Mapping forest productivity across heterogeneous landscapes: methods, patterns and trends

Jennifer Pontius, Shelly Rayback, Emma Tait, , Jesse Little and John Kilbride

University of Vermont Department of Geography, RSENR and USFS Northern Research Station

Objectives:

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 patterns in forest growth patterns**.

Methods:

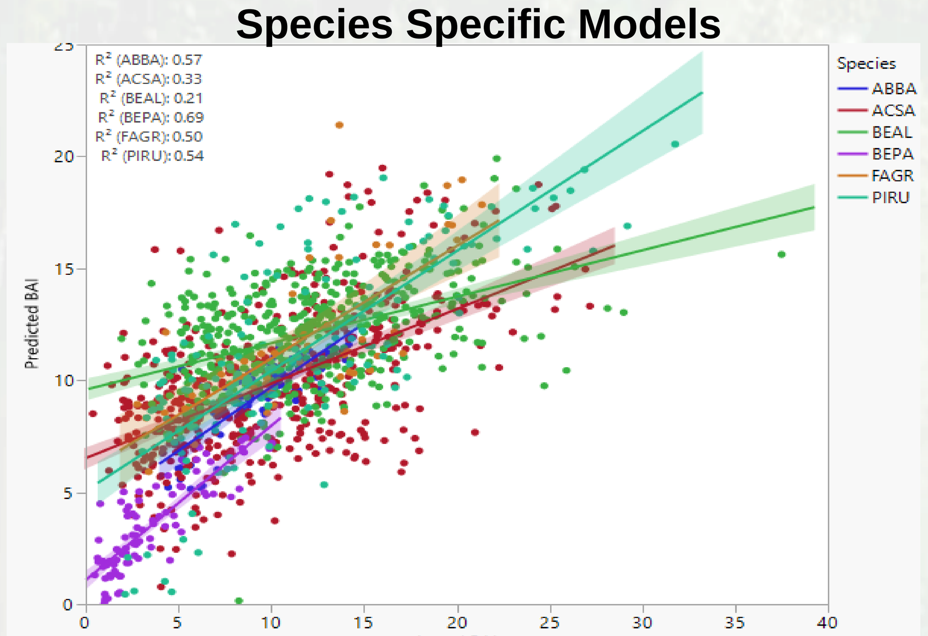
We developed models of annual basal area increment (BAI) based on tree ring data from 71 sites across Vermont and New Hampshire. Linked to widely available remote sensing data products (MODIS yearly phenology and vegetation index data layers from 2001 and 2012) as well as ancillary spatial data layers to capture site, stand, and relative habitat suitability, we developed 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
(Modeling Productivity):

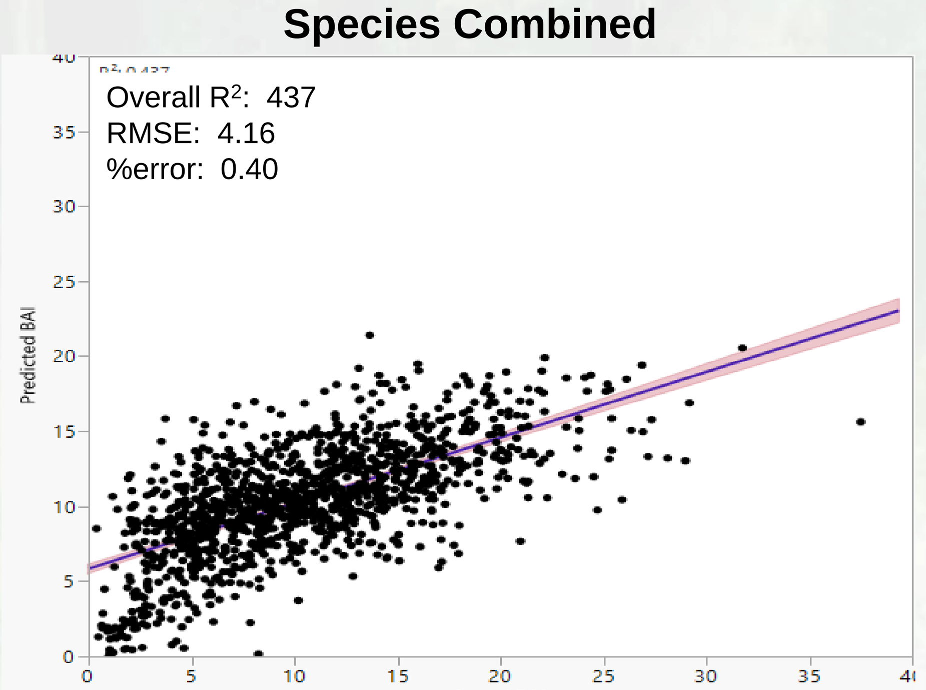
We found that a single landscape scale model for all species was not accurate, but when individual species were modeled independently, accuracy and stability increased significantly. This likely results from inherent spectral differences and typical productivity values across species.

Individual 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.

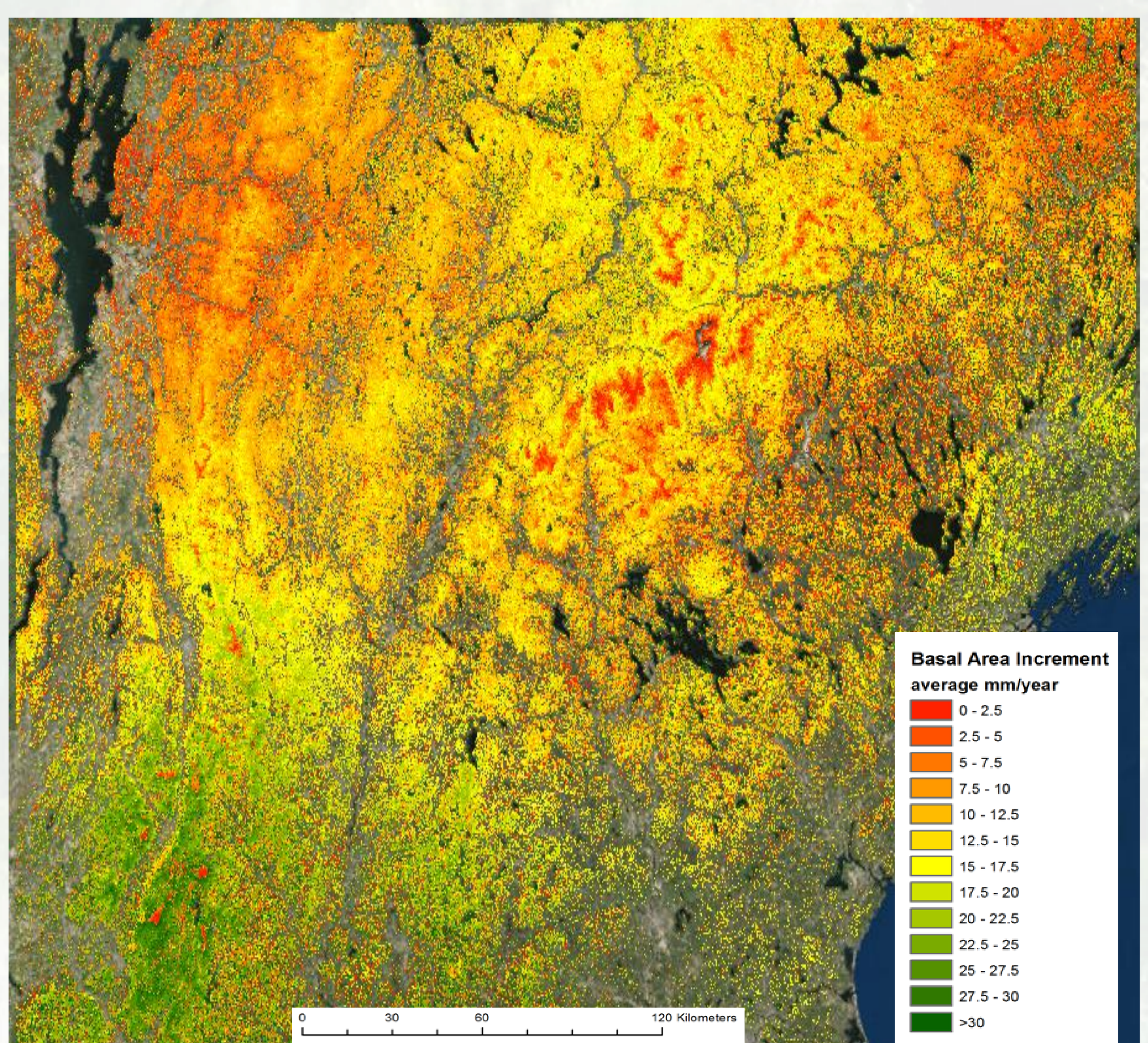
Species Specific Models



Species Combined



Models were most accurate when calibrated individually for each species. Accuracy varied by species but provides a useful relative assessment of productivity across the landscape and over time.

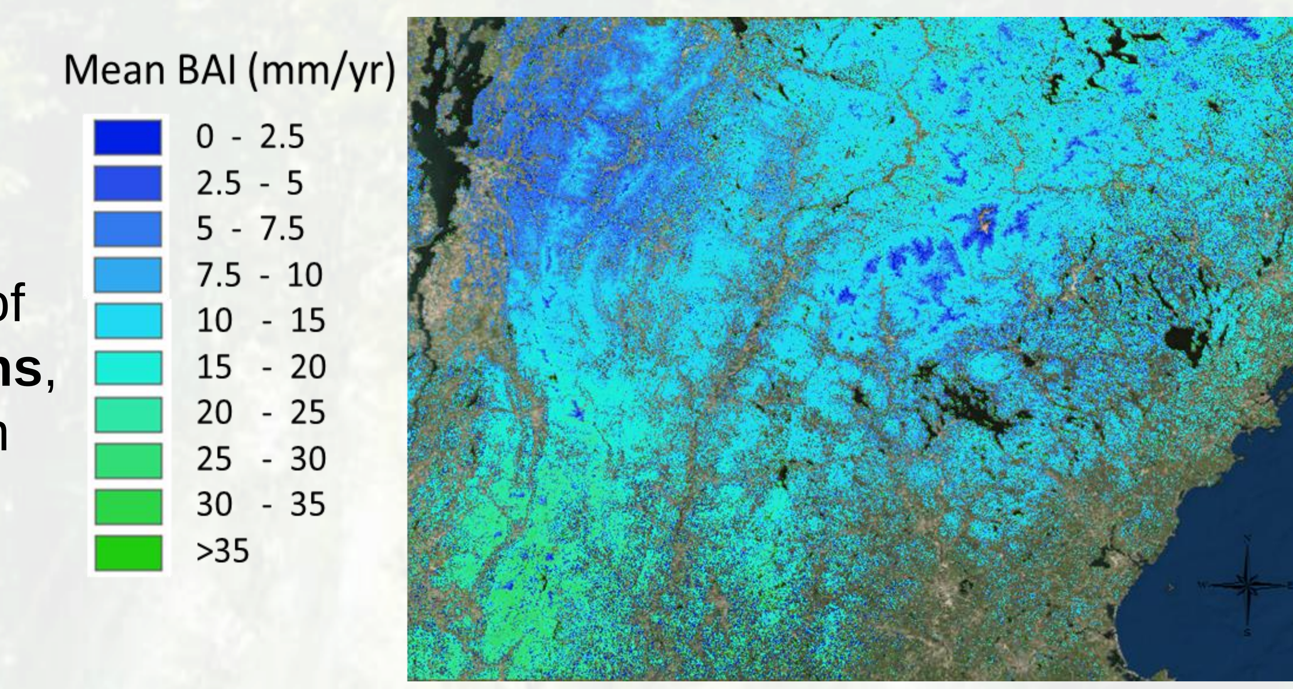


Model of 2012 productivity using the six species with sufficient calibration coverage. Individual species models were averaged to illustrate overall productivity in a given location based on Landfire species distribution maps.

Results
(Productivity Patterns):

Mean Productivity

Averaging remotely sensed assessments of productivity shows **distinct spatial patterns**, with the highest mean yearly productivity in southern Vermont, with lower mean yearly productivity at higher elevations and in the Champlain Valley of Vermont.



Differences also exist among species, with significantly higher yearly BAI for red spruce, and lower yearly BAI for balsam fir among the species included. Significant discrepancies exist between landscape predictions and core measured paper birch BAI, likely resulting from the dominance of declining paper birch included in the core data set.

Mean Yearly Basal Area Increment (BAI)

Species	Max	Landcape Predicted Mean	Stdev	Core Data Mean
ABBA	23	10.59	2.78	9.30
ACSA	109	15.17	15.03	9.80
BEAL	75	12.98	6.18	11.90
BEPA	26	14.90	2.74	3.40
FAGR	210	15.02	16.90	11.90
PIRU	94	17.09	9.65	10.90

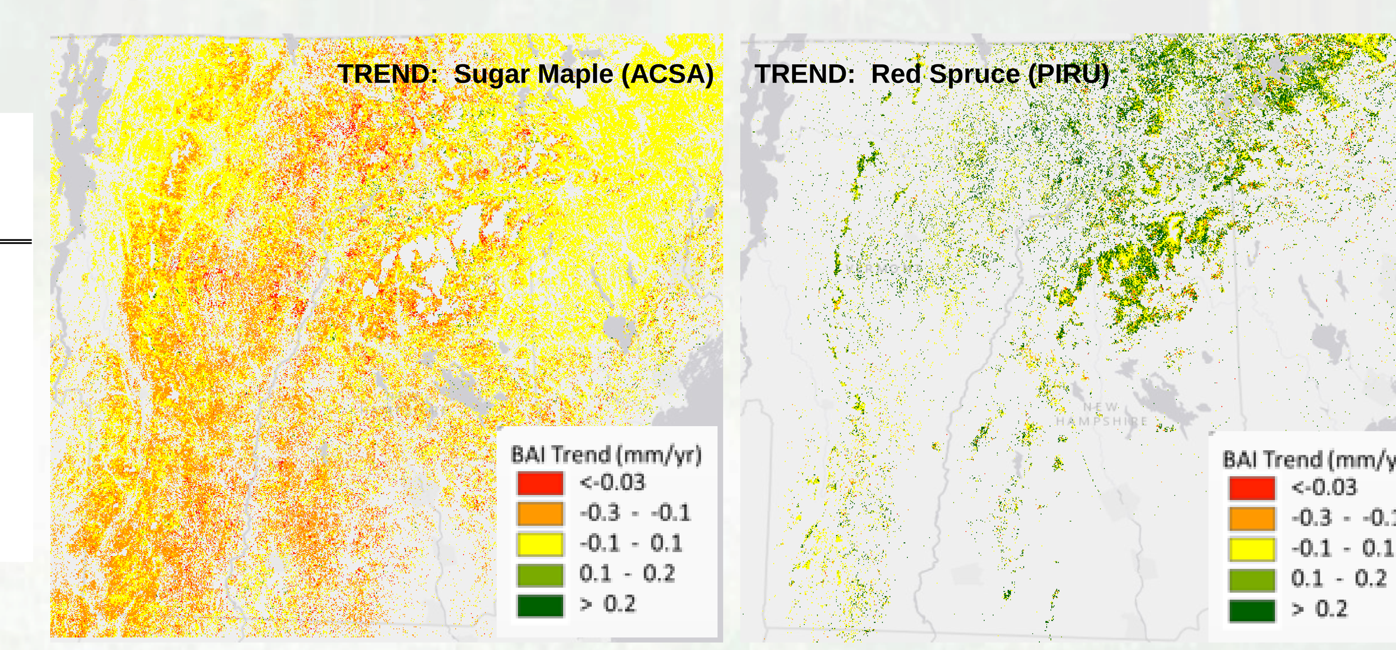
Averaged over all years, mean yearly BAI measurements differ among species and across the landscape over the 11 year study period.

Species Trends in Productivity

Fitting a line to the yearly BAI measurements at each pixel provided an estimate of general trends in productivity over the 11 year study. We found some **species with increasing growth trends (American beech and red spruce)** and some with **decreasing growth trends (balsam fir and sugar maple).** Mapped across the landscape, these trends are not uniform, but vary based on site and climate conditions.

Trend in Basal Area Increment (BAI)

Species	Min	Max	Mean	Stdev
ABBA	-0.33	0.15	-0.07	0.04
ACSA	-1.02	0.99	-0.10	0.11
BEAL	-1.23	1.21	0.00	0.16
BEPA	-1.24	1.68	0.07	0.19
FAGR	-3.47	4.05	0.16	0.37
PIRU	-0.86	1.03	0.13	0.16



Productivity trends over the 11 year study period show some species with significantly increasing or decreasing growth rates. This varies across the landscape based on site and climate conditions.