Predicting forest productivity across heterogeneous landscapes

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Objective: Using remote sensing and ancillary environmental variables, develop spatial models to quantify forest productivity across a heterogeneous landscape.

Remote sensing can provide a relatively low-cost approach to large scale assessment of forest productivity but the connection between remote sensing products and scalable field metrics is not well understood. Much of the existing research has focused on homogeneous, single species forests, with limited remote sensing inputs for model calibration or field data to assess accuracy of productivity predictions. Here we develop and evaluate yearly basal area increment models for common species across the northeastern US. Applying these models across the landscape highlights spatial and temporal variability in forest growth patterns.

Methods:

We developed models of annual basal area increment (BAI) based on tree ring data from 71 sites across Vermont and New Hampshire. Linked to widely available remote sensing data products (MODIS yearly phenology and vegetation index data layers from 2001 and 2012) as well as ancillary spatial data layers to capture site, stand, and relative habitat suitability, we compare full, and species specific BAI growth models in a mixed-stepwise linear regression platform with conservative significance, autocorrelation and fit thresholds. Species with sufficient calibration coverage included: *Abies balsamea*, *Acer saccharum, Betula alleghaniensis, Betula papyrifera, Fagus grandifolia, Picea rubens.* Species specific models were then applied across the landscape based on Landfire forest cover type maps to examine spatial and temporal patterns in forest productivity.

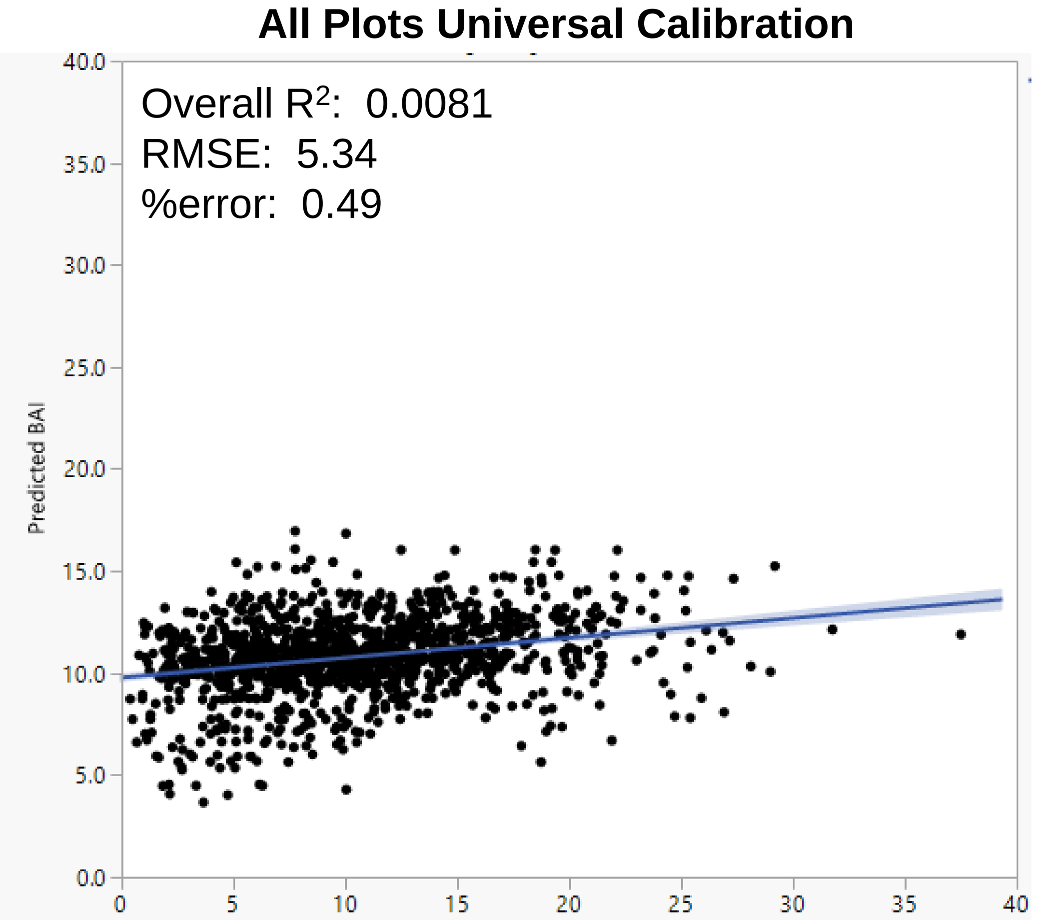
Results:

We found that a single landscape scale model for all species was not accurate, accounting for only 16 percent of the total variability in yearly BAI. However, when individual species were modeled, accuracy and stability increased significantly. This likely results from inherent spectral differences and typical productivity values across species.

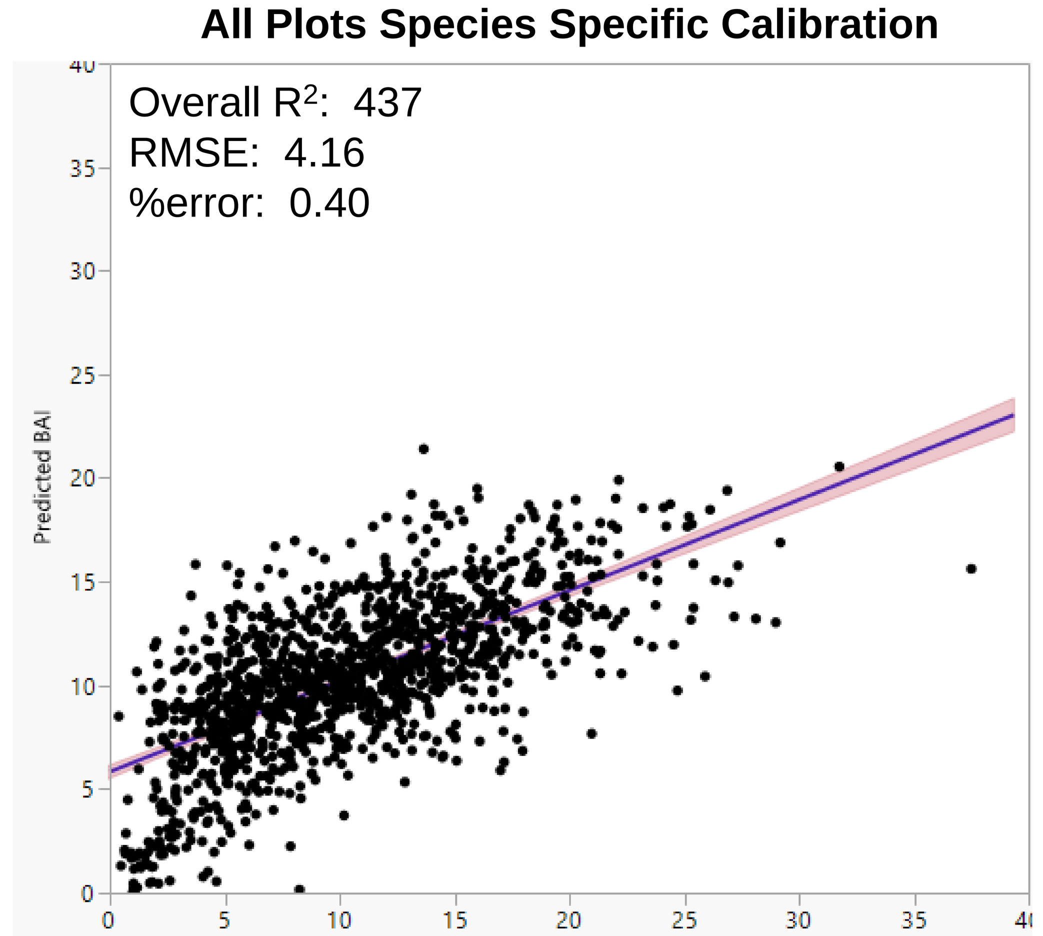
Species models were most accurate for species that occur in relatively homogeneous stands (i.e. red spruce and balsam fir). However, percent error is still relatively high compared to the mean response (between 39% and 17% across species). This indicates that resulting maps may be more useful for relative assessments of productivity over space and time, rather than accurate estimates at a given location.

Species	Samples (core years)	R^2	RMSE	Mean yearly BAI	Model # Terms
All species	1322	0.165	5.986	11.147	9
Betula alleghaniensis (Yellow Birch)	454	0.207	4.552	12.094	6
Acer saccharum (Sugar Maple)	476	0.333	4.470	9.7804	7
Fagus grandifolia (American Beech)	50	0.503	3.490	11.955	3
Picea rubens (Red Spruce)	140	0.589	4.180	10.997	6
Abies balsamea (Balsam Fir)	64	0.570	1.589	9.316	4
Betula papyrifera (Paper Birch)	86	0.690	1.353	3.453	3

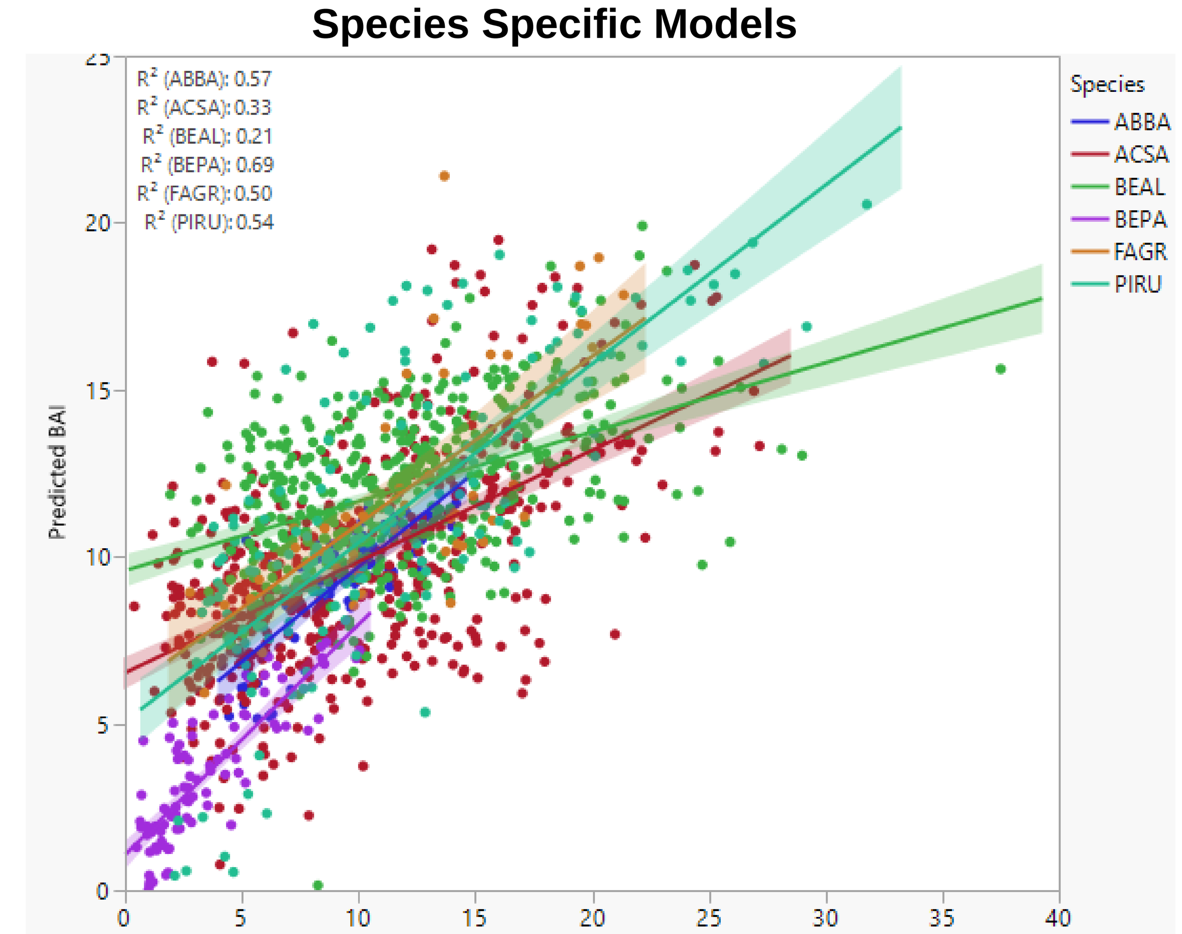
All Plots Universal Calibration



All Plots Species Specific Calibration



Species Specific Models



Conclusions: These results indicate that:

- Modeling forest productivity across heterogeneous landscapes is difficult based on the complexity of spectral characteristics in mixed stands, site variability across the landscape and diversity of factors influencing tree growth on a micro-scale.
- However, species specific models can be built and applied across these landscapes with sufficient accuracy to inform spatial and temporal patterns in forest productivity.
- Applied across the landscape the resulting productivity models:
  - Match the variability in dendrochronological records of tree growth, successfully differentiating low and high growth years.
  - Highlight spatial patterns of consistently high and low growth across the landscape.

This information will allow us to investigate possible drivers of spatial and temporal patterns in forest growth. This is of particular importance considering the potential impact of climate change on forest structure and function over the coming decades.