

Building Community Models of Disturbance and Vegetation Dynamics



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With contributions from T. Powell, E. Conlisk, C. Castanha, Y. Fang, R. Negrón-Juarez, C. Koven, R. Knox, R. Fisher, N. McDowell, J. Chambers and others



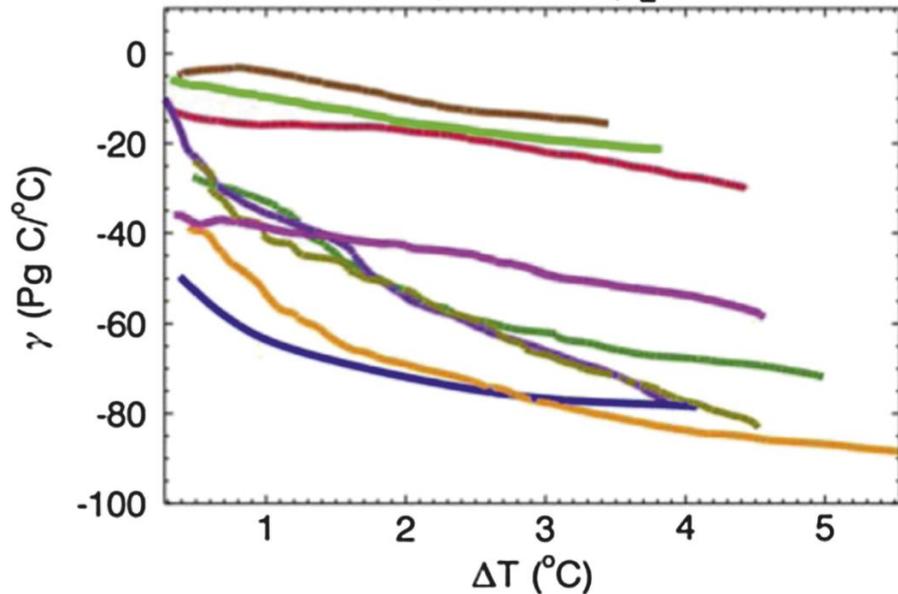
NGEE-TROPICS
NEXT-GENERATION ECOSYSTEM EXPERIMENTS

Berkeley
UNIVERSITY OF CALIFORNIA

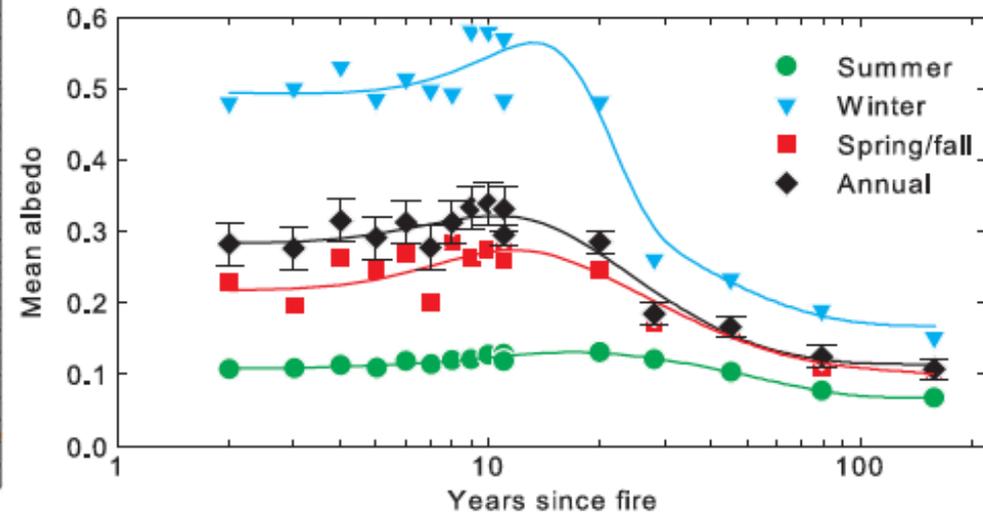


Vegetation change affects climate

Global land carbon feedback to climate

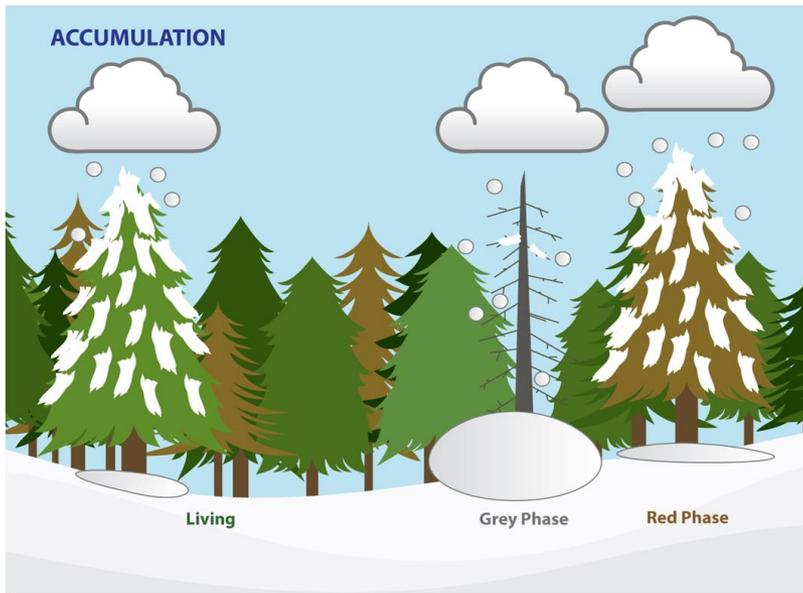


Boreal forest albedo following fire



- Carbon cycle and biogeophysical (energy balance) effects

Vegetation change affects climate and watersheds

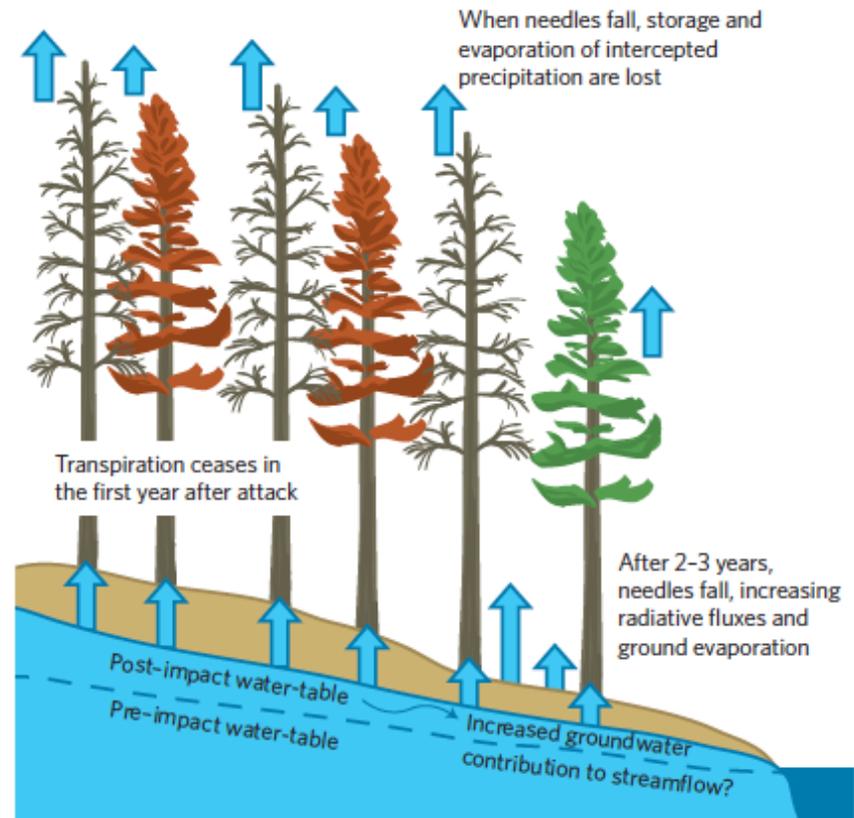


Bark beetle tree mortality can alter

- Snow accumulation
- Transmission of radiation

(Pugh & Small 2012; Bearup et al. 2014)

- Transpiration & evaporation
- Recharge/discharge



Disturbance and Vegetation Dynamics in Earth System Models Workshop

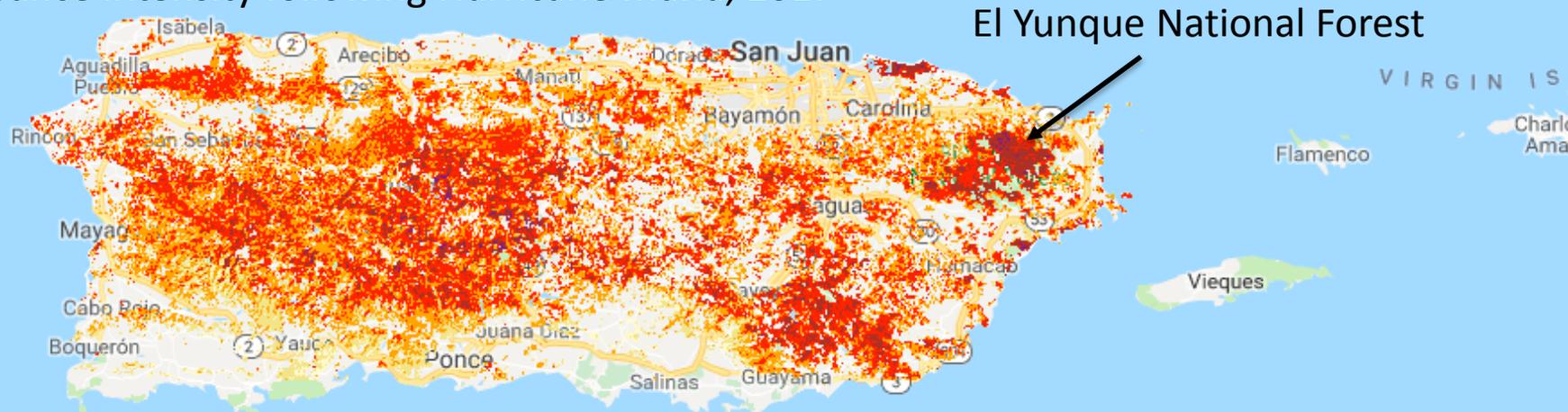
- March 15-16, 2018 Gaithersburg, MD
- Co-organized with Jim Clark, Duke U.
- Participants had expertise in
 - ❑ Earth system modeling, vegetation dynamics (demography), individual-based models, disturbance (fire, hurricane, insect outbreak, drought) impacts, ecophysiology, statistical methods, manipulative experiments, etc.
- Report in draft form
 - ❑ Expected end of May 2018

Terms

- **Vegetation dynamics** – birth, growth, death & competition/dispersal
- **Disturbance** – discrete events that disrupt the structure and function of an ecosystem
- Chronic **environmental change** can alter vegetation dynamics and disturbance regimes
- Crossing (unknown) thresholds into novel regimes → probable large-scale **biome transitions**
- Major challenge for understanding and prediction

Hurricanes

Disturbance intensity following Hurricane Maria, 2017



Disturbance Intensity

(Δ NPV)

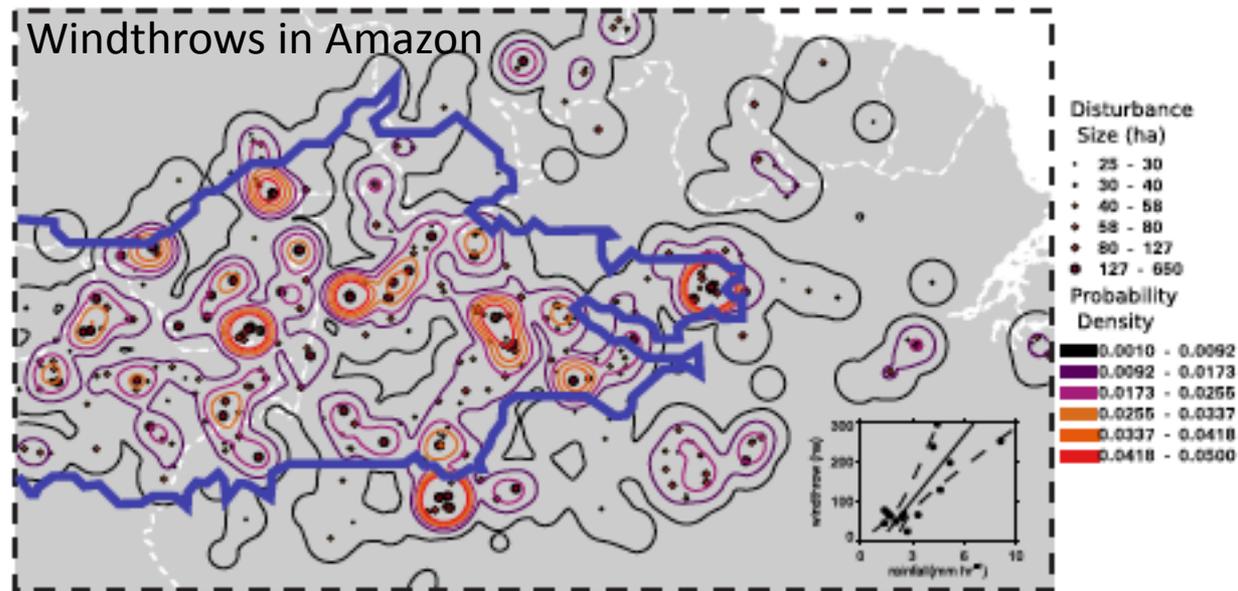
- < 0
- 0.0 - 0.2
- 0.2 - 0.4
- 0.4 - 0.6
- 0.6 - 0.8
- 0.8 - 1.0



(Fang et al. 2018)

Forest damage and resilience

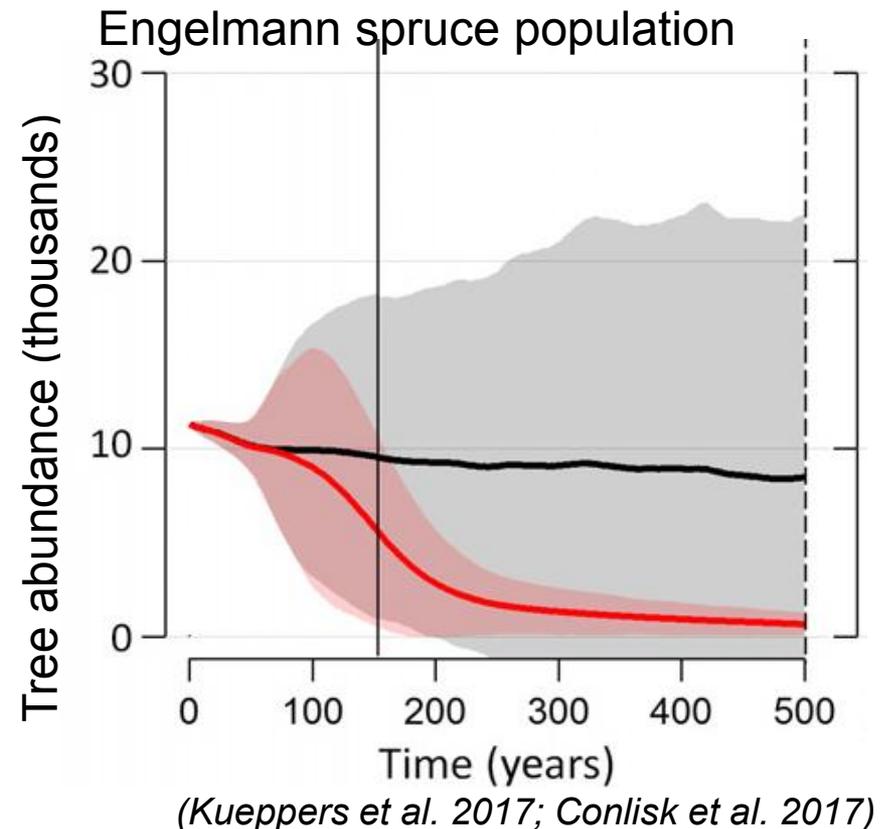
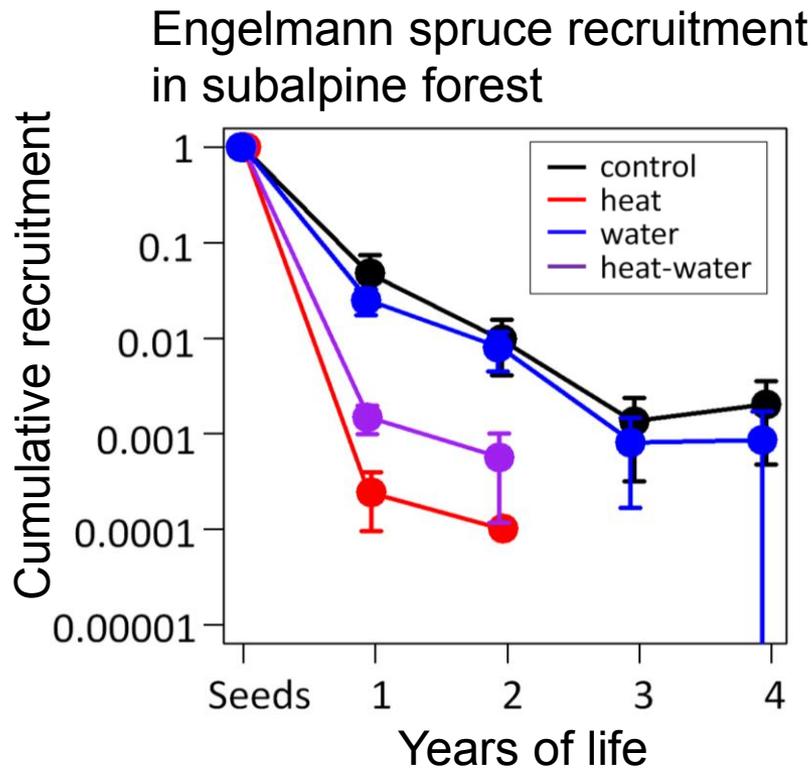
- Differential tree mortality and damage
 - Palms
 - Strategies for regrowth?
- Massive litterfall, rapid decomposition
 - Fate of C, nutrients?
- Damaging winds occur elsewhere (e.g., Amazon basin)



(Negron-Juarez et al. in press)

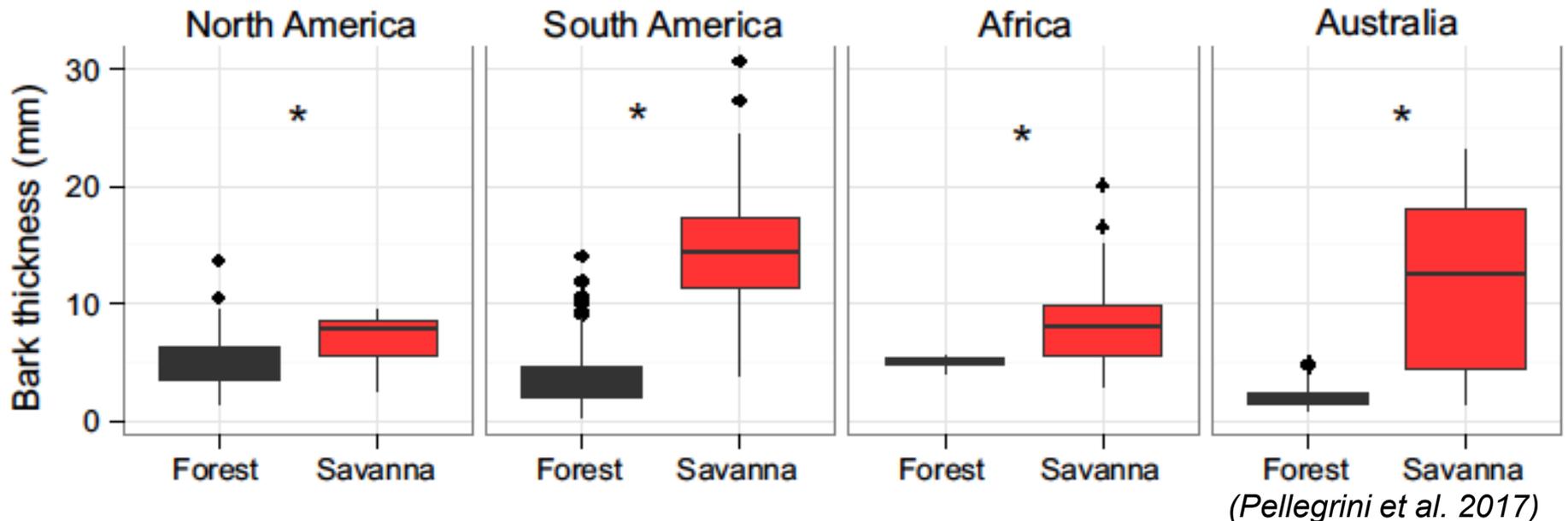
Rising temperature alters dynamics

- Recruitment declines with warmer temperatures in subalpine forest
- Increasing mortality in many Western US forests
 - Temperature? Drought? Insects? Tree density?

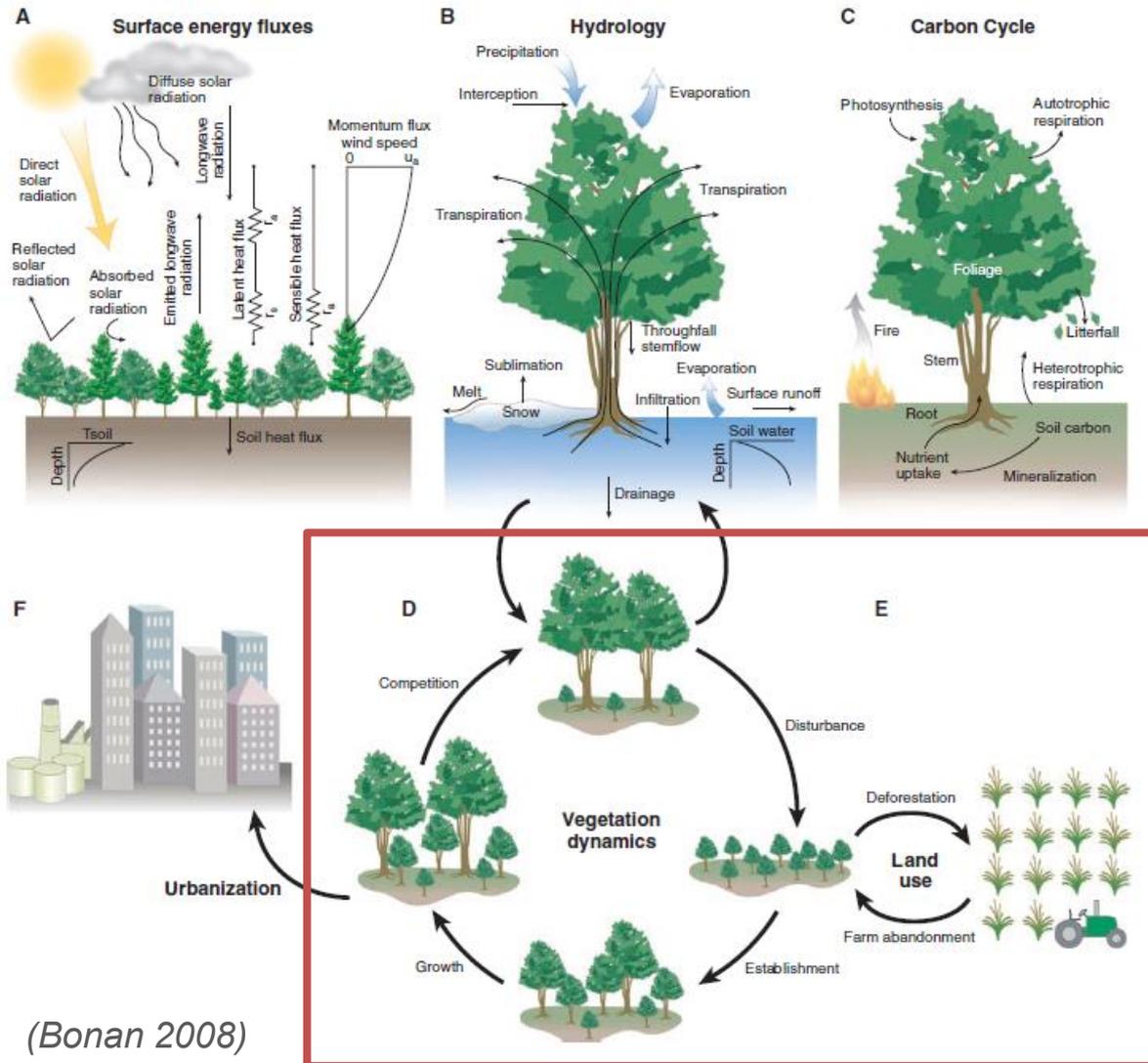


Traits determine vulnerability, resistance and resilience

- Combinations of plant traits yield ecological strategies that reflect adaptations to disturbance regimes
 - Frequent fire → thick bark (3:1, savanna:forest)



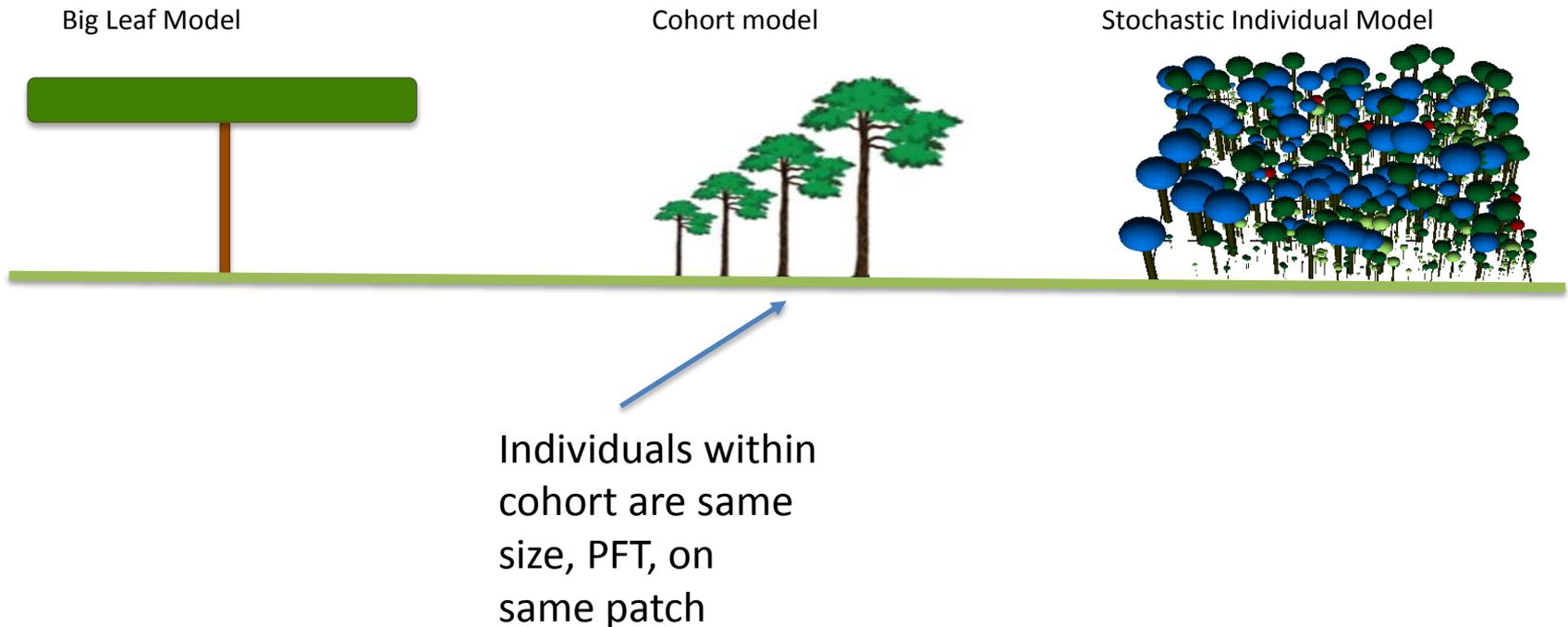
The complexity challenge: putting ecology back into ecosystems



(Bonan 2008)

'Cohort-based' models are intermediate solutions

e.g., Functionally Assembled Terrestrial Ecosystem Simulator (FATES)



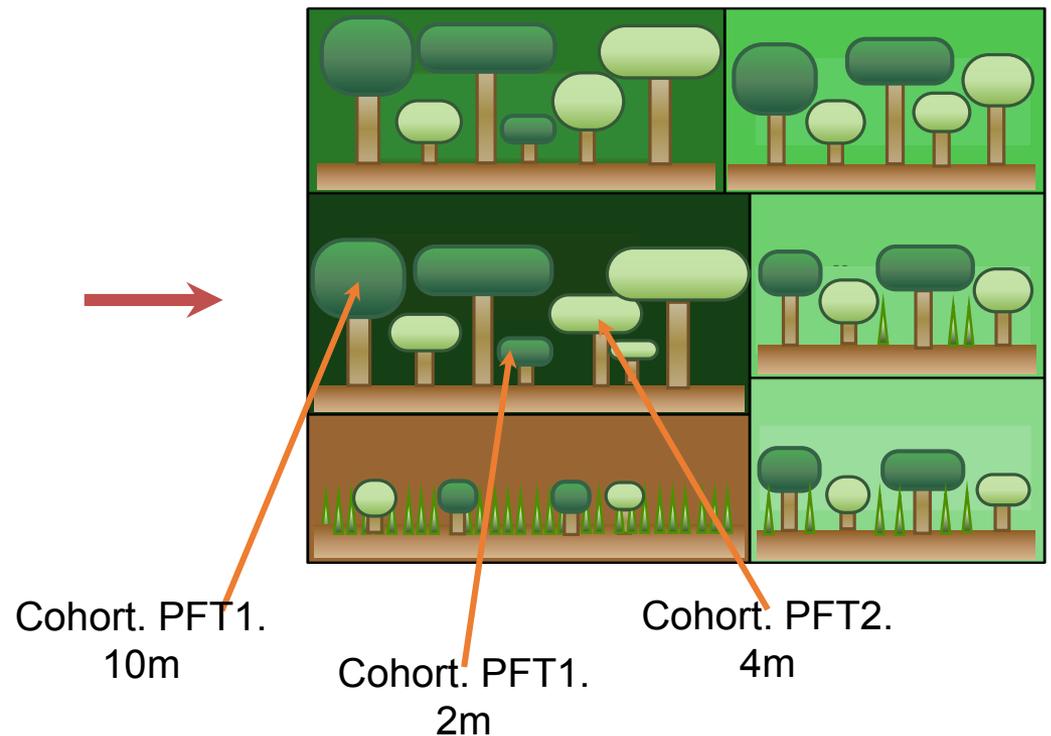
Cohorts coexist on each tile (patch)

Each **time-since-disturbance** tile contains **cohorts** of plants, defined by **PFT** and **size**.

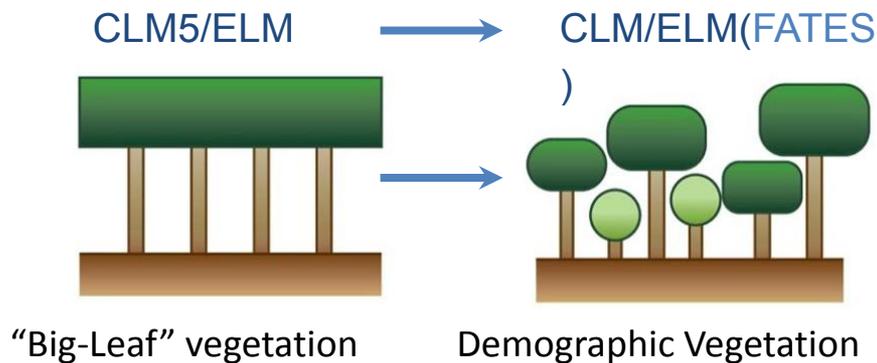
Time-Since-Disturbance tiling



Time-Since-Disturbance tiling



Benefits for modeling vegetation dynamics and disturbance



Heterogeneity in light availability

Competition (for light), exclusion & coexistence

Mechanistic Ecosystem Assembly

Recovery after Disturbance (fire, land use, mortality)

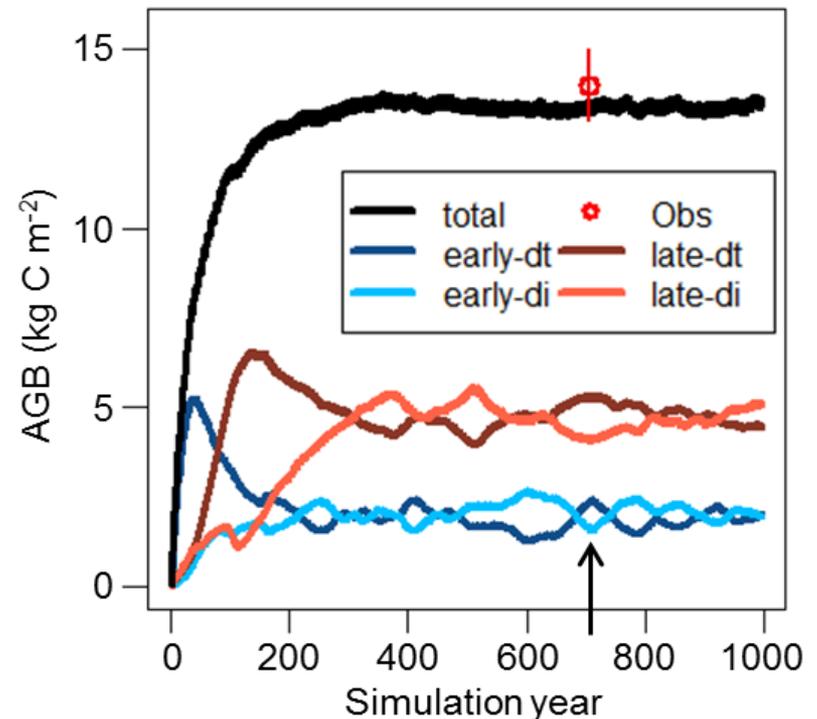
Arbitrary PFT definition

PFT distribution emerges from trait filtering

Are tropical forests resilient to drought?

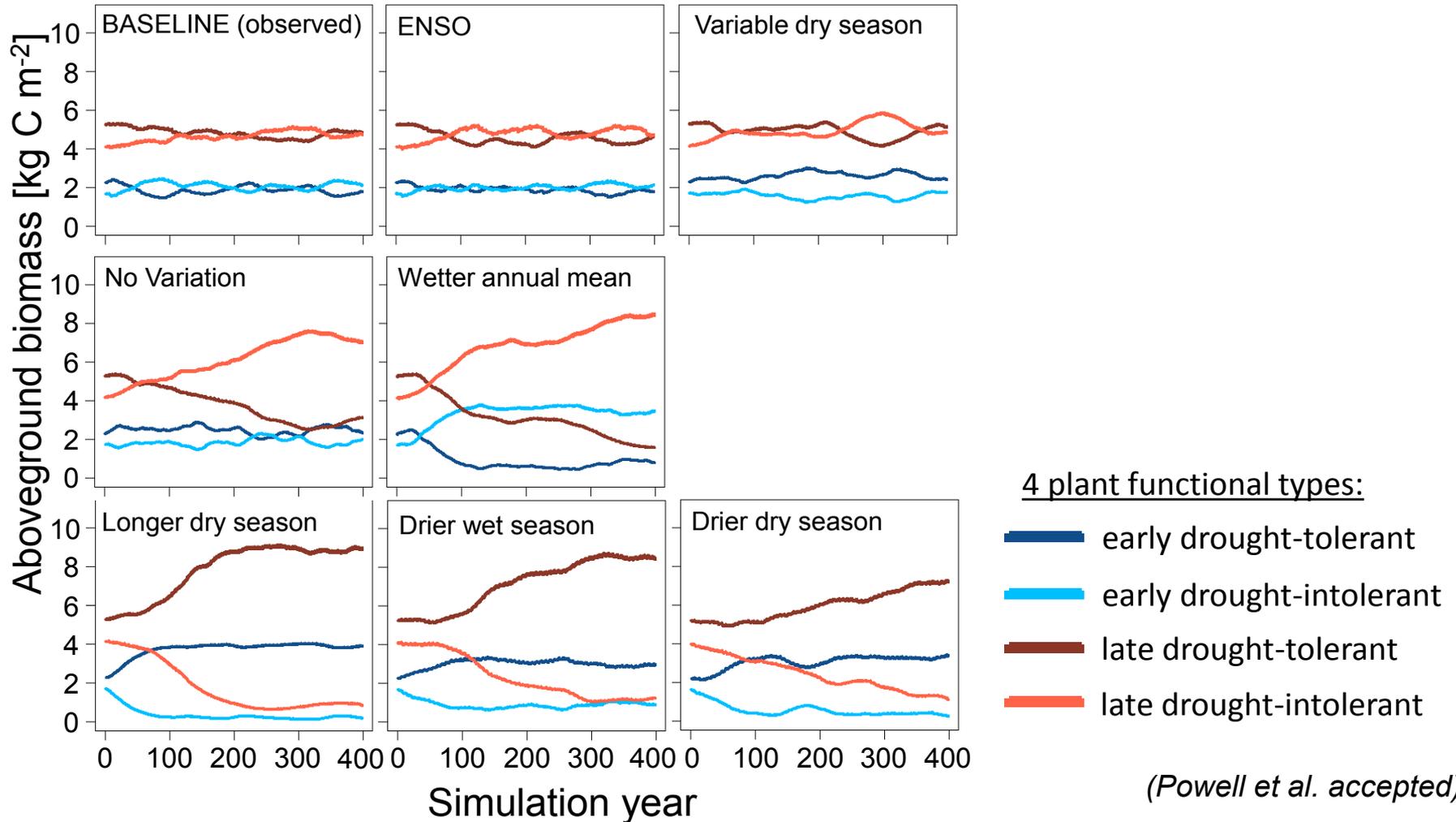
- ED2-hydro cohort model
- Two axes of competition
 - **Light:** early- vs late-successional (wood density and photosynthesis traits)
 - **Water:** drought-tolerant vs -intolerant (hydraulic traits)
- Stable coexistence under historical hydroclimate variation at BCI, Panama

Predicted biomass matches observed

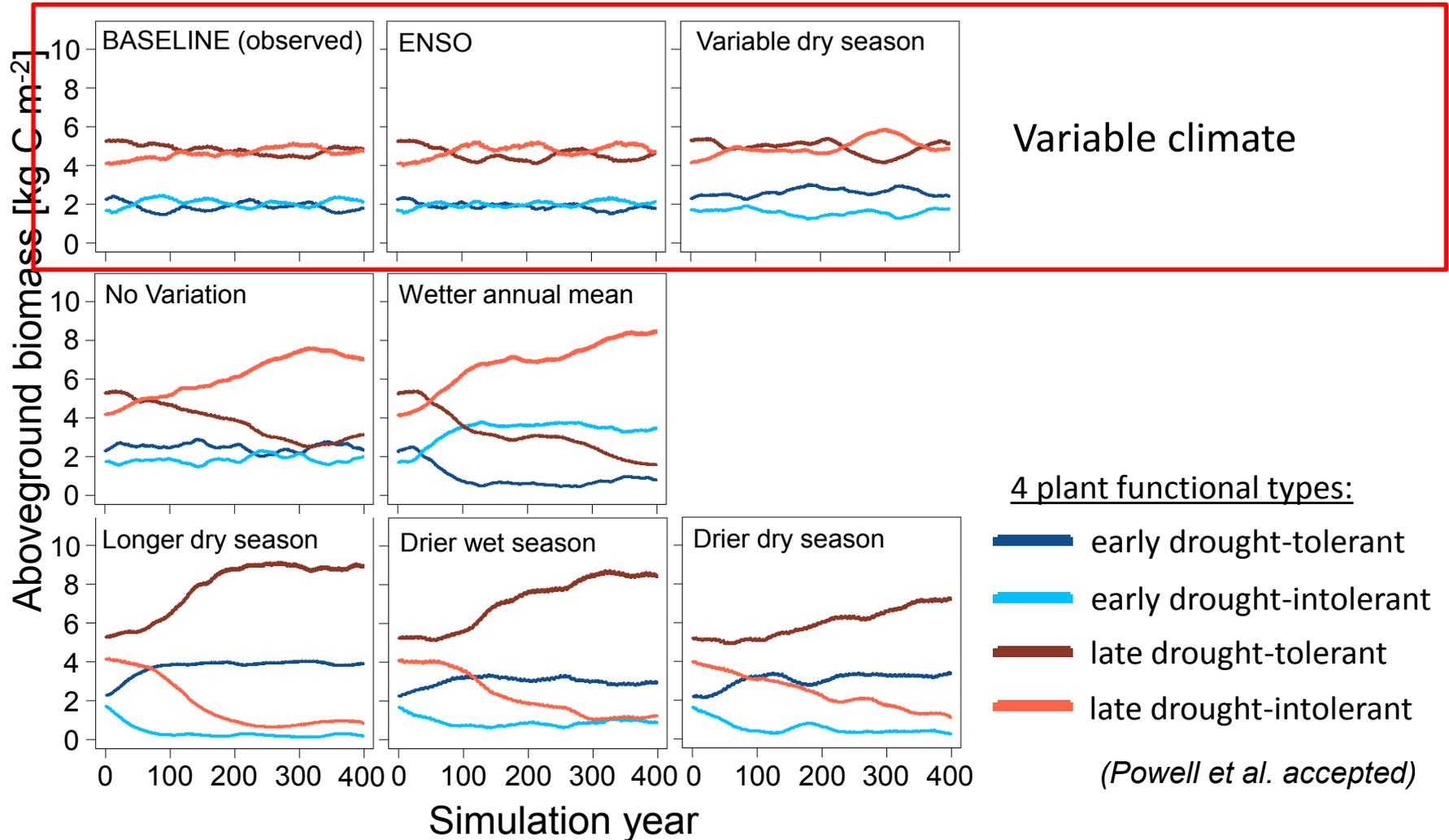


(Powell et al. accepted)

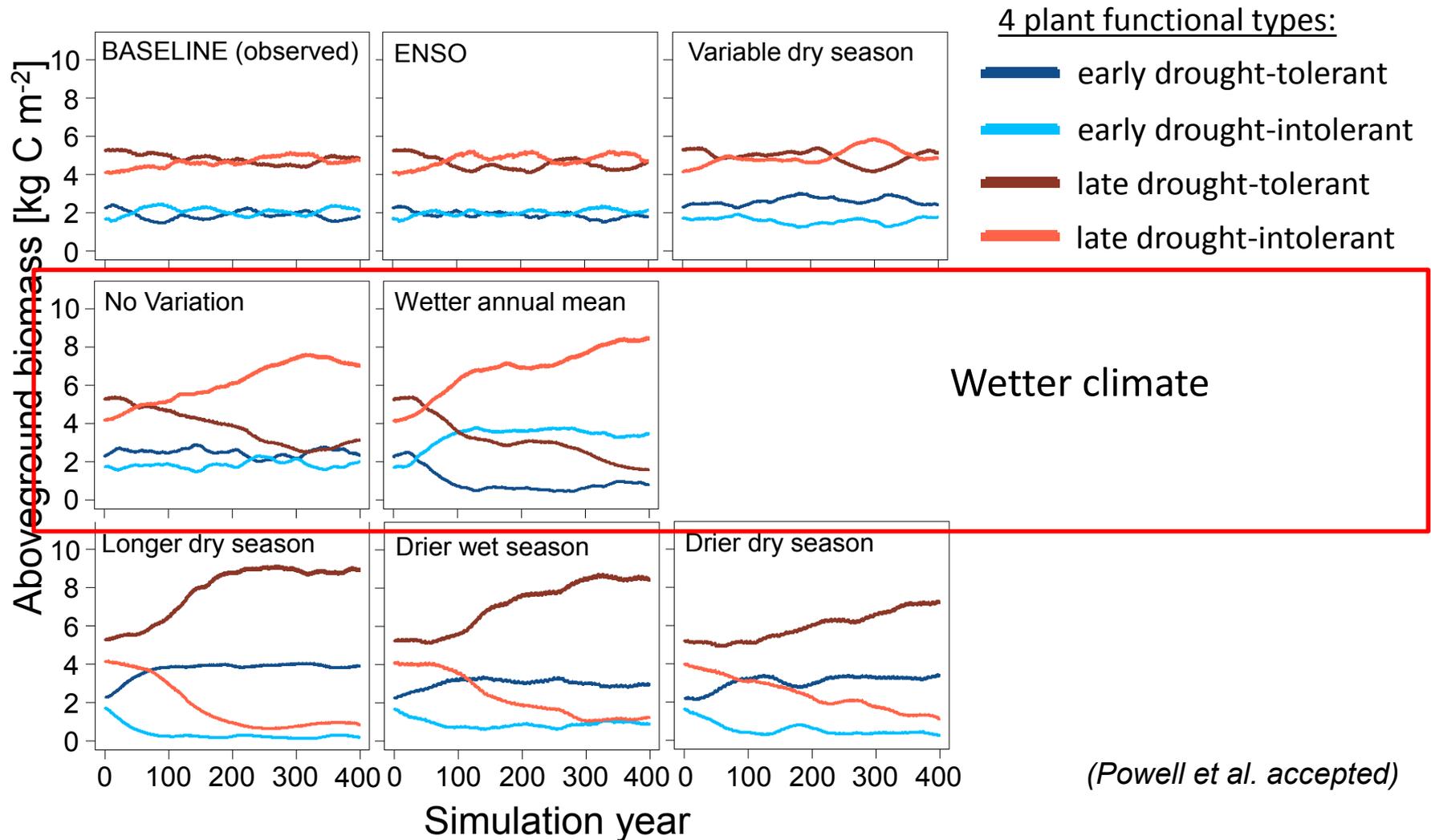
Functional types responded to hydroclimate change



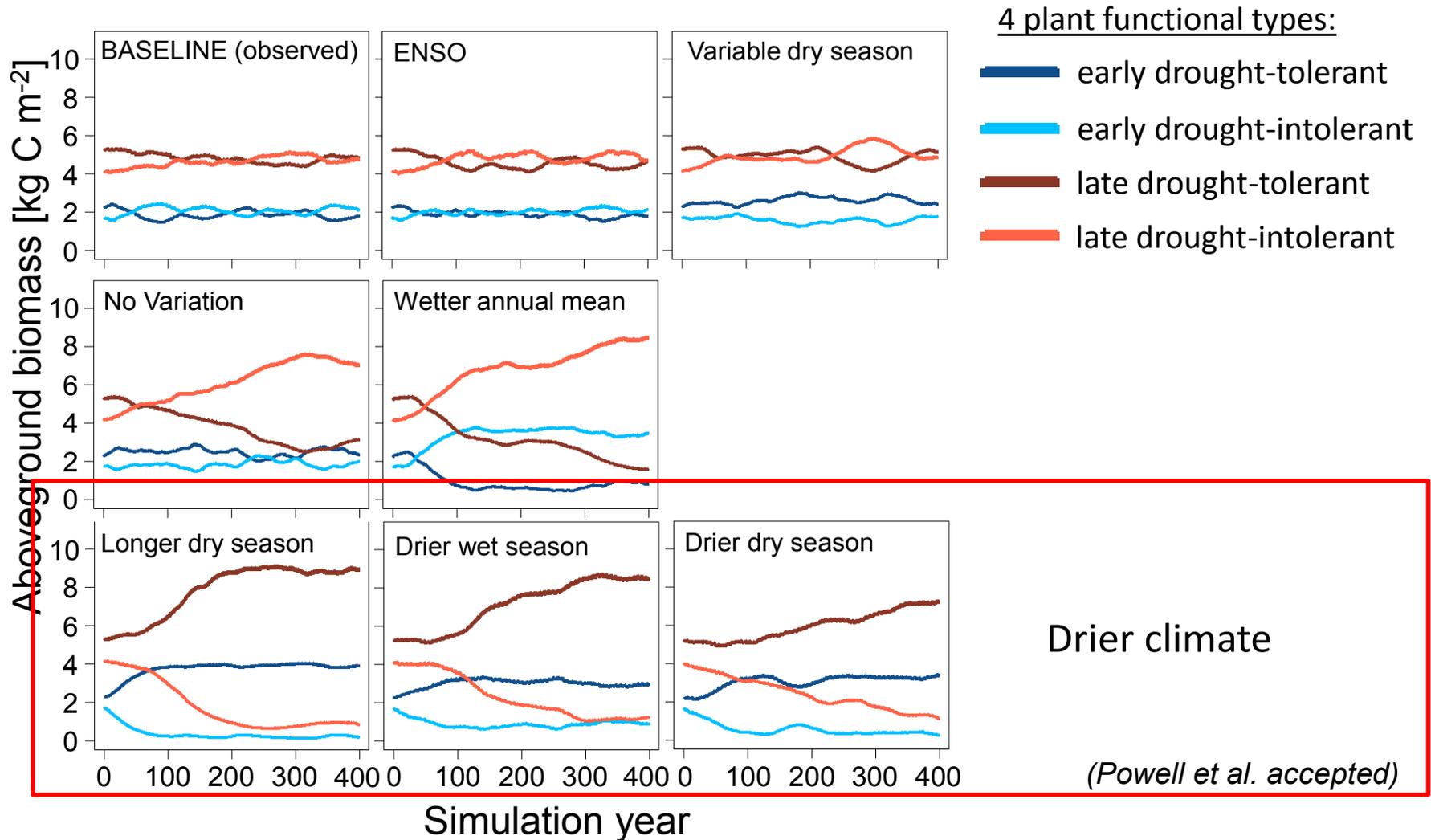
Variable hydroclimates maintains functional diversity



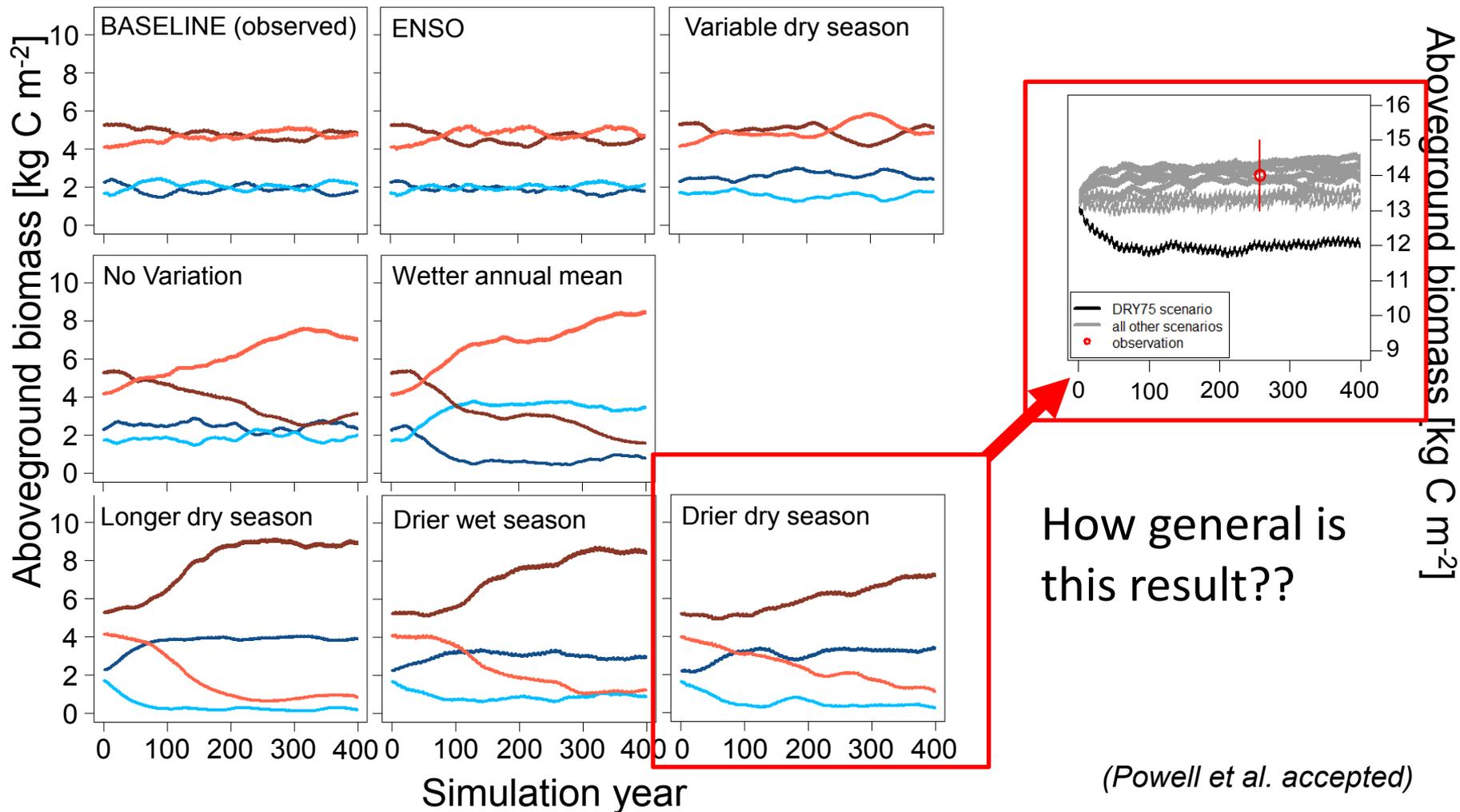
Wetter hydroclimates favor drought-intolerant functional types



Drier hydroclimates favor drought-tolerant functional types

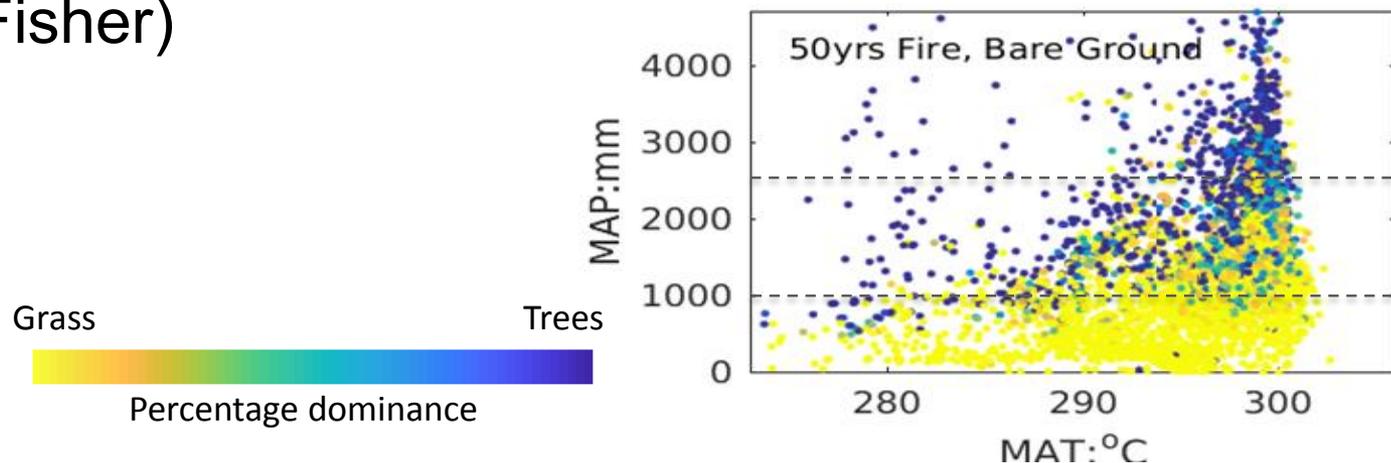


Functional diversity provides resilience to hydroclimate change



FATES as a community model: status

- FATES – demographic vegetation model for use in E3SM/CESM (<https://github.com/NGEET/fates-release>)
- Global parameterization & testing (Holm, Fisher)
- Initial disturbance processes in FATES
 - ❑ Plant hydrodynamics for drought effects (Xu, Christoffersen)
 - ❑ Fire spread and effects on vegetation (Shuman, Fisher)

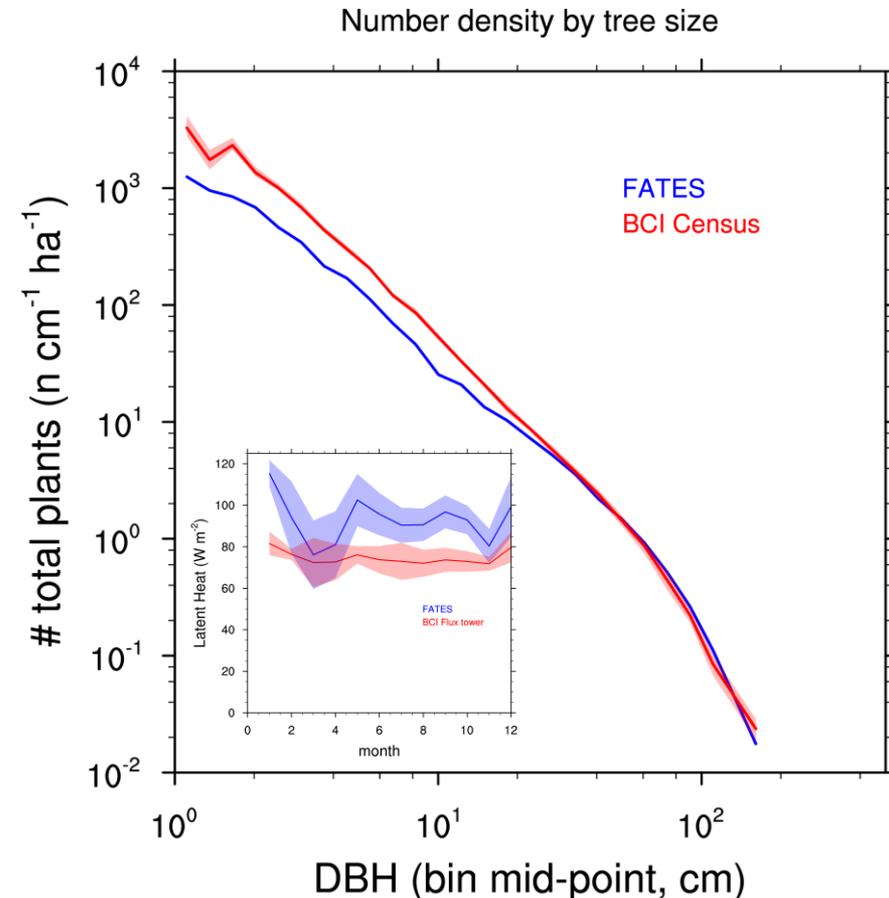


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 - ❑ Tree harvest (Huang, Xu)
- Site-scale tropical forest testbeds at BCI, Panama; Manaus, Brazil; Panama rainfall gradient (emerging)

Needs: Observational testbeds for FATES evaluation and development

- Site scale
 - Demographic measurements + flux data + meteorology + land use history
- Landscape-regional scale targeting disturbance-recovery dynamics
- Environmental gradients to test ecological strategies



Knowledge gaps

- What are the environmental sensitivities of key demographic and disturbance processes?
- What is the relationship between vegetation damage and mortality?
- How fast can ecosystem transitions occur?
- How does anthropogenic disturbance or its legacy alter ecosystem vulnerability to disturbance and recovery?
- How do nutrients constrain vegetation development & competitive dynamics?
- ...

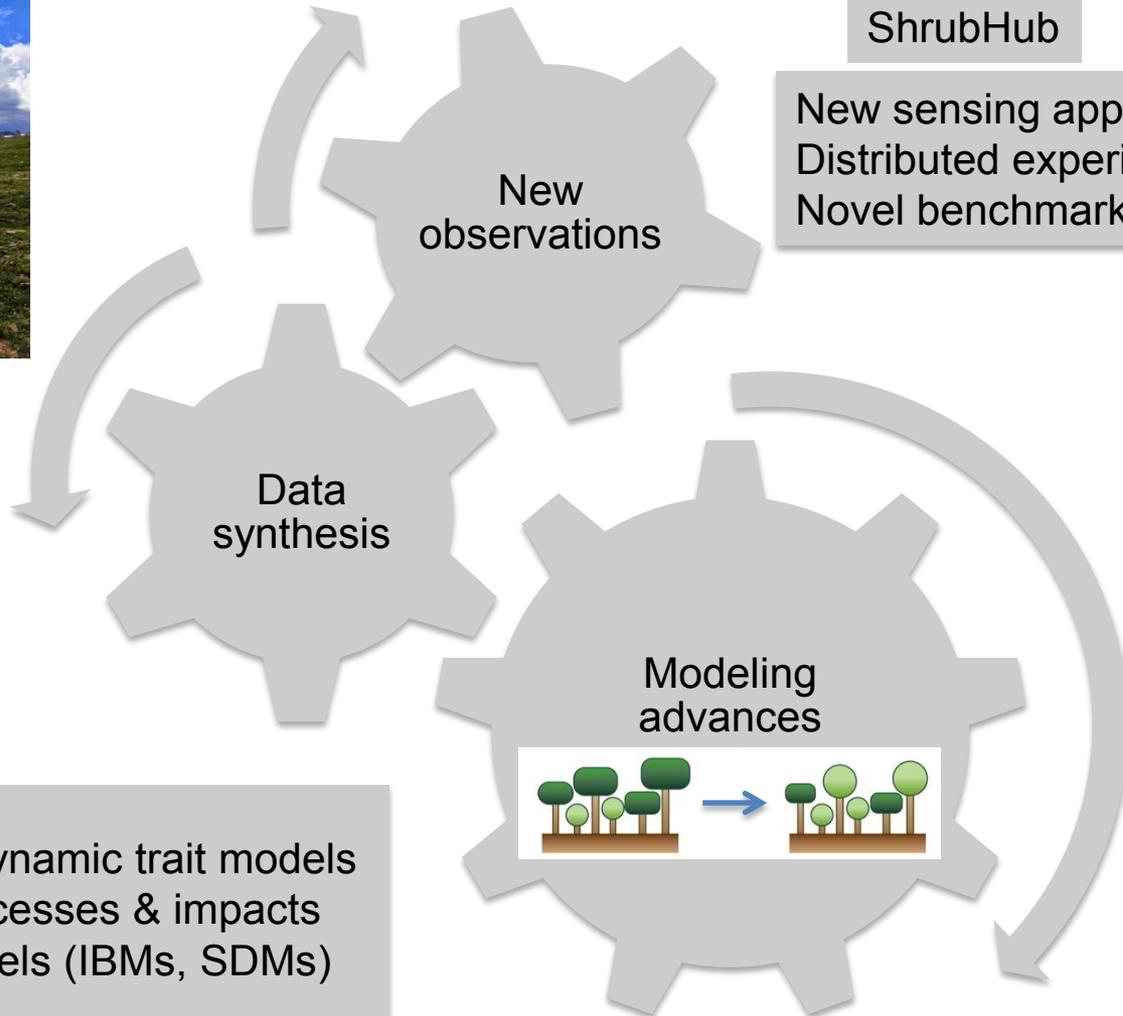
Elements needed



Ameriflux BADM

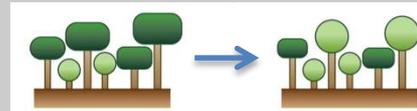
ShrubHub

New sensing approaches
Distributed experiments
Novel benchmarks



Complex dataset
integration and use
Community effort

Demographic, dynamic trait models
Disturbance processes & impacts
Benchmark models (IBMs, SDMs)



Thanks!