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Simulating plant functional acclimation & trait evolution using an eco-evolutionary vegetation model (PlantFATE)

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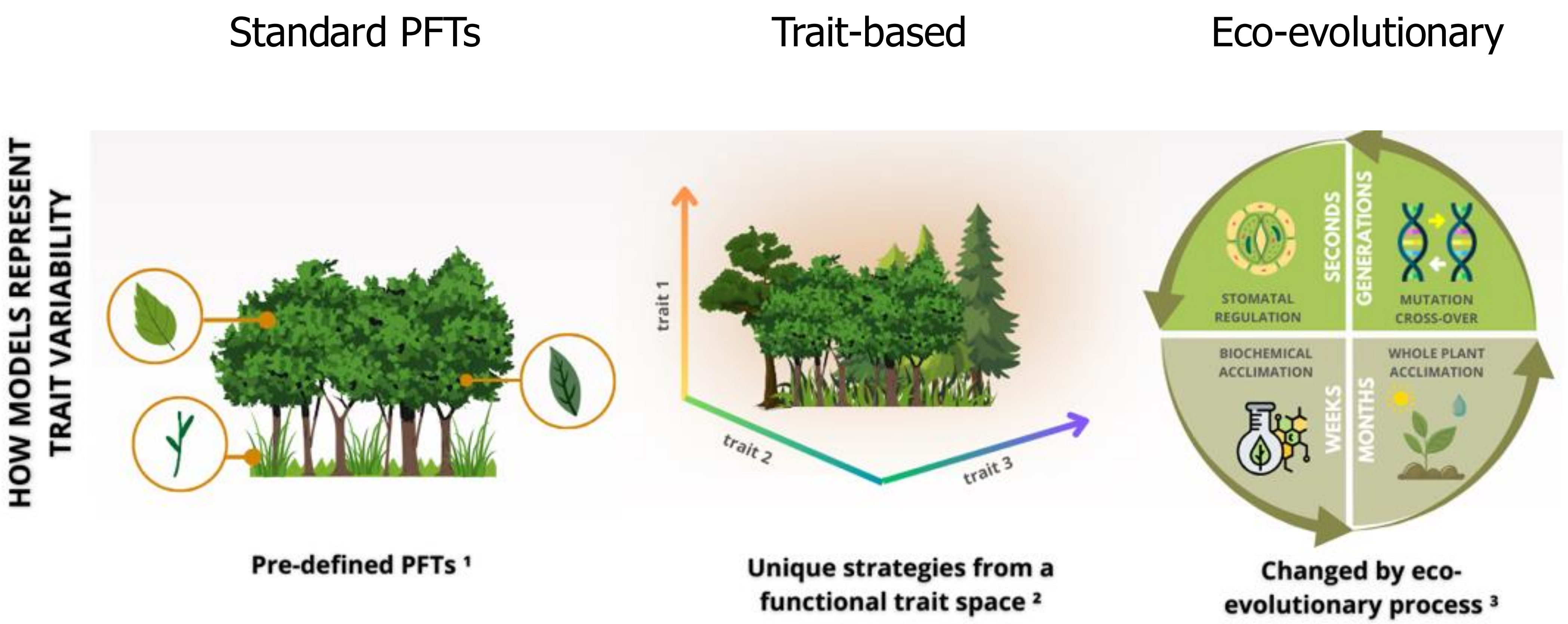
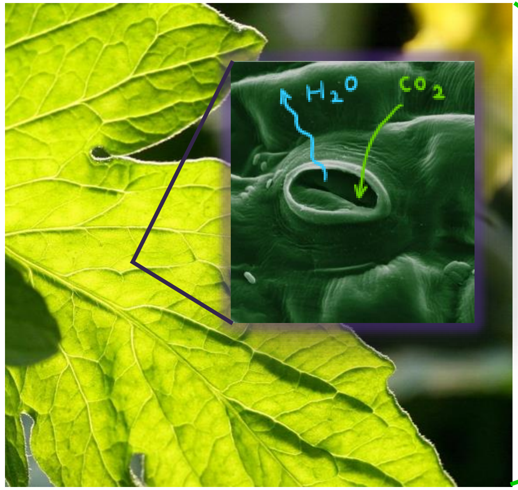
Introduction: representation of plant functional ecology

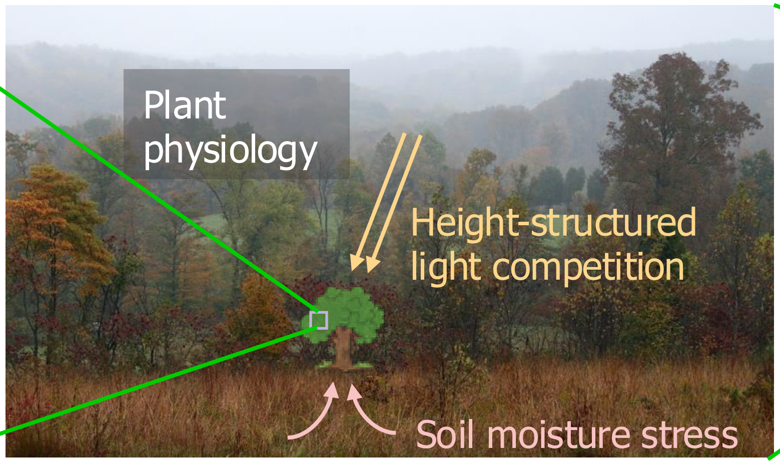


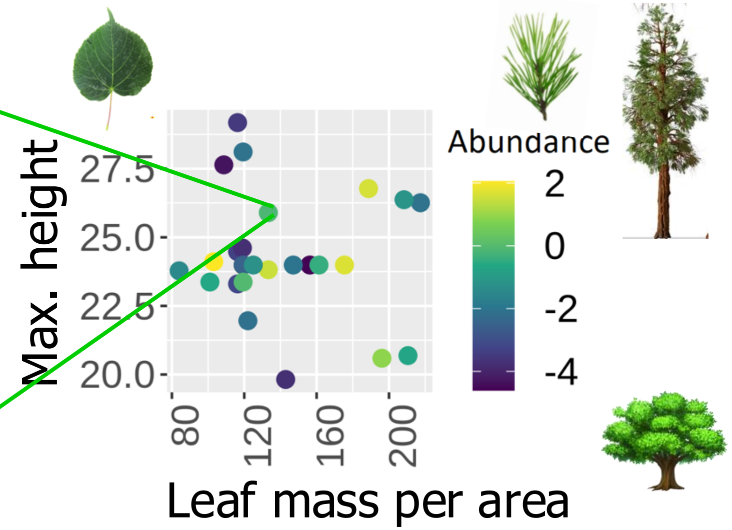
Blanco, et al., (in prep.). Trait-based vegetation modeling and data integration to advance our knowledge on the functional ecology of ecosystems.

Method: simulate processes across multiple scales

Plant-level adaptations	Species-level adaptations	Ecosystem-level adaptations
Maximise growth / C-uptake	Stress, demographics, mortality	Plant functional diversity
Physiological acclimation	Species composition shifts	Recovery and resilience







Days - Months — Years — Decades

Image Credits: Muffet, Huw Williams, Falster et al. (2017)

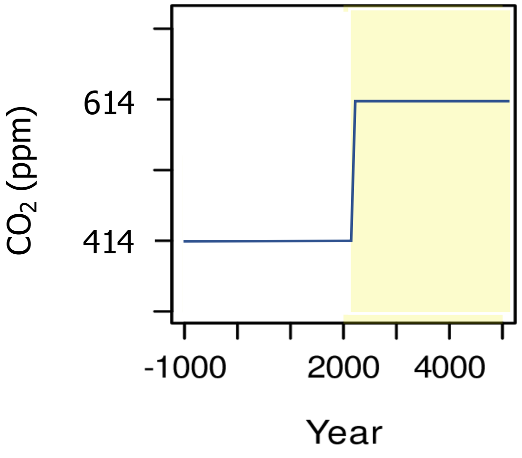
Study-site: apply model to a hyperdiverse Amazonian forest

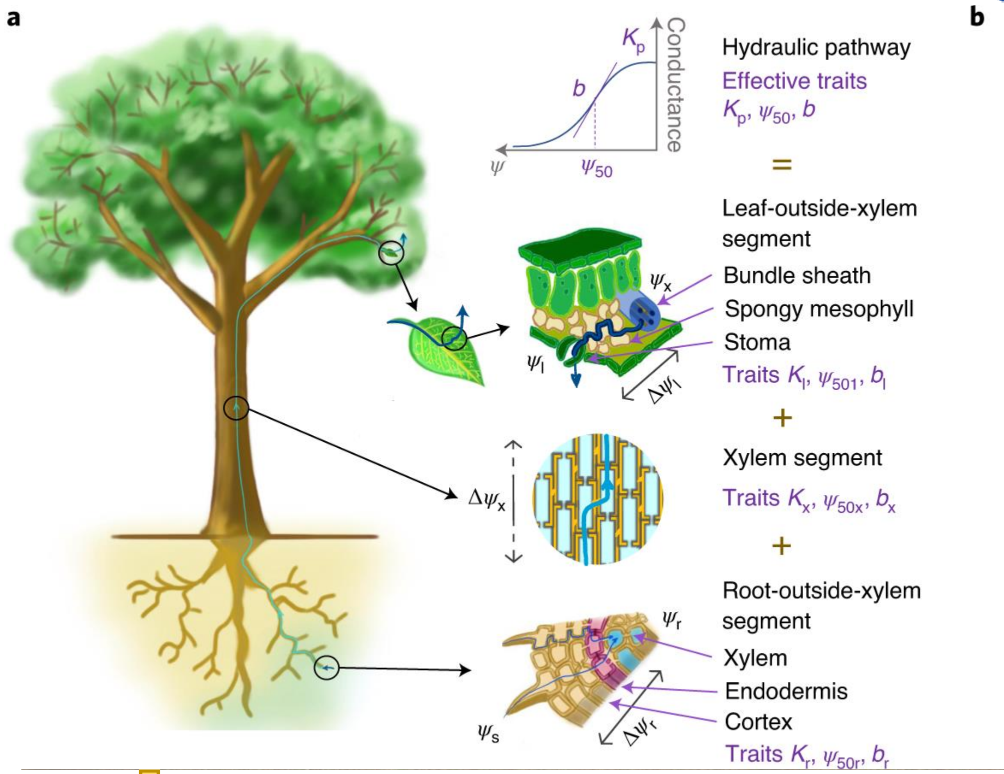
1. Forced with periodic extension of observed meteorological data from 2000-2015 (CO_2+200ppm)

2. Species defined as unique combinations of 4 plant traits: LMA, height, wood density, P_{50}

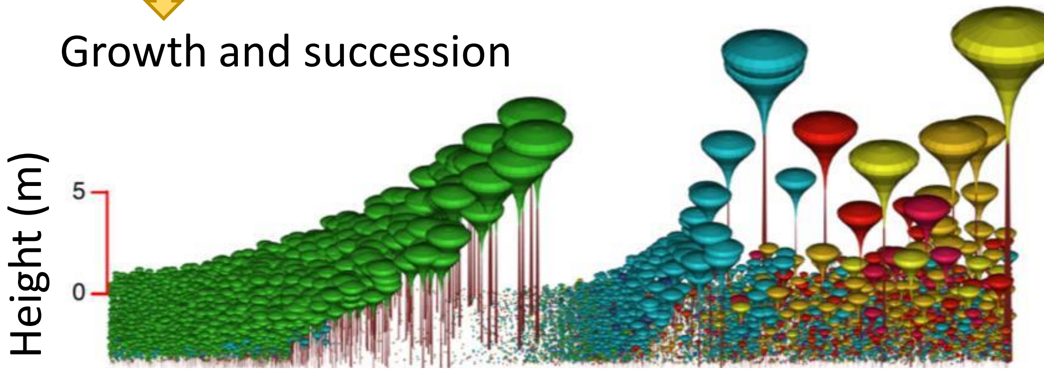
3. Start with 100 species with equal abundance & random trait values

➢ Let community composition evolve via competitive exclusion



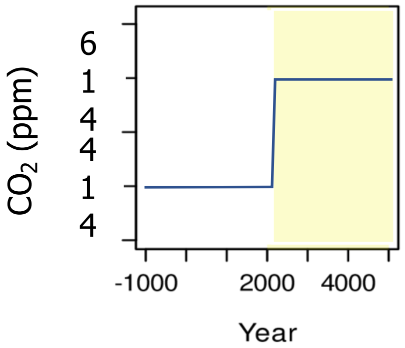


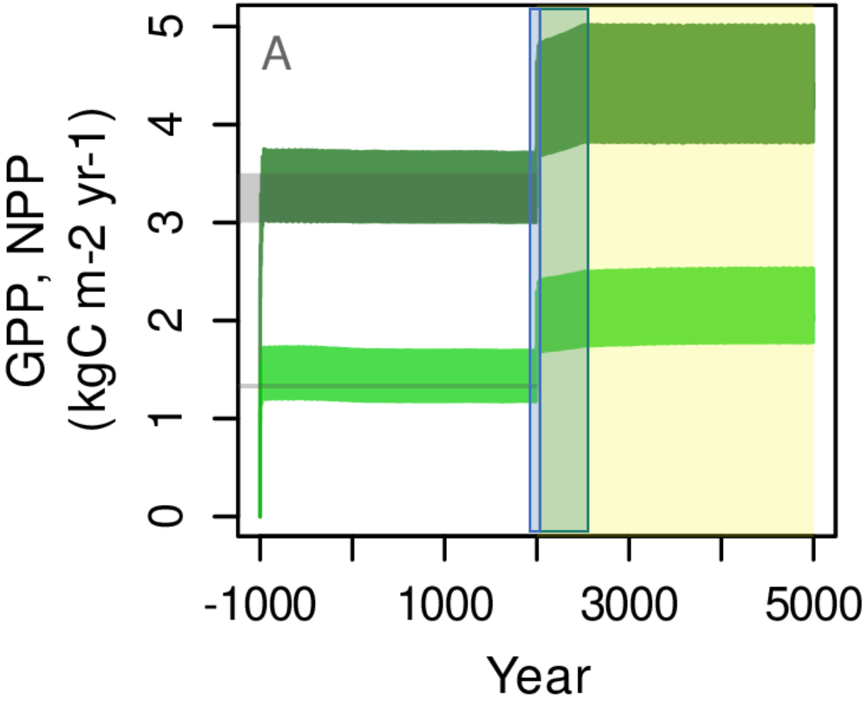
Growth and succession

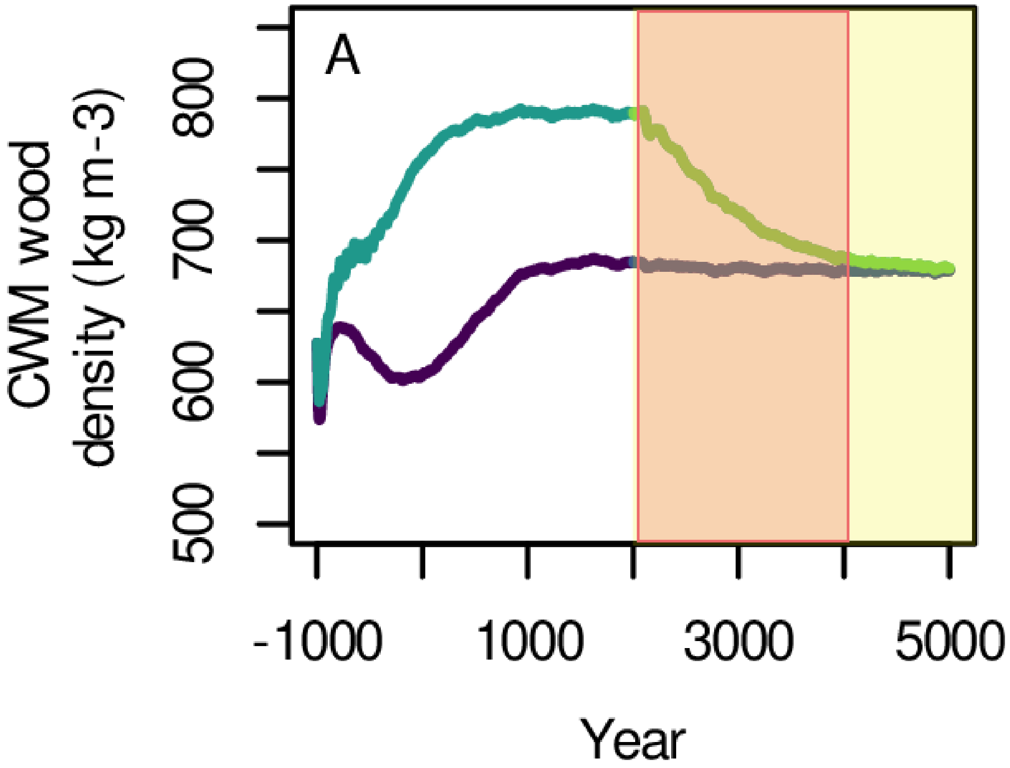


Joshi, Hofhansl *et al.,* (2023). Competition for light can drive adverse species-composition shifts in the Amazo

Hypothesis: community response on three timescales







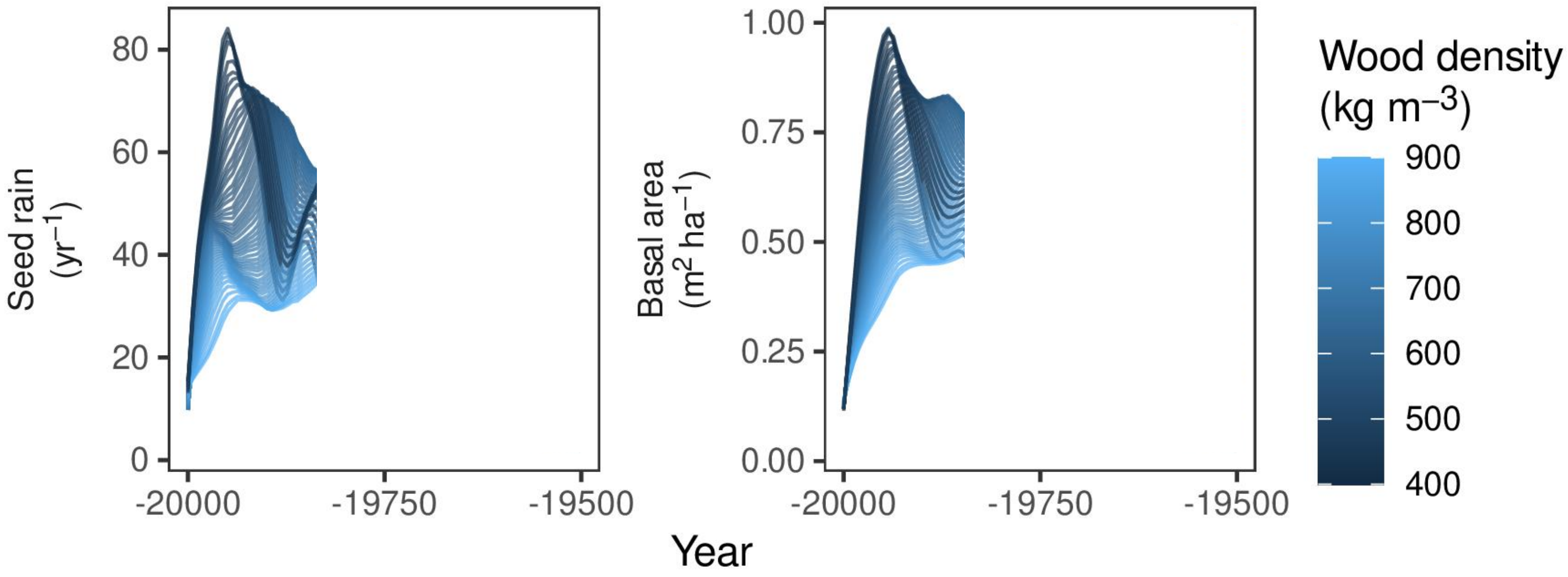
1. Physiological response in increased leaf-level photosynthesis 1 year

2. Demographic change due to changing light environment 500 years

3. Evolutionary change due to changing species composition 2000 years

Joshi, Hofhansl *et al.,* (2023). Competition for light can drive adverse species-composition shifts in the Amazon Forest under elevated CO2. *bioRxiv*. https://doi.org/10.1101/2023.07.03.547575

Results: vegetation dynamics capture forest succession



Successional forest dynamics:

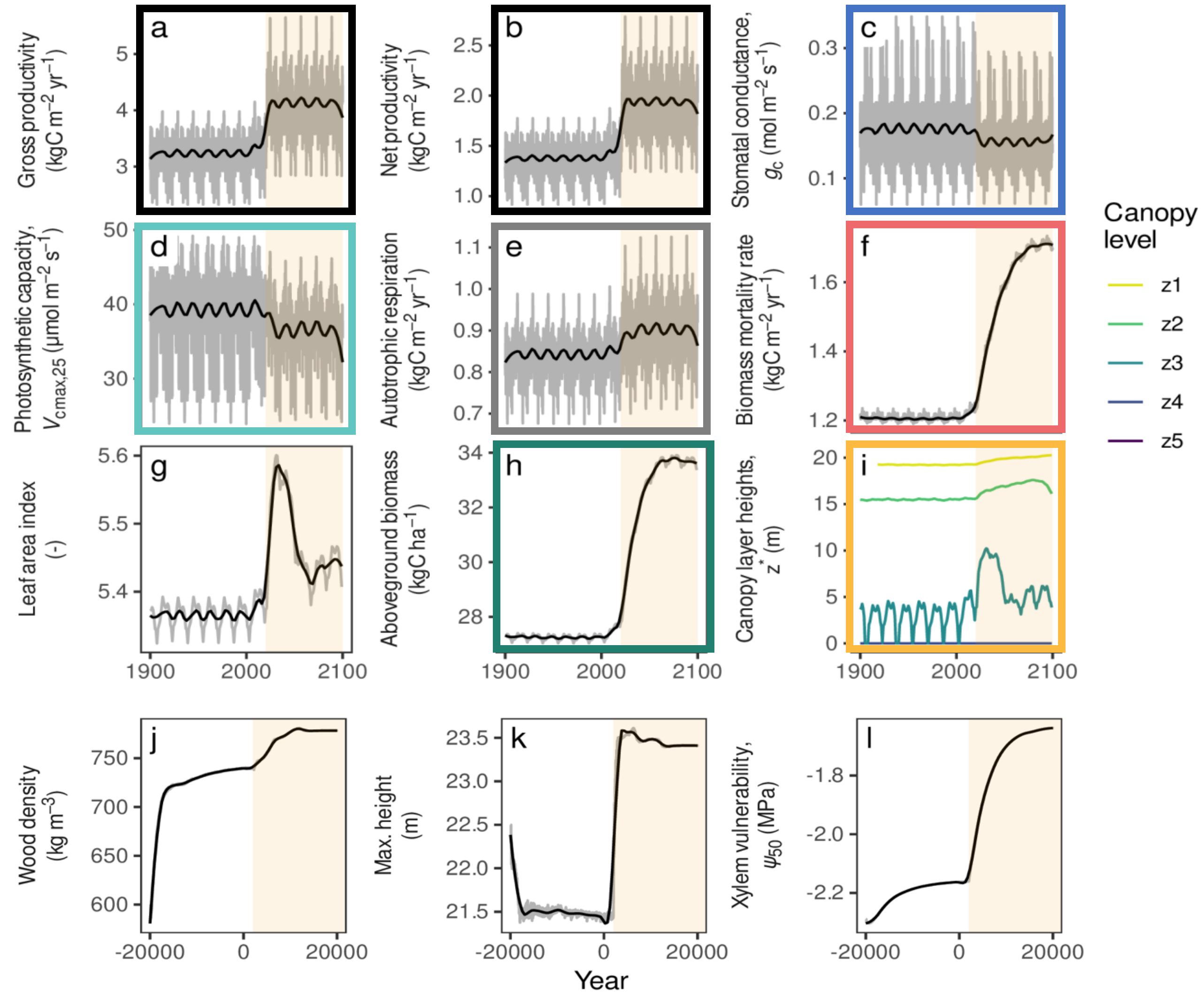
Consistent with ecological theory

fast-growing species with low wood densities initially dominate,

but are gradually and successively replaced by **slow-growing species** with longer lifespan.

Joshi, Hofhansl *et al.,* (2023). Competition for light can drive adverse species-composition shifts in the Amazon Forest under elevated CO2. *bioRxiv*. https://doi.org/10.1101/2023.07.03.547575

Results: eCO_2 enhances aboveground biomass and turnover



→ increase in **productivity** GPP (a), NPP (b), and **respiration** (e)

→ decrease in stomatal conductance (c) and photosynthetic capacity (d)

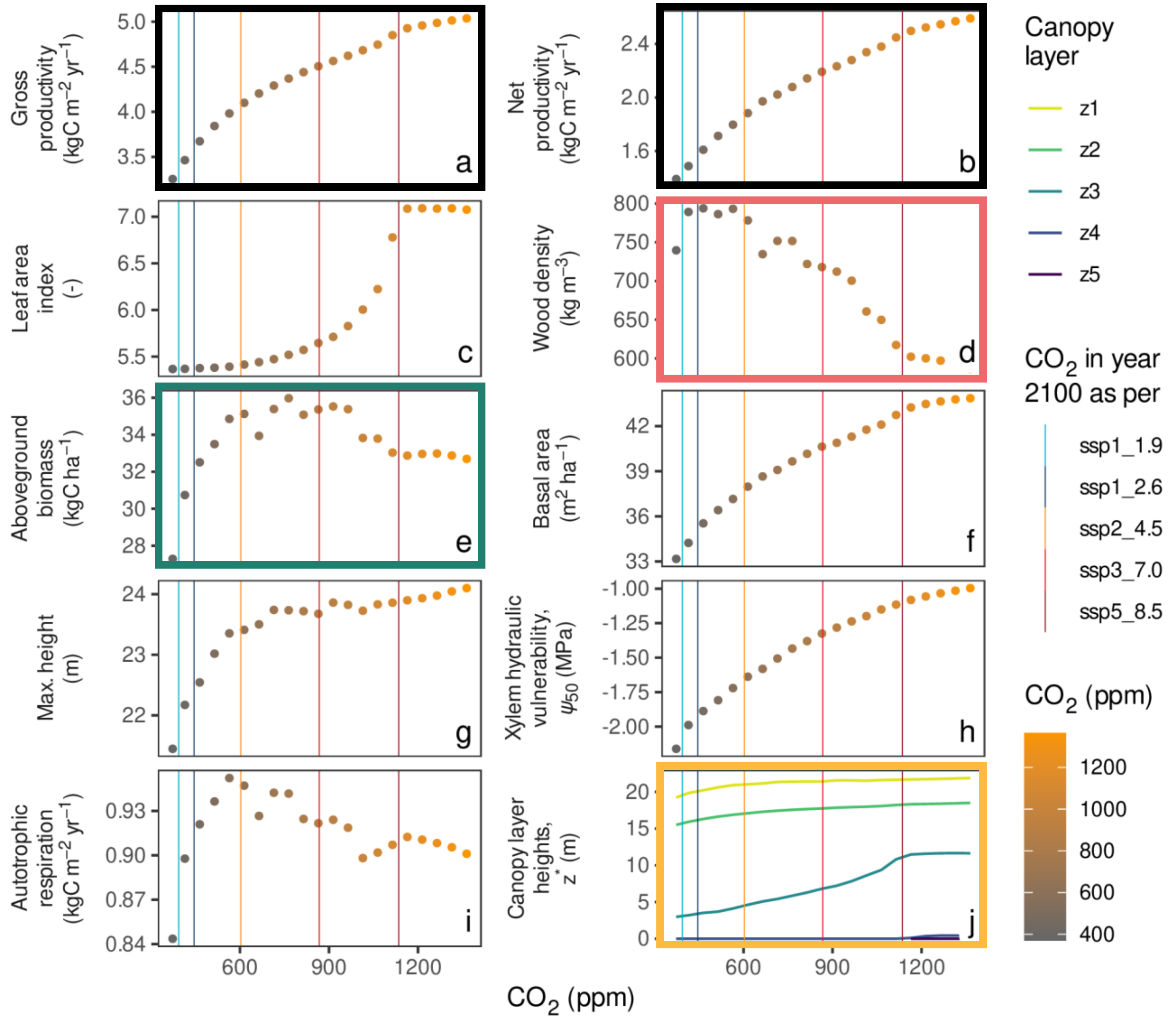
→ Leaf area and aboveground biomass increase (g-h), but also mortality rate (f)

→ Heights of canopy layers increase (i), making the understory darker.

→ Traits evolve towards higher wood density (j), higher maximum height (k), and less negative xylem hydraulic vulnerability (l).

Joshi, Hofhansl *et al.,* (2023). Competition for light can drive adverse species-composition shifts in the Amazon Forest under elevated CO2. *bioRxiv*. https://doi.org/10.1101/2023.07.03.547575

Results: reverse trends with progressively increasing eCO_2



Each point represents the respective steady state with CO_2 level indicated by point color (400 ppm – 1200 ppm)

<u>with increasing CO2 concentrations:</u>

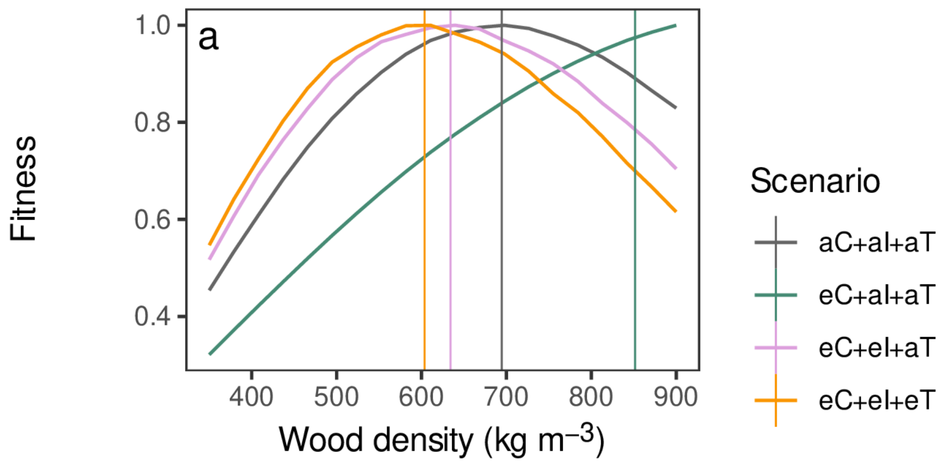
productivity increases monotonically (a,b),

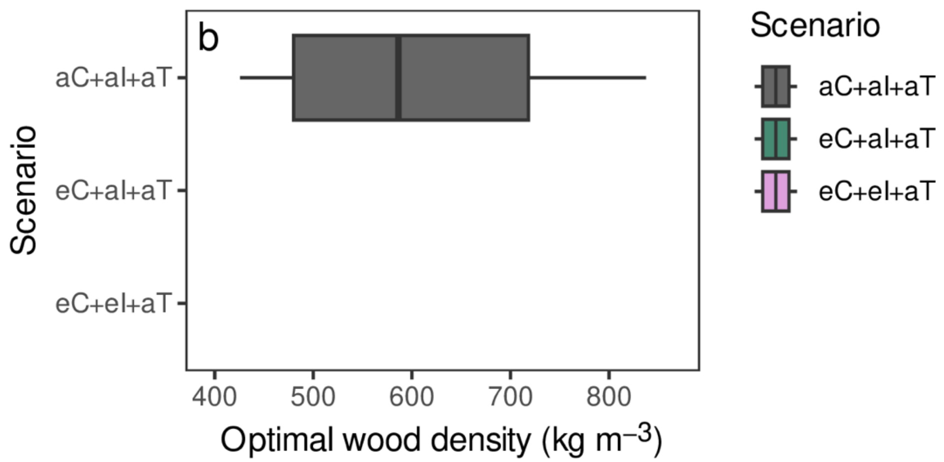
wood density and **aboveground biomass initially increase** but then peak and **decrease beyond 600 ppm** (d,e).

canopy layer heights increase, causing intensifying competition for light and thus <u>increasing understory mortality</u> (j).

Joshi, Hofhansl *et al.,* (2023). Competition for light can drive adverse species-composition shifts in the Amazon Forest under elevated CO2. *bioRxiv*. https://doi.org/10.1101/2023.07.03.547575

Results: eCO_2 affects wood density, but feedbacks!





Fitness of individual trees as a function of wood density under the **scenario: aC+aI+aT/eC+aI+aT/eC+eI+aT/eC+eI+eT**

→ Fitness peaks at different values of wood density (vertical lines), reflecting the **trade-off between growth and survival**.

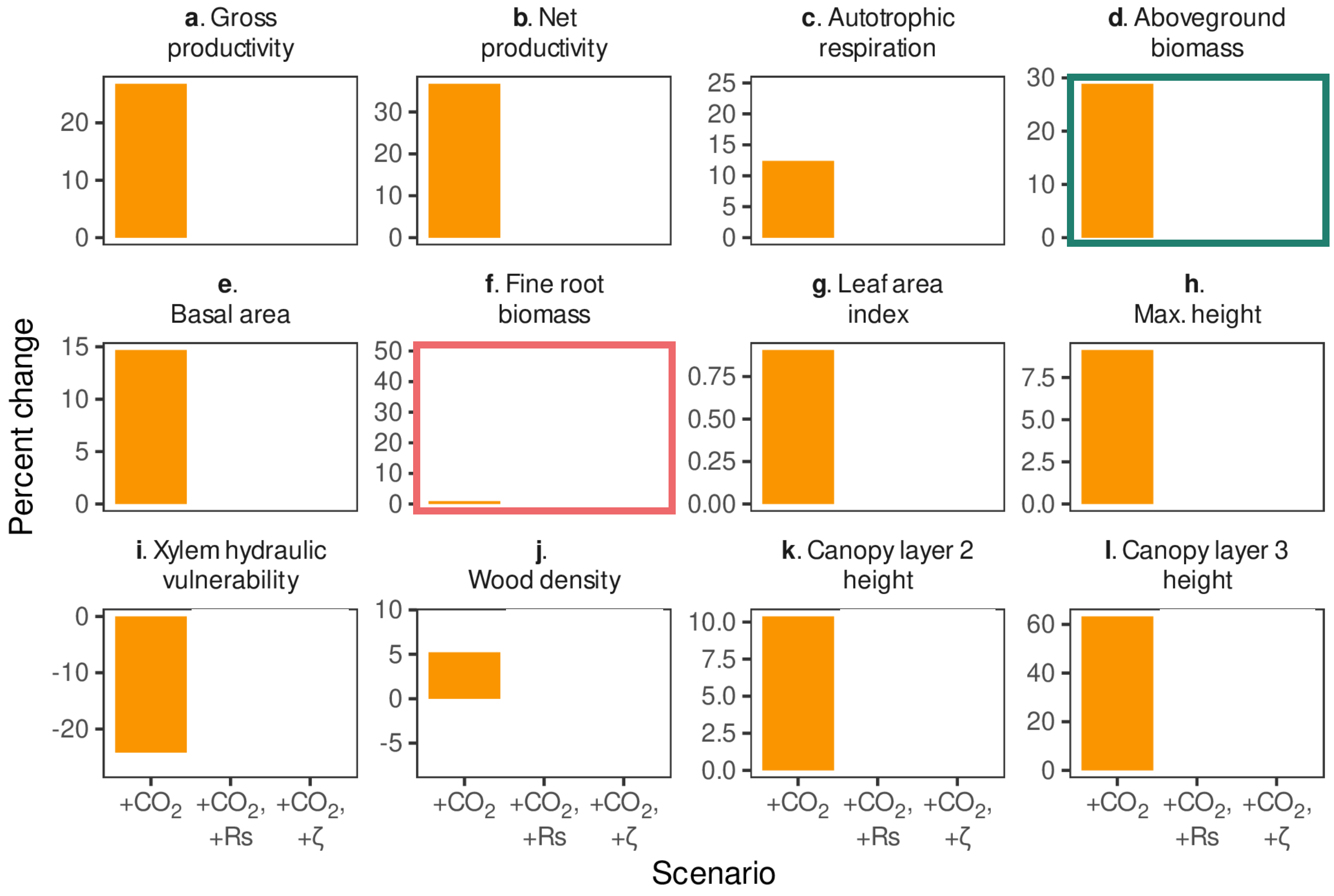
Optimal wood density (corresponding to the fitness maxima):

→ **under elevated CO_2** but in the absence of environmental feedbacks, **trees with higher wood density are fitter.**

→ However, when **environmental feedbacks** are accounted for **optimal wood density decreases** as compared to baseline.

Joshi, Hofhansl *et al.,* (2023). Competition for light can drive adverse species-composition shifts in the Amazon Forest under elevated CO2. *bioRxiv*. https://doi.org/10.1101/2023.07.03.547575

Results: increased respiration and belowground allocation reduce the CO_2-fertilization effect on aboveground biomass



- **Elevated CO_2 (614.2 ppm)**

eCO_2 + 50% increase in feedback

- **sapwood respiration (+Rs)**

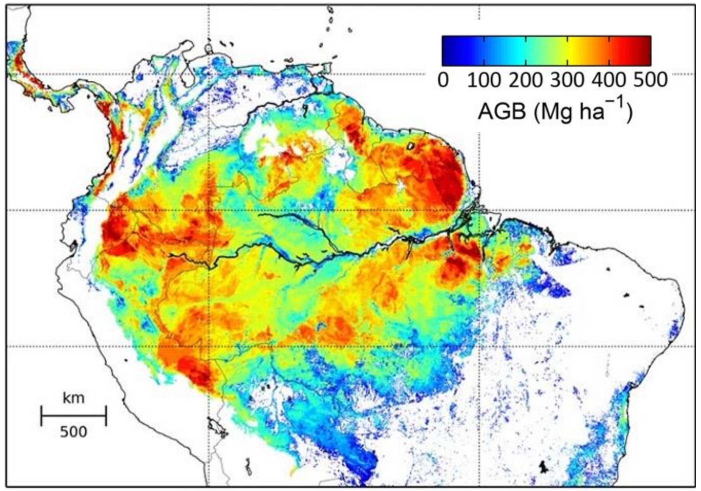
increase in sapwood respiration rate, (due to increasing temperature)

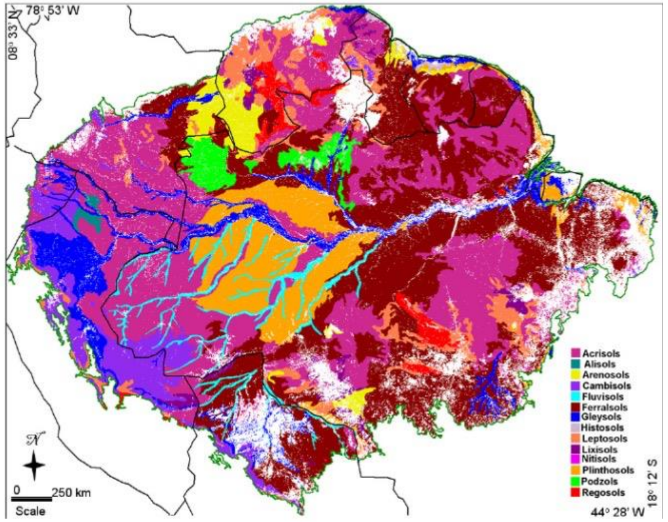
- **belowground allocation (+ζ)**

increased belowground allocation (response to nutrient limitation)

Joshi, Hofhansl *et al.,* (2023). Competition for light can drive adverse species-composition shifts in the Amazon Forest under elevated CO2. *bioRxiv*. https://doi.org/10.1101/2023.07.03.547575

Outlook: account for belowground processes





Above-ground

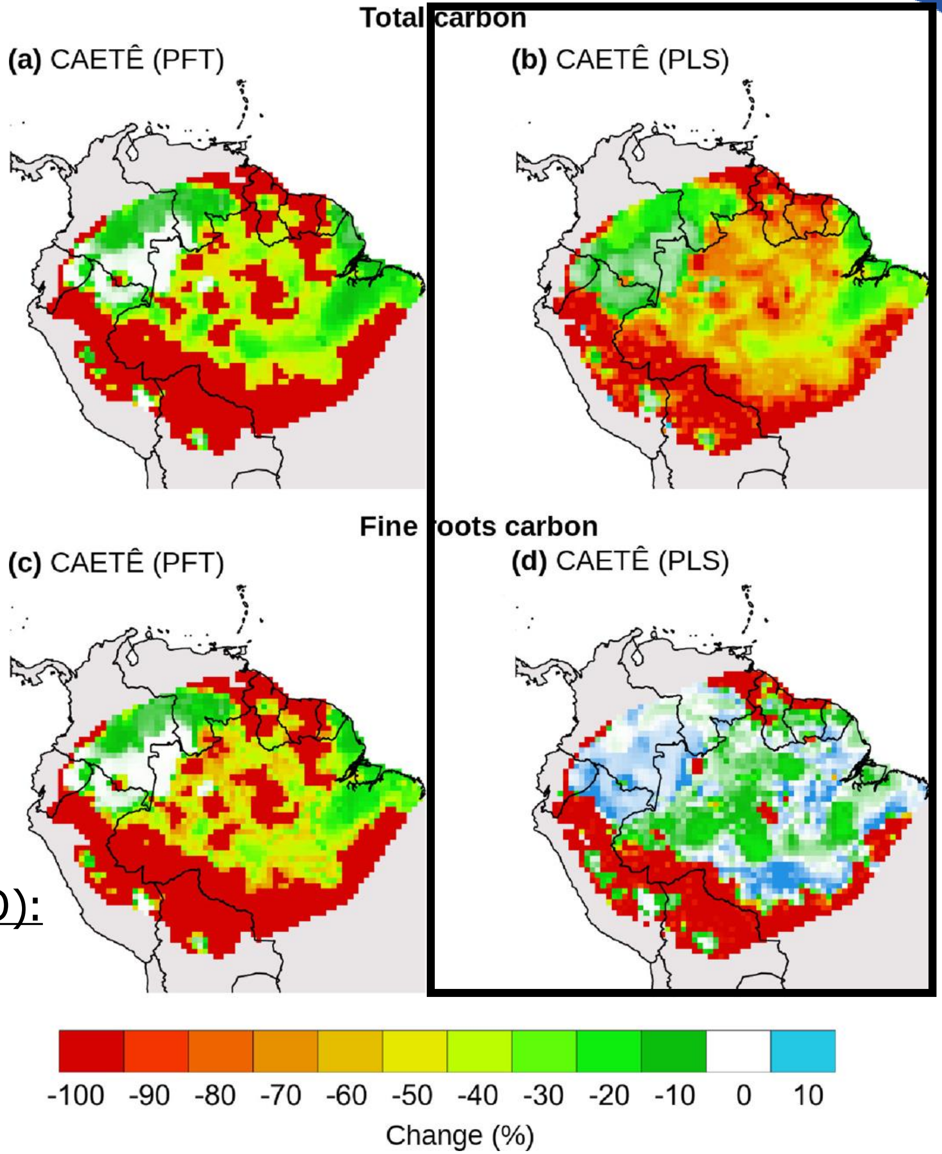
Below-ground

Plant life strategy (PLS):

→ Functional response

Eco-Evolutionary Optimization (EEO):

→ Functional process



References: Rödig et al., (2017); Quesada et al. (2012); Rius et al., (2023); Hofhansl et al., (2021)

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Thank you for your attention – contact me!

For further info (and follow-up questions) **please scan QR code to my profile!**

Joshi, J., Stocker, B.D., Hofhansl, F., et al., (2022). *Nature Plants* 10.1038/s41477-022-01244-5.