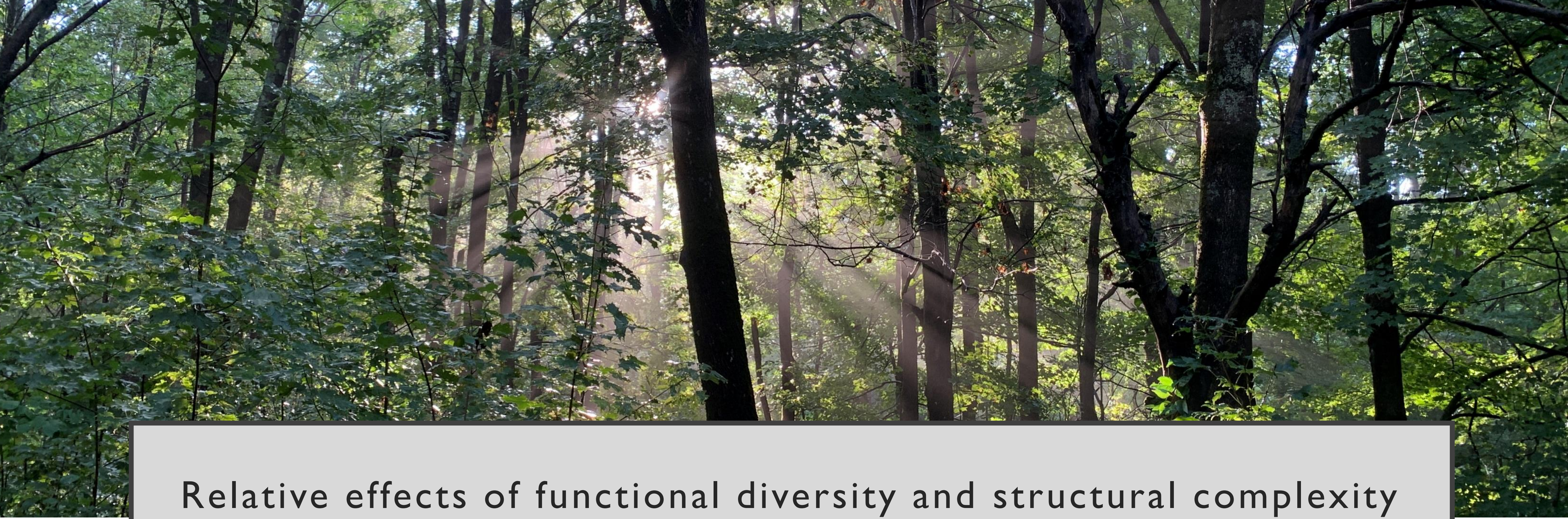


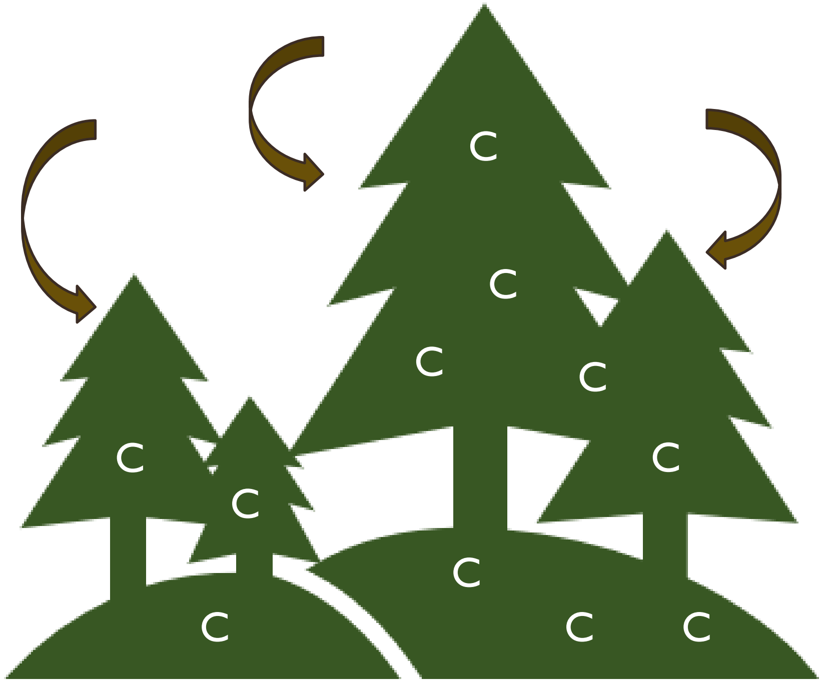
Relative effects of functional diversity and structural complexity on late-successional, northeastern mixed hardwood forest carbon

Samantha Myers
Applied Forest Ecology lab
UMass Amherst

Forest Ecosystem Monitoring Cooperative (FEMC) Conference, December 15th, 2022

BACKGROUND

- Forests serve as a key climate mitigation tool due to their ability to sequester and store carbon



BACKGROUND

- Forests serve as a key climate mitigation tool due to their ability to sequester and store carbon
- However, forests face a variety of compounding threats which could fundamentally shift Northeastern forest dynamics and impact their ability to sequester and store carbon

BACKGROUND

- Forests serve as a key climate mitigation tool due to their ability to sequester and store carbon
- However, forests face a variety of compounding threats which could fundamentally shift Northeastern forest dynamics and impact their ability to sequester and store carbon
- **Adaptive forest management** can help improve forest resilience to these stressors and protect carbon stores (D'Amato et al. 2011, Ontl et al. 2020)

ADAPTIVE FOREST MANAGEMENT

- 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)

VS.

ADAPTIVE FOREST MANAGEMENT

- 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)

VS.

Are these the best stand-level guidelines for maximizing forest carbon benefits?

FUNCTIONAL TRAIT DIVERSITY

- **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)

Image credit: New Phytologist

FUNCTIONAL TRAIT DIVERSITY

- **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)
- Can be examined at the individual level, aggregated to species scale (species-level means), and scaled up to ecosystem level

Image credit: New Phytologist

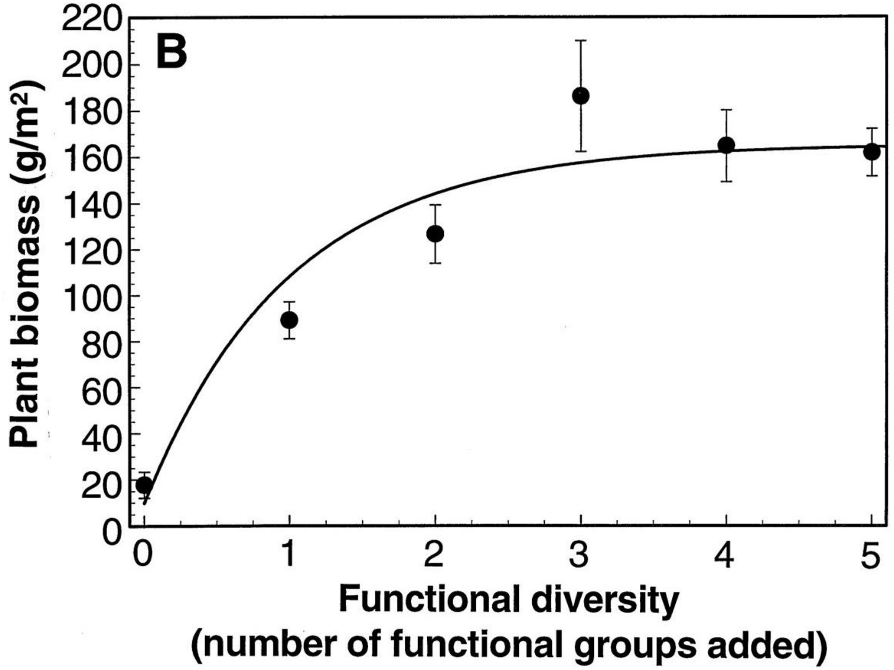
FUNCTIONAL TRAIT DIVERSITY

- **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)
- Can be examined at the individual level, aggregated to species scale (species-level means), and scaled up to ecosystem level
- 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

Functional diversity could be considered along with other benchmarks to improve forest carbon management

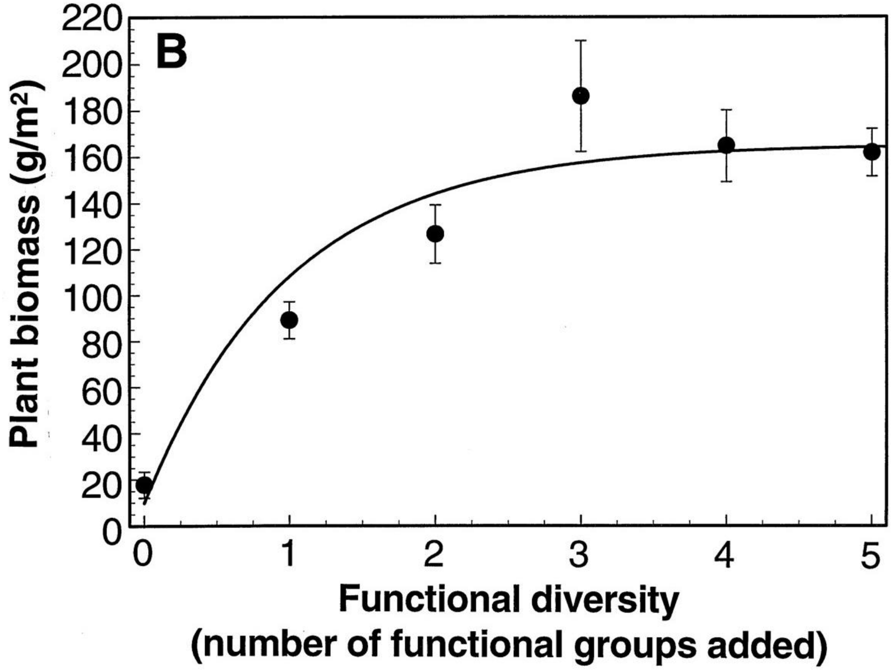
Functional diversity relates to ecosystem productivity and stability



Tilman et al. (1997)

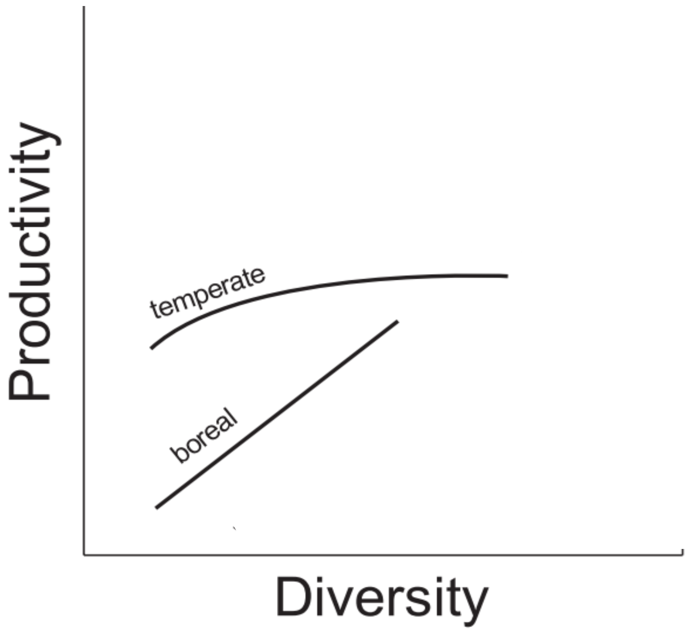
Functional diversity could be considered along with other benchmarks to improve forest carbon management

Functional diversity relates to ecosystem productivity and stability



Tilman et al. (1997)

A number of studies have found that functional traits drive forest productivity



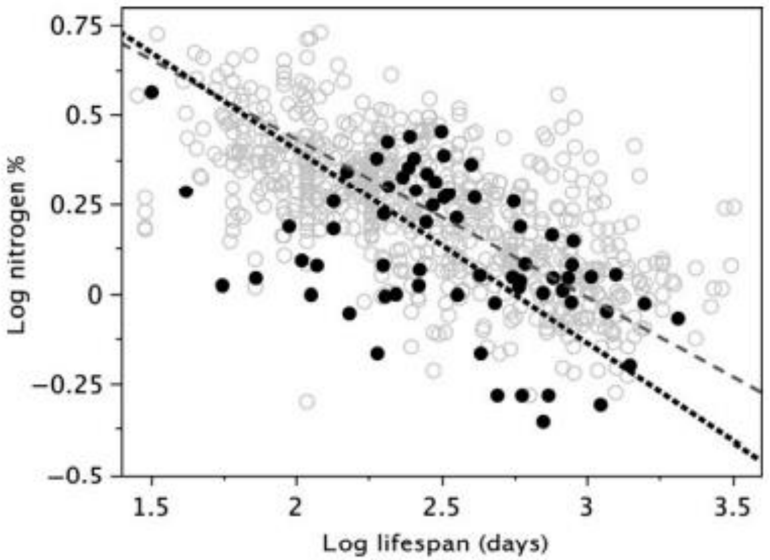
Paquette and Messier (2011)

Few studies have integrated **functional diversity** to examine forest carbon dynamics

- Need to account for:
  - Trait variability within species to make connections between traits and demographic processes (Laughlin and Messier 2015)

Few studies have integrated **functional diversity** to examine forest carbon dynamics

- 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)



Few studies have integrated **functional diversity** to examine forest carbon dynamics

- 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.

RESEARCH AIM

Apply both Massachusetts continuous forest inventory (CFI) data and local, individual functional trait observations to predict AGB in response to functional diversity.

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

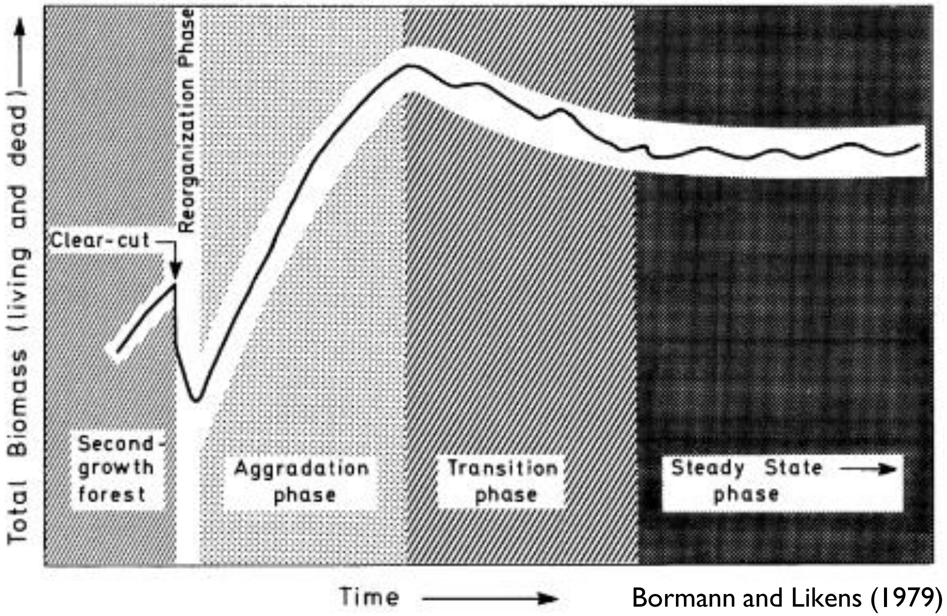
- Model study systems for forest carbon storage
  - High carbon stores, high structural complexity, lower species diversity (Franklin et al. 2002, Gravel et al 2010)

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)
  - Assumed to have lower carbon sequestration rates

CARBON DYNAMICS IN LATE-SUCCESSIONAL FORESTS

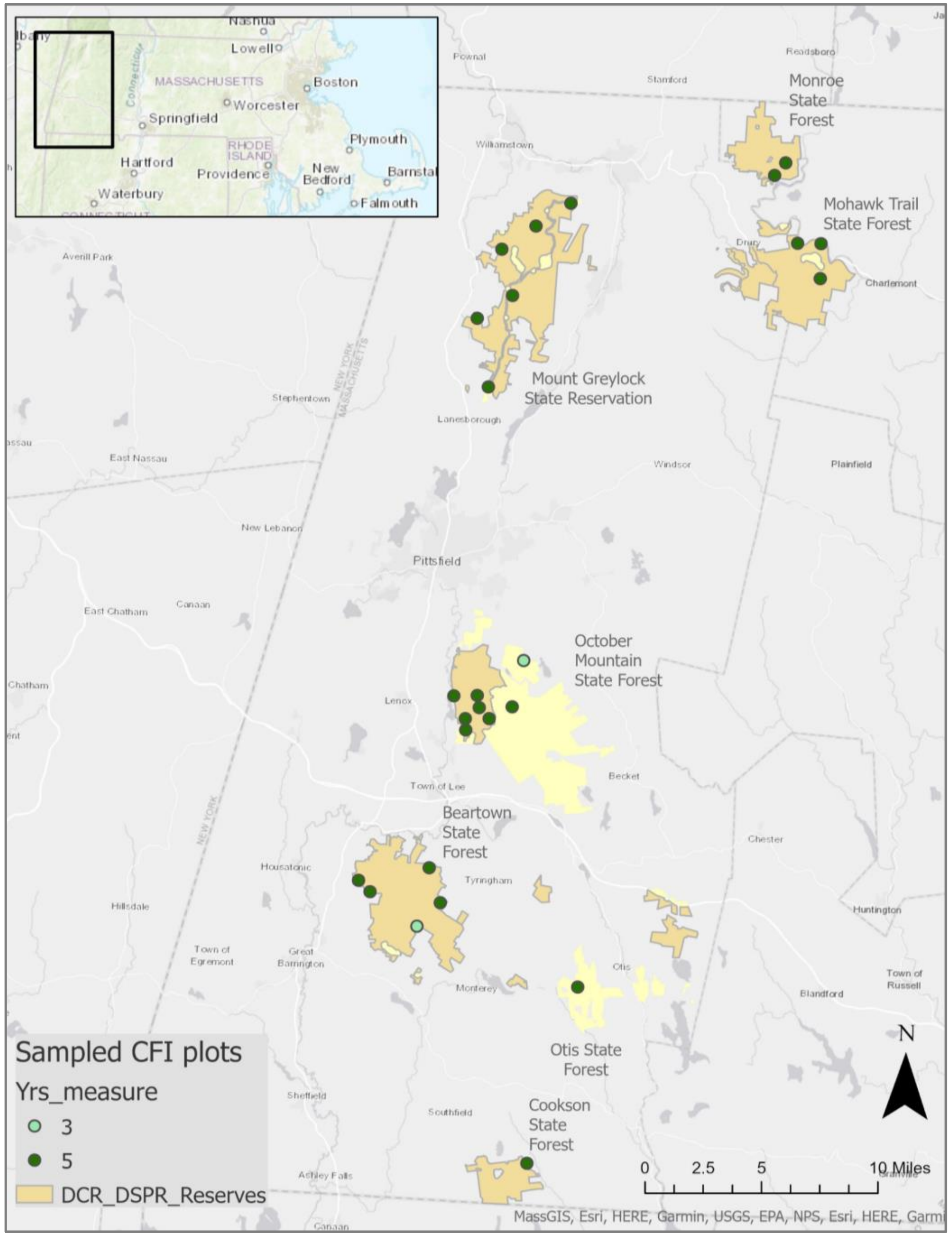
- Model study systems for forest carbon storage
  - High carbon stores, high structural complexity, lower species diversity (Franklin et al. 2002, Gravel et al 2010)
  - Assumed to have lower carbon sequestration rates



Bormann and Likens (1979)

DATA COLLECTION

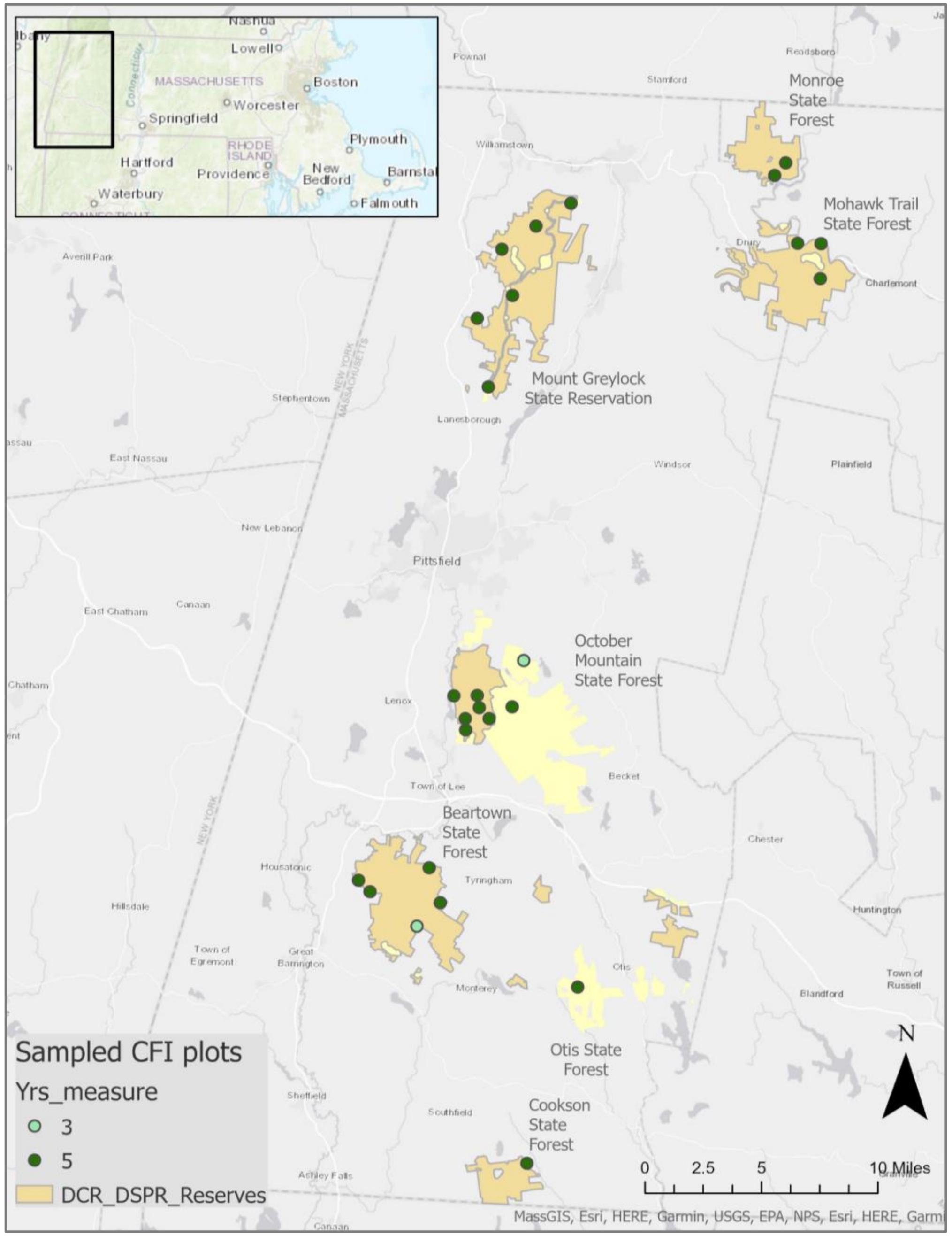
- We utilized Massachusetts DCR CFI data from 7 state forest reserves with plots identified as late-successional/old-growth (Lorimer and Halpin 2014)



Map of sampling plots

DATA COLLECTION

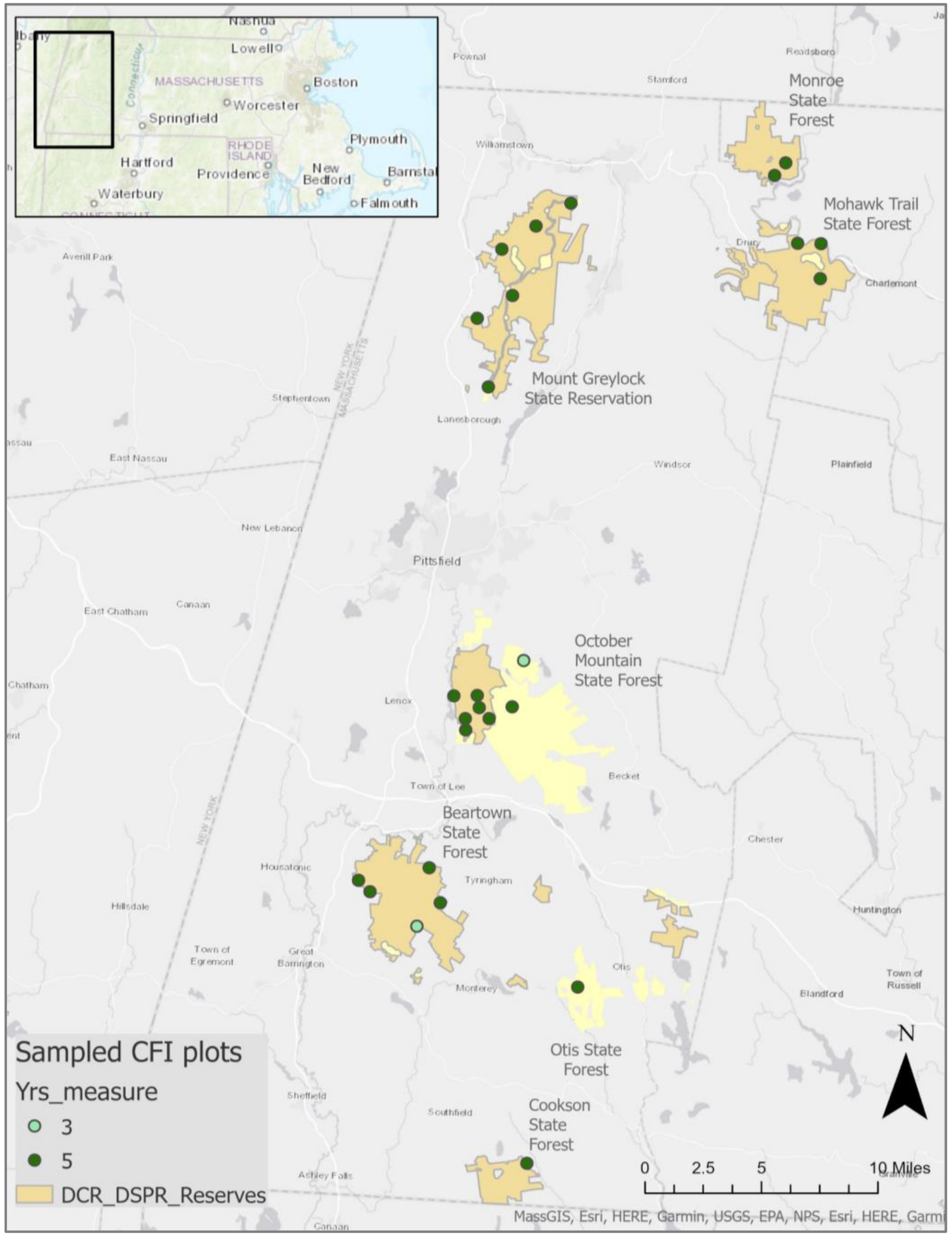
- We utilized Massachusetts DCR CFI data from 7 state forest reserves with plots identified as late-successional/old-growth (Lorimer and Halpin 2014)
  - Sampled functional traits at 26 CFI plots within these forests (Specific leaf area, leaf nutrient content, wood density)



Map of sampling plots

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)
  - 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)



Map of sampling plots

MODEL BACKGROUND

Obstacle: Integrate individual functional trait observations with stand-level structure and AGB

MODEL BACKGROUND

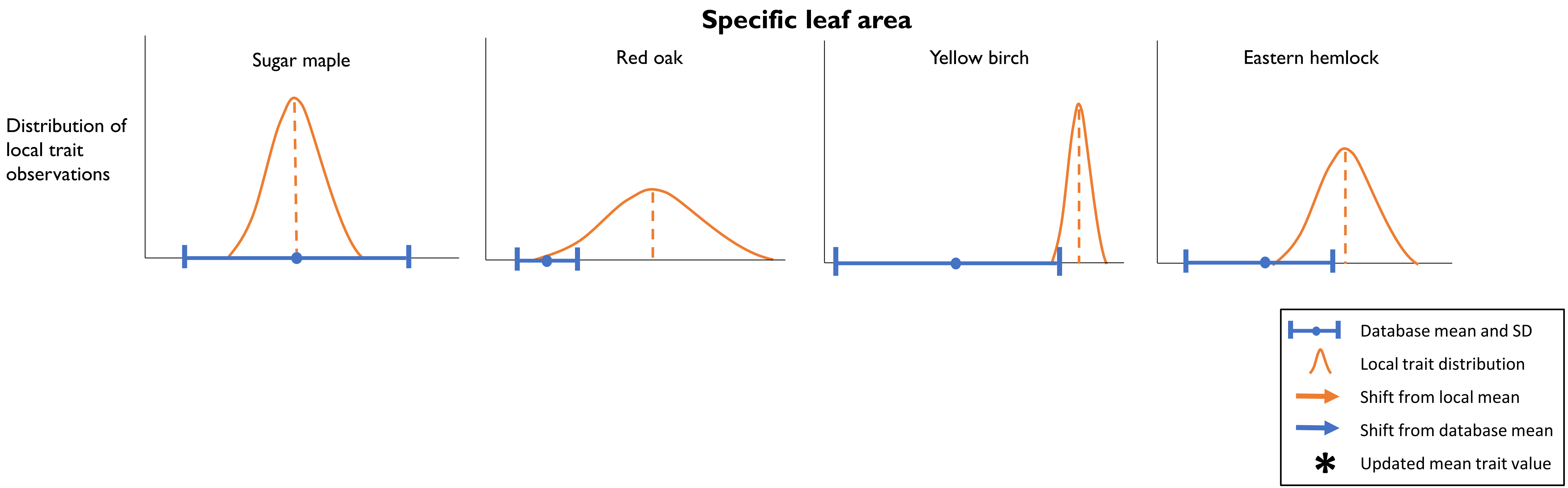
Obstacle: Integrate individual functional trait observations with stand-level structure and AGB

- Our model updates database species mean trait values using information from local, individual trait observations

MODEL BACKGROUND

Obstacle: Integrate individual functional trait observations with stand-level structure and AGB

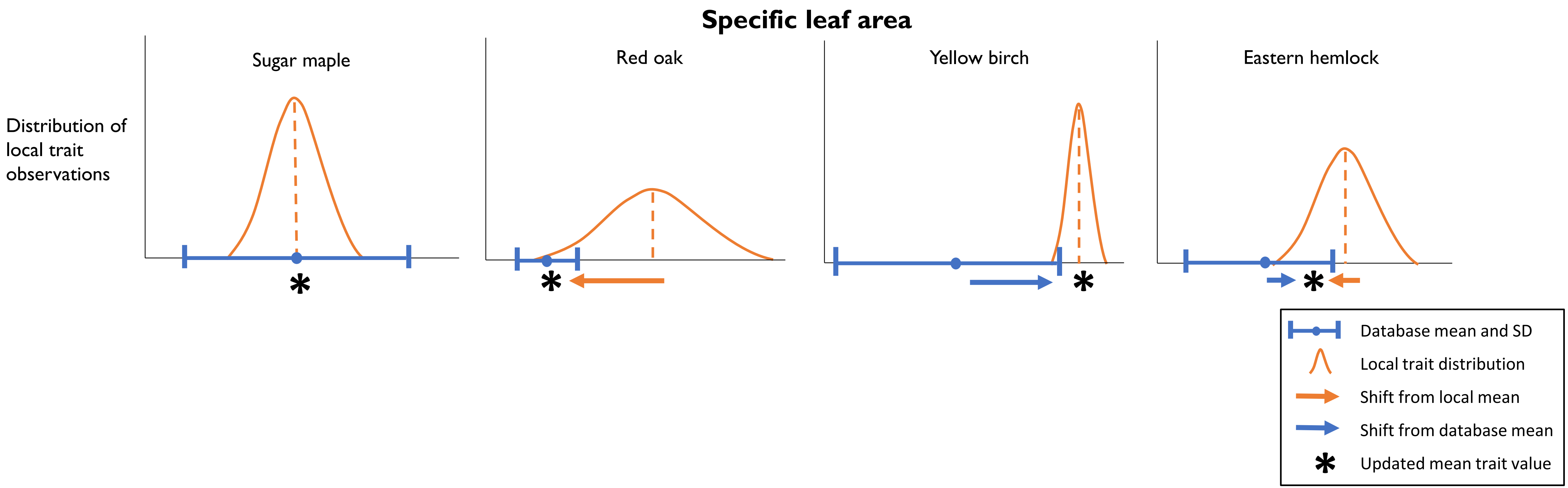
- Our model updates database species mean trait values using information from local, individual trait observations



MODEL BACKGROUND

Obstacle: Integrate individual functional trait observations with stand-level structure and AGB

- Our model updates database species mean trait values using information from local, individual trait observations



MODEL BACKGROUND

Obstacle: Integrate individual functional trait observations with stand-level structure and AGB

- Our model updates database species mean trait values using information from local, individual trait observations
  - Explicitly modeled dependence among traits (inherent trait syndromes)

MODEL BACKGROUND

Obstacle: Integrate individual functional trait observations with stand-level structure and AGB

- Our model updates database species mean trait values using information from local, individual trait observations
  - Explicitly modeled dependence among traits (inherent trait syndromes)
- Use updated mean trait values to calculate functional diversity at each CFI plot

MODEL BACKGROUND

Obstacle: Integrate individual functional trait observations with stand-level structure and AGB

- Our model updates database species mean trait values using information from local, individual trait observations
  - Explicitly modeled dependence among traits (inherent trait syndromes)
- Use updated mean trait values to calculate functional diversity at each CFI plot

Live aboveground biomass ~ Functional diversity + Structural complexity + Density (BA/ac) + Proportion softwood + error

MODEL BACKGROUND

Obstacle: Integrate individual functional trait observations with stand-level structure and AGB

- Our model updates database species mean trait values using information from local, individual trait observations
  - Explicitly modeled dependence among traits (inherent trait syndromes)
- Use updated mean trait values to calculate functional diversity at each CFI plot

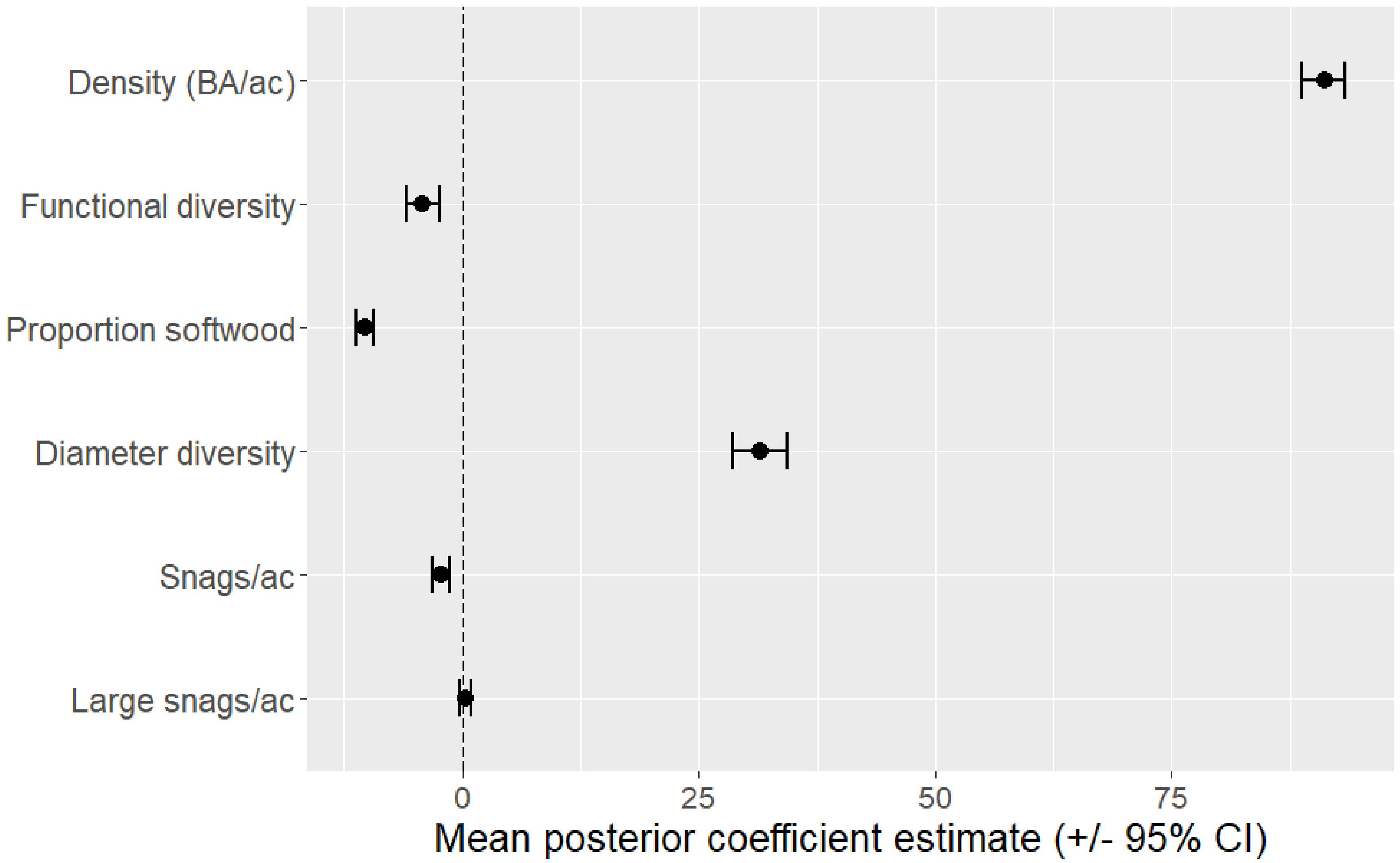
Live aboveground biomass ~ Functional diversity + Structural complexity + Density (BA/ac) + Proportion softwood + error

- Compared 3 models:
  - Functional diversity with local trait update
  - Functional diversity with database species means only
  - Species diversity

RESULTS

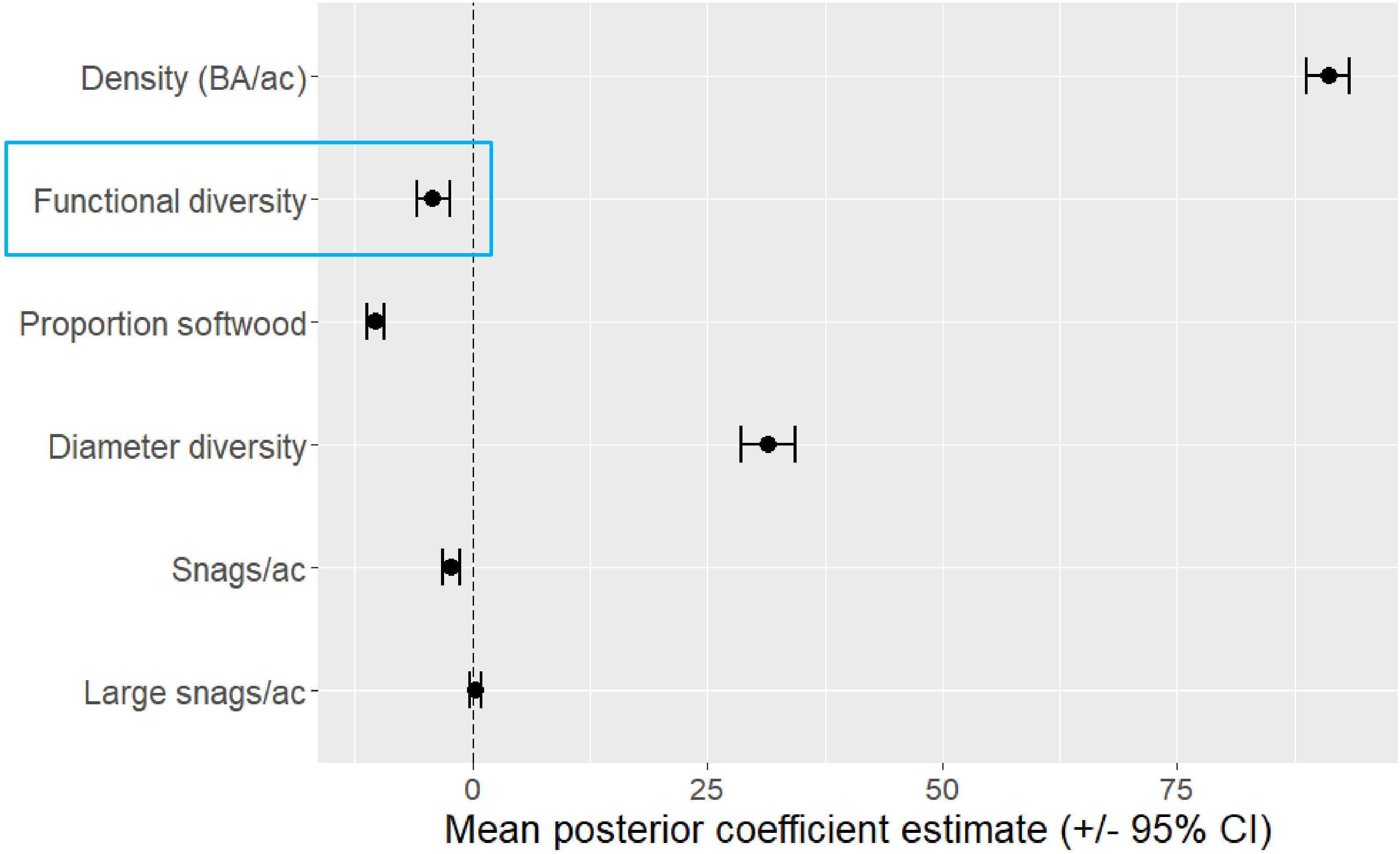
- Integrating local, individual functional trait information yielded the best predictions of live AGB

There were strong effects of density, proportion of softwood species, and diameter diversity on live AGB



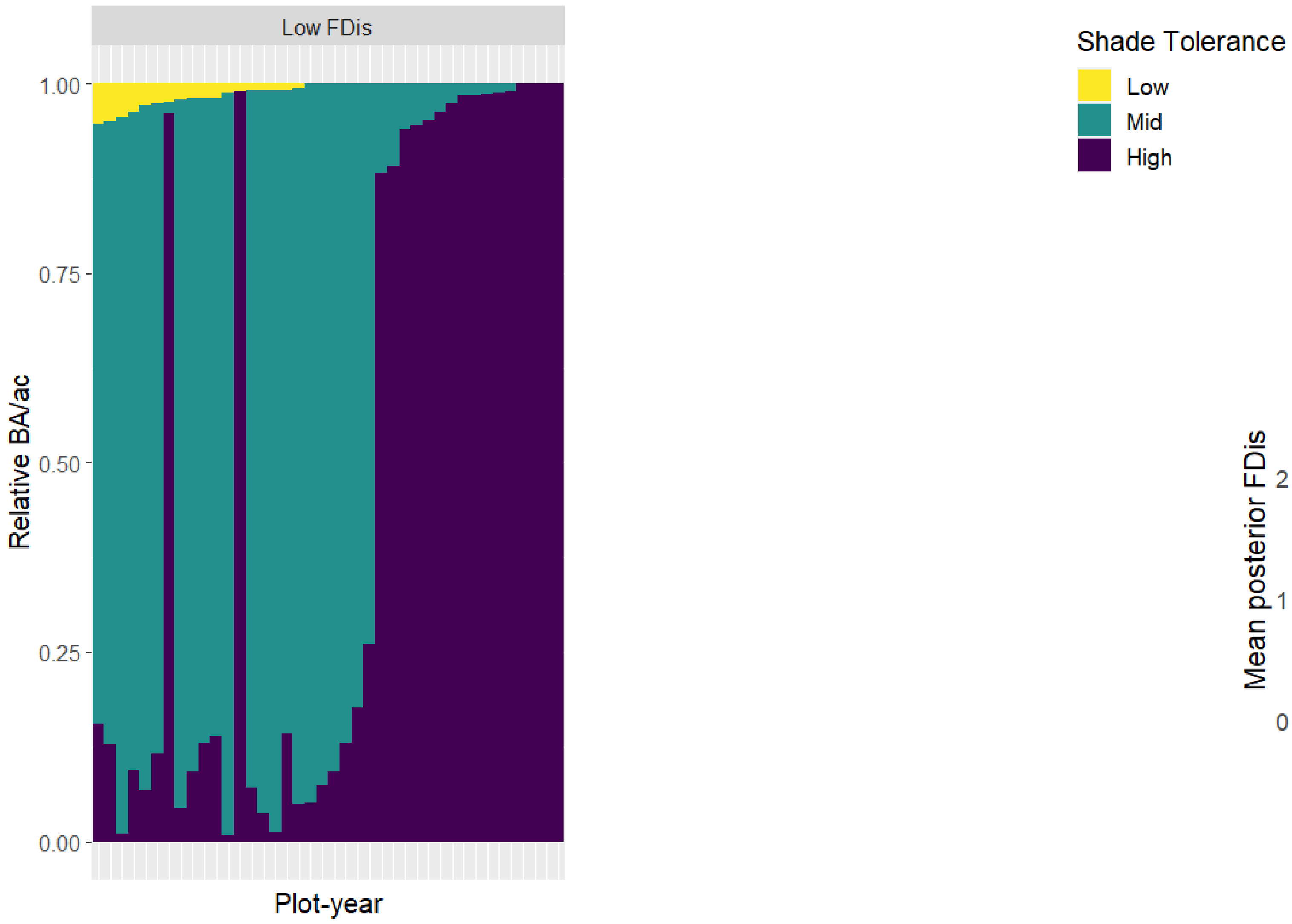
Myers *et al.* (in prep)

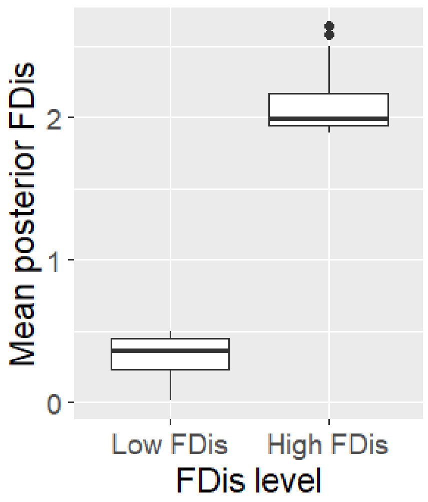
Functional diversity had a negative effect on live AGB



Myers *et al.* (in prep)

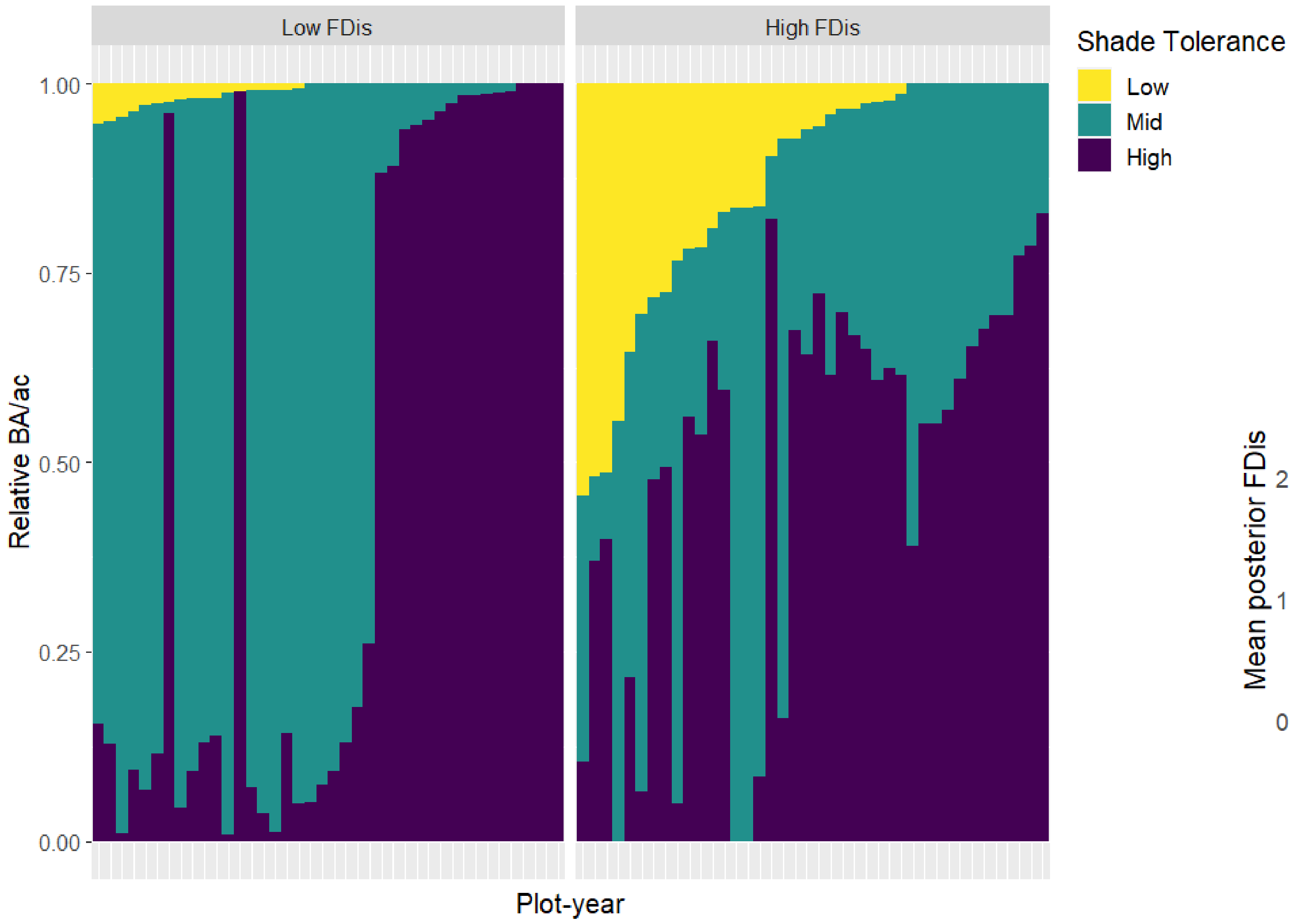
Plots with low functional diversity were dominated by mid to high shade-tolerant hardwood species

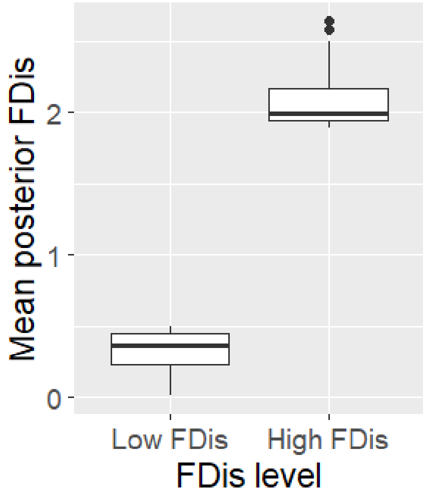




Myers *et al.* (in prep)

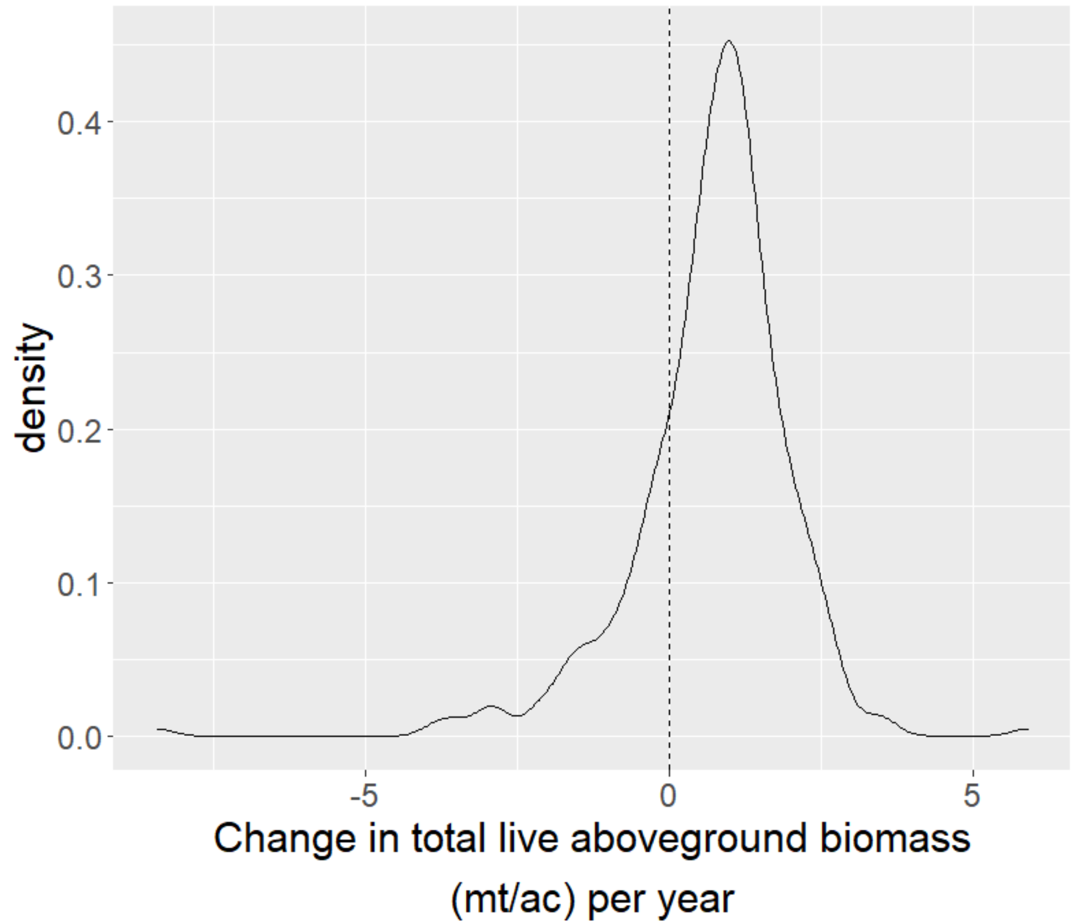
Plots with high functional diversity had more shade-intolerant and mid-tolerant species and softwoods





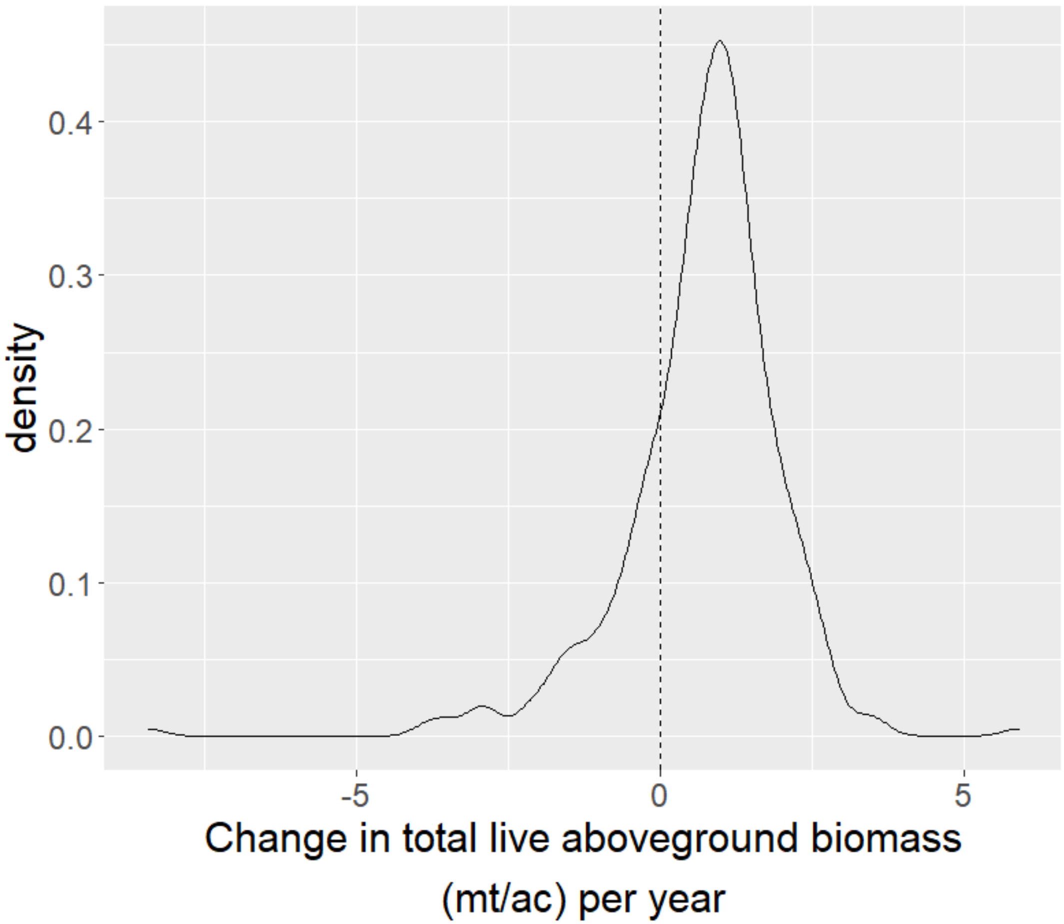
Myers *et al.* (in prep)

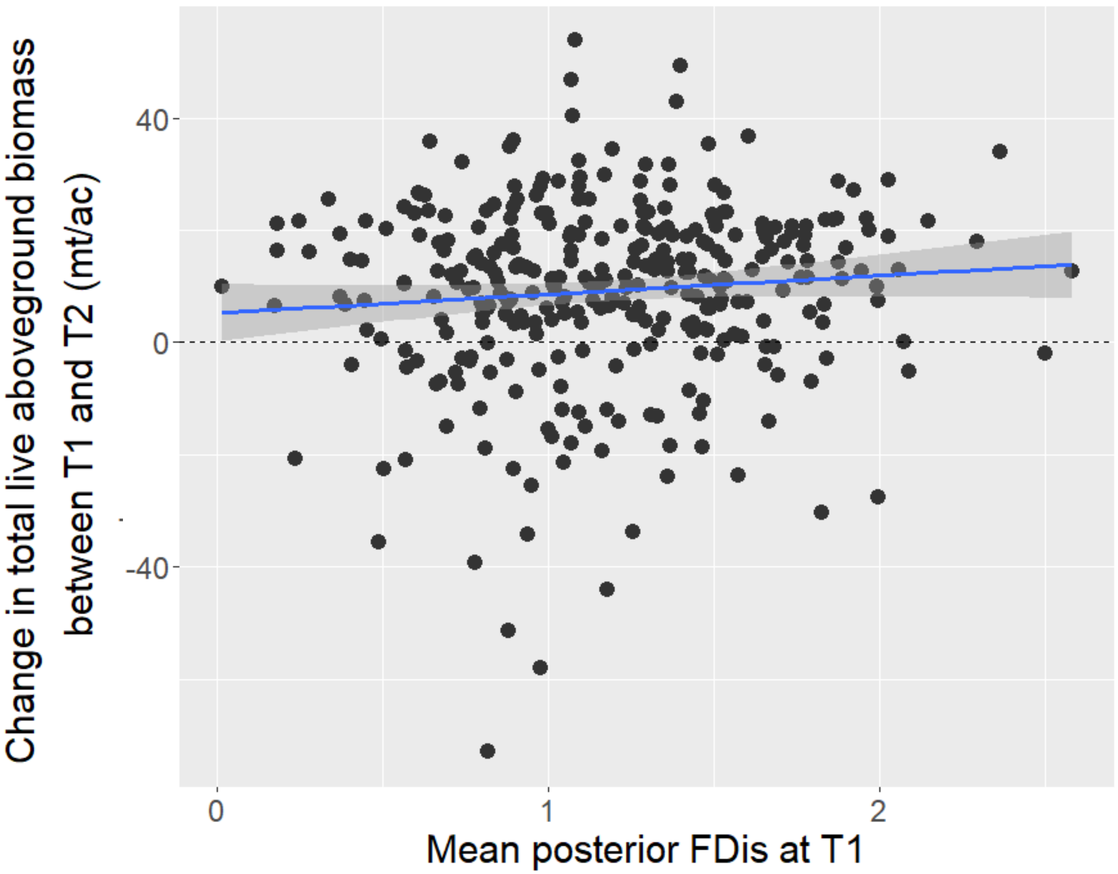
Rates of aboveground biomass accrual were slightly positive and had a positive relationship with functional diversity



Myers *et al.* (in prep)

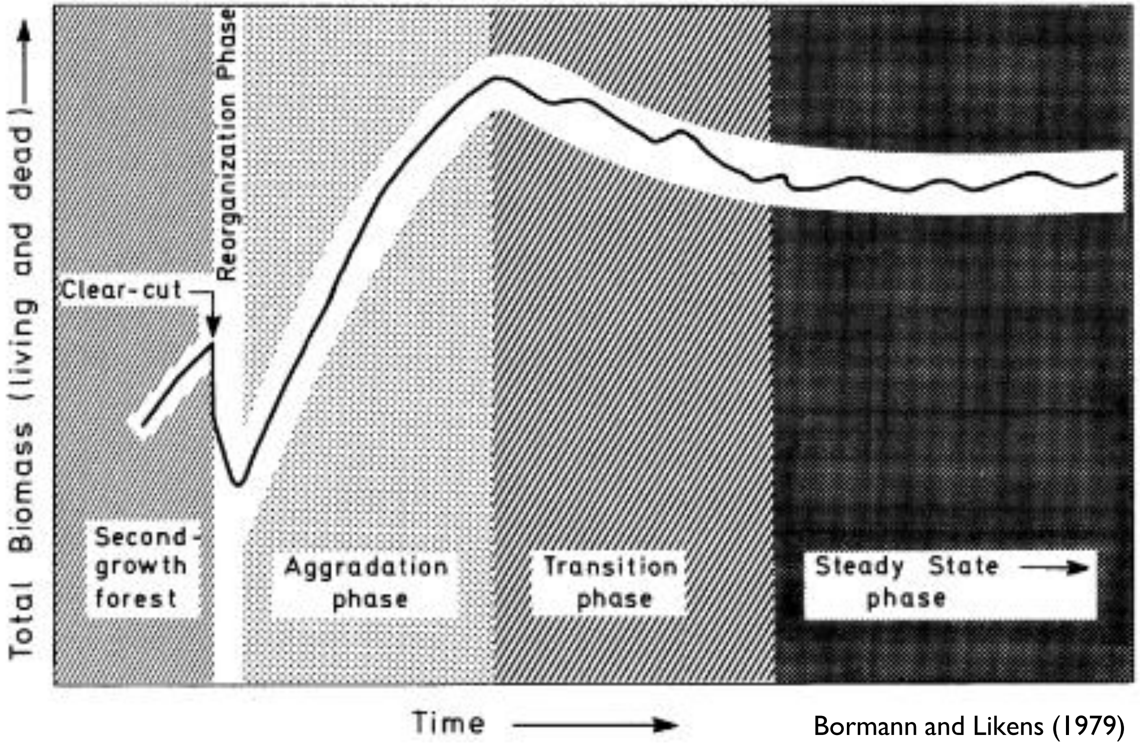
Rates of aboveground biomass accrual were slightly positive and had a positive relationship with functional diversity



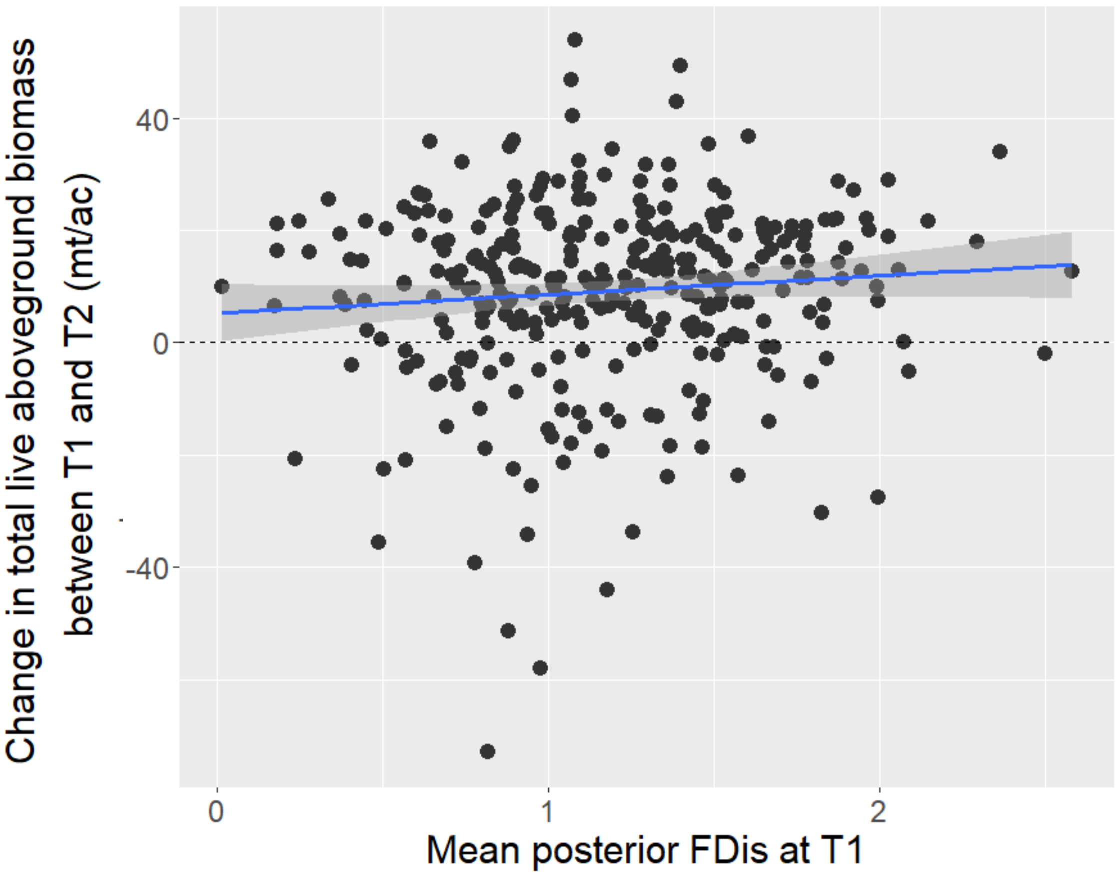


Myers *et al.* (in prep)

Rates of aboveground biomass accrual were slightly positive and had a positive relationship with functional diversity

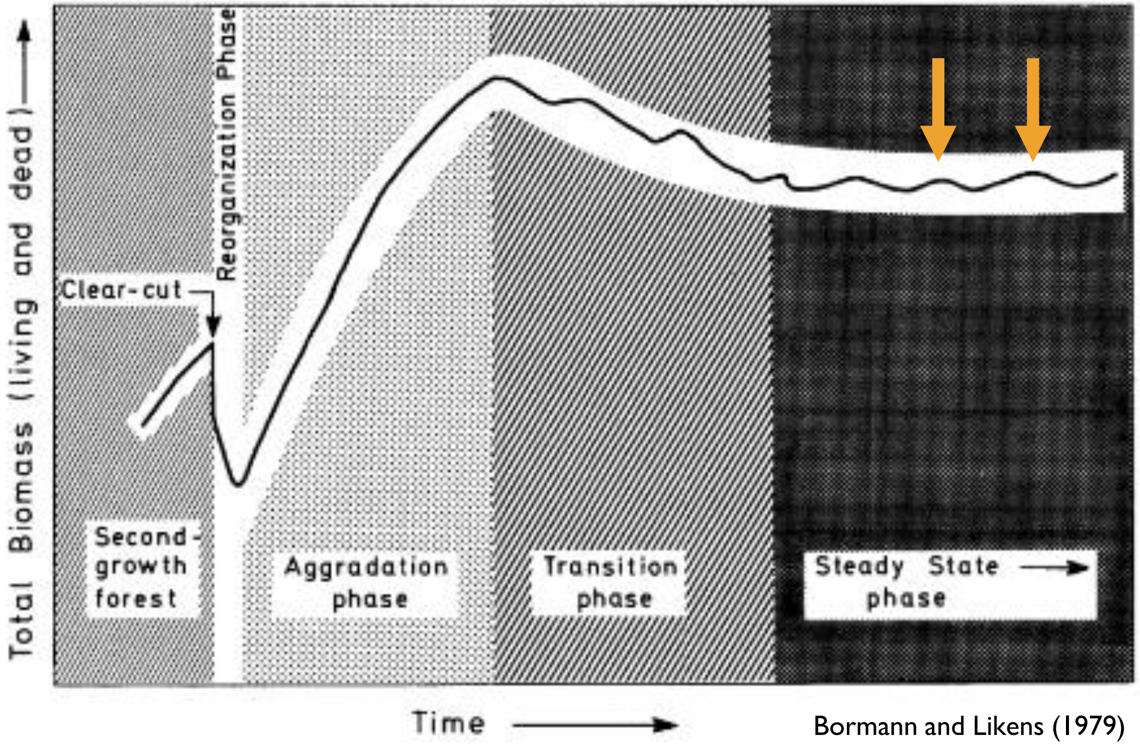


Bormann and Likens (1979)

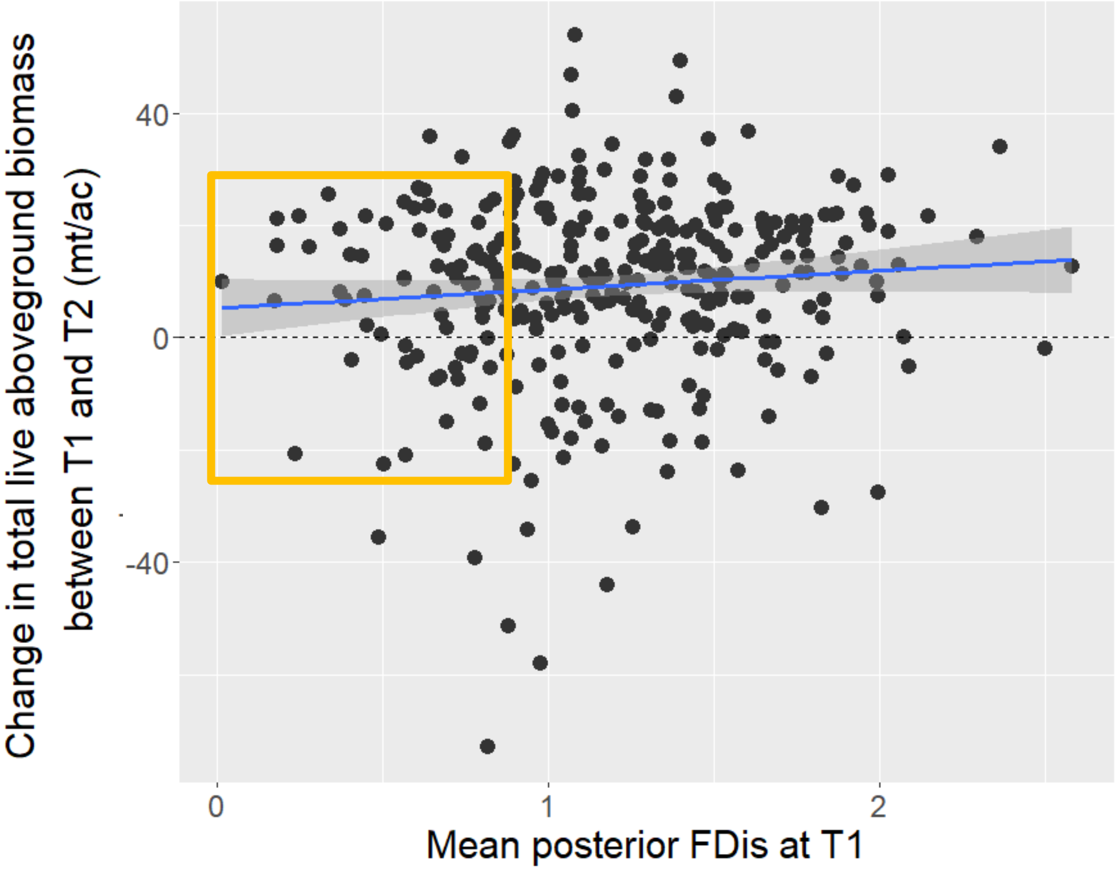


Myers *et al.* (in prep)

Rates of aboveground biomass accrual were slightly positive and had a positive relationship with functional diversity

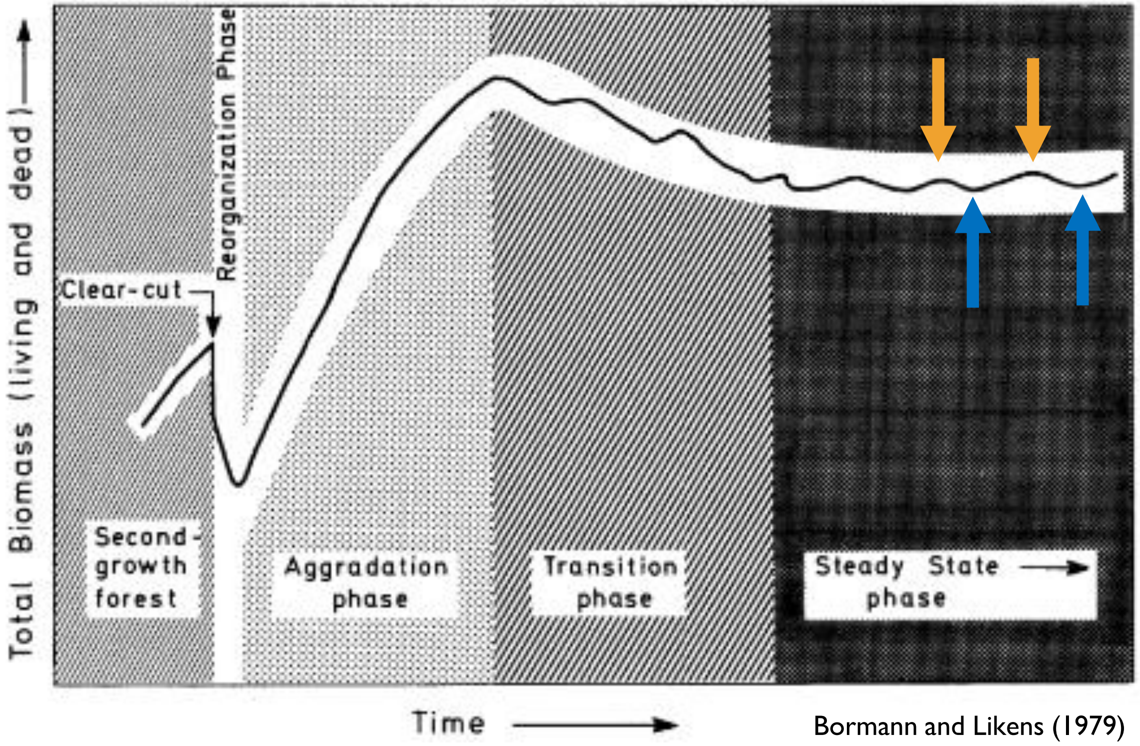


Bormann and Likens (1979)

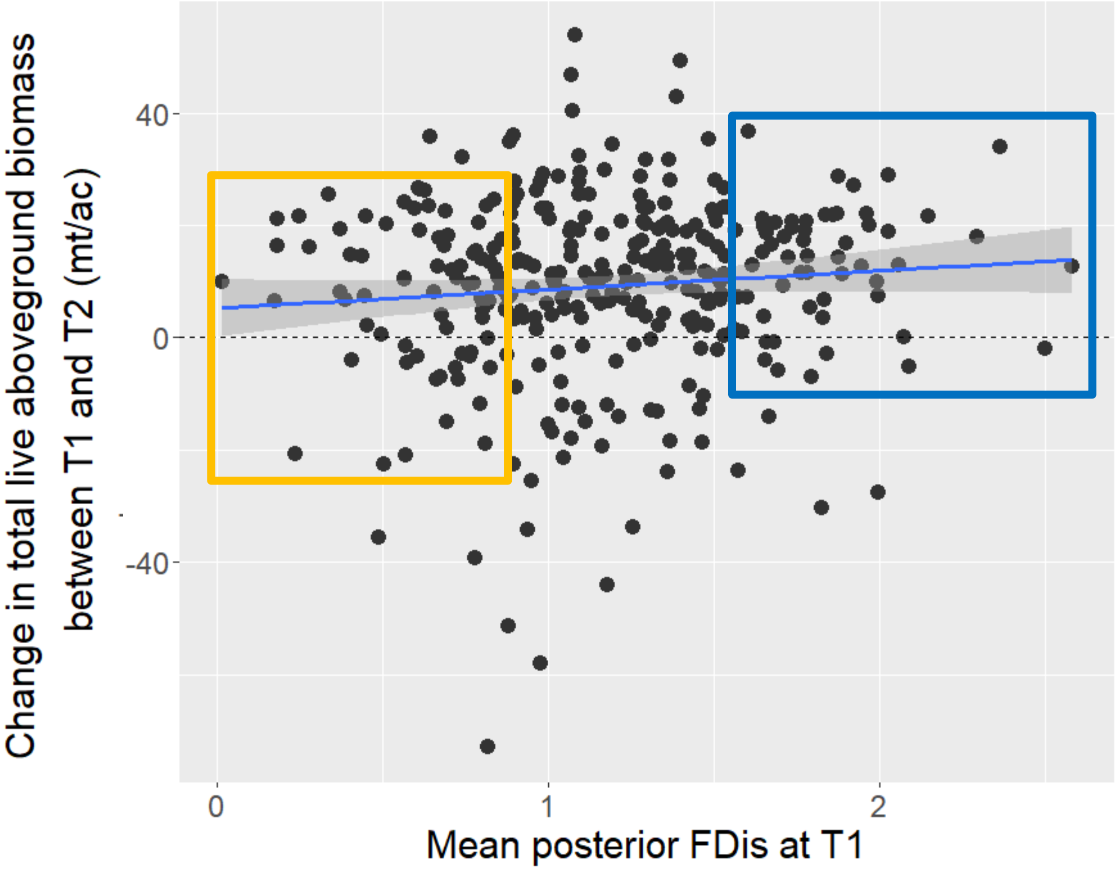


Myers *et al.* (in prep)

Rates of aboveground biomass accrual were slightly positive and had a positive relationship with functional diversity



Bormann and Likens (1979)



Myers *et al.* (in prep)

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 ?

- Adaptive forest carbon management should focus on emulating a "shifting gap mosaic" at a landscape scale (Bormann and Likens 1979):

SO, WHAT DOES THIS MEAN FOR FOREST CARBON MANAGEMENT ?

- Adaptive forest carbon management should focus on emulating a "shifting gap mosaic" at a landscape scale (Bormann and Likens 1979):
  - Preserving late-successional stands of relatively stable, high aboveground carbon stores

SO, WHAT DOES THIS MEAN FOR FOREST CARBON MANAGEMENT ?

- Adaptive forest carbon management should focus on emulating a "shifting gap mosaic" at a landscape scale (Bormann and Likens 1979):
  - 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

ACKNOWLEDGEMENTS

- Malcolm Itter (UMass Amherst)
- MS Thesis Committee
  - Paul Catanzaro (UMass Amherst)
  - Miranda Curzon (Iowa State)
- Will Thayer (UMass Amherst)
- Bill VanDoren (Massachusetts DCR)

- This work was supported by the National Institute of Food and Agriculture, U.S. Department of Agriculture, the Center for Agriculture, Food and the Environment and the Department of Environmental Conservation at University of Massachusetts Amherst, under project number MAS00041
- This work was further supported by NSF grant number 1945910

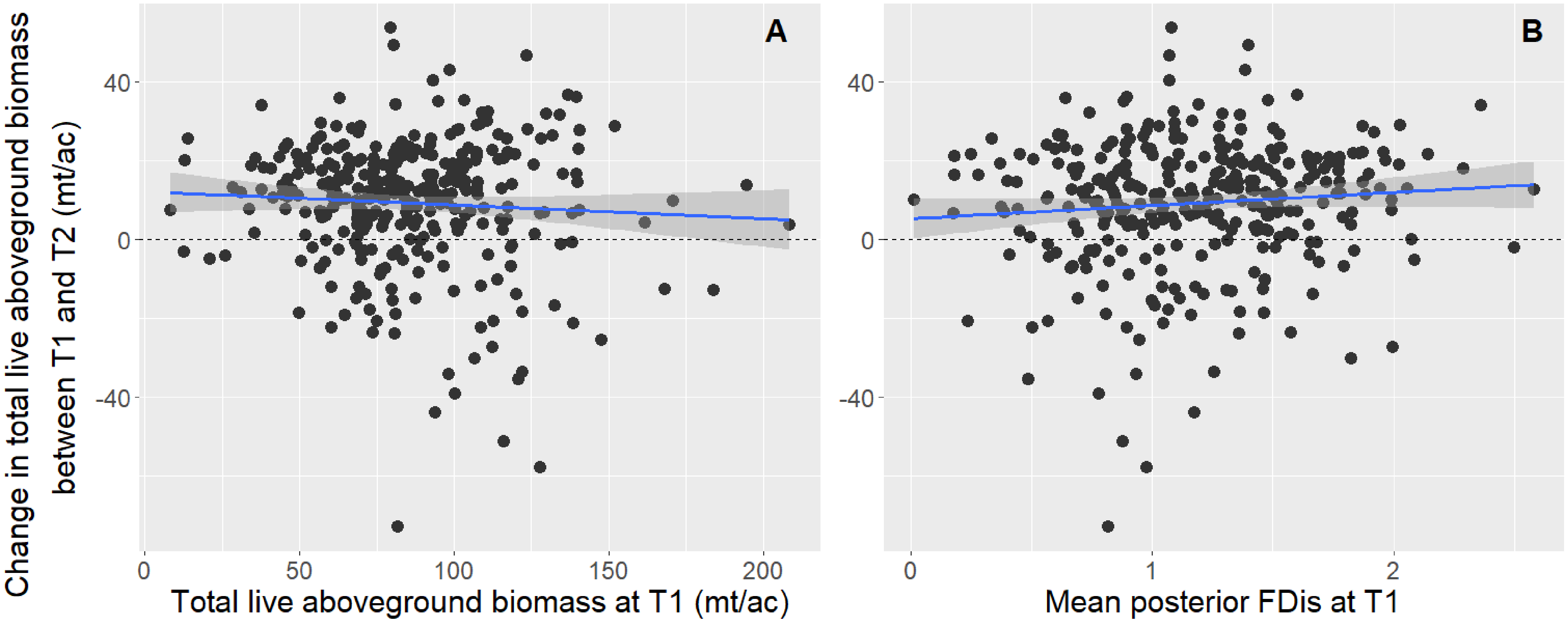
UMassAmherst

Center for Agriculture, Food, and the Environment

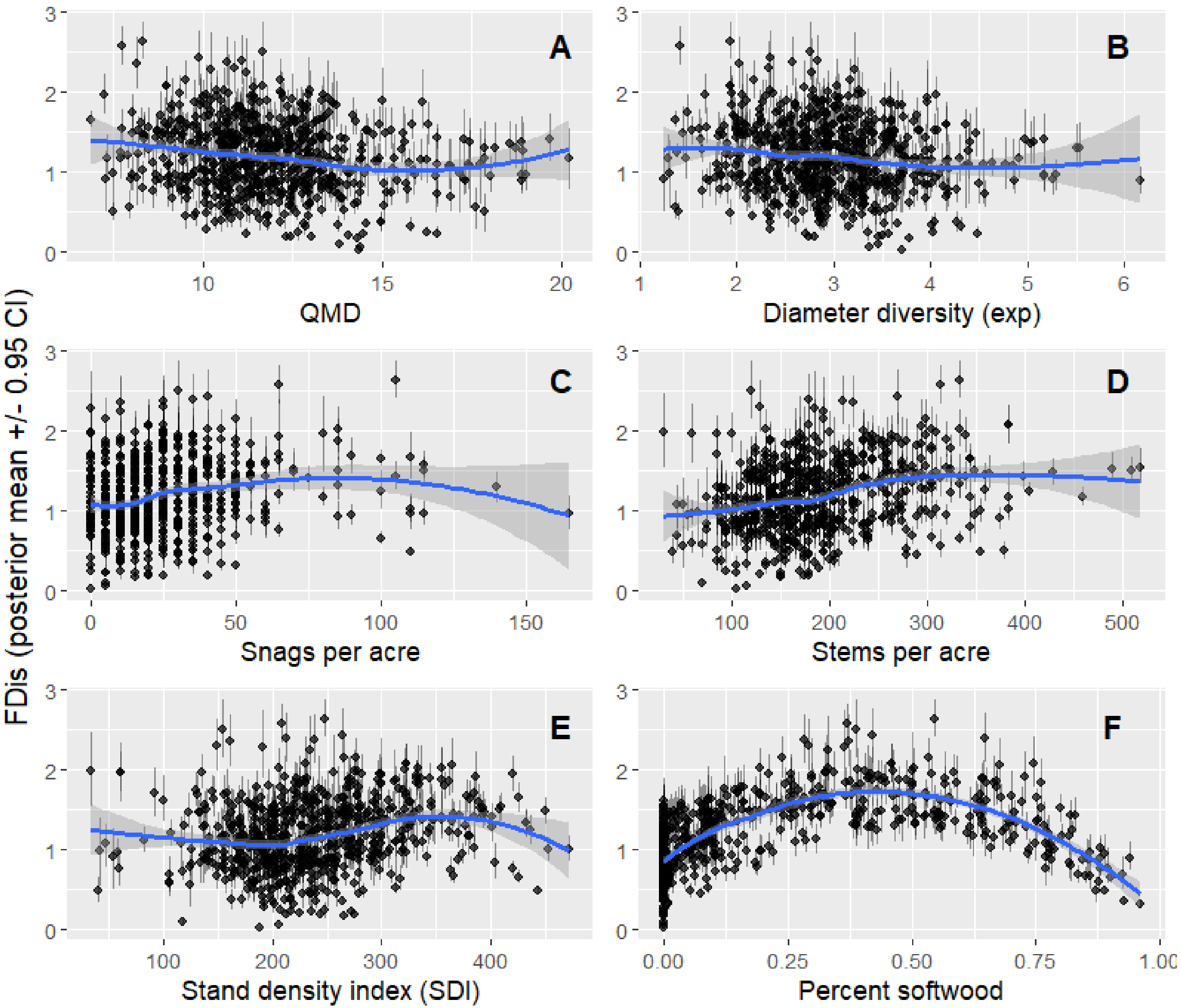
USDA NIFA

United States Department of Agriculture
National Institute of Food and Agriculture

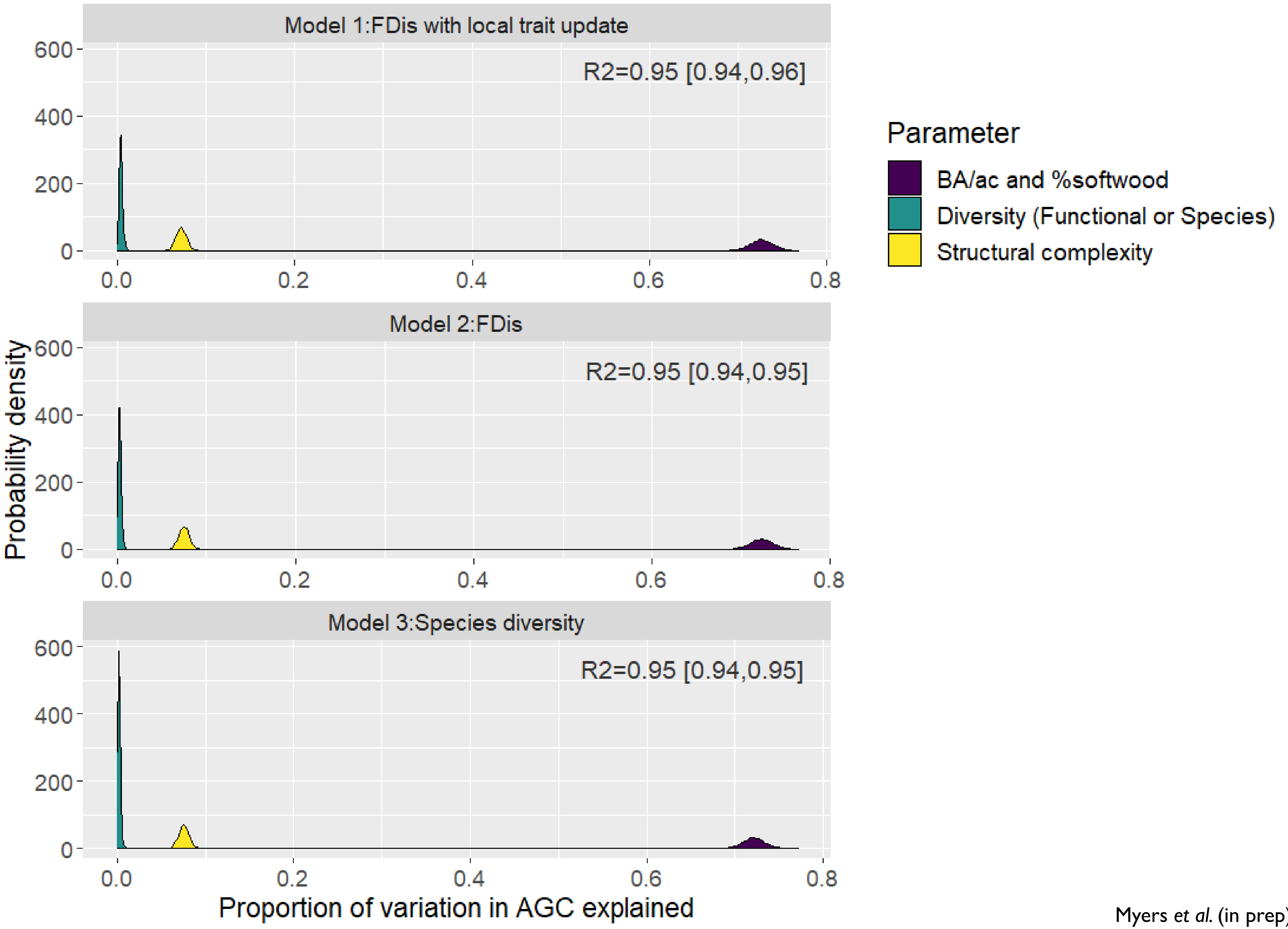

THANK YOU! QUESTIONS?



Myers *et al.* (in prep)



Myers *et al.* (in prep)



Myers *et al.* (in prep)