How light competition intensity on tree growth and mortality varies across climate stress gradients for 34 European species ?

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PhD with Benoit Courbaud and Georges Kunstler

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Introduction

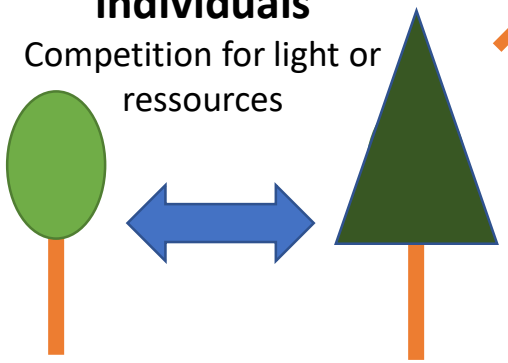
Confounded effect of abiotic factors and interaction between individuals for tree growth and survival

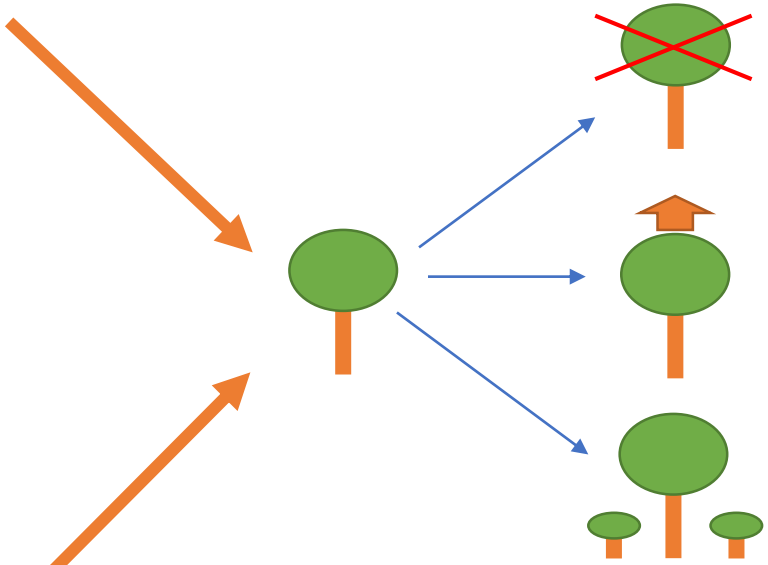
Abiotic factors

- Soil fertility (C/N, pH, OC)
- Climate (temperatures, water availability)

Interactions between individuals

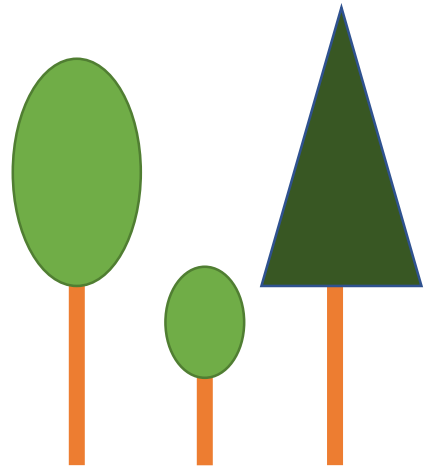
Competition for light or ressources





Individual dynamics

Growth, survival, fertility



Community assembly

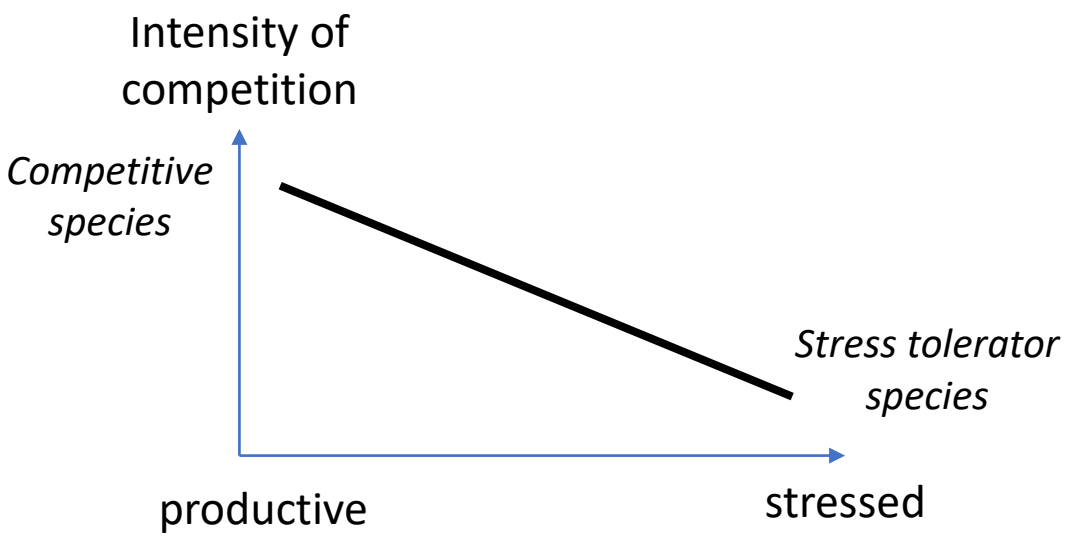
Structure, composition

Forest functions and services

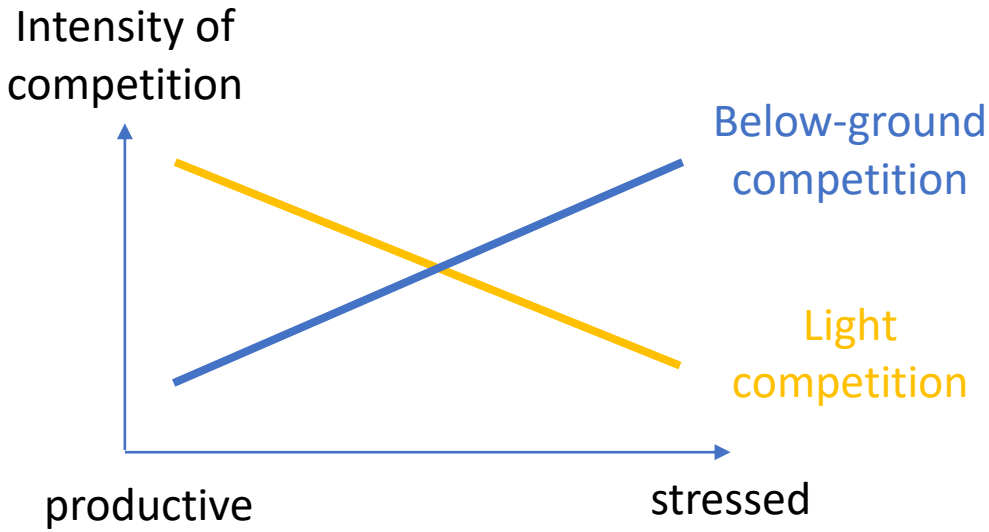
- Wood production
- Biodiversity
- Carbon storage
- Recreative activities

Introduction

Theories of Grime and Tilman



Grime 1977

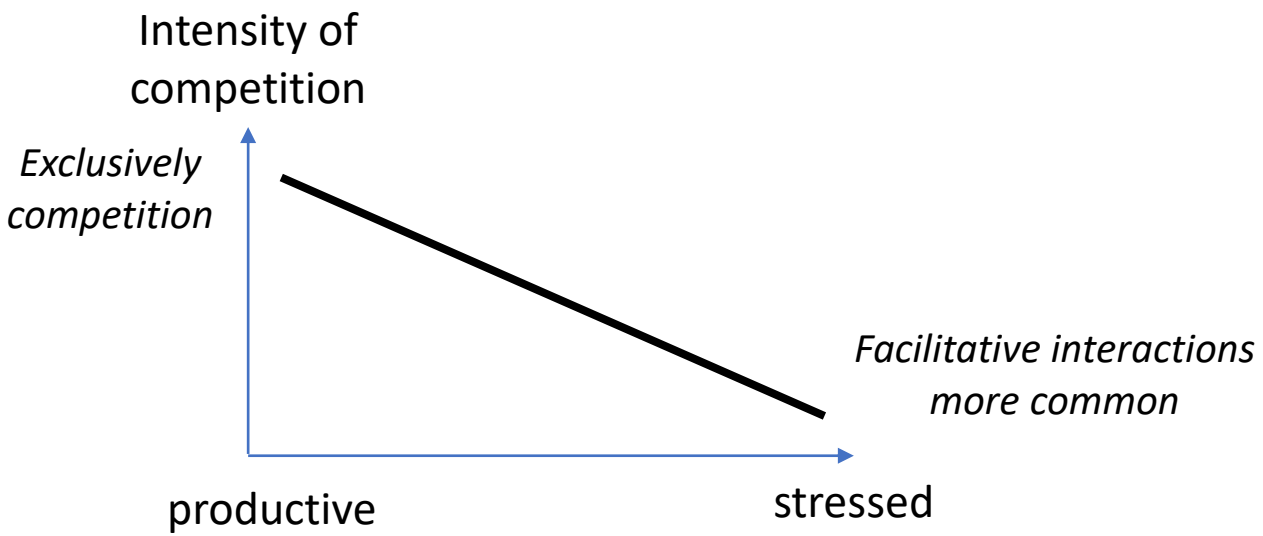


Newman 1973;
Tilman 1987, 1988

Introduction

Stress gradient hypothesis

$$intensity\ of\ competition \sim \frac{facilitative\ interactions}{competitive\ interactions}$$



Bertness & Callaway 1994; Maestre 2005

Introduction

Few quantitative studies for tree communities

Difficulties with long-lived species:

- Lack of quantitative studies (theories mainly tested with annual plants)
- Difficulties to observe effect of competition (lag effect)

Actual studies for tree communities:

- Few species
- Limited climatic range
- Mainly for growth, less for survival and rarely by comparing both
- Competition represented with global indicators, and not resource specific

Introduction

Objectives of the current study

New opportunities :

- Large NFIs dataset (several species, large climate gradient, growth and mortality)
- Precise light competition index using SamsaraLight (Courbaud, Ligot) and tree allometries (Touzot et al.)

Questions:

1. Does light interception represent competition better than global neighbouring index ?
2. Are interactions between climate and light competition important ?
3. Can we observe a specific pattern of competition intensity across a climatic stress gradient?

Hypothesis: Competition for light is less intense in stressed sites

- Facilitative effect of shadow
- Competition for below-ground resources
- Individuals more stress-tolerator than competitive

Materials and methods

Calibration dataset – *Forest inventories*

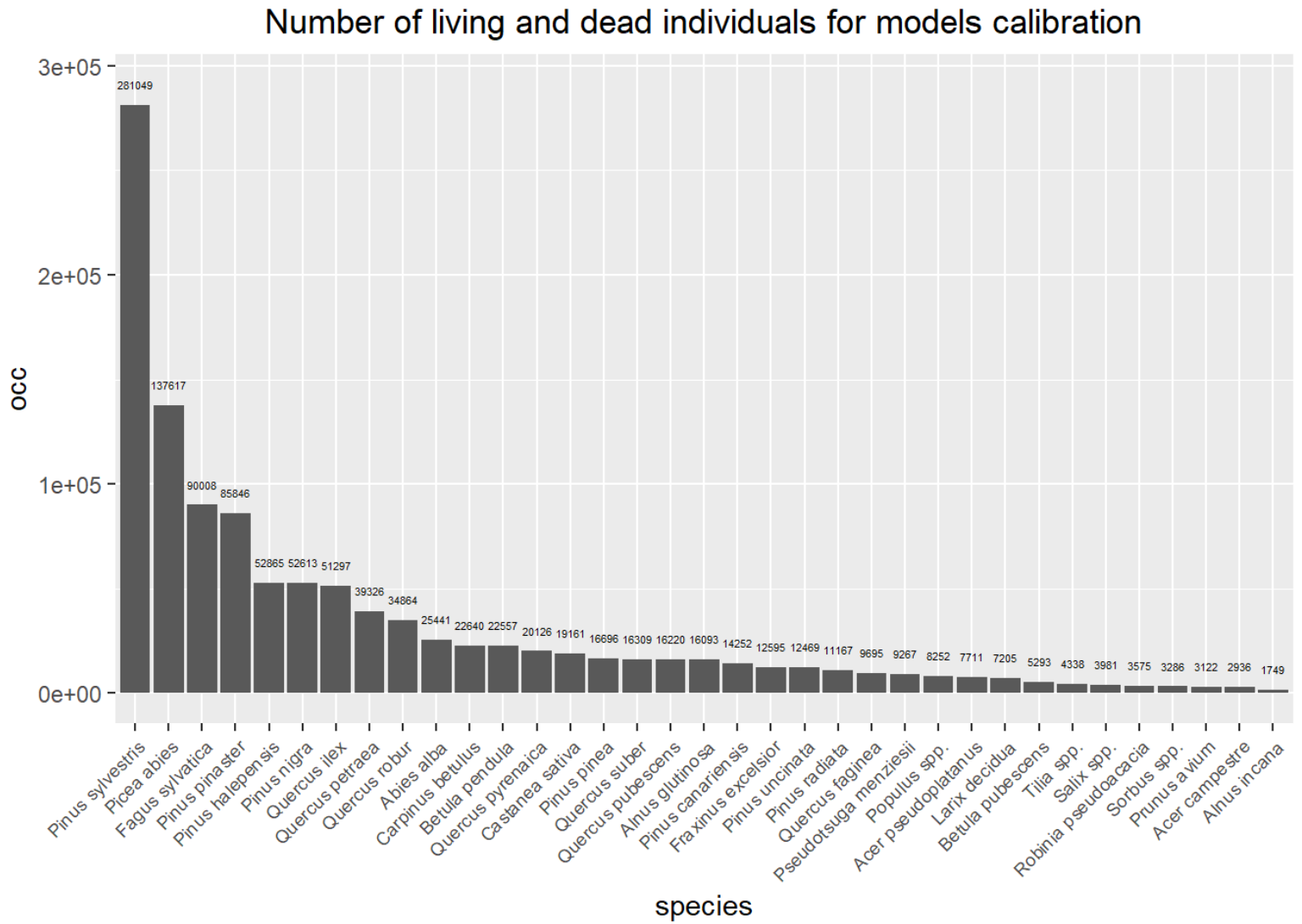
10 European countries:
Spain, France, Wallonia, Germany, Slovaquia, Slovenia, Czech Republic, Poland, Sweden and Norway

Visit-Revisit dataset
(diameter increment and tree status)

1,121,621 living and dead individuals

107,366 plots
(without management)

34 main European tree species



Materials and methods

Calibration dataset – *Climate variables*

Plot-level annual variables

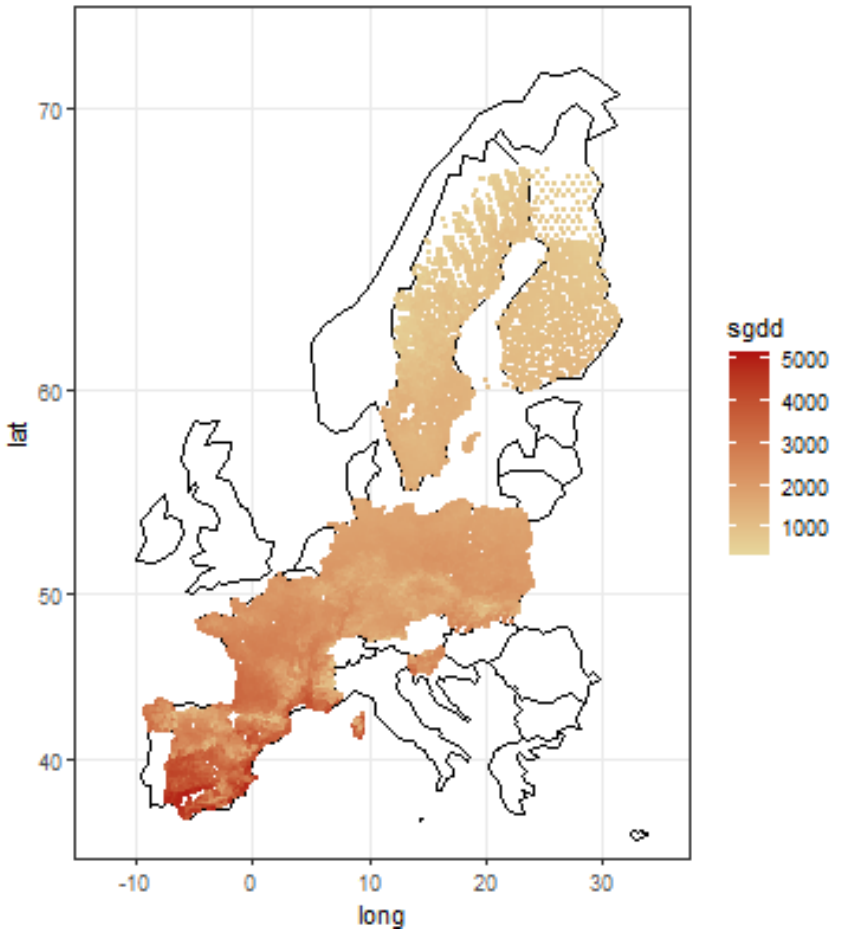
Averaged on the period between the two surveys

From monthly climatic variables
(mean temperatures, precipitations, potential evapotranspiration)
(CHELSA 1km)

and soil variables
(soil texture, organic content and rooting depth)
(SoilGrids 250m)

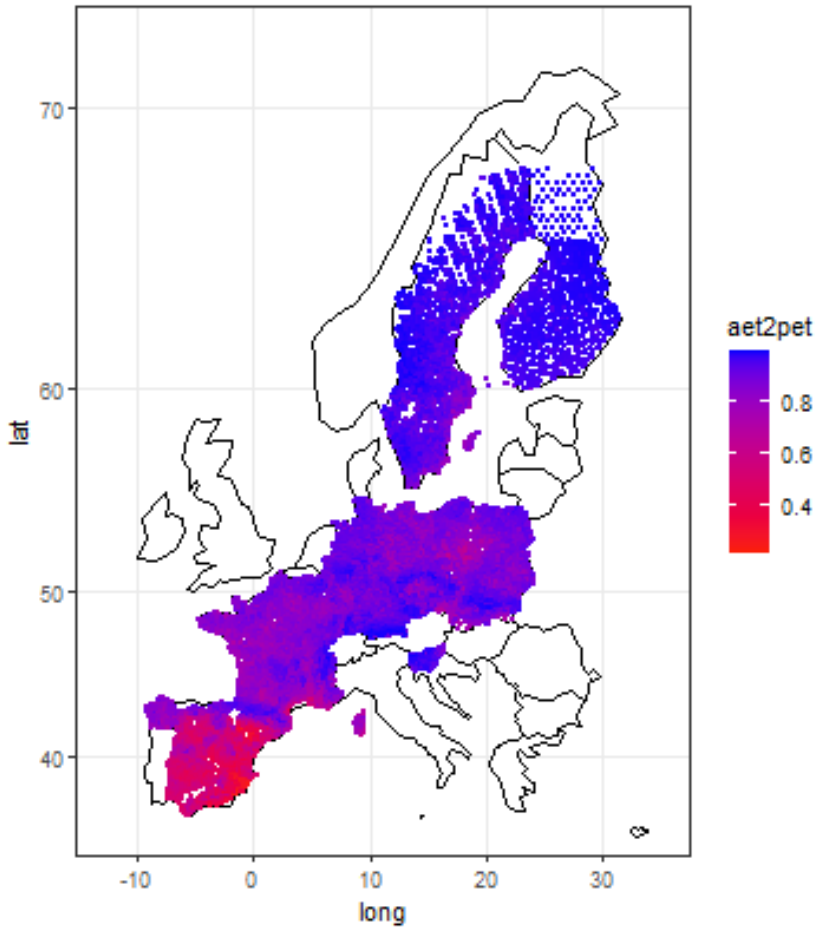
Temperature-based

SGDD: sum of growing-degree days (in °C/year)



Water-based

Aet2pet: actual to potential evapotranspiration (in mm/mm)



Materials and methods

Calibration dataset – *Competition variables*

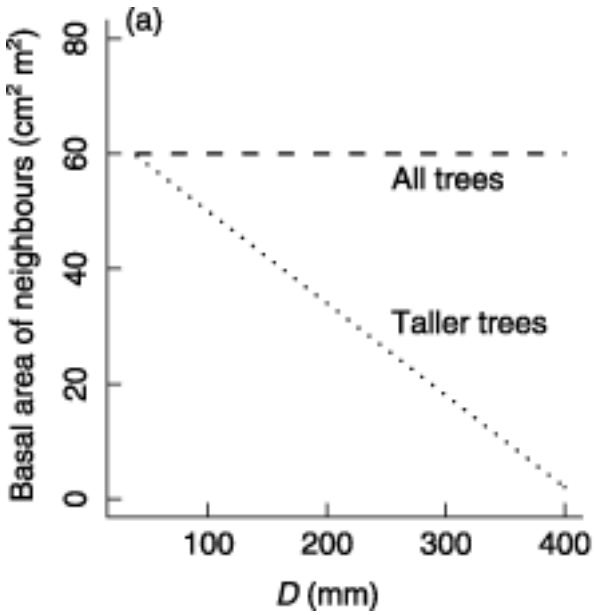
Global density indicators

Total basal area (BAT):

- Symetric competition

Basal area of larger trees (BAL):

- Asymetric competition



Coomes and Allen 2007

Light competition index (LCI)

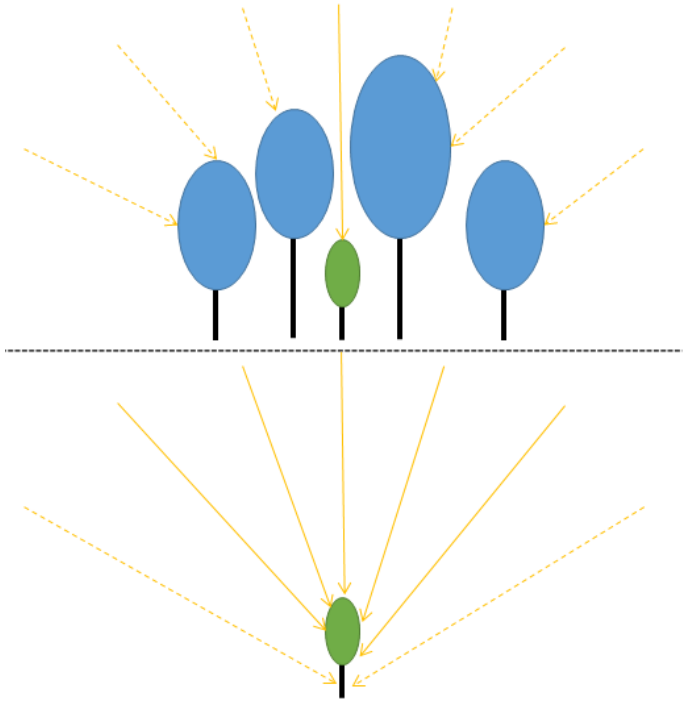
Using SamsaraLight and allometries from *Touzot et al. (in revision)*

$$LCI = 1 - \frac{intercepted\ energy}{potential\ energy}$$

LCI=0 dominant → LCI=1 repressed

Intercepted energy

Potential energy



Materials and methods

Model fit

$$\ln(dD_{year}) = dbh + \ln(dbh) + compet + \frac{1}{sgdd} + \frac{1}{aet2pet} + compet{:}\,sgdd + compet{:}\,aet2pet + country + (1|plotcode)$$

ontogeny

competition

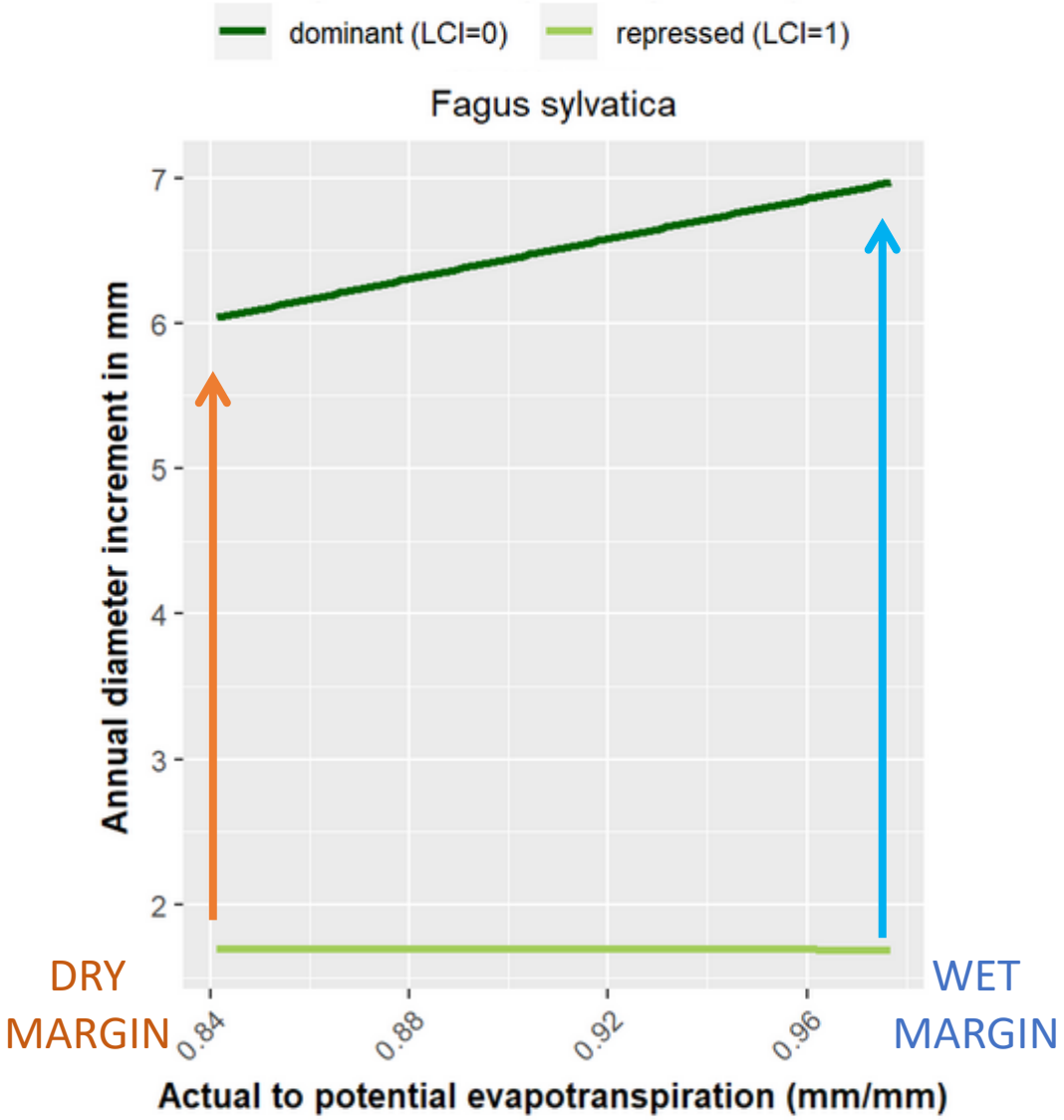
climate

Interactions climate/competition

$$cloglog(P(mortality)) = dbh + \ln(dbh) + compet + sgdd + aet2pet + compet{:}\,sgdd + compet{:}\,aet2pet + country + offset(\log(dyears))$$

Materials and methods

Intensity of competition across a climatic stress gradient



$$Icompet_{climate} = \log\left(\frac{dD_{LCI=0,climate}}{dD_{LCI=1,climate}}\right)$$

$dD_{supressed} > dD_{dominant}$ 0 $dD_{supressed} < dD_{dominant}$

$$\Delta Icompet = Icompet_{productive} - Icompet_{stressed}$$

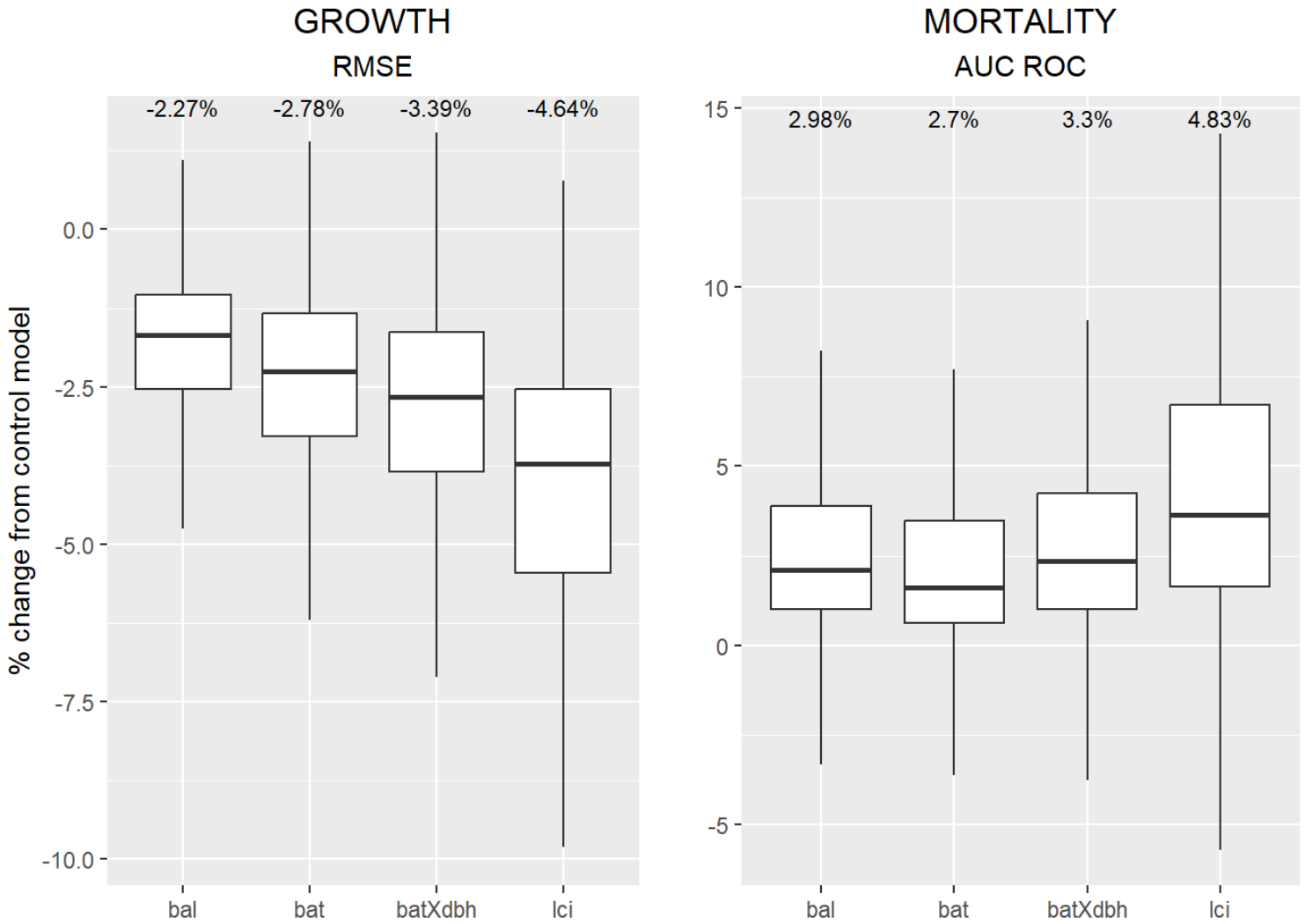
Intensity of competition higher in stressed sites 0 Intensity of competition higher in productive sites

Models comparison

Q1: Does LCI perform better than total basal area ?

Results

Q1: Does LCI perform better than total basal area ?



SamsaraLight indicator represent competition better than global neighbouring indices

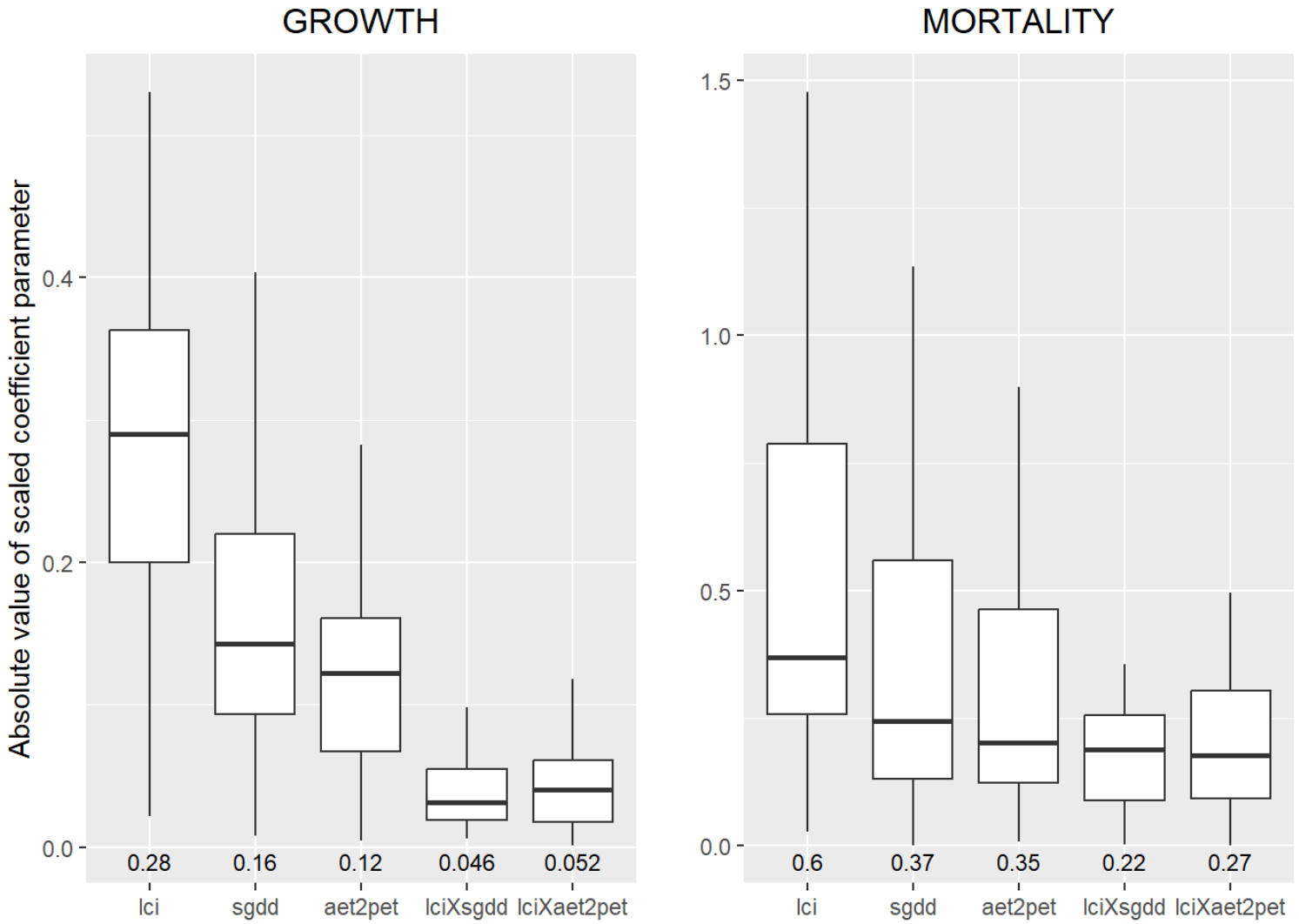
Light competition model

Q2: Are interactions between climate and competition important ?

Q3: Is light competition less intense in a stressful environment ?

Results

Q2: Are interactions between climate and competition significant ?

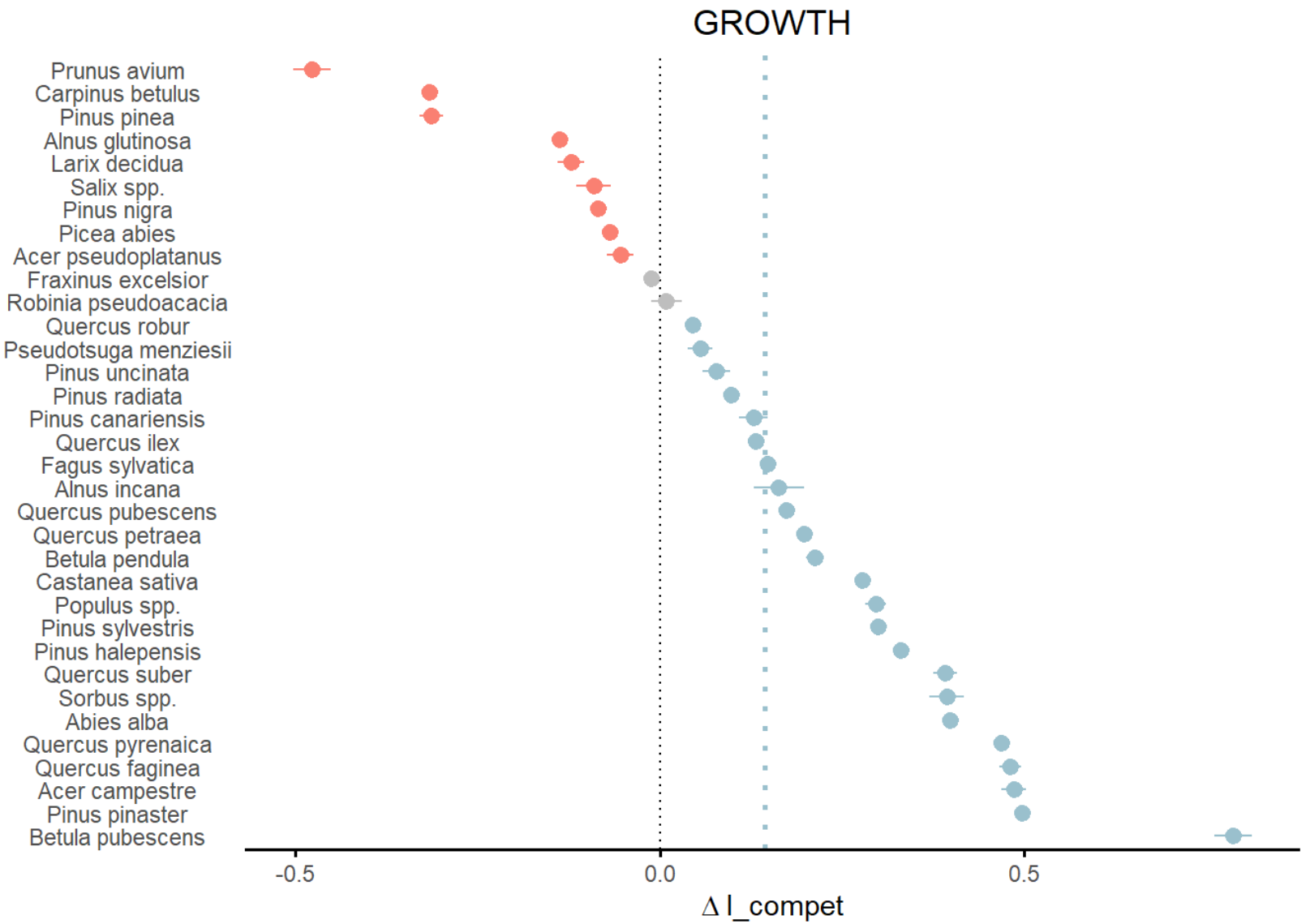


Interactions are important to consider, especially in mortality models

Q3: Is light competition less intense in a stressful environment ?

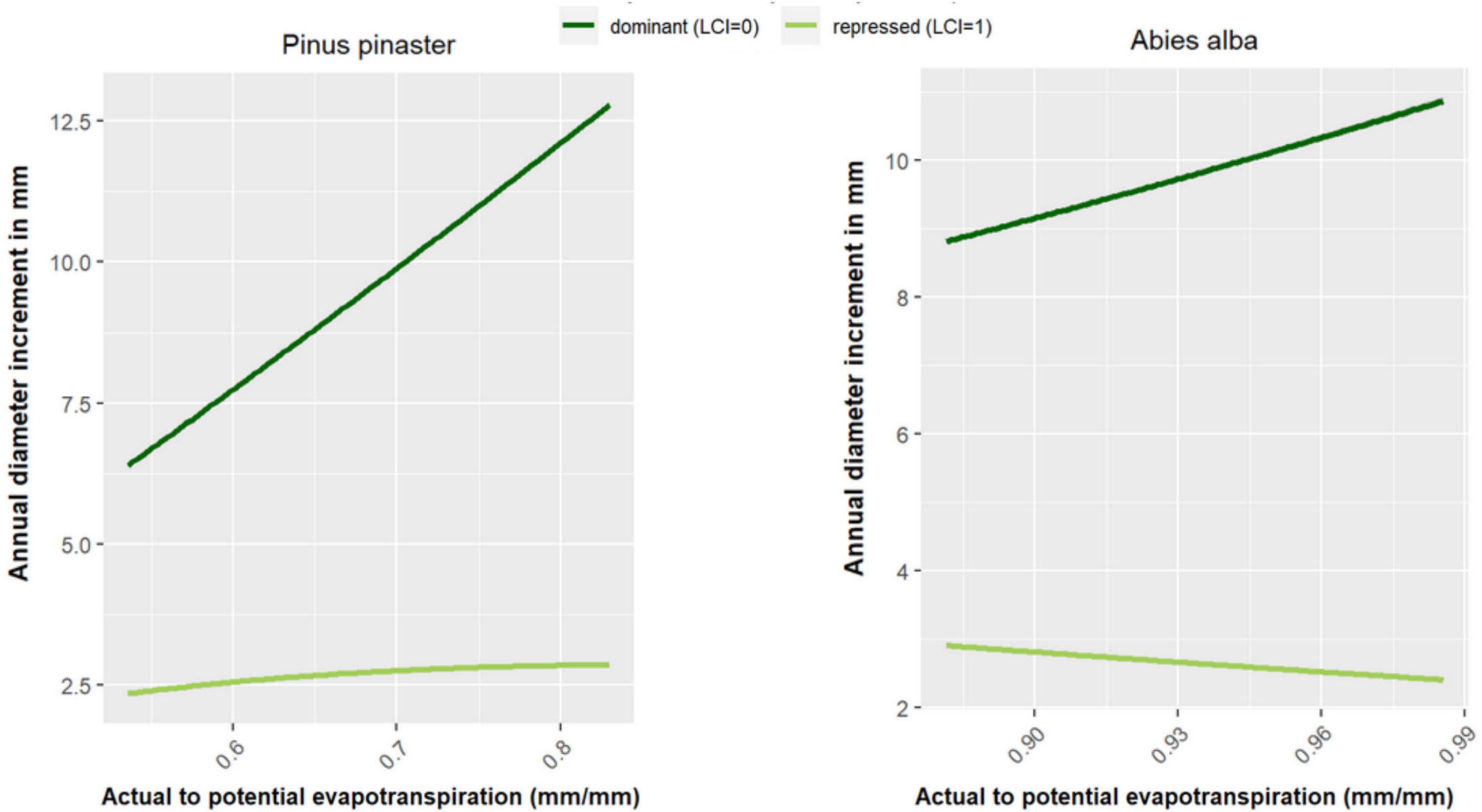
Along a resource gradient (water availability)

Results - Water stress gradient

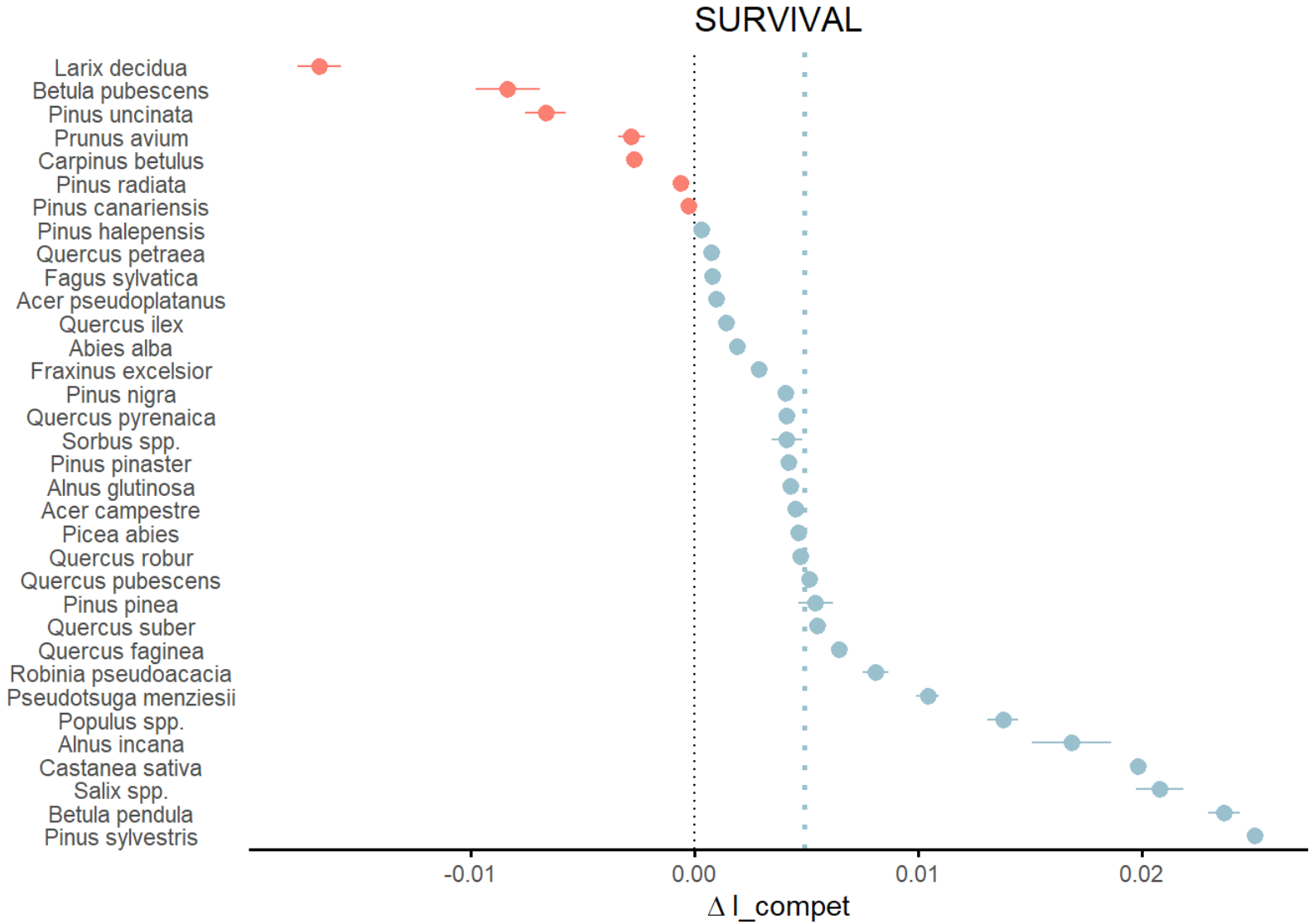


<u>For 23 species over 34</u>: intensity of competition on growth is higher in their wet margin

Results - Water stress gradient

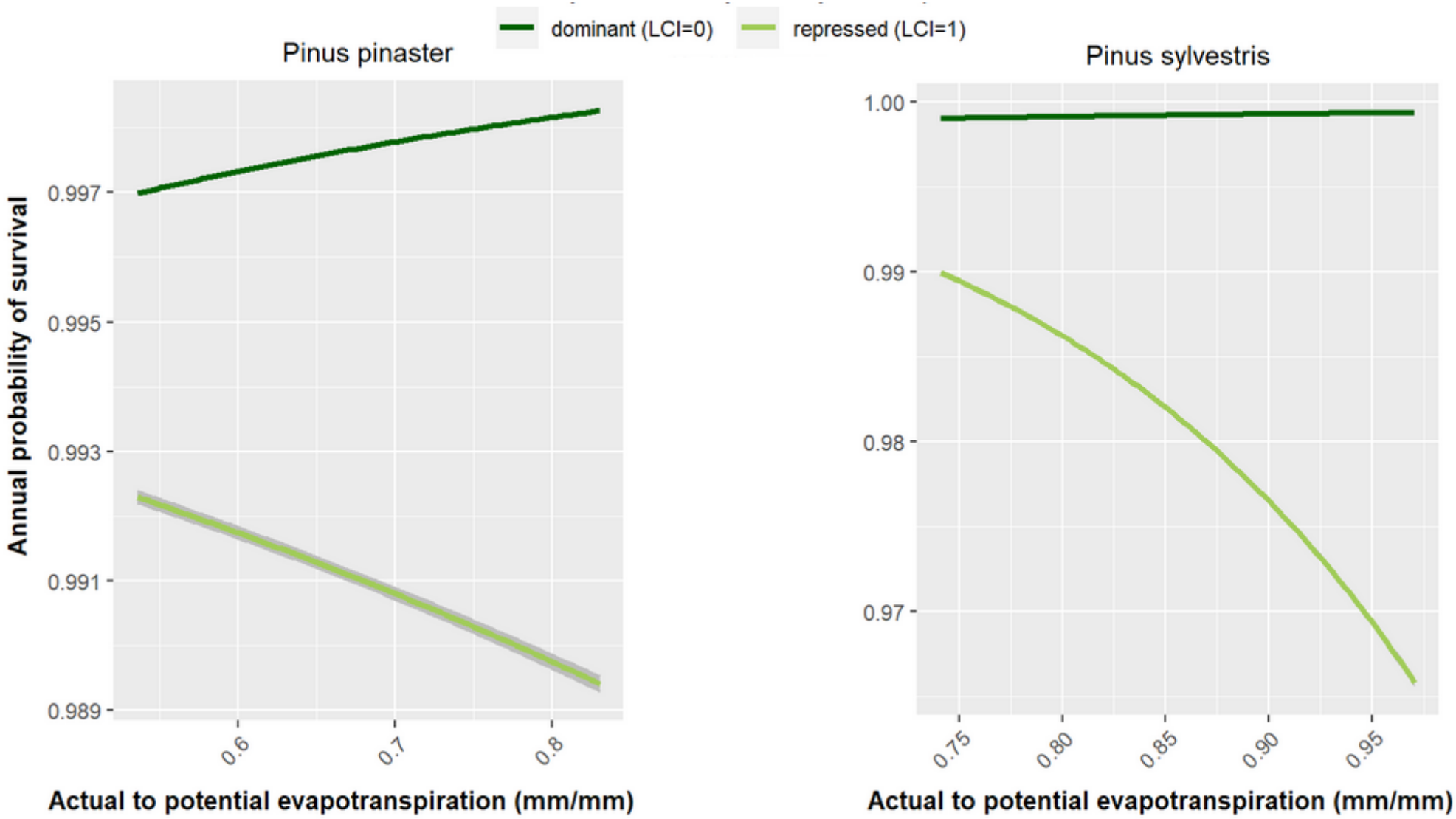


Results - Water stress gradient



<u>For 27 species over 34</u>: intensity of competition on survival is higher in their wet margin

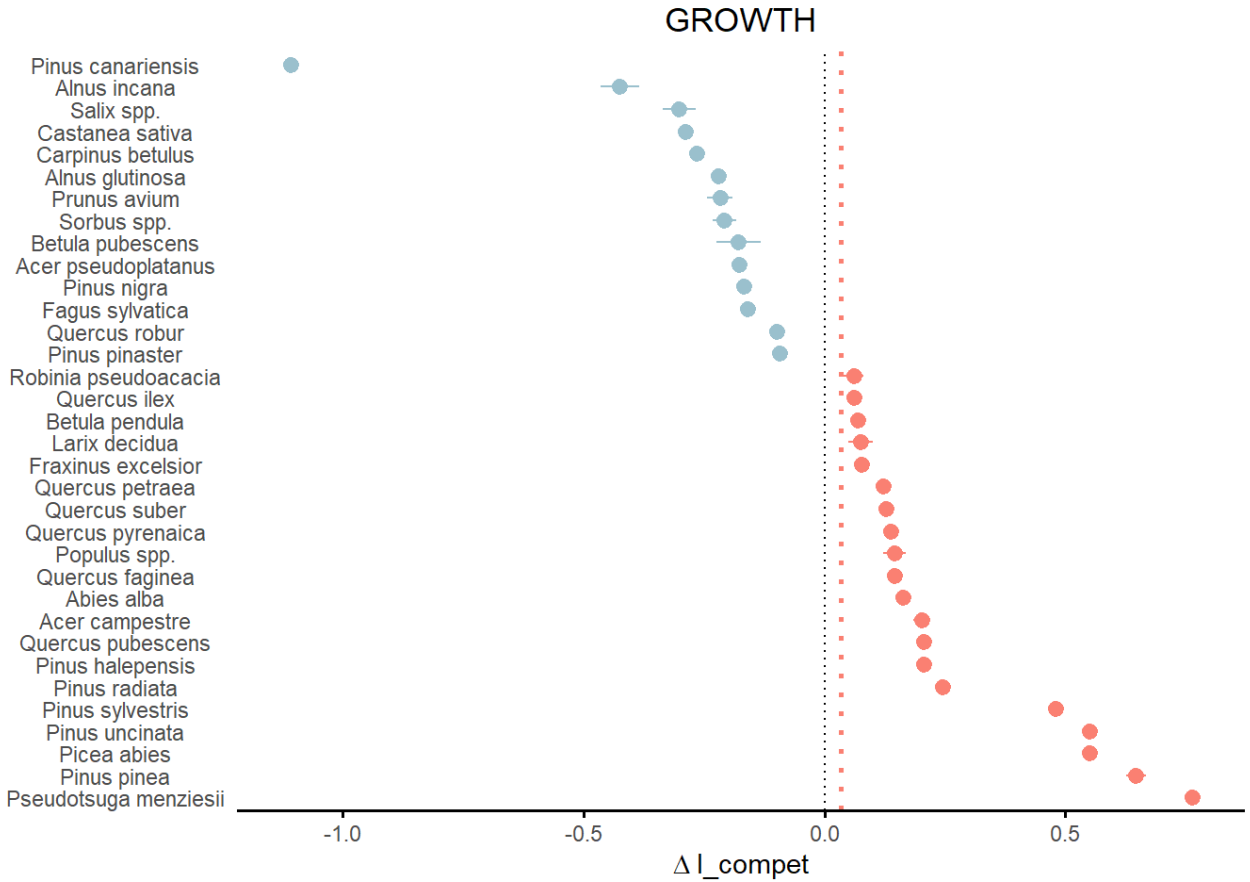
Results - Water stress gradient - Survival

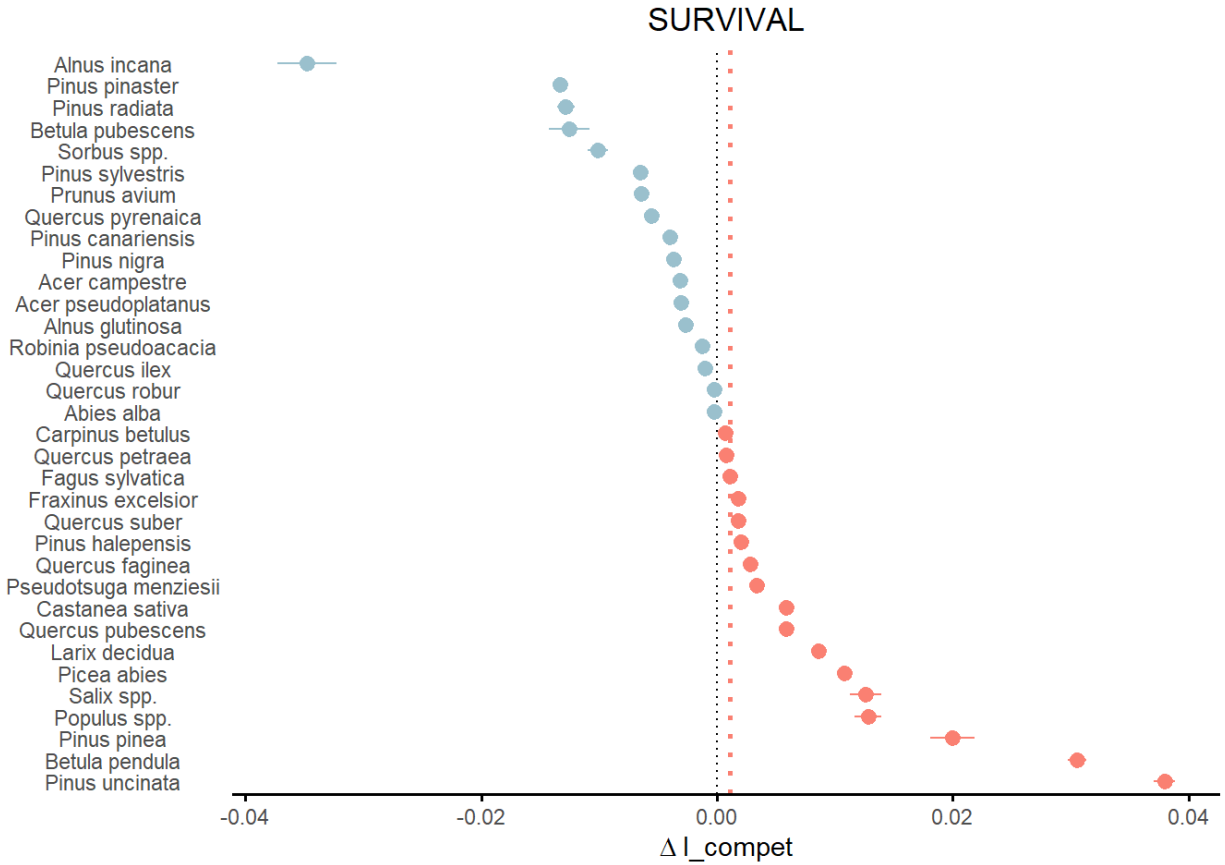


Q3: Is light competition less intense in a stressful environment ?

Along a non-resource gradient (temperature)

Results – Temperature stress gradient





No specific pattern of intensity of competition across a temperature gradient

Discussion

Q2: Interactions between climate and light competition are more important to consider for mortality than growth

➔ Species in arid climates are not the more competitive but those who can survive during period of drought (longer in driest climates) (Goldberg, D. & Novoplansky, A. (1997))

Q3.1: Effect of light competition on growth and mortality is lower in drier than wetter species climate niche

- According to Grime theory (individuals more stress-tolerant than competitive) ?
- According to Tilman theory (shift from light to below-ground competition) ?
- According to SGH theory (importance of shadow facilitative effect) ?

Q3.2: No specific pattern along a temperature gradient, even if interactions can be strong

- Temperature stress gradient is not as clear as the water deficit gradient (high temperatures can lead to low water availability)
- Non-resource gradient
- Facilitative effect of crowding on protection to freeze not as clear as protection to drought

Q3.3: Shift of aridity effect whether we consider a dominant or a repressed tree (principally for survival)

- Differentiative effect of trees strong in wetter margin (competitive strategy)
- Wetter climate can be negative for supressed trees

Limits and perspectives

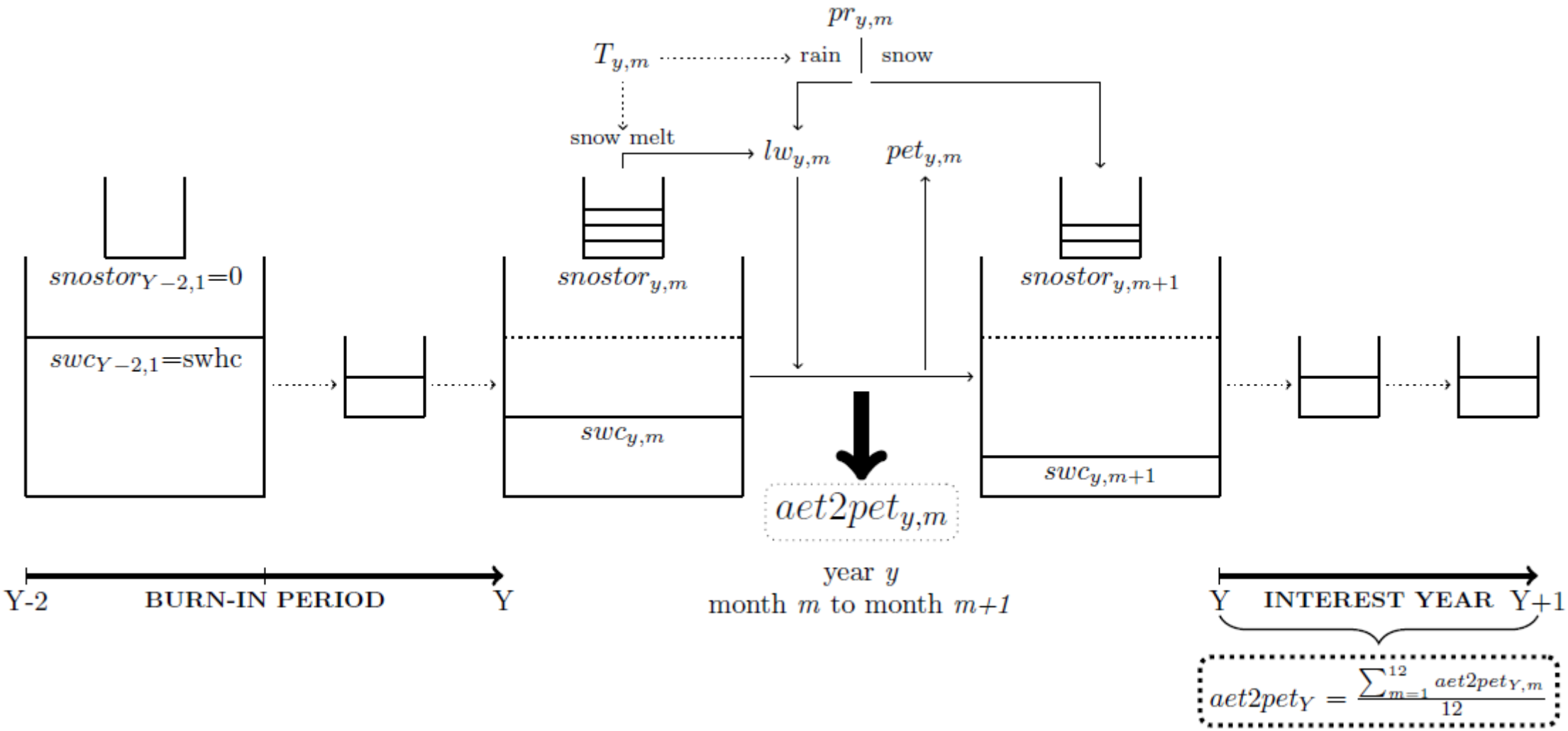
Limits:

- Space for time calibration
- Do not account for soil fertility
- No index of below-ground competition
- Bias coming from different management strategies between our plots

Perspectives:

- Modelling
  - Consider direct and also interaction effect of climate on species dynamics modelling
  - Species shade tolerance may be dependant on climatic environment
- Forestry
  - Better understanding of tree differenciation in a changing climate
  - Choice of focal trees (more stress-tolerant or competitive) depends on climatic environment

Additional materials



Additional materials

$$theta_{FC} = 0.2449 - 0.1887 * \frac{1}{OC+1} + 0.004527 * Cl + 0.001535 * Si + 0.001442 * Si * \frac{1}{OC+1} - 0.00005110 * Si * Cl + 0.0008676 * Cl * \frac{1}{OC+1}$$

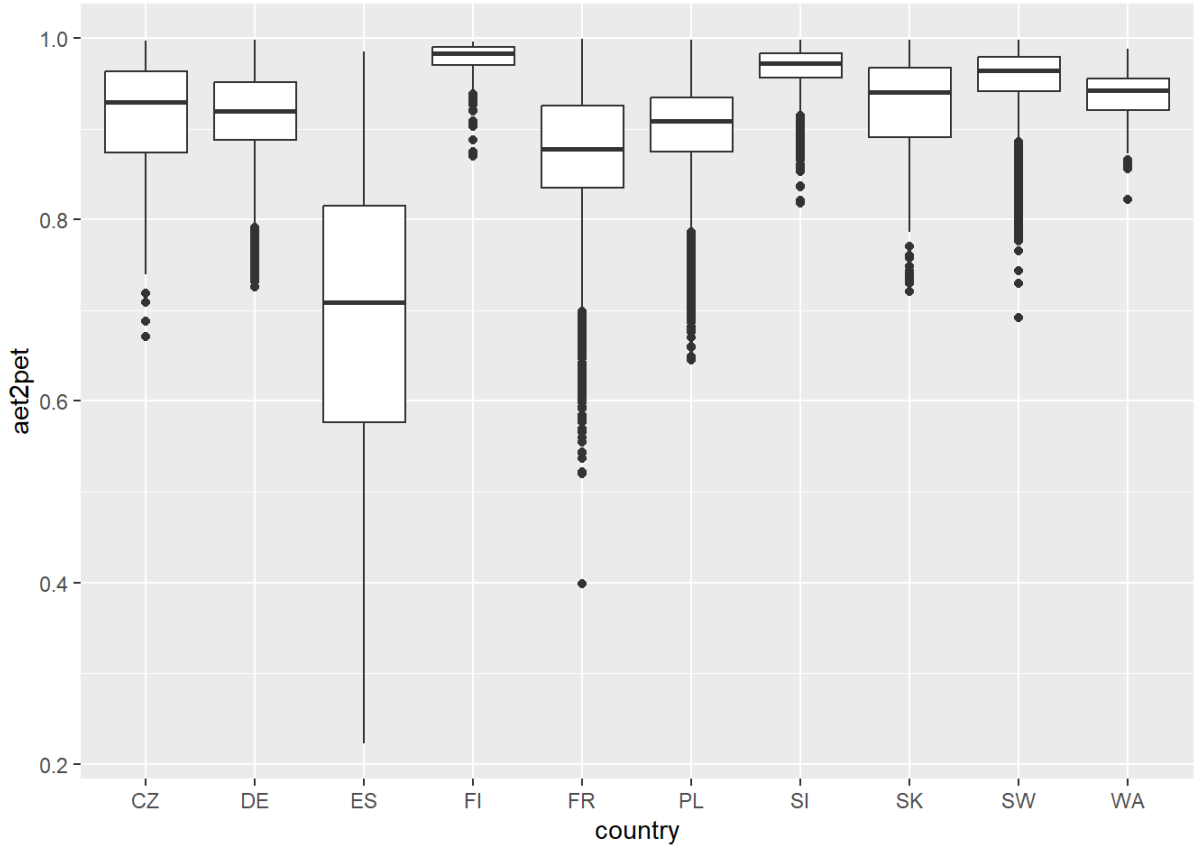
$$theta_{WP} = 0.09878 + 0.002127 * Cl - 0.0008366 * Si - 0.07670 * \frac{1}{OC+1} + 0.00003853 * Si * Cl + 0.002330 * Cl * \frac{1}{OC+1} + 0.0009498 * Si * \frac{1}{OC+1}$$

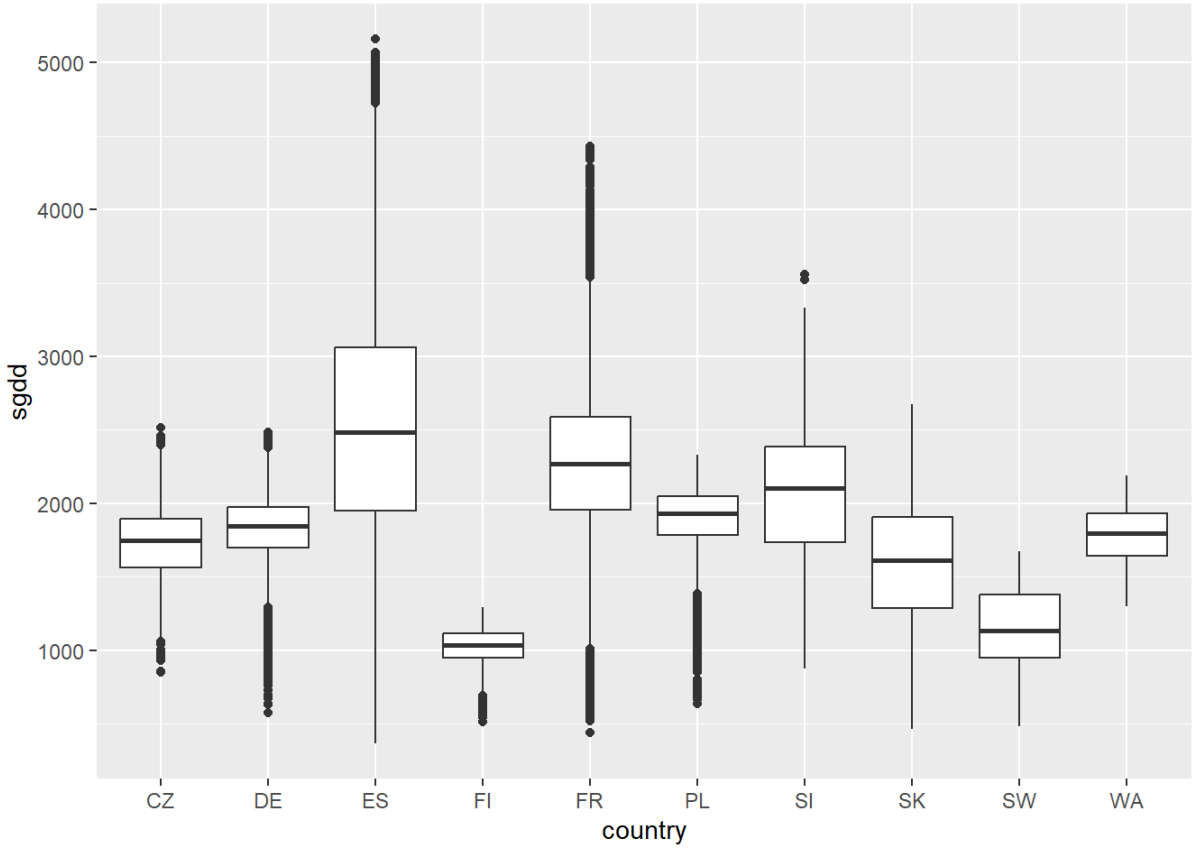
$$SWHCprop = \theta_{FC} - \theta_{WP} \qquad SWHCmm = \sum_{h=1}^{6} SWHCprop_h * size_h * min(1, max(0, \frac{rootingdepth - depthmin_h}{depthmax_h - depthmin_h}))$$

$$if \quad lw_{y,m} \geq pet_{y,m}, swc_{y,m+1} = min(swhc, swc_{y,m} + lw_{y,m} - pet_{y,m})$$
$$if \quad lw_{y,m} < pet_{y,m}, swc_{y,m+1} = swc_{y,m} * e^{\frac{lw_{y,m} - pet_{y,m}}{swhc}}$$

$$if \quad lw_{y,m} \geq pet_{y,m}, aet_{y,m} = pet_{y,m}$$
$$if \quad lw_{y,m} < pet_{y,m}, aet_{y,m} = lw_{y,m} + swc_{y,m} - swc_{y,m+1}$$

Additional materials





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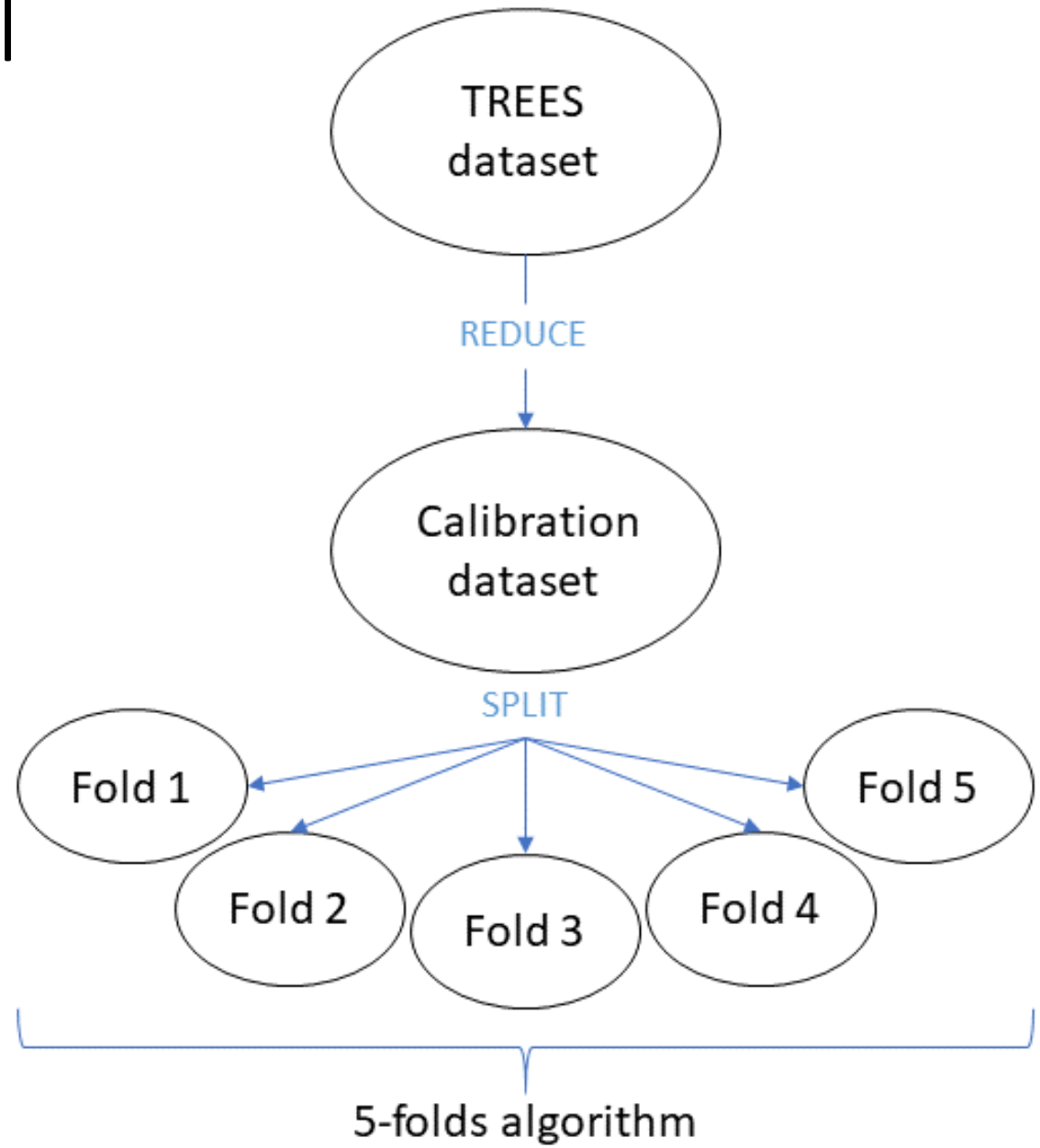

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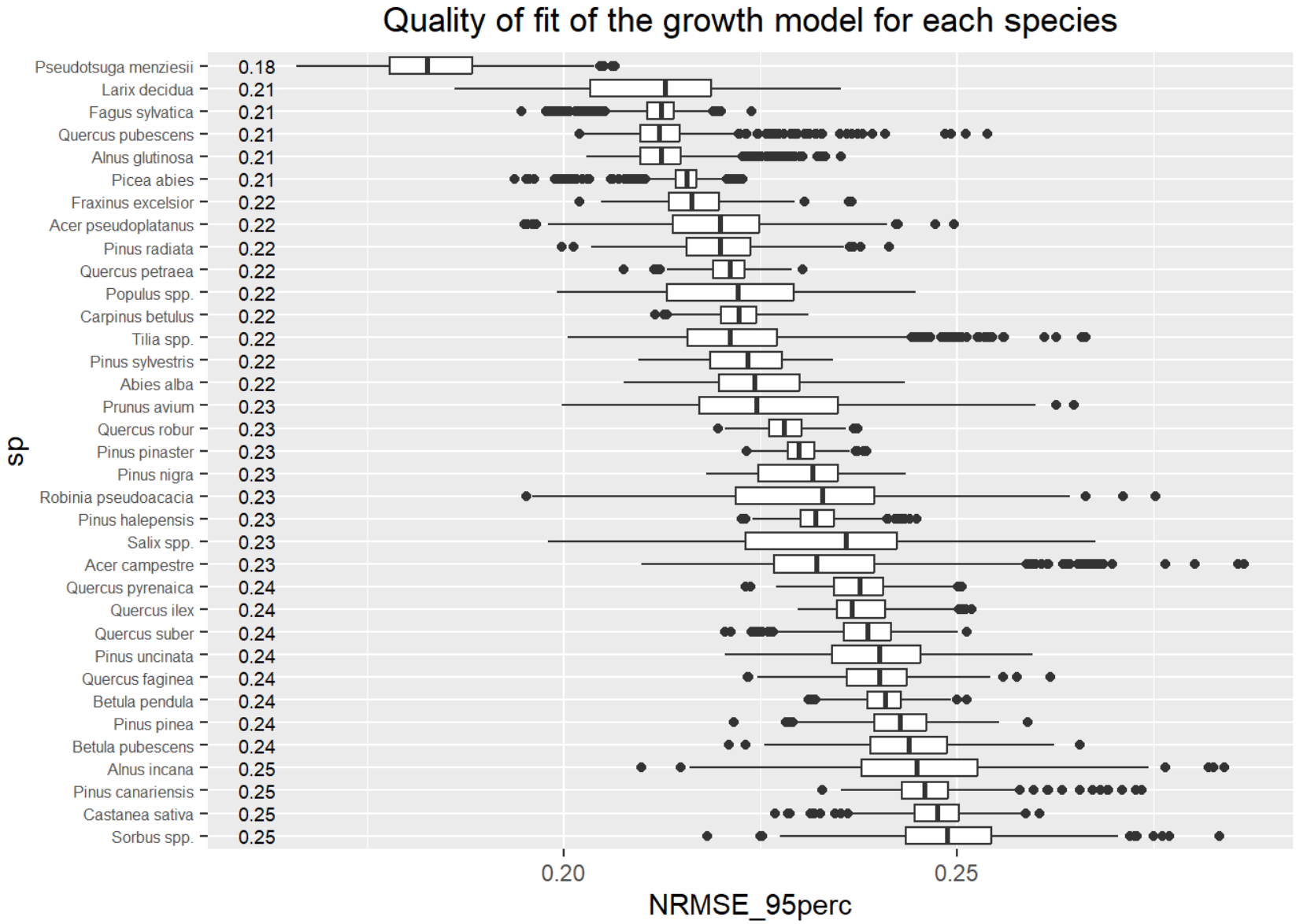

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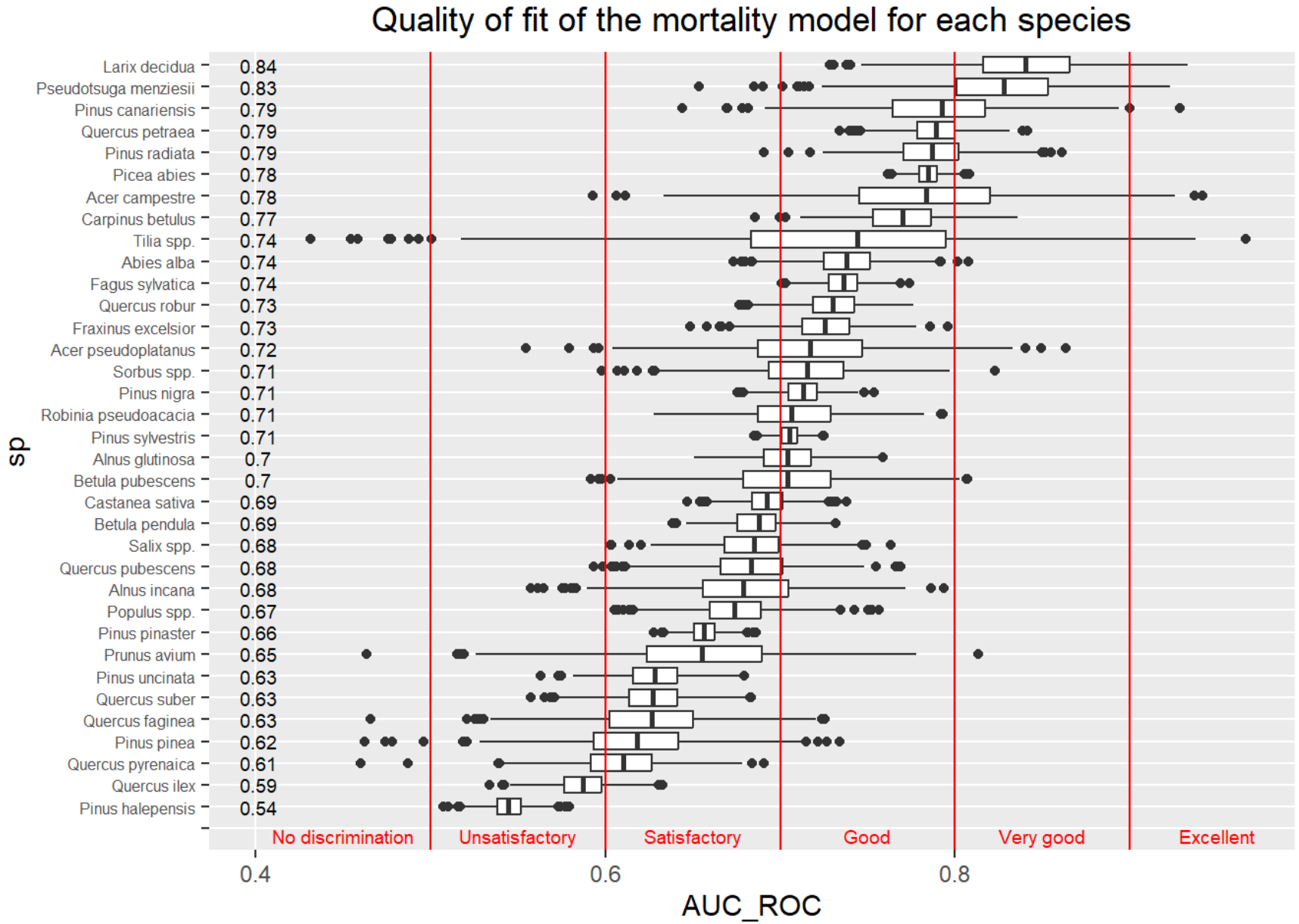

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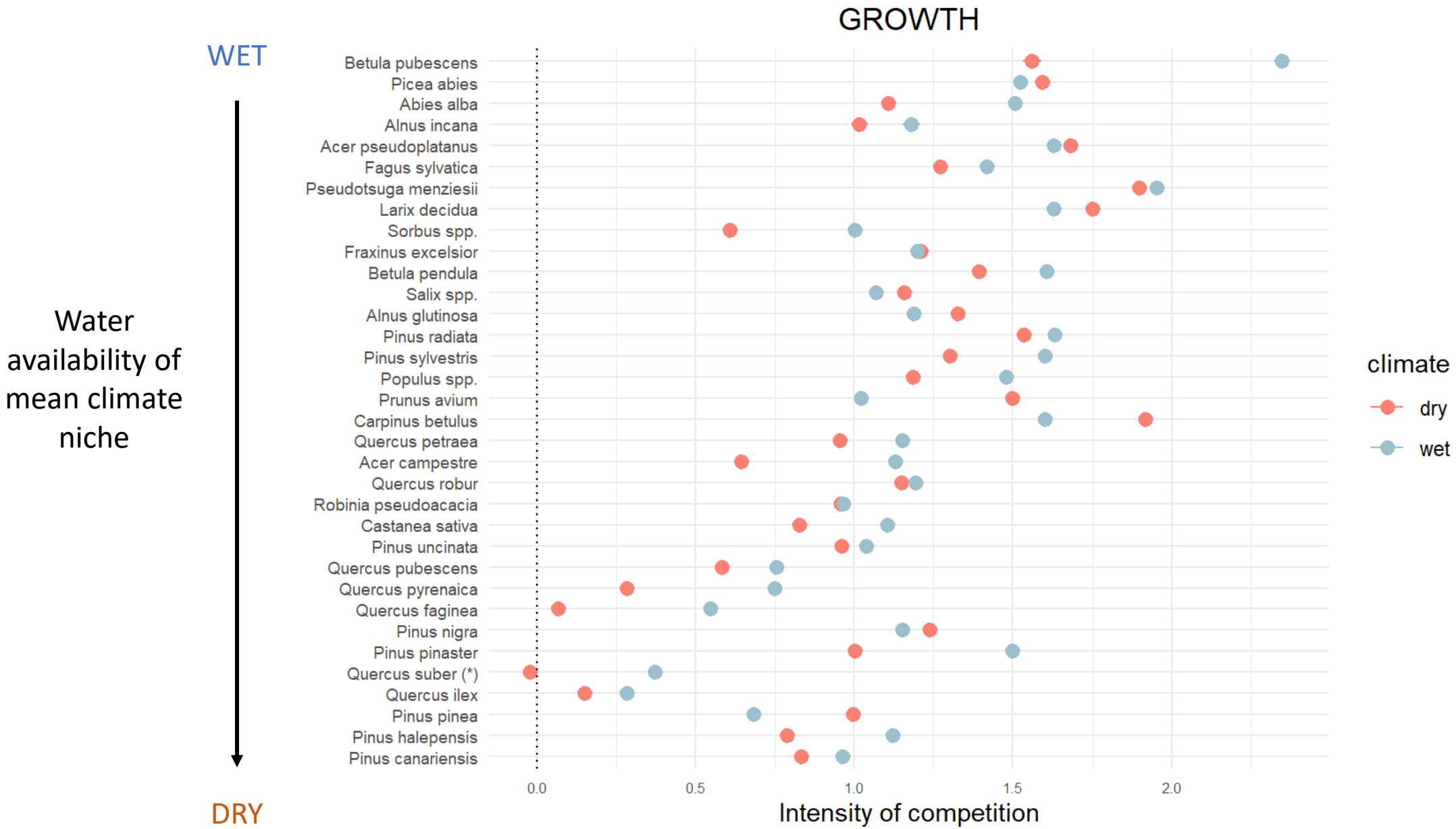

Additional materials

WET

Water availability of mean climate niche

DRY