GEO-TREES:

The critical need for ground-based forest carbon monitoring

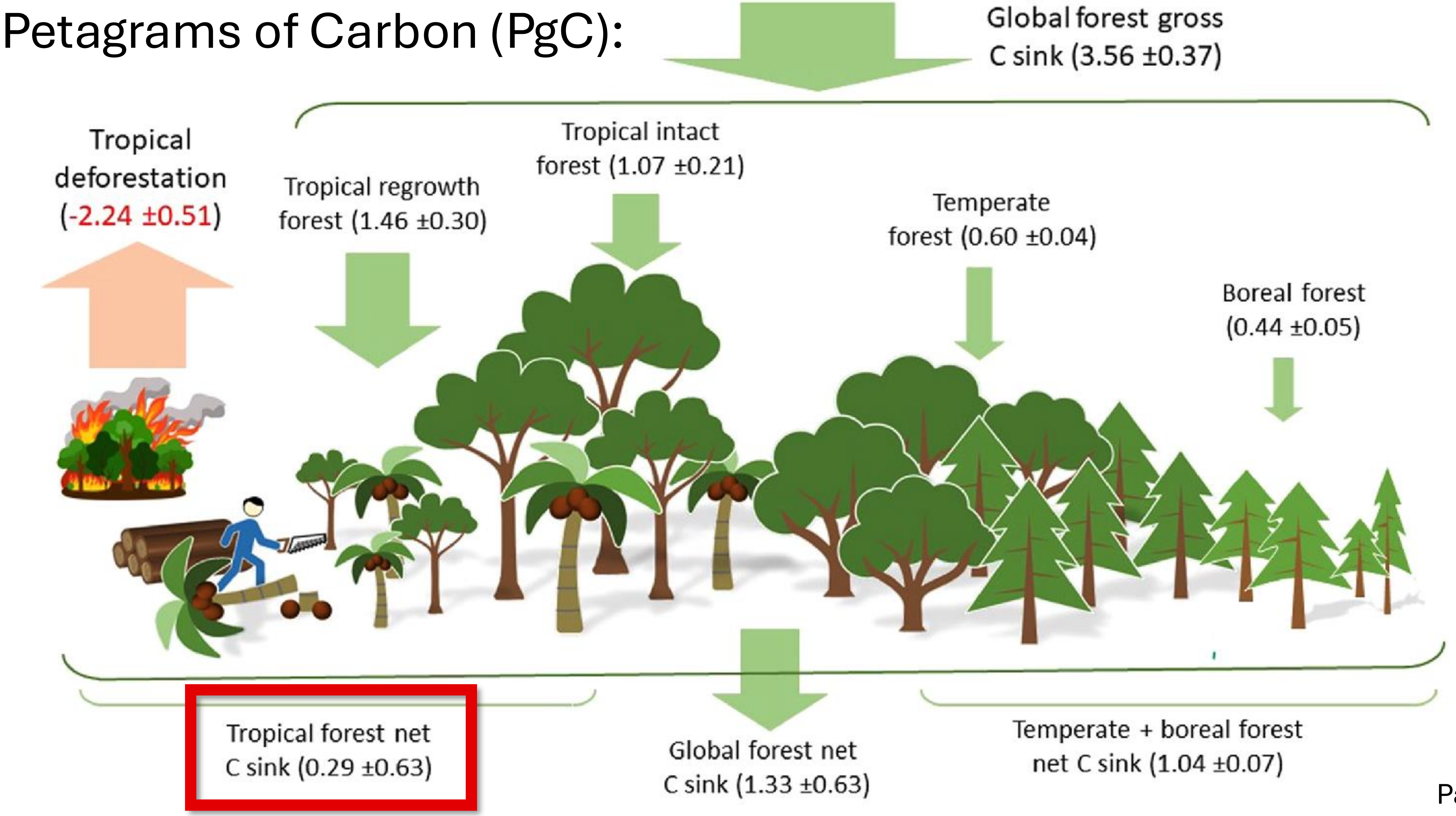
John L. Godlee

GEO TREES

ForestGEO
GLOBAL EARTH OBSERVATORY NETWORK

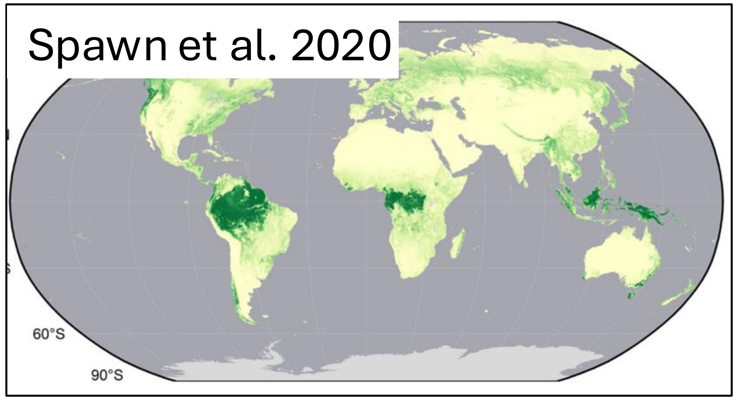
SMITHSONIAN INSTITUTION

Tropical forests drive uncertainty in the carbon cycle

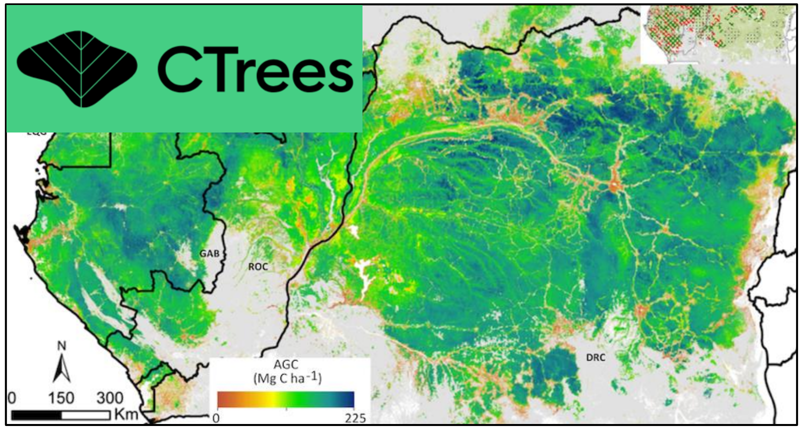


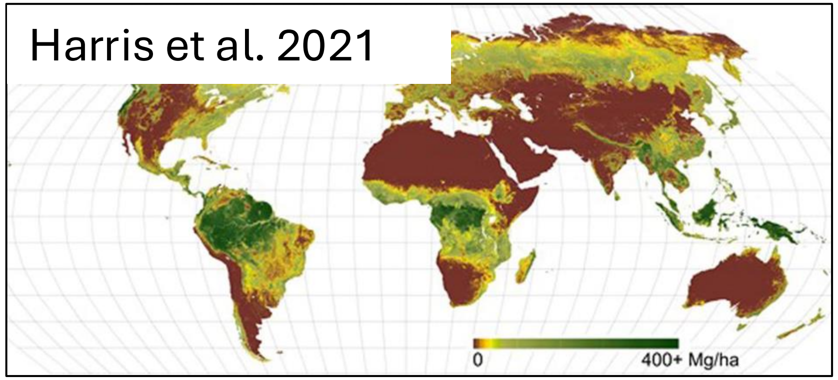
Pan et al. 2024

There are LOTS of biomass maps

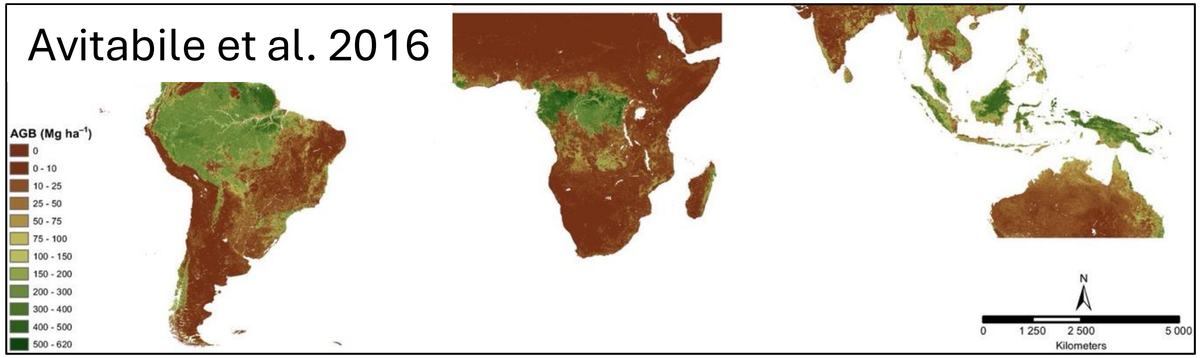


Spawn et al. 2020





Harris et al. 2021

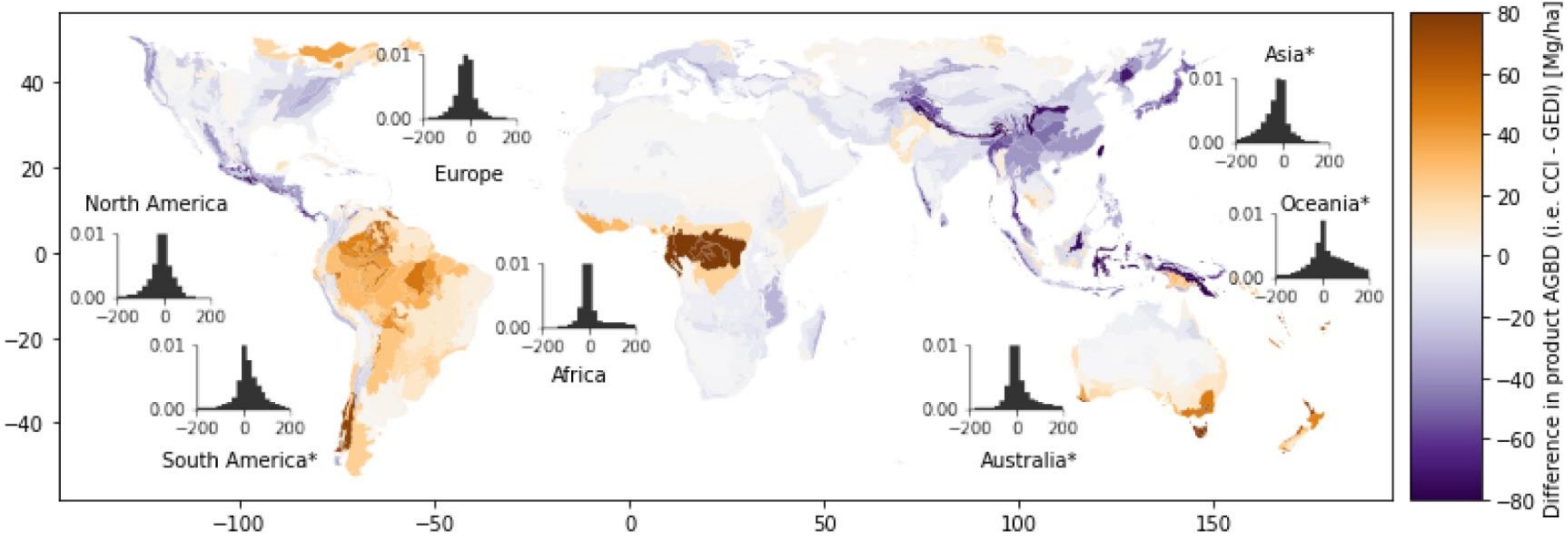


Avitabile et al. 2016

Biomass maps disagree!

Comparison of ESA CCI and GEDI biomass maps.

Systematic regional differences in biomass estimates (±80 Mg ha^{-1}), driven by availability and treatment of validation data.



Hunka et al. 2023

GEO-TREES is a global collaboration

GEO TREES

FORESTPLOTS.NET Partners

ForestGEO

GEO GROUP ON EARTH OBSERVATIONS

CEOS Committee on Earth Observation Satellites

esa

NASA

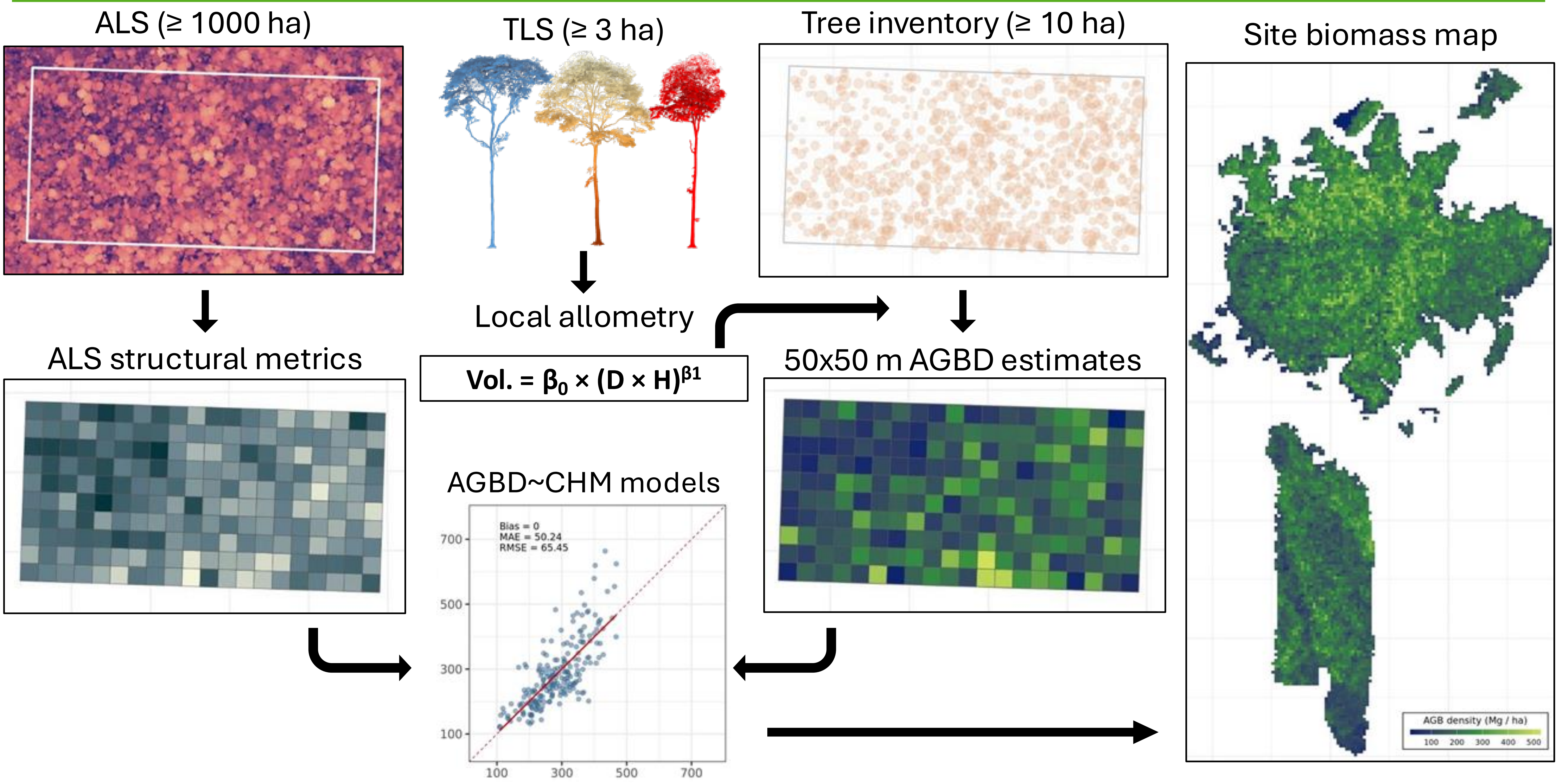
cnes

cnrs

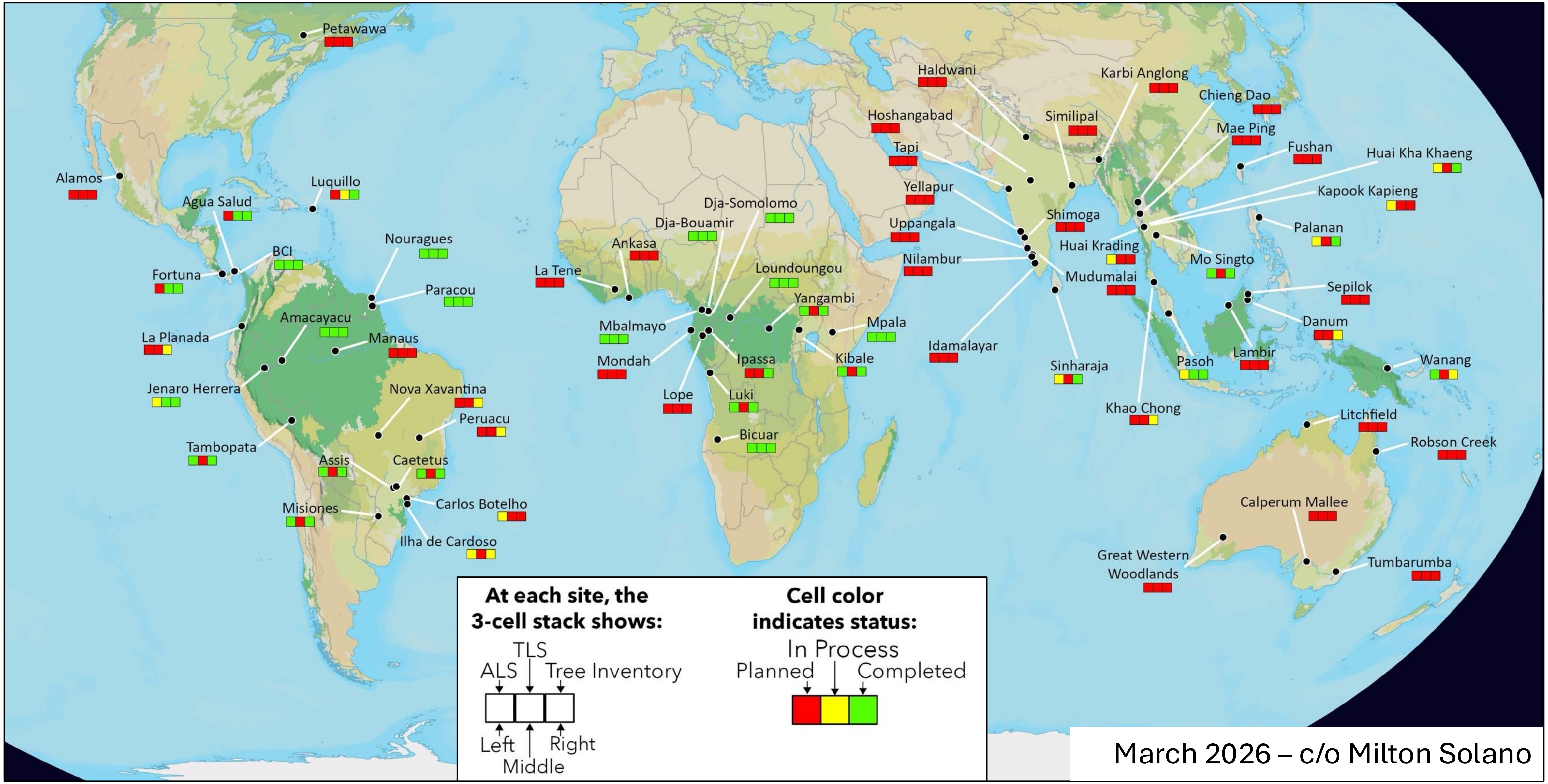
ForestGEO GLOBAL EARTH OBSERVATORY NETWORK

SMITHSONIAN INSTITUTION

GEO-TREES will provide validation data



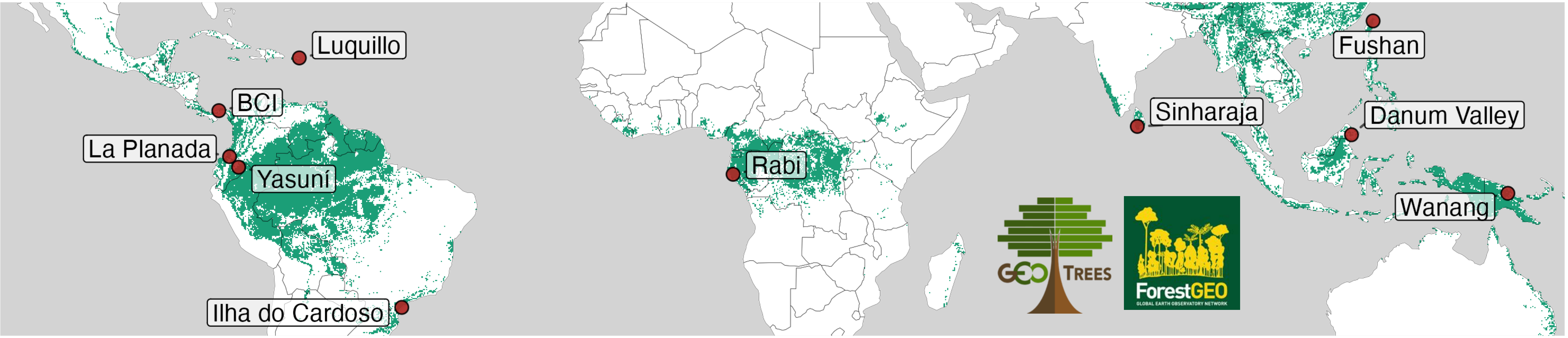
GEO-TREES sites: data collection progress



March 2026 – c/o Milton Solano

Ecological covariates of biomass at local scales

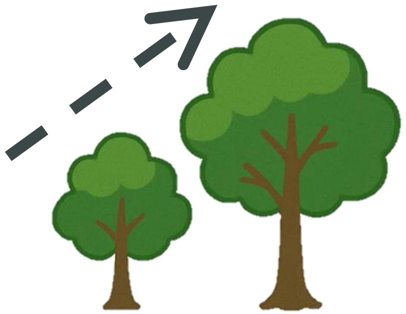
Do forests follow different "functional recipes" to achieve high biomass?



Community weighted means of species functional traits in 50×50 m quadrats

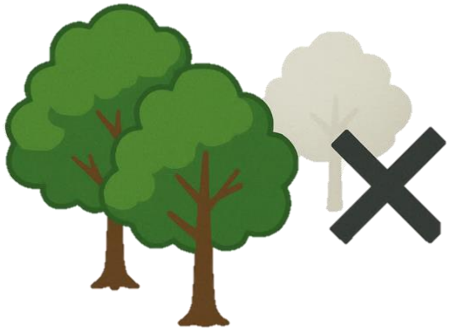
Potential growth rate

95th percentile basal area growth



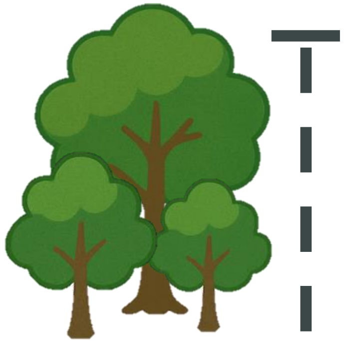
Potential survival

Annual survival of 25% largest trees



Maximum size

99th percentile diameter



Wood density

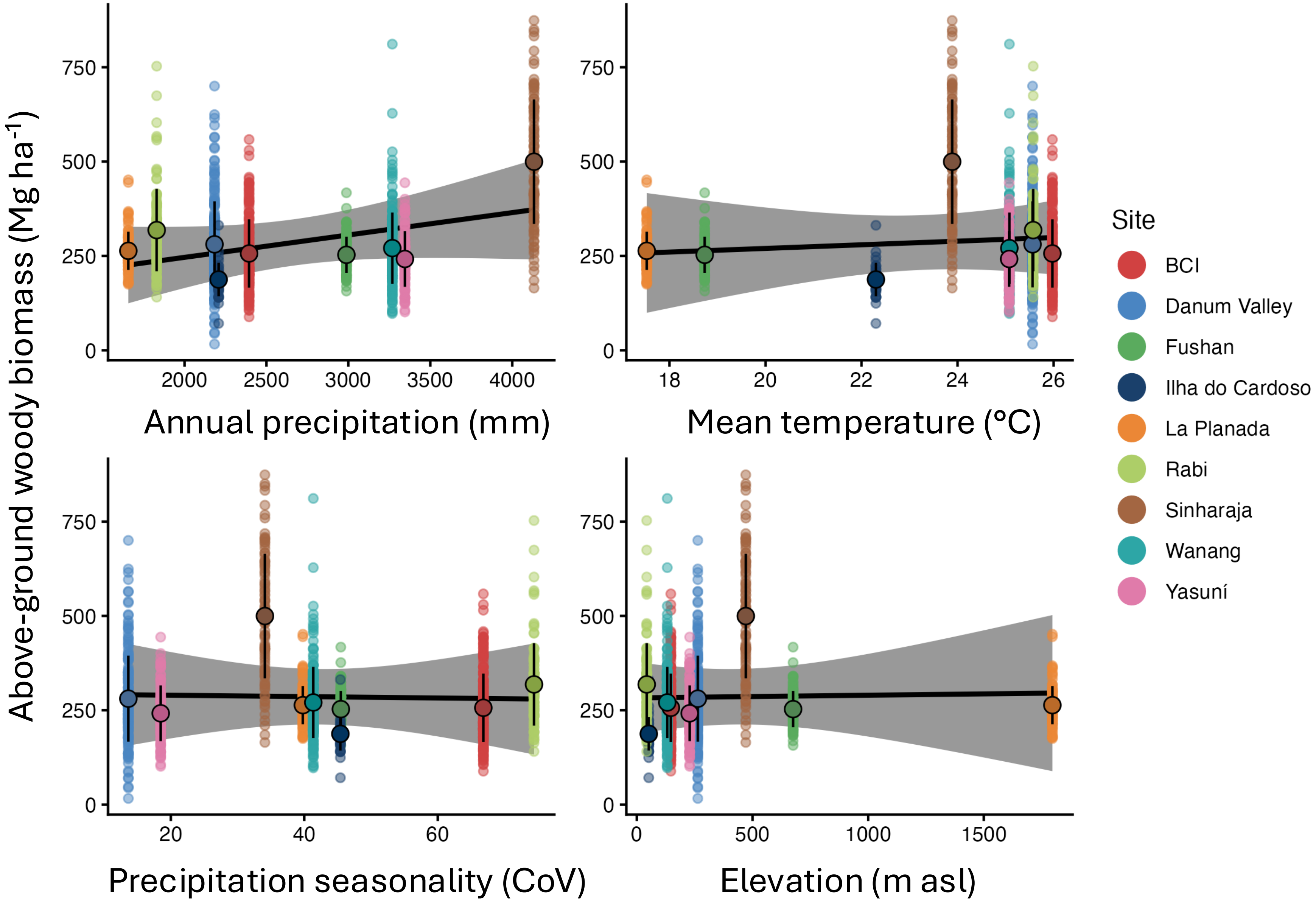
Per species (Zanne et al. 2009)

Climatic gradients do not capture local variation

More within- than among-site variation in biomass stocks.

Climate gradient effects on biomass stocks are weak.

Local environmental factors (e.g. topography, soils) have site-specific effects.

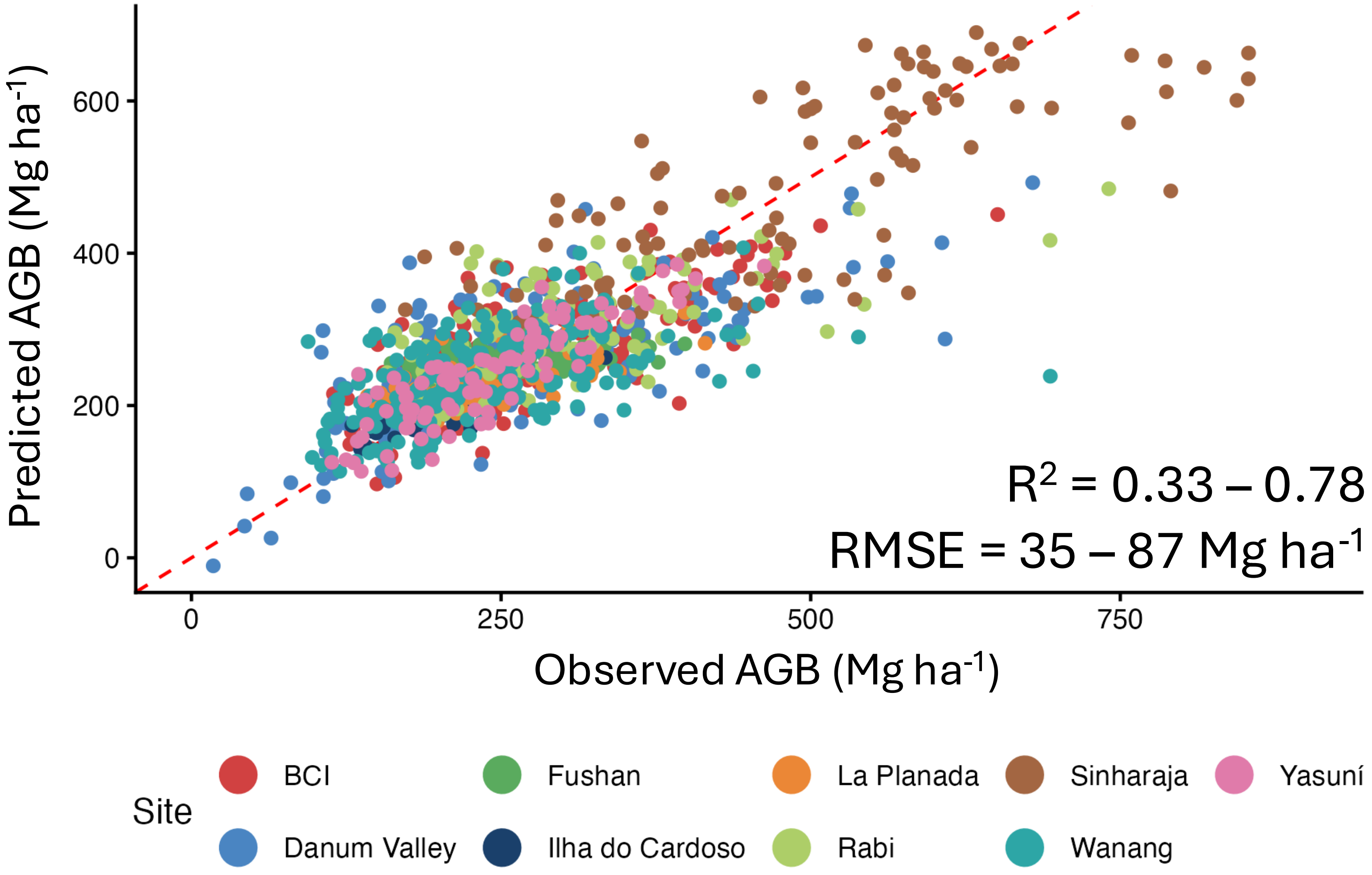


Composition is highly predictive of biomass stocks

One model per site.

Predictors: axes from Principal Coordinates Analysis (PCoA) of composition dissimilarity matrix.

No information on traits or biomass, only relative abundance.

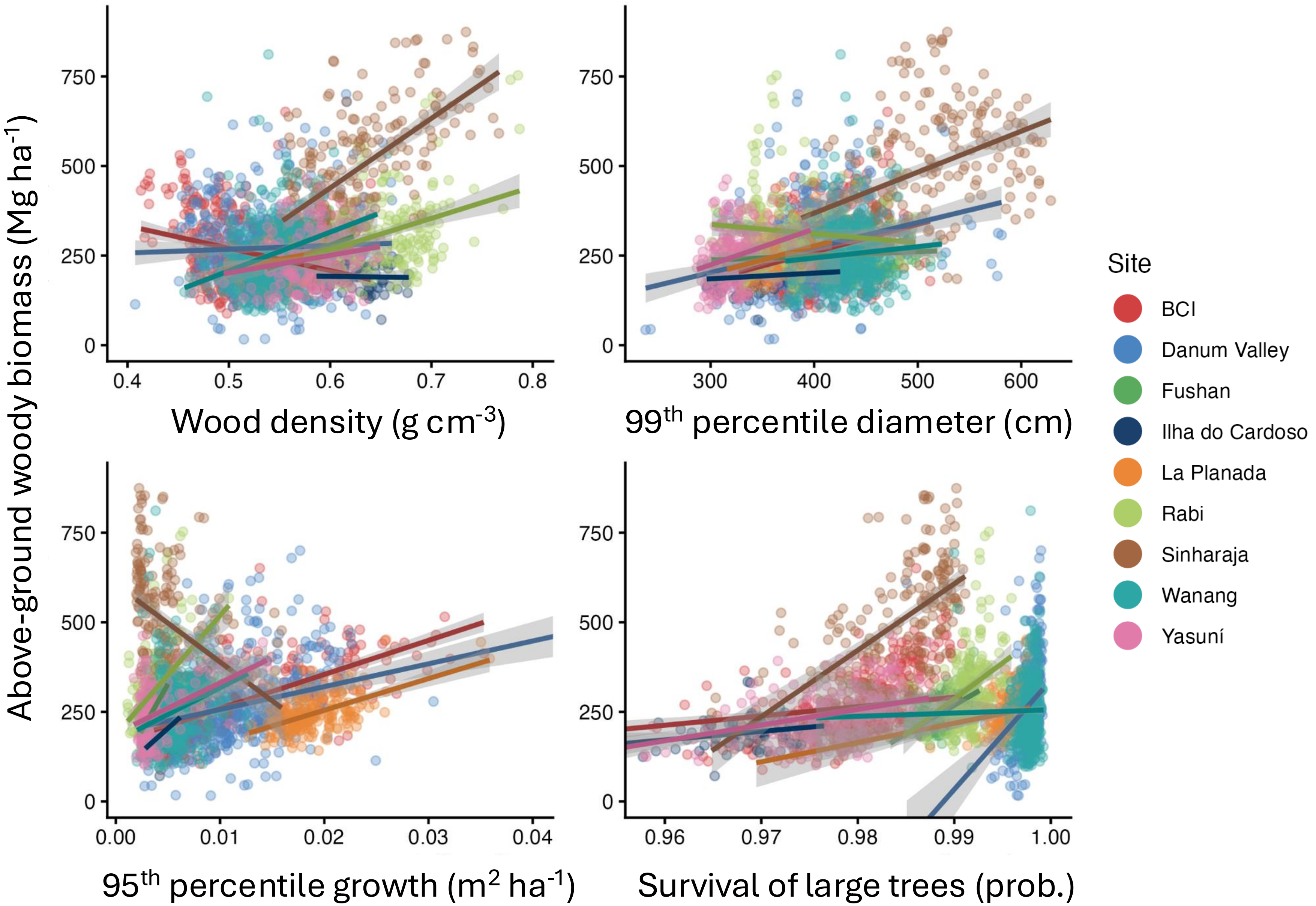


Many different functional recipes for high biomass

Importance of different traits varies by site.

Among sites, similar biomass stocks can result from different trait values.

Negative effects of some traits at some sites implies co-variation of traits.

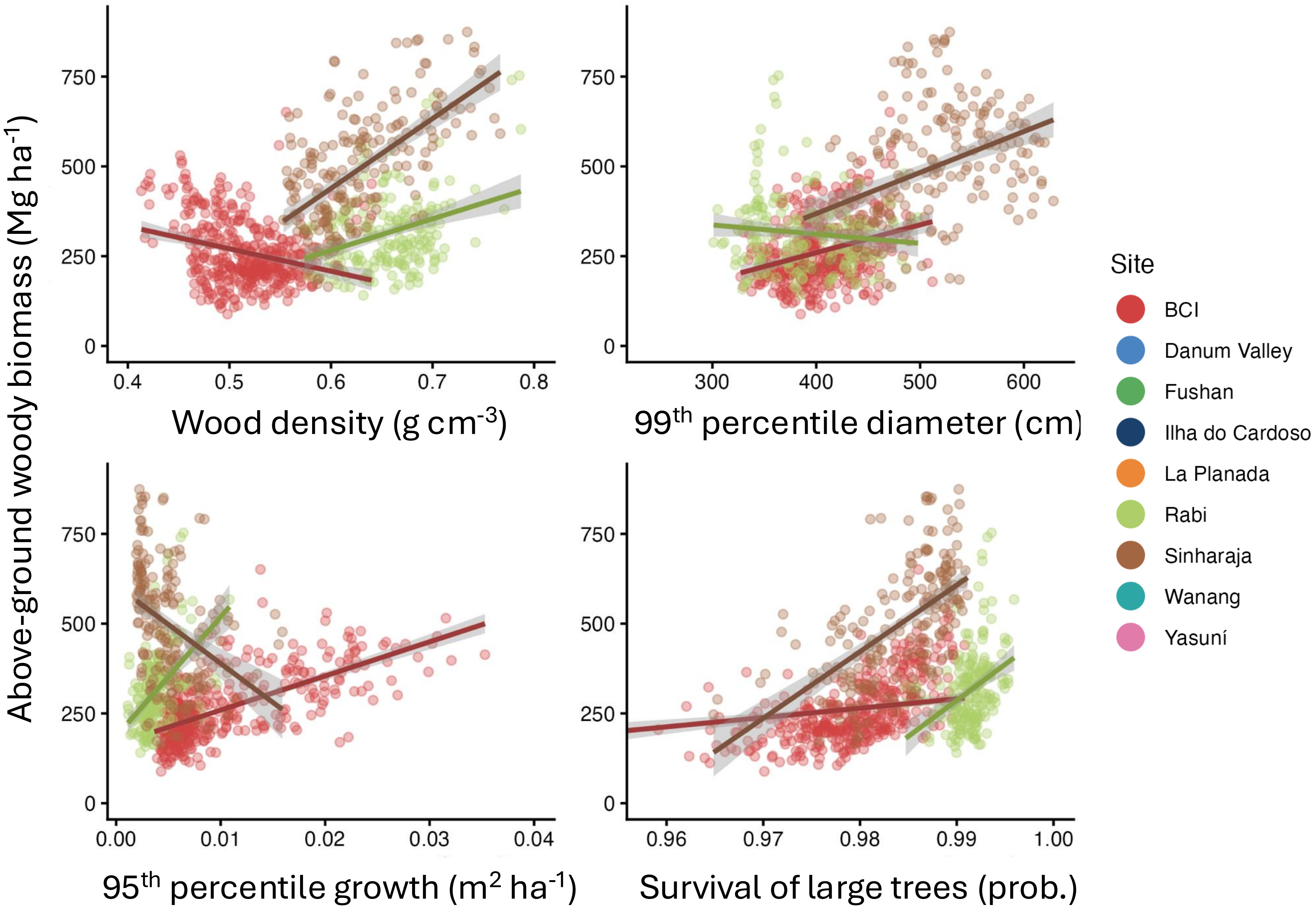


Many different functional recipes for high biomass

BCI (Panama):
semi-deciduous
El Niño drought forest.

Sinharaja (Sri Lanka):
mid-elevation sub-montane rainforest.

Rabi (Gabon):
lowland moist flooded forest.

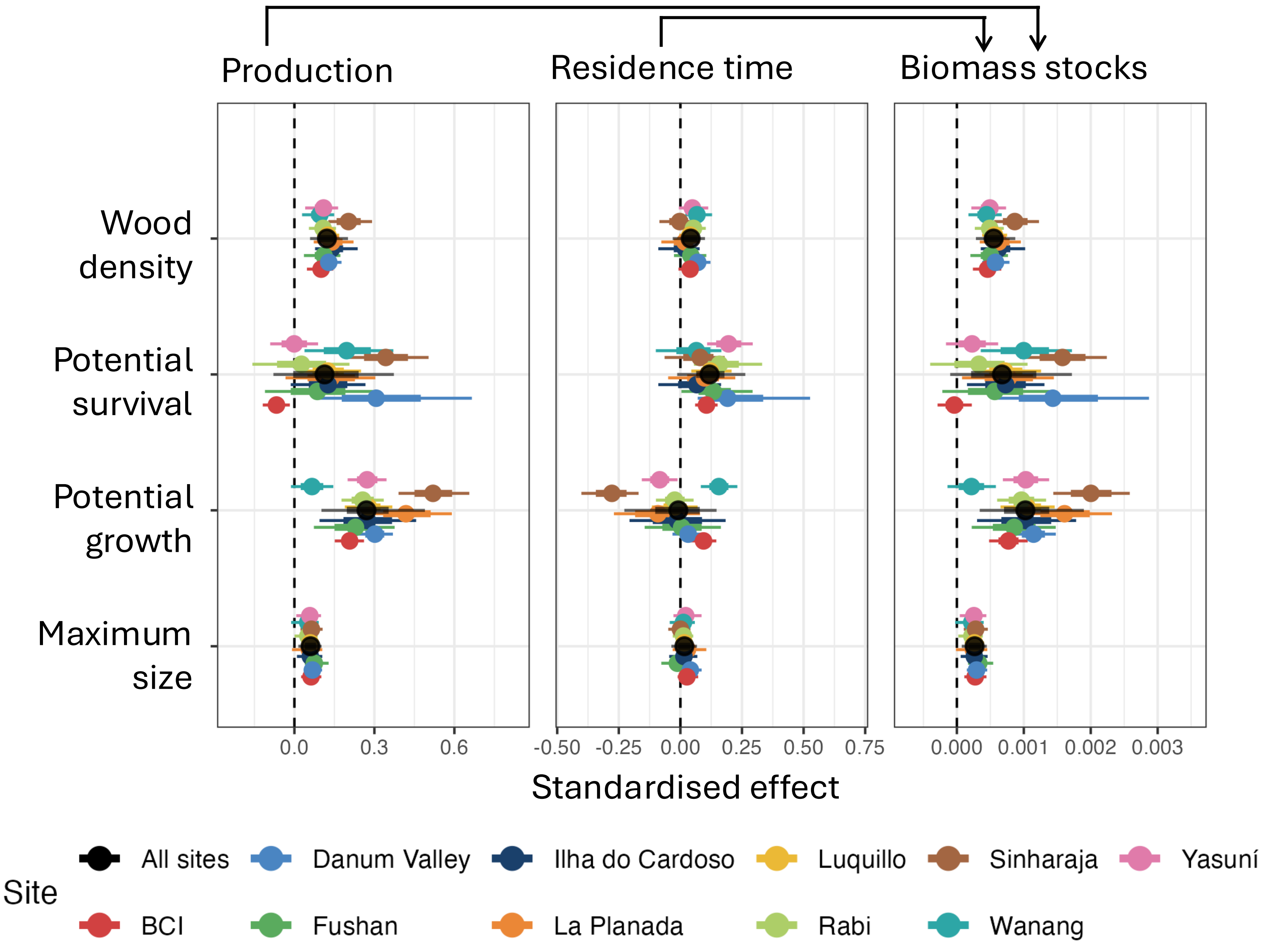


Importance of community traits for biomass

Importance of growth and survival for biomass stocks varies among sites.

Wood density a consistent driver of biomass across sites.

Potential size not important. An outcome of growth and survival?



References

Pan, Y. *et al*. – **The enduring world forest carbon sink.** *Nature* **631**(8021), 563–569. https://doi.org/10.1038/s41586-024-07602-x

Pan, Y. *et al*. – **A large and persistent carbon sink in the world's forests.** *Science* **333**(6045), 988–993. https://doi.org/10.1126/science.1201609

McNicol, I. M., Ryan, C. M. & Mitchard, E. T. A. – **Carbon losses from deforestation and widespread degradation offset by extensive growth in African woodlands.** *Nature Communications* **9**, 1–11. https://doi.org/10.1038/s41467-018-05386-z

Spawn, S. A., Sullivan, C. C., Lark, T. J. & Gibbs, H. K. – **Harmonized global maps of above and belowground biomass carbon density in the year 2010.** *Scientific Data* **7**(1). https://doi.org/10.1038/s41597-020-0444-4

Yang, Y. *et al*. – **From Snapshot Maps to Continuous Monitoring of Global Forest Carbon at 100 m Resolution (2000–2025).** https://doi.org/10.31223/x5kj4q

Santoro, M. & Cartus, O. – **ESA Biomass Climate Change Initiative (Biomass_cci): Global datasets of forest above-ground biomass for the years 2010, 2017, 2018, 2019 and 2020, v4.** NERC EDS Centre for Environmental Data Analysis. https://doi.org/10.5285/AF60720C1E404A9E9D2C145D2B2EAD4E

Dubayah, R. *et al*. – **GEDI launches a new era of biomass inference from space.** *Environmental Research Letters* **17**(9), 095001. https://doi.org/10.1088/1748-9326/ac8694

Baccini, A., Walker, W., Carvalho, L., Farina, M., Sulla-Menashe, D. & Houghton, R. A. – **Tropical forests are a net carbon source based on aboveground measurements of gain and loss.** *Science* **358**(6360), 230–234. https://doi.org/10.1126/science.aam5962

Avitabile, V. *et al*. – **An integrated pan-tropical biomass map using multiple reference datasets.** *Global Change Biology* **22**(4), 1406–1420. https://doi.org/10.1111/gcb.13139

Hunka, N. *et al*. – **On the NASA GEDI and ESA CCI biomass maps: aligning for uptake in the UNFCCC global stocktake.** *Environmental Research Letters* **18**(12), 124042. https://doi.org/10.1088/1748-9326/ad0b60

Sullivan, M. J. P. *et al*. – **Variation in wood density across South American tropical forests.** *Nature Communications* **16**(1). https://doi.org/10.1038/s41467-025-56175-4

Chave, J. *et al*. – **Improved allometric models to estimate the aboveground biomass of tropical trees.** *Global Change Biology* **20**(10), 3177–3190. https://doi.org/10.1111/gcb.12629

Réjou-Méchain, M., Tanguy, A., Piponiot, C., Chave, J. & Herault, B. – **BIOMASS: an R package for estimating above-ground biomass and its uncertainty in tropical forests.** *Methods in Ecology and Evolution* **8**(9), 1163–1167. https://doi.org/10.1111/2041-210X.12753

Réjou-Méchain, M. *et al*. – **Upscaling Forest Biomass from Field to Satellite Measurements: Sources of Errors and Ways to Reduce Them.** *Surveys in Geophysics* **40**(4), 881–911. https://doi.org/10.1007/s10712-019-09532-0