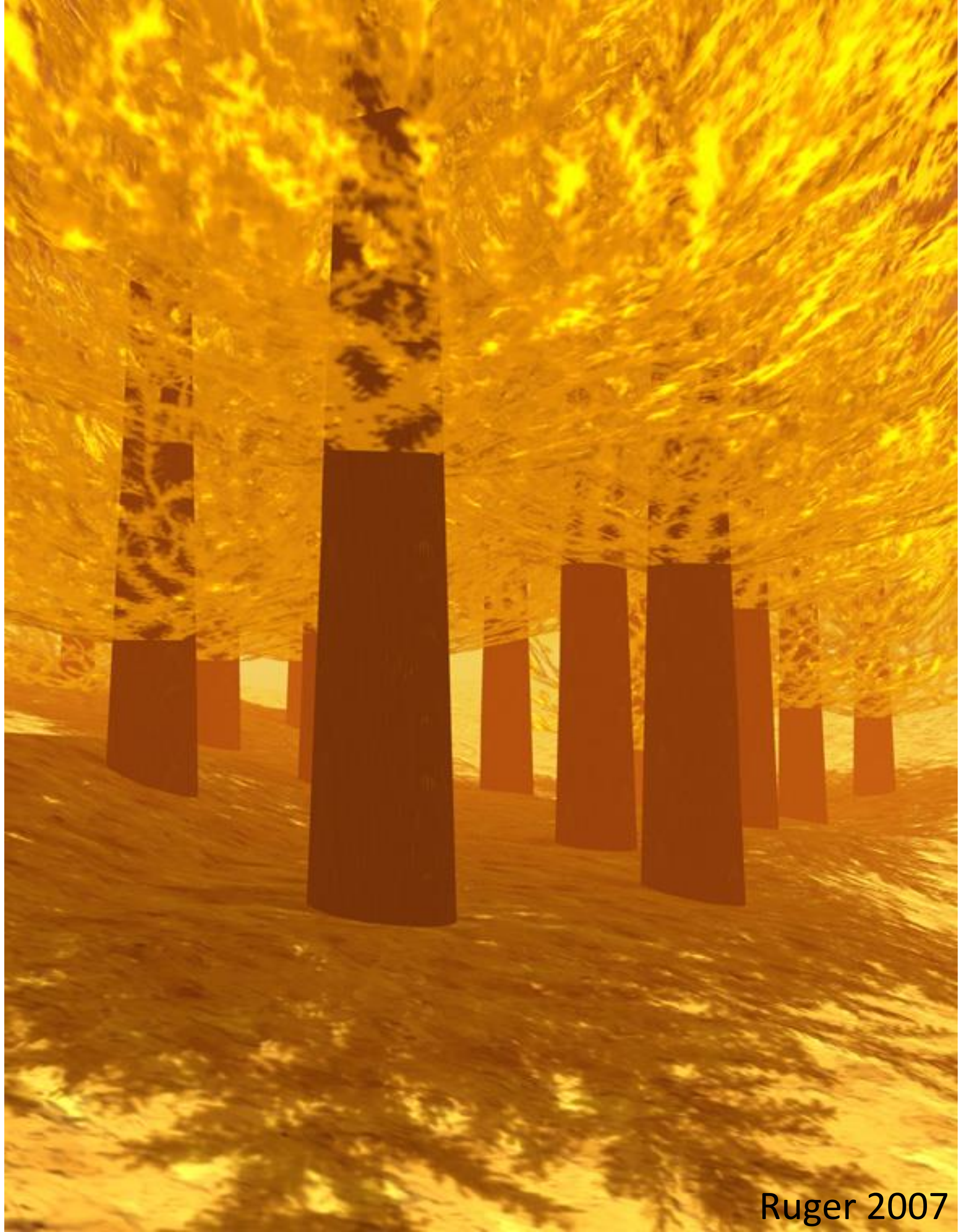

Ruger 2007

Variation in the processes structuring forests, assessed by airborne remote sensing

David Coomes

Forest Ecology and Conservation Group

Department of Plant Sciences

UNIVERSITY OF CAMBRIDGE

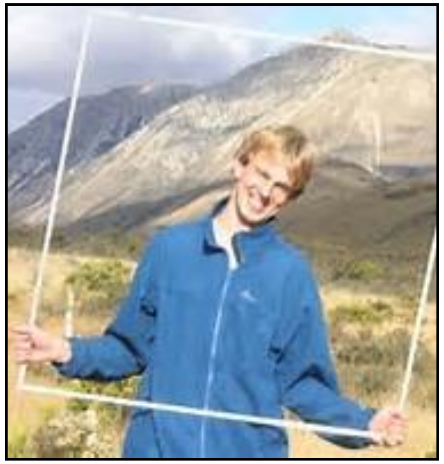
Cambridge Conservation Initiative

With thanks

Tommaso Jucker

Michele Dalponte

James Shepherd



Robbie Holdaway

Dan Safka

NERC SCIENCE OF THE ENVIRONMENT

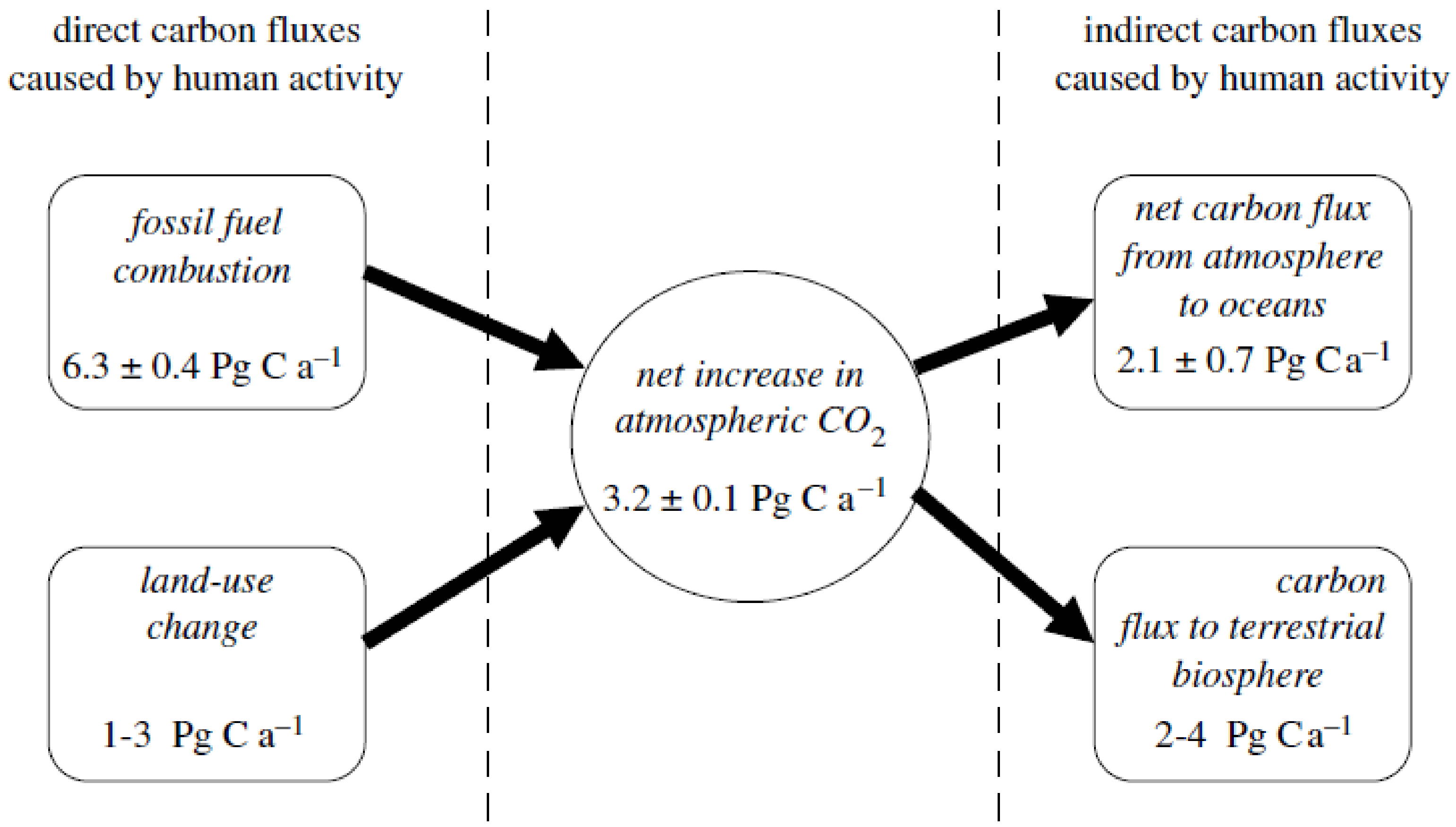
Outline of talk

- Why monitor forest carbon?
- Carbon mapping by airborne laser scanning
- Can we produce a general equation for estimate forest carbon density anywhere in the world from laser scanning data?

[plug Laura Duncanson's talk]

Deforestation and degradation is a major source of C02 and intact forests are major sinks of C02

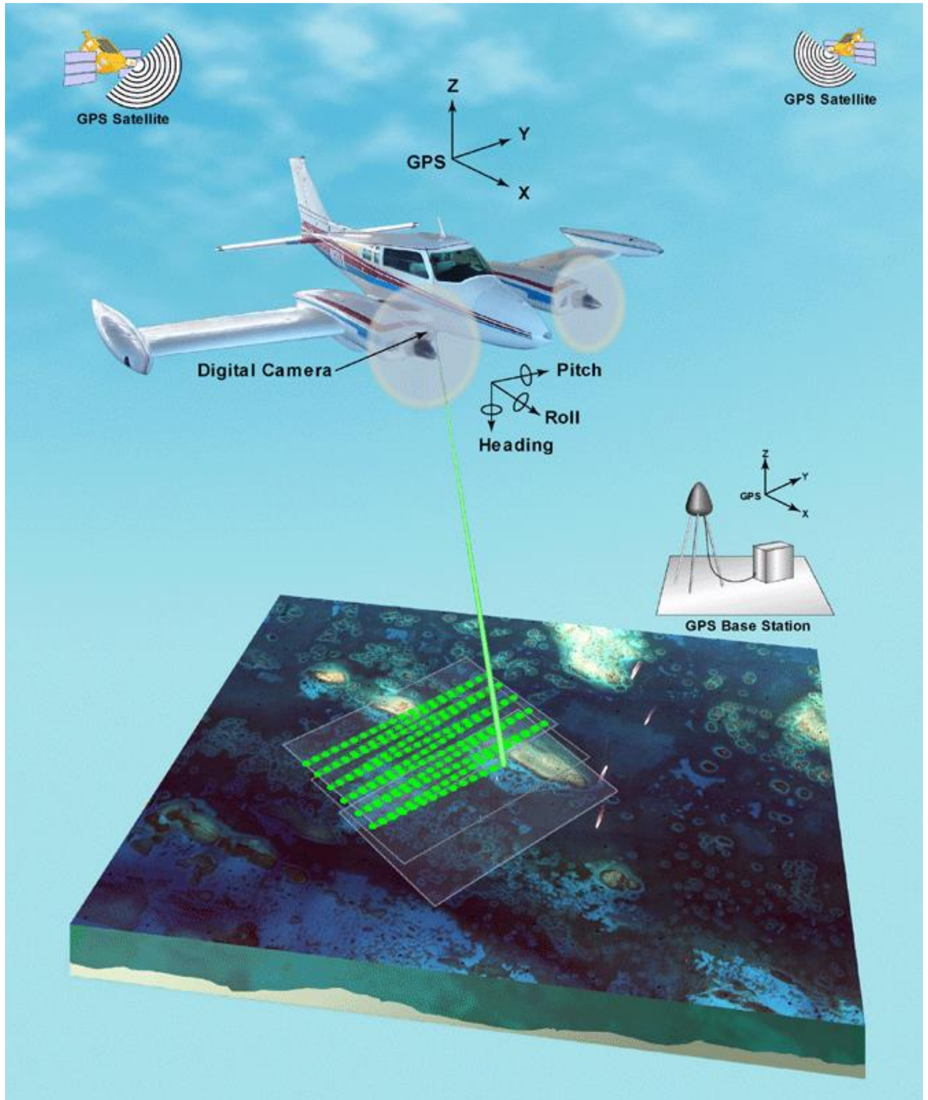
Forest important in the context of global warming



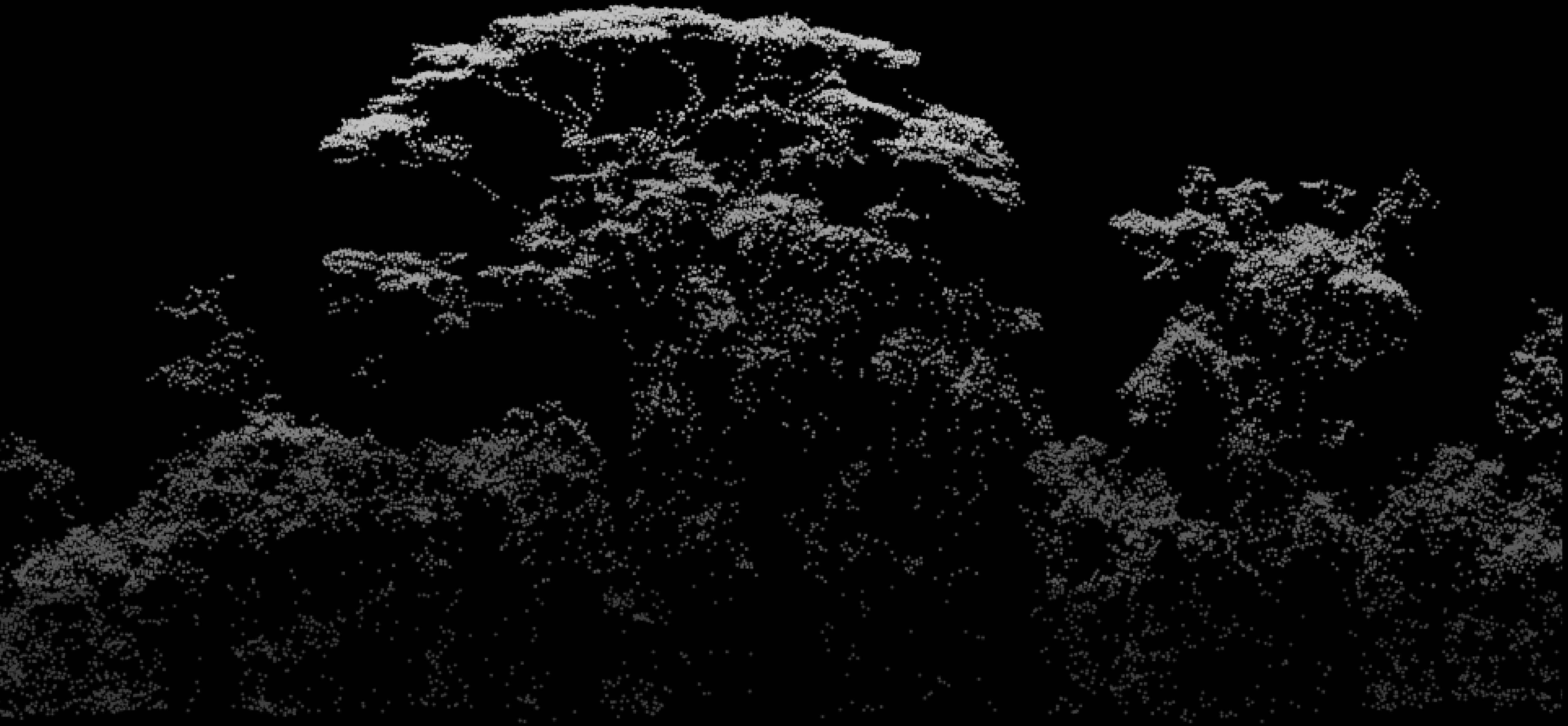
1 Pg = 1 billion metric tonnes

From Lewis (2006)

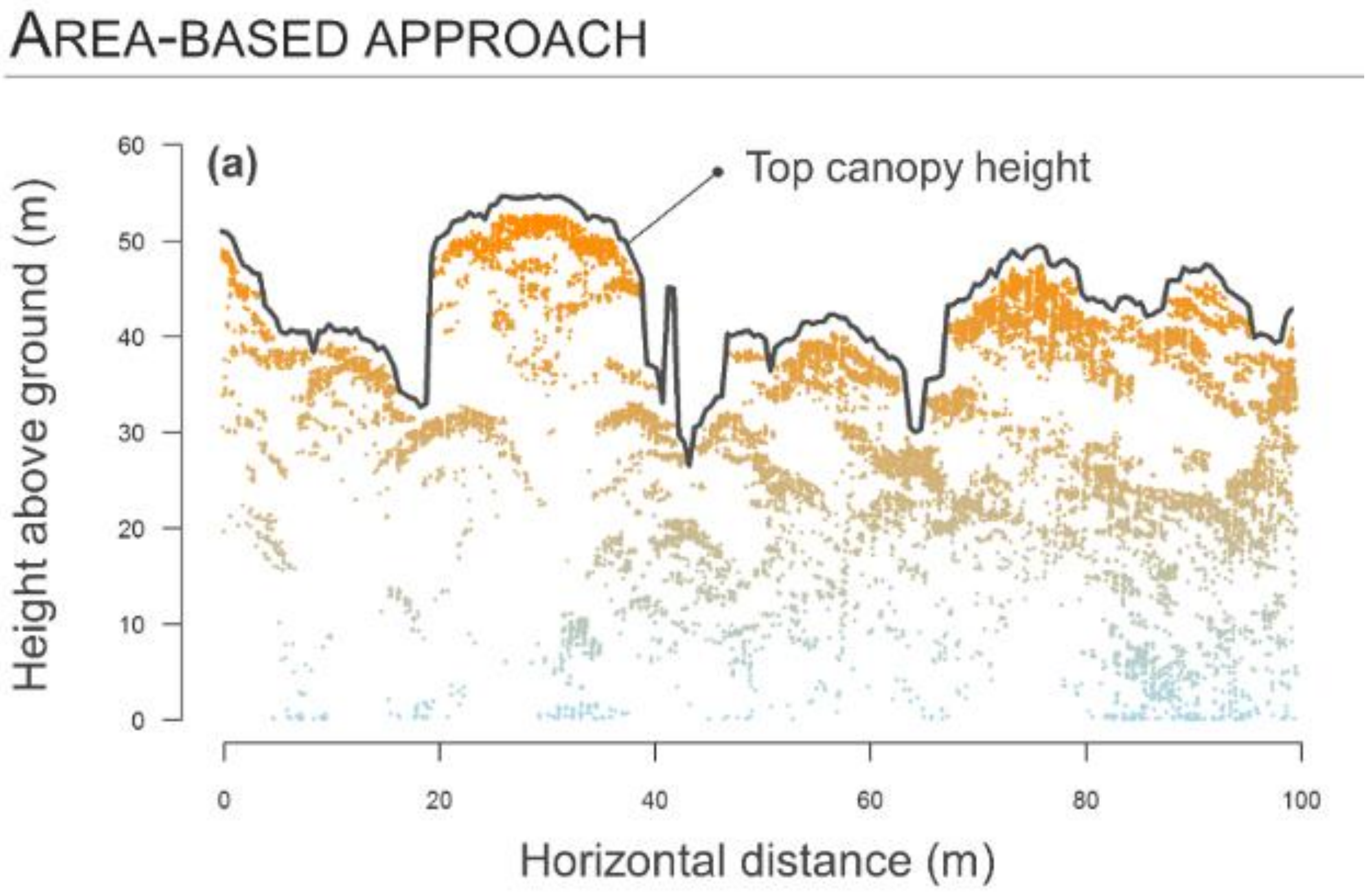
Airborne Laser Scanning to measure forest carbon



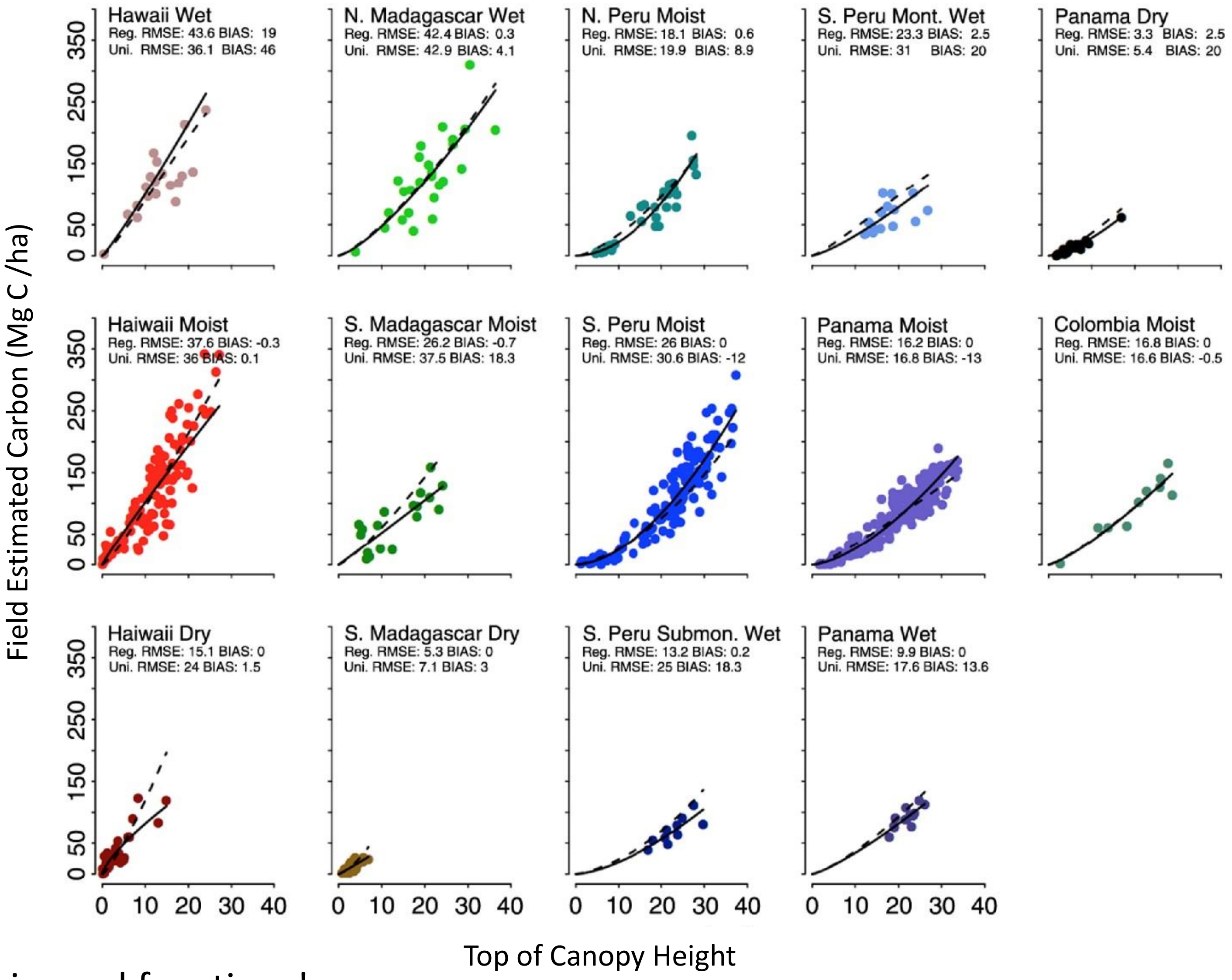
www. gulfsci.usgs.gov/tampabay/data/1mapping/lidar



Estimating aboveground carbon density (ACD) from canopy height

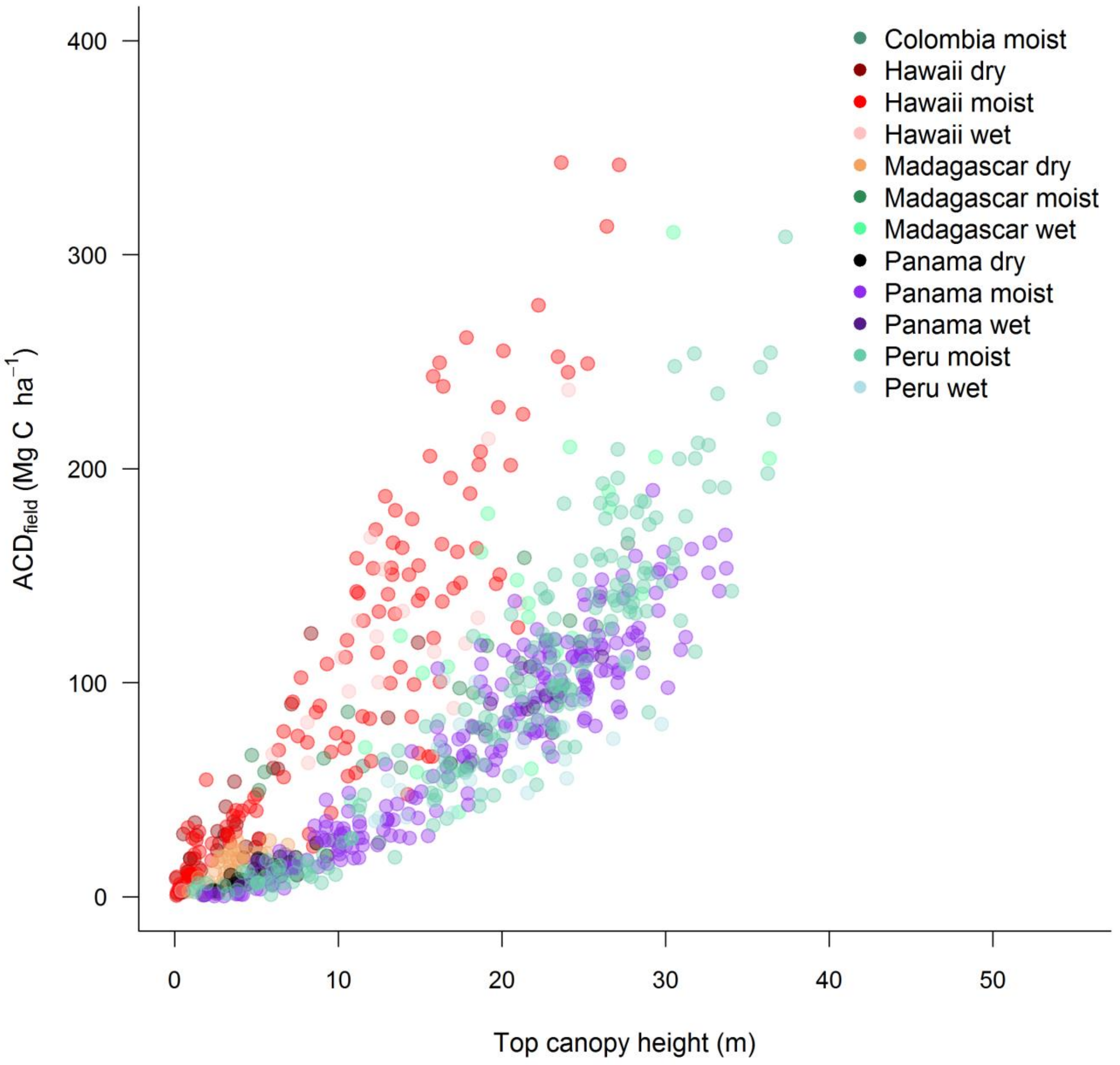


Estimating aboveground carbon density (ACD) from canopy height



Many other metrics and functions!

Asner and Mascaro (2014) Remote Sensing of Environment



Redrawn from Asner and Mascaro (2014) Remote Sensing of Environment

Example 1: Mapping carbon in New Zealand's natural forests

RESEARCH

Airborne laser scanning of natural forests in New Zealand reveals a major influence of wind on forest carbon

David A Coomes[1*], Daniel Šafka[1,2], James Shepherd[2], Michele Dalponte[3] and Robert Holdaway[4]

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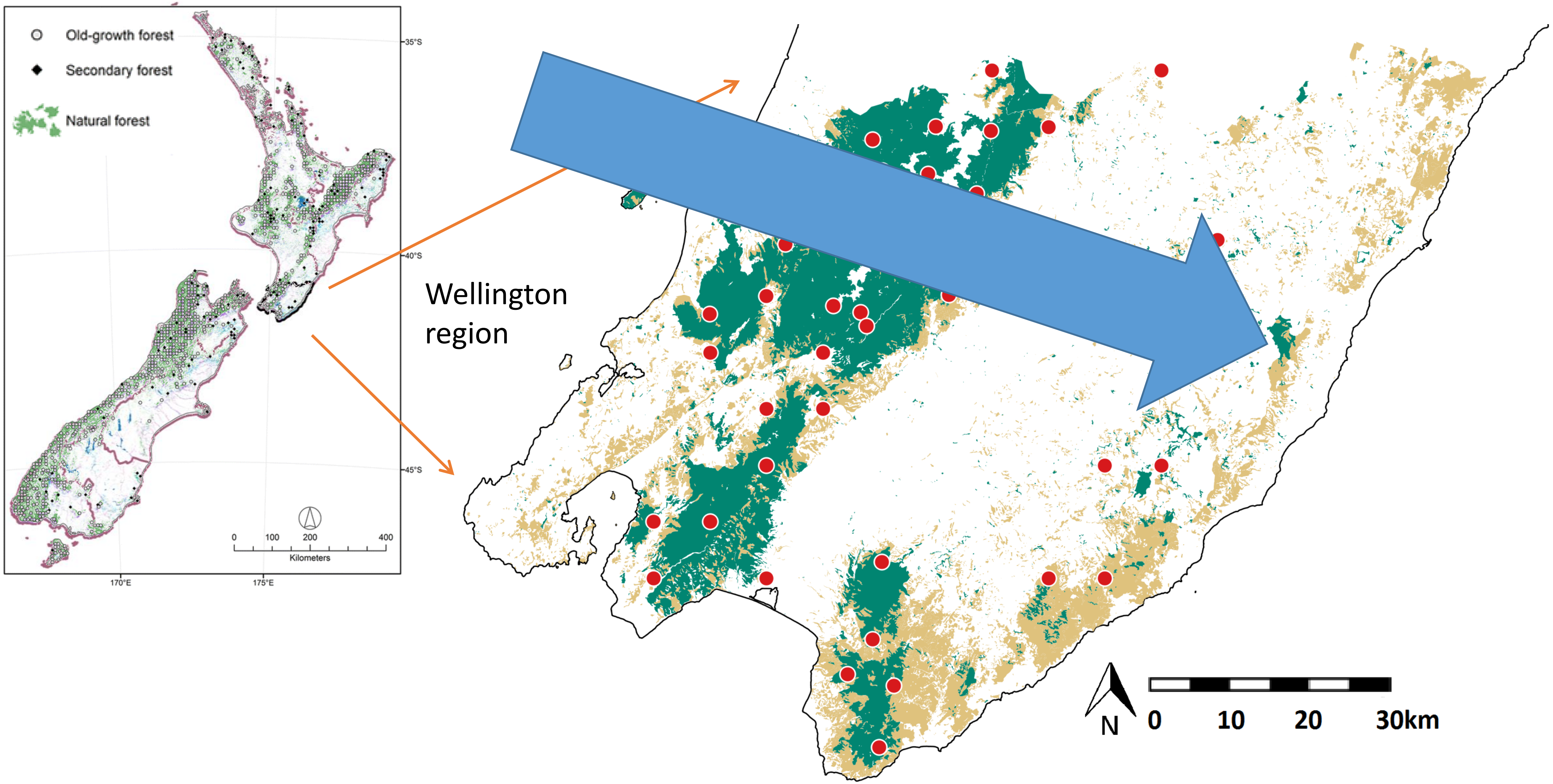
Abstract

Background: Forests are a key component of the global carbon cycle, and research is needed into the effects of human-driven and natural processes on their carbon pools. Airborne laser scanning (ALS) produces detailed 3D maps of forest canopy structure from which aboveground carbon density can be estimated. Working with a ALS dataset collected over the 8049-km^2 Wellington Region of New Zealand we create maps of indigenous forest carbon and evaluate the influence of wind by examining how carbon storage varies with aspect. Storms flowing from the west are a common cause of disturbance in this region, and we hypothesised that west-facing forests exposed to these winds would be shorter than those in sheltered east-facing sites.

Methods: The aboveground carbon density of 31 forest inventory plots located within the ALS survey region were used to develop estimation models relating carbon density to ALS information. Power-law models using rasters of top-of-the-canopy height were compared with models using tree-level information extracted from the ALS dataset. A forest carbon map with spatial resolution of 25 m was generated from ALS maps of forest height and the estimation models. The map was used to evaluate the influences of wind on forests.

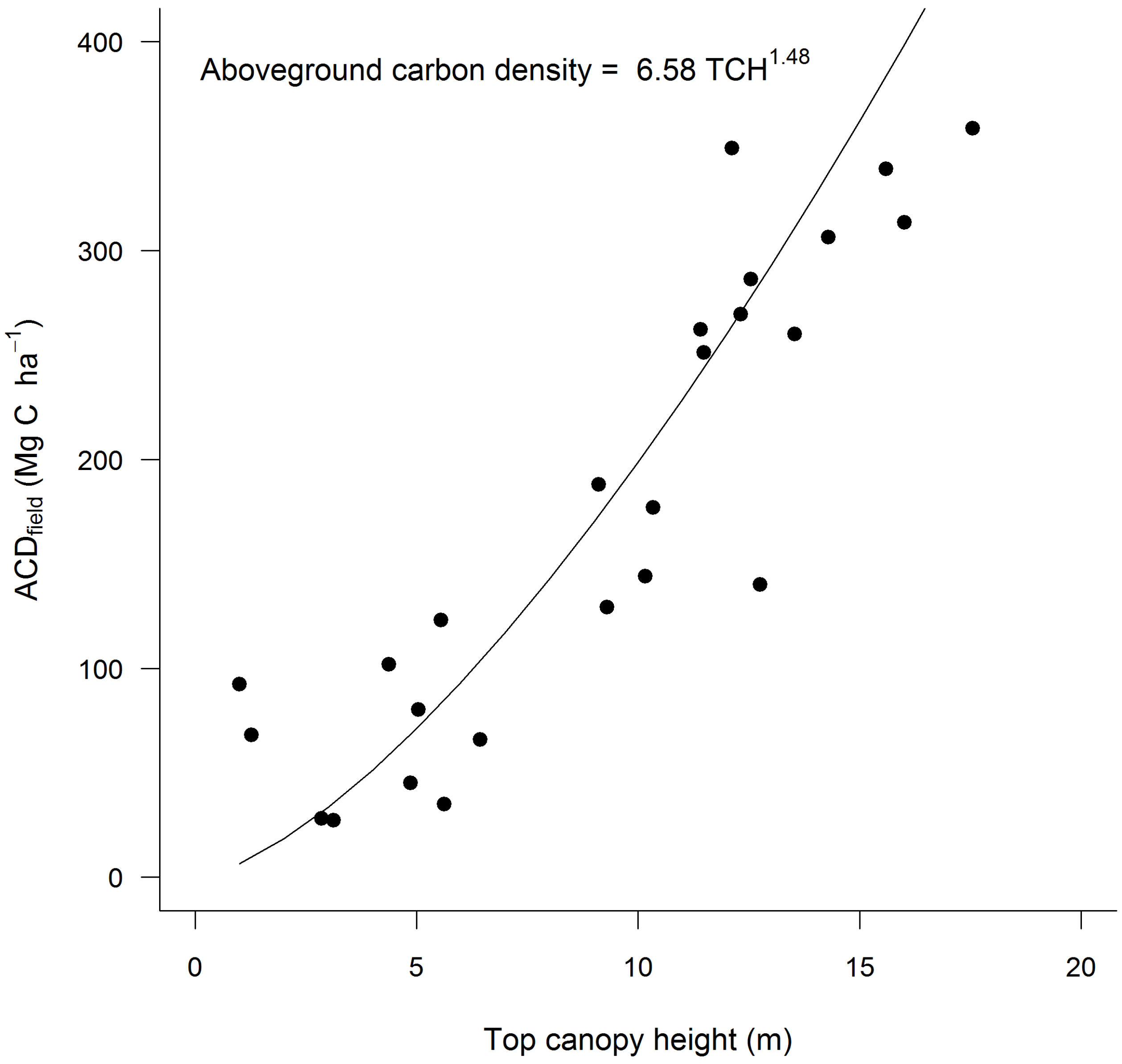
Coomes et al. (submitted) Forest Ecosystems

Example 1: New Zealand

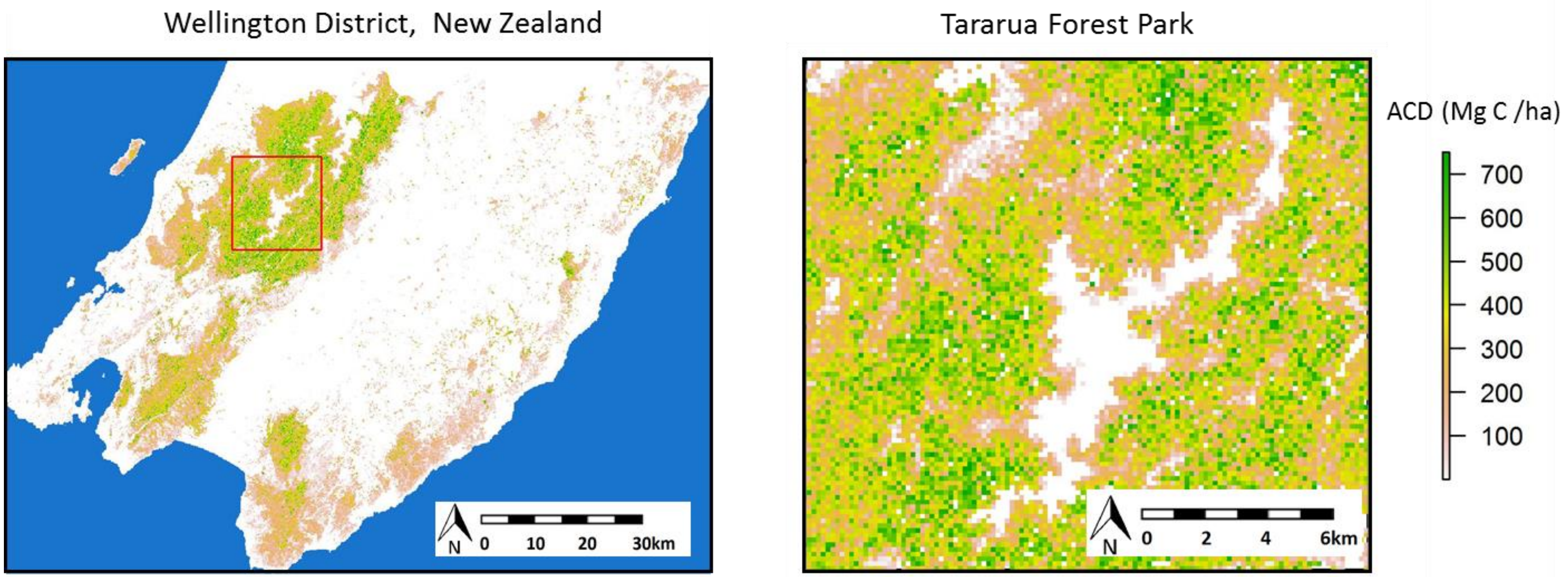


8,049 square kilometres

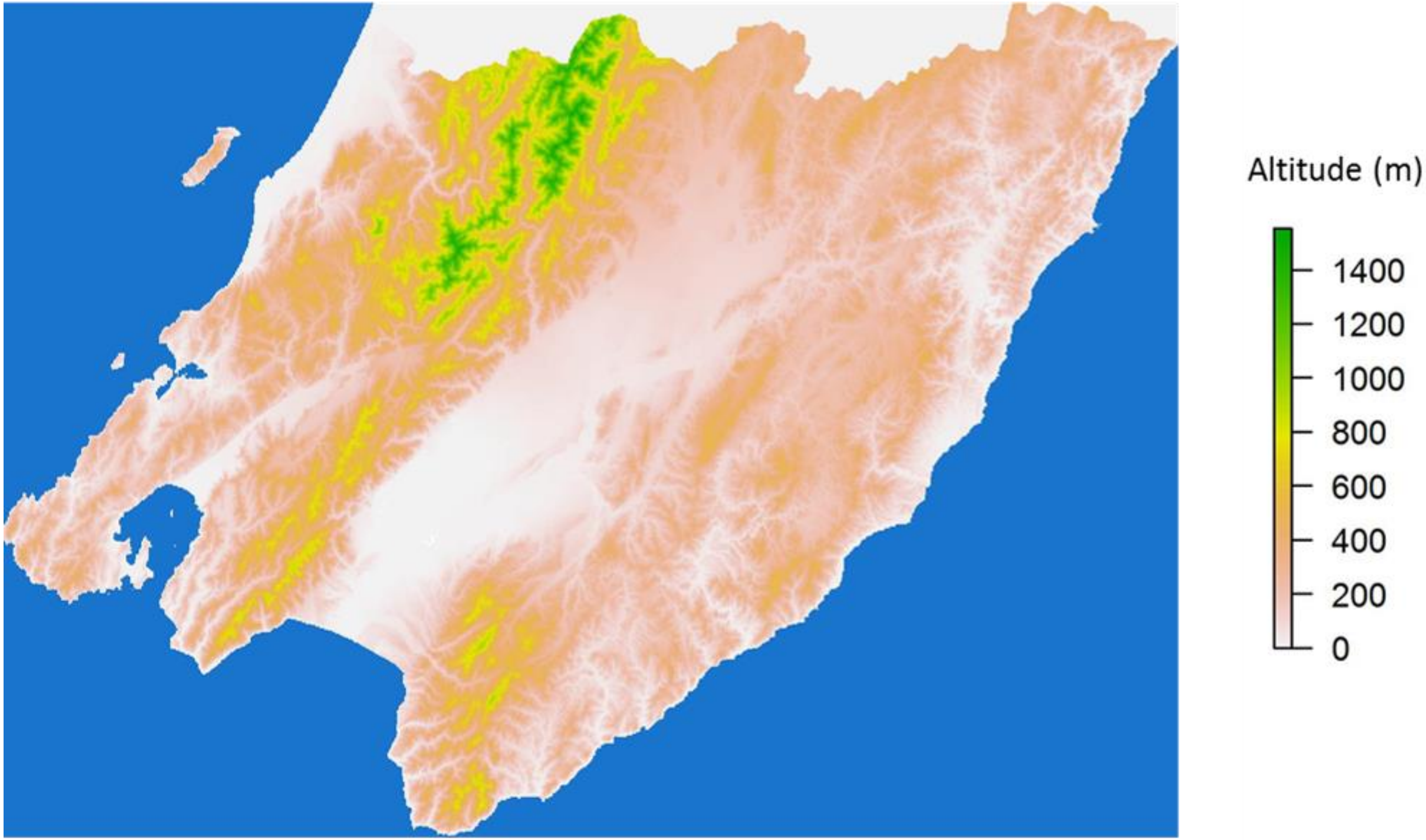
Relating remotely sensed height to field carbon density



Aboveground carbon density map



Altitude map of region, showing mountains



How carbon density changes with altitude and aspect

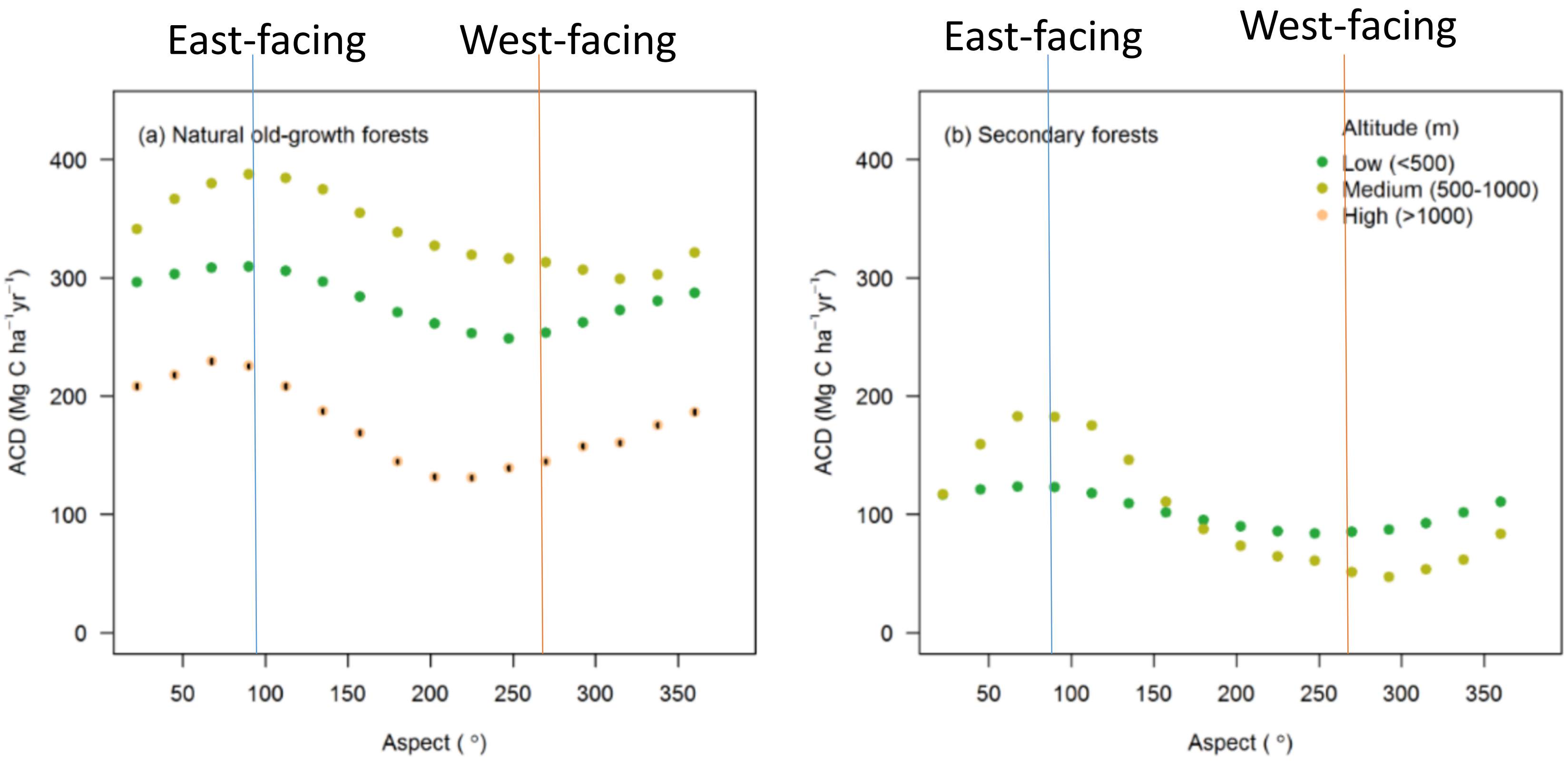
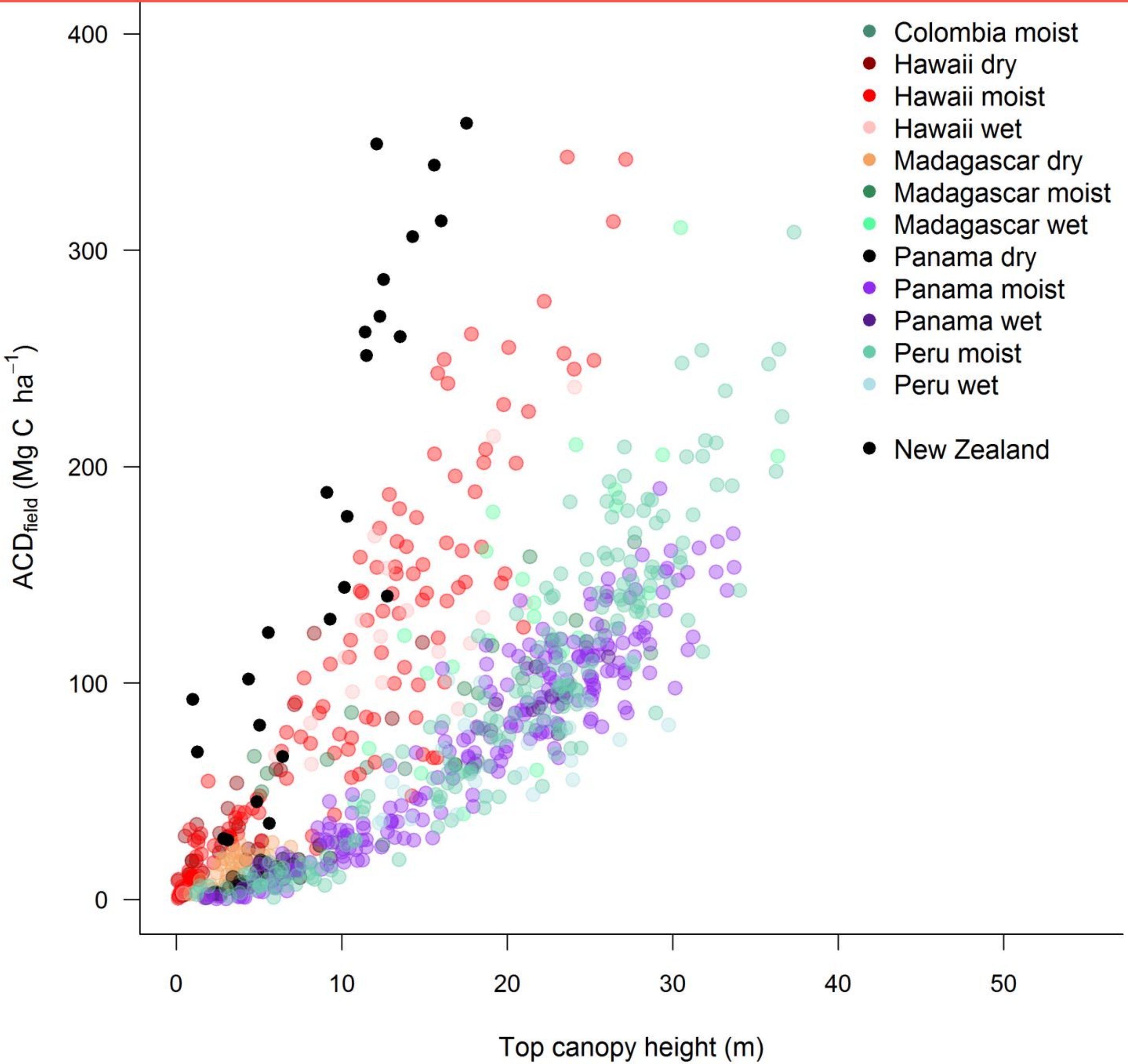


Figure 5: Influences of aspect and altitude on aboveground carbon density (ACD) of (a) old-growth and (b) secondary forests in the Wellington District of New Zealand, based on 4.5 million measurements of top-of-the-canopy height made by airborne laser scanning. Mean (± 1 SEM as black arrows) are shown,

How does New Zealand compare to the tropics?



Towards a conceptual basis for understanding variation

Jerome Chave and colleagues have developed allometric equations for individual trees:

$$Biomass_{tree} = \alpha \cdot H \cdot BA \cdot \rho \qquad (1)$$

where H is height, BA is basal area, ρ is wood density, and α is a term accounting from tree geometry. Asner and Mascaro argue this ACD be approximated as:

$$ACD_{plot} = a \cdot BA^{b}_{plot} \cdot \rho^{c}_{plot} \cdot TCH^{d} \qquad (2)$$

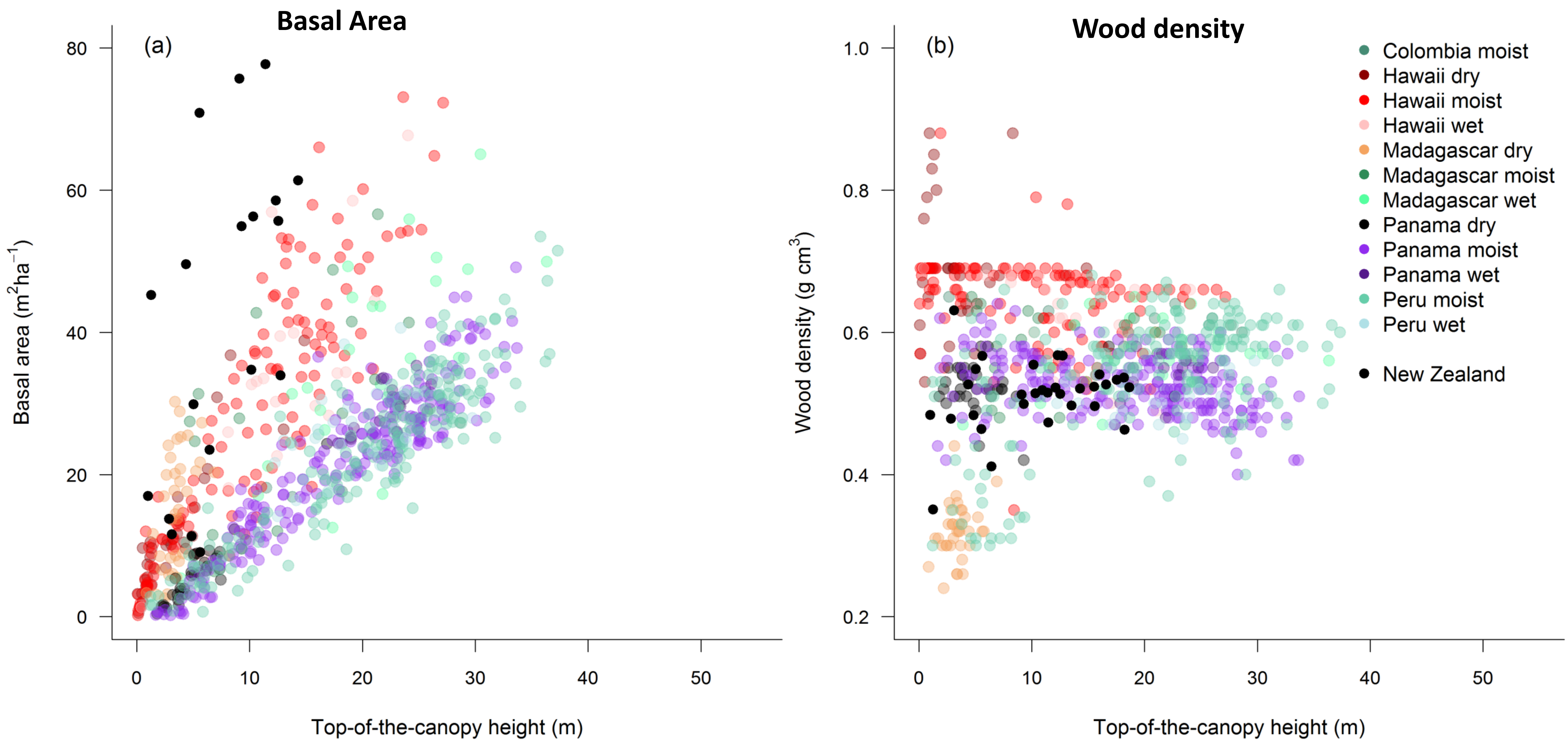
Where BA and ρ are described by the following submodels:

$$\rho_{plot} = e + f \cdot TCH, \qquad BA_{plot} = g \cdot TCH.$$

They report coefficients from a model fitted to 14 contrasting forest types after correcting for regional variation in BA - TCH and ρ - TCH relationships. They argue that this single "general model" is almost a good as fitting local models to each of the 14 sites

$$ACD_{plot} = 3.8358 \cdot TCH^{0.2807} BA^{0.9721} \rho^{1.376}$$

How does New Zealand compare to the tropics?

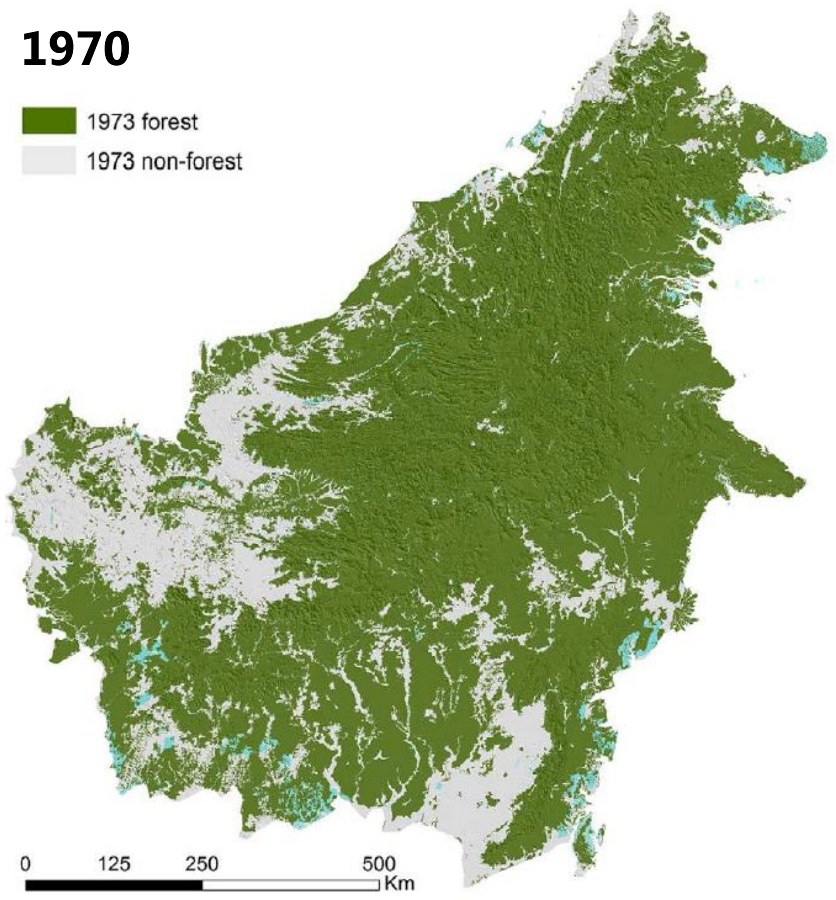


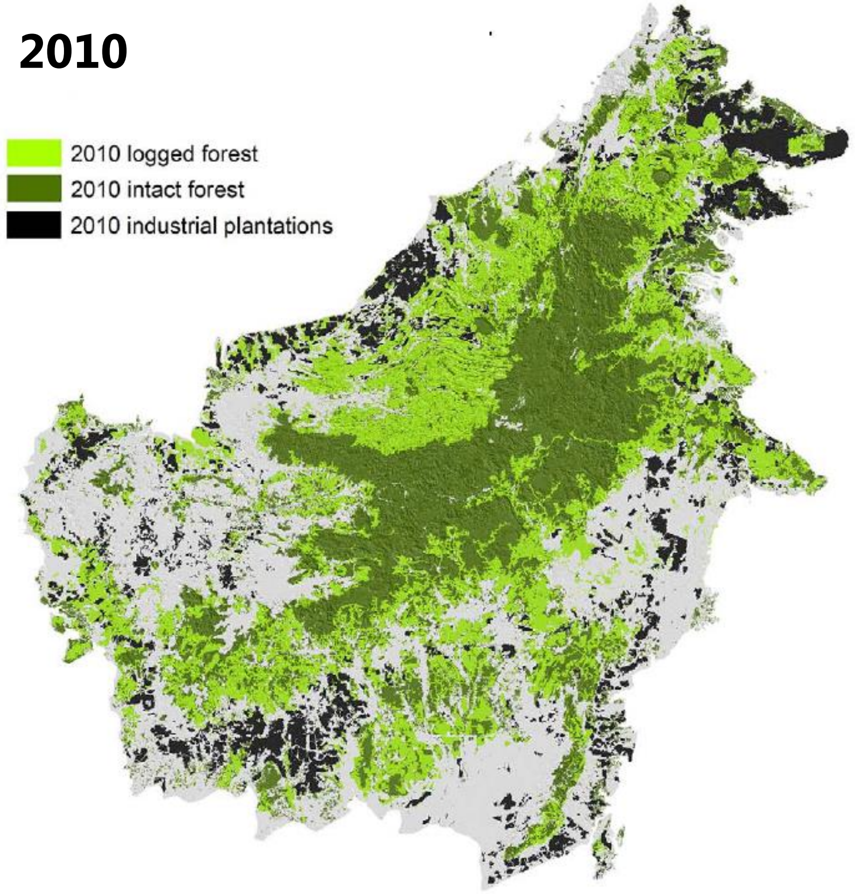
Summary of work in New Zealand

- Airborne laser scanning is a power tool for mapping forest structure and carbon
- Here I have shown the strong influences of wind on forest height across a large region of New Zealand
- I have (tried to) explain Asner and Mascaro’s conceptual model
- I have shown the forest to have very high basal area for their height
- The ecological reason why this is the case remains a mystery!

Example 2: The rain forests of Sabah state, Borneo

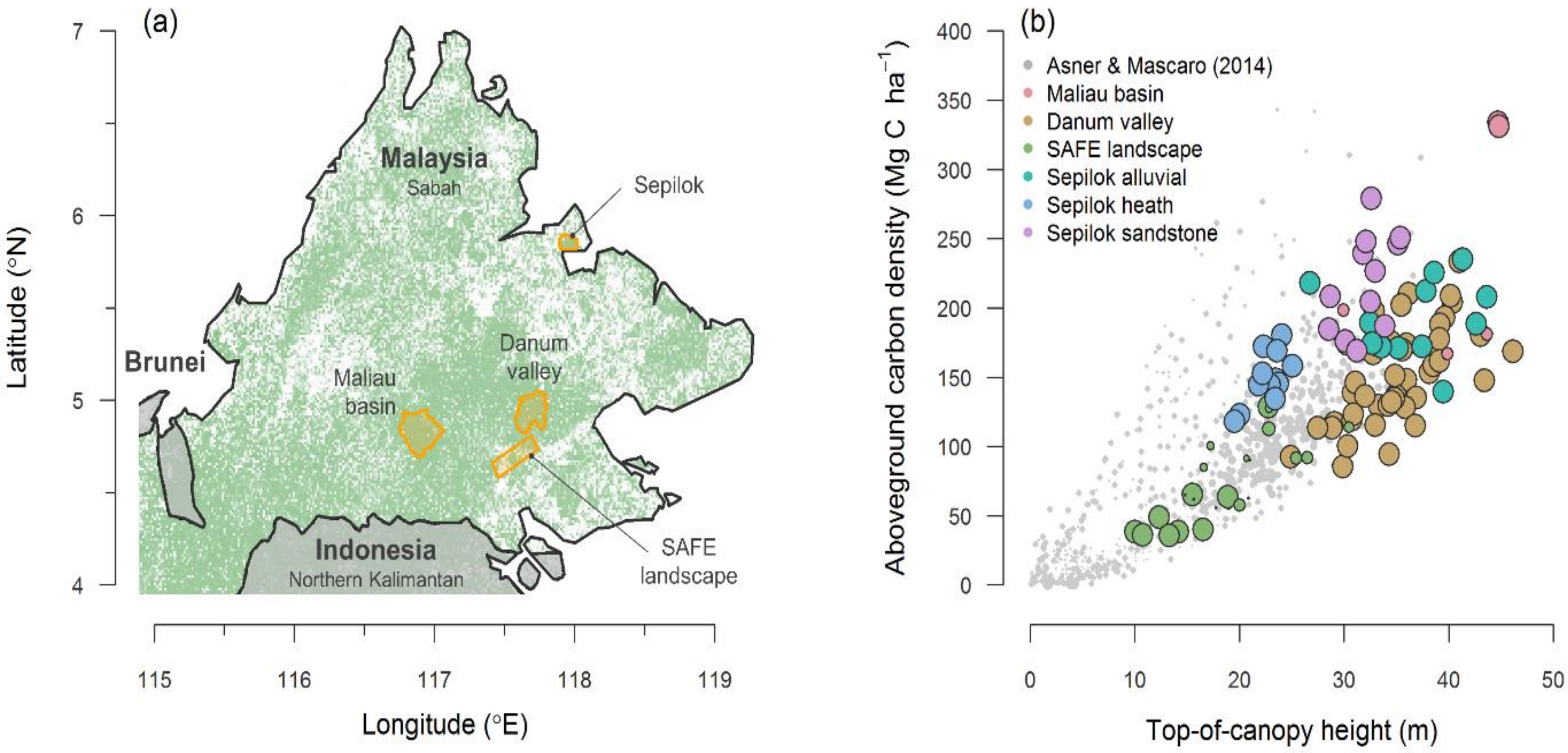
Half of Borneo's forest logged since 1970





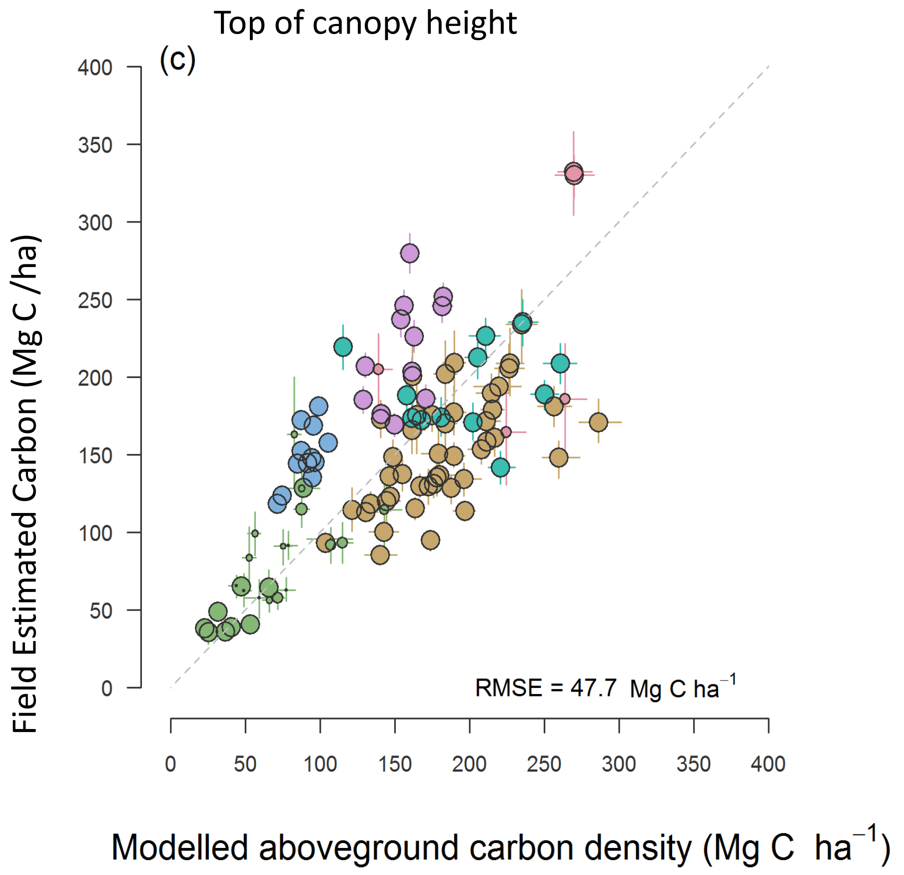
Gaveau *et al.* 2014 PLOS One

Laser scanning survey of Sabah by Cambridge in 2014



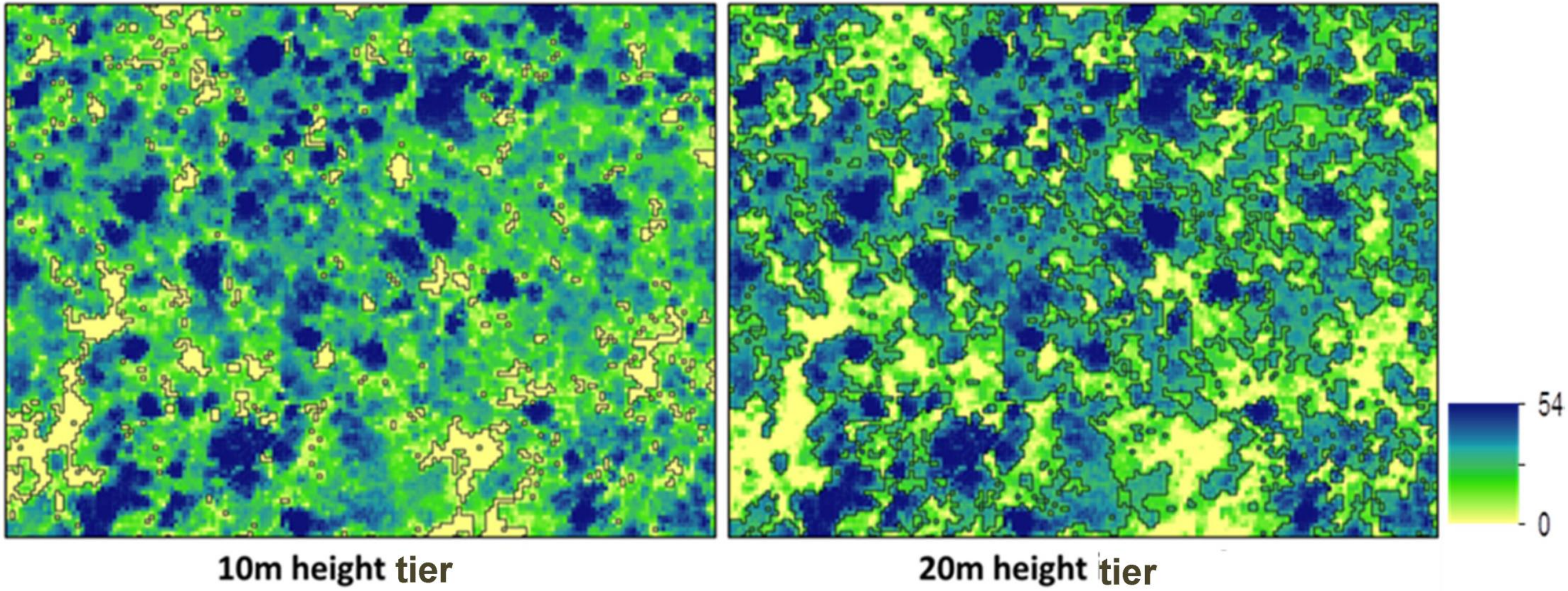
Jucker et al (in review) RSE

Carbon estimated as a function of canopy height



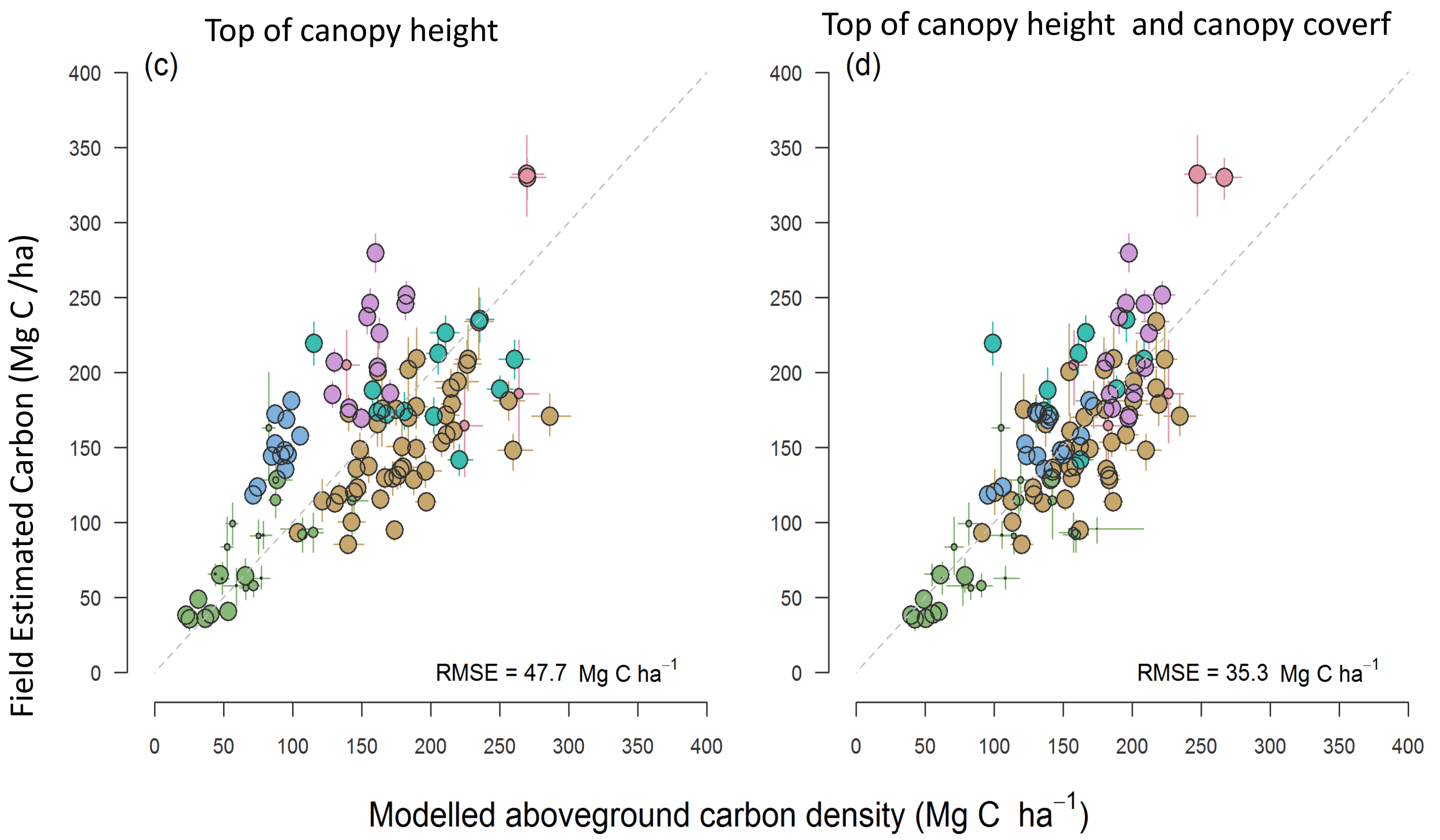
Jucker et al (in review) RSE

Including LiDAR canopy openness in carbon estimation models



Jucker et al (in review) RSE

Model improved by including canopy cover

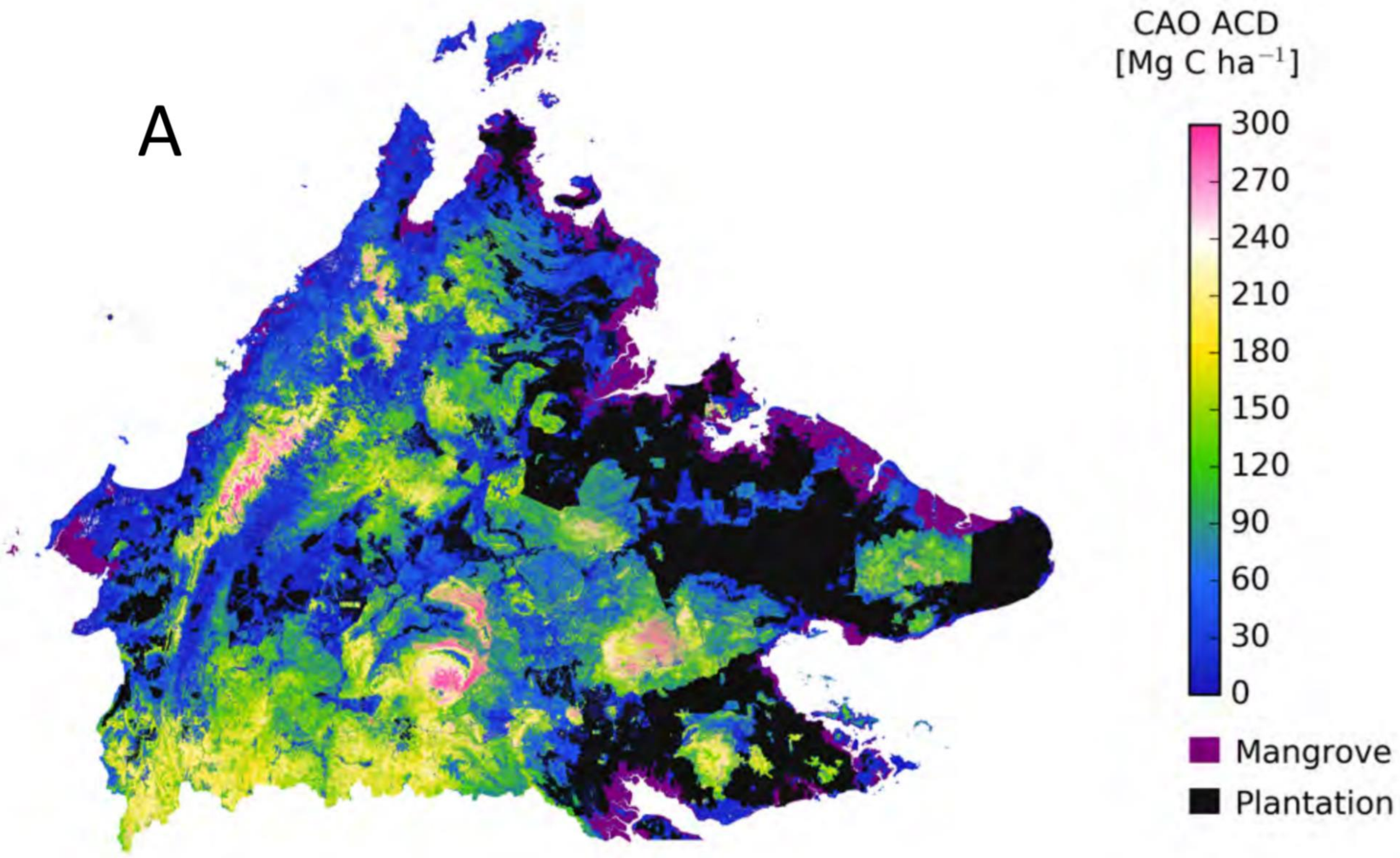


Jucker et al (in review) RSE

Carnegie Airborne Observatory's flights in 2016

Asner et al (in review)

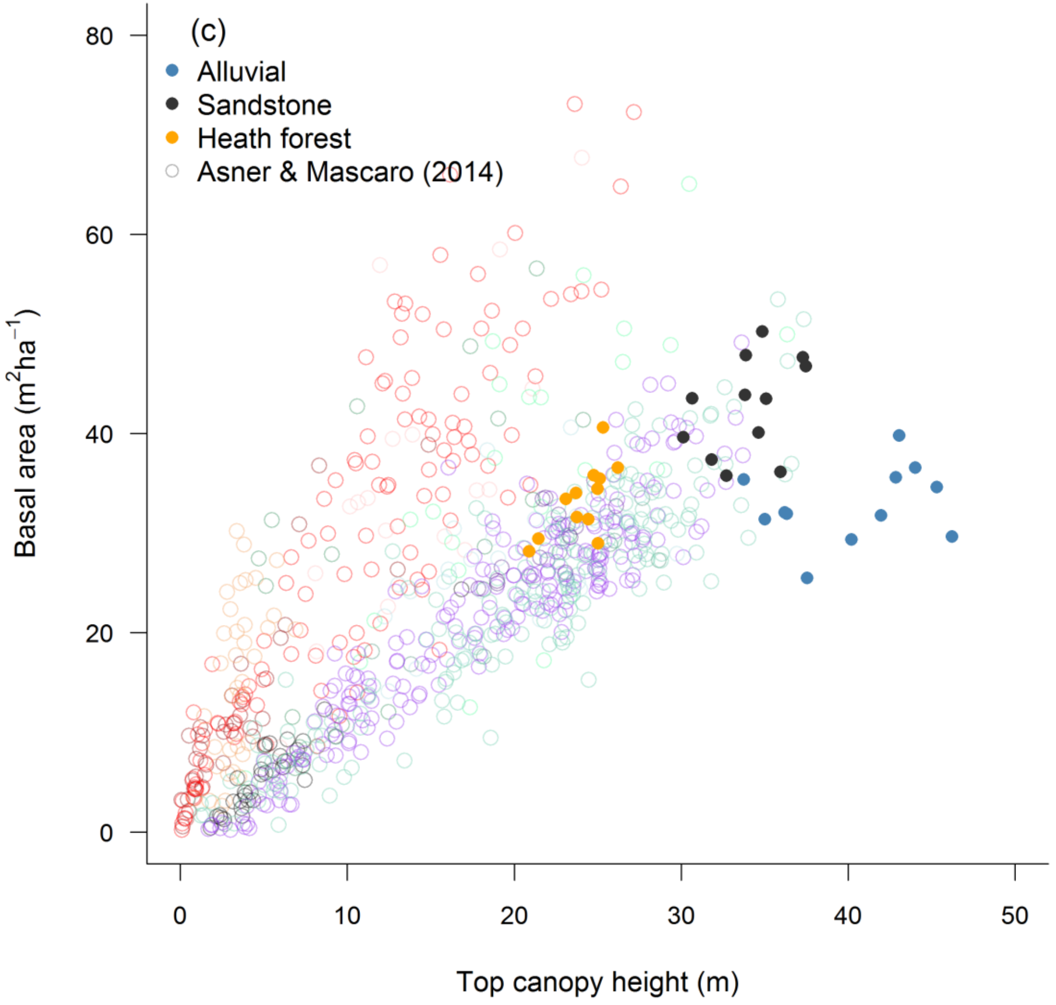
Statewide carbon map



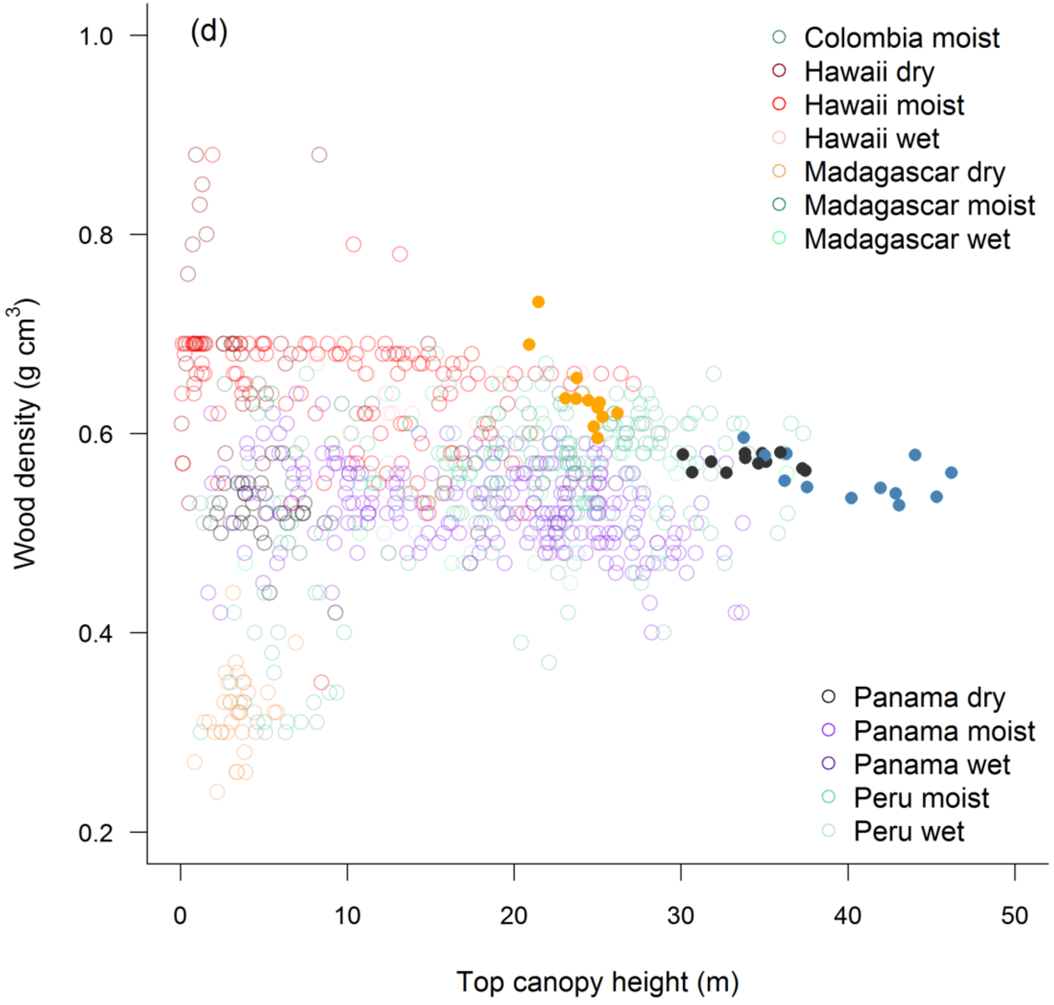
Asner et al (in review)

How do the neotropics and paleotropics compare tropics?

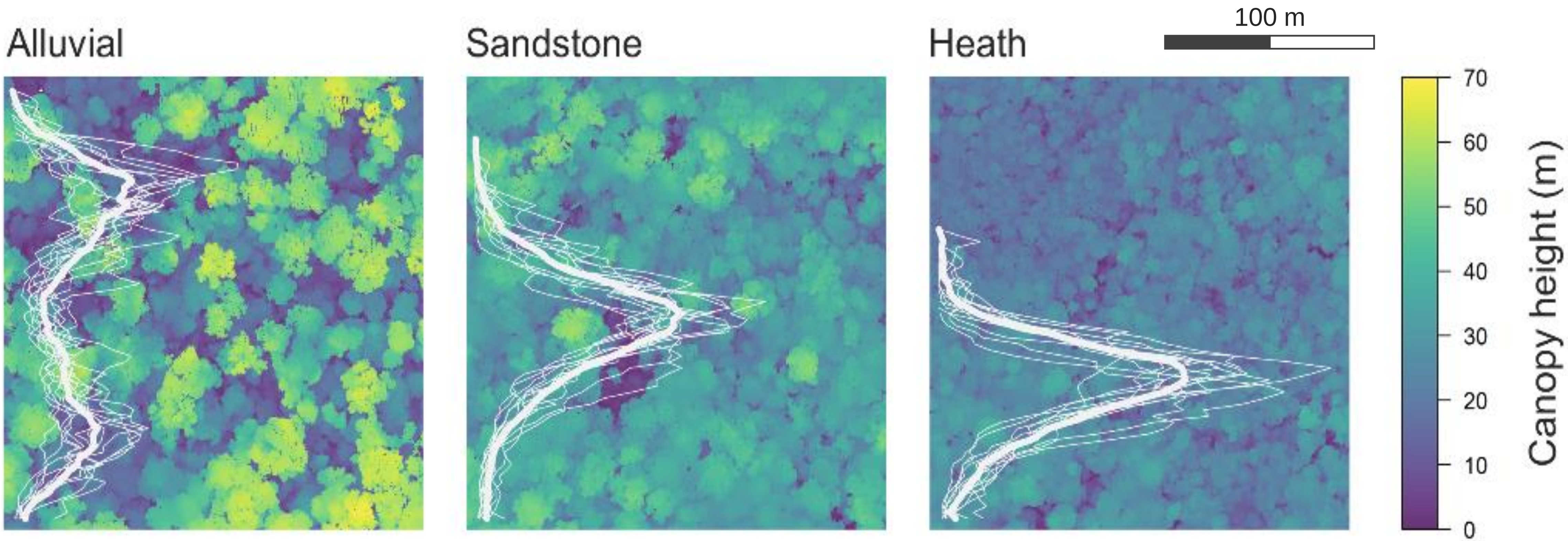
Basal Area



Wood density



Variation in forest structure responsible

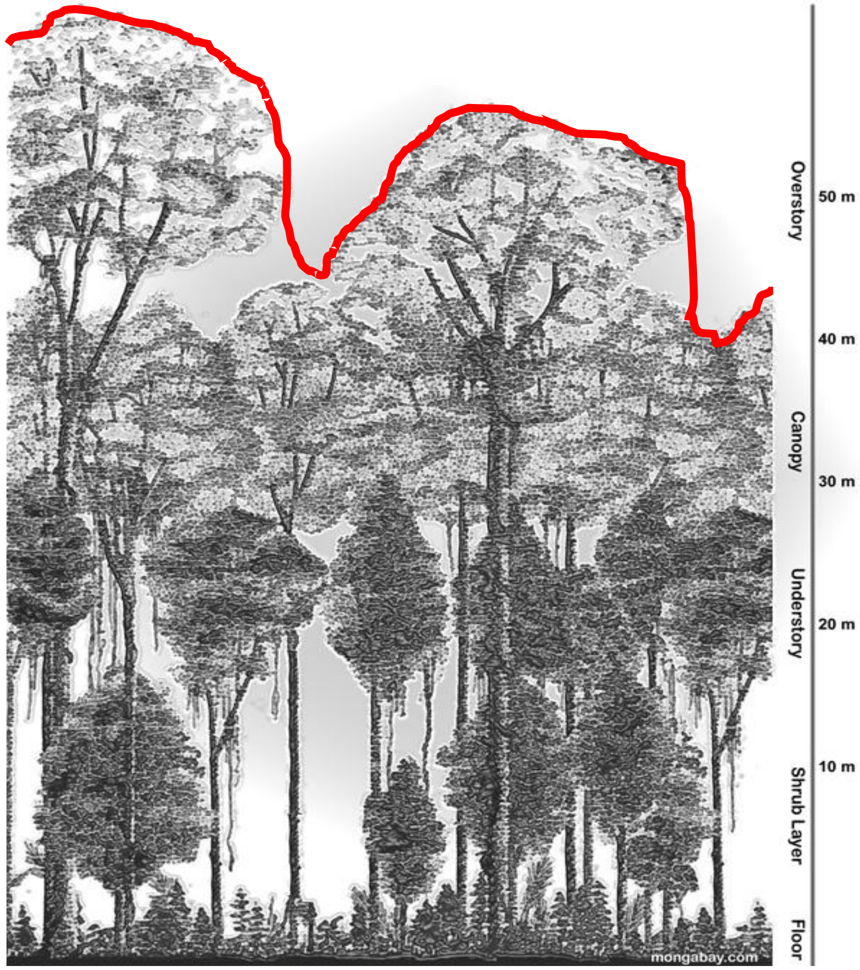


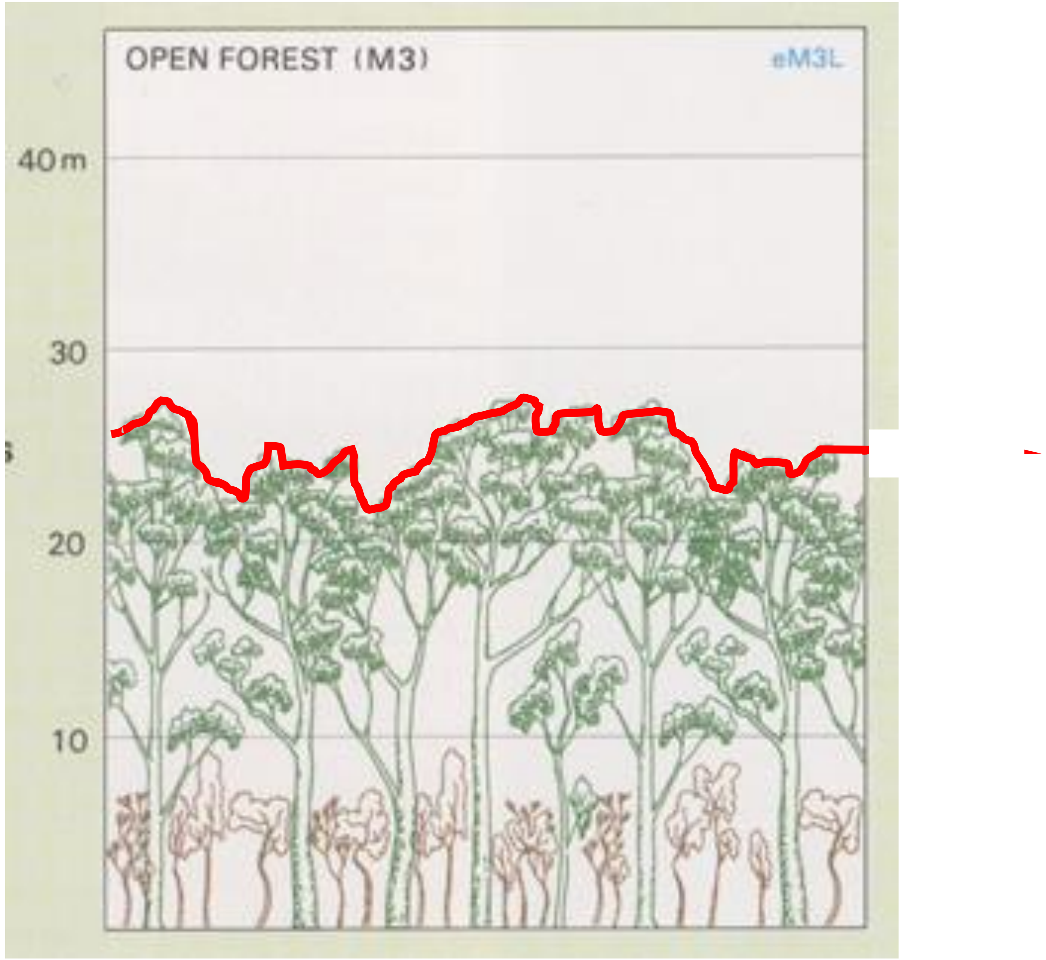
Jucker et al. (unpublished)

Summary of Borneo work

- Need to model include “variance” in TCH (i.e. canopy cover) as well as mean TCH in order to model carbon accurately
- Needed because of the very different structures of forest types in the region
- Separating out basal area and wood density effects was again insightful.

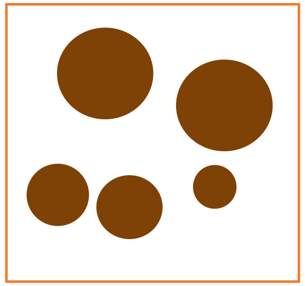
Canopy height : basal area ratio
An interesting index of forest structure



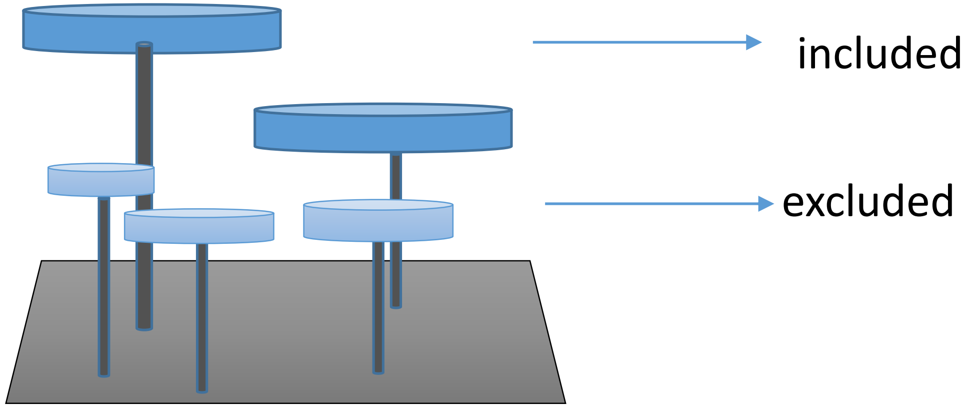


TCH : BA ratio can be calculated from plot data.

Basal Area



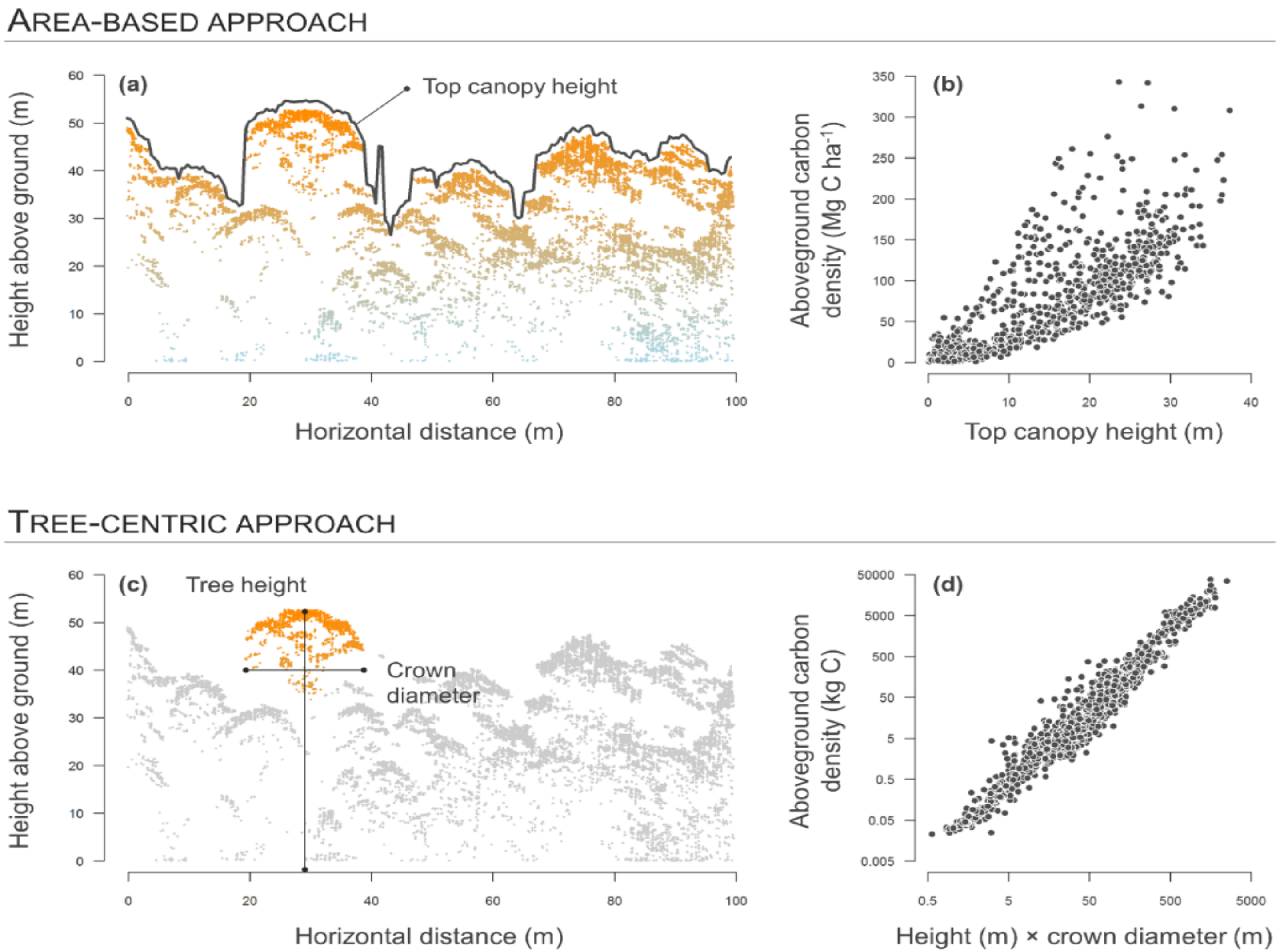
Top of the canopy height



The crown-area weighted height of overstory trees

Time?

Tree-centric modelling

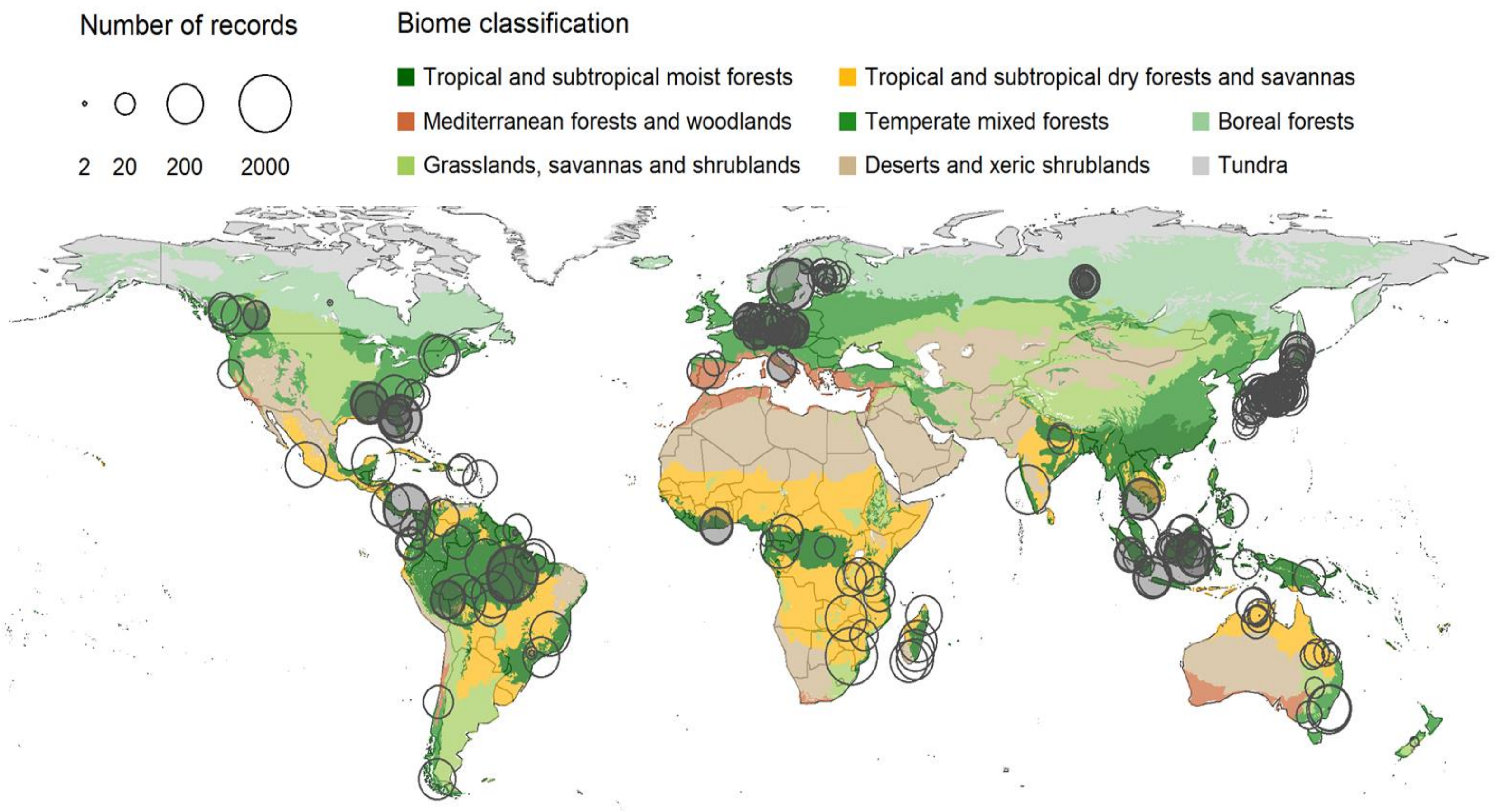


Traditional plot based approaches to carbon measurement

Lindsay Banin

Coomes et al (2017) Remote Sensing of Environment

Global relationship between tree height, crown width and biomass



Jucker et al. (2016) Global Change Biology

Summary of tree-centric work

- Equations available to convert LiDAR height and crown diameter measurements into tree biomass
- Potentially useful to gain a generalised understand of forest carbon dynamics and ecology
- Allows us to track trees if we repeat the LiDAR survey, e.g. to detect responses to drought events
- Currently limited by accuracy of the segmentation algorithms and by computational power.

Overall summary

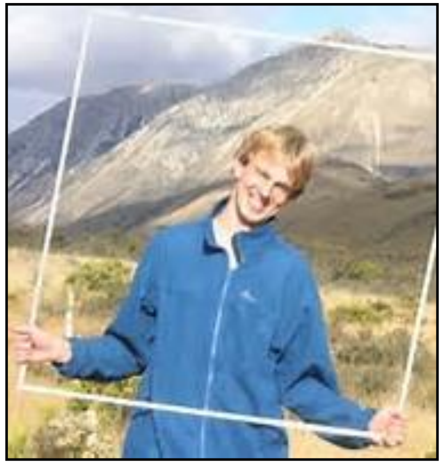
- Airborne laser scanning (LiDAR) is widely used to measure forest carbon, but we lack a common modelling approach based on fundamental principles
- Here we show that Asner and Mascaro's approach provides useful starting point in the search for generality
- Analysis of canopy height : basal area ratios will help us understand the ecology of carbon density

With thanks

Tommaso Jucker

Michele Dalponte

James Shepherd



Robbie Holdaway

Dan Safka

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Acknowledgments

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Microsoft® Research

The Leverhulme Trust

FunDiv EUROPE

Manaaki Whenua Landcare Research

RSPB

UNEP WCMC

UNIVERSITY OF CAMBRIDGE

Cambridge Conservation Initiative

BALI

Biodiversity And Land-use Impacts on Tropical Ecosystem Function