Can forest structure affect elevational range shifts?

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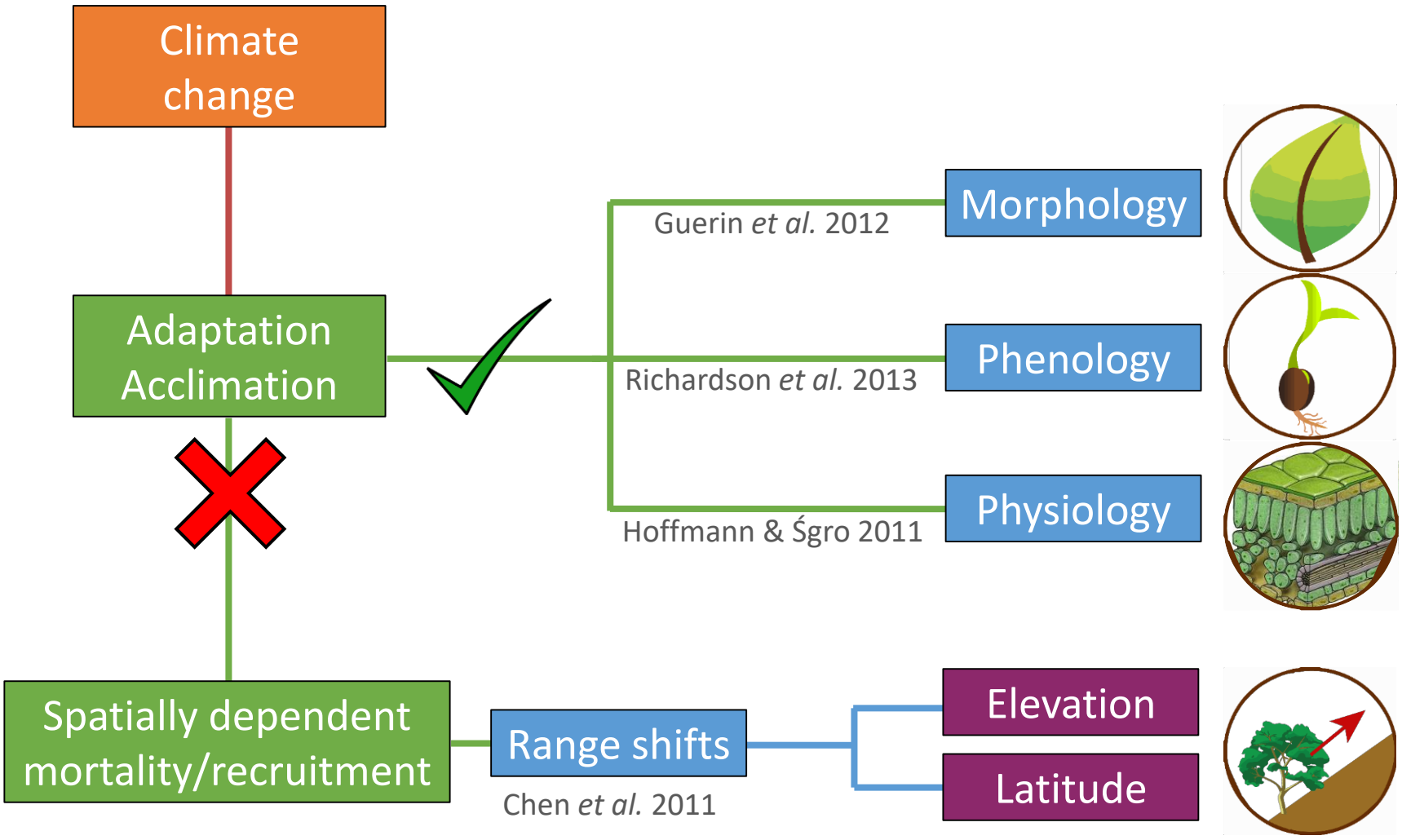
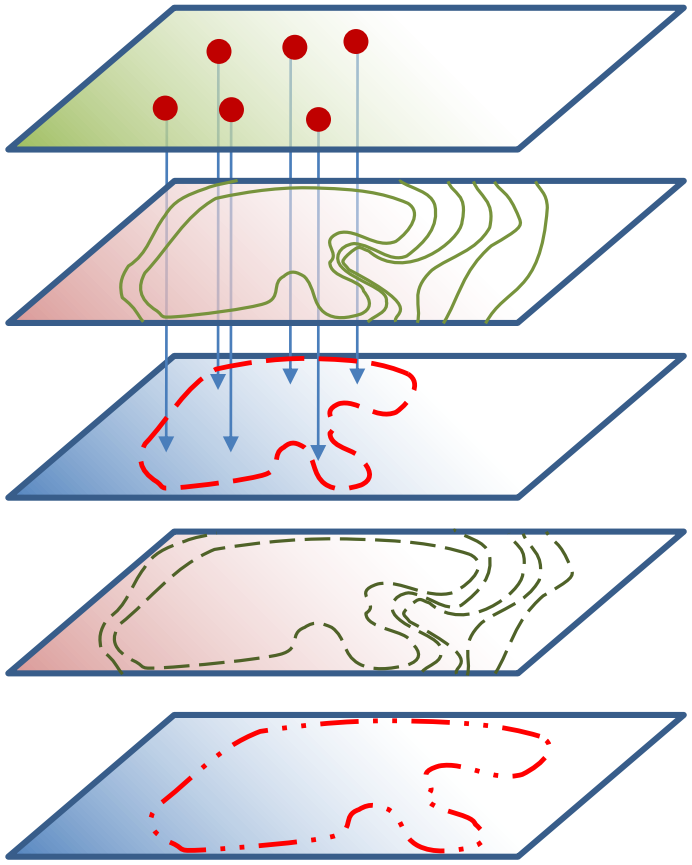
Climate change & range shifts



Bioclimatic envelope models



Current species distribution

↓

Climate data

↓

Bioclimatic envelope

↓

Climate predictions

↓

Predicted species range

Pearson & Dawson 2003

Models fail to predict elevation shifts

Mean range shift ± 1 S.E.

Birds

Arthropods

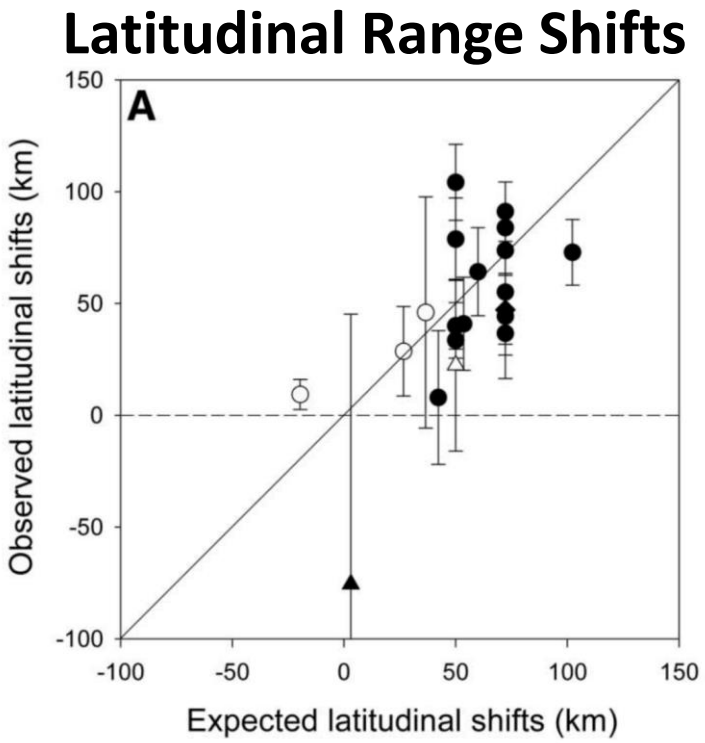
Mammals

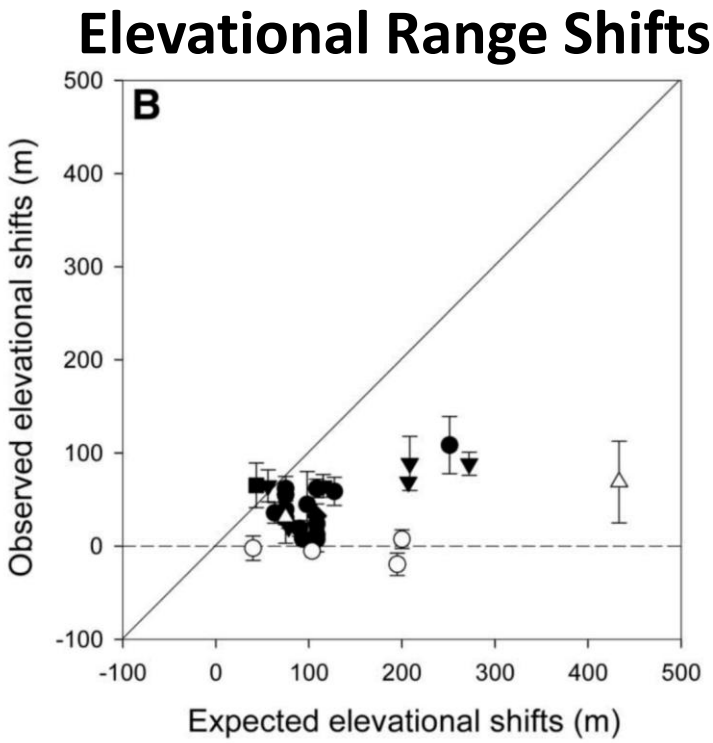
Molluscs

Plants

Herptiles

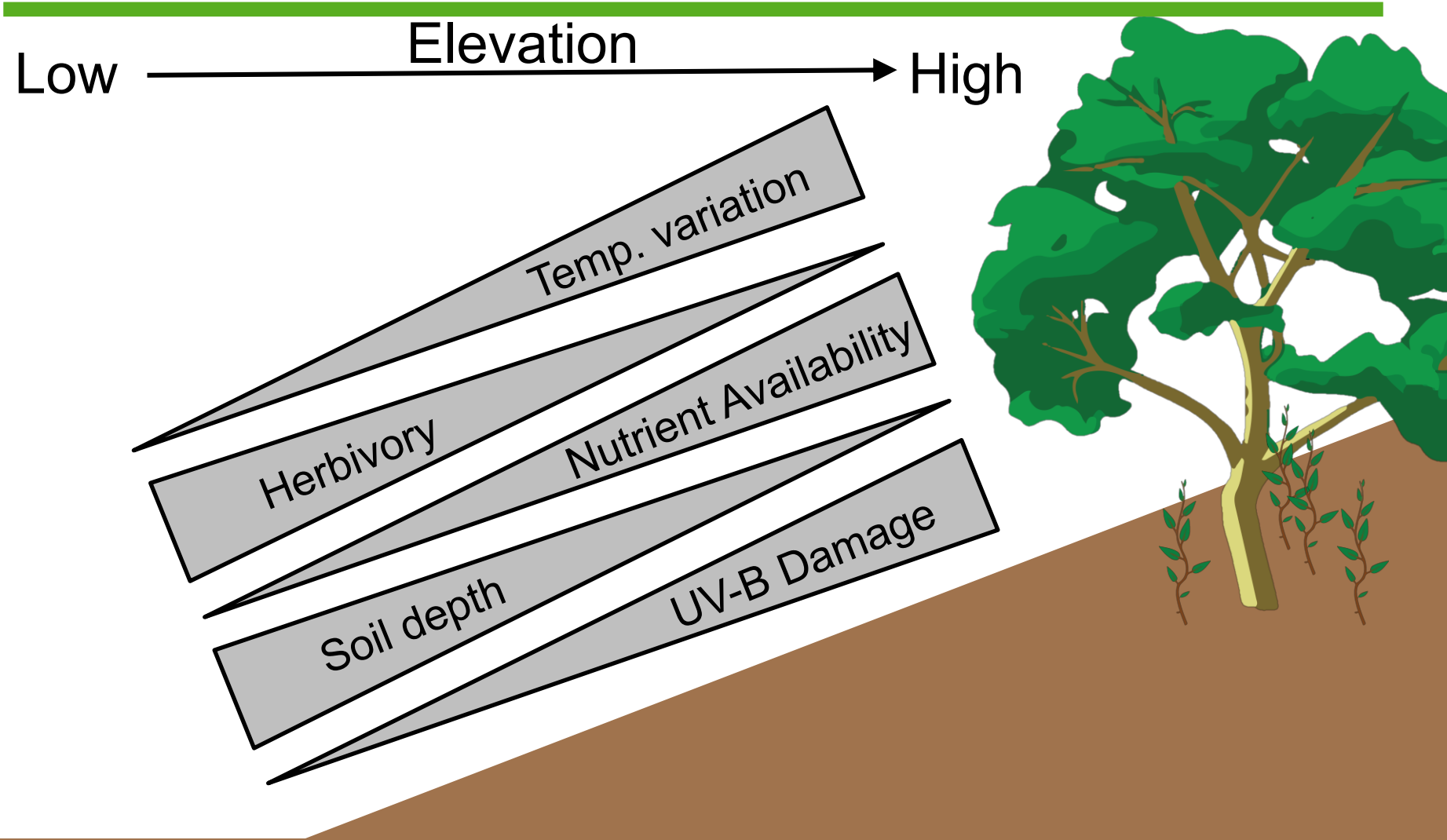
Fish





Chen *et al.* 2011

Other variables change with elevation

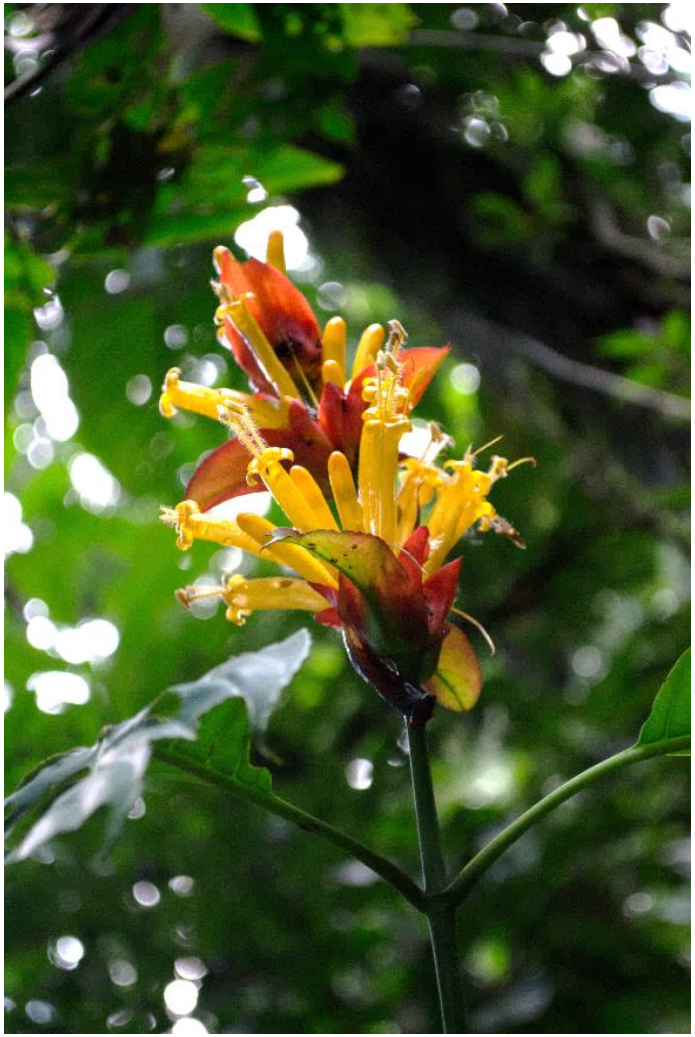


Whitaker *et al.* 2014,
Nottingham *et al.* 2015

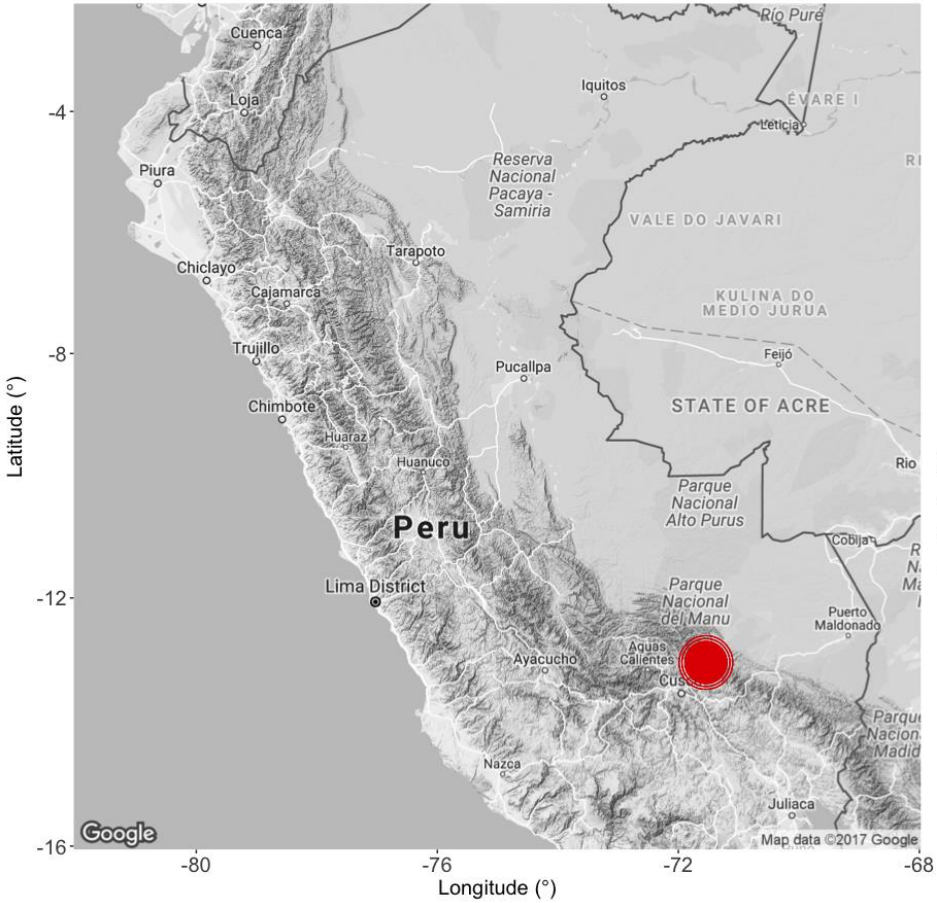
Research question

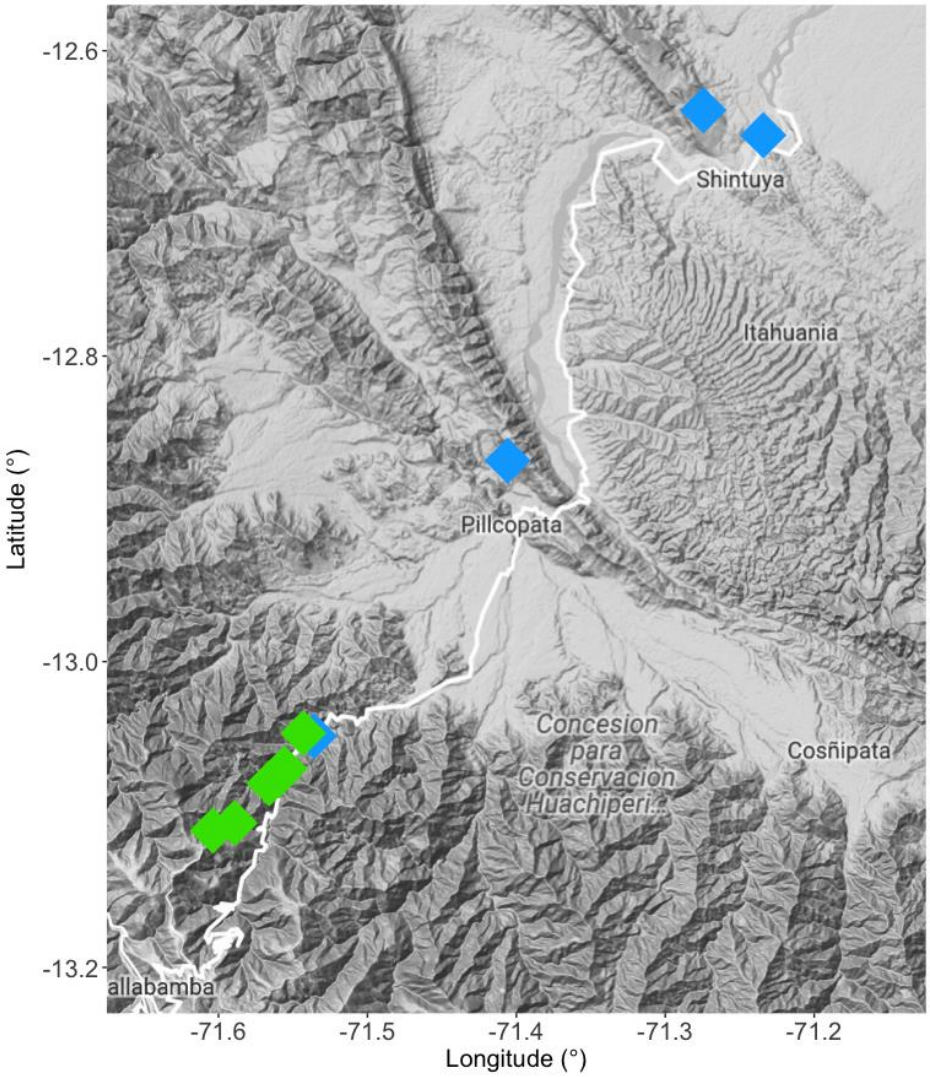
1. Can forest structure explain variation in plant stress?

    i. *Should forest structural parameters be included in range shift models to improve their accuracy?*



Study site





< cloud base > cloud base

Study species

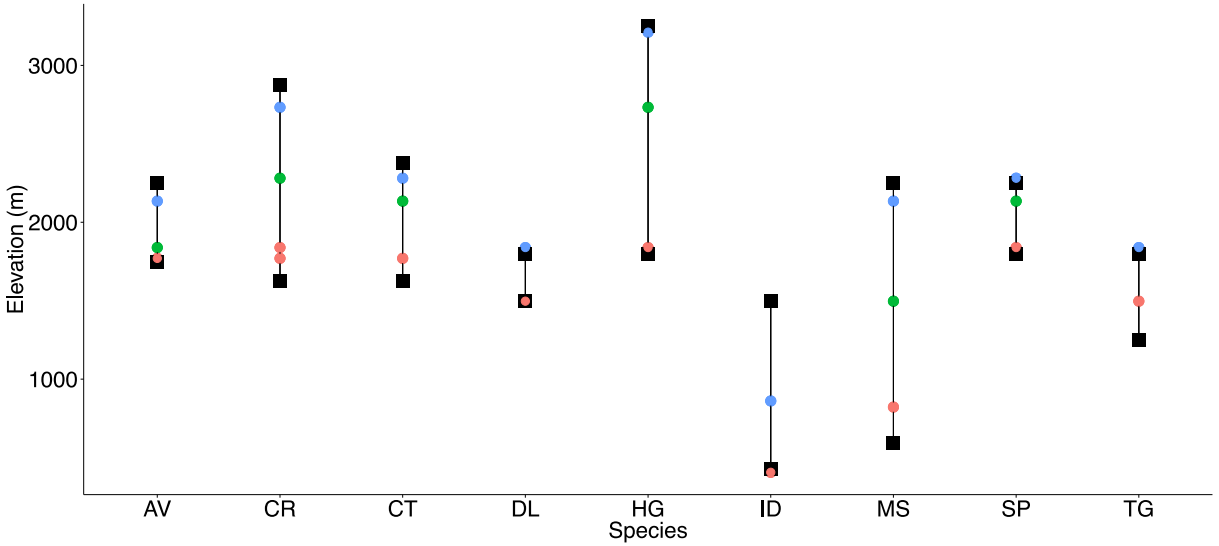
Range Limits

Upper

Middle

Lower

Sample Site



Alzatea verticillata

Clethra revoluta

Clusia thurifera

Dictyocaryum lamarckianum

Hedyosmum goudotianum

Iriartea deltoidea

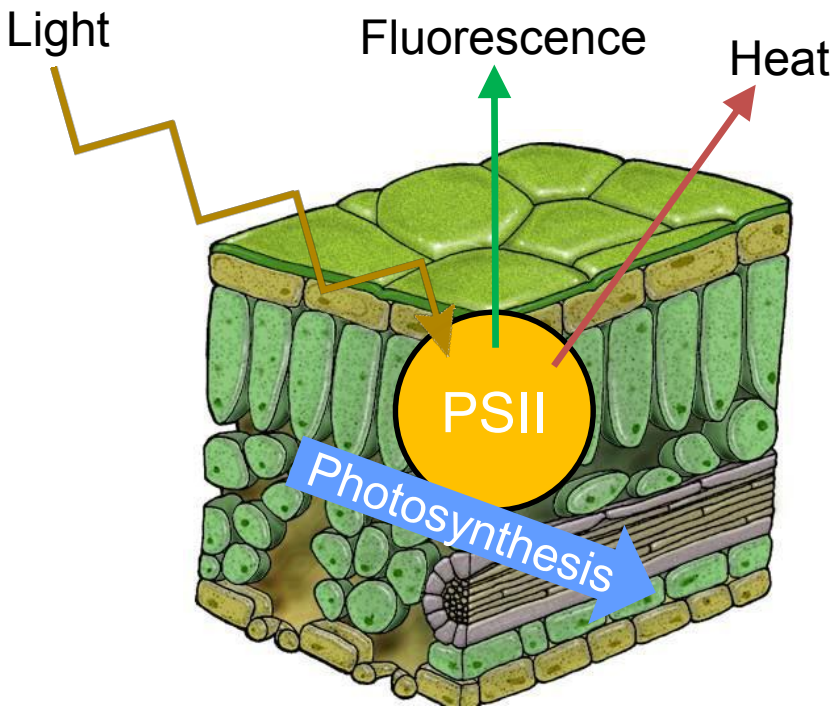
Myrcia spp.

Schefflera patula

Tapirira guianensis

Stress – Chlorophyll fluorescence & content

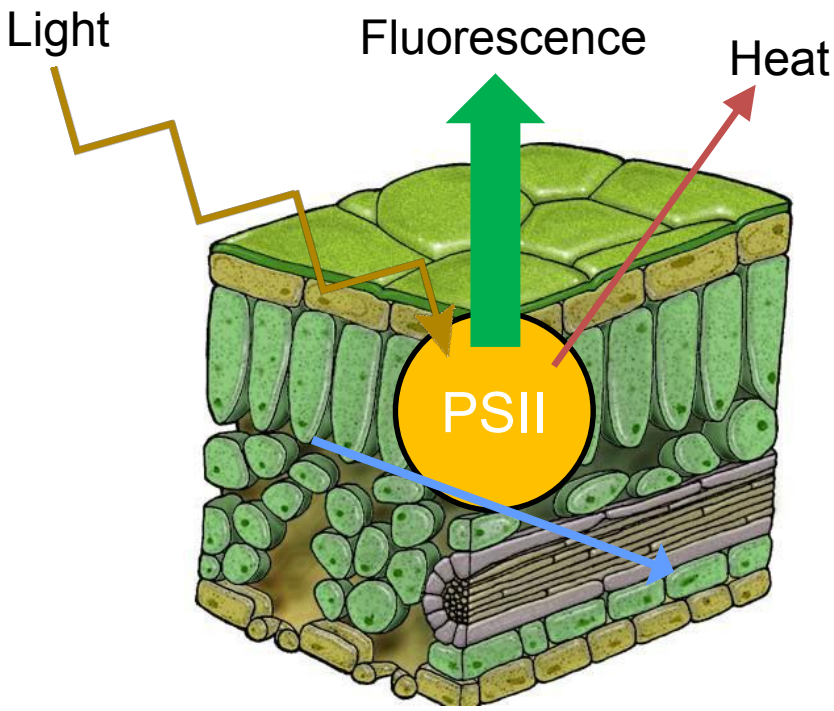
Healthy Plant – photosynthetic efficiency (F_v/F_m) ~ 0.8



Chlorophyll fluorescence using a MINI-PAM-II fluorometer

Stress – Chlorophyll fluorescence & content

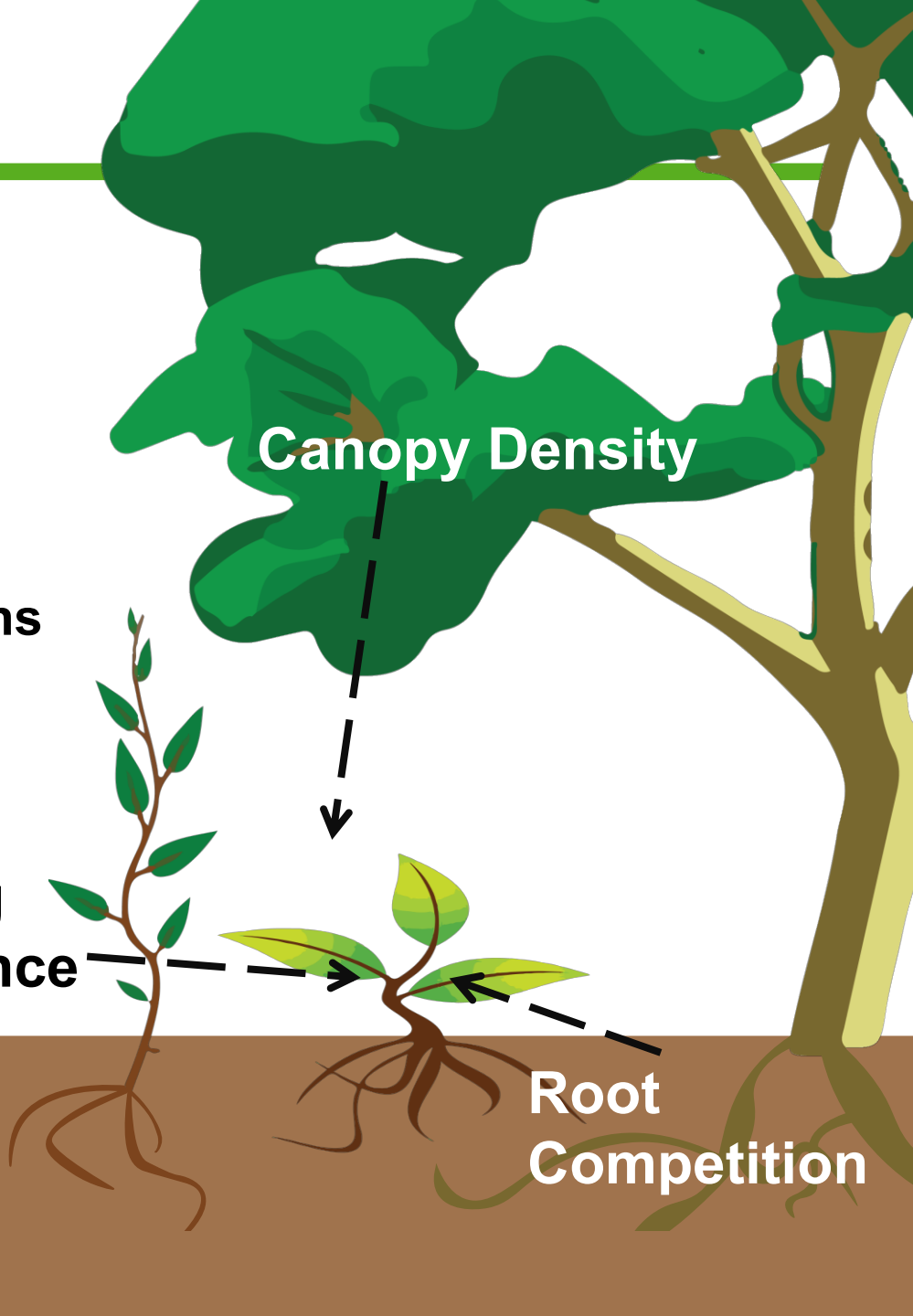
Stressed Plant – photosynthetic efficiency (F_v/F_m) < 0.7



Chlorophyll fluorescence using a MINI-PAM-II fluorometer

Forest Structure

- **Adult-Seedling Interactions**
  - Canopy Density
  - Root Competition
- **Seedling-Seedling Interactions**
  - Seedling Abundance



Statistical analysis – effect of forest structure

Response

Photosynthetic Efficiency

Chlorophyll Content

~

Fixed Effect

Elevation

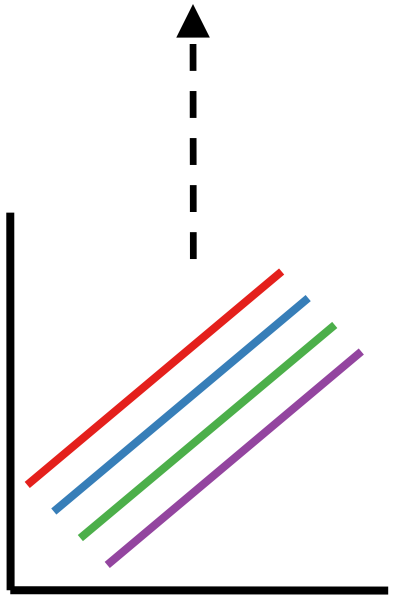
Root Competition

Canopy Density

Seedling Abundance

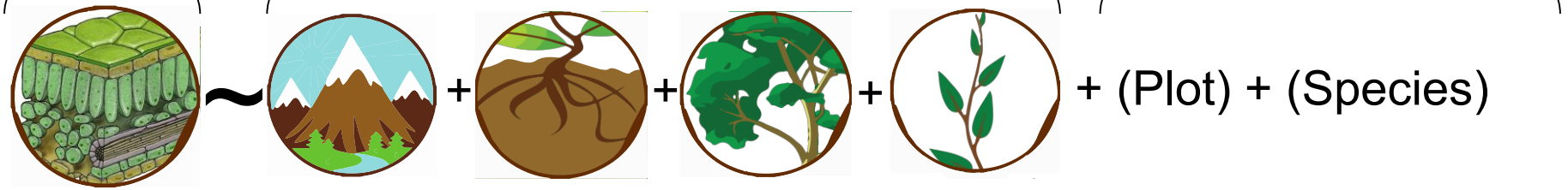
Random Effects

+ (Plot) + (Species)



Statistical analysis – effect of forest structure

Response ~ Fixed Effects + Random Effects



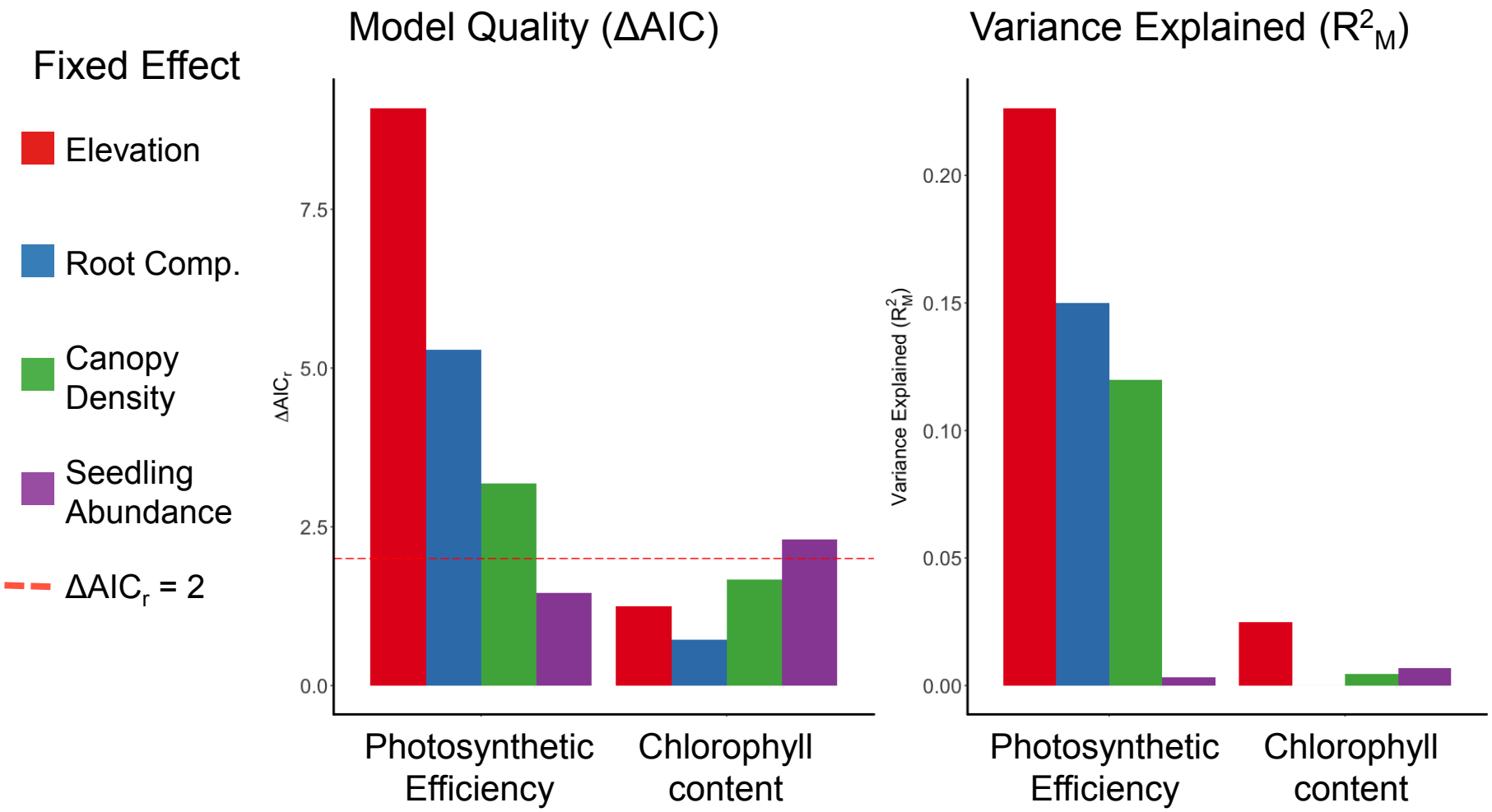
Best quality model chosen using:

- AIC (Akaike Information Criterion)
- Pseudo-R-squared (Barton 2015)

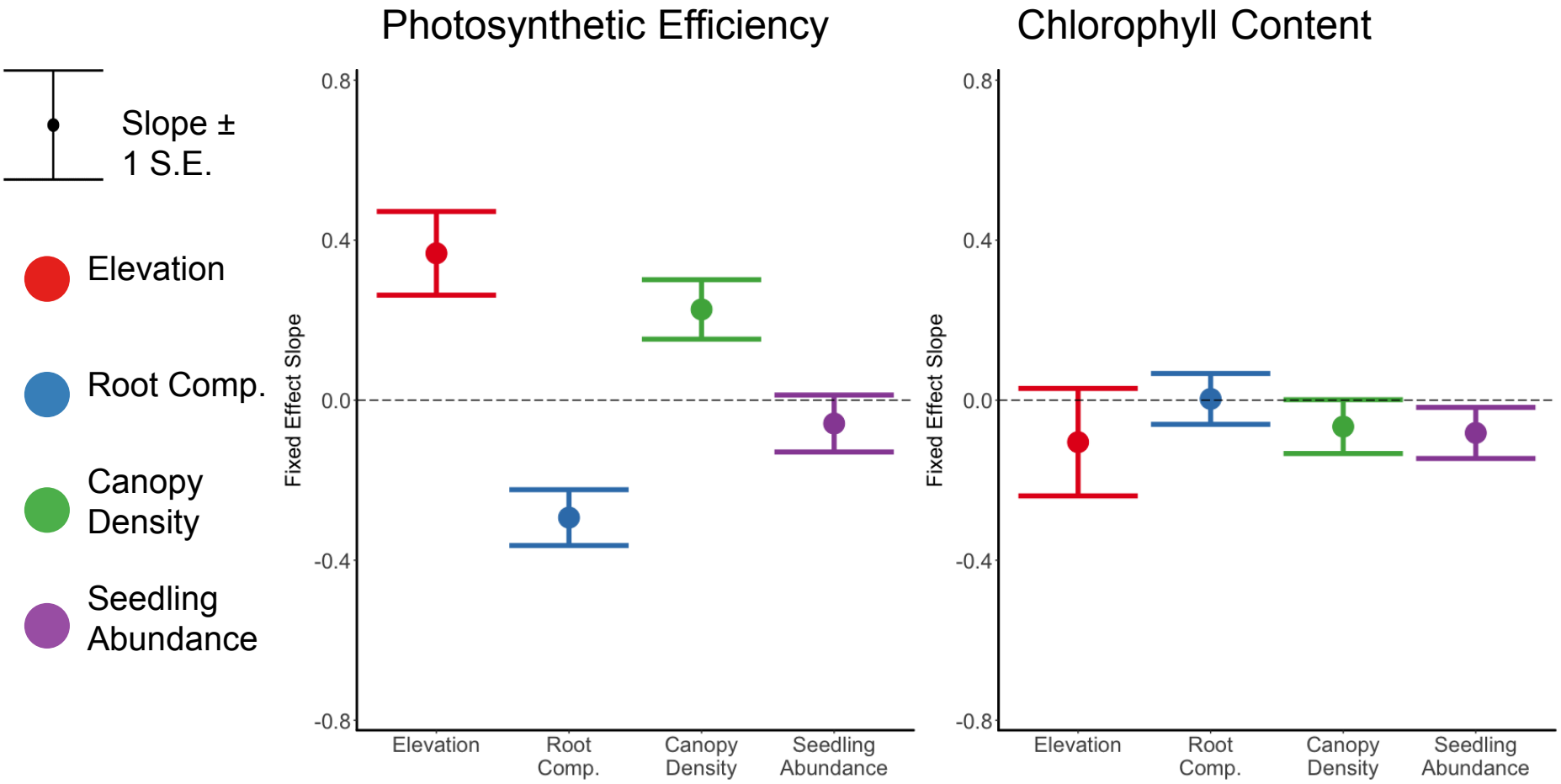
Model validation using:

- Variance Inflation Factors
- Predicted vs. observed values

Results – effect of forest structure



Results – effect of forest structure

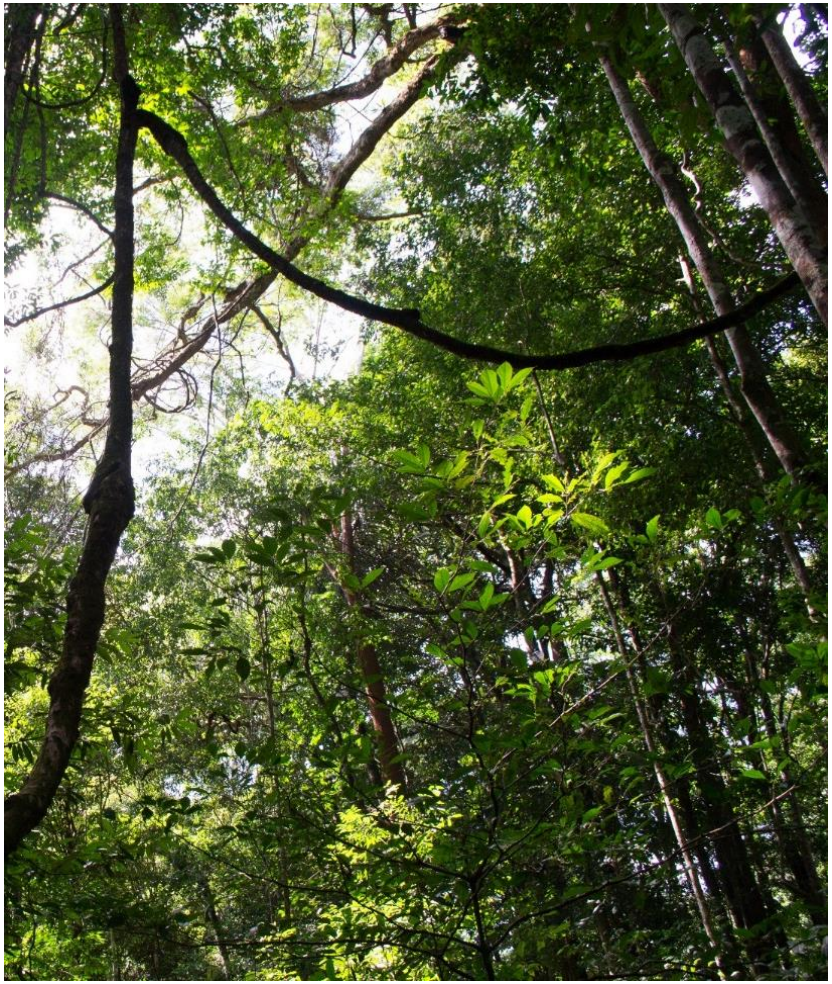


Results – Best Model

Response		Fixed Effects	Random Effects
Photosynthetic Efficiency	~		+ (Plot) + (Species)
$R^2 = 0.56$			
Chlorophyll Content	~	N/A	+ (Plot) + (Species)
$R^2 = 0.004$			

Summary

- Adult-seedling interactions affect seedling stress.
- No forest structure parameters had a greater effect than elevation.
- Cloud forest transition could be a barrier to upslope migration.
- Photosynthetic efficiency best predicted by elevation and adult-seedling interactions.



Future Studies

- Seedling transplant experiments
  - Mortality
  - Correlation ≠ Causation
- Adult trees
  - Adult trees react differently
    (Larcher 2003)
- Rare species
  - Rare species react differently
    (Lyons et al. 2005, Mouillot et al. 2013)
- Collect forest structure data!
  - Remote sensing
  - Drones

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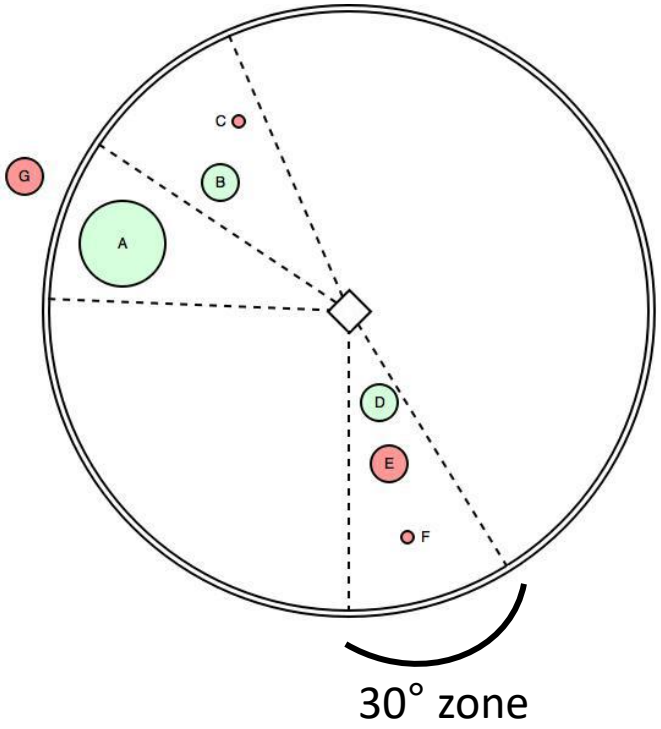
Root Competition – Iterative Seedling Index

$$ISI_i = \log(\sum_{j=1}^{n}\left(\frac{1}{DIST_{ij}}D_j\right)$$

D_j = Diameter of tree *j*

$DIST_{ij}$ = Distance between tree *j* and seedling *i*



Active competitor

Inactive competitor

Seedling

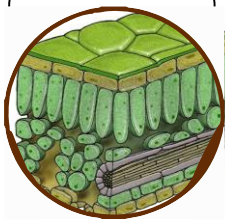
Adapted from:
Hegyi *1974*

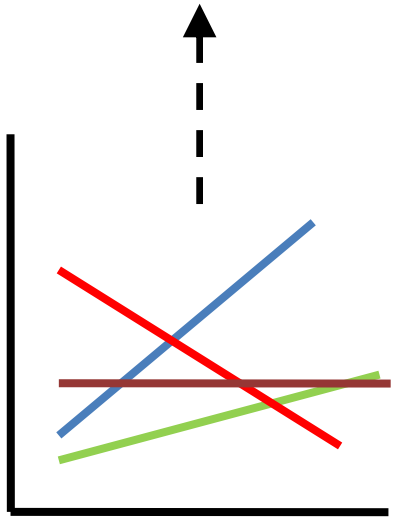
2. Do species differ in their sensitivity to variation in elevationally dependent environmental variables
    i. *Should each species be treated separately in future models?*

Statistical analysis – species sensitivity

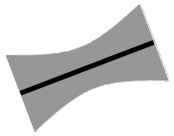
Response ~ Fixed Effect + (Plot) + (Elevation|Species)

Random Effects

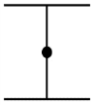




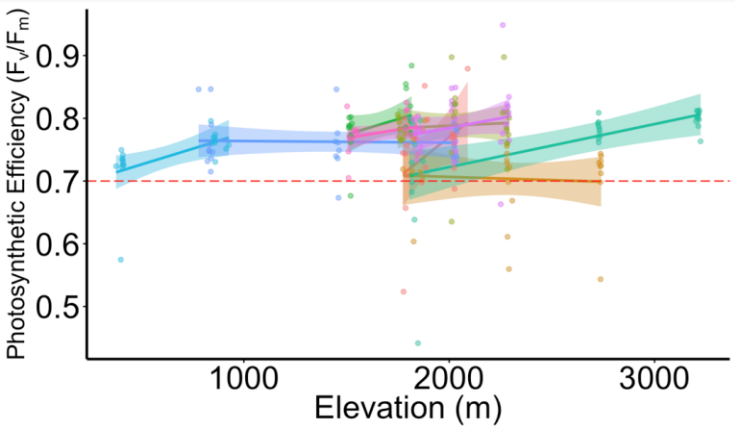
Results – Species sensitivity

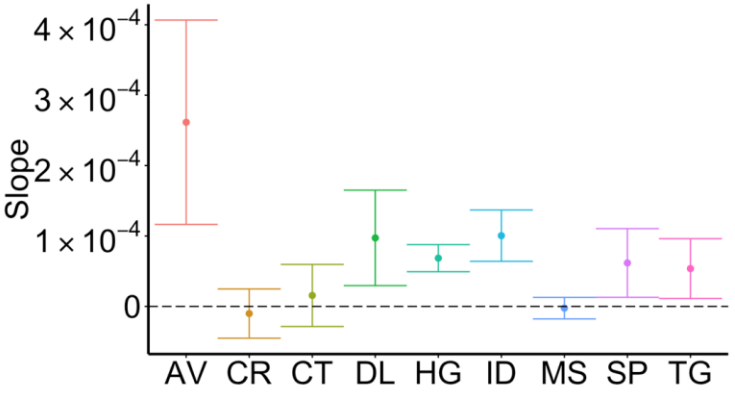


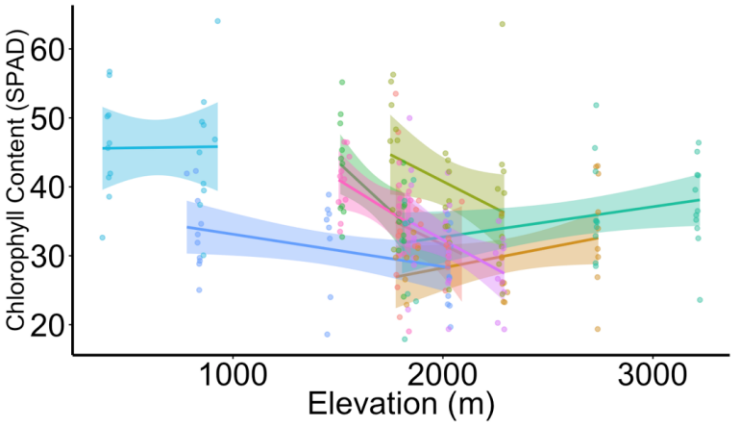
Regression ± 95% Confidence Interval

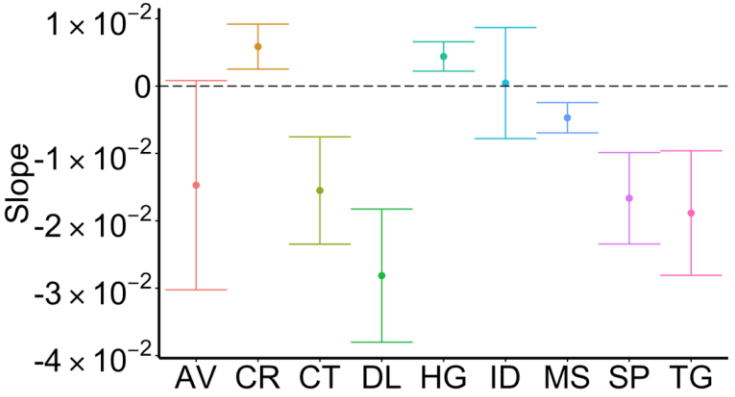


Slope ± 1 S.E.

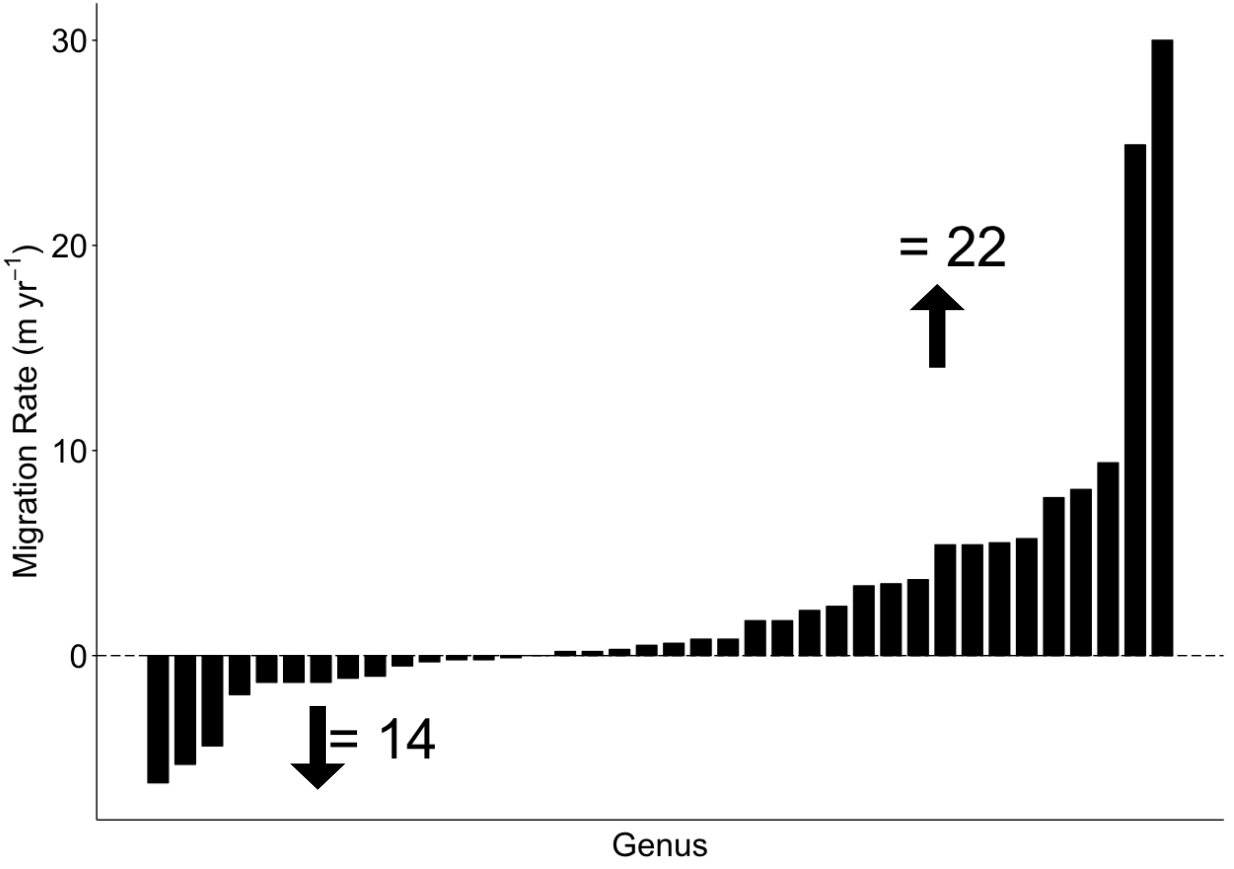








Species differ in their climate sensitivity



Data from:
Feeley *et al.* 2011