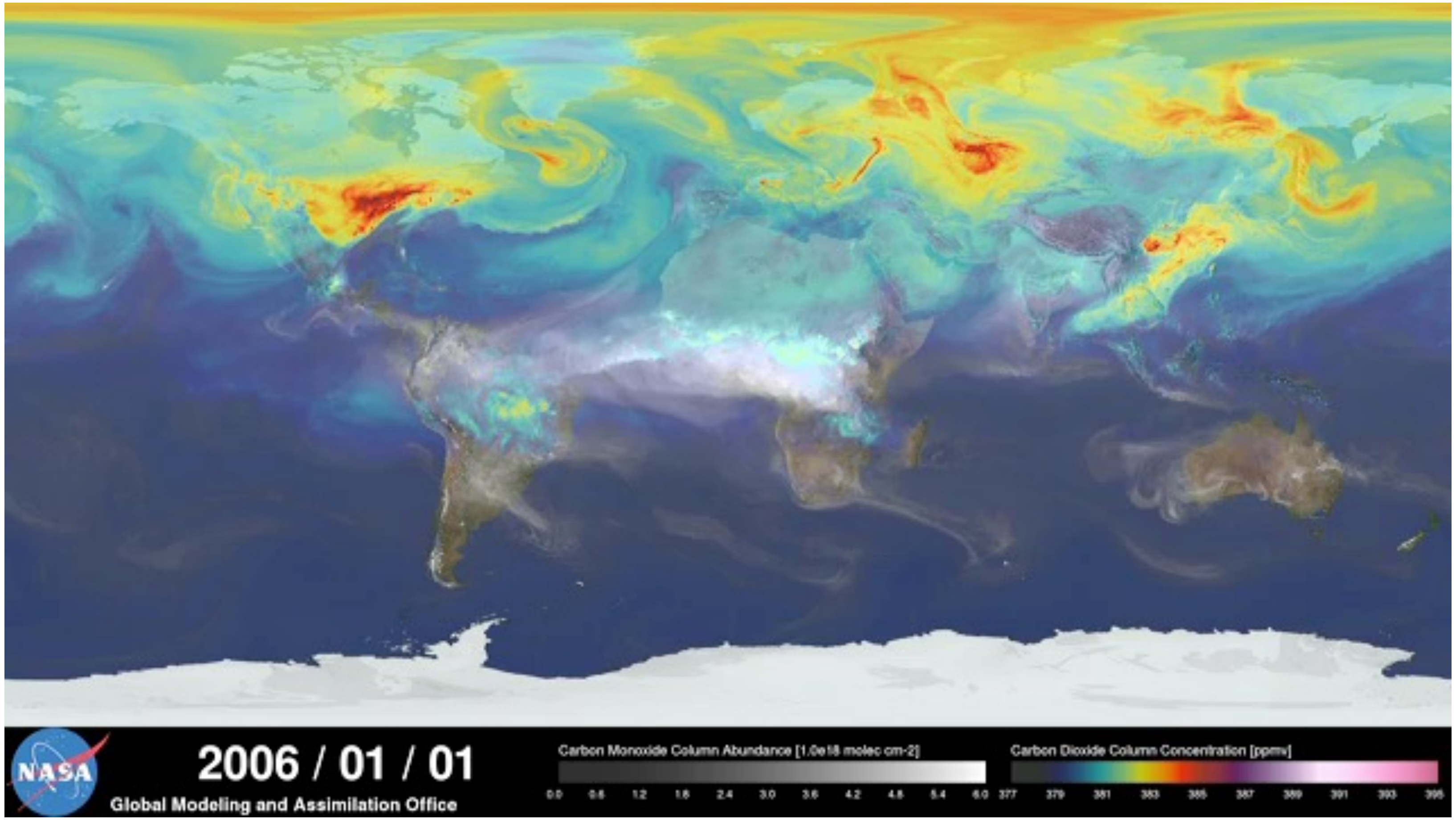
Amazon forest responses to projected climate change, elevated CO_2 and biodiversity loss

Dr. Florian Hofhansl, Research Scholar, Biodiversity, Ecology, and Conservation (BEC) Research Group, Biodiversity and Natural Resources (BNR) Program, International Institute for Applied Systems Analysis (**IIASA**)

Annual Meeting of the British Ecological Society (BES), 18 - 21 December 2022, Edinburgh, Scotland

Response of tropical rainforest to global CO_2 emissions



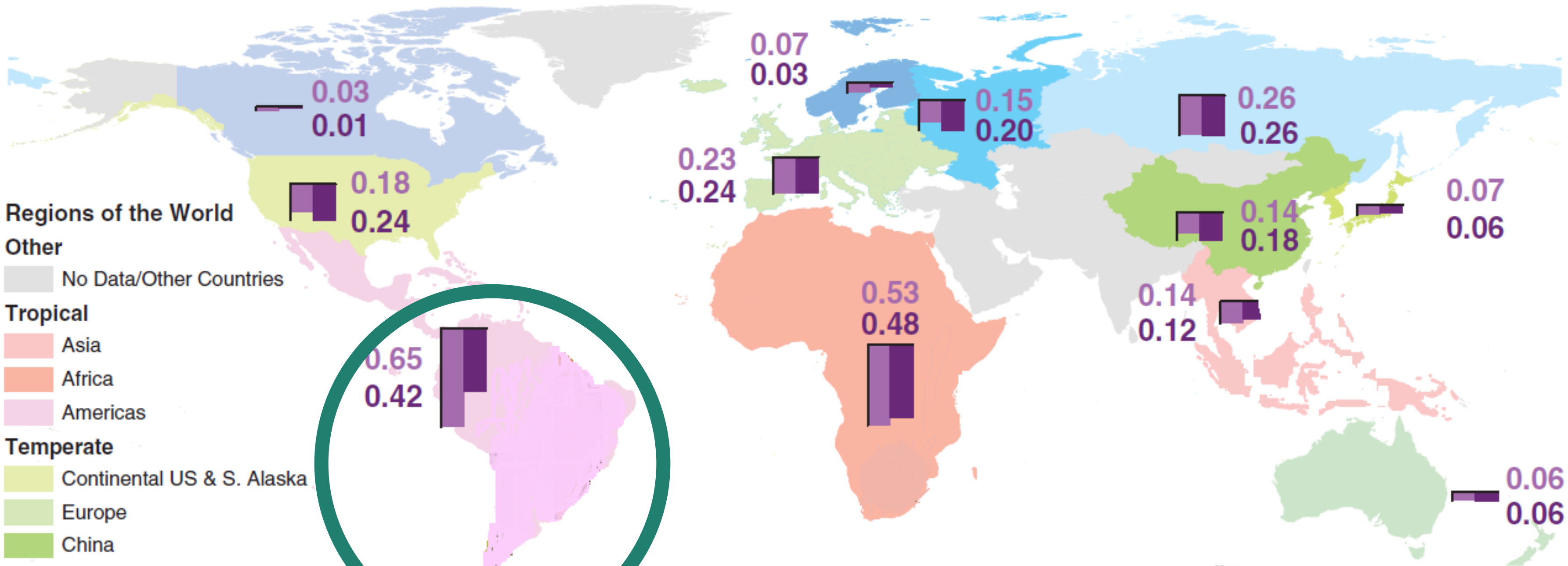
Simulation by NASA's Goddard Space Flight Center

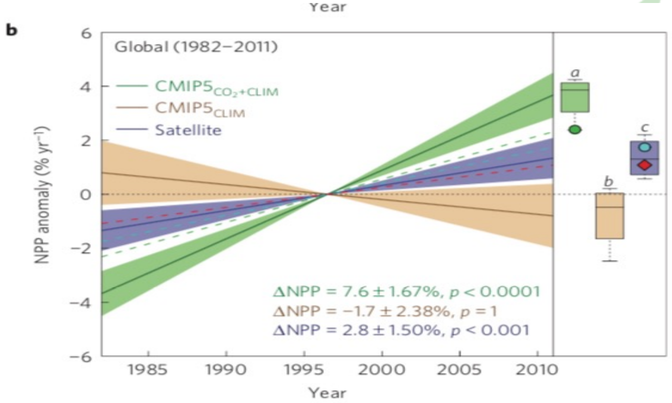
The simulation illustrates plumes of carbon dioxide in the atmosphere that swirl and shift as winds disperse the greenhouse gas away from its sources.

- <u>Spatial differences:</u> in CO_2 levels between the northern and southern hemispheres
- <u>Temporal oscillations</u> in global carbon dioxide concentrations as the metabolism of plants changes with the growing season
- <u>Diurnal fluctuations</u> reflect the photosynthetic assimilation during the day/night cycle

NASA's Goddard Space Flight Center http://svs.gsfc.nasa.gov/11719

Tropical forests provide crucial ecosystem services





Tropical forests contribute greatly to the terrestrial C sink and provide multiple ecosystem services:

- 50% of global carbon cycle
- 30% of global water cycle
- 25% of fossil fuel emissions
- 20% of oxygen production

Tropical forest species diversity:

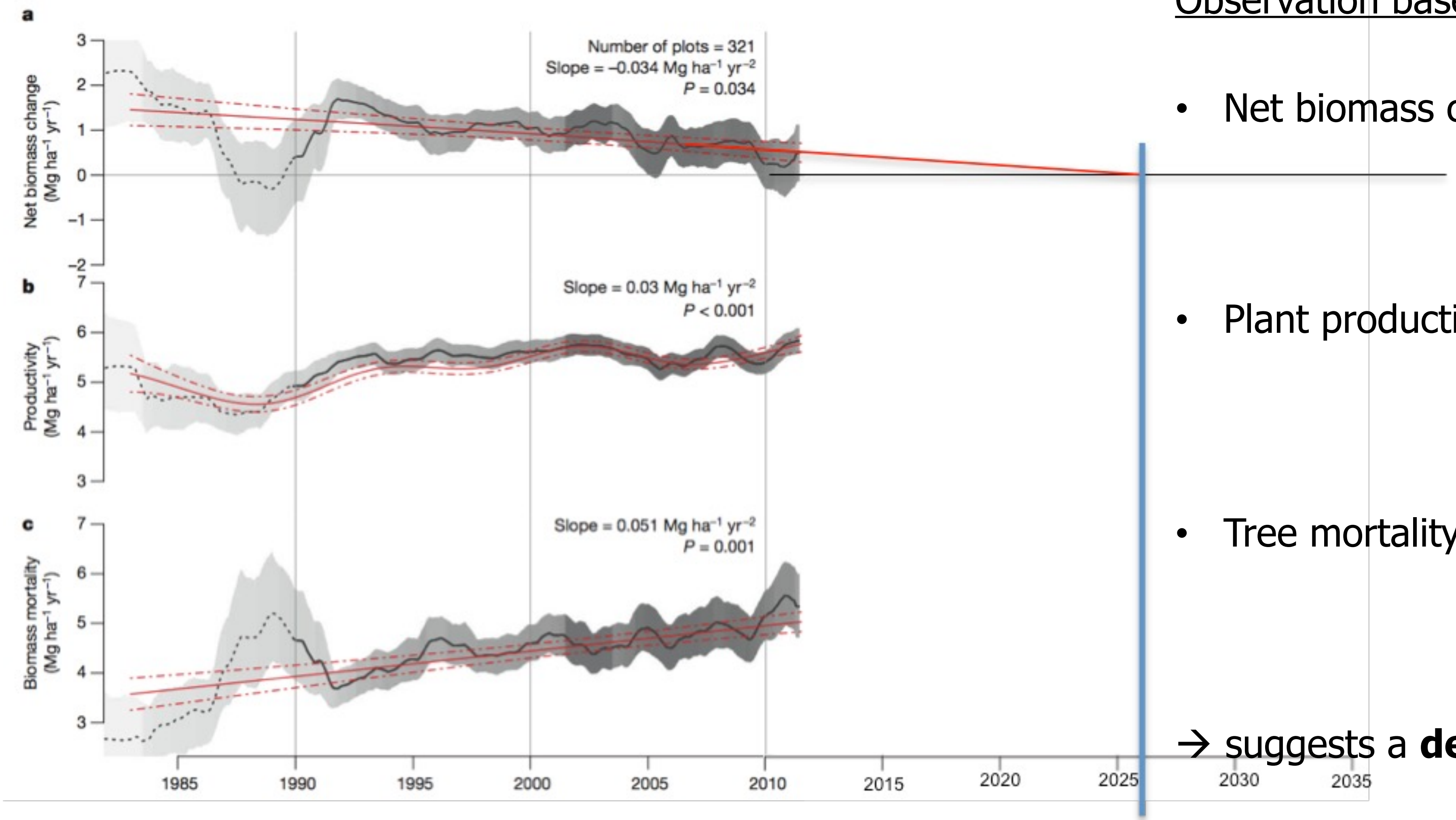
- 390 billion trees
- 16,000 tree sp.
- Biomass accumulates C worldwide but decreasing sink strength (1990-2007)
- ~0.4-0.6 / 2.3 Pg C yr^{-1} (~25%)

Discrepancy between estimates:

- **Field research**
- **Remote sensing**
- **Model simulations**

Pan et al. 2011 Science; Le Quéré et al. 2018 ESSD

Reduction of C sink strength (ground observation)



Observation based NPP estimate:

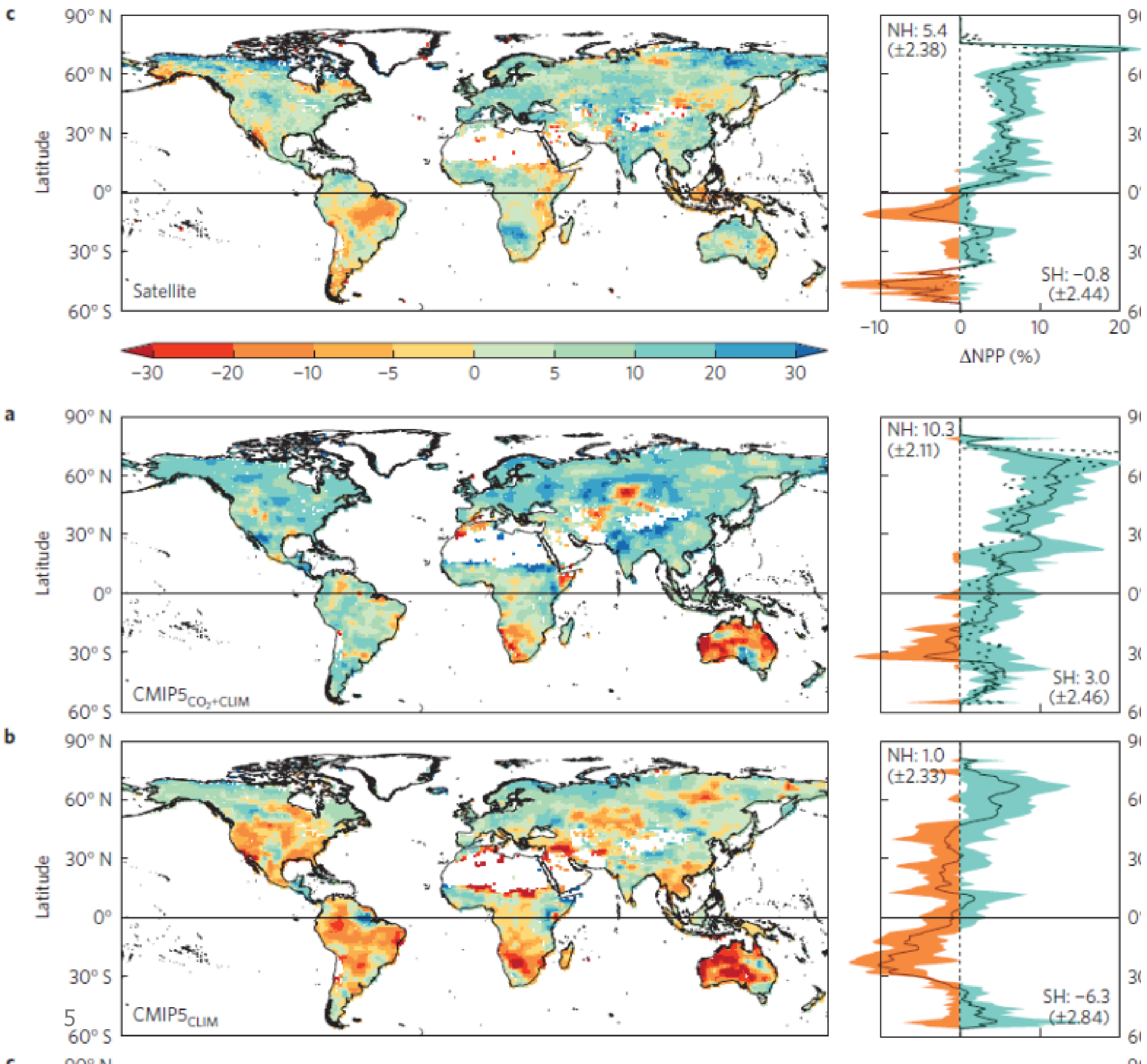
- Net biomass change **decreasing**
- Plant productivity is more or less stable
- Tree mortality rates are **increasing**

→ suggests a **decline of C sink strength**

→ **tree mortality rates** and **turnover time** should be accounted for when projecting C sink strength

Brienen et al., (2015) Nature doi:10.1038/nature14283; Brienen et al., (2019) Nature Comm doi:10.1038/s41467-020-17966-z

Increase of C sink strength (remote sensing)

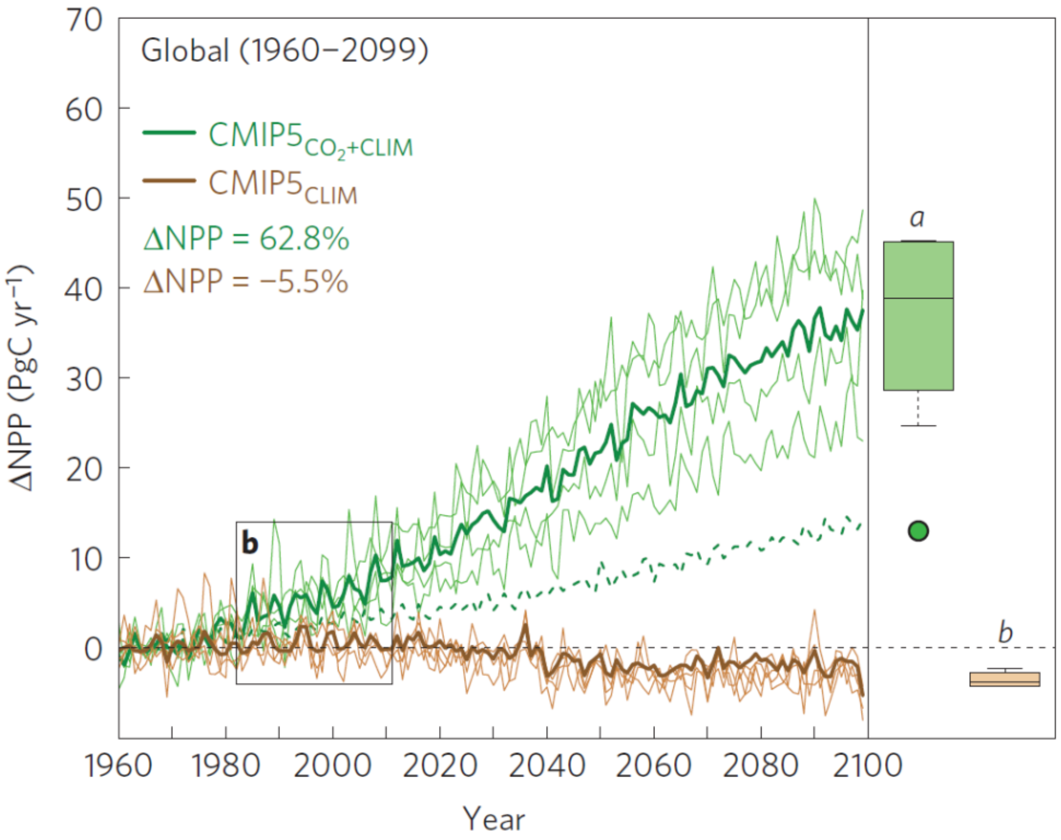


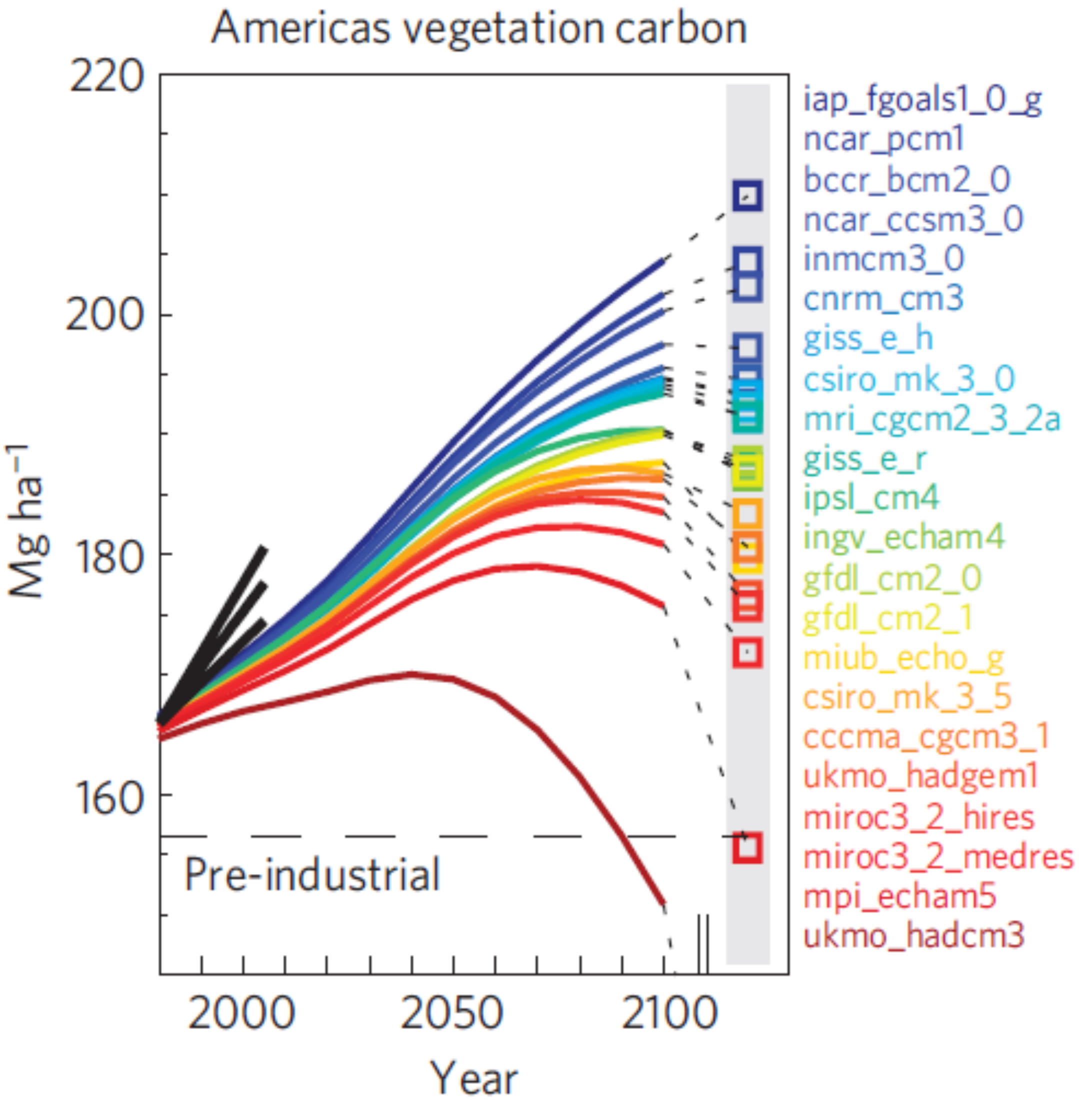
<u>Satellite-based NPP estimate:</u>

- Satellite observation **+ 3%**
- CMIP5 (CO2 + clim.) **+ 8%**
- CMIP5 (climate only) **- 2%**

Smith et al. (2016) Nature Geoscience

CO2 fertilization effect on plant growth (models)

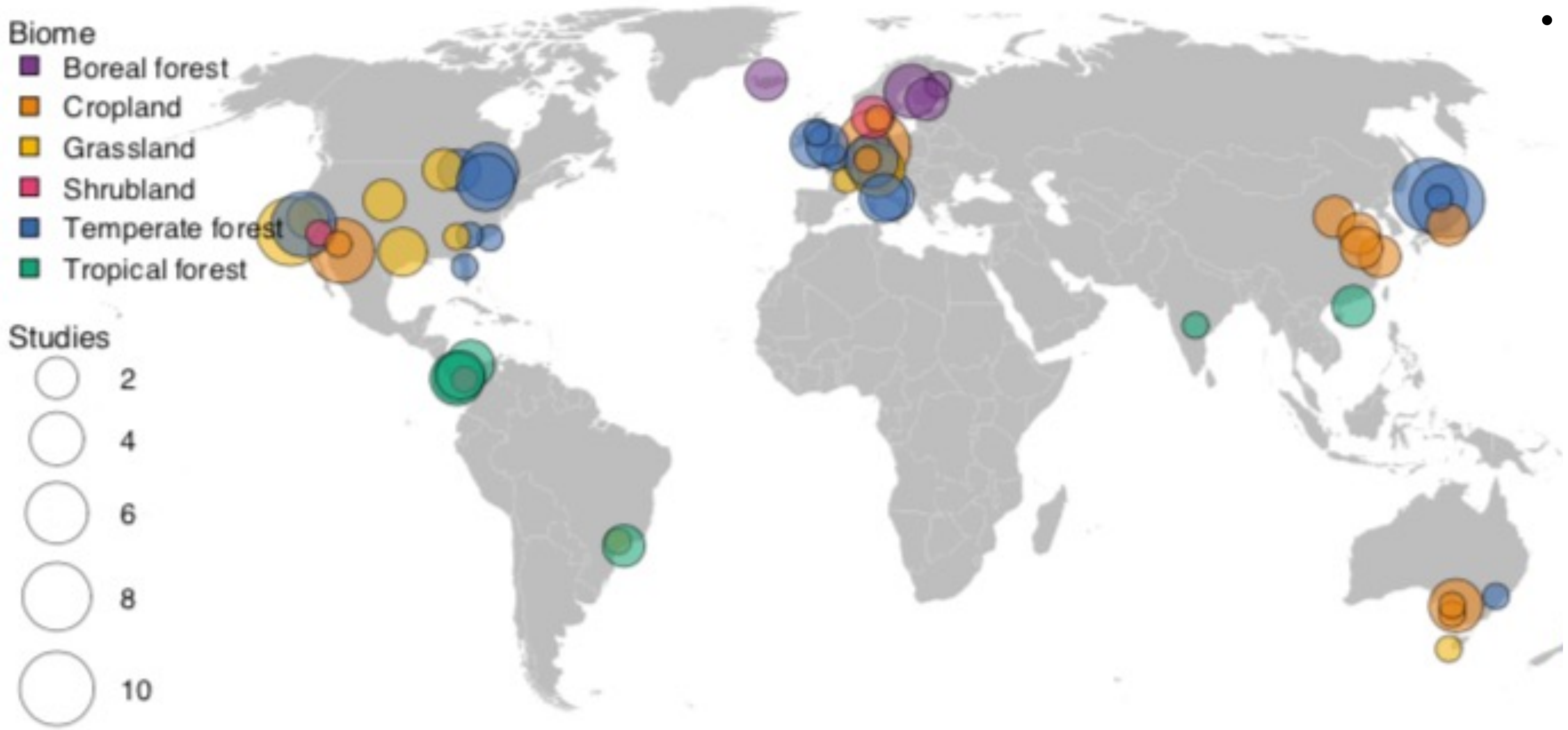




- Earth System Models predict increase in NPP (+ **63%**)
- Excluding CO_2 fertilization effect suggests reduction (- **6%**)
- **Large uncertainties in model representation of vegetation response to projected climate change!**

Huntingford 2013 Nature Geoscience; Smith et al. 2016 Nature Geoscience

FACE experiments – geographical distribution



Nitrogen and phosphorus constrain CO_2 fertilization

- The **strength of CO2 fertilization** is primarily driven by **nitrogen (N) in ~65%** and by **phosphorus (P) in ~25%** of global vegetation, with N- or P-limitation modulated by mycorrhizal association, which would suggest that **CO2 levels by 2100 may enhance plant biomass by 12 ± 3%**, equivalent to 59 ± 13 PgC

Terrer et al. 2019 Nature Climate Change: 1–11. doi:10.1038/s41558-019-0545-2

Belowground controls over aboveground processes

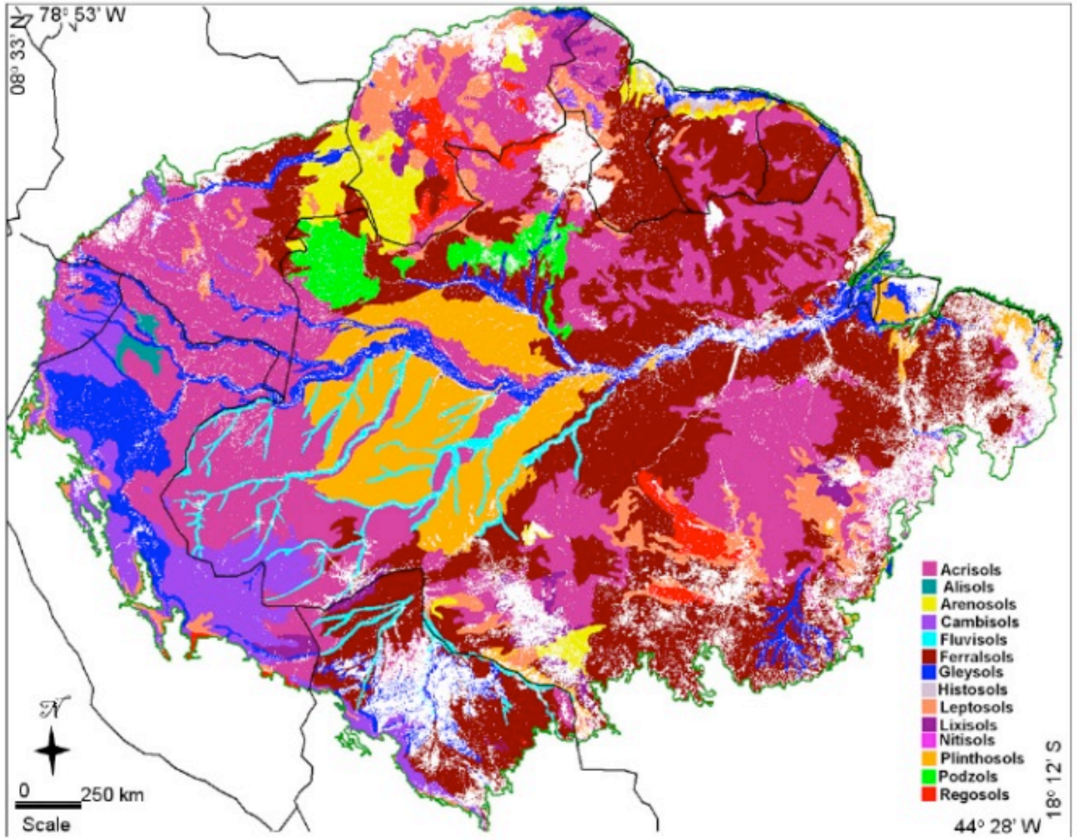


Fig. 4. Basin wide distributions of soils under forest vegetation. Map based on the SOTERLAC–ISRIC soil database (version 2.0, 1:5 million scale) and the vegetation database of Saatchi et al. (2008) for South America.

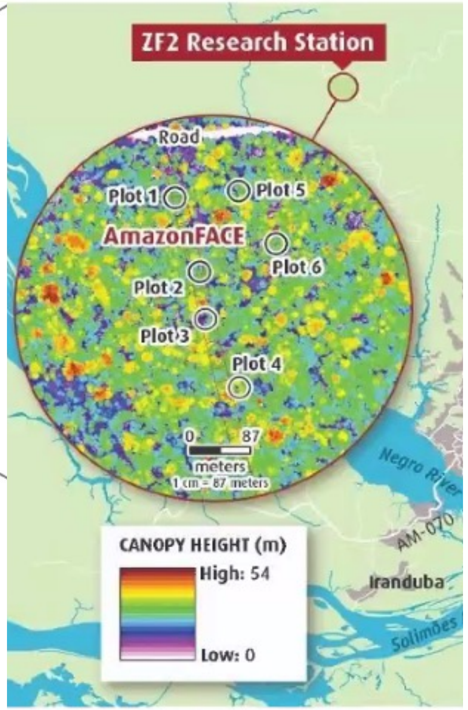
Evidence from the scientific literature suggests that:

- Soil texture and chemistry affect aboveground C storage via the productivity & turnover of plant species across the Amazon basin[1]
- Basin-wide differences in nutrient (P) availability affect tree mortality and turnover across the Amazon basin[1]
- Nutrient availability significantly affects C sink strength but large uncertainty[2]
- Phosphorus availability enhances forest growth but the response to fertilization is not consistent among species[3]
- Some species respond to fertilization others don't (effect of plant functional strategy?!)

[1]Quesada et al. 2010, 2012; [2]Wieder et al. 2015, Yang et al. 2016; [3]Wright et al. 2018, 2019

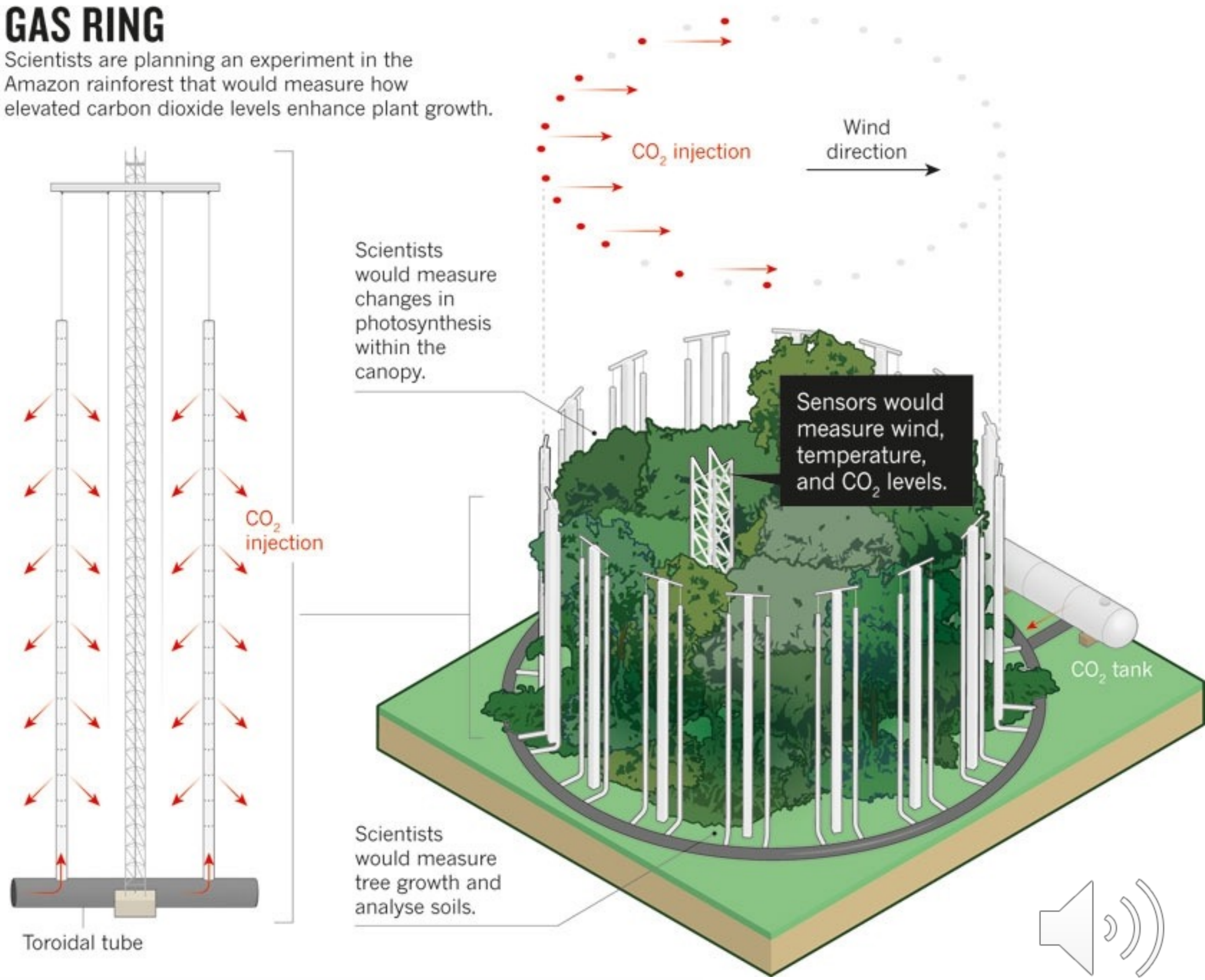
AmazonFACE (Free-Air Carbon Enrichment) in Brazil

The Amazon FACE site

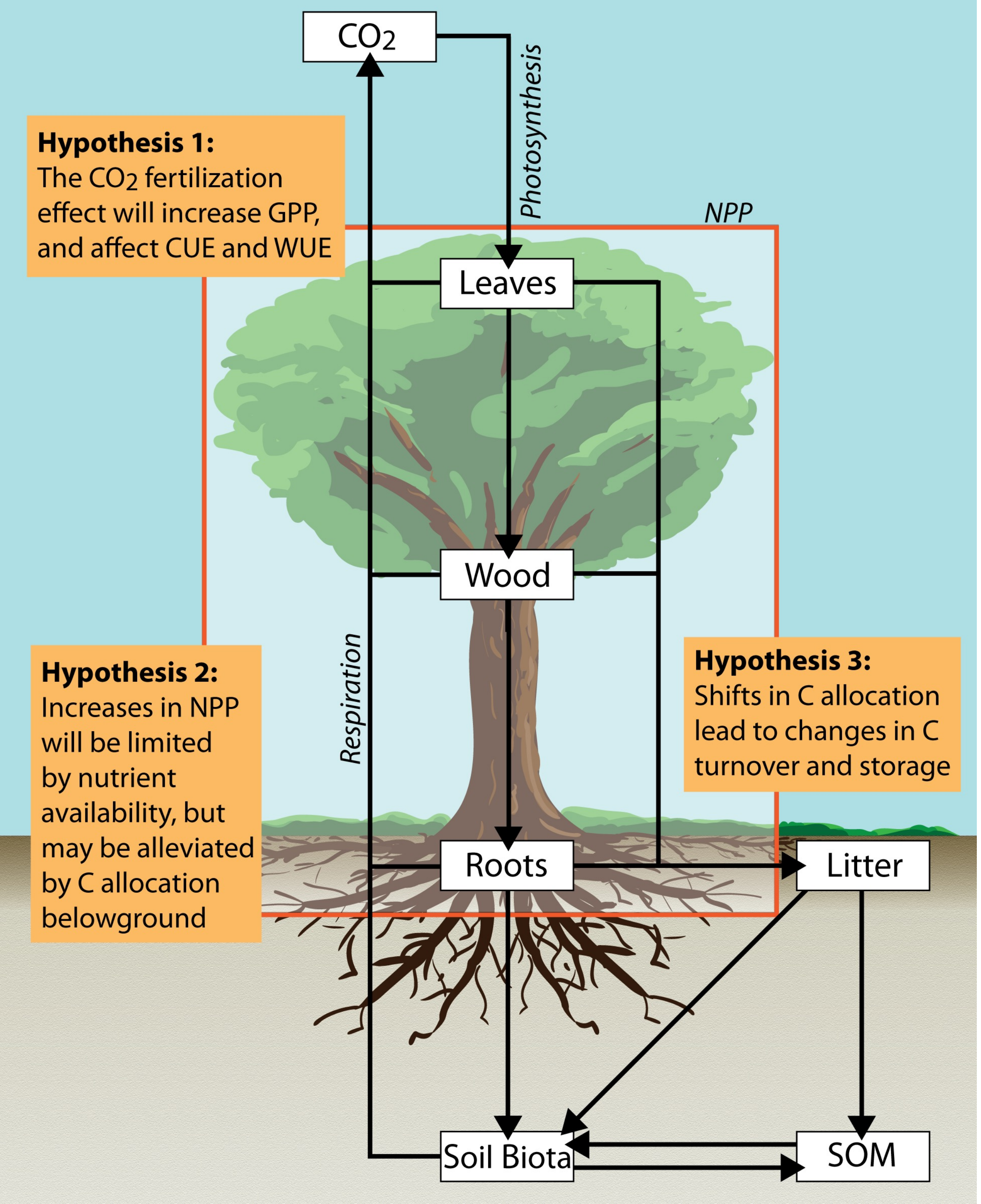


Six plots located in old-growth
Replicate plot design with thr

Mean temperature: 26°C
Precipitation: 2400 mm (dry s
Soil: Ferralsol/Oxisol



Hart et al., (2019) Global Change Biology 15: 5–15. doi:10.1111/gcb.14786



Response to eCO_2

What would we expect in response to elevated CO_2 ?

- <u>CO2 fertilization might affect</u>

→ Increased plant productivity (i.e. GPP / NPP)

- <u>Limited by nutrient availability</u>

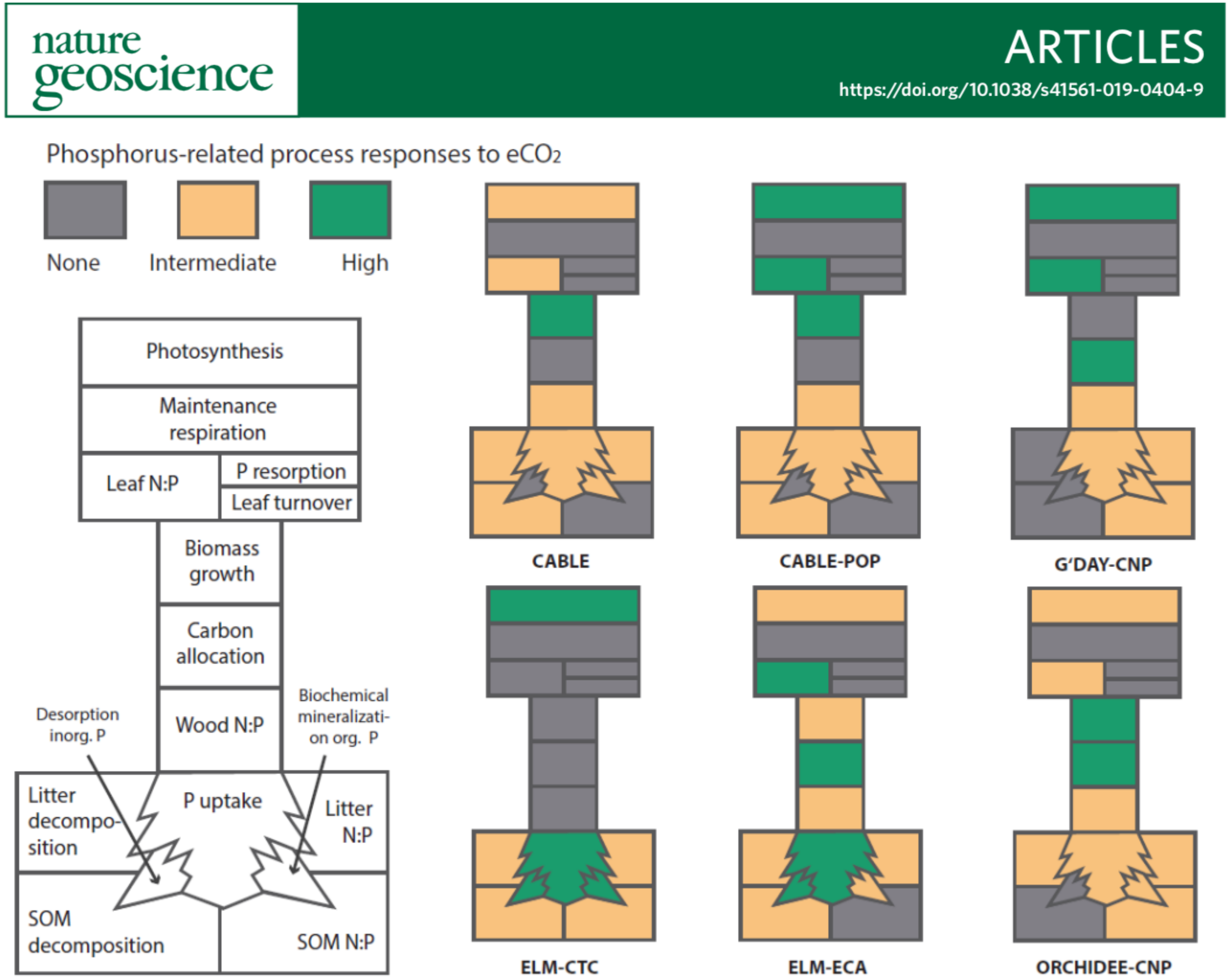
→ Belowground allocation of root tissues to acquire resources

- <u>Shift in C allocation likely affects</u>

→ Turnover and storage of carbon in the ecosystem (source / sink)

Hofhansl et al., (2016) Frontiers in Earth Science 4: 1540–9. doi:10.3389/feart.2016.00019

Response to elevated CO_2 hinges on nutrient limitation



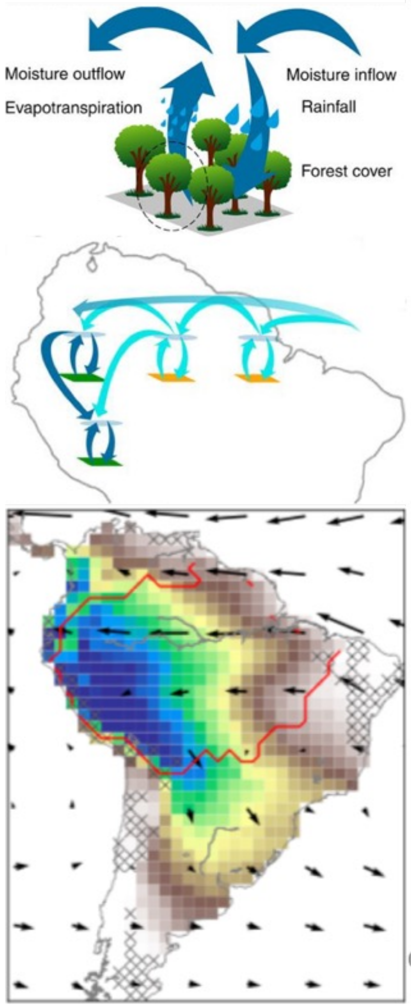
- **First model-ensemble including 6 CNP models;** (ORCHIDEE, CABLE, CABLE-POP, G'DAY, ELM-CTC, ELM-ECA)
- Differing in parameterization and thus representation of P control on biomass growth and nutrient dynamics

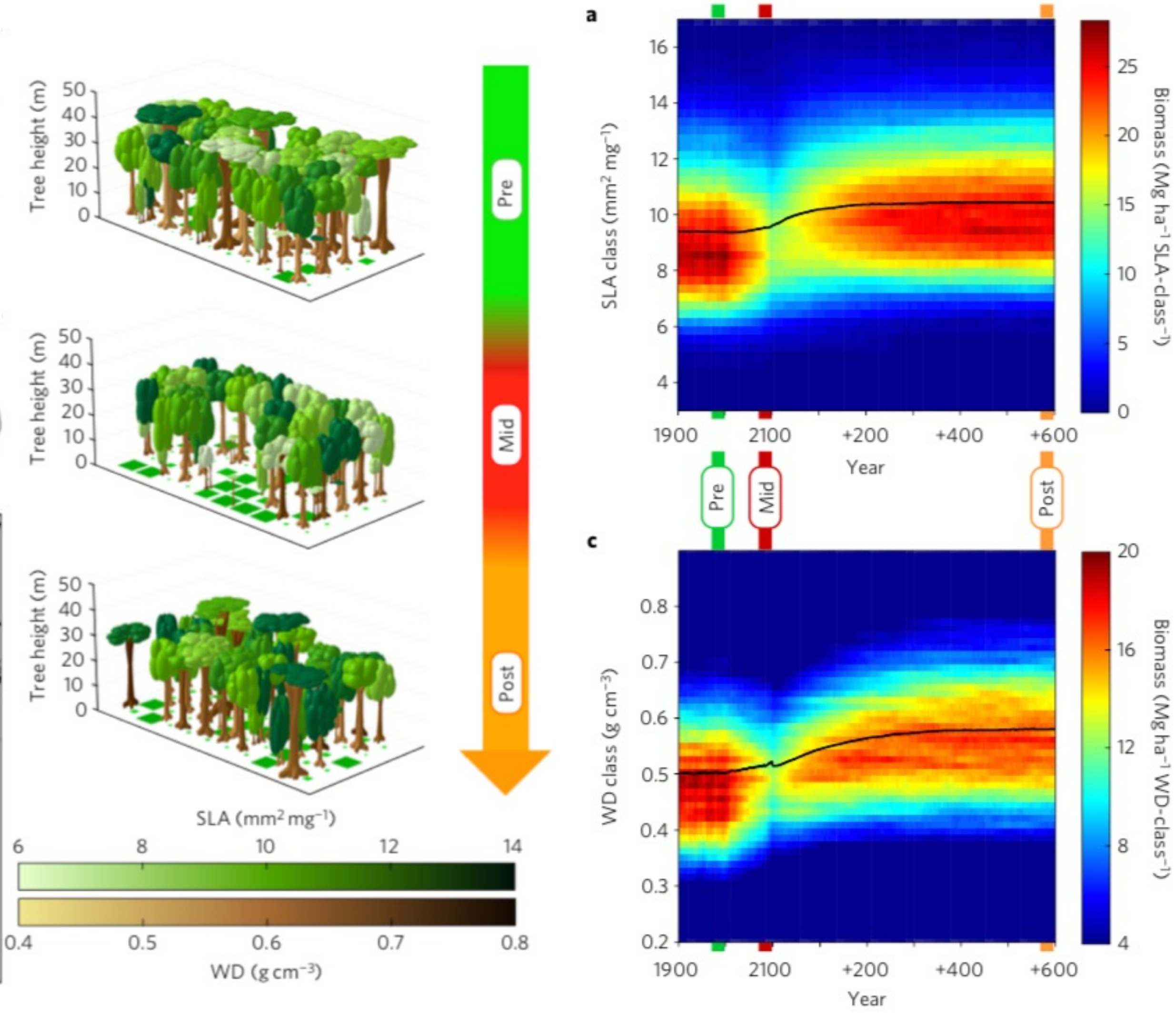
➢ reveals **P feedbacks** on biomass response to eCO2

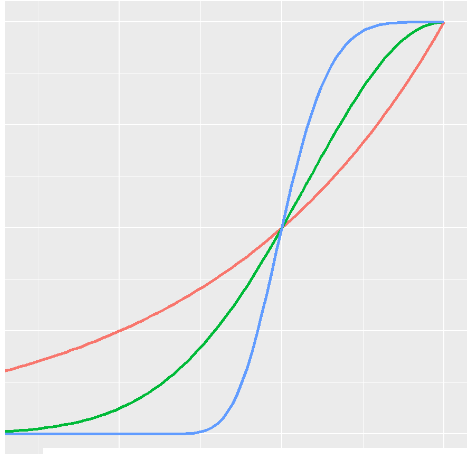
➢ enhanced **P acquisition** belowground alleviates P limitation (ELM/ORCHIDEE)

Fleischer et al., (2019) Nat. Geosci. 12, 736–741. https://doi.org/10.1038/s41561-019-0404-9

Project plant functional diversity and ecosystem functions

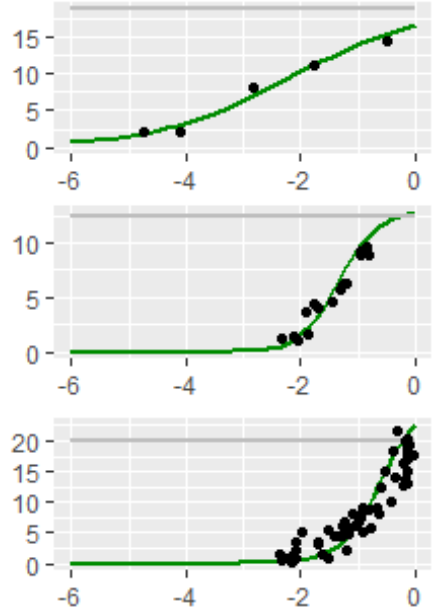






Conductivity as a function of water potential

parametrize plant hydraulic strategies



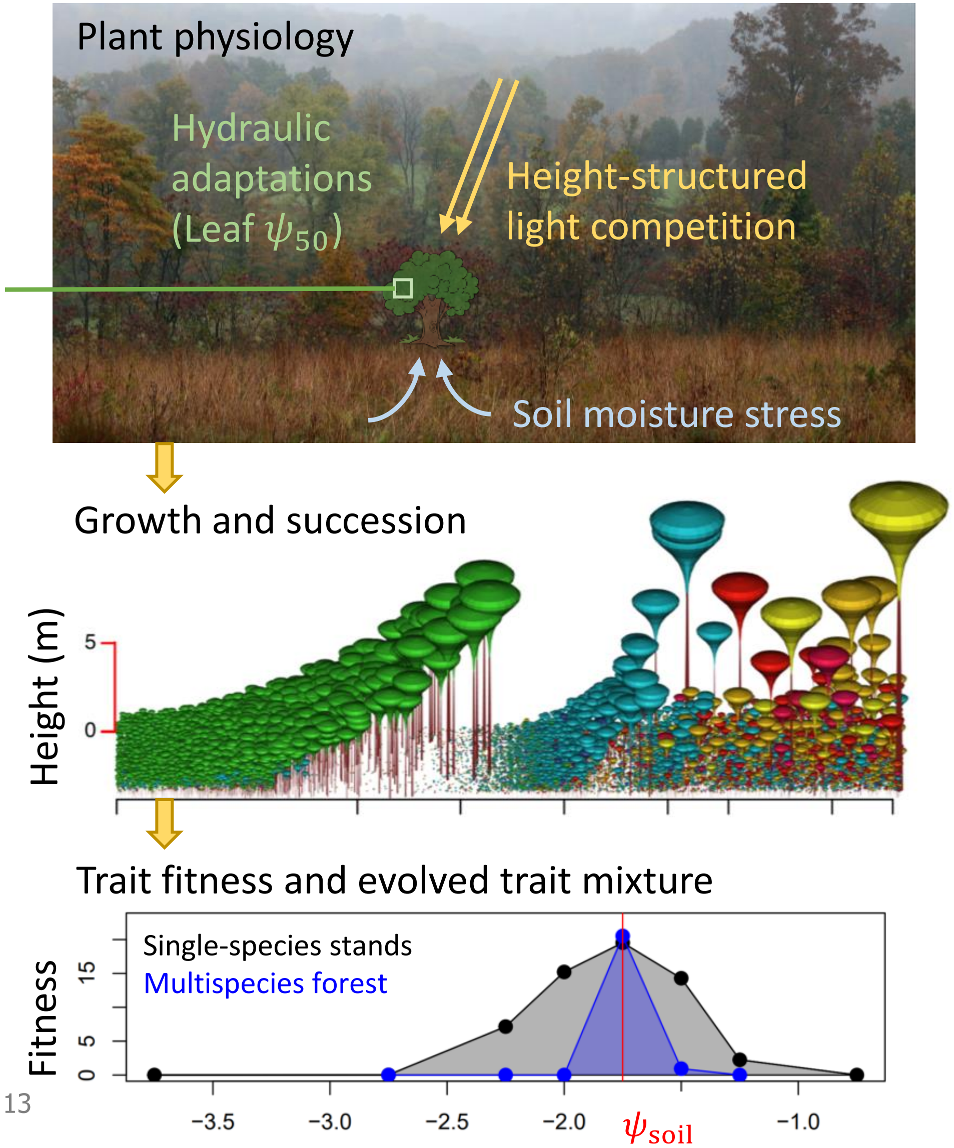
Quercus suber

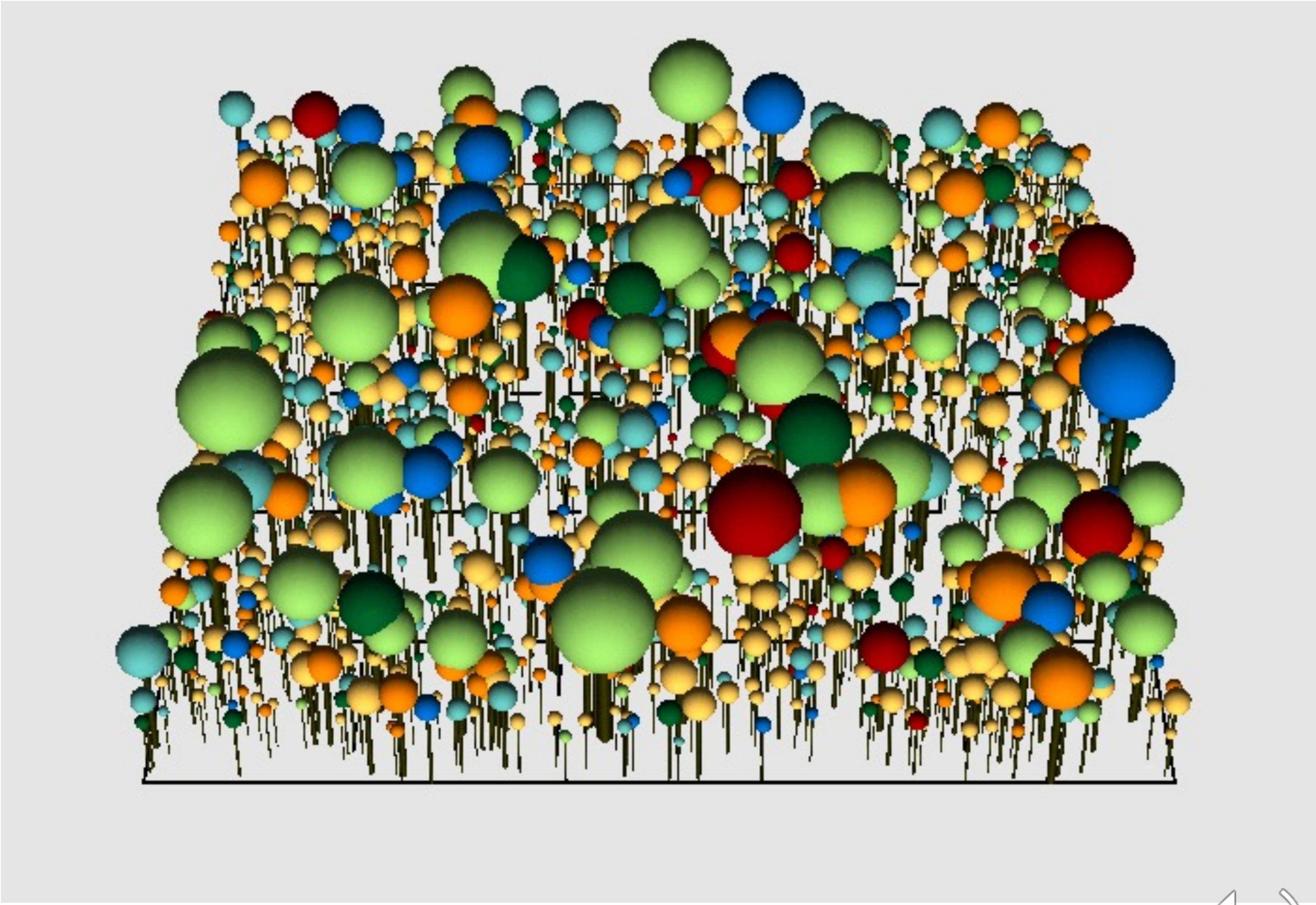
Ficus tikoua

Eucalyptus pilularis

Zemp et al. (2017) Nature Communications 8: 14681; Sakschewski et al. (2016). Nature Climate Change, 1–6; Joshi et al. (2021) EGU General Assembly, EGU21-11142.

Plant-FATE – Plant FuntionAl Trait Evolution Model





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

For further questions please contact me via the QR code linked to my personal website: https://tropicalbio.me/

Dr. Florian Hofhansl, Research Scholar, Biodiversity, Ecology, and Conservation (BEC) Research Group, Biodiversity and Natural Resources (BNR) Program, International Institute for Applied Systems Analysis (**IIASA**)

Annual Meeting of the British Ecological Society (BES), 18 - 21 December 2022, Edinburgh, Scotland