EARTH & ENVIRONMENTAL SCIENCES

BERKELEY LAB

Data-driven approach to represent multiple plant functional types across the wet and dry tropics with FATES

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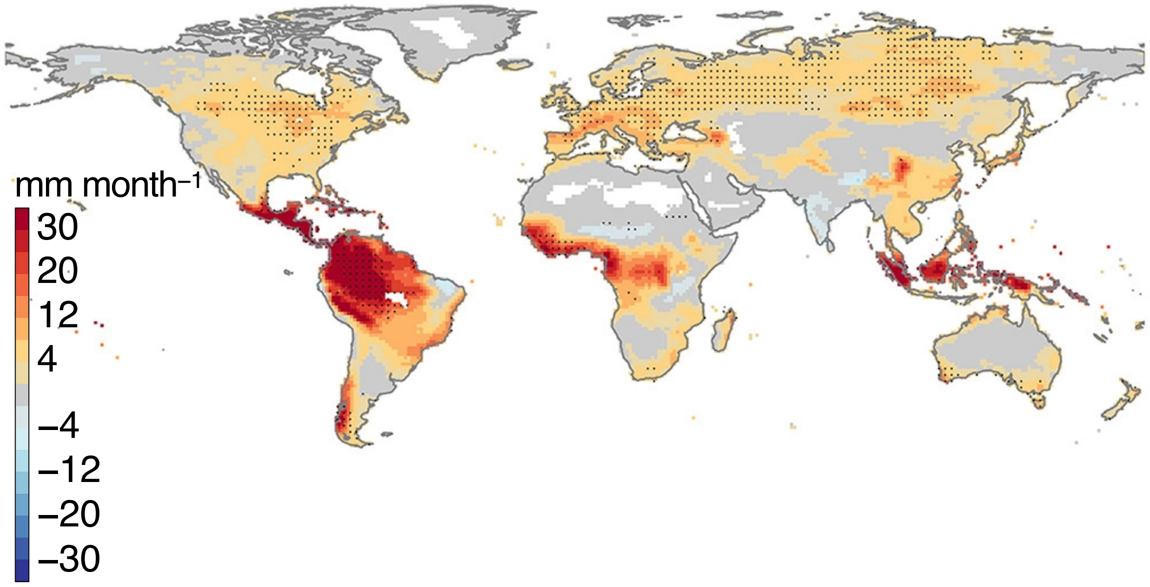
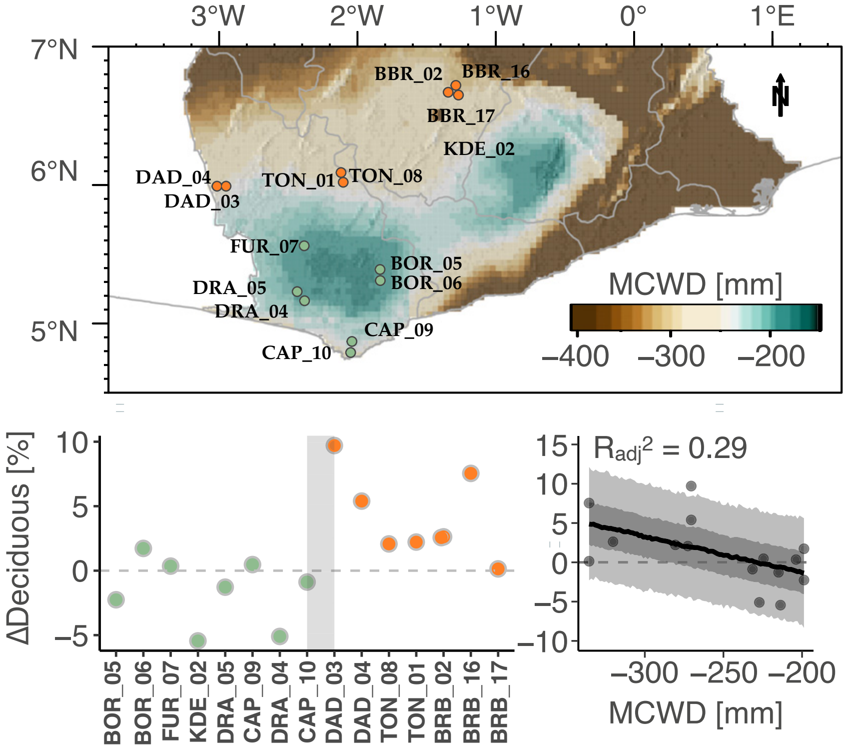
NGEE-Tropics

Introduction

Changes in drought intensity
CMIP6 (2051–2100)



Ukkola et al. (2020) *GRL*
10.1029/2020GL087820



Aguirre-Gutierrez et al. (2021) *Ecol. Lett.*
10.1111/ele.13243

Warming and rainfall decrease → hydrological drying in tropical South America

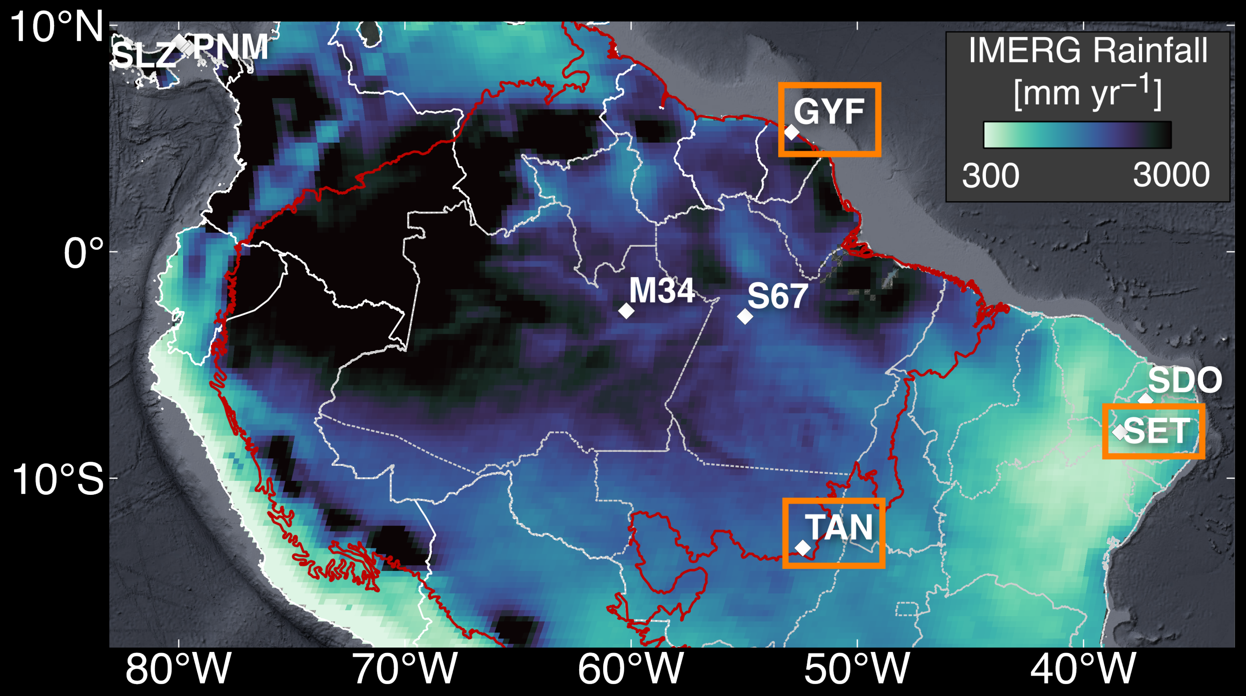
Ongoing drying → increase in drought deciduousness in seasonal tropical forests

Objectives and research questions

Implement drought-deciduous phenology in a cohort-based dynamic vegetation model (FATES)

Use multiple trait databases to define regional tropical plant functional types (PFTs) in FATES

Assess FATES coexistence of PFTs along a precipitation gradient in the Neotropics



Precipitation data from 10.5067/GPM/IMERG/3B-MONTH/06

Data-driven PFT definition

Input data sets

TRY
Kattge et al. (2020) *GCB*
10.1111/gcb.14904

LT-Brazil
Mariano et al. (2021) *GEB*
10.1111/geb.13381

Sustainable Landscapes
dos Santos et al. (2021)
10.3334/ORNLDAAC/2007

TALL
Jucker et al. (2022) *GCB*
10.1111/gcb.16302

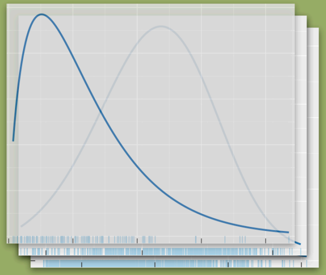
NGEE-Tropics
https://ngt-data.lbl.gov/dois/

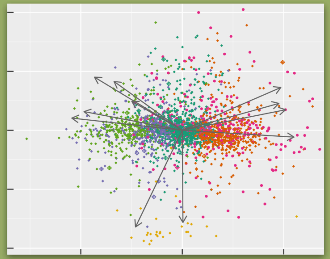
and additional data from literature

PFT attribution

1

Normalize numeric traits based on best fitted distribution

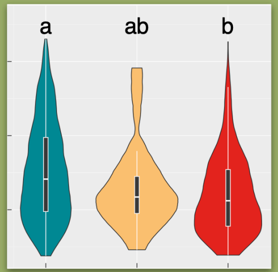


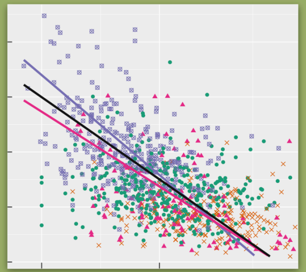


2

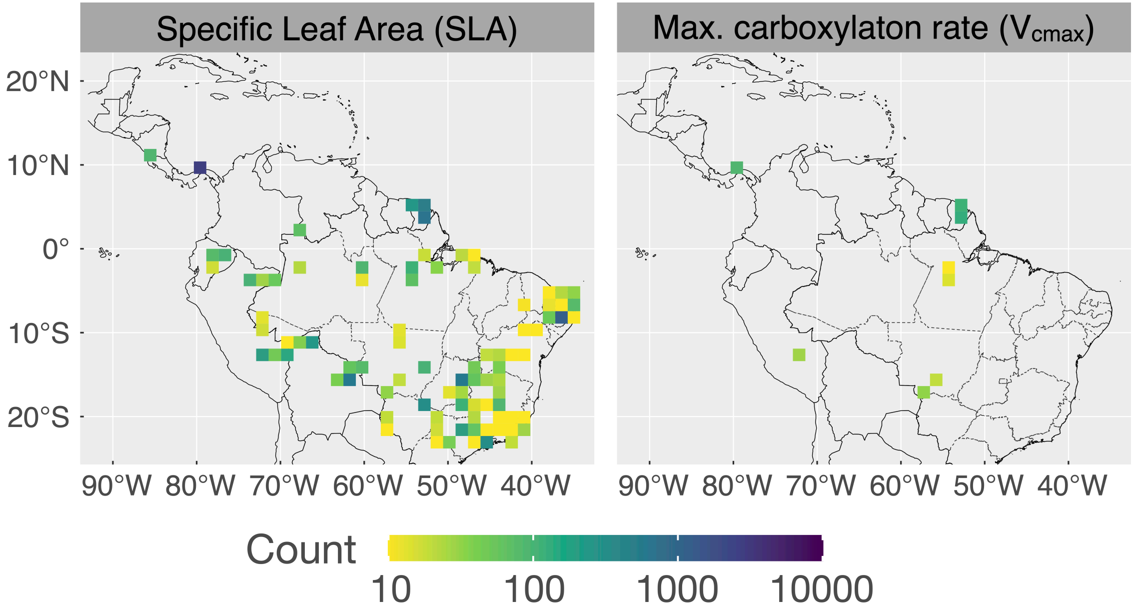
Obtain the optimal number of clusters (gap statistics)

3 Obtain trait distributions and trait tradeoffs globally and for each cluster

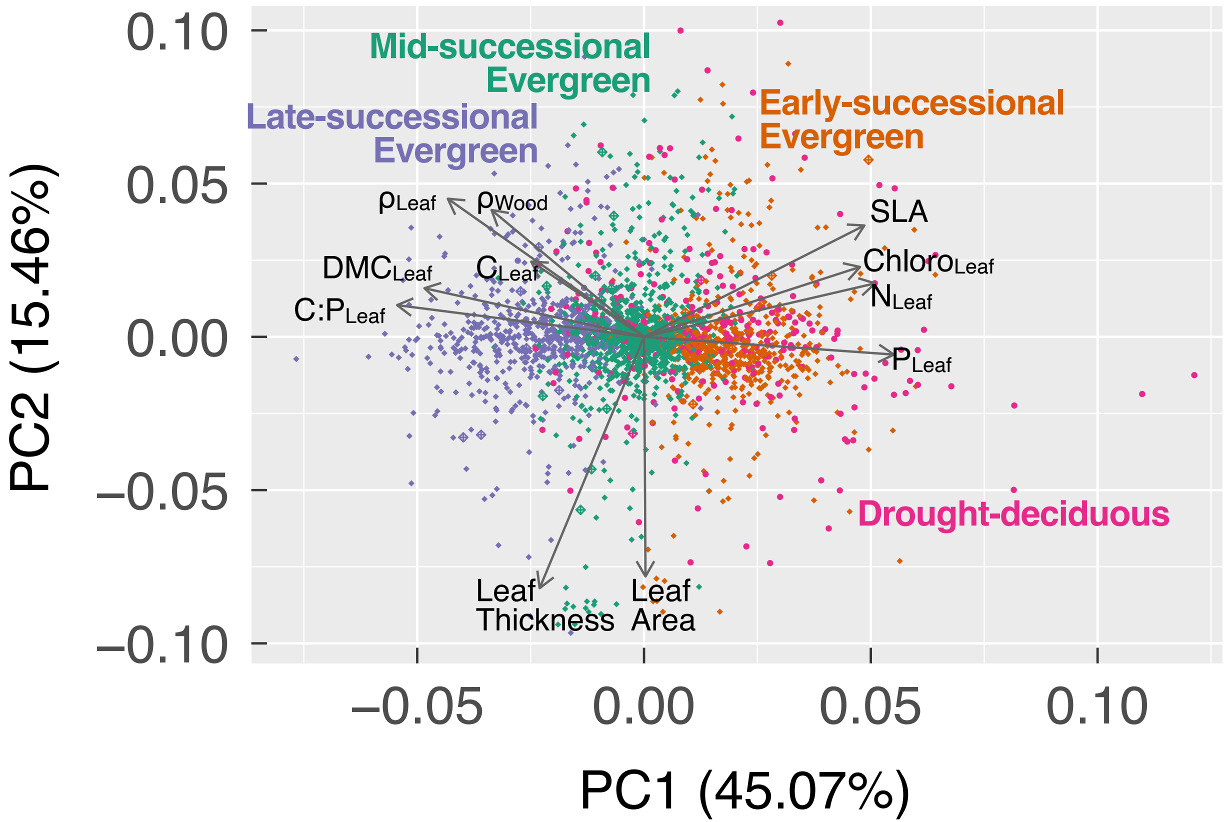


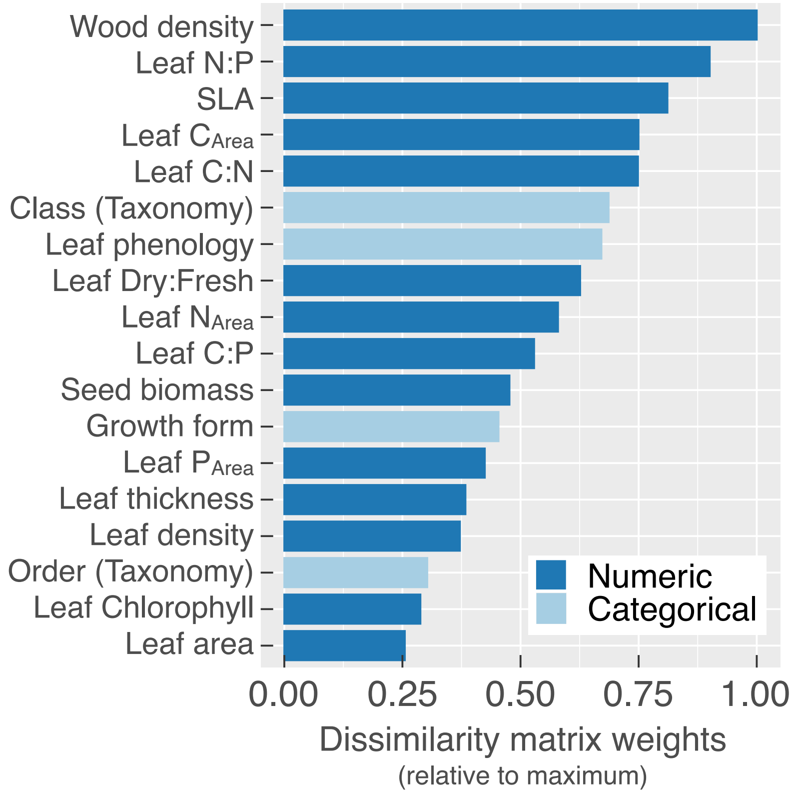


- **144,150** observations in Neotropics
- **4130** species
- **68** traits (**24** traits for > 500 species)



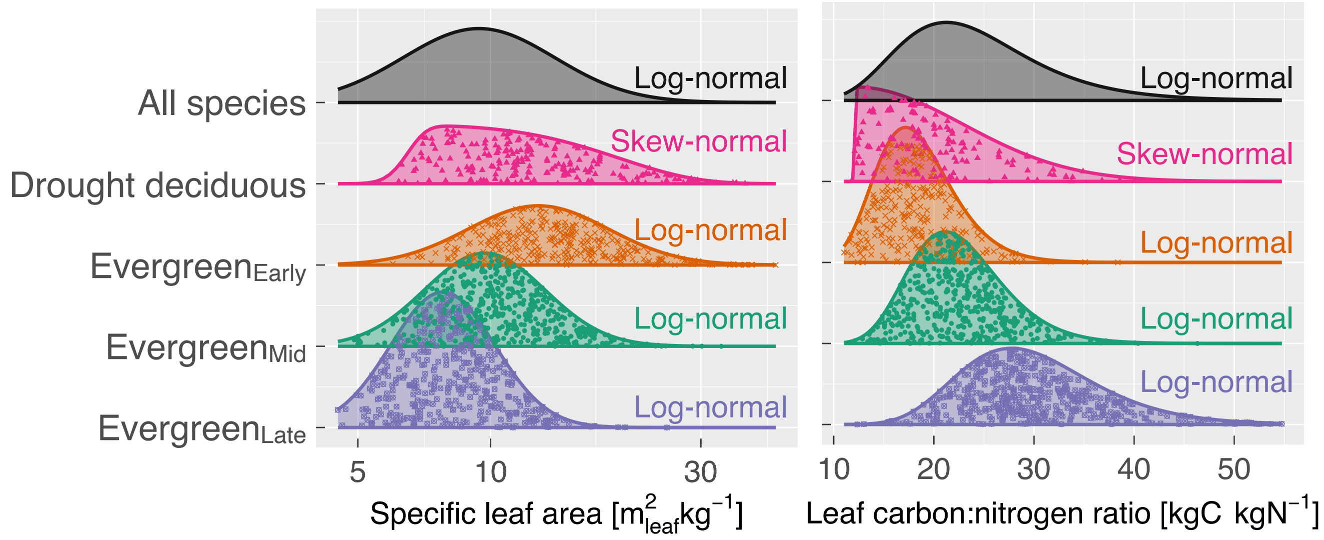
Trait-based PFT definitions



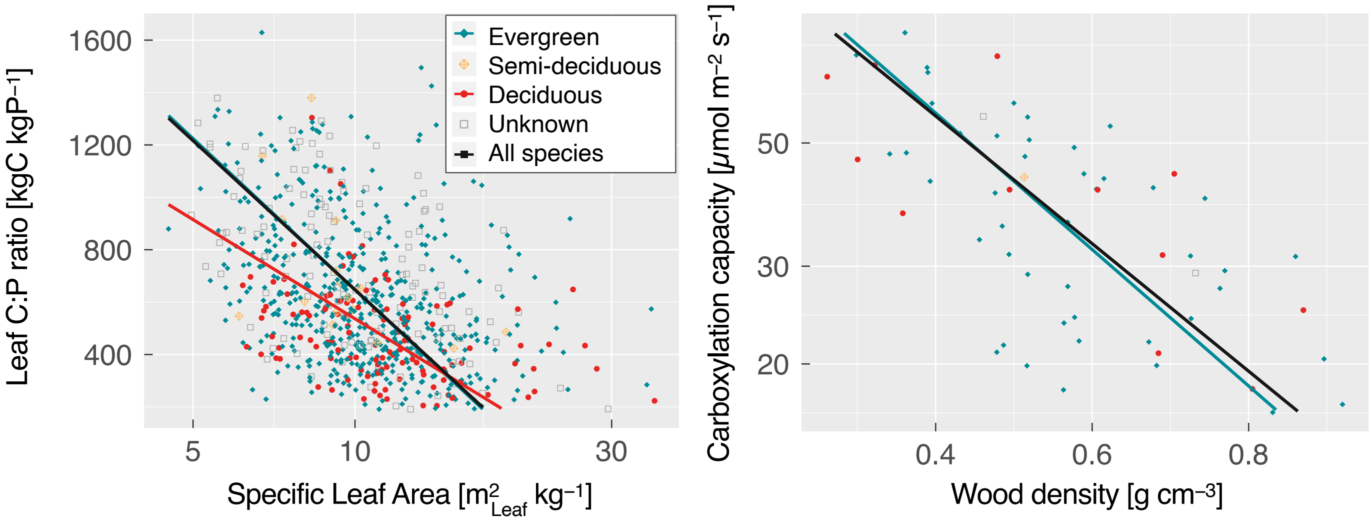


- Optimal number of clusters (k=4) based on gap statistics
- Evergreen clusters associated to acquisition-survivorship trade-offs; single deciduous cluster
- Few semi-deciduous measurements (mostly grouped with evergreens)

Trait distribution and trade-offs across clusters



- Trait distribution across clusters:
  - Clear separation across evergreens
  - Drought-deciduous: similarities with early- or mid-evergreens



- Trait trade-offs:
  - Distinct relationships between evergreen and deciduous
  - Similar across evergreen groups
  - Lack of data limited most trade-offs to global (or no trade-off at all)

Drought-deciduous implementation in FATES

Water stress function:

$$\left\langle \psi_{\mathrm{PFT}} \right\rangle (t) = \frac{1}{10} \sum_{t'=t-9}^{t} \left[-\exp \left(\frac{\sum_{z=2}^{Z_{\mathrm{PFT}}} \left\{ \ln \left[-\psi_z \left(t' \right) \right] \rho_{\mathrm{PFT}_z} \, \Delta z \right\}}{\sum_{z=2}^{Z_{\mathrm{PFT}}} \left\{ \rho_{\mathrm{PFT}_z} \, \Delta z \right\}} \right) \right]$$

Running time-average

Average within rooting zone

Root abundance

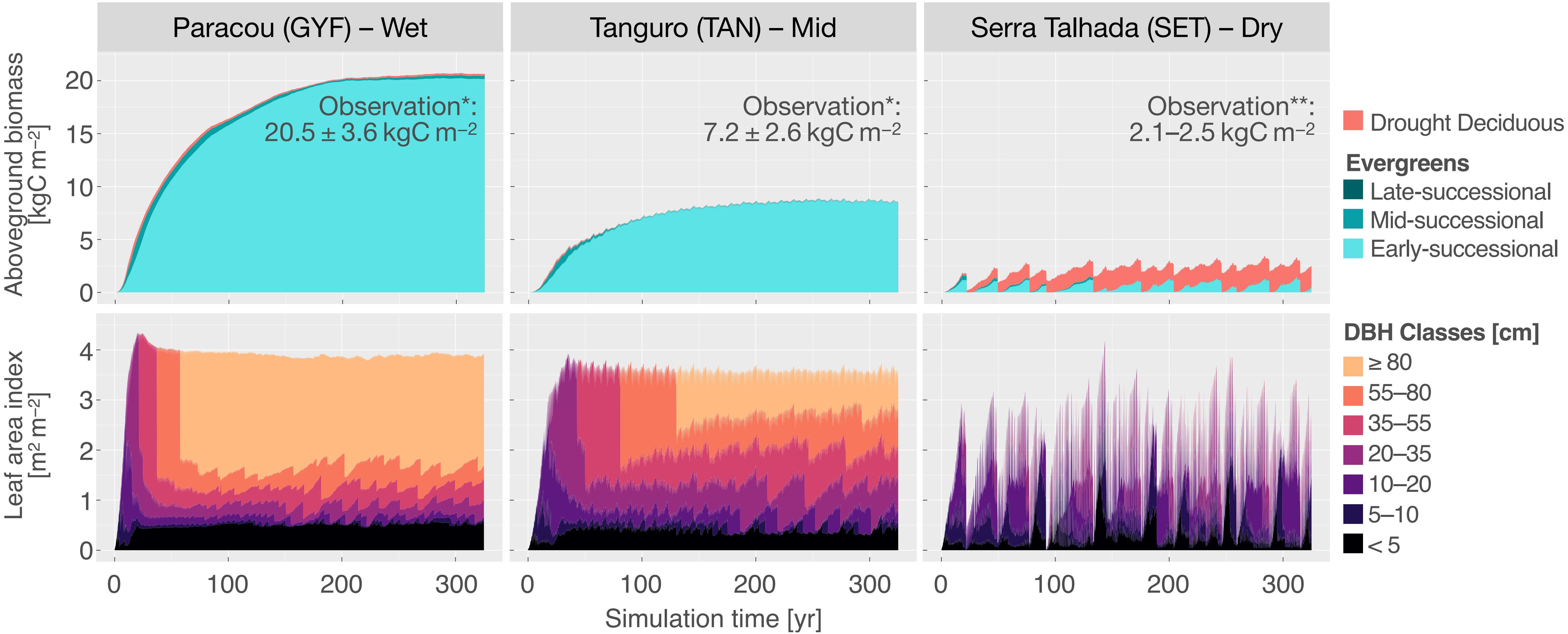
Soil layer thickness

Drought deciduous phases	
Leaf abscission	⟨ψ⟩ ≤ ψ_{crit} (no recent flushing) **or** Leaf age ≥ Leaf longevity
Leaf flushing	⟨ψ⟩ > ψ_{crit} (no recent abscission) **or** Last flushing > 13 months ago

Additional features:

- Phenological phase controls on carbon allocation
- Option for fine-root deciduousness
- Option for semi-deciduous phenology

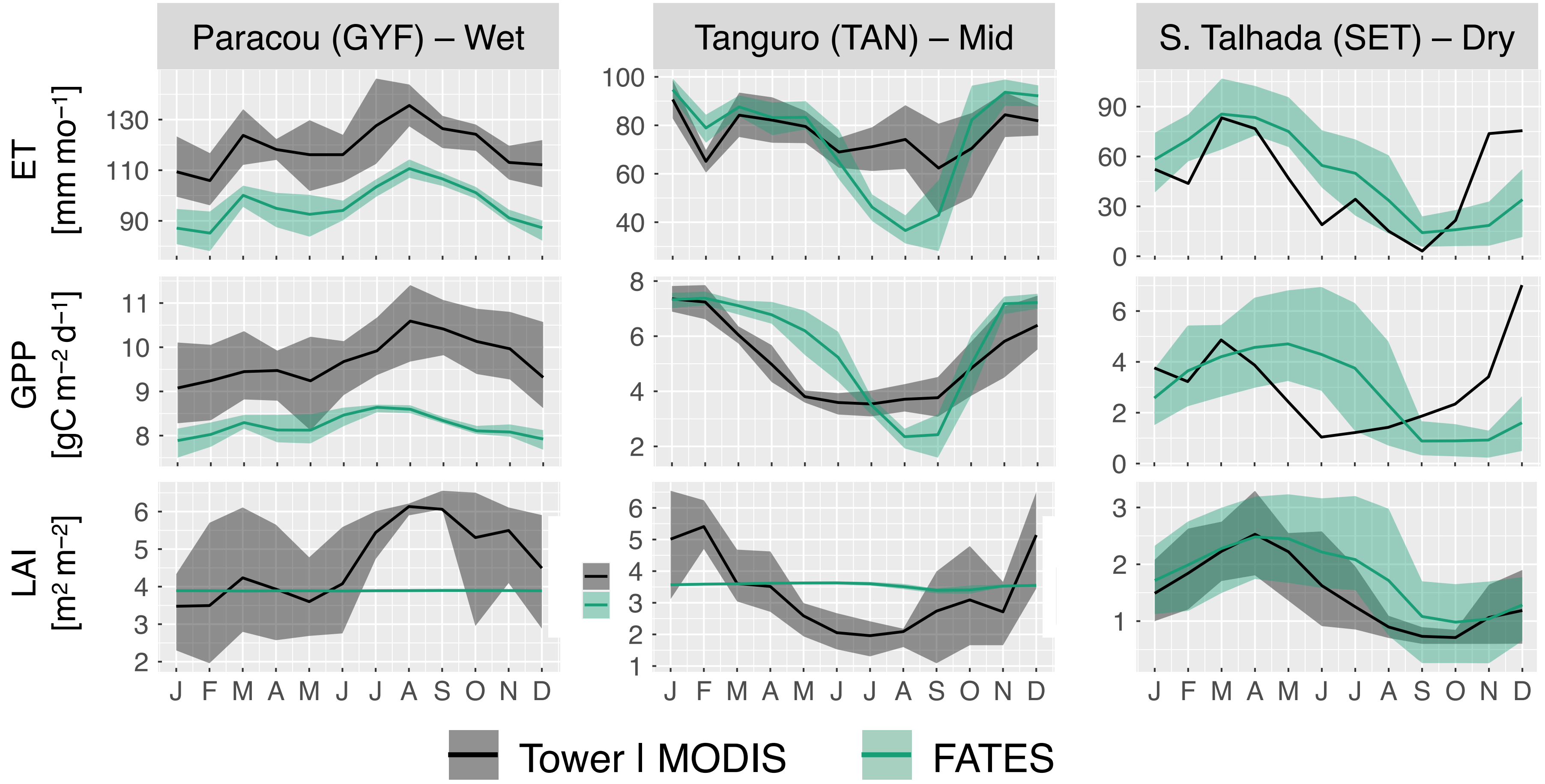
Long-term dynamics of biomass and LAI across rainfall gradient



*Estimate from plots, using allometry from Chave et al. (2014) *GCB* 10.1111/gcb.12629

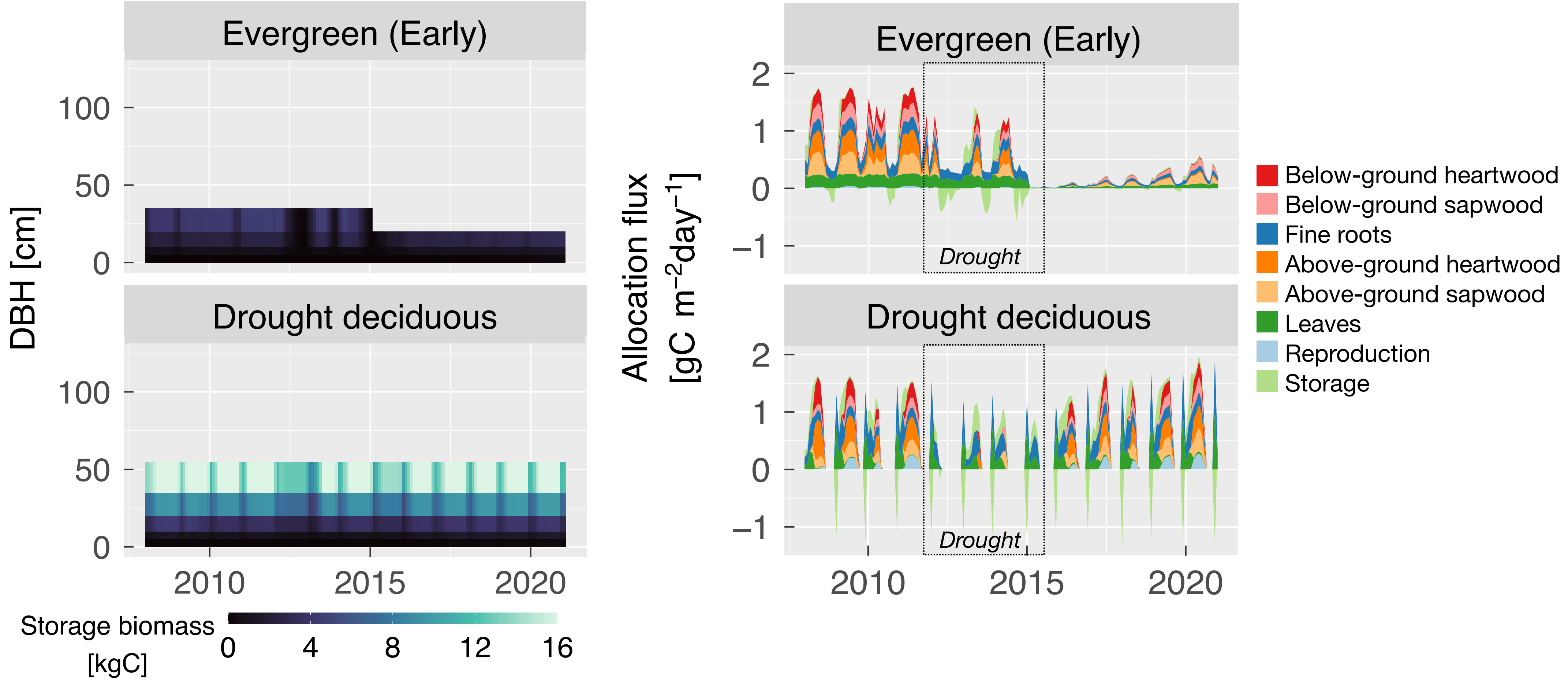
**Castanho et al. (2020) An. Acad. Bras. Ciênc. 10.1590/0001-3765202020190282

How well does FATES represent fluxes and phenology?



- Wet site: GPP and ET are biased low, but reasonable seasonal cycle
- TAN and SET: delayed dry-season drop → evergreen overestimation + water stress underestimation

Carbon allocation strategy – Serra Talhada



- Deciduous allocation allow higher survivorship during the 2012–2015 drought
- Evergreen fast recovery between drought allows maintaining population

Conclusions

- Seasonal carbon allocation strategies are critical for survivorship of drought deciduous trees

- Trait databases can be useful for defining PFTs, however distributions and trade-offs are limited by low sampling of many traits

- Next steps
  - Multi-site and multi-process model optimization based on trait distributions and trade-offs
  - Study impacts of climate change on leaf phenology dominance in the tropics.