Supplementary 6 – IFM Pathway

The improved forest management (IFM) pathway models potential changes to forest practices that increase carbon across the New England landscape through the concept of stocking, which is defined by the USFS as the percent of total tree density that is required to fully use the growth potential of the land.[1] The study uses this definition of stocking as a proxy for the fullness of carbon in a stand; in other words, the more fully stocked a stand, the less room there is for more trees to store more carbon. Stocking data is provided by FIA in the following five classes:

- Nonstocked: 0 to 9%
- Poorly stocked: 10 to 34%
- Medium stocked: 35 to 59%
- Fully stocked: 60 to 100%
- Overstocked: >100%

A "poorly stocked" acre of forest, in other words, is forest where the tree density is only accounting for 10 to 34% of the growth potential of the land. According to FIA data, about 35 – 40% of New England's forests are inadequately stocked, which we define as non-stocked, poorly-stocked, and medium-stocked FIA classes (Figure 1).

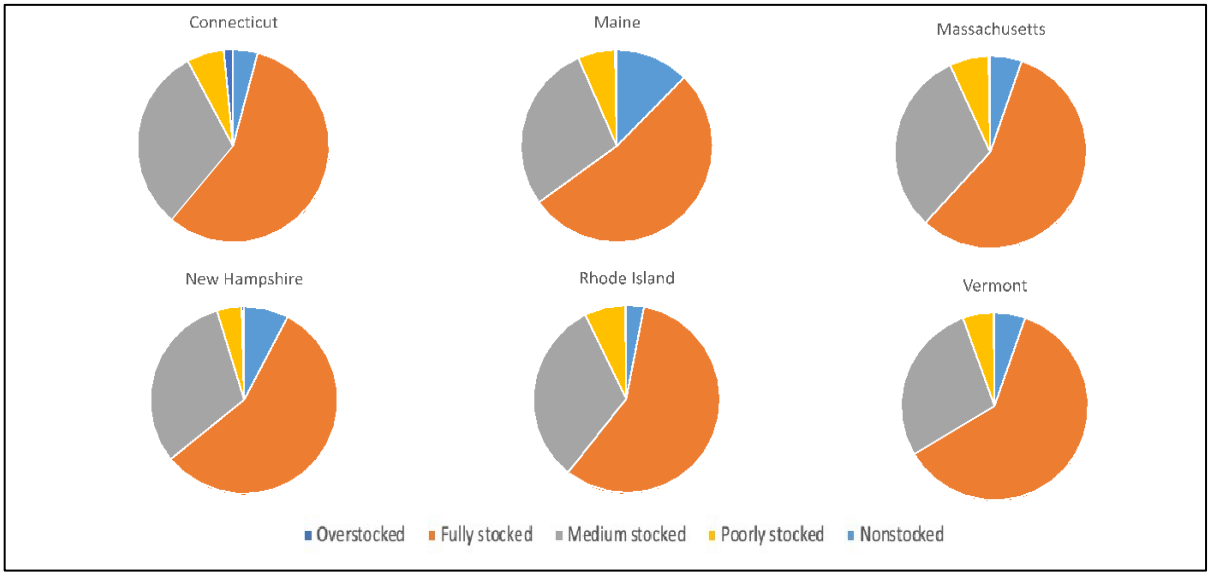

Figure 1: Timberland stocking in New England states

Note: Figures display stocking levels of aboveground carbon in live trees (at least 1 inch) in short tons per acre on timberland.
Source: FIA Evalidator

[1] Stocking is not density, but rather the relative density of a stand compared to what it could contain: it is a function of the growing capacity of a stand based on allometric and geometric functions of tree size, canopy size, and stem density. For example, a fully stocked (100%) stand could contain many small trees or a few big trees. These stands would have very different stem densities, but the same stocking. The silviculture required to increase stocking would inherently manipulate stocking through reallocation of growing space.

The carbon benefits of IMF in the current study are modeled as a shift across the New England landscape to higher stocking levels. Specifically, a certain percentage of acres in each stocking class (the 20%/50%/100% tier levels) move up a stocking class from the non-stocked, poorly-stocked, and medium-stocked FIA classes. In other words, at the 50% tier, 50% of non-stocked acres move to the poorly-stocked class; 50% of poorly-stocked acres move to the medium-stocked class; and 50% of medium-stocked acres move to the fully-stocked class. These changes are assumed to happen over the period 2020-2050, such that in 2050 a landscape-scale alteration of the overall stocking in New England's timberlands has occurred due to changes in harvest and management practices.

The number of acres of timberland in New England in 2050 is modeled as a function of BAU forest loss and interaction with other pathways on the baseline timberland area, specifically the avoided deforestation and wildlands pathways. Avoided deforestation leaves more timberland on the ground that could be harvested and reduces forest conversion from the BAU scenario; additional wildland designation reduces timberland acres that could be harvested and is added to the BAU wildland designation in the model. The total number of baseline acres of timberland in New England is adjusted to account for the tier levels selected in other pathways. Table 1 shows this adjustment assuming wildlands at the 10% tier and the avoided deforestation pathway at the 75% tier. The study uses the midpoint between current timberland acres and adjusted 2050 timberland acres to account for the uncertainty in when over the 30-year period of analysis the wildland and avoided deforestation impacts occur to specific acres.

Table 1: Estimate of 2050 Timberland Acres

Forest Data (acres)	**CT**	**ME**	**MA**	**NH**	**RI**	**VT**	**New England Total**
Baseline timberland area	1,737,978	16,873,315	2,848,785	4,420,004	343,736	4,273,598	30,497,416
BAU forest loss (medium estimate, 30 years)	49,569	371,769	86,215	137,563	27,775	172,825	845,717
BAU timberland area 2050	1,688,409	16,501,546	2,762,570	4,282,441	315,961	4,100,773	29,651,699
Pathways timberland area 2050 [1]	1,576,901	15,578,161	2,655,371	4,195,136	316,682	4,026,130	28,353,383
Midpoint BAU & pathways 2050	**1,657,439**	**16,225,738**	**2,752,078**	**4,307,570**	**330,209**	**4,149,864**	**29,425,399**
Notes: [1] Pathways timberland area represents 2050 timberland acres with a 10% wildlands pathway and 75% avoided deforestation pathway assumed.							

The midpoint acres of timberland estimated between the BAU and pathways scenarios in 2050 are distributed across stocking classes following the baseline distribution of timberland acres across stocking classes as seen in the FIA data (Table 2).

Table 2: Distribution of Timberland Acres Across Stocking Classes

		2050 Acres in Each Stocking Category - Adjusted to Midpoint 2050 (Distributing Across Stocking Classes)				
State	**Total 2050 Acres - Midpoint Estimate 2020/2050**	**Overstocked (>100%)**	**Fully stocked (60-80%)**	**Medium stocked (35-59%)**	**Poorly stocked (10-34%)**	**Nonstocked (0-9%)**

CT	1,657,439	68,595	945,573	512,745	103,765	26,761
ME	16,225,738	2,005,499	8,538,607	4,618,923	1,018,271	44,439
MA	2,752,078	142,875	1,556,142	859,498	182,517	11,047
NH	4,307,570	332,167	2,434,985	1,339,097	183,769	17,551
RI	330,209	9,906	190,396	105,953	23,320	635
VT	4,149,864	227,960	2,529,338	1,153,655	229,762	9,148
Total New England	**29,422,898**	**2,787,002**	**16,195,041**	**8,589,869**	**1,741,405**	**109,581**
% of Total 2050 acres		**9%**	**9%**	**55%**	**29%**	**6%**

The carbon additionality of the IFM pathway is reflected in the increased carbon stock evident in higher stocked classes in the FIA data. Table 3 shows the change in carbon stock across stocking classes from FIA. The study does not ascribe carbon sequestration benefits to the stocking class changes as carbon stock gains in the 30-year period of analysis necessarily include sequestration gains.

Table 3: Carbon Stock Gains of Improved Stocking on Timberland

State	C Stock Gains/Acre (Absolute Gain)		
	Non -> Poor	**Poor -> Med**	**Med -> Full**
CT	15.82	10.85	17.92
ME	8.44	6.91	7.34
MA	11.91	15.03	16.57
NH	12.75	9.33	14.35
RI	10.98	13.72	15.66
VT	13.00	10.46	13.69

Using the FIA data, carbon stock gains are applied to the number of acres moving up a stocking category. Table 4 shows the number of acres moving at the 50% tier level, where 50% of acres in each understocked category move up to the next category.

Table 4: Number of acres moving stocking categories

State	Medium stocked -> Full	Poorly stocked -> Med	Non-stocked -> Poor
CT	256,372	51,882	13,380
ME	2,309,461	509,136	22,220
MA	429,749	91,259	5,523

NH	669,548	91,885	8,775
RI	52,976	11,660	317
VT	576,828	114,881	4,574

Other studies

A prominent example of an improved forest management systems is the "Exemplary Forestry" standard developed by the New England Forest Foundation (NEFF) Exemplary Forestry provides landscape-scale standards that "[i]n addition to protecting forests and their ecosystem services…is designed to accomplish three goals: enhance the role forests can play to mitigate climate change, improve wildlife habitat, and grow more and better-quality wood." (NEFF Exemplary Forestry) Exemplary Forestry standards are different depending on the characteristics of the region's climate and forests; specific standards for the Acadian Forest in Maine are available from NEFF (NEFF Exemplary Forestry Standards for the Acadian Forest 2018) and include elements such as maintaining a diverse size class distribution, implementing Best Management Practices, and stocking to fully occupy the site. In a recent analysis, NEFF estimated that Exemplary Forestry management practices in Northern New England could increase carbon storage by increasing stocking, in Maine for example from an average of 17 to 25 cords per acre (NEFF 2019). The study concluded that increased stocking across Northern New England could absorb an additional 542 million metric tons of CO2e. Other frameworks, such as "carbon forestry" provide guidelines for practices such as thinning; harvest with a focus on overall net carbon stocks remaining on the landscape; and including areas where harvest is absent (Keeton and Hancock 2019).