Relative effects of functional diversity and structural complexity on late-successional, northeastern mixed hardwood forest carbon

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Adaptive forest management can help improve forest resilience to these stressors and protect carbon stores (D’Amato et al. 2011, Ontl et al. 2020).
• Goal: Prepare the forest to withstand increasingly severe disturbances (Millar et al. 2007)

• Traditional benchmarks include:
  • **Species diversity**
  • **Structural complexity** (diversity of tree sizes, canopy strata, forest gaps, standing and downed deadwood)
ADAPTIVE FOREST MANAGEMENT

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Are these the best stand-level guidelines for maximizing forest carbon benefits?
• **Functional traits** are measurable traits that contribute to the fitness (potential growth, fecundity, and mortality risk) of an individual and impact ecosystem function (Reich et al. 2003)
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Image credit: New Phytologist
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• Functional diversity is linked to species diversity and structure, but not commonly considered in the context of adaptive management (Thom et al. 2020)

*Image credit: New Phytologist*
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Tilman et al. (1997)
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A number of studies have found that functional traits drive forest productivity.
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  - Trait variability within species to make connections between traits and demographic processes (Laughlin and Messier 2015)
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- Need to account for:
  - Trait variability within species to make connections between traits and demographic processes (Laughlin and Messier 2015)
  - Correlation among traits due to functional trade-offs (Reich 2014)
- **However, there are sparse datasets** with both long-term demographic data and local individual functional trait information
RESEARCH AIM

Apply both Massachusetts continuous forest inventory (CFI) data and local, individual functional trait observations to predict AGB in response to functional diversity.
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**Objective:**
Quantify the effects of functional diversity, species diversity, and structural complexity as drivers of live aboveground biomass (AGB) in late-successional forests.
CARBON DYNAMICS IN LATE-SUCCESSIONAL FORESTS

- Model study systems for forest carbon storage
- High carbon stores, high structural complexity, lower species diversity (Franklin et al. 2002, Gravel et al. 2010)
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DATA COLLECTION

- We utilized Massachusetts DCR CFI data from 7 state forest reserves with plots identified as late-successional/old-growth (Lorimer and Halpin 2014)
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• Sampled functional traits at 26 CFI plots within these forests (Specific leaf area, leaf nutrient content, wood density)
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- Sampled functional traits at 26 CFI plots within these forests (Specific leaf area, leaf nutrient content, wood density)
- Calculated total live AGB using allometric equations (Jenkins 2003) and structural complexity indices at each plot (2000-2021)
MODEL BACKGROUND

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**Specific leaf area**

- **Sugar maple**
- **Red oak**
- **Yellow birch**
- **Eastern hemlock**

**Legend**
- Database mean and SD
- Local trait distribution
- Shift from local mean
- Shift from database mean
- Updated mean trait value
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**Live aboveground biomass ~**

Functional diversity + Structural complexity + Density (BA/ac) + Proportion softwood + error
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- Compared 3 models:
  - Functional diversity with local trait update
  - Functional diversity with database species means only
  - Species diversity
• Integrating local, individual functional trait information yielded the best predictions of live AGB
There were strong effects of density, proportion of softwood species, and diameter diversity on live AGB.
Functional diversity had a negative effect on live AGB
Plots with low functional diversity were dominated by mid to high shade-tolerant hardwood species.
Plots with high functional diversity had more shade-intolerant and mid-tolerant species and softwoods.
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Myers et al. (in prep)
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CONCLUSIONS

• Forest successional dynamics shift the effects of functional diversity on AGB productivity

• Strong positive diversity-productivity effects in early-to-mid-successional forests can decrease in mid- to late-successional forests (Urgoiti Otazua et al. 2022, Fahey et al. 2015, Hardiman et al. 2011)
CONCLUSIONS

• Forest successional dynamics shift the effects of functional diversity on AGB productivity

• Strong positive diversity-productivity effects in early-to-mid-successional forests can decrease in mid- to late-successional forests (Urgoiti Otazua et al. 2022, Fahey et al 2015, Hardiman et al. 2011)

• Example of the classical model of a “dynamic steady-state” equilibrium of AGB (carbon stores) in late-successional mixed hardwood forests

• Disturbance-mediated tradeoffs between slight increases in functional diversity and decreases in AGB stores
SO, WHAT DOES THIS MEAN FOR FOREST CARBON MANAGEMENT?

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- Preserving late-successional stands of relatively stable, high aboveground carbon stores
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- Preserving late-successional stands of relatively stable, high aboveground carbon stores
- Active management in early-mid successional stands where diversity-productivity relationships are stronger and biomass accrual rates are higher

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THANK YOU! QUESTIONS?