NGEE-Tropics

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Towards coexistence: data-driven FATES simulations across the Amazon

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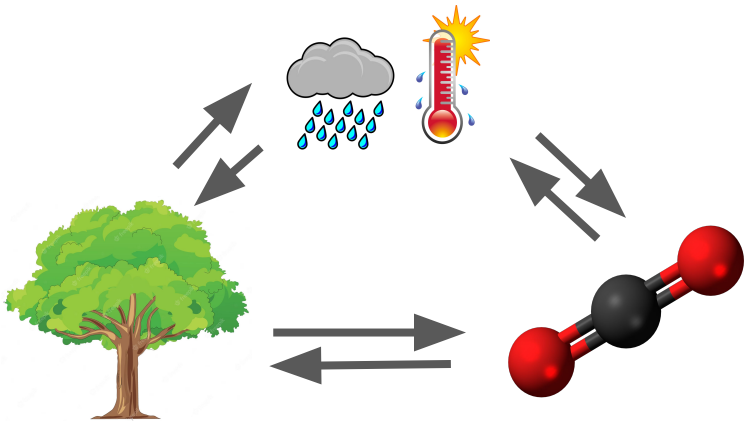
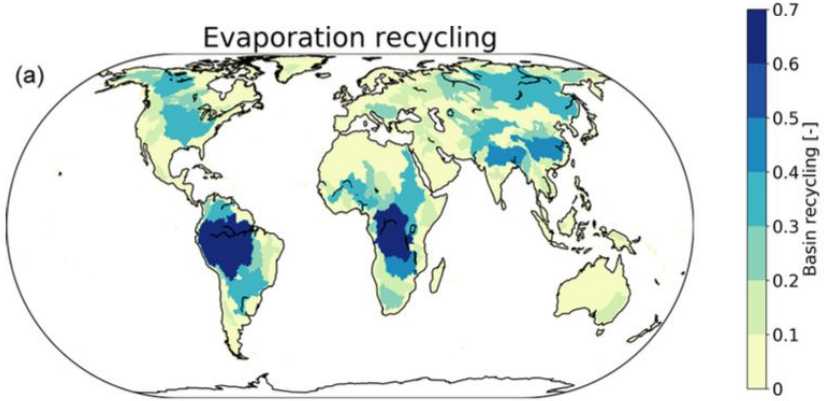
Motivation

How will rising CO_2, climate change, and land use affect climate-vegetation feedbacks and hydrology in the Amazon?



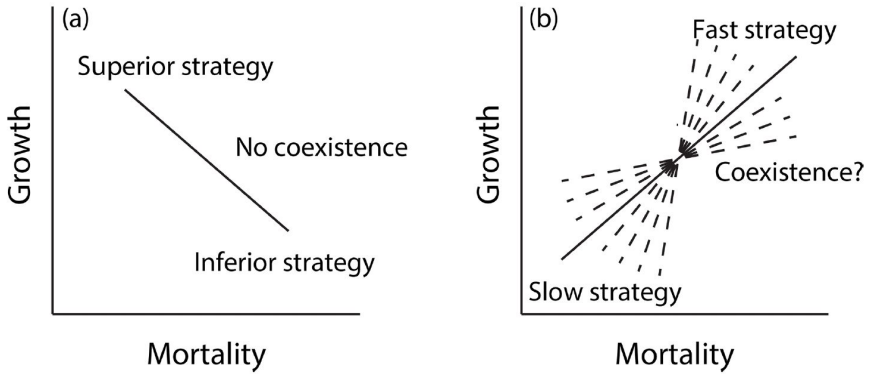


Tuinenburg et al. (2020)

We need to calibrate and test FATES with offline regional-scale simulations before conducting coupled land-atmosphere simulations.

Goal: realistic, continental-scale FATES simulations with multiple PFTs

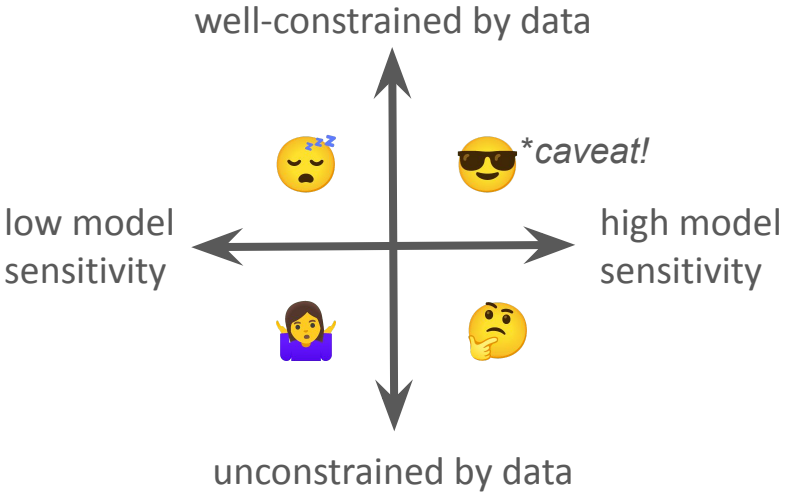
Challenge: coexistence is tricky…



Koven et al. (2020)

- Coexistence arises from interspecific trade-offs in life history strategy (e.g. Detto et al., 2021)
- Forest structure depends on balance of growth and mortality rates (e.g. Moore et al., 2020)

and parameter space is large



Our approach: data-based plant functional types (PFTs)

Use trait values from Marcos Longo's TRY+ cluster analysis (v 08.24.2023)

172,462 observations

Current status of the data in the Neotropics

4655 species

slide from Marcos Longo

Traits data available for more than 250 species*								
Crown Area	Diameter at Breast Height	Growth Form	Specific Leaf Area	Leaf N:P Ratio	Leaf Area (Single Blade)	Leaf Force (Puncture)	Photosynth. Pathway	Leaf Chlorophyll (Area-based)
Crown Diameter	Height	Plant Woodiness	Leaf Width	Leaf Density	Leaf Nitrogen (Mass-based)	Leaf Toughness (Puncture)	Net Photosyn. Rate (Mass-based)	Net Photosyn. Rate (Area-based)
Bark Thickness	Crown Depth	Bark Density	Leaf Thickness	Leaf Carbon (Mass-based)	Leaf Dry Matter Content	Leaf Nitrogen (Area-based)	Xylem P_{50}	$R_{Dmax}:V_{Cmax}$ Ratio
Seed Biomass	Seed Dispersal Syndrome	Wood Density	Leaf Width	Leaf Phosphorus (Mass-based)	Leaf C:P Ratio	Leaf Carbon (Area-based)	Leaf turgor loss point	Leaf Phenology
Biome	Climate	Plant Functional Type	Nitrogen Fixer	Mycorrhiza Association	Leaf C:N Ratio	Leaf Phosphorus (Area-based)	Saturated Wood Water Content	Wood Hydraulic Conductivity

This excludes non-canopy observations for traits with high photo-plasticity

Marcos's cluster analysis identified 4 tropical tree PFTs

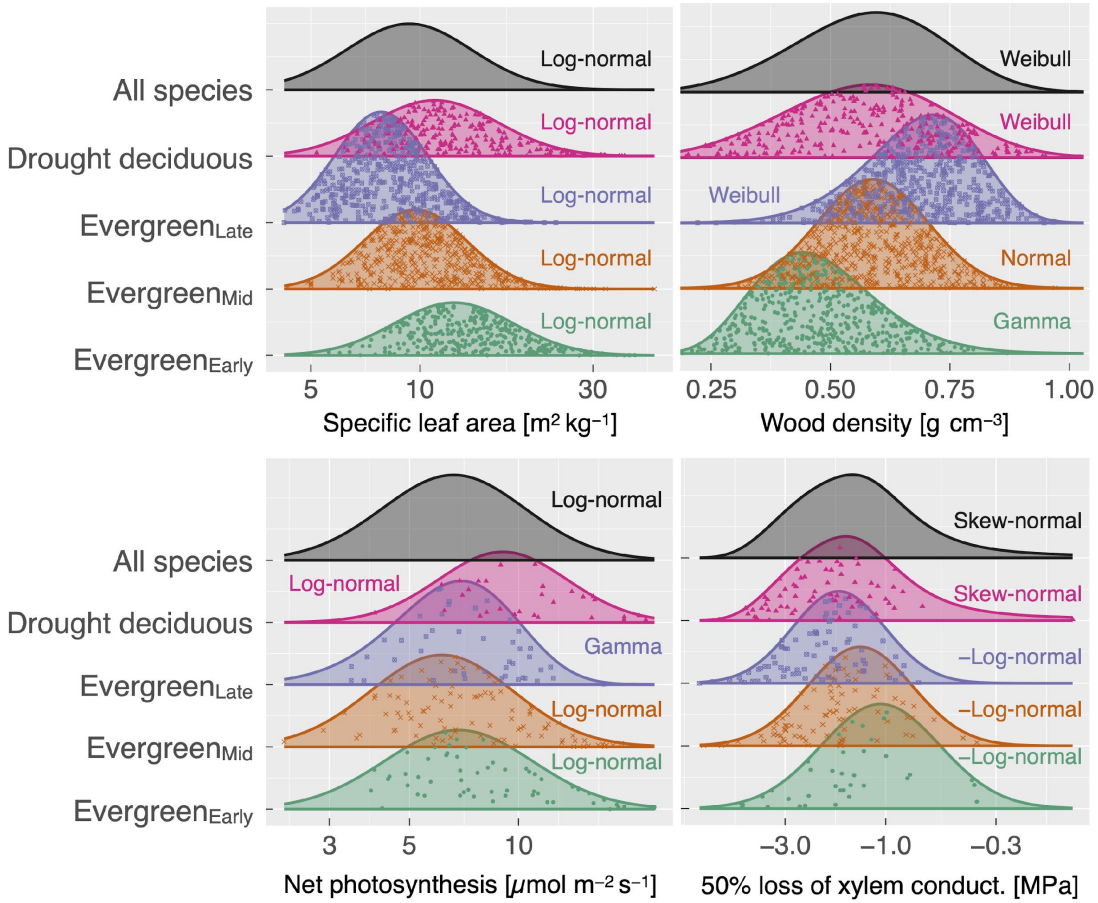
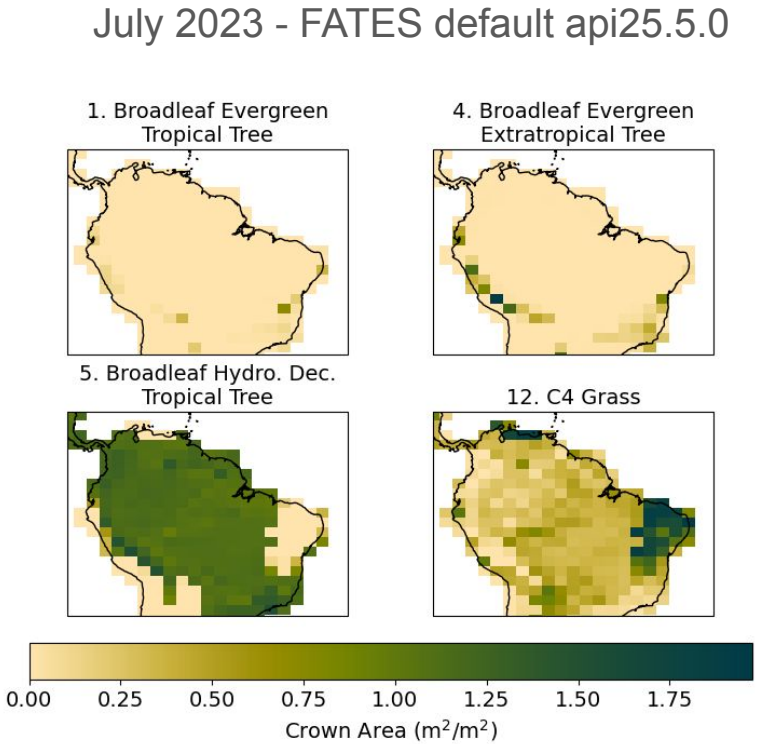


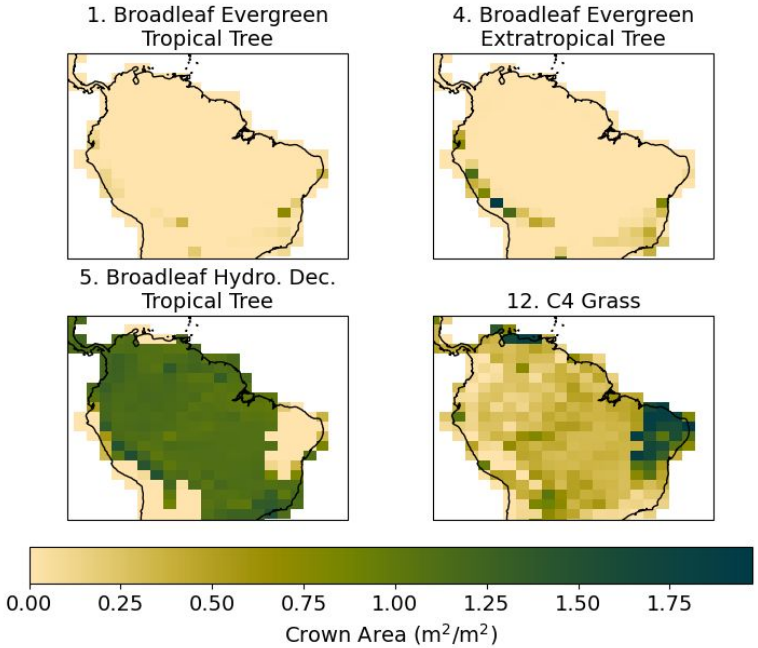
Figure from Marcos Longo- 08.24.2023 version

Results from initial simulations with competition

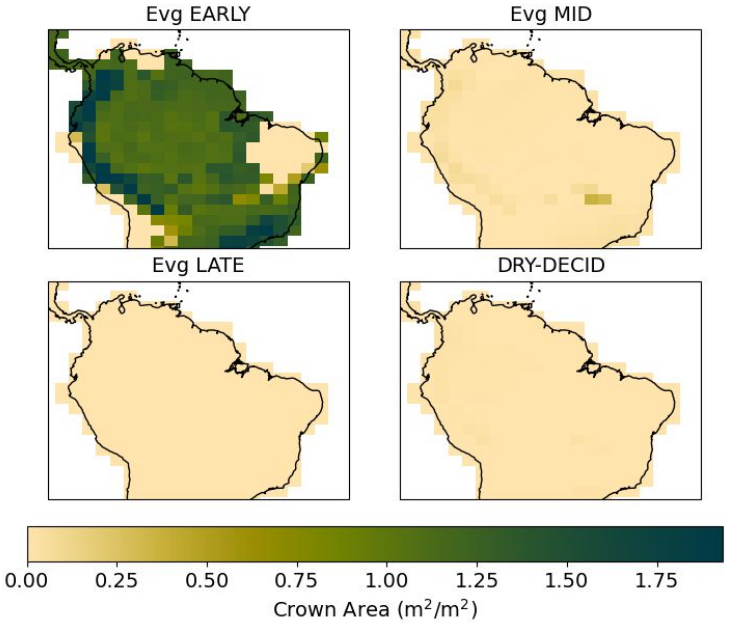


Initial results from simulations with competition

July 2023 - FATES default api25.5.0



Sep 2023 - initial run with Marcos's TRY+ cluster analysis medoid species



Initial results from simulations with competition

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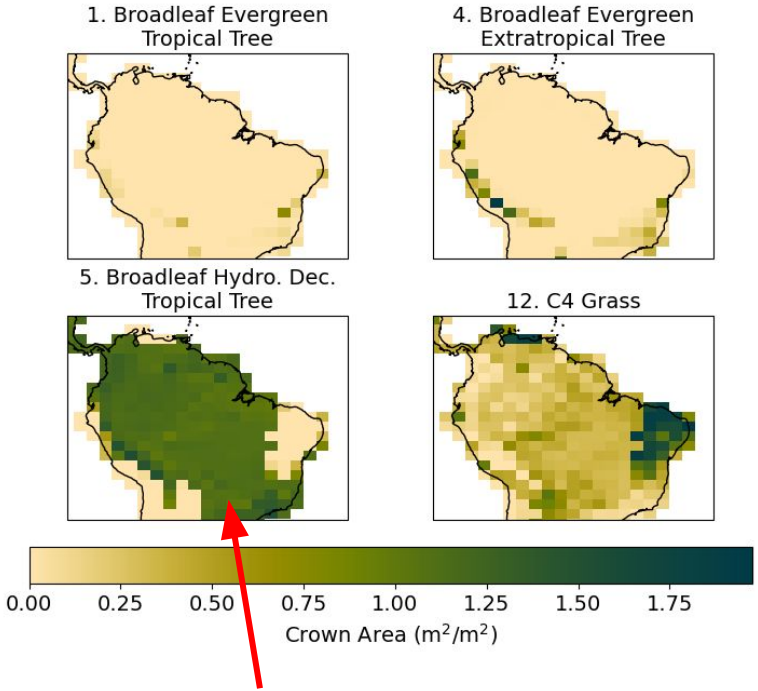
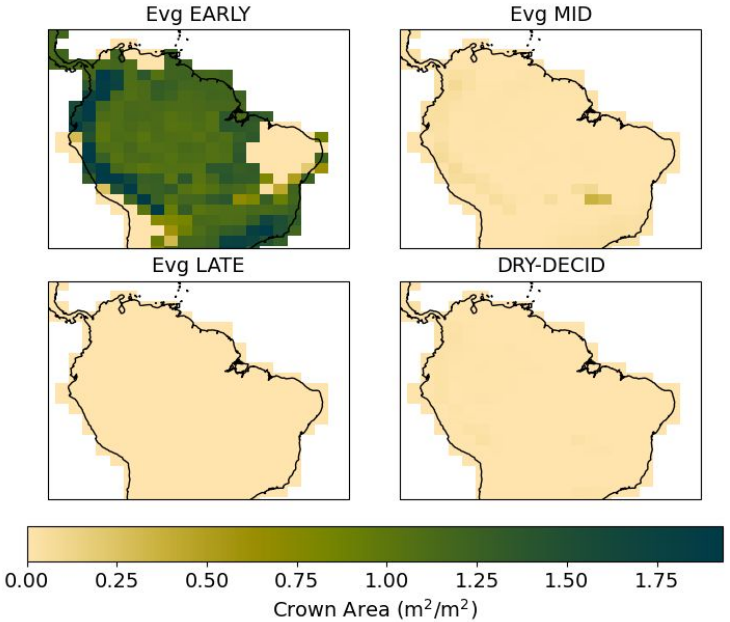


Because of high SLA

Sep 2023 - initial run with Marcos's TRY+ cluster analysis medoid species



Initial results from simulations with competition

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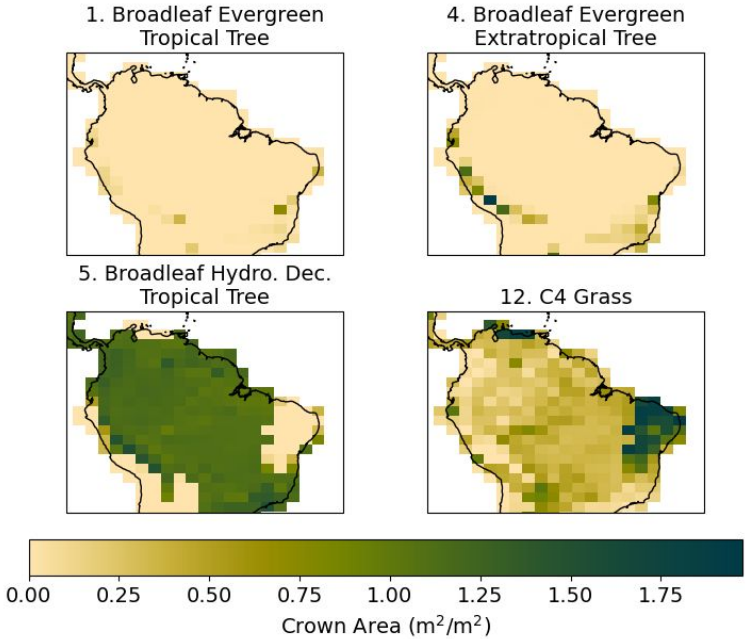

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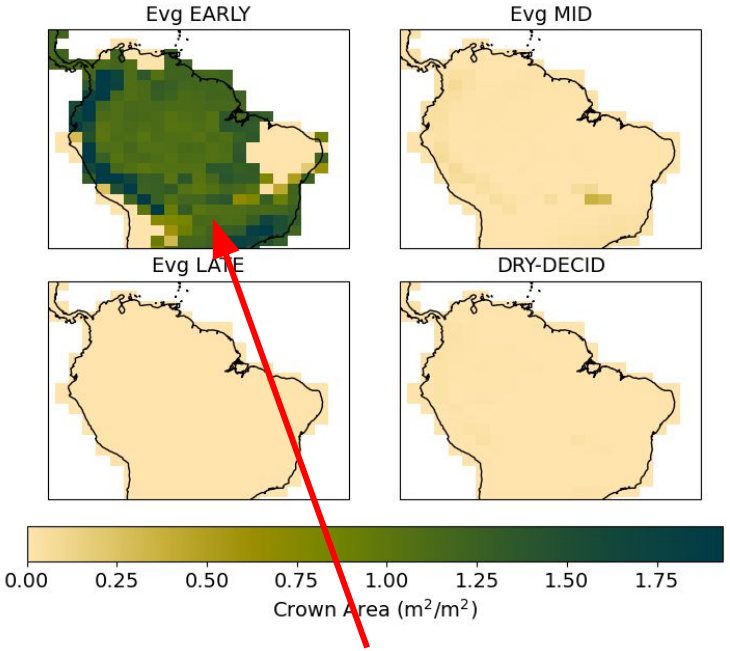


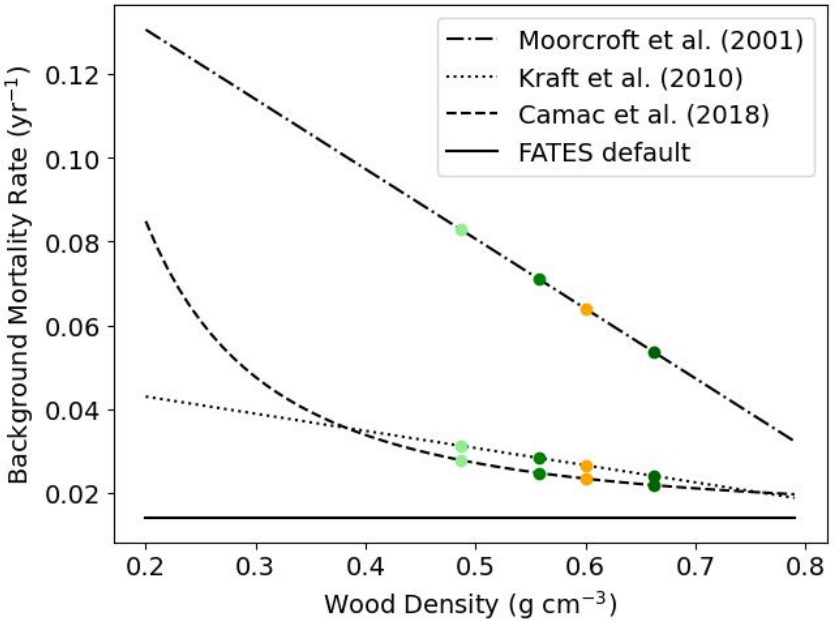
Living fast but not dying young

Our process to increase PFT coexistence

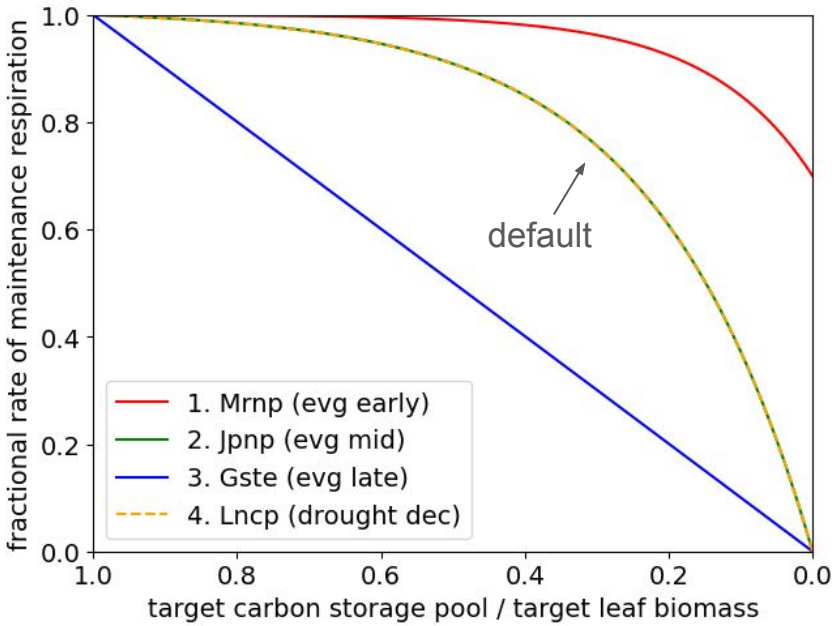
In offline continental-scale simulations driven by GSWP3 climatology (Van den Hurk et al., 2016):

1. Adjust values of parameters related to mortality and carbon balance
2. Assess results in **no-competition** mode relative to our ecological expectations (Buotte et al., 2021): e.g. early successional trees should not survive in the understory, late successional should
3. Iterate 1-2 until ecological expectations met in no-comp mode, then turn competition back on 🤞

PFT-dependent mortality and carbon balance



Denser wood: less vulnerable to embolism, pathogens, breakage



Conservative strategy of late successionals

Summary of parameter changes

- Use N and P stoichiometric ratios for leaves, SLA, and wood density for the medoid species from Marcos's TRY+ cluster analysis
- Background mortality: negative linear function of wood density from Kraft et al. (2010)
- Leaf lifespan increases with wood density, values from Moorcroft et al. (2001). Fine root lifespan = leaf lifespan
- Carbon storage cushion increases with wood density for evergreen PFTs (loosely inspired by Signori-Müller et al., 2021)
- Realistic hydraulic failure soil moisture thresholds (P. Thornton) that decrease with increasing wood density
- Edit function that reduces maintenance respiration when target carbon storage pool < target leaf biomass so that late successional PFT is very conservative while early successional PFT respires away.
- Maximum C-starve mortality rate raised for early and lowered for late.
- Allometry parameters from Jessica Needham's analysis using BAAD (Falster et al., 2015) and Tallo (Jucker et al., 2022) databases

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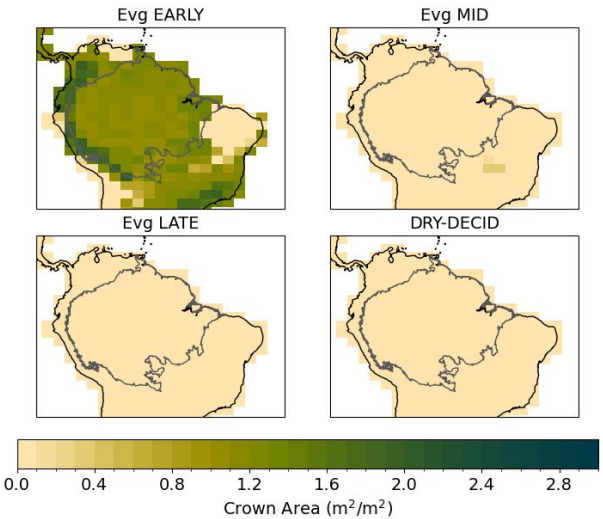
Note: fates_leaf_vcmax25top = 50, 50, 50, 58

Turning competition back on…

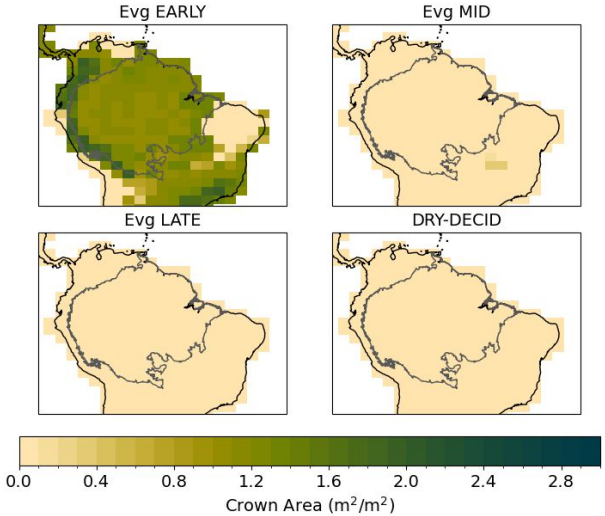
Sep 2023



Initial run

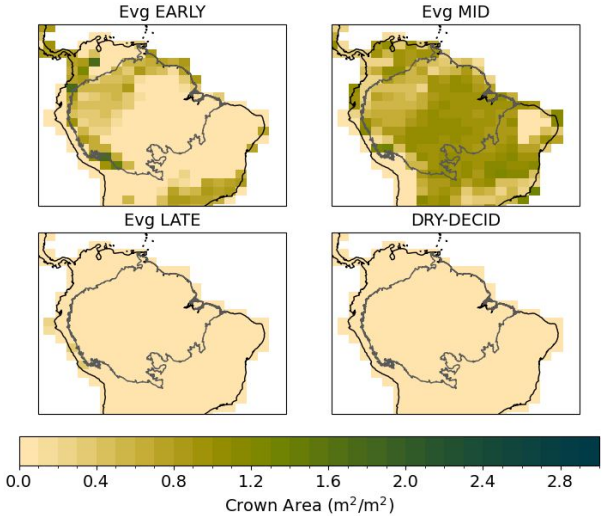
Turning competition back on…

Sep 2023



Initial run

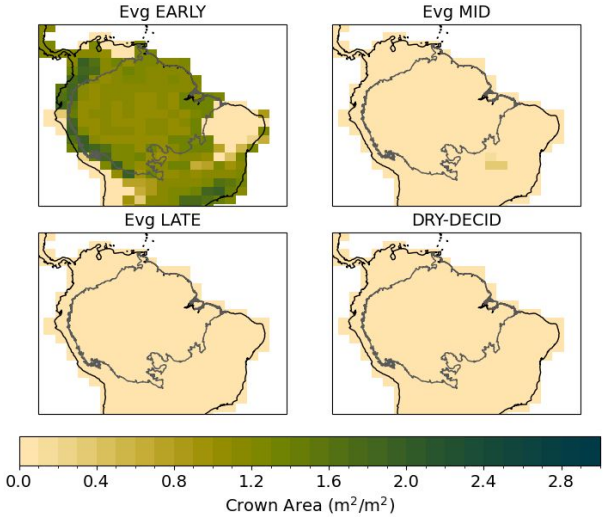
Nov 2023



Mid-successionals take over

Turning competition back on…

Sep 2023



Initial run

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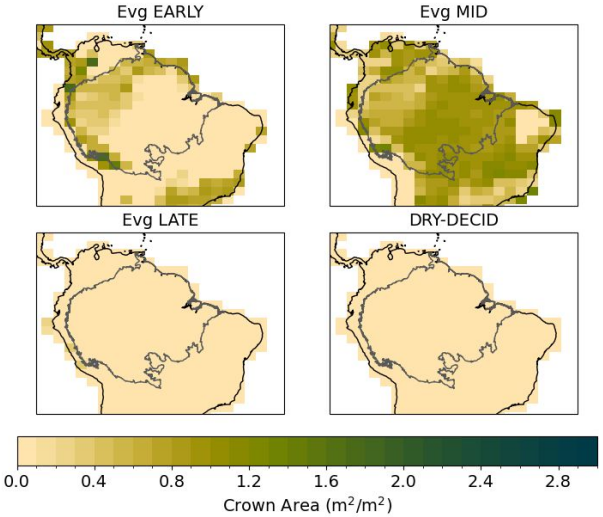
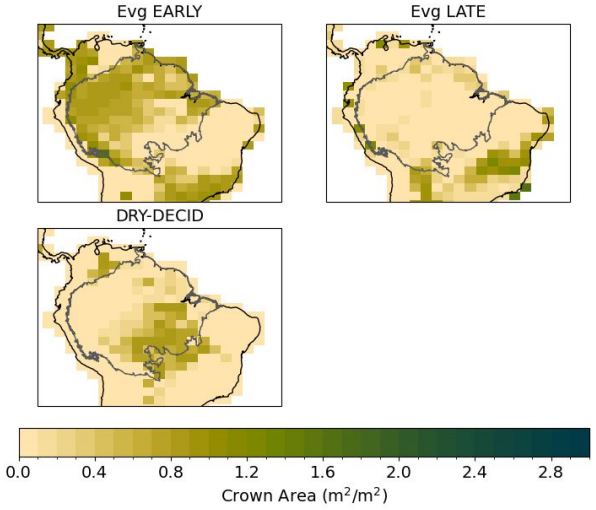


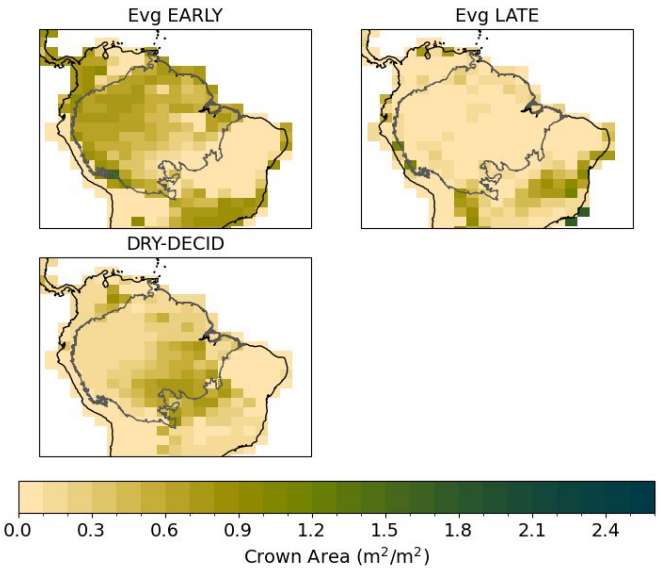
Mid-successionals take over



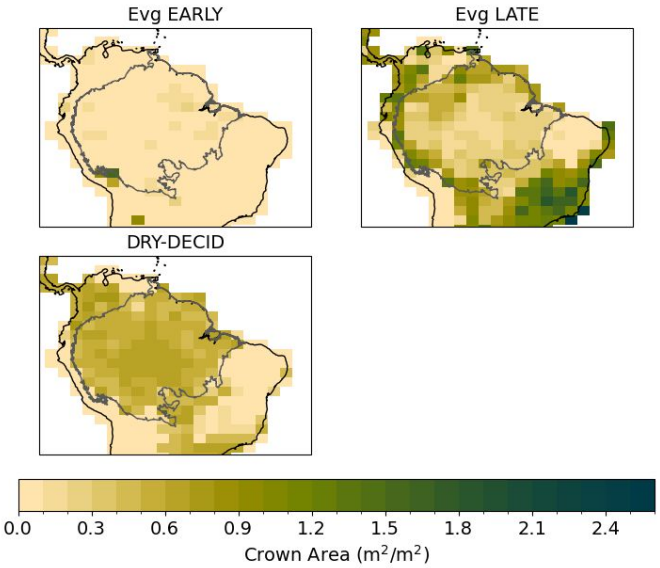
Without mid-successionals, some degree of coexistence between remaining PFTs

Recent code developments help late successional PFT

Nov 2023



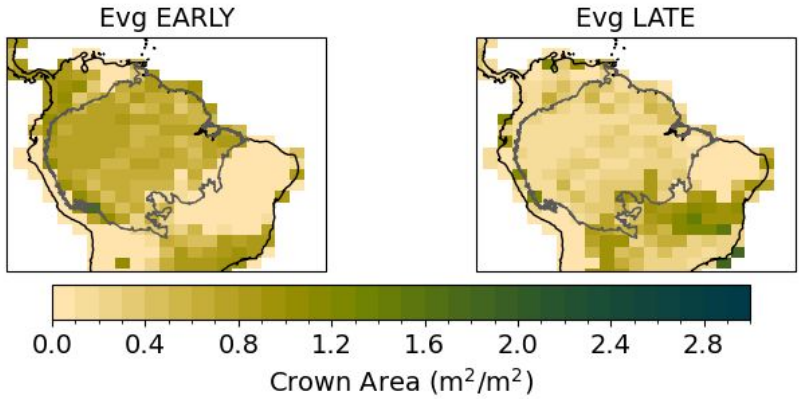
Jan 2024



- 3rd canopy layer
- Longer understory leaf lifespan - Jessica Needham
- Exponential function for carbon starvation mortality - Marcos Longo

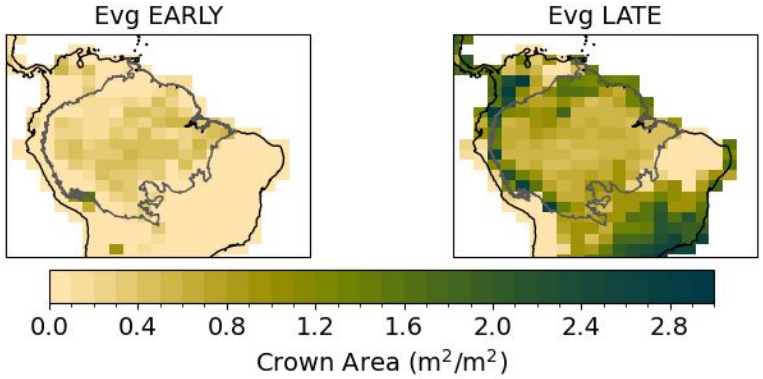
High sensitivity to variations in C-starve mortality function

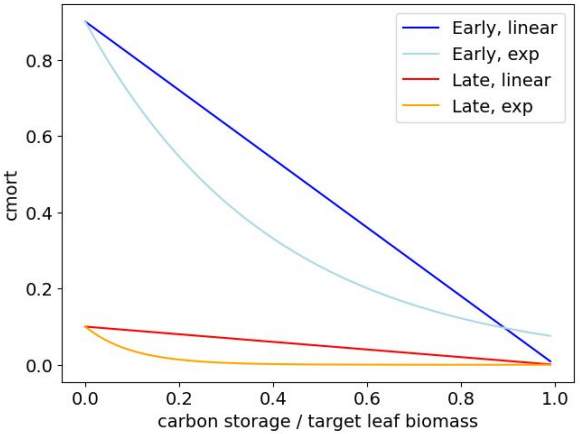
Linear cmort



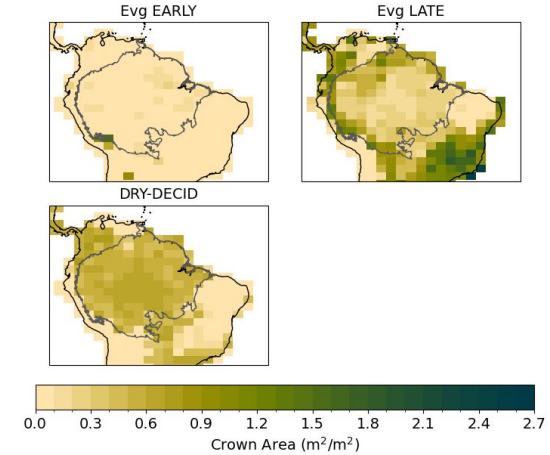
Exponential cmort

Early e-folding param = 0.4

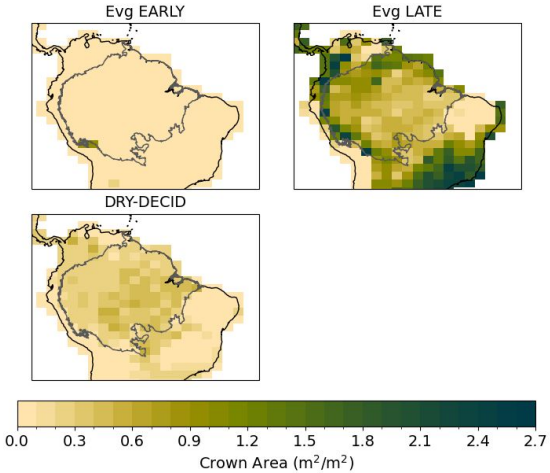




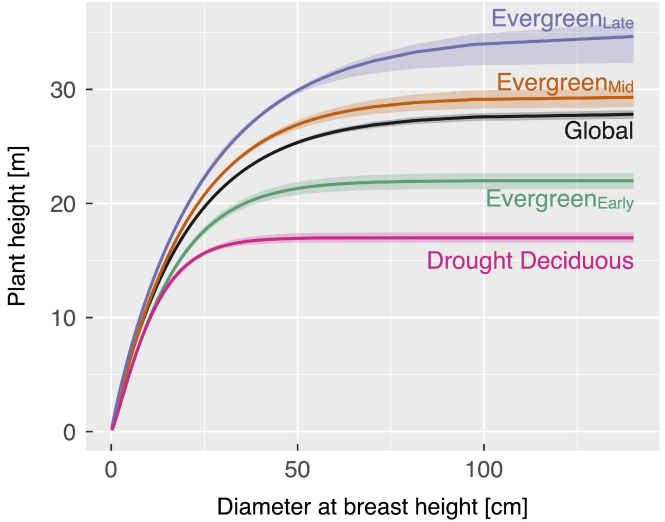
In progress: PFT-specific height allometry



← Same allometry parameter values for all PFTs



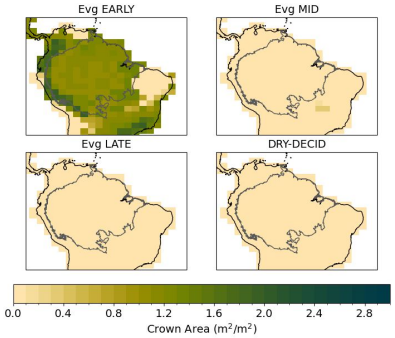
← Using Marcos's allometry fits for height (08.24.2023)

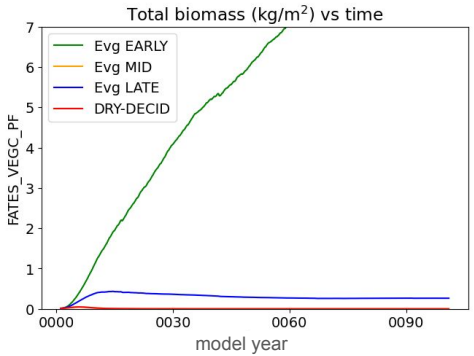


Summary

Our FATES simulations with competition show progress from early-successional dominance to late-successional dominance via parameter adjustments to reflect trade-offs in PFTs' life history strategies

Initial





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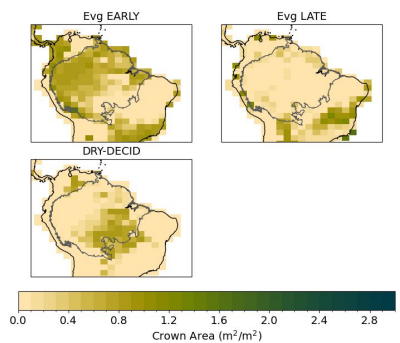
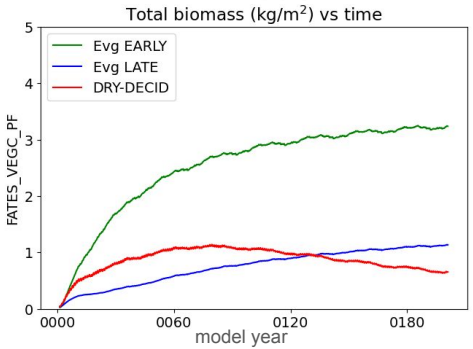
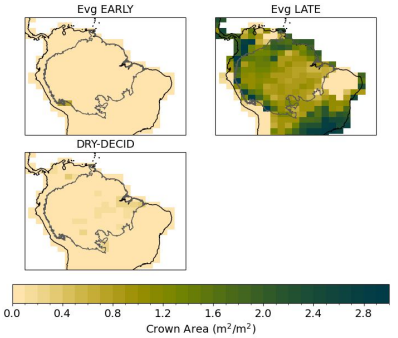
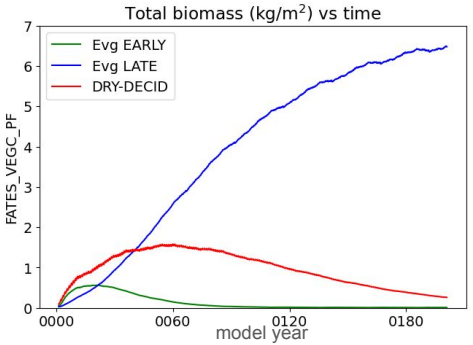




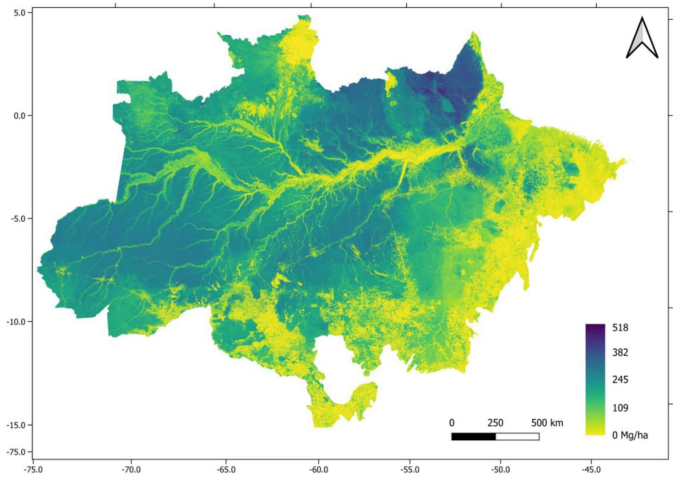
current





Next steps

- Benchmarking
  - Census data: growth and mortality rates
  - ILAMB
  - Remote sensing data, e.g. Ometto et al. (2023)
- FATES-Hydro (in progress) and SPITFIRE
- Expand exploration of parameter space with single site PPEs - Marcos Longo
- Can NN ML surrogate models predict coexistence from traits, growth and mortality rates at year N?
  - Build on Li et al. (2023)



Above ground biomass (Ometto et al., 2023)

Acknowledgement

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Collaborators

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