Overlooking plant physiological processes in land surface models: how lumping tree species across scales undermine key information of forest functioning under stress

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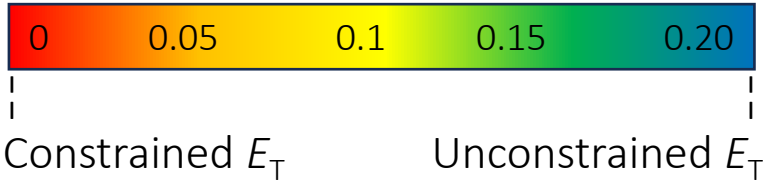
Methodological Approach

- Multiyear Analysis [2001-2020]
- Extended Summer Period (May to September)
- Community Land Model 5.0
- Actual transpiration (SapFluxNet)
- Index of transpired energy:

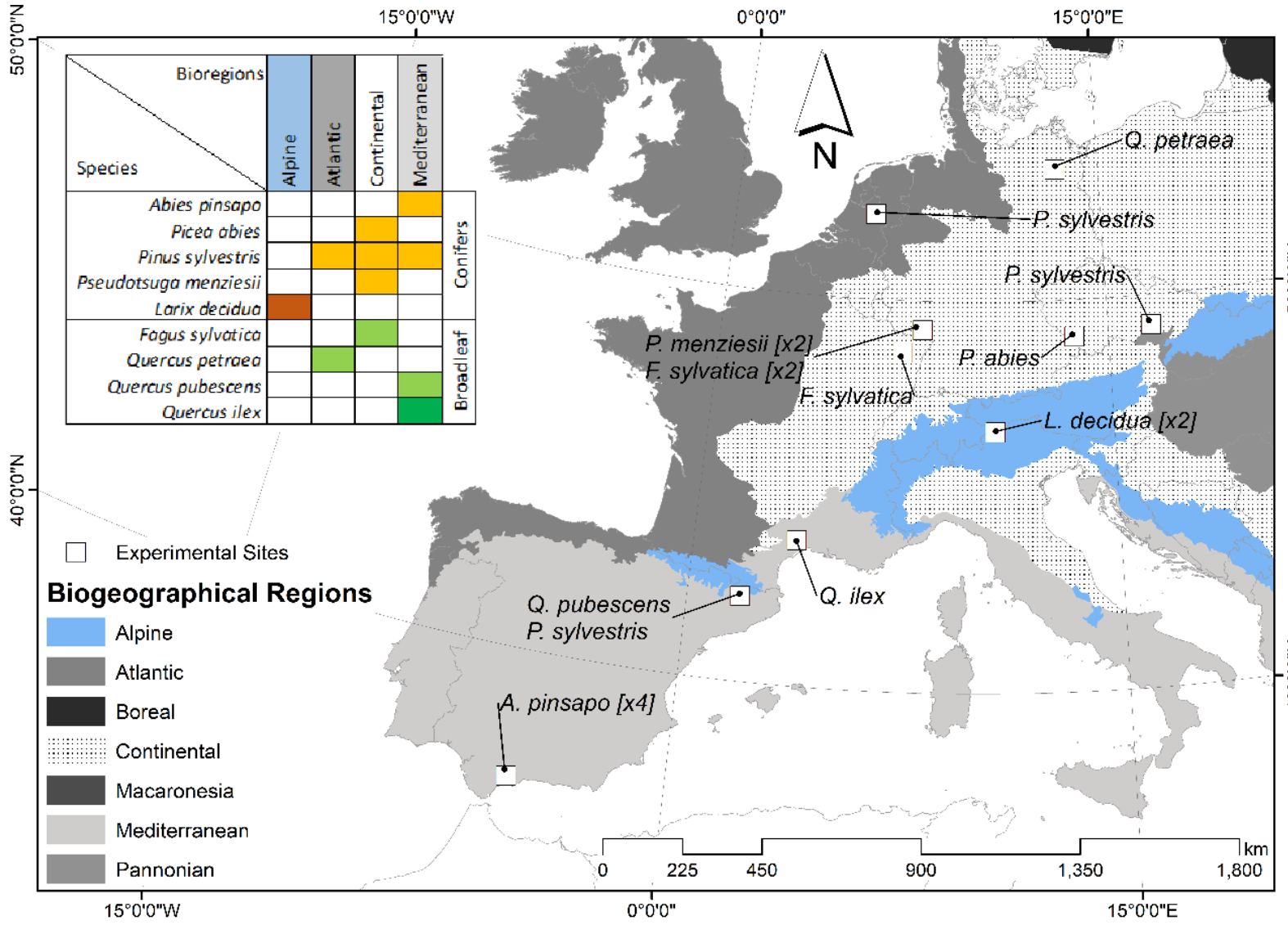
$$I_{TE} = \frac{E_T}{R_s}$$



- Model Stress Indicators (PLC, β)

PLC	Phase
0 – 12 %	Full recovery
12 – 50 %	Minor stress
50 – 88 %	Major stress
88 – 100 %	Lethal stress

Based on: Choat et al. (2012), Meinzer et al. (2009), and Preisler et al. (2022).



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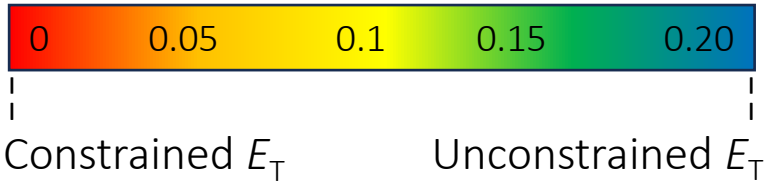
I_{TE} shows significant differences in the forest's energy use for transpiration across the 18 sites.

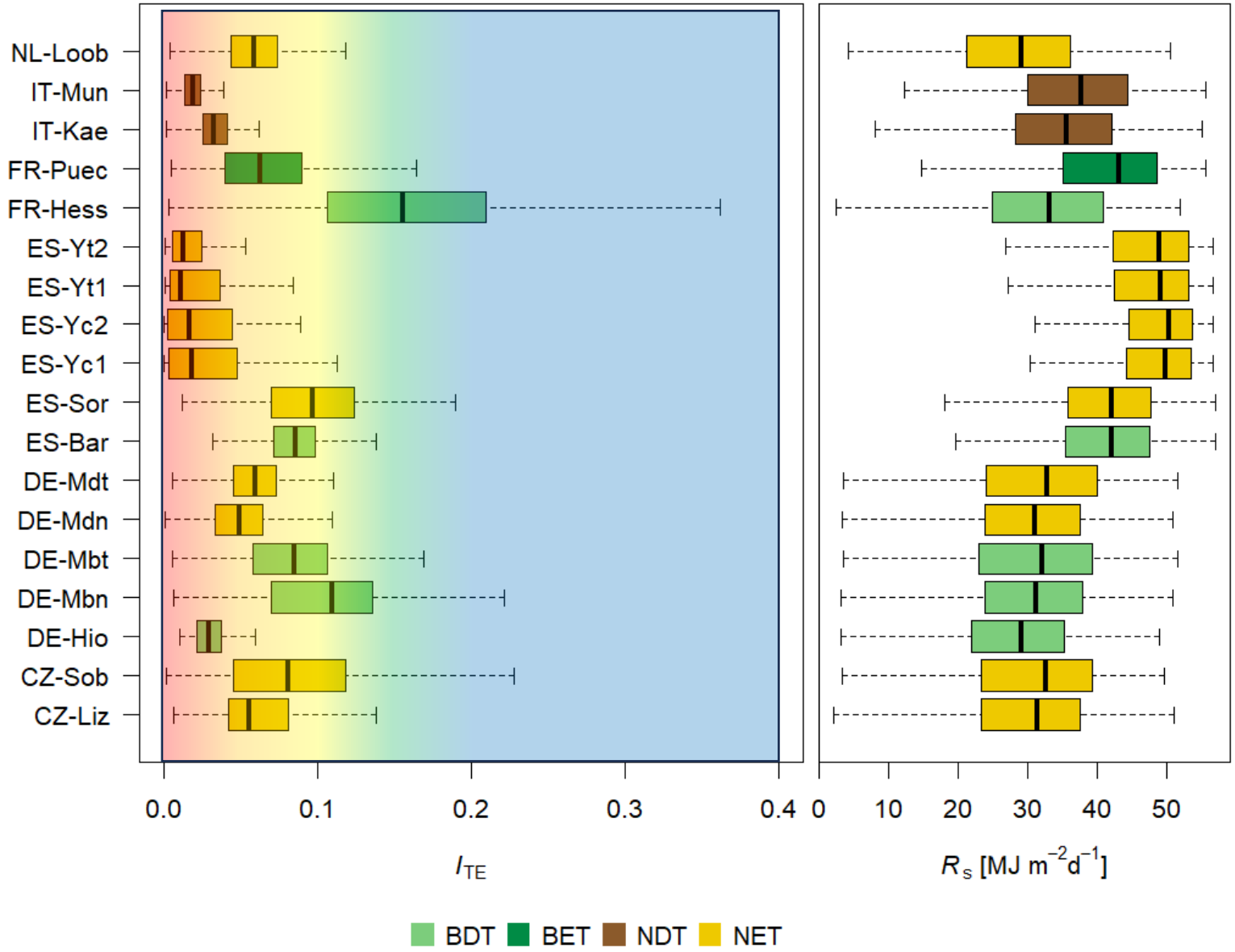
I_{TE} allows to detect ecosystems with transpiration constrained by different factors such as soil, species differences, or management practices.

I_{TE} of the Spanish sites (ES-…) differ despite their large energy availability as consequence of local soil conditions.

Allow to identify differences linked to species under same environmental conditions (e.g., DE-M…).

Limitation by extremely high-water table (e.g., DE-Hio).





Variability of the transpired energy index (I_{TE}) and the daily incident solar radiation (R_s) for each experimental site.

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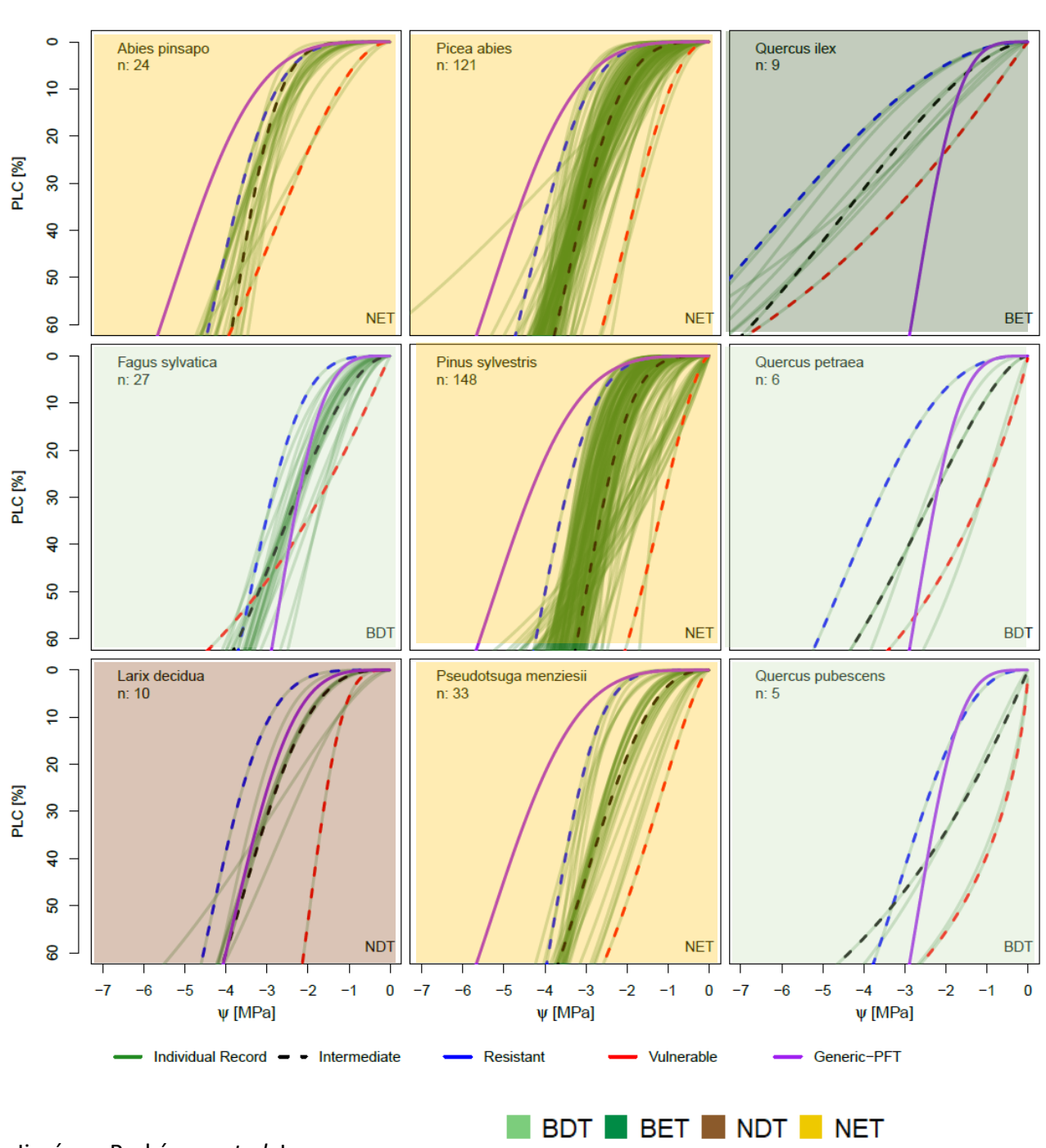

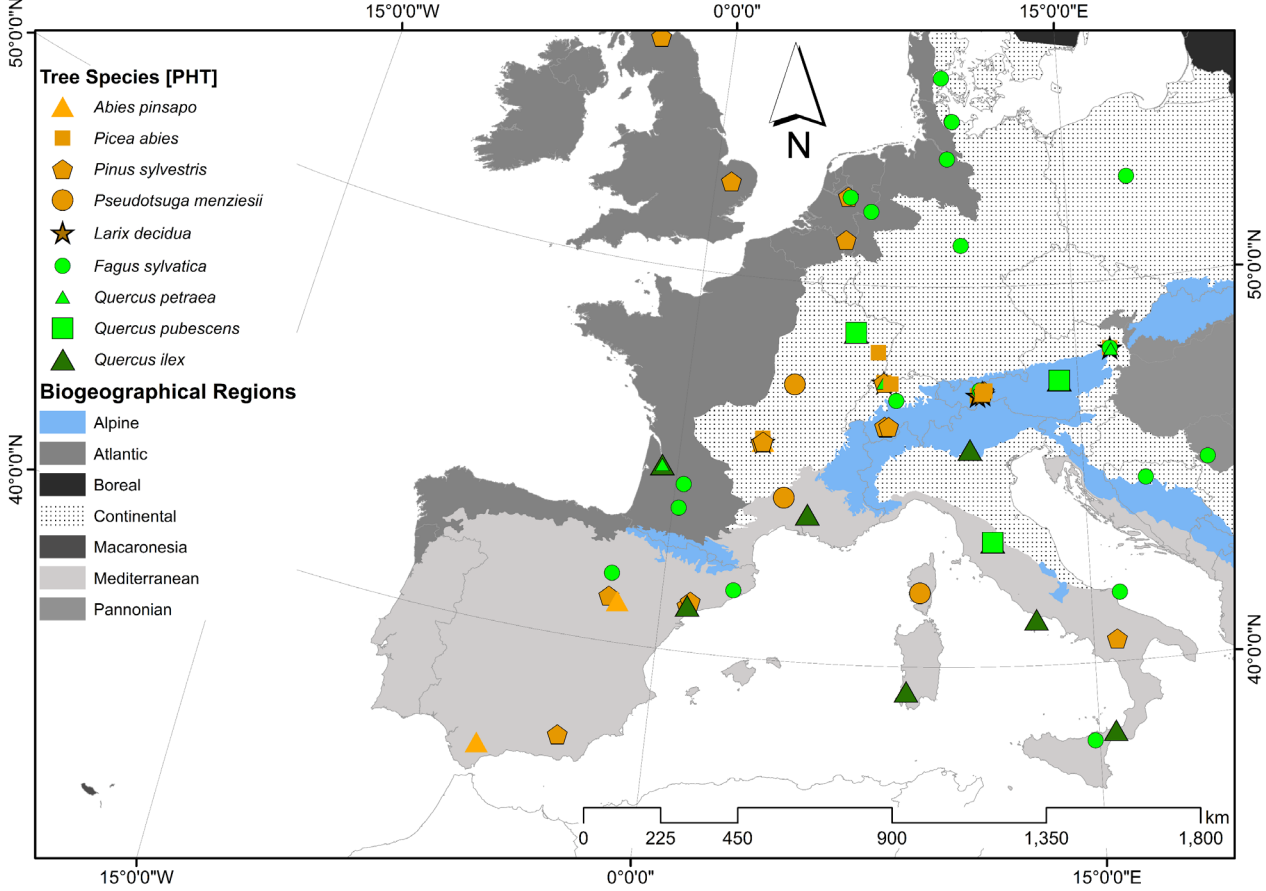

GMP: Generic Model Parameterization

RMP: Resistant Model Parameterization

VMP: Vulnerable Model Parameterization

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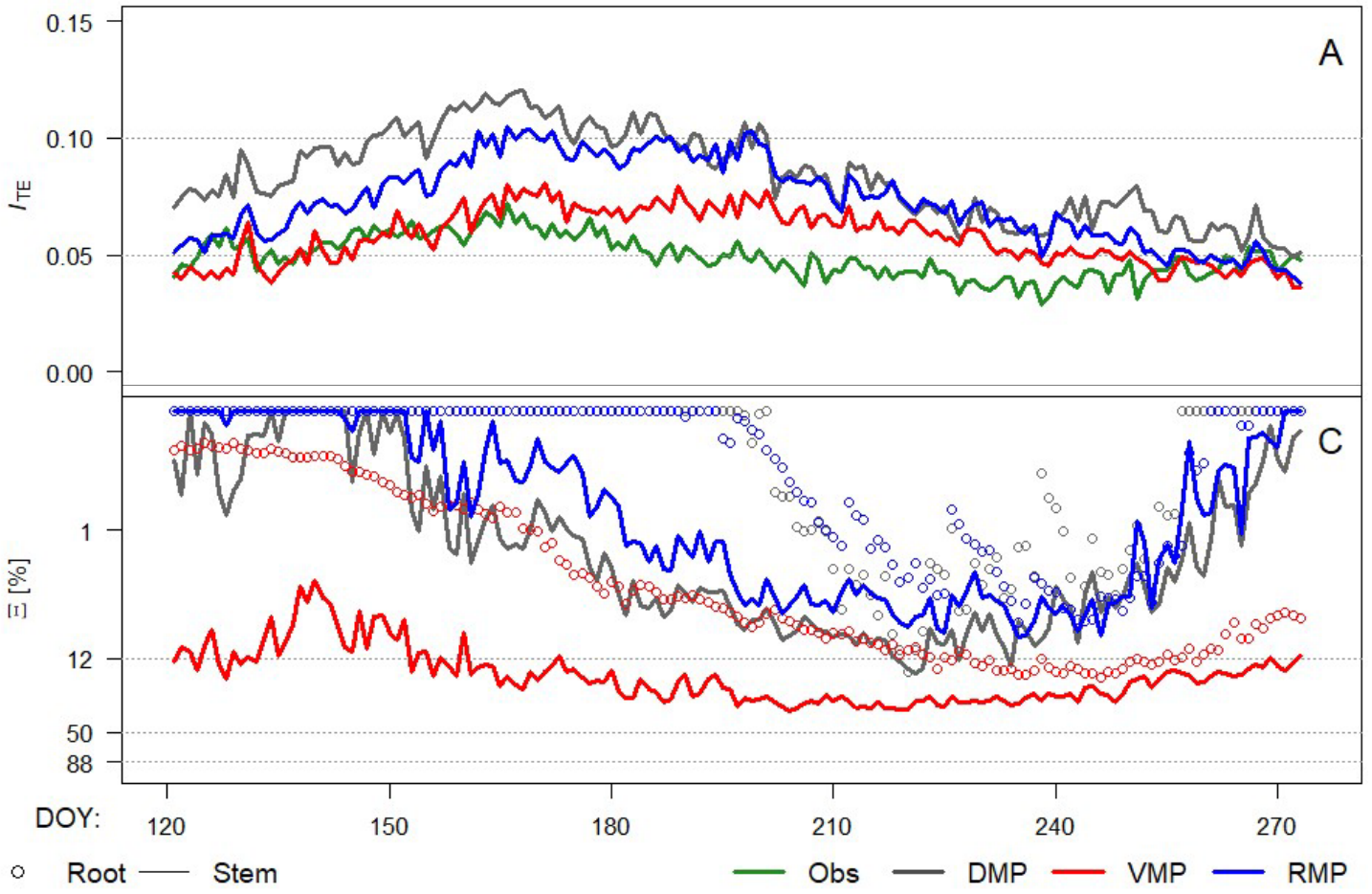
What happen lumping at Continental scale?

The temporal pattern of I_{TE} at European scale shows how half of the time the sampled forests used around 5% of the R_s for transpiration purposes.

The three parameterizations (i.e., DMP, VMP, RMP) lead CLM5 to overestimate the I_{TE} with medians larger than 0.05.

The VMP model parametrization provides the best representation of observed I_{TE} during the beginning of the ESP but overestimates I_{TE} during the rest of the season.

Only the VMP shows a hydraulic plant system with under a minor stress, meanwhile all other show a full recovery condition for all forests.



Temporal differences of the multiannual median of the transpired energy index (I_{TE}) and and percent loss of conductivity (Ξ) as logarithmic scale for the root and stem segments at European scale.

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What happen lumping per Bioregion?

VMP better represents the I_{TE} of Continental sites.

RMP and DMP overestimates the energy use for transpiration.

The overestimation of I_{TE} happens when PLC values (Ξ) are within the fully recovery phase.

Mediterranean sites depict the best estimation of I_{TE} with the best estimations during the driest part of summer.

Species \ Bioregions	Alpine	Atlantic	Continental	Mediterranean	
Abies pinsapo					Conifers
Picea abies					
Pinus sylvestris					
Pseudotsuga menziesii					
Larix decidua					
Fagus sylvatica					Broadleaf
Quercus petraea					
Quercus pubescens					
Quercus ilex					

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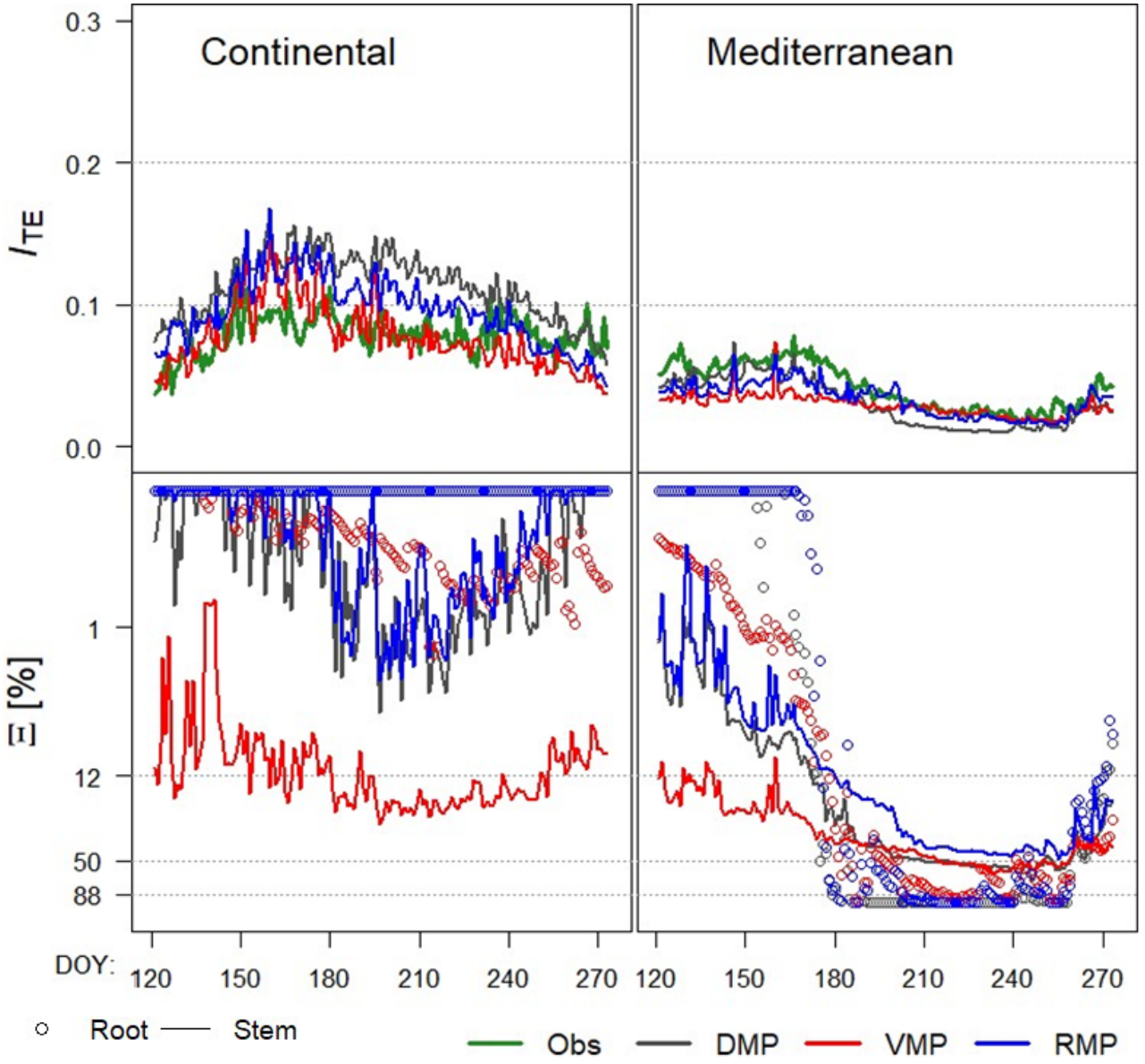


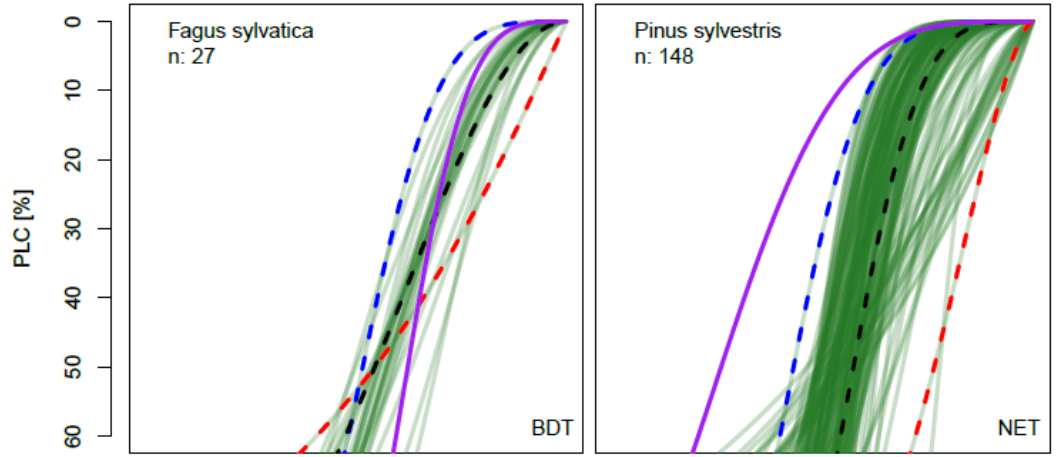
Temporal differences of the multiannual median of the transpired energy index (I_{TE}) and percent loss of conductivity (Ξ) as logarithmic scale for the root and stem segments per Bioregion.

What happen lumping per PFT?

NET model parameterizations allow a good representation of the I_{TE}, but the roots show PLC (Ξ) values on the lethal stress conditions.

The PLC (Ξ) of NET stems remains within a minor stress range

BDT parameterizations showed a consistent overestimation of the I_{TE} for all the ESP.



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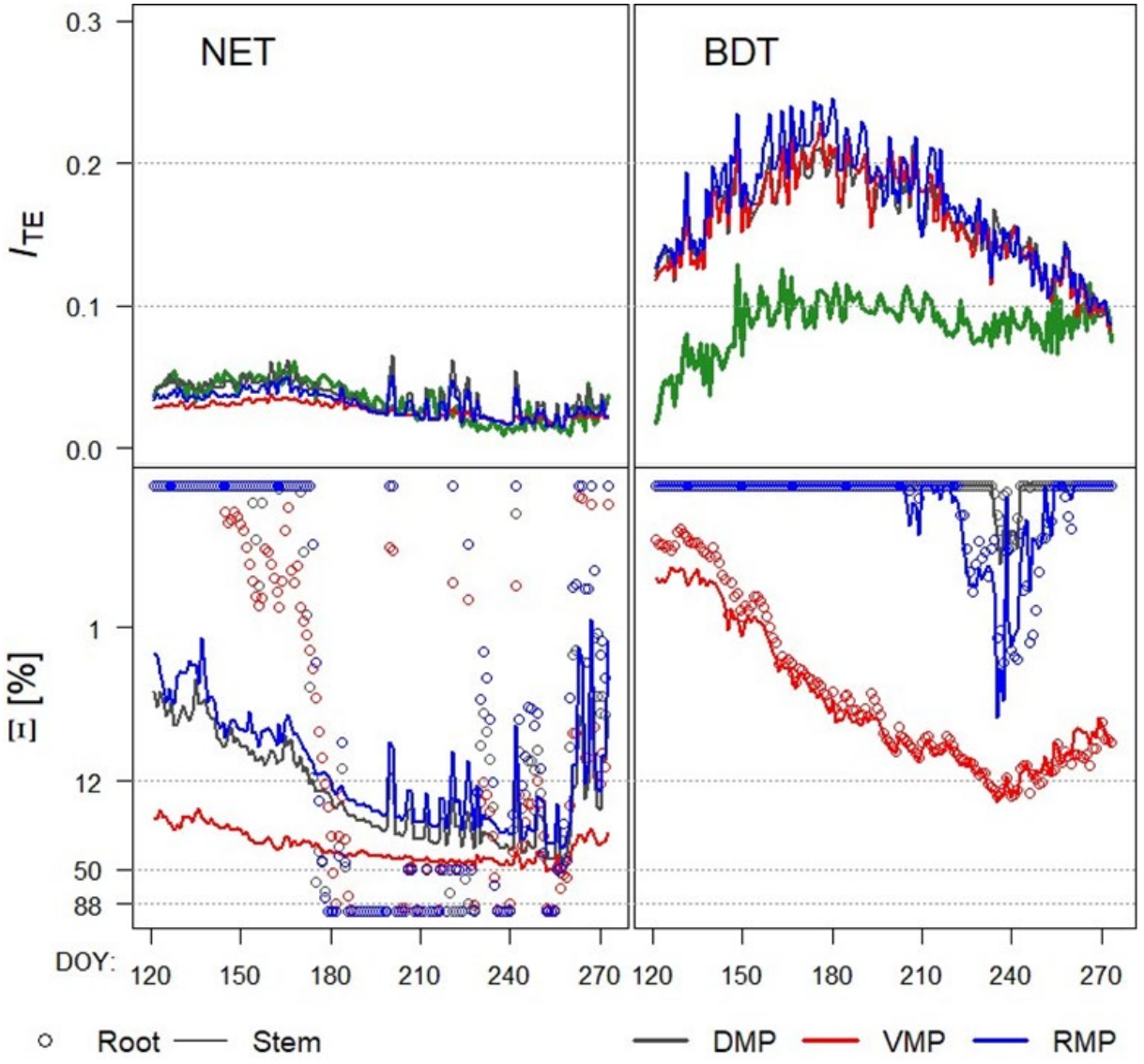

Temporal differences of the multiannual median of the transpired energy index (I_{TE}), and percent loss of conductivity (Ξ) as logarithmic scale for the root and stem segments per plant functional type.

Take Home Message

- Using the I_{TE} is a practical method for evaluating the effect of plant hydraulic stress based on transpiration measurements and model estimates.

- The interaction between parameterization and local climate conditions is highly influential to the energy use for transpiration by the model.

- The representation of plant hydraulic stress using the PVC has to be addressed carefully due to the seasonal mismatch across bioregions and PFTs.

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