a two-hour program in the forest which indicated physiological benefits from stress recovery.[38] A recent "Forests Make Us Healthier" campaign by the Northeast Forest Network provides a toolkit with much more information on the important connection between forests and mental and physical health.[39]

Forests provide shade and make communities more livable

By providing shade, street trees can help alleviate the urban "heat island effect" by reducing surface temperatures that, combined with air temperatures, have caused deaths in some cities during heat waves, which may become more common with higher extreme temperatures.[40] An improved tree canopy can cool residential neighborhoods and reduce energy use, while potentially making communities more attractive, livable, and safe.

Connecticut should balance public safety with the health benefits of urban and suburban street trees in reviewing policies for tree planting in residential areas and hazard tree removal implemented by utility companies or municipalities.

By maintaining Connecticut's existing forests, and significantly increasing the acreage of permanently protected forest land, we can help ensure our state's natural and human communities can continue to thrive in the face of climate change.

Adopt Statewide "No-Net-Loss of Forest" Policy

Top Priority Action

- **Adopt a statewide "No-Net-Loss of Forest" policy** in the CT General Assembly.

The Forests Sub-Group recommends an overarching "no-net-loss of forest" (NNLF) policy for Connecticut. This policy would support the top priority recommendation in both the Adaptation/Resilience and Mitigation sections of this report which is to KEEP FORESTS AS FORESTS.

To achieve this NNLF policy goal will take concerted actions at the local, regional, and statewide levels. Fortunately, the state of Maryland has been working on implementing its "no-net-loss of forest" policy which was adopted in 2013 with passage of the MD Forest Preservation Act.[41] This landmark legislation accomplished four goals:[42]

- Establishing no-net-loss of forest as the policy of the State of Maryland.
- Encouraging the retention of family-owned forests by doubling the income tax credit for forest management activities and expanding the range of activities to include the planting of streamside forests, removing invasive species, and improving wildlife habitat.
- Broadening the State Reforestation Law to support tree planting and forest health management on family-owned forests.
- Ensuring that local fees under the Forest Conservation Act of 1991 are used for tree planting and conservation.

The NNLF policy has helped establish several mechanisms at the statewide and county levels to slow the rate of forest losses in Maryland. This policy should be adapted to work for Connecticut, and the climate crisis makes this an urgent priority. The following recommendations are based on those proposed for Maryland to implement its NNLF policy:[43]

(1) **Avoid Forest Conversion** – protect existing public- and privately-owned forestland from conversion to non-forest purposes to retain the benefits of increased carbon storage, biodiversity, public health, green infrastructure, etc. (see benefits in previous chapter);

(2) **Protect Healthy, Intact Forests** – ensure that impacts upon forests, sensitive habitats, and other natural climate solutions and priorities (wetlands, soils, rivers, farmland, etc.) are considered at every level of planning – urban, suburban, and rural – and across all landscapes;

(3) **Offset All Planned or Permitted Forest Losses** – it is not practical to protect all forested areas from conversion and periodic natural disturbances may also result in unplanned tree mortalities. However, it is essential to offset all planned or permitted forest losses through a combination of compensatory mitigation requirements and tools such as compensatory reforestation, replanting programs, and acquiring local or regional forest mitigation banks;

(4) **Provide Incentives for Stewardship, Forest Retention, and Forest Resiliency** – since 71% of the state's woodlands are privately owned by individuals/families, corporate landholders, and land trusts, a no-net-loss policy must include financial and technical assistance measures to

engage private landowners in maintaining and increasing sequestration and storage of forest carbon as well as incentives for critical ecosystem services that their forests provide.

For example, as a participating state in the Regional Greenhouse Gas Initiative or RGGI, Connecticut should study forest carbon offset allowances available through compliance and voluntary markets for reforestation, improved forest management, avoided conversion, and forest reserves as well as programs that aggregate, evaluate and monitor forest offsets, in order to implement a system of paying landowners for enhanced carbon sequestration and storage with verifiable climate benefits and strict certification standards in place; and

(5) **Protect Urban Forests, Build More Parks, and Plant More Trees** – planting, re-planting, and caring for trees and establishing neighborhood parks in Connecticut's cities not only provides improved health, reduced energy costs, and other co-benefits, but also often provides more equitable access to parks and the outdoors for people of color and other vulnerable communities disproportionately impacted by climate change. If this is implemented with appropriate community engagement rather than as a top-down program, this can result in more healthy, equitable, and resilient communities.[44]

Adaptation and Resilience Considerations for Connecticut's Forests

Resilience is the fundamental ecological ability of a forest to change and adapt to stressors and provide the functions and values that society demands.[45,46]

Following are the primary components of resilience and their relevance for Connecticut's forests:

1. Forests and their native species (especially trees) have an inherent ability to endure and self-organize after disturbances with which they have co-evolved.

In Connecticut, the predominant oak-hardwood forest type has co-evolved with disturbances that are mostly episodic (e.g. hurricanes, microbursts, tornadoes, droughts, flooding by beavers) – rather than frequent and chronic (e.g. small canopy wind events).[47,48] The historic frequency and intensity of storms may be different in the future as climate changes occur.

2. Greater tree species diversity confers greater stability, in the form of resistance to change in forest stands (and landscapes) related to disturbance and stress.[49,50]

The primary environmental drivers of our forest diversity follow (in general order of importance for forests in Connecticut):

a) The ability of plant species to specialize in relation to each other on different soils and topographies (a.k.a. niche partitioning);[51]

b) The ability of different plant species (trees) to have different growth habits and forms such as herbs, shrubs, small trees and canopy trees which is closely tied to precipitation and soil moisture (a.k.a. crown stratification);[52,53,54,55]

c) The ability of different tree species to grow and live for different lengths of time as a forest grows back after an episodic disturbance such as tornadoes, microbursts and hurricanes (a.k.a. successional development);[56,57]and

d) Ability for various species to "hide" amongst unrelated neighbors to avoid insects and diseases specific to that species. This process in and of itself promotes diversity (a.k.a. negative density dependence).[58,59]

Connecticut's forest diversity is relatively young, since these drivers have been dynamically interacting over the past 20,000 years (since the peak of the last glaciation) with human-related land uses, climate, and other stressors (mostly human-related) and disturbances. Its current diversity is largely controlled by three diversity drivers: a) niche partitioning - because of Connecticut's inherent soil and topographic variability; b) crown stratification - promoted by moist soils from the relatively high rainfall Connecticut receives; and c) succession - disturbances that are punctuated by periods of recovery long-enough to promote sun-loving long-lived canopy trees (ash, oak, hickory and pine) to grow as canopy dominants with longer-lived shade tolerant species (beech, hemlock, maple) more characteristic of northern New England Forests.

3. Redundancy is a form of resilience where multiple species have the same roles or functions in a developing forest.[60]

Generally speaking, Connecticut's forest redundancy is high meaning that there are multiple species and multiple unrelated genera. For example, oak, hickory, and maple trees all have multiple species found across the state that can inhabit the same space and function in a forest. Hence, the elimination of one species through insects, disease, or other stressors would not limit the ability of a forest to recover and retain its basic structure and composition. Of course, the removal of multiple species will reduce or eliminate redundancy and will have a dramatic impact in a forest's resilience. Evidence suggests this is beginning to happen, for example with the functional elimination of chestnut, elm and ash and the decline in beech, hemlock, and oak.

There are other drivers of Connecticut's forest resiliency that are not covered in this report, such as "driver" and "passenger" species relationships[61,62,63] and biogeographic effects.[64]

The Resilience of Connecticut's Forests is currently Threatened and Declining

There are multiple factors and stressors that have combined to threaten the resilience of our forests:

1. Forest Age Classes and Structure are Not Diverse – Legacies of Connecticut's agriculture, chronic selective logging, and development history has left a relatively age- and structure-simplified second growth forest across most of our state.[65,66]

2. Most Forests Are Mature and Getting Older – The pattern of a large proportion of forests in the landscape simultaneously reaching maturity has the potential to reduce resilience as maturing forests are more susceptible to multiple stressors (e.g. insects, disease, pollutants, and drought).[67] Old growth forests have enormous ecological and social value, are rare in the modern landscape, and can have substantial resilience to disturbance. Also disturbances in mature forests can promote the age and structural diversity missing from the forest landscape, but novel stressors described below may affect these values and outcomes.[68,69]

3. Most stressors are human caused but beyond our immediate control – Abiotic stressors to trees such as ozone and NOx[70] can be significant, as can biotic stressors such as invasive insects, plants, and diseases. Both have been impacting the development of the Connecticut forest for over a century and will continue to impact future forest composition and structure.[71,72]

4. Fragmented forests with permanent "edge" are more prone to degradation -- Permanent edge exists because of persistent and continuous disturbance from: i) farming and agricultural activities; ii) development and suburban expansion through roads, lawns, and lots; and iii) through continuous activities in the forest such as recreation (e.g. trails), frequent rather than episodic timber harvesting, and the chronic imbalance of predator-prey in wildlife populations with associated problems such as excessive deer browse that directly impacts the ability of young forests to regenerate.[73] It's worth noting that edge, when it is not permanent, can provide dense areas for travel, nesting, and cover for various species of wildlife, and can contain flowering and fruiting plants beneficial for many pollinators and wildlife species that may be less prevalent in interior forests.

5. Climate Change is Increasing Disturbances – Climate change is exacerbating chronic issues for forests such as incremental mean increases in temperature resulting in increased respiration stresses and decomposition processes. Climate change also heightens episodic stresses such as

periods of drought during the growing season, extra-normal rainfall and snowfall events, and increased abnormal and high severity disturbance events such as ice storms, tornadoes, hurricanes, and microbursts.[74,75]

6. Climate Change Can Reduce Forest Carbon Sink Potential -- Climate change is producing, facilitating, and reinforcing negative impacts from stressors already present in low-resilience forests. This can cause a degradation spiral which further simplifies forest composition and structure, increases dominance of non-native species, may reduce standing biomass, increases decomposition processes, and lowers soil carbon.[76,77,78]

The bottom line is that forests will not be impactful to mitigate climate and carbon if they are not resilient.

Actions to Increase Adaptation and Resilience of Connecticut's Forests

Top Priority Actions

- **KEEP FORESTS AS FORESTS** with mechanisms to encourage private landowners to protect forestland through easements, tax incentives, ecosystem payment mechanisms, and strong markets for local forest products.
- **Create forest monitoring network** to evaluate forest ecosystem conditions in naturally regenerating forests across the rural to urban gradient, various land ownerships, and including trees in more developed areas.
- **Sponsor research on ways to create greater resiliency in forests** through alteration or natural development of structure, function, and diversity. Encourage financial incentives to apply the results of this research on public and private lands by stakeholders to promote more resilient forests.
- **Ensure statewide, regional, and local actions align to maintain un-fragmented forests** within and across political boundaries with emphasis on connections to waterways and wetlands, core forests, and wildlife habitat linkages.

Short Term (1-5 year) Recommendations

Monitoring, Evaluation, and Planning

- Create a monitoring network to evaluate forest ecosystem conditions in naturally regenerating forests (i.e., not mowed or maintained ground cover) across the rural to urban gradient throughout Connecticut at a more refined scale than the National FIA and that complements other existing programs such as the Breeding Bird Survey. Incorporate or establish additional network for "maintained trees" (i.e., those that are not naturally regenerating) across the state.
    - Include a wide diversity of measurements beyond forest growth and change in composition: such as breeding bird census, invasive plant monitoring, insects and diseases, disturbance characterization from a variety of sources (timber harvest, wind, insects, pathogens, and fire) and periodic measures of soil carbon.

    - Ensure that data are accessible and usable by stakeholders through an open access data portal and that the importance and utility of the data are communicated to potential users.
    - Create a citizen science program where trained and mentored individuals (from across life stages – including students and adults) conduct some of the monitoring – e.g., bird census on a specific series of days at the sampling points, camera trap monitoring for mammals, or amphibian surveys. If well planned, this could be systematic part of the design for the monitoring program carried out by or alongside professionals. This could be developed as a component of a college or high school curricula.
- Identify areas that are especially important to landscape-level resilience through partnerships with TNC's Staying Connected Initiative,[79] HVA's Follow the Forest Initiative,[80] and other climate corridor proponents to identify and prioritize the protection and enhancement of climate and habitat corridors in Connecticut. TNC's Resilient Lands Mapping Tool[81] can also be used for site assessments in Connecticut to measure the capacity of different lands to withstand climate change.
    - Identify areas where wildlife movement between core forests becomes constrained by roads, culverts and bridges, and design mitigation efforts to improve wildlife passage.

Experimentation

- Sponsor experimental studies to investigate ways to create greater resiliency in forests through management-promoted or natural development of structure, function, and diversity. Use these studies as baselines for adaptive management of forests in different contexts. Initiate studies across the rural-urban gradient, ownership and land use types, and in both maintained and naturally regenerating forest systems.
    - Promote and expand on existing examples such as Adaptive Silviculture for Climate Change program at UConn[82] and many efforts of USFS Northern Institute of Applied Climate Science.[83] Create a state-wide list/portal of existing and newly created projects where their outcomes can be communicated.
    - Explore funding streams through USFS and other agencies for expanded efforts.

Forest Management Approaches

- Implement forest management approaches that can increase structural, age class, and species diversity in low-diversity second-growth forests.[84,85]
    - Promote silviculturally-informed, resilience-focused management approaches across ownership categories and especially on private lands.
- Respond to ongoing elevated tree mortality (related to gypsy moth, drought, EAB, etc.) across the urban to rural gradient based on regeneration monitoring.
    - Coordinate and share information between forest researchers and land managers on tree mortality patterns and safety concerns.

    - Set up specialized monitoring program to assess tree regeneration patterns across affected and unaffected stands.
    - Retain snags and deadwood to promote wildlife habitat and carbon storage wherever feasible based on hazards, economic considerations, and forest regeneration goals.
- Respond to ongoing invasive pests and pathogens and prepare for future introductions.
    - Adopt and promote biocontrol methods where possible and work with partners from the federal level to test and apply these methods.
    - Continue and expand monitoring programs and early warning systems.
    - Continue and fund firewood and horticulture regulations to limit new introduction.
- Promote regeneration of native and future-adapted tree species (especially oaks and hickories) across forest types, stand conditions, and ownership types.
    - Develop and promote herbivore population control measures where appropriate and based on monitoring of regeneration and herbivore populations.
    - Include regeneration as a primary focus of monitoring and experimentation plans outlined above.
    - Implement forest management approaches and planting initiatives to promote regeneration of mid-tolerant and intolerant species such as oaks and hickories where needed and appropriate (based on monitoring or protected status).

Education and Outreach

- Continue and expand education and outreach/training efforts focused on promoting the importance of resilient forests, and forest management approaches that promote resilience, as linchpins of state climate adaptation and mitigation strategies.
    - Create and fund a Connecticut Youth Conservation Corps, on the model of the Civilian Conservation Corps, to provide jobs and paid job training to young people that prioritize tree planting and reforestation activities with an emphasis on explicitly creating employment and career opportunities for young people from Environmental Justice communities (as defined under section 22a-20a of the CT General Statutes) to carry out planting and reforestation activities in EJ communities.

Longer Term (5-10 year) Recommendations

Forest Protection Strategies

- KEEP FORESTS AS FORESTS with “no-net-loss of forest” policies and financial incentives to encourage private landowners to protect forestland through easements, tax incentives, ecosystem sustaining payments, and strong markets for forest products.
- Develop active outreach programs to connect and engage private woodland owners with conservation-based estate planning resources, such as tax benefits of conservation, family facilitation in succession planning, and guidance about options to sell carbon credits as market opportunities emerge. Efforts by DEEP’s service foresters, UConn

extension, conservation organizations, and partnership efforts like the new Master Woodland Manager program all play important roles with this critical, ongoing work.

- Ensure statewide, regional, and local actions align to maintain un-fragmented forests within and across political boundaries with emphasis on connections to waterways and wetlands, core forests, and wildlife habitat linkages.
    - Reduce fragmentation, protect sensitive soils and waterways, and create a more diverse forest structure and composition that is resilient to both acute (hurricanes) and chronic (pollutants) disturbances.
- Keep wetlands as wetlands, wooded wetlands and riparian forests (floodplains), and enact amplified land protection strategies to avoid wetland and riparian forest conversion.
    - Promote restoration of forested wetlands to more diverse species composition, including coniferous component where appropriate.[86]
- Ensure connectivity between the most significant forest cores and wildlife habitats, and actively restore connections where wildlife movement (terrestrial and aquatic) is constrained by roads, culverts, dams, and bridges.

Forest Restoration and Acquisition Strategies

- Acquire riparian lands to protect water quality, soil stability, and diverse, forested habitats.
- Look for appropriate opportunities to reforest currently non-forested lands that would have historically supported forest vegetation and are not currently or likely in the near term to be utilized for agriculture, to provide additional habitat for early successional species.
- Sponsor and develop a network of forest resilience nurseries developed and managed by landowners to propagate plant species of ecological concern for out-planting in forests and regions of Connecticut with extirpated populations (with appropriate oversight) as well as trees that are resilient in more developed streetscapes.

Implementing Forest Resiliency

- Encourage financial incentives to implement what we learn from adaptive experimentation and monitoring (above) on public and private lands by stakeholders to promote more resilient forests in structure, function and diversity.
- Create a funded program for municipalities (especially in underserved/EJ areas) to increase urban tree canopy cover and resilience in plantings and post-establishment treatments/monitoring as well as in appropriate circumstances to maintain mature and large trees which provide especially high levels of ecosystem services such as cooling, pollution reduction, and habitat.
- Fund strategic state programs to control important emerging invasive insects, plants, and diseases.
- Develop and promote programs to increase resiliency of trees and forests in proximity to human (gray) infrastructure and reduce tree-infrastructure conflicts. This can be

complemented by re-using wood from trees that have to be removed due to conflicts with infrastructure to help reduce lost carbon and/or substitute for other carbon intensive materials.

Education and Outreach

- Create a funded educational program for forest landowners and interested citizens around what a resilient forest is and how promoting a resilient forest benefits society.
- Enhance outreach and education efforts focused on promoting the importance of tree and forest cover to human health and well-being to constituents.
- Develop programs and outreach/education materials that educate citizens, stakeholder institutions (e.g., highway departments and utilities), and policy-makers about the exceptional ecosystem services of maintaining large, healthy, and sound trees in gray infrastructure areas, but also balance with the "right tree, right place" message to avoid disbenefits[87] and work with communities to determine local priorities rather than a cookie-cutter, top-down approach.

Changing Laws and Regulations

- Enact and enforce tougher firewood and horticultural State laws around invasives, fuelwood, and packaging across state lines – including a well-funded enforcement program.
- Very carefully regulate hunting of top predators to encourage development of intact top-down trophic food webs and to remediate the current imbalance regarding herbivory.

Creating Strong Markets for Products and Services with Multiple Benefits

- Strengthen local markets for long-lived forest products to promote a local rural economy so that treatments to create more resilient forests are not paid for by the taxpayer but come “free.”
    - Include “Build with Wood” programs and market local timber products (e.g., Connecticut Grown wood) with certifications and requirements for implementation of resilience-focused forest management approaches to incentivize construction in wood and mass timber technologies and discourage more carbon-intensive building materials.
    - Incentivize local production and marketing of Connecticut Grown non-timber forest products (e.g., forest gardening of non-timber forest foods – maple syrup, ramps, mushrooms, herbs, and berries as well as understory spices and medicinals like witch hazel).
- Create a fund to strengthen local markets and provide payments or services to promote social and economic resilience for landowners - particularly for rural economically-disadvantaged and small-acreage landholders who are currently incentivized to sell or develop.
    - Watershed services payments for private landowners.

- Recreational trail payments to landowners for public access on private lands.
- Payments for enhanced sequestration and/or storage of carbon through reforestation, improved forest management, or avoided conversion, with strict standards in place through programs that aggregate verified carbon credits from private lands in order to sell carbon offsets in voluntary or compliance markets.

Mitigation Considerations for Connecticut's Forests

Climate mitigation involves both reducing the emissions of carbon dioxide (CO_2) and other greenhouse gases, and increasing the removal of CO_2 and other GHG's - e.g. methane, nitrous oxides, and ozone - from the atmosphere to reduce potential adverse effects of climate change.

Natural ecosystems (grasslands, wetlands, forests) are, on balance, the best and most effective climate solutions available both for the uptake ("sequestration") and long-term storage of carbon, whereas human-made carbon capture technologies are still in their infancy.[88] Of these natural systems, forests sequester and store the most carbon and likely have the largest potential to remove additional CO_2 from the atmosphere.[89]

Available climate mitigation solutions in forests

- A*voided conversion of forest* to non-forest sustains the mitigation value of forests and is a prerequisite for *mitigation-focused forest management.*[90]
- *Mitigation-focused forest management – (*e.g., extending rotation periods and retaining more and larger trees) has important potential to retain carbon storage on managed lands, while providing long-lived wood products.
- *Reforestation* (conversion from non-forest to forest) is an important tool for sequestering carbon dioxide in newly forested areas.

Connecticut's Forest Carbon Storage

Connecticut's forests are, on average, the most carbon dense – in aboveground carbon stored per acre – of the nine Northeastern US states[91] and therefore have extraordinary mitigation value for this region in terms of their accumulated carbon stocks. A combination of *avoided conversion and mitigation-focused forest management* is critical to maintain these carbon stocks.[92]

Carbon is also stored in long-lived forest products. A number of independent analyses conducted by experts in academia, state and federal agencies, organizations, and institutions document that forests managed for a sustainable yield of forest products is an important element of climate mitigation.[93,94,95] The fourth report of the IPCC states: "In the long term, a sustainable forest management strategy aimed at maintaining or increasing forest carbon stocks, while producing an annual sustained yield of timber, fiber, or energy from the forest, will generate the largest sustained mitigation benefit."[96]

Connecticut's Forest Carbon Sequestration and Future Role in Climate Mitigation

Approximately 16% of Connecticut's forests are estimated to be >100 years of age, the highest percentage in the Northeast.[97] Annual net growth of Connecticut's forests is also estimated to be the highest in the region,[98] suggesting that forest age is not currently constraining aboveground forest carbon. In fact, Connecticut's forests have increased their standing biomass significantly over the past 10 years.[99] Connecticut's current forest resilience in the face of increased tree mortality can likely be attributed to the following:

- Natural disturbance events in recent decades have resulted in relatively small fluctuations in carbon across the state as a whole.[100]

- Temperate deciduous forests typically develop structural complexity naturally as they age and are exposed to moderate severity disturbances; this complexity can lead to greater carbon sequestration that helps maintain carbon storage in mature forests well beyond the 100-year mark.[101,102]
- Professional forest management.

Though growth rates and carbon uptake rate will eventually slow as Connecticut's forests enter late successional and old growth stages, most of these forests will continue to accumulate carbon in live tree biomass, down and dead trees, and soils well past 200 years of age.[103,104,105] Connecticut's forests may have the potential to significantly increase their carbon storage.[106] Natural disturbances, predicted with climate change to increase in both frequency and intensity, will generally sustain carbon sequestration levels up to a relatively high disturbance severity threshold, beyond which sequestration tends to decline.[107]

Forest Conversion threats

Connecticut's forests cover ~59% of the state's land area,[108] and 53% of these forested areas is considered to be "core forest" as defined by UConn CLEAR in its landmark forest fragmentation study.[109] Over the past 10 years, Connecticut's forest area has changed little, ranging from a net loss of 400 acres per year to a net gain of 1,400 acres per year, depending on the calculation.[110] However, large core forest blocks of greater than 500 acres have declined sharply (see Figure 2 on page 7). The biggest ongoing and future threats from forest conversion and fragmentation occur in the Connecticut River valley and northern Fairfield, New London and Windham counties.[111]

Reforestation Potential in Connecticut

Four hundred years ago, Connecticut was almost entirely forested.[112] Moderate mitigation potential exists for reforestation on lands that were once forested and are not currently being used for agriculture (i.e., lawns, vacant lots, barren lands and other non-agricultural fields in rural, suburban, and urban areas).[113] In Connecticut, the reforestation potential is highest in the rural areas of Litchfield county and in the settled areas of the Connecticut River valley and Fairfield County.[114]

The Settled Treescape

Because of increased light, trees and forests that grow near edges, along roads and in settled areas are generally larger and store more carbon than trees in forest interiors.[115] Settled treescapes also cool buildings in summer and insulate them in winter, reducing CO_2 emissions from heating and air conditioning.[116] Large trees provide the largest cooling/insulation benefits and airborne pollution reduction compared to small trees.[117] Because of these significant benefits, the carbon storage impacts of programs by utilities and highway departments to maintain and remove trees near electric infrastructure and highways require careful scrutiny.

Timber harvesting in Connecticut

Connecticut's forests are currently harvested at a relatively low intensity – 17% of the state's annual forest growth in volume is being cut each year.[118] However, some of Connecticut's

forests are being high-graded (i.e., only the largest and most valuable trees are being harvested, typically on privately-owned forest lands).[119] *Mitigation-focused forest management* combined with incentives for landowners could help ensure that forests remain as forests and contribute to carbon uptake. Forest science continues to provide research-based recommendations which increasingly guide forestry decisions.[120]

Actions to Increase Mitigation of GHG from Connecticut's Forests

Top Priority Actions

KEEP FORESTS AS FORESTS

- Set statewide goal to permanently protect at least 50% of core forests greater than 250 acres by 2040.
    - Increase land protection funding from all available sources.
- Develop Action Plan to Increase statewide forest cover from 59% to over 60% by 2040.
- Retain large trees and forest cover in urban and residential areas to reduce carbon emissions from buildings and retain health and other co-benefits.
- Improve forestry practices in Connecticut's working forests.

Forests offer the single most effective land-based solution for removing carbon dioxide from the atmosphere and storing it long-term to limit some of the worst impacts of climate change.[121] From large "core forest"[122] areas to individual, mature trees that shade our streets, all of our treescapes are essential to meeting the state's carbon emission reduction goals.

As a co-benefit, forests sustain the health and well-being of the state's residents and the broad diversity of plant and animal life that comprise Connecticut's natural heritage. Forests also sustain renewable resources and fossil fuel alternatives through forest products. The protection of forests from conversion, science-based management of forests, and the expansion of forests are central to an effective and equitable approach to climate mitigation that Connecticut requires and deserves. The following recommendations are bold and necessary to address the enormous threats associated with climate change.

Permanently Protect at least 50% of Core Forests >250 acres Statewide by 2040

Avoided conversion of forest to non-forest is a critical climate mitigation strategy. Connecticut's Forest Action Plan already recognizes core forest protection as a conservation priority**.** Public Act 17-218 further requires that the Commissioner of DEEP consider the environmental impacts to core forests from proposed solar projects and certify to the Connecticut Siting Council that such projects will not materially impact the status of core forests. Because of the many co-ecological benefits core forests provide in addition to climate mitigation, Connecticut should ensure that conversion of core forest to non-forest purposes does not occur, or is offset by core expansion. Permanently protecting from conversion to non-forest 50% or more of the state's core forests of 250+ acres by 2040 should be a conservation goal with the same statutory authority as the State's current 21% overall land conservation goal.[123]

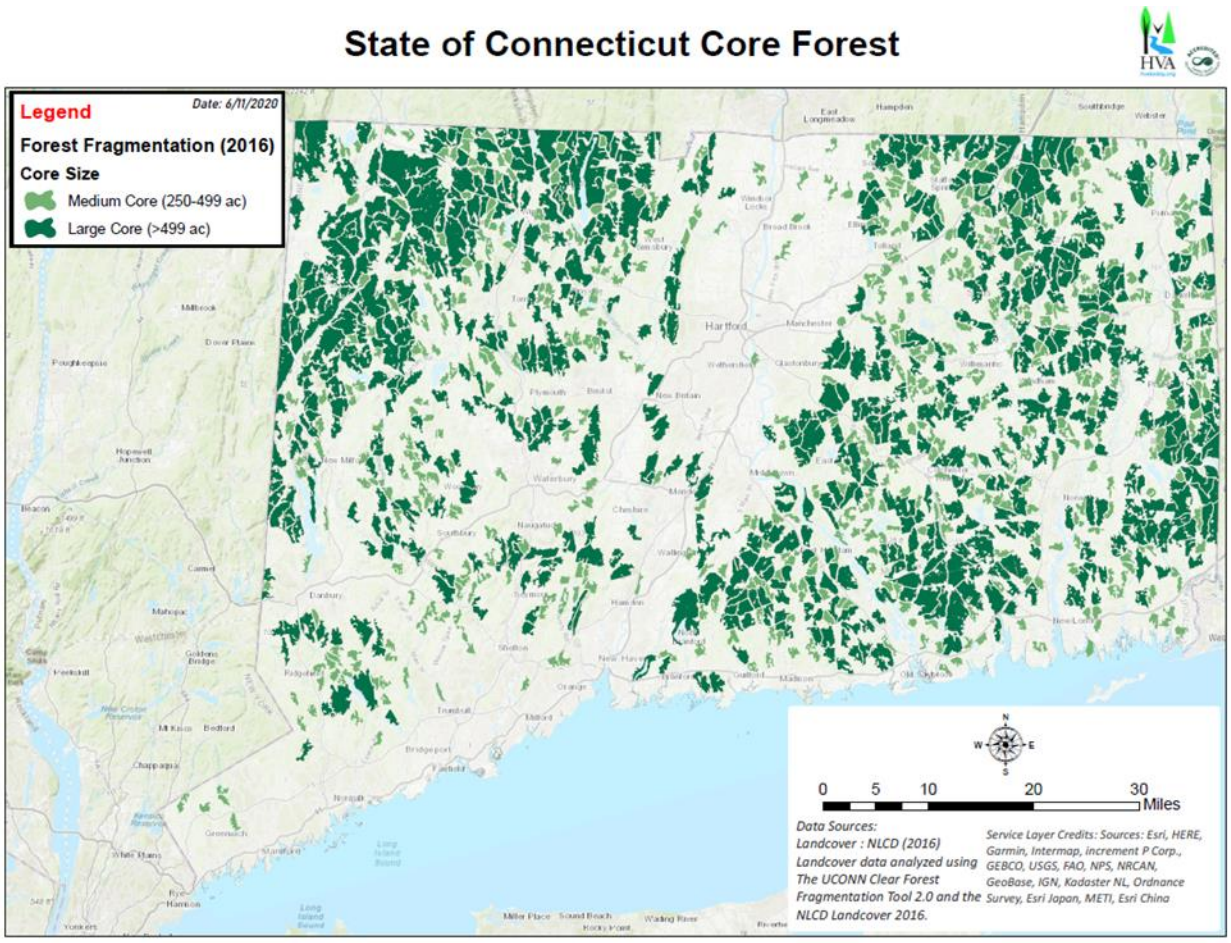

Figure 7. Map of Medium and Large Core Forest Areas in Connecticut produced by Housatonic Valley Association using NLCD Landcover 2016 data with UConn CLEAR Forest Fragmentation Tool 2.0.

Short Term (1-5 year) Actions

- KEEP FORESTS AS FORESTS and adopt statewide goal of permanently protecting 50% of core forests larger than 250 acres on private forest lands from conversion to non-forest purposes by 2040.[124]
- Realign state land protection programs and funding sources in the Green Plan to reward and incentivize land protection that protects core forest land of 250+ acres.
- Actively discourage loss of forest by conversion to incompatible land-uses through implementing required mitigation, financial disincentives, and strong policies to avoid land-use conversion.
- Increase land protection funding from all available sources, including funds to increase capacity of DEEP land protection and stewardship staff necessary to sustain a fivefold increase in acres protected from conversion to non-forest and tripling the number of conservation transactions accomplished each year. This should include annual bond authorizations of at least $25 million for DEEP's Recreation and Natural Heritage Trust Fund and $25 million for the Open Space and Watershed Land Acquisition (OSWA) program which funds fee and easement acquisitions.
- Convene a taskforce to evaluate ways to extend or strengthen the effectiveness of the Public Act 490 program and other financial incentives to provide benefits to private forest landowners who keep forests as forests.

Longer Term (5-10 year) Actions

- Dedicate significant state and private resources to educate landowners about the value of keeping their forests as forests and of mitigation-focused forest management.
- Ensure Forest Management Plans for state conservation lands include managing forests for resilience, carbon, and local, long-lived forest products.
- Require an individual permit for any petition before the Connecticut Siting Council that would result in a conversion/loss of core forest.
- Consider increasing financial incentives such as PILOT payments to municipalities that exceed the statewide average of protected core forest.

Develop Action Plan to Increase Forest cover from 59% to over 60% by 2040

Approximately 59% of Connecticut is forested.[125] Although of varied size and uneven distribution, these forests already have significant aboveground carbon storage, especially compared to other states in the northeastern U.S. [126]

Using a no-net-loss policy in Connecticut to avoid deforestation and building upon it to increase forest cover to above 60% of the state's land area with *reforestation* (defined here as conversion of land from non-forest to forest) will expand carbon storage capacity, and increase the rate of carbon uptake ("sequestration"). In fact, reforestation can be the single most effective forest-based solution to increase the sequestration rate on a per-acre basis in Connecticut.[127]

This increase in forest land cover could be achieved through natural forest succession on currently unforested land in residential, rural, and urban areas (i.e., grass and turf, reclaimed and remediated lands, marginal and abandoned fields). It could also be achieved by deliberate re-plantings (as needed), expanding forested riparian buffers, and curtailing unnecessary tree pruning and removals along transportation, residential utility transmission, and telecommunications lines and infrastructure.

This increase in forest land cover would not require the reforestation of active agricultural fields, except in areas where the priority may be to expand riparian buffers or conduct agroforestry. Reforestation potential is particularly high in Litchfield, Tolland, and Windham Counties and in the urban areas of the Connecticut Valley and northern Fairfield County.[128] Co-benefits of reforestation include improved water quality, soil stability, and enhanced wildlife connectivity between larger areas of forested habitats.

Short Term (1-5 year) Actions

- Adopt a statewide forest cover goal of "over 60% by 2040" and launch rapid action planning process to determine areas and incentives to target for reforestation efforts.
- Create and fund a Connecticut Youth Conservation Corps, on the model of the Civilian Conservation Corps, to provide jobs and job training to young people that prioritize tree planting, forest stewardship, and reforestation activities with an emphasis on employment and work in environmental justice communities as defined under section 22a-20a of the CT General Statutes.

- Actively discourage conversion of forest, particularly core forest, for industrial solar projects, while increasing incentives for renewable energy projects on the built environment, such as on brownfields or along highway infrastructure.
- Develop educational programs for policy makers and local governments on the climate mitigation benefits of reforesting urban and settled areas, and update existing public information to highlight Connecticut's land-based carbon and renewable forest products.

Longer Term (5-10 year) Actions

- Establish financial incentives for landowners who allow their lawns or abandoned fields to reforest.
- Invest in scientific monitoring, remote sensing and GIS capacity, by DEEP or its partners in the public and non-profit sectors, to track progress toward increasing overall forest cover using remote sensing and the most current land cover and protected lands data.

Retain Large Trees and Forest Cover in Settled Landscapes (urban and residential)

Because of higher light levels and reduced competition from other trees, edge forests and residential and urban treescapes typically contain larger trees, on average, and therefore store more carbon per tree or area of forest than do interior forests and trees.[129] Hence their climate mitigation value is disproportionately large and should be reflected in the level of protection that they are afforded.

Residential and urban trees and forests also shade and cool buildings in summer and insulate them in winter, which significantly reduces energy levels of air conditioning and heating fuel and associated carbon emissions.[130] Moreover, large trees reduce airborne pollutants (i.e., carbon monoxide, sulfur dioxide, nitrogen dioxide, ozone, and particulate matter) to a much greater extent than do small trees.[131]

Short Term (1-5 year) Actions

- Do not permit removals of healthy street trees, and limit removals to trees in hazardous poor condition that are imminent threats to people or electric infrastructure. If trees are removed, PURA should require a plan and support funding for utilities to replant trees, especially in EJ communities with higher percentages of impervious surfaces and related heat island impacts. Pruning should focus on protecting the structural integrity, strength, and health of the trees, and not risk creating hazardous trees in the future by adherence to rigid clearance standards.
- Appropriate roadside trees, including those that will become large, should be planted with priority to residential areas and especially in EJ communities with higher percentages of impervious surfaces and related heat island impacts.
- Establish priorities for planned and opportunistic conversion from overhead pole and wire electric distribution to underground wires and upgraded circuits for electric reliability and reduced tree-wire conflicts.
- Create model municipal ordinances to encourage replacement of and mitigation offsets for non-emergency removals of street trees within the municipal road right-of-way.
- Establish new standards for state roads that minimize losses of healthy trees.

Improve the Management of Connecticut's Working Forests

Encourage forest management following scientific principles, including the emerging body of knowledge on how to manage forests for resilience and to store carbon. Large trees store by far the largest amount of carbon in the forest and therefore contribute disproportionately to climate mitigation.[132]

Implementing "sustainable forestry" on managed forests can incorporate climate mitigation and adaptation, management for wildlife species, and best management practices for soil and water alongside improved silvicultural practices to increase forest regrowth. In a 2020 paper, the New England Forestry Foundation (NEFF) defines sustainable forestry as "forest management that ensures forests contribute maximally to mitigating and adapting to climate change during the next 30 years as seen through a systems lens that includes in-forest carbon, forest product carbon storage, and substitution benefits, while also maintaining the ability of forests to help current and future generations to meet their social, economic, ecological, cultural, and spiritual needs."

The Forests Sub-Group received considerable public comment from academic, professional forestry, wildlife conservation, and others expressing concerns about an over-reliance on forest reserves or preserves to mitigate climate change. Reasons for concern included such considerations as:

- One-third of State Forests, Parks, and Wildlife Management Areas are already passively managed (see page 13 of this report);
- Many private woodlands and land trust properties are currently passively managed; and
- Certain forest types (e.g., oak, hickory, tulip poplar) and wildlife species (e.g., New England Cottontail and many bird species that depend upon young forest habitats) may depend upon active management for survival.

At the same time, most public comments also acknowledged that limited forest reserves[133] are compatible as part of a matrix of actively and passively managed forests.

Reserves can play several important roles on the landscape, including providing scientific benchmarks for assessing the impacts of climate change and forest management, serving as refugia for species that require late-successional habitat, informing the public about "natural" processes, offering people opportunities for wilderness experiences, and serving as reservoirs of genetic diversity within tree species. Forested reserves can also contribute to climate change mitigation through the large stores of carbon found in the soils, trees, and legacy features of old-growth forests.

Short Term (1-5 year) Actions

- Provide support, including funding, for the prevention of new invasive forest pests, and for reducing and managing the ones that are here, with an initial focus on those that impact forest regeneration.
- Support CT certified forest practitioners in implementing practices to further "sustainable forestry" as noted above in managed forests.[134]

- Increase funding for forest management planning. Connecticut's forest certification standards include criteria for management planning which can expand the planning framework used in forest management plans and timber harvests. This would include assessment of the forested landscape in which the property is situated, together with its contributions to maintaining core forest cover and embedded habitats.[135]
- Increase resources for service foresters to help private landowners practice exemplary forestry. That includes hiring at least three more DEEP service foresters and partnering with organizations like NEFF to help advance the principles of sustainable forestry.
- Increase the number of state land foresters to manage state forests for resilience, carbon, and other benefits, and to showcase state forests as a management model for private landowners and managers.
- Strategically locate forest reserves or Natural Area Preserves (as defined in Connecticut's General Statutes)[136] to maximize their benefits from a landscape perspective, for example by protecting rare or underrepresented habitats or by providing habitat connectivity**.**

Longer Term (5-10 year) Actions

- Support the use of forest products from local forests.
- Support thoughtful reuse of wood products to help reduce waste and demand for new wood products.[137]
- Review indigenous forest and wildlife management practices for ideas on different techniques to achieve more resilient mature forests.[138]

Climate Change Threats to Vulnerable Populations

Top Priority Actions

- **Address the social determinants of health inequities** at the individual and community levels that lead to increased vulnerability to the threats from climate change, and can be improved through pro-active forest policies.
- **Support community interest in tree planting, parks, and/or community gardens** in densely populated areas to support climate solutions that could meet multiple needs such as increasing health outcomes, employment, and entrepreneurial opportunities. Youth Conservation Corps could help community-based groups with implementation.
- **Build a market for creative re-use of urban wood waste** to store carbon while simultaneously creating education, employment, and stewardship opportunities.
- **Engage, train, and educate on adaptation planning, resiliency, and risks** from climate change with emphasis on local officials, planners, community organizations, and emergency responders.

Vulnerability to Climate Change is often described as some combination of exposure, sensitivity and ability to respond, or adaptive capacity. It is helpful to think of vulnerability in terms of these component parts, because there are instances in which exposure is greater for some groups over others, while in other circumstances it is ability to respond or adaptive capacity that is the ruling factor. For example, exposure to the urban heat island effect is much greater among urban populations, within whom those without the means to use personal vehicles or run their air conditioning continuously can be considered as having a lesser ability to respond. Those with existing medical conditions, such as hypertension or heart conditions, are also apt to have greater sensitivity to the urban heat island effect, and so it a factor in their vulnerability to an increase in this phenomenon in the course of climate change.

Among the groups generally cited in the United States as most apt to be vulnerable to climate change are communities of color, low-income groups, people with limited English proficiency (LEP), and undocumented immigrant groups.[139]

These populations are at increased risk of exposure given their higher likelihood of living in risk-prone areas (such as urban heat islands, isolated rural areas, or coastal and other flood-prone areas), areas with older or poorly maintained infrastructure, or areas with an increased burden of air pollution. These groups of people also often have an increased sensitivity to these climate change threats due to relatively greater incidences of chronic medical conditions, such as cardiovascular and kidney disease, diabetes, asthma, and COPD.

Finally, the ability to respond to these threats is often impeded by socioeconomic and educational factors, limited transportation, limited access to health education, and social isolation related to English language deficiencies. Likewise, these populations also may have limited access to medical care and may not be able to afford medications or other treatments. High poverty rates, language and cultural barriers, and citizenship status can each limit access

to and use of health care and other social services. Some members of these groups are likely to be hesitant to seek help out of concern that effort might cause their immigration status in the United States to become compromised.

Many of these factors are beyond the scope of the Forests Sub-Group to address. However, there are some areas where forests and the role of forests has the potential to be helpful in terms of reducing the vulnerability to climate change, such as:

- Through urban forestry, reducing the exposure and providing the means to adapt to those climate change exposures that primarily occur in urban areas. Many of these are heat-related, and include not just the urban heat island effect, but also the exposure to greater amounts of air and water pollution and flooding, due to greater, temperature-influenced exposure to ozone, increased generation of electricity in response to higher temperatures, and more extensive run-off due to more intensive rainstorms.
- Through careful analysis of meaningful economic data, identify ways in which both the urban and rural forests can contribute more to economic development, including jobs, in order to give vulnerable populations greater wherewithal to deal with exposure to increased threats from climate change.
- Through recognition of the importance of being outdoors in green spaces to enjoy positive physical and mental health benefits and provide increased opportunities for all residents of Connecticut to gain access to and feel welcome in all public forests, from city parks to State Parks and Forests. This includes intentional efforts to remove barriers that exist for vulnerable populations to access outdoor opportunities safely.

As noted earlier in the Status of CT Forests section of this report, 36.4% of the land area of Connecticut is considered by the U.S. Census to be “urban” (1.13 million acres), with 87.7% of the population, nearly 3 million people, living in these urban areas. Despite the high population concentration in these areas, these same lands have a fairly high degree of tree cover, with tree canopy cover estimated at over 60%. However, there is good evidence that this canopy cover is not equitably distributed, particularly in Connecticut’s larger and more densely-populated cities, but potentially also in Connecticut’s rural areas. Efforts need to be made to better identify areas of low canopy cover in settled areas throughout Connecticut and how those areas correlate to lower income neighborhoods, communities of color, and communities exposed to other environmentally-related public health concerns.

Figure 8. Urban areas like Hartford are hotter than more rural areas during summer. Tree cover can help reduce health and other problems associated with urban heat islands.[140]

Vulnerability to Climate-Related Health Stressors

Race and class are important factors in the vulnerability to climate-related stress. In many situations, it can be difficult to isolate the role of race from other related socioeconomic and geographic factors. Some racial minorities are also members of low-income groups, immigrants, and people with limited English proficiency, and it is their socioeconomic status (SES) that contributes most directly to their vulnerability to climate change-related stressors.

SES is a measure of a person's economic and social status, often defined by income, education, and occupation. Minority race and low SES are jointly linked to increased prevalence of underlying health conditions that may affect sensitivity to climate change. When adjusted for age, gender, and level of education, the number of potential life-years lost from all causes of death was found to be 35% greater for Blacks than for Whites in the United States, indicating an independent effect of race.

Extreme heat events. Some communities of color and some low-income, homeless, and immigrant populations are more exposed to heat waves as these groups often reside in urban areas affected by heat island effects.

Other weather extremes. As observed during and after Hurricane Katrina and Hurricane/Post-Tropical Cyclone Sandy, some communities of color and low-income people experienced increased illness or injury, death, or displacement due to poor-quality housing, lack of access to emergency communications, lack of access to transportation, inadequate access to health care services and medications, limited post-disaster employment, and limited or no health and property insurance.

Degraded air quality. Climate change impacts on outdoor air quality will increase exposure in urban areas where large proportions of minority, low-income, homeless, and immigrant populations reside. Fine particulate matter and ozone levels already exceed National Ambient Air Quality Standards in many urban areas.

Waterborne and vector-borne diseases. Climate change is expected to increase exposure to waterborne pathogens that cause a variety of illnesses—most commonly gastrointestinal illness and diarrhea. Health risks increase in crowded shelter conditions following floods or hurricanes, which suggests that some low-income groups living in crowded housing may face increased exposure risk.

Food safety and security. Climate change affects food safety and is projected to reduce the nutrient and protein content of some crops, like wheat and rice. Some communities of color and low-income populations are more likely to be affected because they spend a relatively larger portion of their household income on food compared to more affluent households.

Psychological stress. Some communities of color, low-income populations, immigrants, and LEP groups are more likely to experience stress-related mental health impacts, particularly during and after extreme events. Other contributing factors include barriers in accessing and affording mental health care, such as counseling in native languages, and the availability and affordability of appropriate medications.

Improve Community Health and Reduce Health Inequities

The impacts of climate change on health and health inequities are moderated by individual and community vulnerability and resilience. Interventions that improve the social determinants of health and population health and reduce health inequities can significantly reduce vulnerability and increase resilience to climate change, at the individual and community-levels. Increasing resilience to climate change will require investing significantly in the public sphere, including in social determinants of health and in public health infrastructure.

Many climate actions bring significant health co-benefits, but some may have significant adverse health consequence and/or increase health inequities. Some health interventions also have climate co-benefits. Thoughtful implementation of actions to reduce greenhouse gas emissions and adapt to climate impacts will help maximize co-benefits and minimize co-harms.

Urban trees and other natural systems provide a range of physical health benefits. Trees can improve air and water quality, mitigate the heat island effect, and help alleviate noise.[141] Trees can shield people from ultraviolet (UV) radiation, the cause or contributing factor for three types of skin cancer.[142] Urban ecosystems are increasingly recommended by national and State environmental protection agencies to mitigate the harmful impacts of air and water pollutants, harmful emissions, and the negative effects of urban heat and noise.[143] Trees also help reduce flooding by slowing rainwater runoff.

The demands of modern life can often be mentally exhausting. Focusing attention on flows of information and tasks, screening out distractions, and responding to the constant stimuli of commuting, work, school, and family leaves many people feeling drained, with memory loss and reduced capacity for sustained attention.[144] Rachel and Stephen Kaplan's Attention

Restoration Theory (ART) suggests that we can use nature to restore depleted cognitive functions and maintain performance.[145]

Access to green spaces also provides other health benefits. Researchers at the University of Exeter surveyed 10,000 urban residents in the United Kingdom, asking how satisfied they were with their lives and whether they had signs of depression, anxiety, or other psychological disorders. After controlling for other factors known to significantly influence well-being such as income, employment, marital status, health, and housing, researchers found a strong correlation between a boost in a feeling of well-being overall and increases in green space within a 2.5-mile radius of residents' homes.[146]

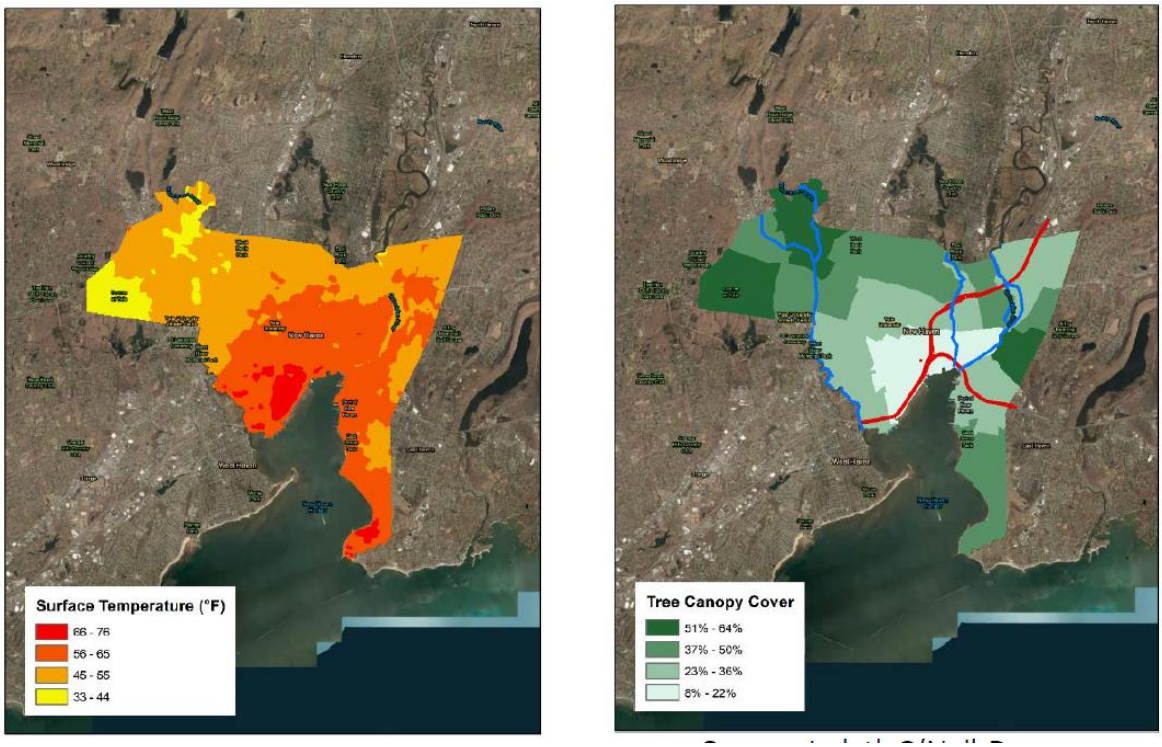

Figure 9. Maps showing tree canopy cover and surface temperatures in New Haven help to show the urban heat island effect that trees help to mitigate.[147]

Support Community Interest in Tree-Planting, Green Spaces, and/or Gardens

Tree planting and stewardship of new and existing trees in urban areas provides many potential benefits to human health, but it's important to note that the top green priority for a neighborhood may not be tree-planting, and policy-makers should be careful to not approach community green spaces with a "top-down" approach.[148] It is critical to engage the community locally to understand local needs and discuss trees as one potential solution rather than approaching the community with the assumption that tree-planting is the answer. Ongoing stewardship of local investments in green spaces is critical and may be more important than tree-planting depending upon various factors. Ultimately, community support is the foundation for long-term stewardship. As an additional benefit, work done to increase access to community green spaces may also inspire young people of color to consider outdoor employment opportunities, and perhaps this kind of locally-driven effort might provide the first step to a conservation career.

Underrepresented communities are adversely impacted by climate conditions, but historically, these communities have been marginalized, set aside, and not engaged in these discussions. While this report addresses Climate Change Threats to Vulnerable Populations, assessing community needs without their input would further exacerbate the vulnerabilities these communities face. Decisions about others without their input would further perpetuate the effects of climate when leaders are not communicating with the communities they represent. So, it is critical that we connect with leaders within the communities we're identifying as vulnerable populations and learn with them while assisting them.

That said, the existence of trees in areas with limited canopy cover can sometimes literally be the difference between life and death. Neighborhoods with little to no trees can, on average, be 5 to 7 degrees hotter during the day and up to 22 degrees hotter at night than neighborhoods with good tree cover. Treeless neighborhoods also have worse air pollution because trees trap air pollutants and the hotter temperatures in these treeless neighborhoods help cook air pollutants into dangerous smog. That's one of the reasons why health experts project a ten-fold increase in heat-related deaths across America's cities.[149]

Another reason for considering tree planting amongst community options is that some trees in urban areas are in poor condition and need to be removed and/or replaced. For example, Connecticut is currently losing many ash trees due to the emerald ash borer. A recent study suggests that the loss of trees to emerald ash borer is increasing human mortality related to cardiovascular and lower-respiratory-tract illnesses. [150] This finding adds to the growing evidence that the natural environment provides major public health benefits.

The need to maintain and increase urban tree cover (UTC) in Connecticut is not a new issue and is well-documented. Studies of UTC were conducted in New Haven (2009),[151] Hartford (2010),[152] Bridgeport (2012),[153] and the Greater Bridgeport region (2014)[154] to map UTC, show areas where heat islands are a current problem, and suggest areas where UTC could be increased through a combination of plantings or replantings and stewardship of existing trees. There have been follow-up studies and recommendations such as Hartford's Urban Tree Canopy Assessment and Planting Plan (2014).[155]

The City of Hartford, working with the city's Tree Advisory Commission, developed a Hartford Tree Canopy Action Plan (June, 2020)[156] with the following laudable long-term goals:

- Maintain the health of the urban forest.
- Ensure public safety.
- Increase our tree canopy to at least 35% (current tree canopy is ~25%).
- Reduce the urban heat island effect through targeted planting in the urban heat islands.
- Increase tree plantings aimed at energy savings.
- Reduce storm water run-off through target plantings.
- Improve air quality through forest management and careful selection of new trees.
- Design and implement an environmental stewardship program for Hartford schools, City of Hartford employees, and Hartford citizens.
- Become an urban forestry model for cities in the northeast and beyond.

The Hartford Tree Canopy Action Plan calls for the a 5-year goal of planting 3,000+ trees each year to increase its canopy from 25% to 35% over the next 50 years. According to the Tree Plan, planting ~1,500 trees each year is required just to maintain the current tree canopy. Of course, to maintain and increase tree cover in a healthy urban forest requires more than tree planting alone. Hartford and other cities must also make investments to remove dead trees, care for diseased, damaged or aging trees, and have a plan for replacing trees that are lost through storms or other common stressors for trees in cities.

Tree planting programs are more impactful when complemented by local environmental education and green jobs programs at the municipal level. KNOX for example, provides hands-on environmental education for Hartford students through their Gaia's Guides program which offers a combination of after-school educational opportunities and in-school programming on the benefits of trees to communities. In addition, KNOX offers Green Jobs Apprenticeships that provide job counseling and hand-on experience for out-of-work Hartford residents in the fields of landscaping (which includes tree planting), and horticulture. These kinds of job opportunities build experience for potential careers in landscaping, landscape design, land management, plant and soils science, agriculture, arboriculture/tree care, forestry, and many more fields.

Actively nurturing a broad appreciation of trees at the community level through outreach and education is important because there are ongoing costs associated with maintaining tree health that individual land-owners and community residents should consider. Well-maintained trees can be seen as a community asset and point of pride, but poorly maintained, unhealthy, or dead trees can be viewed as symbols of community neglect.

The plans and goals for Hartford's urban tree canopy are very good. However, due to budget shortfalls and other challenges, Hartford has been losing ground and has only been able to plant a few hundred trees in recent years. In the Tree Plan, it is suggested that Hartford's urban tree cover may have actually decreased by approximately 2% between 2014 and 2018 due to inadequate plantings despite best intentions, strong plans, and an appreciation for trees.

Without additional state or federal funding, human resources, and support with technical elements such as GIS mapping of heat islands and potential planting zones, to assist cities like Hartford and local partners like KNOX, Connecticut's urban areas will continue to struggle just to maintain the status quo for their urban tree canopies. A program like a Youth Conservation Corps could help provide some human resources to complement and extend the capacity of existing community-based organizations such as KNOX (Hartford), Urban Resources Initiative (New Haven), and Groundwork Bridgeport.

A Youth Conservation Corps, funded through a model like the national AmeriCorps program or perhaps a model like the "Greening the Gateway Cities" program being implemented in 13 towns in Massachusetts,[157] could employ high school or recently graduated students to build trust and cultural understanding at the community level around environmental restoration. Work that could be led by this youth corps could include controlling invasive plants or protecting native plants, working on trails connecting green spaces, and cleaning-up/planting-up open spaces in urban and rural environments. This could be a great program for expanding outdoor youth employment and career enrichment opportunities for students of color in fields

such as landscaping, horticulture, and land management/conservation, and can bring multiple benefits when students from the local community are employed.

Support Market for Local Wood Re-use

A program to encourage the local re-use of wood from the urban forest can accomplish multiple goals. Trees in urban areas provide many benefits while trees are growing and healthy, especially if they are well-maintained. However, some trees are not in good condition and need to be removed. In this situation, urban trees can move from being seen as a benefit to becoming a cost for the municipality. If the wood from that tree were re-used, it could reduce costs associated with tree removal and disposal, create job opportunities, partially offset the use of wood products from international forests that can be poorly regulated and leave a larger carbon footprint, and store carbon in long-lived wood products.[158,159]

It's worth noting that some tools and equipment that would support local wood re-use can represent barriers to entry. Some tools and equipment – e.g., a portable sawmill or lathe or chipper or kiln for drying wet wood – may be more apt to be readily accessed if it were available for rent from an equipment rental business or loanable through a local/regional co-op. Start-up job incubators that allow for shared use of space and equipment are also helpful. There are significant resources on urban wood re-use to provide models that work.[160]

Better use of local or regionally grown wood in construction in densely developed neighborhoods as a substitute for more carbon-dense materials (e.g. steel, aluminum, or concrete) can provide carbon offset benefits.[161,162] Wood products have many important benefits when used as a construction material. New techniques, such as cross-laminated timber and wood fiber insulation, are allowing use of wood in new ways that expand potential beneficial impacts. In a climate context, long-lived wood products have two benefits. First, they can store carbon previously captured by trees; as living forests may potentially experience increasing mortality and associated carbon release due to climate change, this could become an increasingly important benefit.[163,164,165] Greater focus and incentives toward reduced-impact techniques of forest harvest, improved forest management to enhance growth rates, and directing more of the harvest to long-lived products has potential to improve the efficiency of this carbon benefit over past performance.

There are two economic studies on rural forestry markets and urban forestry respectively that are being conducted under the auspices of the Northeastern and Midwest State Foresters Alliance[166] that can inform partnerships between the statewide forest products industry and urban forest managers that would benefit vulnerable populations in both urban and rural areas.

Lastly, energy savings, through the use of trees properly placed so as to provide shade and windbreaks to buildings, along with other building energy-saving approaches, such as the use of wood fiber in insulation[167] and the use of local lumber in home upgrades and repair, can also significantly reduce carbon emissions. A recent study of Hartford's street trees shows that the amount of carbon emissions avoided due to those street trees exceeded that amount of carbon sequestered by those street trees, at a ratio of 2,167 tons to 1,825 tons of carbon.[168]

Climate Threats to Vulnerable Forest Types

Top Priority Actions

- **Reevaluate Connecticut's Green Plan and open space grant programs** to prioritize acquisition of land and conservation easements for habitats most at risk from climate change.
- **Increase efforts to model and map vulnerable natural communities** and their buffers to increase efficiency of protection efforts to create better and integrated mapping of all natural resources and better inform decisions (e.g., Natural Resource Atlas and Monitoring Project).
- **Increase pace of forest and open space protection** with a focus on vulnerable natural communities and important buffers.
- **Advocate for passage of federal funding programs** such as the Recovering America's Wildlife Act, and others that support habitat stewardship and protection.
- **Invest in research and actions supporting adaptive management** for vulnerable natural communities.

Because of the uncertainty of climate change, all types of Connecticut Forest could be considered vulnerable. Unpredictable changes in temperature regimes, precipitation and importantly invasive species, pests and pathogens may mean that forest types thought to have low vulnerability, such as northern hardwood and central hardwood pine, may in fact be more vulnerable than we expect. For the purposes of this section we will focus on forest communities that are most likely to be negatively affected by climate change:[169,170]

- Black spruce bogs
- Lowland mixed conifer
- Beech, birch, maple forest
- Freshwater forested wetlands (forested swamps)
- Pitch pine-scrub oak (not called out in the literature, but added because of threat from southern pine beetle)
- Cold water streams and headwaters and the associated shading forests
- Lowland Atlantic white cedar forests
- Floodplain forests
- Coastal forests
- Young forests and oaks for wildlife

The climate-related threats to forests in Connecticut and the northeastern U.S. are well-described by Swanston et al. (2018):[171]

“Forests of the Midwest and Northeast significantly define the character, culture, and economy of this large region but face an uncertain future as the climate continues to change. Forests vary widely across the region, and vulnerabilities are strongly influenced by regional differences in climate impacts and adaptive capacity. Not all forests are vulnerable; longer growing seasons

and warmer temperatures will increase suitable habitat and biomass for many temperate species. Upland systems dominated by oak species generally have low vulnerability due to greater tolerance of hot and dry conditions, and some oak, hickory, and pine species are expected to become more competitive under hotter and physiologically drier conditions. However, changes in precipitation patterns, disturbance regimes, soil moisture, pest and disease outbreaks, and non-native invasive species are expected to contribute to forest vulnerability across the region. Northern, boreal, and montane forests have the greatest assessed vulnerability as many of their dominant tree species are projected to decline under warmer conditions. Coastal forests have high vulnerability, as sea level rise along the Atlantic coast increases damage from inundation, greater coastal erosion, flooding, and saltwater intrusion. Considering these potential forest vulnerabilities and opportunities is a critical step in making climate-informed decisions in long-term conservation planning."

Black Spruce Bogs

This is a rare habitat type in Connecticut and we represent the southern terminus of its range and a habitat expected to be adversely affected by climate change in general.[172] As such changes in temperature regimes may decrease suitability for this habitat type in Connecticut.

Lowland mixed conifer

This forest type is generally uncommon in Connecticut and is considered to be of moderate to high vulnerability in the Northeast (though upland mixed conifer at above 1,000-foot elevation is doing better in Connecticut).[173] Good examples may be found in Norfolk and Eastford. Changes in temperature regimes and increased threat of non-native pests (hemlock woolly adelgid, *Adelges tsugae*) may stress this habitat type in Connecticut, particularly hemlock which is included in this grouping.

Beech, birch, maple forest

This forest type is considered highly vulnerable in Southern New England because of temperature changes, precipitation changes, change in timing of seasons, invasive plants and animals, pests and diseases, and is already stressed by development and habitat loss as well as terrestrial connectivity loss (roads and development).[174]

Freshwater forested wetlands

This forest type is considered highly vulnerable in Connecticut because of temperature changes, precipitation changes, changes in hydrology, changes in winter, sea level rise, storms and floods, change in timing of seasons, invasive plants and animals, pests and diseases, development as well as habitat loss and terrestrial connectivity loss (roads and development).[175]

Pitch pine-scrub oak

Generally thought to have low vulnerability,[176] this is already a rare habitat type in Connecticut, threatened by development, invasive plants and insect pests. Climate change is making our habitats more suitable for the southern pine beetle, but restoration projects on old sand plains may offer hope.

Cold water streams and headwaters and the associated shading forests

It is the cold water streams and headwaters that are the vulnerable community, but associated riparian forests are important for reducing water temperature and creating suitable habitat for Brook Trout and other associated wildlife.[177] It's important to note that in urbanized watersheds, existing riparian forests can be relatively intact, less stressed than roadside forests, and important to protect for carbon storage, habitat, floodwater retention, aesthetic, shade and other community benefits.

Lowland Atlantic white cedar forests

An already rare habitat type in Connecticut. These forested wetlands are threatened by increased severity and length of droughts in Connecticut.[178] Coastal examples could be threatened with increased saltwater intrusion into groundwater.

Coastal Forests

Rising sea levels, the associated landward migration of tidal marshes, and increased salinity of ground water, as well as our attempts to protect developed infrastructure threatens the viability and resilience of our coastal forests.[179]

Young Forests and Oaks for Wildlife

Although young forests and oaks may be less vulnerable to climate change than the other forest types listed above, young forests are Connecticut's least abundant forest age other than old growth of 120+ years and oaks require extra management to regenerate under current conditions. Both offer a special opportunity for creating wildlife habitats as forests are managed for greater resiliency in a climate context.

Not only do species such as Blue-winged warbler, Prairie warbler, American woodcock, and New England cottontail require young forest habitats, but also several forest interior birds use these open areas that provide abundant berries and insects for foraging during the nesting season as well as in migration. The bird-banded data collected in shrubland fields maintained for early successional species at the Bent of the River Audubon Center confirms this.

Both oaks and hickories are incredibly important to birds and other wildlife. Large birds (Wild Turkey, Wood Ducks, etc.) and a variety of mammals consume their nuts; while the caterpillars that they host are an important source of food for songbirds during the nesting season. Oaks in particular are the host plant for 557 species of lepidoptera.[180] Considering how intolerant oaks are to shade, if we want this genera to continue to be a part of Connecticut forests, forest management is necessary. Loss of this long-lived native hardwood would have an impact on Connecticut's carbon storage potential and dramatically influence forest bird species diversity and abundance.

Over browsing by white-tailed deer can reduce or eliminate forest regeneration, alter forest composition and structure, eliminate or reduce other wildlife species through direct or indirect competition, and drive some local plant species to extinction. White-tailed deer are widespread in Connecticut and are an increasing threat to forest regeneration, habitat value, and resilience.[181]

Funding, Programs, and Resources Needed for Implementation

Top Priority Actions

Enhance Existing State & Federal Funding Programs

- Bonding & Community Investment Act
- State Revolving Funds (Water Quality and Drinking Water)
- Regional Greenhouse Gas Initiative
- Federal LWCF and USDA Farm Bill Programs

Establish New Sources of Revenue

- Include comprehensive forest protection component in a Carbon Tax
- Enable Municipal Funding Option
- Establish Compensatory Mitigation Fund as part of "No Net Loss of Forest" policy

Provide Tax Incentives for Acquisition and Stewardship

- Expand existing corporate tax credit to individuals for land donations

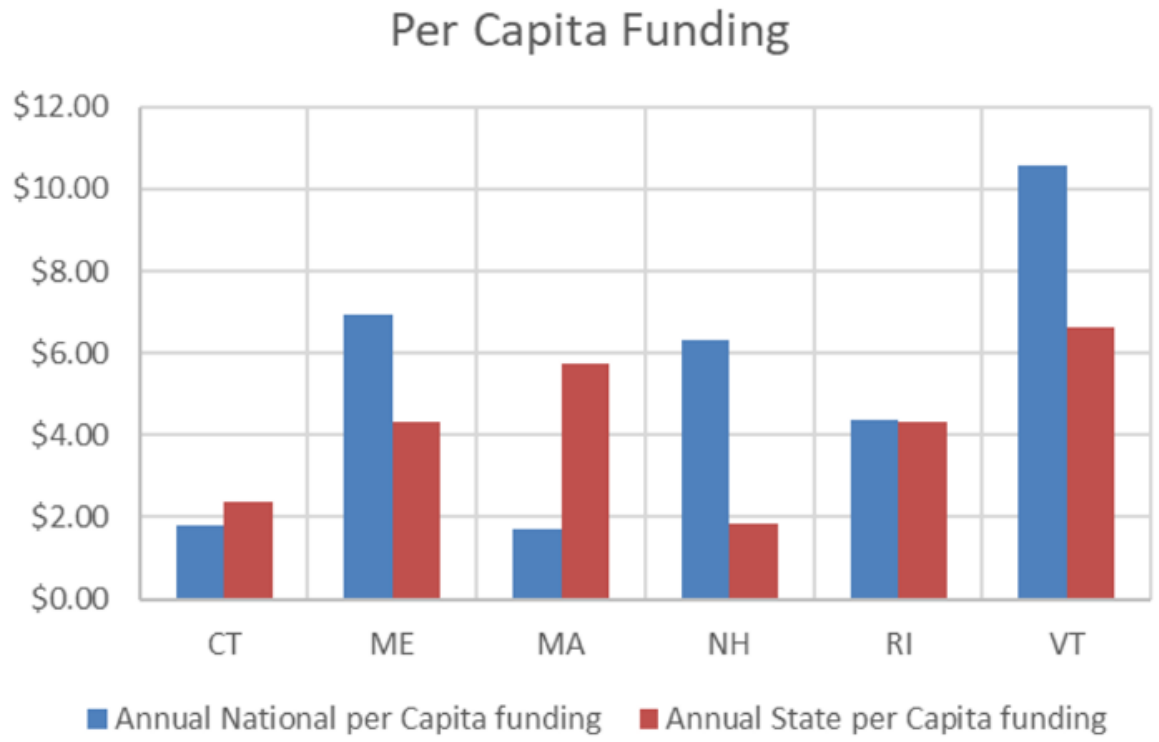

Figure 10. Connecticut's spending on land conservation -- $2.12 per year per person -- places the state last in combined state and federal per capita public funding among other New England states.[182]

Connecticut must ramp up investments in natural lands protection which is a necessary component of the state's plans to meet its ambitious goals of achieving a 100% net zero-carbon target by 2040.[183] Investments in natural climate solutions are relatively inexpensive compared to the costs of doing nothing or simply responding to magnified impacts of climate change.

1. Enhance Existing State & Federal Land Conservation Programs

State Programs

Increase state investments for existing land conservation programs and incorporate more specific climate-related criteria into selection of projects/level of funding. These include the Open Space and Watershed Land Acquisition Grant Program (OSWA), the Recreation and Natural Heritage Trust Program (RNHT), and the Recreational Trails Program (RTP).

- Source of funds: State Bonding
- Action required: Legislative
- Note: Typical bond authorizations for these programs have ranged from $3 to $7.5 Million per year, but allocation of those funds has neither been consistent nor adequate to meet project demands. Based upon specific Sub-Group recommendations related to forest protection, annual bond authorizations for OSWA and RNHT should be $25 Million, respectively, and $10 Million for the Recreational Trails Program. In states offering statewide bond referendums, voters have approved the dedication of significantly higher levels of funding for open space conservation.[184] With more specific carbon accounting criteria, the OSWA scoring may be further refined to award projects that provide higher carbon mitigation benefits.

Increase funding for Community Investment Act (CIA)

- Source of funds: Increase surcharge on local recording fee (currently $40)
- Action required: Legislative
- Note: The CIA provides dedicated funds to support community-level investments across four sectors: Open Space Conservation, Farmland Preservation, Affordable Housing, and Historic Preservation. The CIA is currently funded through a $40 surcharge on municipal recording fees, which is distributed as follows: $1 remains with the Town Clerk; $3 go to the municipality to pay for local capital improvement projects; $10 supplements the income to dairy farmers; and the remaining $26 is distributed to state agencies to fund matching grants to the four sectors enumerated above. The Forests Sub-Group recommends an increase in the surcharge on recording fees, ranging from $10 to $20, with the additional revenue to the CIA account distributed evenly to the four sectors. A $10 - 20 increase to the recording fee would add an estimated $1.5 - 3.0 million per year for the open space sector of the CIA account. This additional funding could be dedicated to urban forest improvement projects such as tree planting or re-planting and stewardship in underserved areas, as well as support for CT DEEP to administer the program.

Expand Urban Green and Community Garden Program to include Urban Forest Improvement Projects

- Source of funds: Community Investment Act
- Action required: Legislative
- Note: CT DEEP's Urban Green and Community Garden Program provides assistance to communities designated as targeted and/or distressed to develop or enhance urban

open spaces for public enjoyment and/or environmental education, including the development of a community garden or reclaiming and enhancing existing open space for the public's use. The Forests Sub-Group recommends expanding this program to specifically include funding for urban forest improvement projects. See also, Urban Forest Carbon Credit Program.

Utilize Portion of State Revolving Funds for Land Conservation/Green Infrastructure Projects

- Source of funds: Existing state revolving funds (SRF) for clean water and drinking water
- Action Required: None. Currently up to 10% of SRF may be used to finance green infrastructure projects, which may include street trees, bio-swales, land conservation, etc. However, legislative action would be required to mandate spending on green infrastructure projects. In 2019, S.B. No. 927, **An Act Creating the Environmental Infrastructure Fund Within the Connecticut Green Bank**, proposed expanding the types of projects the Green Bank can promote investment in to include environmental infrastructure, which, under the bill, is structures, facilities, systems, services, and improvement projects related to water, waste and recycling, zero-emission vehicle refueling, climate adaptation and resiliency, agriculture, land conservation, parks and recreations, and other environmental markets.
- Note: This is an opportunity for cross-sector dialogue about tapping into the Green Bank for creative financing for infrastructure projects to leverage co-benefits of land conservation including air pollution reduction, carbon removal, flood protection, food production, avoided costs for healthcare system, etc. See also, Urban Forest Carbon Credit Program.

Expand Use of Regional Greenhouse Gas Initiative (RGGI) funds to Forest Land Conservation

- Source of funds: Proceeds from sale of RGGI State Emission Allowances
- Action Required: Legislative
- Note: While RGGI participating states may use afforestation projects to award offset allowances (project-based GHG emission reduction outside of the capped electric power generation sector),[185] this recommendation proposes the state reinvest the proceeds from the CO2 allowance auctions to fund CT DEEP land protection projects, land acquisition staff capacity, due diligence, scientific studies related to forest science (including an assessment of current forest management practices and policies and impacts on climate mitigation goals), development of a state mapping system to identify forests of highest current or future conservation value, and public education and outreach programs promoting the importance of resilient forests, forest stewardship, etc. New Jersey is an example of a RGGI state that has a legislative mandate to spend a portion of RGGI proceeds on land sector activities.[186] At the same time, Connecticut should study forest carbon offset allowances available through compliance and voluntary markets for reforestation, improved forest management, and avoided conversion as well as programs that aggregate, evaluate and monitor forest offsets, in order to implement a system of paying landowners for enhanced carbon sequestration and storage with verifiable climate benefits and strict certification standards in place.

Federal Programs

Land and Water Conservation Fund (LWCF) – Forest Legacy & Highlands Conservation

- Source of Funds: $900 million authorized by Great American Outdoors Act
- Action Required: DEEP staff and funding (particularly in the Division of Forestry and Land Acquisition and Management Offices that administer the LWCF/Forest Legacy and Highlands Conservation Act programs) are needed to compete for these funds in a timely, coordinated way. Funding could also be used to update DEEP's GIS Property layer.
- Notes: LWCF funds support the protection of federal public lands and waters (e.g. national parks, forests, and wildlife refuges), but also supports voluntary conservation on private land. LWCF investments secure public access, improve recreational opportunities, and preserve ecosystem benefits for local communities.

  The Forest Legacy Program (FLP) is funded by the LWCF and administered by the USDA Forest Service in a partnership with state forestry divisions. Funds are used to protect privately owned forest lands through conservation easements or land purchases. It protects environmentally sensitive forest lands while allowing for ongoing sustainable forest management, and is critical in protecting forests from conversion to non-forest uses.

  The Highlands Conservation Act (HCA) is funded by the LWCF as a 1:1 matching grant program to protect lands with the highest conservation values in Connecticut, New York, New Jersey and Pennsylvania that are critical to provide a plentiful supply of clean water to the cities of the Northeast.

  In addition to the programs listed here, it's important to note that USDA Forest Service funding also helps support staff costs associated with DEEP's state service foresters and urban forestry program.

USDA Farm Bill Conservation Programs

- Source of Funds: Federal Farm Bill
- Action required: Support Farm Bill conservation title programs
- Note: There are many important conservation programs funded through the federal farm bill, and this is certainly not an exhaustive list. Emphasized here are a few programs that have particular application to forest acquisition and stewardship.

  The Environmental Quality Incentives Program (EQIP) is administered by the USDA Natural Conservation Service (NRCS). EQIP provides financial and technical assistance to agricultural producers and forest landowners to address natural resource concerns such as invasive species. Additional ecosystem benefits that this program provides include improved water and air quality, conserved ground and surface water, increased soil health, improved wildlife habitat, and mitigation against increasing weather volatility.

  The Regional Conservation Partnership Program (RCPP) is also administered by the NRCS. RCPP projects include on-the-ground conservation activities implemented by

farmers, ranchers and forest landowners that support land management, improvement, and restoration practices as well as acquisition of conservation easements to keep forests as forests.

The Working Lands for Wildlife (WLFW) program is a partnership between the NRCS, U.S. Fish and Wildlife Service, states, and local partners to provide technical assistance and funding to implement practices that enhance wildlife habitat on working forests. Of particular focus in Connecticut has been the creation of young forest habitats for New England Cottontail and over 50 other species of greatest conservation need that require these habitats.

2. Tax and Other Incentives

Expand Corporate Tax Credit for Donations/Bargain Sale of Open Space to Individuals for Land that meets certain Climate Mitigation Criteria and/or for Forest Carbon Services

- Source of Funds: Individual Tax Credit
- Action required: Legislative
- Note: The Forest Sub-Group should include recommendations for climate mitigation criteria to include in the next iteration of the State's Green Plan, which may then be tied into legislation providing for an individual income tax incentive for forestland protection. We may also want to consider transferable tax credits for conservation easement donations as offered in multiple states, allowing landowners with little taxable income to transfer tax credits to another taxpayer and/or carry the credit forward over a number of years. The New York tax credit is unique, offered not at the time of donation, but every year in an amount equivalent to 25% of the property taxes paid on land under easement.[187] Tax credits may also be allocated to landowners engaging in afforestation, reforestation, and other forest stewardship and restoration efforts with defined carbon mitigation benefits.[188] Extra incentives may be built in to the program to encourage landowners to pursue other co-benefits.

Enable Compensatory Mitigation for State and Local Projects

- Source of Funds: Developers make payments to a mitigation fund if unavoidable conversion of forest and other natural lands occurs.
- Action required: Legislative
- Note: Requiring mitigation for forest loss through the adoption of "no-net-loss of forest" laws would provide an opportunity to generate significant new funding for conservation from developers mitigating their forest impacts.[189] This program should also apply to disturbances on public land, i.e. any project conducted on public land that leads to a loss of forest cover must be compensated for by the state or municipality with an equivalent amount of replanting in another location (e.g., models in New Jersey and Maryland). Any program needs to carefully consider what is deemed "unavoidable conversion," which must be strictly construed (see below).

Incentivize the Siting of Renewable Energy Infrastructure to Avoid Loss of Forests, Farmland and Other Sensitive Lands

- Source of Funds: N/A
- Action Required: Legislative/Regulatory
- Note: Incentivize the development of renewable energy infrastructure on areas other than forests and other open lands by loosening regulatory requirements to do so (e.g. requiring only a general permit) and/or disincentivizing development on open lands by developing more stringent siting approval requirements. Require developers to make payments to a mitigation fund if unavoidable conversion occurs.

3. Municipal Funding Programs (See also Urban Forest Carbon Credit)

Enable Municipal Option to Fund Local Land Conservation, Stewardship and Climate Mitigation Strategies

- Source of Funds: Local Buyer's Conveyance Fee
- Action required: Legislative
- Note: The legislation is enabling, giving municipalities the option, if they so choose, to establish a buyer's conveyance fee program to generate a local source of revenue to implement nature-based climate solutions and other local environmental projects. 2020 draft legislation included specific authorization to use funds for local climate mitigation strategies and to offset loss of tax revenue from land that has been permanently protected. See www.ctconservation.org for case studies and other information.

4. Tax Revenue Options

Sales Tax Increase or a Percentage of Current Sales Tax Devoted to Fund Land Conservation and Related Programs

- Source of funds: Increase CT General Sales Tax by .125% (from 6.35% – 6.475%)
- Action required: Legislative
- Note: Using the State of Minnesota Clean Water, Land and Legacy Amendment model (funds natural and cultural heritage programs), a sales tax increase of .125% would generate an estimated $78.4 million to fund a variety of climate-related programs, including land conservation. Based upon an overall New England average, this tax increase would cost approximately $47 per family per year.[190] The revenue would not be a substitute for other state conservation funding; rather it would provide an additional source of dedicated funds which may be available to CT DEEP, as well as non-profits and municipalities through a competitive grant process. An alternative to a tax increase is to allocate a percentage of the existing general sales tax paid on outdoor recreation and related goods and services to fund land conservation and stewardship programs.

Carbon Tax

- Source of funds: Tax on power plants, developments, and other uses (including renewable energy infrastructure projects on forest or agricultural lands) responsible for greenhouse gas (GHG) emissions and/or loss of CO2 storage, with revenues to help pay for climate initiatives including forest carbon mitigation programs.

- Action required: Legislative
- Note: Carbon legislation in Washington State is a notable example.[191] If other subgroups are suggesting a carbon tax, then a portion of the revenue should go to investments in natural climate solutions.

5. Public – Private Partnership Pilot Programs to Advance Land Conservation

Connecticut Land Conservation Partnership Program

- Source of funds: State Bonding
- Action required: Legislative
- Note: This, and other suggested programs funded through bonding, could be packaged as part of a larger green bond program. Using the well-established New York State Conservation Partnership Program as a model, the state would partner with a private non-profit organization to offer competitive matching grants to qualified Connecticut land trusts for organizational capacity building, collaborations, stewardship/resource management, and conservation transaction support. Studies commissioned by the Land Trust Alliance found that stronger, more professional land trusts save more land.[192] Other public-private partnership programs may include DEEP personal services agreements with NGOs to provide direct services to municipalities and other NGOs for grant writing, grant administration, and project administration.

Urban Forest Carbon Credit Project

- Source of funds: Urban Forest Carbon Credit[193]
- Action required: None unless the state wants to incentivize partnerships, including (i) enacting enabling legislation for municipalities that want to set up special carbon districts; and/or (ii) using SRF; and/or (iii) expanding Urban Green and Community Garden Program, or other incentives.
- Note: This program would value carbon credit (metric tons of CO2 captured in urban forests), including quantifiable ecosystem and other co-benefits associated with urban trees (stormwater reduction, air quality, energy savings, health and equity benefits, as well as employment); value the carbon revenue; establish a value per year; and sell the carbon credits to garner funding for local preservation, planting, restoration and other projects. Whether or not there is an urban forest carbon credit program established in Connecticut, the state should fund a program for municipalities (especially in underserved/EJ areas) to increase urban tree canopy cover and resilience in plantings and post-establishment treatments/monitoring as well as, in appropriate circumstances, to maintain mature and large trees which provide especially high levels of community benefits services such as cooling, mental health, pollution reduction, and habitat.

Establishing a Forest Carbon Baseline for Connecticut

Top Priority Actions

- Develop a usable model to reliably monitor carbon sinks related to working and natural lands, or to utilize models developed by state, academic, and nonprofit partners involved with the U.S. Climate Alliance.
- Report on Connecticut's "forest carbon inventory" over time alongside reported emissions for the building, energy, and transportation sectors.
- Include goals for increasing Connecticut's forest carbon sink (a.k.a. "negative emissions") with the next update to the Global Warming Solutions Act.

Connecticut relies heavily on the U.S. Environmental Protection Agency's State Inventory Tool (SIT) modules[194] for estimating annual GHG emissions. SIT is an interactive spreadsheet model that calculates sector-by-sector GHG emissions based on numerous state-level data sets.

Currently, the Connecticut annual GHG inventory does not use the "land use, land use change, and forestry" (LULCF) SIT module. The SIT LULCF module applies national emission factors to state forest inventories. Data used in this model comes primarily from USDA Forest Service reports,[195] which can have significant sampling errors and inconsistent inventory methodologies over time. For Connecticut, this tool produces results that are not well understood.[196] For example, there are two large unexplained swings in total forest carbon flux (Figure 9). In 1998, a large increase in soil organic carbon and dead wood results in the total carbon flux in LULC changing from a sink to a source. Then in 2006, this trend sharply reverts, and soil organic carbon and litter becomes a large sink for CO_2 emissions. There are no changes in forest policy or disturbances that can account for these fluctuations.

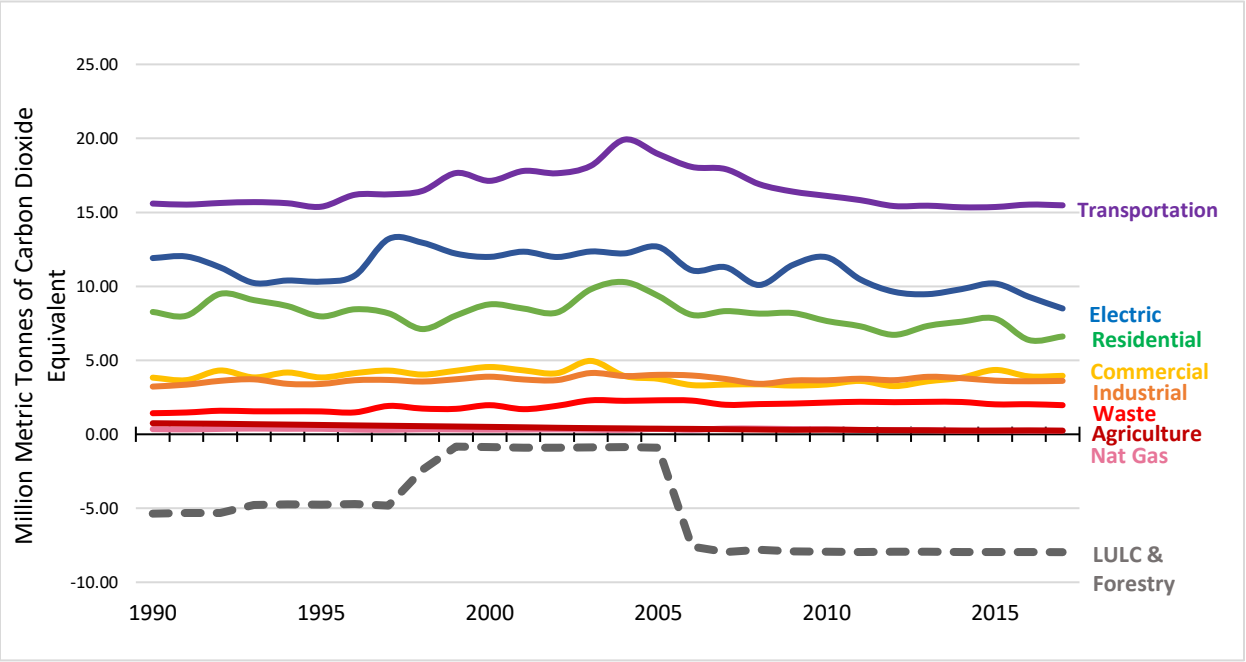

Figure 11. Annual Connecticut GHG emissions by sector 1990-2017. Sectoral estimates are from EPA SIT modules and state-level data. LULCF module data included in figure but not counted in annual GHG total.

In effect, Connecticut does not account for carbon sinks. Connecticut statutes PA-08-98 and PA-18-82 established several future reduction goals below baseline estimates. Baseline estimates are based on 1990 and 2001 annual emission totals, years in which carbon sinks have not been estimated for Connecticut forests. Methods to quantify and assess sources and sinks of carbon in the forestry and land use sectors will help inform Connecticut's policy efforts to meet its statutory emission targets.

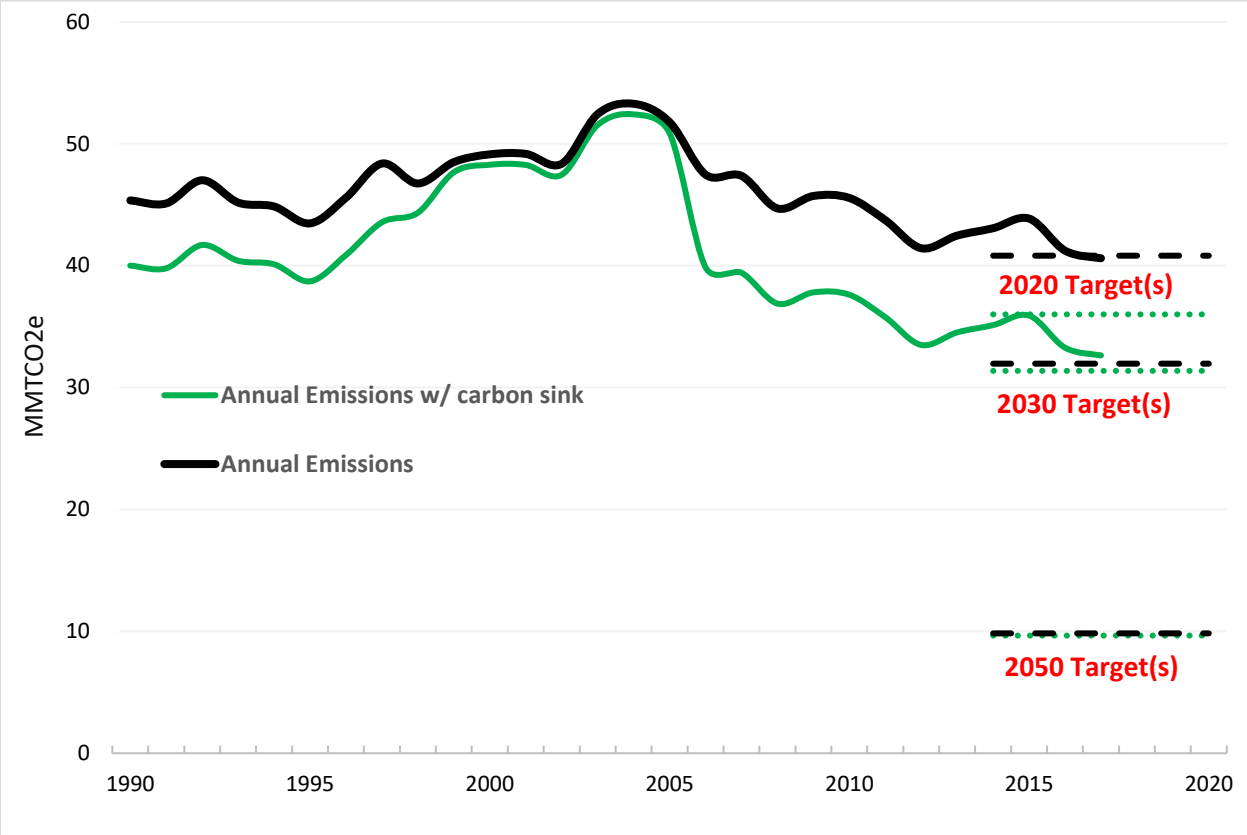

Figure 12. Annual Connecticut, sector-wide GHG emissions and future emission targets, 1990-2017. Black lines (solid and dashed) are annual emission totals without LULCF carbon sink accounting. Green lines (solid and dashed) are annual emission totals with LULCF carbon sink accounting.

Although the SIT LULCF estimates leave much to be desired in terms of accuracy, it does suggest that the carbon sequestered and stored in forests and related soils accounted for the equivalent of 20% of total emissions in 2017 (Figure 2). If estimates were reliable, the carbon sink from forests and related soils could represent about a decade's worth of emission reductions.

Another way to look at this challenge may be similar to what is currently done in Maryland (see Figure 3 below) where the state estimates that it can reduce emissions by 80% by 2040 using all available tools. However, the remaining 20% of emissions are proposed to be offset by "negative emissions" or carbon sinks from natural climate solutions such as management and protection of additional forest lands with increased carbon capture in mind.

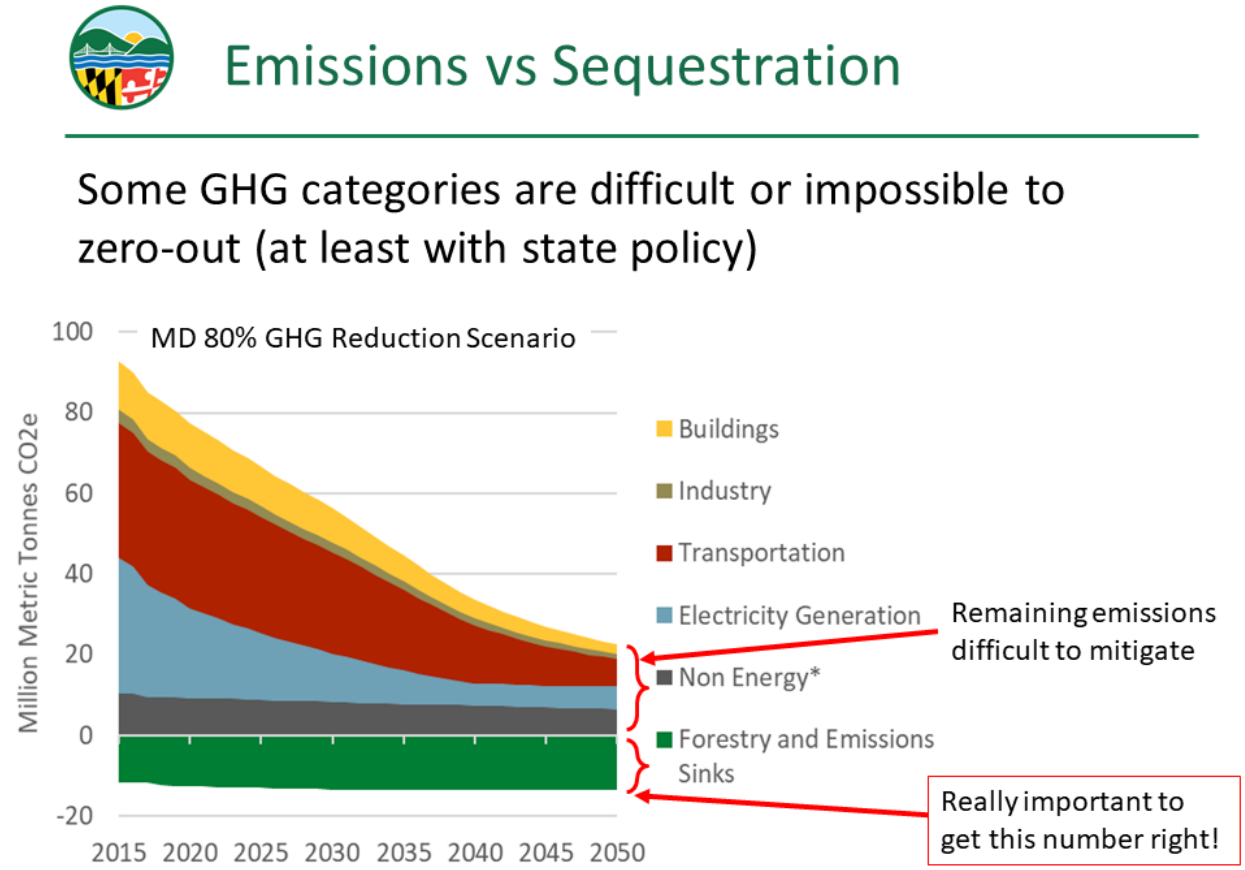

Figure 13. From presentation by Chris Hoaglund, Climate Change Program Manager with MD Department of the Environment showing the State efforts to both reduce emissions and account for sequestration from natural climate solutions, e.g. forests.

Accounting for carbon sink estimation through forestry is an important potential aspect of Connecticut's GHG emission inventory. Forests can be significant sinks for atmospheric carbon, potentially offsetting GHG emissions. For the New England region, projections show that despite land-use, land cover (LULC) change projected trends, carbon storage will increase.[197,198] Regardless of projected increases in soil respiration due to increased temperatures, the longer growing season and increased CO_2 fertilization account for this growth in carbon stock.

In a 2014 study,[199] a method was created to use land cover data for estimating land use, land change, and forestry (LUCF) impacts on GHG inventories. The authors used Stanford's Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) Carbon Storage and Sequestration model,[200] applied to the University of Connecticut's land cover change data (discussed below) for which carbon pool valuations had been assigned. The study was thus able to account for "foregone carbon sequestration" lost due to decreases in forested land cover over the 25-year period of the land cover dataset. Continuation of this work can inform state and local policy by accounting for CO_2 emissions from LUCF impacts while highlighting the potential for carbon sequestration to meet state statutory GHG emission goals.

The data that provided the basis for the Tomasso and Leighton (2014) study is from the University of Connecticut's Center for Land Use Education and Research (CLEAR). CLEAR has a long-running project, Connecticut's Changing Landscape (CCL), that uses remote sensing technology to chart changes in the state's major land cover categories over time. CLEAR developed the CCL project specifically to enable the public to compare multi-temporal land cover data sets, based on 30-meter pixel Landsat imagery.

The data in the CCL viewer dates back to 1985, the first year for which imagery of this resolution was available. CLEAR used cross-correlation analysis, which employs statistical analysis to identify pixels indicating a potential change between images, to produce a consistent land cover dataset for land cover change over time (Hurd et al., 2003[201]). Potentially changed pixels were identified and then merged with the 1985 classification to create the 1990 classification. This process was done for the 1995, 2002, 2006, 2010, and 2015 classifications, resulting in a 30-year record of land cover change for the state with 12 land cover categories. Land cover change data is compiled for the entire state, by town, by watershed, and shown in geographically-specific maps.

Previous work to construct a baseline in forest carbon storage has not yet resulted in a reproducible methodology for annual reporting. It should be a top priority to develop a usable model for reliably charting carbon sinks related to working and natural lands, and/or to utilize models developed by state, academic, and nonprofit partners involved with the U.S. Climate Alliance.

Review & Rank of 2011 Climate Preparedness Report Recommendations

One of the important charges to the Forests Sub-Group was to review the recommendations made in the 2011 Connecticut Climate Change Preparedness Plan: Adaptation Strategies for Agriculture, Infrastructure, Natural Resources and Public Health Climate Change Vulnerabilities.

This important report included recommendations on 15 Best Management Practices, 30 Research, Monitoring, and Education priorities, and 22 Policy, Legislation, Regulation, and Funding priorities. The members of the Forests Sub-Group utilized a survey and voted to determine the highest priority actions for Forests. The top priorities in each category follow:

Top Priority Actions: Best Management Practices

- Identify and conserve ecosystem services vulnerable to climate change.
- Encourage land management behaviors that support ecosystem services.
- Encourage adaptation strategies, including natural habitat conservation, Low Impact Development (LID) Best Management Practices (BMPs), agriculture water BMPs and drinking water treatment standards that will ameliorate the effects of water inundation.
- Apply adaptive management procedures.
- Increase active management of upland forests and reduce non-climatic stressors.
- Consider the public health needs of vulnerable populations in climate change adaptation planning.

Top Priority Actions: Research, Monitoring, and Education

- Engage and educate private landowners to manage their lands to minimize risk from climate change.
- Build public consensus for adaptation strategies through education and outreach.
- Develop educational campaigns for climate change adaptation awareness in Connecticut targeted at multiple sectors.
- Advance regional research and modeling to guide conservation efforts.
- Assess future flooding risks to natural and built infrastructure, including agricultural operations and public health and safety.
- Develop Connecticut- specific climate change projections for temperature, precipitation and sea level rise and support monitoring efforts for these climate drivers.
- Include students (future stakeholders) in climate change programs.
- Partner with educational institutions or organizations that conduct research.

Policy, Legislation, Regulation, and Funding: Top-Ranked Priorities

- Acquire land and conservation easements in riparian areas adjacent to coldwater streams.
- Target headwaters for protection throughout the state.
- Reevaluate Connecticut's Green Plan and open space grant programs to prioritize acquisition of land and conservation easements for habitats most at risk from climate change.
- Collaborate among state agencies, municipalities and non-profits within Connecticut to implement regulations and policies that promote and facilitate the conservation of habitats and species most at risk from climate change.
- Continue to support regional cooperation on climate change adaptation through involvement in regional planning activities.
- Proceeds from RGGI auctions should support climate change adaptation work identified in this report and in accordance with Section 22a-200c(c).
- Implement new or modified policies that would encourage appropriate land use and reduce repetitive losses.
- Acquire land and conservation easements to provide upslope advancement zones adjacent to tidal marshes.

Synergies with CT Forest Action Plan and Other GC3 Working Groups

The Forests Sub-Group did not develop this report in a vacuum, and tried to stay connected to the efforts of other Working Groups, Sub-Groups, and Subcommittees of the Governor's Council on Climate Change. In addition, we were mindful of the development of the 2020 Forest Action Plan for Connecticut by the Department of Energy and Environmental Protection, and hosted a presentation on this topic. Following are some of the notable synergies with these other efforts.

2020 Connecticut Forest Action Plan

Every 10 years, each State and US Territory is required to develop and submit to the USDA Forest Service a statewide comprehensive Forest Action Plan that covers all lands within its jurisdiction; Federal, State, private, municipal, and non-profit. The Plan requires considerable stakeholder input and public outreach ensuring identified strategies are the "State's" priorities but based upon three overarching national priorities 1) Conserving and managing working forest landscapes for multiple values and uses, 2) Protecting forests from threats, 3) Enhancing public benefits from trees and forests. State-based strategies are built upon an in-depth assessment of current forest and tree conditions.

As required in the 2008 Farm Bill, Connecticut developed and submitted its first Forest Action Plan in 2010. This plan was slightly revised in 2015 and by December 31, 2020 a new Forest Action Plan will be submitted to USDA Forest Service. Having a Forest Action Plan allows Connecticut to receive substantial annual federal financial assistance to address the threats and issues we as a State have identified.

Other GC3 Working Groups and Sub-Groups

As the Forests Sub-Group was holding public meetings and preparing this report, other GC3 Working Groups and Sub-Groups were developing recommendations that at times touched on forests. The following groups deserve special recognition for their partnership and coordination:

- Agriculture/Soils, Rivers, and Wetlands Sub-Groups;
- Equity and Environmental Justice Working Group;
- Science & Technology Working Group; and
- Progress on Mitigation Strategies Working Group.

This report is being shared with those Working Groups and others to solicit additional input and suggestions before presenting an updated report to the full GC3 Council.

Glossary of Terms & Endnotes

We are grateful to Mark Ashton, Robert Fahey, Edward Faison, and CT State Forester, Chris Martin for identifying definitions for the terms listed below from sources such as the USDA Forest Service FIA Glossary of Terms[202] that provided multiple definitions, and additional sources which we cite individually below:

Active Management: Attaining desired forest objectives and future conditions using silvicultural management practices. These may include timber harvesting, thinning, invasive plant control, prescribed fire and other activities for improving forest health, age and species diversity, wildlife habitat, erosion control, and fire suppression.[203]

Adaptation: How forests react over time to all impacts including climate, fragmentation, insect disease, and pollution.

Carbon sequestration: The process of removing carbon from the atmosphere for use in photosynthesis, resulting in the maintenance and growth of plants and trees. The rate (or amount and speed) at which a forest sequesters carbon changes over time. In the northeastern United States, carbon sequestration rates typically peak when forests are young to intermediate in age (around 30–70 years old), but they continue to sequester carbon through their entire life span.[204]

Carbon storage: The amount of carbon that is retained in a carbon pool within the forest. Storage levels increase with forest age and typically peak in the northeastern United States when forests are old (>200 years old).[205]

Competitive hierarchy: Longer lived species are site restrictive and will dominate specific sites reducing structural diversity and complexity.

Core forest: unfragmented forest land that is three hundred feet or greater from the boundary between forest land and nonforest land. In its forest fragmentation study, UConn-CLEAR divided core forests into Small Core (<250 acres), Medium Core (250 – 500 acres), and Large Core (500+ acres).[206]

Diversity Theory (a.k.a. "negative density dependence hypothesis"): Forests have evolved complexity over time including the adaptation and resistance to native insects and disease.

Forest health: A tricky term because it is often used in the "eye of the beholder" and can refer to several different aspects of a forest. Most common use refers to an absence of invasive insects, disease, and related problems for tree survival.

Forest land: Land that is at least 10 percent stocked by forest trees of any size, or formerly having had such tree cover, and not currently developed for non-forest use. The minimum area considered for classification is 1 acre. Forested strips must be at least 120 feet wide.

Forest management: Forest management is the process of planning and implementing practices for the stewardship and use of forests to meet specific environmental, economic, social and cultural objectives. It deals with the administrative, economic, legal, social, technical and scientific aspects of managing natural and planted forests. It may involve varying degrees

of deliberate human interventions, ranging from actions aimed at safeguarding and maintaining forest ecosystems and their functions, to those favoring specific socially or economically valuable species for the improved production of forest goods and services.[207]

Forest preserve/reserve: an area of land that is protected and managed in order to preserve a particular type of habitat and its flora and fauna which are often rare or endangered.[208] Natural Area Preserves are defined in the Connecticut General Statutes (Section 23-5b) as "an area ... containing, or potentially containing, plant or animal life or features of biological, scientific, educational, geological, paleontological, or scenic value worthy of preservation in their natural condition." The statute further defines "protected resources" as "the particular conditions, vegetation or natural features within a natural area preserve, including, but not limited to, any species of plant or wildlife, which require protection and preservation in order to continue and flourish."

Forest protection: Forest land withdrawn from conversion to other uses such as commercial, industrial, or residential development through statute or administrative regulation.[209]

Intermediate disturbance hypothesis: Relates to forest succession. How forests adapt and interact to site disturbance and climate. Guided by length in between disturbances and severity of disturbance. Forest diversity simplifies over time to late successional species.

Mitigation (of forest carbon): Action taken to alleviate potential adverse effects of climate change by increasing carbon sequestration in forest ecosystems.

Natural Forest Management: not subject to artificial regeneration, maintained or restored to conditions demonstrating absence of post-colonial human settlement and influence.[210]

Old-growth forest: a stand of trees characterized by a diversity of tree species in several size classes, advanced age, downed logs and snags, large canopy trees, tree fall gaps, undisturbed soils, and other plants and animals that prefer old growth.

Passive Management: The conscious management decision not to actively manipulate the vegetation, and "let nature take its course." Not considered a silvicultural system however does require monitoring, and certain events may necessitate implementation of some short-term active management. Examples include control of exotics, fire management, disease and insect management, wildlife management, recreation management, removal of diseased or weakened trees that pose safety hazards, and loss of desirable attributes Other treatments may be allowed if the future of the area is compromised by external factors such as heavy browsing by deer or other animals. Control measures are limited, and their only purpose is to protect the area from destruction.[211]

Redundancy: A form of resilience. Multiple species comprising the same functional role.

Reforestation: Area of land previously classified as forest that is regenerated by seeding, planting trees, or natural regeneration.

Resilience: Rate of recovery from a disturbance. The ability of forest to absorb impacts over time. The capacity of an ecosystem to return to its previous pre-disturbance condition.

Resistance: Affiliated with resilience. The capacity to absorb disturbance and remain unchanged.

Silviculture: the art and science of controlling the establishment, growth, composition, health, and quality of forests and woodlands to meet the diverse needs and values of landowners and society on a sustainable basis.[212]

Sustainable forestry: forest management that ensures forests contribute maximally to mitigating and adapting to climate change during the next 30 years as seen through a systems lens that includes in-forest carbon, forest product carbon storage, and substitution benefits, while also maintaining the ability of forests to help current and future generations to meet their social, economic, ecological, cultural, and spiritual needs.[213]

Urban Forest: Land that would otherwise meet the criteria for forest land but is in an urban-suburban area surrounded by commercial, industrial, or residential development.[214]

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