Forest Carbon and Climate Program
Department of Forestry
MICHIGAN STATE UNIVERSITY

Report: Predictors of Family Forest Harvest Behavior in the Northeastern United States

Kylie Clay (MSU FCCP)
Chad Papa (MSU FCCP)

Forest Harvest Behavior in the Northeastern United States

Kylie Clay* and Chad Papa*

* Michigan State University, Forest Carbon and Climate Program
Contact: kclay@msu.edu

Michigan State University, Forest Carbon and Climate Program (FCCP) has conducted plot-level statistical analysis with the following objectives:

1) Identifying covariates that best predict harvest likelihood (HL) and harvest intensity (HI) on non-industrial private forestland in Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont for four forest type groups (FTGs) of interest (Maple/ Beech/ Birch [MBB], Oak/ Hickory [OH], Spruce/ Fir [SF], and White/ Red/ Jack Pine [Pine])[1];
2) Identifying appropriate subregions for analysis and FFCP donor pool selection (i.e., subregions where distinct forest management behaviors exist);
3) Identifying tiers of plot-level carbon potential (i.e., predicted harvest intensity) according to key indicators (e.g., levels of merchantable volume, percent stocking, etc.) to inform FFCP participation requirements or funding tiers (cap impact analysis); and
4) Assessing the impact of selected caps on available donor plots by FTG and ecoregion (cap feasibility testing).

This report details the processes and results of those analyses.

[1] Note that all Oak/Pine plots with Oak making up at least 40% of the plot's relative density were merged with the Oak/Hickory FTG; likewise, Oak/Pine plots with Pine making up at least 40% of the relative density were merged with the Pine FTG. The six plots that met both criteria (and so could not be determined to follow a predominantly Oak or Pine management regime) were dropped from the analysis.

Contents

Figures

Tables

Statistical Methods

To conduct the plot-level analysis of key determinants of HL and HI, we developed a random forest (RF) model. In this section, we detail briefly what a random forest model is and why this approach was selected.

Machine learning is a widely used technique to automate both supervised and unsupervised classifications in order to identify patterns within datasets. Specifically, RF models, a type of machine learning algorithm and an extension of classification and regression trees (CART) techniques, are a suite of non-parametric models that utilize decision trees to classify datasets. RF models split observations in a pairwise hierarchical manner based on an algorithm-generated basic rule that minimizes within-group variation and maximizes between-group variation (Breiman, 2001). This enables rapid classification and estimation of importance for dependent variables (Ziegler and Konig, 2014). RF models have grown in popularity due to ease of parameter tuning (i.e., an analyst needs only to determine input variables, number of trees to generate, and the number of variables to sample at each decision step) and model insensitivity to variable magnitudes and distribution (i.e., models do not require data rescaling) (Wager et al., 2014).

RF offers advantages over other parametric approaches (such as generalized linear models or logistic regression models), including handling residual noise for predictions and probability estimates for multi-category dependent variables (Ziegler and Konig, 2014). RF models can be prone to overfitting, since models inherently reduce variance and mean square error through complex model building processes that can generate many trees. However, bootstrapping samplers and bootstrap aggregation inherent to RF model techniques generally minimize overfitting; additionally, straight-forward checks of model results can limit bias and increase validity (Ziegler and Konig, 2014). RF model estimates characterize error, strength, and correlation and can also be used to measure variable importance (Breiman, 2001), including for high-dimensional problems involving many features (Ziegler and Konig, 2014).

Data Description

Here, we provide a description of the input used in the statistical analyses.

We derive all input data (i.e., independent and dependent variables) from:

1. The US Department of Agriculture, Forest Inventory and Analysis Database: https://www.fia.fs.usda.gov/ [using the rFIA R package: https://rfia.netlify.app/]
2. US Census: https://www.census.gov/data/datasets/time-series/demo/popest/2010s-counties-total.html
3. Forest Ownership data [Sass E., B. Butler, M.A. Markowski-Lindsay. (2020). Forest ownership in the conterminous United States circa 2017: distribution of eight ownership types—geospatial dataset. Fort Collins, CO: Forest Service Research Data Archive. https://doi.org/10.2737/RDS-2020-0044]

4. Mill location data [provided by state DNRs]:
    - Connecticut: https://portal.ct.gov/-/media/deep/forestry/forest_practitioner_certification/primaryprocessorspdf.pdf
    - Maine: https://static1.squarespace.com/static/5da9047aa7b835389a38c978/t/5dd6f5690ab5465cb20418ed/1574368620425/Online_Portable_Sawmills_2018.pdf
    - Massachusetts: https://ag.umass.edu/sites/ag.umass.edu/files/pdf-doc-ppt/2006_ma_sawmill_directory.pdf
    - New Hampshire: https://extension.unh.edu/sites/default/files/migrated_unmanaged_files/Resource000251_Rep271.pdf
    - New York: https://www.dec.ny.gov/docs/lands_forests_pdf/directory17.pdf
    - Rhode Island: https://www.dandb.com/businessdirectory/rhodeisland-sawmillsandplaningmillsgeneral-2421.html
    - Vermont: https://anrweb.vt.gov/FPR/vtFPR/Sawmill.aspx

We consider only plots encompassing privately-owned forestland in our analyses (including tribal lands). See `src/summarizeVariables.R` for the procedures used to summarize condition-level FIA data.

We exclude any plot not meeting the following conditions:

- Plot falls exclusively on private forestland
- Single condition is present, and its attributes are constant through time (e.g., has always been recorded as a red pine plantation)
- Trees present at least one plot visit (e.g., post-clearcut is considered non-treed forestland)
- Annual-to-Annual plot, i.e., same plot design used at all visits and excludes all periodic inventories

Input data are stored in `Outputs/plot_vars_v3.csv`. Variable definitions are as follows:

Dependent Variables (Harvest Indicators)

Harvest intensity:

- `REMV_NETVOL_ACRE`: (numeric) average annual net merchantable volume (cu.ft.) per acre harvested during the remeasurement interval. We compute HI for all remeasured plots (most have been remeasured multiple times) in terms of a percentage of net merchantable volume removed that can be attributed to tree harvesting across all plot visits (i.e., sum across remeasurements).

Harvest (binary):

- `HARVESTED`: (factor/ binary) binary code indicating if tree harvesting occurred on the plot between the remeasurement interval (`HARESTED=1` when harvesting occurred, and `HARVESTED=0` otherwise)

Independent Variables (Predictors/ Co-Variates)

- `FORTYPCD`: (factor) code for forest types
- `SITECLCD`: (factor) code for site productivity classes
- `STDORGCD`: (factor) binary code indicating clear evidence of artificial regeneration (i.e., plantation status)
- `PHYSCLCD`: (factor) code for physiographic classes
- `ECOSECCD`: (factor) code for ecoregion
- `STATECD`: (factor) code for state
- `RDDISTCD`: (factor) code for straight-line distance to nearest improved road
- `SLOPE`: (numeric) slope of condition (%)
- `ASPECT`: (numeric) aspect of condition (degrees)
- `ELEV`: (numeric) elevation of condition
- `PREV_BAA`: (numeric) live tree basal area per acre at initial measurement (ft sq ac^{-1})
- `PREV_QMD`: (numeric) live tree quadratic mean diameter at initial measurement
- `PREV_NETVOL_ACRE`: (numeric) net merchantable volume at initial measurement (cu ft ac^{-1})
- 'PREV_rdplot': (numeric) relative density, measurem of number and average size of trees, per plot at initial measurement
- 'LOREY': (numeric) weighted mean height proportional to individual tree basal area
- 'PREV_BIO': (numeric): all aboveground tree biomass per acre at initial measurement (short tons ac^{-1})
- 'PREV_CARB': (numeric): all aboveground tree carbon per acre at initial measurement (short tons ac^{-1})
- `GSSTK`: (numeric) initial stocking of growing stock (absolute value 0-167%)
- `prop.forest`: (numeric) proportion of landscape within 10km of fuzzed plot locations that is classified as forestland (derived from [National Land Cover Database 2016] https://www.mrlc.gov/national-land-cover-database-nlcd-2016).
- `dist.to.mill`: (numeric) distance to nearest mill, calculated using fuzzed and swapped plot coordinates and mill coordinates.
- `n.mills.50km`: (numeric) number of mills within a 50km radius
- `pop.current`: (numeric) 2019 county population [US Census data]
- `pop.growth`: (numeric) county population growth 2011-2019 [US Census data]

- `prop.small.private`: (numeric) proportion of forestland within 1km of fuzzed plot location that is classified as private (family/ small owner) ownership (derived from [Sass et al, 2020] https://www.nrs.fs.fed.us/pubs/61623).
- 'PERC_HARV_ANNUAL': (numeric) proportion of FIA plots harvest annually within each county
- 'PERC_HARV': (numeric) total proportion of FIA plots harvest within each county across the entire timeseries
- 'REMV_INTENSITY_BOLE: (numeric) dry biomass in the merchantable bole removed per acre of harvested plots

Please see the FIA Database Documentation: (https://www.fia.fs.usda.gov/library/database-documentation/current/ver90/FIADB%20User%20Guide%20P2_9-0-1_final.pdf) for definitions associated with forest type, site productivity, stand origin, and physiographic class codes.

Omitted Counties

While a number of ecological forest dimensions influence harvest decision-making among private landowners, as will be demonstrated in subsequent sections, political and cultural dimensions too influence harvest decision-making. Because the FIA database includes only plot-level measurements, and not survey data on landowner political preferences or cultural indicators, any such dimensions cannot be included in the covariate analysis, or in the FFCP donor plot matching methodology, at the plot level. This analysis has, therefore, taken a blunt approach to handling political and cultural dimensions, particularly those that would lead toward no or extremely little harvest behavior.

In looking at previous harvest incidences at the county-level, we observe a series of counties with no or very little historic harvest on FIA plots, despite ecological conditions that might predict otherwise. The FFCP team has elected to remove these counties from the covariate analysis (and eligible FFCP participation) out of an assumption that the dominant cultural and political dimensions of the counties will continue to lead to little or no harvest in the baseline. **Figure 1** visualizes county-level historic harvest (as a percentage of FIA plots where harvest has been recorded) and **Figure 2** visualizes which counties have seen zero harvest across their FIA plots since first FIA inventory. See **Table 1** for a list of those counties removed and their historic harvest on FIA plots (% of plots harvested at any cycle).

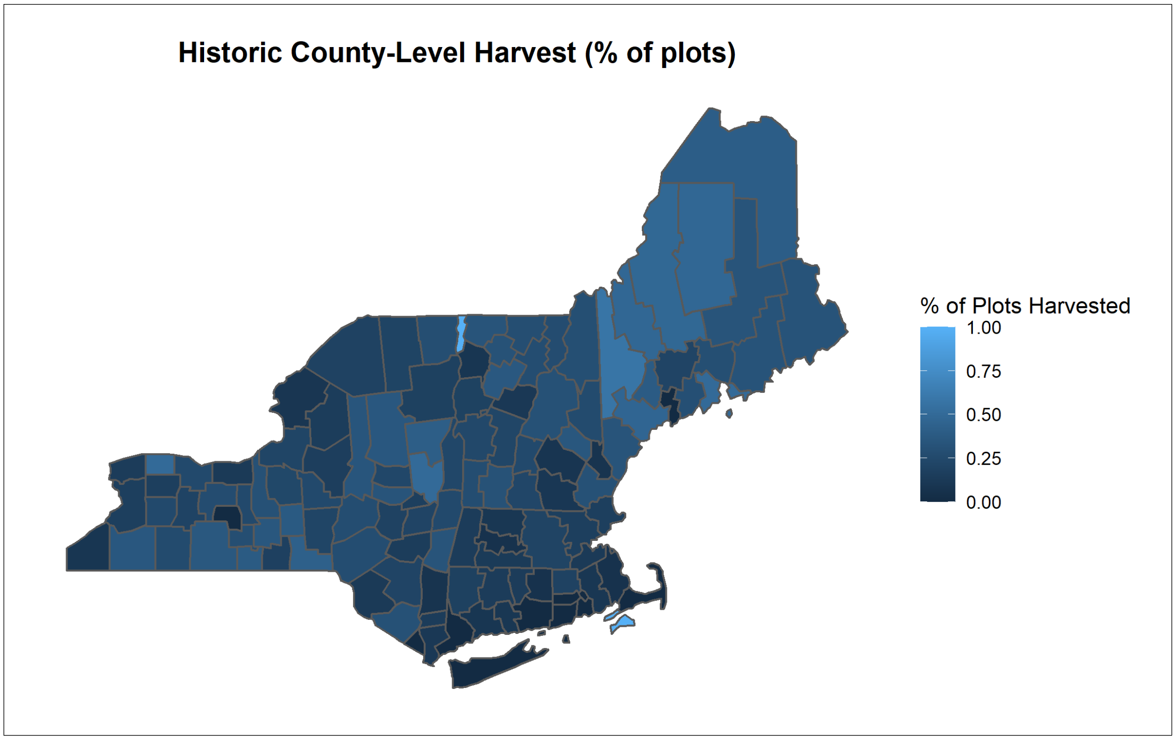

Figure 1. Historic county-level harvest (% of plots harvested in any cycle).

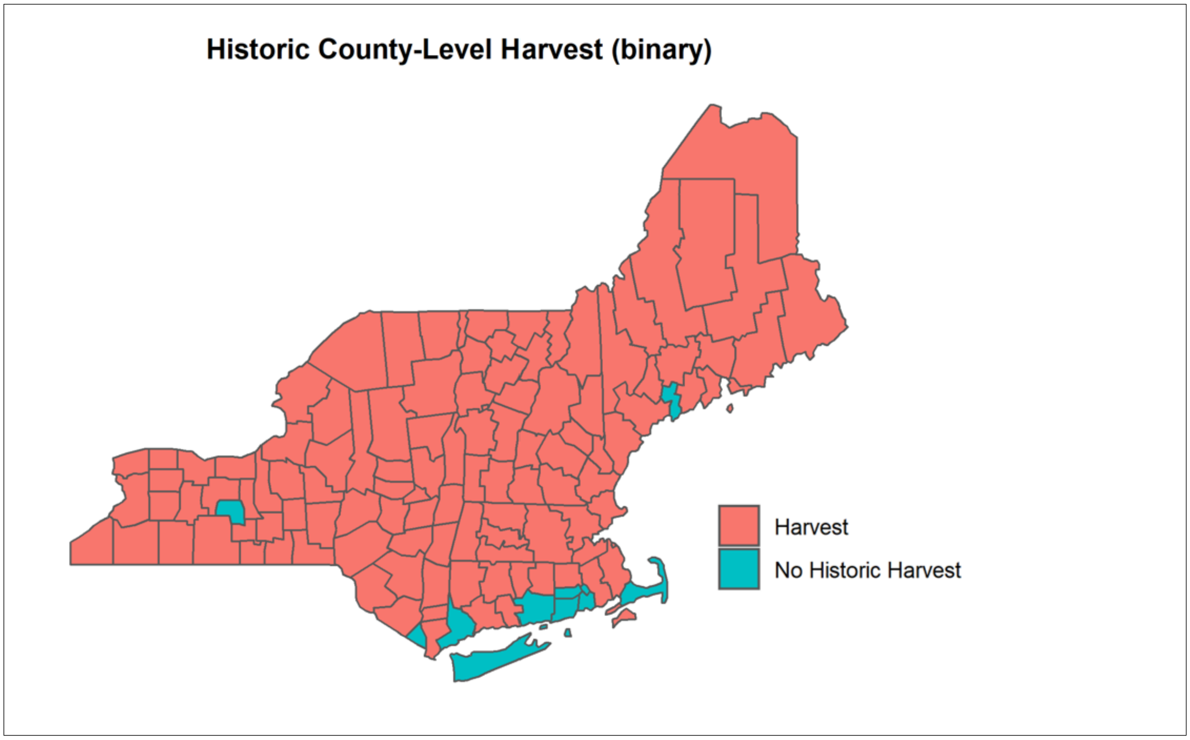

Figure 2. Counties with zero historic harvest (since first FIA inventory).

Table 1. Counties Omitted from the Subsequent Analyses as well as from FFCP Landowner Enrollment

Omitted Counties

State	County	Historic Harvest on FIA plot (% of plots harvested)
New York	Suffolk	0%
New York	Nassau	0%
New York	Rockland	0%
New York	Westchester	11.11%
Massachusetts	Barnstable	0%
Massachusetts	Bristol	10.00%
Massachusetts	Plymouth	6.25%
Massachusetts	Dukes	100%
Massachusetts	Nantucket	0%
Connecticut	Fairfield	0%
Connecticut	New Haven	9%
Connecticut	Middlesex	10%
Connecticut	New London	0%
Rhode Island	Washington	0%
Rhode Island	Kent	0%

Subregions for Donor Pool Selection

To create more appropriate and refined donor pools, we binned two discrete groups of US counties based on trends in forest harvest behavior, namely, observed differences in harvest intensity independent of existing forest conditions. After analyzing previous harvest trends at the state- and county-levels, we identified Maine plus the extension of ecosection M211A (which covers much of western Maine and extends into six counties across Vermont and New Hampshire) as harvesting more intensely than other areas, controlling for forest ecological conditions. Accordingly, we have grouped those six counties together with all counties of Maine into a distinct group for analysis (**Figure 3**).

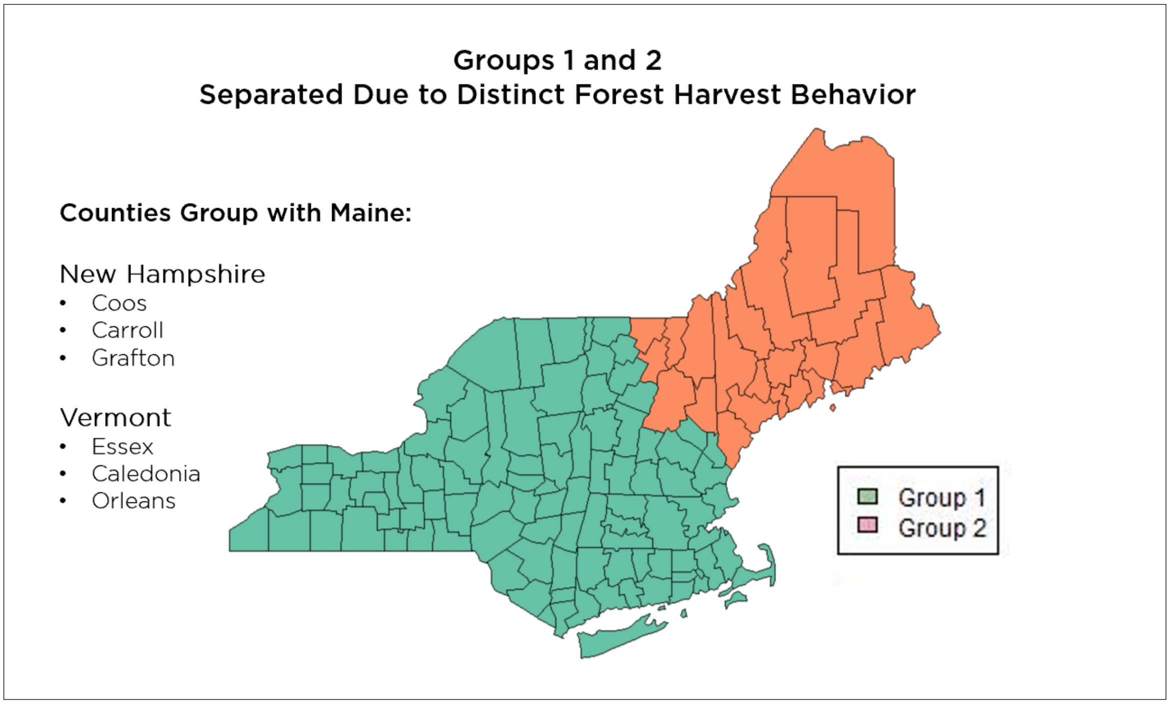

Figure 3. Selected regional groups to be applied to the covariate importance, cap impact, and cap feasibility analyses, sufficient donor plots permitting.

As **Figure 4** and **Figure 5** demonstrate, plots in Group 2 harvest more intensively (shown here in terms of basal area and merchantable volume removed) than those plots in Group 1, controlling for existing forest conditions.

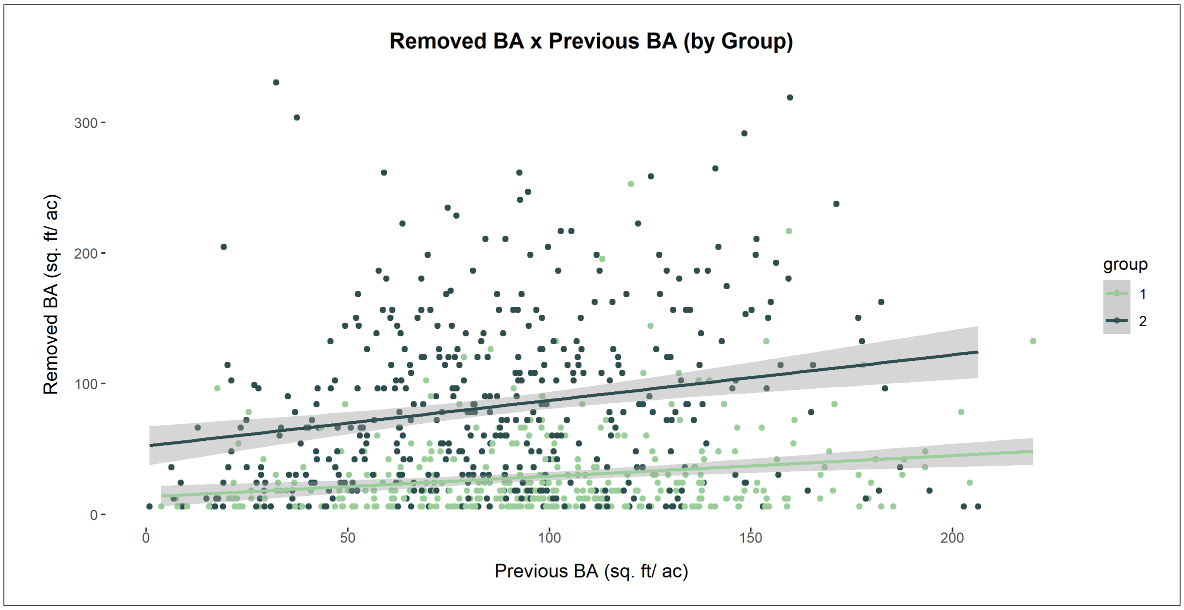

Figure 4. Comparison of removed basal area by previous basal area among harvested plots in Groups 1 and 2.

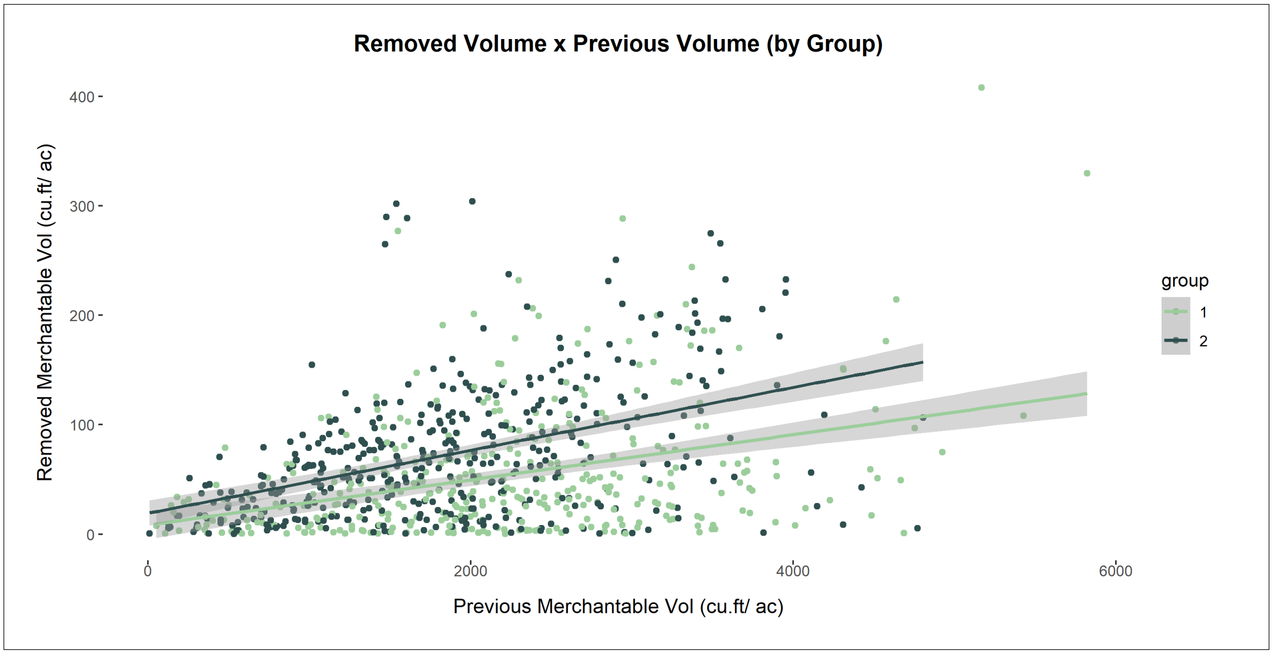

Figure 5. A comparison of removed merchantable volume by previous merchantable among harvested plots in Groups 1 and 2.

These groupings are applied to subsequent modeling stages where sufficient donor plots in each of the two groups exist. Because there were insufficient Oak/ Hickory plots in Group 2, all Oak/ Hickory plots are analyzed together in the caps analyses; likewise, because there were insufficient Spruce/ Fir plots in Group 1, all Spruce/ Fir plots were analyzed together for the cap analyses. While Pine plots were analyzed separately across the two distinct groups for the caps impacting testing, all Pine plots are merged into one group for cap feasibility testing as the selected Pine caps led to too few plots across the two groups to merit their separation.

Covariate Importance Results

To assess variable importance associate with the HL and HI models, we calculated the loss in predictive accuracy associated with the removal of each variable. To calculate model predictive accuracy, we used a 5-fold cross validation technique to evaluate out-of-sample performance (that is, we systematically and sequentially removed a portion of the plots and tested the ability of the model to predict results on those plots). Figures 6-9 visualize the results of both the HL and HI analyses across groups 1 and 2, respectively.

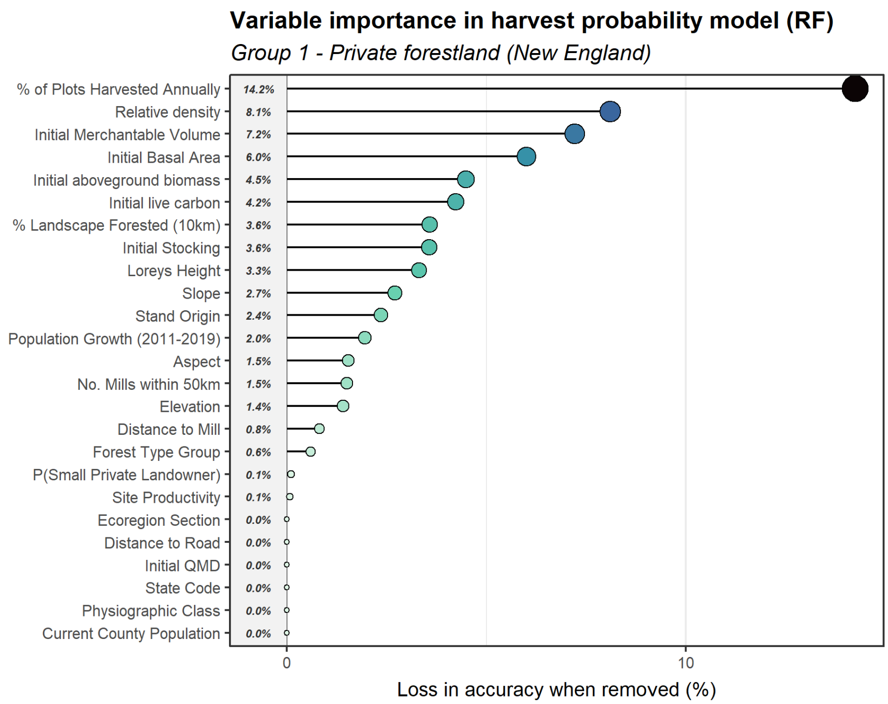

Figure 6. Variable Importance in explaining harvest likelihood (binary of harvest versus no harvest) on FIA plots in Group 1 using the Random Forest model.

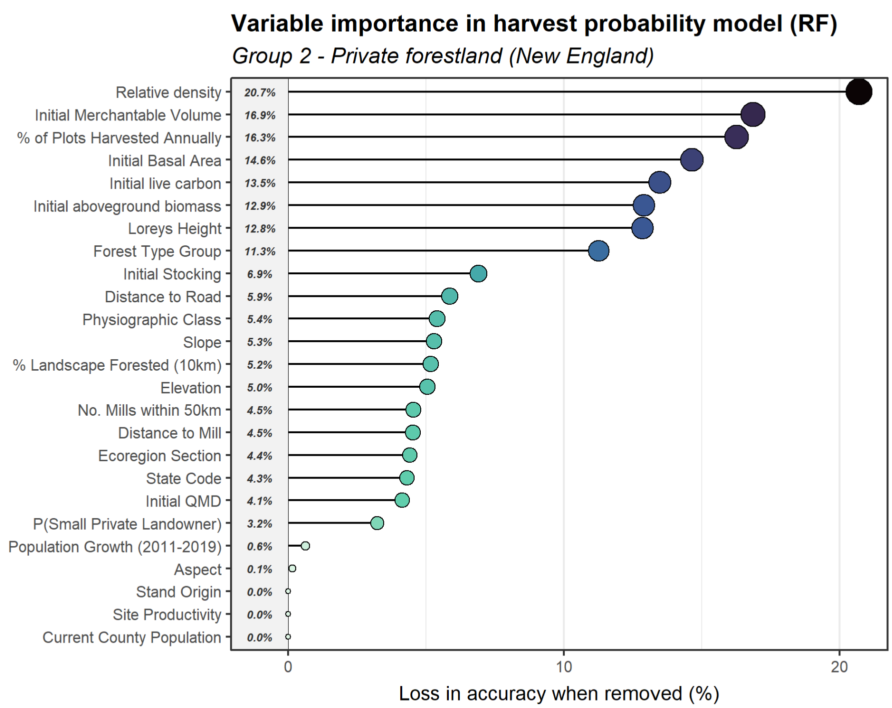

Figure 7. Variable Importance in explaining harvest likelihood (binary of harvest versus no harvest) on FIA plots in Group 2 using the Random Forest model.

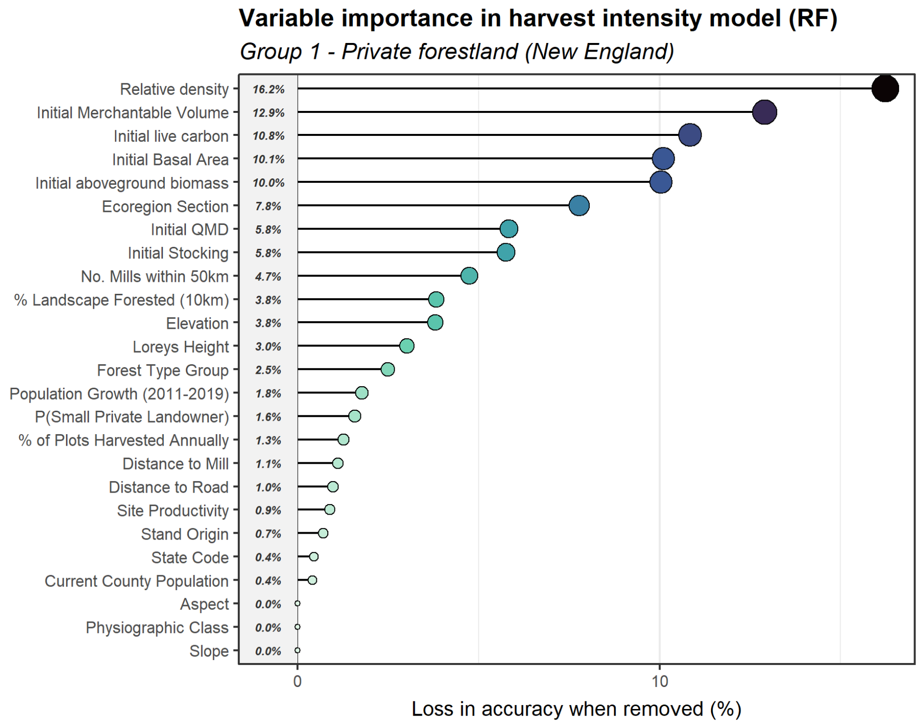

Figure 8. Variable Importance in explaining harvest intensity (cubic feet removed) on FIA plots in Group 1 using the Random Forest model. Model R^2 is 19.7.

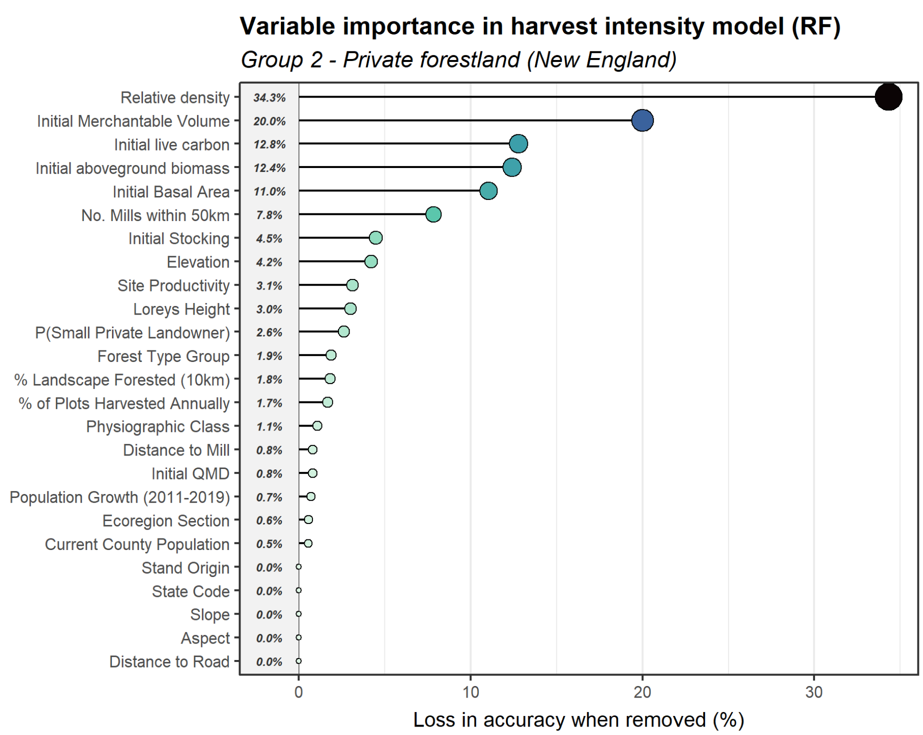

Figure 9. Variable Importance in explaining harvest intensity (cubic feet removed) on FIA plots in Group 2 using the Random Forest model. Model R^2 is 48.8.

Cap Impact Testing and Selection

With an aim of informing potential 1) landowner and donor pool caps (i.e., cutoffs to program participation) or 2) tiered payment structures, we systematically assessed how caps (or cutoffs) on each covariate and groups of covariate caps influenced harvest intensity. Together with the FFCP team, the objective was to identify covariates 1) whose caps would have the greatest positive impact on predicted harvest intensity without unduly reducing the donor pool and 2) that would not be excessively difficult or costly to measure, with programmatic considerations in mind.

Our process was to first determine a starting point for cap assessment for each of the covariates (where harvest intensity sees notable increase across plots) and then to systematically assess their impact on n and HI as those caps became systematically stricter and looser and across different covariate cap groupings (i.e., different combinations of caps being applied across a group of nine key covariates).

To determine the initial, or what we term 100%, cap selections for each covariate, we used partial dependence plots (PDP), histograms, and knowledge about the FTG-specific harvesting practices (see Appendix I for all PDPs and initial caps selected for testing). The PDPs help visualize predicted HI at different levels of the covariate of interest (e.g., the shifts in harvest intensity as stocking increases), while the histograms help visualize the effect different potential caps would have on the donor pool (n). Combing these sources of information, we identified initial data-driven, theoretically relevant caps for testing across each of the covariates.

To determine the impact of the caps on predicted harvest intensity and n, we reran the random forest model on the subset of selected plots (i.e., those not eliminated by the caps) across 30 distinct variable groupings and calculated the predicted harvest intensity and n based thereon.

The results of the caps analysis are shown in Tables 2 – 13, below. When caps are set at 0%, no cap has been applied to the donor pool; 100% caps represent the initially determined cap. In order to show *relative* performance, the harvest intensity tables below display the percent *change* in predicted harvest intensity *relative a reference point of applying the full (or 'ALL') cap grouping* (i.e., applying the determined caps on all 9 variables). See Appendix II for additional tables showing absolute predicted harvest intensity by cap grouping and intensity. The HI impact results are sorted by average performance across each of the cap levels and color-coded to reflect the strength of each of the cap groupings across the varying cap intensities. Dark blue indicates the top cap grouping/s and lighter blue indicates the next ten best performers. Where fewer than 50 donor plots were available, the cell reads "U50" rather than presenting the relative harvest intensity.

Maple/Beech/Birch—Group 1

Table 2. Impact of Diverse Cap Groupings on Predicted Harvest Intensity for Maple/Beech/Birch—Group 1, Shown Here as Harvest Intensity Relative to the Reference Point of Applying Caps on all Variables ('ALL').

Impact of Caps on Harvest Intensity
MBB - Group 1

Grouping	0%	25%	50%	75%	100%	125%	150%	AVG
QMD, Carb, BAA, Vol	0%	-1%	-2%	-2%	3%	16%	91%	18%
Carb, QMD, BAA	0%	-1%	-2%	-2%	3%	16%	91%	18%
AGB, Carb, BAA, QMD	0%	-1%	-2%	-2%	2%	16%	87%	17%
BAA & QMD	0%	-2%	-4%	-4%	0%	14%	88%	15%
QMD, BAA, Vol	0%	-2%	-4%	-3%	0%	14%	86%	15%
AGB, Carb, BAA, Vol	0%	-1%	-1%	-2%	0%	12%	73%	14%
AGB, Carb, BAA	0%	-1%	-3%	-2%	1%	11%	73%	13%
BAA & Carb	0%	-2%	-2%	-2%	0%	12%	74%	13%
QMD & Vol	0%	-2%	-5%	-5%	-1%	14%	79%	13%
Carbon, AGB, RD, Vol	1%	-1%	-1%	-2%	-2%	10%	70%	13%
AGB & Carbon	0%	-1%	-4%	-3%	0%	11%	70%	12%
Carbon	0%	-1%	-3%	-3%	-1%	10%	71%	12%
AGB & QMD	-1%	-3%	-8%	-9%	-4%	15%	74%	11%
BAA & Vol	0%	-2%	-4%	-4%	-3%	6%	61%	9%
AGB & BAA	0%	-2%	-5%	-4%	-3%	6%	61%	9%
BAA & St	0%	-2%	-5%	-4%	-3%	5%	60%	9%
AGB & Vol	0%	-2%	-6%	-4%	-2%	6%	59%	9%
Vol	0%	-2%	-5%	-5%	-3%	6%	61%	9%
BAA	0%	-2%	-5%	-4%	-3%	5%	60%	8%
BAA & RD	-1%	-1%	-3%	-5%	-5%	4%	56%	8%
QMD	0%	-6%	-12%	-15%	-9%	12%	60%	5%
AGB	0%	-3%	-8%	-10%	-7%	0%	49%	3%
AGB & St	0%	-4%	-8%	-10%	-7%	0%	49%	3%
Lorey	0%	-5%	-11%	-14%	-11%	3%	56%	3%
RD	-1%	-4%	-6%	-9%	-9%	-3%	42%	2%
ALL	0%	0%	0%	0%	0%	0%	*U50*	0%
Stocking	0%	-5%	-11%	-15%	-16%	-11%	30%	-5%
Slope	0%	-4%	-11%	-15%	-16%	-12%	28%	-5%
Elevation	0%	-6%	-12%	-15%	-17%	-20%	1%	-11%
Slope & Elevation	0%	-5%	-11%	-15%	-17%	-19%	-3%	-12%

Table 3. Impact of Diverse Cap Groupings on Plot Count (n) for Maple/Beech/Birch—Group 1

Impact of Caps on plot count (*n*)
MBB - Group 1

Grouping	0%	25%	50%	75%	100%	125%	150%
QMD, Carb, BAA, Vol	933	882	830	759	665	380	75
Carb, QMD, BAA	933	882	830	759	665	380	75
AGB, Carb, BAA, QMD	933	883	834	761	665	380	75
BAA & QMD	933	897	857	805	718	399	83
QMD, BAA, Vol	933	891	852	799	715	399	82
AGB, Carb, BAA, Vol	933	882	830	759	685	565	434
AGB, Carb, BAA	933	883	834	761	685	565	434
BAA & Carb	933	883	834	761	685	565	434
QMD & Vol	933	892	858	816	733	417	82
Carbon, AGB, RD, Vol	933	877	822	755	675	556	422
AGB & Carbon	933	887	840	766	691	570	438
Carbon	933	887	840	766	691	570	438
AGB & QMD	933	910	887	866	791	439	88
BAA & Vol	933	891	852	799	740	663	592
AGB & BAA	933	896	857	805	746	673	596
BAA & St	933	897	857	805	747	673	596
AGB & Vol	933	892	857	816	758	696	633
Vol	933	892	858	816	758	696	633
BAA	933	897	857	805	747	673	596
BAA & RD	933	889	841	795	728	652	571
QMD	933	933	933	927	842	461	99
AGB	933	910	887	866	840	803	766
AGB & St	933	910	887	866	840	803	766
Lorey	933	933	929	912	851	541	119
RD	933	903	865	842	796	750	702
ALL	933	873	809	716	539	154	5
Stocking	933	932	931	931	931	931	930
Slope	933	929	924	910	888	803	659
Elevation	933	933	932	927	842	544	240
Slope & Elevation	933	929	923	905	807	466	175

Maple/Beech/Birch—Group 2

Table 4. Impact of Diverse Cap Groupings on Predicted Harvest Intensity for Maple/Beech/Birch—Group 2, Shown Here as Harvest Intensity Relative to the Reference Point of Applying Caps on All Variables ('ALL').

Impact of Caps on Harvest Intensity
MBB - Group 2

Grouping	0%	25%	50%	75%	100%	125%	150%	AVG
QMD, BAA, Vol	0%	0%	-1%	2%	3%	11%	-1%	2%
QMD, Carb, BAA, Vol	1%	-1%	-1%	2%	3%	11%	-2%	2%
Carb, QMD, BAA	0%	-1%	-2%	1%	2%	11%	-1%	2%
AGB, Carb, BAA, QMD	0%	-1%	-1%	1%	2%	11%	-2%	2%
QMD & Vol	0%	0%	-1%	1%	3%	11%	-4%	2%
BAA & QMD	0%	-1%	-2%	1%	2%	11%	-2%	2%
ALL	0%	0%	0%	0%	0%	0%	*U50*	0%
AGB & QMD	0%	-2%	-5%	-5%	-4%	6%	-7%	-3%
BAA & Vol	0%	-1%	-1%	2%	3%	2%	-24%	-3%
AGB, Carb, BAA, Vol	0%	0%	-1%	2%	3%	2%	-25%	-3%
Vol	0%	0%	-1%	1%	3%	2%	-26%	-4%
AGB & Vol	0%	-1%	-2%	1%	3%	1%	-27%	-4%
BAA	1%	-1%	-2%	0%	2%	0%	-26%	-4%
BAA & Carb	0%	-1%	-2%	1%	2%	0%	-27%	-4%
AGB, Carb, BAA	1%	-1%	-2%	1%	2%	0%	-27%	-5%
AGB & BAA	1%	-1%	-2%	1%	1%	1%	-27%	-5%
BAA & St	0%	-1%	-2%	0%	1%	0%	-27%	-5%
Carbon, AGB, RD, Vol	0%	0%	-2%	-2%	-2%	-3%	-29%	-7%
QMD	0%	-3%	-8%	-10%	-10%	1%	-11%	-7%
BAA & RD	0%	0%	-2%	-3%	-3%	-4%	-30%	-7%
Carbon	1%	-2%	-5%	-4%	-6%	-8%	-34%	-10%
AGB	0%	-2%	-5%	-5%	-5%	-8%	-34%	-10%
AGB & St	0%	-2%	-5%	-5%	-6%	-8%	-35%	-10%
AGB & Carbon	1%	-2%	-5%	-5%	-6%	-8%	-34%	-10%
Lorey	0%	-3%	-6%	-9%	-13%	-15%	-36%	-14%
RD	0%	-2%	-6%	-10%	-14%	-17%	-41%	-15%
Slope	0%	-3%	-7%	-9%	-13%	-18%	-43%	-16%
Stocking	0%	-3%	-8%	-10%	-14%	-18%	-43%	-16%
Stocking & Elevation	0%	-3%	-7%	-9%	-13%	-23%	-53%	-18%
Elevation	0%	-3%	-7%	-9%	-13%	-23%	-52%	-18%

Table 5. Impact of Diverse Cap Groupings on Plot Count (n) for Maple/Beech/Birch—Group 2

Impact of Caps on plot count (*n*)
MBB - Group 2

Grouping	0%	25%	50%	75%	100%	125%	150%
QMD, BAA, Vol	644	619	579	529	465	305	87
QMD, Carb, BAA, Vol	644	619	579	529	463	305	87
Carb, QMD, BAA	644	623	587	542	477	308	87
AGB, Carb, BAA, QMD	644	623	587	542	477	308	87
QMD & Vol	644	619	584	536	472	316	94
BAA & QMD	644	623	590	543	480	308	87
ALL	644	614	571	502	401	182	15
AGB & QMD	644	636	620	598	556	357	99
BAA & Vol	644	619	579	529	470	404	338
AGB, Carb, BAA, Vol	644	619	579	529	468	404	337
Vol	644	619	584	536	477	416	359
AGB & Vol	644	619	584	536	475	416	358
BAA	644	623	590	543	486	420	352
BAA & Carb	644	623	587	542	483	420	350
AGB, Carb, BAA	644	623	587	542	483	420	350
AGB & BAA	644	623	587	542	483	420	350
BAA & St	644	623	589	542	485	419	351
Carbon, AGB, RD, Vol	644	617	582	528	455	399	340
QMD	644	644	644	643	610	385	109
BAA & RD	644	621	587	534	466	402	333
Carbon	644	636	620	598	567	539	489
AGB	644	636	620	598	567	539	489
AGB & St	644	636	619	597	566	538	488
AGB & Carbon	644	636	620	598	567	539	489
Lorey	644	643	637	627	620	563	362
RD	644	637	624	605	573	542	503
Slope	644	641	640	635	624	602	536
Stocking	644	644	643	643	643	643	643
Stocking & Elevation	644	641	640	630	586	461	278
Elevation	644	644	644	639	604	488	307

Oak/Hickory

Table 6. Impact of Diverse Cap Groupings on Predicted Harvest Intensity for Oak/Hickory, Shown Here as Harvest Intensity Relative to the Reference Point of Applying Caps on all Variables ('ALL').

Impact of Caps on Harvest Intensity
Oak/Hickory

Grouping	0%	25%	50%	75%	100%	125%	150%	AVG
AGB, Carb, BAA	-2%	-2%	-6%	-1%	3%	-11%	27%	2%
BAA & Carb	0%	-1%	-5%	-1%	3%	-12%	28%	2%
AGB, Carb, BAA, Vol	-1%	0%	-4%	-2%	2%	-11%	27%	2%
Carbon, AGB, RD, Vol	0%	-1%	-3%	-1%	0%	-13%	21%	1%
AGB & Carbon	0%	-1%	-6%	-2%	2%	-11%	20%	0%
ALL	0%	0%	0%	0%	0%	0%	*U50*	0%
Carbon	0%	-2%	-6%	-3%	1%	-12%	20%	0%
AGB & QMD	-1%	-3%	-11%	-10%	-5%	-9%	32%	-1%
AGB & BAA	-1%	-2%	-6%	-2%	0%	-13%	15%	-1%
BAA & Vol	-1%	-2%	-5%	-2%	0%	-14%	17%	-1%
BAA	-1%	-2%	-6%	-2%	0%	-14%	16%	-1%
BAA & St	-1%	-3%	-7%	-2%	0%	-14%	17%	-2%
AGB, Carb, BAA, QMD	0%	-1%	-5%	-2%	2%	-2%	*U50*	-2%
QMD, Carb, BAA, Vol	-1%	-1%	-5%	-2%	3%	-4%	*U50*	-2%
Carb, QMD, BAA	-1%	-1%	-5%	-2%	3%	-4%	*U50*	-2%
BAA & RD	0%	-2%	-2%	-4%	-4%	-15%	15%	-2%
BAA & QMD	-1%	-2%	-7%	-2%	1%	-6%	*U50*	-3%
QMD, BAA, Vol	0%	-1%	-6%	-2%	0%	-6%	U50	-3%
AGB & Vol	0%	-2%	-9%	-4%	-3%	-13%	11%	-3%
Vol	-1%	-1%	-10%	-5%	-5%	-14%	13%	-4%
QMD & Vol	-1%	-2%	-8%	-5%	-6%	-5%	U50	-5%
QMD	-1%	-5%	-15%	-16%	-11%	-14%	26%	-6%
AGB	-1%	-3%	-12%	-10%	-6%	-18%	5%	-7%
AGB & St	0%	-4%	-11%	-10%	-7%	-18%	5%	-8%
RD	-1%	-4%	-8%	-7%	-8%	-22%	2%	-8%
Lorey	0%	-4%	-14%	-16%	-12%	-19%	-5%	-12%
Slope & Elevation	-1%	-5%	-14%	-15%	-14%	-23%	-12%	-14%
Slope	-1%	-4%	-14%	-16%	-16%	-26%	-7%	-14%
Elevation	0%	-5%	-15%	-16%	-14%	-26%	-12%	-15%
Stocking	-2%	-6%	-15%	-16%	-17%	-28%	-9%	-15%

Table 7. Impact of Diverse Cap Groupings on Plot Count (n) for Oak/Hickory

Impact of Caps on plot count (*n*)
Oak/Hickory

Grouping	0%	25%	50%	75%	100%	125%	150%
AGB, Carb, BAA	388	362	327	300	260	213	164
BAA & Carb	388	362	327	300	260	213	164
AGB, Carb, BAA, Vol	388	360	324	299	259	213	163
Carbon, AGB, RD, Vol	388	354	318	295	256	214	165
AGB & Carbon	388	363	332	301	261	216	170
ALL	388	353	312	284	220	104	17
Carbon	388	363	332	301	261	216	170
AGB & QMD	388	374	363	350	299	189	54
AGB & BAA	388	369	344	313	292	258	218
BAA & Vol	388	364	336	308	285	253	210
BAA	388	369	344	313	292	258	218
BAA & St	388	368	343	312	292	258	218
AGB, Carb, BAA, QMD	388	362	327	300	249	147	36
QMD, Carb, BAA, Vol	388	360	324	299	249	147	36
Carb, QMD, BAA	388	360	324	299	249	147	36
BAA & RD	388	362	330	305	283	254	209
BAA & QMD	388	369	344	313	273	162	41
QMD, BAA, Vol	388	364	336	308	270	161	41
AGB & Vol	388	364	339	312	292	264	231
Vol	388	364	339	312	292	264	231
QMD & Vol	388	364	339	312	277	171	46
QMD	388	388	388	384	328	201	58
AGB	388	374	363	351	332	317	301
AGB & St	388	372	362	350	332	317	301
RD	388	369	344	322	310	295	274
Lorey	388	388	383	372	330	222	50
Slope & Elevation	388	387	385	380	370	344	298
Slope	388	387	385	380	370	344	298
Elevation	388	388	388	388	388	388	388
Stocking	388	385	384	384	384	384	384

Spruce/Fir

Table 8. Impact of Diverse Cap Groupings on Predicted Harvest Intensity for Spruce/Fir, Shown Here as Harvest Intensity Relative to the Reference Point of Applying Caps on all Variables ('ALL').

Impact of Caps on Harvest Intensity
Spruce/ Fir

Grouping	0%	25%	50%	75%	100%	125%	150%	AVG
QMD, Carb, BAA, Vol	0%	-1%	0%	5%	9%	*U50*	*U50*	3%
QMD, BAA, Vol	0%	-1%	-1%	5%	9%	U50	U50	3%
QMD & Vol	0%	-1%	-2%	5%	7%	*U50*	*U50*	2%
AGB, Carb, BAA, QMD	0%	-3%	-2%	2%	6%	*U50*	*U50*	1%
BAA & QMD	0%	-4%	-4%	2%	5%	4%	*U50*	1%
Carb, QMD, BAA	1%	-4%	-3%	1%	6%	*U50*	*U50*	0%
ALL	0%	0%	0%	0%	0%	*U50*	*U50*	0%
AGB, Carb, BAA, Vol	1%	-1%	-1%	5%	6%	-1%	-18%	-2%
BAA & Vol	0%	-1%	-1%	5%	4%	-3%	-16%	-2%
AGB & QMD	1%	-7%	-8%	-1%	4%	1%	*U50*	-2%
AGB & Vol	-1%	-1%	-1%	4%	5%	-2%	-19%	-2%
Vol	0%	0%	-2%	4%	5%	-2%	-18%	-2%
AGB & BAA	0%	-3%	-3%	2%	4%	-2%	-21%	-4%
AGB, Carb, BAA	0%	-3%	-3%	1%	2%	-2%	-21%	-4%
BAA & Carb	0%	-4%	-3%	2%	2%	-3%	-21%	-4%
BAA & St	2%	-3%	-3%	3%	1%	-7%	-21%	-5%
BAA	1%	-4%	-4%	1%	2%	-8%	-21%	-6%
Carbon, AGB, RD, Vol	0%	0%	-2%	-2%	-2%	-8%	-24%	-6%
AGB & St	0%	-7%	-7%	-2%	0%	-8%	-26%	-8%
Carbon	0%	-7%	-8%	-2%	-1%	-7%	-26%	-8%
AGB & Carbon	0%	-7%	-8%	-2%	-1%	-8%	-24%	-8%
AGB	0%	-7%	-8%	-2%	-1%	-9%	-25%	-9%
BAA & RD	1%	-2%	-4%	-5%	-7%	-12%	-28%	-10%
QMD	0%	-9%	-15%	-16%	-11%	-11%	U50	-13%
Lorey	1%	-10%	-14%	-14%	-19%	-24%	-29%	-18%
RD	0%	-7%	-10%	-15%	-21%	-27%	-42%	-20%
Stocking	0%	-9%	-15%	-16%	-21%	-30%	-44%	-22%
Elevation	1%	-9%	-13%	-16%	-21%	-30%	-46%	-23%
Slope & Elevation	1%	-8%	-14%	-16%	-21%	-31%	-47%	-23%
Slope	1%	-10%	-15%	-17%	-22%	-31%	-45%	-23%

Table 9. Impact of Diverse Cap Groupings on Plot Count (n) for Spruce/Fir

Impact of Caps on plot count (*n*)
Spruce/ Fir

Grouping	0%	25%	50%	75%	100%	125%	150%
QMD, Carb, BAA, Vol	246	214	184	160	129	48	7
QMD, BAA, Vol	246	214	185	162	130	49	7
QMD & Vol	246	214	186	162	130	49	8
AGB, Carb, BAA, QMD	246	222	194	170	132	49	7
BAA & QMD	246	223	197	175	139	52	7
Carb, QMD, BAA	246	222	194	170	132	49	7
ALL	246	212	182	151	114	36	3
AGB, Carb, BAA, Vol	246	214	184	160	139	117	89
BAA & Vol	246	214	185	162	140	120	90
AGB & QMD	246	237	212	182	139	51	7
AGB & Vol	246	214	184	160	139	118	90
Vol	246	214	186	162	140	121	92
AGB & BAA	246	222	194	170	146	124	100
AGB, Carb, BAA	246	222	194	170	146	124	100
BAA & Carb	246	222	194	170	146	124	100
BAA & St	246	223	197	175	154	134	106
BAA	246	223	197	175	154	134	106
Carbon, AGB, RD, Vol	246	212	183	158	135	115	84
AGB & St	246	237	212	182	157	141	113
Carbon	246	237	212	182	157	141	113
AGB & Carbon	246	237	212	182	157	141	113
AGB	246	237	212	182	157	141	113
BAA & RD	246	220	194	172	150	130	100
QMD	246	246	246	245	190	75	16
Lorey	246	246	245	236	230	197	125
RD	246	235	223	212	199	189	162
Stocking	246	246	246	246	246	246	246
Elevation	246	246	245	241	237	209	138
Slope & Elevation	246	246	245	241	234	205	135
Slope	246	246	246	246	242	240	237

Pine—Group 1

Table 10. Impact of Diverse Cap Groupings on Predicted Harvest Intensity for Pine—Group 1, Shown Here as Harvest Intensity Relative to the Reference Point of Applying Caps on all Variables ('ALL').

Impact of Caps on Harvest Intensity
Pine - Group 1

Grouping	0%	25%	50%	75%	100%	125%	150%	AVG
BAA & Vol	0%	-5%	-8%	-7%	-7%	12%	116%	17%
BAA & St	0%	-6%	-10%	-8%	-6%	10%	118%	16%
AGB & BAA	-1%	-5%	-10%	-8%	-7%	11%	116%	16%
AGB, Carb, BAA	1%	-6%	-9%	-7%	-7%	8%	112%	15%
BAA	2%	-5%	-10%	-8%	-8%	9%	112%	15%
AGB, Carb, BAA, Vol	1%	-5%	-10%	-8%	-6%	8%	110%	15%
BAA & Carb	-1%	-6%	-10%	-7%	-7%	8%	111%	15%
AGB & Carbon	1%	-7%	-13%	-8%	-9%	1%	77%	7%
Carbon	0%	-6%	-13%	-9%	-11%	-1%	78%	6%
AGB & Vol	0%	-5%	-14%	-13%	-15%	1%	77%	5%
AGB & St	0%	-6%	-14%	-14%	-16%	1%	79%	5%
AGB	0%	-6%	-14%	-14%	-15%	-1%	77%	4%
Vol	0%	-7%	-15%	-14%	-18%	-4%	81%	4%
QMD & Vol	-1%	-7%	-14%	-14%	-18%	0%	56%	0%
ALL	0%	0%	0%	0%	0%	0%	*U50*	0%
BAA & QMD	0%	-5%	-9%	-7%	-6%	11%	*U50*	-3%
QMD, Carb, BAA, Vol	0%	-5%	-9%	-6%	-5%	10%	*U50*	-3%
Carb, QMD, BAA	0%	-5%	-9%	-6%	-5%	10%	*U50*	-3%
AGB, Carb, BAA, QMD	0%	-6%	-9%	-7%	-5%	9%	*U50*	-4%
QMD, BAA, Vol	0%	-5%	-9%	-7%	-6%	9%	U50	-4%
BAA & RD	1%	-4%	-6%	-4%	-5%	-10%	*U50*	-6%
Elevation	1%	-9%	-17%	-20%	-21%	-17%	44%	-7%
Carbon, AGB, RD, Vol	-1%	-3%	-6%	-6%	-8%	-15%	*U50*	-8%
RD	-1%	-4%	-6%	-6%	-10%	-15%	*U50*	-8%
AGB & QMD	-1%	-6%	-15%	-13%	-14%	5%	*U50*	-8%
Slope & Elevation	0%	-7%	-15%	-20%	-20%	-17%	23%	-9%
Lorey	1%	-9%	-19%	-24%	-27%	-17%	38%	-10%
QMD	0%	-8%	-20%	-23%	-29%	-14%	30%	-11%
Stocking	-1%	-8%	-19%	-23%	-29%	-24%	32%	-12%
Slope	2%	-7%	-18%	-24%	-28%	-25%	12%	-15%

Table 11. Impact of Diverse Cap Groupings on Plot Count (n) for Pine—Group 1

Impact of Caps on plot count (*n*)
Pine - Group 1

Grouping	0%	25%	50%	75%	100%	125%	150%
BAA & Vol	184	177	154	132	106	80	55
BAA & St	184	177	154	132	106	80	55
AGB & BAA	184	176	154	132	106	80	55
AGB, Carb, BAA	184	176	154	131	106	80	54
BAA	184	177	154	132	106	80	55
AGB, Carb, BAA, Vol	184	176	154	131	106	80	54
BAA & Carb	184	176	154	131	106	80	54
AGB & Carbon	184	178	166	141	122	101	81
Carbon	184	178	166	141	122	101	81
AGB & Vol	184	177	165	148	128	111	91
AGB & St	184	178	169	152	130	113	93
AGB	184	178	169	152	130	113	93
Vol	184	178	168	153	139	120	103
QMD & Vol	184	178	168	153	137	102	52
ALL	184	161	131	100	69	28	4
BAA & QMD	184	177	154	132	105	71	34
QMD, Carb, BAA, Vol	184	176	154	131	105	71	33
Carb, QMD, BAA	184	176	154	131	105	71	33
AGB, Carb, BAA, QMD	184	176	154	131	105	71	33
QMD, BAA, Vol	184	177	154	132	105	71	34
BAA & RD	184	168	141	119	86	60	32
Elevation	184	180	173	158	144	123	106
Carbon, AGB, RD, Vol	184	168	145	120	94	64	36
RD	184	170	148	122	96	68	40
AGB & QMD	184	178	169	152	127	95	47
Slope & Elevation	184	178	171	155	140	112	81
Lorey	184	184	183	182	171	128	59
QMD	184	184	184	184	174	136	75
Stocking	184	183	183	183	183	183	183
Slope	184	182	182	181	176	167	144

Pine—Group 2

Table 12. Impact of Diverse Cap Groupings on Predicted Harvest Intensity for Pine—Group 2, Shown Here as Harvest Intensity Relative to the Reference Point of Applying Caps on all Variables ('ALL').

Impact of Caps on Harvest Intensity
Pine - Group 2

Grouping	0%	25%	50%	75%	100%	125%	150%	AVG
ALL	0%	0%	0%	U50	U50	U50	NA	0%
AGB & BAA	-1%	-2%	-6%	-18%	U50	U50	NA	-9%
QMD, Carb, BAA, Vol	1%	-3%	-6%	-17%	U50	U50	NA	-9%
BAA & St	-1%	-3%	-5%	-18%	U50	U50	NA	-9%
QMD, BAA, Vol	0%	-2%	-5%	-18%	U50	U50	NA	-9%
BAA	0%	-3%	-5%	-18%	U50	U50	NA	-9%
AGB, Carb, BAA, Vol	1%	-2%	-6%	-18%	U50	U50	NA	-9%
BAA & Carb	1%	-3%	-5%	-19%	U50	U50	NA	-9%
BAA & Vol	0%	-3%	-5%	-18%	U50	U50	NA	-9%
AGB, Carb, BAA, QMD	-1%	-3%	-6%	-18%	U50	U50	NA	-9%
Carb, QMD, BAA	0%	-3%	-5%	-18%	U50	U50	NA	-9%
BAA & RD	1%	-1%	-7%	-19%	U50	U50	NA	-9%
BAA & QMD	1%	-3%	-6%	-19%	U50	U50	NA	-9%
AGB, Carb, BAA	1%	-3%	-6%	-19%	U50	U50	NA	-9%
Elevation	0%	-7%	-12%	U50	U50	U50	NA	-10%
Slope & Elevation	0%	-7%	-14%	U50	U50	U50	NA	-10%
Carbon, AGB, RD, Vol	1%	-3%	-9%	-22%	U50	U50	NA	-11%
AGB & Vol	0%	-4%	-7%	-21%	-13%	U50	NA	-11%
QMD & Vol	1%	-4%	-8%	-20%	-15%	U50	NA	-12%
AGB	-1%	-2%	-10%	-21%	-14%	U50	NA	-12%
AGB & St	0%	-3%	-10%	-22%	-13%	U50	NA	-12%
Vol	0%	-3%	-9%	-22%	-15%	U50	NA	-12%
AGB & Carbon	1%	-2%	-10%	-21%	-15%	U50	NA	-12%
AGB & QMD	1%	-4%	-10%	-22%	-14%	U50	NA	-12%
Carbon	0%	-5%	-11%	-22%	-19%	U50	NA	-14%
RD	0%	-3%	-13%	-26%	-27%	U50	NA	-17%
QMD	0%	-8%	-18%	-31%	-30%	-5%	NA	-19%
Lorey	0%	-9%	-17%	-31%	-27%	-15%	NA	-20%
Stocking	0%	-9%	-18%	-32%	-30%	-21%	NA	-22%
Slope	0%	-8%	-18%	-32%	-30%	-25%	NA	-22%

Table 13. Impact of Diverse Cap Groupings on Plot Count (n) for Pine—Group 2

Impact of Caps on plot count (*n*)
Pine - Group 2

Grouping	0%	25%	50%	75%	100%	125%	150%
ALL	93	72	48	23	13	1	0
AGB & BAA	93	83	72	61	38	27	10
QMD, Carb, BAA, Vol	93	83	72	61	38	24	8
BAA & St	93	84	72	61	38	27	11
QMD, BAA, Vol	93	83	72	61	38	24	8
BAA	93	84	72	61	38	27	11
AGB, Carb, BAA, Vol	93	83	72	61	38	27	10
BAA & Carb	93	84	72	61	38	27	11
BAA & Vol	93	83	72	61	38	27	11
AGB, Carb, BAA, QMD	93	83	72	61	38	24	7
Carb, QMD, BAA	93	84	72	61	38	24	8
BAA & RD	93	83	71	60	35	21	9
BAA & QMD	93	84	72	61	38	24	8
AGB, Carb, BAA	93	83	72	61	38	27	10
Elevation	93	84	66	41	27	18	13
Slope & Elevation	93	83	65	39	25	14	9
Carbon, AGB, RD, Vol	93	83	76	67	44	30	17
AGB & Vol	93	85	77	68	50	39	28
QMD & Vol	93	86	77	69	57	41	20
AGB	93	85	80	70	53	40	28
AGB & St	93	85	80	70	53	40	28
Vol	93	86	77	69	57	45	37
AGB & Carbon	93	85	80	70	53	40	28
AGB & QMD	93	85	80	70	52	35	17
Carbon	93	88	80	73	65	49	39
RD	93	85	81	75	62	48	35
QMD	93	93	93	93	89	61	32
Lorey	93	93	92	91	85	57	25
Stocking	93	93	93	93	93	93	93
Slope	93	92	92	91	89	85	77

Selected Caps

After reviewing the impact (on harvest intensity and sample plots, n) associated with varying degrees and groupings of caps, the FFCP team elected to pursue continued donor plot testing using the cap criteria detailed in **Table 14**. It is this cap selection that will be applied in the subsequent section where we test the available donor plots by geographical area and forest type group, with and without these caps applied.

Table 14. Final Caps Selected by the FFCP Team

Selected Caps by Group and Forest Type Group

FTG	Group	Cap Description	BAA	QMD	Volume
MBB	1	100% caps on BAA and QMD	>50 ft^2/ ac	>8 in	-
MBB	2	100% caps on BAA and QMD	>50 ft^2/ ac	>7 in	-
OH	Both	100% caps on BAA and QMD	>50 ft^2/ ac	>8 in	-
SF	Both	75% caps on QMD, BAA, Vol	>37.5 ft^2/ ac	>5.25 in	>750 ft^3/ ac
Pine	Both	125% cap on BAA and Vol	>125 ft^2/ ac	-	>1875 ft^3/ ac

Cap Feasibility Testing: Donor Plot Counts

The FFCP methodology for Improved Forest Management requires that there be at least 50 potential donor plots from which to draw the ten closest matches, using a k-nearest neighbor optimal matching approach relying on Mahalanobis distance calculations on important predictors of harvest behavior (FFCP, 2022). Those 50 donor plots must meet a series of exact matching criteria (including same FTG, forest origin, and ownership category, among others). If possible, those 50 donor plots should also come from the same ecoregion. Where there are insufficient (i.e., under 50) donor plots in the same ecoregion, the donor pool may extend to the ecoprovince. Where there are still insufficient donor plots, the donor pool may extend to the 'ecoprovince state', that is, all plots (meeting exact matching criteria) that fall in a state (within the NE region and, where relevant, subgroup) where the sample plot's ecoprovince exists. Donor plots do not need to fall within the sample plot's ecoprovince; they merely need to be in a state where the sample plot's ecoregion exists. Each loosening of the donor pool criteria (from ecoregion to ecoprovince and then ecoprovince state) expands the potential donor pool considerably.

To test the impact of applying landowner participation caps (per **Table 14**) on donor pool size, we calculate the number of existing donor plots (by FTG and ecoregion/ ecoprovince/ ecoprovince states) with and without applying the identified caps. As expected, applying caps in all cases reduces the number of plots in the available donor pool at all levels. **Table 15** shows the number of potential donor plots by FTG and ecoregion, both with and without the caps applied. All FTG/ ecoregion combinations with at least 50 plots are highlighted in gray; all FTG/ ecoregion combinations that *had* at least 50 plots before the cap was applied but not after are highlighted in red.

Table 15. Number of Available Donor Plots by Forest Type Group (FTG) and Ecoregion Both with and without Exclusionary Caps Applied. (Gray Indicates at least 50 Available donor plots; red indicates a loss of sufficient donor plots with the cap applied.)

Donor Plots by Forest Type Group and Ecoregion (with and without caps applied)

	FTG	Group	211C	211B	M211C	M211B	221A	M211D	211E	211J	222I	211A	M211A	211F	211D	221B	221F	211G	211I
No Caps	MBB	1	-	-	127	107	44	208	61	56	51	-	-	134	-	22	18	20	83
	MBB	2	21	70	11	40	48	-	-	-	-	28	354	-	72	-	-	-	-
	OH	Both	1	-	13	22	137	7	15	6	38	-	2	66	16	39	4	4	15
	SF	Both	19	44	4	15	-	15	7	3	-	19	88	2	26	-	-	-	1
	Pine	Both	5	15	17	50	59	20	16	8	1	1	9	13	31	11	-	-	7
Caps Applied	MBB	1	-	-	111	96	29	162	35	40	28	-	-	104	-	16	13	16	68
	MBB	2	14	44	9	34	40	-	-	-	-	18	275	-	46	-	-	-	-
	OH	Both	1	-	9	18	107	6	6	3	19	-	2	49	8	27	2	4	11
	SF	Both	10	33	3	15	-	10	2	2	-	13	53	2	16	-	-	-	1
	Pine	Both	1	4	10	24	26	6	4	2	-	-	6	4	7	4	-	-	4

Table 16 shows the number of potential donor plots by FTG and ecoprovince, both with and without the caps applied. Again, all combinations with at least 50 plots are highlighted in gray and all combinations that lost the requisite 50 plots when the cap was applied are highlighted in red.

Table 16. Number of Available Donor Plots by Forest Type Group (FTG) and Ecoprovince Both with and without Exclusionary Caps Applied. (Gray indicates at least 50 available donor plots; red indicates a loss of sufficient donor plots with the cap applied.)

Donor Plots by Forest Type Group and Ecoprovince (with and without caps applied)

	FTG	Group	211	M211	221	222
No Caps	MBB	1	354	442	84	51
	MBB	2	191	405	48	-
	OH	Both	123	44	180	38
	SF	Both	121	122	-	-
	Pine	Both	96	96	70	1
Caps Applied	MBB	1	263	369	58	28
	MBB	2	122	318	40	-
	OH	Both	82	35	136	19
	SF	Both	79	81	-	-
	Pine	Both	26	46	30	-

Table 17 shows the number of potential donor plots by FTG and ecoprovince states, both with and without the caps applied. Here also, all combinations with at least 50 plots are highlighted in gray and all combinations that lost the requisite 50 plots when the cap was applied are highlighted in red.

Table 17. Number of Available Donor Plots by Forest Type Group (FTG) and Ecoprovince State Both with and without Exclusionary Caps Applied. (Gray indicates at least 50 available donor plots; red indicates a loss of sufficient donor plots with the cap applied.)

Donor Plots by Forest Type Group and Ecoprovince State (with and without caps applied)

	FTG	Group	211	M211	221	222
No Caps	MBB	1	805	931	931	632
	MBB	2	559	644	644	-
	OH	Both	242	382	385	201
	SF	Both	237	243	243	27
	Pine	Both	186	263	263	72
Caps Applied	MBB	1	611	718	718	471
	MBB	2	411	480	480	0
	OH	Both	158	269	272	132
	SF	Both	157	160	160	17
	Pine	Both	64	102	102	23

References

Breiman, L. (2001). Random Forests. *Machine Learning*. 45:5-32.

Cleland, D.T.; Freeouf, J.A.; Keys, J.E.; Nowacki, G.J.; Carpenter, C.A.; and McNab, W.H. (2007). Ecological Subregions: Sections and Subsections for the conterminous United States. Gen. Tech. Report WO-76D [Map on CD-ROM] (A.M. Sloan, cartographer). Washington, DC: U.S. Department of Agriculture, Forest Service, presentation scale 1:3,500,000; colored. https://www.fs.usda.gov/research/treesearch/48672

Family Forest Carbon Program (2022). Methodology for Improved Forest Management. 11 April 2021.

Sass, Emma M.; Butler, Brett J.; Markowski-Lindsay, Marla. (2020). Distribution of forest ownerships across the conterminous United States, 2017. Res. Map NRS-11. Madison, WI: U.S. Department of Agriculture, Forest Service, Northern Research Station. https://doi.org/10.2737/NRS-RMAP-11. [Scale 1: 10,000,000, 1: 80,000,000].

Wager, S., T. Hasie, B. Efron. (2014). Confidence Intervals for Random Forests: the Jackknife and the infinitesimal Jackknife. *Journal of Machine Learning Research*. 15:1625-1651.

Ziegler, A., Inke R. Konig. (2014). Mining data with random forests: current options for real-world applications. *WIREs Data Mining Knowl Discov*. 4:55-63

Appendix I: Partial Dependence Plots

Each of the below partial dependence plots (PDPs) demonstrates how shifts in individual variables impacts probability of harvest by group and FTG. Orange lines show the initial 100% caps selected for testing, based on marked increase in harvest probability per the PDPs as well as knowledge about regional harvesting behavior. In the majority of cases, identified caps sought to exclude any plots *below* a certain threshold (the orange line); where the opposite is the case (e.g., with slope), an orange X indicates the plots that should be excluded per the cap. Where no orange line exists (e.g., for aspect and bole biomass), no initial cap was identified or tested.

Note that because so few Oak/Hickory plots exist in Group 2, all Oak/Hickory plots are shown below as falling in Group 1; likewise, though Spruce/Fir is shown here in Group 2 only, it also includes the small number of Spruce/Fir plots from Group 1.

Aboveground Biomass

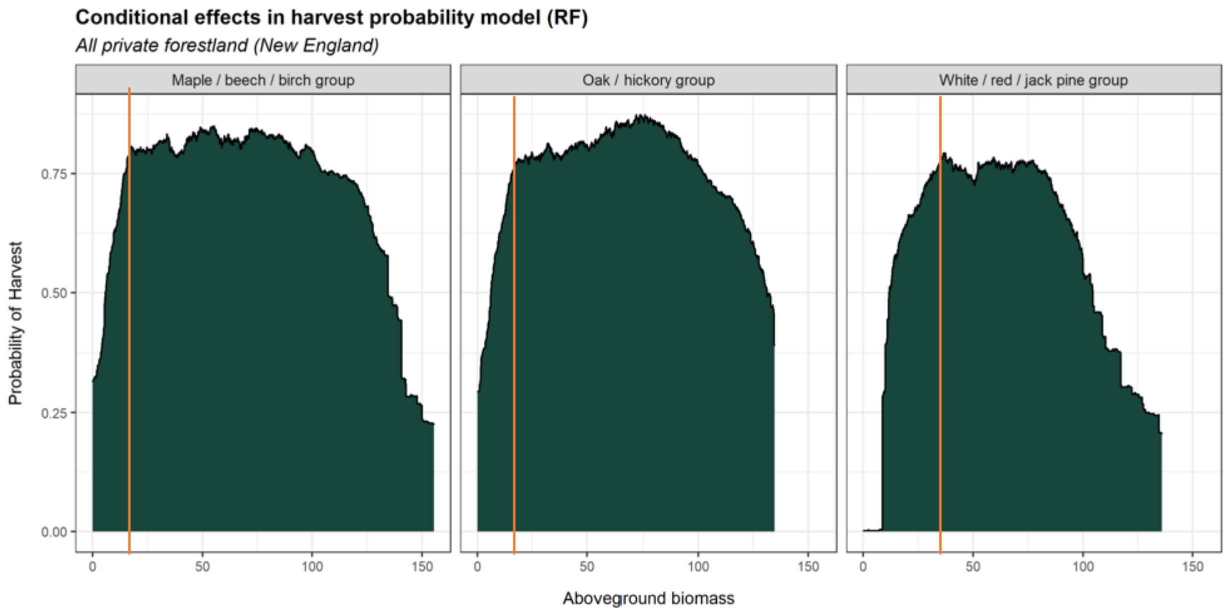

Figure 10. Partial dependence plot for aboveground biomass (Group 1)

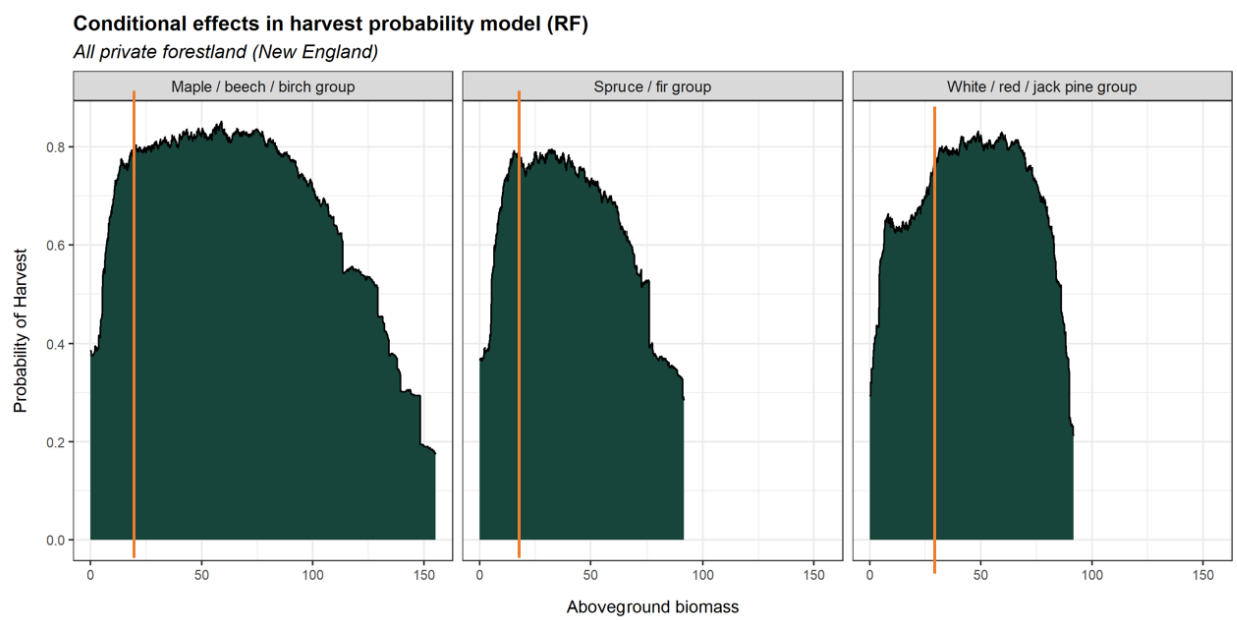

Figure 11 Partial dependence plot for aboveground biomass (Group 2)

Basal Area

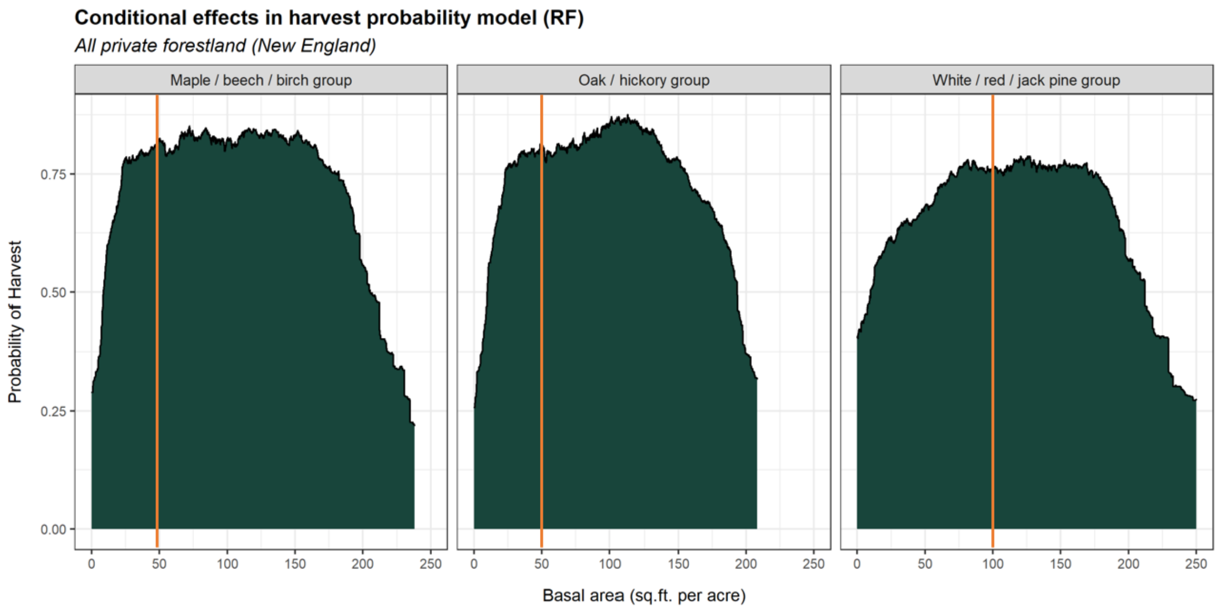

Figure 12. Partial dependence plot for basal area (Group 1)

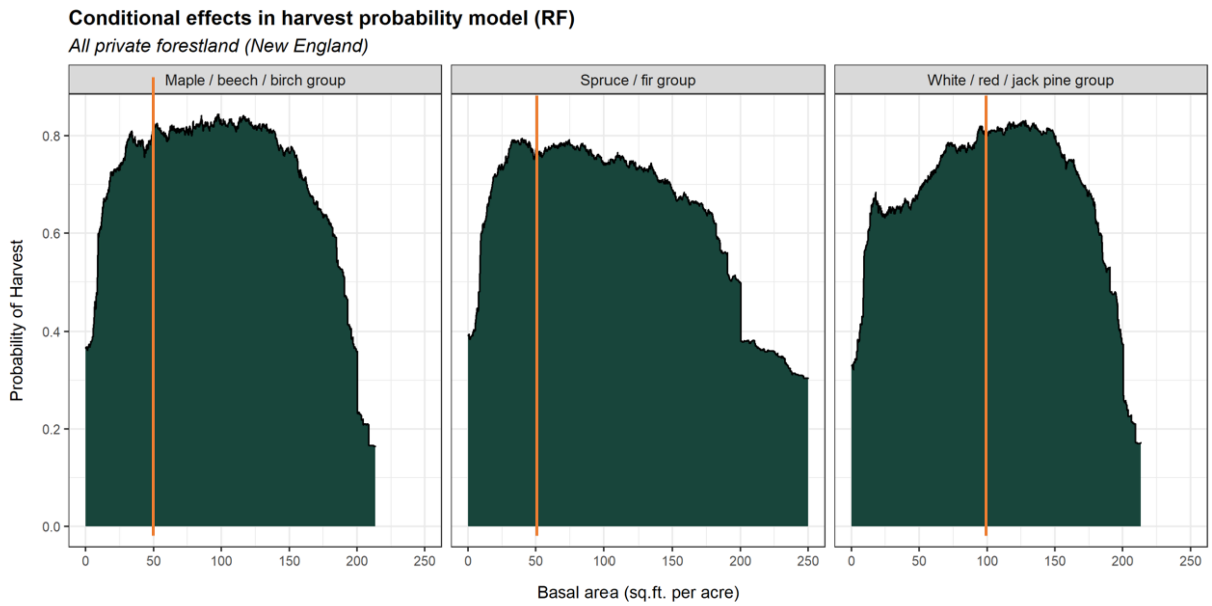

Figure 13. Partial dependence plot for basal area (Group 2)

Carbon

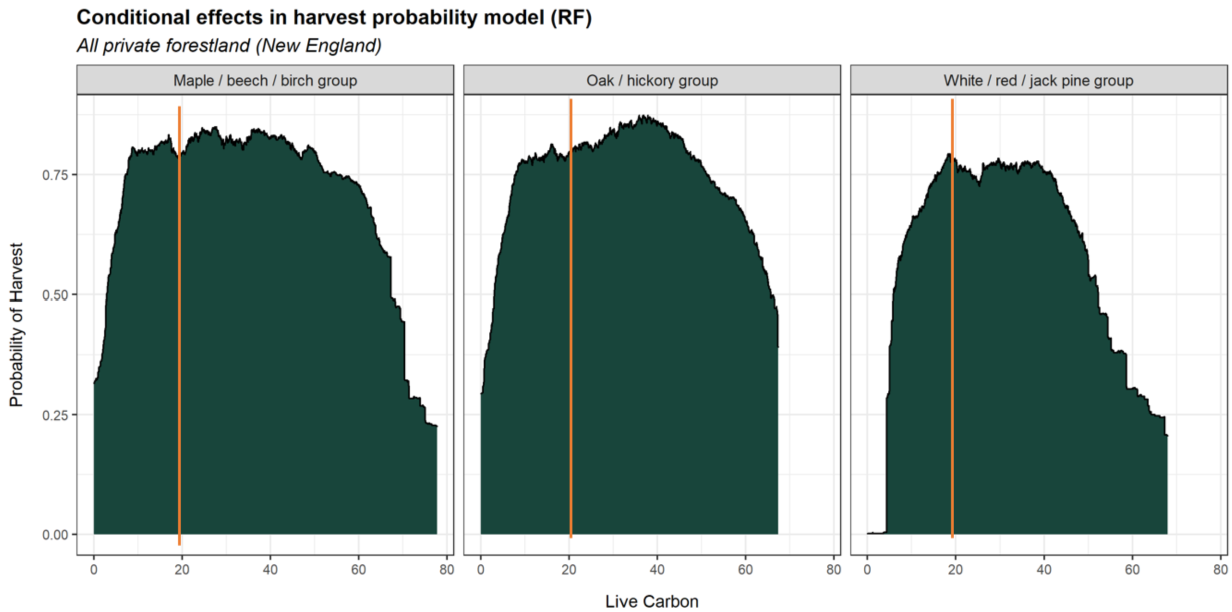

Figure 14. Partial dependence plot for carbon (Group 1)

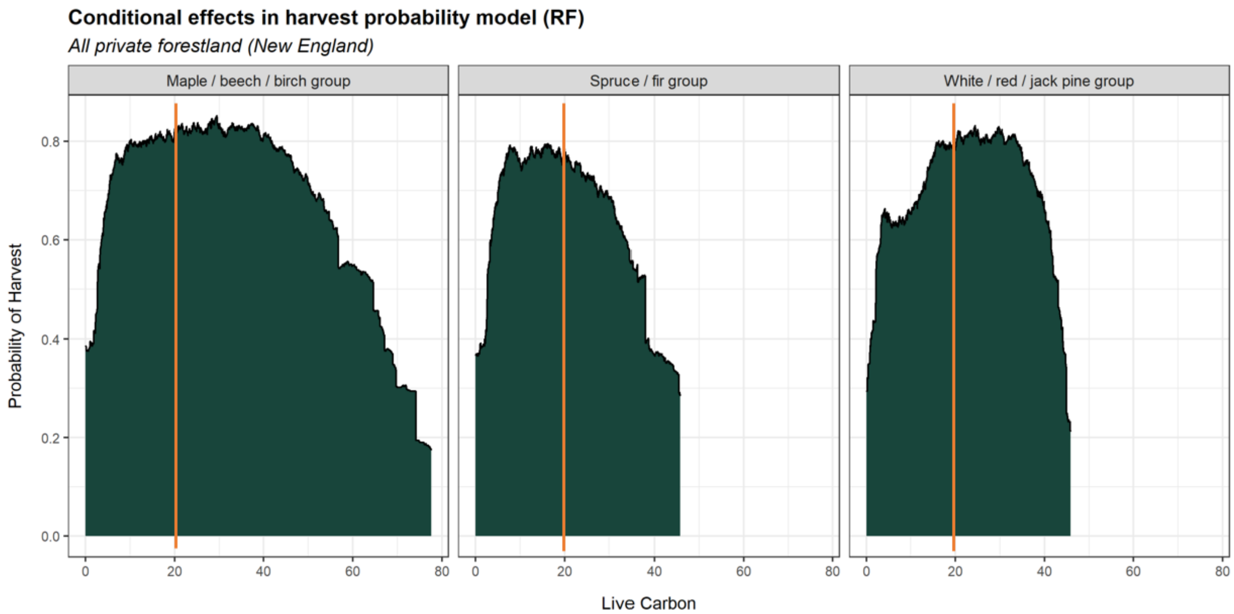

Figure 15. Partial dependence plot for carbon (Group 2)

Lorey's Height

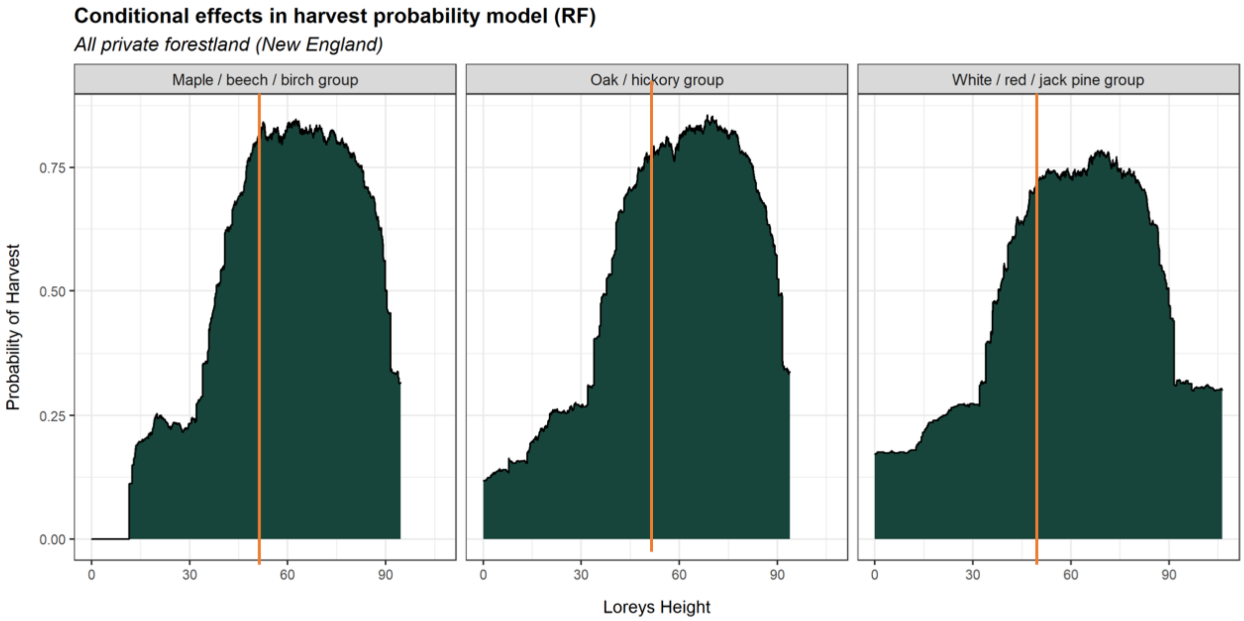

Figure 16. Partial dependence plot for Lorey's Height (Group 1)

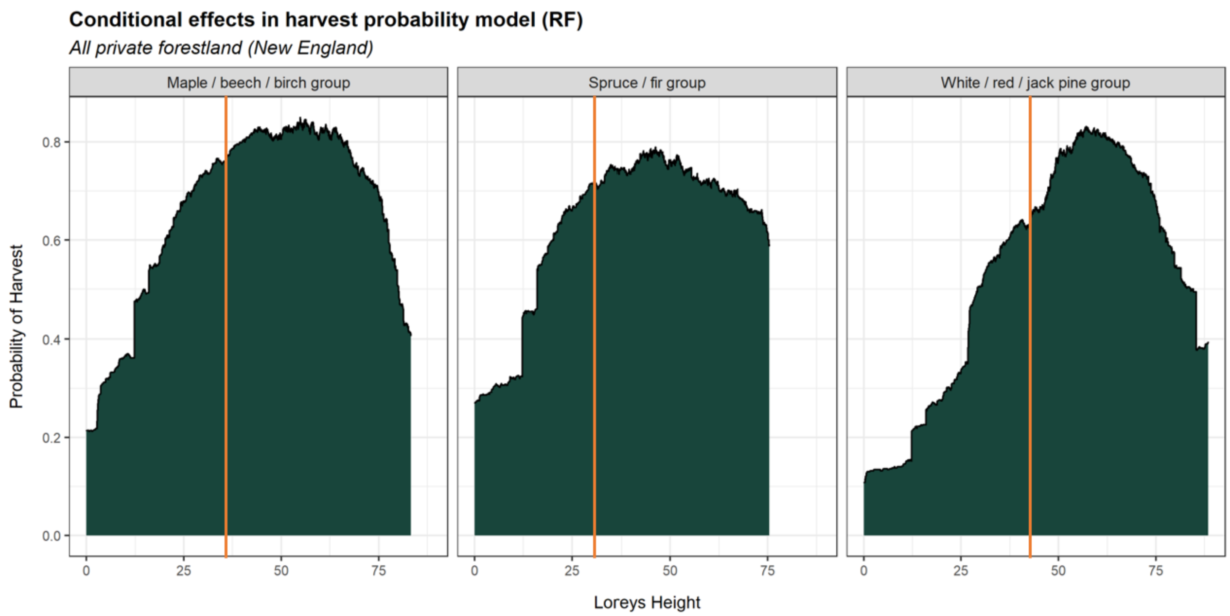

Figure 17. Partial dependence plot for Lorey's Height (Group 2)

Quadratic Mean Diameter

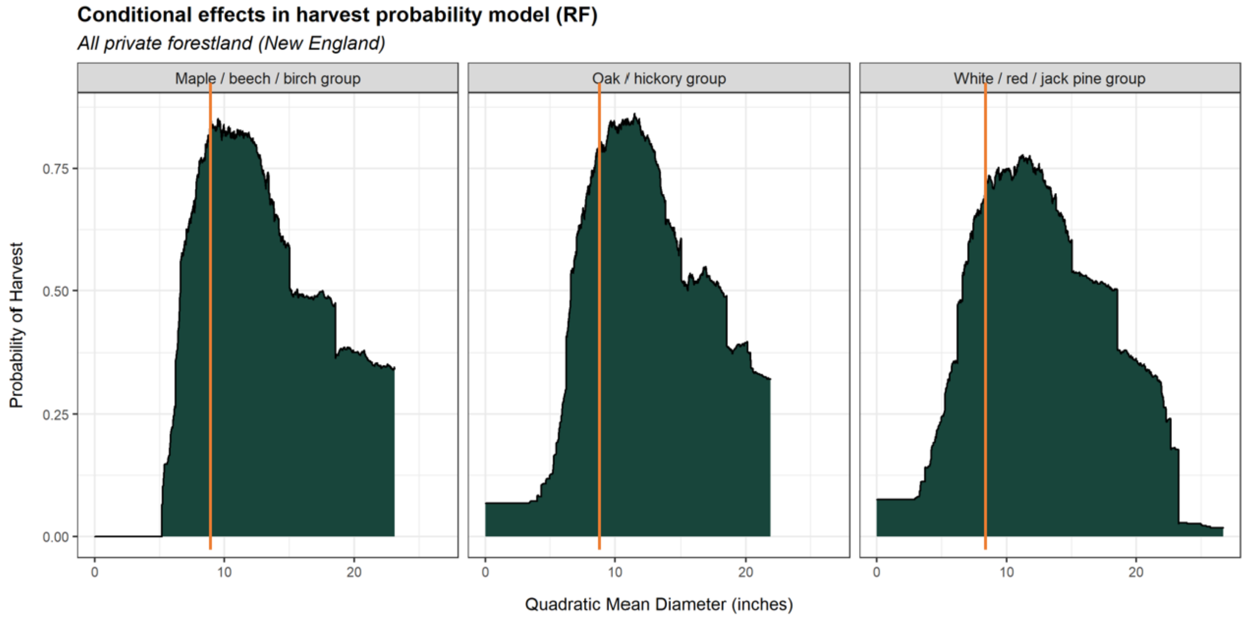

Figure 18. Partial dependence plot for QMD (Group 1)

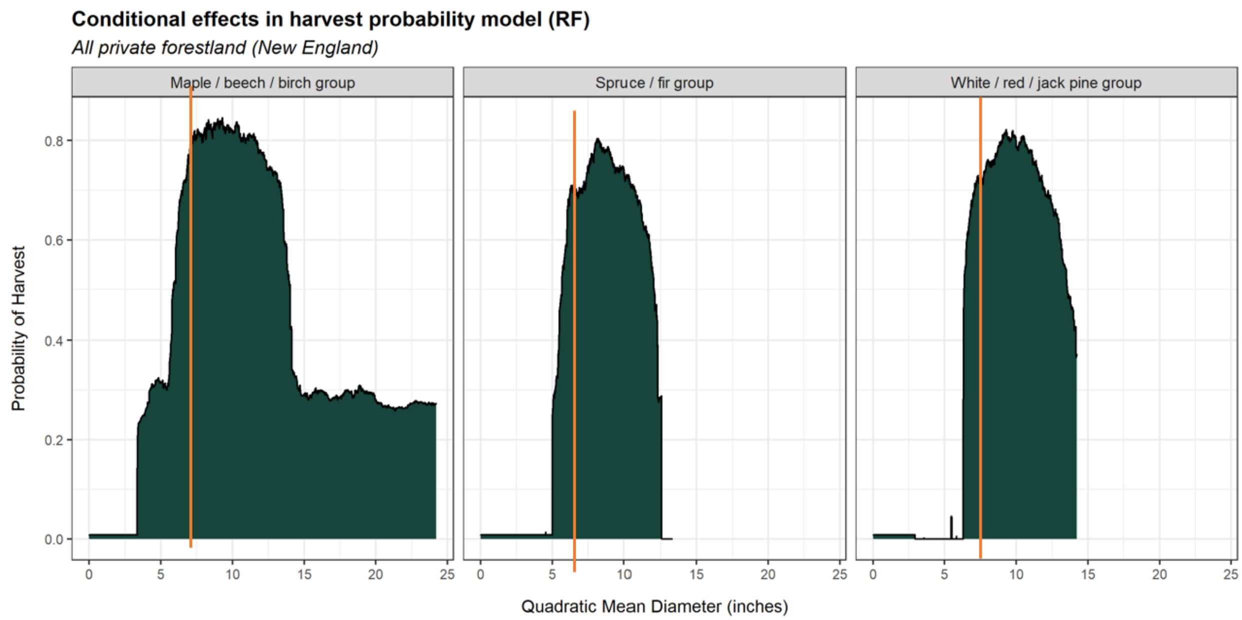

Figure 19. Partial dependence plot for QMD (Group 2)

Stocking Percent

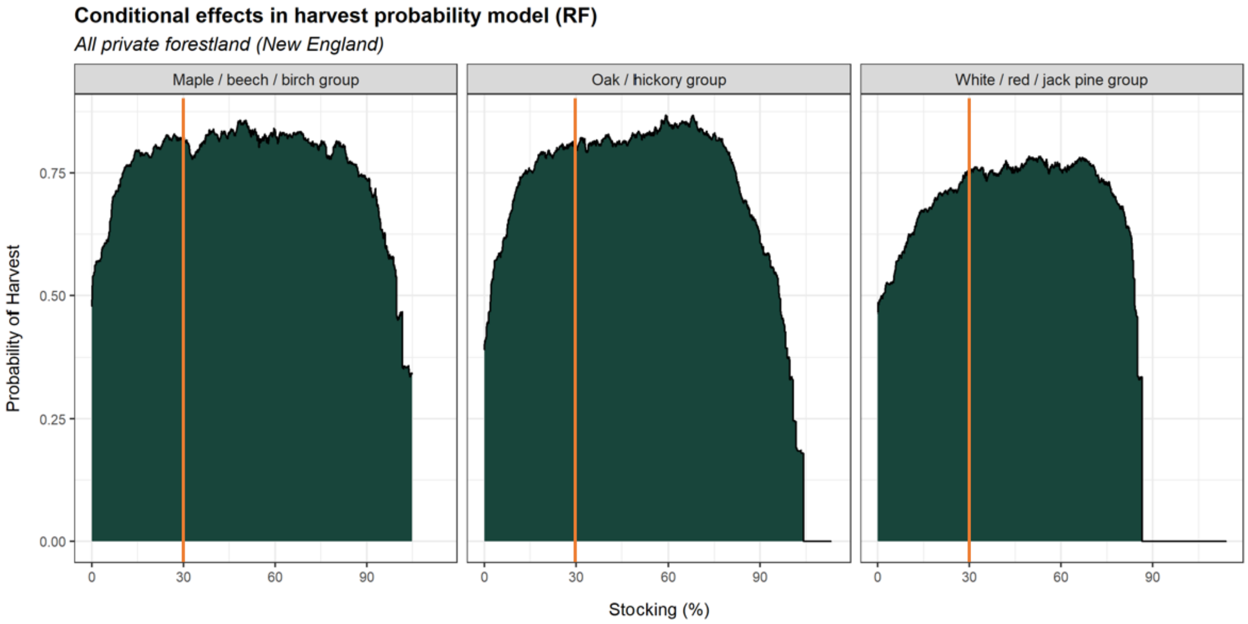

Figure 20. Partial dependence plot for Stocking Percent (Group 1)

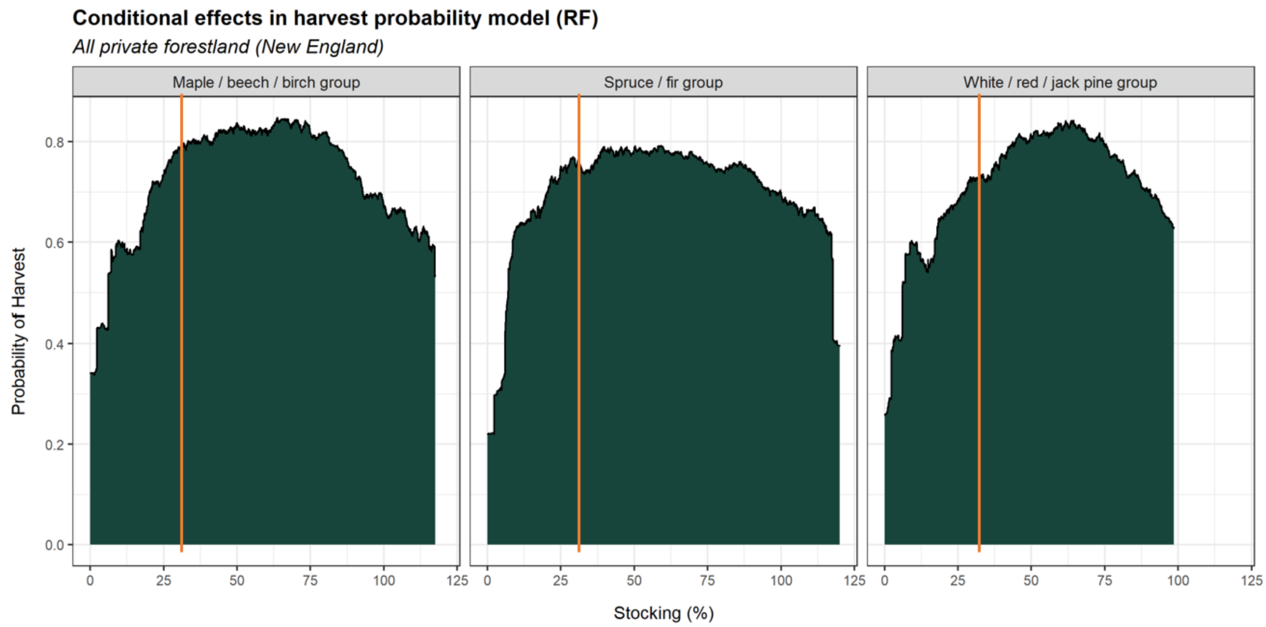

Figure 21. Partial dependence plot for Stocking Percent (Group 2)

Merchantable Volume

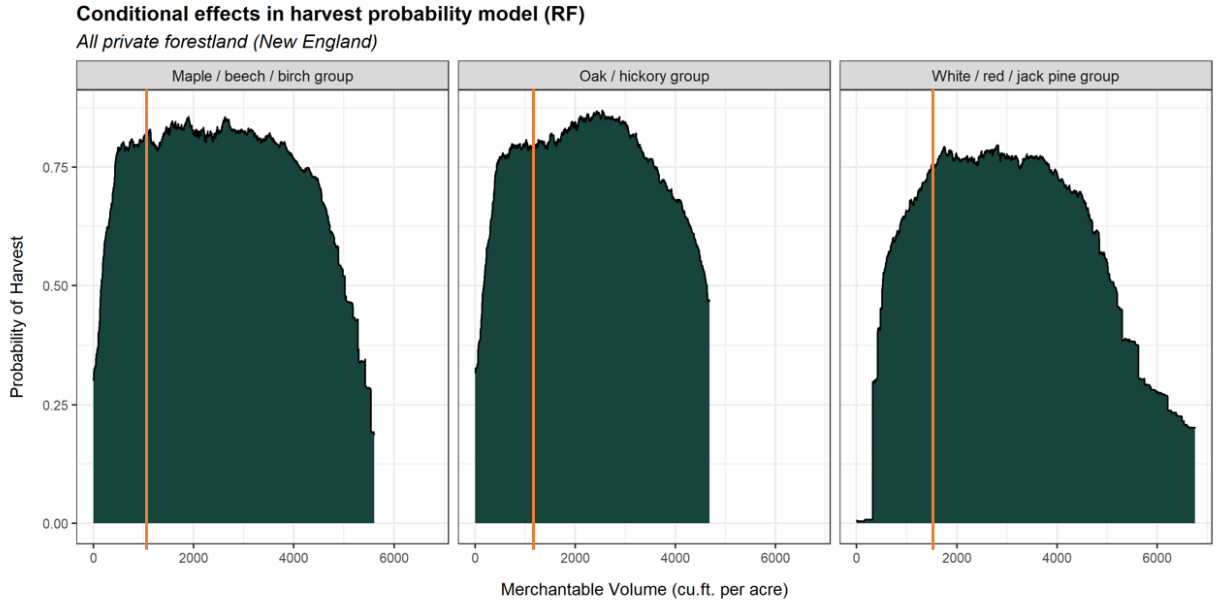

Figure 22. Partial dependence plot for Merchantable Volume (Group 1)

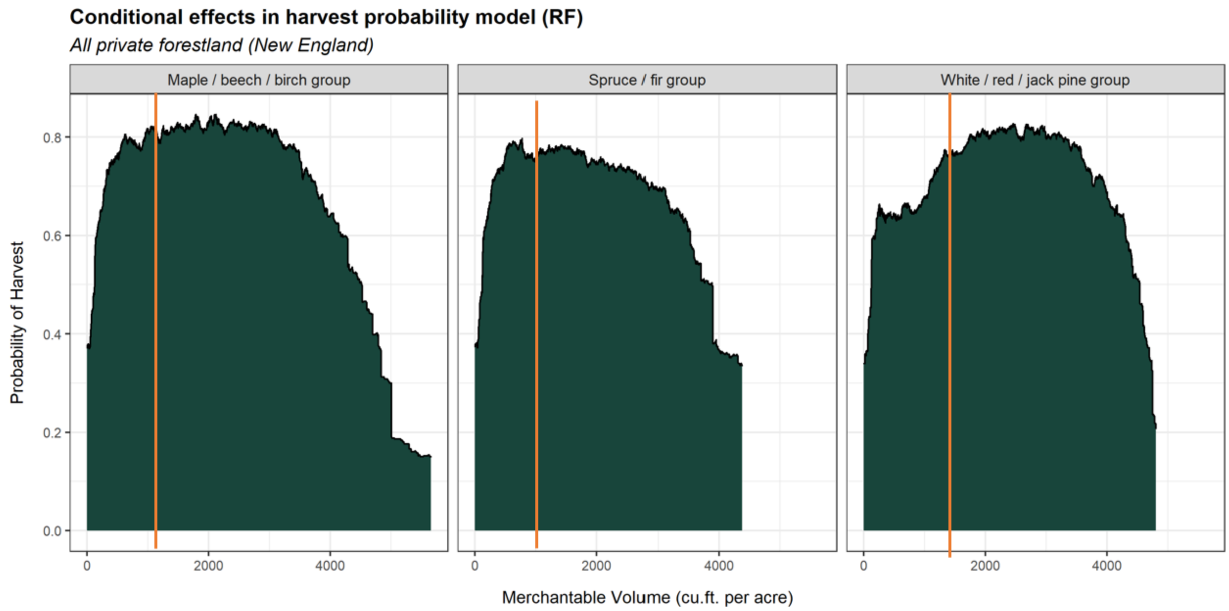

Figure 23. Partial dependence plot for Merchantable Volume (Group 2)

Relative Density (> 5 in diameter trees)

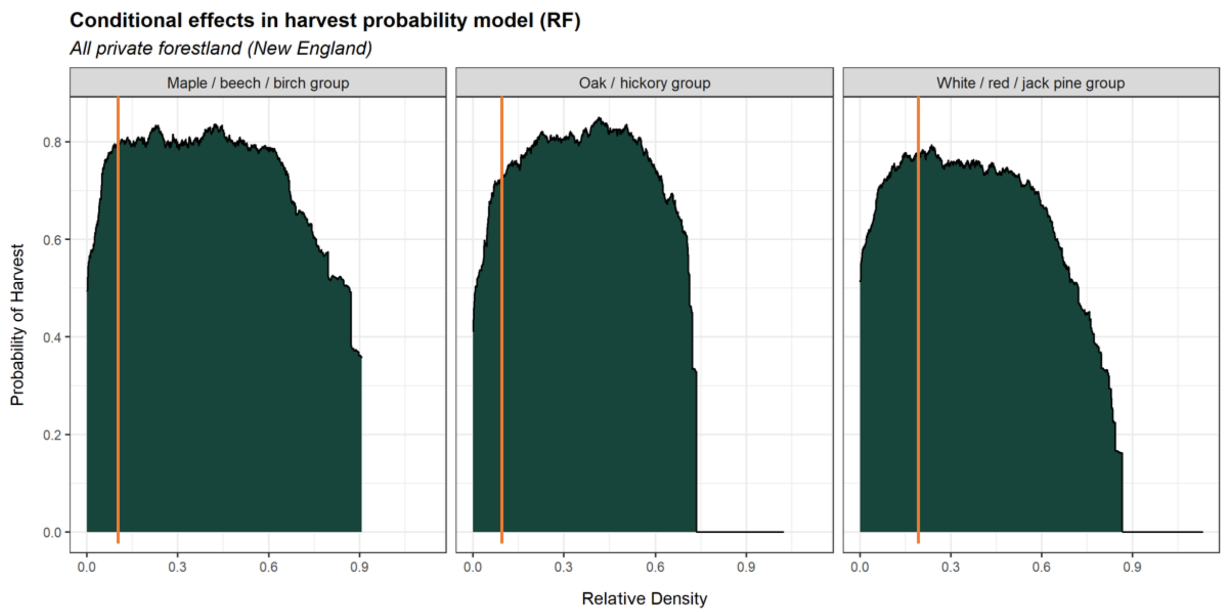

Figure 24. Partial dependence plot for Relative Density (Group 1)

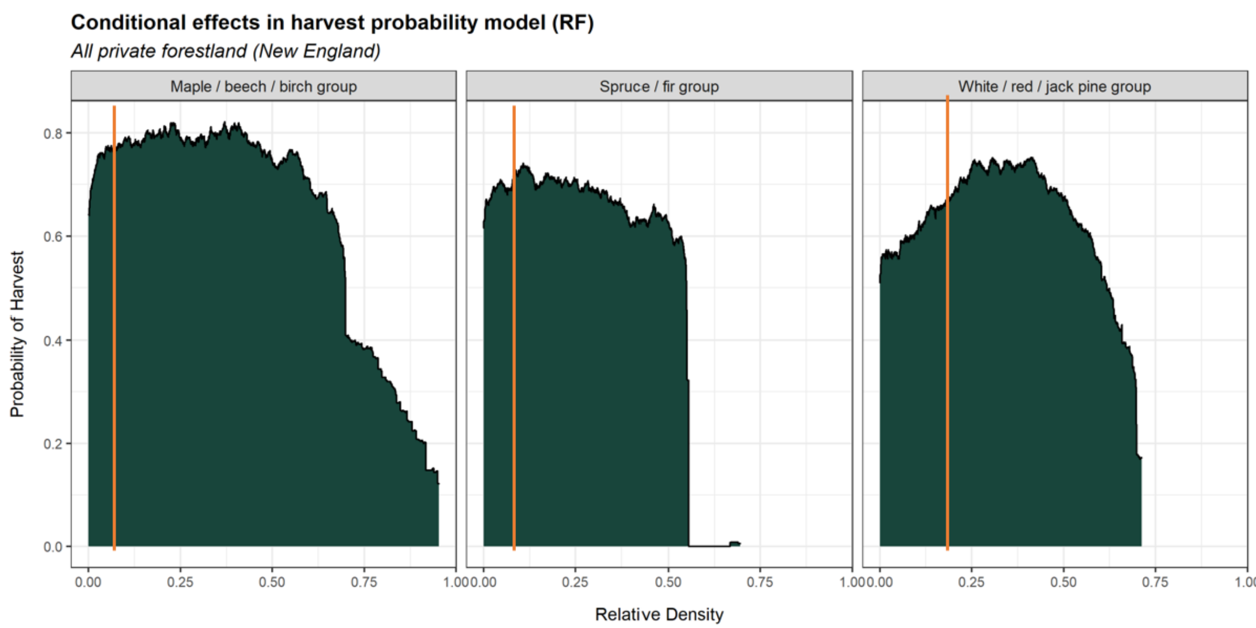

Figure 25. Partial dependence plot for Relative Density (Group 2)

Elevation

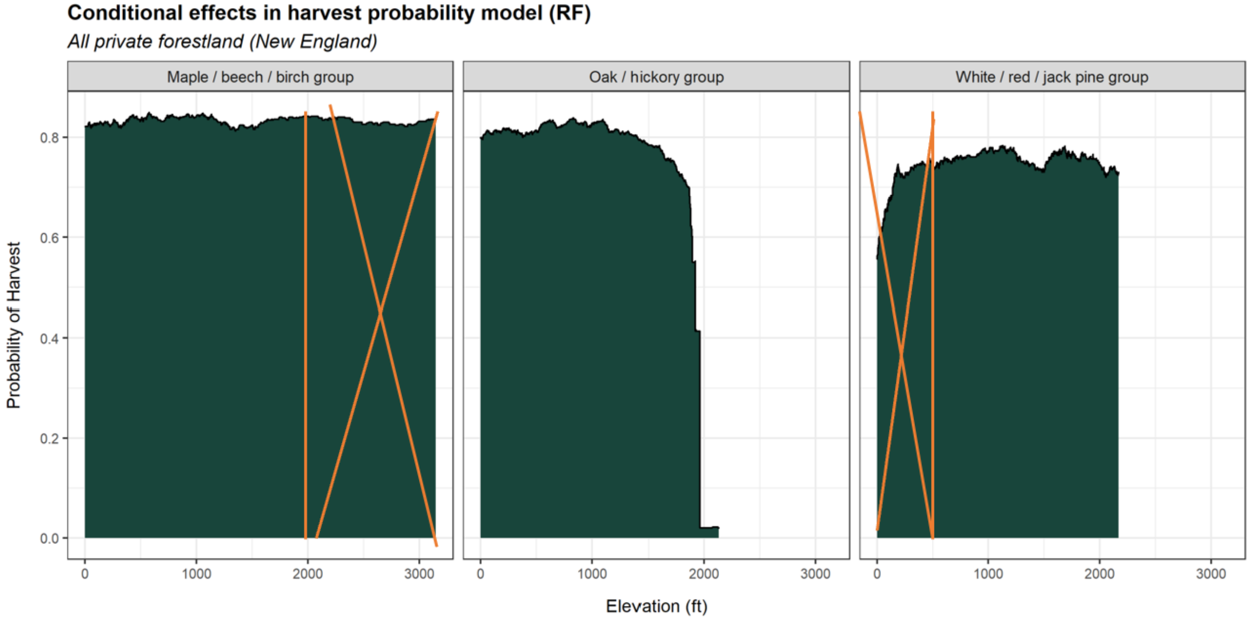

Figure 26. Partial dependence plot for Elevation (Group 1)

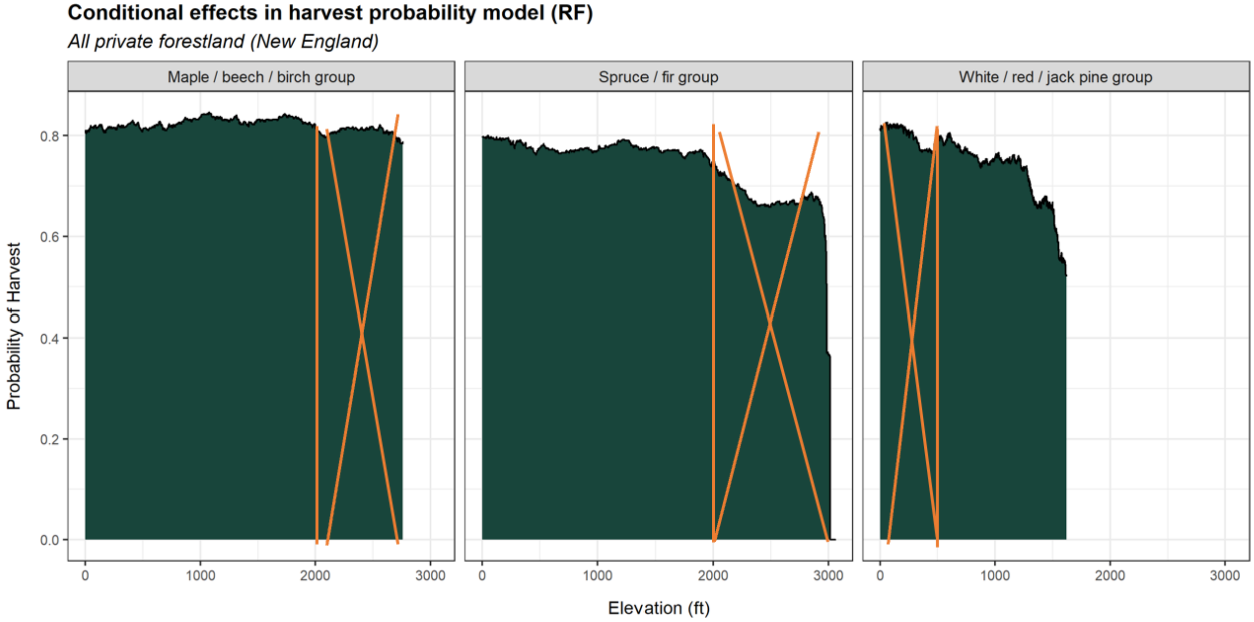

Figure 27. Partial dependence plot for Elevation (Group 2)

Slope

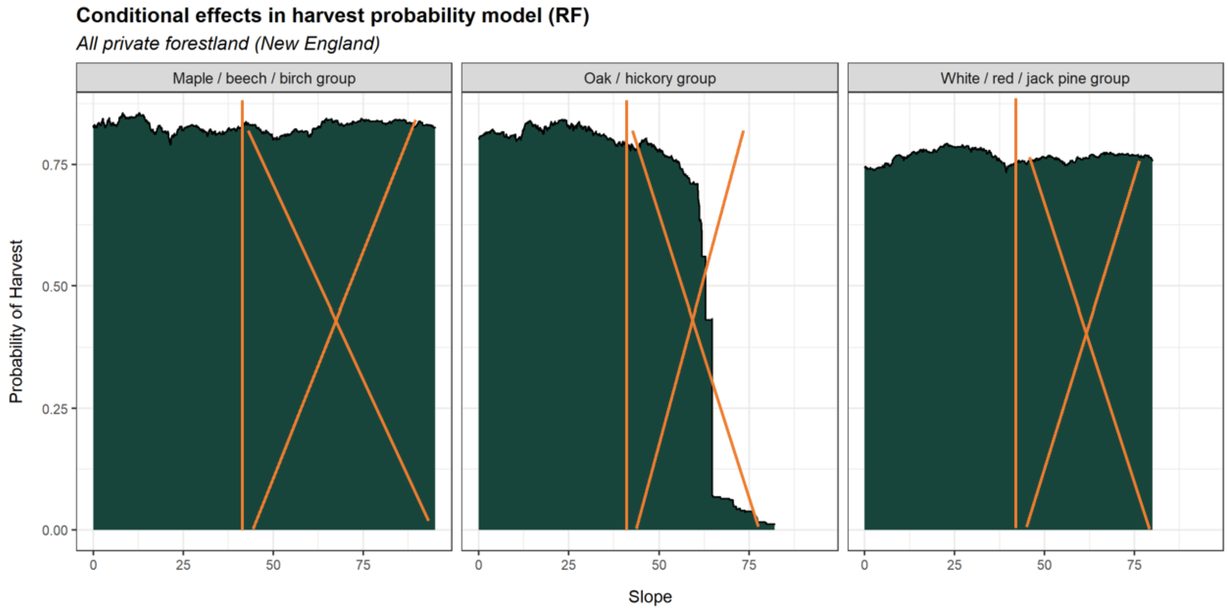

Figure 28. Partial dependence plot for Slope (Group 1)

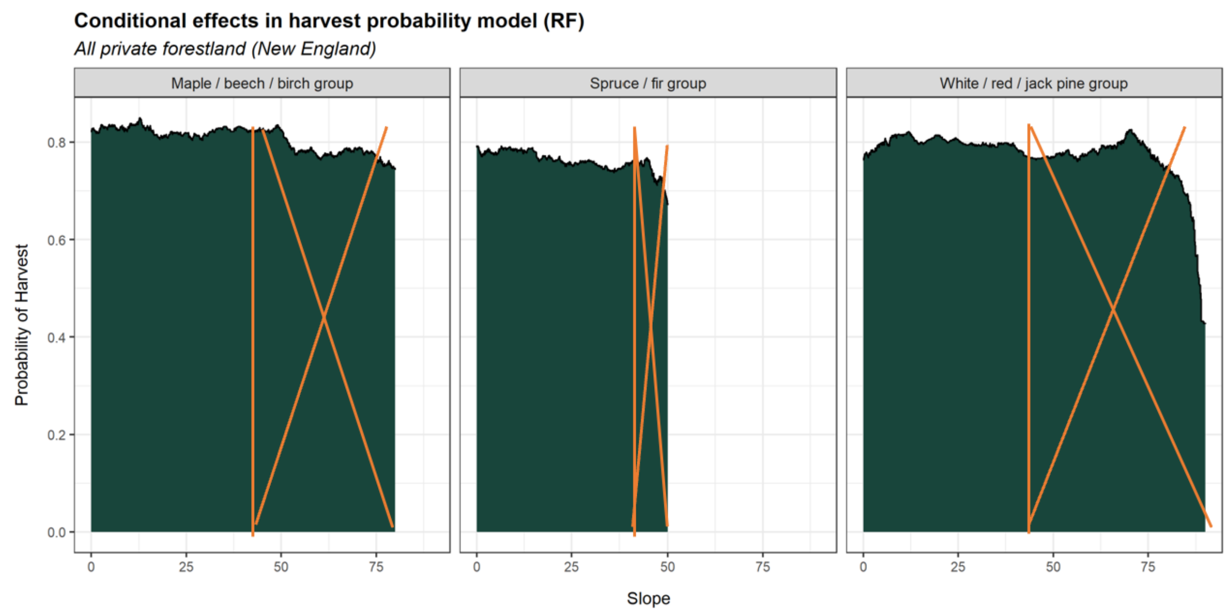

Figure 29. Partial dependence plot for Slope (Group 2)

Aspect

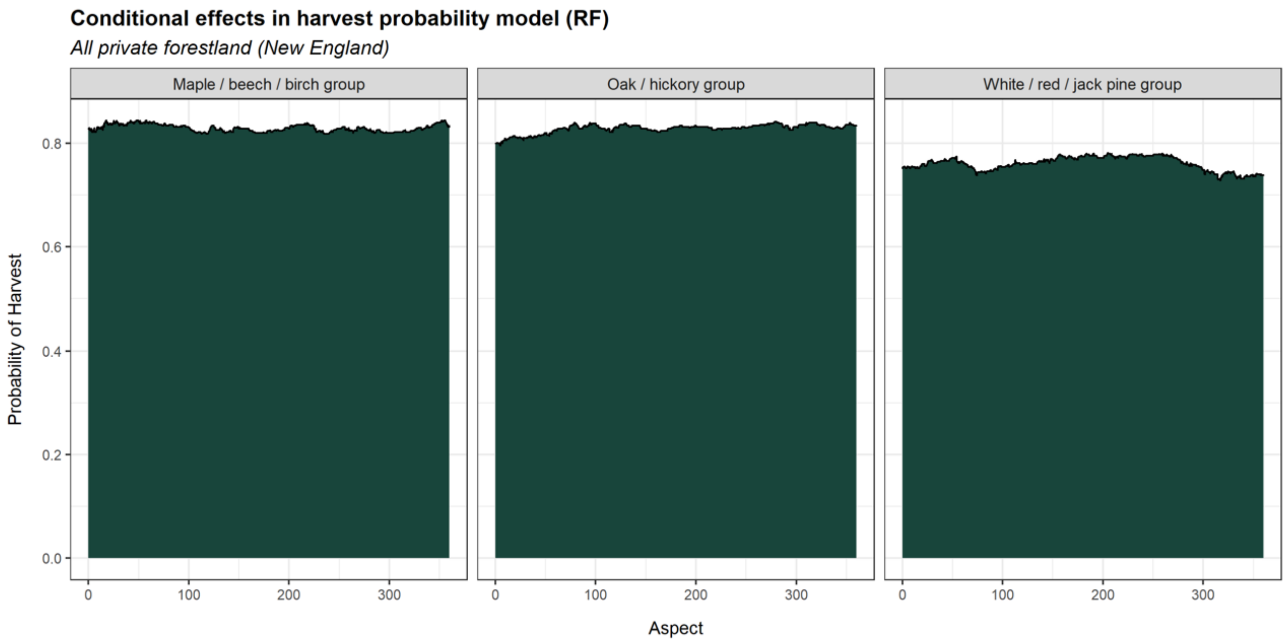

Figure 30. Partial dependence plot for Aspect (Group 1)

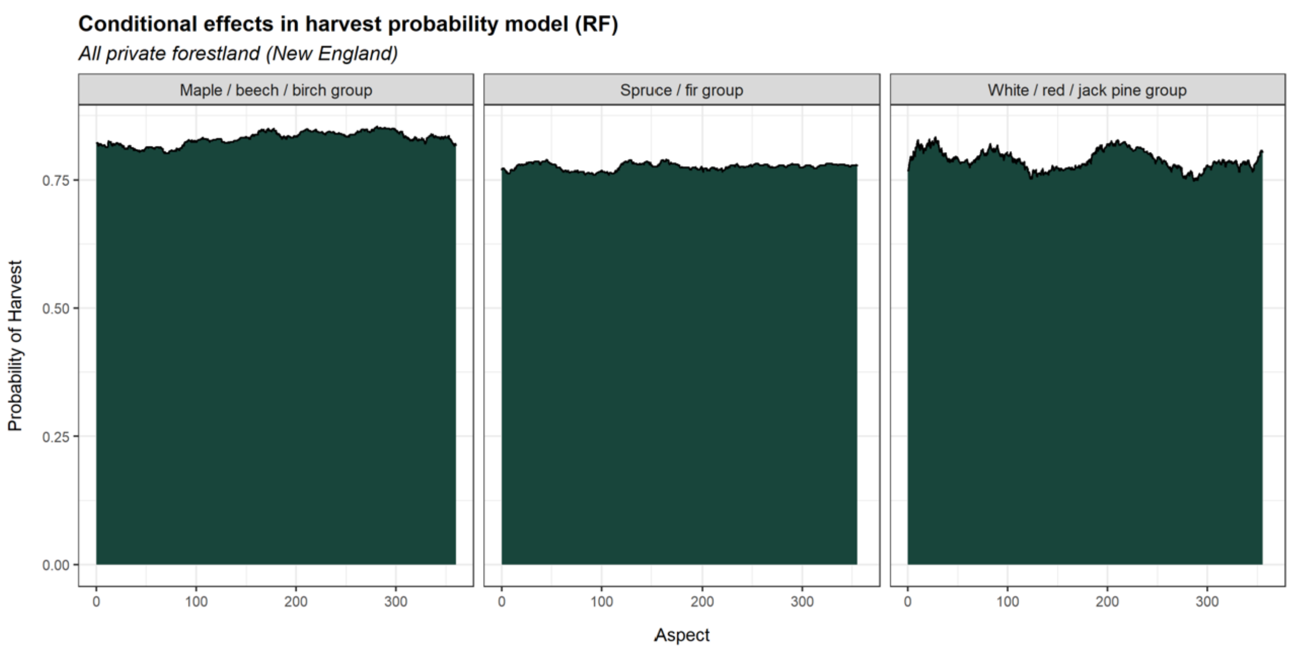

Figure 31. Partial dependence plot for Aspect (Group 2)

Bole Biomass

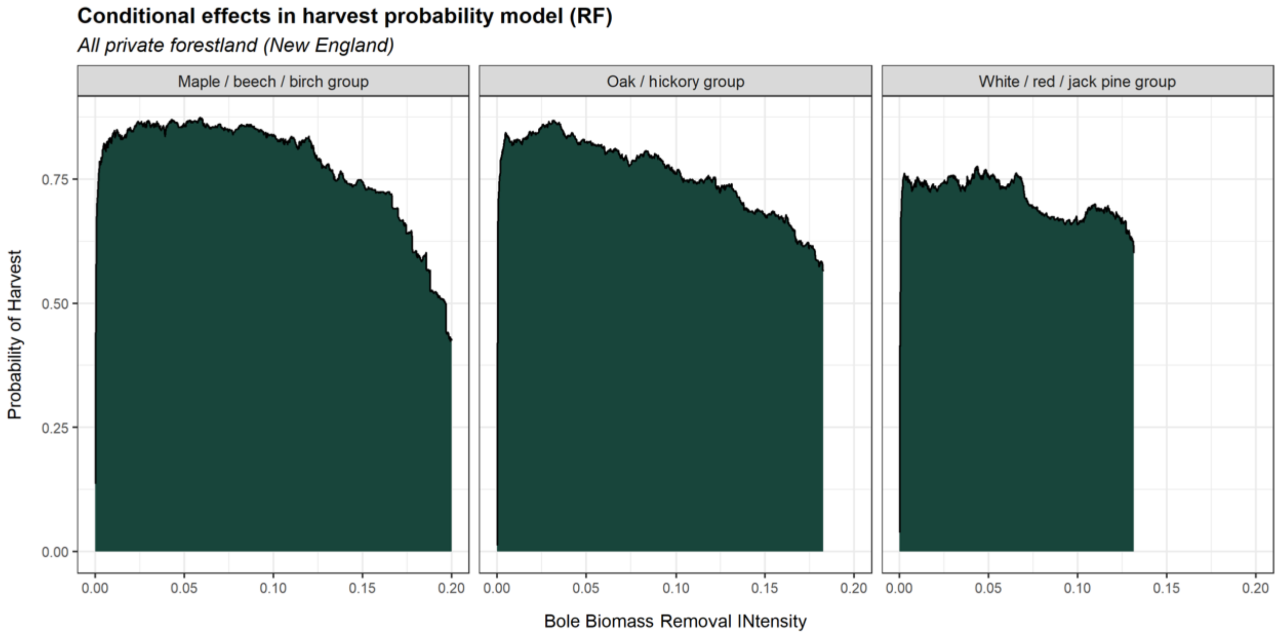

Figure 32. Partial dependence plot for Bole Biomass (Group 1)

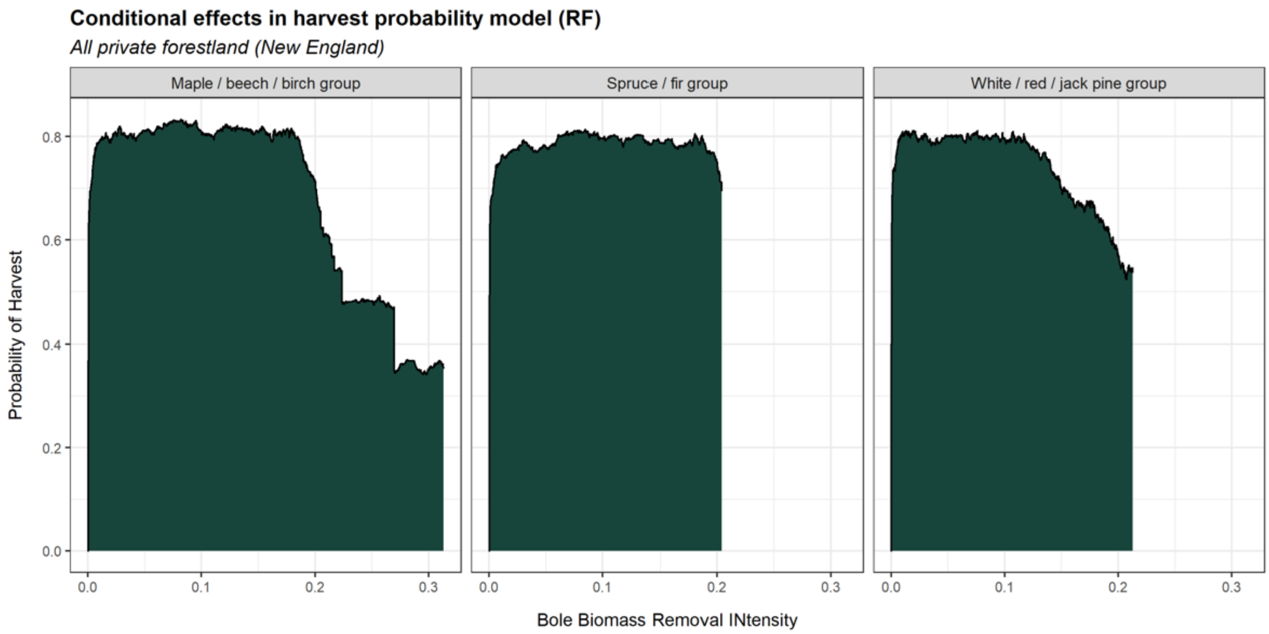

Figure 33. Partial dependence plot for Bole Biomass (Group 2)

Appendix II: Cap Impact on Harvest Intensity (BF/acre)

Maple/Beech/Birch—Group 1

Table 18. Impact of Diverse Cap Groupings on Predicted Harvest Intensity (BF/acre) for Maple/Beech/Birch—Group 1,

Impact of Caps on Harvest Intensity (BF/ acre)
MBB - Group 1

Grouping	0%	25%	50%	75%	100%	125%	150%
QMD, Carb, BAA, Vol	56.0316	57.9433	61.9024	64.5234	68.1873	72.5507	82.4414
Carb, QMD, BAA	56.0316	57.9433	61.9024	64.5234	68.1873	72.5507	82.4414
AGB, Carb, BAA, QMD	55.6165	58.2024	61.4805	64.5983	67.6882	72.7399	80.5249
BAA & QMD	55.8371	57.3479	60.1216	63.118	66.1798	71.4579	80.9255
QMD, BAA, Vol	55.7382	57.7302	60.6054	63.4269	66.3946	71.2449	80.0064
AGB, Carb, BAA, Vol	55.8798	58.3289	62.0579	64.1918	66.311	70.1729	74.657
AGB, Carb, BAA	55.6471	58.1644	61.3554	64.4516	67.0401	69.5744	74.6456
BAA & Carb	55.6155	57.7292	61.4714	64.2356	66.4239	70.3458	74.8988
QMD & Vol	55.6077	57.3396	59.539	62.2141	65.7003	71.7658	77.2979
Carbon, AGB, RD, Vol	56.1783	58.0101	62.4956	64.071	65.1209	69.2936	73.3897
AGB & Carbon	55.6779	57.8837	60.6892	63.7983	66.1285	69.9196	73.2842
Carbon	55.7928	58.0177	61.0506	63.5142	65.7033	68.9972	73.4833
AGB & QMD	55.3967	56.6581	57.9511	59.5189	63.3767	72.0973	74.8481
BAA & Vol	55.5796	57.5341	60.3302	63.3228	64.3968	66.8116	69.2587
AGB & BAA	55.91	57.7191	60.0653	63.1325	64.4977	66.6595	69.1753
BAA & St	55.8024	57.4503	59.923	62.9322	64.3602	66.1794	68.9108
AGB & Vol	55.5351	57.4143	59.4318	62.7912	64.586	66.7148	68.6952
Vol	55.802	57.5149	59.6139	62.2363	64.2152	66.388	69.1972
BAA	55.6383	57.2501	59.9361	62.6905	64.0688	66.1366	68.7692
BAA & RD	55.4287	57.7659	61.351	62.6518	62.5702	65.2057	67.1415
QMD	55.8528	55.3761	55.478	55.9932	59.9941	70.2355	69.0982
AGB	55.8661	56.8401	57.8094	59.1301	61.425	62.9902	64.1106
AGB & St	55.8546	56.4328	57.8037	59.1725	61.2319	63.0141	64.1021
Lorey	55.5853	55.6904	55.745	56.1965	59.1967	64.6212	67.3503
RD	55.5121	56.568	59.0844	59.793	59.9538	60.8472	61.0162
ALL	55.7942	58.6349	62.9364	65.6231	66.1821	62.7413	43.0947
Stocking	55.7918	55.4541	55.8251	55.6905	55.7175	56.1182	55.982
Slope	55.6723	56.1514	55.8592	55.5611	55.8105	55.4657	55.1064
Elevation	55.7897	55.3903	55.4711	55.868	54.802	49.9319	43.589
Slope & Elevation	55.8664	55.9215	55.8431	56.0399	54.9083	51.0905	41.6966

Maple/Beech/Birch—Group 2

Table 19. Impact of Diverse Cap Groupings on Predicted Harvest Intensity (BF/acre) for Maple/Beech/Birch—Group 2,

Impact of Caps on Harvest Intensity (BF/acre)

MBB - Group 2

Grouping	0%	25%	50%	75%	100%	125%	150%
QMD, BAA, Vol	68.9659	71.1328	73.8951	78.044	82.5693	93.8125	119.445
QMD, Carb, BAA, Vol	69.3503	70.8578	74.0928	78.0223	82.2556	93.6966	118.881
Carb, QMD, BAA	68.8074	70.7487	73.4062	77.2655	81.1451	93.3669	119.896
AGB, Carb, BAA, QMD	69.0207	70.7324	73.572	77.2179	81.1177	93.6795	119.105
QMD & Vol	69.0821	71.3548	73.6763	77.3363	81.9205	93.4256	116.235
BAA & QMD	68.9278	70.6598	73.3385	77.2235	81.2695	93.5407	118.949
ALL	68.8005	71.4473	74.6803	76.6542	79.8648	84.1765	120.924
AGB & QMD	69.0991	69.8483	70.9436	72.9438	76.5354	89.3143	112.68
BAA & Vol	68.996	70.8831	74.3041	77.9946	82.0871	86.2697	91.3302
AGB, Carb, BAA, Vol	69.1074	71.2373	73.7479	77.9101	81.9394	86.1475	90.1974
Vol	68.983	71.4548	73.6791	77.27	82.1357	85.7405	89.2353
AGB & Vol	69.1347	71.0116	73.4697	77.2463	81.9325	85.3555	88.5282
BAA	69.1758	70.7944	73.3132	76.7444	81.2319	84.2979	89.5223
BAA & Carb	68.992	70.62	73.4239	77.2859	81.2279	84.2459	88.7756
AGB, Carb, BAA	69.1482	70.6477	73.181	77.3294	81.1468	84.5096	88.5088
AGB & BAA	69.1774	70.7801	73.1584	77.1293	80.9992	84.6054	88.2332
BAA & St	69.0071	70.7448	73.3624	76.9336	80.7738	84.3622	88.8623
Carbon, AGB, RD, Vol	69.028	71.1858	73.4256	74.7969	77.8748	81.3027	85.2758
QMD	69.0178	69.3352	68.9753	69.2281	71.5388	84.8184	107.543
BAA & RD	69.1094	71.1857	73.2095	74.5873	77.3056	80.6305	85.0534
Carbon	69.2005	69.91	70.9412	73.4335	75.1091	77.7718	79.3777
AGB	69.0879	69.8757	71.0611	72.9791	75.6053	77.5159	79.5091
AGB & St	68.9131	70.0887	70.8783	73.0014	75.4324	77.6194	79.1167
AGB & Carbon	69.3168	69.6771	70.9913	73.174	75.0823	77.5695	79.3361
Lorey	69.0798	69.1477	70.0021	69.7953	69.7461	71.4745	77.968
RD	69.0628	69.9689	70.5167	68.6675	68.4663	69.4891	70.979
Slope	69.091	69.2746	69.2439	69.7547	69.2539	69.2459	68.3581
Stocking	69.1349	69.1937	68.8768	69.0983	68.8319	69.124	68.9821
Stocking & Elevation	69.1121	69.3939	69.5	70.0818	69.7684	65.1397	56.6631
Elevation	69.0124	68.9656	69.5805	69.4803	69.5923	64.7205	57.654

Oak/Hickory

Table 20. Impact of Diverse Cap Groupings on Predicted Harvest Intensity (BF/acre) for Oak Hickory

Impact of Caps on Harvest Intensity (BF/acre)
Oak/Hickory

Grouping	0%	25%	50%	75%	100%	125%	150%
AGB, Carb, BAA	39.506	41.2626	44.1486	47.1942	49.6153	49.725	56.5099
BAA & Carb	40.059	41.3059	44.5397	47.0414	49.3236	49.2154	56.85
AGB, Carb, BAA, Vol	39.9135	41.7357	44.8087	46.7663	48.7642	49.8512	56.2488
Carbon, AGB, RD, Vol	40.0129	41.5562	45.5625	47.223	48.025	48.4277	53.7889
AGB & Carbon	40.0981	41.5771	44.1052	46.622	48.7692	49.5577	53.1999
ALL	40.1844	41.9017	46.7964	47.703	47.9855	55.955	44.4148
Carbon	40.3734	41.0502	44.0194	46.2513	48.4689	49.0941	53.1277
AGB & QMD	39.6741	40.4626	41.5556	43.1138	45.4313	51.0807	58.4133
AGB & BAA	39.7642	41.2393	43.8172	46.6212	48.055	48.9458	51.1054
BAA & Vol	39.7341	40.8556	44.2813	46.5553	47.805	48.1862	51.8772
BAA	39.8112	40.9158	43.8888	46.7969	47.9125	48.2484	51.4706
BAA & St	39.6887	40.5522	43.7522	46.699	47.8346	48.2595	51.7489
AGB, Carb, BAA, QMD	40.3235	41.5129	44.4597	46.801	48.8298	54.8323	76.4882
QMD, Carb, BAA, Vol	39.6806	41.6496	44.4196	46.5742	49.2906	53.5581	75.7217
Carb, QMD, BAA	39.6806	41.6496	44.4196	46.5742	49.2906	53.5581	75.7217
BAA & RD	40.0954	41.1145	46.0129	45.7776	46.0329	47.5106	51.1317
BAA & QMD	39.8186	41.1272	43.6755	46.917	48.2612	52.5593	74.8797
QMD, BAA, Vol	40.3098	41.2898	43.8281	46.7	47.9494	52.3478	74.6644
AGB & Vol	40.1503	41.2357	42.492	45.9174	46.3136	48.6138	49.3407
Vol	39.7745	41.3709	42.2855	45.3018	45.6237	47.9072	50.22
QMD & Vol	39.6984	40.8657	42.9201	45.4957	45.0132	53.2761	63.9671
QMD	39.8147	40.0051	39.6754	40.0246	42.5526	47.8974	55.9278
AGB	39.6169	40.8534	41.0407	42.7194	45.0594	46.0695	46.7822
AGB & St	40.3022	40.1658	41.7853	42.8112	44.4386	46.0969	46.5607
RD	39.6263	40.0436	43.2113	44.2803	44.3445	43.4145	45.2469
Lorey	40.0472	40.1441	40.1719	40.147	42.3804	45.198	42.39
Slope & Elevation	39.6711	39.769	40.2439	40.5255	41.2671	43.2487	39.2509
Slope	39.9444	40.1968	40.2505	40.1026	40.0933	41.5805	41.112
Elevation	40.0076	39.705	39.5964	40.2614	41.4793	41.3615	39.2188
Stocking	39.5766	39.5676	39.8534	40.0781	39.6809	40.039	40.2027

Spruce/Fir

Table 21. Impact of Diverse Cap Groupings on Predicted Harvest Intensity (BF acre) for Spruce/Fir

Impact of Caps on Harvest Intensity (BF/acre)
Spruce/Fir

Grouping	0%	25%	50%	75%	100%	125%	150%
QMD, Carb, BAA, Vol	52.9126	57.7302	61.9448	66.415	73.0153	78.4933	86.8068
QMD, BAA, Vol	52.6714	57.5742	61.819	65.9457	72.7191	77.8407	87.1572
QMD & Vol	52.7419	57.6661	61.14	66.0767	71.4347	79.6777	81.4446
AGB, Carb, BAA, QMD	52.7778	56.31	60.929	64.3441	71.1734	77.9838	88.9596
BAA & QMD	52.7549	56.1687	60.0237	64.2322	70.0766	78.09	84.8673
Carb, QMD, BAA	53.042	56.1677	60.1541	63.639	71.1004	78.4919	89.2411
ALL	52.6886	58.2547	62.2364	62.9625	67.009	74.9399	94.6984
AGB, Carb, BAA, Vol	53.2657	57.4225	61.6189	65.8717	71.0159	74.5472	77.4157
BAA & Vol	52.93	57.5593	61.7296	66.0105	69.9142	73.0251	79.569
AGB & QMD	53.1956	53.9372	57.4536	62.1603	69.471	75.7317	83.7179
AGB & Vol	52.3732	57.4902	61.8561	65.2109	70.6083	73.4731	76.6043
Vol	52.6164	57.9798	61.0788	65.381	70.0404	73.2932	77.4076
AGB & BAA	52.8786	56.5312	60.3162	64.127	69.51	73.1235	74.9078
AGB, Carb, BAA	52.8085	56.5603	60.3265	63.6677	68.6752	73.2583	75.2123
BAA & Carb	52.7984	56.0851	60.5591	64.3769	68.1176	72.5775	74.8747
BAA & St	53.5529	56.4132	60.2756	64.5518	67.7789	69.507	74.7345
BAA	53.248	55.9981	59.9737	63.4756	68.1744	68.9613	74.8904
Carbon, AGB, RD, Vol	52.7161	58.0512	61.2887	61.9724	65.618	68.8008	71.9785
AGB & St	52.8509	54.3548	57.5748	61.9982	66.7333	69.237	70.2741
Carbon	52.9121	54.2538	57.4046	61.7504	66.2956	69.6337	70.0847
AGB & Carbon	52.9317	54.3172	57.2893	61.5751	66.1528	68.8401	71.5863
AGB	52.5664	54.0016	57.3824	62.0037	66.549	68.4035	70.7871
BAA & RD	53.0101	57.0879	59.4434	60.0461	62.4074	66.3126	67.8598
QMD	52.5633	52.8539	52.5938	53.0847	59.6101	66.6085	64.1741
Lorey	53.0099	52.5957	53.2358	54.4213	54.5952	56.7714	67.0723
RD	52.6838	54.343	55.9703	53.4777	53.2495	54.6289	55.1471
Stocking	52.5032	52.9973	52.9954	52.8276	53.1816	52.7581	52.744
Elevation	53.1182	52.8417	54.0157	53.0375	52.9634	52.5403	50.9278
Slope & Elevation	53.0536	53.3333	53.3166	53.0546	52.659	51.5294	50.5002
Slope	53.0409	52.524	53.1062	52.5015	52.2623	51.9021	52.3548

Pine—Group 1

Table 22. Impact of Diverse Cap Groupings on Predicted Harvest Intensity (BF/acre) for Pine—Group 1

Impact of Caps on Harvest Intensity (BF/ acre)
Pine - Group 1

Grouping	0%	25%	50%	75%	100%	125%	150%
BAA & Vol	57.2873	59.4924	65.2014	70.3876	76.6524	84.3698	95.7093
BAA & St	57.2512	59.0679	64.2236	69.5435	77.1434	82.9149	96.7285
AGB & BAA	56.837	59.3726	63.6663	69.3303	76.6166	83.7058	96.0815
AGB, Carb, BAA	57.7577	59.0311	64.7451	70.5222	76.8696	81.7135	93.9032
BAA	58.4645	59.2601	64.2516	69.5947	75.7703	81.9042	94.06
AGB, Carb, BAA, Vol	58.169	59.5076	63.7716	69.7023	77.5378	81.5469	93.1879
BAA & Carb	57.112	58.9488	64.24	69.8478	76.5338	81.755	93.4695
AGB & Carbon	57.815	58.4799	61.5627	69.0551	75.2945	76.4884	78.7234
Carbon	57.492	58.5724	61.9759	68.9798	72.9998	74.3596	79.1706
AGB & Vol	57.5796	59.4095	61.0434	66.0103	69.7804	76.4583	78.4251
AGB & St	57.3531	59.0219	61.1523	65.192	69.1397	76.2955	79.4699
AGB	57.3102	58.7591	61.0472	64.81	70.1266	75.0446	78.3805
Vol	57.6872	58.433	60.1371	65.0457	67.1474	72.6977	80.1266
QMD & Vol	57.1572	58.0176	61.153	64.8717	67.7703	75.7748	69.0953
ALL	57.4667	62.6355	71.1186	75.4417	82.3573	75.4859	44.382
BAA & QMD	57.5618	59.4096	64.669	70.0095	77.2195	84.1434	85.4176
QMD, Carb, BAA, Vol	57.5232	59.4957	64.5432	70.6703	77.8662	82.7835	90.103
Carb, QMD, BAA	57.5232	59.4957	64.5432	70.6703	77.8662	82.7835	90.103
AGB, Carb, BAA, QMD	57.4575	58.7574	64.7146	70.2131	78.2275	82.3874	87.6125
QMD, BAA, Vol	57.4347	59.3728	64.4345	69.9361	77.5504	82.489	87.1581
BAA & RD	57.8715	60.4041	66.9757	72.2231	77.9273	68.0148	79.8034
Elevation	58.2515	56.95	58.7394	60.7259	64.8075	62.8649	63.8799
Carbon, AGB, RD, Vol	57.1293	60.8958	66.6977	70.7103	75.6863	64.4011	73.1182
RD	56.9291	59.8337	66.6013	70.7566	74.2714	63.9834	70.567
AGB & QMD	56.9819	59.0554	60.698	65.2728	71.0786	79.3299	70.4704
Slope & Elevation	57.6148	58.317	60.2082	60.4461	65.6267	62.9539	54.8055
Lorey	57.8256	57.2671	57.6855	57.5217	60.2171	62.3301	61.2511
QMD	57.5164	57.7391	57.1296	58.103	58.3916	65.1121	57.7842
Stocking	56.8983	57.9118	57.3926	58.2117	58.1628	57.6783	58.6417
Slope	58.5364	58.5121	58.0367	57.2129	58.9708	56.5725	49.5254

Pine—Group 2

Table 23. Impact of Diverse Cap Groupings on Predicted Harvest Intensity (BF/acre) for Pine—Group 2

Impact of Caps on Harvest Intensity (BF/acre)
Pine - Group 2

Grouping	0%	25%	50%	75%	100%	125%	150%
ALL	51.9283	57.0064	63.1065	75.8243	73.9348	66.5598	NA
AGB & BAA	51.5099	56.0706	59.4053	62.1247	72.1175	78.0269	77.5377
QMD, Carb, BAA, Vol	52.2045	55.2448	59.633	62.9322	72.1804	78.7501	78.3251
BAA & St	51.6374	55.4268	60.0745	62.0717	72.1966	77.2847	79.894
QMD, BAA, Vol	52.1379	55.7337	59.7299	62.0547	72.1185	80.494	77.6995
BAA	52.1822	55.0816	60.0697	62.2813	72.8708	78.1636	79.6341
AGB, Carb, BAA, Vol	52.5652	55.8032	59.4199	61.9502	71.6782	78.5285	78.5544
BAA & Carb	52.2103	55.5094	59.7974	61.7798	72.1447	78.4587	80.1612
BAA & Vol	51.8788	55.2069	59.9379	61.9984	71.963	77.2041	79.5812
AGB, Carb, BAA, QMD	51.6331	55.3349	59.6186	62.1532	71.4604	79.7518	76.7985
Carb, QMD, BAA	51.9953	55.3835	59.7427	61.8707	71.2954	79.9237	78.4771
BAA & RD	52.3451	56.3388	58.8386	61.18	68.484	76.6147	71.0257
BAA & QMD	52.2766	55.189	59.5577	61.7219	71.0557	79.0491	78.9917
AGB, Carb, BAA	52.2536	55.1791	59.521	61.156	71.4477	78.4533	79.1953
Elevation	52.0566	52.7852	55.3684	59.0899	66.9595	72.4506	69.5658
Slope & Elevation	51.853	53.0589	54.2818	58.7581	66.2437	60.8588	64.0444
Carbon, AGB, RD, Vol	52.3786	55.5555	57.1448	59.4968	60.6782	64.0033	65.3608
AGB & Vol	52.1776	54.9389	58.3753	59.8266	64.2436	69.5517	76.8227
QMD & Vol	52.2499	54.5938	58.292	60.4934	62.9101	72.262	77.7557
AGB	51.3946	55.763	56.9242	59.8041	63.6487	68.5233	76.7178
AGB & St	51.8776	55.5333	56.6826	58.8171	64.5853	69.0855	76.7236
Vol	51.9461	55.2461	57.3701	59.4634	63.1792	68.4755	71.9678
AGB & Carbon	52.2731	55.7309	56.6982	59.62	63.0418	69.3962	77.5137
AGB & QMD	52.2998	54.9861	56.9292	58.8877	63.7013	74.0305	80.7994
Carbon	51.8326	54.3153	56.3873	58.9274	60.2218	65.176	70.2264
RD	52.0199	55.0242	55.1739	55.7489	53.8509	52.7109	48.8473
QMD	51.7502	52.242	51.5474	52.2466	52.0447	63.1347	68.1685
Lorey	52.018	51.7263	52.12	52.6306	54.1089	56.5983	59.155
Stocking	51.9874	52.0959	51.536	51.7876	51.8403	52.5003	51.6954
Slope	51.7143	52.2603	51.8322	51.9027	51.7793	50.1486	50.7838