Landscape scale assessments of forest productivity: methods, patterns and trends

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Objectives:

Remote sensing can provide a relatively low-cost approach to large scale assessment of forest productivity but much of the existing research has focused on homogeneous, single species forests. Here we:

- **develop and evaluate landscape-level yearly basal area increment models to estimate stand productivity**
- **apply these models to 250m pixels across the landscape**
- **examine spatial and temporal patterns in forest growth**

Methods:

Tree ring basal area increment (BAI) 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, were used to developed species specific BAI growth models for:

Abies balsamea*, *Acer saccharum*, *Betula alleghaniensis*, *Betula papyrifera*, *Fagus grandifolia*, *Picea rubens

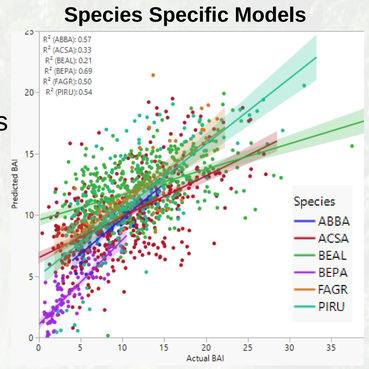
Species specific regression models were then applied to 250m pixels across the landscape for 2001 to 2012 based on Landfire forest cover type maps.

Pixel-level overall mean and trend slopes were used to examine spatial and temporal patterns in forest productivity.

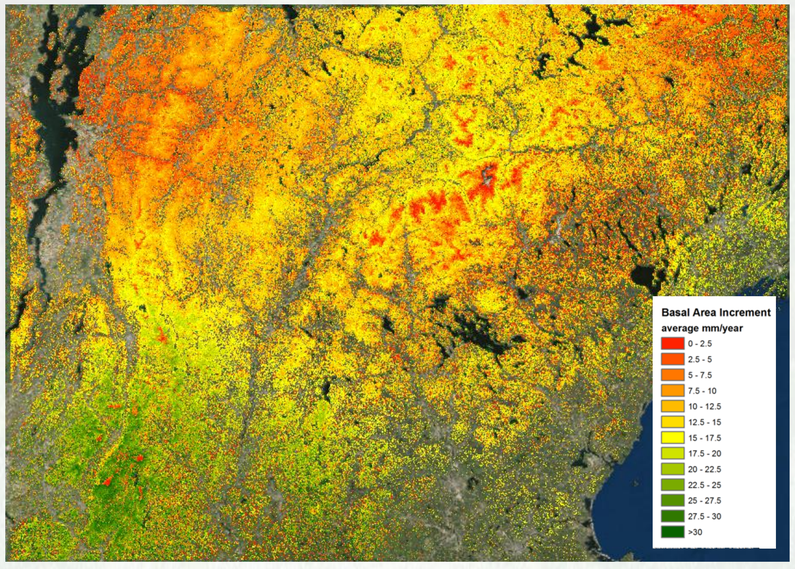
Results

Modeling Productivity:

We found that a single landscape Scale model for all species was not accurate, but when individual species were modeled independently—using both remote sensing and ancillary environmental variables—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 indicating that resulting maps may be more useful for relative assessments of productivity over space and time, rather than accurate estimates at a given location.



Model of 2012 productivity. Individual species models were averaged where multiple species occur to illustrate overall productivity in a given location based on Landfire species distribution maps.

Productivity Patterns:

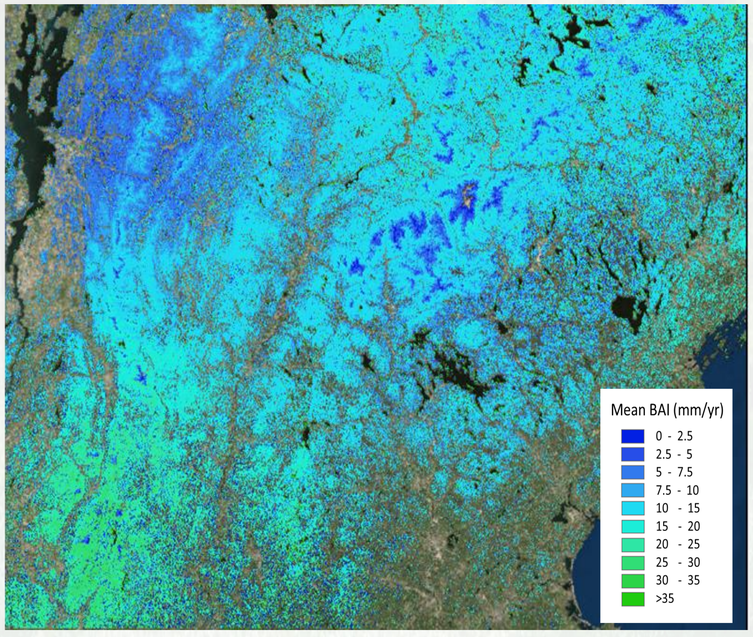
Averaging remotely sensed assessments of productivity over the 11 years of data shows **distinct spatial patterns**, with the highest mean yearly productivity in southern Vermont, and generally lower mean yearly productivity at higher elevations and in the Champlain Valley of Vermont.

These patterns are primarily driven by species distribution, with distinct differences in typical BAI across the 6 species.

Landscape predicted BAI was highest for red spruce and American Beech and lowest for balsam fir.

Mean Yearly BAI

	random points	*full raster*	*Cores*	mean
ABBA	10.6	10.6	9.3	10.2
ASCA	11.3	15.2	9.8	12.1
BEAL	13.0	13.0	11.9	12.6
BEPA	15.0	14.9	3.5	11.1
FAGR	14.8	15.0	11.9	13.9
PIRU	16.6	17.1	10.9	14.9



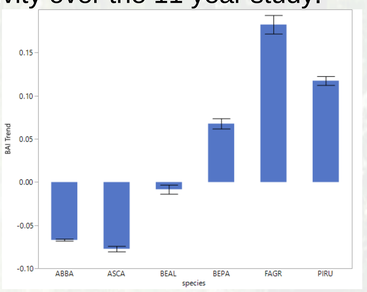
Averaged over all years, mean yearly BAI measurements differ among species and across the landscape over the 11 year study period.

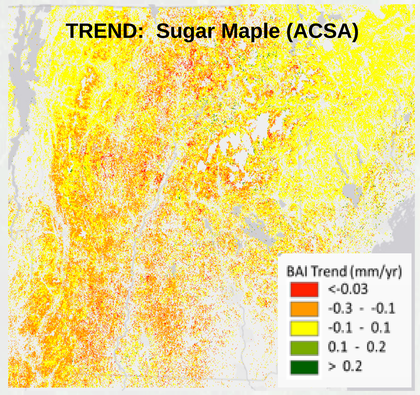
Productivity Trends:

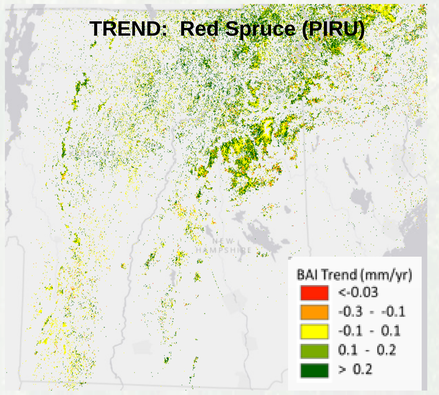
Fitting a line to the yearly BAI measurements at each pixel provided an estimate of general trends in productivity over the 11 year study.

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.







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

Environmental drivers of trends differed by species but only accounted for a small proportion of the overall variability. The most consistent relationships included: decreasing productivity at higher elevations, on shallow soils and low available water capacity sites.

BAI Trends	ABBA	r^2 = 0.04	ACSA	r^2 = 0.12	BEAL	r^2 = 0.02	BEPA	NA	FAGR	NA	PIRU	NA	Overall	r^2 = 0.21
Variable	*Corr.*	*p-value*	*Corr.*	*p-value*	*Corr.*	*p-value*	*Corr.*	*p-value*	*Corr.*	*p-value*	*Corr.*	*p-value*	*Corr.*	*p-value*
AWC	Neg	0.0007	Neg	<0.0001									Neg	<0.0001
Elev	Pos	<0.0001	Neg	<0.0001	Neg	<0.0001							Neg	<0.0001
Exceedance														
Precipitation														
Rock Depth													Pos	<0.0001
Slope														
Soil Permiability														
Soil pH														
Tmax			Neg	<0.0001										
Tmean					Neg	0.0003								
Tmin														