What are the minimum plant traits needed for improved drought simulation?

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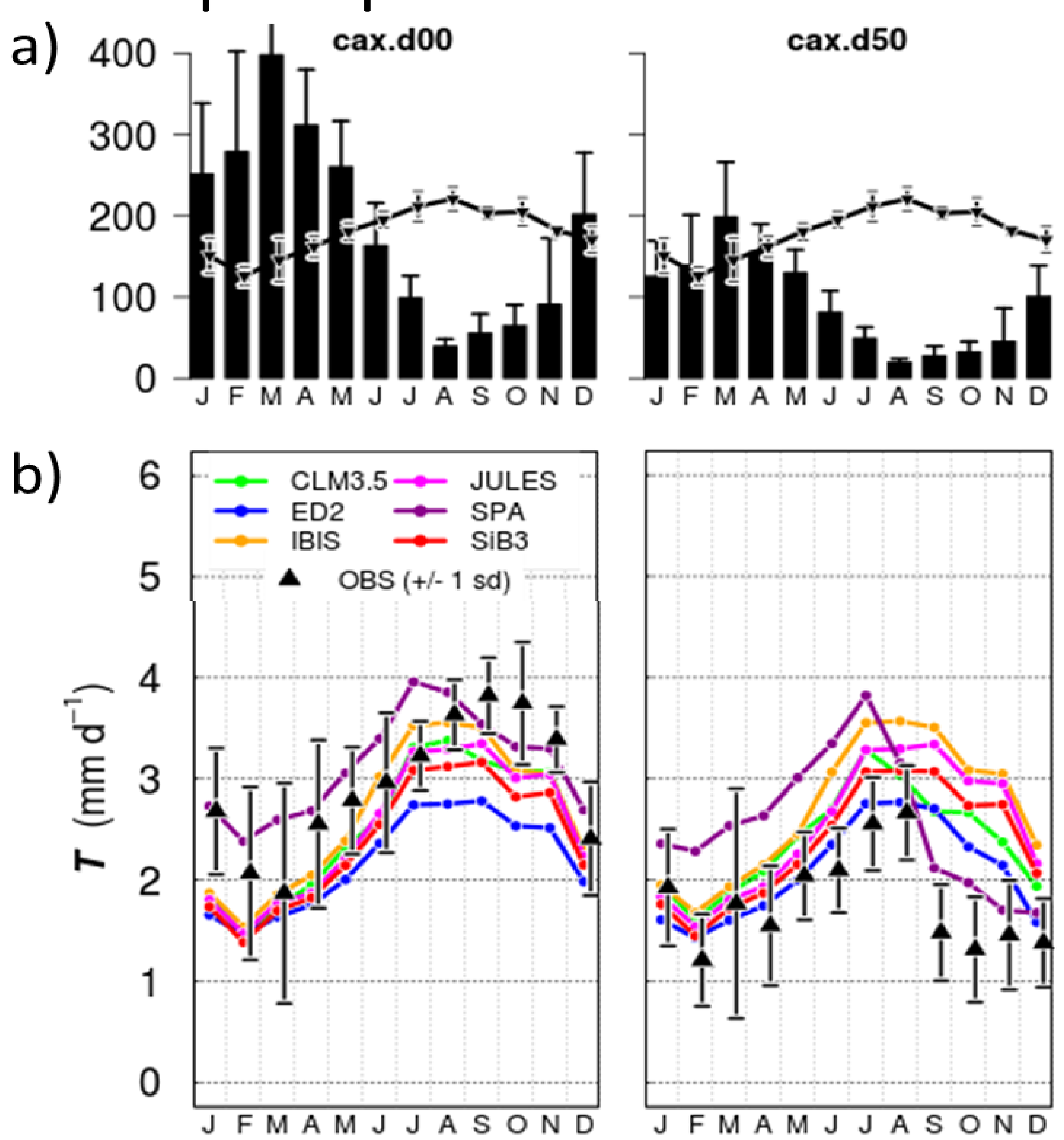
UNIVERSITY OF LEEDS

1. Models are undersensitive to precipitation reduction



Christoffersen, et al., in prep

2. Why? Simplistic representation of soil water stress not linked to plant traits; only soil properties

$$\beta = \begin{cases} 0 & \text{for} \quad \theta < \theta_w \\ \dfrac{\theta - \theta_w}{\theta_c - \theta_w} & \text{for} \quad \theta_w < \theta < \theta_c \\ 1 & \text{for} \quad \theta > \theta_c \end{cases}$$

REFERENCES

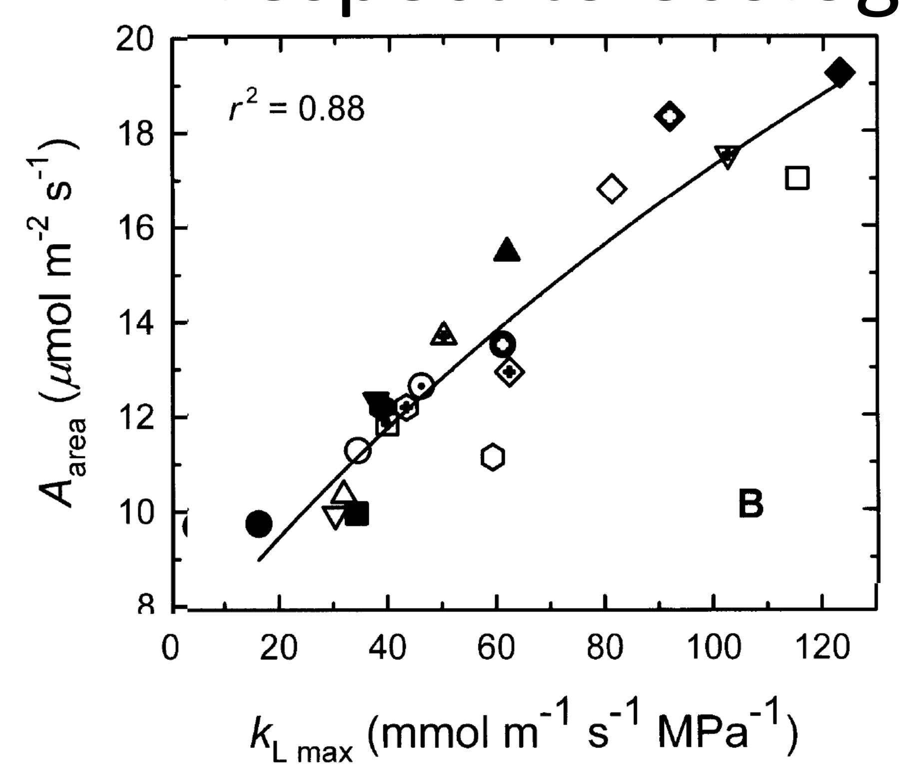
Christoffersen BO, et al. Plant water availability in dynamic vegetation models applied to Amazonia: The role of root water uptake functions under contemporary and simulated drought conditions. In prep for *Global Change Biology*.

NM Fyllas et al. 2014. Analysing Amazonian forest productivity using a new individual and trait-based model (TFS v.1). *Geoscientific Model Development* 7: 1251–1269.

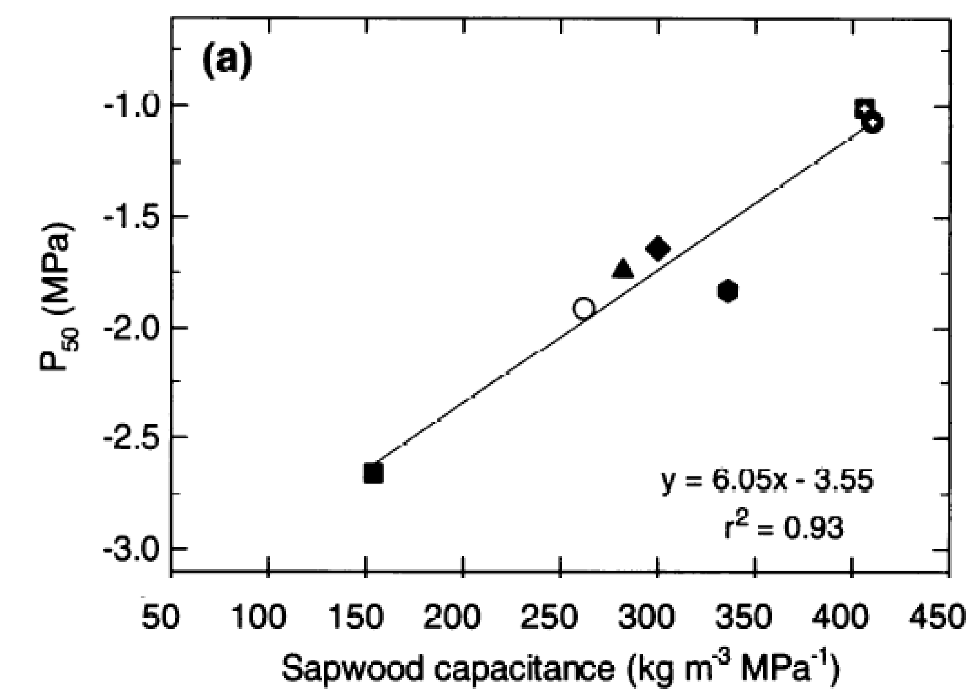
Meinzer FC, et al. 2008. Coordination of leaf and stem water transport properties in tropical forest trees. *Oecologia* 156(1): 31-41.

Santiago LS, et al. 2004. Leaf photosynthetic traits scale with hydraulic conductivity and wood density in Panamanian forest canopy trees. *Oecologia* 140(4): 543-550.

3. Plant traits in tropical forests demonstrate two key features with respect to ecological/drought strategy



Hydraulic supply matches **photosynthetic capacity** (Santiago et al. 2004)



A trade-off in **drought avoidance** vs. **drought tolerance** strategy (Meinzer et al. 2008)

The famous **"safety-efficiency"** trade-off is **weak** for tropical forests (Christoffersen et al., unpublished results from TRY database)

4. How can we represent these key trait strategies in ecosystem models?

Step 1: Incorporate missing process detail via simple hydrodynamic model.

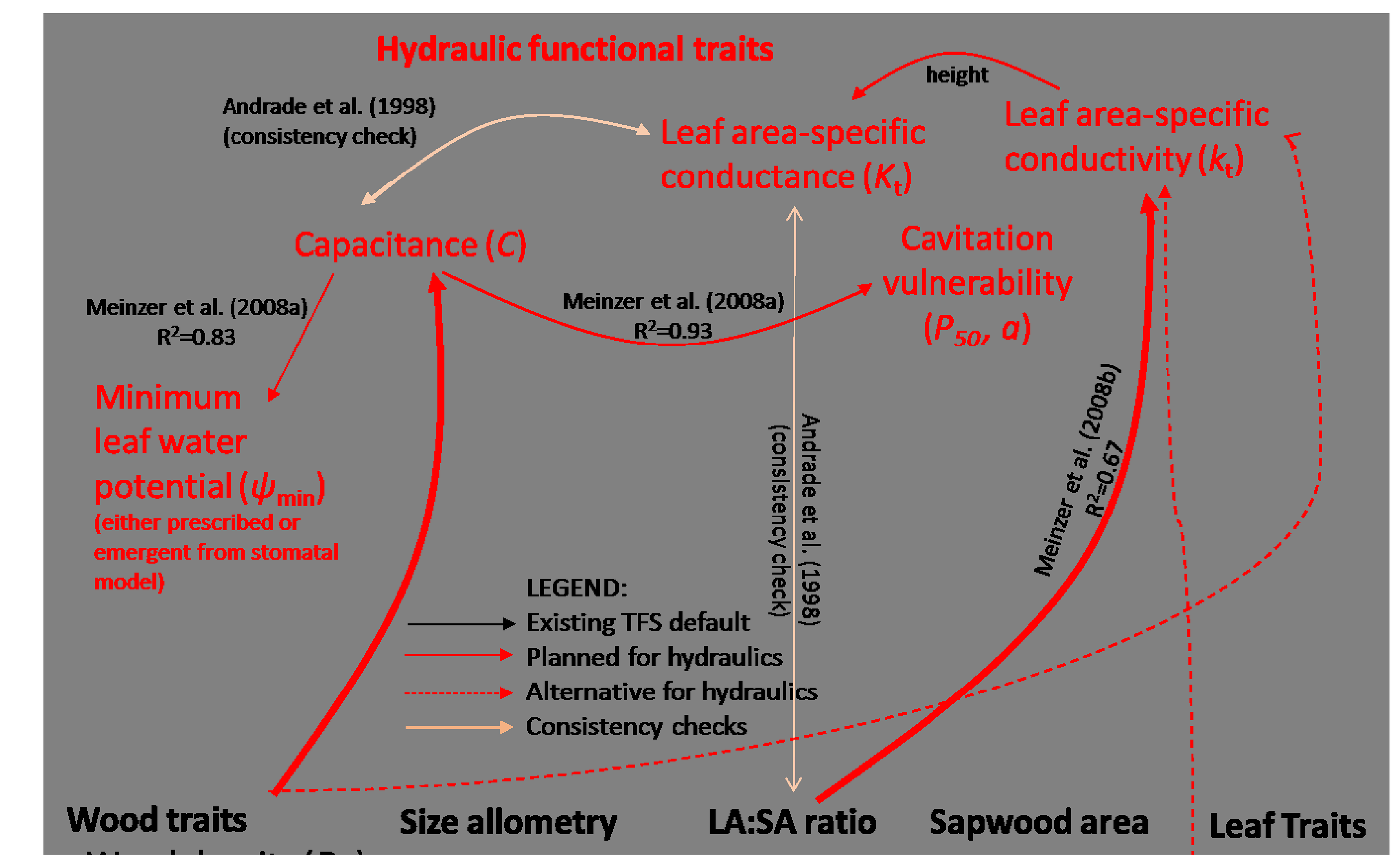
$$q_r = q_s = E_l = \frac{(\psi_{soil} - \psi_{leaf})}{R_t}$$

$$\frac{dW}{dt} = \frac{dW}{d\psi_l}\frac{d\psi_l}{dt} = C\frac{d\psi_l}{dt} = q_s - E_l$$

stomata
leaf storage
node 1
stem xylem
stem storage
node 2
SOIL SURFACE
node 3
node 4
node n
Transport root
Absorbing root
root xylem
BULK SOIL
PLANT
RHIZOSPHERE

Step 2: Experimental test-bed with individual tree model, TFS (Fyllas et al. 2014)

Link plant hydraulic properties in newly developed hydrodynamic model to plant functional traits



Step 3: JULES

Use hydrodynamic model to conduct combined sensitivity analysis of minimum leaf water potential and stomatal sensitivity to drought: Impacts of the avoidance-survival tradeoff on reproducing observed drought-mortality relationships

CONCLUSION

A minimum of three plant traits are necessary to derive plant hydraulic properties in ecosystem models:

Wood density (WD) → Capacitance

Jmax → Hydraulic Conductance

Leaf-to-Sapwood Area (LA:SA) → Size scaling

We are deriving novel approaches for representing these traits and their sub-PFT-level variability in coarse-scale ecosystem models like JULES.

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