NEW ENGLAND FORESTRY FOUNDATION

A Climate Wedge: Estimating New England's Carbon Storage Opportunities

New England Forestry Foundation (NEFF) Report on Methodology and Analysis

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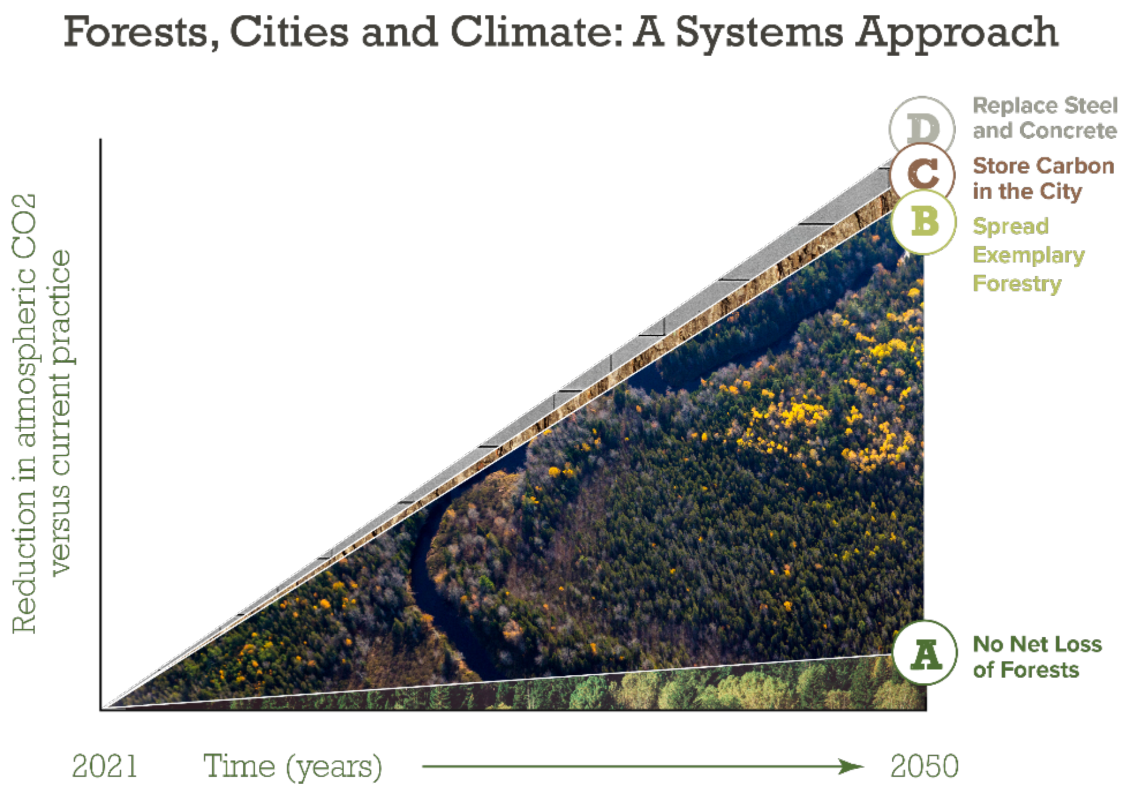
I. INTRODUCTION

New England Forestry Foundation (NEFF) has identified four categories in which New England—and more specifically New England's forests, the forest products industry, and communities—can achieve significant contributions to mitigate climate change. These contributions not only can be made for the long term but also, importantly, are achievable within the next 30 years. Climate scientists now widely agree that rapid and deep cuts to atmospheric greenhouse gas emissions are needed throughout the next three decades to avert the worst projections of climate change effects [IPCC 2022]. Identifying the four categories, and quantifying the climate change mitigation opportunity of each, is important. It can assist in prioritizing resources for further study, inform policy decisions, and empower the communities, organizations, businesses, and governments of New England to recognize and act upon our collective potential to create real change.

NEFF proposes that a "climate wedge" is useful as a means of summarizing and depicting the potential of New England's forests and forest products to mitigate greenhouse gas emissions. The wedge has four component parts, which are listed below.

- Replace Steel and Concrete – This portion of the Climate Wedge represents the potential reduction in carbon dioxide emissions by building with construction materials made from wood, which can be produced with lower greenhouse gas emissions compared to steel and concrete.
- Store Carbon in the City – This portion of the Climate Wedge includes the potential to increase the amount of carbon that is stored within wood building materials in urban and suburban centers.
- Spread Exemplary Forestry – This portion of the Climate Wedge is the potential additional carbon that can be stored in New England's forests if forest land is managed in accordance with NEFF's Exemplary Forestry standards, which call for forest management from a landscape perspective that achieves three co-equal goals of improved productivity, wildlife habitat enhancement, and increasing carbon storage over time.
- No Net Loss of Forests – This portion of the Climate Wedge represents the avoided loss of in-forest carbon storage if future anticipated forest loss from development does not occur. In other words, this assumes that the new infrastructure associated with future population increases would not require forest conversion, but instead is accommodated through redevelopment, smart development, and in-development principles). This strategy does not assume reforestation to offset converted forest land.

Figure 1. NEFF Climate Wedge, with potential for reduction of carbon dioxide emissions from four climate change mitigation pathways from the forestry industry, from present day through 2050



Note: This draft includes Methods and Results from the Spread Exemplary Forestry component only.

SPREAD EXEMPLARY FORESTRY

To answer the question of how much more carbon New England forests could store while maintaining harvest, NEFF compared average merchantable timber stocking on private land in each county of New England[1] against what NEFF has approximated as "ideal" stocking given the diversity of stand sizes recommended by ecologists to benefit biodiversity while producing timber. This target is approximately 25 cords per acre and 16 counties in Maine, New Hampshire, and Vermont were found to have potential. A USFS program which queries FIA data, EVALIDator, was used to determine the carbon storage in forest land with 25 cords per acre per county and landowner class. Based on the FIA data provided through EVALIDator, such forest land has approximately 167 MTCO2e per acre for all carbon pools excluding soil carbon. By calculating the difference between existing and target stocking for each county, NEFF estimated the potential to store more carbon in the forest as approximately 542 million MTCO2e. This is equivalent to taking 117 million cars off the road for a year.

[1] Except counties in Rhode Island and areas like Cape Cod where the pitch pine-oak forest type dominates.

A note on units: All carbon data in this report is given in metric tons of carbon dioxide equivalents (MT CO_2e) or million metric tons CO_2e (MMT CO_2e). Though other data are largely given in U.S. customary units (e.g., acres, cords, square feet), we have followed the common practice of reporting carbon in metric units. Carbon was converted to CO_2e using the following equation: 1 MT C = 3.67 MT CO_2e.

II. METHODOLOGY – SPREAD EXEMPLARY FORESTRY

OVERVIEW OF APPROACH

Forest lands already store a large volume of carbon, globally storing approximately 400 gigatons (Kayler et al 2017). Here in New England, they also store and sequester a lot of carbon. Maine's forests sequester an amount each year equivalent to roughly 70 percent of total emissions in the state (Daigneault et al, 2020). In Vermont, the carbon stored in forests is equivalent to more than 290 years of Vermont's current levels of carbon dioxide emissions (Forest Resources Associates, 2020). NEFF proposes that New England's privately owned managed forest land has the potential to do far more to address the climate emergency if it were intentionally managed and stocked with consideration for climate mitigation goals in combination with forest productivity and wildlife objectives. To achieve its climate mitigation potential, NEFF proposes a twofold approach: that management in understocked working forest land should result in increased in-forest stocking and associated carbon storage, and that management in fully stocked working forest land should take a measured, intentional approach in harvesting, where appropriate, and converting harvested wood into long-lived wood products. By increasing in-forest carbon storage in understocked stands and substituting a portion of carbon emissions-intensive construction materials such as steel and concrete with long-lived wood products harvested from fully stocked stands (in anticipation of natural mortality), the forests of New England have potential to substantially increase their contribution to climate change mitigation.

To quantify this potential, NEFF has conducted an analysis of FIA data and calculated existing carbon storage across New England by county. Calculations of existing carbon storage were then used to calculate carbon storage opportunities: the potential for additional storage that could be achieved if understocked private forest land were managed to achieve higher in-forest stocking. The potential for capturing mortality through harvesting forest products from fully stocked private forest land and utilizing them in long-lived wood products, replacing a portion of more carbon-intensive construction materials such as concrete and steel, has not yet been calculated, as the forest modeling needed for such stands has not been conducted.

NEFF has developed two sets of Exemplary Forestry standards that outline a suite of management strategies aimed at three co-equal goals: improving forest productivity, maintaining or improving wildlife habitat, and mitigating climate change (including but not limited to carbon storage). The management approach described in

Exemplary Forestry in the Acadian Forest (Perschel and Giffen, 2018) is applicable to Acadian forest types, which extend across most of the landscape of northern New England (Maine, New Hampshire, and Vermont). *Exemplary Forestry for the 21st Century: Managing New England's Central and Transition Hardwood Forest for Bird's Feet and Board Feet at a Landscape Scale* (NEFF, 2022) describes Exemplary Forestry standards and recommended silvicultural systems for the Central and Transition Hardwood forest types, which cover most of Connecticut, Massachusetts, and Rhode Island, as well as portions of southern Vermont, New Hampshire, and Maine.

NEFF's Exemplary Forestry standards for the Acadian Forest call for an average stocking of approximately 25 cords of merchantable wood per acre on actively managed forest lands. This determination is based on extensive modeling for the Acadian forest types: northern hardwoods and spruce-fir. Though modeling has not been completed for the Central and Transition Hardwoods region, the target stocking for these types appears to be in the same general range, based on analysis of stand size class distribution recommended by expert ecologists for the region and the average existing stand condition. In the analysis described herein, NEFF's calculation of the opportunity for additional carbon storage and/or utilization is focused on privately owned forest land. All government ownerships (federal, state, and municipally owned lands) are excluded. The category of privately owned land is inclusive of all private forest land and therefore includes the full spectrum of private landownerships: individuals and families, organizations, institutions, corporations, and ENGO lands. Further, translating increasing in-forest stocking to reductions in GHG levels (e.g., the calculations included here on the equivalency between increased stocking and cars off the road) requires assuming that forest harvest on managed private lands will be sustained rather than reduced or ceased entirely as would be the case under forest preservation or wilderness designation scenarios.

The calculations used in this analysis are based on data from the USDA Forest Service FIA database, using 2019 inventory data, which were the most recent available in 2021. NEFF used the EVALIDator tool (Version 1.8.0.01, available at https://apps.fs.usda.gov/Evalidator/evalidator.jsp, version updated October 31, 2019) to access, sort, and filter the FIA data. In calculating current and potential additional carbon stocking, NEFF also used a multiplier acquired from the Environmental Protection Agency (EPA) to convert the region-wide carbon storage opportunities as described below into an equivalent number of cars taken off the road.

DETAILED METHODS

Defining Carbon Pools

EVALIDator quantifies five pools of carbon, each with its own specific definition and bounds, which can be independently queried:

- Above Ground Live Carbon: Carbon in the aboveground portions (excluding foliage) of live trees with a diameter >=1 inch and for seedlings and shrubs. Calculated for both timber and woodland species.
- Below Ground Live Carbon: Carbon in the belowground portion of live trees (coarse and fine roots) with a diameter of >=1 inch and for seedlings and shrubs. Calculated for both timber and woodland species.

- Dead Wood Carbon: Carbon in down dead and standing dead wood. Carbon of woody material >3 inches in diameter on the ground, and stumps and their roots >3 inches in diameter as well as carbon in standing dead trees, including coarse roots.
- Litter Carbon: Carbon of organic material on the forest floor, including fine woody debris, humus, and fine roots in the organic forest floor layer above mineral soil.
- Soil Organic Carbon: Carbon in fine organic material below the soil surface to a depth of 1 meter. Does not include roots.

In this analysis, NEFF included all carbon pools *except* the soil organic carbon pool. The soil carbon pool as calculated by EVALIDator uses a model calculation. Based on a review of scientific literature and consultation with regional experts in soil carbon research, NEFF has found that data from studies using soil carbon models and data from various in-field soil carbon measurements associated with different management practices are widely variable, in some cases contradictory, and highly dependent on the density of sampling, and assumptions. It is therefore challenging to compare results across studies and to rely with confidence on results from any one particular modeling or field study. Further, and perhaps more pertinent to NEFF's goal in this study, a review of the most relevant literature has led us to conclude that the soil carbon response to differences in forest management is not well understood (NEFF, 2020). We assume that Exemplary Forestry management may, over time, increase soil carbon, but for the purposes of these opportunity calculations we have been conservative and excluded the soil carbon pool but included four carbon pools: Above Ground Live, Below Ground Live, Dead Wood, and Litter. It has been demonstrated through empirical data that those carbon pools can be impacted through silvicultural management within the 30-year timeframe addressed here.

NEFF utilized separate but related methods to query and analyze data and describe results for this study for the Acadian Forest (generally, northern New England) and the Central and Transition Hardwoods Forest (generally, southern New England). The methodologies utilized are described below, followed by a brief description of results and implications for management and the associated potential to mitigate climate change.

Estimating the Level of Carbon Stocking Achievable through Exemplary Forestry

NEFF used two approaches to estimate how much carbon could be stored in the forest under management that meets the Exemplary Forestry standards (referred to here as EF management). The first approach modeled the application of the silvicultural approach called for in the Exemplary Forestry standards for the Acadian Forest across a large region of northwestern Maine in order to estimate the average carbon storage per acre that could be maintained over the long term in the Acadian Forest. The second approach calculated the amount of carbon per acre estimated to be stored in forests with the benchmark stocking (in merchantable volume per acre) expected under EF management.

EF management in the Acadian Forest is expected to lead to a benchmark volume of 25 cords of merchantable wood per acre. The EF standards call for stocking that fully occupies the site, defined as an average of B-line stocking for stands not currently being regenerated. B-line stocking from the appropriate stocking guides[2] for the various stand size classes called for in the EF standards for the Acadian Forest translates to an average standing volume of approximately 25 cords per acre.[3] That is the stocking level considered adequate to achieve the three primary objectives of Exemplary Forestry: increasing forest productivity (including wood products), enhancing wildlife habitat for the full range of native vertebrate species[4] present, and mitigating climate change by increasing carbon storage in the forest through time.

Approach 1: Modeling Exemplary Forestry for the Acadian Forest

NEFF conducted detailed modeling using the Forest Vegetation Simulator (FVS) to simulate the effects of applying EF management to a 5-million-acre region of northwestern Maine, starting from current stand conditions as derived from FIA data. The methods and results of this modeling are presented in a NEFF report (Pounch and Giffen 2021) and have been submitted for publication in a peer-reviewed journal.[5] The modeling translated the EF standards into specific silvicultural prescriptions for each stand type, based on forest type, stand size class, and stocking and implemented these prescriptions over 60 years. After some time to allow the forest to recover from previous management, the modeling showed that average standing volume increased to over 25 cords per acre, and average carbon stocking increased to 167 MT CO2e/acre. The modeling suggested that these levels of timber and carbon stocking would be maintained over the long term under EF management.

Approach 2: Exemplary Forestry Proxy – Acadian Forest

As a real-world comparison, NEFF identified a set of lands in Northern New England (Maine, New Hampshire, and Vermont) that have current stocking near the EF target of 25 cords/acre, and calculated the carbon stocking on those lands. We used EVALIDator to query FIA data by county and FIA ownership class in search of areas where the current existing condition was close to 25 cords of merchantable volume per acre. Ownership class was included as a relevant factor because management approaches are thought to differ between public and private landowners. It was assumed that publicly owned forest land would be more likely than any given privately owned forest land to be managed to a stand size class distribution that is closely aligned to that recommended by DeGraaf et al. (2005) and other wildlife experts.

NEFF found that state-owned forest lands in six counties across the northern New England states have existing stocking between 24 and 26 cords per acre. In Table 6 below, the stocking and carbon storage per pool for each county is presented. These lands were used as a proxy for lands that are managed to EF standards. The

[2] Stocking guides are forest-type specific (e.g., Northern Hardwoods) and specify the stocking needed for stands of different mean diameters.

[3] See Pounch and Giffen (2021), Table 14, for details of how this was calculated.

[4] Regarding optimizing for wildlife and timber production, DeGraaf et al. (2005) recommends a stand size class distribution which consists of 5 to 15 percent seedlings, 30 to 40 percent in saplings and poletimber, and 40 to 50 percent in sawtimber.

[5] The paper has been submitted for peer review as of October 2022. The work presented in the paper differs slightly in scope from that presented here. The paper addresses the Acadian Forest only (defined throughout NEFF's work as the areas mapped as Northern Hardwoods and Spruce-Fir zones by Foster, 1992), while this report addresses all of New England. Both analyses were done by county, but the analysis in the paper included only those portions of each county that are mapped as falling within the Acadian Forest zone. As a result, the total carbon storage opportunity reported in the paper was 488 MMT CO2e, rather than the 542 MMT CO2e reported here.

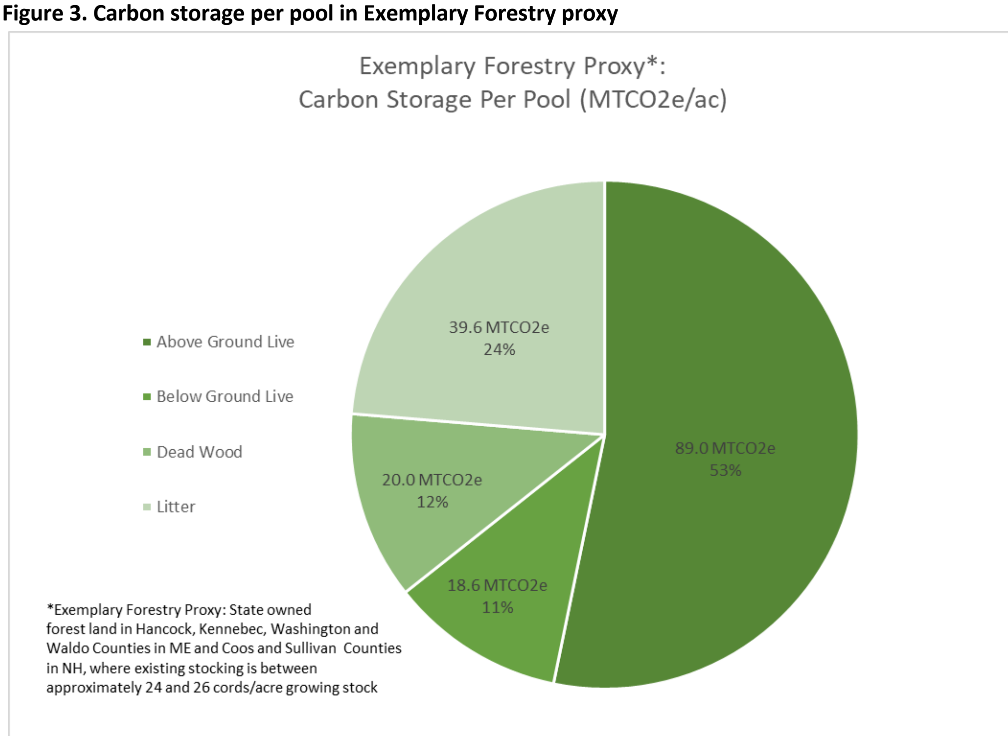
Exemplary Forestry proxy condition (also presented in Table 6) is defined as the average condition across the state-owned lands in these six counties.

Table 6. Acadian Forest Exemplary Forestry proxy: Stocking and carbon storage per pool

Exemplary Forestry Proxy Condition, using MTCO2e Per Acre as Unit						
State-Owned Forest Land Per County	**Cords Per Acre Stocking**	**Sum of 4 Carbon Pools**	**AboveGround Live**	**Belowground Live**	**Dead Wood**	**Litter**
Hancock County, ME	25.9	165.8	87.4	18.5	19.1	40.9
Kennebec County, ME	24.9	173.9	91.0	18.9	14.2	49.9
Washington County, ME	24.5	122.0	56.1	12.2	16.3	37.5
Waldo County, ME	25.7	125.6	80.3	17.0	14.9	13.5
Coos County, NH	25.3	179.4	96.3	19.4	21.2	42.5
Sullivan County, NH	24.7	193.8	110.4	22.1	20.8	40.5
Exemplary Forestry Proxy	***25.2***	***167.2***	***89.0***	***18.6***	***20.0***	***39.6***

As depicted above, there is approximately 167.2 metric tons carbon dioxide equivalent (CO2e) in the four carbon pools assessed on each acre of forest land under the Exemplary Forestry proxy condition. Figure 3 below shows the relative proportion of each pool of carbon. The Above Ground Live pool of carbon is the largest pool, with approximately 89.0 metric tons CO2e per acre, accounting for more than 50% of the total carbon storage in the four pools assessed.

Figure 3. Carbon storage per pool in Exemplary Forestry proxy



Approach 2: Exemplary Forestry Proxy—North Central and Transition Hardwood Forest

As described above, NEFF conducted detailed analysis and modeling of the stand growth response and carbon storage consequences that would result from practicing Exemplary Forestry management in the Acadian Forest of Maine for a 60-year future. Those modeling results informed the selection of a target stocking of 25 cords per acre of merchantable wood. Developing equivalent stocking and carbon storage targets for the Central and Transition Hardwoods forests, which dominate the forests of Connecticut, Massachusetts, Rhode Island, and portions of southern Maine, New Hampshire, and Vermont, will require modeling work similar to the analysis that was conducted for the Acadian Forest.[6] For the analysis presented herein, and until the detailed modeling is complete, NEFF created a preliminary rough estimate of expected stocking under Exemplary Forestry management in the North Central and Transition Hardwoods forests by using FIA data from Massachusetts and Connecticut where the North Central and Transition Hardwoods are the dominant types, summarized below. Although this represents only a preliminary, rough estimation, it is notable that the existing forest conditions in southern New England are generally heavily stocked across all landowner classes (private, state, federal, etc.), with per acre stocking generally greater than 30 cords per acre.

The rough estimate was made by first querying 2019 FIA data in EVALIDator for the volume of merchantable volume in live trees for each FIA-defined stand size class across all counties in Massachusetts and Connecticut except as noted below. Rhode Island plots were not included in the analysis even though forest land in Rhode Island would generally be considered part of the North Central and Transition Hardwoods forest region: based on NEFF's expertise, management activities in Rhode Island are not generally occurring at a scale that would contribute significantly to the region's silviculture or actively managed forest landscape. Certain counties in Massachusetts were also excluded from the analysis, as they do not generally consist of managed forest land or tree cover consistent with the North Central and Transition Hardwoods forest types. These counties include: Barnstable County, Dukes County, Nantucket County, and Suffolk County.

NEFF's Exemplary Forestry standards for both the Acadian Forest and the Central and Transition Hardwoods forest types are based on maintaining a distribution of stand size classes across the landscape as recommended by DeGraaf et al. (2005) that optimizes for wildlife habitat values and timber production together. This distribution includes 5-15% of forest area in seedling stands, 30-40% in sapling and pole stands, and 40-50% in sawtimber stands.

Because DeGraaf et al. grouped sapling and pole stands together in a single size class, whereas the FIA database groups seedling and sapling stands, these stand size class targets needed to be translated into the FIA categories. Table 2 shows how the stand size class categories used in DeGraaf et al. were crosswalked to the FIA categories for this analysis. Based on this crosswalk, the targets from DeGraaf et al. were translated to targets of 20% of the landscape in seedling/sapling stands as defined by FIA, 30% in pole timber stands, and 50% in sawtimber stands.

Table 2. Crosswalk between stand size class distributions recommended by DeGraaf et al. and those used in this analysis based on FIA size class descriptions

DeGraaf et al. Stand Size Class Categories and Percent of Landscape	Equivalent FIA Stand Size Class Categories	Target percent of Landscape Used in This Analysis
Seedling 5-15%	Small (seedling/sapling)	10%
Saplings and pole 30-40%	Small (seedling/sapling)	10%

[6] See Pounch and Giffen (2021) for more on how this analysis was conducted.

	Medium (pole)	30%
Sawtimber 40-50%	Large (sawtimber)	50%

To estimate what the average stocking would be on a landscape managed to Exemplary Forestry standards in the Central and Transition Hardwoods, we used the average current stocking in Massachusetts and Connecticut for each stand size class[7] and calculated what the average stocking would be in a landscape with the desired distribution of stand size classes, as shown in Table 3. This resulted in an estimate of target stocking for the Central and Transition Hardwoods of Massachusetts and Connecticut of 25 cords per acre of merchantable wood in live trees. Because detailed modeling for the Central and Transition Hardwoods forest has not yet been completed, this number is presented as a preliminary approximation of desirable stocking levels.

Table 8. Existing stand stocking conditions in Connecticut and Massachusetts and potential benchmark for Exemplary Forestry stocking per stand size class

Stand Size Class Category (FIA definitions)	**Target Proportion of Working Forest Landscape**	**Mean Existing Cords per Acre in CT and MA Private Forest Land**	**Rough Approximation Cords per Acre Benchmark***
Small diameter	0.2	3.7	0.7
Medium diameter	0.3	18.4	5.5
Large diameter	0.5	37.4	18.7
Total Cords per Acre	-	-	**25.0**
***If each acre of forestland included proportional representation of the size class range recommended.**			

The rough estimation of 25 cords per acre as the target for Exemplary Forestry stocking in the Central and Transition Hardwoods forest types aligns with the 25 cords per acre target stocking for Exemplary Forestry in the Acadian Forest in northern New England. Further, even if the 25 cords per acre is an underestimate, it is unlikely that the actual target stocking would be as high as, or in excess of, the current stocking levels that are present in southern New England.

Calculating Carbon Storage Opportunities

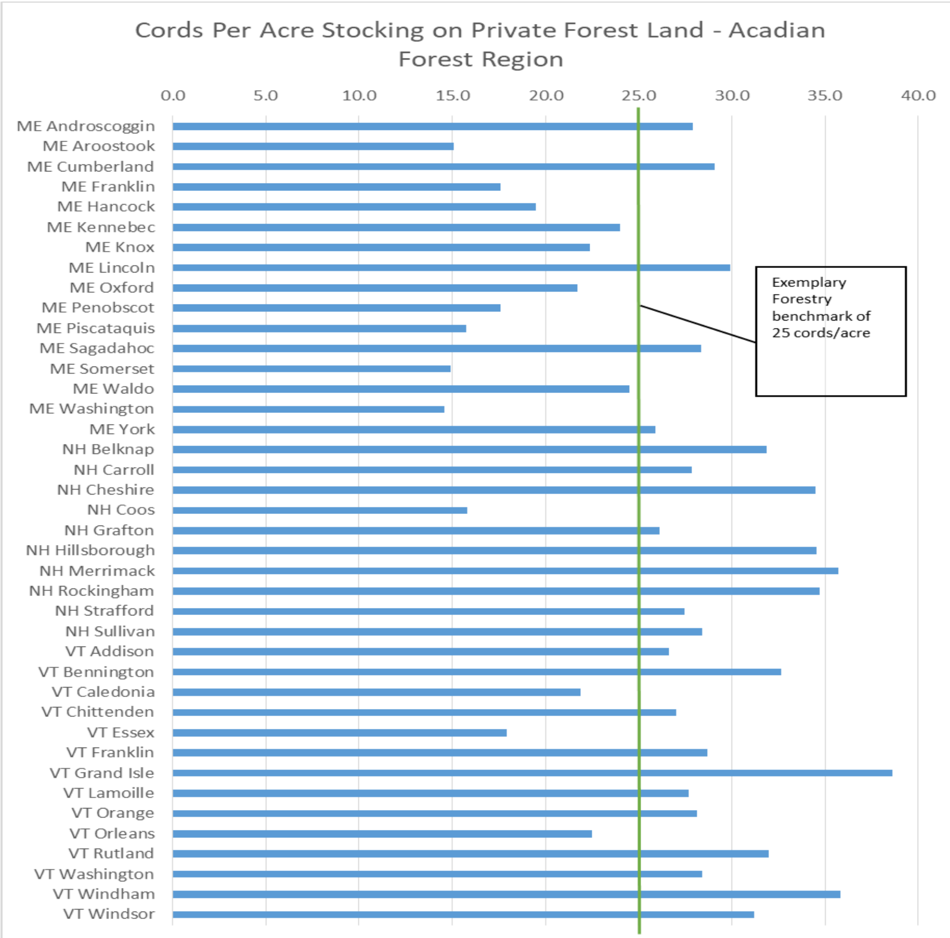
The stocking targets described above were used as a screener to identify counties where there is an opportunity to increase stocking, and thus carbon in the forest, on private forest land through EF management.

Acadian Forest

According to the FIA data, 14 counties in northern New England have average stocking on privately owned forest land below the Exemplary Forestry benchmark of 25 cords per acre. These include Coos County in New Hampshire; Caledonia, Essex, and Orleans Counties in Vermont; and the following 11 counties in Maine: Aroostook, Franklin, Hancock, Kennebec, Knox, Oxford, Penobscot, Piscataquis, Somerset, Waldo, and Washington.

Figure 4. Private forest land timber stocking per county, Acadian Forest region (FIA, 2019)

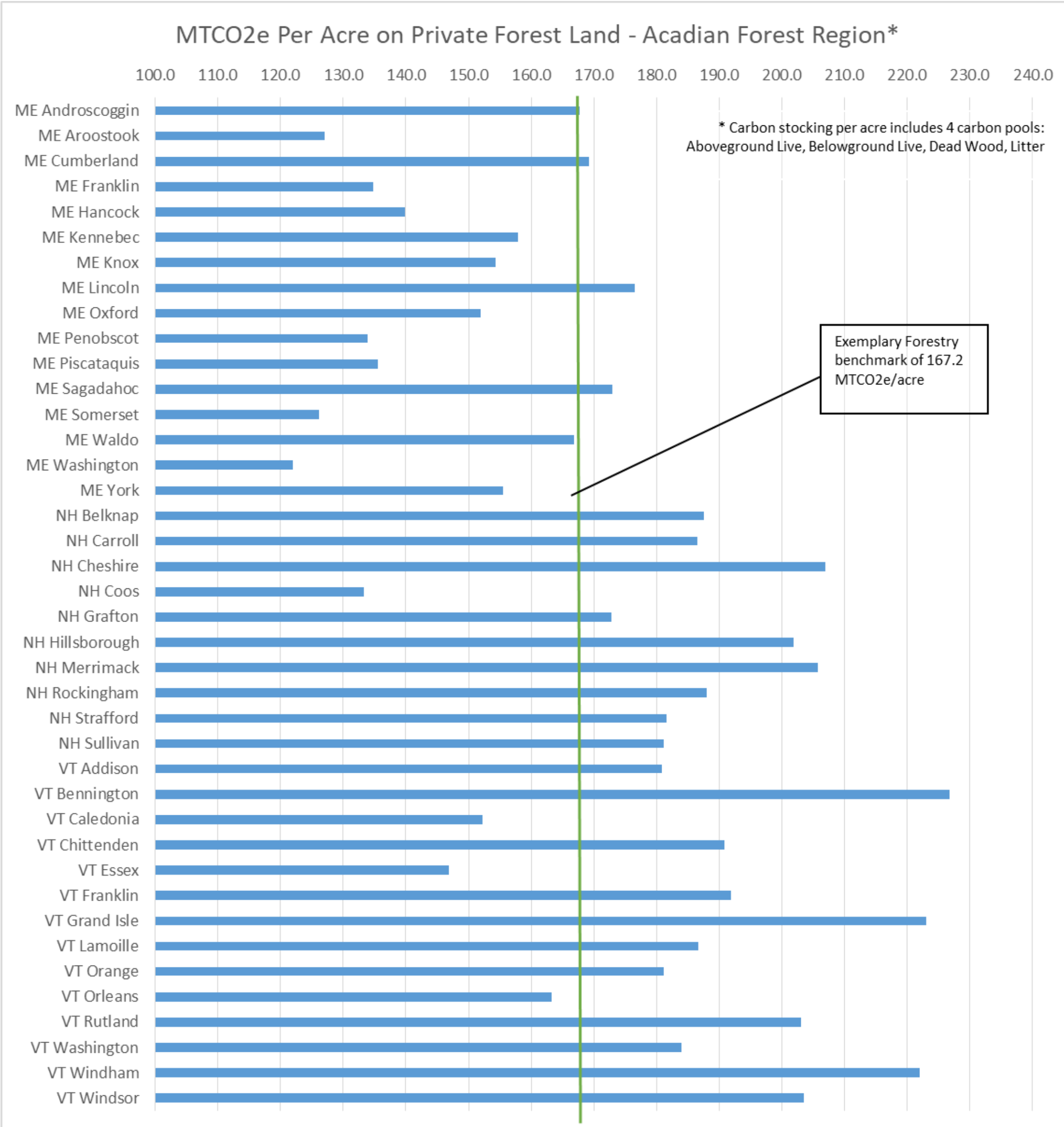
[7] This method may overestimate target stocking as current stocking for any given stand size may be greater than adequate stocking, defined as B line levels on the appropriate stocking guides.



One additional county (York County, ME) has average carbon stocking on private land lower than the Exemplary Forestry target, even though average timber stocking there is slightly higher than the target, at 25.9 cords per acre. We used average carbon stocking to make the final determination of which counties to include in the carbon opportunity calculation, and thus York County was included.

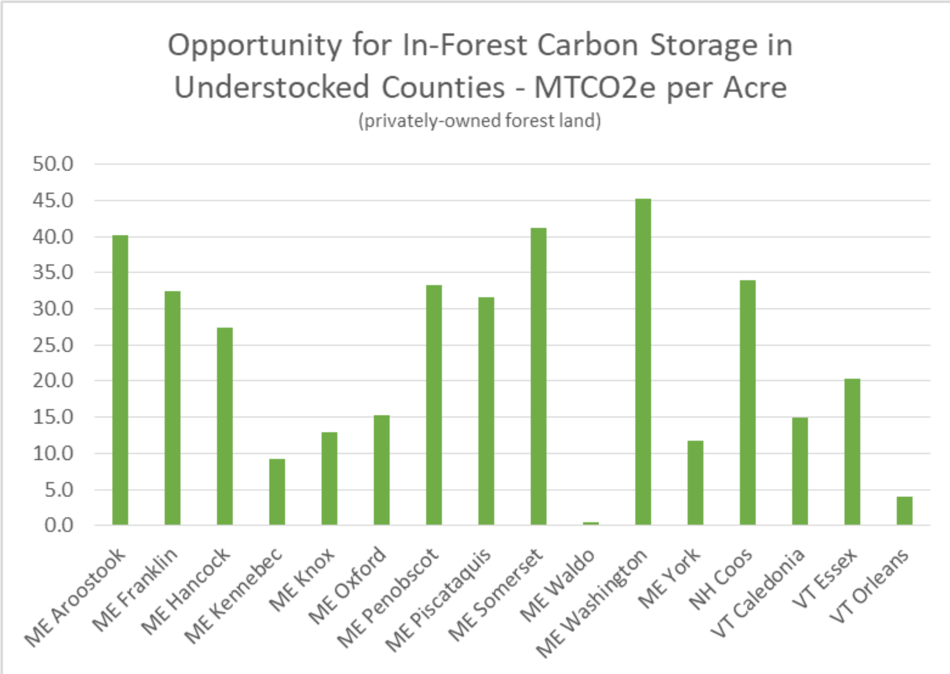
Figure 5 depicts the existing carbon storage by county on private forest land, in comparison to the carbon storage of the Exemplary Forestry proxy condition (167.2 MTCO2e per acre, as calculated in Table 6).

Figure 5. Existing carbon storage per acre on private forest land (FIA 2019)



The average opportunity for additional carbon storage in the understocked counties in Maine, New Hampshire and Vermont is 32.0 MTCO2e per acre, with the greatest per acre opportunity in Washington County, ME at 45.7 MTCO2e per acre. Figure 6 below depicts the relative per acre carbon storage opportunity on privately owned forest land for each understocked county in Maine, New Hampshire, and Vermont, represented in MTCO2e.

Figure 6. Carbon storage opportunity per acre of privately owned forest land, expressed in MTCO2e



After the per acre carbon storage opportunity was calculated, the per acre opportunity was multiplied by the total acreage of private forest land in each of the understocked counties. The resulting values per county are shown in Figure 7 in Section V below, and reflect the total carbon storage opportunity that may be achieved by managing private forest land to the carbon storage of 167.2 MTCO2e per acre for the four carbon pools assessed.

North Central and Transition Hardwoods

As explained earlier, using the stand size distribution from DeGraaf et al., NEFF estimated that target stocking for the Central and Transition Hardwoods would be roughly 25 cords per acre of merchantable wood (see Table 3). Though derived by a different method, this number aligns with the 25 cords per acre target generated by NEFF's detailed modeling of Exemplary Forestry in the Acadian Forest. This is not intended as the definitive stocking target for the Central and Transition Hardwoods, but rather as a preliminary approximation that is within reason. Based on 2019 FIA data, stocking on private forest land in the Central and Transition Hardwoods region of southern New England generally exceeds 33 cords per acre.[8] Therefore, based on this analysis, it appears unlikely that there is any significant opportunity to increase carbon stocking in the North Central and Transition Hardwood region of New England by managing to Exemplary Forestry standards. Instead, the climate mitigation opportunity in this region is likely to come from careful harvesting of long-lived wood products that store carbon and provide substitution benefits when they are used.

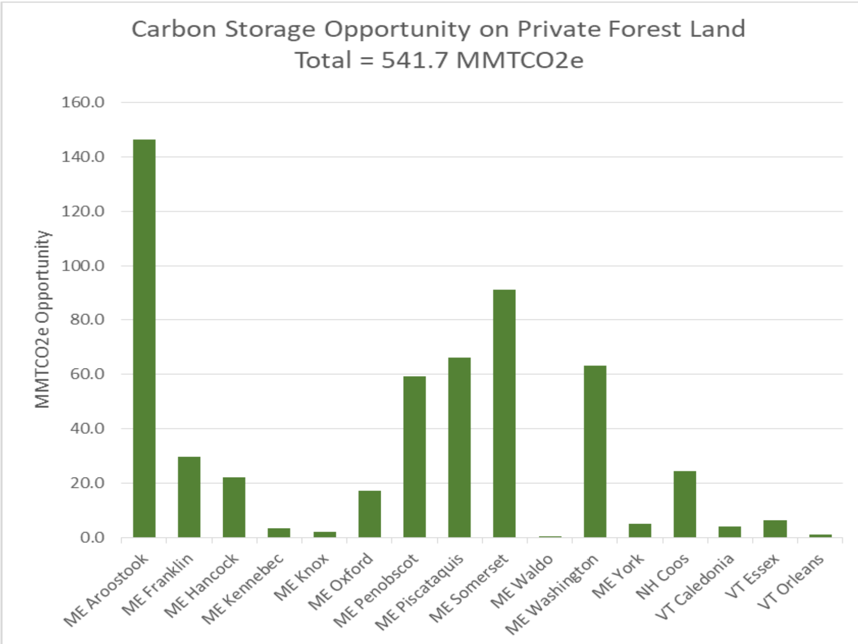
NEW ENGLAND-WIDE CARBON STORAGE OPPORTUNITY FROM EXEMPLARY FORESTRY

Based on this analysis, NEFF estimates that approximately 542 million metric tons CO2e of additional carbon storage could be achieved through Exemplary Forest management on privately owned forest land in New

[8] All counties in southern New England exceed the average stocking target of 25 cords per acre, with the exception of the three Massachusetts counties (Barnstable, Dukes, and Nantucket) that make up Cape Cod and the Islands. As this area is in the Pitch Pine-Oak forest zone, it is excluded from this analysis.

England. As has been described above, the opportunities for additional carbon storage lie in certain portions of the Acadian Forest region in northern New England states, with the largest opportunity found to be in Maine. Figure 5 shows the total opportunity for each county in New England to store more carbon.

Figure 7. Carbon storage opportunity for privately owned forest land, expressed in MMTCO2e



This same information is shown below for each county with potential and for each state with potential as a whole.

Table 9. Total carbon storage opportunity for forest land per county in Maine, New Hampshire, and Vermont (9a), and Statewide total carbon storage opportunity (9b)

9a.

State	Counties with Understocked Privately Owned Forestland	MMTCO2e Opportunity for all Privately Owned Forest Land in Understocked Counties
ME	Aroostook	146.2
	Franklin	29.8
	Hancock	22.0
	Kennebec	3.4
	Knox	2.0
	Oxford	17.1
	Penobscot	59.4
	Piscataquis	66.1
	Somerset	91.2
	Waldo	0.1
	Washington	63.2
	York	5.1
NH	Coos	24.3
VT	Caledonia	4.2
	Essex	6.4
	Orleans	1.2

9b.

State	Storage Opportunity (MMTCO2e)
ME	505.7
NH	24.3
VT	11.8
Total All States	**541.7**

As an alternative perspective, using the EPA's assessment that an average car produces approximately 4.6 metric tons of CO2e per year, the total of 542 MMTCO2e is equivalent to taking approximately 118 million cars off the road for a year. Further, according to 2020 statistics collected by the Federal Highway Administration, Maine has approximately 1.1 million motor vehicles. Therefore, the opportunity to store additional carbon in Maine's forests is equivalent to taking all the cars in Maine off the road for a century. With approximately 276 million registered motor vehicles in the United States in 2020, the carbon storage opportunity outlined above is equal to taking roughly 43% of all motor vehicles in the United States off the road for a full year.

CONSIDERATIONS

In conducting the calculations and analysis described above, a number of assumptions and considerations are notable, and are summarized below. Overall, NEFF presents this study as a working draft, and understands that additional information and/or current and future research may call for adjustments to these calculations.

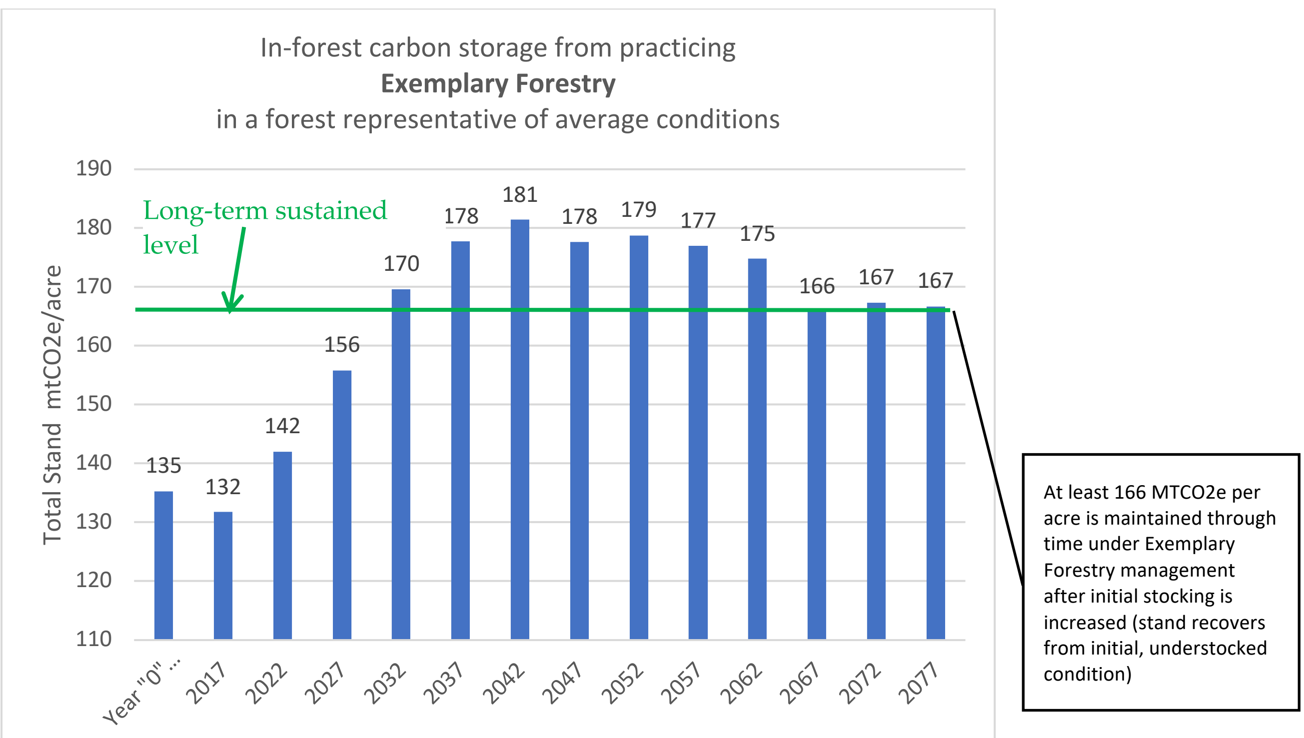
- It is notable that this study examined only average stocking across privately owned forest land by county, not by individual parcel or stand. There are undoubtedly privately owned parcels with stocking below 25 cords per acre that are within a county with an average stocking greater than 25 cords per acre. There are also individual parcels which may have stocking higher than 25 cords per acre but are located in a county with an overall private land stocking of less than 25 cords per acre. These calculations are based on the average, not the distribution around that mean.

- For both the Acadian Forest and Central and Transition Hardwood Forest regions of New England, the proportion of carbon in each pool from the proxy conditions used is informative. It supports NEFF's objective to increase carbon storage through silvicultural management (i.e., managing aboveground live woody material) as being aligned with the greatest opportunity to increase total storage relative to other carbon storage pools. As stated above, the soil organic carbon pool is not included because it is not clear how to manage to increase it. As calculated using 2019 FIA data queried with EVALIDator, the soil carbon for the Exemplary Forestry proxy condition would be approximately 119.9 MTCO2e per acre.

- As noted above, NEFF's calculations and data queries in EVALIDator were conducted for Maine's "forest land," which is distinct from "timberland" using FIA definitions. Timberland is forested land which provides or has the potential to provide timber or other wood products, whereas forest land is inclusive of timberland as well as forested land which is reserved and therefore not considered available to provide wood products as well as other forested land. A primary reason that forest land was used in this analysis is that EVALIDator provides more flexible options for reporting carbon data for forest land queries compared with timberland queries. As also described above, NEFF's assessment of carbon storage opportunity is specific to privately owned forest land and does not include federal, state, municipal, or other non-private ownership. It is assumed that much of the forest land that is reserved (and therefore not managed to produce wood products) is under public rather than private ownership, and therefore excluded from the calculations and analysis. Therefore, even though NEFF has conducted this assessment using forest land acres, we believe that it is reasonably accurate in representing the carbon storage opportunity that may be achieved through Exemplary Forestry management.

- During the development of the Exemplary Forestry standards for the Acadian Forest in Maine, NEFF used the stand size class distribution recommended in DeGraaf et al. in determining the recommended stocking of approximately 25 cords per acre growing stock. NEFF's modeled results from the implementation of Exemplary Forestry did not fully achieve the recommended stand size class distribution within a 60-year future condition (for a stand of typical conditions for the Acadian Forest in western Maine), but suggested that if modeling had extended for a longer future projection they would be achieved. What the model results demonstrated was that at least 166 MTCO2e per acre could be maintained over the long term in the same four carbon pools as used in this EVALIDator-based opportunity analysis. As described above, the Exemplary Forestry proxy condition was found to provide approximately 167 MTCO2e per acre, which is closely aligned with the FVS-modeled results of the implementation of Exemplary Forestry on a forest stand of average condition in northwestern Maine. Figure 9 below is excerpted from NEFF's Acadian Forest Exemplary Forestry report, which shows the projected MTCO2e through time for a stand of average condition in northwestern Maine.

Figure 8. In-forest carbon storage through time under Exemplary Forestry management in a representative forest stand of the Acadian Forest region, Maine



- As described earlier, recommendations from DeGraaf et al. for stand size class distribution and stocking data for existing stands were used as a basis for roughly estimating the target stocking condition in the Central and Transition Hardwoods region. To accomplish this the size classes specified by DeGraaf et al were grouped to correspond with the classes generated from FIA data using EVALIDator (i.e., seedling and sapling sizes were grouped as "small diameter") as shown earlier in Table 7. Rather than the B-line stocking that was used to generate the equivalent estimate for the Acadian Forest, as explained earlier, the average of stand volumes (by size class) for existing stands were used to estimate average volumes for each stand size class. NEFF recognizes that further work is needed to generate a more reliable number that is defensible based on similar methodology (detailed modeling) as was conducted for New England's Acadian Forest. Stocking in all the counties of the southern New England states, except for counties on Cape Cod or the Islands significantly exceed average stocking of 25 cords per acre. Based on these findings, the primary carbon storage opportunity on forest land in southern New England is to increase active management to capture mortality as a means of reducing emissions from decomposition of dead wood, increasing sequestration rates in the residual stand, storing carbon in long-lived wood products, and substituting sustainably grown wood products for more carbon-intensive construction materials such as steel and concrete.
- NEFF used averages rather than ranges within confidence intervals throughout this analysis. This could be refined in a future study.

III. RESOURCES AND REFERENCES

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