Tropical forests: ~~Research questions,~~ representation in models, and the ForestGEO plots

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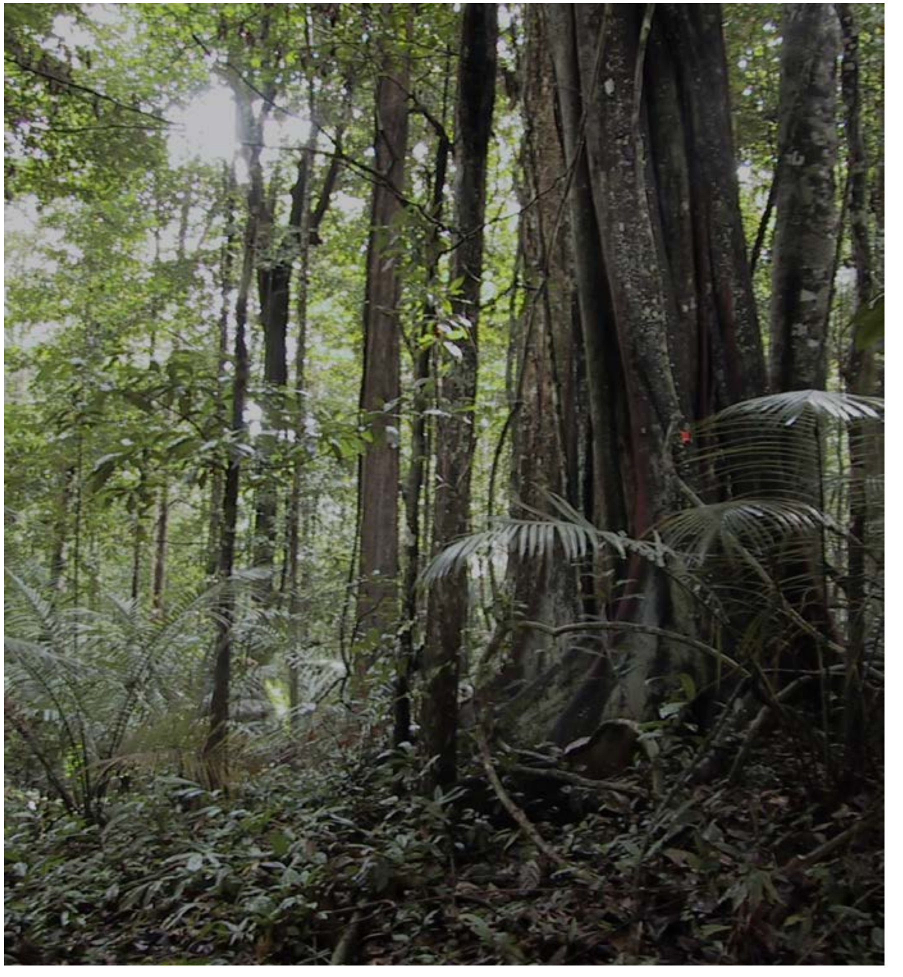
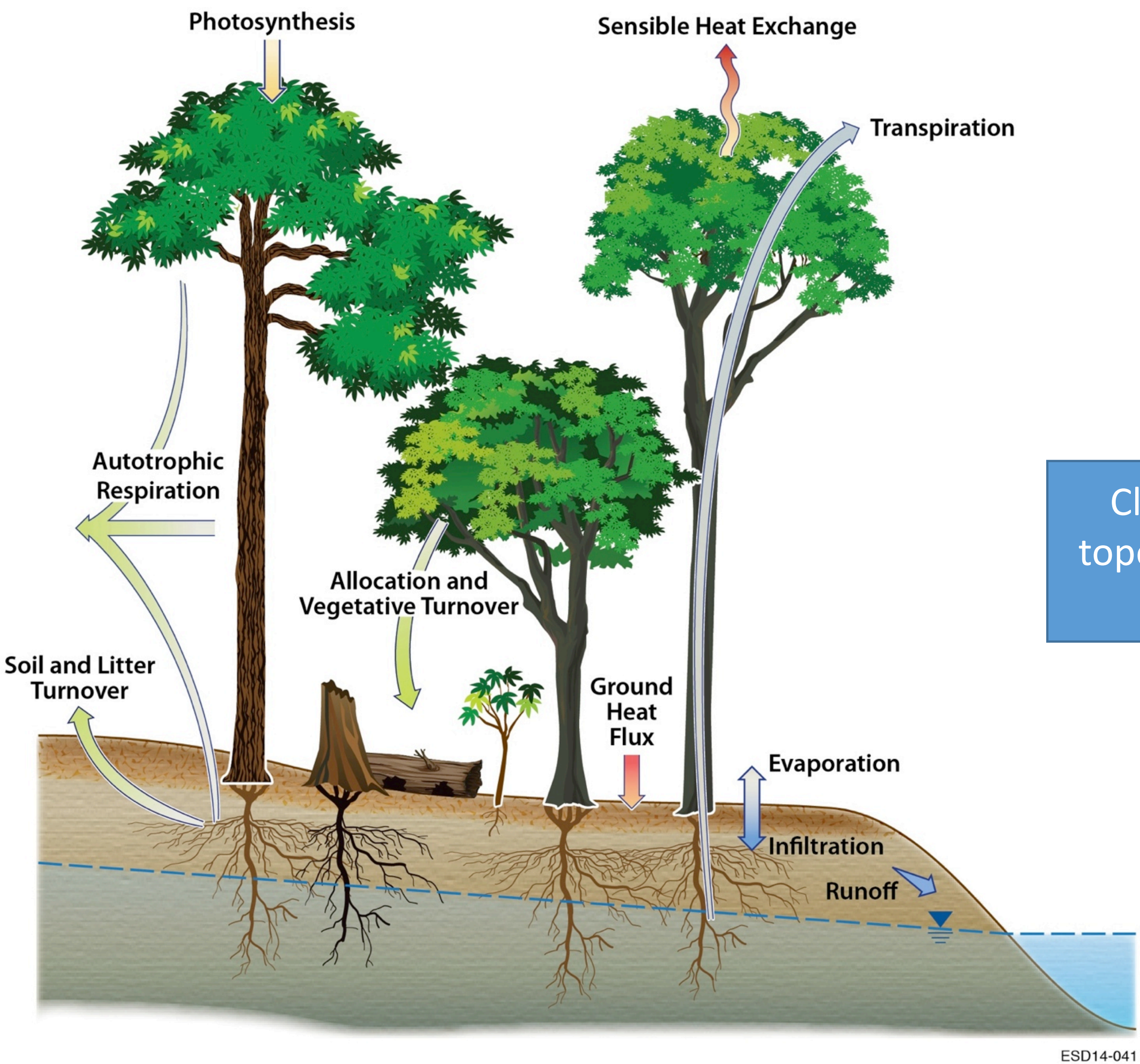
Importance of tropical forests

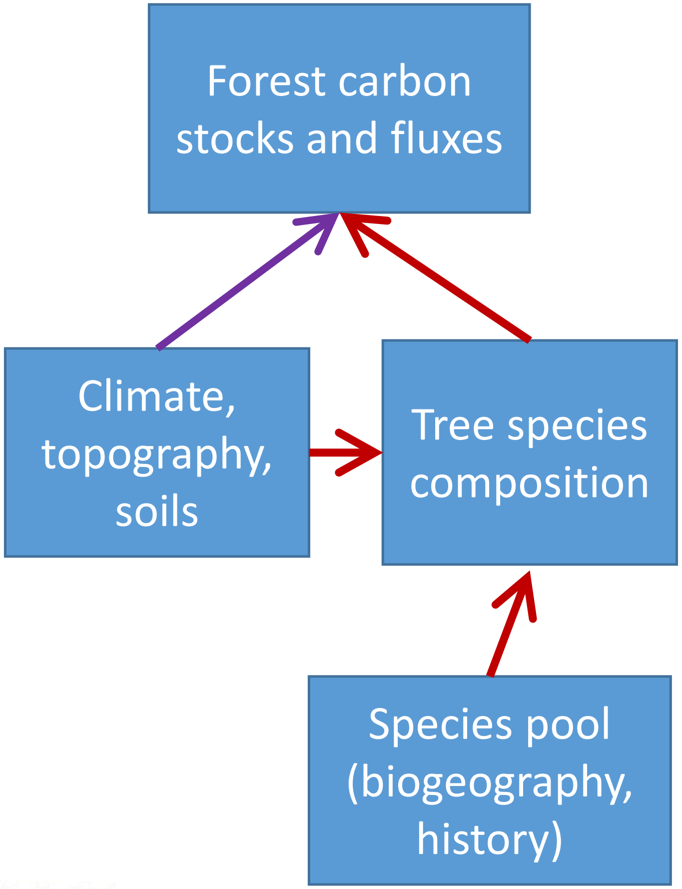
- Major role in global carbon cycle:
  - 1/3 of terrestrial GPP (gross primary productivity)
  - 2/3 of terrestrial biomass carbon stocks
  - Intact tropical forests ~ 1/2 of current terrestrial C sink
  - *Uncertainty regarding tropical forest response to global change dominates uncertainty in future global C budget*
- Majority of terrestrial species diversity
  - ~2/3 of tree species
  - ~3/4 of terrestrial vertebrate species



Tropical forests in global vegetation models

What do the models try to capture? Everything needed to get the carbon budget right!





What do global vegetation models need?

- Driver data:
  - Climate – temperature, rainfall, solar radiation, lightning, fires, soil moisture
  - Topography, geology, geomorphology – high resolution ground topography, insights into nutrient availability from hyperspectral
  - Human influences – roads, timber extraction, fires, proximity to settlements
- For parameterization:
  - Plant functional trait data – tree height and crown allometry, leaf traits, wood traits, root traits, carbon allocation rules
- For evaluation:
  - Forest structure – tree size distributions, above-ground biomass
  - Forest dynamics – productivity, mortality
  - Woody plant composition – relative abundances of functional types, of different trait combinations
  - Plant “behavior” – leaf phenology, leaf area index, sap flux, individual growth
  - Stand-level fluxes – eddy covariance, evapotranspiration

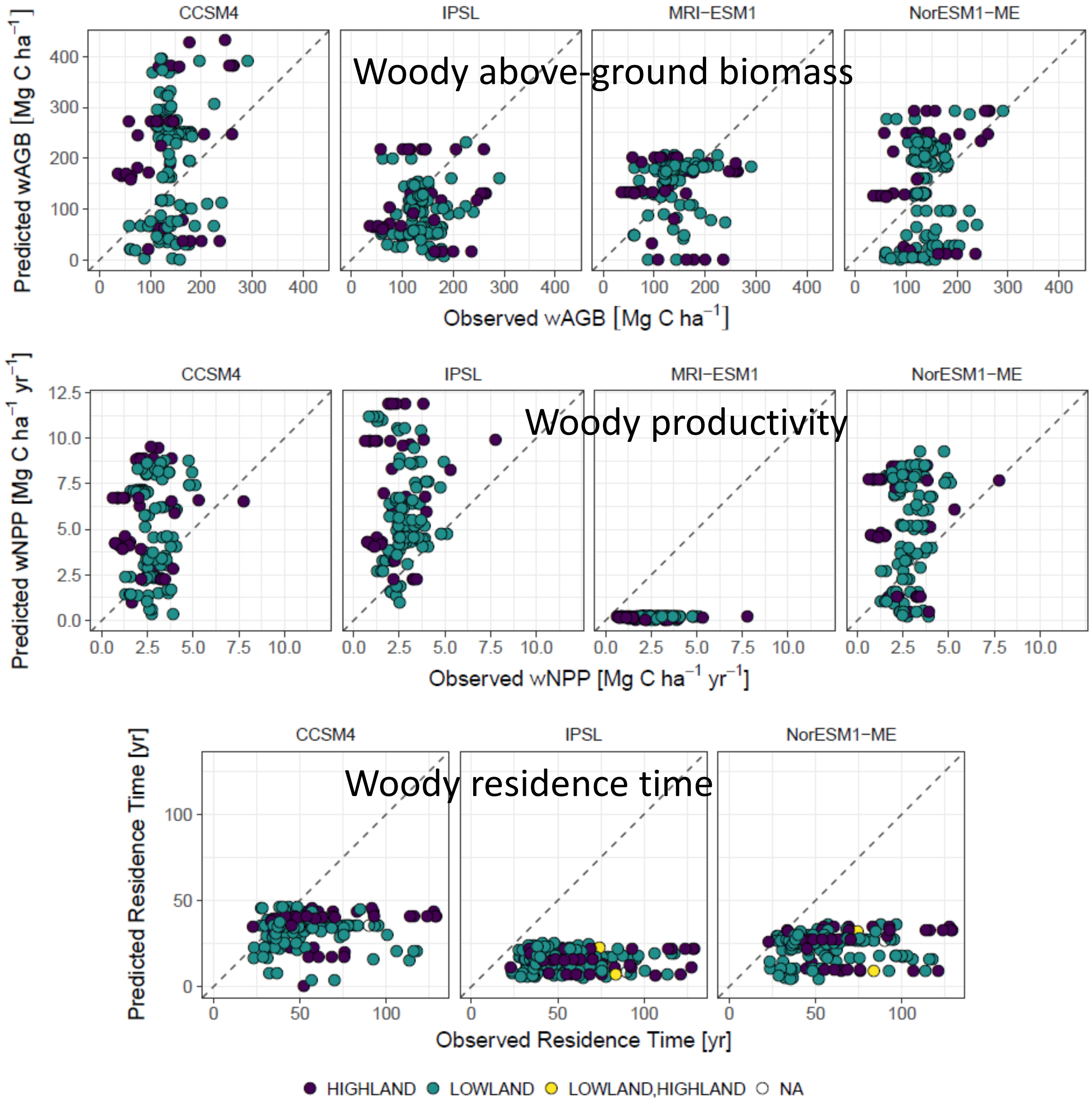
What questions can global vegetation models help with?

- Elucidating underlying mechanisms:
  - what is needed to reproduce observed patterns of spatial and temporal variation?
  - what is the relative importance of different processes and mechanisms?
- Predicting responses to novel future conditions
  - *Only if the models capture the mechanisms sufficiently well!*

How well do the models do?

- Y axis: CMIP 5 model output, for the 4 models that provided these variables
- X axis: ground-based observations synthesized in Galbraith et al. 2013

These models fail to capture spatial variation in biomass stocks and fluxes in old-growth tropical forests.



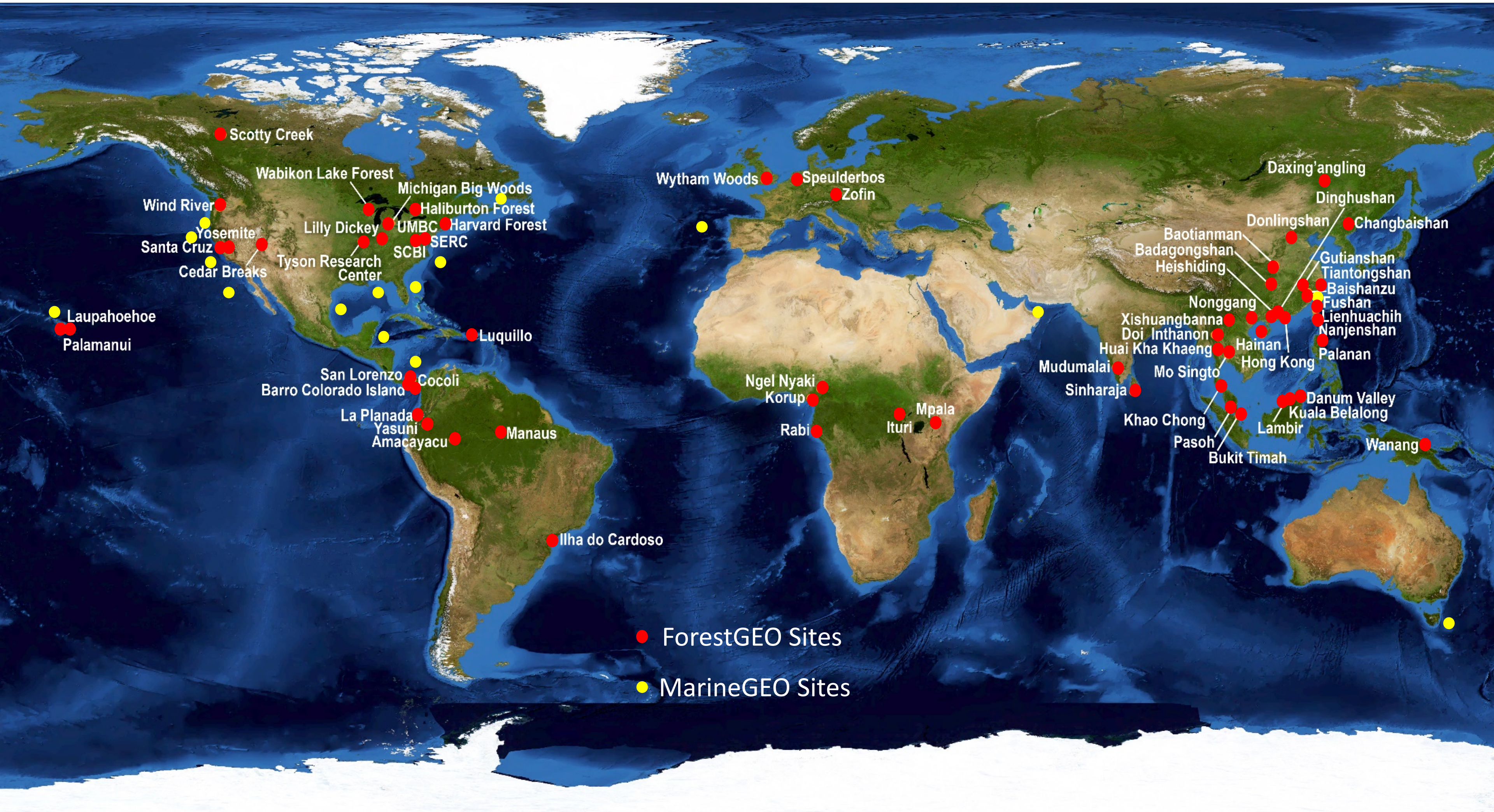
Muller-Landau et al., in preparation, Tansley review for *New Phytologist*

Ground-based datasets for tropical forests

Smithsonian ForestGEO

(formerly known as the Center for Tropical Forest Science, CTFS)

Large-scale forest census plots



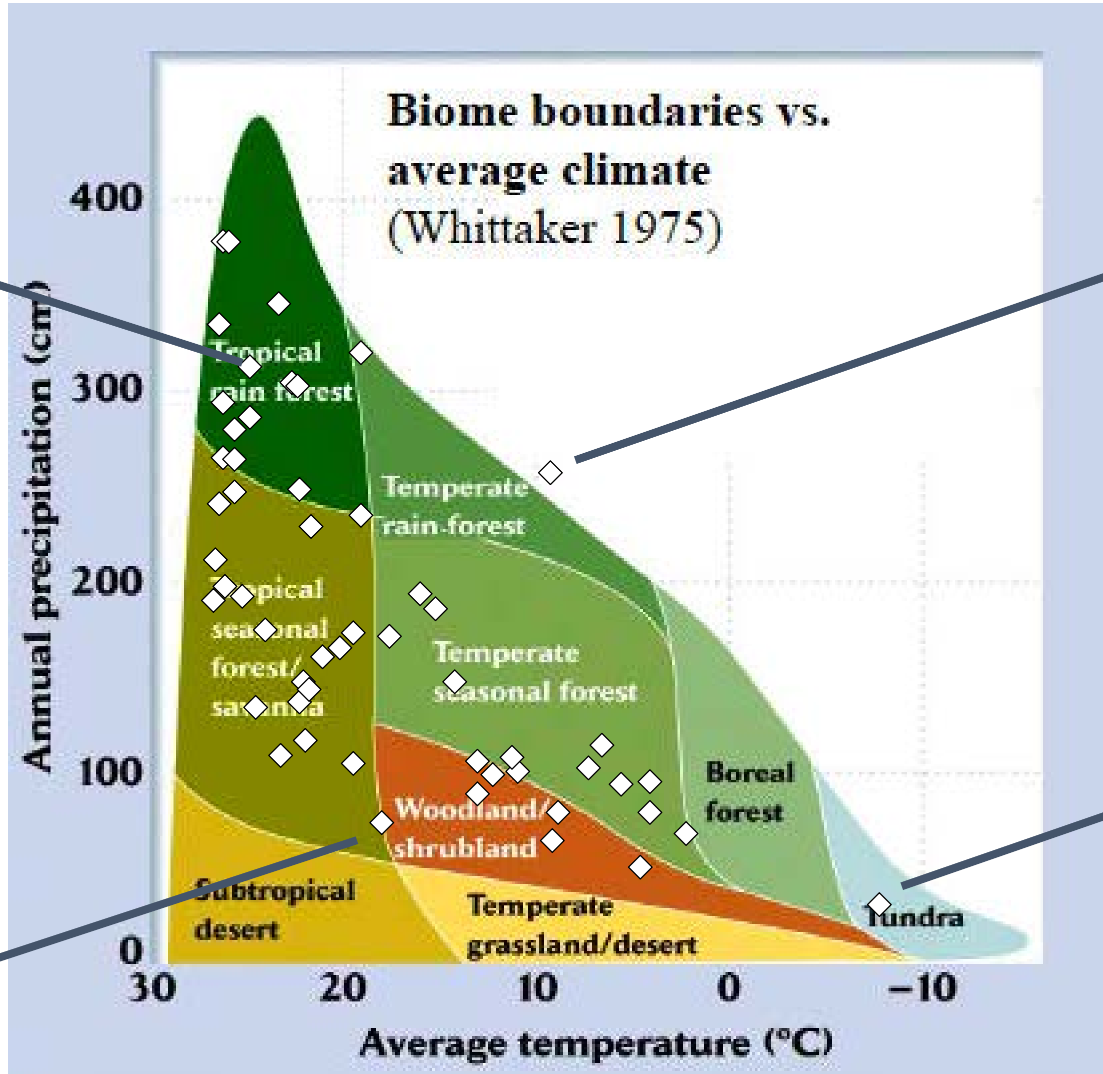
6.4 million living trees, 10,000 species, 901 forest years

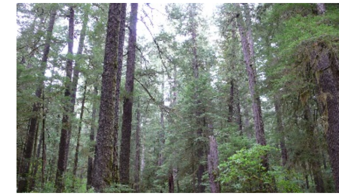
67 sites, 26 countries, >100 partner institutions

ForestGEO sites span global variation in forest type

Lambir

Mpala





Wind River

Scotty Creek

Anderson-Teixeira, et al. GCB 2015

Core tree censuses
(plots mostly >16 ha)

All trees > 1 cm diameter are

- Tagged and mapped
- Identified to species
- Measured in diameter

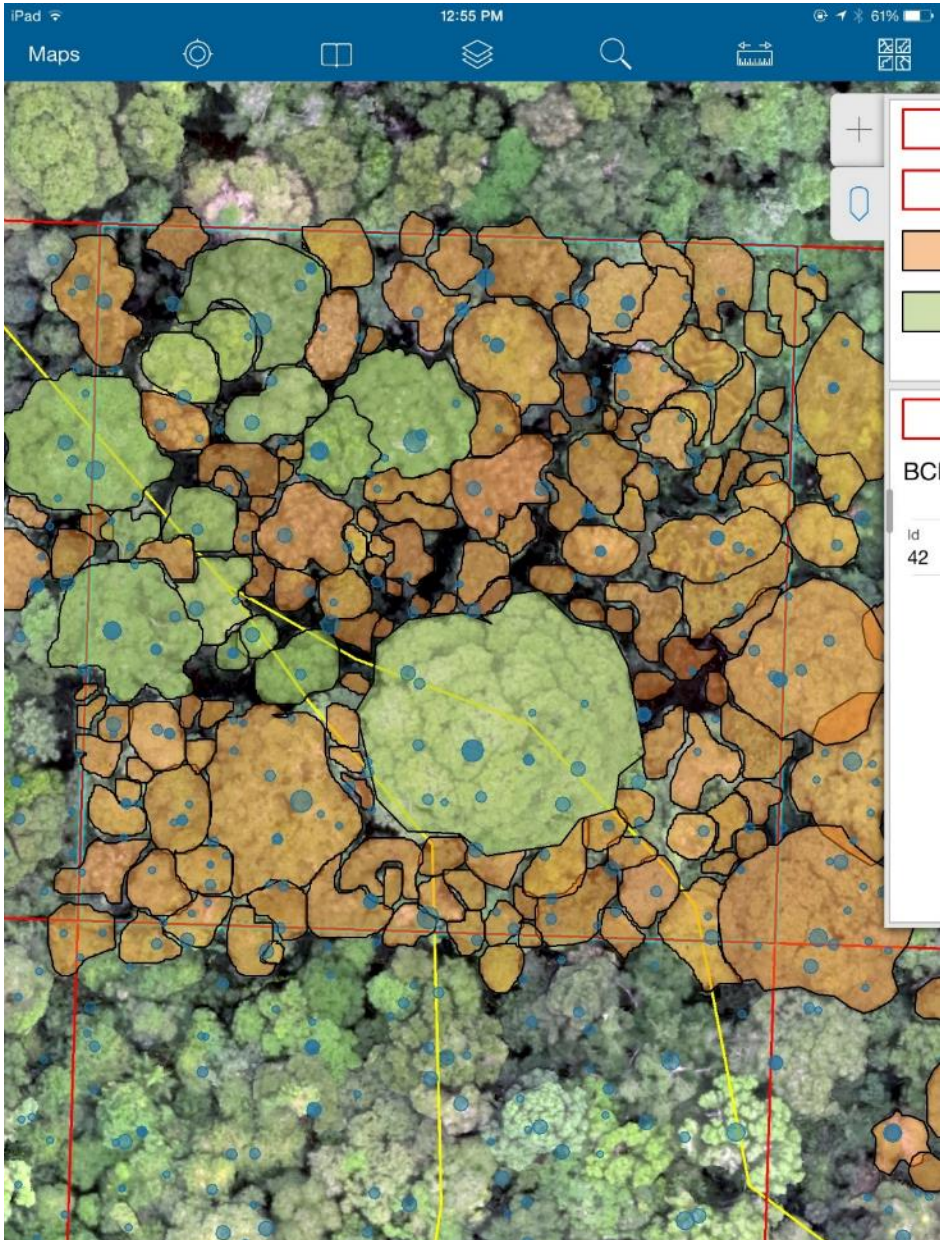
Associated products

- Forest structure and biomass stocks
- Dynamics: mortality, recruitment, productivity
- Composition

Ground-based data collection at ForestGEO plots

Near-surface remote sensing at ForestGEO

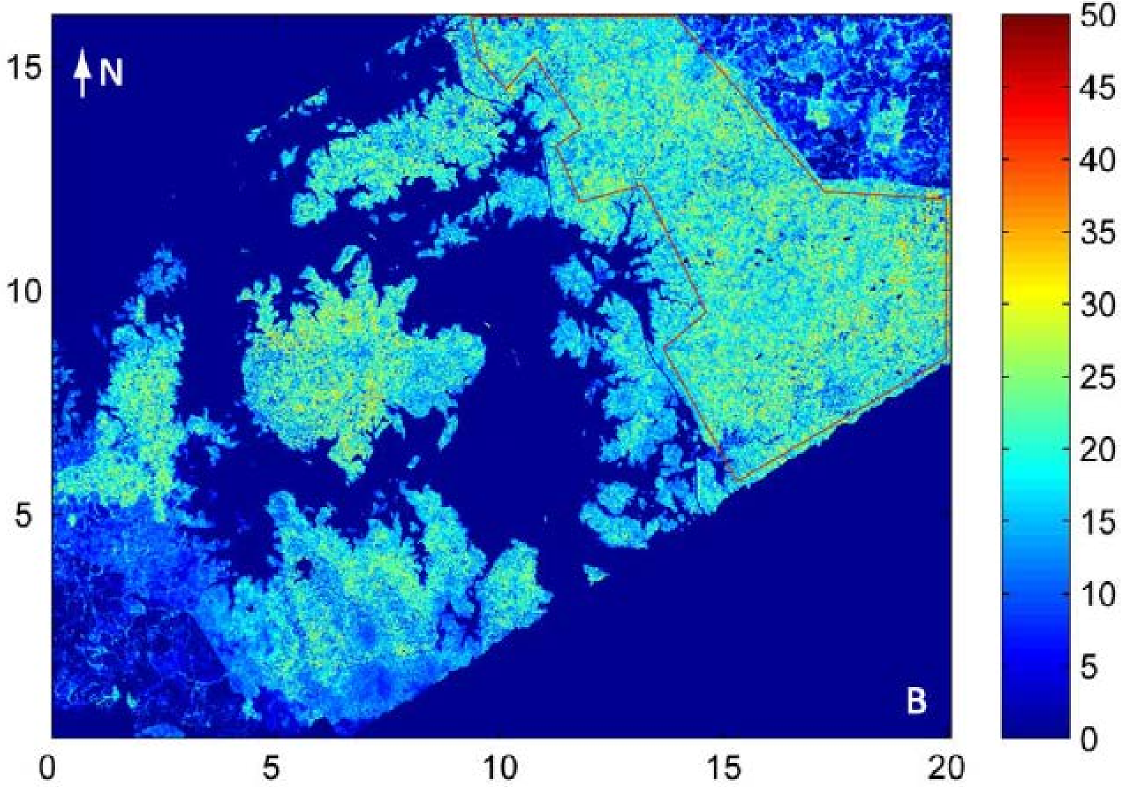
UAV imagery linked to tagged trees to track phenology, crown dynamics



Field work by Carrie Tribble, Pablo Ramos, Paulino Villareal, and Areli Benito

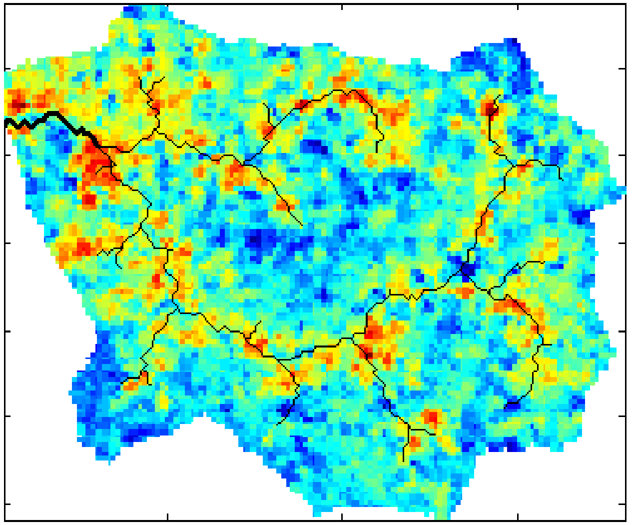
Park et al., submitted
Muller-Landau et al., in prep

LiDAR for some plots & surrounding



Canopy
height
(m)

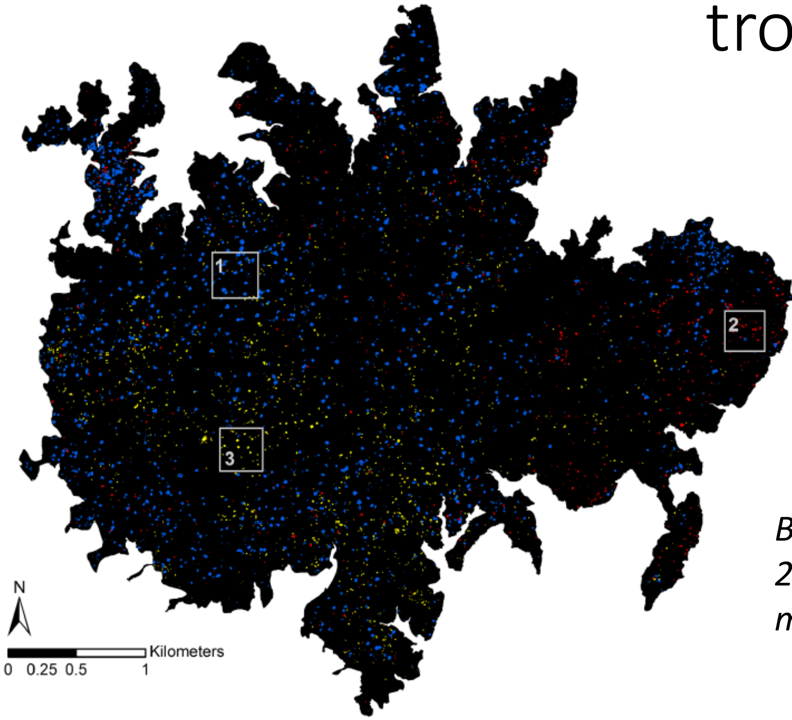
Has resulted in new knowledge of spatial patterns in forest structure at landscape scale with respect to topography and geology.



For example, canopy height is greater on valleys than in ridges.

Detto et al., 2013, *PLOS ONE*

Promise of hyperspectral to map species and traits in tropical forests



Some tree species can be specifically identified and mapped.

Baldeck et al. 2015 Plos One mapped 3 species

The more species, the harder to classify them individually.

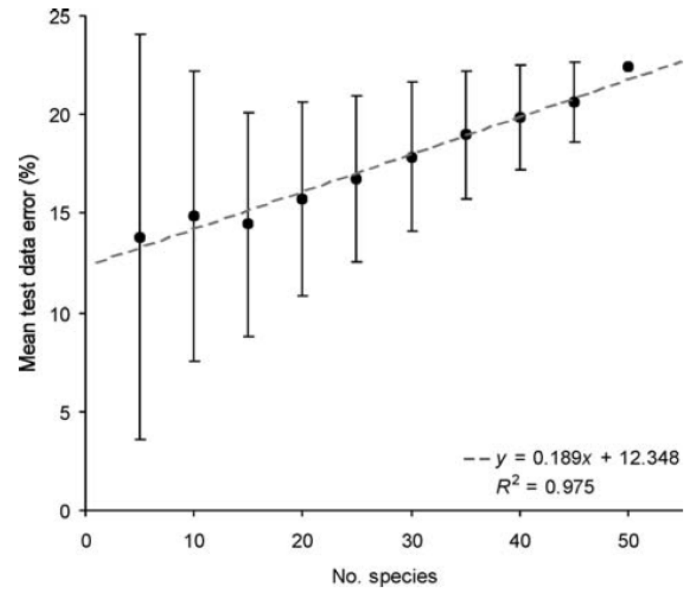
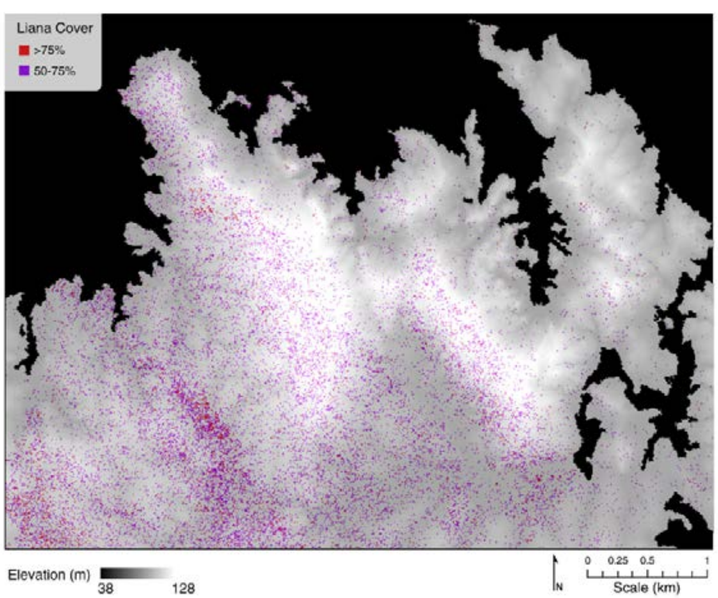


Fig. 7. Classification analysis for 50 species from three sites, Parque Natural Metropolitano, Fort Sherman, and Chamela. Data were gathered in the 2003 wet season using the UniSpec. Mean test data error ±1SD was computed from 10 000 classifications each per set of 5, 10, 15, 20, 25, 30, 35, 40, and 45 species. Sets of species were selected at random for each classification.

Castro-Esau et al. 2006 Am J Bot

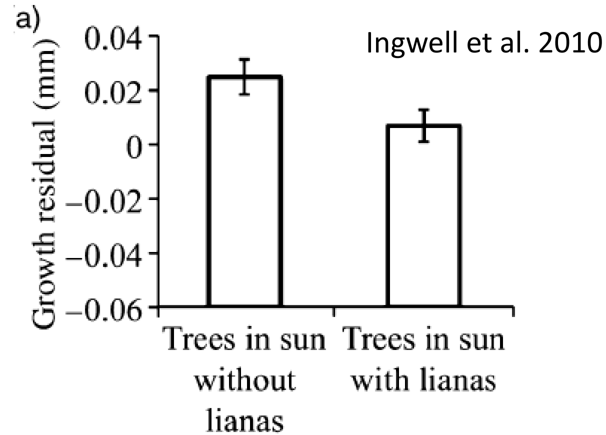


Liana cover can be estimated across landscapes.

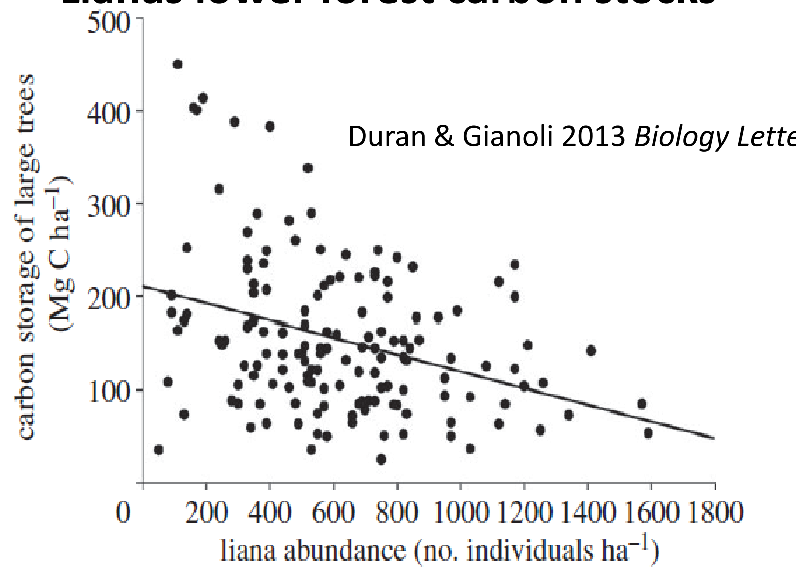
Marvin et al. 2016 Rem Sens Env

Lianas (woody vines) – important and difficult to study

Lianas reduce tree growth

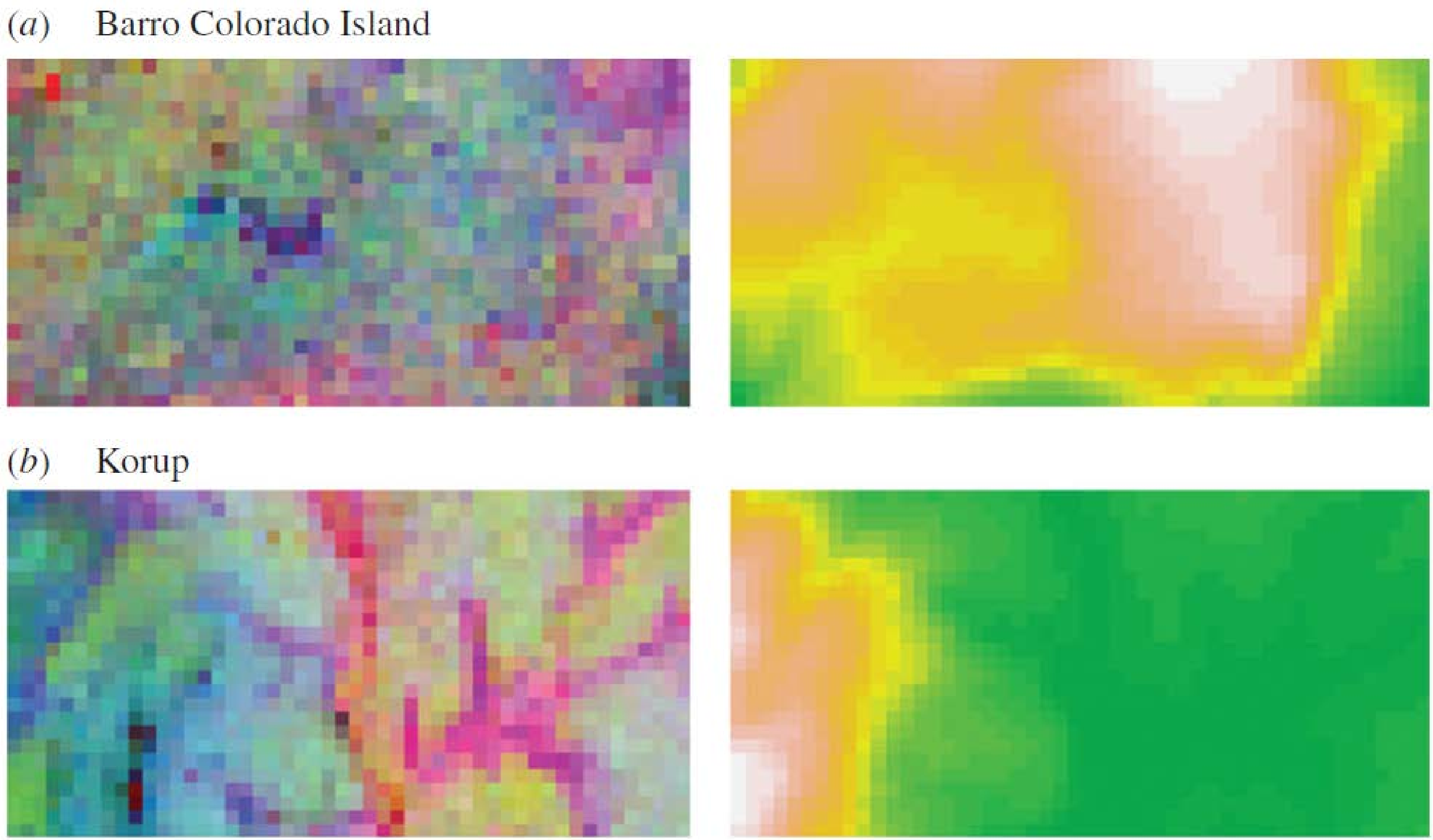


Lianas lower forest carbon stocks



Some findings from ForestGEO

Finding: Tree community composition varies strongly with topography and soils

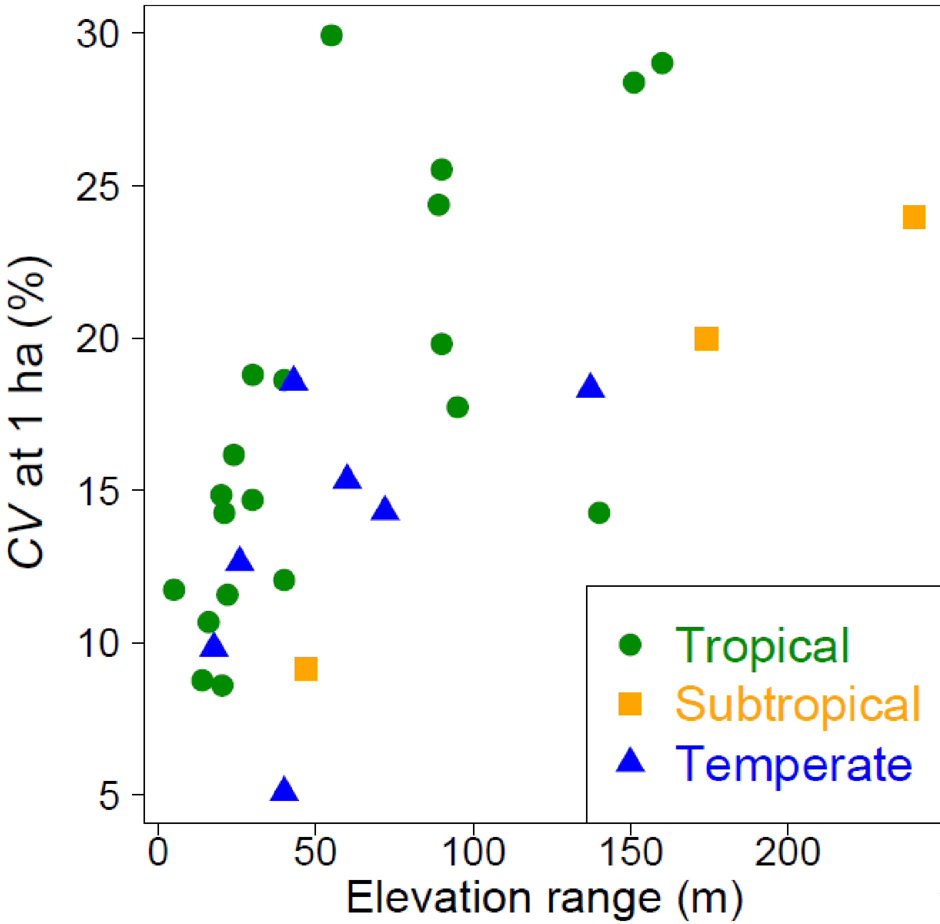


Measured soil and topographical variables explain 13-39% of tree community variation at 20 m scales in eight large forest plots.

Baldeck et al. 2012 *Proc Roy Soc*

Finding: Carbon stocks vary greatly among tropical forests

even very locally – among 1-ha plots within a 16-50 ha plot

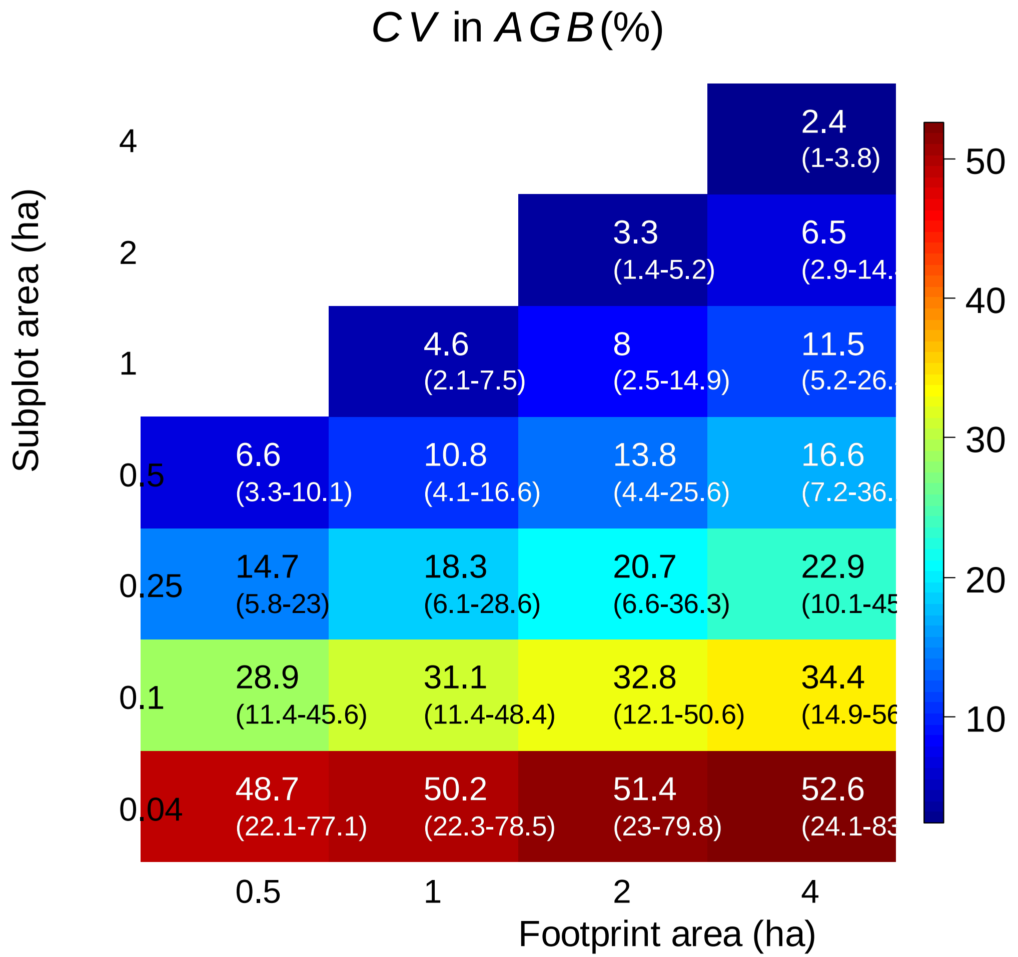


Local variability is higher in tropical than temperate forests

Variability increases with topographical complexity

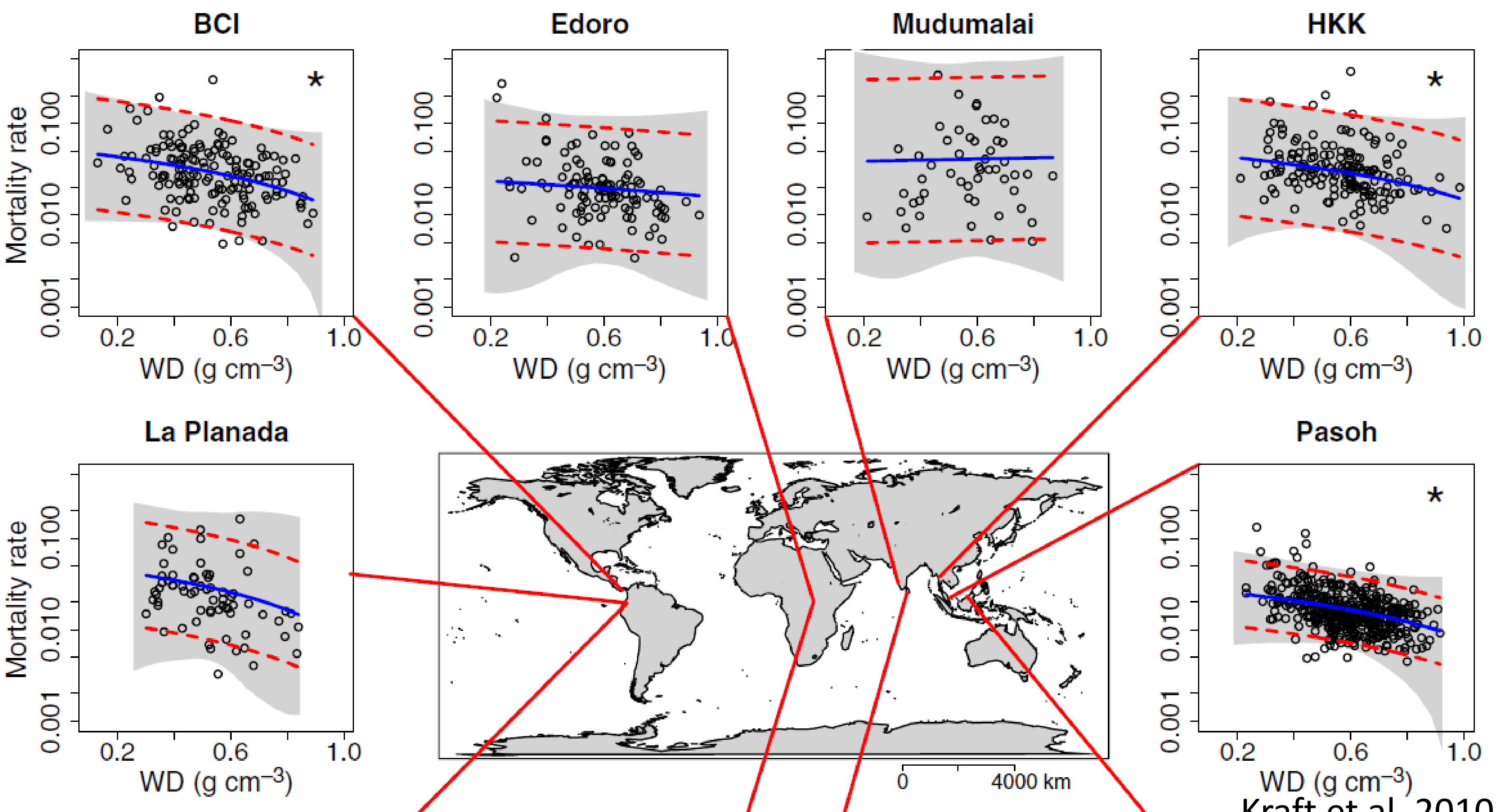
Réjou-Méchain, Muller-Landau et al. 2014

This heterogeneity means that calibration plots smaller than footprint area greatly increase uncertainty



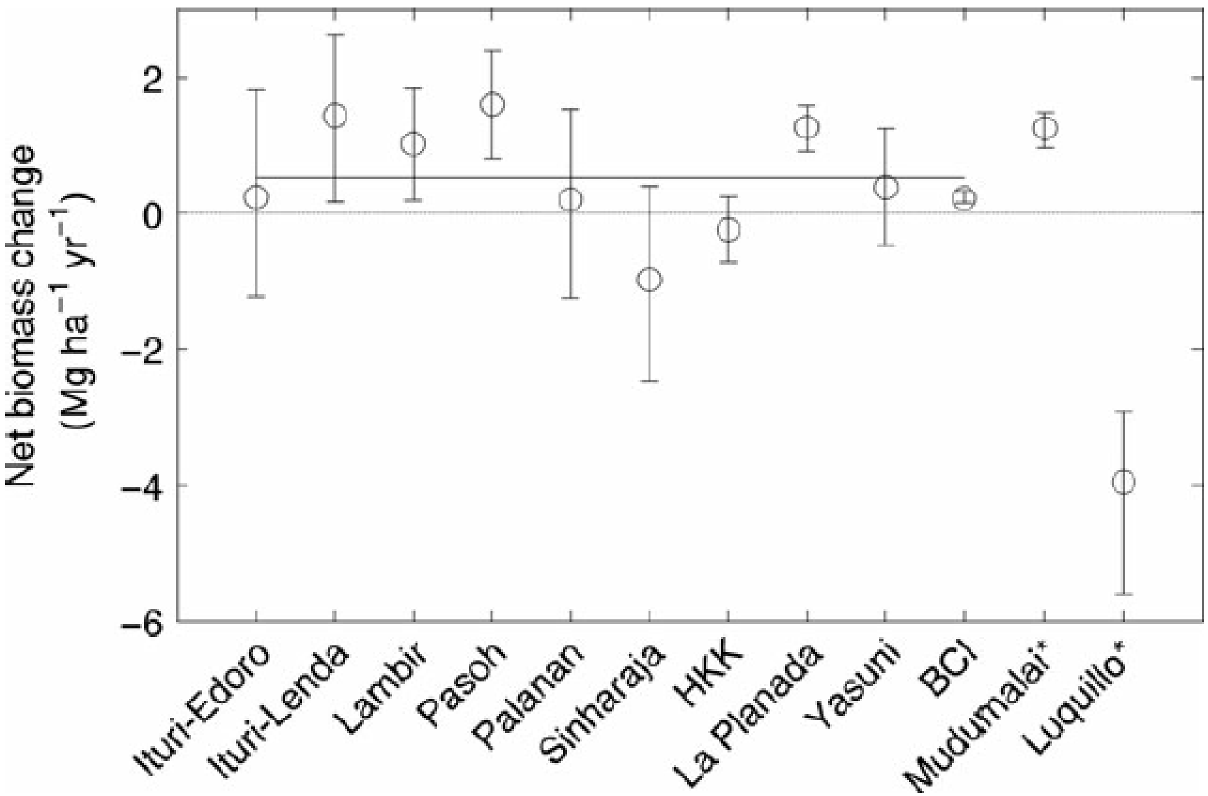
Finding: Wood density predicts species demographic rates within and across sites

So changing functional composition is expected to affect demography.



Kraft et al. 2010

Finding: Old-growth tropical ForestGEO / CTFS sites are on average carbon sinks



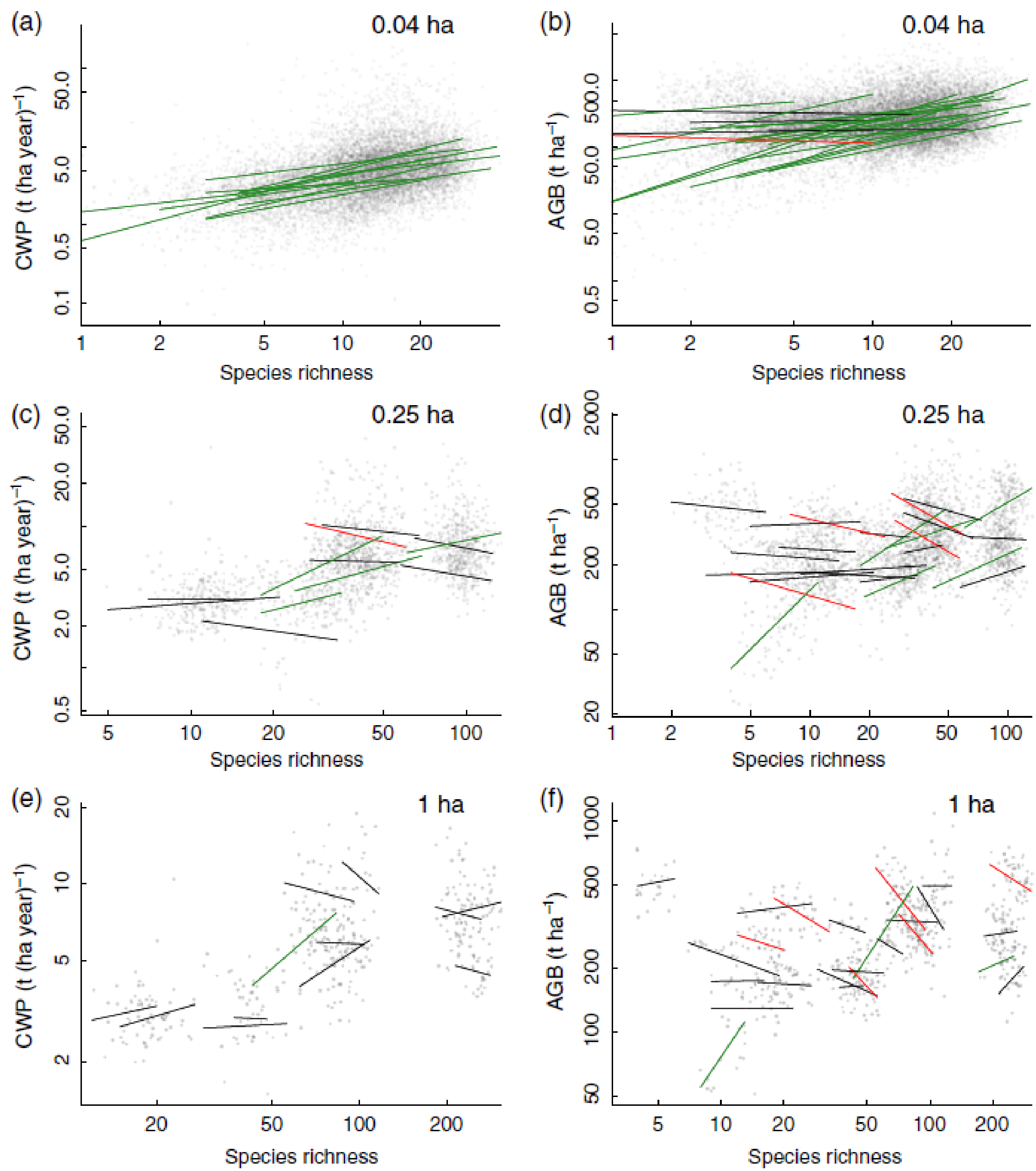
Anderson-Teixeira et al. 2014, redrawn from Chave et al. 2008

Finding: Functional composition is shifting over time within sites

Site	High Wood Density	Low Wood Density	Large Seeds	Small Seeds
BCI	0.18 [−0.36,0.66]	0.14 [−0.55,0.76]	0.15 [−0.55,0.75]	−0.01 [−0.64,0.55]
Edoro	0.17 [−0.38,0.72]	−**0.94** [−1.80,−0.23]	0.29 [−0.21,0.77]	−**0.66** [−1.26,−0.12]
Lenda	0.23 [−0.05,0.48]	0.4 [−0.17,0.89]	**0.3** [0.02,0.54]	0.15 [−0.50,0.68]
HKK	**0.31** [0.04,0.57]	−0.21 [−0.63,0.14]	0.16 [−0.11,0.40]	**0.62** [0.31,0.91]
Lambir	0.16 [−0.12,0.40]	0.22 [−0.08,0.48]	**0.35** [0.06,0.62]	0.14 [−0.12,0.38]
La Planada	0.16 [−0.32,0.64]	**0.59** [0.28,0.90]	**0.51** [0.21,0.78]	**0.77** [0.10,1.36]
Palanan	**0.61** [0.14,1.04]	−**0.88** [−1.83,−0.03]	−0.32 [−1.09,0.36]	**0.8** [0.27,1.28]
Pasoh	**0.56** [0.12,0.95]	0.07 [−0.55,0.60]	**0.53** [0.03,0.96]	**0.72** [0.32,1.03]
Sinharaja	−**3.67** [−4.97,−2.44]	**0.92** [0.56,1.29]	−**2.01** [−2.89,−1.16]	**0.89** [0.37,1.62]
Yasuni	0.03 [−0.42,0.46]	0.09 [−0.47,0.62]	0.1 [−0.28,0.45]	0.29 [−0.36,0.90]
Average	−0.12 [−0.30,0.04]	0.04 [−0.16,0.22]	0.01 [−0.17,0.16]	**0.37** [0.19,0.54]
Average (without Sinharaja)	**0.27** [0.12,0.41]	−0.06 [−0.26,0.13]	**0.23** [0.07,0.37]	**0.31** [0.13,0.48]
Luquillo[a]	−0.43 [−1.07,0.21]	−0.08 [−1.14,1.22]	0.47 [−0.58,1.43]	−**2.61** [−3.66,−1.64]
Mudumalai[a]	**0.60** [0.30,0.90]	−**2.82** [−3.98,−1.77]	**0.83** [0.61,1.05]	**1.49** [1.04,1.98]

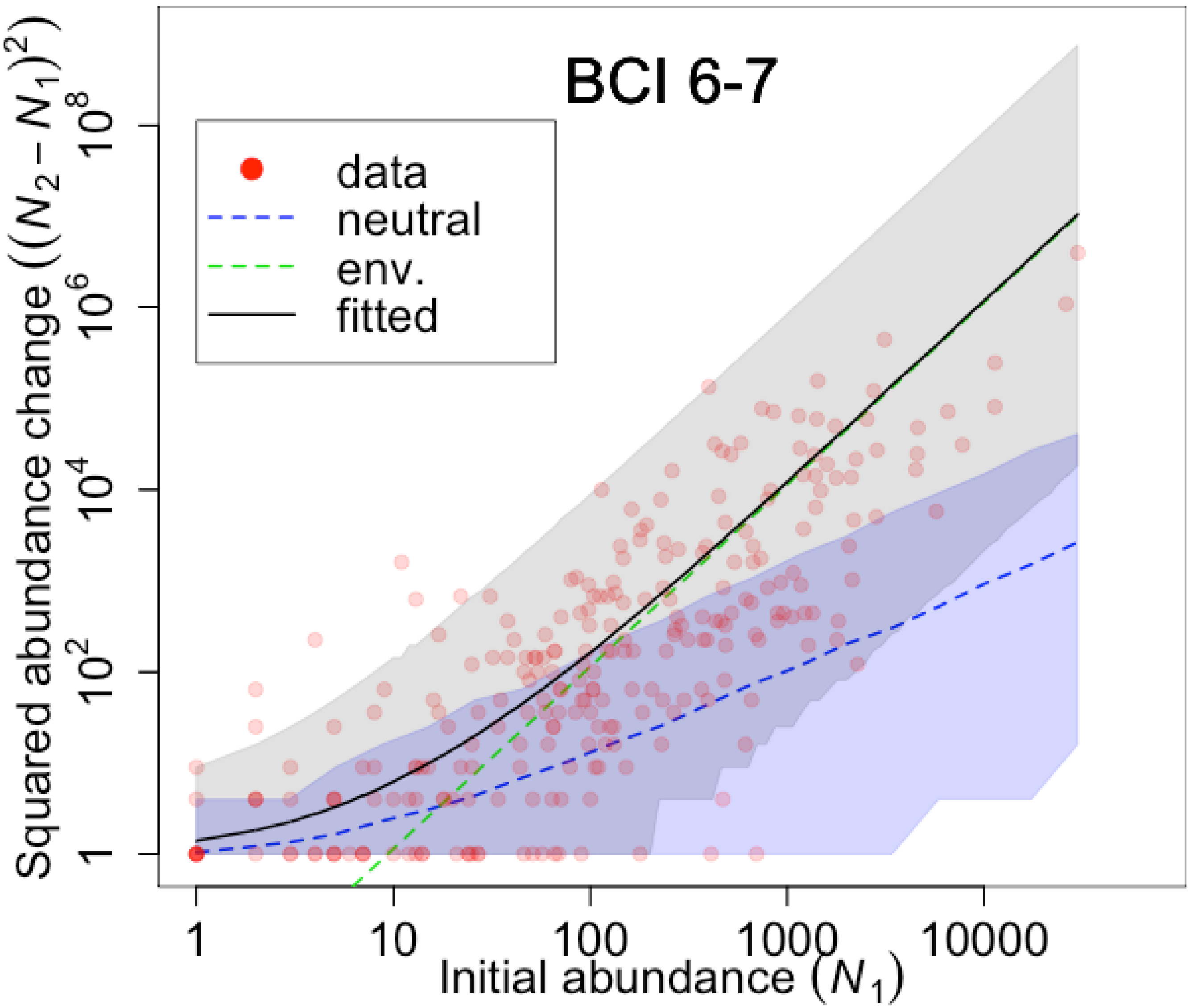
Chave, Condit, Muller-Landau et al. 2008

Finding: The relationship of tree species richness to productivity and biomass varies with spatial scale.



Chisholm, Muller-Landau et al. 2013 *J. Ecology*

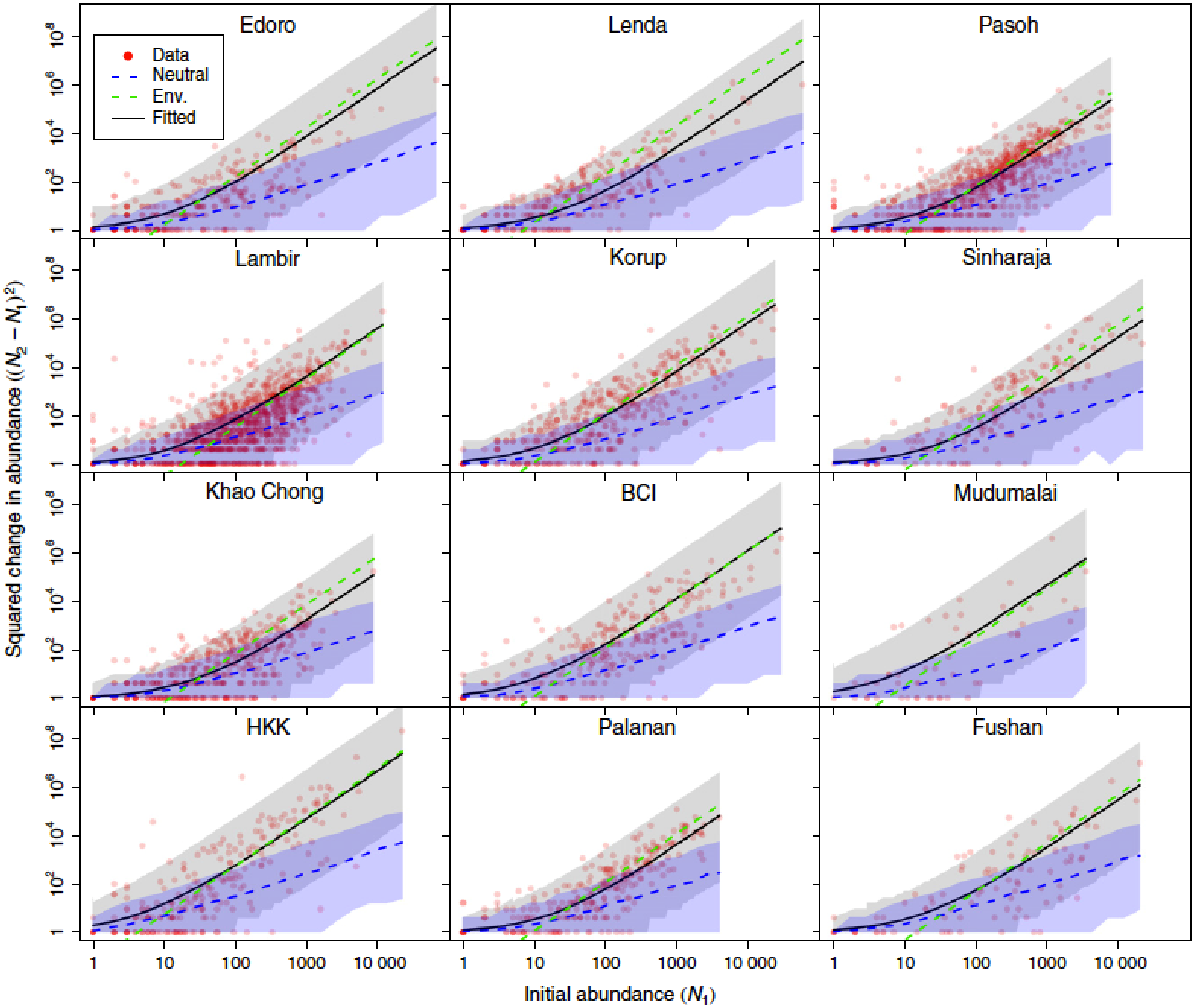
Finding: Tree species abundances are changing faster than can be explained by drift/chance alone



Not only in one site…

Chisholm et al. 2014 *Ecology Letters*

Finding: Tree species abundances are changing faster than can be explained by drift/chance alone



But in all 12 tested sites!

Chisholm et al. 2014 *Ecology Letters*