30-meter Resolution Forest Characteristics Map for New England

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Summary

A 30-meter resolution map and spatial data set describing the distribution of 13 major forest types found in New England was produced for the states of VT, NH, and MA. The forest type map was produced by 1) determining the probability of forest type occurrence in climate space from available forest inventory data, 2) modeling the macro- and micro-climate of the region at 30-m resolution, and 3) using satellite remote sensing classification of gross forest types (evergreen, deciduous, mixed) available in the National Land Cover Data (NLCD) to guide final classification. Accuracy of the classification was determined from field survey data that were independent from those used to develop climate - forest type relationships. Overall classification accuracy was 73% and was limited by the accuracy of the NCLD (76%). When the NLCD correctly classified gross forest type, the climate model was 80% accurate in predicting specific forest types. Forest characteristics such as leaf area index and stand biomass were found to be primarily functions of forest type and stand height (a proxy for age). Accuracy was sensitive to georeferencing errors and improved toward the interior of large stands.

Motivation

Knowledge of the spatial extent and stand characteristics of the major forest types of New England is valuable in analysis of a variety of ecosystem and atmospheric research questions. For example, atmospheric deposition models require estimates of leaf area index (LAI), stomatal response to environmental conditions, leaf morphology, and canopy height. Nutrient cycling models require information on growth rates, standing biomass, litter fall rates, and the chemical composition of biomass by ecosystem component. These parameters and others may be generalized by forest type and are a function of the relative proportions of different forest species with different morphological and physiological properties.

Concepts

Climate is the primary control on the distribution of different forest types. Both macro- (latitude, continentality, large-scale water balance) and micro- (elevation, solar radiation, slope, aspect, local water balance, wind regime) determine the suitability of a site for specific forest species and species assemblages. Locally, substrate characteristics (bedrock and soil chemistry, soil depth, texture and drainage), fire, herbivore and pathogen pressures, human disturbance history (forestry, agriculture, fire), and time since disturbance (successional status) all act to select the forest type expressed on the landscape from the range of forest types possible for the climate of a given location.

We show how climate modeling coupled with satellite remote sensing techniques (to assess some local substrate and disturbance effects) yields robust predictions at 30-meter ground resolution of the spatial distribution forest types across New England. Independent forest survey data are used to assess the accuracy of forest type prediction by the model and to characterize key properties of the major forest types (total stand biomass, biomass by species and component, leaf area by species and stand height).

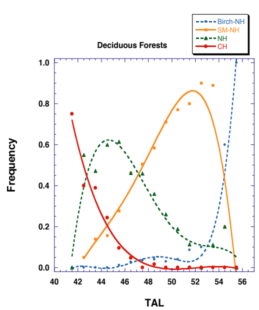
Approach

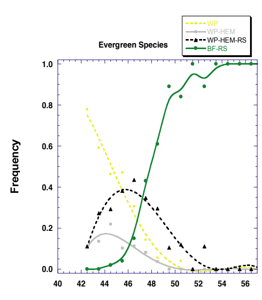
The dominant effects of both macro- and micro-climate on the distribution of forest species were distilled into a single variable, the terrain adjusted latitude (TAL). This involved the development of transfer functions to represent the effects of variance in elevation and solar radiation (slope, aspect, elevation) in terms of an equivalent shift in latitude on a horizontal surface at sea level.

Values of the TAL were computed for plots in the USFS Forest Inventory and Analysis (FIA) database for VT, NH, and MA. We screened the FIA plots, using only those where there was one forest type expressed over the full plot, and where the forest type was the same in the most recent two surveys. Frequency distributions of TAL for each forest type were used to estimate the probability of finding a particular forest type at a given value of TAL (Figures 1 and 2).

There are obvious overlaps in the TAL frequency distributions of certain evergreen and deciduous forest types (Figures 1 and 2). The USGS/USEPA National Land Cover Data (NLCD) developed using comparative analysis of leaf-on and leaf-off period Landsat Thematic Mapper (TM) scenes provides a means for distinguishing between the most climatically probable evergreen, deciduous or mixed forest type likely to be present at a specific site. The TM data alone are only suitable for prediction of the gross evergreen, deciduous, or mixed forest types.

The accompanying map (right) shows the distribution forest types predicted by this approach for VT, NH and MA.





Figures 1 and 2. Frequency of (1) deciduous and (2) evergreen forest types in the FIA sample for VT, NH, and MA as a function of terrain adjusted latitude (TAL), a proxy for the combined effects of several climate variables (see above). The FIA forest types northern red oak, red maple, and white oak - black oak - hickory were combined into a single class identified as central hardwoods (CH). Northern hardwoods (NH) include American beech, sugar maple, and yellow birch with lesser proportions of northern red oak, red maple, and white birch. The SM-NH class identifies northern hardwoods where sugar maple dominates the basal area. The birch-NH class identifies northern hardwoods where the sum of white birch and yellow birch basal area is greater than 50%. For the evergreen classes WP = white pine, HEM = hemlock, RS = red spruce, and BF = balsam fir.

Accuracy Assessment

Because the climate distributions of forest types were derived from the FIA data, we conducted a separate forest survey of 454 plots in VT and MA (the NH survey is currently in progress) to provide independent data for accuracy assessment. Plots were selected randomly, primarily within public lands, distributed over latitude, elevation, slope, aspect, and predicted forest type (see map to right). An observer located a plot via GPS navigation, sampled a variable-area plot based on a 10-factor prism, measured the heights of dominant trees, and recorded basic landscape observations. Forest types were derived from the survey information based on the percentage of basal-area associated with each species.

The model successfully predicted the forest type present at a given location with an overall accuracy of 73%. Both overall accuracy and specific class accuracy were limited by the accuracy of the NLCD gross forest type (evergreen, mixed, deciduous) classification. The NLCD classes were separated by comparing satellite images from periods with leaves-on and leaves-off for deciduous species. Our ground-truth survey indicates the accuracy of the NLCD evergreen class is only 38%, primarily due to errors of comission (Table 1). The NCLD misidentifies areas of deciduous and mixed forest as evergreen where the understory observed in the leaf-off scenes is mixed or evergreen (Table 1). The accuracy of the NLCD is also sensitive to the distance of the ground truth observation from the edge of an area classified as a single cover type (Table 1). This likely results from georeferencing errors in the TM scenes and some error in the GPS location of the ground-truth plots.

Observed	Predicted deciduous	mixed	evergreen
deciduous	87.9	18.9	5.4
mixed	12.1	74.8	56.3
evergreen	0	6.3	38.3

observed understory	match no	yes
deciduous	11.9	22.7
mixed	57.1	27.3
evergreen	31.0	50.0

Distance to edge	match no	yes
<30 m	37.3	62.8
>30 m	35.9	64.1
>50 m	18.3	81.7

Table 1. Correspondence analysis of NCLD forest classes with ground-truth. The NLCD significantly overestimates the evergreen forest type, misidentifying evergreen and mixed understories as evergreen canopies. A drop off in accuracy toward the edge of classified areas indicates that georeferencing errors contribute significantly to the overall error rate.

The 13-class climate model performs poorly for classes containing hemlock, but very well for other forest types (Table 2). The error rates and identities of misclassifications for specific forest classes are in-line with the degree of separation of forest types as a function of TAL (Figures 1 and 2). If the classification is condensed to 9 forest classes, accuracy is improved (Table 3). Overall accuracy of the classification improves with distance from the edge of a consistently classified area (e.g. Table 3). The overall accuracy of the 9-class model is 80%, because the classes with the highest error rates are also those predicted to occupy the least land area (see Table 3 and map at right).

Observed	Predicted Birch-NH	SM-NH	NH	CH	WP	WP-HEM-RS	HEM-RS-BF	BF-RS	WP-CH	WP-HEM-RS-CH	BF-RS-HEM-NH	BF-RS-SM-NH	BF-RS-Birch
Birch-NH	**na**												
SM-NH		**54.8**	18.5	3.7									
NH		38.1	**57.6**	5.6									
CH		7.1	23.9	**90.7**									
WP					**65.0**	66.7	13.3						
WP-HEM-RS					35.0	**33.3**	20.0						
HEM-RS-BF							**20.0**						
BF-RS							46.7	**100.0**					
WP-CH									**na**	61.1	3.3		
WP-HEM-RS-CH										**33.3**	23.3		
BF-RS-HEM-NH										5.6	**70.0**	31.6	
BF-RS-SM-NH											3.3	**68.4**	
BF-RS-Birch													**100.0**

Table 2. Correspondence analysis between model predictions and ground-truth for 13 forest class model. The location of classes containing hemlock is predicted poorly, while other classes are predicted well.

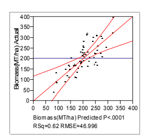
Observed	Predicted NH	CH	WP	WP-HEM-RS-BF	BF-RS	WP-HEM-HW	BF-RS-HW	BF-RS-SM	BF-RS-Birch
NH	**81.3**	9.3							
CH	18.7	**90.7**							
WP			**65.0**	40.0					
WP-HEM-RS-BF			35.0	**36.7**					
BF-RS				23.3	**100.0**				
WP-HEM-HW						**94.4**	26.7		
BF-RS-HW						5.6	**70.0**	31.6	
BF-RS-SM							3.3	**68.4**	
BF-RS-Birch									**100.0**

Distance to edge	match no	yes
<30 m	28.1	71.9
>30 m	22.7	77.3
>50 m	17.6	82.5

Table 3. Correspondence analysis between model predictions and ground-truth for 9 forest class model. Accuracy of the classification is improved by consolidating hemlock into fewer classes and grouping all northern hardwood types.

Forest Characteristics

The forest survey data were used to quantify key characteristics of the major forest types (Table 4) and test for possible relationships between those characteristics and climate variables. Multiple regression, ANCOVA and ANOVA revealed only significant effects of forest type and canopy height (proxy for age) on key forest characteristics such as biomass and leaf area. There were no significant effects of climate variables (mean annual temperature, growing degree days, mean annual precipitation, mean annual evapotranspiration, mean annual available water) on these characteristics. While tree height at a particular age (stand index) does relate to local site conditions, height is most closely related to stand age. In our sample, height (proxy for age) and forest type were the only significant effects on stand biomass and LAI (e.g. Figure 3), suggesting that forest type, land use history, and time since disturbance primarily control the distribution of these parameters in New England. The values of these parameters (or their ranges) can be linked to the forest types on the accompanying map.



Analysis of Variance

RSquare		0.621557		
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	15	185002.43	12333.5	5.5842
Error	51	112640.88	2208.6	Prob > F
C. Total	66	297643.31		<.0001

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Max(height(m))[ForestType]	8	8	84718.067	4.7947	0.0002
ForestType	7	7	61498.666	3.9778	0.0015

Figure 3.
Forest type and stand height (proxy for stand age) are the only significant predictors of stand biomass in the ground truth survey plots.

Table 4. Some example characteristics of major forest types.

Forest Type Characteristics Forest Type	LAI (m2/m2)	+/- 1se	Biomass (T/ha)	+/- 1se
Deciduous Forest				
Birch - Northern Hardwoods	6.23	0.58	149	41
Sugar Maple - Northern Hardwoods	6.23	0.58	213	11
Northern Hardwoods	7.43	0.53	212	9
Central Hardwoods	3.35	0.79	193	12
Evergreen Forest				
White Pine	2.46	0.73	165	14
White Pine - Hemlock - Red Spruce	2.70	0.62	151	12
Hemlock - Red Spruce - Balsam Fir	3.65	1.47	231	1
Balsam Fir - Red Spruce	7.51	0.37	132	12
Mixed Forest				
White Pine - Central Hardwoods	1.96	1.38	182	19
White Pine - Hemlock - Red Spruce - Central Hardwoods	1.52	0.49	215	20
Balsam Fir - Red Spruce - Hemlock - White Pine - Northern Hardwoods	5.00	0.50	199	9
Balsam Fir - Red Spruce - Sugar Maple - Northern Hardwoods	6.13	0.53	152	8
Balsam Fir - Red Spruce - Birch	7.89	0.85	146	27

These are examples of forest characteristics that can be mapped by forest type using this classification.
The characteristics are derived from the ground-truth survey plots associated with this study (Miller et al., in preparation)
Other forest characteristics available are: biomass by species and tree component, chemistry of biomass by species and tree component, leaf area by species, canopy height, density, and basal area.

Acknowledgements

Rachel Riemann at the USFS extracted the appropriate plot data from the FIA database for this analysis. This work was partially funded by Northeast States for Coordinated Air Use Management, Massachusetts Department of Environmental Protection, USDA Forest Service, Northeastern Ecosystem Research Cooperative, and the USEPA STAR Program.

Data Availability

The forest type and forest characteristics spatial data sets are currently accessable to scientists engaged in collaborative research with the authors. The data sets will be made available to the general public after peer-reviewed publication of a series of papers describing the development and application of the forest type and characteristics spatial data sets.

We are currently seeking funding to complete vegetation mapping, accuracy assessment, and forest characteristics measurements in the remaining New England States (ME, CT, RI) as well as in NY and PA. Contact Eric Miller for updates on the progress of mapping in these areas.

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