MEMORANDUM

To: New England Forestry Foundation – Climate Wedge Project File
Composed by: Carla Fenner, PWS
Date: September 30, 2019
Re: Approximating Existing and Potential Carbon Storage in Northern New England

INTRODUCTION

The New England Forestry Foundation ("NEFF") is developing estimates for the existing carbon storage in forests of northern New England. NEFF is also estimating the potential additional storage that may be achieved if forests were managed in accordance with the Exemplary Forestry Standards put forth in NEFF's 2018 paper *Exemplary Forestry in the Acadian Forest* (Giffen and Perschel, 2018), in which an average stocking of approximately 25 cords per acre is maintained.

Calculations of current and potential additional carbon storage are presently in working draft form, and this memorandum is intended to summarize the steps taken in developing these calculations to be used in an external technical review. Based on the current calculations, there are portions of northern New England ("NNE", defined as Maine, Vermont, and New Hampshire for the purposes of this study) which are not sufficiently stocked to meet the Exemplary Forestry standard, and other portions of the region which have higher stocking.

NEFF primarily used data from the U.S. Forest Service ("USFS") Forest Inventory and Analysis ("FIA") program in conducting calculations. The three FIA reports used are identified here and available online (see Resources section for full citation).

- Forests of Maine, 2017;
- Forests of New Hampshire, 2017;
- Forests of Vermont, 2017.

NEFF also used metrics and multipliers acquired from other agency and scientific sources as noted in the attached summary table footnotes.

METHODS

As stated above, NEFF used state-level FIA data summaries provided by the USFS. FIA data is from 2017 and is presumed to be suitable as representation of current 2019 forest conditions. NEFF used data at the County and Inventory Unit scale in making calculations, and used values for volume of Growing Stock (at least 5 inches DBH), All Live Trees (at least 5 inches DBH), acres of Timberland in deriving estimates of current stocking and then carbon storage. An outline of the steps taken to estimate stocking, carbon storage, and potential additional storage under Exemplary Forestry management is provided below. The actual calculations and values used are presented in the attached tables.

- See Table M1, N1, and V1. Cords per acre stocking of growing stock (at least 5 inches DBH) on timberland was calculated using county and inventory unit volumes of growing stock and the total acres of timberland, both per county and inventory unit. Values were calculated for cubic feet per acre and then converted to cords per acre using 85 cubic feet of wood per cord as the conversion factor.
- See Table M2, N2, V2, M3, N3, and V3. Cords per acre stocking of all live trees (at least 5 inches DBH) on timberland per county and inventory unit were calculated by using the statewide total of growing stock and all live tree volumes (in million cubic feet) and dividing them each by the total statewide acres of timberland, then converting cubic feet to cords per acre. This provided a value for cords per acre delta between growing stock and all live trees (example: in Maine, there is a 1.78 cord/acre difference statewide between growing stock and all live trees stocking). This step was necessary because the FIA summary data only provided county and inventory unit level volume in growing stock, and not for all live trees. A statewide value for volume of all live trees was available, however and so county and inventory unit estimations of stocking for all live trees was possible by comparing statewide growing stock to statewide all live tree data and dividing the difference by the statewide timberland acres value. NEFF's calculations of statewide stocking of all live trees on timberland per state according to the working calculations are listed below:
    - Maine: 18.2 cords/acre;
    - New Hampshire: 28.1 cords/acre;
    - Vermont: 31.8 cords/acre.
- Using all live tree stocking value estimates for county and inventory units, NEFF then calculated the cords per acre stocking of all aboveground biomass. The all aboveground biomass values were determined for three forest types: hardwood, softwood, and mixed wood, and then summed for an estimate of total.
    - The values for all above ground biomass were determined by multiplying the all live tree stocking by 1.16 for softwood, 1.19 for hardwood, and 1.175 for mixed wood. These expansion factors were taken from a 2009 USFS publication authored by Heath et al. as noted in the attached table footnotes and in the Resources section below. All above ground biomass as used here includes limbs, tops, and stumps. The expansion factor multipliers represent that 16% of total above ground biomass of softwood trees is in limbs, tops, and stumps, 19% for hardwoods, and an average of 17.5% for mixed wood forest types.
    - Relative percentage of timberland acres represented by softwood, hardwood, and mixed wood were 35.29%, 31.17%, and 33.55% respectively. These values are taken from NEFF's previous analysis of forestland in Maine (Pounch, 2018) in support of development of the Exemplary Forestry standards (NEFF, 2018) and subsequent use of those standards as the basis of estimating potential carbon storage opportunities. The use of Maine-specific forest type coverage in estimating above ground biomass for the forests of Vermont and New Hampshire is noted, and it is NEFF's position that the resulting estimates are conservative (i.e. the relative cover of softwood , which has a lower density/weight per ton and therefore a lower carbon storage value in comparison to hardwood, may be overestimated in New Hampshire and Vermont and so carbon storage for these states as estimated may be conservatively low).

- See Table M4, N4, and V4. Cords per acre of all above ground biomass per county and inventory unit were then converted into a per acre live tree weight value for each of the three forest types. Values of 2.3 tons per cord for softwood and 2.7 tons per cord for hardwood were used, per a 2013 Maine Forest Service publication noted in the summary table footnotes. Statewide values for all above ground biomass stocking for NNE are:
    - Maine: 22.8 cords/acre;
    - New Hampshire: 35.2 cords/acre;
    - Vermont: 39.5 cords/acre.
- See Table M5, N5, and V5. A comparison of cords per acre of all aboveground biomass for existing conditions per county and inventory unit in relation to the Exemplary Forestry standards for stocking was then done. First, converting the 25 cords per acre stocking under Exemplary Forestry, which is an all live tree value, to an all above ground biomass value. The Exemplary Forestry cords per acre stocking for all above ground biomass is 29.4, which was determined by increasing the 25 cords for all live tree stocking by 17.5%, the average increase across softwood, hardwood, and mixed wood forest types. The resulting values from this calculation included positive values for those counties and inventory units where estimated existing stocking is less than the Exemplary Forestry Standard and negative values for counties and/or inventory units where estimated current stocking exceeds the Exemplary Forestry standard.
- See Table M6, N6, V6, and M7 N7, and V7. The existing carbon storage of above ground biomass for states in NNE per county and inventory unit were then estimated. This process first converted cord per acre above ground biomass to tons of biomass per acre (using cord tonnage provided by Maine Forest Service) per county and inventory unit and calculated the dry weight of carbon in softwood, hardwood, and mixed wood stands. This calculation used specific gravity values provided by USFS (Miles and Smith, 2009) for dry weight to green weight per cord of 41% for softwood, 52% for hardwood, and 52% for mixed wood. Using the dry weight of carbon for softwood, hardwood, and mixed wood forest types the carbon dioxide equivalency for each could be estimated using the conversion factor of 3.67 between tons of carbon dioxide and tons of carbon. The resulting estimate values reflected in Table M7, N7, and V7 are in metric tons of carbon dioxide equivalence per acre for each forest type and an average of the three forest types.
- See Table M8, N8, V8, and Table 9. Tons per acre of carbon dioxide equivalence were then multiplied by the total acres of timberland per county and inventory unit to get total existing carbon storage in million metric tons of carbon dioxide equivalence ("MMTCO2e") for each county, inventory unit, and state. Also, the difference (in cords per acre) between existing stocking and Exemplary Forestry were multiplied by timberland acres to approximate the potential additional storage that could be achieved through implementation of Exemplary Forestry for those counties and inventory units which had a lower stocking.
    - Estimates of total existing storage for NNE was found to be:
        - Maine: 4,928.9 MMTCO2e
        - New Hampshire: 3133.3 MMTCO2e
        - Vermont: 4,015.3 MMTCO2e
    - Estimates of potential additional carbon storage through Exemplary Forestry stocking were found to be:

- Maine: 1,794.8 MMTCO2e
- New Hampshire: 94.4 MMTCO2e
- Vermont: 14.1 MMTCO2e
- TOTAL: 1,903.3 MMTCO2e
- Note: There are counties with a higher existing stocking than as identified in the Exemplary Forestry standards. The potential additional storage quantities identified here and in the attached tables include only the counties with an identified deficit under existing stocking.

- The amount of carbon emitted by an average vehicle in the US today in a year is 4.6 metric tons/year (https://www.epa.gov/greenvehicles/greenhouse-gas-emissions-typical-passenger-vehicle)
  - Thus the 1,903.3 MMTCO2e is equivalent to the emissions of 413,760,870 vehicles for one year, or all vehicles in New England for 30 years.
  - Conservatively, to allow for ongoing review of the calculations, one could say that applying exemplary forestry to understocked northern New England forests could offset the emissions from all the vehicles in New England for more than 20 years or alternatively from millions of vehicles for more than 20 years.

Resources:

Butler, Brett J. 2018. Forests of Maine, 2017. Resource Update FS-160. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 3 p. https://www.nrs.fs.fed.us/fia/data-tools/state-reports/default.asp

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/.

Heath, Linda et al. 2009. Investigation into Calculating Tree Biomass and Carbon in the FIADB Using a Biomass Expansion Factor Approach. USDA Forest Service Proceedings – RMRS-P-56. January, 2009.

Miles, Patrick D.; Smith, W. Brad. 2009. Specific gravity and other properties of wood and bark for 156 tree species found in North America. Res. Note NRS-38. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 35 p.

Morin, Randall S. 2018. Forests of New Hampshire, 2017. Resource Update FS-163. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 3 p. https://www.nrs.fs.fed.us/fia/data-tools/state-reports/default.asp

Maine Department of Agriculture Conservation and Forestry, 2013. Maine Forest Service 2012 Stumpage Prices by Maine County. Available online at: https://digitalmaine.com/cgi/viewcontent.cgi?article=1002&context=for_docs

Morin, Randall S. 2018. Forests of Vermont, 2017. Resource Update FS-164. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 3 p. https://www.nrs.fs.fed.us/fia/data-tools/state-reports/default.asp

Pounch, Mike. 2018. Exemplary Forestry Growth and Yield Modeling Project Synopsis. New England Forestry Foundation and Maine Mountain Collaborative, November 28, 2018. Document file maintained by NEFF.

Table 9

Summary of Existing and Potential Storage Per State (MMTCO2e)

	Inventory Unit	County	Million Metric Tons CO2e in Above Ground Biomass	Potential Additional Million Metric Tons CO2e Under Exemplary Forestry
MAINE	Washington	Washington	370.8	247.0
	Aroostook	Aroostook	847.3	487.6
	Penobscot	Penobscot	527.2	217.8
	Hancock	Hancock	275.5	81.5
	Piscataquis	Piscataquis	514.7	253.8
	Capitol Region	Kennebec	190.8	12.1
		Knox	73.9	6.1
		Lincoln	135.7	-14.6
		Waldo	180.2	18.6
	Somerset	Somerset	531.0	299.3
	Casco Bay	Androscoggin	113.5	-4.1
		Cumberland	267.3	-32.0
		Sagadahoc	69.6	-4.1
		York	273.6	-8.1
	Western Maine	Franklin	303.0	101.9
		Oxford	509.7	69.1
	Statewide Total		4928.9	1794.8
NEW HAMPSHIRE				
	Northern	Carroll	367.7	-42.4
		Coos	321.1	94.4
	Southern	Grafton	553.7	-38.1
		Belknap	161.6	-25.8
		Cheshire	342.6	-94.1
		Hillsborough	406.5	-101.0
		Merrimack	557.1	-163.2
		Rockingham	250.3	-69.3
		Strafford	93.2	-5.0
		Sullivan	201.8	-21.3
	Statewide Total		3133.3	94.4
VERMONT				
	Northern	Caledonia	186.4	-6.0
		Essex	184.4	14.1
		Franklin	217.2	-40.4
		Grand Isle	20.1	-5.5
		Lamoille	234.3	-51.4
		Orange	274.5	-52.5
		Orleans	209.2	-12.2
		Washington	281.5	-57.8
	Southern	Addison	199.8	-34.6
		Bennington	316.8	-85.9
		Chittenden	176.0	-39.8
		Rutland	427.8	-118.9
		Windham	623.0	-226.7
		Windsor	489.2	-133.8
	Statewide Total		4015.3	14.1

Current and Potential Additional Storage (MMTCO2e)

TOTAL CURRENT STORAGE	**12279.5**
POTENTIAL ADDITIONAL STORAGE	**1903.3**