Woody carbon in the dry tropics:

Biodiversity, structure and environment

John L. Godlee &
the SECO team

THE UNIVERSITY *of* EDINBURGH
School of GeoSciences

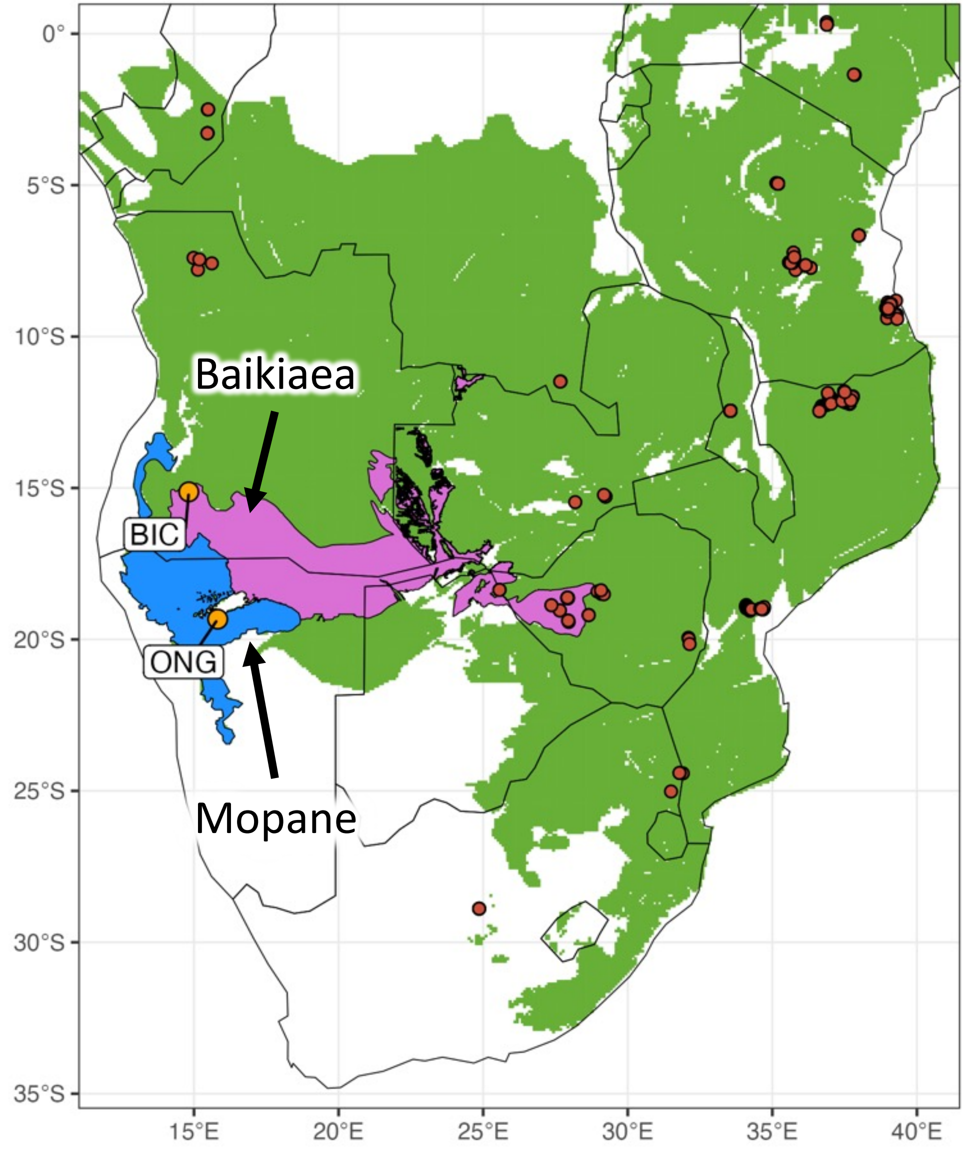
My background

- Functional/community ecologist
  - Ecosystem productivity, biogeography, structure
  - Tropical savannas, dry forests, temperate woodlands
- PhD (2021) at the University of Edinburgh
  - Biodiversity and ecosystem function in African savannas
- Post-Doc (2021-now) SECO: dry tropical carbon dynamics
  - Global multi-network plot analyses
  - Where and why is woody biomass changing?
  - How does biogeography affect responses to change?
  - https://blogs.ed.ac.uk/seco-project/

Open savanna, southwest Angola

Ancient woodland, North Yorkshire, UK

Developing vegetation monitoring infrastructure



Godlee et al. (2020) *Diversity*

Miombo savanna, Bicuar National Park (BIC)

Succulent dry forest, Ongava Reserve (ONG)

Funded by:

NATIONAL GEOGRAPHIC

UKaid from the British people | Department for International Development

SEOSAW

Collaboration with:

Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

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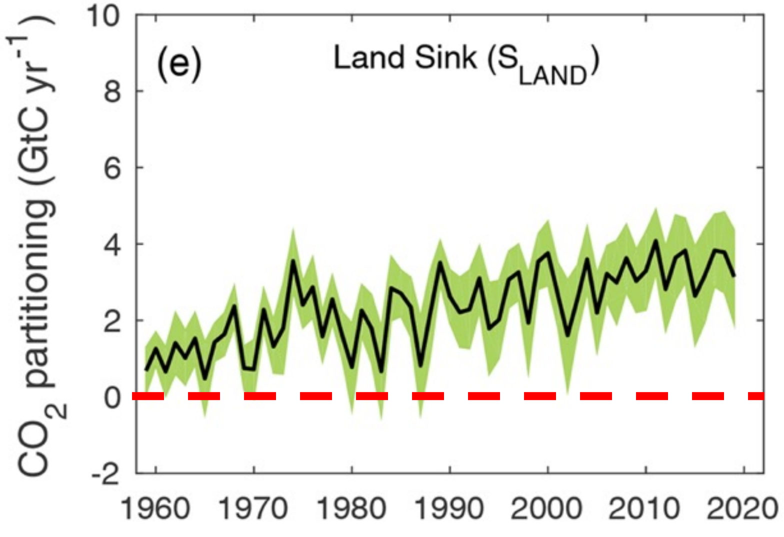
Dry tropical vegetation and global change

SECO: Motivations and approach

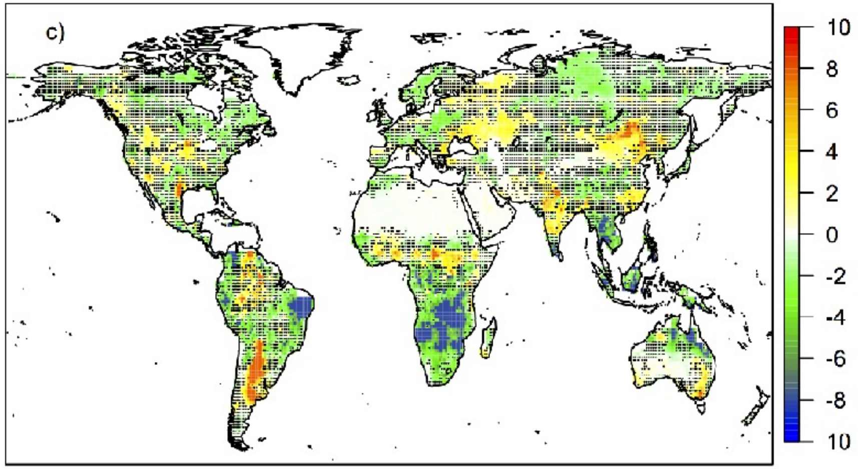
1. What is the role of terrestrial vegetation in global biogeochemical cycles?

- Process-based models predict high sensitivity to increasing CO_2.
- Increasing CO_2 coincides with warming trend and changes in rainfall.

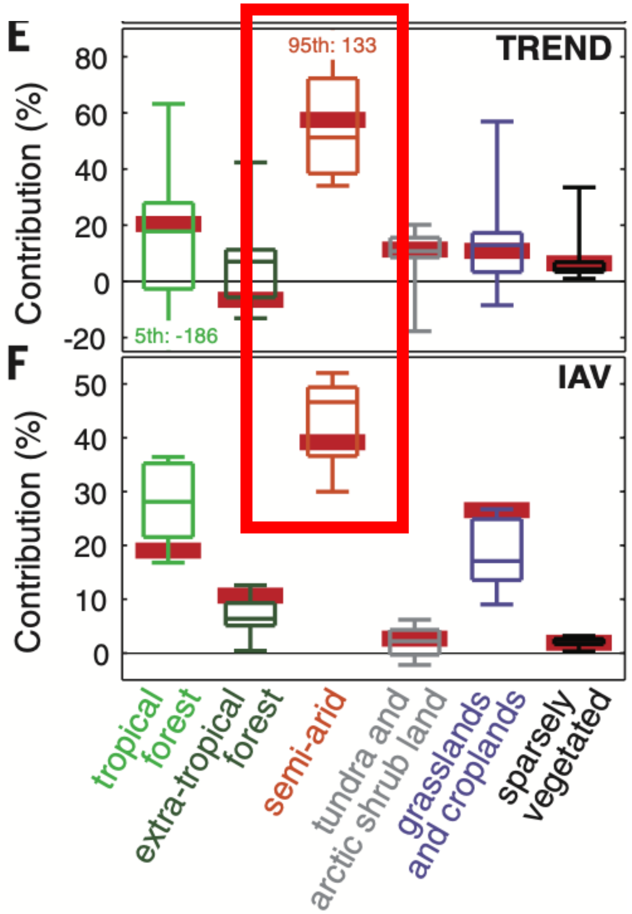
Models: increasing terrestrial carbon sink



Spatial variability in carbon flux trend

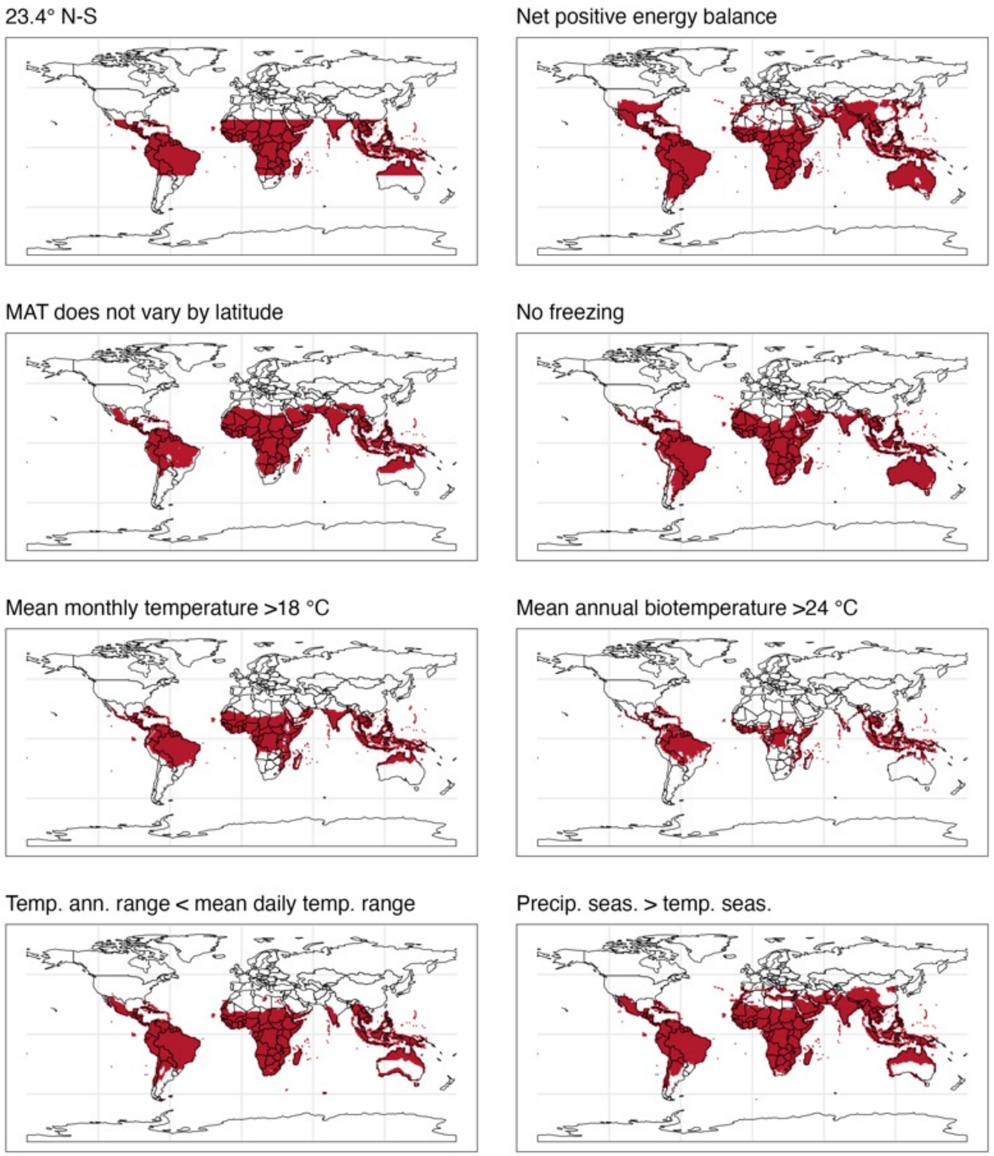


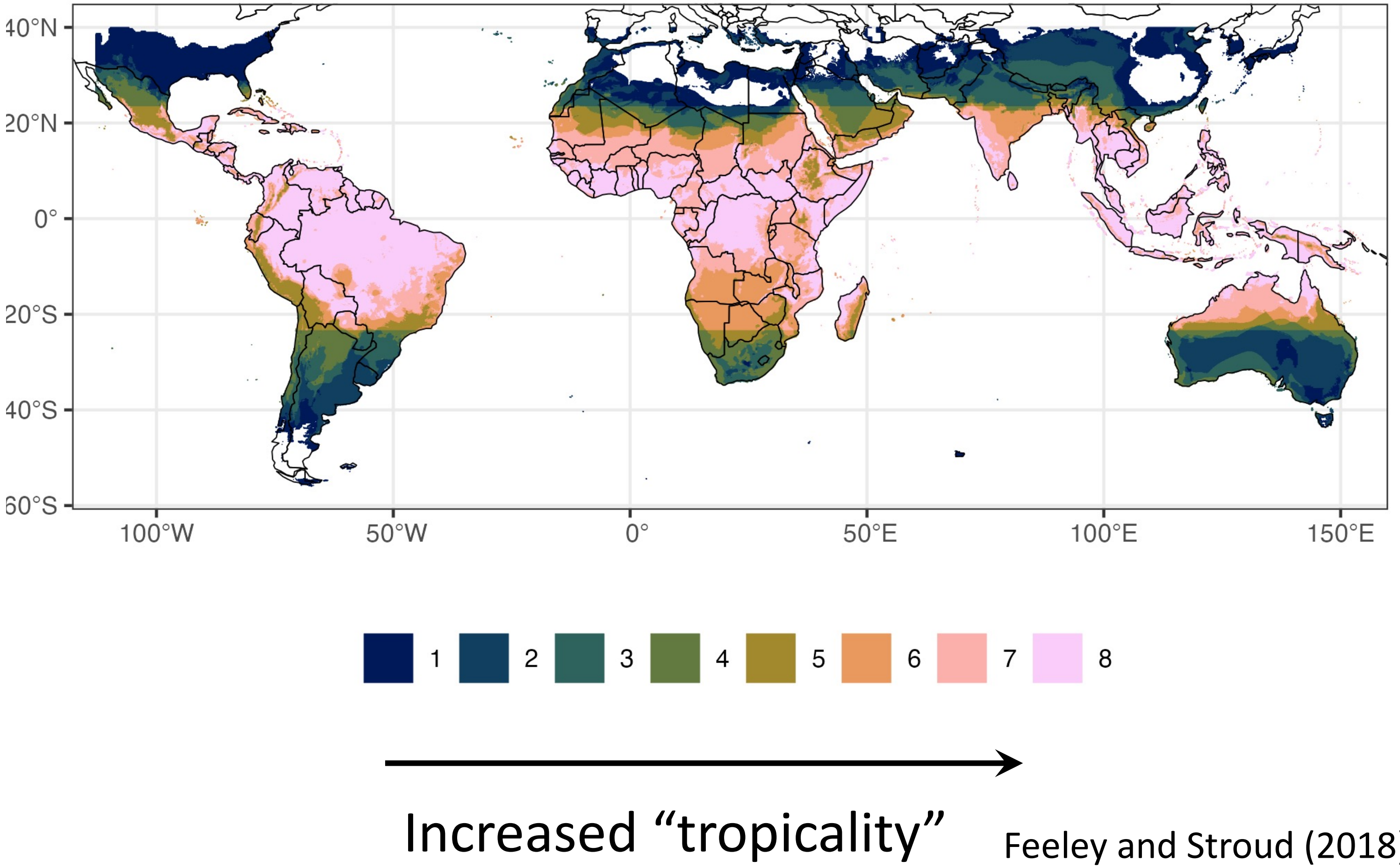
Uncertainty in trend and inter-annual variability of carbon sink



Ahlstrom et al. (2015), Sitch et al. (2015), Le Quere et al. (2020)

Where are the (dry) tropics?

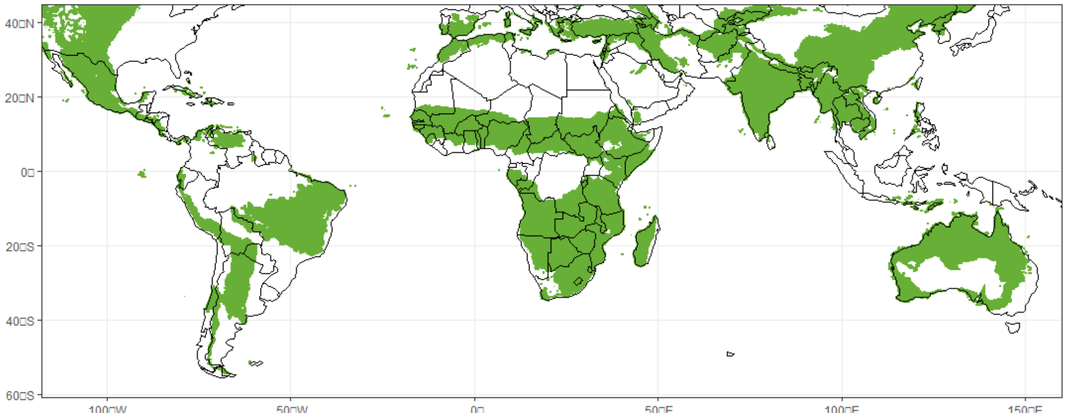




Feeley and Stroud (2018)

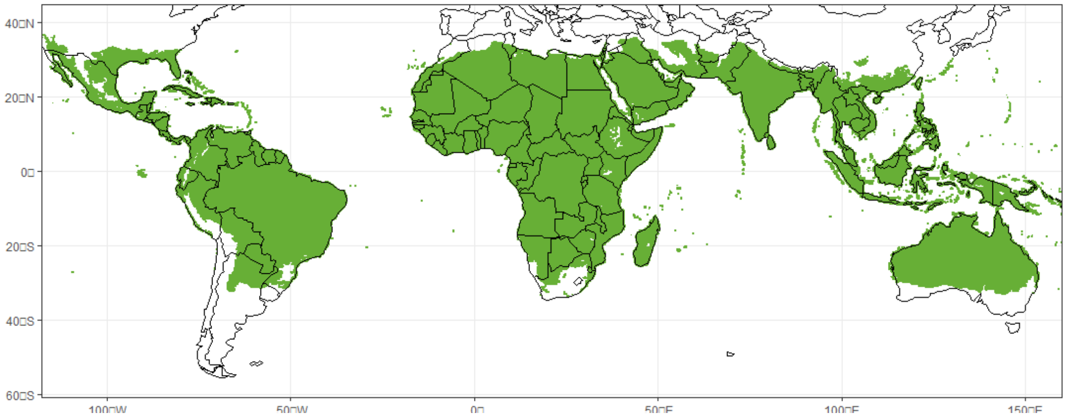
Where are the (dry) tropics?

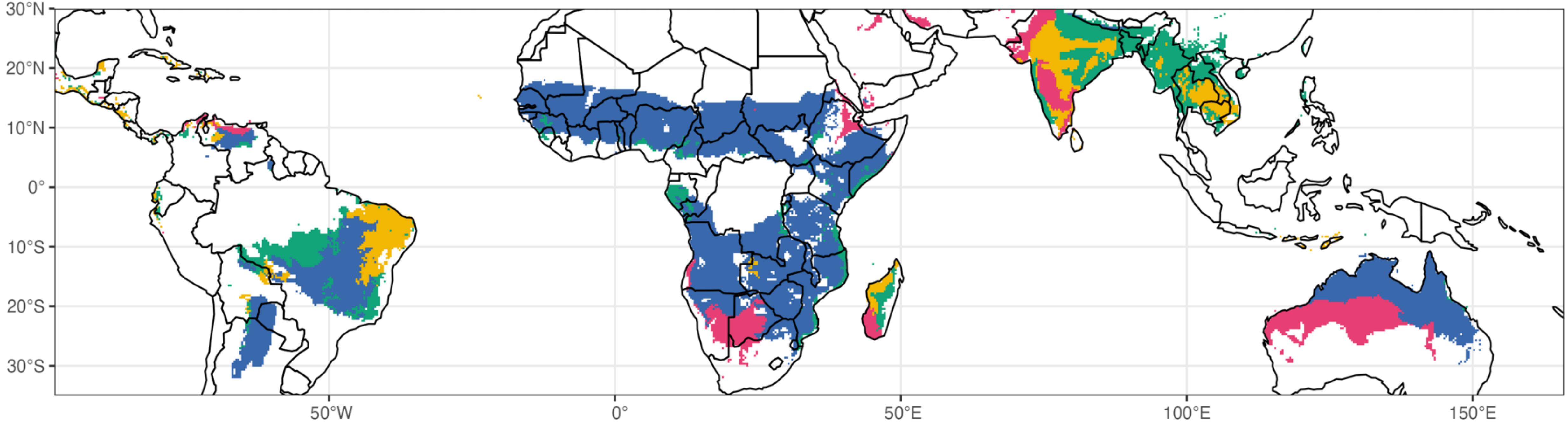
Mean temperature of coldest quarter >15°C)



+

≥3 dry months (<30 mm rainfall)





Ack: Sam Harrison, Dinerstein et al. (2017)

Half of the global tropics is seasonally dry

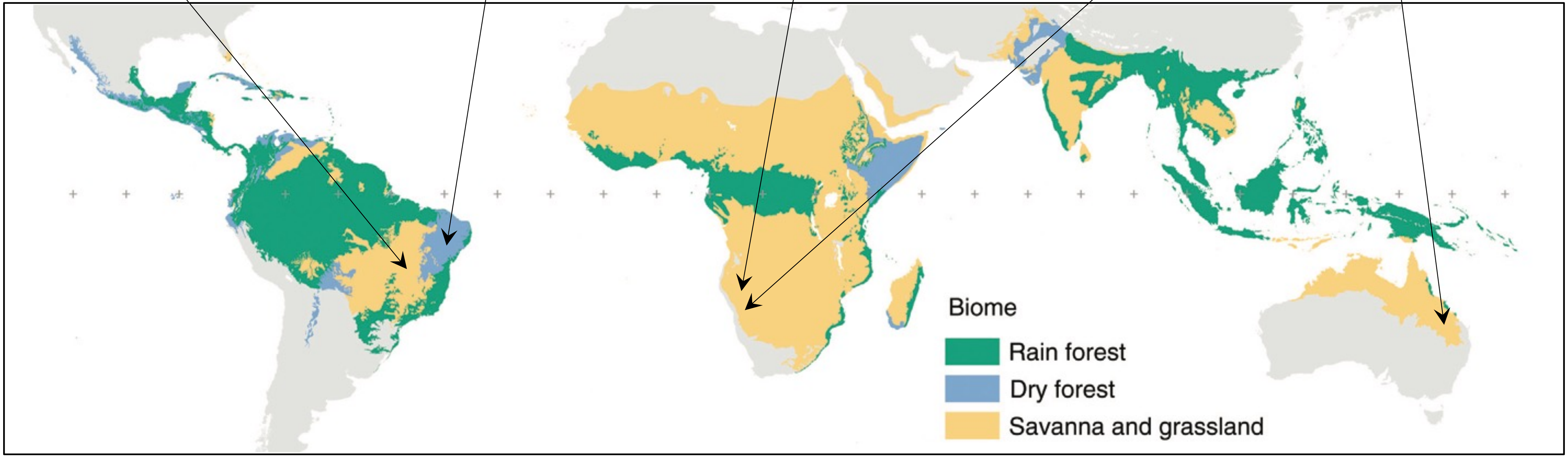
Cerrado,
Brazil

Caatinga,
Brazil

Miombo,
Angola

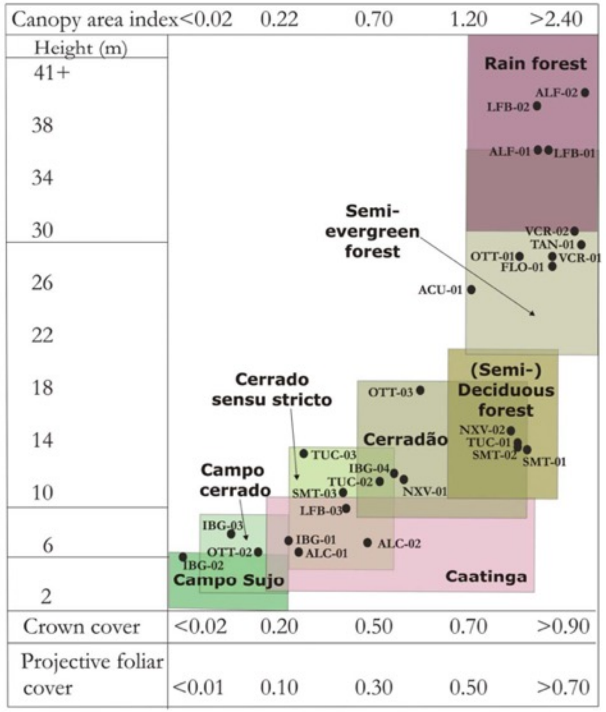
Mopane dry forest,
Namibia

Eucalypt savanna,
Australia

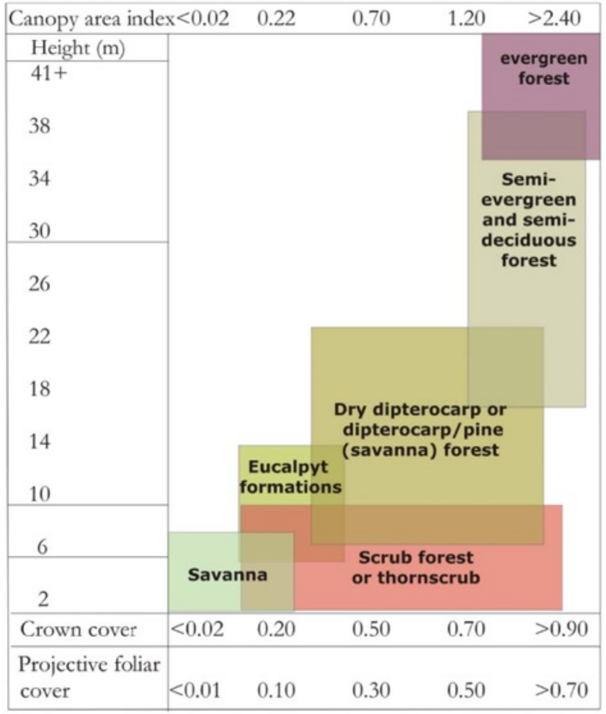


Pennington et al. (2018), after Olson et al. (2001)

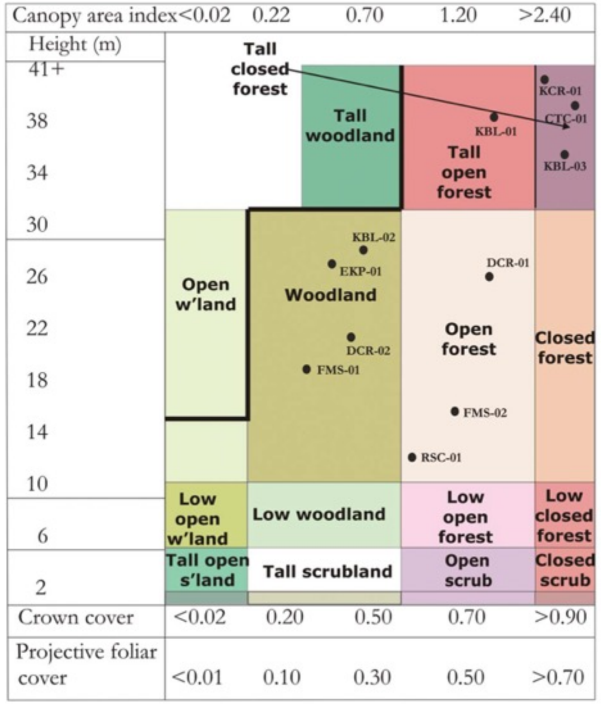
How variable are dry tropical biomes?



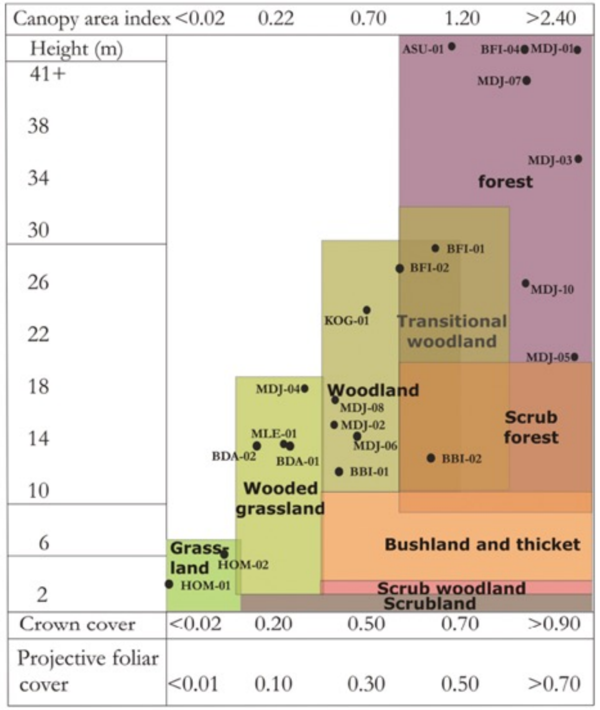
South America



South-East Asia



Africa



Australia

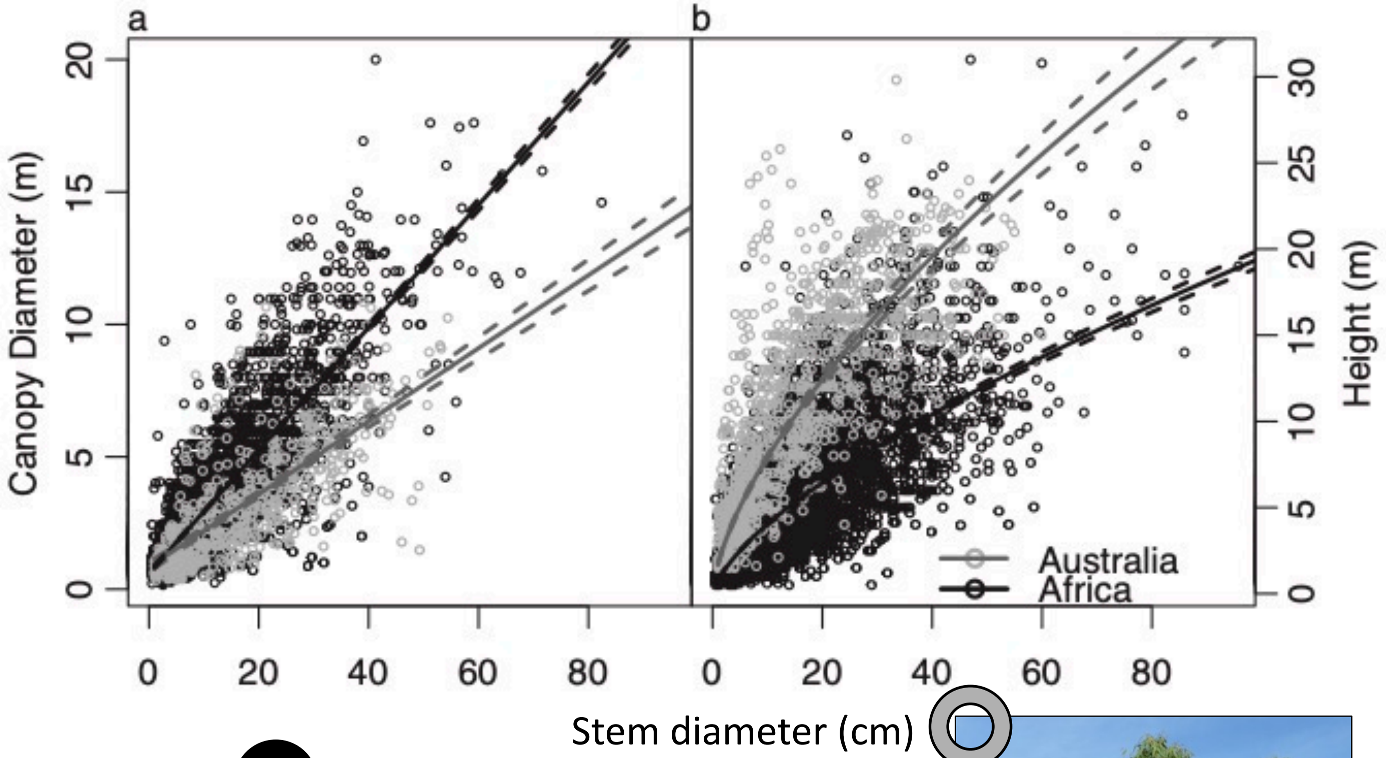
Torello-Raventos et al. (2013)

Biogeography, continent effects

- Wide crown miombo vs. tall and skinny eucalypt savanna (Moncrieff et al. 2014).
- Nitrogen fixers, mycorrhizae might increase growth rates in more arid ecosystems (Pellegrini et al. 2016).

How does variation in species composition and function affect ecosystem function?

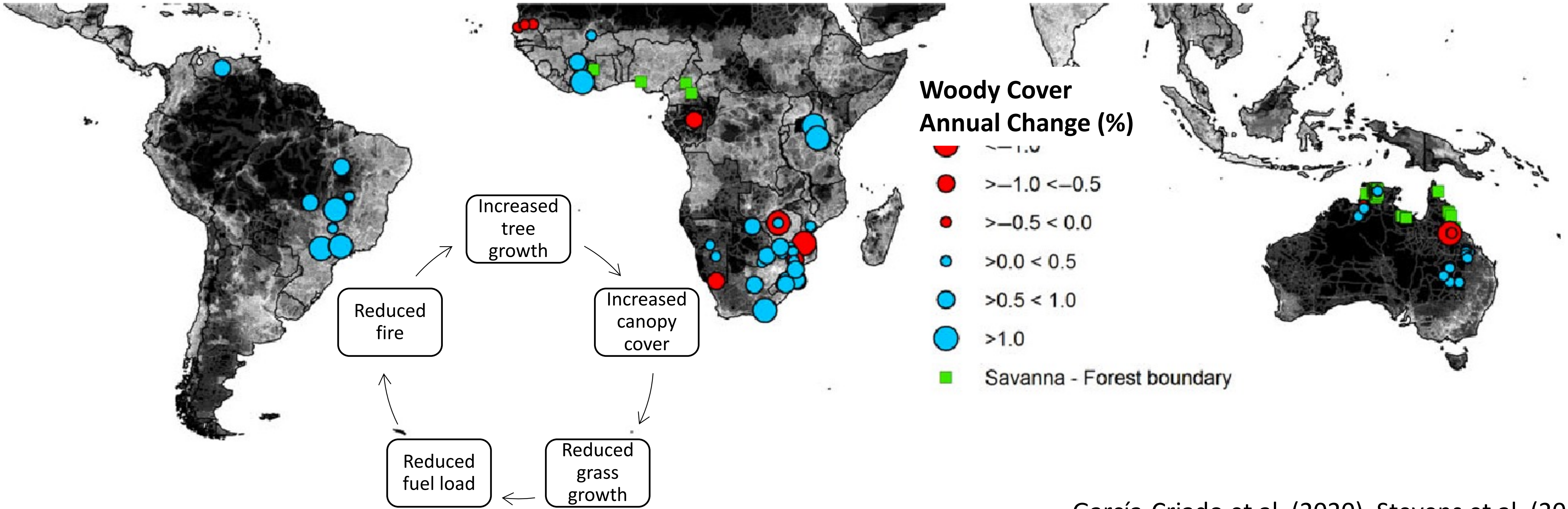
Which groups contribute most to biomass turnover / persistence?



Moncrieff et al. (2014)

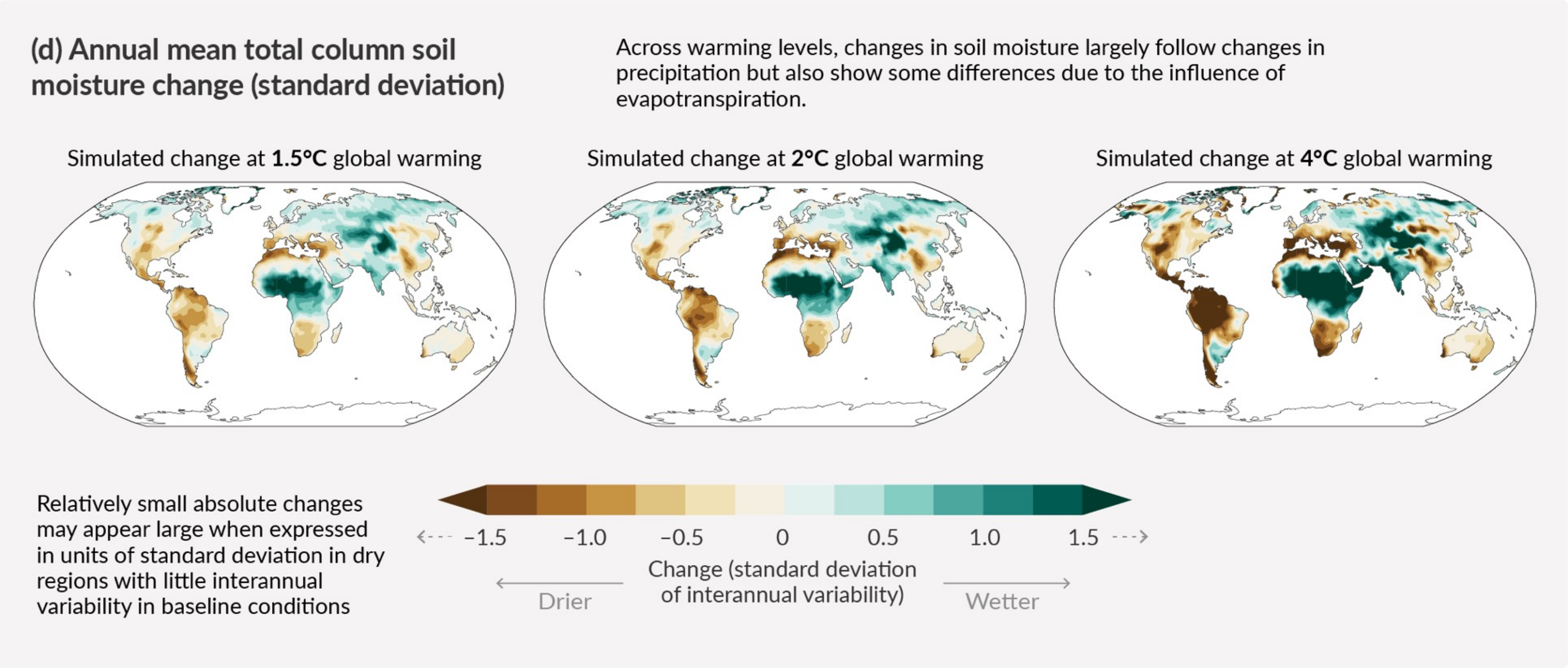
Woody encroachment, CO_2 fertilisation

- Expected to boost tree growth, especially in savannas.
  Trees can benefit from higher CO_2 while grasses cannot.
- Is this pervasive across other dry tropical vegetation like dry forests? Areas with lower rainfall?
- Rate of encroachment greater in African than Australian savannas



García-Criado et al. (2020), Stevens et al. (2016)

Warming and drying trend

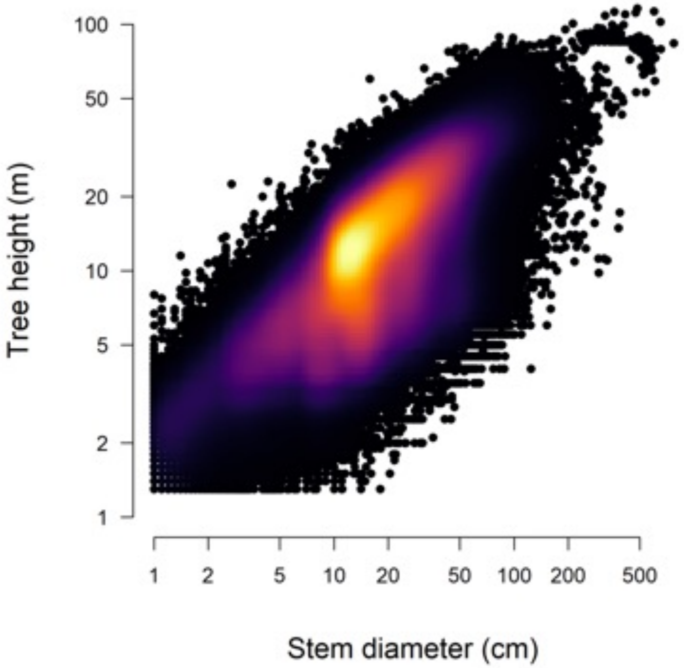


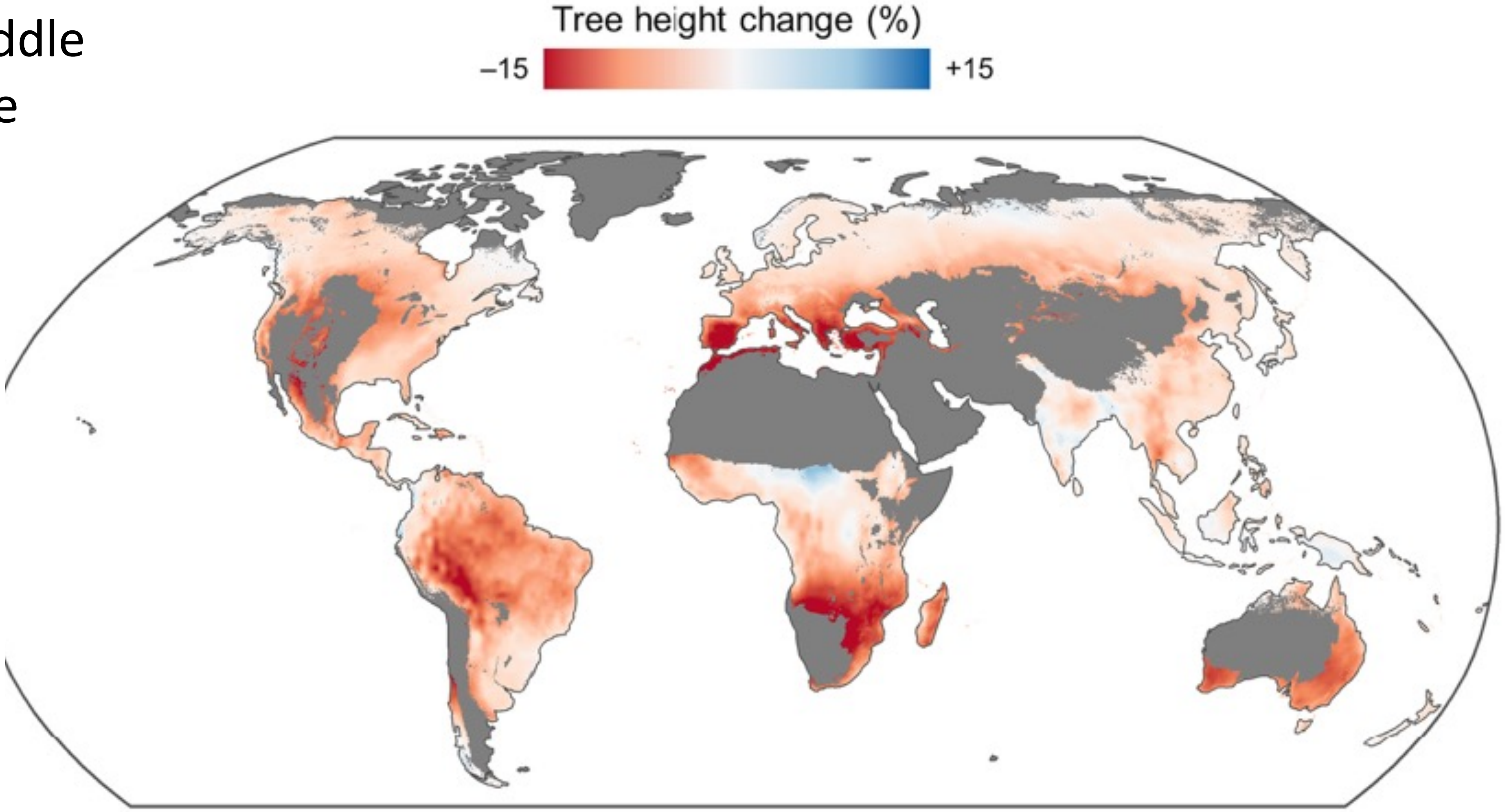
IPCC Chap. 3 (2021)

Drying and warming → reduced tree height

Projected relative tree height change under SSP 245 "Middle of the road" climate change pathway.

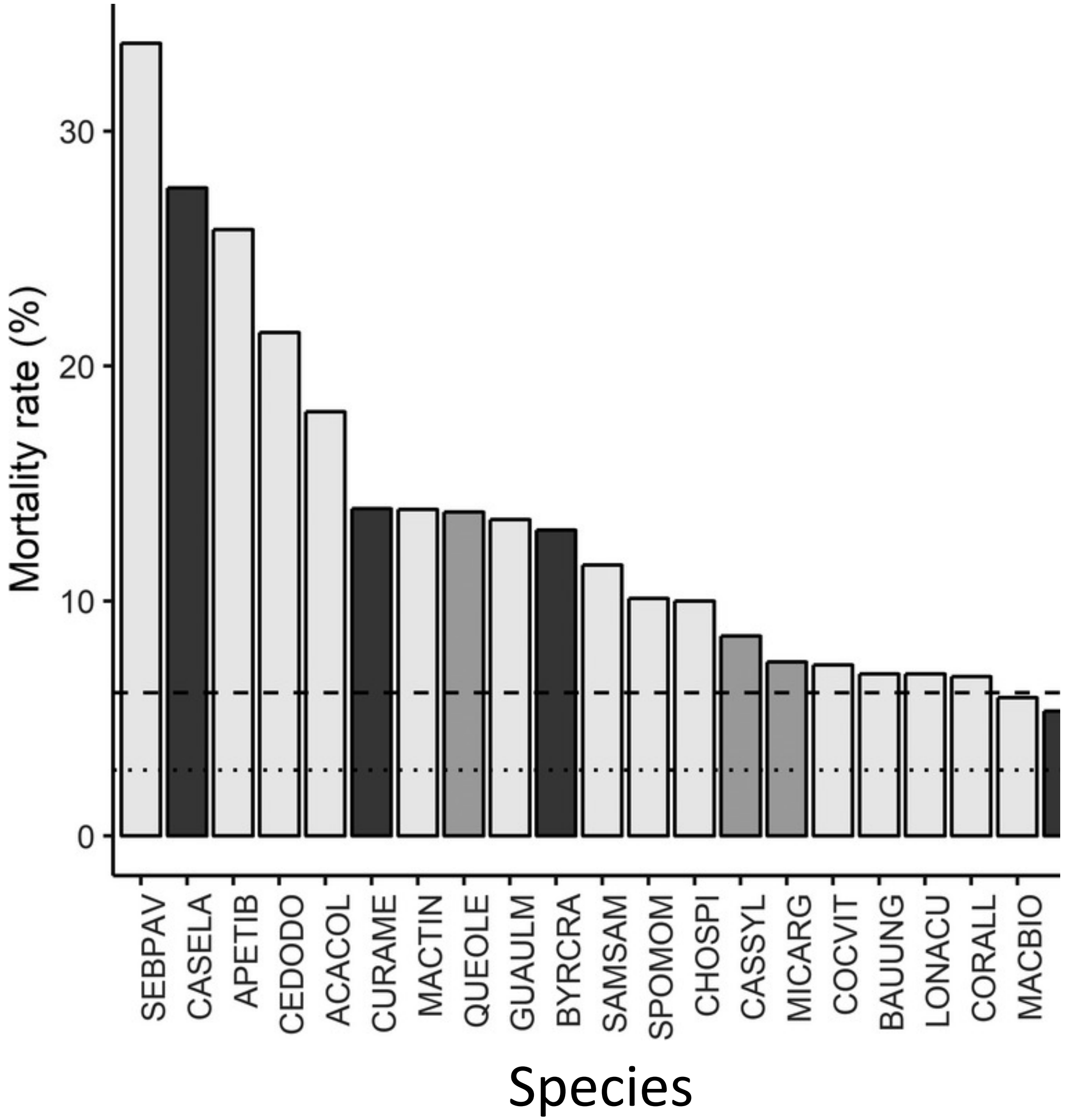
"Tallo" tree allometry database

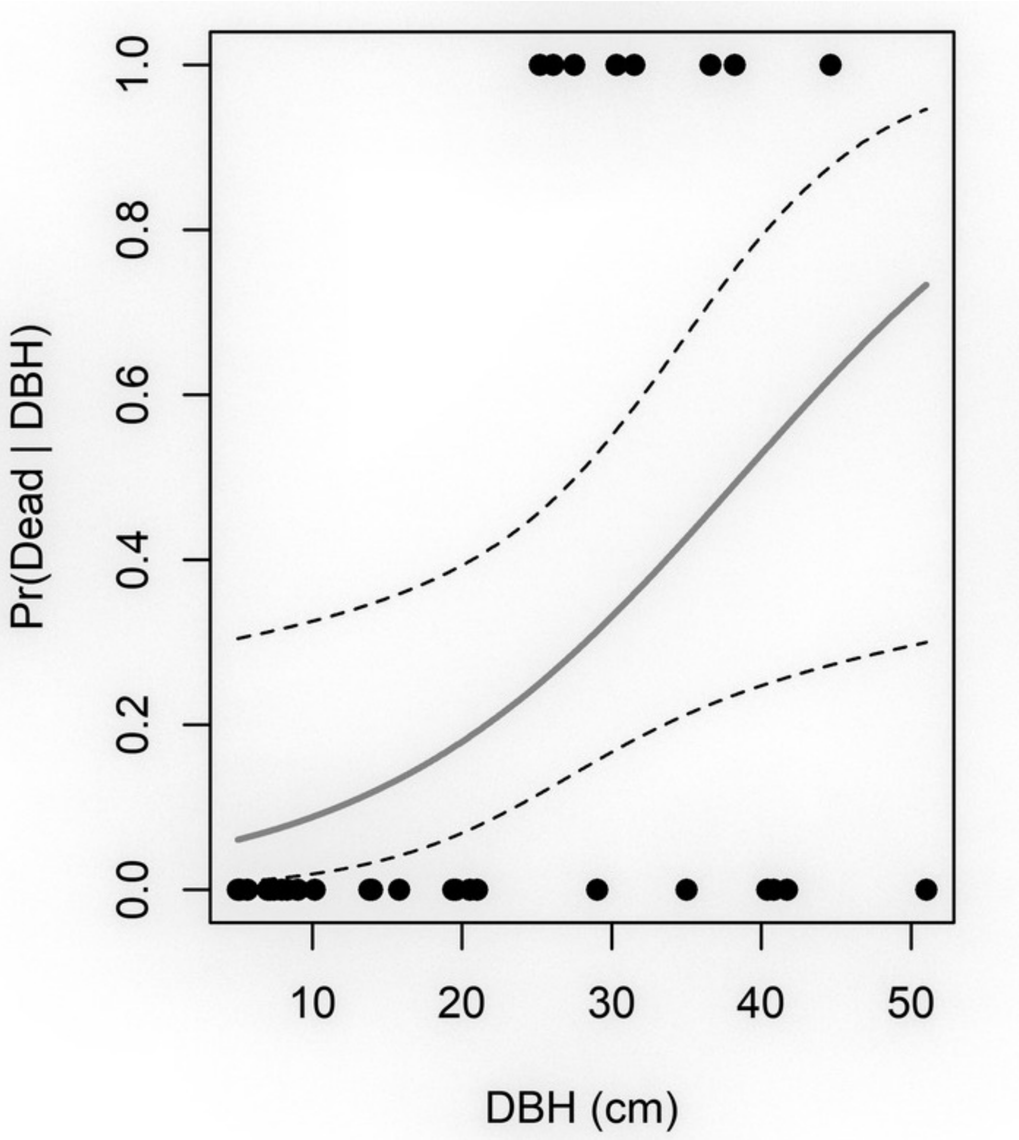




Jucker et al. (2022)

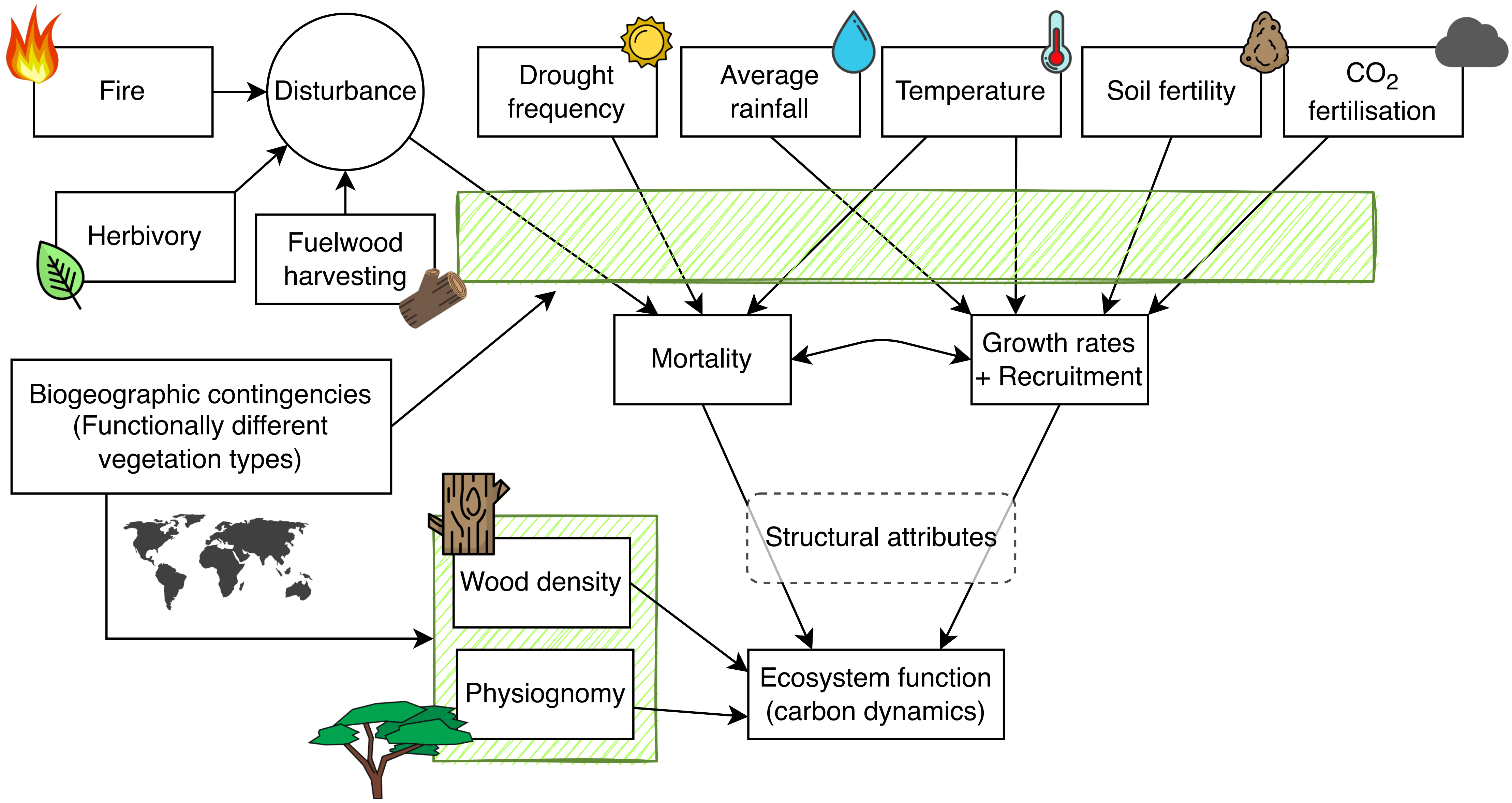
Warming and drying trend





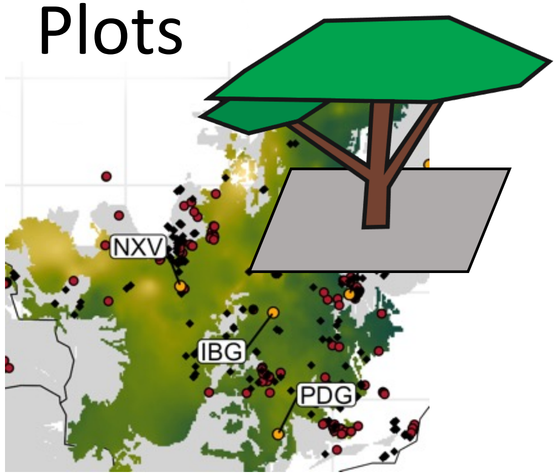
Powers et al. (2020)

Drivers of biomass (change) in the dry tropics

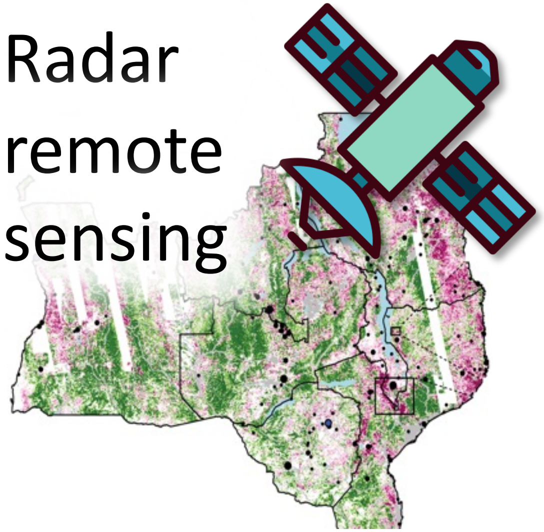


The SECO project: Methodological approach

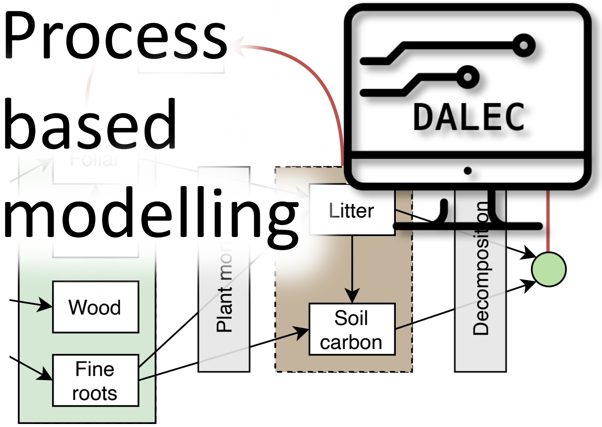
Plots



Radar remote sensing



Process based modelling



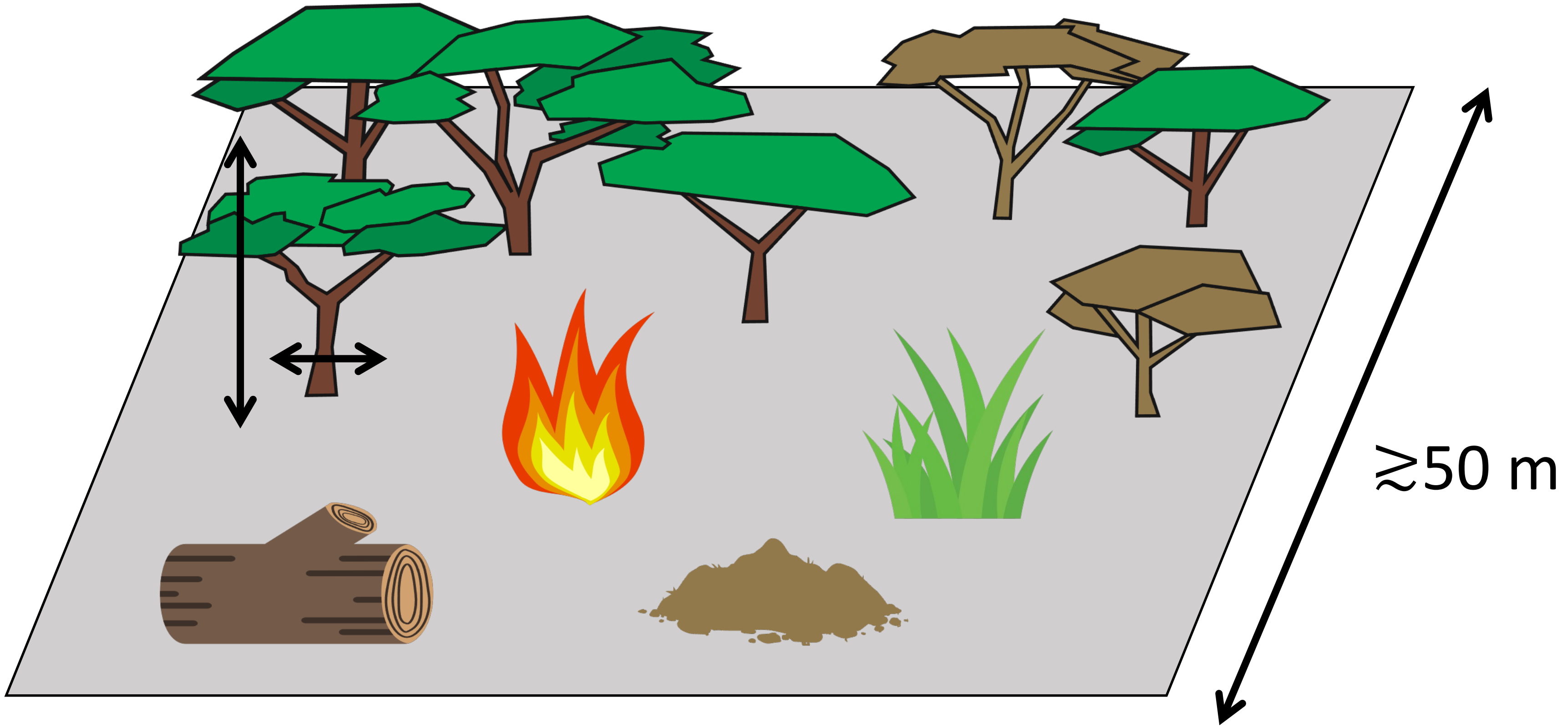
Plots provide:

- Individual-level rates of growth and mortality
- Species composition and community structure
- Infrastructure to collect auxiliary data –
  plant traits, phenology, soil, woody debris, herbaceous biomass etc.
- Woody biomass stocks and canopy structure to calibrate remote sensing

PI: Dr. Casey Ryan (Univ. of Edinburgh)

What's in a plot?

SEOSAW FORESTPLOTS.NET tern Ecosystem Research Infrastructure



- Tree species
- Stems within a tree
- Stem diameter
- Stem height
- Coarse woody debris

- Fire disturbance regime
- Soil carbon and nutrients
- Herb. biomass and comp.
- Tree mortality
- Leaf phenology

All woody stems >5 (or 10) cm diameter are tagged

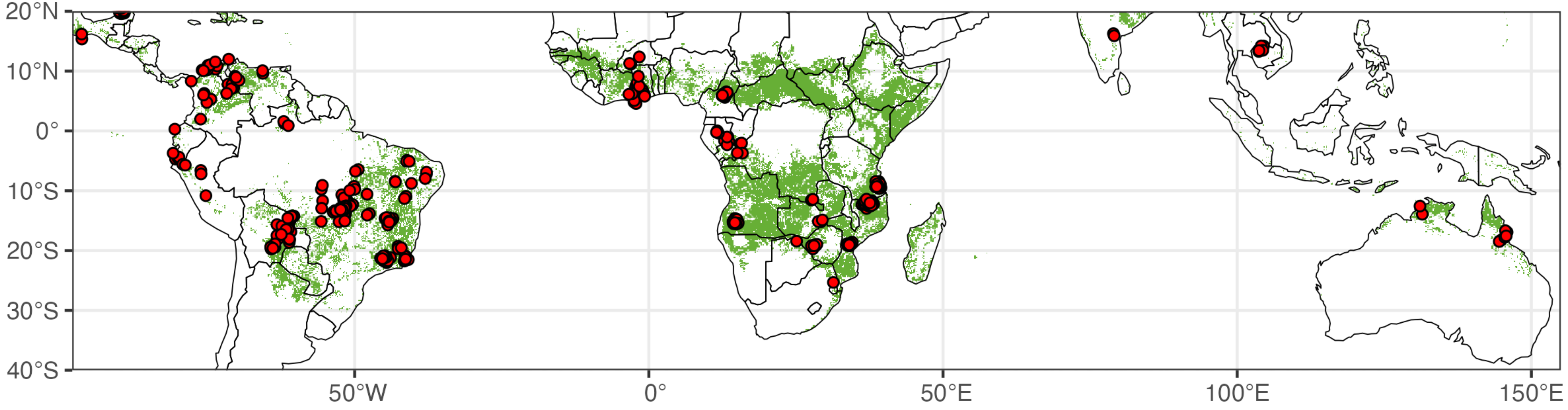
SEOSAW (2020), ForestPlots.net (2021), Hutley et al. 2011)


Biomass change
across the dry tropics

Biomass change across the dry tropics

~640 plots with >1 census since the year 2000

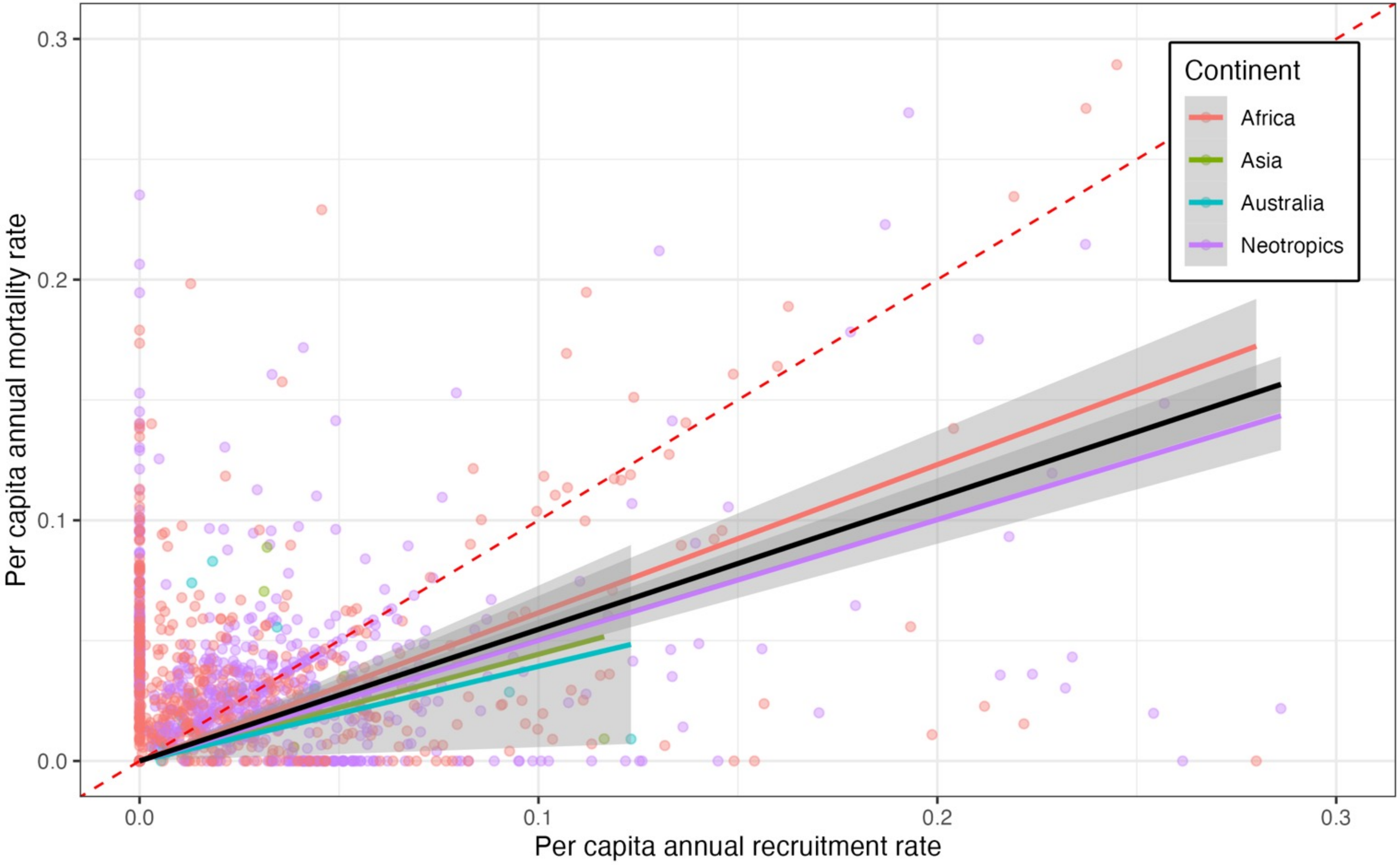
Across Neotropics, Africa, Asia (only 8 plots!), and Australia



Woody biomass and moisture availability

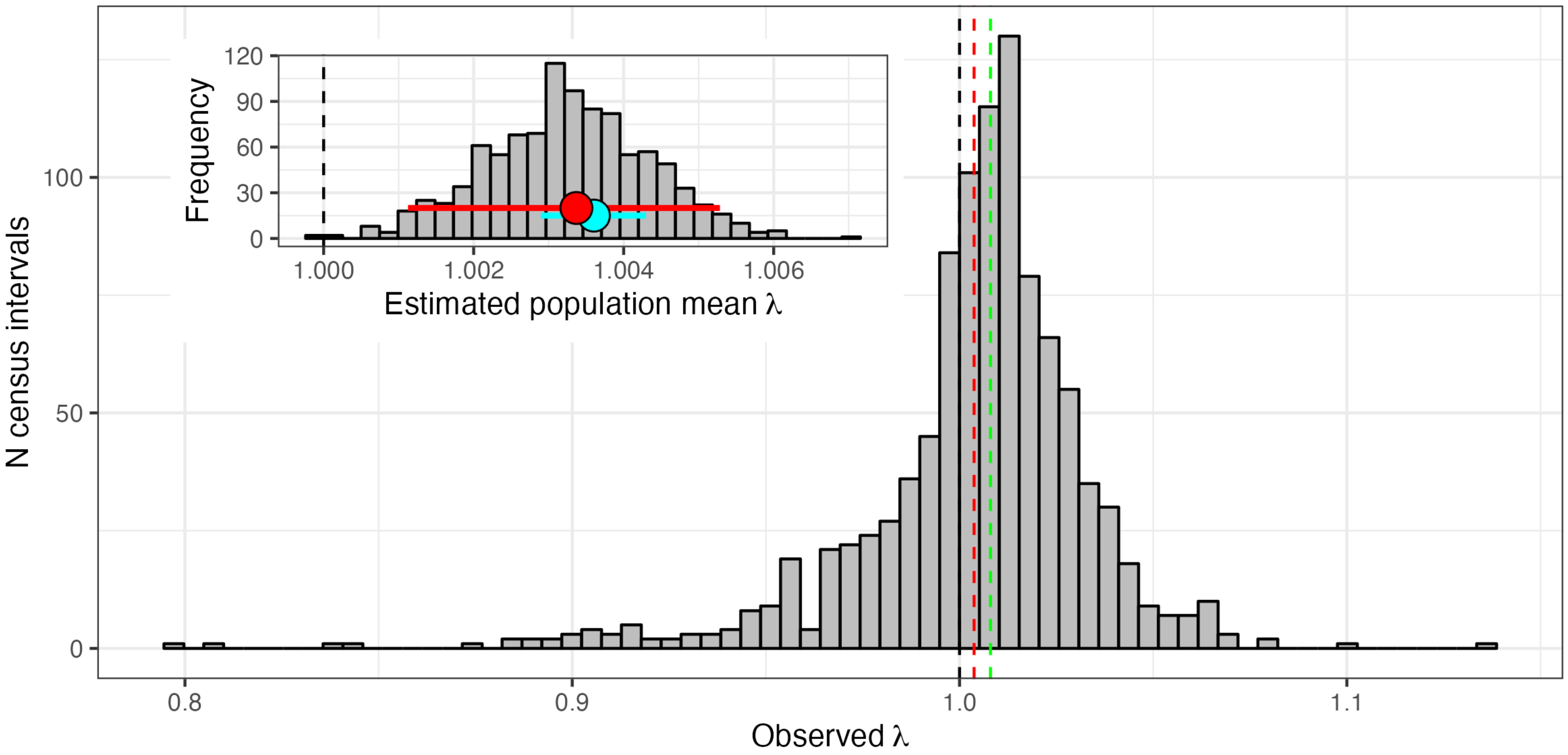
ERA-Land: Muñoz-Sabater et al. (2021)

Generally, stem recruitment > mortality …



Kohyama et al. (2018)

… and, biomass gains > losses



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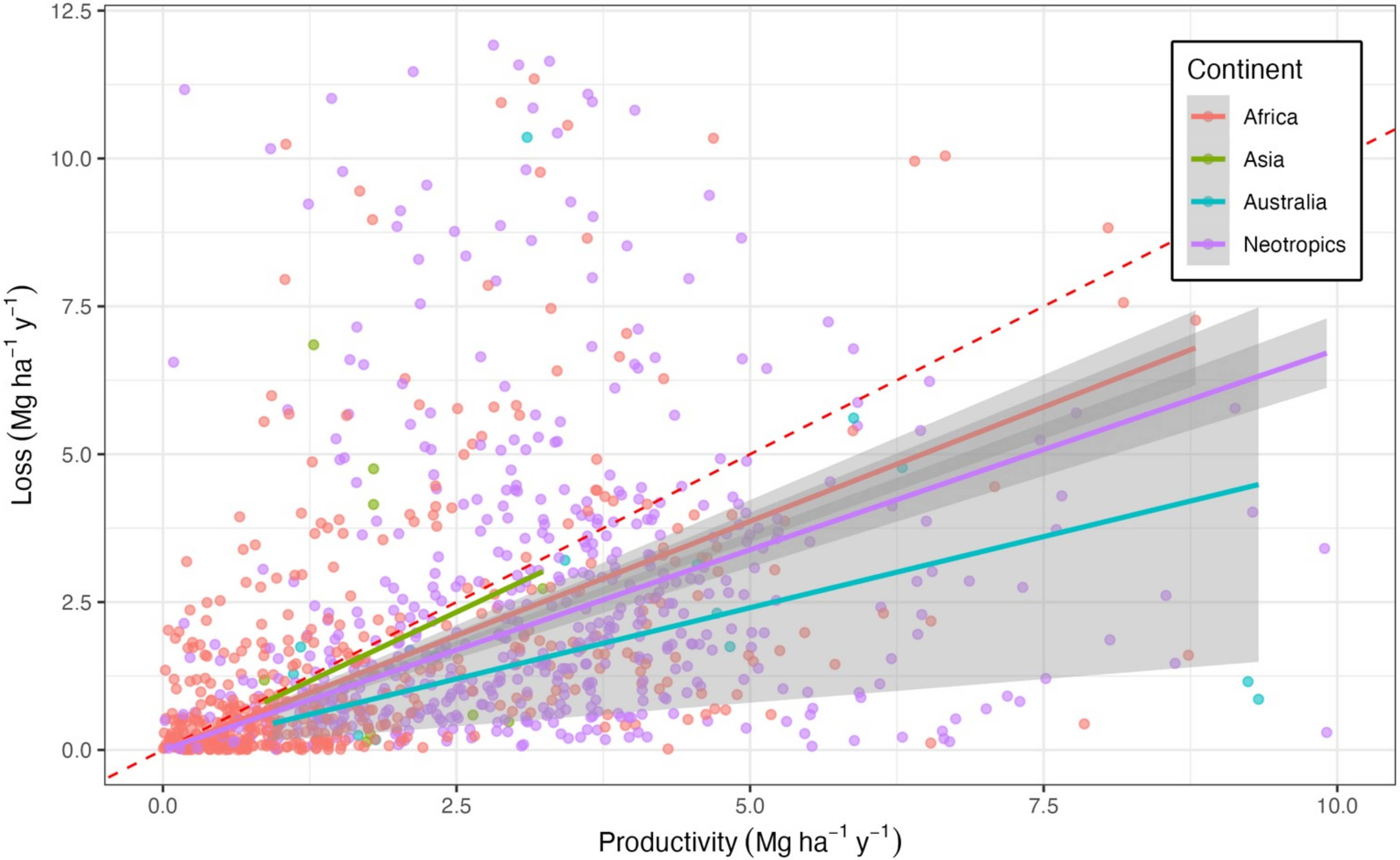
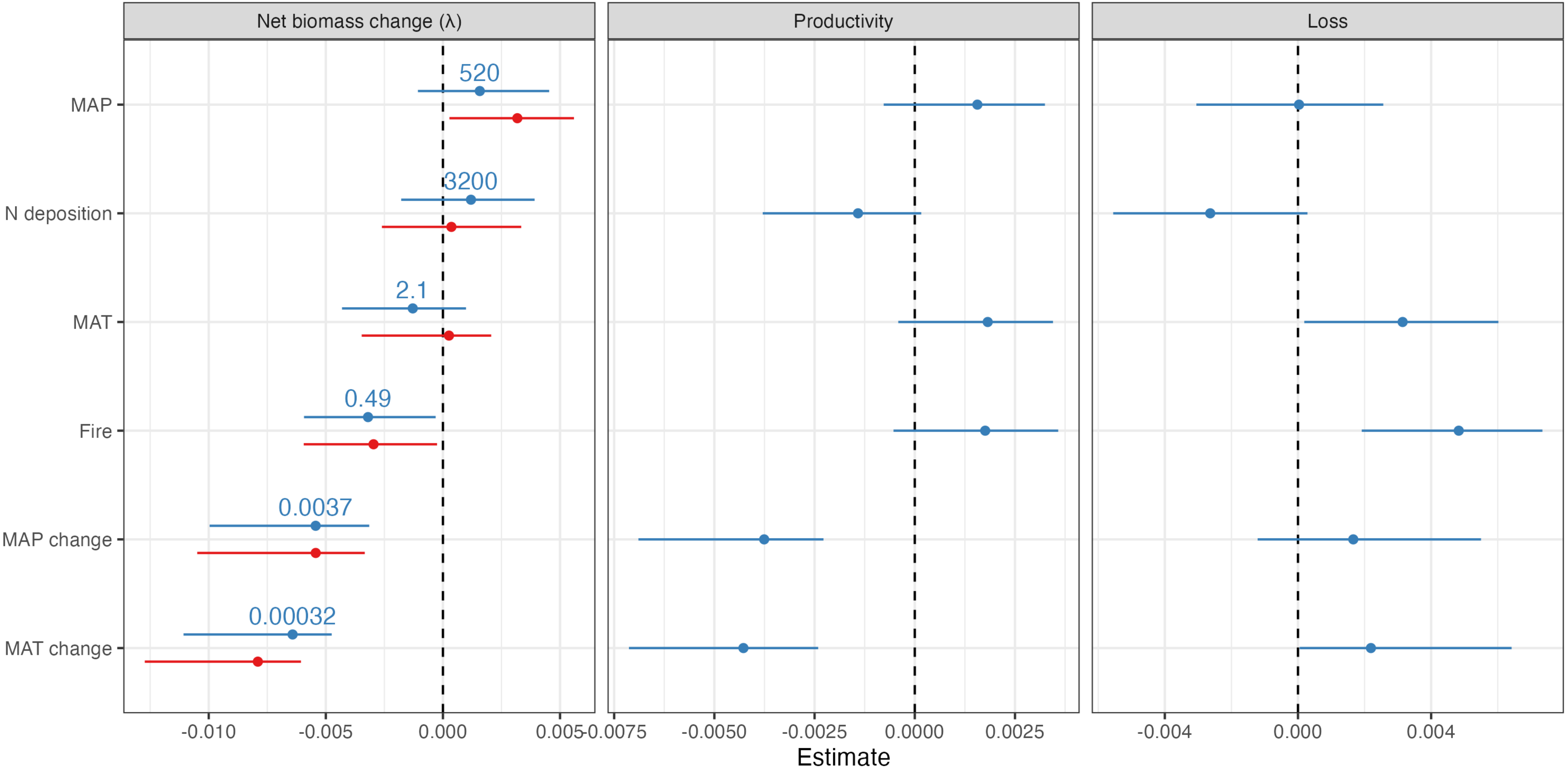
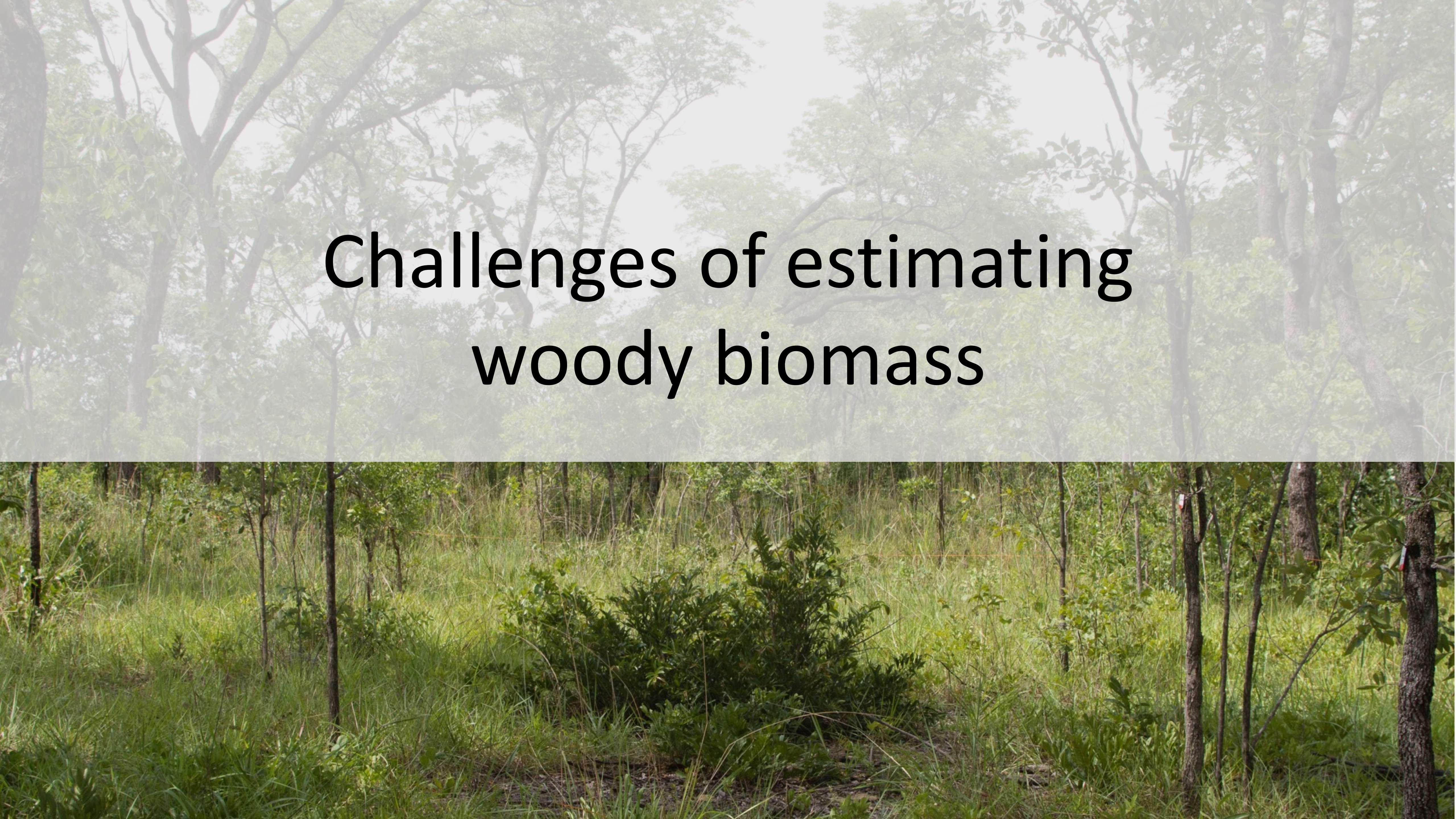


Kohyama et al. (2019)

Environmental predictors of biomass change





Challenges of estimating woody biomass

Estimating biomass in the dry tropics

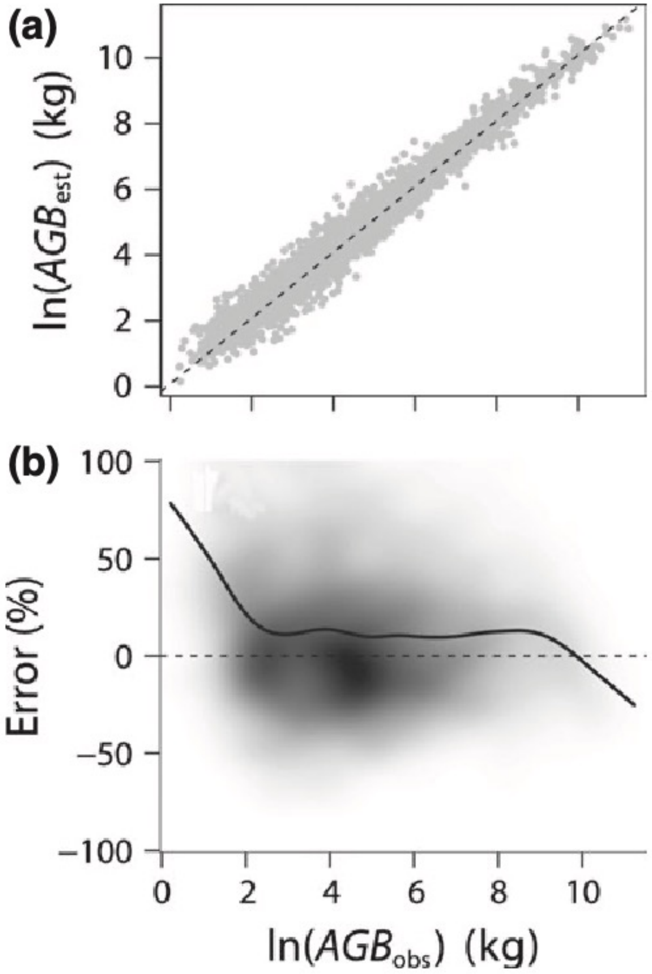
Global Change Biology
celebrating 20 years
Global Change Biology (2014), doi: 10.1111/gcb.12629

Improved allometric models to estimate the aboveground biomass of tropical trees

JÉRÔME CHAVE[1], MAXIME RÉJOU-MÉCHAIN[1], ALBERTO BÚRQUEZ[2], EMMANUEL CHIDUMAYO[3], MATTHEW S. COLGAN[4], WELINGTON B.C. DELITTI[5], ALVARO DUQUE[6],

$$AGB_E = e[-1.8 - 0.98E + 0.98\ln(\rho) + 2.68\ln(D) - 0.03[\ln(D)]^2]$$

$$AGB_H = 0.0673 \times (\rho D^2 H)^{0.976}$$

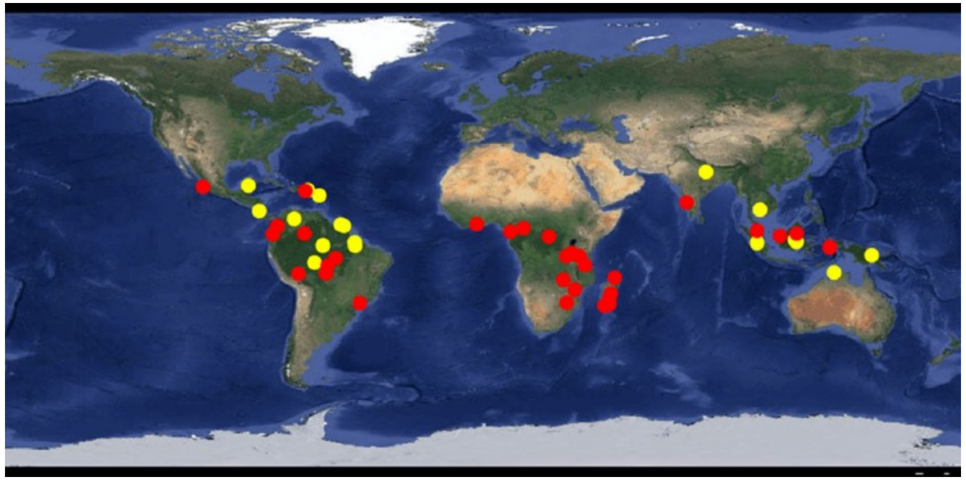


D = Stem diameter

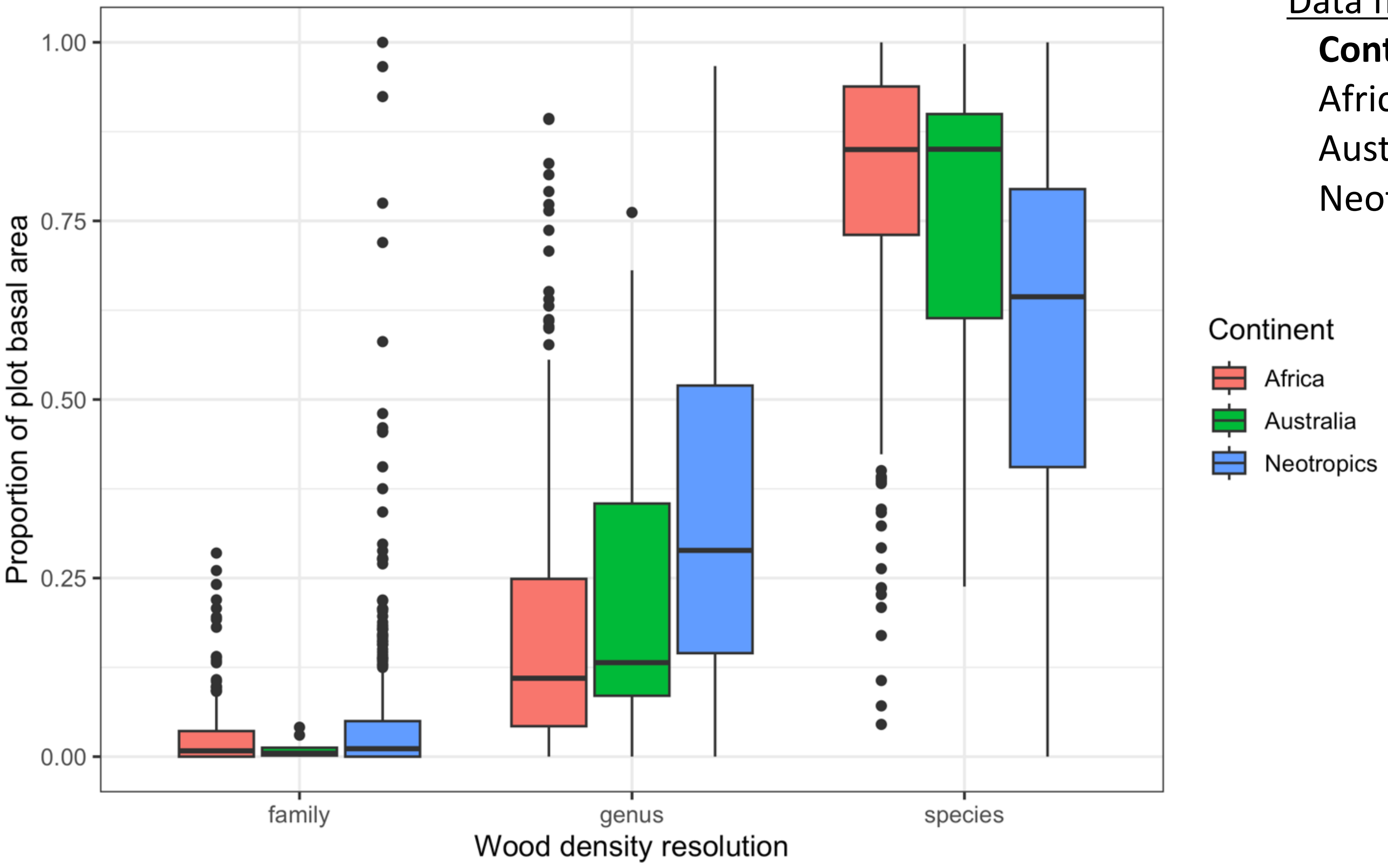
H = Stem height

ρ = Wood density

E = Environmental Stress



Wood density data availability



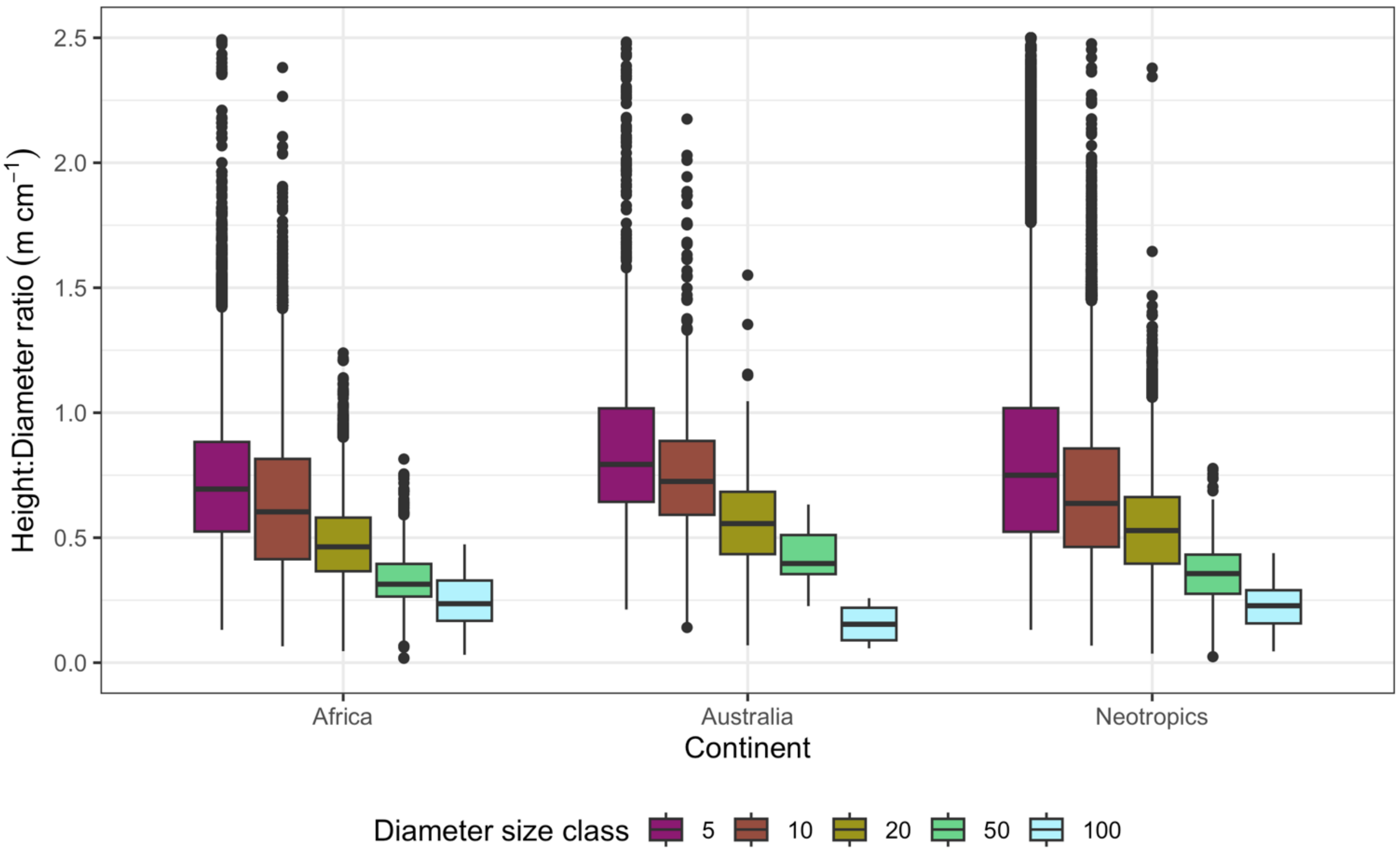
Data from Zanne et al. (2009)

Continent	N samples
Africa	3077
Australia	2238
Neotropics	5355

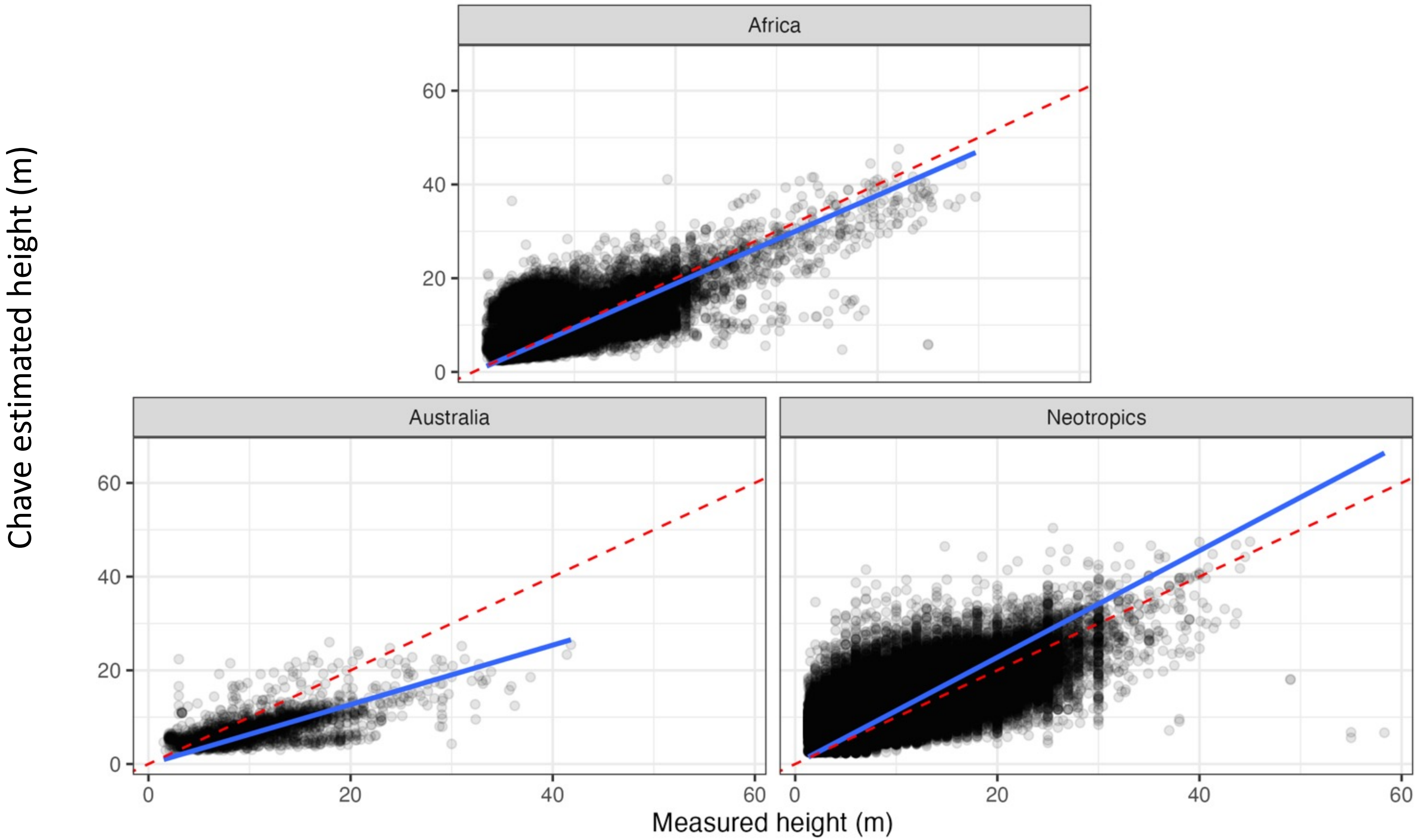
Mostly wet tropics

Chave et al. (2009), Zanne et al. (2009), Vieilledent et al. (2018)

Height:diameter relationships vary



Estimating height: Is Chave's method appropriate?



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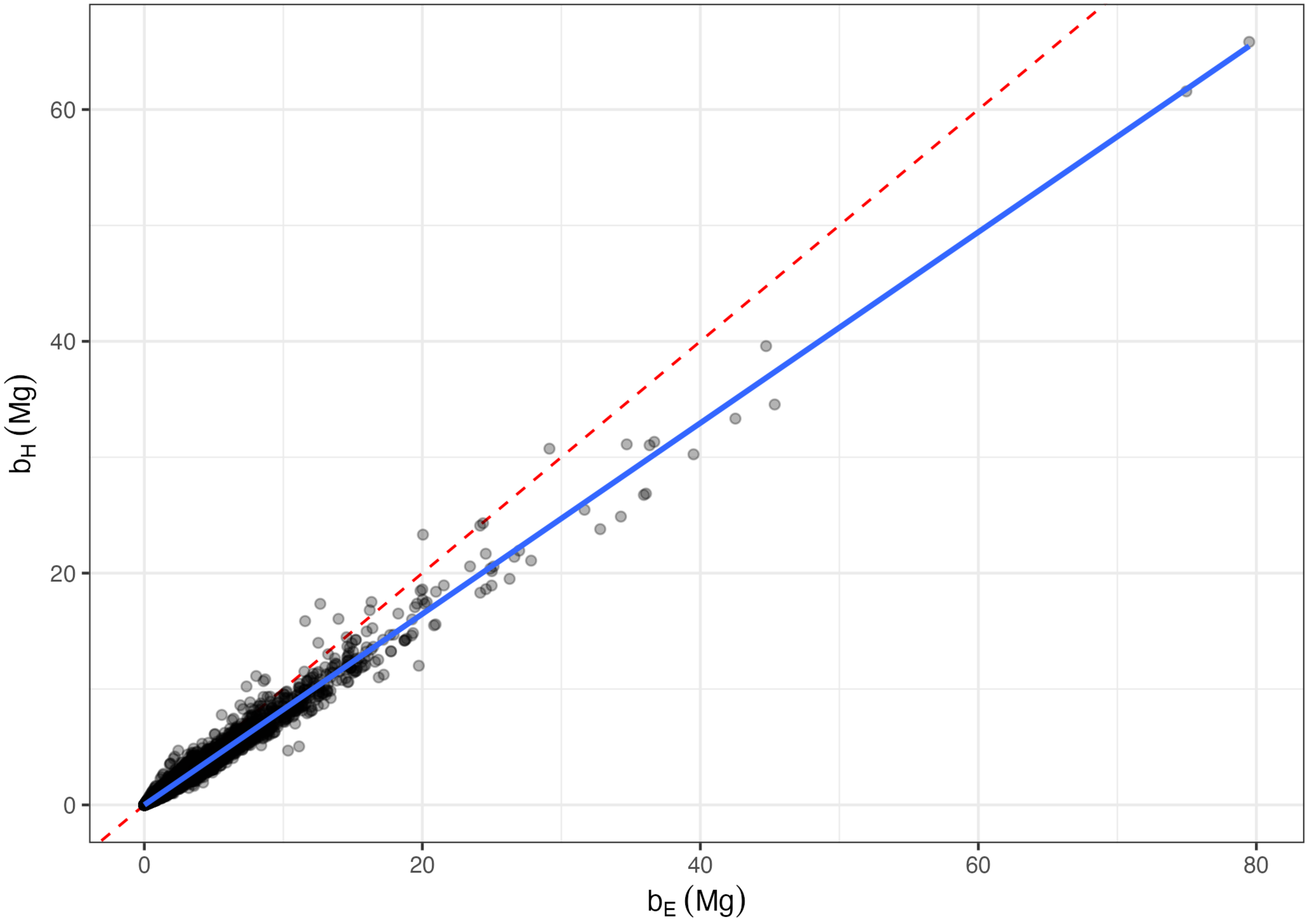
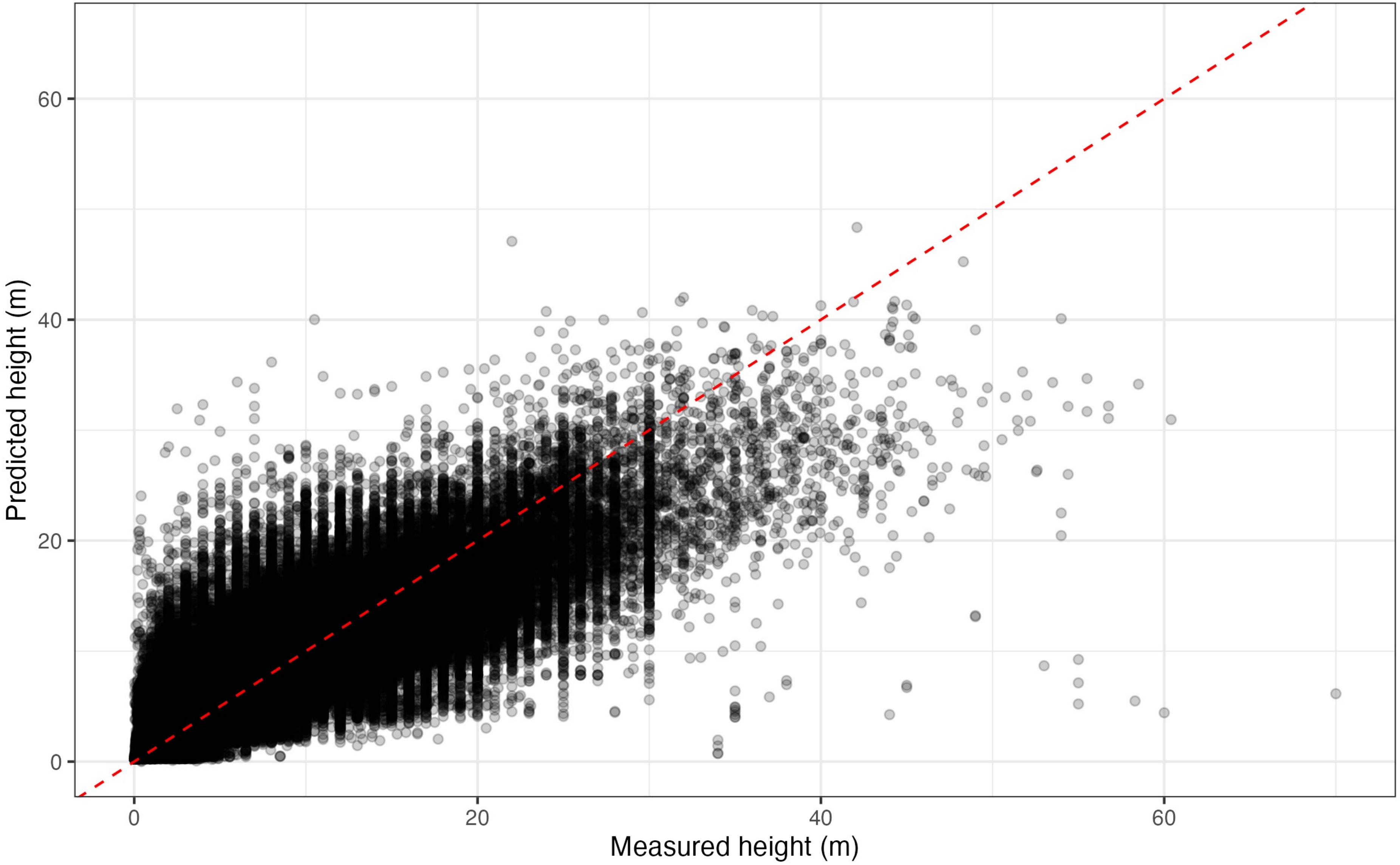


Estimating height: Is Chave's method appropriate?

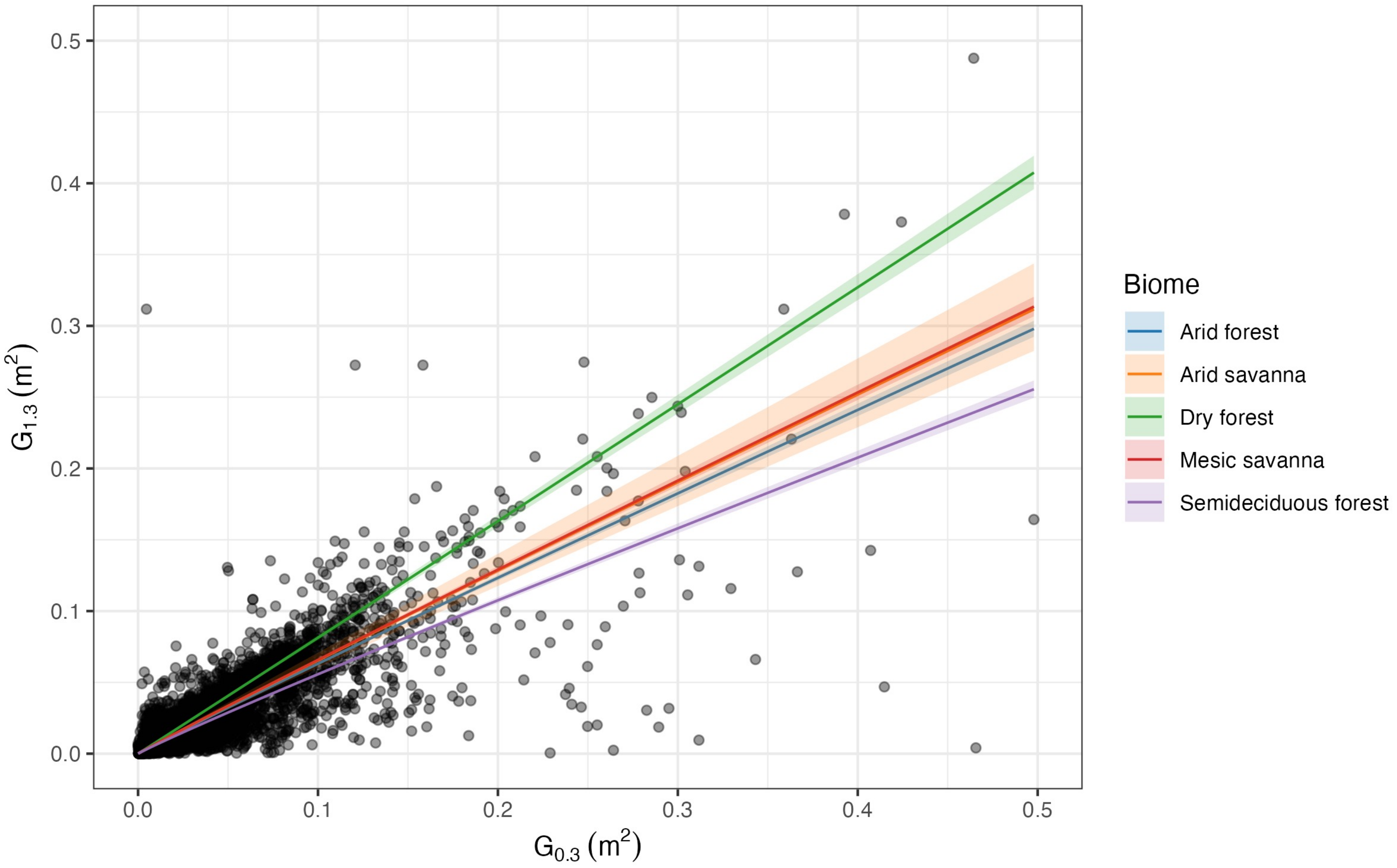
$$\log h = \log d + G + \log d + \log d : E + V + \log d^2$$



Stem taper varies across regions

To predict stem diameter at 1.3 m:

Multiple regression of basal area (G) at 0.3 m and basal area at 1.3 m, with a factor for vegetation type.



Summary

- Global environmental change is causing shifts in dry tropics vegetation structure and carbon dynamics.
- Dry tropical vegetation is globally important to the terrestrial carbon cycle.
- Across the dry tropics, woody biomass and woody biomass change responds to disturbance, climate, soil.
- Estimating woody biomass is not straightforward in the dry tropics, and naïve use of existing methods can introduce bias.

Acknowledgements and contact

My email: john.godlee@ed.ac.uk
More links: https://blogs.ed.ac.uk/johngodlee/

SEOSAW website: https://seosaw.github.io
SECO website: https://blogs.ed.ac.uk/seco-project

Acknowledgements:

Kyle Dexter, Casey Ryan

Sam Harrison, David Milodowski (SECO postdocs)
SECO core team
All SECO data contributors

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SEOSAW

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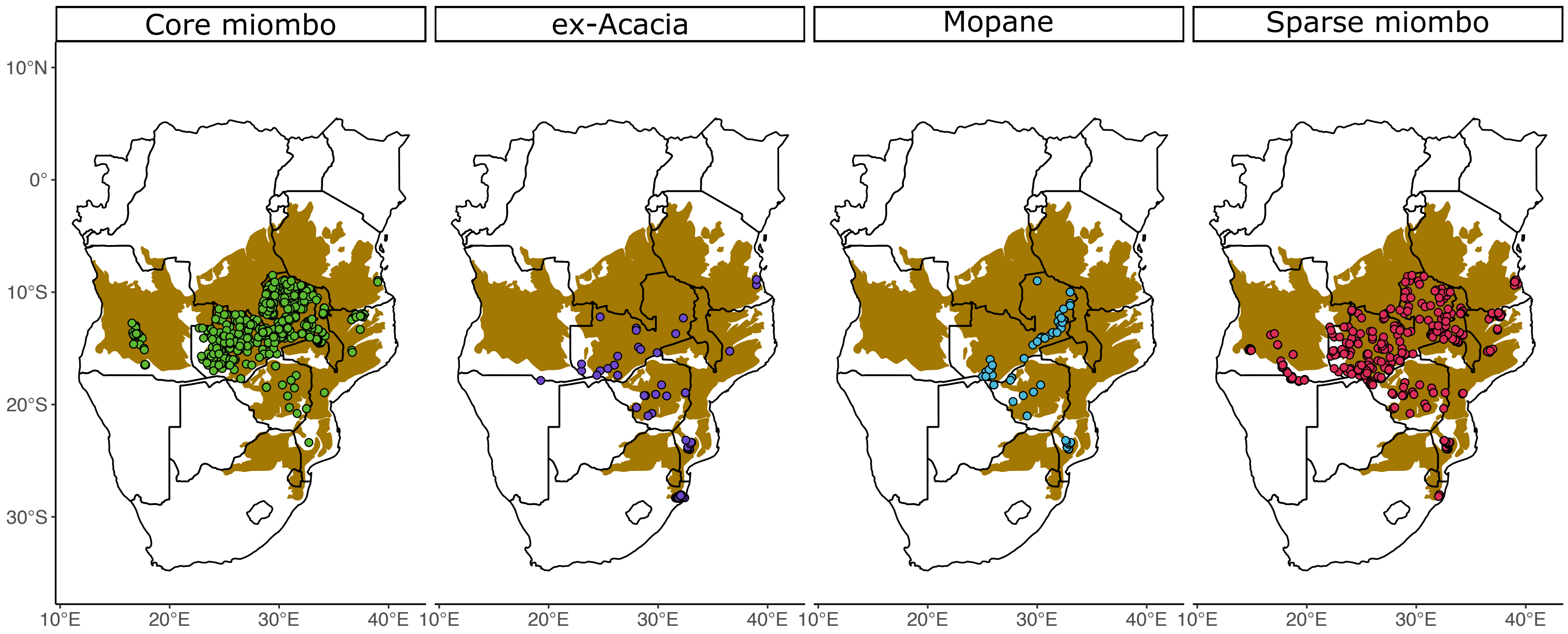
EXTRA

Biodiversity effects on biomass and productivity in African savannas

Determinants of woody biomass in African savannas

How do biodiversity and environment jointly affect woody biomass in African savannas?

SEOSAW



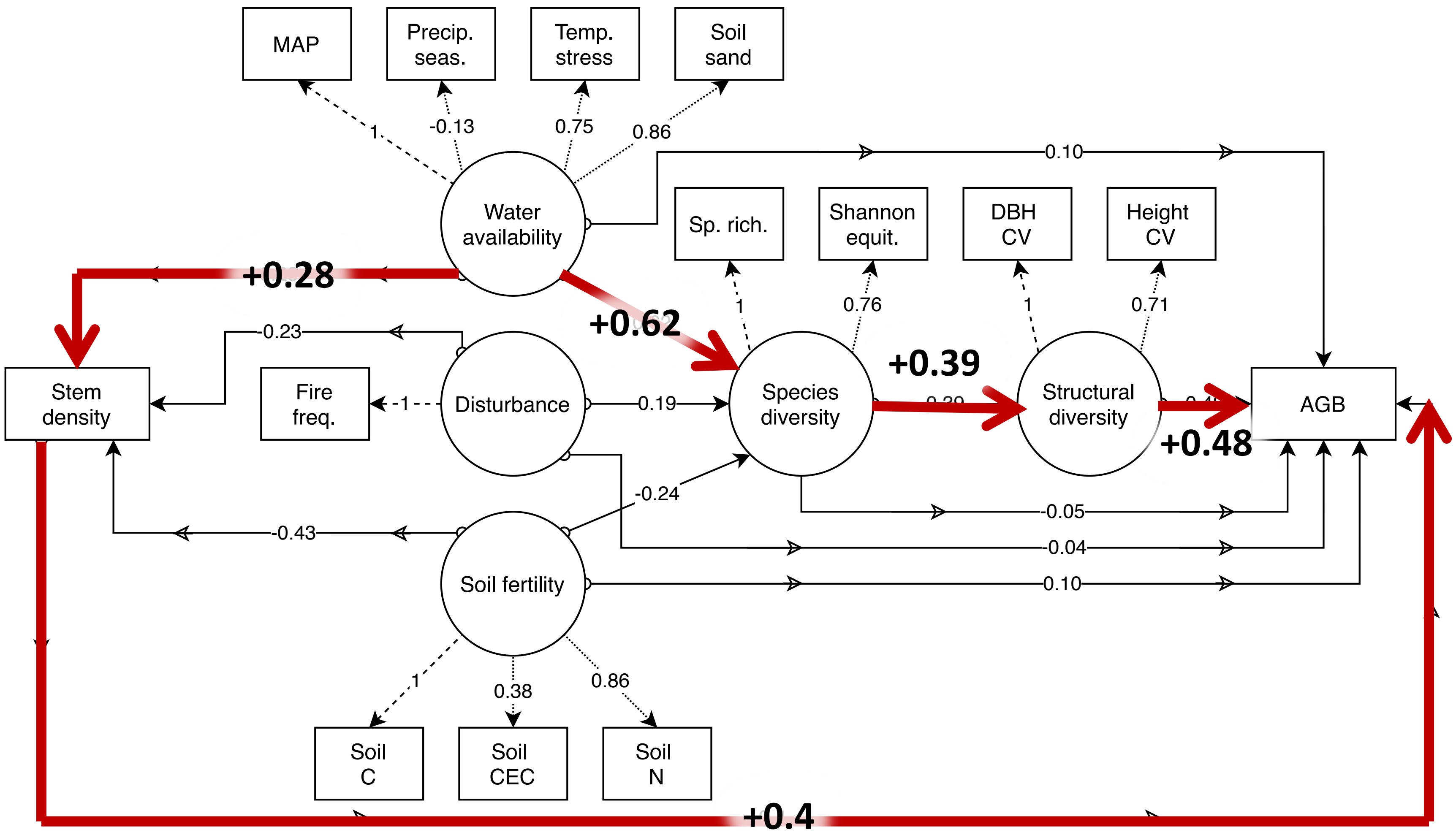
Godlee et al. (2021) *New Phytologist*

Determinants of woody biomass in African savannas

1. Water availability drives biomass via species diversity and stem density

2. Structural diversity as an axis of niche differentiation

3. Bootstrapping:
   Stem density mediates species diversity – biomass relationship



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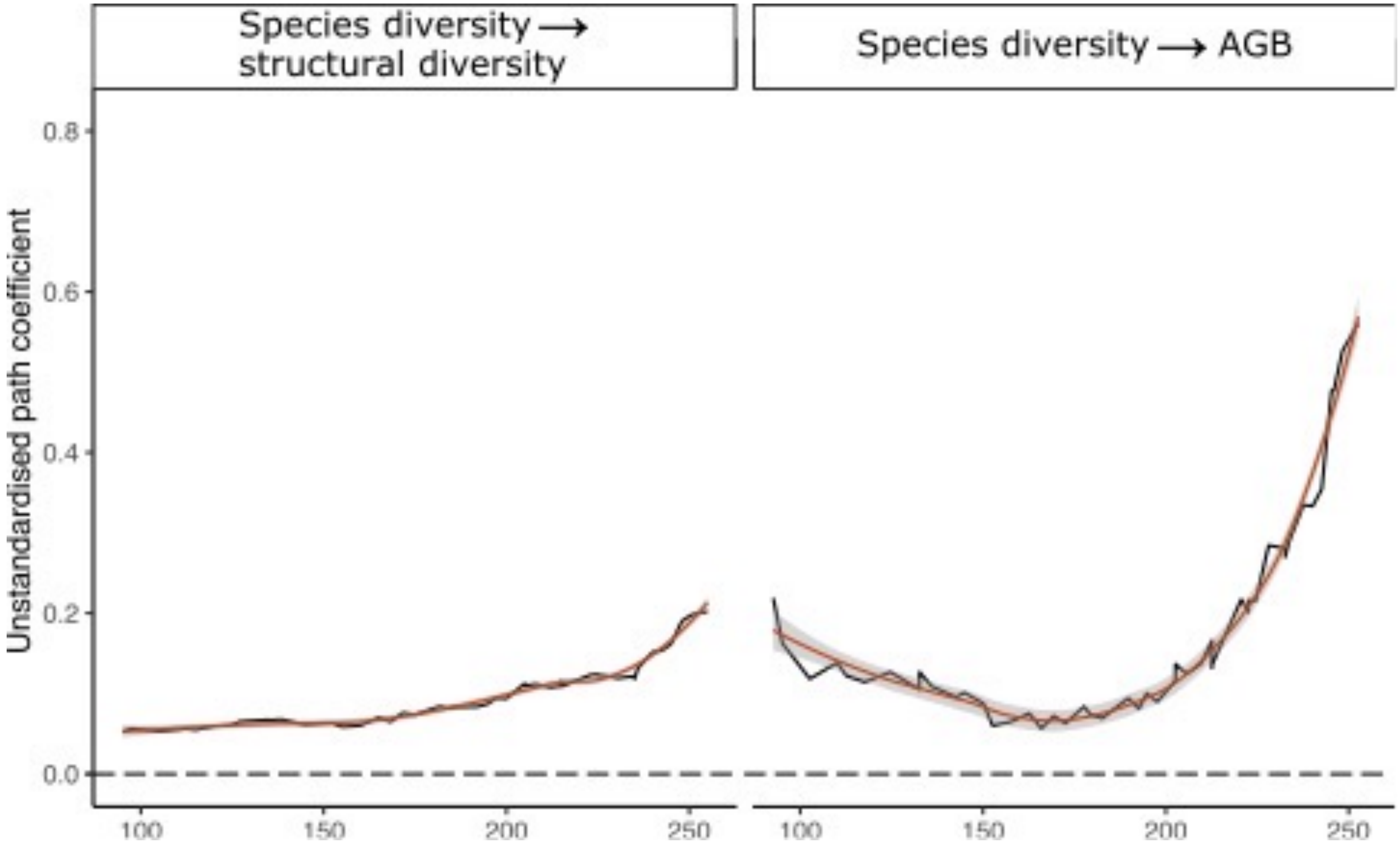
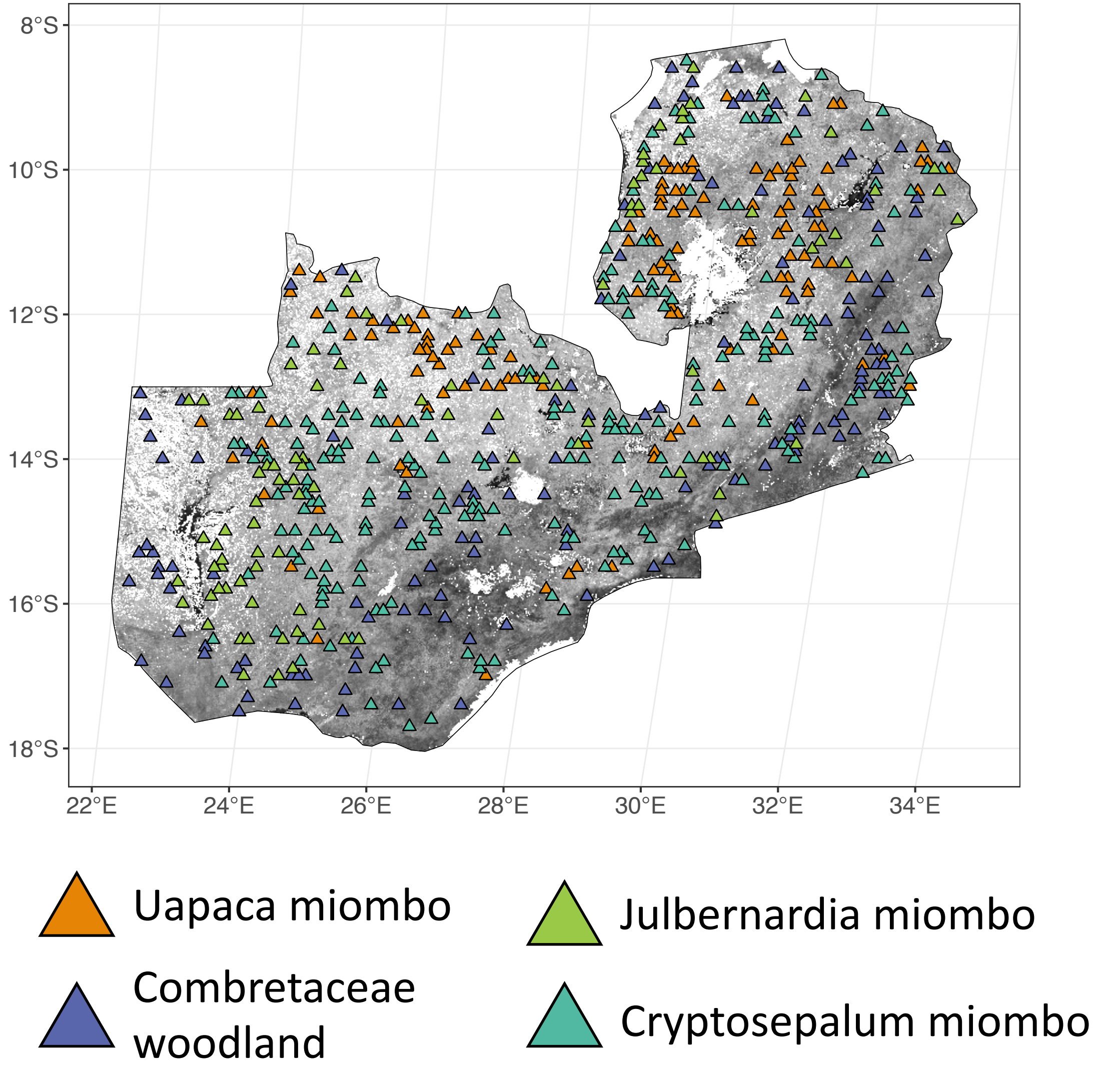


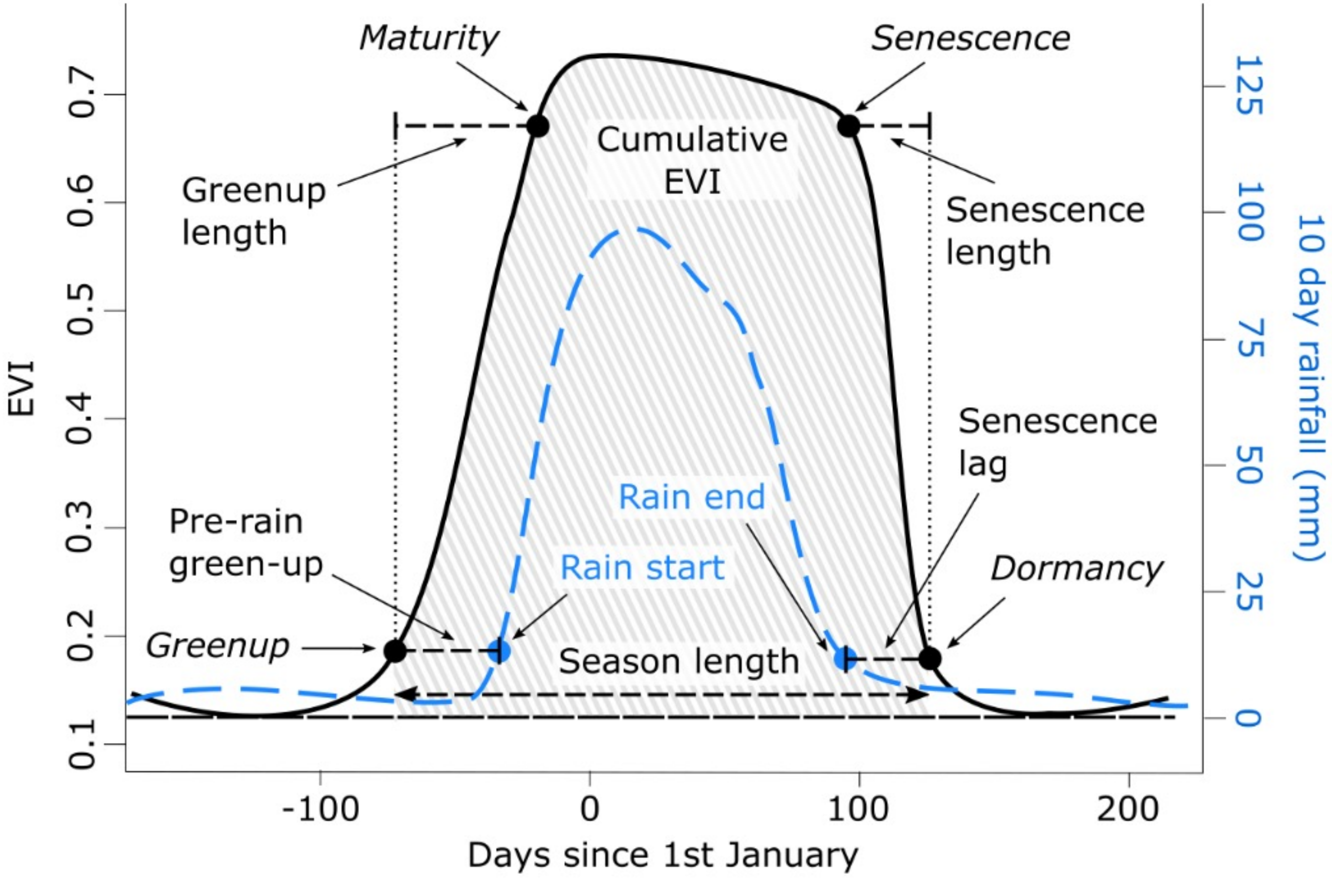
Godlee et al. (2021) *New Phytologist*

Linking land surface phenology and diversity

Zambian Integrated Land Use Assessment – 617 plots

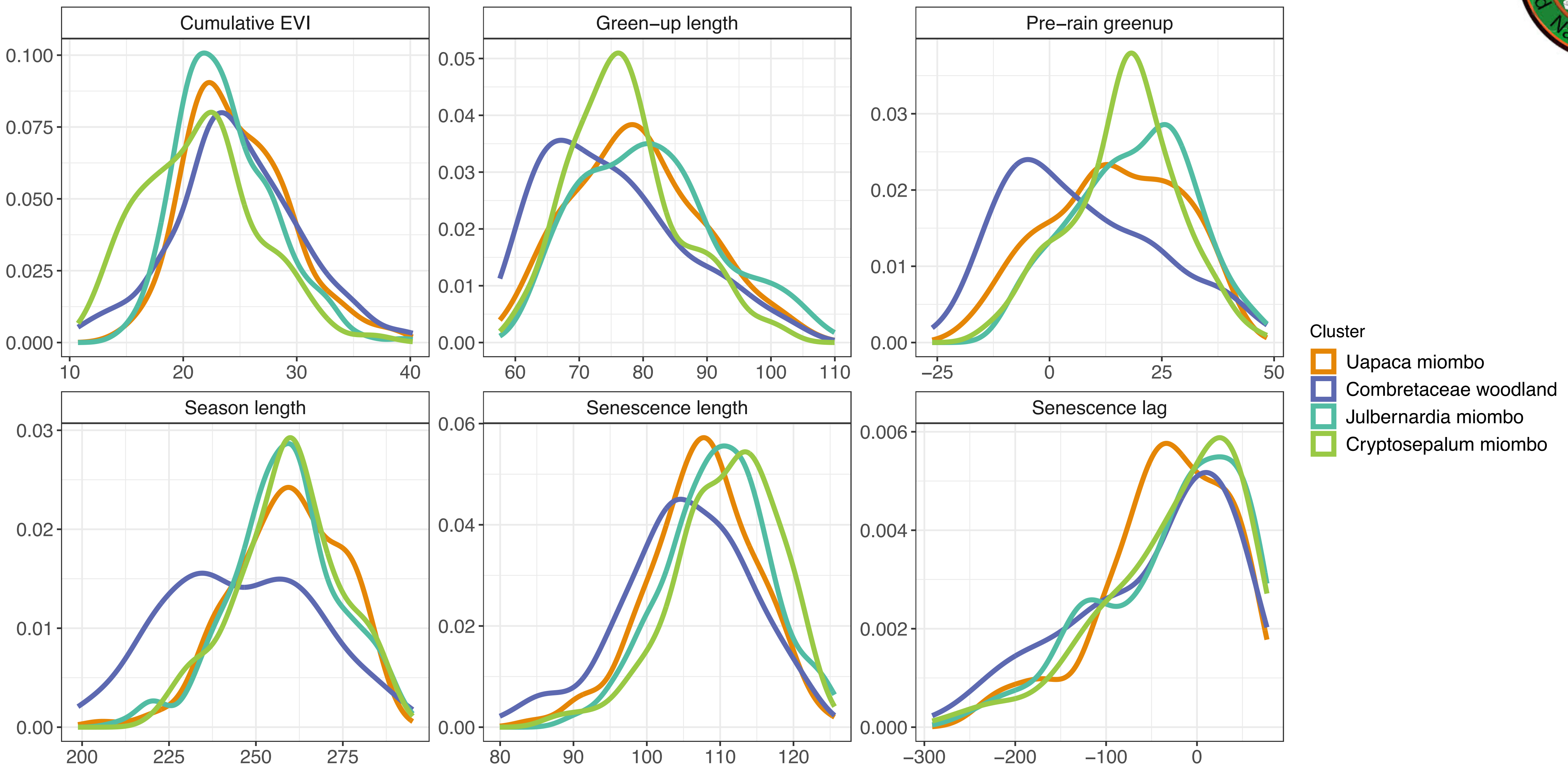


MODIS land surface phenology time series
EVI – Enhanced Vegetation Index



Godlee, Ryan, Siampale & Dexter (in revision) *Journal of Ecology*

Linking land surface phenology and diversity

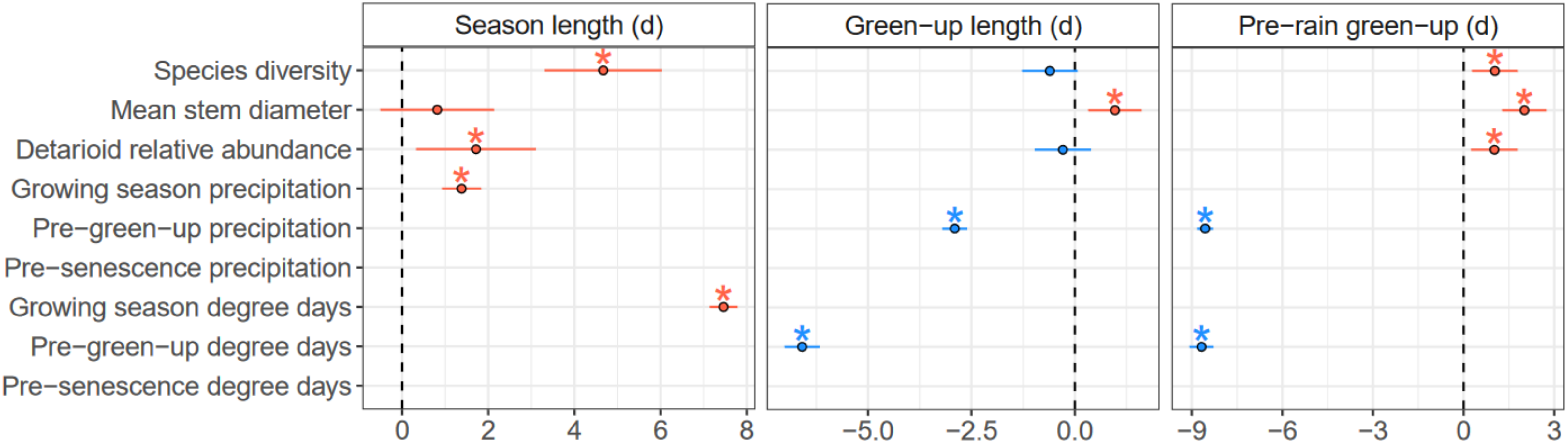


Godlee, Ryan, Siampale & Dexter (in revision) *Journal of Ecology*

Linking land surface phenology and diversity

Tree species diversity and detarioideae abundance associated with longer growing season length, earlier pre-rain greenup.

Niche complementarity and keystone species effect.



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