The carbon costs of tropical deforestation through changes on regional climate

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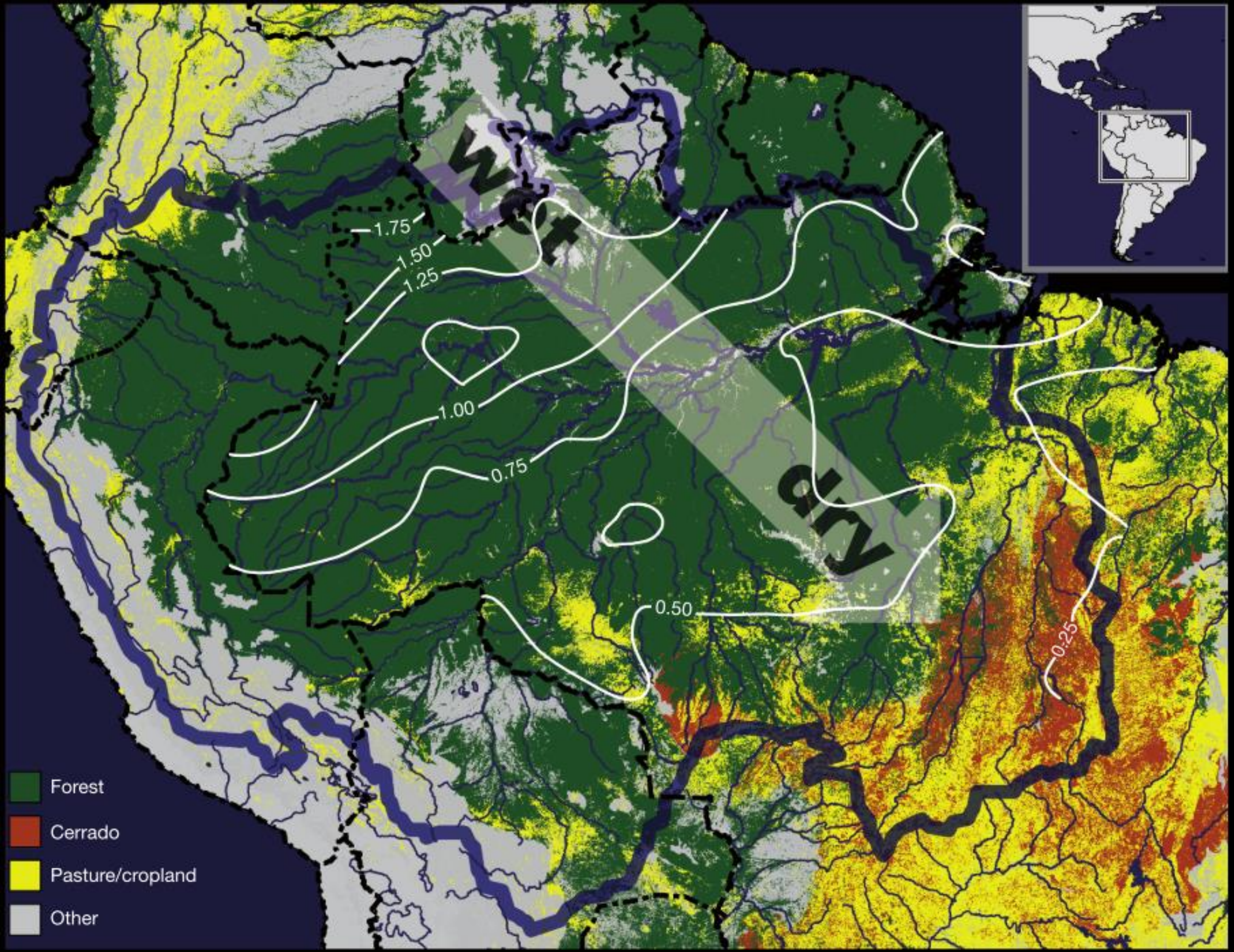
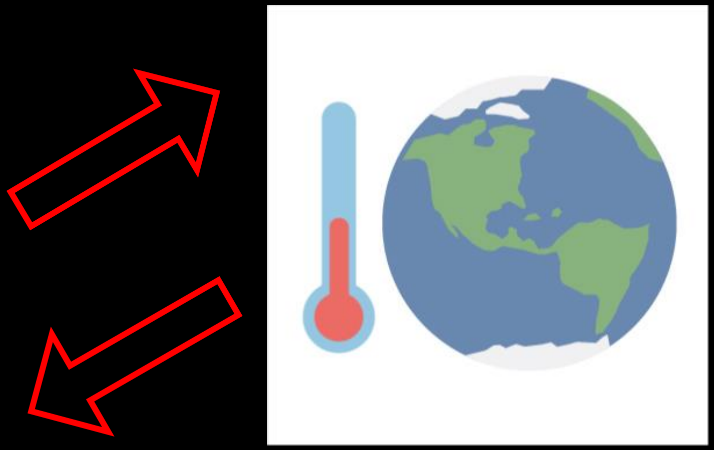
Climate & land-use change are two main risks to tropical ecosystems



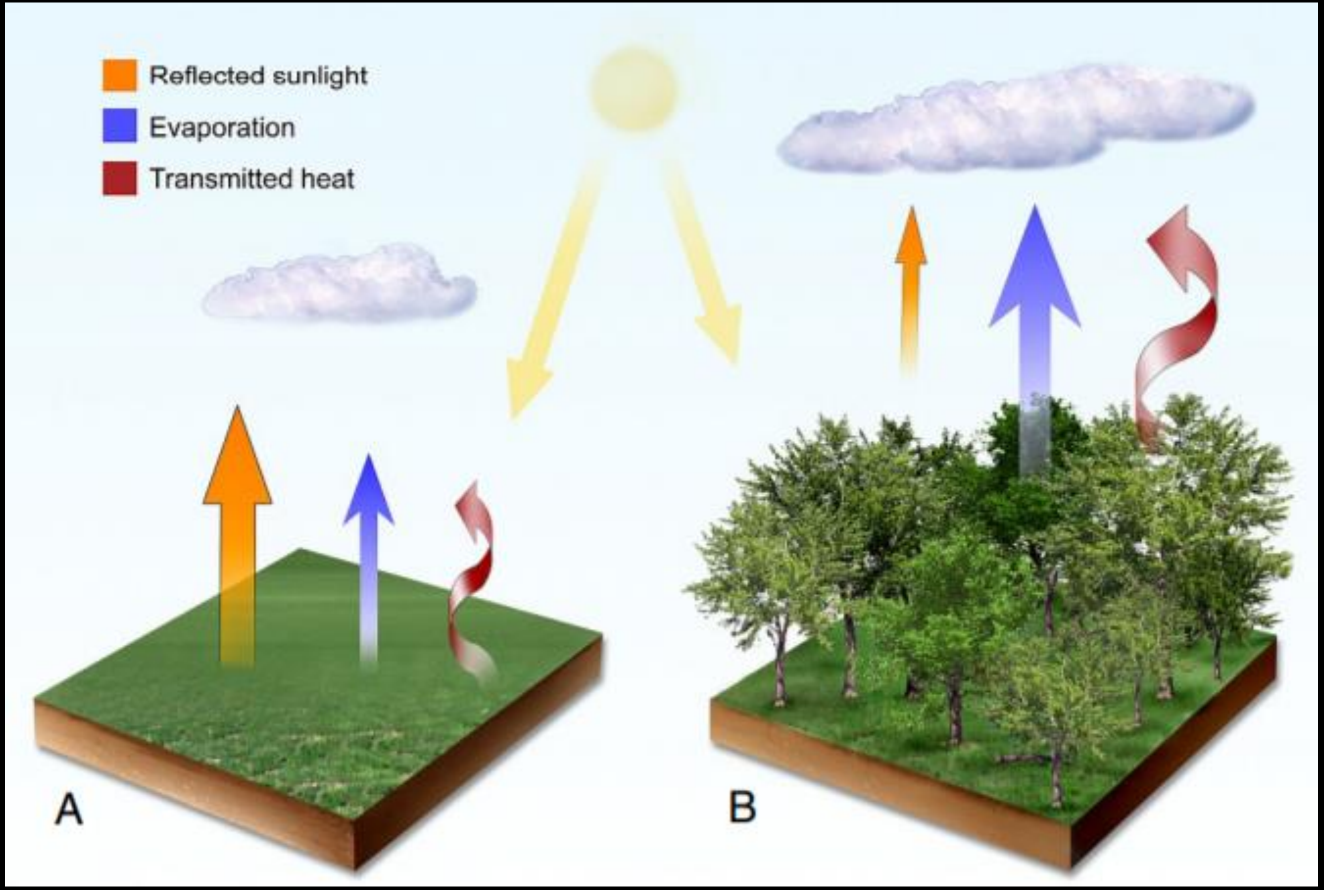
(Davidson et al. 2012, *Nature*)



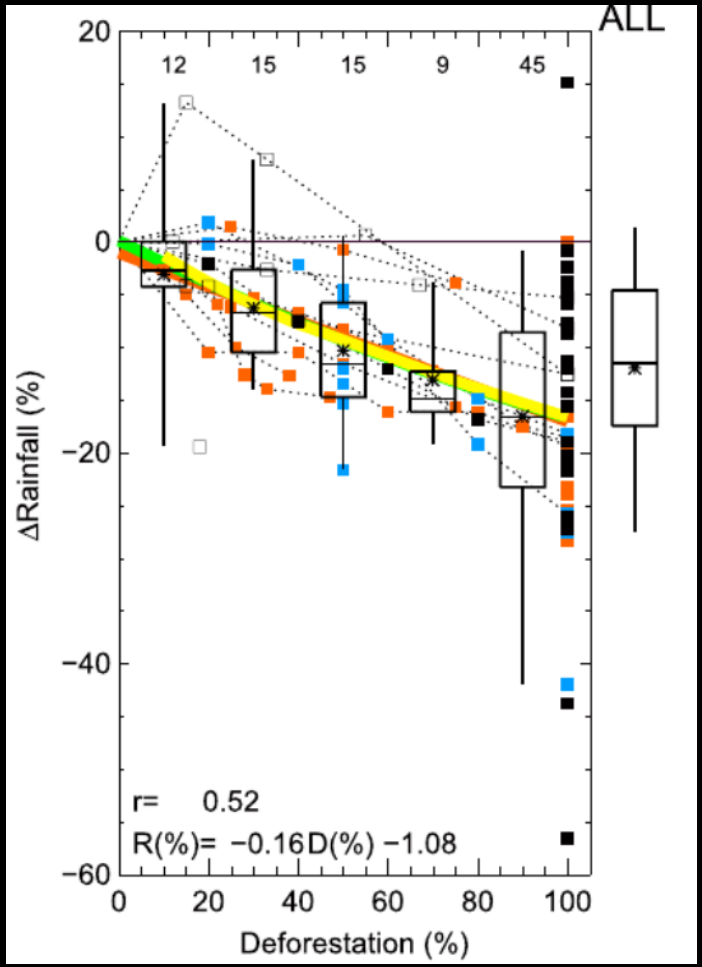
Big question: Tipping point

Tropical deforestation:
Major source of land use emissions (REDD+)

Tropical deforestation also alters surface biophysics and climate

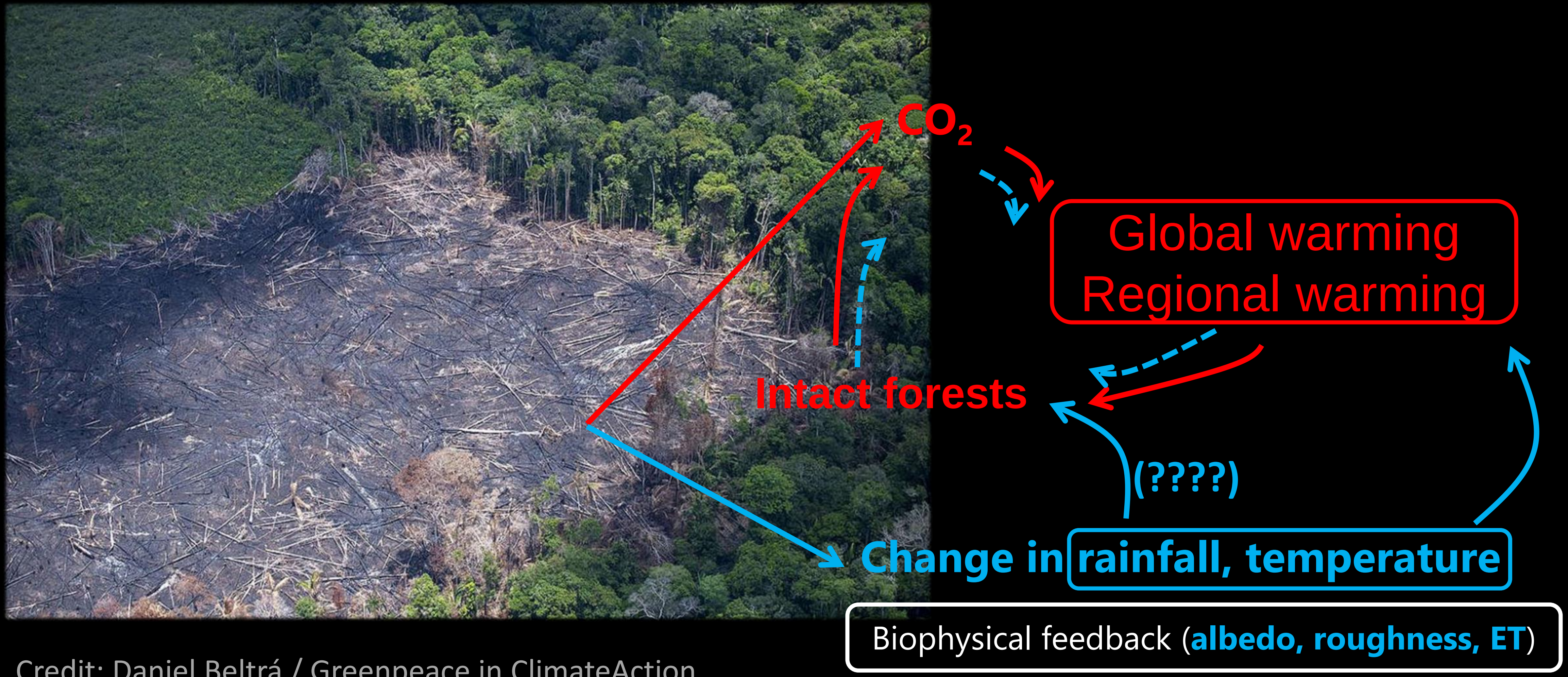


(Jackson et al. 2008)



(Spracklen et al. 2015)

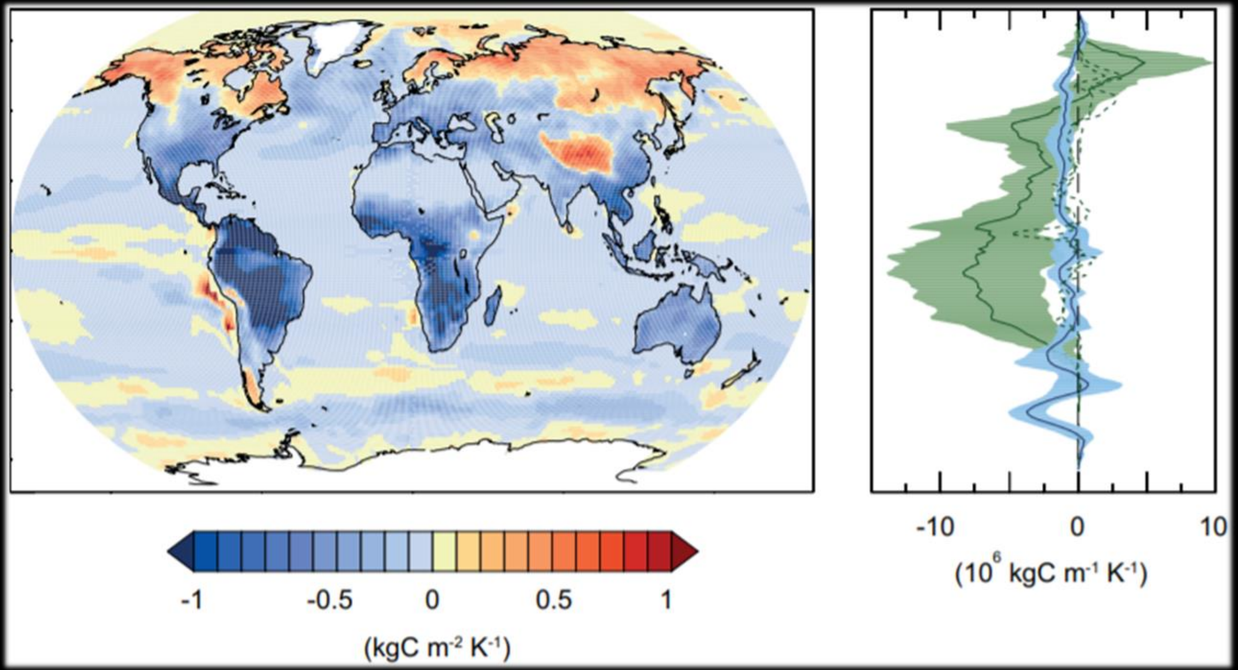
Biomass loss and positive climate feedback of tropical deforestation



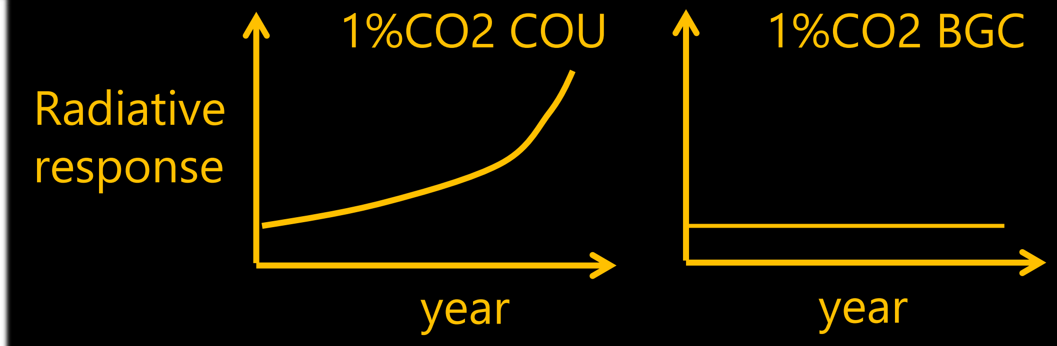
Credit: Daniel Beltrá / Greenpeace in ClimateAction

Question 1: What is the aboveground biomass (AGB) costs of tropical deforestation through changing biophysics and regional climate ?

CO_2-driven climate-carbon cycle feedback

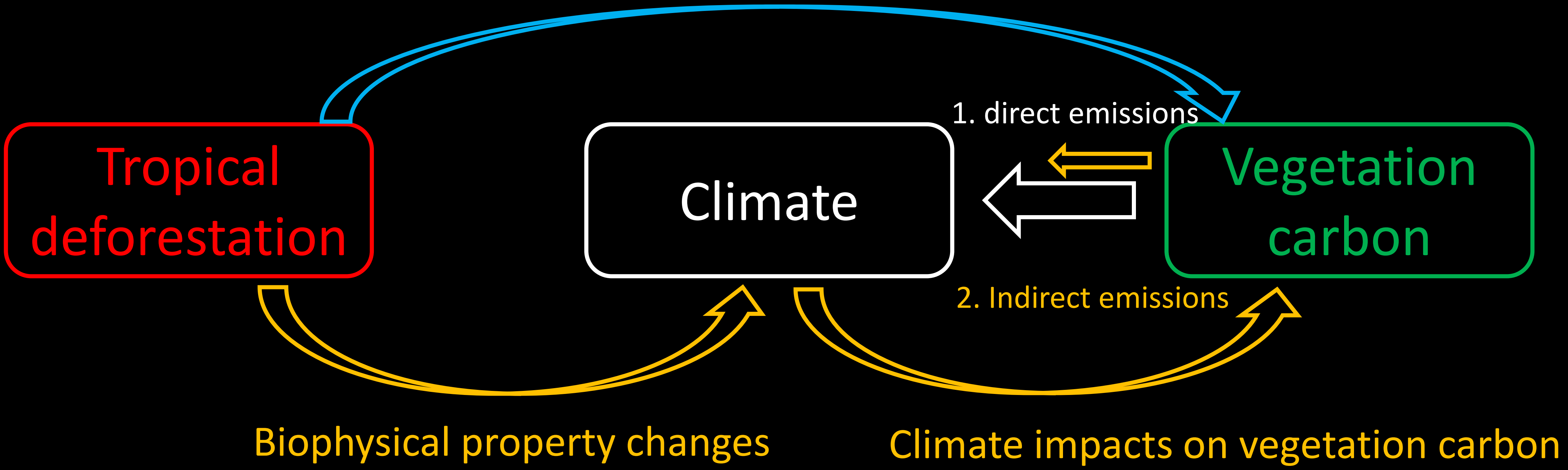


(Ciais et al. 2013, *IPCC AR5 Chap5*)



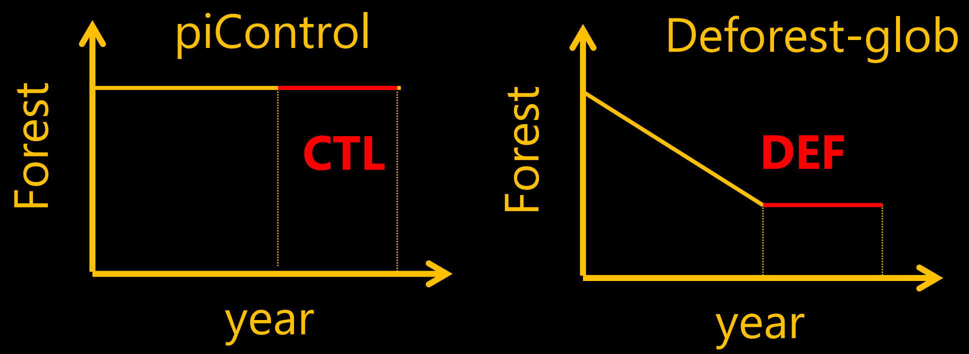
$$\gamma = \frac{\Delta C_{COU} - \Delta C_{BGC}}{\Delta T_{COU}}$$

This gamma is quantified without considering land use change, which neglects climate changed by deforestation.
Question 2: Does climate change associated with land-use change yield a larger or smaller gamma ?



CMIP6-LUMIP, CMIP6-piControl simulations

Deforestation impacts (DEF minus CTL)



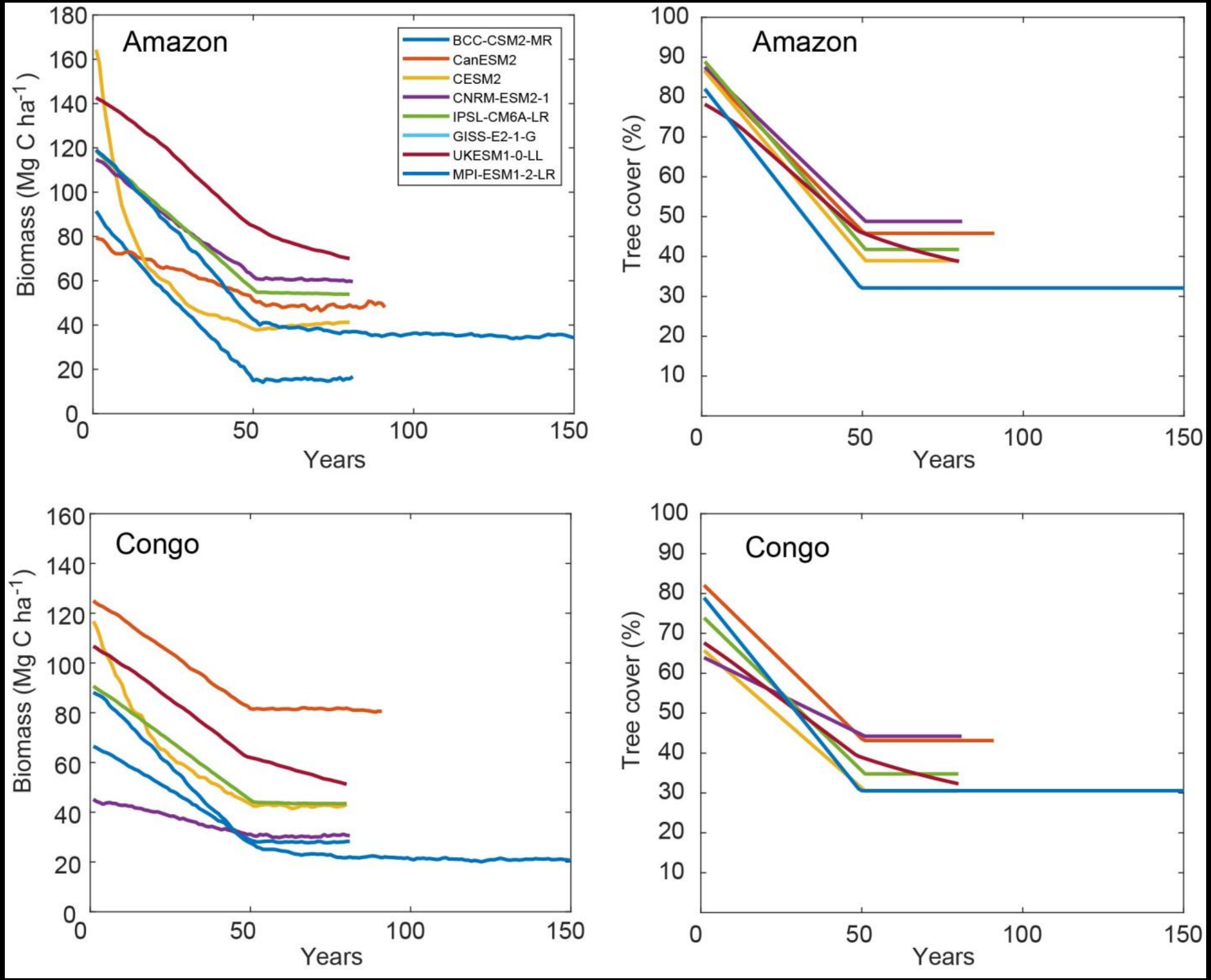
Additional experiments using CESM2 for tropics only

Observational spatial sensitivity

Waveform-based ESA-CCI aboveground biomass

Observational climate products (TRMM rainfall, CRU air temperature)

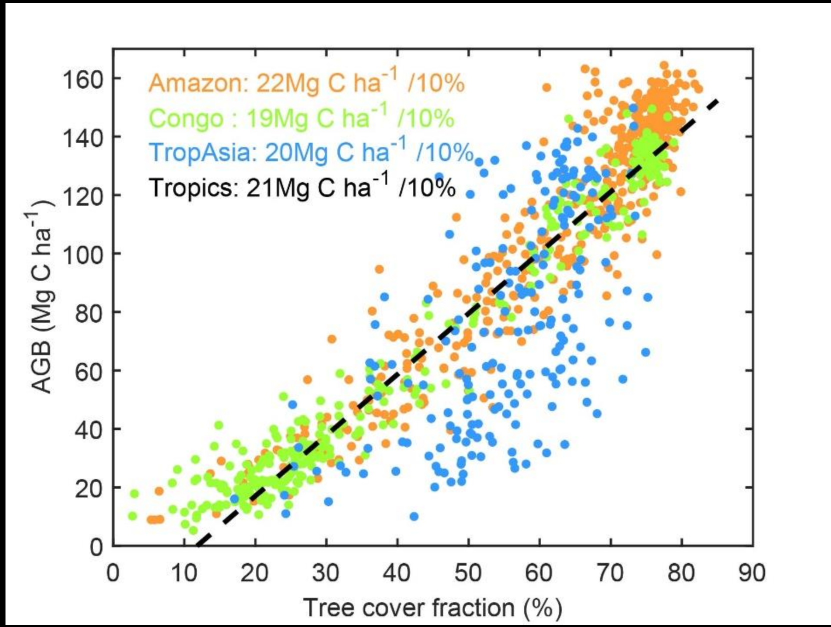
Idealized deforestation trajectories in LUMIP



Total area of forest loss is identical across models:

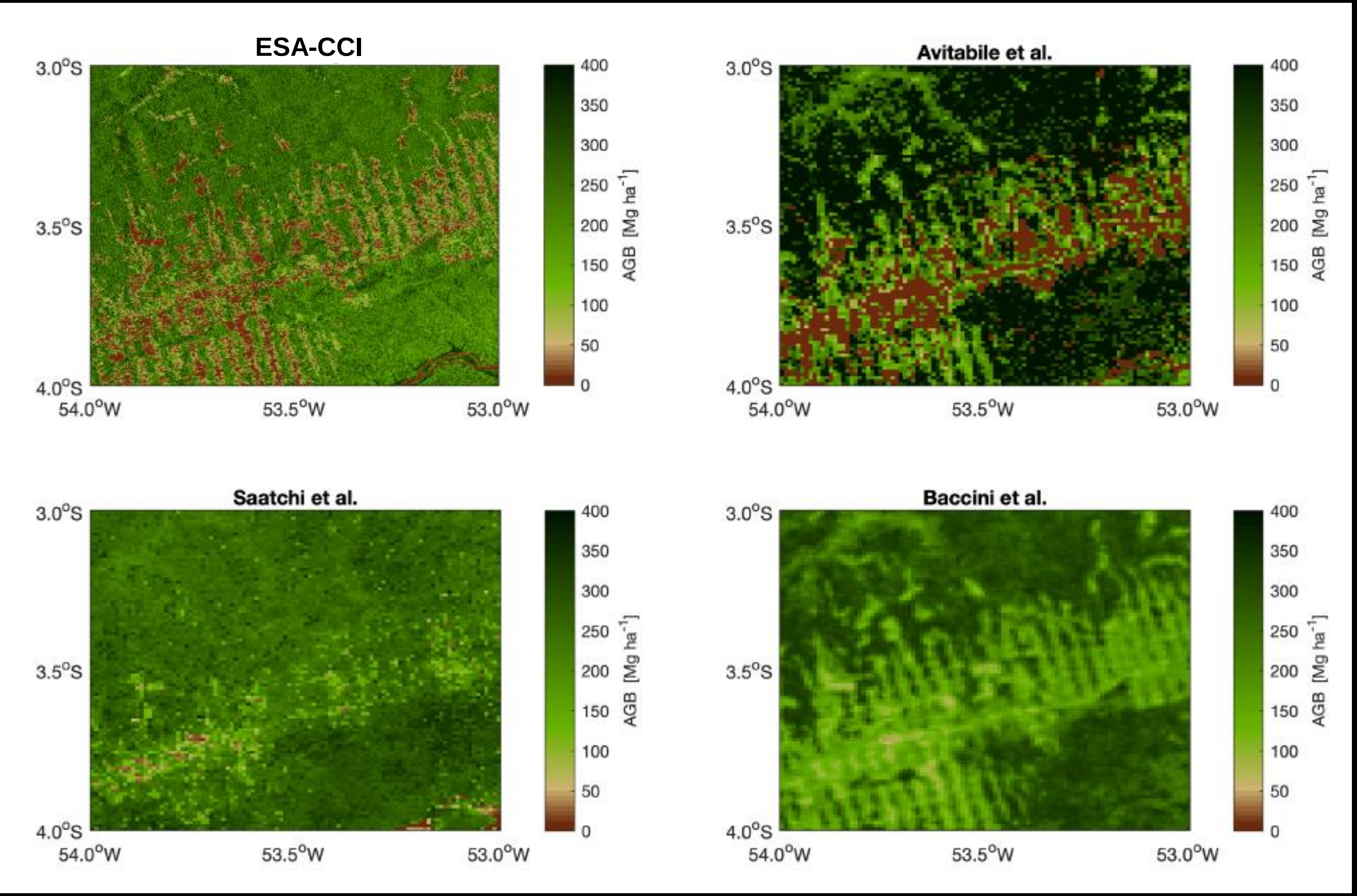
50 years, 20 million km^{-2}

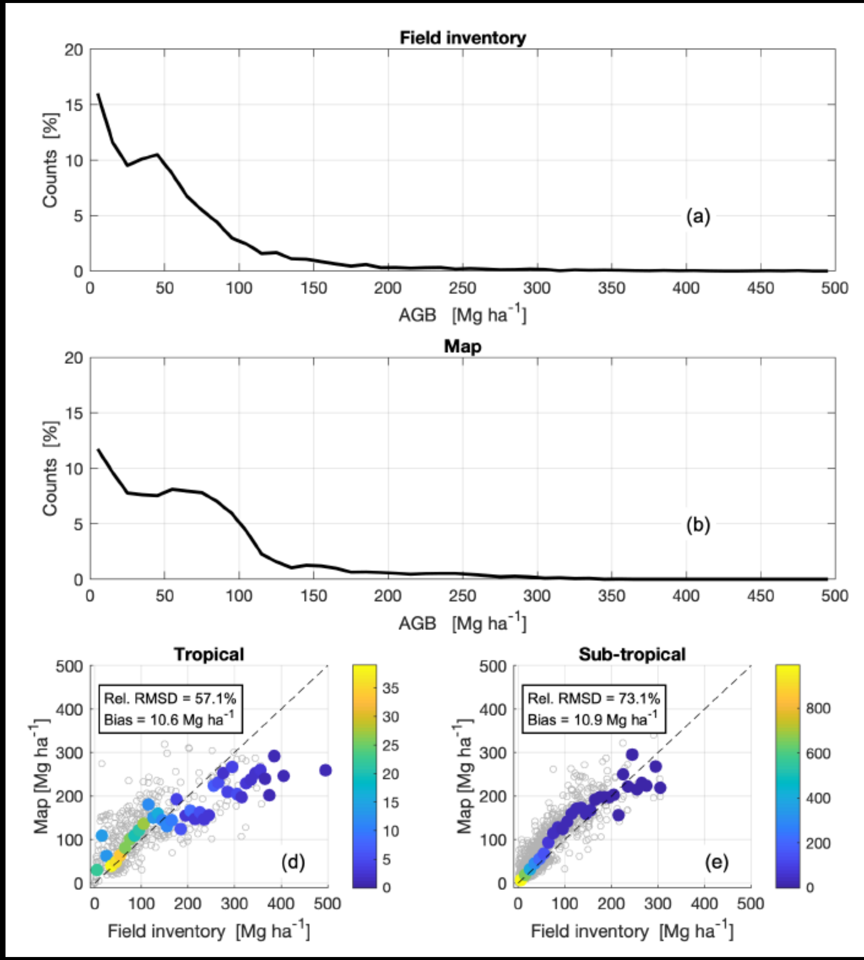
Observed AGB-tree cover relationship



Observed AGB data is from ESA-CCI (mid 1990s, 2010, 2017, 2018)

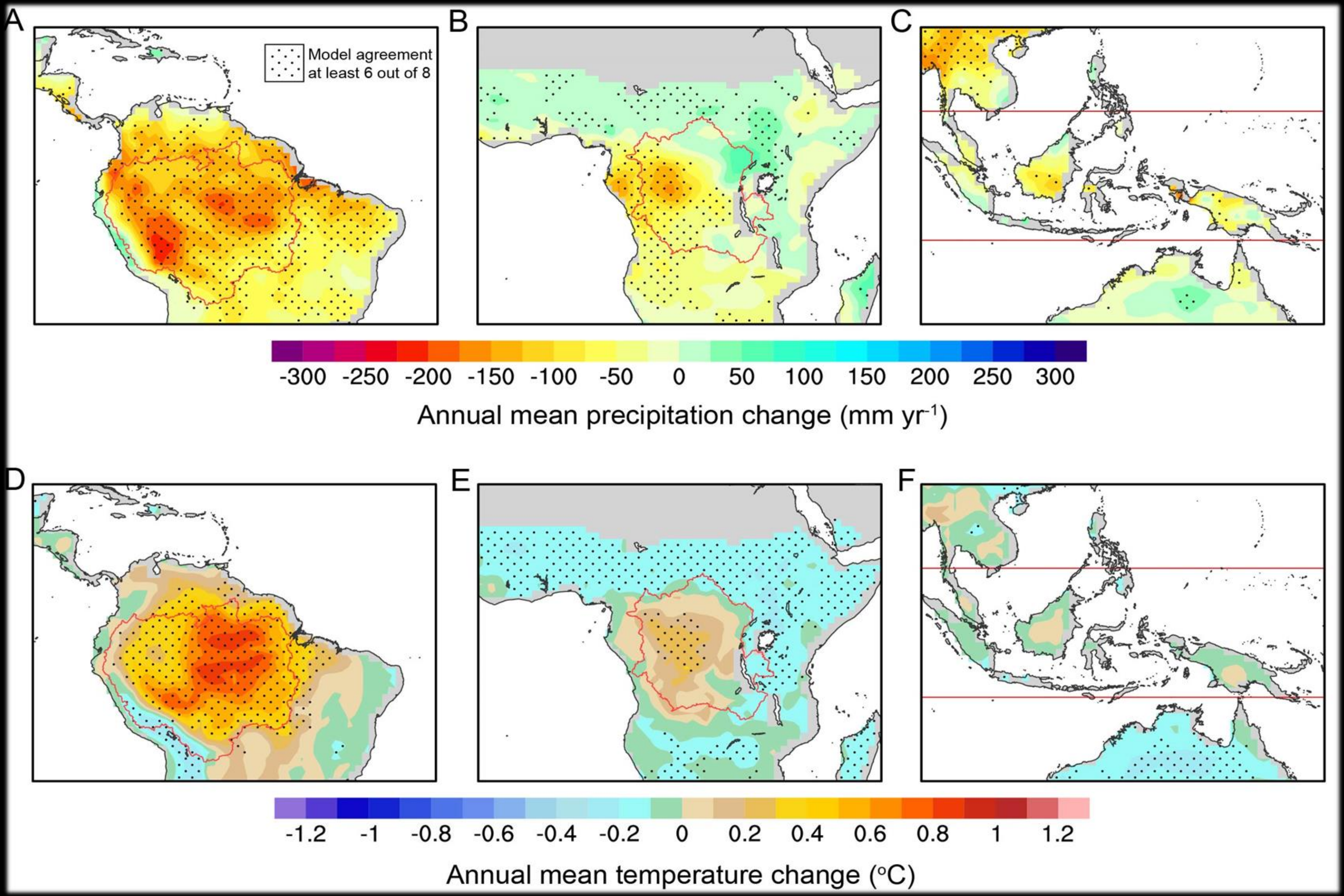
100m×100m





(Santoro et al. 2020)

Idealized deforestation causes local warming & decrease in rainfall



Tree cover fraction

Amazon: -44.7±6.0 %,
Congo: -38.7±8.8 %,
TropAsia:-31.2±8.9 %

Annual rainfall

Amazon:-150±105 mm yr^{-1} (-6.7%)
Congo:-41±56 mm yr^{-1} (-2.7%)
TropAsia:-38±58 mm yr^{-1} (-1.3%)

Annual temperature

Amazon: 0.5±0.5 °C
Congo: 0.1±0.5 °C
TropAsia: -0.1±0.2 °C

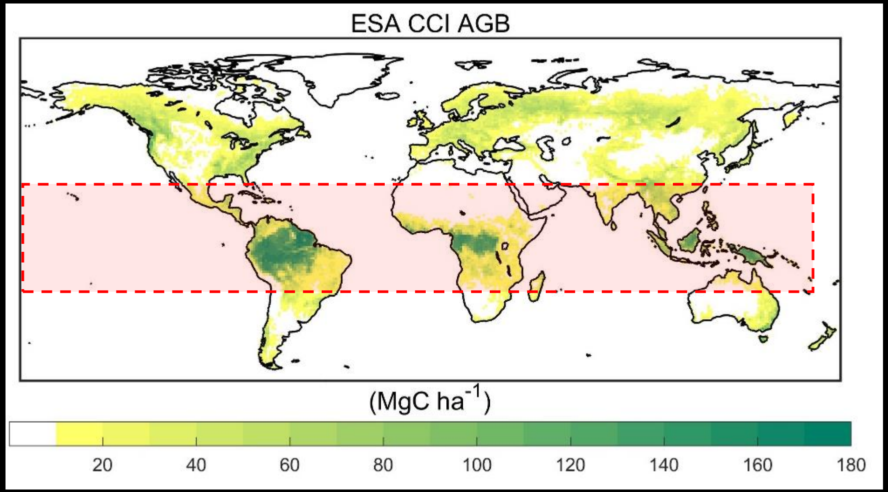
(More biophysical response could be found in Boysen et al. 2020)

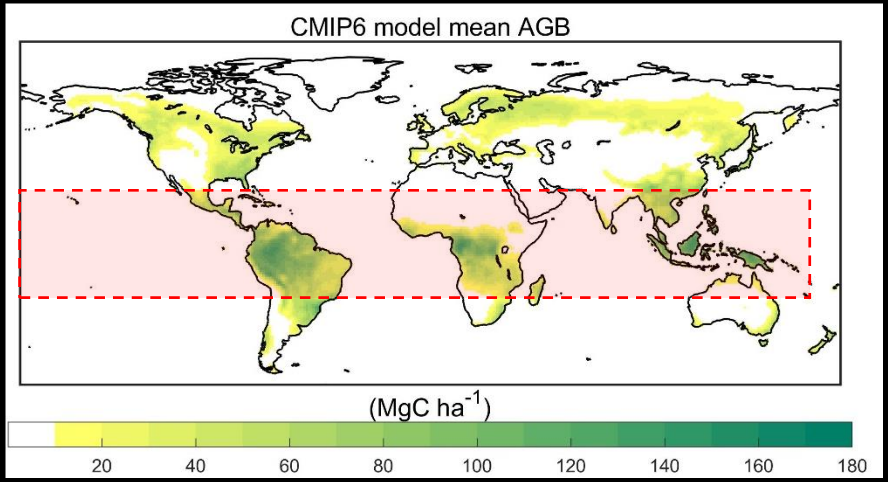
Revisit the observational spatial climate sensitivity of vegetation carbon

AGB: aboveground biomass

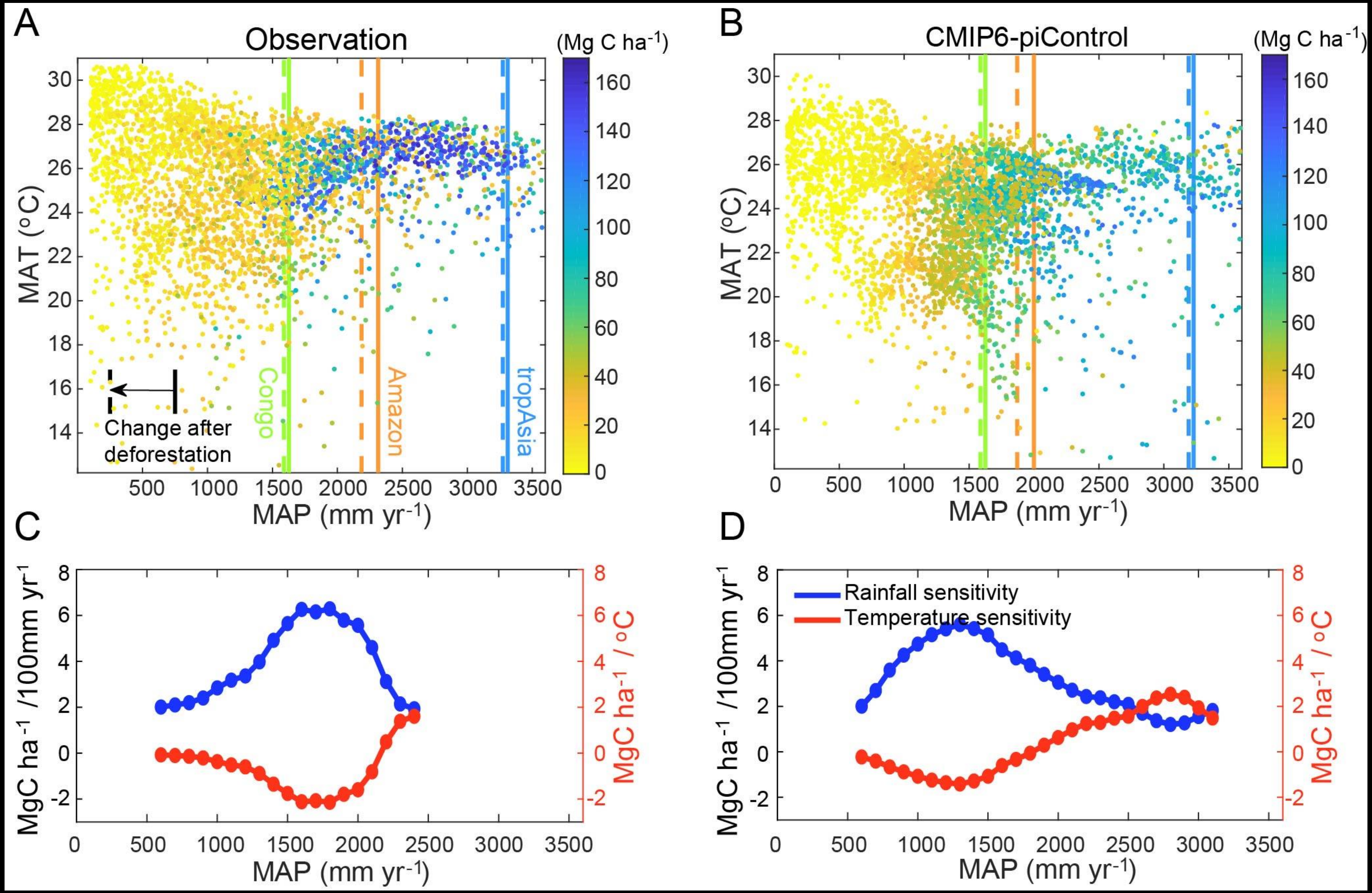
AGB	Rainfall coefficient	Temperature coefficient	R^2	$\partial_{AGB}/\partial_{Rainfall}$	$\partial_{AGB}/\partial_{Temperature}$
Observations*	3.4	-0.32	0.49	8.2% /100mm yr^{-1}	-0.8% /°C
CMIP6 piControl	3.2	-0.04	0.60	6.9% /100mm yr^{-1}	-0.09% /°C

*Equation: Aboveground biomass (AGB) = a*Rainfall + b*Temperature + ε. The units are mm yr^{-1} and °C, and Mg C ha^{-1}. Sensitivity is computed as the relative value of the coefficients a and b to the observed/simulated AGB.



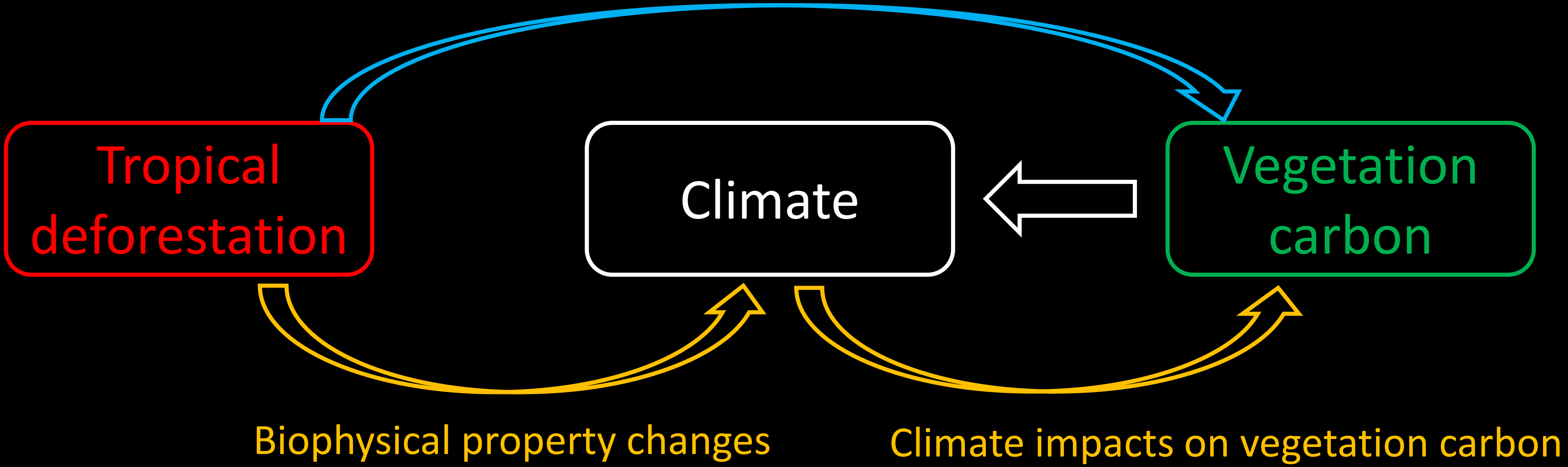


Varied climate sensitivity depending on rainfall climatology



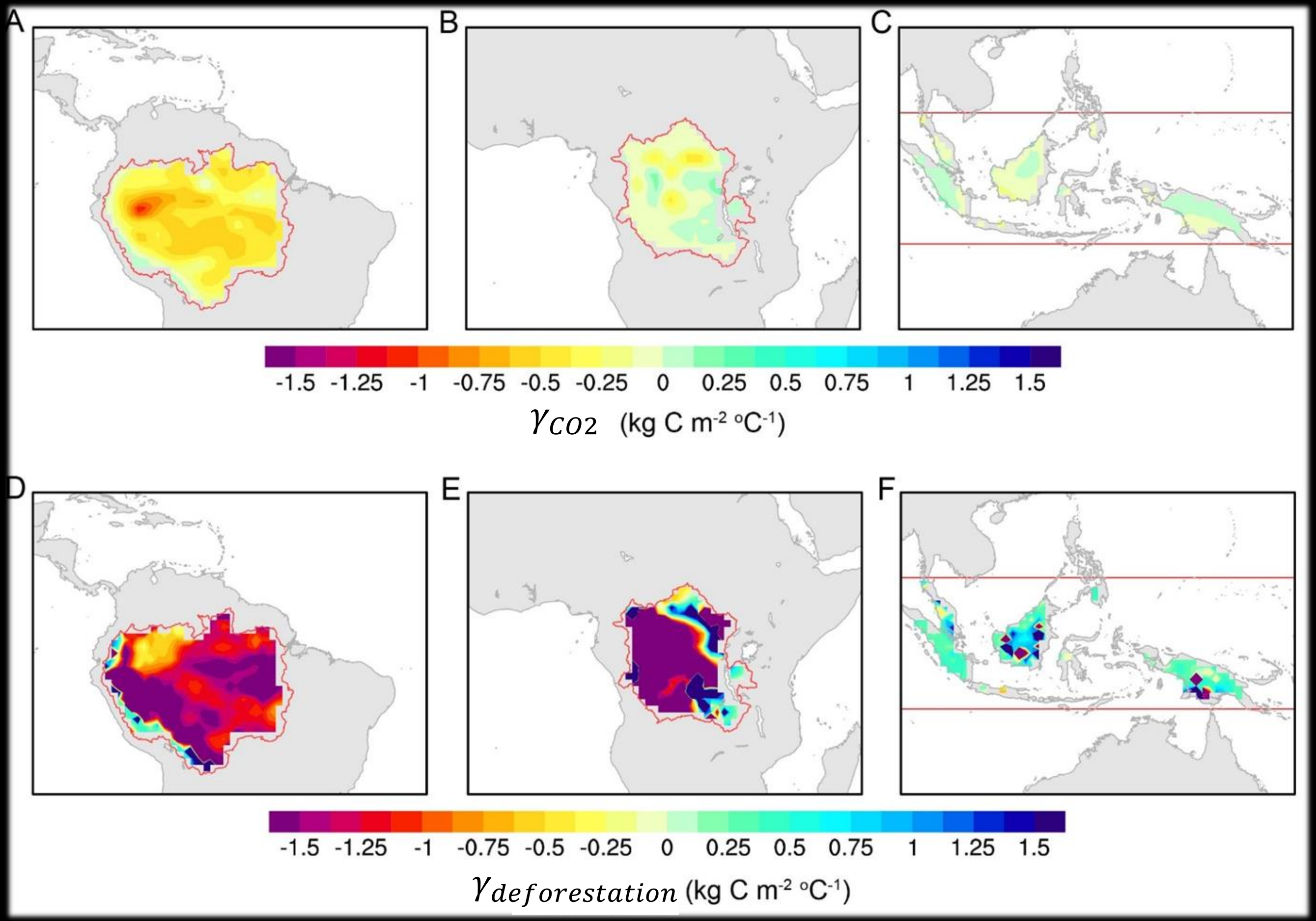
We also examined sensitivity to other climate metrics (e.g., VPD, maximum T)

Largest sensitivity in Amazon & Congo



Amazon	-150 mm yr^{-1}, +0.5^{o}C	-6.7 Mg C ha^{-1} (6.8%)
Congo	-41 mm yr^{-1}, +0.1^{o}C	-3.1 Mg C ha^{-1} (4.1%)
TropAsia	-38 mm yr^{-1}, -0.1^{o}C	-0.2 Mg C ha^{-1} (0.3%)

Implication: Deforestation-driven climate change yields a larger climate-carbon cycle feedback



- CO_2-driven climate-carbon cycle feedback

$$\gamma_{CO2} = \frac{\Delta Cveg_{COU} - \Delta Cveg_{BGC}}{\Delta T_{COU}}$$

- Deforestation-driven climate-carbon cycle feedback

$$\gamma_{deforestation} = \frac{\Delta Cveg_{def\_biophys}}{\Delta T_{def\_biophys}}$$

Take home message:

In the Amazon, deforestation-driven climate change causes intact forests to lose an additional 6.8% of their biomass as a consequence of decreasing rainfall.

Carbon credits for avoided deforestation should be larger to account for positive forest effects on regional climate.

Land use effects on precipitation would amplify the climate-carbon cycle feedback in the tropics.

Thanks for your listening and particular thanks to the NCAR team for early discussions and help on computing on Cheyenne.