New England Forestry Foundation
Estimating New England's In-Forest Carbon Storage Opportunities

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I. SUMMARY

To answer the question of how much more carbon New England forests could store while maintaining harvest, the New England Forestry Foundation (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 except soil carbon. From calculating the difference between existing and target stocking for each county, NEFF was able to estimate 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.

II. INTRODUCTION

Forest lands already store a large volume of carbon. Globally, they store approximately 400 gigatons of carbon (Kayler et al 2017). Specific to New England, in Maine forests store approximately 1.25 billion tons of carbon according to U.S. Forest Service (USFS) Forest Inventory and Analysis (FIA) data, and Maine's forests sequester an amount each year equivalent 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, 2020NEFF 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

[1] Except counties in Rhode Island and areas like Cape Cod with large areas of species like pitch pine.

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 state. 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 and utilizing forest products from fully stocked private forest land in long-lived wood products and replacing a portion of more carbon-intensive construction materials such as concrete and steel cannot be calculated precisely at this point as the forest modeling needed for such stands has not been conducted.

NEFF has developed two sets of Exemplary Forestry standards which outline a suite of management strategies that achieve three co-equal goals: improving forest productivity, 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 the Acadian forest region that generally extends across northern New England (Maine, New Hampshire, and Vermont). The report describing Exemplary Forestry standards for the North Central and Transition Hardwood forests of Connecticut, Massachusetts, and Rhode Island is under development by NEFF. The standards themselves, including determination of the silvicultural systems appropriate for the region, have been established. NEFF's Exemplary Forestry standards for the Acadian Forest call for an average stocking of approximately 25 cords of merchantable wood per acre on managed forest lands. This determination is based on extensive modeling for the northern hardwood and spruce-fir forest types in the Acadian Forest. Based on analysis of stand size class distribution recommended by expert ecologists for the North Central and Transition Hardwood region and average existing stand condition, the target stocking for the North Central and Transition Hardwoods appears to be in the same general range. 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.

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) for its calculation. EVALIDator is a USFS tool that queries, sorts, and filters data from the FIA database. In calculating current and potential additional carbon stocking, NEFF also used a multiplier acquired from the Environmental Protection Agency (EPA) to convert volumes of carbon to a carbon dioxide equivalency (CO_2e), as well as estimate the number of cars taken off the road that the region-wide carbon storage opportunities as described below represent.

This memorandum is intended to summarize and memorialize the steps that were taken to date, so that NEFF's methods can continue to undergo internal and external technical review and be used to inform discussions of policymakers and advisors.

III. 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.

For the purposes of assessing the geographical limits of opportunity for increasing carbon storage on private forest lands in New England, NEFF did not include 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 a timeframe comparable to that of the current climate change crisis, that is the next 30 years.

NEFF utilized similar methods to query, analyze, and describe results for this study between the Acadian Forest (generally, northern New England) and the North Central and Transition Hardwood 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.

IV. DETERMINING AN EXEMPLARY FORESTRY PROXY CONDITION

Exemplary Forestry Proxy – Acadian Forest

NEFF's Exemplary Forestry standard for the Acadian Forest lead to a benchmark of 25 cords of merchantable wood per acre stocking. That is, B line stocking from the appropriate stocking guides[2] for the various stand size classes called for in the Exemplary Forestry standards for the Acadian Forest yields a stocking of approximately 25 cords per acre. 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[3] present, and mitigate climate change by increasing carbon storage in the forest through time.

FVS modeling for Exemplary Forestry including FIA plot data for an approximately 5 million acre region in western Maine, demonstrated that an increase in carbon storage can be achieved by implementing the silviculture called for. For the analysis described herein, NEFF used EVALIDator to find a proxy for the benchmark Exemplary Forestry condition. Through EVALIDator, FIA data was queried in search of geographic portions of New England's Acadian Forest region (portions of Maine, New Hampshire, and Vermont) where the current existing condition for a landowner class is equivalent to the 25 cords of merchantable volume per acre. NEFF's reason for this is twofold: the goal in this study is specifically focused on the opportunities to increase carbon storage on private land (EVALIDator enables data to be easily sorted by landowner class) and also EVALIDator's ability to examine existing carbon storage per carbon pool.

NEFF found that State-owned forest lands in six counties across the northern New England states, which are generally categorized as being the Acadian Forest region in this study, have an existing stocking between 24 and 26 cords per acre, which was considered to approximate the Exemplary Forestry benchmark stocking of 25 cords per acre. It was assumed that State-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 more closely aligned to that recommended by DeGraaf et al. (2005) and other experts than other lands. In Table 1 below, the stocking and carbon storage per pool for each county is presented. The Exemplary Forestry proxy condition (also presented in Table 1) is defined as the average condition across the state-owned lands in these six counties.

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

[3] 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.

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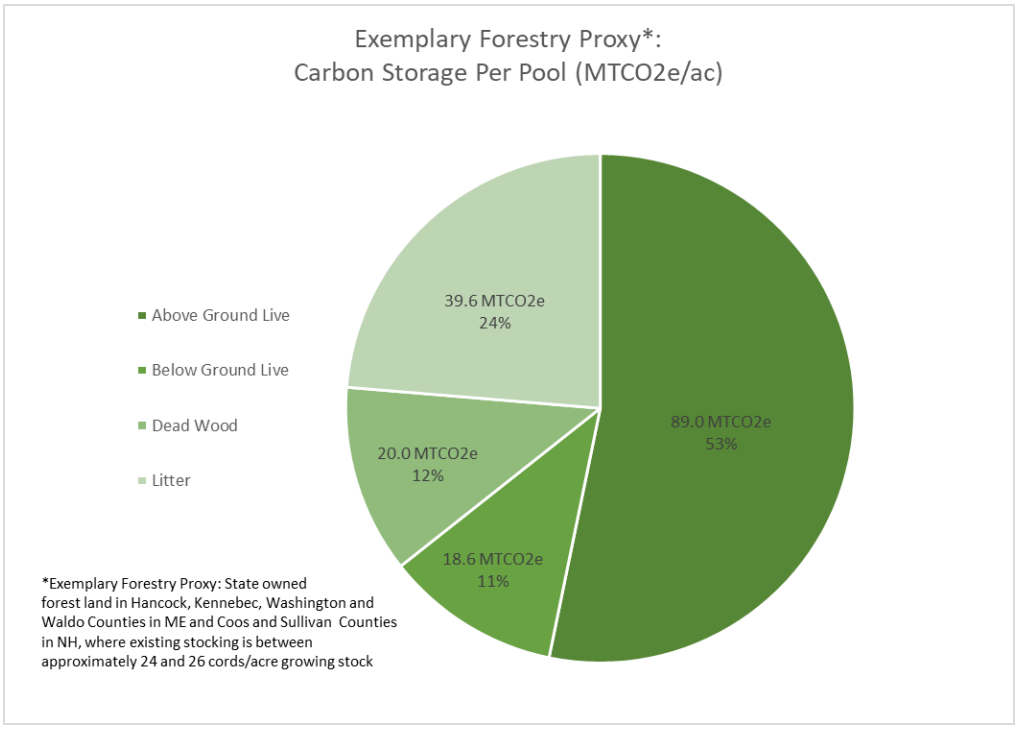
Table 1. Acadian Forest Exemplary Forestry proxy: Stocking and carbon storage per pool

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) for the four pools assessed on each acre of forest land under the Exemplary Forestry proxy condition. Figure 1 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 percent of carbon storage in the four pools assessed.

Figure 1. Carbon storage per pool in Exemplary Forestry proxy



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 an equivalent stocking target for the North 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.[4] 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 North 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. that optimizes for wildlife habitat values and timber production. This distribution includes 5-15 percent of forest area in seedling stands, 30-40 percent in sapling and pole stands, and 40-50 percent in sawtimber stands. The average stocking for the target landscape managed to Exemplary Forestry standards in the North Central and Transition Hardwoods, composed of the target mix of stand size classes, was estimated using the average current stocking in Massachusetts and Connecticut for each stand size class[5] and calculating what the target stocking would be in a landscape with the desired distribution of stand size classes.

[4] See Pounch (2020) for more on how this analysis was conducted.

[5] 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.

An assumption was made when analyzing FIA data for each of the landscape targets to account for the fact that DeGraaf et al. grouped sapling and pole stands together in a single size class, whereas the FIA database groups seedling and sapling stands. This is discussed in more detail below and detailed in Table 2. The targets from DeGraaf et al. were translated to targets of 20 percent of the landscape in seedling/sapling stands as defined by FIA, 30 percent in pole timber stands, and 50 percent in sawtimber stands. This resulted in a rough approximation of target stocking for the North Central and Transition Hardwoods of Massachusetts and Connecticut of 25 cords per acre of merchantable wood in live trees.

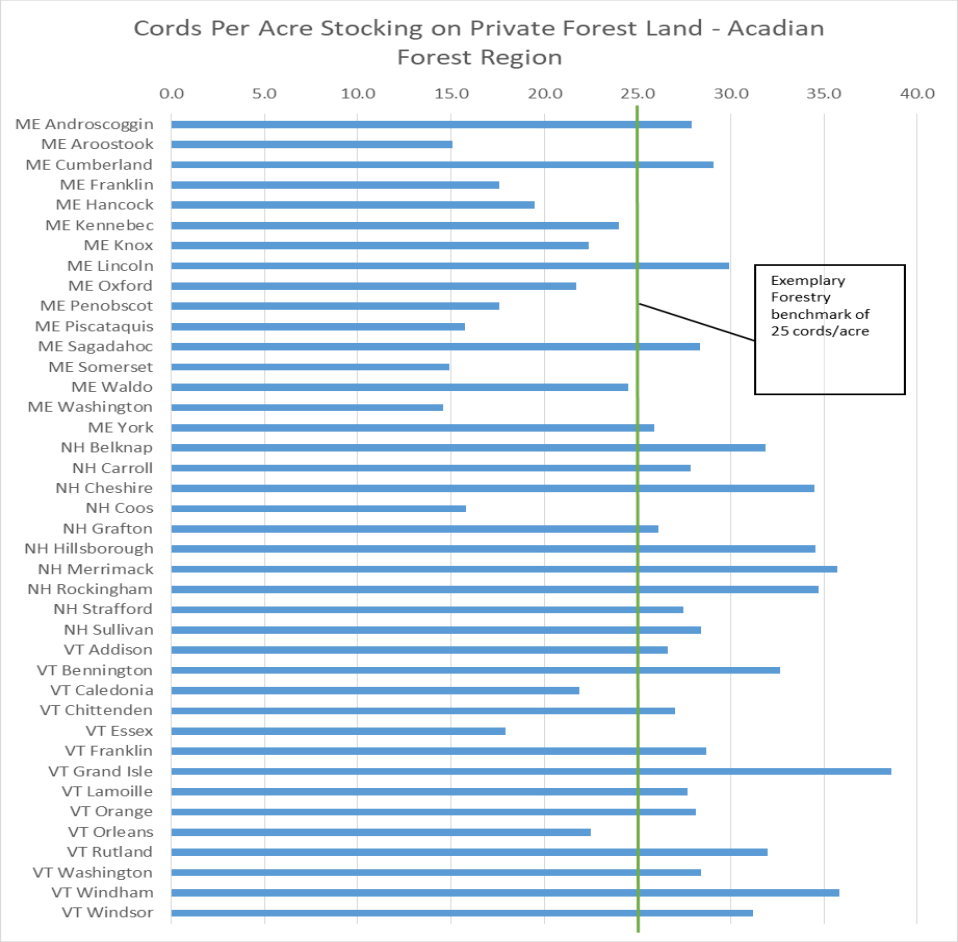
The rough estimation of 25 cords per acre as the target for Exemplary Forestry stocking in the North Central and Transition Hardwoods forest types aligns with the 25 cords per acre target Exemplary Forestry stocking for the Acadian Forest in northern New England. Further, even if the 25 cords per acre 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.

V. CALCULATING CARBON STORAGE OPPORTUNITIES

Carbon Storage Opportunity—Acadian Forest

After the Acadian forest Exemplary Forestry proxy condition was defined as described above, the stocking data for privately owned forest land in each county was assessed. According to the most recent USFS Forest Inventory and Analysis data, of Maine's 16 counties, 11 counties have privately owned forest land that has average stocking below the Exemplary Forestry benchmark of 25 cords per acre. Counties with stocking of less than 25 cords per acre on private forest land include the following: Aroostook, Franklin, Hancock, Kennebec, Knox, Oxford, Penobscot, Piscataquis, Somerset, Waldo, Washington. Figure 2 below includes the estimated per acre stocking (in cords of merchantable volume per acre) for private forest land in each county of Maine. In New Hampshire, Coos County is the only one with private forest land stocking are estimated to be less than 25 cords per acre, on average, and in Vermont three counties are estimated to be understocked in relation to this same metric: Caledonia County, Essex County, and Orleans County.

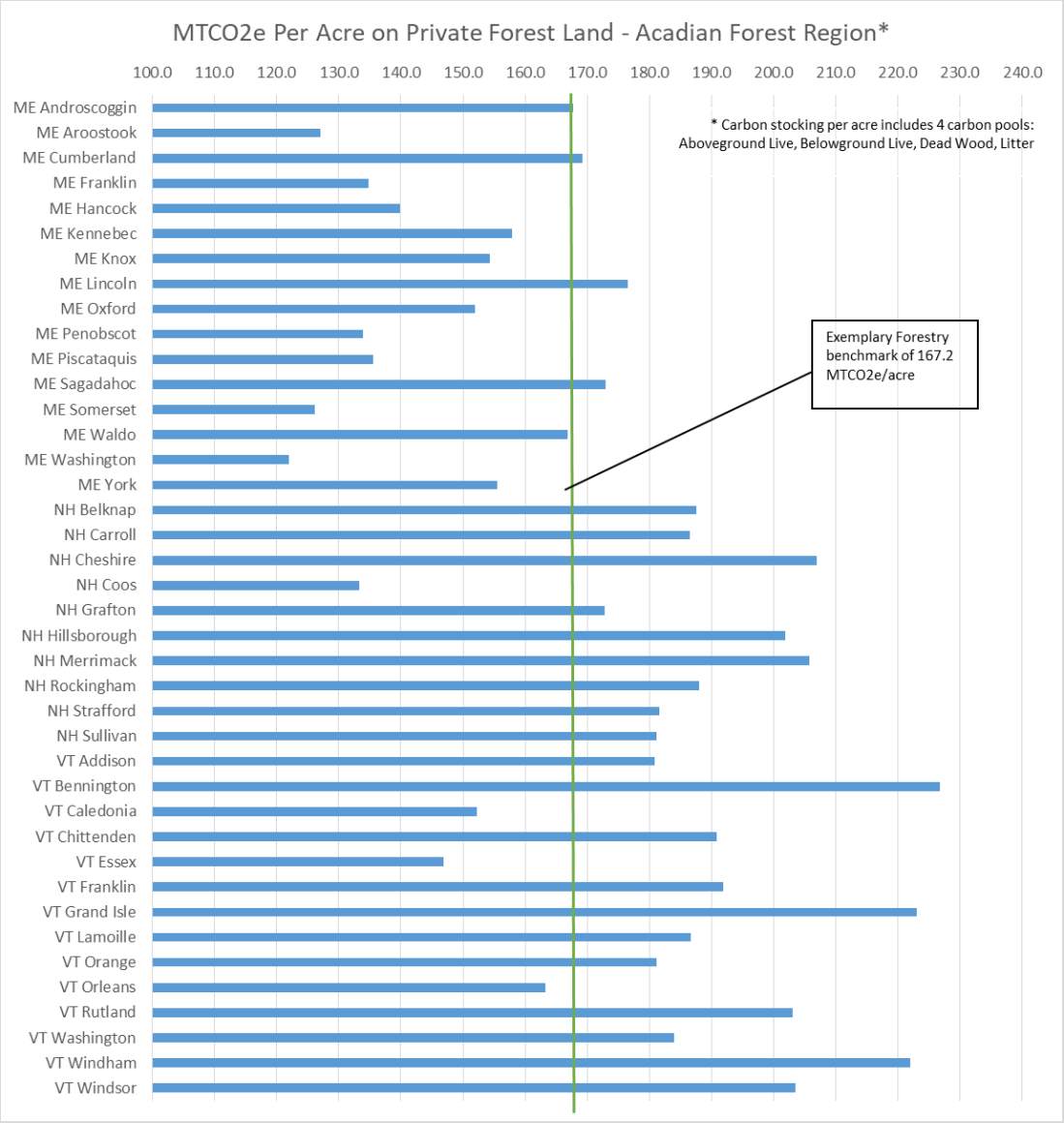
Figure 2. Private forest land timber stocking per county, Acadian Forest region (FIA, 2019)



Further, while York County, ME has a per acre timber stocking of 25.9 cords per acre (0.9 cord per acre higher than the Exemplary Forestry target), the carbon stocking is only 155.5 MTCO2e per acre (11.7 MTCO2e per acre lower than the Exemplary Forestry target). NEFF used average timber stocking to identify counties that may have carbon stocking lower than 167.2 MTCO2e per acre, but then used average carbon stocking to make the final determination. The results of estimating additional carbon storage opportunities for 12 counties in Maine, 1 county in New Hampshire, and 3 counties in Vermont as shown in Figure 3 below.

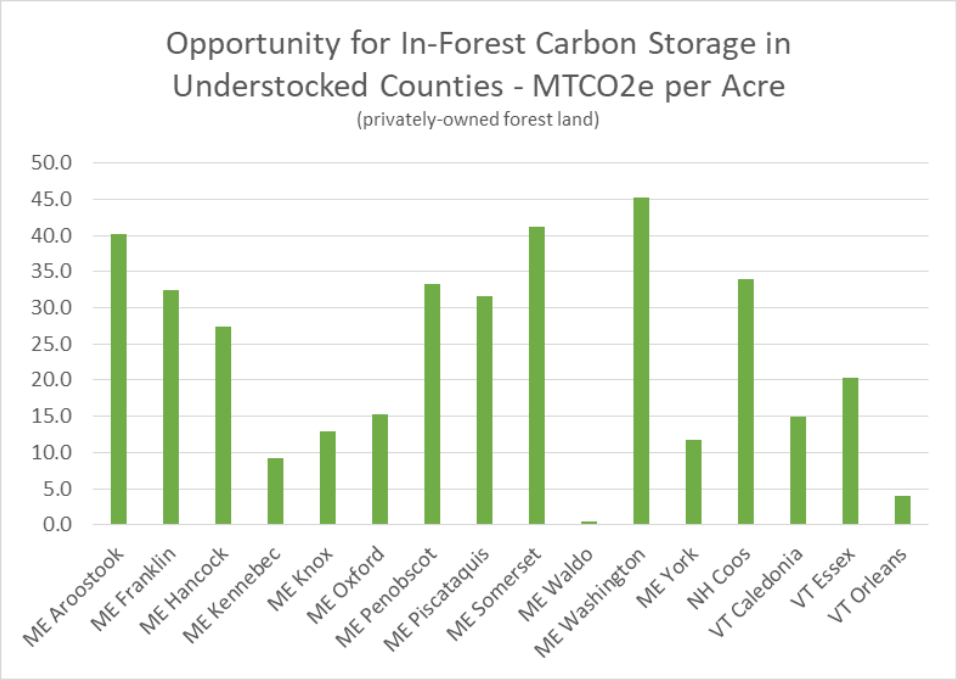
The potential carbon storage opportunities have been calculated as metric tons of carbon dioxide equivalents ("MTCO2e"). Converting from carbon the MTCO2e is accomplished by multiplying the carbon (metric tons per acre) in the four pools assessed by 3.67 (the molecular weight of CO2 divided by the molecular weight of carbon = 44/12 = 3.67). Figure 3 depicts the existing carbon storage for private forest land using MTCO2e per acre. Figure 3 also shows the carbon storage of the Exemplary Forestry proxy condition, which as described earlier was found to be 167.2 MTCO2e per acre (see Table 1).

Figure 3. 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 23.9 MTCO2e, with the greatest per acre opportunity in Washington County, Maine at 45.7 MTCO2e per acre. Figure 4 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 4. 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 per county values are shown in Figure 5 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. These values are presented in million metric tons CO2e (MMTCO2e) in Section 5.

Carbon Storage Opportunity—North Central and Transition Hardwoods

As explained earlier, using the stand size distribution from DeGraaf et al., NEFF estimated that target stocking for the North Central and Transition Hardwoods would be roughly 25 cords per acre of merchantable wood. Though derived by a different method than the steps taken to assess carbon storage opportunities in the Acadian Forest region of New England, surprisingly this number aligns with the 25 cords per acre target generated by NEFF's extensive modeling for Exemplary Forestry in the Acadian Forest. This is not intended as the definitive stocking target for the North 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 North Central and Transition Hardwoods region of southern New England generally exceeds 33 cords per acre on average. Because DeGraaf et al. uses different size categories for stands than those used in FIA, Table 2 shows how the stand size class categories used in DeGraaf et al. were adapted for uses in this analysis.

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

Table 3 below includes the landscape-scale stand size class distribution categories and the associated existing condition of private forest land in the region, and explains NEFF's rough approximation of the stocking level that is likely to occur under management to Exemplary Forestry Conditions. Note that detailed modeling for the North Central and Transition Hardwoods forest has not yet been completed and so these numbers are presented as a preliminary approximation of desirable stocking levels.

Table 3. 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.**			

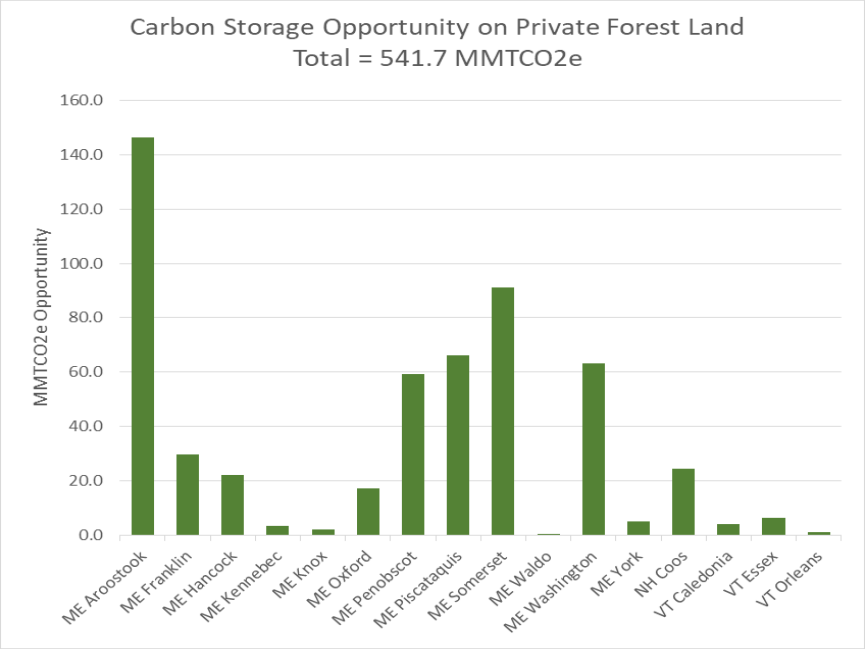
Therefore, based on this analysis, it appears unlikely that there is any significant opportunity to increase carbon stocking in the North Central and Transition Hardwood region of New England.

VI. New England-Wide Carbon Storage Opportunity from Improved Management

Based on this analysis, NEFF estimates that 541.7 million metric tons CO_2e[6] of additional carbon storage could be achieved through Exemplary Forest management on privately-owned forest land in New England. As has been described above, the opportunities for additional carbon storage exist 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 opportunity for each county in New England to store more carbon.

[6] Plus or minus a margin of error not reported by FIA.

Figure 5. Carbon storage opportunity for privately owned forest land, expressed in MMTCO2e



This same information is shown below in MTCO2e for each county with potential and for each state with potential as a whole.

Table 4. Total carbon storage opportunity for forest land per county in Maine, New Hampshire, and Vermont (4a), and Statewide total carbon storage opportunity (4b)

4a.

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

4b.

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 uses approximately 4.6 metric tons of carbon dioxide per year, the total of 541.7 MMTCO2e is equivalent to taking approximately 117.8 million cars off the road for a year. Further, according to 2010 statistics collected by the Federal Highway Administration, Maine has approximately one 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 over a century. With approximately 242 million registered motor vehicles in the United States in 2010, the carbon storage opportunity outlined above is equal to taking roughly 49 percent of all motor vehicles in the United States off the road for a full year.

VII. 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 those counties whose average stocking across privately owned forest land is below the Exemplary Forestry standard of 25 cords, or 167.2 MTCO2e, per acre. There are undoubtedly privately owned parcels with less than 25 cords per acre stocking 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.

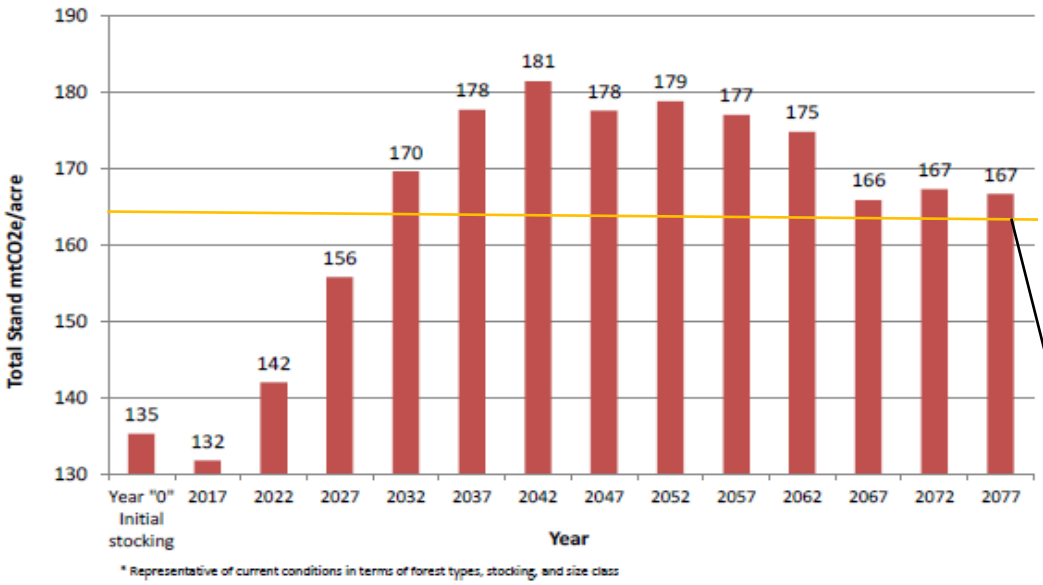
- For both the Acadian Forest and North Central and Transition Hardwood Forest regions of New England, the proportion of carbon in each pool from the proxy conditions used is informative. It supports NEFF's objective to increase carbon storage through silvicultural management (i.e. managing above ground 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 "timber land" using FIA definitions. Timber land is forested land which provides or has the potential to provide timber or other wood products, whereas forest land is inclusive of timber land 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 the FIA carbon data in EVALIDator is only provided for forest land queries and not timberland. 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 publically owned or non-private ownership. It is assumed that much of the forest land which 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, NEFF believes 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 165 MTCO2e per acre (approximately 45 tons of carbon) 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 167.7 MTCO2e per acre (approximately 45.7 MTC 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 6 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 6. In-forest carbon storage through time under Exemplary Forestry management in a representative forest stand of the Acadian Forest region, Maine



- As described earlier, DeGraaf et al. recommendations for stand size class distribution and stocking data forest existing stands were used as a basis for roughly estimating the target stocking condition in the North 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 2. Rather than B line stocking 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.

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VIII. RESOURCES AND REFERENCES

Daigneault, A., Simons-Legaard, E., Birthisel, S., Carroll, J., Fernandez, I., Weiskittel, A. July 27, 2020. Maine Forestry and Agriculture Natural Climate Solutions Mitigation Potential – Interim Report. University of Maine. 74 pp.

DeGraaf, R. M., M. Yamasaki, W. B. Leak, and A. M. Lester. 2005. Landowner's guide to wildlife habitat: Forest management for the New England region. Vermont: University of Vermont Press. 128 pp.

Giffen, R. Alec and Perschel, Robert, 2018. Exemplary Forestry in the Acadian Forest. July 16, 2018. Available online at: https://newenglandforestry.org/connect/publications/forestry-guides/

Kayler, Z.; Janowiak, M.; Swanston, C. 2017. Global Carbon. June, 2017. U.S. Department of Agriculture, Forest Service, Climate Change Resource Center. Available online at: https://www.fs.usda.gov/ccrc/topics/global-carbon

Pounch, Mike. 2020. Exemplary Forestry Growth and Yield Modeling Project and Link to Financial Modeling. New England Forestry Foundation and Maine Mountain Collaborative, November 28, 2018. Updated July 24, 2020. Document file maintained by NEFF

Weyerhaeuser, Blake and Giffen, R. Alec. 2020. Forest Management Effects on Soil Carbon: A Literature Review. New England Forestry Foundation. Maintained by NEFF and available upon request.