Can forest structure affect elevational range shifts?

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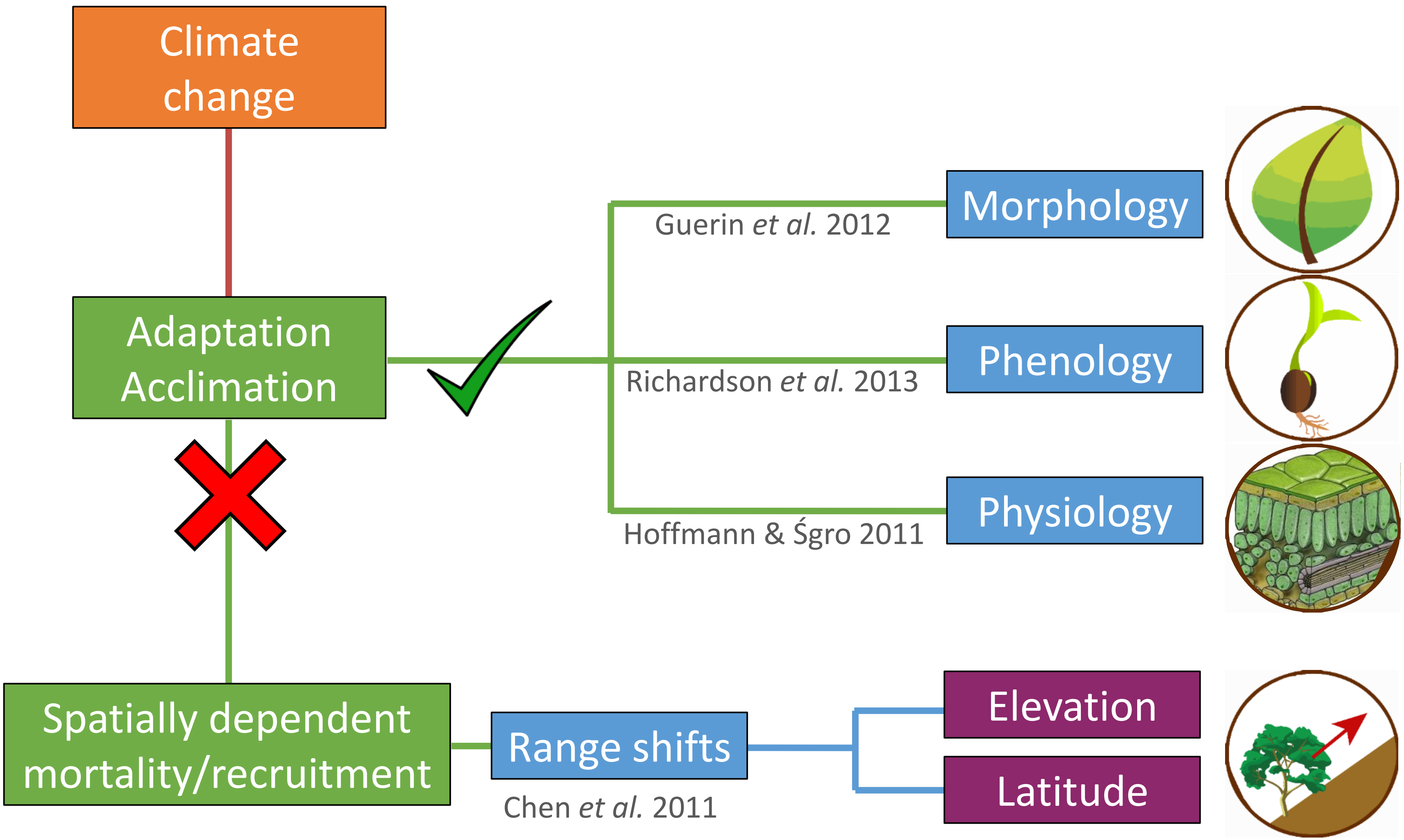
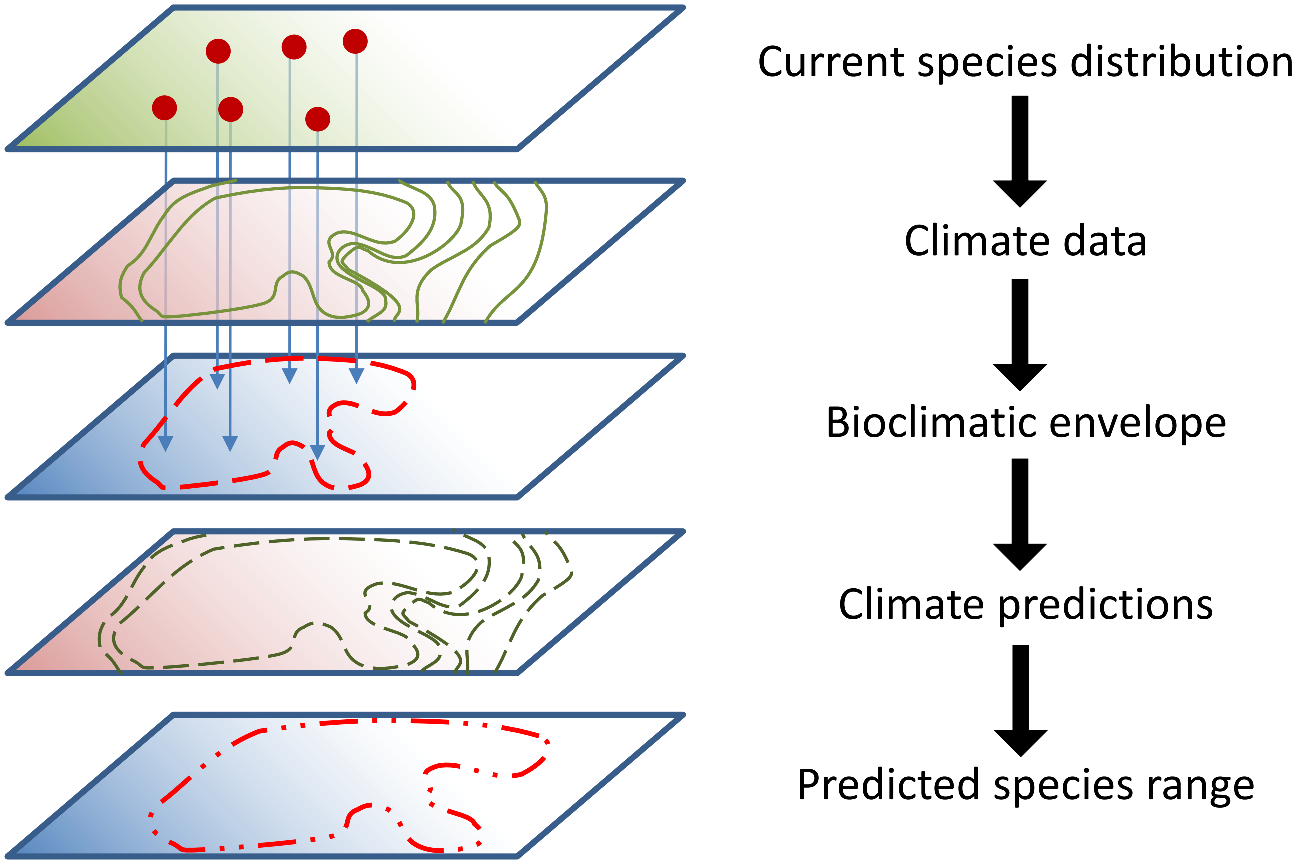
Climate change & range shifts



Bioclimatic envelope models

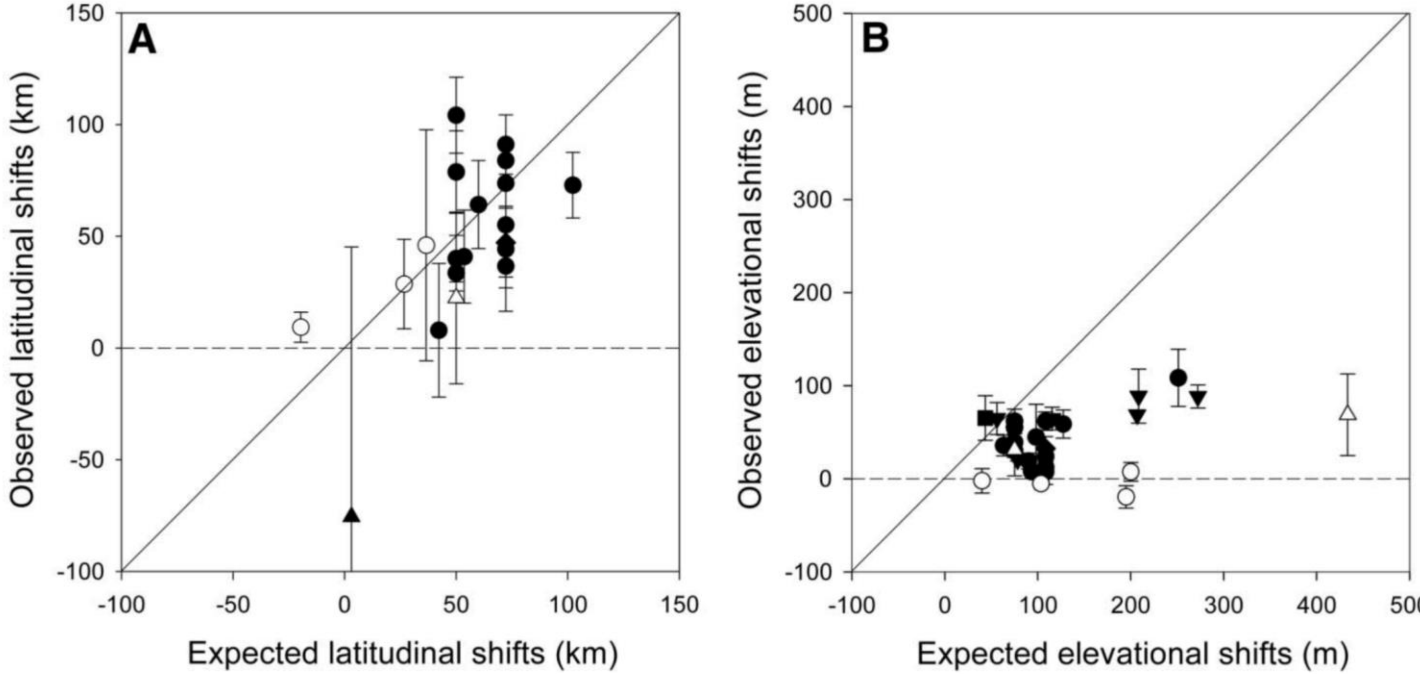


Pearson & Dawson 2003

Models fail to predict elevation shifts

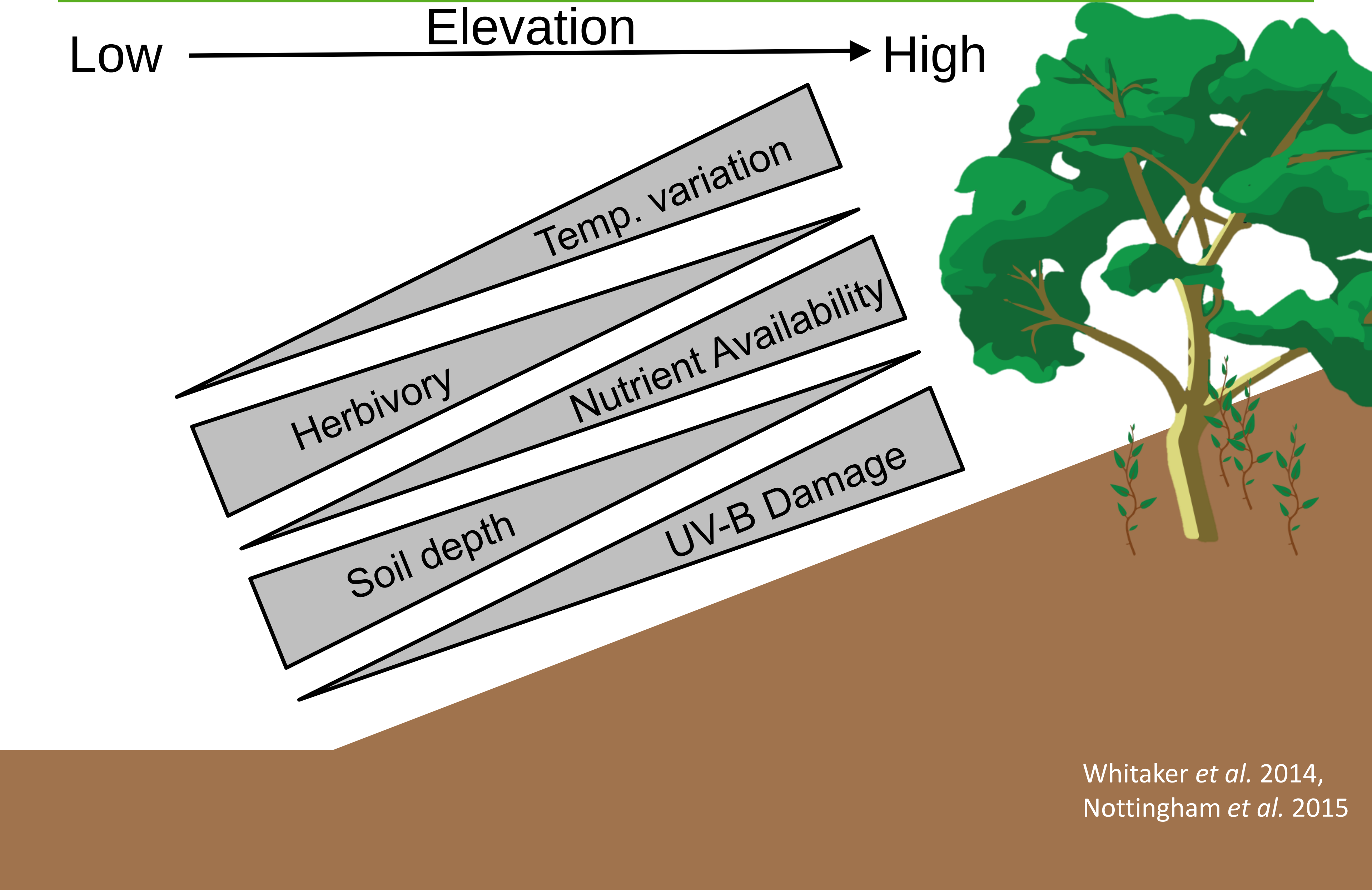
- Mean range shift ± 1 S.E.
- Birds
- Arthropods
- Mammals
- Molluscs
- Plants
- Herptiles
- Fish

Latitudinal Range Shifts **Elevational Range Shifts**



Chen *et al.* 2011

Other variables change with elevation

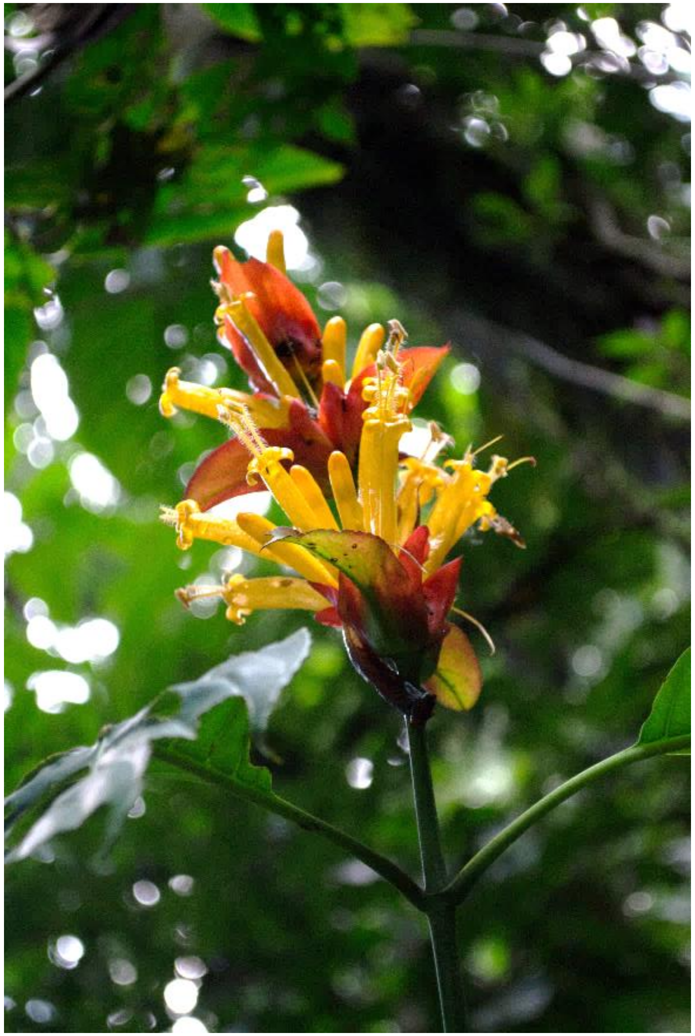


Whitaker *et al.* 2014,
Nottingham *et al.* 2015

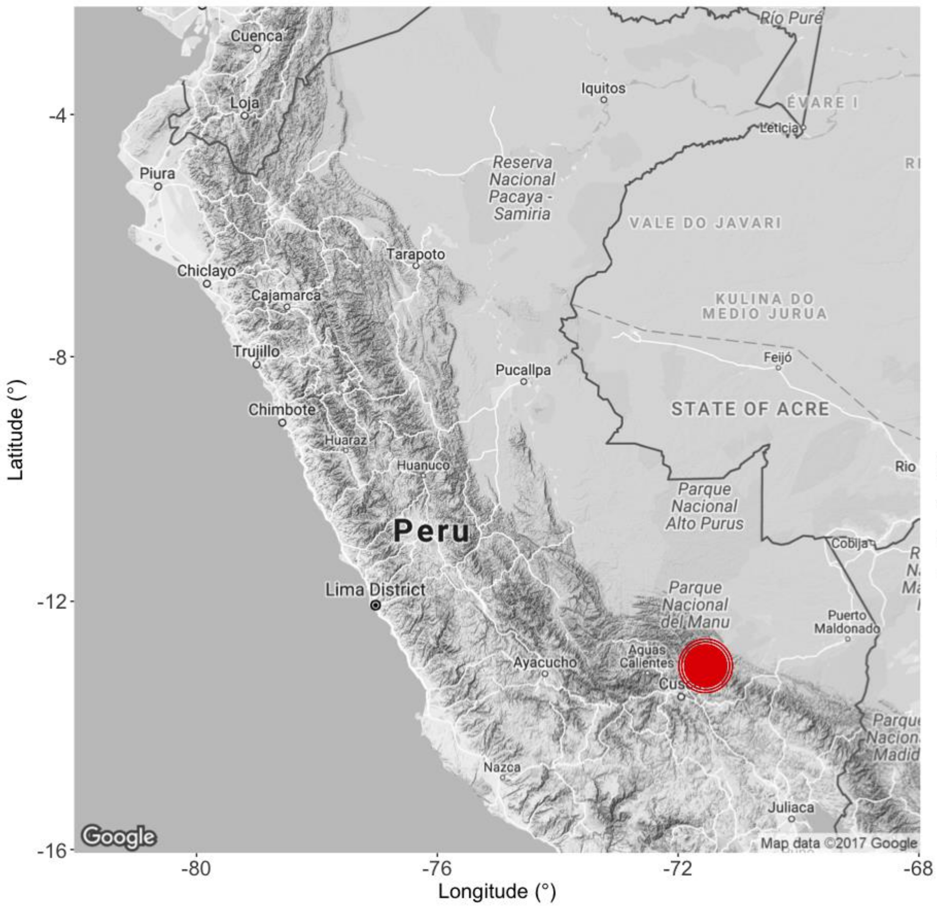
Research question

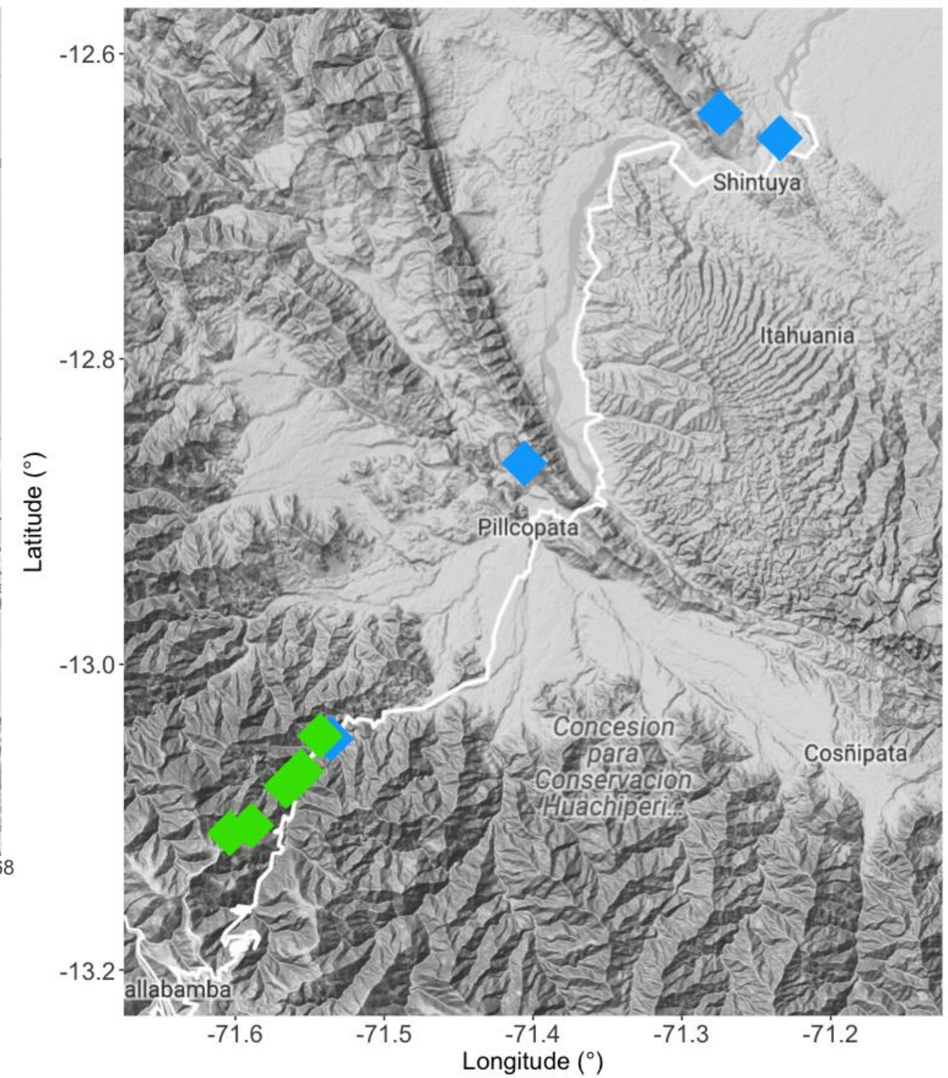
1. Can forest structure explain variation in plant stress?

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



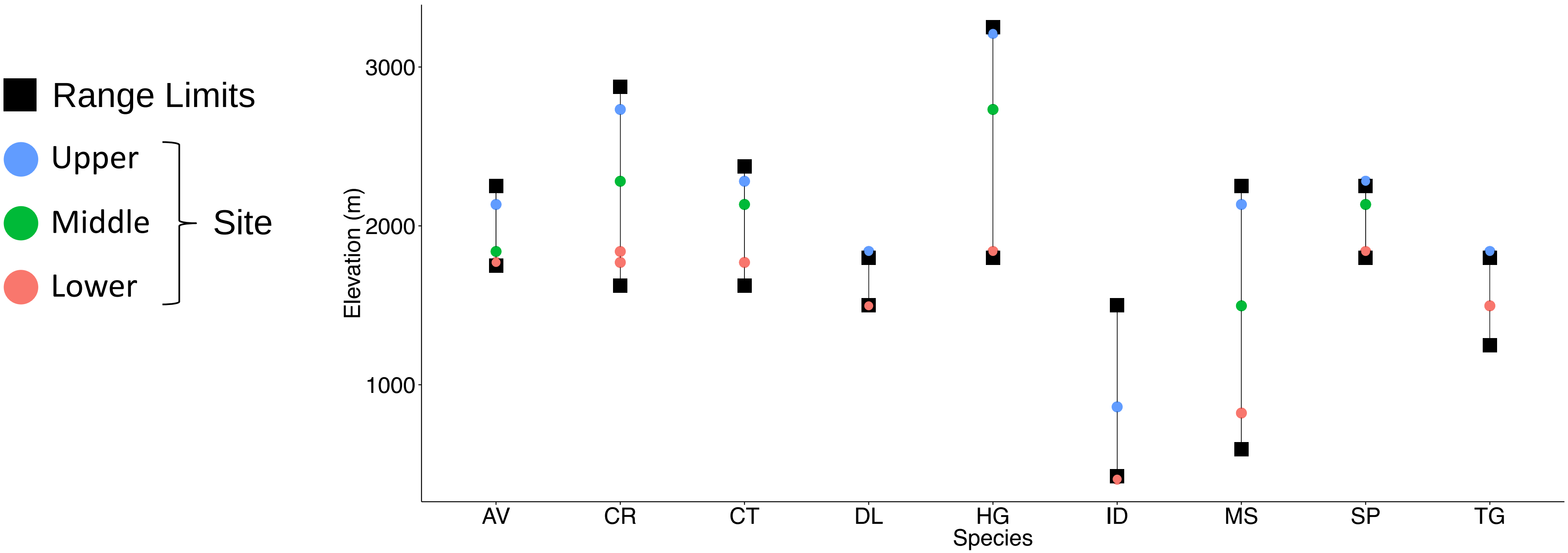
Study site





< cloud base
> cloud base

Study species



Alzatea verticillata

Clethra revoluta

Clusia thurifera

Dictyocaryum lamarckianum

Hedyosmum goudotianum

Iriartea deltoidea

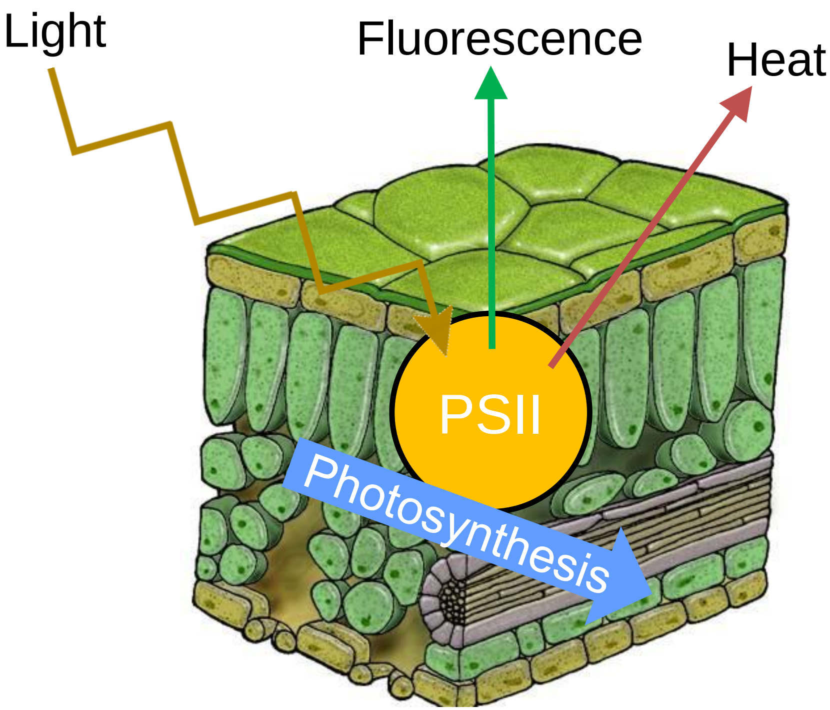
Myrcia spp.

Schefflera patula

Tapirira guianensis

Stress – Chlorophyll fluorescence & content

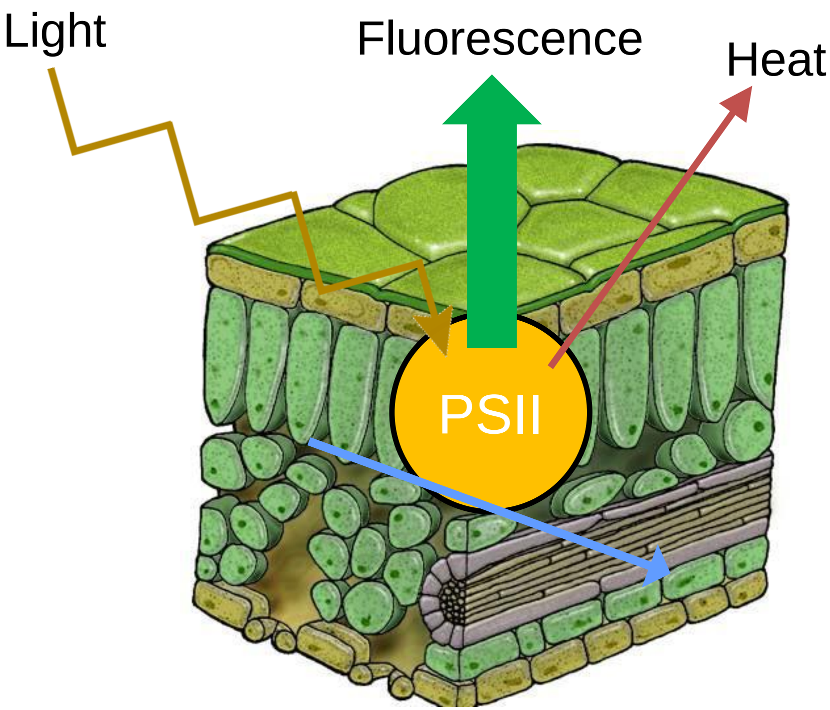
Healthy Plant – photosynthetic efficiency (F_v/F_m) ~ 0.8



Chlorophyll fluorescence using a MINI-PAM-II fluorometer

Stress – Chlorophyll fluorescence & content

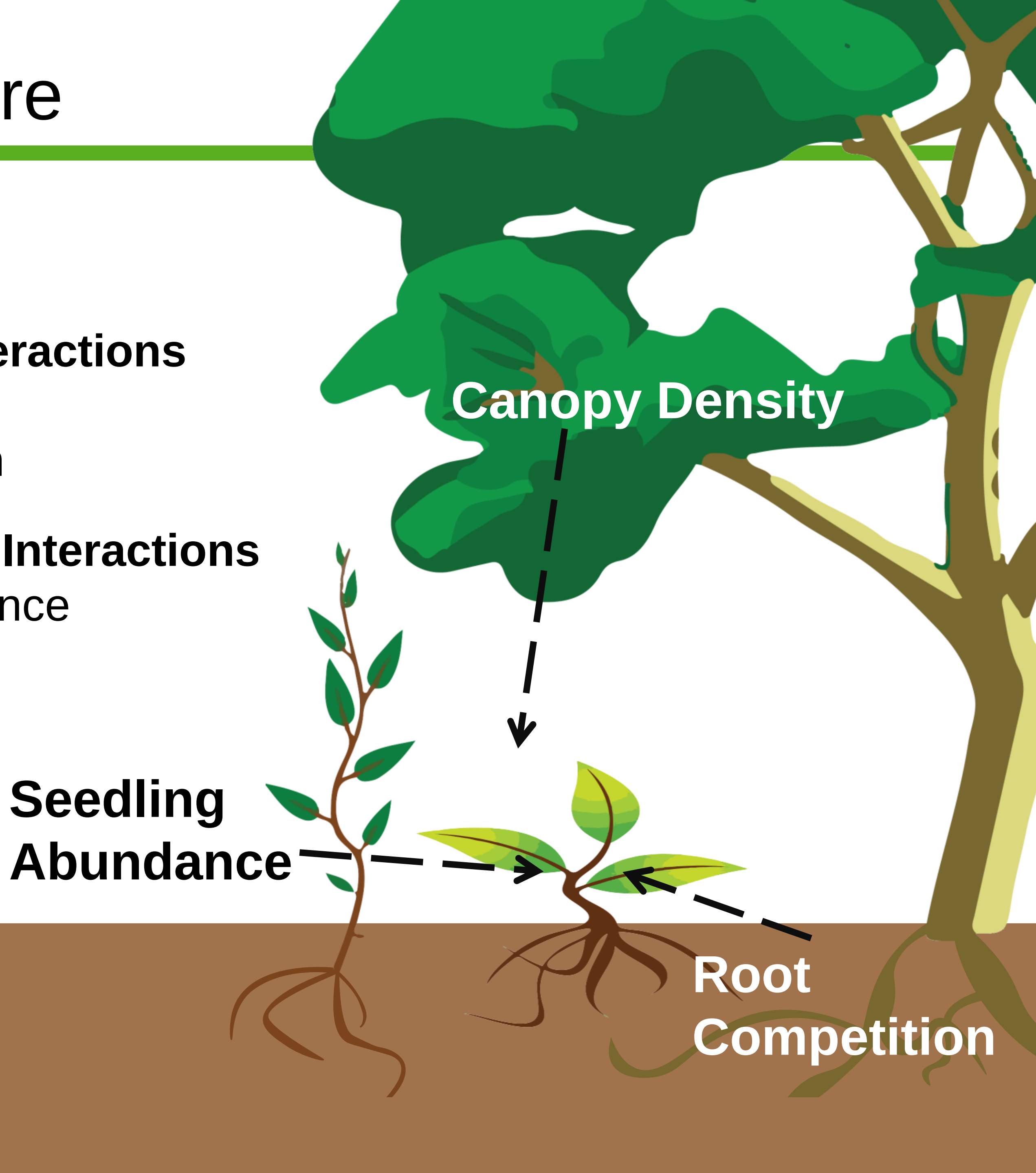
Stressed Plant – photosynthetic efficiency (F_v/F_m) < 0.7



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

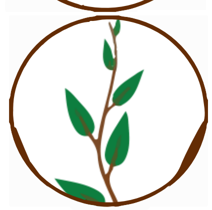
~

Fixed Effect

Elevation

Root Competition

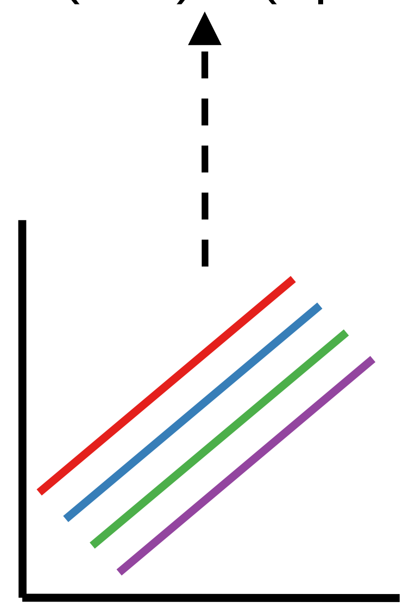
Canopy Density



Seedling Abundance

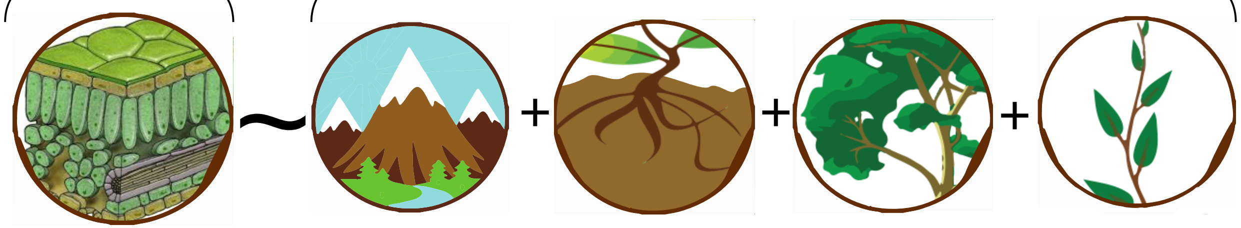
Random Effects

+ (Plot) + (Species)



Statistical analysis – effect of forest structure

Response ~ Fixed Effects + Random Effects



+ (Plot) + (Species)

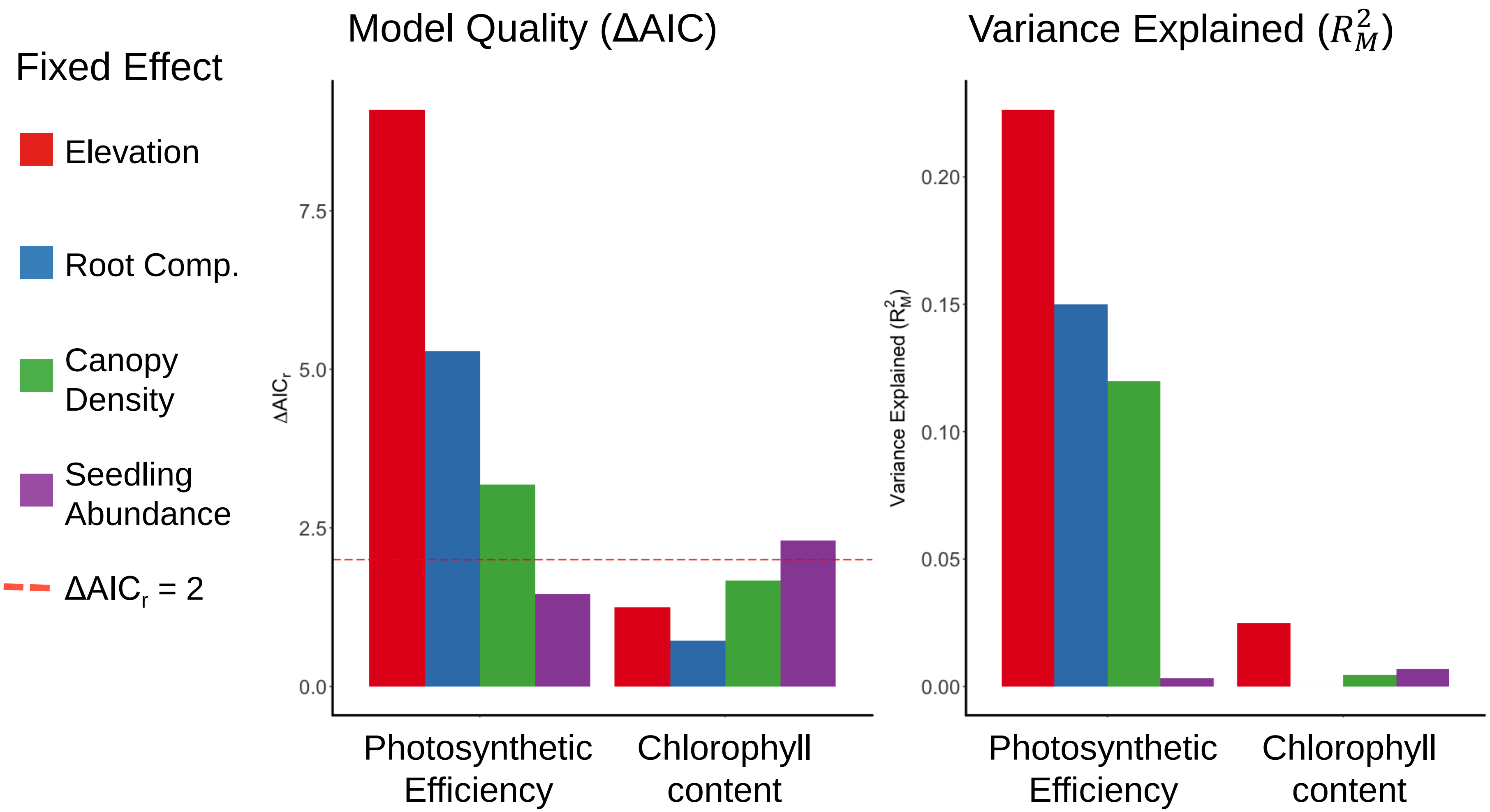
Best quality model chosen using:

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

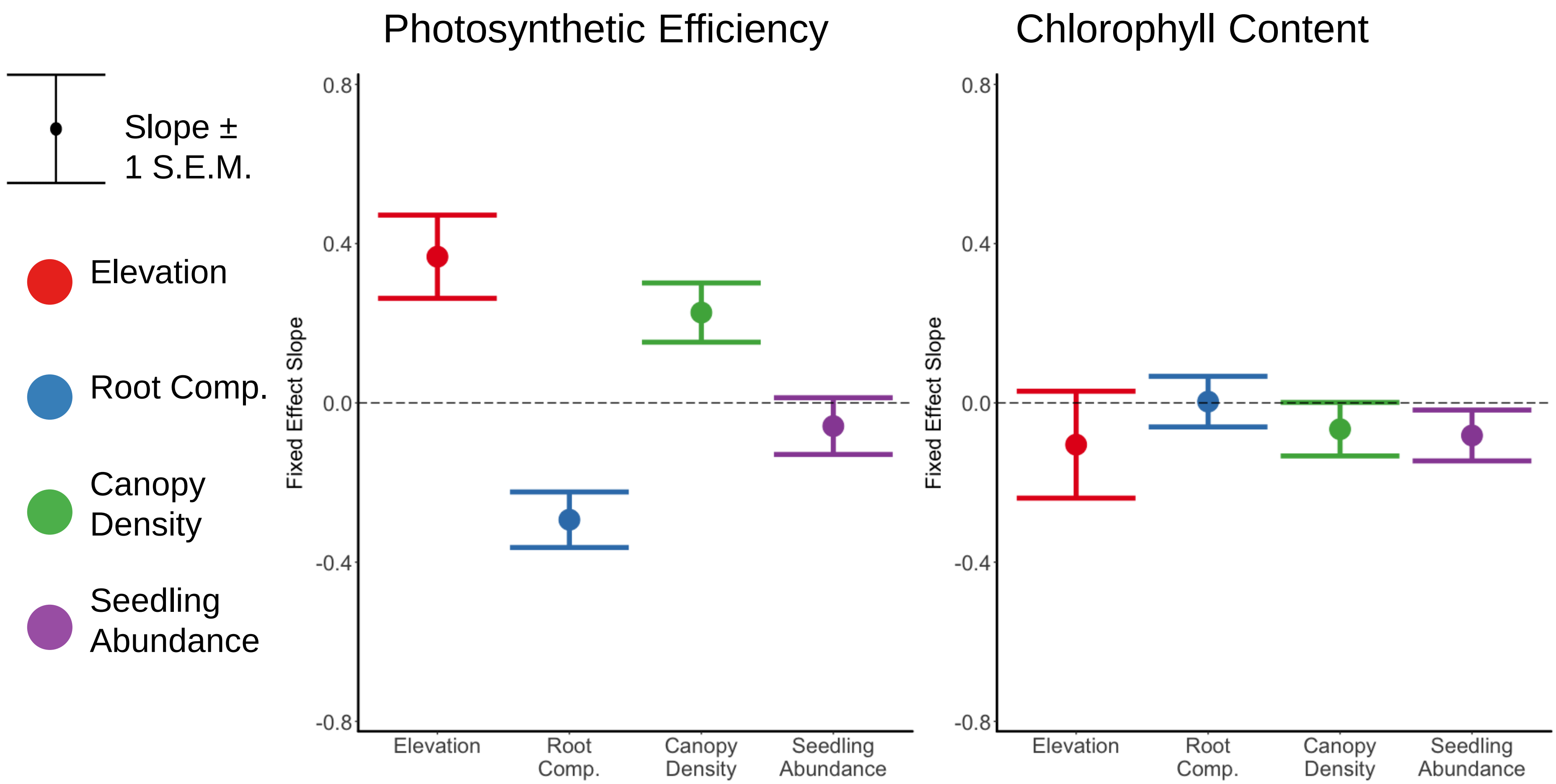
Model validation using:

- 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)

$R^2 = 0.004$

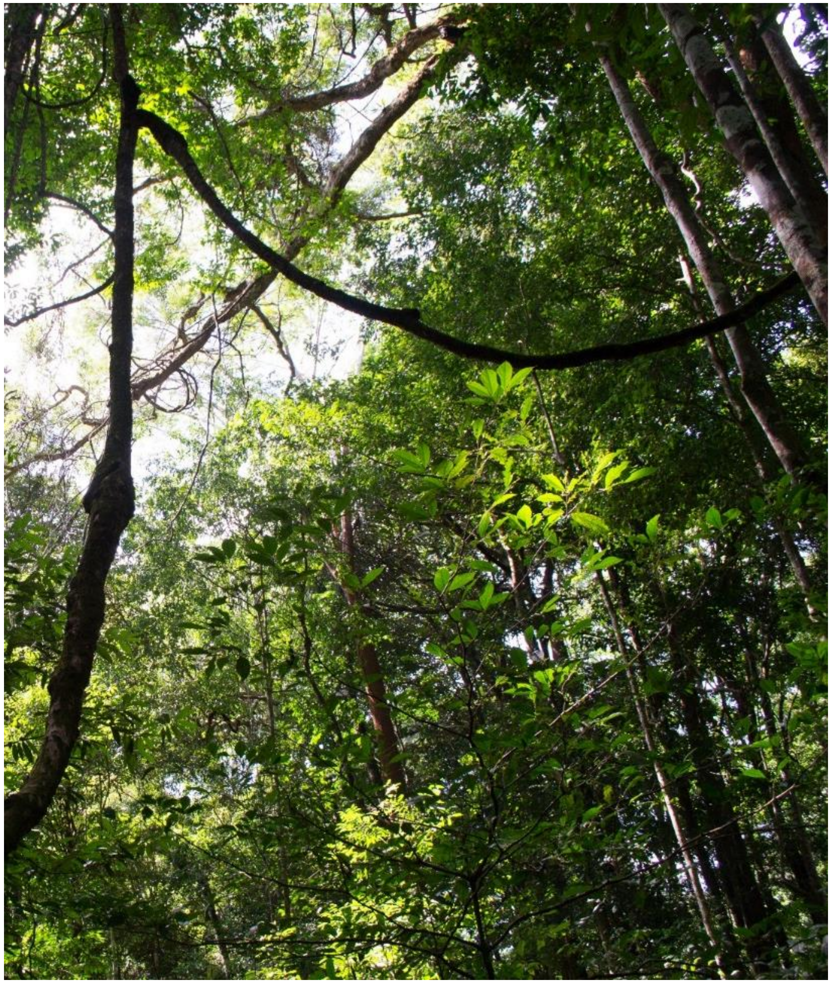
Summary

- Adult-seedling interactions affect seedling stress.

- No forest structure parameters had a greater effect than elevation.

- Photosynthetic efficiency best predicted by elevation and adult-seedling interactions.

- Cloud forest transition could be a barrier to upslope migration.



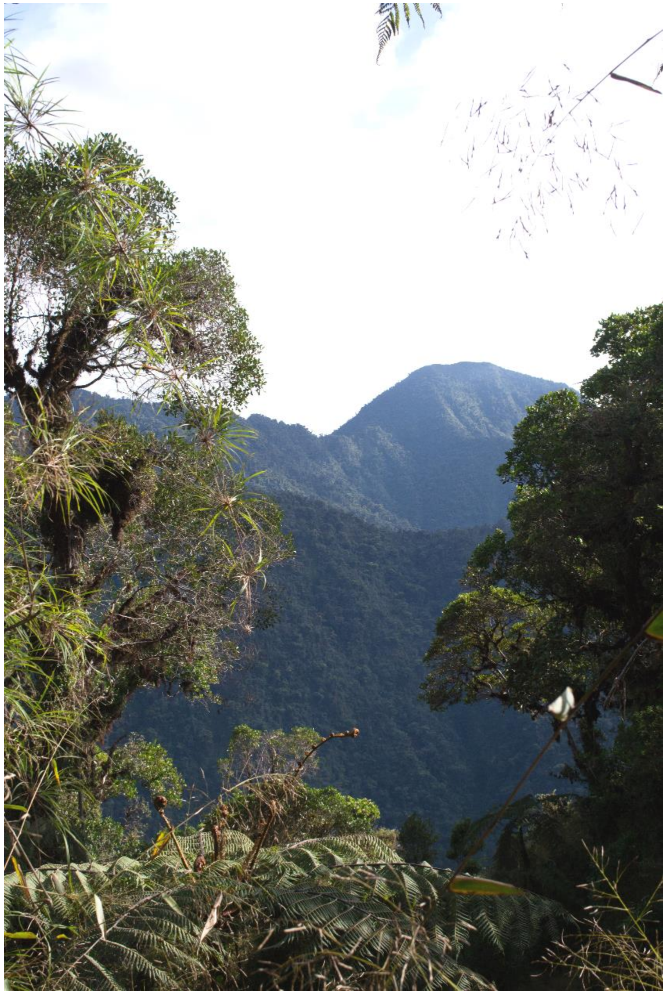
Future Studies

- Transplant experiments
  - Extended genotype
  - Fungal pathogens
  - Herbivory

- Compare with other biomes

- Rare species
  - Rare species react differently (Lyons et al. 2005, Mouillot et al. 2013)

- Collect forest structure data!
  - Remote sensing
  - Drones



References

Barton K. (2015). MuMIn: Multi-Model Inference. http://CRAN.R-project.org/package=MuMIn.

Chen I.-C., Hill J. K., Ohlemuller R., Roy D. B., & Thomas C. D. (2011). Rapid range shifts of species associated with high levels of climate warming. *Science*, *333*(**6045**), 1024–1026.

Feeley K. J., Silman M. R., Bush M. B., Farfan W., Cabrera K. G., Malhi Y., … Saatchi S. (2011). Upslope migration of Andean trees. *Journal of Biogeography*, *38*, 783–791.

Guerin G. R., Wen H., & Lowe a. J. (2012). Leaf morphology shift linked to climate change. *Biology Letters*, *8*(**5**), 882–886.

Hegyi F. (1974). A simulation model for managing jack-pine stands. In *Growth models for tree and stand simulation* (pp. 74–90).

Hoffmann A., & Sgrò C. (2011). Climate change and evolutionary adaptation. *Nature*, *470*(**7335**), 479–485.

Larcher W. (2003). *Physiological Plant Ecology: Ecophysiology and Stress Physiology of Functional Groups* (4th ed.). Berlin: Springer-Verlag.

Mouillot D., Bellwood D. R., Baraloto C., Chave J., Galzin R., Harmelin-Vivien M., … Thuiller W. (2013). Rare Species Support Vulnerable Functions in High-Diversity Ecosystems. *PLoS Biology*, *11*(**5**).

Nottingham A. T., Turner B. L., Whitaker J., Ostle N., McNamara N. P., Bardgett R. D., … Meir P. (2015). Soil microbial nutrient constraints along a tropical forest elevation gradient: a belowground test of a biogeochemical paradigm. *Biogeosciences Discussions*, *12*(**8**), 6489–6523.

Pearson R. G., & Dawson T. P. (2003). Predicting the impacts of climate change on the distribution of speces: are bioclimate envelope models useful? *Global Ecology and Biogeography*, *12*, 361–371.

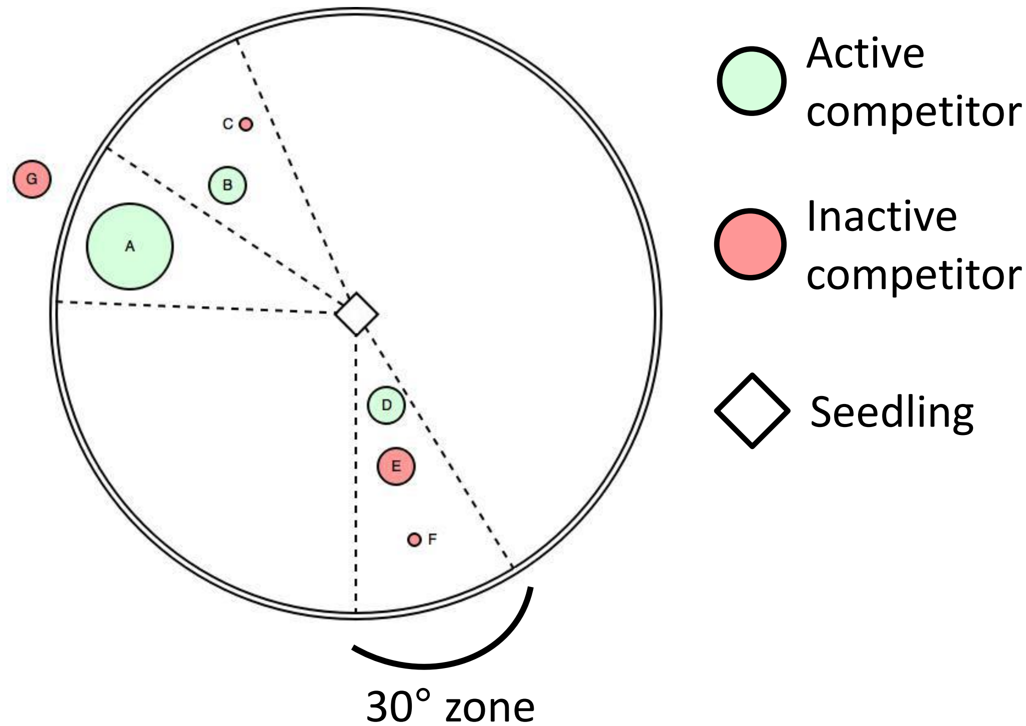
Whitaker J., Ostle N., Nottingham A. T., Ccahuana A., Salinas N., Bardgett R. D., … McNamara N. P. (2014). Microbial community composition explains soil respiration responses to changing carbon inputs along an Andes-to-Amazon elevation gradient. *Journal of Ecology*, *102*(**4**), 1058–1071.

Root Competition – Iterative Seedling Index

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

D_j = Diameter of tree *j*

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

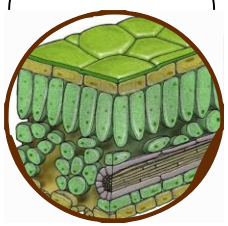


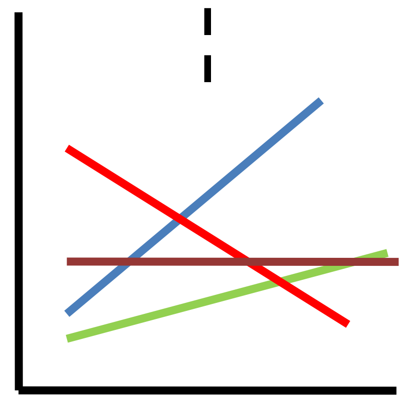
Adapted from:
Hegyi *1974*

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

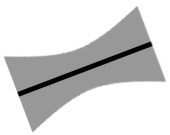
Statistical analysis – species sensitivity

Response | Fixed Effect | Random Effects

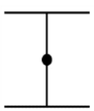
 ~  + (Plot) + (Elevation|Species)



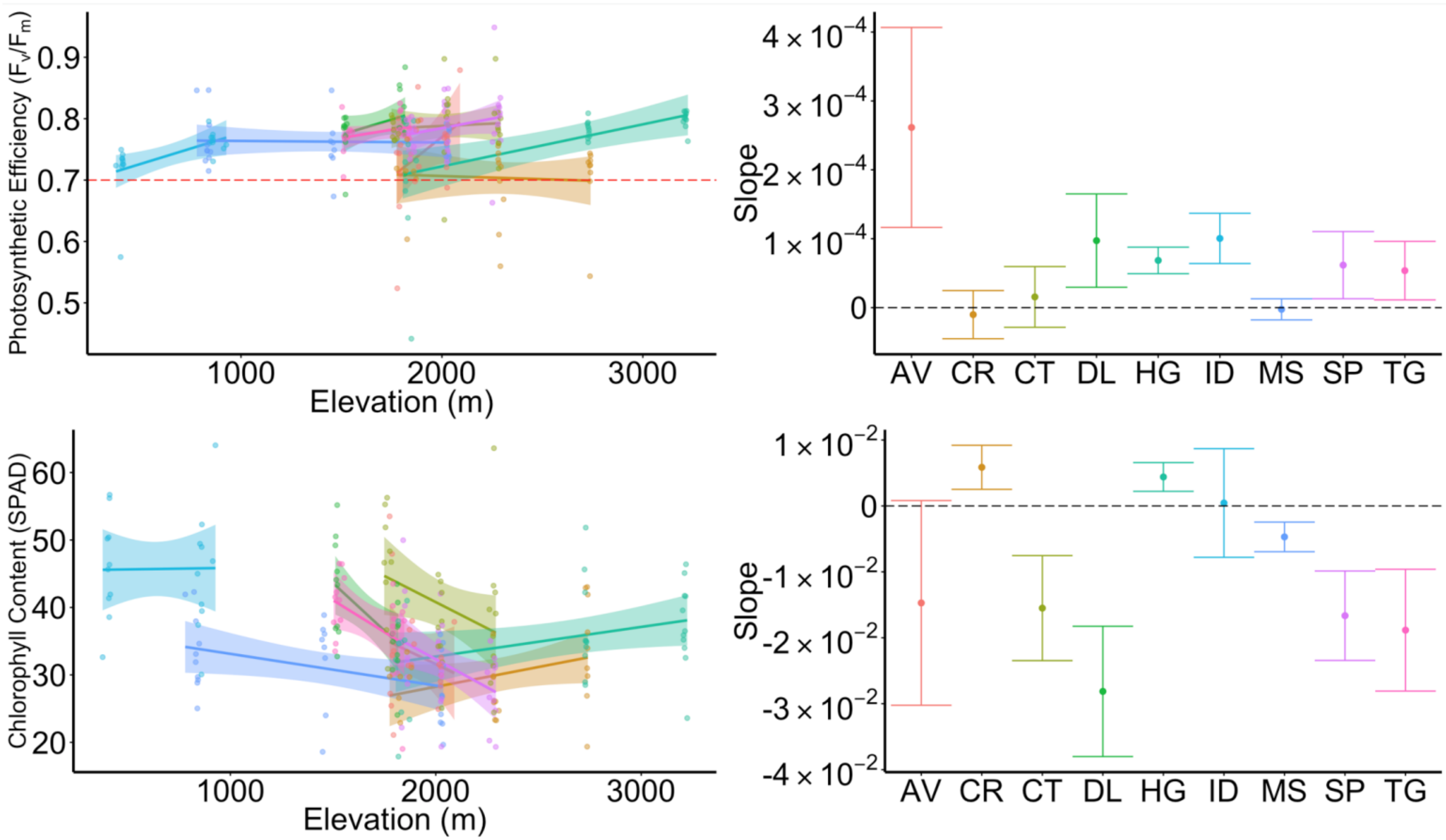
Results – Species sensitivity



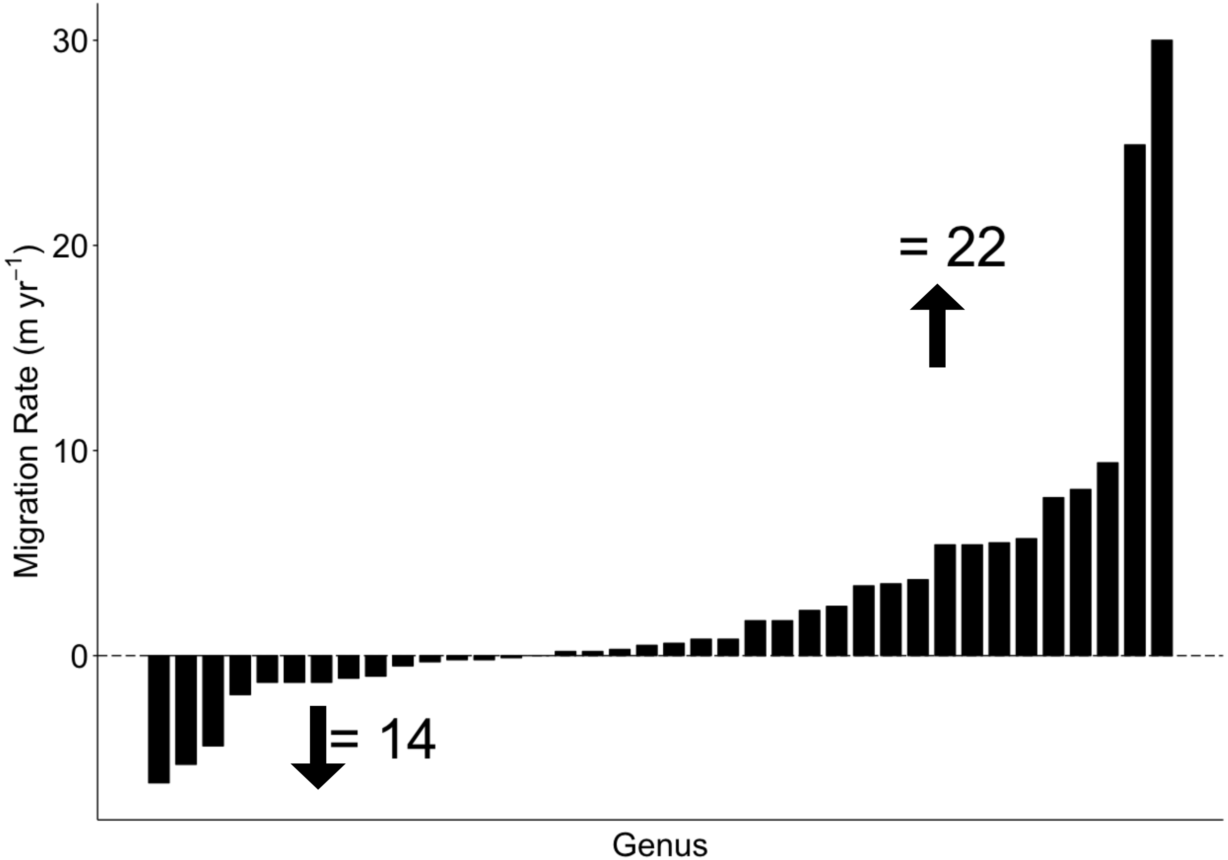
Regression ± 95% Confidence Interval



Slope ± 1 S.E.



Species differ in their climate sensitivity



Data from:
Feeley *et al.* 2011

Relative Abundance