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Future increase in Amazonia water stress from CO_2 physiology and deforestation

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Article

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Future increases in Amazonia water stress from CO_2 physiology and deforestation

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Check for updates

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Several different drivers are contributing to climate change within the Amazon basin, including forcing from greenhouse gases and aerosols, plant physiology responses to rising CO_2, and deforestation. Attribution among these drivers has not been quantified for Shared Socioeconomic Pathway (SSP) climate simulations. Here we identify the contribution of CO_2 physiology and deforestation to future hydroclimate change in the Amazon basin by combining information from four experiments and eight different Earth system models in Coupled Model Intercomparison Project Phase 6. Together, forcing from CO_2 physiology and deforestation account for about 44% of the projected annual precipitation decline, 48% of surface relative humidity decline and 11% of warming over the Amazon basin by 2100 for SSP3-7.0. Other Coupled Model Intercomparison Project Phase 6 SSP simulations have similar contributions from the two drivers. Insight from our attribution analysis can aid in identifying research priorities aimed at reducing uncertainty in future projections of water availability, carbon dynamics and wildfire risk.

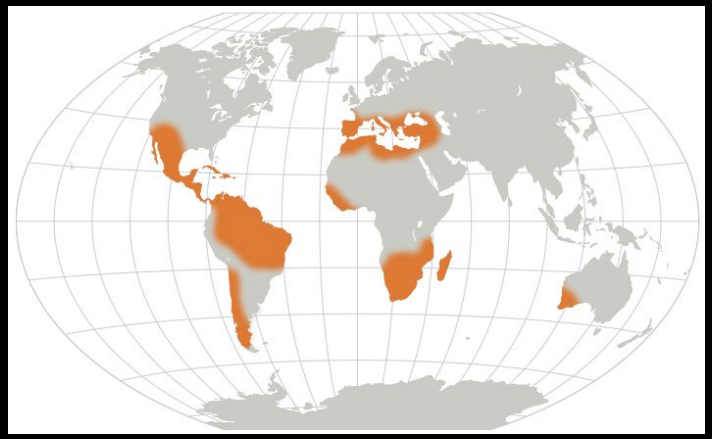
https://rdcu.be/dkR4Z

Deforestation and future drought risks in Amazonia

Pic credit: Dr. Paulo Brando

- Increasing ATM CO_2
- Climate risks
  e.g. extreme drought

Future drought hotspots



(IPCC AR6, Chapter 8)

Accumulated evidence of "CO_2 fertilization" for carbon sink

New Phytologist

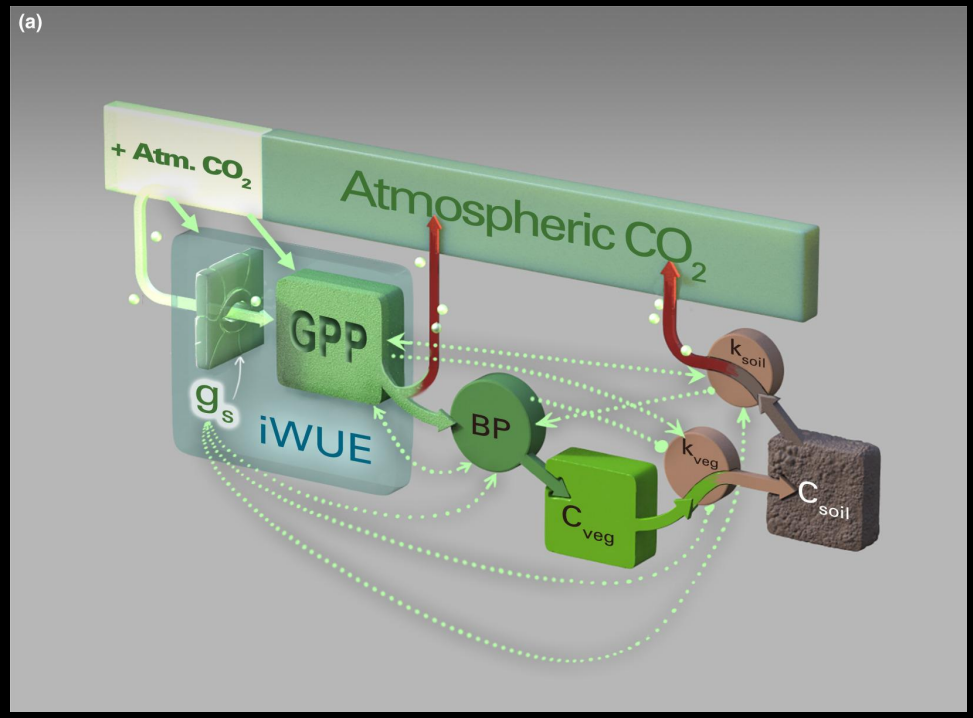
Tansley review | Free Access

Integrating the evidence for a terrestrial carbon sink caused by increasing atmospheric CO_2

Anthony P. Walker, Martin G. De Kauwe, Ana Bastos, Soumaya Belmecheri, Katerina Georgiou, Ralph F. Keeling, Sean M. McMahon, Belinda E. Medlyn, David J. P. Moore ... See all authors

First published: 12 August 2020 | https://doi.org/10.1111/nph.16866 | Citations: 231

See also the Commentary on this article by Way *et al.*, **229**: 2383–2385.



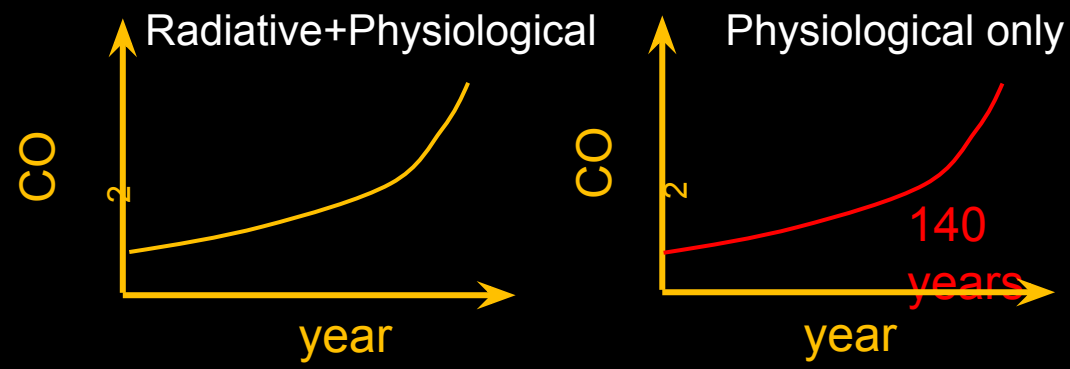
Theory and experiment evidence support increased GPP and water use efficiency in response to CO_2.

g_s response is yet negative □ declined evapotranspiration, precipitation (Amazonia)

How does plant physiological response to CO_2 affect rainfall?

CMIP6-C4MIP

(Jones et al. 2016, GMD)



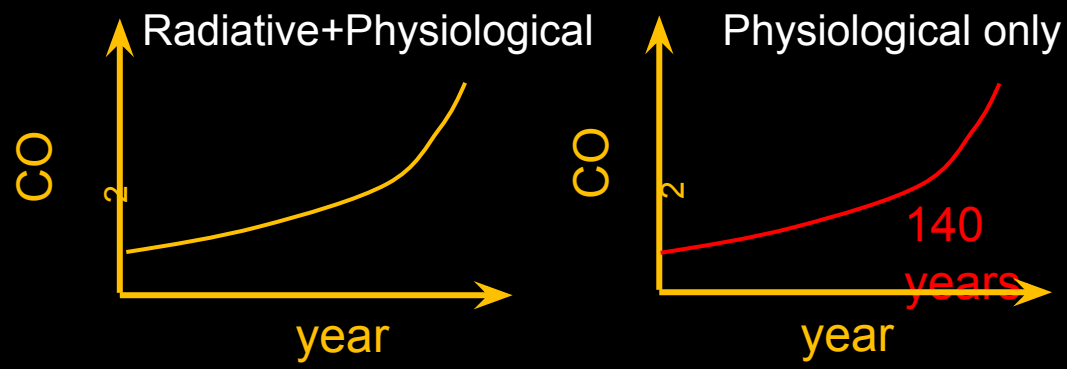
8 CMIP6 models averaged in this study:

BCC-CSM2-MR (Wu et al. 2019),
CanESM5 (Swart et al. 2019),
CESM2 (Danabasoglu et al. 2020),
CNRM-ESM2-1 (Séférian et al. 2019),
IPSL-CM6A-LR (Boucher et al. 2020),
GISS-E2-1-G (Kelley et al. 2020),
MPI-ESM1-2-LR (Mauritsen et al. 2019),
UKESM1-0-LL (Sellar et al. 2020)

How does plant physiological response to CO_2 affect rainfall?

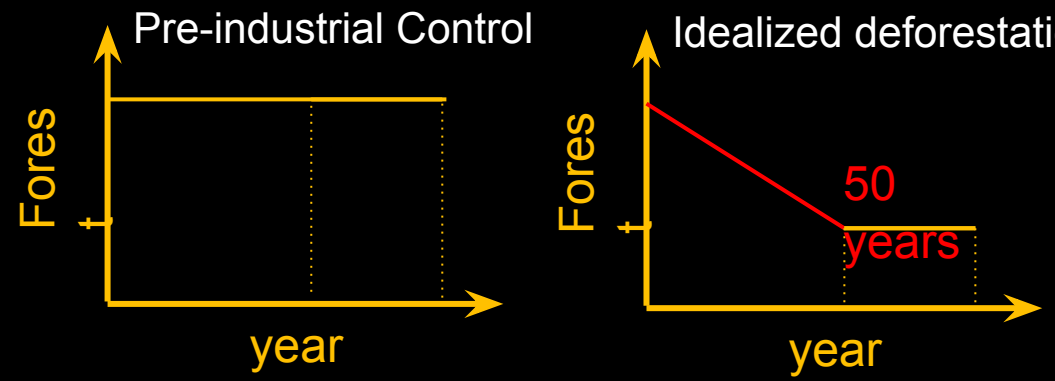
CMIP6-C4MIP

(Jones et al. 2016, GMD)



CMIP6-LUMIP

(Lawrence et al. 2016, GMD)



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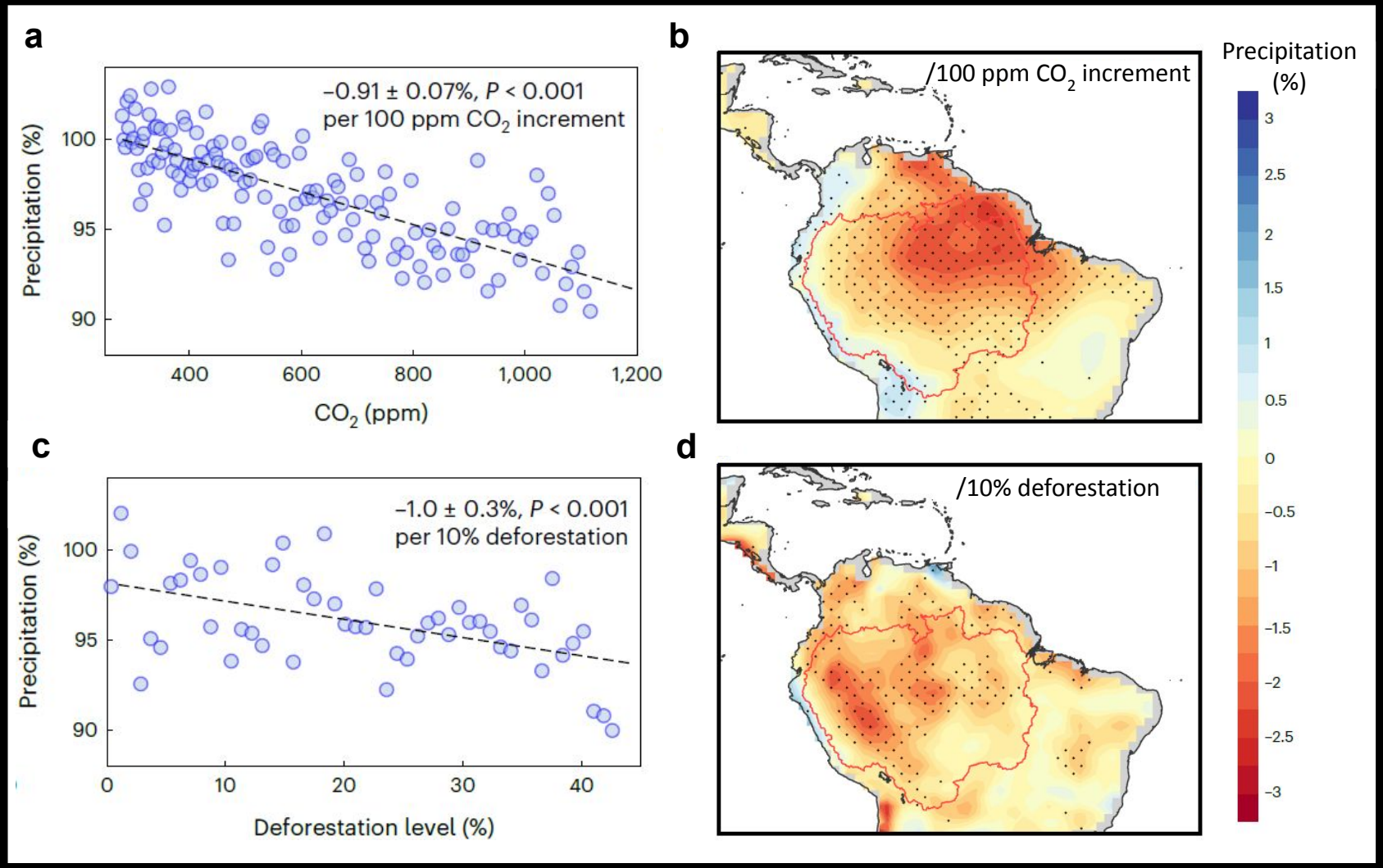
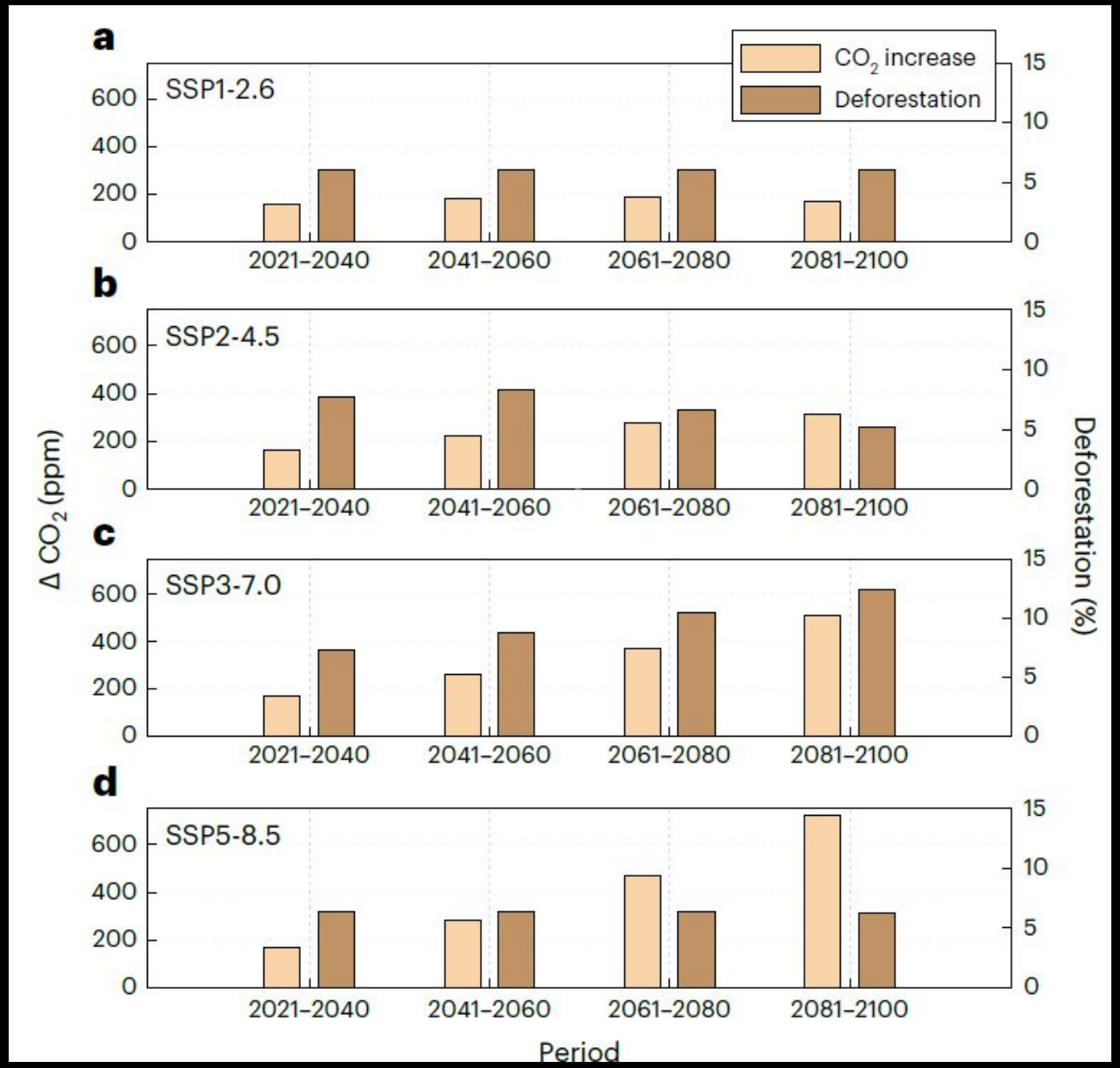


Most models agree more on the rainfall decline in the northeastern Amazon regarding CO_2 physiology

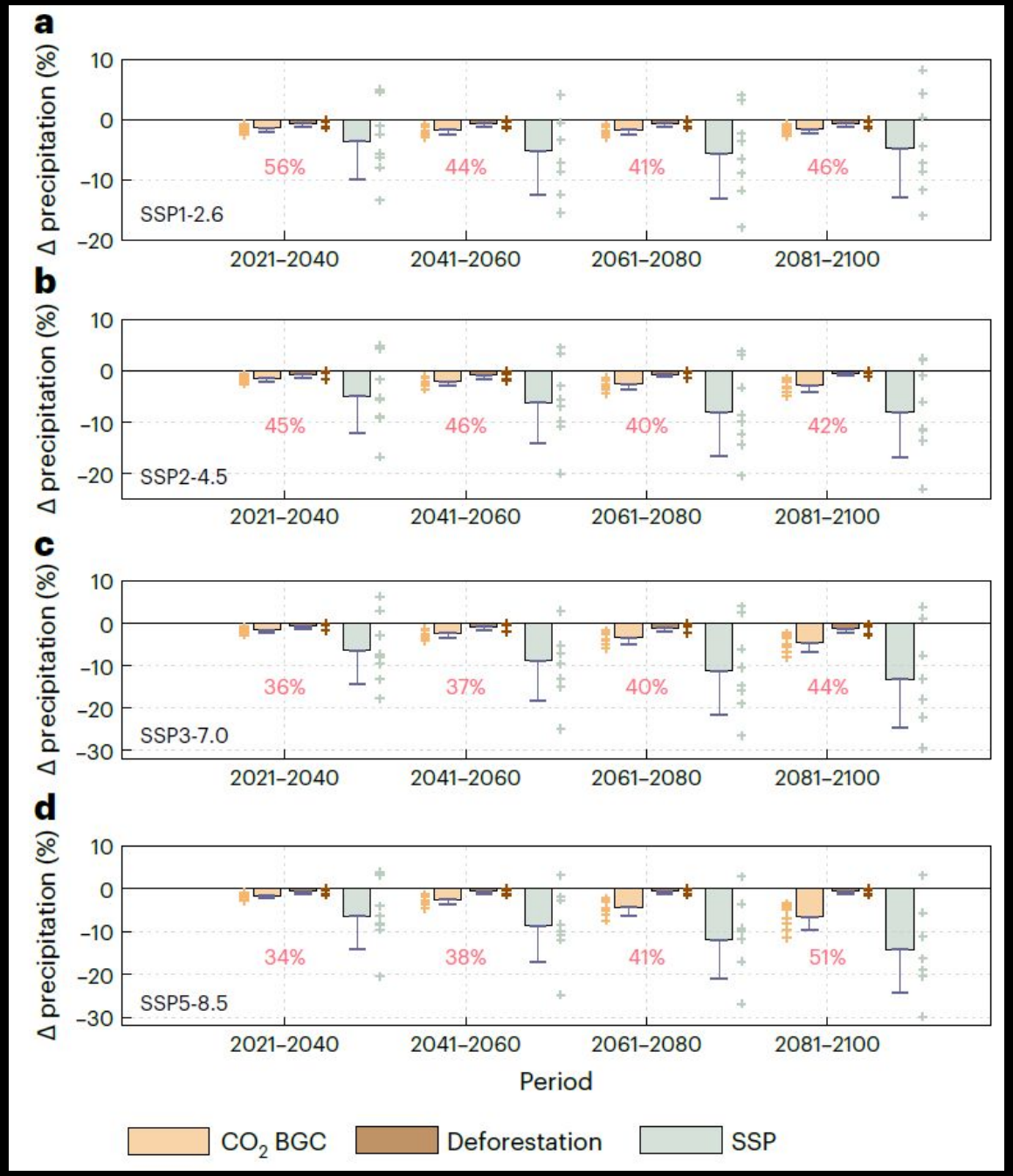
Most models agree more on the rainfall decline in the middle-west Amazon in response to deforestation

Li Y. *et al.* (2023). *Nat Water*



Li Y. *et al.* (2023). *Nat Water*

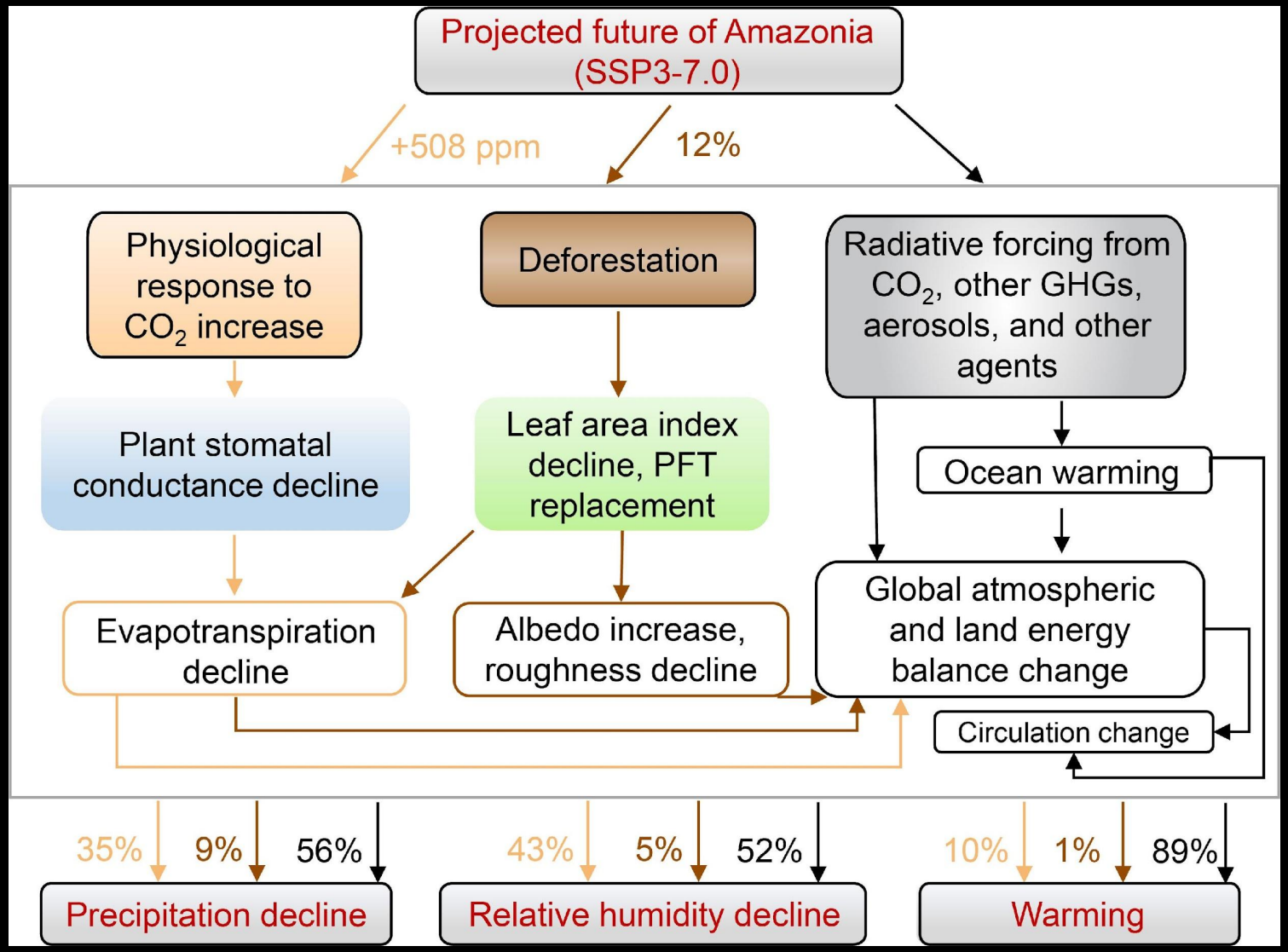
- Varied CO_2 concentration and deforestation fraction across future SSP scenarios



- CO_2 fertilization and deforestation account for **at least 40%** of future decline in rainfall in the Amazon

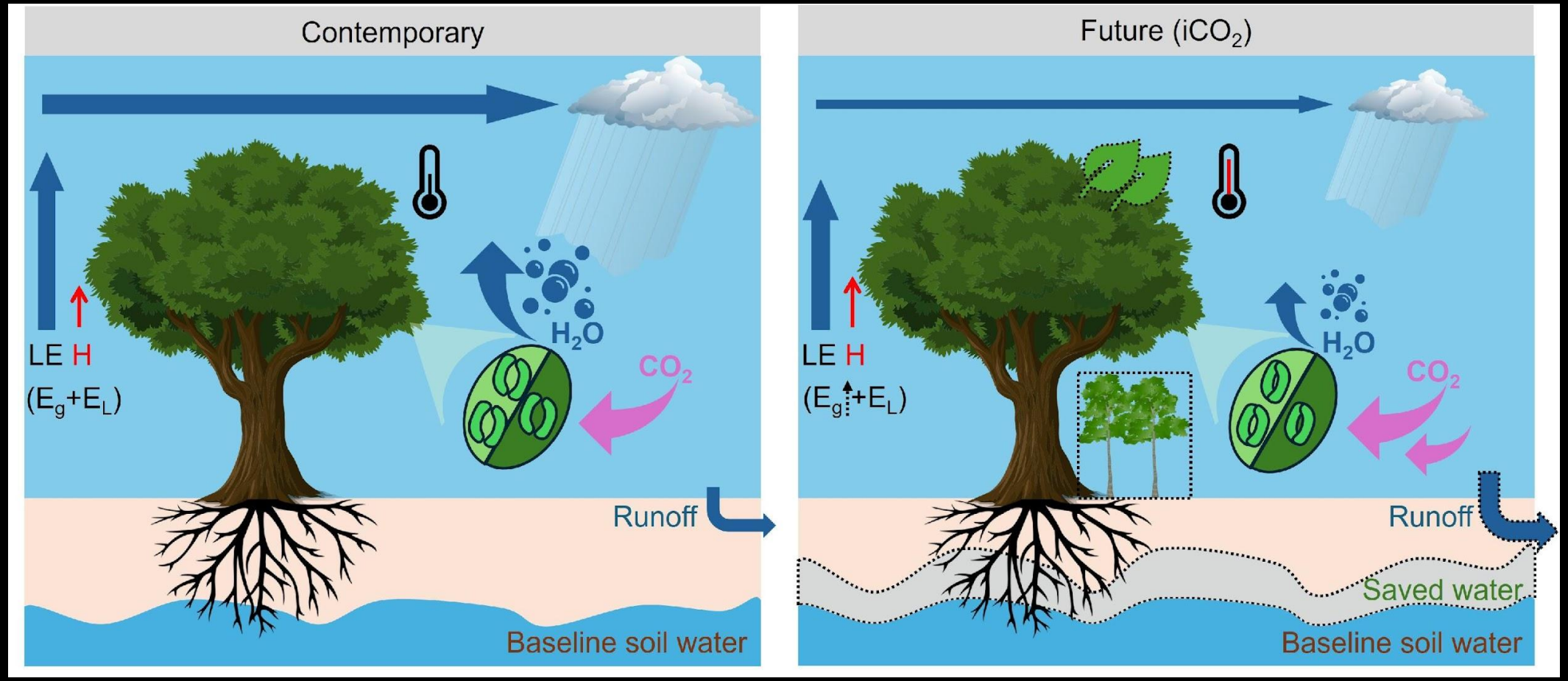
Li Y. *et al.* (2023). *Nat Water*

- **At least 40%** of future precipitation and relative humidity decline are attributed to land surface drivers in the Amazonia.
- Contributions to warming are about 11% from these two.



Li Y. *et al.* (2023). *Nat Water*

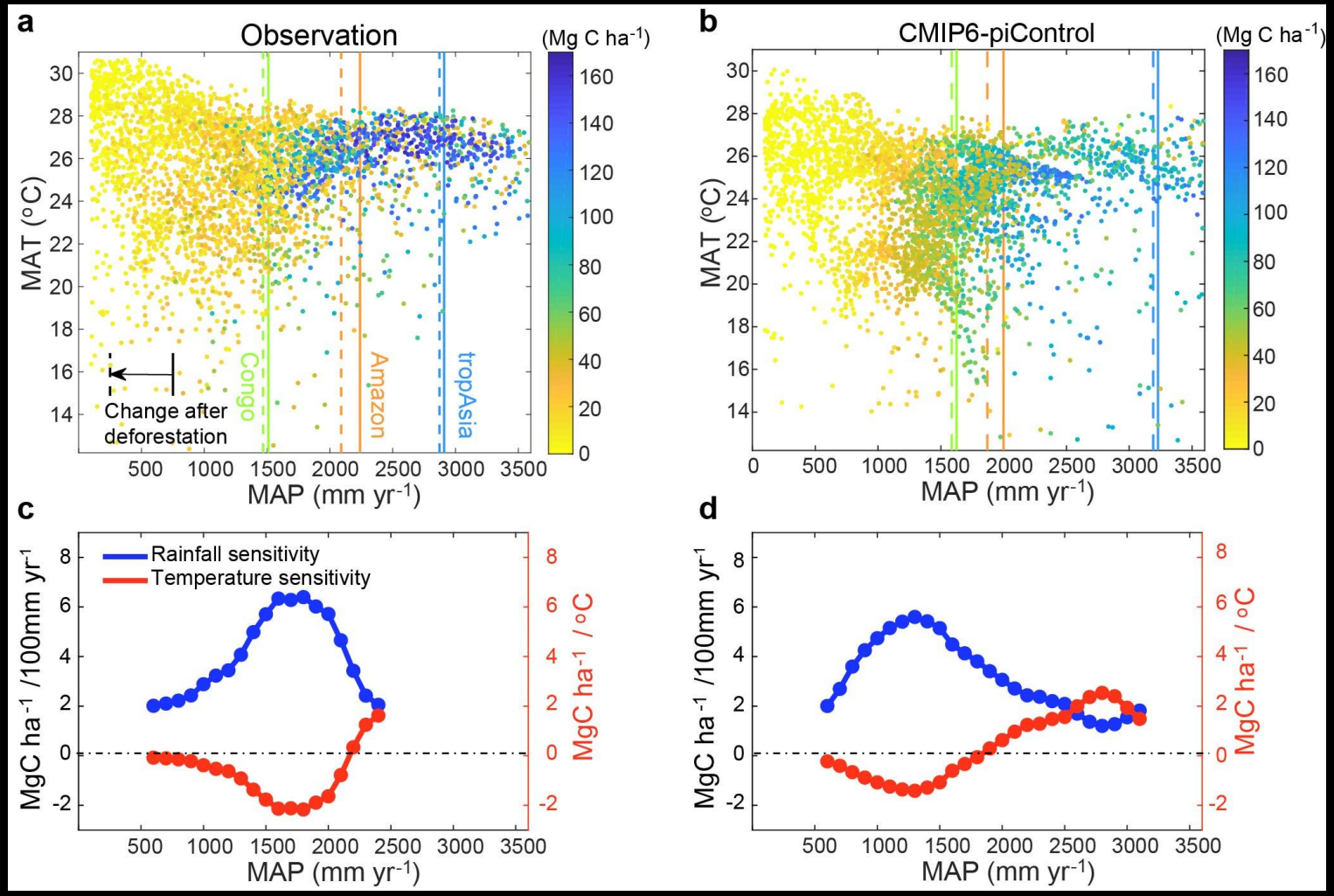
Is rainfall decline really a water stress?



Li Y. in prep

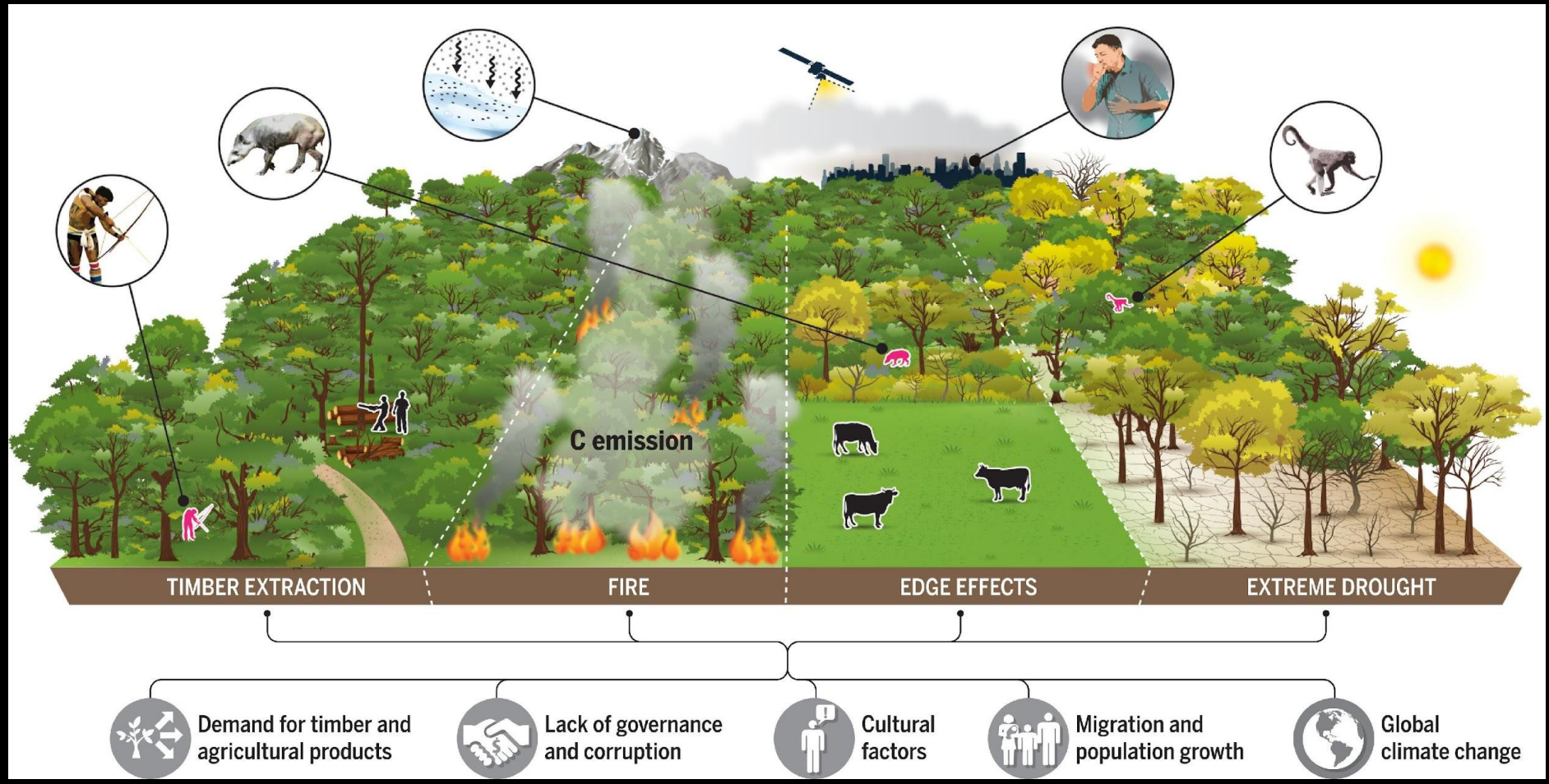
See increased runoff/soil moisture in Swann et al. (2016), Lemordant et al. (2018), Kooperman et al. (2018), Fowler et al. (2019), etc.

Evidence 1: observed biomass follows rainfall gradient



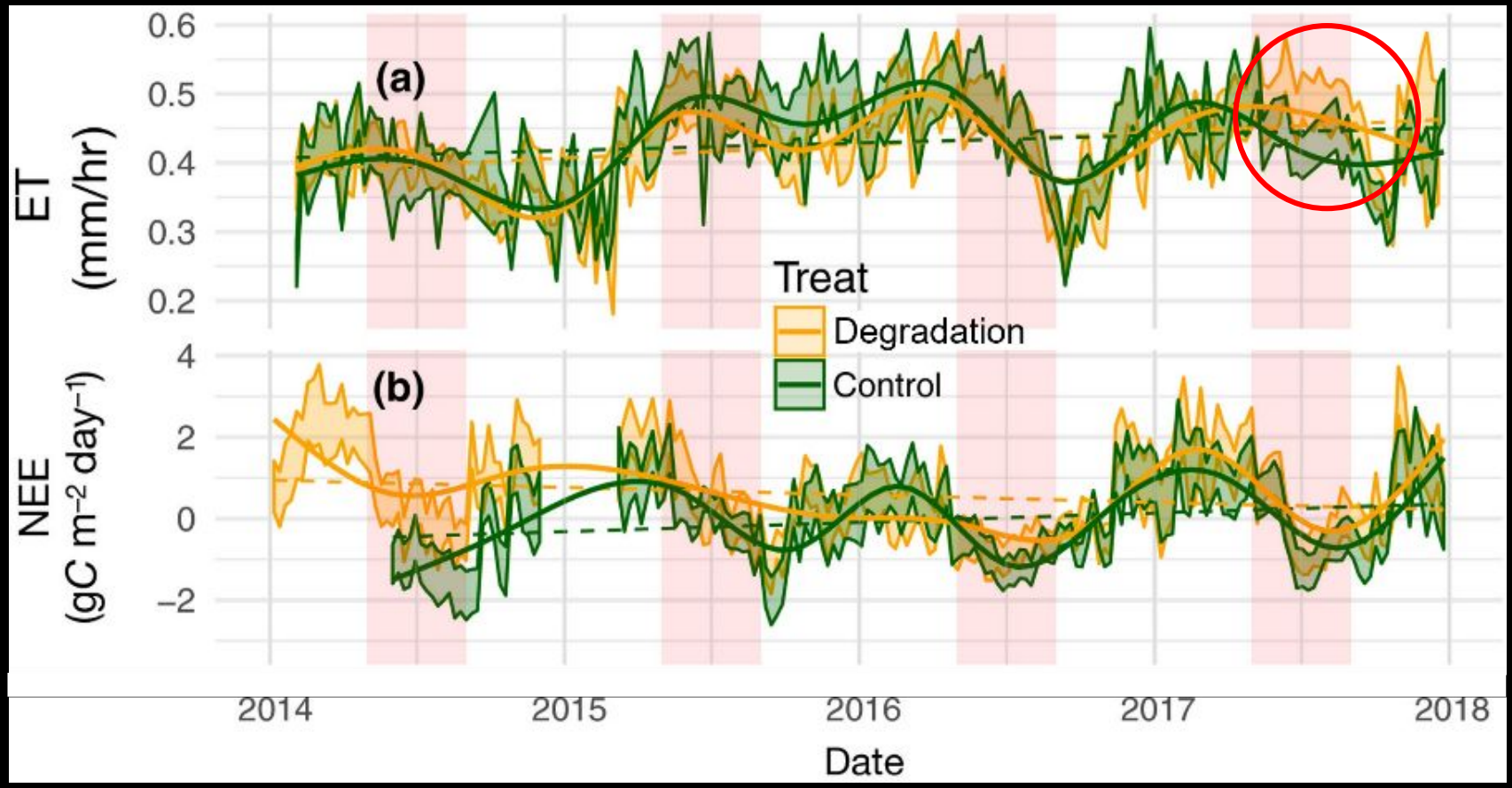
Li Y. *et al.* (2022). *Nat Commun*

Evidence 2: disturbances not well represented in CMIP6



Lapola et al. (2023)
Science

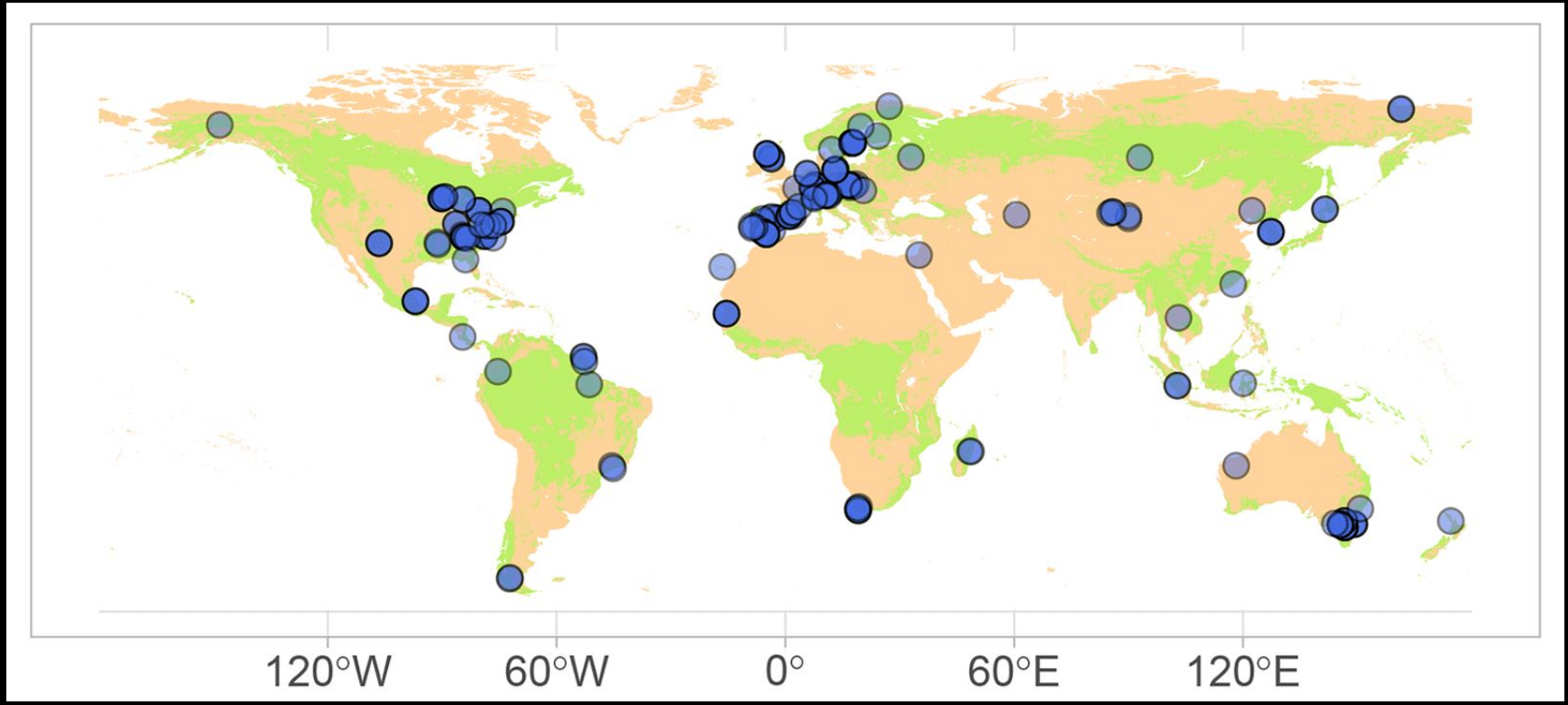
Forest degradation does not necessarily decline ET



Brando et al. 2019

More observations and process understanding are needed!

Tropical observations are still sparse

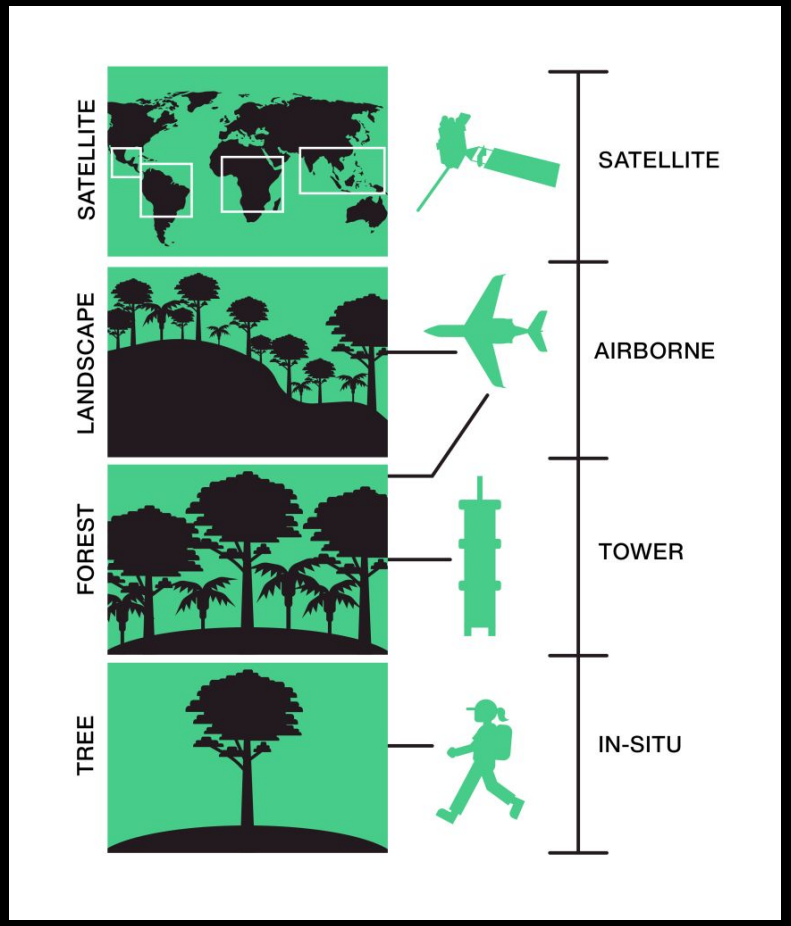


SAPFLUXNET, Poyatos et al. 2021

Tropical observations are still sparse

International soil moisture network,
Dorigo et al. 2011

PANGEA – PAN tropical investigation of bioGeochemistry and Ecological Adaptation



1. Examine similarities and differences in forest composition, structure, and biogeochemical cycling across tropical regions.

2. Evaluate the vulnerability and resilience of tropical forest ecosystems to global change.

3. Guide decision-making to support societal responses to climate change mitigation, adaptation, and biodiversity conservation.

https://tropicalforestscoping.com/

PANGEA – a new opportunity for model community

Climate Feedback & Interaction Working Group (CFI WG)

Co-Leads:

Robinson Negron-Juarez, LBNL
Yue Li, UCLA
Sarah Worden, UCLA
Junjie Liu, JPL
Xiangming Xiao, OU

- Opportunities to be engaged in scoping the white paper together as a whole community

Feel free to reach out: yli@geog.ucla.edu