Uncovering Competitive Mechanisms of Tree Competition with Data Assimilation

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Background

- Understanding competitive interactions between tree species is critical to predicting how forest communities will adapt to future shifts in climate and land use.
- Current knowledge of species interactions is limited because of the long timescale required to observe forest growth and species interactions.
- Using data-informed simulation models to investigate species interactions allows us to assess species interactions and forest growth.
- The oak-maple dynamics in the forest of New England is one of the most well-studied species relationships in ecological literature.
- Historically, red oak (Quercus rubra) dominated New England Forests. Recently, many stands have transitioned to being dominated by red maple populations (Acer rubrum). Only a few forests, such as those at Harvard Forest in Petersham, MA, persist being dominated by red-oak populations.

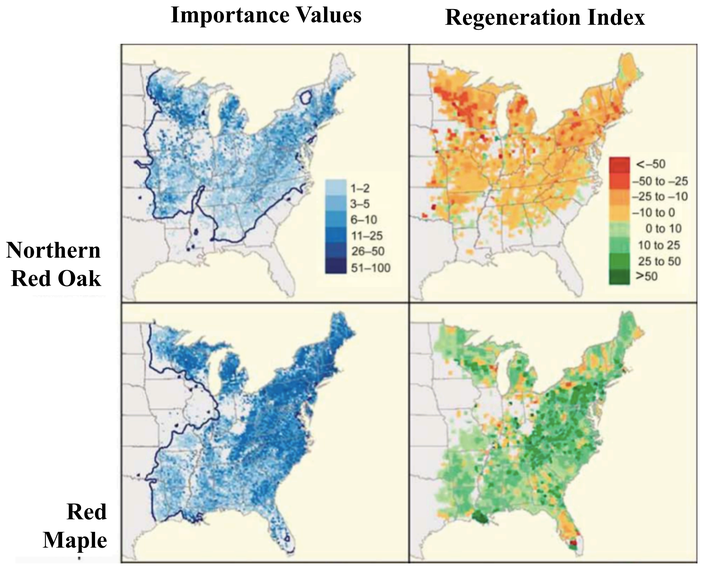

Figure 1. 2010 distribution of red maple and red oak populations in northeastern United States as measured in USFS FIA plots. Regeneration index is the calculated difference between each species' percentage of all small trees (less than 13 cm. diameter) and its percentage of large trees (greater than 38 cm. diameter). [McEwan et al. 2011]

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Objective

- Use a data-informed simulation model to investigate the oak-maple dynamic at Harvard Forest
- Analyze model output and parameter data to pinpoint the specific species interaction that allows red oak to maintain its dominance

State Data Assimilation

State data assimilation (SDA) is the process of informing a model with observed data so as to constrain and improve model forecasts. The process follows the data-forecast cycle. In this cycle, the model first makes a prediction. Then, we use observed data to assess the accuracy of the prediction and constrain the model output so it accurately reflects the observed state before it begins to make its next prediction.

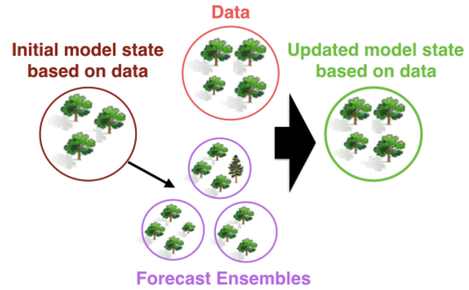

Figure 2. Illustration of state data assimilation process

Methods

Data & Model

- LINKAGES, an individual-based forest-gap model which functions on yearly steps
- simulated forests included yellow birch, white pine, red maple, and red oak
- tree-ring data from tree cores taken at Harvard Forest in 2010
- calibrated the model using biomass data from the Harvard Forest EMS flux tower

Partial SDA Workflow

- 200 ensemble-based model runs
- 3 distinct periods within each model run: spin-up (1861-1961), assimilation (1962-1984), and forecast (1985-2009)

Analysis of Model Data

- analyzed correlation coefficients to determine the species parameters most significant to resulting compositional differences
- used visual characterizations of model output to pinpoint differences in stand structure, stand age, and canopy composition between different types of runs

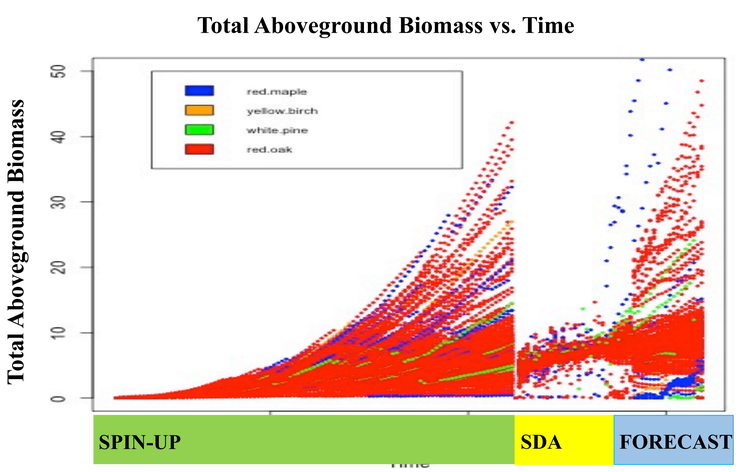

Figure 3. Total aboveground biomass of each ensemble member over time. The color of the data points represent the forecasted dominant species of that specific run.

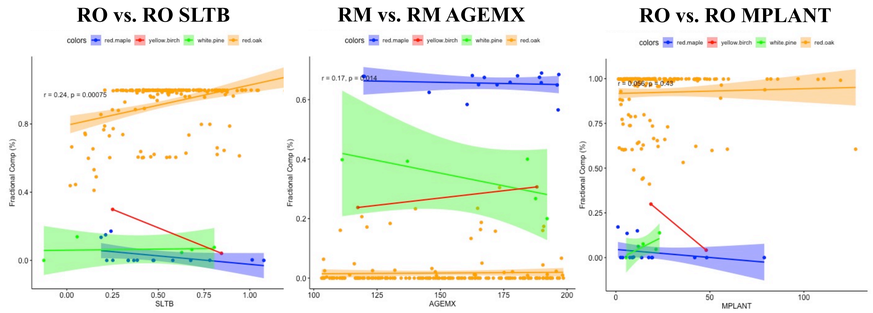

Figure 4: Average fractional composition of species in forecast period vs. notable parameter values for all ensemble members.

Results

- Parameters affecting red oak canopy size and maximum age of red maple were most important for red oak dominance.
- Ensemble members dominated by red oak trees indicate 2 things:
  1. The majority of red oak biomass in the model is supplied by large overstory trees that are not easily overcome by competitors.
  2. Red oak trees are largely absent in the model's understory due to the species' limited ability to regenerate.
- Available light was the driving factor in the development of the red-oak forest.

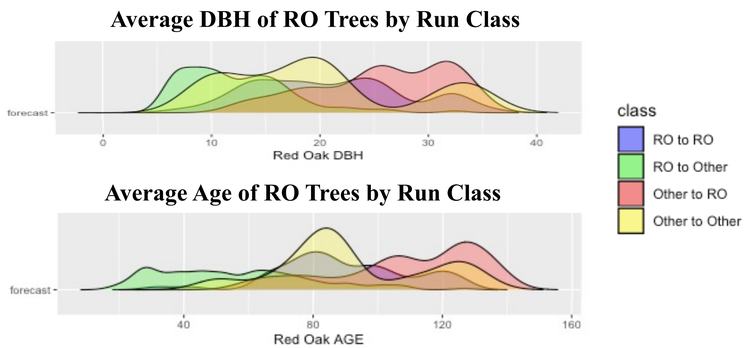

Figure 5: Density curves showing averaged model output in forecast period for all ensemble members in each run class.

Discussion

- Canopy structure and light are the primary factors limiting growth in oak-maple forests.
- Our analyses indicate Harvard Forest could be dominated by red maple in the future as older red oaks in the forest die.
- The likelihood and timeline of this transition depends on red oak longevity, the effect of gap size, and red oak regeneration, which need further study.
- Our next step is to apply this SDA approach to study other sites in New England and gain a more general understanding of the species dynamics in the region.